

Estudio Experimental de la Hidrodinámica de Zona de Rompientes

ANEXO A

-Artículos Publicados-

Andrés Rodriguez

Marzo de 1997

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Artículos

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A1. *Image Analysis of Surf-Zone Hydrodynamics.*

Este artículo ha sido presentado en la Conferencia Internacional "Coastal Dynamics'94", y publicado por la ASCE (CD'94, ISBN 0-7844-0043-1, pg 350-365). Una versión posterior y más detallada de la técnica desarrollada sido aceptada en la Conferencia "Coastal Dynamics'97" de la ASCE en el artículo *Image-processing of Surf-Zone Mixing*, elaborado por Rodriguez, S.Arcilla, Bahia, Redondo y Diez.

IMAGE ANALYSIS OF SURF ZONE HYDRODYNAMICS

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ABSTRACT: A serie of relatively novel techniques is presented to study surf-zone hydrodynamics by means of digital processing of video image recordings of the sea surface near the coast. Image analysis may be used to estimate spatial and temporal characteristics of wave fields, surface circulation, mixing and morphodynamics in the surf zone. Preliminary field measurements were conducted in May 1993 along the Ebro Delta (Spanish Mediterranean Coast), to test the methodology. Spectral analysis on the images was applied used to estimate energetic wave frequency bands as well as dispersion relations of shear instabilities. These results are compared with numerical model predictions. Results from a recent campaign at the same site in December 1993 were used to validate the analysis. Results from three days with quite different sea conditions are compared and longshore current and dispersion measurements from the tracking of dye blobs are presented.

INTRODUCTION

The study of near-shore processes, and especially the interaction between wave fields, longshore currents, turbulence characteristics and beach morphology, needs detailed measurements of the simplest possible events to understand the complexity of coastal dynamics. A step by step approach starting from a well behaved (linear) coastal area was selected.

The generation of longshore currents by wave fields has been measured and discussed in detail by e.g. Thornton (1970). Since then, many authors have shown the complexity of the wave-current-turbulence interactions which has helped to gain insight into the time and space variability of longshore currents due to e.g. edge waves and shear instabilities.

The study of coastal hydrodynamics and morphodynamics by means of aerial images has also been treated by several researchers. Sonu (1969) utilized a 35mm motor-driven photocamera to study nearshore current patterns and mixing. Sasaki and Horikawa (1972/76) improved the resolution and accuracy

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for mapping the quantitative flow field in the surf zone applying the idea of Stereo-Bacs (with two balloons and 70mm motor-driven cameras). Maresca and Seibel (1976) have used land based phogrammetry to measure breaking waves and longshore currents; buoys and fluorescein dyes were the tracers used. Recent work by Kuriyama and Ozaki (1993) has compared numerical model results with extensive field measurements using a 400 m long offshore pier perpendicular to a sandy beach in Hazaki, Japan. In this work the longshore current was measured by tracking tracers on the sea surface.

Since the 80's, video and digital processing techniques have allowed flow visualization in accurate and efficient ways, for a complete description of these techniques see Hesselink (1988). The Army corps of Engs. during Duck, N.C. experiments, replaced photographic material by video, and began to explore the potential of this technique (Holman and Sallenger, 1986). The expected capabilities of video recording and digital processing for the study of coastal processes include horizontal velocity fields, dye mixing, angle and period of incident waves, wave runup, surf zone width, sand bar morphology, shoreline response, etc.

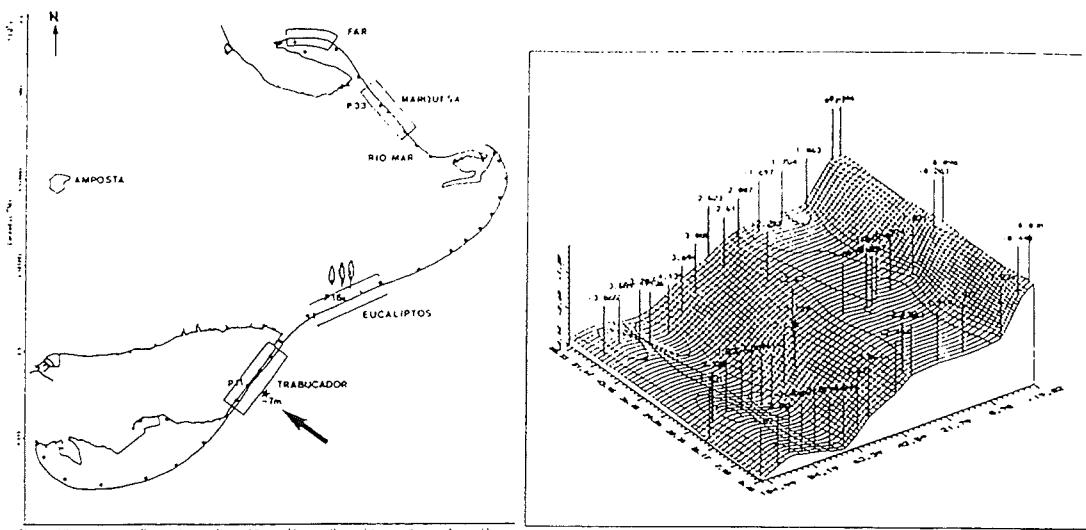
Holman and Lippmann (1987/89/93) have employed extensively video techniques in the quantification of sand bar morphology. Breaking waves characteristics such as overwash bore velocities (Holland et al., 1991), or phase speed and angle (Lippmann and Holman, 1991) have also been measured using video techniques. These authors have also quantified the long period time scales associated with breaking waves during DELILAH experiment on North Carolina, (Lippmann and Holman, 1992). Recently, the wave runup has also been measured using video records of a beach on Maryland by Walton (1993). This list shows the extensive use of these techniques, which appear to be an useful complementary tool for remote sensing (field and laboratory measurements) of coastal dynamics.

The paper starts with a description of the site, the set up of the DELTA 93/94 field experiments, and the conditions on the different days. In section three results from the image analysis are presented and compared with other measurements. The numerical model used is then discussed and its results compared with the experimental results.

FIELD WORK AND METHODOLOGY

The site chosen for this study was the Trabucador bar in the Ebro delta which has a long history of data gathering and simple linear geometry. In figure 1 a map of the area is shown together with other zones considered for the study. Two sets of measurements will be discussed in the paper, corresponding to May and December 1993. The bathymetry was measured both before and after the field campaign. A bottom elevation plot at the start of measurements on the 26th of May is shown in figure 2. On this day, the profile showed both a primary and a secondary bar. The profiles measured in December showed only a single bar, with no trace of the inner bar. This difference is due to the varying weather and sea conditions described below.

The DELTA 93/94 measurements include simultaneous time series of waves, velocities and sediment concentrations from the surf zone of this



Figures 1 and 2: Map of the Ebro Delta showing the Trabucador studied area (P11), and the P11 bathymetry for 26/May/93, respectively.

microtidal barred beach, during calm and storm conditions. The main characteristics of the incident wave field were measured by means of a video camera (*VTR*), a directional wave rider (*DWR*) placed just in front of the Trabucador site, (1500 m offshore at 7 m water depth) and a X-band radar.

In the December measurements, in addition to the *DWR*, a conductivity type wave gauge (*WG*) was placed on a movable "sledge" and used to measure surf zone wave transformation. The vertical structure of the velocity field was measured by means of six electromagnetic current meters (*EMCM*) deployed in the vertical pole of the sledge. Suspended sediment concentrations were measured with three optical back-scatter sensors (*OBS*) and the time averaged suspended sediment transport was measured by means of two portable sediment traps (*PST*). These sediment transport measurements will not be discussed in here.

During the experiments video images were recorded in a S-VHS system. The BW video camera was placed in a waterproof housing at 20 m above the sea surface by means of a crane. Several fiducial points were marked with white flags both at the coastline and 60 m offshore. An elevation view, with the shore details, the equipment and the camera position is shown in figure 3. The height and orientation of the camera could be changed by means of the crane controls. Two types of video images were collected, viz. frontal and lateral views of the shoreline. The frontal imaged area ranges from the beach to the horizon in cross-shore direction (with an effectively resolvable area from the shoreline to the outer bar -200m-). In the longshore direction the images cover 150 m along the shoreline and 300 m along the inner bar (50 m from the shoreline). The most detailed measurements were restricted to the points inside the fiducial points, where the camera distortion was lower.

Quantitative information from the video images is accomplished using the *DigImage* video processing system, and an arithmetic frame grabber (*DT2861*)

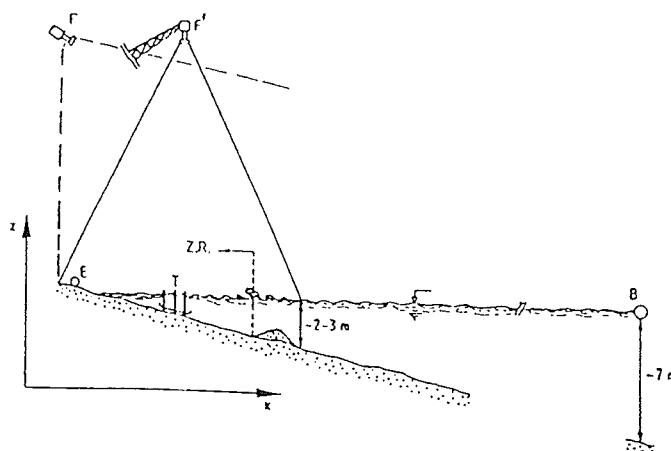


Figure 3.: A sketch of the area and equipment: E: measurement station, T: sledge with EMCM, OBS, PST and WG, B: DWR, F: video camera.

on an IBM compatible computer, which allows a resolution of 512 by 512 pixels and 256 grey levels. Images can be digitally enhanced to stretch the contrast and filter "noise" before analysis. The video may be controlled by the computer, allowing, remote control of the processing.

The images were corrected for optical deformations due to camera angle and lens distortion. World coordinates are assigned to known points marked in the video image and pixel values may be easily converted to real calibrated coordinates. The resolution in frontal view image pixels is less than 0.4 m in the cross-shore direction, and 0.1-0.4 m in the longshore direction up to the outer bar. The video recordings show clearly areas of breaking-induced turbulence and foam, which correspond to the swash zone and to first and second breaklines. See figure 4 for a false colour sequence of time averaged (equivalent to a long exposure) and instantaneous images of the area. The first bar and the swash are seen as dark bands, and contour lines are also shown.

The analyzed video series correspond to the three days indicated below, displaying fairly different sea conditions:

- i) a post storm situation with double peaked waves coming from NE during May 26 1993. The spectrum corresponding to the time of video measurements is shown in figure 5a. The observed peaks of the spectrum were $T_{p1} = 13$ s and $T_{p2} = 3$ s. The evolution of wave heights during the day is shown in figure 6a. The storm which developed during the previous day reached a maximum in wave height in the early hours of the morning $H_{1/3} = 1.10$ m. At the time of the video measurements $H_{1/3}$ was 0.5 m.
- ii) a calm situation with waves coming from SE during December 15 1993. The spectra of low energy incident waves shows two close peaks corresponding to $T_{p1} = 8.3$ s and $T_{p2} = 6.6$ s ($H_{1/3} = 0.25$ m according to DWR data). See figure 5b for the wave spectrum and figure 6b for the evolution of the $H_{1/3}$. An arrow indicates the time of detailed

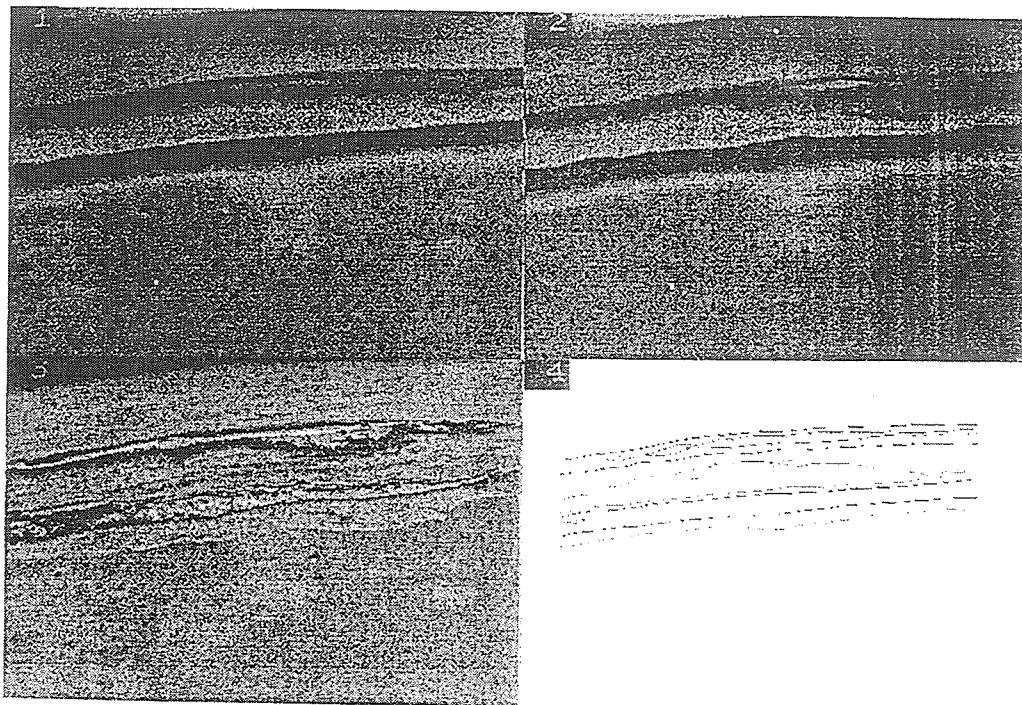


Figure 4: (1-2) Averaged images of the surf-zone, (3) single frame and (4) isolines of intensity.

measurements.

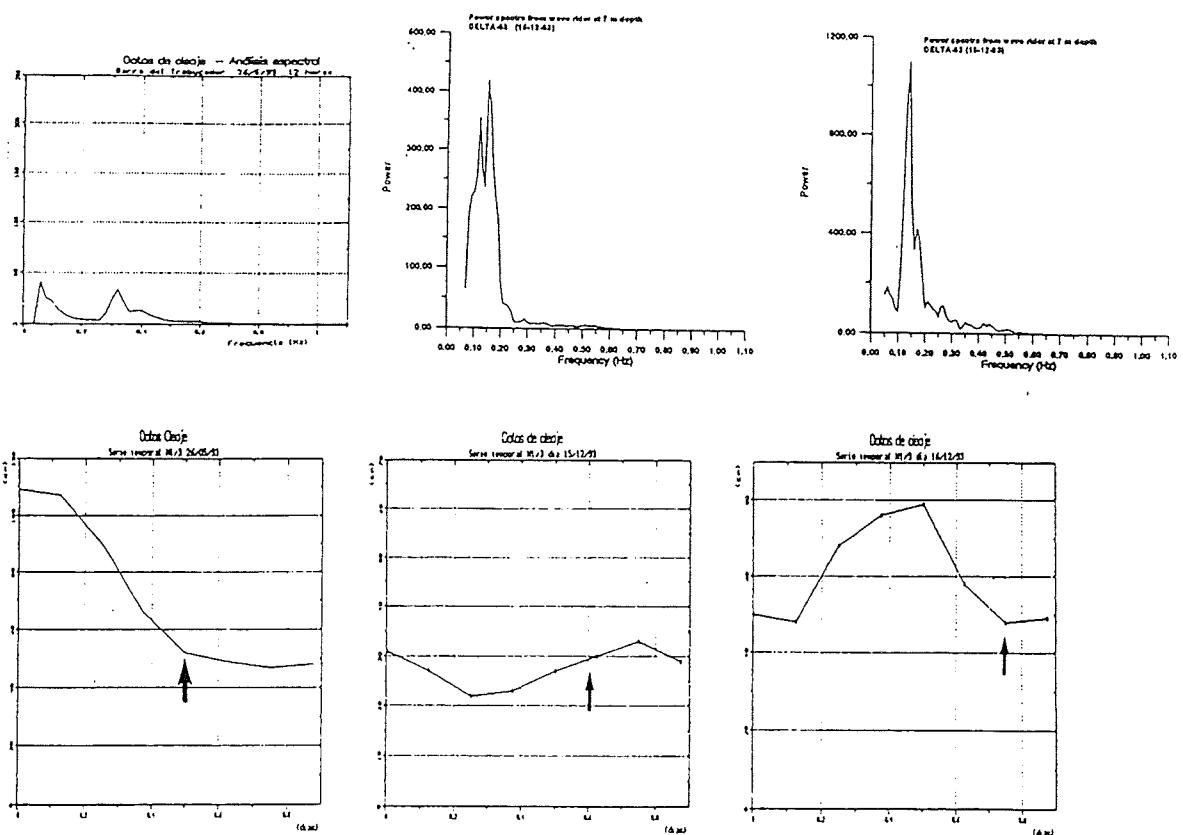
- iii) a moderate situation storm with waves coming from SE during December 16 1993. The spectra shows a dominant peak at 7.1 s with lower energy signatures corresponding to a low frequency oscillation ($T=18.3$ s) and to a higher wave frequency with period of $T=5.1$ s, see figure 5c. The wave height evolution during the day is shown in figure 6c where the passage of the storm produce an increase of $H_{1/3}$ between 0.50 - 0.80 m. The video and WG data were obtained around 16 h GMT (shown with an arrow). The $H_{1/3}$ during the experiment was 0.6 m.

Spectral analysis of VTR/WG/DWR time series

Three types of time series were used in the spectral analysis: intensities from video images (VTR), water level oscillations from the WG and the DWR. The sampling intervals were respectively 0.20-0.60-1.64 s, 0.25 and 0.78 s. The length of the time series corresponding to video images were 100-300-840, and 1200 s for both WG and DWR.

The time series were detrended using a simple linear regression tapered with a Welch window prior to applying FFT. The raw spectra have been calculated over series with a minimum of 512 points grouped in subseries of 128 records (50 % overlapped). After that a high pass filter with a folding frequency of 0.000001 Hz has been used to eliminate the undesired frequencies. The associated spectral variance was 14 %.

The intermediate frequency wind-wave components, and the infragravity



Figures 5 and 6: Measured wave spectra and $H_{1/3}$ evolution respectively for the three selected days: 26 May, 15 and 16 December 1993.

and shear instabilities were investigated. Due to the short time series used in the video data (up to 15 min), the low frequency ranges had to be handled with extreme caution.

FIELD RESULTS

The use of time series of horizontal and vertical pixel intensities allowed to measure wave frequencies, as well as the longshore component of the velocity thanks to the traces of advected surf (foam). In figure 7(1-4) an example of the time evolution (vertical) of the color coded reflected light intensities of a line is shown at four locations offshore.

Fast Fourier transform (FFT) methods applied to the digitized video images and to their correlations were used to detect the dominant wavenumbers and wave directions. Time averaged spatial images and time series of a transect (see figure 8) are seen to be convenient techniques for the characterization of wave fields. The relationship between light intensity, which has been the main parameter studied, and the surface elevation needs further study, but it is clear that for the non breaking waves, the angle between the wave surface, (bisecting the sun direction), and the video camera, will produce a maximum reflected intensity. This is also true for cloud covered skies. In addition, wave breaking,

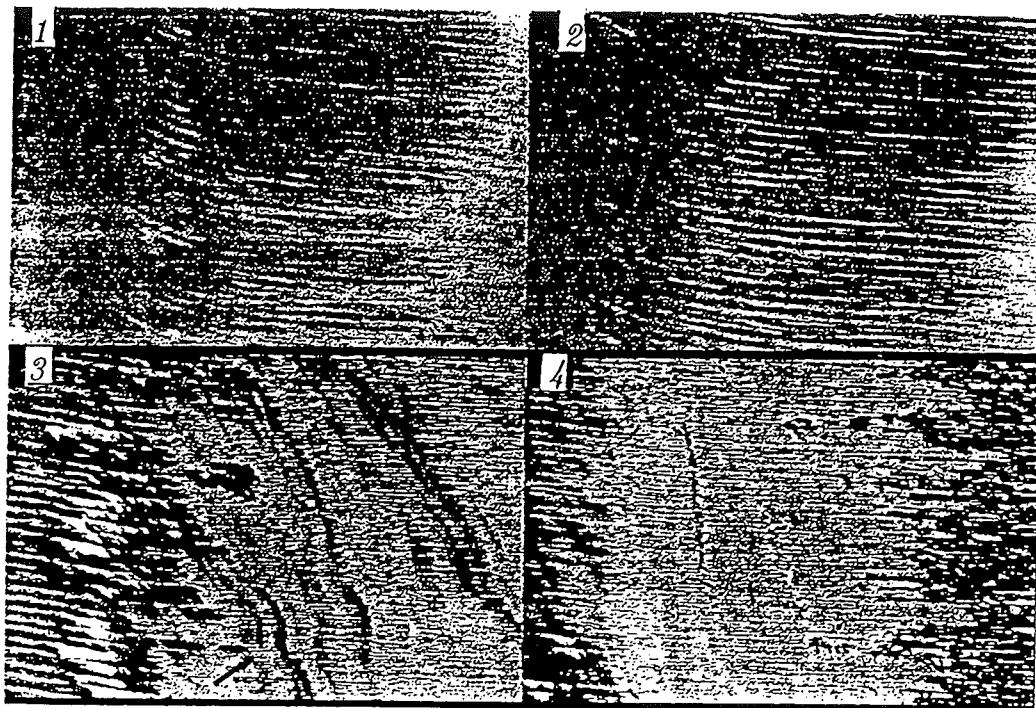


Figure 7: Time series of colour coded reflected light intensity showing the drift of surf. Light areas indicate wave breaking, (1) area behind the bar, (2) inside near the bar, (3) between the bar and the swash, (4) swash area. See in figure (3) the oscillations of the longshore current.

can be clearly seen and whitecaps may be easily traced.

Power spectra across-shore

Analysis of breaking and non breaking time series of 100, 300 and 840 s length and their intensity power spectra are presented as a function of cross-shore distance. These image spectra are then compared with *WG* and *DWR* spectra. In figure 9 the intensity spectra of four points near the *WG* structure are presented, together with the spectrum obtained from the *WG* data. The agreement, as seen in this figure, is very good.

i) 26/May/93: Four long time series of 300 s are presented in figure 10(a), and their respective spectra in figure 10(b). The intensity series are presented with an offset of 20 in the range 0-256 given by the digitizer resolution. The spectra from the longer series (including several 840 s series) are compared with low frequency shear waves obtained from the numerical model described below. The sites chosen were the outer bar, the inner bar, the trough and the swash zone. The dominant frequencies were: a low frequency oscillation with period of 77 s and a wave induced peak of period 6 s, which appeared in all positions. The *DWR* spectra for the incident wave field showed dominant waves of periods 13 s and 2 s. The incident wave groups appeared to merge, giving a dominant period of 6 s. At the swash zone the intensity variations are much larger, as seen in figure 11, and other significant periods are found at 19 s, 11 s and 7.7 s.

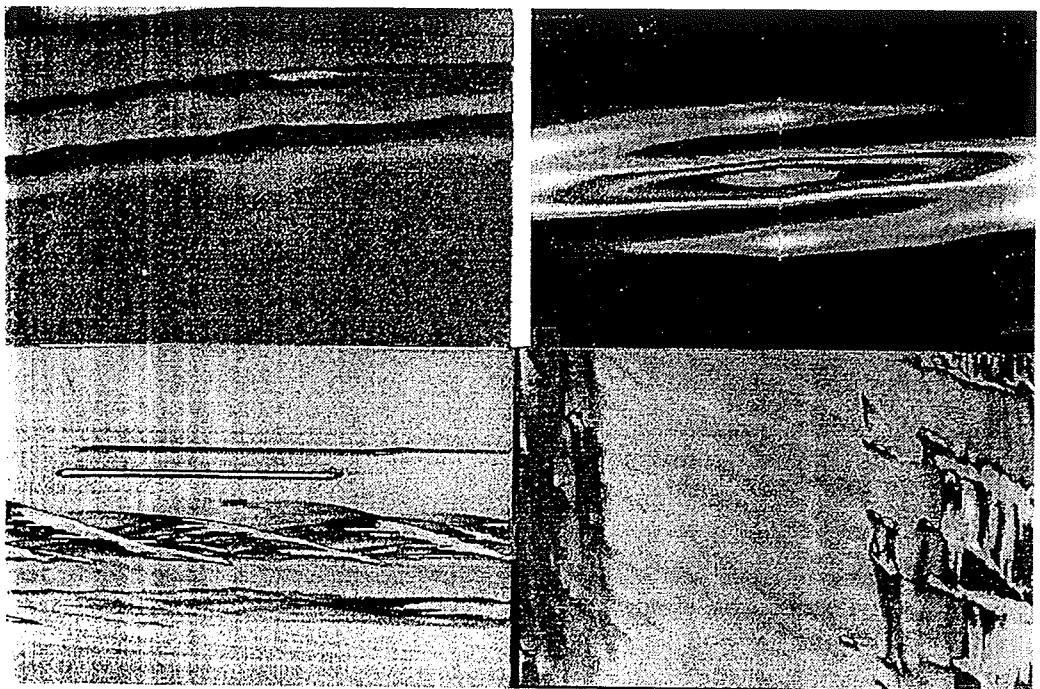


Figure 8: (Top/left) Colour coded intensity of a time averaged image showing the average surf zone width, (Top/right) Auto correlation function of the previous image showing the preferred directions, (Bottom/left) Time series of the central vertical line of the frame showed above showing period and direction of the incident waves, (Bottom/right) Time series of the central horizontal line. showing surface velocities across the surf zone.

ii) 15/December/93: The evolution of wave frequencies with cross-shore distance was investigated using 100s video intensity time series in order to resolve wave generated frequencies. The seven selected cross-shore positions are described in figure 11(a), and the agreement with the *DWR* was also good, measuring a period of 6.4 s from the video images, and a period of 6.6 from the *DWR* showed in figure 11(b). Other periods detected at the *DWR* were 8.3 s and 10.5 s. A transition from the 6.6 s period, (*DWR* dominant incident waves) to the recorded periods at the *WG* of 7.9 s and 2.8 s could be followed with the aid of the video images.

As mentioned above, the dominant waves at a position offshore, in the vicinity of the *DWR* have a period of 6.4 s. At the outer bar, where there is very little breaking, during calm conditions, the 6.4 s waves are maintained, but some period doubling occurs and a 12.8 s peak appears. In addition, waves of period 4.2 s are also generated near the outer bar. During these experiments, the position of the *WG* was just outside the surf zone and the video images near it show dominant periods of 6.6 s and 2.9 s just before to the surf zone. The observed periods are also 6.6 s and 2.9 s, with a new developing period of 4 s. There is some breaking at the surf zone which generates some new spectral peaks. Inside the surf zone, the dominant peak corresponds to 8.5 s. and there are smaller peaks corresponding to wave periods of 5.1 s and 3.6 s.

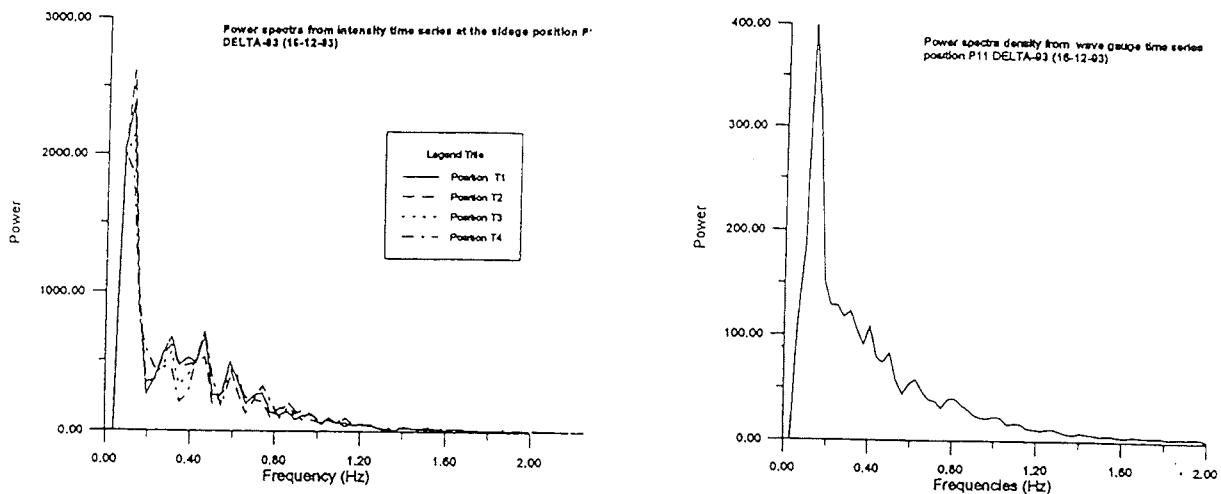


Figure 9: Comparison of spectra from WG data and video intensities at the same position.

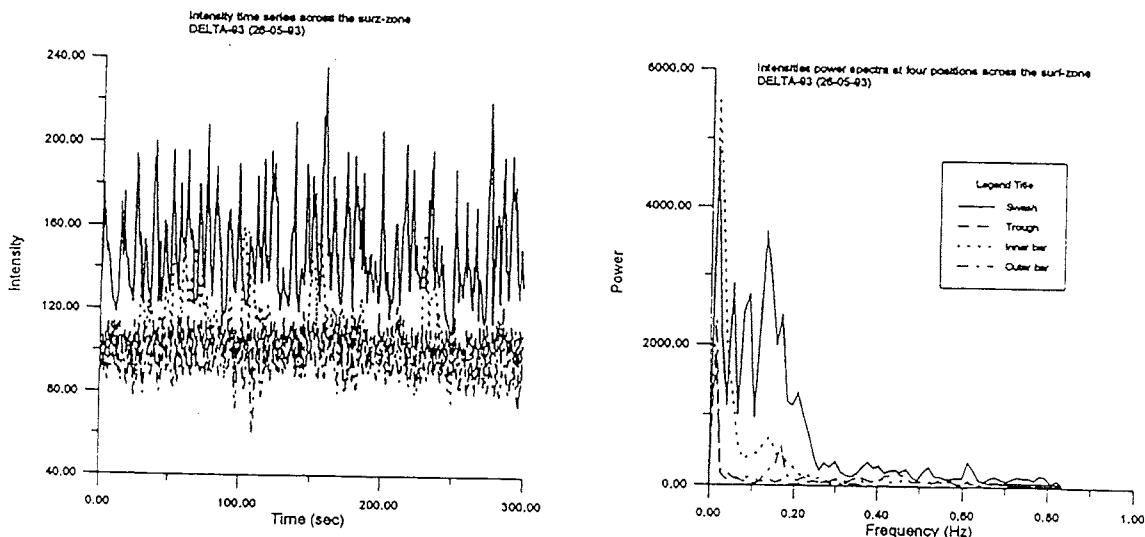


Figure 10: (a) Intensity time series, (b) Intensity spectra of four cross-shore positions.

It is interesting to note waves of period 8.5 s, which are close to some of the incident wave periods at the *DWR*. At the swash zone the dominant period is of 12.8 s, with a secondary one at 2.8 s, and at the shore line, the periods are 5.1 s and again 12.8 s.

The interpretation of this spectral cross-shore evolution is as follows: due to the low energy of the incident wave field, the dominant wave field interacts with the outer bar producing a reinforcement of every other wave. The intermediate 7.9 - 8.5 s waves appear only outside the surf zone and inside the trough, where the breaking distorts the periodicity, as may be seen in a video

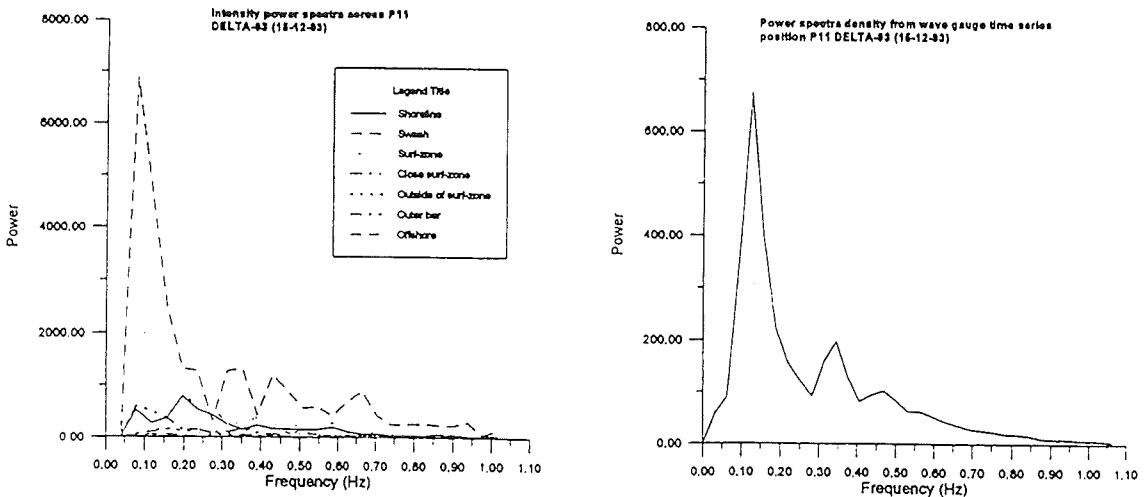


Figure 11: (a) Intensity spectra of seven cross-shore positions, (b) spectra from the WG.

image of a time evolution of a line inside the surf zone (figure 12). Finally the long (slow) waves ($T = 12.8$ s) break against the shore with some superimposed faster wave components.

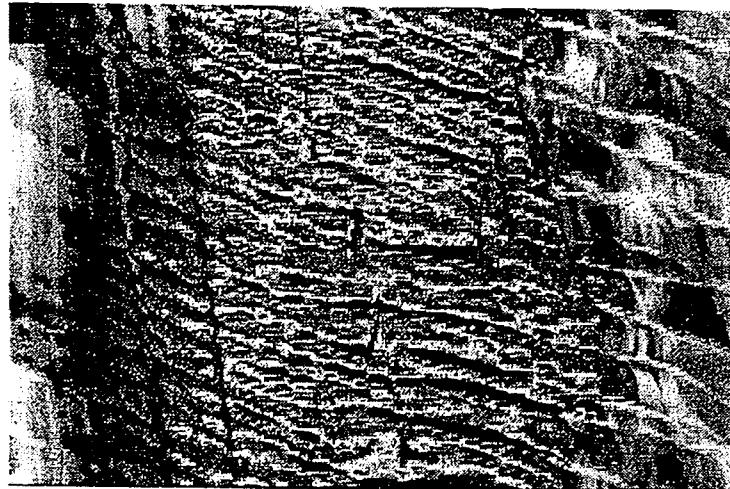


Figure 12: Intensity time serie at a horizontal line showing wave distortion across the surf zone.

iii) 16/December/93: The evolution of wave frequencies with cross-shore distance was investigated using 100s video intensity time series. The sites chosen are described in figure 13, where the spectra are also shown.

The agreement with the DWR was also good, and a transition from the

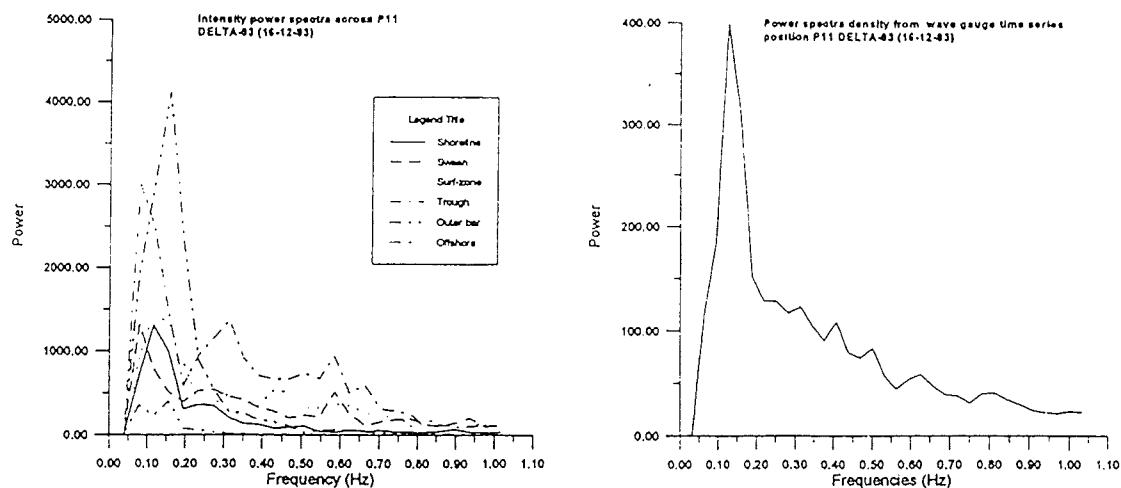


Figure 13: (a) Intensity spectra of six cross-shore positions,(b) spectra from the WG.

6.4 s period waves to the 8.0 s waves detected at the *WG* could be followed as waves approached the coastline. The offshore video spectra, (closer than the *DWR*) shows dominant periods of 1.8 s 6.4 s and 12.8 s , as in the previous day. The *DWR* during the time of video measurements showed periods of 5.8 s and 7.1 s, which are close enough to the 6.4 s. This period is seen at several locations, but not at the trough, where the *WG* was placed. The *WG* measurements show wave periods of 3.2 s and 8 s, just offshore the position where the *WG* video measurements showed periods of 1.7 s , 3.2 s and 12.8 s. Closer to the surf zone, periods of 2.3 s, 3.2 s and 8.5 s are detected. At the swash zone, the periods are 3.6 and 12.8, again a multiple of the offshore one, and at the shoreline 1.9 s , 4.2 s and 8.5 s periods are detected.

The main aim of the spectral analysis presented here for the December campaign is to show that much more spatial information may be quantitatively obtained at wave spatial and temporal ranges. The use of light intensity data in order to describe wave frequencies and their structure was used by Lippmann and Holman mostly for breaking waves, but due to the good resolution of the images, changes in the sea surface angle could also be detected with the present data. In order to justify the use of the video time series, a detailed comparison was made with the *WG* data and the video intensity series for the december campaign.

The measurements with longer video time series have not been as successful in revealing the infragravity wave range and the longer periodicities, mostly due to the lack of sufficiently long and steady measurements.

Dye dispersion measurements

Measurements of dye dispersion at different distances from the shore (inside the surf zone) have been used to obtain estimates for longshore current and turbulence characteristics, such as the mean Lagrangian trajectories, mean and r.m.s. velocity integral lengthscales, shape and anisotropy of blobs, etc.

The tracers were selected after field intercomparisons of different substances (fluoresceine, rhodamine, MnO_4K_2 , SO_4Ca and milk). The best tracer varies depending on weather conditions because of the difference of contrast between dye and marine water, but milk and fluoresceine were the best ones because of their good contrast and persistence. Figure 14 shows a time averaged image during 30 seconds of dye trajectory (20 gr of fluoresceine).

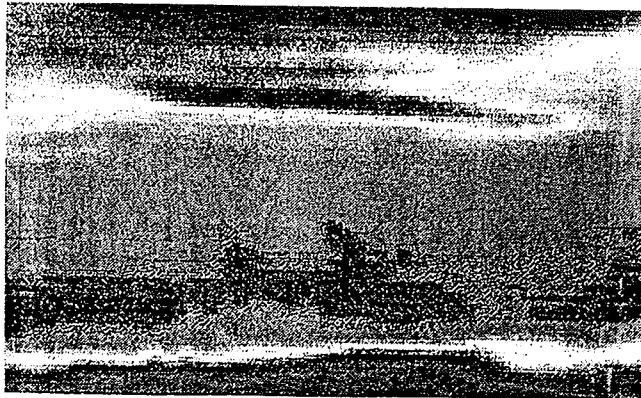


Figure 14: Average picture obtained integrating point video intensities during 30s as one of the dye blobs is released. The trajectory may be identified near the center of the image.

From dye dispersion measurements and from the evolution of intensity isolines, fractal measures of selfsimilarity ranges and of dominant scales are also obtained. The spatial and time evolving characteristics of the surface velocity fields, are used to complement the vertical velocity profiles obtained by means of electromagnetic current meters.

NUMERICAL MODEL RESULTS

Numerical longshore currents models have been used to predict the most relevant modes taking into account the measured boundary conditions. The dispersion relations and pattern of edge waves for the actual bathymetry and longshore current have been computed using the numerical method described in Falques and Irazo (1992). The steady longshore current profile has been computed with an incoming wave height of 0.46 m, and an incidence angle of 23.4° . Under the assumption of alongshore uniformity, the occurrence of shear instabilities of the longshore current has also been investigated by means of a numerical simulation. For this purpose, the basic current profile (Figure 15 c) and the lateral momentum diffusion distribution (Figure 15 b) have been obtained from the incident wave field applying a propagation and circulation model (Rivero and S.Arcilla, 1991) and the measured bathymetry (Figure 15 a).

The longshore current profile has two peaks: the strongest one near the shoreline with $V_m \simeq 0.46m/s$ and maximum backshear $f_s \simeq 0.08s^{-1}$ and the weaker one over the inner longshore bar with $V_m \simeq 0.13m/s$ and maximum backshear $f_s \simeq 0.0007s^{-1}$. Similarly, the eddy viscosity coefficient distribution has also two peaks of about $0.04m^2s^{-1}$. A constant drag coefficient of $c_d = 0.0015$ has been taken for bottom friction.

COASTAL DYNAMICS

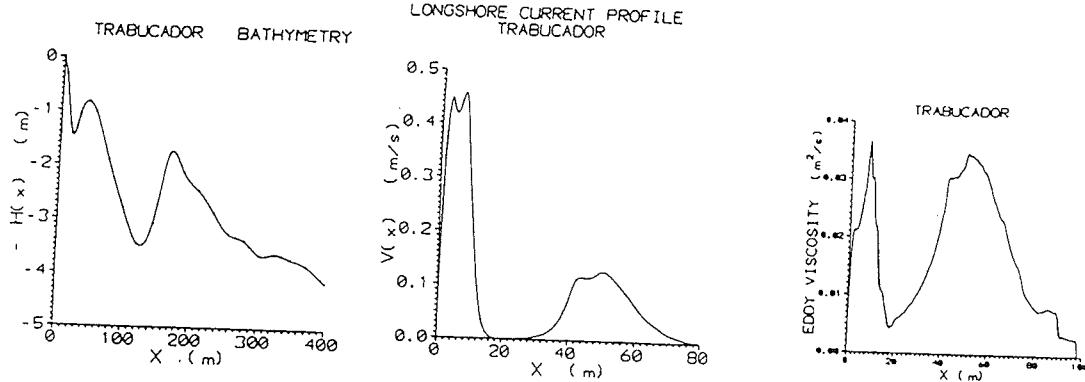


Figure 15: (a) Bathymetry, (b) eddy viscosity and (c) computed longshore velocity profiles at P11 considered in the shear instabilities simulation.

The shear instability analysis started from the shallow water equations

$$\frac{\partial v_i}{\partial t} + v_j v_{i,j} + g \eta_{,i} = -\frac{c_d}{h} |\vec{v}| v_i + \frac{1}{h} S_{ij,j} + \frac{1}{h} [\epsilon h (v_{i,j} + v_{j,i})]_{,j} \quad i = 1, 2 \quad (1)$$

$$\frac{\partial \eta}{\partial t} + [hv_j]_{,j} = 0 \quad (2)$$

following the approach of Falqués and Iranzo, 1994 (hereinafter FI94). A linear stability analysis has been performed by assuming perturbations with the form

$$e^{(\omega_r + i\omega_i)t} e^{iky} v'(\vec{x}),$$

where $k = 2\pi/\lambda$. The same spectral method of FI94 based on rational Chebyshev expansions has been used here. However, the present calculation uses bathymetry, current and eddy viscosity interpolated from the experimental data. The considered eddy viscosity coefficient, $\epsilon(x)$, has therefore a cross-shore variation.

Two linear unstable shear modes have been found. As it can be seen in Figures 16(a-b), the dominant one has a fastest growing wavelength about $\lambda = 31m$, a period $T = 104s$ and a growth rate $\omega_i = 0.006s^{-1}$. The other one has $\lambda = 70m$, $T = 1000s$ and $\omega_i = 0.0018s^{-1}$. Figure 16(c) shows the cross-shore structure of both modes.

Since the dominant mode is located near the shoreline it appears to be associated with the strongest current peak. On the other hand, the other mode is distributed in a wider region centered at the inner bar. Therefore, it is likely associated to the lowest current peak. Assuming this correspondence, both solutions agree quite well with the rough predictions for plane beach and inviscid flow in FI94. For instance, the phase speed to peak longshore current ratio, is $c_1/V_{m1} = 0.65$ for the first mode and $c_2/V_{m2} = 0.54$ for the second one. Further,

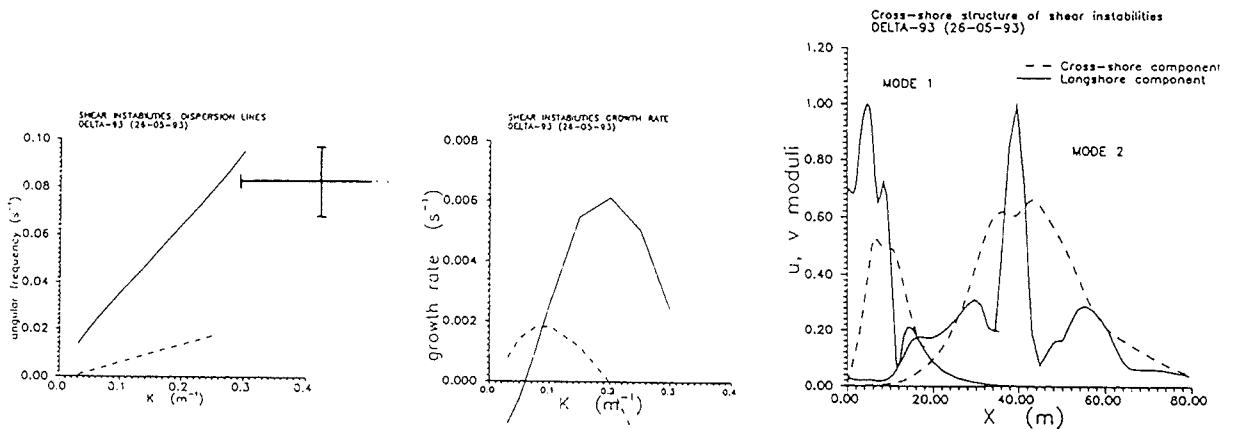


Figure 16: Linear unstable shear modes.

the wavelength to current width ratio is about 1.7 for the first mode and 2.3 for the second one. According to the estimates for inviscid flow in FI94, growth rates should be around $\omega_i \sim 0.1f_s$. For the second mode this would give 0.008 s^{-1} whereas the present calculation gives 0.006 s^{-1} , which shows a small decrease due to dissipation. However, for the second mode the inviscid estimate gives 0.0007 s^{-1} and the present calculation (which takes dissipation into account) gives 0.0018 s^{-1} . Dissipation seems to de-stabilize the flow in this case. Which is in line with some recent calculations for a more general situation where it was found that some eddy viscosity distributions may in some cases destabilize the basic flow.

In order to estimate dispersion relations from the field measurements, two methods were used: the first one was to consider the low frequency amplitude spectrum peaks as indications of slow sea surface undulations. The estimates range between 70 s and 84 s. A clearer indication of the shear instability may be the recorded oscillations in the longshore current, in which dye (milk and fluorescein) blobs sometimes showed large mean velocity oscillations as noted in figure 17 (a). In this figure the evolution of dye spots may be seen for two days with opposing longshore currents.

Quantitative measurements for the period of oscillation of the longshore current can be seen in figure 7(3). The oscillations of the longshore current on the 26th of May were of the order of 100 s. The lengthscales corresponding to the largest waves obtained by means of spatial fourier transforms in the trough lie between 10 and 20 m, which give an estimate of T and λ . These data are also plotted for comparison in figure 16 (c), together with the dispersion relation for the 1st and 2nd shear instability modes.

CONCLUSIONS

Digitized video images of field events seems a promising technique for

COASTAL DYNAMICS

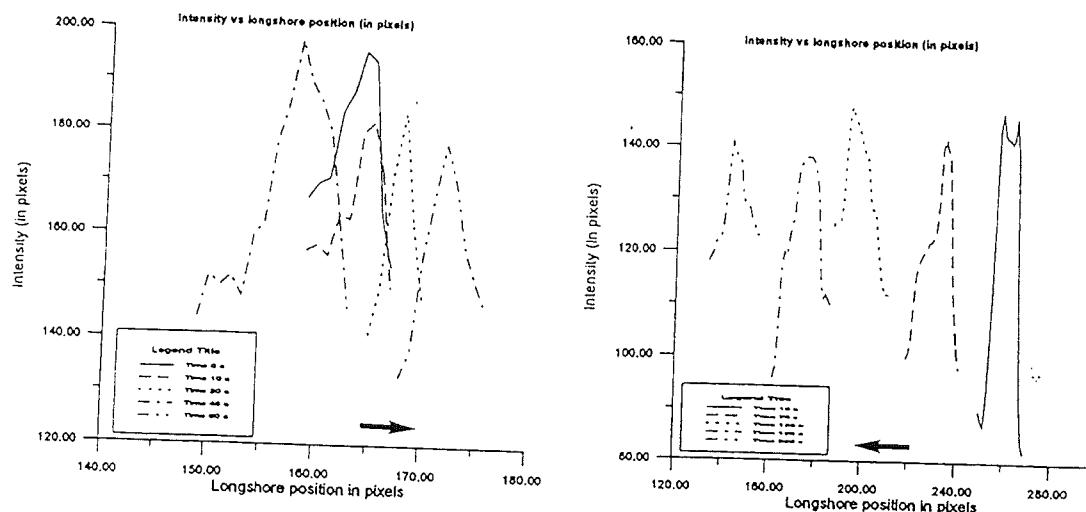


Figure 17: Blob evolution from video images, (a) 26/May/93 and (b) 15/December/93.

extended quantitative measurements of sea surface instabilities. The agreement between Video spectra and *DWR* and *WG* is qualitatively good and allows to describe in more detail the global characteristics of the surf zone.

The evolution of wave characteristics as they interact with the surf zone may be followed in detail. The outer and the inner bars act as a filter to some frequencies that reappear near the shoreline or at the trough, the variation of frequencies being clearer for the more energetic sea conditions.

The non-linear effect of the surf zone is apparent in enhanced images, such as figure 14. There is a process of wave dislocations, between the surf and swash zones that needs further study. This is also reflected in the changes in dominant wave period as the waves approach the coastline, from measurement with image analysis. The dynamic response of the surf zone to different incoming wave fields may be, thus, investigated in detail.

The numerical model shows some agreement in time scales for the dispersion relationship, but the spatial scales are somewhat lower than predicted. Considering that the model is linear and several approximations (e.g. constant bottom drag) have been used, there seems to be ground for improvement. In future models other important effects, like variable friction should be taken into account.

The measured longshore current at the position where the dye blobs were released is of 0.5 ms^{-1} , which agrees well with the predicted maximum longshore currents, see figure 17. The detailed longshore velocity distribution needs further comparison with field data. In the December campaign, several series of simultaneous blobs were released at different cross-shore locations and further work will include comparisons between these measurements and the numerical models.

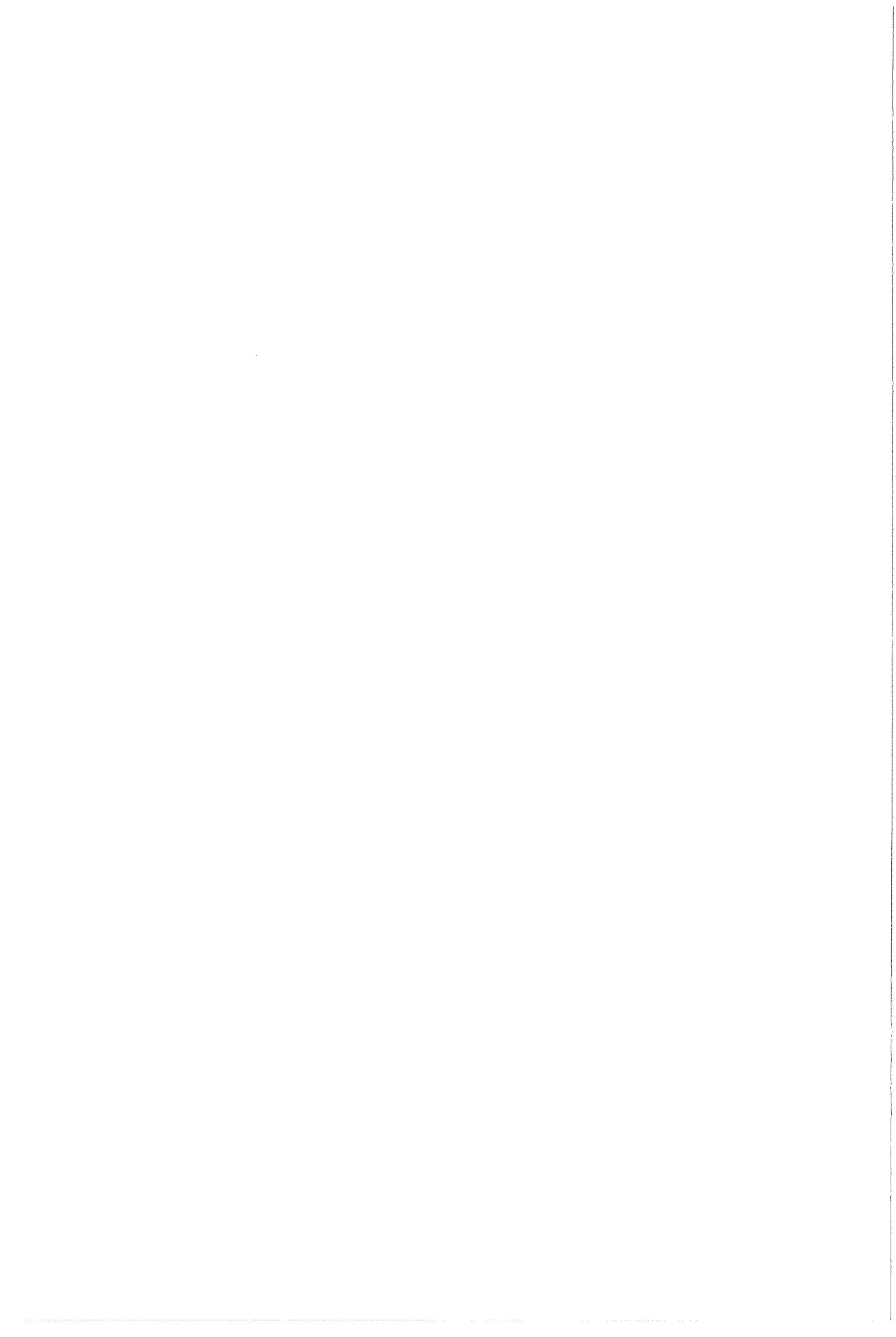
ACKNOWLEDGEMENTS

This work was undertaken as part of the Surf Zone Research project of LIM-UPC. It was funded jointly by the Programa de Clima Marítimo PCM-MOPTMA and the Ministerio de E. y C. (DGICYT) of Spain, with some support from the MAST-II Euromarge contract of the EU. We want to thank the research staff of LIM-UPC, particularly to J. Gomez, F. Rivero, J. Sospedra and all those who endured the field work. Thanks are also due to G. Voulgaris and M.A. Tenorio from Southampton University for their OBS and radar, and research staff of DFA-UPC, particularly to V. Iranzo and D. Crespo.

REFERENCES

- Falqués,A. and Iranzo,V., 1992. "Edge waves on a longshore shear flow", *Physics Fluids A 4 (10)*, 2169-2190.
- Falqués,A. and Iranzo,V., 1994. "Numerical Simulation of Vorticity Waves in the near-shore", *J.Geophys Res.* 99, (C1), 825-841 (1994).
- Hesselink,L., 1988. "Digital Image processing in flow visualization" *Ann. Rev. Fluid Mech.*, 20, 421-485.
- Holland,K.; Holman,R. and Sallenger,A., 1991. "Estimation of overwash bore velocities using video techniques" *Coastal sediments ASCE*, 489-497.
- Holman,R. and Sallenger,A., 1986. "High-energy nearshore processes" *EOS Trans. Americ. Geoph. Union*, December 9, 1369-1371.
- Holman,R. and Lippmann,T., 1987. "Remote sensing of nearshore bar systems - making morphology visible" *Coastal sediments ASCE*, 929-944.
- Kuriyama,Y. and Ozaki,Y., 1993. "Longshore current distribution on a bar-trough beach" Report of Port and Harbour Research Institute. Japan. Vol. 32. 3, 3 - 37.
- Lippmann,T. and Holman,R., 1989. "Quantification of sand bar morphology: a video technique based on a wave dissipation", *J.Geophys.Res.* Vol 94, No C1, 995-1011.
- Lippmann,T. and Holman,R., 1991. "Phase speed and angle of breaking waves measured with video techniques" *Coastal sediments ASCE*, 542-556.
- Lippmann,T. and Holman,R., 1992. "Wave group modulations in cross-shore breaking patterns", Proc. I.C.C.E., ASCE, 918-931.
- Lippmann,T., Holman,R. and Hathaway, K., 1993. "Episodic, nonstationary behavior of a double bar system at Duck, N.C., USA, 1986-1991" *Jour. of Coastal Reseach, SI,15*, 49-75.
- Maresca,J. and Seibel,E., 1976. "Terrestrial photogrammetric measurements of breaking waves and longshore currents in the nearshore zone", Proc. I.C.C.E., ASCE, 681-700.
- Sonu,C., 1969. "Tethered balloon for study of coastal dynamics", Amer. Soc. Photogram., Tech. Rep., 66, 91-103.
- Thornton,E.B., 1970.- "Variation of longshore current across the surf zone" Proc. I.C.C.E., ASCE, . 12. , 291-308.
- Sasaki,T., Horikawa,K. and Hotta,S., 1976. "Nearshore current on a gently sloping beach" Proc. I.C.C.E., ASCE, . 36., 626-644.
- Rivero,F. and Sánchez Arcilla,A., 1991. "Quasi-3D nearshore current modelling", *Computer Modelling in Ocean Engineering 91*, Balkema, 171-178.
- Walton,T., 1993. "Ocean City, Maryland, wave runup study" *Jour. of Coastal Reseach, 9,1*, 1-10.





A2. Comparación entre Mediciones y Teorías del Flujo Oscilatorio en la Zona de Rompientes.

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Comparación entre mediciones y teorías para el flujo oscilatorio en la zona de rompientes

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Se presentan resultados numéricos y experimentales del estudio del flujo oscilatorio en la zona de rompientes. Los experimentales corresponden a medidas de campo realizadas durante las campañas DELTA'93 en el delta del río Ebro, España. Estas medidas incluyen la realización de varias pruebas en la zona de rompientes con alta resolución en el perfil vertical. Las velocidades orbitales medidas son comparadas con las principales teorías de olas para aguas someras.

Palabras clave: hidrodinámica costera, medidas de campo, olas, flujo oscilatorio, modelado numérico, zona de rompientes.

Introducción

La necesidad de cuantificar con precisión las velocidades orbitales inducidas por el oleaje, se basa en el importante papel que éstas juegan tanto en aspectos prácticos de la ingeniería costera, como en el cálculo del transporte de sedimentos y de las fuerzas hidrodinámicas sobre estructuras, o en aspectos teóricos, como suministrar las entradas en modelos numéricos para el cálculo de tensiones de fondo, términos impulsores de oleaje, etcétera.

Existen numerosas comparaciones entre las medidas del flujo oscilatorio inducido por el oleaje y las diversas teorías disponibles. Estas comparaciones van desde el trabajo pionero de Le Méhauté *et al.* (1968) a otros más recientes como los de Kirgöz (1986) o Graw (1994). La gran mayoría de estos trabajos han utilizado datos de laboratorio sin considerar oleaje en rompiente. En cambio, las comparaciones que consideran el caso particular de la zona de rompientes (ZR) son menos frecuentes. Entre los experimentos de laboratorio que consideran la ZR, uno de los primeros fue el realizado por Adeymo (1968). Otros más recientes como los de Stive (1980) o Koyama e Iwata (1986) comparan medidas mediante ALD (anemómetros láser) con las teorías Cnoidal y de Dean, respectivamente.

Si bien existen varios antecedentes de medidas directas en la ZR como las realizadas en campo por Thornton (1968), Steer (1972), Fürböter y Büsching (1974), Thornton y Richardson (1974), Bub (1974), Galvin (1975), Isobe (1981) o Leont'ev (1988), todas padecen una insuficiente resolución vertical ya que no superan los tres puntos de medición en la columna de agua.

Un extenso análisis de las medidas realizadas en la década de los años 70 en las playas de California, Estados Unidos de América, es presentado por Thornton *et al.* (1976), quienes mencionan discrepancias de un 20% y hasta del 100% entre las medidas disponibles y los valores obtenidos con teoría lineal de Airy (ver punto siguiente).

Teorías de olas

No existe aún una teoría ideal que represente adecuadamente a las olas en todo el rango de profundidades relativas, y menos aún el caso de olas en rompiente (caso de la ZR).

Sin embargo la ingeniería hidráulica y costera requiere la estimación de las velocidades orbitales en la ZR para numerosas aplicaciones (*e.g.* el transporte de sedimentos es más intenso en esta zona o se requiere la evaluación de esfuerzos hidrodinámicos en tuberías, pilas, etc.).

En consecuencia, para el cálculo del flujo oscilatorio en la ZR es frecuente el uso de diversas teorías que, por haber sido desarrolladas para condiciones más simples o diferentes, están fuera de su estricto rango de validez.

Las teorías de olas se basan en la solución de un sistema de ecuaciones definido en general por la ecuación de conservación de masa, los componentes u y w , $-(2DV)$, de la ecuación de conservación del *momentum* y la definición de la rotación de una partícula de fluido. Este sistema requiere, además, tres condiciones de contorno, dos cinemáticas para el fondo y la superficie libre, y una tercera (dinámica) para la presión (Dean y Dalrymple, 1984).

De acuerdo a las hipótesis particulares y al método de solución del sistema mencionado las teorías de olas se pueden clasificar en tres grupos:

- Irrotacionales
- Rotacionales
- Modificadas.

En el primer grupo, se encuentran las de tipo *Stokes* que expanden en serie de Taylor el potencial de velocidad Φ , la superficie libre y la celeridad. Estas teorías son válidas, en general, para aguas profundas. De este subgrupo se ha evaluado la expresión de 1^{er} orden que coincide con la teoría lineal de Airy por su simplicidad y ser un valor de referencia ampliamente utilizado. Bajo crestas y valles tiene la siguiente forma:

$$|u_{\text{sw}}^{(1)}| = \pi H/T \cosh [k(z+d)]/\operatorname{senh}(kd) \quad (1)$$

donde H es la altura de ola, T es el periodo del oleaje, z la coordenada vertical, k el número de onda ($2\pi/\lambda$), λ es la longitud de onda y d la profundidad. Estas teorías asumen $H/\lambda \ll 1$.

Un segundo tipo de teorías irrotacionales lo constituyen las denominadas *cnoidales* que asumen simultáneamente d/λ y $H/d \ll 1$, por lo que son válidas solamente para aguas poco profundas. De este segundo subgrupo se ha evaluado la expresión de segundo orden propuesta por Hardy y Kraus (1987):

$$u_{\text{cn}}^{(2)} = C [(B_{00} + B_{10} cn^2 \theta + B_{20} cn^4 \theta) - \\ \frac{1}{2} ((z+d)/d)^2 (B_{01} + B_{11} cn^2 \theta + B_{21} cn^4 \theta)] \quad (2)$$

donde C es la celeridad, (λ/T) , B_{ij} son coeficientes de unas funciones de integrales elípticas completas de primera y segunda clases y cn son funciones elípticas jacobianas de la fase.

El tercer tipo de teorías irrotacionales se denominan *numéricas* debido a que emplean directamente series de Fourier en la solución de la ecuación de Laplace: $\nabla^2 \Phi = 0$. Este tipo de soluciones ha sido utilizado por Dean (1965) y se conoce como Función de Corriente de Dean, (de la que se ha evaluado una variante simplificada descrita en el tercer grupo de teorías). La teoría numérica evaluada es la aproximación de Fourier de alto orden presentada por Rienecker y Fenton (1981), que para la velocidad orbital bajo cresta tiene la siguiente expresión:

$$u_{\text{iou}}^{(2)} + = C + B_0 + k \sum_i^N j B_i \cosh(jkz)/\cosh(jkd) \quad (3)$$

donde el supraíndice + indica que se trata de la velocidad orbital bajo la cresta, B_0 y B_i son coeficientes constantes para cada tipo de oleaje. De acuerdo a estudios previos este tercer subgrupo de teorías tiene validez en un rango de calados o profundidades más amplio que los dos anteriores.

El segundo grupo de teorías de olas, como ya se mencionó, es el denominado *rotacionales* dentro del que se encuentran las propuestas por Van Hijum (1975), o Mejlhede (1975). El grado de rotacionalidad que una teoría puede contener es variable, como ha demostrado Bleach (1982) para el caso de la teoría *vocoidal*. En el presente trabajo se han evaluado tres teorías de este grupo:

- La *de ondas en aguas someras* (o *shallow-water waves*, SWT) presentada por Svendsen (1984).
- La *vocoidal* propuesta por Swart y Loubser (1978) y su generalización para fondo inclinado denominada *covocoidal* de Swart y Crowley (1988), cuyas expresiones respectivas tienen la siguiente forma:

$$u_{\text{swt}+1} = C \eta_{cr}/d \quad (4.1)$$

$$u_{\text{swt}+2} = C \eta_{cr}/(d+\eta_{cr}) \quad (4.2)$$

$$u_{\text{swt}+3} = C [\eta_{cr}/d - (\eta_{cr}/d)^2] \quad (4.3)$$

$$u_{\text{swt}+4} = C' \eta_{cr}/(d+\eta_{cr}) \quad (4.4)$$

$$u_{\text{swt}-} = C \eta_{cr}/d \quad (4.5)$$

$$u_{\text{voc}}^{(2)} = \{C \eta M(x) k \cosh[M(x) kz]\} / \{\operatorname{senh}[M(x) k(d+\eta)]\} \quad (5)$$

$$u_{\text{cov}}^{(2)} = u_{\text{voc}}^{(2)} + q_a/C (d+\eta) \quad (6)$$

donde los supraíndices + o - indican que se trata de velocidades orbitales bajo la cresta o los valles respectivamente, C' es la celeridad corregida como

$\sqrt{g(d+\eta)}$, $M(x)$ es el denominado parámetro de velocidad orbital, función de H/d , λ/d y x/λ ; q_α es el flujo másico debido al fondo inclinado, función de H/d , T y la pendiente del fondo: $\tan(\alpha)$. El parámetro $M(x)$ se encuentra tabulado o puede obtenerse mediante expresiones simples, ajustadas empíricamente y disponibles en el trabajo de Swart y Crowley (1988).

- La de *Modificadas* está constituida por simplificaciones y/o modificaciones de los dos grupos anteriores. Entre las más conocidas se encuentran: la modificación empírica a la T . de Airy propuesta por Goda (1964), la simplificación de la T . *cnoidal* presentada por Van Huijum en 1972 (Swart y Loubser, 1978), o la simplificación a la Función de Corriente de Dean denominada *Función de Transferencia Modificada*, FTM, propuesta por Koyama e Iwata (1986). De este grupo se ha evaluado esta última teoría mediante las siguientes expresiones:

$$U_{lm^{(z)}}+ = 2\pi/T \cosh(kz)/\{\operatorname{senh}[k(d+\eta_{cr}(1-z/(d+\eta_{cr})))]\}\eta_{cr} \quad (7.1)$$

$$U_{lm^{(z)}}- = 2\pi/T \cosh(kz)/\operatorname{senh}(kd)\eta_{cr} \quad (7.2)$$

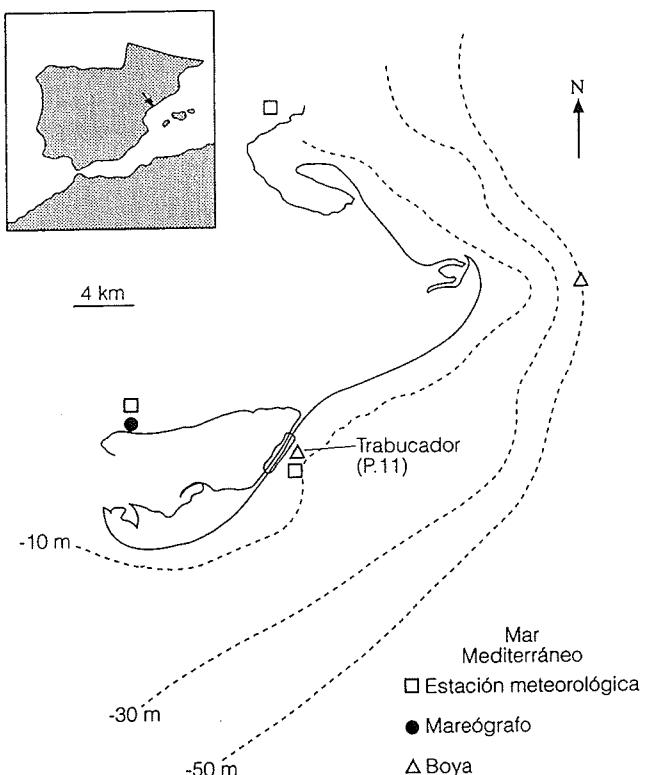
En este trabajo se han considerado las siete teorías ya mencionadas de uso frecuente utilizadas en la zona de rompientes, cubriendo los tres tipos posibles de aproximación al problema. Un resumen de las teorías, grados de libertad necesarios y fuente bibliográfica se muestra en el cuadro 1.

Estas teorías tienen distintos rangos de validez, hipótesis y grados de libertad (ver referencias). De acuerdo a estas características se ha evaluado su comportamiento utilizando como entradas los siguientes datos obtenidos durante los experimentos: profundidad d , periodo T , altura de ola H , distancia del fondo

1. Teorías de olas utilizadas en la zona de rompiente

Teoría	Datos (Gr. de Libertad)	Referencia
1.- Lineal de Airy	d, T, H, z, θ	Wiegel (1964)
2.- de Fourier (alto orden)	d, T, H, z, θ	Rienecker y Fenton (1981)
3.- Cnoidal (2º orden)	d, T, H, z, θ	Hardy y Kraus (1987)
4.- SWT ₁₄	$d, T, \eta_{cr}, \eta_{tr}$	Svendsen '84
5.- Tipo Dean (FTM)	$d, T, z, \theta, \eta_{cr}, \eta_{tr}, \eta_{lcr}, \eta_{ltr}$	Koyama e Iwata (1986)
6.- Vocoidal	d, T, H, z, θ	Swart '78 / Hamm, et al. '92
7.- Covocoidal	$d, T, H, z, \theta, \tg \alpha$	Swart y Crowley (1988)

1. Área del delta del Ebro y sitio de medición: P11 en la barra del Trabucador



z , fase θ , distancia entre el nivel medio y las crestas o valles η_{cr}, η_{tr} y la pendiente de fondo $\tg \alpha$.

Experimentos de campo en el delta del río Ebro

Los experimentos de campo se realizaron en la costa mediterránea, en la barra del Trabucador en el delta del río Ebro (ilustración 1), entre el 13 y 17 de diciembre de 1993. Esta playa fue seleccionada por su geometría quasi-uniforme longitudinalmente y la disponibilidad de información previamente obtenida por el grupo de Laboratorio de Ingeniería Marítima-Universidad Politécnica de Cataluña, LIM-UPC.

El trabajo experimental incluyó la medición simultánea de numerosas variables tales como altura, dirección y periodo del oleaje incidente, fuera y dentro de la ZR, mediante una boya direccional (dwr) y un sensor de altura (wg) combinado con filmaciones de video. El campo de velocidades se midió mediante correntímetros electromagnéticos (cem) y filmación en video de trazadores.

El posterior tratamiento digital de las imágenes de los trazadores permitió estudiar la dispersión de contaminantes pasivos. Las mediciones incluyeron también

2. Condiciones experimentales medidas

Prueba núm.	Distancia a la orilla (m)	d (m)	T _p (s)	Hrms (m)	H _{1/3} (m)	U orb ^{im} (m/s)
5	38.9	1.29	7	0.47	0.71	0.61
6	24.2	0.80	7	0.38	0.55	0.57
7	16.1	0.70	8	0.31	0.46	0.53
8	44.5	1.34	7	0.41	0.61	0.44
9	30.8	0.71	7	0.40	0.58	0.71
10	25.0	0.68	7	0.33	0.47	0.51
11	20.5	0.60	8	0.27	0.41	0.47
12	11.0	0.38	8	0.12	0.27	0.52

el transporte de sedimentos en suspensión mediante trampas y sensores ópticos (*obs*), y la batimetría al inicio y al final de la campaña.

El cuadro 2 muestra el número de prueba y un resumen de las condiciones experimentales encontradas (coordenada perpendicular a la costa, calado medio, periodo del pico espectral, alturas de ola y velocidad orbital) el 16 de diciembre de 1993 durante un estado de mar posterior a un temporal de intensidad media. Las pruebas 5-7 se efectuaron durante la mañana, con un estado de mar quasi-estacionario, mientras que las pruebas 8-12 se midieron por la tarde, con un oleaje decreciente en energía. Más información sobre los experimentos realizados durante la campaña DELTA'93 y su modelado hidrodinámico pueden verse en Rodríguez *et al.* (1994).

En este trabajo se analizan ocho de las 12 pruebas medidas durante los experimentos DELTA'93. Las pruebas seleccionadas corresponden al 16 de diciembre de 1993, día en que se presentó el oleaje de mayor energía.

Medidas en la zona de rompientes

Las medidas dentro de la ZR se obtuvieron mediante un trineo en el que se colocó diverso instrumental (ilustración 2). Las series de velocidad se obtuvieron con 6 *cem* bidimensionales (tipo Delft-S) situados en una barra vertical a 10, 20, 30, 40, 60 y 80 cm del fondo. La frecuencia de muestreo fue de 20 Hz, pero para el análisis del flujo oscilatorio las señales se filtraron eliminando oscilaciones con frecuencia superior a 4 Hz. El rango máximo de velocidades medido fue de ± 2.5 m/s con un error del 1% (2.5 cm/s). La ilustración 3 muestra un ejemplo de las series de velocidad.

Simultáneamente se midió la variación de la superficie libre mediante un sensor de contacto (Etrometa WG) colocado en la misma vertical con una precisión de 2.5 cm y 4 Hz de frecuencia de muestreo (ilustra-

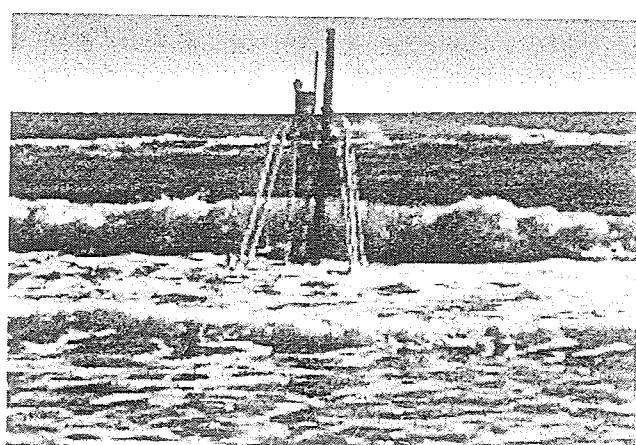
ción 3). La orientación del trineo se midió mediante un compás digital (Anderaa) con un error de 0.3 grados y una frecuencia de un dato por minuto. La orientación de los *cem* se obtuvo haciendo coincidir sus ejes x-y con los del trineo con un error cercano a los ± 2 grados.

La posición horizontal y vertical del trineo se realizó mediante el uso de un prisma óptico montado en la barra vertical y una estación total con distancímetro infrarrojo. Esta metodología asegura una precisión cercana al cm en z y al dm en x-y. La longitud de las series temporales osciló entre 20 y 40 min, lo cual garantizó cubrir un número de olas suficientemente representativo del oleaje irregular medido (superior a 150 olas).

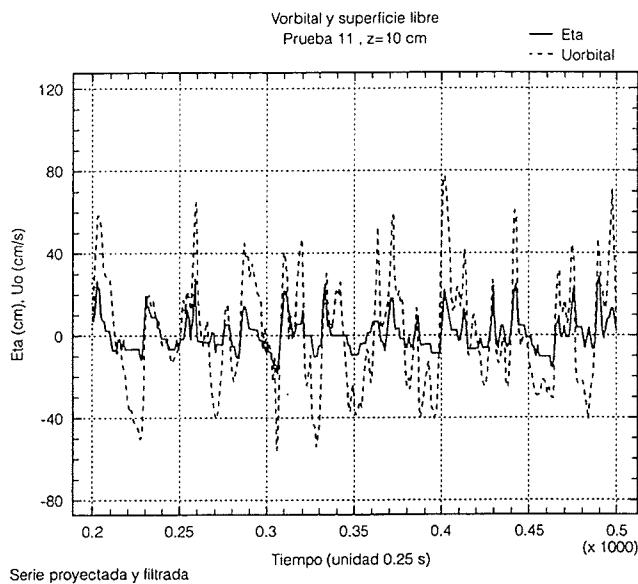
Proceso de datos

A partir de las medidas brutas fue obtenida la siguiente información:

2. Trineo con instrumental: 6 cem, 1 wg, 3 obs, 1 compás y prisma



3. Ejemplo de velocidad orbital y variación de la superficie libre η (t) medidas, (prueba 11)

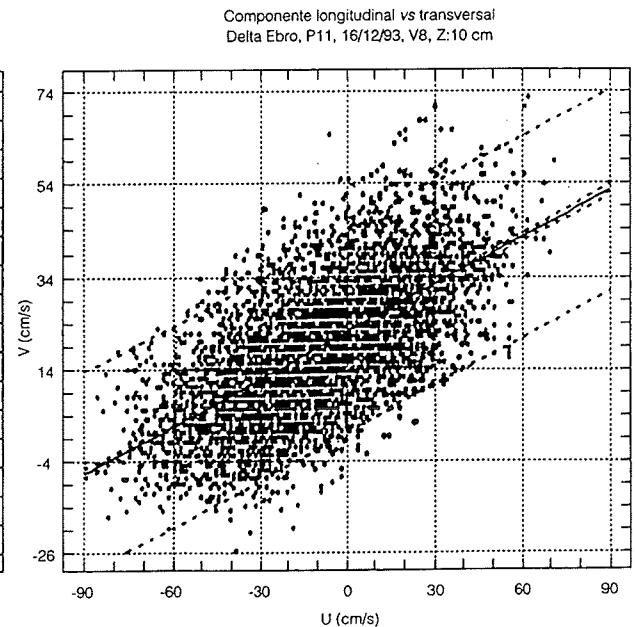
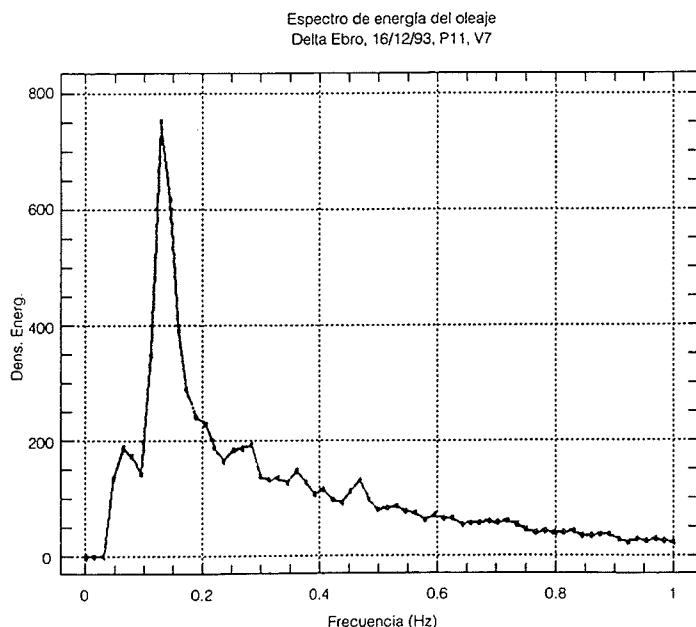


- Profundidad media: como el promedio temporal de las señales del sensor de alturas Etrometa, considerando la cota del cero respecto del trineo.
- Niveles de cresta y valle: en sus distintas variantes *individuales* (para cada ola), *rms* (media cuadrática) y *significante* (promedio del tercio superior de la se-

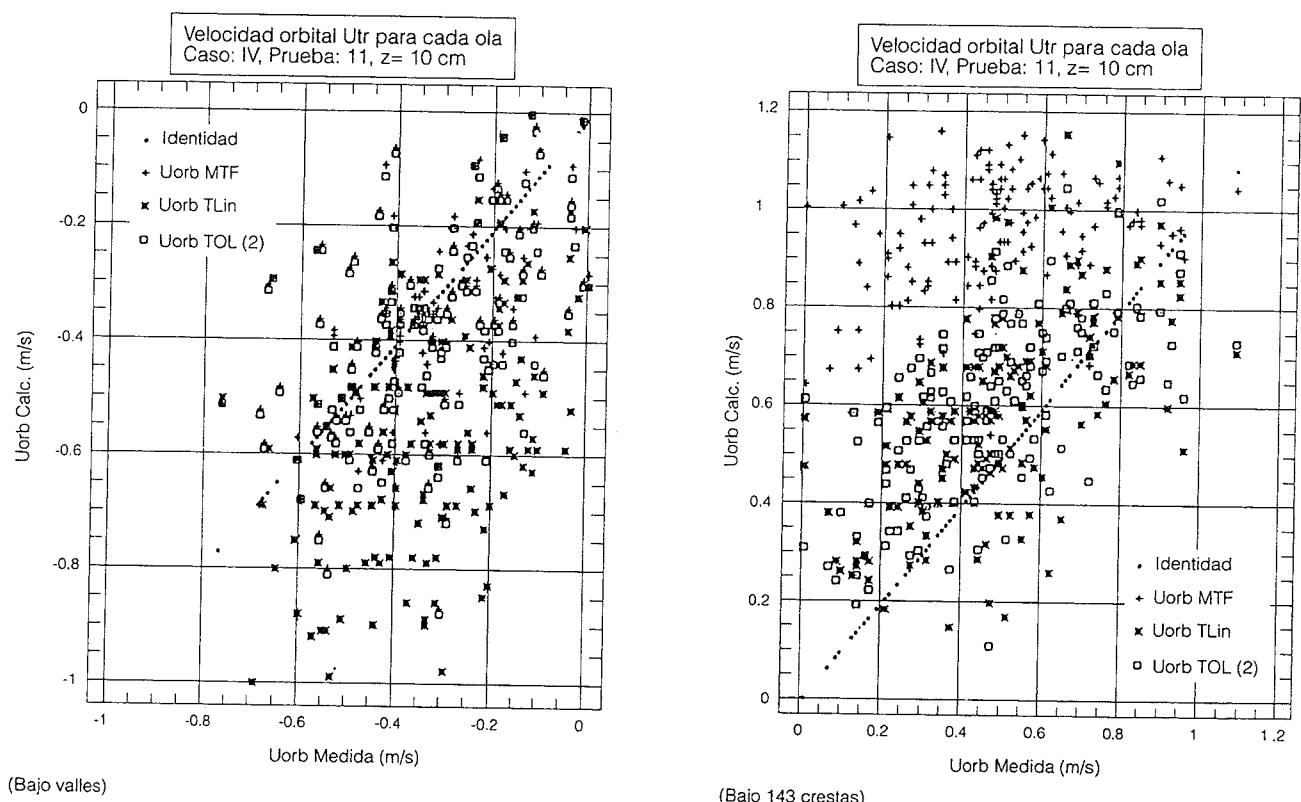
rie ordenada en forma descendente). Estos valores se obtuvieron considerando un criterio de cruce por cero descendente (*zero-down-crossing*) aplicado sobre la media móvil de la señal para evitar las distorsiones que provocarían las oscilaciones de baja frecuencia presentes en la serie total.

- Alturas de ola: en sus tres variantes *individuales*, o promediadas *rms* y *significante* a partir de las crestas y los valles.
- Periodos del oleaje: obtenidos como los correspondientes a los picos de los espectros de energía de cada serie de niveles. Estos espectros se calcularon mediante técnicas de Transformada Rápida de Fourier con ventanas tipo Welch en el agrupamiento de datos. El error en el periodo así obtenido depende de la resolución del espectro y fue siempre inferior a 0,5 s (ilustración 4).
- Dirección media de propagación del oleaje: necesaria para proyectar las velocidades horizontales en la dirección de propagación y así obtener la componente oscilatoria. Se obtuvo a partir de la regresión lineal entre las componentes N-S y E-O de las velocidades horizontales medidas con los *cem*, (ilustración 5).
- Velocidades orbitales: para cada uno de los seis niveles medidos se obtuvo el flujo oscilatorio mediante la proyección de la velocidad horizontal en la dirección de propagación media. Esta componente se filtró numéricamente para eliminar oscilaciones

4, 5. Espectro de energía de η (t) en [cm²/s] de la prueba 7 (izquierda) y velocidades horizontales instantáneas de la prueba 8 (derecha)



6, 7. Velocidades orbitales instantáneas bajo cresta (derecha) y valle (izquierda), prueba 11, z = 10 cm, (núm. olas > 100)



correspondientes a ondas de baja frecuencia (con períodos mayores a 20 s). De esta manera se obtuvieron los valores correspondientes a las velocidades orbitales *rms* y *significantes* bajo cresta y valle. Para una de las pruebas (núm. 11) se calcularon además los valores *individuales* para comparar con las predicciones de diversas teorías.

Resultados

Los principales resultados obtenidos se presentan en las siguientes ilustraciones:

Las velocidades orbitales instantáneas (para 143 olas) versus las teorías: FTM, Airy y SWT se muestran en las ilustraciones 6 y 7 para la prueba 11 y $z=10$ cm.

La comparación entre las medidas de campo y las teorías descritas previamente -para las pruebas 9 y 11 y para el caso de velocidades orbitales *rms*- se muestran en las ilustraciones 8 y 9.

La comparación entre medidas y teorías para las pruebas 5 y 10 y para el caso de velocidades orbitales *significantes* (subíndice $_{1/3}$) se muestran en las ilustraciones 10 y 11.

La distribución del error cuadrático medio relativo a través de la ZR se muestra en las ilustraciones 12 a 15 para los valores *rms* bajo crestas y valles, tanto en el fondo ($z=10$ cm) como para la media de las seis medidas en la vertical.

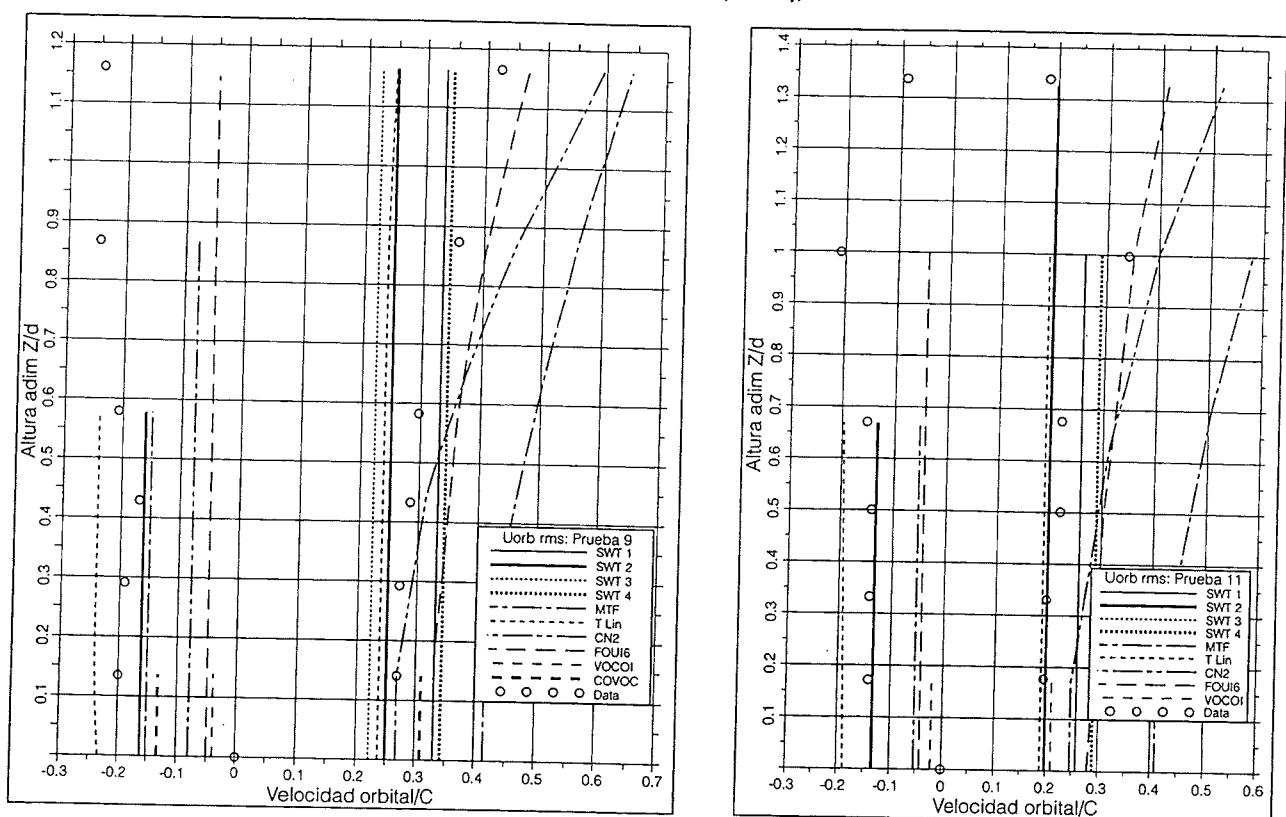
Discusión y conclusiones

El estudio comparativo del flujo oscilatorio presentado cubre un amplio rango de condiciones para la ZR. Por una parte incluye información experimental obtenida en distintas posiciones de medición (ocho pruebas) con alta resolución vertical (hasta 6 cm). Por otra parte, se han evaluado las principales teorías de olas existentes que son de aplicación en la zona de rompientes.

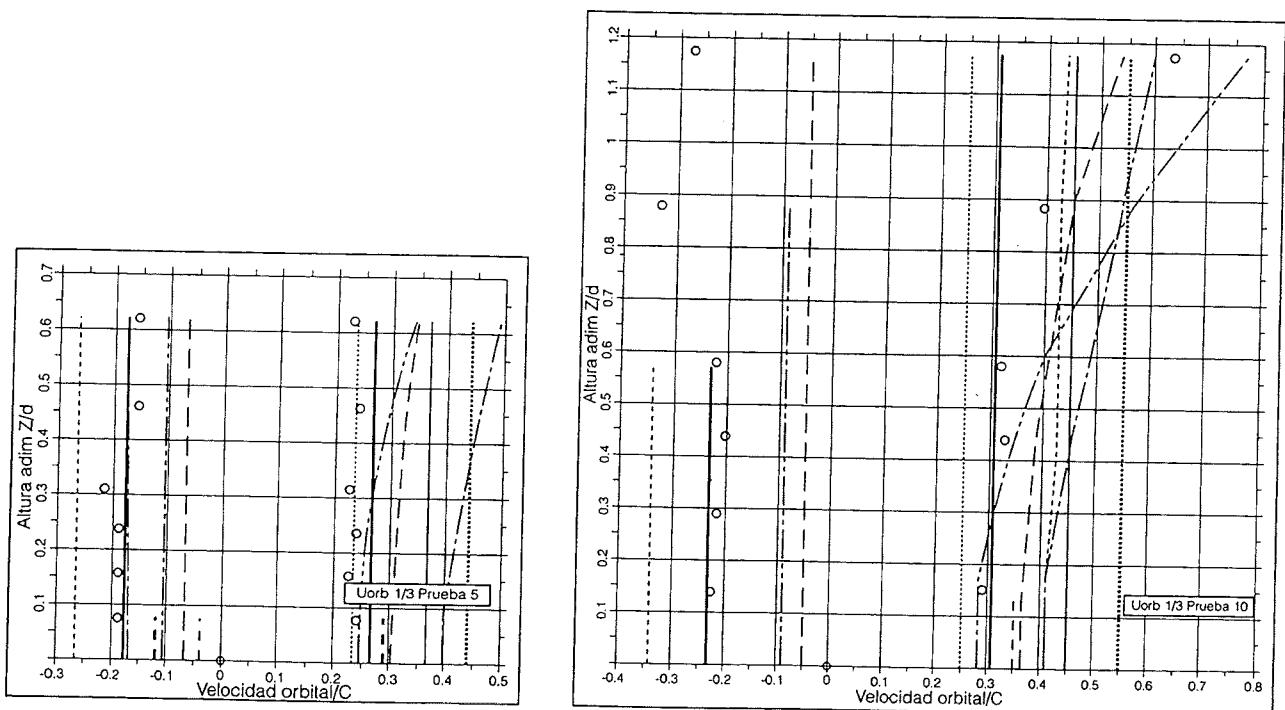
Los siete modelos considerados representan a los tres grupos de teorías de olas:

- Irrotacionales (Stokes-Airy, Cnoidal y Fourier).
- Rotacionales (*Shallow water wave*, *vocoidal* y *covo-coidal*).
- Modificadas (FTM tipo Dean).

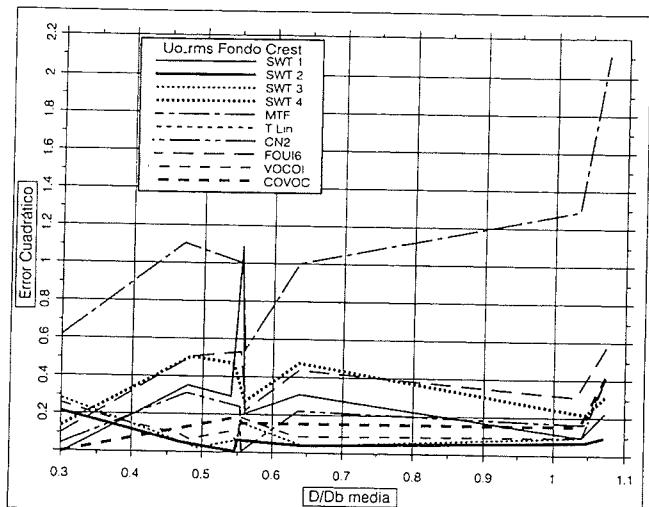
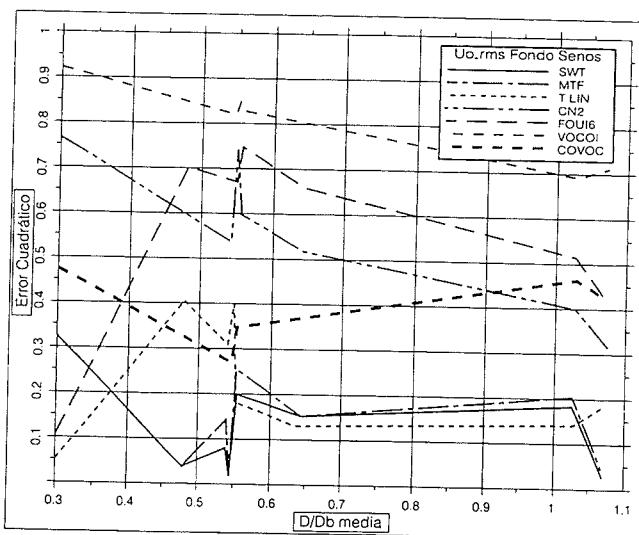
8, 9. Velocidades orbitales rms para la prueba 11 (derecha) y prueba 9 (izquierda), $z = 10$ cm



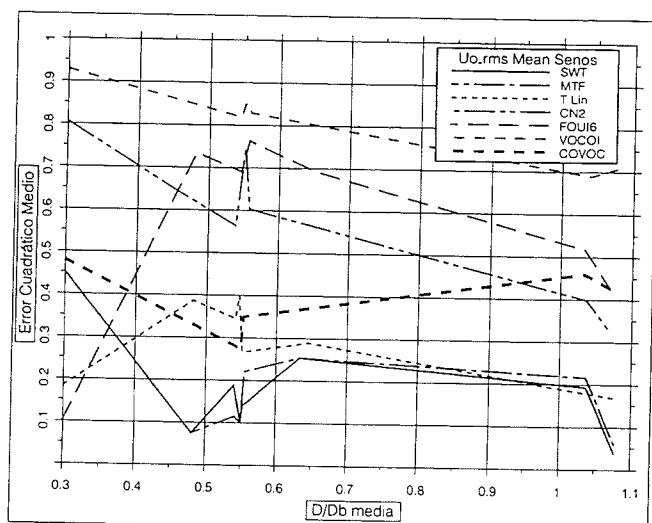
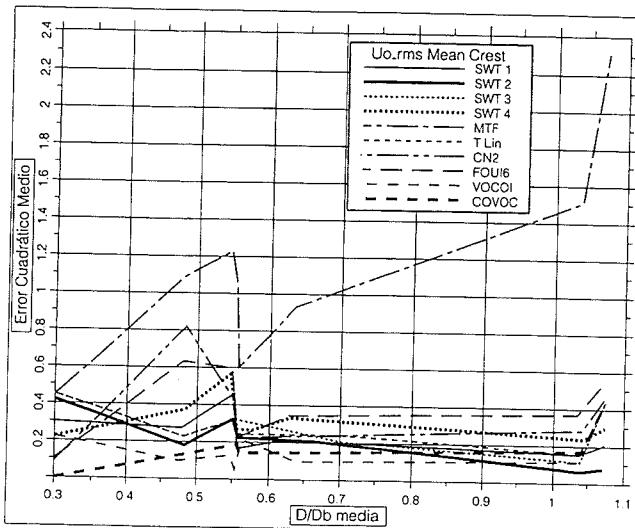
10, 11. Velocidades orbitales significantes para la prueba 10 (derecha) y prueba 5 (izquierdo), $z = 10$ cm, (idem)



12, 13. Distribución del error cuadrático medio relativo a través de la ZR de las distintas teorías para las velocidades orbitales *rms* en el fondo bajo la cresta (izq.) y valle (der.)



14, 15. Distribución del error cuadrático medio relativo a través de la ZR de las distintas teorías para las velocidades orbitales *rms* promediadas bajo la cresta (izq.) y valle (der.)



Las pruebas cubrieron ocho posiciones a través de la ZR para profundidades en un rango entre 1,3 m y 0,3 m, lo que permitió abarcar la ZR interior y exterior cerca de la primera línea de rotura. El tipo de rotura fue predominantemente *de decrestamiento (spilling)*, con rotura *en voluta (plunging)* ocasional.

Las diversas teorías fueron evaluadas con alturas, períodos y profundidades medidas, y posteriormente comparadas con distintos valores experimentales: *individuales, rms y significantes* ($_{1/3}$), tanto para el caso bajo crestas como bajo valles de las olas.

El análisis de las medidas *individuales* (ilustraciones 6 y 7) refleja que el error es mucho mayor (para todas las teorías) que para el caso de valores promediados (*rms* o significantes). No hay una teoría que pueda considerarse claramente como la mejor, ya que su ajuste depende del caso particular que se considere. Así por ejemplo, la teoría lineal sobreestima claramente las velocidades bajo valles, mientras que las teorías SWT y FTM entregan valores mejores y semejantes entre sí. No sucede lo mismo bajo crestas donde las predicciones de la T. lineal mejoran notablemente super-

rando a la FTM e igualando a la SWT. Notar que para las crestas la FTM sobreestima excesivamente los valores medidos.

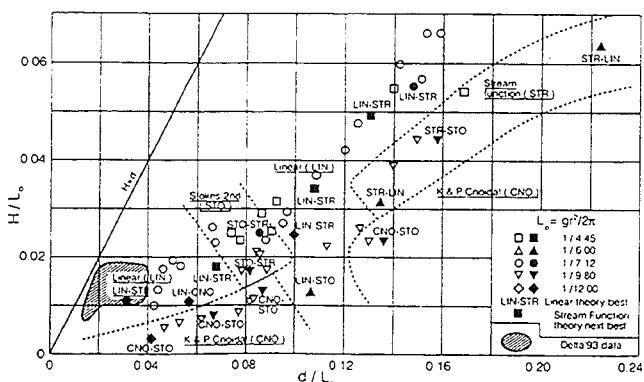
El análisis de las medidas promediadas se ha realizado para las siete teorías (ilustraciones 8 a 13). Estas comparaciones se cuantificaron mediante el cálculo del error medio cuadrático relativo (*emcr*) tanto para el fondo (*cem* inferior a 10 cm del fondo) como para el valor medio en toda la columna de agua.

Puede decirse que en general la SWT (versiones 2 y 3) es la que mejor se ajusta a los datos. La teoría *covo-coidal* es la segunda en calidad pero con un costo computacional mayor. La teoría *vocoidal* en las pruebas estudiadas no da resultados tan buenos, probablemente debido a que desprecia los efectos de la pendiente de fondo (cercana al 2,6%). Las teorías FTM y Lineal dan resultados aceptables y similares, pero la *T. lineal* se mostró más regular en la calidad de los ajustes. Las teorías FTM y *vocoidal* se mostraron muy irregulares en la calidad de los ajustes, ya que en varias ocasiones fueron las de peor calidad. En general la teoría *cnoidal-II* no ha demostrado ser superior a la teoría lineal, sus cálculos bajo crestas son mucho mejores que los correspondientes a los valles de las olas.

Los resultados principales se resumen en la tabla 3. En la misma se presentan los mejores ajustes de cuatro de las siete teorías evaluadas, –las tres mejores y la peor–, para los diversos casos seleccionados. Estos incluyen la evaluación combinada de las velocidades orbitales en:

- El fondo y la media en la vertical.
 - Bajo crestas y bajo valles.
 - Uorb *rms* y *significante*.

16. Teorías de olas para U_{∞}^+ de acuerdo a Kirgöz (1986) y datos de DELTA'93



3. Resumen de resultados con las tres mejores y la peor teoría para cada caso analizado

Flujo oscilatorio bajo oleaje rompiente					
Orden	Teoría	emcrm	Orden	Teoría	emcrm
Uo - rms - media - cresta			Uo - rms - fondo - cresta		
1	COV	0.153	1	SWT ₂	0.064
2	VOC	0.183	2	TLIN	0.102
3	SWT ₂	0.213	3	VOC	0.153
-	-	-	-	-	-
7	FTM	1.143	7	FTM	1.089
Uo - rms - medio - valle			Uo - rms - fondo - valle		
1	SWT	0.182	1	SWT	0.128
2	FTM	0.186	2	FTM	0.148
3	TLIN	0.275	3	TLIN	0.224
-	-	-	-	-	-
7	VOC	0.811	7	VOC	0.811
Uo - _{1/3} - medio - cresta			Uo - _{1/3} - fondo - cresta		
1	VOC	0.151	1	SWT ₂	0.107
2	COV	0.218	2	CNO	0.122
3	SWT ₂	0.221	3	VOC	0.150
-	-	-	-	-	-
7	SWT ₄	0.680	7	SWT ₄	0.818
Uo - _{1/3} - medio - valle			Uo - _{1/3} - fondo - valle		
1	SWT	0.164	1	SWT	0.116
2	FTM	0.167	2	FTM	0.123
3	COV	0.266	3	COV	0.267
-	-	-	-	-	-
7	VOC	0.913	7	VOC	0.914

El error *emcrm* de las teorías seleccionadas fue calculado como la media de los *emcr* de cada una de las ocho pruebas medidas. Para observar la variación del *emcr* a través de la ZR ver las ilustraciones 12 a 15.

En la ilustración 16, adaptada de Kirgöz (1986), se han agregado los datos obtenidos durante los experimentos DELTA'93. Puede observarse que estos datos cubren un rango en la ZR donde la información experimental es escasa. En esta ilustración Kirgöz sugiere la aplicación de las teorías lineal (LIN) y de Dean (STR) para Uorb bajo crestas en la ZR. Sin embargo el presente trabajo demuestra que otras teorías, como SWT, covocoidal y vocoidal, son más adecuadas.

De la tabla 3 puede obtenerse, además, una indicación de las mejores teorías para Uorb en situaciones más generales como: bajo valles, discriminando el valor en el fondo o la media en la vertical y tanto para valores *rms* como significantes.

El uso de estos valores de U_{orb} depende obviamente de la aplicación ingenieril en particular, así por ejemplo, para calcular la fricción media en el fondo para corrientes en presencia de olas se suele utilizar el valor rms en el fondo, mientras que para calcular el transporte de sedimentos es más adecuado utilizar valores

significantes en el fondo, discriminando además crestas y valles ya que cambia el sentido (o signo) del transporte. Otra aplicación importante se tiene en el cálculo de la circulación inducida por oleaje en la ZR, donde se utiliza el concepto de tensor de radiación (Dean y Dalrymple, 1984) cuya evaluación puede realizarse mediante la utilización de alguna teoría de olas que considere la variación de las velocidades u y w en la vertical; para este caso interesa que la teoría seleccionada sea representativa de la variación en toda la columna de agua, y no sólo en el fondo.

Estos resultados son de utilidad como criterios a la hora de escoger la teoría de olas más adecuada para evaluar las velocidades orbitales para distintas aplicaciones ingenieriles como las mencionadas precedentemente (e.g. transporte de sedimentos, presiones sobre estructuras, etcétera).

Finalmente debe mencionarse que lo limitado de la muestra experimental impide la extracción de conclusiones más universales o definitivas que puedan utilizarse en la elaboración de fórmulas empíricas. Este tipo de formulaciones empíricas, si bien son de utilidad, son *peligrosas* porque suelen utilizarse fuera de su estricto rango de validez (para el que se obtuvieron), y para evaluar velocidades distintas para las que fueron propuestas. Notar por ejemplo que este es al caso de la FTM que es semi-empírica y da estimaciones buenas para valores significantes y malas para valores *rms*. Más ejemplos de este tipo de formulaciones empíricas para Uorb en la ZR han sido presentadas, por ejemplo, por Kroon (1994) modificando la teoría lineal con un factor de asimetría experimental, y otras aproximaciones similares pueden verse en Leont'ev (1988) o Ansyferov *et al.* (1990).

En síntesis, dado que no hay teoría disponible aún para la ZR, (sino aproximaciones como el tipo *dientes de sierra*, Fredsøe y Deigaard, 1992), y los datos siguen siendo escasos, los autores opinan que se deben continuar los esfuerzos de investigación en esta línea.

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Referencias

- Adeymo, M. 1968. Velocity field in the wave breaker zone. *Proc. ASCE Int. Conf. Coast. Engineering*. p. 435-459.
- Antsyferov, S.; Belberov, Z. y Massel, S. (Eds.). 1990. *Dynamical Processes in coastal regions*. Sofía: Pub. House Bulg. Ac. of Sciences.
- Bleach, G. 1982. Integral properties for vocoidal theory and applications. *Proc. ASCE Int. Conf. Coast. Engineering*. p. 887-900.
- Bub, F. 1974. *Surf zone wave kinematics*, Master Tesis, Naval Postgraduate School, Monterrey, USA.
- Dean, R. 1965. Stream function representation of nonlinear ocean waves. *J. Geophysical Research* 70:4561-4572.
- Dean, R. y Dalrymple, R. 1984. *Water wave mechanics for engineers and scientists*. New Jersey: Prentice Hall.
- Fredsøe, J. y Deigaard, R. 1992. *Mechanics of coastal sediment transport*. Singapur: World Scientific Pub.
- Fürbötter, A. y Büsching, F. 1974. Wave measuring instrumentation for field investigation on breakers. *ASCE Int. Simp. Ocean Wave Measurements and Analysis*. pp. 649-668.
- Galvin, J. 1975. *Kinematics of surf zone breaking waves: measurements and analysis*. Master tesis, Naval Potgraduate School, Monterrey, USA.
- Goda, Y. 1964. *Wave forces on vertical circular cylinder: experiments and a proposed method for wave force computation*, Report No. 8. Port and Harbour Tech. Res. Inst. Japón.
- Graw, K. 1994. Comparison of wave theories with velocity measurement, *Proc. ASCE Int. Symp. Waves*. Vancouver. pp.561-569.
- Hamm, L.; Fornerino, M. y Sauvaget, P. 1992. *Calcul des propriétés intégrales et cinématique de la houle*, Report MAST G6M, 5 2147R1, Sogreah, Grenoble, Francia,
- Hardy, T. y Kraus, N. 1987. *A numerical model for shoaling and refraction of second-order cnoidal waves over irregular bottom*, Misc. paper CERC-87-9. Vicksburg: US AWES.
- Isobe, M. 1981. *Field observation of vertical distribution of water particle velocity in the nearshore zone*, NERC Rep., 14, TR-80-2, (251-260), Japón.
- Kirgöz, M. 1986. Particle velocity prediction at the transformation point of plunging breakers, *Coastal Engineering* 10:139-147.
- Koyama,H. e Iwata,K. 1986. Estimation of water particle velocities of shallow water waves by a modified transfer function method. *Proc. ASCE Int. Conf. Coast. Eng.* p.425-436.
- Kroon, A. 1994. *Sediment transport and morphodynamics of the beach and nearshore near Egmond, The Netherlands*, Tesis Doctoral, Universidad de Utrecht. 275 p.
- Le Méhauté, B.; Divoky, D. y Lin, A. 1968. Shallow water waves: a comparison of theories and experiments, *Proc. ASCE Int. Conf. Coast. Eng.* p.86-107.
- Leont'ev,I. 1988. Randomly breaking waves and surf-zone dynamics. *Coastal Engineering* 12:83-103.
- Mejlhede, N. 1975. *Cnoidal waves on arbitrary depth*, Prog. Rep. 36. Dinamarca: Inst. Hydrodyn. and Hidraulic Engrg. Tech. Univ.

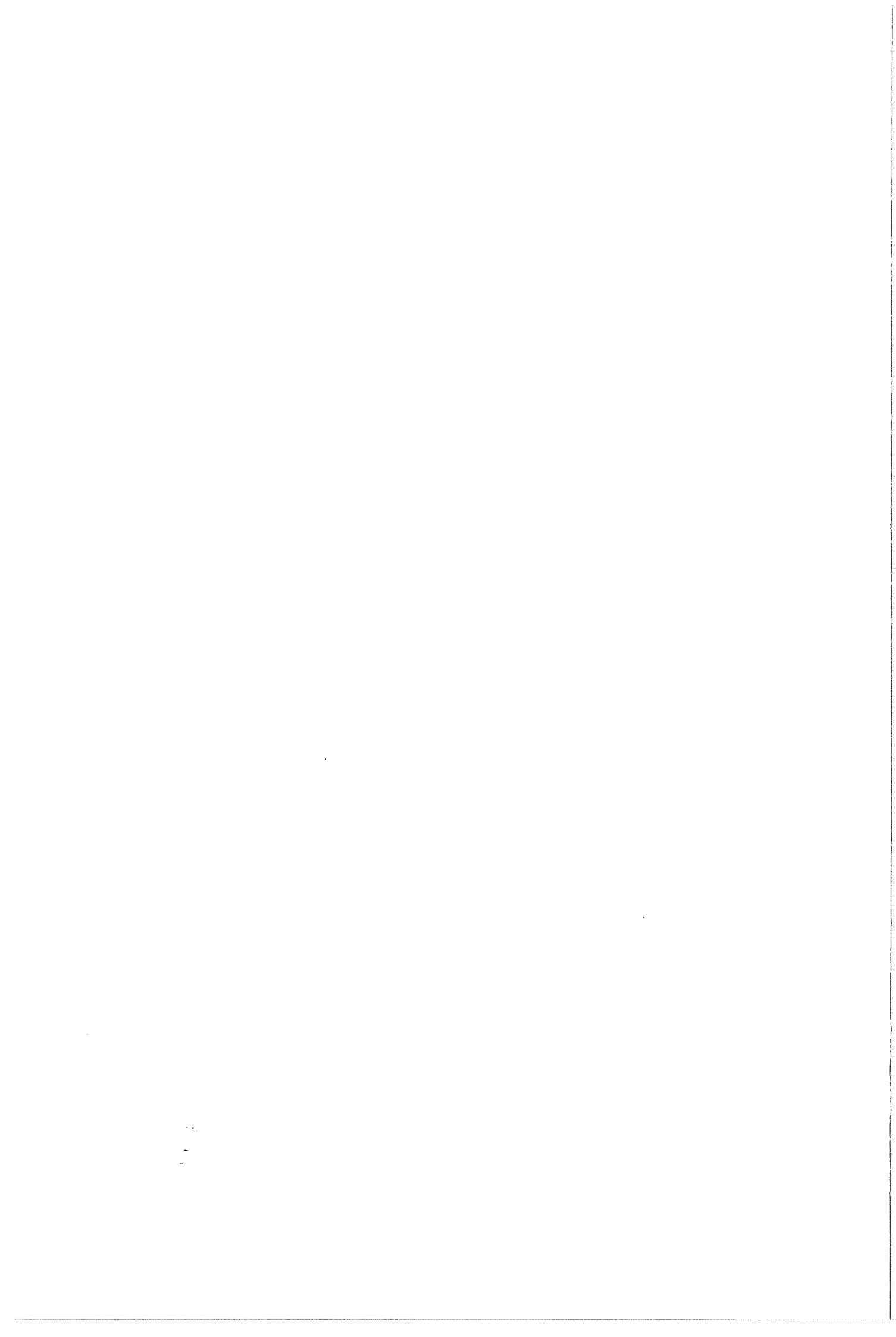
- Rodriguez, A.; S.Arcilla, A.; Collado, F.; Gracia, V.; Cousirat, M. y Prieto,J. 1994. Waves and currents in the Ebro Delta surf zone: measurements and modelling. *Proc. ASCE Int. Conf. Coast. Eng.* p. 2542-2556.
- Rienecker, M. y Fenton, J. 1981. A Fourier approximation method for steady water waves. *Journal of Fluid Mechanics* 104: 119-137.
- Steer, R. 1972. *Kinematics of water particle motion within the surf zone*. Master Thesis, Naval Postgraduate School, Monterrey, USA.
- Stive, M. 1980. Velocity and pressure feed of spilling breakers, *Proc. ASCE Int. Conf. Coast. Eng.* p.547-586.
- Svendsen, L. 1984. Mass flux and undertow in a surf zone. *Coastal Engineering* 8:347-365.
- Swart, D. y Loubser, C. 1978. Vocoidal theory for all non-breaking waves. *Proc. ASCE Int. Conf. Coast. Eng.* p.467-486.
- Swart, D. y Crowley, J. 1988. Generalized wave theory for a sloping bed, *Proc. ASCE Int. Conf. Coast. Eng.* p.181-203.
- Thornton, E. 1968. A field investigation of sand transport in the surf zone. *Proc. ASCE Int. Conf. Coast. Eng.* p. 335-351.
- Thornton, E. y Richardson, D. 1974. *The kinematics of water particle velocities of breaking waves within the surf zone*, Tech. rep. NPS-58TM74011A, Naval Postgraduate School, Monterey, USA.
- Thornton, E.; Galvin, J.; Bub, F. y Richardson, D. 1976. Kinematics of breaking waves. *Proc. ASCE Int. Conf. Coast. Eng.* p.461-476.
- Van Huijum, E. 1975. *Niet-rotatie vrije benadering van de waterbeweging bijregelmatige korte golven in water met eenconstante diepte*, Speurwerkverslag S171 deel II.
- Wiegel,R. 1964. *Oceanographical Engineering*, New Jersey: Prentice Hall.

Abstract

Rodriguez, A.; A. Sanchez-Arcilla; C. Mössö; B. Mercader. "A Comparison of Real and Theoretical Values of Oscillatory Flow in the Surf Zone". *Hydraulic Engineering in Mexico* (in Spanish). Vol XII. Num. 2, pages 17-27 May-August, 1997.

Numerical and experimental results of oscillatory flow under breaking waves are presented. The experimental results have been obtained during DELTA'93 large-scale experiments in the Ebro Delta, (Spain). The measurements include several tests across the surf zone with high vertical resolution. The measured orbital velocities are compared with the main wave-theories for shallow waters.

Key words: Coastal hydrodynamics, field measurements, breaking waves, oscillatory flow, numerical modeling, surf zone.





A3. *Waves and Currents et the Ebro Delta Surf-Zone: Measurements and Modelling.*

Este artículo ha sido presentado en la "Int. Conf. Coastal Engineering'94", Kobe (Japón), y publicado por la ASCE (ICCE'94, pg. 2542-2556, ISBN 0-7844-0089-x).



WAVES AND CURRENTS AT THE EBRO DELTA SURF ZONE: MEASUREMENTS AND MODELLING

Rodriguez,A.; Sánchez-Arcilla,A.; Collado,F.R.;
Gracia, V. Coussirat M.G. and Prieto J.¹

Abstract

The wave incidence and the wave-induced circulation in the surf zone (SZ) is studied from both experimental and numerical point of view. The *DELTA'93* experiments were carried out in the Trabucador bar of the Ebro Delta, in the Spanish mediterranean coast. The emphasis of *DELTA'93* was on the SZ vertical flow structure, measuring simultaneously undertow and longshore current in a barred profile. The numerical simulation with *NEARCIR* Q3D model assumes longshore uniformity and stationarity. The wave decay, 2DH currents and 1DV undertow and longshore currents are modelled. The agreement is quite reasonable as can be seen in the included figures.

Introduction

The Ebro delta, one of largest in the Mediterranean, is located on the Spanish coast, 200 Km Southwest of Barcelona (figure 1). As in many other deltas of the world, the Ebro delta is experiencing a severe erosion due to the nearly total reduction of solid river discharges associated to dam construction (Jimenez and S.-Arcilla, 1993). Because of this there is an important monitoring activity around the deltaic coastline from which hydrodynamic, morphodynamic and meteorological data have been extracted to support the surf-zone campaign, which is the main object of this paper.

The data recorded during the surf-zone campaign, which took place along the Trabucador bar, will be described in this paper, together with some references to the wealth of previously recorded information along the deltaic coastline. The numerical model used to simulate surf-zone processes and to gain insight into the physics at the Ebro delta surf-zone during the time of the campaign, is the *NEARCIR* model presented in (S.-Arcilla et al., 1990/1992). This Q3D model works at the current time-scale and is structured into three modules:

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- i. Wave Propagation Module (based on the kinematic conservation principle and the wave action balance equation).
- ii. Depth Uniform Current Module (based on the 2DH rigid-lid mass and momentum equations).
- iii. Depth Varying Current Module, including the Bottom Boundary Layer (this module is briefly described for completeness within this paper).

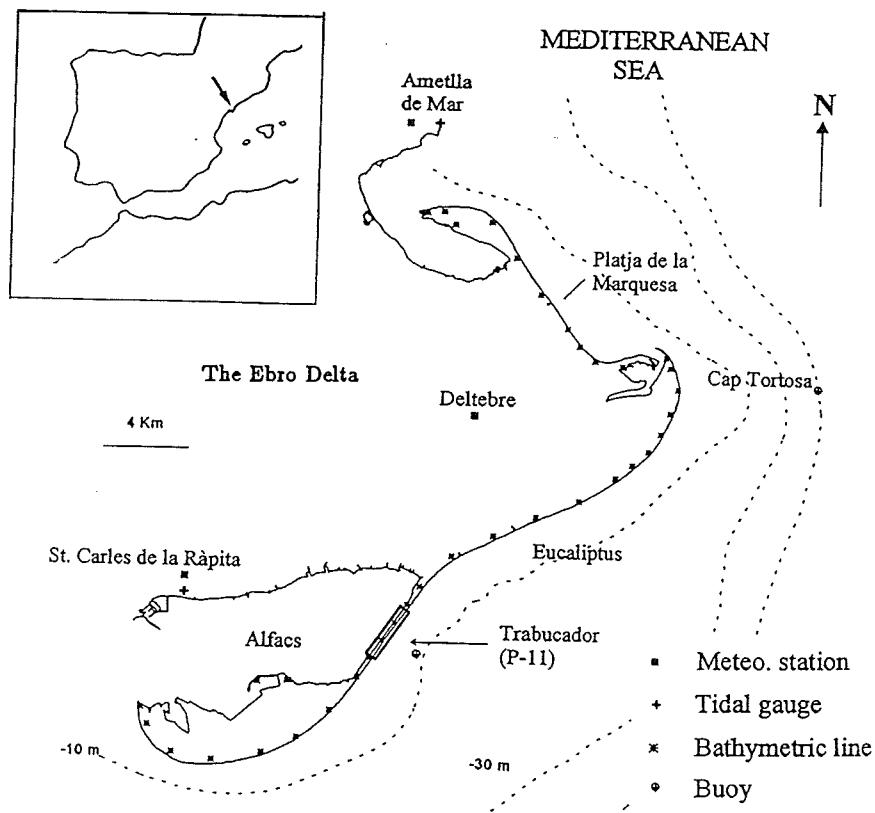


Figure 1. The Ebro Delta

DELTA '93 Field Experiments

The motivation for this campaign was the lack of detailed 3D data on surf-zone hydrodynamics in a microtidal environment. The campaign was thus focussed on the 3D structure of wave-induced circulation, i.e. on the simultaneous vertical structure of shore-normal (undertow) and shore-parallel (longshore current) flows. Because of this, and trying to avoid excessive complexities and/or unknowns, it was decided to look for an alongshore uniform beach subject to unidirectional waves and a time interval without significant wind.

Based on these considerations and because of the availability of previously recorded field data, the Trabucador bar in the Ebro delta was selected as the most suitable coastal stretch to carry out the surf-zone field exercise. The campaign was centered around the beach profile P11 (see figure 1). The obtained field data include bathymetry, shoreline, wave data outside and inside the SZ, mean water levels across the SZ, and the associated velocity fields (both

horizontal and vertical structure).

The bathymetry in the field site is shown in figure 2. Only relatively modest bottom variations were recorded during the three days of the campaign, which allows assuming a steady bottom geometry for the hydrodynamic analyses. The wave climate was recorded at 50 m and 7.5 m water depth by means of two directional wave rider buoys recording 20 minutes every 3 hours. An Etrometa step wave-gauge was located at the beach sledge, which was used to monitor hydro- and morphodynamic conditions across the surf-zone from the shoreline down to 2.5 m water depth. A BW video camera, placed at 20 m height, was used to record SZ images from which, after digital image processing, information on wave direction, breaking intensity, etc. could be obtained. An X-band radar was also used to measure mean surface roughness (mean wave height) and low-frequency oscillations of the mean water level in the SZ and adjacent nearshore area.

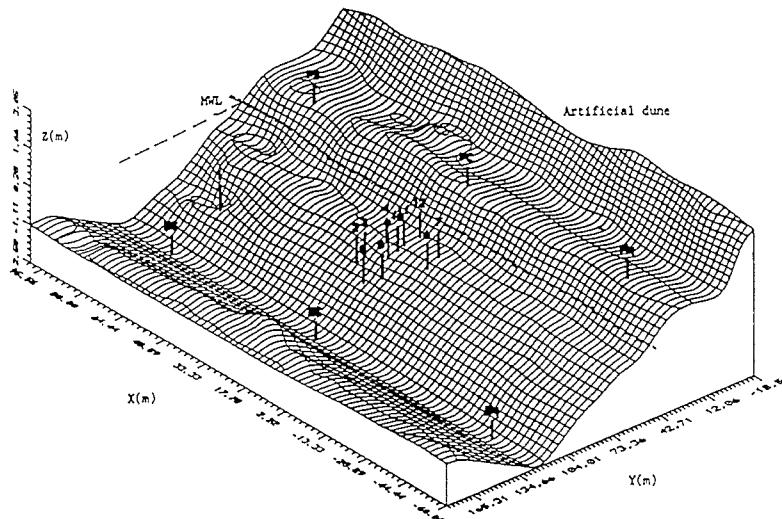


Figure 2. The Trabucador bar bathymetry (P11) for 16/December/93.

Some wave field characteristics plus 2DH circulation and mixing patterns derived from the video images using the developed digital processing technique have been presented in Redondo et al. (1994). This technique allows to quantify the time and space evolution of sea surface tracers (foam, dyes and Lagrangian buoys) and the horizontal mixing properties associated to dye spots.

The vertical structure of horizontal instantaneous velocities was measured with six electromagnetic current meters (Delft Hydraulics-S type) placed in a vertical pole at the sledge, see figura 3. The vertical spacing of the electromagnetic sensors (ems) range from 0.10 to 0.20 m above the bottom up to maximum level of 0.80 m above the bottom, with a sampling rate of 20 Hz allowing therefore to measure some macroturbulence features. Simultaneously with the velocities, the local water level evolution was measured at the same vertical with the step wave-gauge mentioned above (sampling rate 4 Hz). The MWL was computed by averaging the free surface time series, while crest and trough

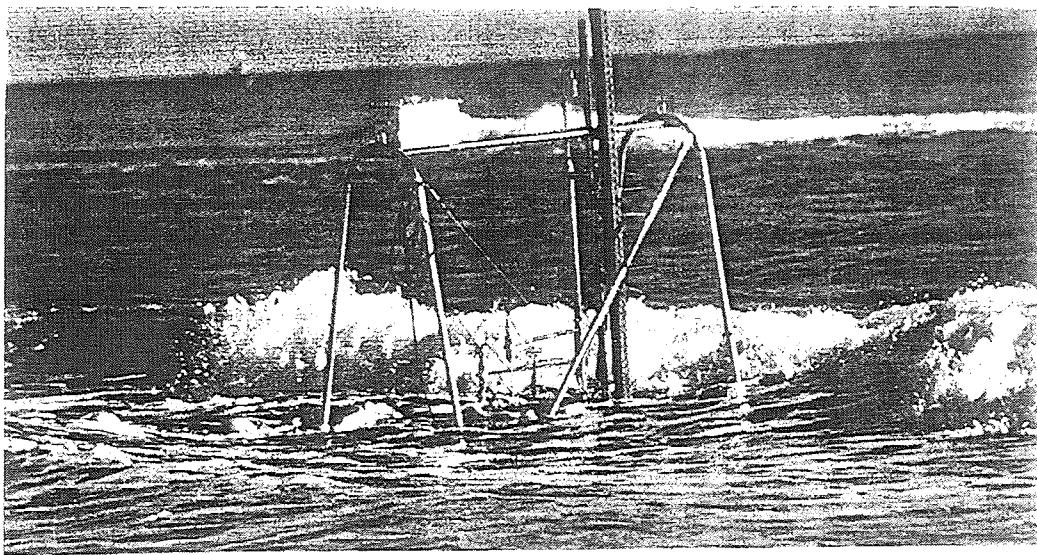


Figure 3. Movable Sledge with: 6 EMS, 1 WG, 3 OBS, 1 COMPASS, Data-Logger and 1 Optic-Prism).

levels were obtained as the mean of the upper "1/3" series of individual crest and trough values. The crests and troughs were obtained after numerically filtering the original water-surface series to remove the effect of long waves and other alien-phenomena.

Waves: Measurements and Modelling

Wave Features

Table 1 summarizes the 5 cases measured during the *DELTA'93* experiments.

Cases	Date	I. E. L.	Spectra	T_p (s)	Sea State	Test n.
I	26/05/93	High	doubled-peak	T_{p1} 18 T_{p2} 3	unsteady	-
II	15/12/93	Low	wide	7.5	Q-steady	NT1-NT4
III	16/12/93 a.m.	Medium-High	sharp	6.0	Q-steady	NT5-NT7
IV	16/12/93 p.m.	Medium	sharp	5.5-7.0	unsteady	NT8-NT12
V	17/12/93	Low	wide	7.5	steady	-

Table 1: Measured conditions I.E.L.: Incident wave energy level;
Spectra: type of wave spectra; T_p : wave period; Test n.: Test number

In this paper only cases III and IV, measured during 16th December 1993, are considered for an in-depth analysis because they were the most complete cases with strong enough wave-induced currents. There are several potential sources of error, such as the linear interpolation in directional wave data recorded every

3 hours by the buoy (to have time correspondance with the wave gauge data recorded every half-hour), the spreading in wave direction given by the buoy or those inherent to the measurement equipment and processing techniques. In spite of this, there was reasonable agreement between the surf-zone spectra from wave-gauge and video images data, showing a good correspondance of frequencies or dominant periods. The comparison between wave angles from the video (VTR) and the ems is not finished because of the large amount of data-processing necessary to obtain a mean angle of wave incidence. The incident wave conditions during the 16th December 1993 (outside and inside the SZ) are summarized in tables 2 and 3. Hrms (m) is the root mean square wave height, Tp(s) is the wave period, θ_m is the mean angle of wave incidence, X is the crossshore coordinate, h is the mean water depth and U-V (m/s) are the depth-averaged cross- and alongshore velocity components at different sledge positions (test) inside the surf-zone.

Wave incident conditions (DWR)				
Test	Hrms (m)	Tp(s)	θ_m	GMT
5	.61	6.0	177.0	10:04
6	.60	6.1	175.3	10:55
7	.59	6.3	173.0	12:05
8	.50	5.7	179.5	14:07
9	.44	5.4	183.3	15:07
10	.43	5.4	180.6	15:46
11	.425	5.6	176.1	16:20
12	.42	5.8	171.9	16:51

Table 2: Incident wave conditions at *dwr* position (1500 m offshore, *h*:7.5m) during 16/December/93.

Hydrodynamic measurements in the SZ						
Test	Hrms	Tp(s)	X(m)	<i>h</i> (m)	<i>V</i> *	<i>U</i> *
5	.47	7.1	87.9	1.29	.48	.15
6	.38	7.1	73.2	0.80	.88	.19
7	.31	8	65.1	0.70	.66	.13
8	.41	7.1	93.5	1.34	.23	.08
9	.40	7.1	79.8	0.70	.62	.24
10	.33	7.1	74.0	0.68	.60	.16
11	.27	8	69.5	0.60	.46	.11
12	.18	8	60.0	0.38	.28	.10

* (mean below wave trough level z_{tr})

Table 3: Hydrodynamic conditions from *WG* and *ems*

An image processing technique, still under development, has also been used to evaluate the crossshore distribution of the intensity of wave breaking, Q_b . From an image threshold intensity associated to breaking, the breaking wave distribution acrosshore can be determined for a time series of beach profile transects derived from the video record. The processing technique is able to reproduce some of the features of the crossshore evolution of the fraction of breaking waves, as derived from e.g. the Battjes and Janssen (1978) (hereinafter

BJ'78) model (figure 4).

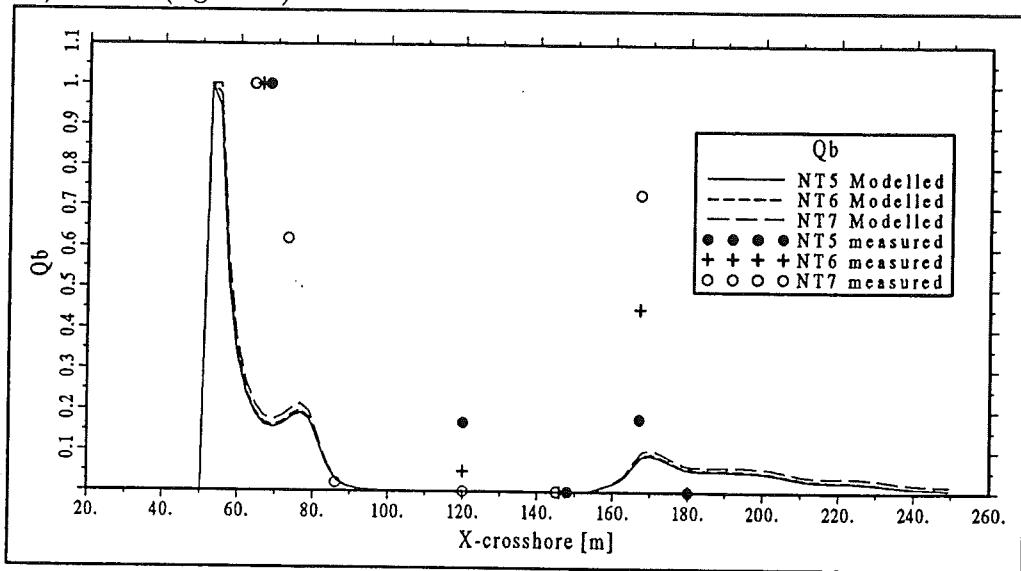


Figure 4. Measured and computed Q_b for case III (around 100 waves)

Wave Propagation

The wave conditions for cases III and IV were quasi-stationary, although in this latter case a transient component was also apparent (see test 8 in figure 5). Wave decay due to breaking has been modelled using the BJ'78 approach for random waves (neglecting bottom dissipation). In spite of the lack of perfect stationarity the obtained results are quite reasonable (figure 6). The single value used for the dissipation parameter α , leads to overestimating the higher wave values near the shore. Moreover, in this shoreline region, the shoaling process dominates over the breaking-induced decay which yields some oscillations in the cells of the computational domain close to the shoreline (not appreciable in figure 6).

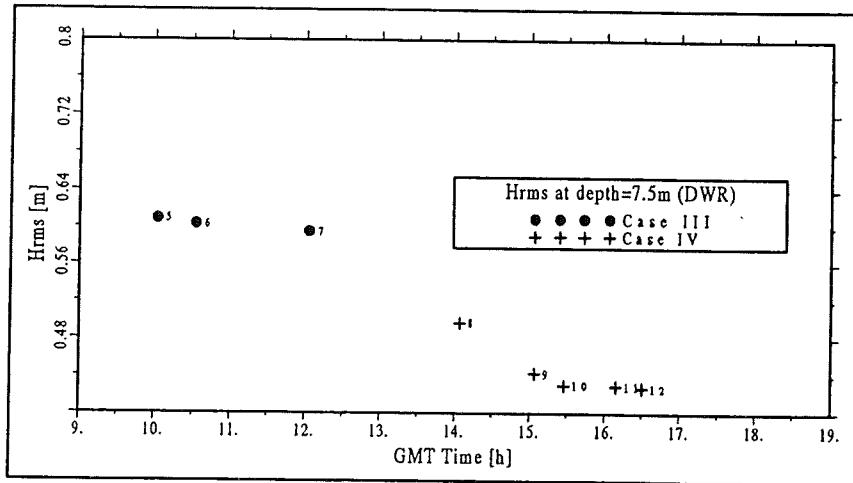


Figure 5. Wave height (Hrms) at 7.5 m depth from DWR

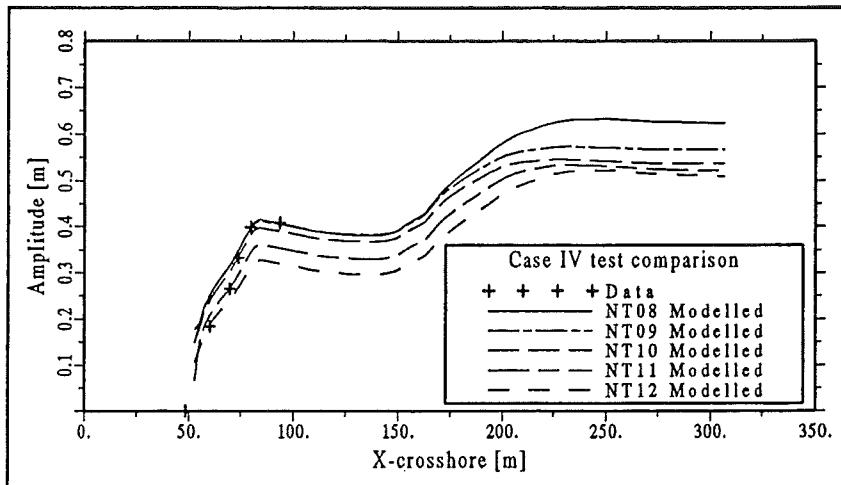


Figure 6. Wave decay Case IV. The different lines correspond to the varying conditions at the offshore boundary corresponding to the SZ-test time.

To achieve a reasonable setup prediction, a general sea level rise due to storm-surge has to be assumed in the field data. This general sea level rise has been estimated in 15cm and 8cm for cases III and IV respectively, using an iterative process. The resulting setdown/up predictions are reasonable although the fit is far from perfect. There is not yet a satisfactory explanation for this mean water level behaviour (figure 7). The predictions of the angle of wave incidence are in general acceptable (see figure 8), although numerical results overpredict systematically the experimental data from the ems. The origins for this could be the procedure used to derive an angle of wave incidence from the ems data, the spreading in wave angle given by the directional buoy (which is quite high when compared to the accuracy of the computations) or wave current interaction effects which have not been considered in this preliminary analysis.

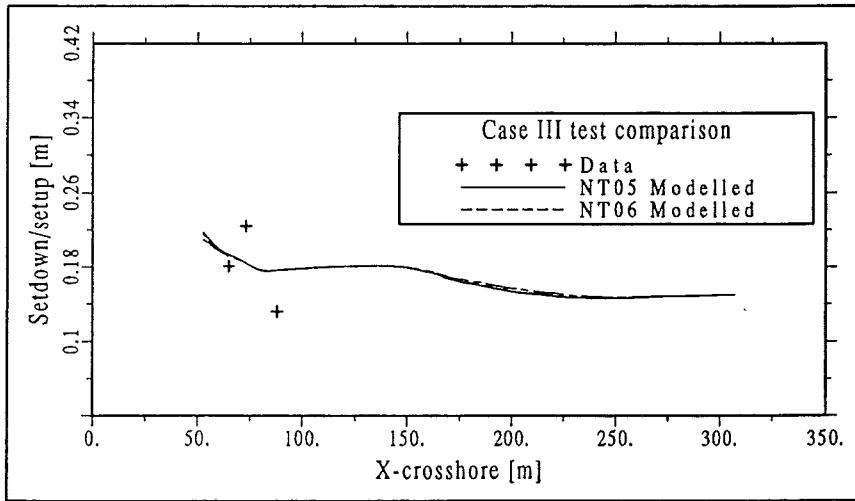


Figure 7. Wave setdown/setup for Case III.

Apart from the incident wind waves, there was evidence of stationary long waves with a period of around 40 s in the water surface time series. This long period pulsations are more clear in the spectral and moving average analysis of the velocity time series, both for the longshore and undertow components. These pulsations were uncoupled for longshore and cross-shore currents in most

of the measured tests. The longer period oscillations and the macroturbulence features are still being processed and will not be further discussed in this paper.

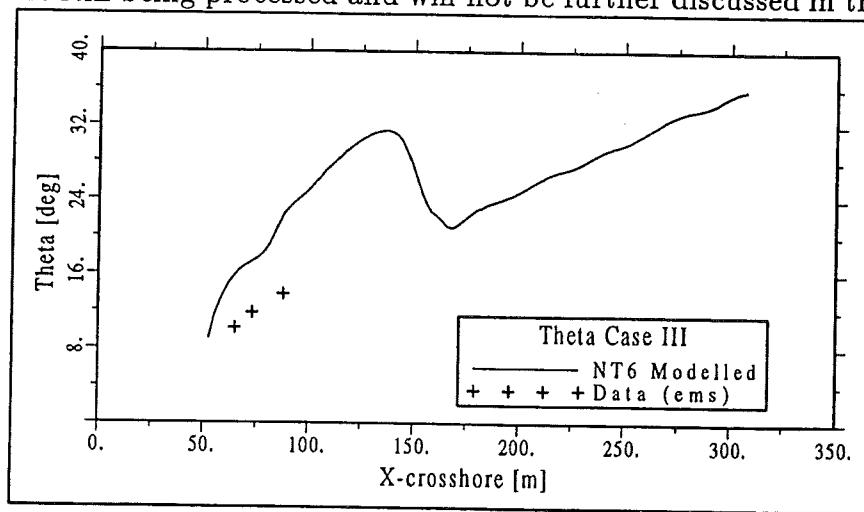


Figure 8. Incident wave angles for Test 6, Case III

The current measurements have shown the coexistence of a strong longshore current with a clear undertow crossshore distribution. The general pattern of measured data agree with the expected 3D "helicoidal" current structure shown in figure 9. Additionally it was observed the maxima for cross- and longshore components located at roughly the same across-shore coordinate.

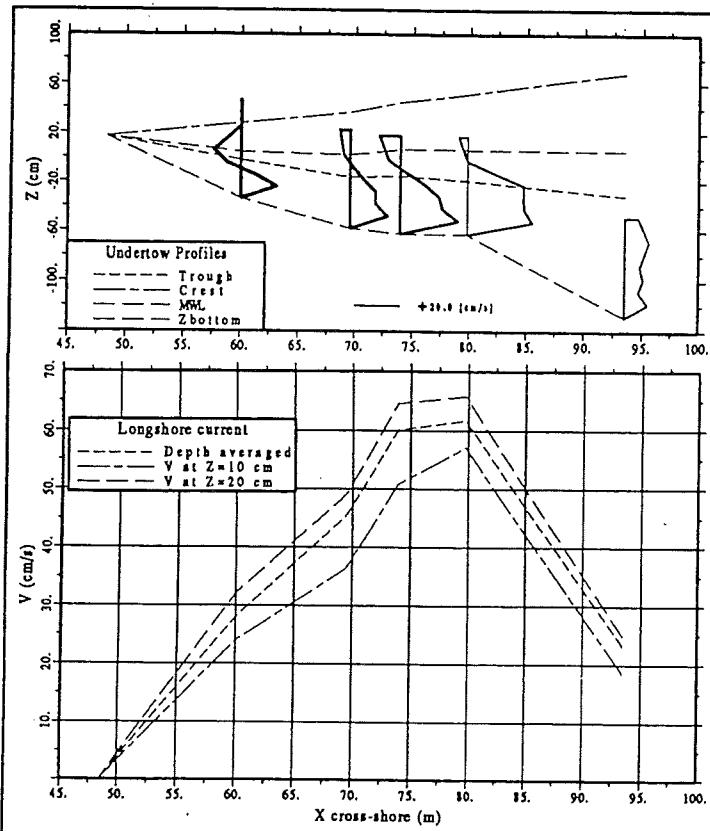


Figure 9. Measured 3D current field structure for Case IV.

Depth Averaged Currents

The velocity data were obtained after debugging, compass-correction and quality controls applied to the "raw" time series. The mean (referring to time and depth average) current values were calculated after time and vertical averaging over the series length (from 20 to 40 minutes depending on the record) and from the bottom up to the highest sensor (always below trough level).

Eulerian (ems) and Lagrangian (buoys and dye-spots) current velocities have been compared for the same time and space intervals, showing reasonable agreement even though the potential sources of error are different for each type of measurements. The main sources of error include the dye-spot location in the vertical, inaccuracies of the pixel-coordinates transfer function, ditto for the ems-orientation, limitations of the scale range and those inherent to the processing/filtering technique.

The 2DH currents have been modelled assuming an alongshore uniform beach which implies a mass balance restriction per profile. The bottom shear stress is modelled using a standard linear expression and the horizontal eddy viscosity coefficient follows the De Vriend and Stive (1987) (hereinafter DVS'87) proposal. These values agree well with the experimental data obtained from the processing of dye dispersion images (see Rodriguez et al, 1995). The numerical domain extends up to the shoreline, considering dynamically the "dry-flood" problem in that region.

The obtained results are quite reasonable (see figure 10) with two maxima roughly in the region of the two bars present in the profile. The mean cross-shore flux, obtained using the external mass flux closure submodel of DVS'87, is acceptable only in some regions. This point must be clearly improved in the future, from which better longshore current predictions can be expected.

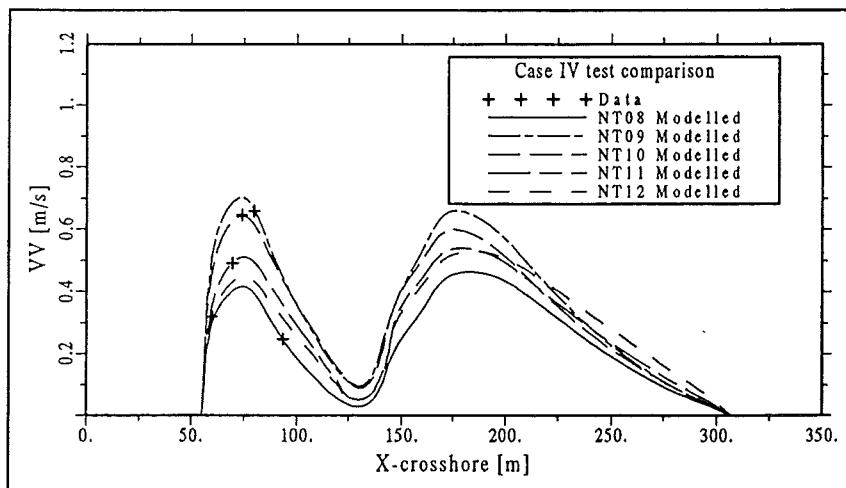


Figure 10. Longshore currents for Case IV. The different lines correspond to the hydrodynamics conditions of fig. 6.

1DV Structure of Currents

The vertical flow structure during *DELTA'93* was monitored with six ems

placed at 0.1, 0.2, 0.3, 0.4, 0.6 and 0.8 m above the bottom, at a single vertical pole located at the sledge. Measurements above z_{tr} were used to estimate the mass flux during the "wet intervals". Measurements below z_{tr} were used to characterize the vertical profiles of longshore and cross-shore currents, outside the bottom boundary layer (BBL).

The undertow profiles show a maximum near the bottom as expected according to previous experimental information (see e.g. Okayasu, 1989 or Smith et al., 1992). The longshore current profiles below z_{tr} show a mildly increasing trend upwards rather than a constant value.

The 1DV module, described in S.-Arcilla et al. (1992), splits the total current velocity vector into depth uniform, \vec{u} , and depth varying, \hat{u} , components. The crest-to-trough layer is not solved because it is considered exclusively via its interaction with the middle layer at trough level through the imposition of the appropriate boundary conditions. The BBL model is inspired on the one proposed by Fredsøe (1984), whose solution leads to algebraic expressions of logarithmic form that have been here parameterized to achieve an economic solution. The middle layer equations are solved using a power series approximation, $\sum_1^N a_i z^i$, to reproduce the vertical variation of \hat{u} .

It can be shown theoretically (S.-Arcilla et al, 1992) that the middle layer equation may not converge under certain conditions. Because of that, in general, the profile obtained consists of a first logarithm within the BBL, from z_o up to z_b , ($z_b - z_o = \delta_m$), a second one up to a given z_l level, and from this level to z_{tr} the power series $a_i z^i$.

The "optimal" z_l level to achieve an efficient convergence and to avoid artificial profile distortions is here considered to be $z_l \simeq 0.2 z_{tr}$. The trough level z_{tr} has been estimated as:

$$z_{tr} = \max [0.8h; h - 0.5H_{rms}]$$

The \hat{u} model needs three main external closure submodels to determine the \hat{u} profile: a) the shear stress $\langle \tau_{tr} \rangle$ at trough level, b) the mass flux over this level, $\langle Q_s \rangle$, and c) the eddy viscosity vertical distribution, $\nu_t(z)$.

For the case of longitudinal uniformity, the mean cross-shore velocity \bar{u} is obtained using a Q_s expression similar to the one proposed in DVS'87. This expression, which is given by:

$$\langle Q_{sx} \rangle = (1.0 + 7.0 Q_b \frac{h}{L}) \frac{E}{\sigma} K_x$$

does not fit well the experimental \bar{u} (see figure 11). In the $\langle Q_{sx} \rangle$ formula Q_b is a measure of the breaking intensity, h is the water depth, L the wave length, E the wave energy density, σ the wave frequency and K_x the x component of the wave number vector.

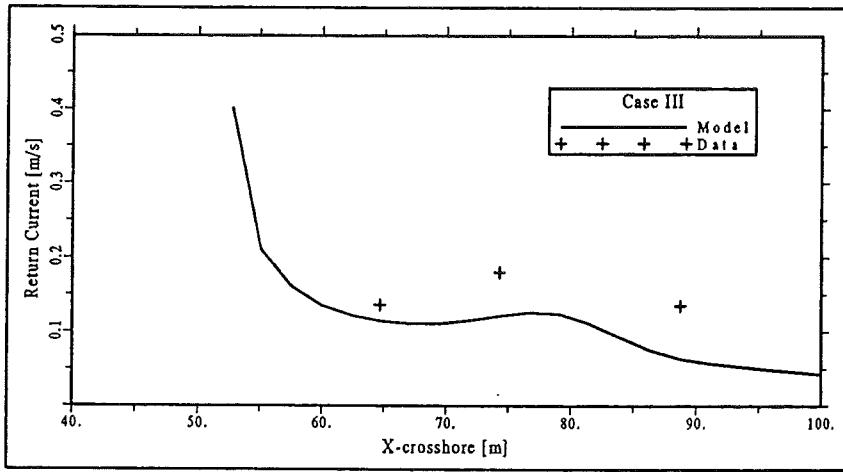


Figure 11. Crest-to-trough mass flux calculated according to DVS'87 and measured mean flow values (across-shore distribution)

The closure model for $\langle \vec{\tau}_{tr} \rangle$ uses the general expression proposed by Deigaard (1993), which extends the 1-dimensional expression obtained in Deigaard and Fredsøe (1989). The closure model for the eddy viscosity allows either a constant or a parabolic form for ν_t . The resulting expression is made up of two terms, the first one corresponding to the current induced eddy viscosity (similar to the one proposed in e.g. Coffey and Nielsen (1984)) and the second one corresponding to the breaking induced eddy viscosity similar to the value proposed by DVS'87 and Battjes (1983).

The resulting undertow profiles for cases III and IV are obtained with a constant ν_t and $N = 20$ in the middle layer equations, see figures 12 and 13. The continuous line represents the modelled undertow using as mean return flow the experimental value, while the dashed line represents the modelled undertow with an analytically calculated mean mass flux. It is apparent that the model fits much better the measured vertical structure when the experimental mean mass flux is used. The obtained fit is quite satisfactory even though there are no data from the bottom boundary layer.

The values above trough level, also indicated in the figures, have only been used to calculate the mean mass flux. Points I and II, physically "unrealistic", have been disregarded. No explanation for these two points is available. It can be, thus, concluded that most of the profiles show a good agreement between experimental and modeled values in the middle layer. This agreement is also reasonable near the bottom, although there is a small trend to underestimate measured current values in the lower part of the water column.

The corresponding longshore current vertical profiles for cases III and IV are shown in figures 14 and 15. The model results, which are preliminary, have been obtained using a parabolic power series. The solution with the complete power series is now been tested although the fit appears to be reasonable enough with the second order approach.

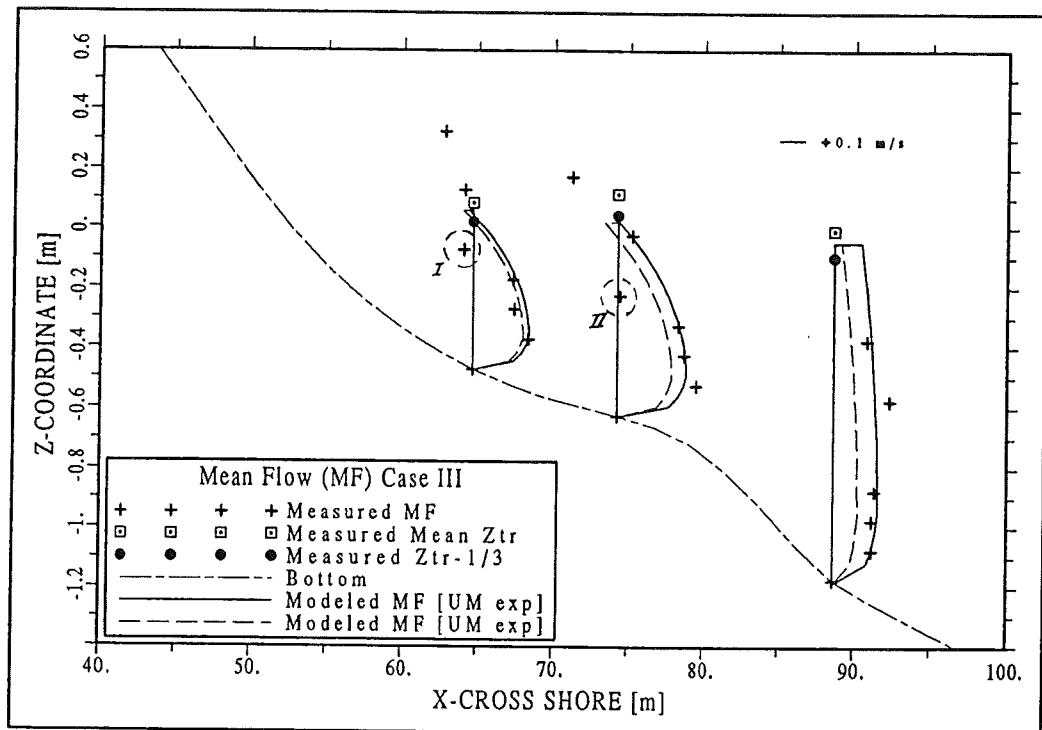


Figure 12. Undertow measured and modeled for Case III.

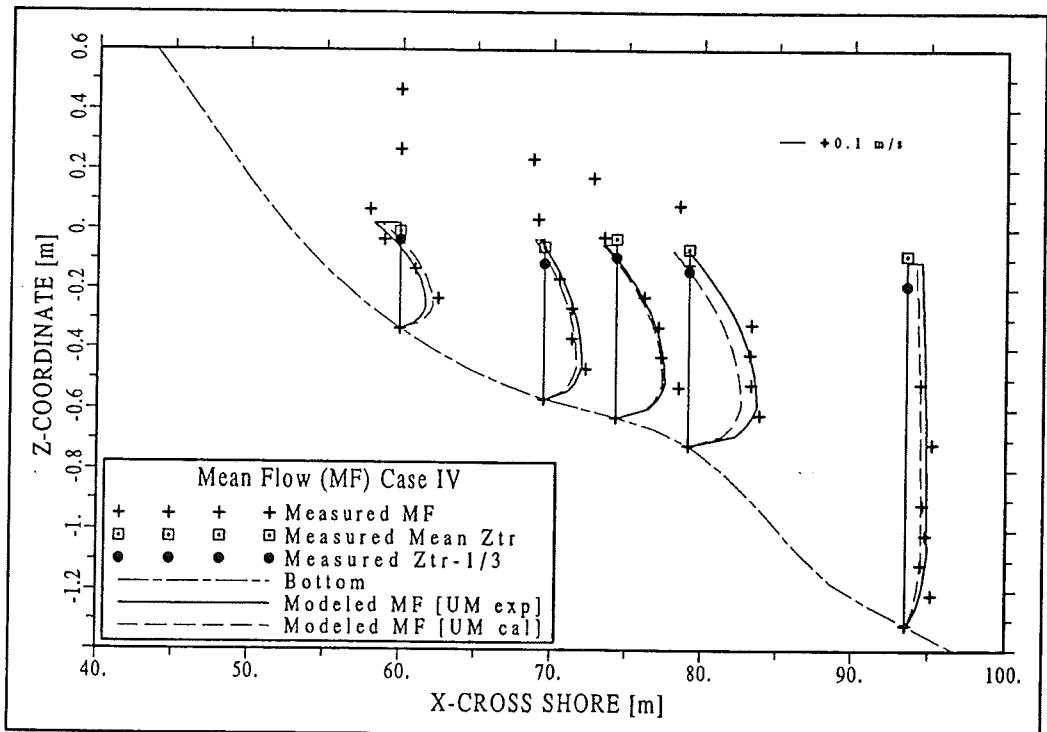


Figure 13. Undertow measured and modeled for Case IV.

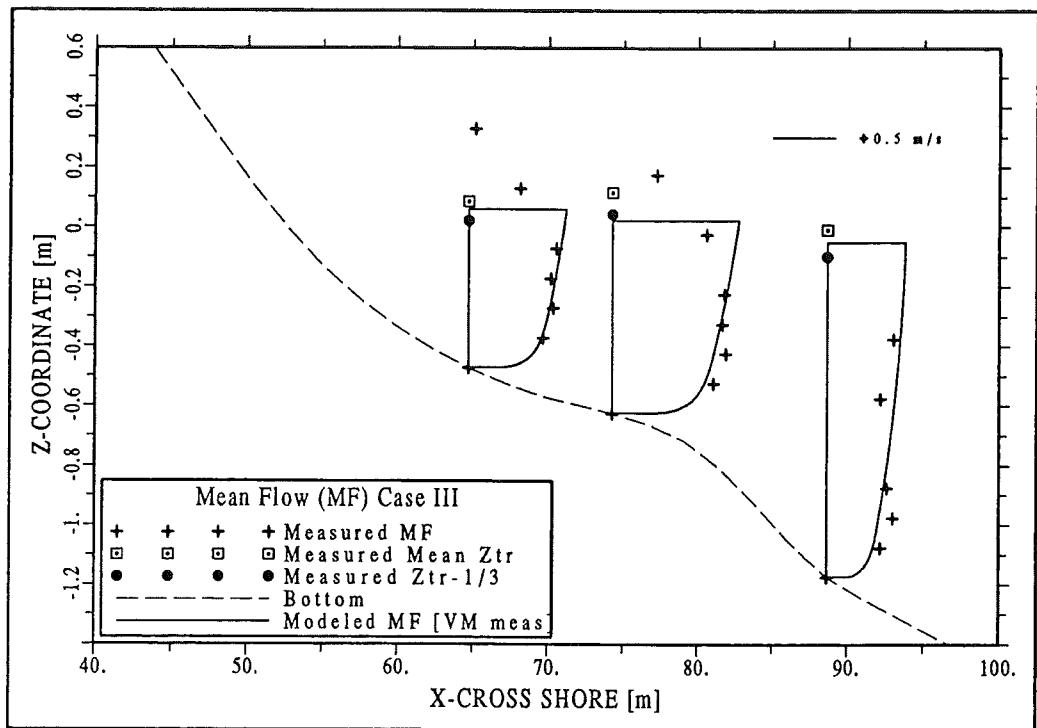


Figure 14. Longshore currents measured and modeled for Case III, (note rotated longshore profiles from the $z-y$ to the $z-x$ plane).

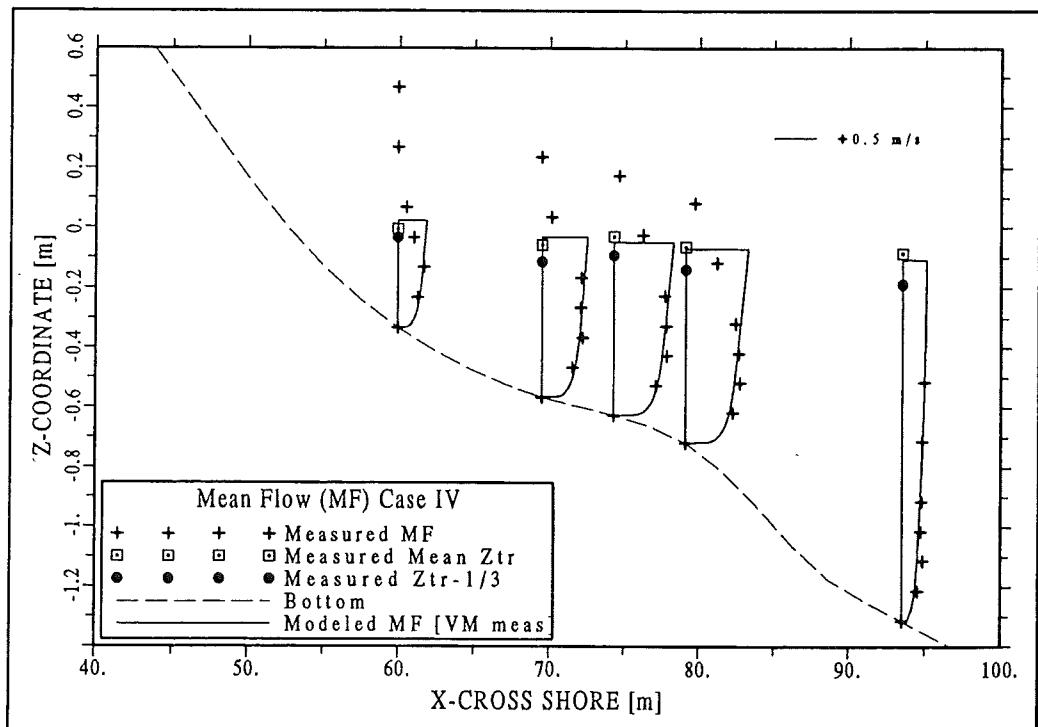


Figure 15. Longshore currents measured and modeled for Case IV.

Final Remarks

The *DELTA'93* field campaign is a modest field effort with respect to other experimental studies (e.g. DUCK, SUPERDUCK, NSTS, B-BAND, EGMOND, C2S2, NERC, DELILAH, etc.). The emphasis of *DELTA'93* was on the SZ vertical flow structure since the Mediterranean sea is an adequate environment to study this kind of processes, due to its microtidal range and medium wave energy-level characteristics.

The developed methodology works successfully even though there were some difficulties to define what was the still water level and what was the mean water level due to setup, setdown and storm surge. The identification of different flow modes (e.g. splitting up between low frequency, high frequency and current type motions) needs to be careful due to the non-negligible dependence on the filtering/processing techniques.

Long period pulsations are clear in the spectral analysis of the velocity time series, both for the longshore and undertow components. These pulsations were uncoupled for longshore and cross-shore currents in most of the tests.

The general pattern of measured data in the SZ agree with the expected 3D "helicoidal" current structure (figure 9). The maxima for cross- and longshore components happen at roughly the same across-shore coordinate.

The undertow profiles show a maximum near the bottom and the longshore current profiles below z_{tr} show a mildly increasing trend upwards rather than a constant value.

A good estimation of Q_b from video images needs time series longer than 100 waves period.

The dissipation model have showed difficulties in the fitting of the measured data when it was applied in the considered domain.

With respect to the modelling effort a general conclusion is the inherent limitation of field data to accurately validate numerical models. These numerical models always simulate a much simplified situation with respect to the field one, which precludes any definite and accurate validation conclusions for the time being.

In the wave modelling part there were in general good agreement with a slight overpredicted wave heights and some decay/shoaling oscillations near the shoreline. The main trouble with respect to the depth-averaged current modelling were the current overpredictions near the shoreline because of the decay oscillations just mentioned.

The 1DV model showed a good enough fitting of the vertical profiles, although the mass flux submodel should be improved due to its systematic underpredictions. It was also noted a slight trend to underestimate the current values near the bottom.

Acknowledgements

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References

- Battjes J. (1983) Surf zone turbulence. *Proc. 20th IAHR Cong.*, Moscow.
- Battjes J. and Jansen J. (1978) Energy loss and set-up due to breaking of random waves. *Proc. ICCE*, ASCE, pp 569-587.
- Coffey F. and Nielsen P. (1984) Aspects of Wave Current Boundary Layer Flows. *Proc. ICCE*, ASCE, pp 2232-2245.
- Deigaard R. and Fredsøe J. (1989) Shear stress distribution in dissipative water waves. *Coastal Engineering*, 13, pp. 357-378.
- Deigaard R. (1993) A note on the three dimensional shear stress distribution in a surf zone. *Coastal Engineering*, 20 , pp. 157-171.
- De Vriend H. and Stive M.J.F. (1987) Quasi-3D modelling of nearshore currents. *Coastal Engineering*, 11, pp 565-601.
- Fredsøe J. (1984) The turbulent boundary layer in Wave-Current Motion, *J.H.E*, ASCE, Vol 110, N° 8, pp 1103-1120.
- Jiménez J. and Sánchez-Arcilla A. (1993) Medium-term coastal response at the Ebro delta, Spain. *Marine Geology*, 114, pp. 105-118. Okayasu A. (1989) Characteristics of turbulence structure and undertow in the surf zone. Ph.D. thesis, University of Tokio, Japan.
- Redondo J., Rodriguez A., Bahía E., Falqués A., Gracia V., Sánchez-Arcilla A. and Stive M.J.F. (1994). Image Analysis of Surf-Zone Hydrodynamics. *Proc. Coastal Dynamics 94*, ASCE, pp. 350-365.
- Rodriguez A., Sánchez-Arcilla A., Redondo J., Bahía E., and Sierra, J.P. (1995), Pollutant dispersion in the nearshore region: modelling and measurements. *Int.Jour.Water Sc. and Tech.*, IAWQ, (in press).
- Sánchez-Arcilla A., Collado F., Lemos C. and Rivero F. (1990) Another quasi-3D model for surf-zone Flows. *Proc. ICCE*, ASCE, Delft, pp. 316-329.
- Sánchez-Arcilla A., Collado F. and Rodriguez A. (1992) Vertically varying velocity field in Q3D nearshore circulation. *Proc. ICCE*, ASCE, Venice, pp. 2811-2824.
- Smith J.M., Svendsen I. and Putrevu, U. (1992) Vertical structure of the nearshore current at Delilah: measured and modeled. *Proc. ICCE*, ASCE, Venice, pp. 2825-2838.



A4. *Measurement and Modelling of Pollutant Dispersion in the Nearshore Region.*

Este artículo ha sido presentado en "Int.Symp. on Pollution in the Mediterranean Sea" (Chipre, Noviembre de 1994) y una versión corregida se ha publicado en la revista "Water Science and Technology" (IAWQ, Vol. 2 Nro. 9-10, pg 169-178). Se ha publicado también una versión similar -en castellano- en la revista "Ingeniería del Agua" (Vol. 2, Nro. 2, pg 53-62).



POLLUTANT DISPERSION IN THE NEARSHORE REGION: MODELLING AND MEASUREMENTS

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ABSTRACT

Some results on pollutant dispersion modelling and tracer measurements for the Mediterranean Spanish coast are presented. Two hydrodynamic models have been used to simulate wind and wave induced circulation in the nearshore and surf zones respectively. A "near field" model has been used in order to simulate the initial conditions for the local "far field" dispersion model. Two study cases are presented: The first one shows the mixing of conservative tracers in a Mediterranean surf zone from an experimental and numerical models used to predict bacterial dispersion from the main sea outfalls of Barcelona City. The comparison between dye dispersion experiments and model in the surf zone is good, while the outfall predictions show the importance of accurately modelling the effects of buoyancy on the plume.

KEYWORDS

Digital images; nearshore; numerical modelling; pollution; sea outfall; surf zone; tracers.

INTRODUCTION

The Mediterranean Sea is an important eco-system where coastal waters have both pollution problems and intensive uses. These are important in the nearshore and surf zones where the mixing and dispersion mechanisms are complex because of breaking wave effects and the non linear interaction between waves and currents.

The study of environmental near-shore processes requires specific information from several fields. These studies provide information on the hydrodynamic, biological, chemical and "water quality" characteristics of the water body. The simulation of coastal dispersion needs detailed measurements and model validations in order to increase our knowledge of the underlying physical processes and to be able to compare effectively numerical predictions with field or laboratory data.

One of the first detailed studies - including measurements - of mixing processes in the surf zone was presented by Harris *et al.* in 1963. Since then, many authors have continued to study the turbulence and mixing induced by wave breaking by means of theoretical (Battjes, 1975; Zeider, 1976; or Svendsen, 1987)

and experimental research (Crickmore, 1972; Horikawa *et al.* 1978; or Nadaoka and Hirose, 1986). These authors have shown the complexity of these phenomena where the non linear turbulence-wave-current interactions play an important role. This complexity is the main reason why after twenty years of studies there are no universally accepted "complete" formulations neither for dispersion nor for eddy viscosity coefficients in the surf zone.

This paper after dealing with some details of the hydrodynamic and dispersion models presents two case-studies of dispersion in coastal waters. The first one shows the mixing of conservative tracers in a Mediterranean surf zone from both experimental and numerical points of view. The second case is an application of a suite of numerical models developed for the main Barcelona sea outfall.

NUMERICAL MODELLING

Hydrodynamic models

The Maritime Engineering Laboratory (LIM-UPC) has developed during the last 15 years several hydrodynamic models. Two of them are used in this work to simulate the velocity field as an input for the dispersion model. These two models have already been extensively calibrated (for further information on the validation process see the list of references). For tide, storm-surges or wind-induced flows in the nearshore zone (Case study 2) a 2DH shallow-water type model has been used. This hydrodynamic model (Sierra, 1990) was derived from Navier-Stokes equations and it was formulated in terms of vertically-integrated mass and momentum conservation laws. This model uses a finite-differences implicit scheme solved with a double sweep algorithm. When provided with suitable initial and boundary conditions, this model can simulate a wide range of physical problems.

The steady wave-induced current circulation in the surf zone (Case study 1) has been computed with a wave propagation and circulation model (see e.g. Sanchez-Arcilla *et al.*, 1992). The propagation module is based on the Kinematic and Wave Action Conservation Principles, requiring as boundary conditions the incoming wave height, period and angle of wave incidence.

The z-uniform current module solves vertically integrated mass and momentum equations quite similar to those of the previous model but including wave driving forces. Some additional "external closure submodels" are needed, namely: bottom shear stress and eddy viscosity. For the bottom shear stress a turbulent boundary layer submodel was parameterized and coupled to the middle layer equations (see details in Fredsie, 1984 and Sanchez-Arcilla *et al.*, 1992). Standard expressions have been used for the horizontal eddy viscosity (e.g. Deguchi *et al.*, 1992) after calibration with measured longshore current profiles.

The solution technique uses an explicit finite-differences method based on a MAC-type grid. The same grid is used by the wave propagation module. The z-uniform module starts from wave data (wave setup, radiation stresses, etc) calculated by the propagation module. The module computes then the z-uniform current velocity field including the possible current setup.

Both hydrodynamic models supply the dispersion model with a horizontal velocity field, including eddy viscosity and bottom shear stress distributions in the corresponding grid.

Dispersion model

The dispersion model is an improved version of the one developed by Holly and Pollantera, (1984) and modified by Carreras and Menendez, (1990). It solves the following 2DH convection-diffusion equation (PDE):

(1)

W $i,j = 1,2$; U_i z-uniform current velocities, C : depth averaged mean concentration, h : mean water depth, K_{ij} : horizontal dispersion coefficients and Td : characteristic time decay scale.

The numerical solution is based on a splitting technique for the different processes involved in the dispersion phenomena (advection, diffusion and decay). Initially, the temporal variation is solved with explicit finite differences. In the next step the advection term is solved with the characteristics' method using a bilinear interpolation of the velocity field in each cell. The diffusion term is then computed by means of a Gaussian analytical approximation, where the bidimensional parameters of the elliptic solution are a function of the diffusion coefficients. Consequently the initial PDE is transformed into two linear uncoupled algebraic systems solved by a sixth order classic Runge-Kutta method. Finally the solution of the decay term, in any, is trivial because it is usually approached as a first order process.

The applicability range of this model is limited to local regions due to the Gaussian approximation and the assumption of a weakly varying dispersion tensor in the zone where pollutant concentrations are significant.

In order to validate the model, its numerical results were compared with analytical solutions of equation 1, taken from Holly and Pollantera (1984) and Ozmidov (1990). The solution for an instantaneous point source in a non-uniform horizontal flow, previously presented by Okubo (1966), was computed by means of the following equation:

(2)

where Q is the source intensity, K_h the horizontal diffusion coefficient, and P , M_1 , M_2 , and M_3 are hyperbolic functions of the velocity field (for further details see Ozmidov, 1990).

Figure 1 shows, as an example, the comparison of analytically (eq. 2) and numerically obtained concentrations. As it can be seen, the agreement is good.

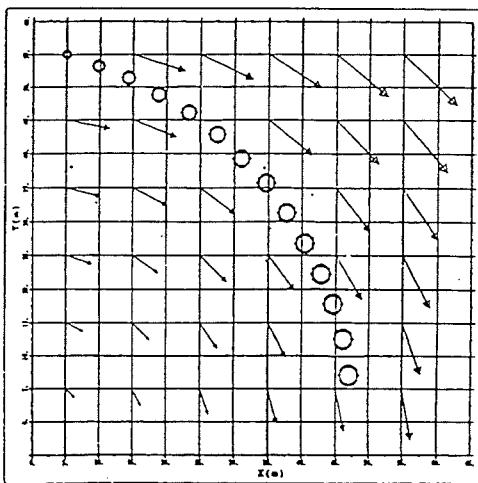


Figure 1. Comparison of Okubo's analytical solution (line) and the numerical simulation (cross) of an instantaneous point source dispersion in non uniform circular flow.

The dispersion model needs several inputs: the bathymetry, the velocity field and mixing coefficients. The bathymetry has been measured, while the velocity field has been obtained from both measurements and the hydrodynamic models. The bacterial decay rate can be estimated by standard expressions from Mancini (1978) or by using measured values. The horizontal dispersion coefficients K_{ij} are computed using Elder-type expressions as shown in equation 3. An advantage of the present formulation is that it is not necessarily an explicit K_{12} evaluation due to the Lagrangian solution-technique employed, which follows the pollutant

spot along stream lines. In this way only perpendicular (K_c) and parallel (K_p) - with respect to the flow direction - coefficients are needed.

$$K_p = \beta_p h u_* \quad K_c = \beta_c h u_* \quad (3)$$

where β_p and β_c are numerical coefficients and u_* is the shear velocity.

To simulate the total concentration C_T of plumes or continuous discharges (Case study 2) the individual solutions have to be superposed. This superposition considers all individual spots which contribute to C_T from a distance smaller than 4 standard deviations from each Gaussian distributed spot.

Results from this model have been compared with experiments under similar conditions and other numerical models. Crossshore and longshore eddy viscosity coefficients can be correlated with numerical model results using dye dispersion measurements such as spot centre and isolines intensities evolution.

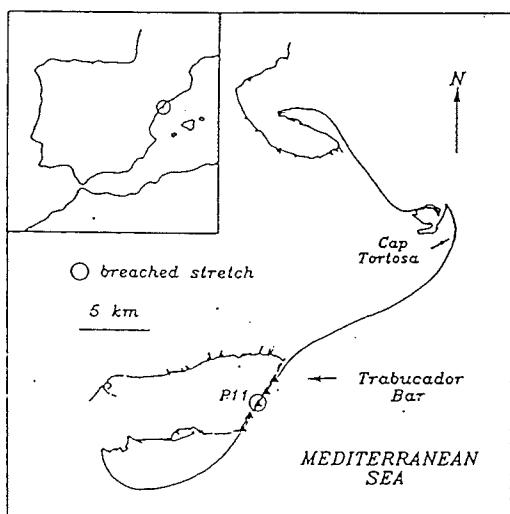


Figure 2. The Ebro Delta area showing the Trabucador bar location (P11).

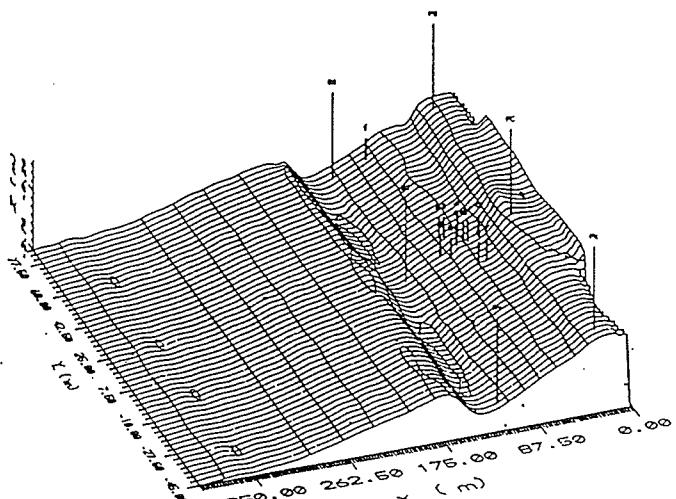


Figure 3. Bathymetry of Trabucador area, for 16 December 1993.

CASE STUDIES IN THE MEDITERRANEAN COAST

Case study 1: The Ebro Delta surf zone. Field experiments

The field experiments were carried out at the Trabucador bar of the Ebro Delta in the Spanish Mediterranean Coast during 13-17 December 1993. This site has been selected because of the simple linear geometry shown in figures 2 and 3.

The experimental work included simultaneous measurements of several parameters such as incident waves with a directional waverider buoy (*dwr*) and a wave gauge (*wg*), spatial velocity field with six electromagnetic current meters (*emc*), and dye dispersion with video recording and subsequent digital analyses. The measurements also include suspended sediment transport profiles and bathymetry.

A recent technique for digital image processing has been applied to study surf-zone hydrodynamics. The images were taken from a SVHS video recording of the sea surface near the coast. The use of image analyses in order to estimate both spatial and temporal hydrodynamic characteristics in the surf zone has been described in more detail by Redondo *et al.*, (1994).

A B/W video camera was placed at 20 m above the sea surface by means of a crane and several fiducial points were marked both at the coastline and 50 m offshore (see vertical lines in figure 3 and a sketch in figure 4). The images were corrected for optical deformations due to the camera angle and lens induced distortion. Video recording allows the identification and tracking of simultaneous spots, buoys and foam at breaker-lines and swash zones. From these images, breaking-induced turbulence and its dispersion parameters can be estimated (see e.g. figures 5 and 6).

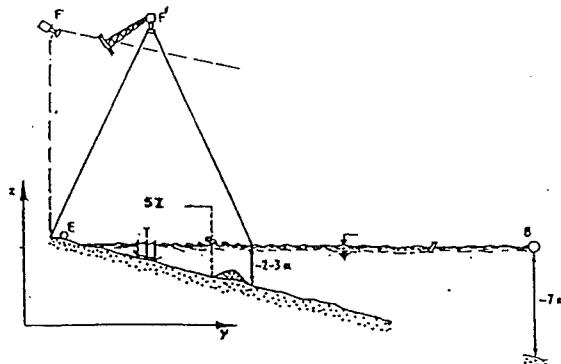


Figure 4. Sketch of recording equipment lay-out across the measured area: E: data-acquisition station; T: movable sledge (and dye release point) with *emc*, *obs*, *pst* and *wg*; F: video camera.



Figure 5. Average picture obtained integrating point video intensities when one of the dye spots is released. The trajectory may be seen near the centre of the image.

Tracers were selected after several field intercomparisons of different types of substances: fluorescein, rhodamine, $KMnO_4$, $CaSO_4$ and milk. A tracer's quality depends on its contrast with the colour of the sea surface (sky reflected) and its persistence it was concluded that milk and fluorescein were the best tracers.

Hydrodynamic measurements (P11)						
Case	Hrms	Tp(s)	Y(m)	h(m)	V	U
5	46.9	7.1	87.9	1.29	48	15*
6	38.4	7.1	73.2	0.80	88	19*
7	30.5	8	65.1	0.70	66	13*
8	40.8	7.1	93.5	1.34	23	8*
9	39.9	7.1	79.8	0.70	62	24*
10	33.3	7.1	74	0.68	60	16*
11	26.6	8	69.5	0.60	46	11*
12	18.4	8	60.0	0.38	28	10*

* (mean below trough level)

Figure 6. Table with the conditions measured during 16 December 1993: longshore (V) and cross-shore (U) vertically averaged velocities.

Figure 6 shows a summary of experimental conditions (case, rms wave height (cm), spectral peak wave period, cross-shore coordinate, mean water depth and horizontal velocities (cm/s)) on 16/December/93 for a post small storm sea state. Cases 5-7 were measured during the morning and cases 8-12 in the afternoon.

More information about the DELTA'93/94 experiments and the corresponding hydrodynamic modelling of waves and currents in the surf zone, can be found in Rodriguez *et al.*, (1994).

The use of time series of horizontal and vertical pixel intensities allow to obtain wave frequencies, as well as the surface component of the velocity thanks to the traces of advected surf (foam). The horizontal velocity is also estimated by tracking the centre (high intensity) of each spot of released dye. These measurements also provide reliable Lagrangian estimates of the horizontal mean velocity because of the strong vertical mixing present in the surf zone.

Measurements of dye dispersion at different distances from the shore (inside and outside the surf zone) have also been used to obtain the variation of dispersion coefficients, longshore/cross-shore currents and turbulence characteristics (such as the velocity r.m.s. integral lengthscales, anisotropy, etc.).

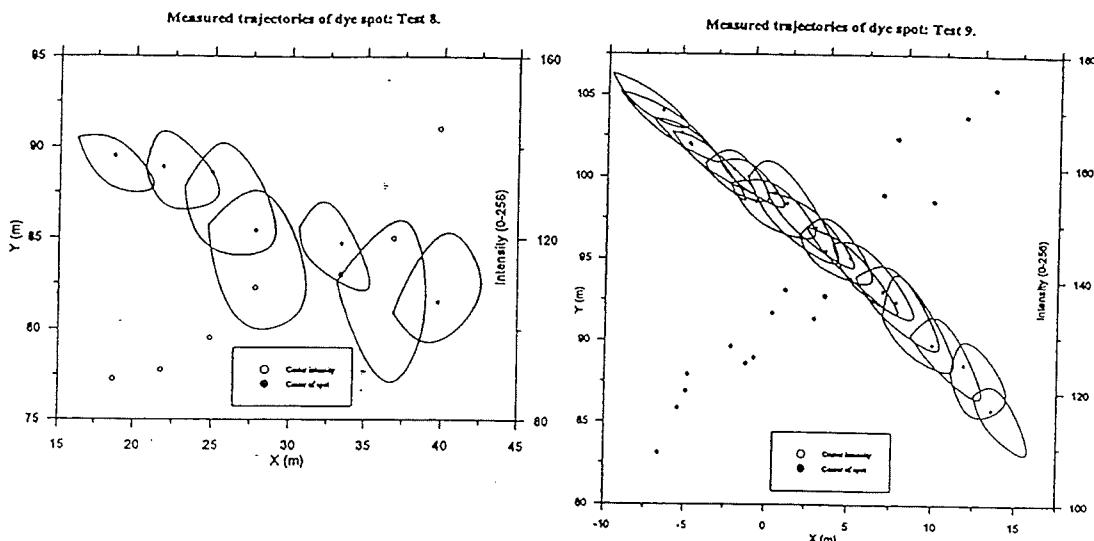


Figure 7. Measured dye spot trajectories during 30 s for cases 8 and 9. Note the relative dispersion and decay of the centre intensities. The time intervals between spots are 5 s and 2 s for tests 8 and 9 respectively.

Figure 5 shows a time averaged image corresponding to 30 seconds of dye trajectory (for a release of 20 g of fluoresceine). The spatial and time evolving characteristics of the Lagrangian surface velocity fields, are used to complement the Eulerian vertical velocity profiles measured by arrays of electromagnetic current meters (*emc*).

Figure 7 shows two time series corresponding to advection and dispersion of a 6 l spot of milk and fluorescein with an interval of 2 seconds between images for Test 9 and 5 s for Test 8 (defined in figure 6). The contours shown correspond to an intensity of 75-80 (in a 0 - 256 grey scale) and the centers correspond to the maximum intensity point of each dye spot.

Figure 8 shows the corresponding modelled time series using a spatial regular grid of 2.5 m in a domain of 362.5 m cross-shore and 130 m longshore. The propagation and circulation model uses measured incident wave conditions and *emc* measurements for the velocity field. The dispersion model starts with an initial condition similar to the experiment, obtained from the corresponding digital image. The dispersion coefficients in the surf zone were $0.03 \pm 0.01 \text{ m}^2/\text{s}$ as given by eq. 3. These values are similar to the eddy viscosity values used in the hydrodynamic model, (these values are typical of the surf zone, see e.g. Deguchi *et al.*, 1992).

In order to show the resolution of the system, figure 9 shows an example of a dye blob image enhancement. The selected image is first enlarged for a given window (*Top*) and then filtered to smooth the pixel structure (*Centre*). After intensity inversion and removal of the background, the intensity range of the spot in re-

scaled to the maximum range (0-256) showing clearly the dye blob internal structure (*Bottom*). This shape and structure are used to characterize the turbulence in the surf zone.

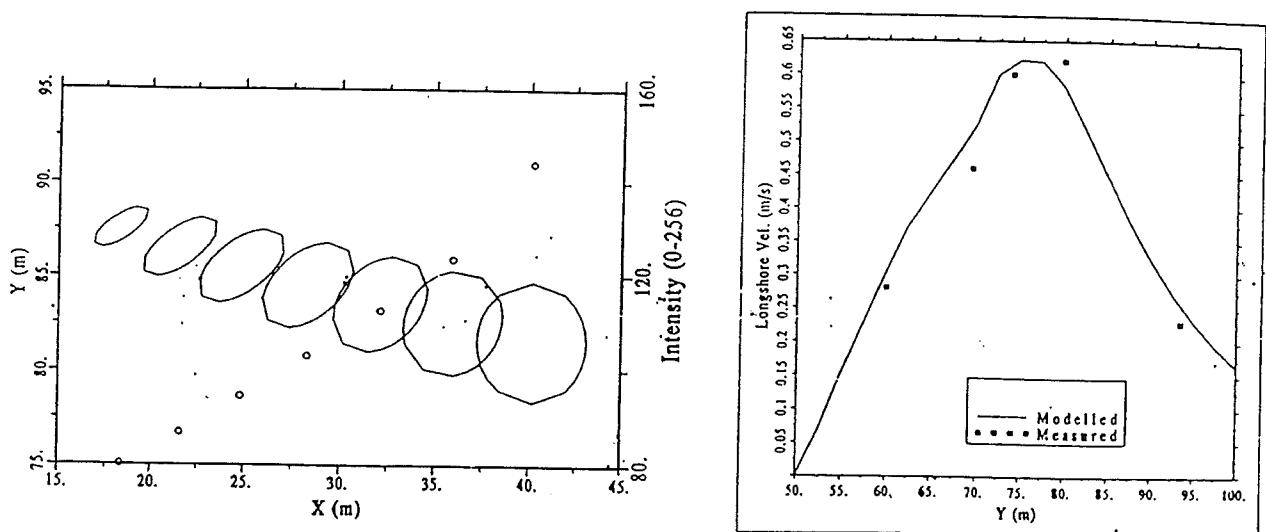


Figure 8. (Left) Measured and computed longshore velocity profiles at P11 and (Right) Computed dye dispersion of test 8: continuous lines show a mean intensity of 75-80, and points correspond to spot centre intensities.

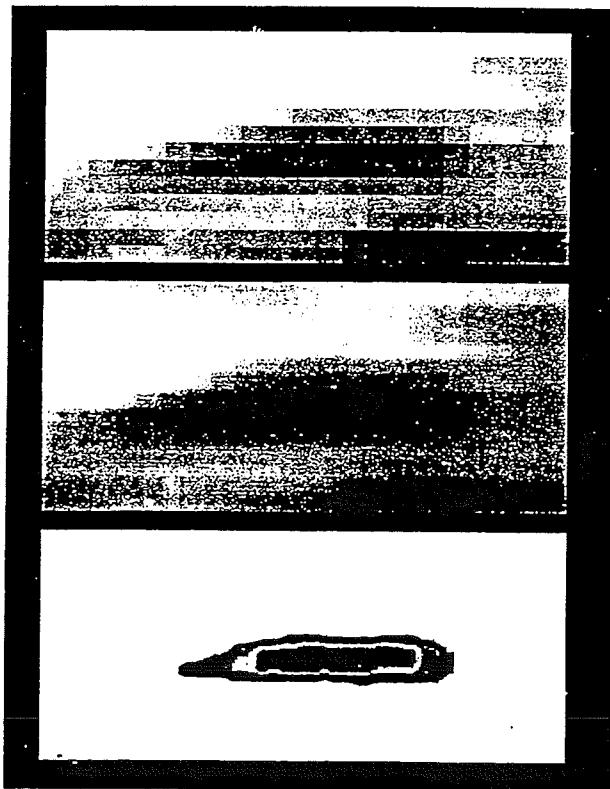


Figure 9. (Top) Original window of test 8 after 25 s of released, (Centre) filtered window (7x7), and (Bottom) final enhanced image showing the internal intensity structure of the spot.

Case study 2: The Barcelona litoral zone. Sea outfall discharges

One of the aims of this case-study is to verify the European Union water quality standards in the beaches near the Besos-Barcelona sea outfall (see figure 10). For this reason the hydrodynamic model has been used

to simulate the circulation for typical winter conditions in the zone, with winds of 5-10 m/s (from NE). The numerical grid was regular with a spacing of 100 m in a domain of 10 km in the cross-shore direction and 17.7 km parallel to the coastline.

The dispersion modelling has included two outfall situations: the old short pipe, 600 m long, and the new one with a length of 2900 m. The initial conditions in the near field and corresponding three-dimensional structure (cases *a* and *b* of figure 11) have been computed with the CORMIX model (see e.g. Jirka, 1991), assuming: water depths of 11 m and 50 m at the corresponding old and new outfalls, mean waste water of 9.1 m³/s, a mean ambient velocity of 0.2 m/s (parallel to coast), sea water with 3.5% salinity and a temperature of 11.5°C (i.e. $\rho_{\text{sea}} = 1027 \text{ Kg/m}^3$).

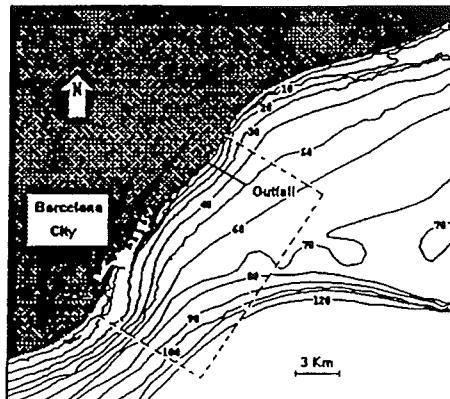


Figure 10. Barcelona coastal area showing the Besos sea outfall location and bathymetry. Dashed lines are the computational boundaries.

To study the 3D mixing structure, under different buoyancy conditions, several density discharges were assumed (two limit cases are shown in figure 11). First, waste water (ρ_{ww}) was considered as fresh water at 17.5°C (case *a* in figure 11 with $\rho_{\text{ww}} = 999 \text{ Kg/m}^3$). Intermediate cases (not shown here) considered several situations of partially mixed water (with ρ_{ww} around 1014 Kg/m³). The other simulated case, assumed a non buoyant discharge (case *b* of figure 11 with $\rho_{\text{ww}} = 1026 \text{ Kg/m}^3$).

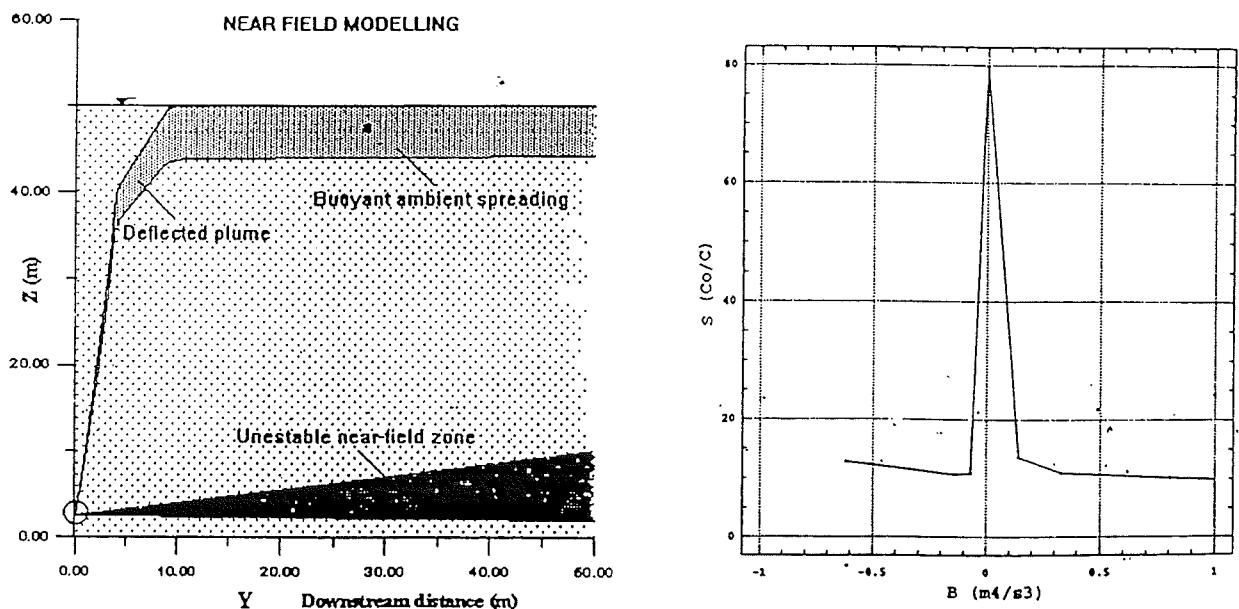


Figure 11. Near field modelling: a (left) 3D mixing structure as a function of density differences between waste and sea water for no stratified sea conditions: (a) fresh water discharge; (b) no buoyant discharge. Long sea outfall case: b (right) Effect of discharge buoyancy on mean dilution S at 2000 m downstream. Short sea outfall case.

As shown in figure 11a, there is a strong density stratification in the fresh water discharge (case a). This situation reduces the mixing, allowing the waste water to reach the coastline with high bacterial concentrations levels. For a non buoyant discharge, the mixing over the full depth takes place about 250 m downstream. The numerical model gives for the non buoyant discharge an horizontal eddy diffusivity of $K_h = 0.018 \text{ m}^2/\text{s}$. This compares well with the case 1 model and experimental diffusivities in the range $K_h = 0.03 + -0.01 \text{ m}^2/\text{s}$.

The influence of the outlet buoyancy flux, defined as $B = g/\rho \rho' w'$, on dilution, $S = C/C_0$ at a location 2000 m downstream of the source, if a single port 600 m from the shore is used, can be seen in figure 11b. There is a marked maximum for neutral discharges, while for negative buoyant plumes, which behave as gravity and turbidity currents, there is a further decrease in dilution.

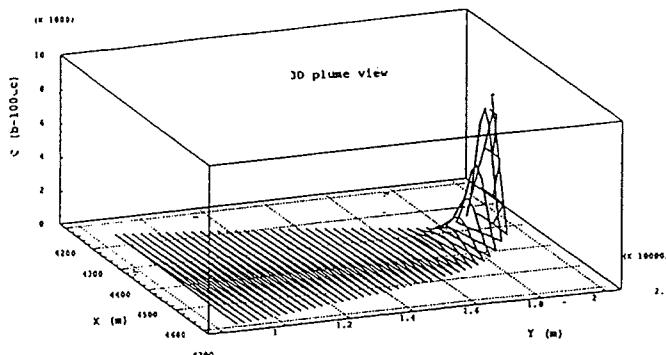


Figure 12. Horizontal bacteria dispersion simulated for conditions without stratification (case b of figure 11) in the far field and long sea outfall case.

The far field simulation considers decay rates typical of the Spanish Mediterranean coast with $T_{90} = 0.5 - 1.5 \text{ hs}$ (see e.g. Bravo, 1985 and Mujerigo, 1989). The dispersion coefficients were estimated from eq. 5 using standard values for $B_p = 5.9$ and $B_c = 0.23$. The predictions were similar to those obtained in previous studies (Mead and Cooper, 1992) with a 3D model, when there were no buoyancy effects and the decay rates were similar, (Mead and Cooper considered T_{90} between 1.5-24 hs). A far field plume for the long outfall and well mixed waste water is shown in figure 12.

CONCLUSIONS

Time averaged spatial images and time series of reflected intensities have shown to be a convenient technique for characterization of pollutant and tracer dispersion under near-shore currents and wave fields. The best tracer should be carefully selected according to weather conditions.

The effects of longshore currents on the advection and distortion of spots were the dominant feature of the experiments. Lagrangian (*video*) and Eulerian (*cem*) measurements of longshore currents were similar, while Eulerian measurements showed smaller offshore velocities, probably due to undertow oscillations. According to the numerical results of the surf zone case, lateral mixing coefficients in this zone (where stratification is negligible) have similar values to the eddy viscosity used in hydrodynamic models for wave-induced currents simulation.

The comparisons between outfalls with and without diffusors (modules 1 and 2 of Cormix) have shown a very high sensibility to the diffusor type in the cases where buoyancy is low. Moreover the effects of the discharge buoyancy are quite marked on the near field dilution rates. As an example, for 100 m downstream

of the source, there is a ratio of 7 between the buoyant and non-buoyant discharge dilutions. These effects have obviously a strong influence on the bacterial concentrations in coastal waters.

The calculated predictions for Barcelona out-fall case are similar to those obtained for previous studies with a 3D model and nonstratified conditions. Only the long sea outfall allows a dilution compatible with the water quality standards for bathing uses of adjacent beaches. The results presented here and those of Mead and Cooper (1992) should, however, be calibrated using measurements (hydrodynamic and bacterial decay).

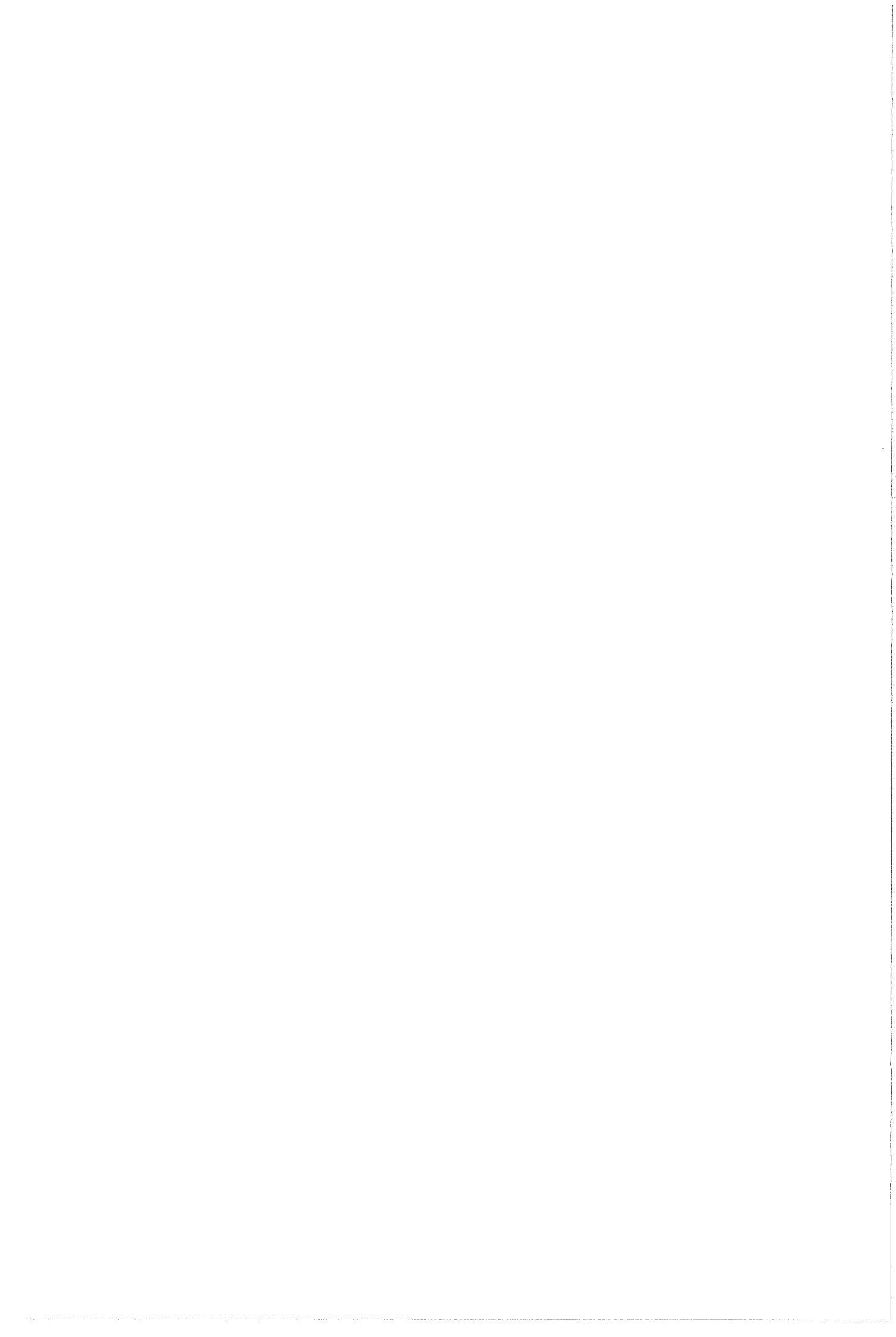
The results allow to evaluate the pollution levels along the coastline for several situations (point or diffuser discharges, different wind and density conditions, etc). The best design and outfall operation could, thus, be selected using this kind of simulation tools, so as to achieve minimum pollution levels.

ACKNOWLEDGEMENTS

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REFERENCES

- Battjes, J. (1975). Modeling of turbulence in the surf zone, *Symp. Mod. Tech.*, ASCE, 1050-1061.
- Bravo, J. (1985). Análisis y Evaluación de la Calidad Microbiológica de las Aguas Costeras, *PhD Thesis*, Univ. Aut. de Barcelona, Spain, (*in spanish*), 257 pp.
- Carreras, P. and Menendez, A. (1990). Mathematical modelling of pollutant dispersion, *Ecological modelling*, 52, 29-40.
- Crickmore, M. J. (1972). Tracer tests of eddy diffusion in field and model, *Jour. Hyd. Div.*, ASCE, 98, no HY10, 1737-1752.
- Deguchi, I., Sawaragi, T. and Ono, M. (1992). Longshore current and lateral mixing in the surf zone *Proc. Int. Conf. Coast. Eng.*, ASCE, 2642-2654.
- Harris, T., Jordaan, J. McMurray, W., Verwey, C. and Anderson, F. (1963). Mixing in the surf zone, *Int. Jour. Air Wat. Poll.*, 7, 649-667.
- Holly, F. M. and Usseglio-Polatera, J. M. (1984). Dispersion Simulation in Two-Dimensional Tidal Flow, *Jour. Hyd. Eng.*, ASCE, 110(7), (July), 905-926.
- Horikawa, K., Lin, M. and Sasaki, T. (1978). Mixing of heated water discharged in the surf zone, *Proc. Int. Conf. Coast. Eng.*, ASCE, 2563-2583.
- Jirka, G. (1991). CORMIX: Cornell Mixing Zone Expert System, I.C.E. *Short Course on Hydraulics of Sea Outfalls*, University of Honk Kong, December 1991.
- Mancini, J. (1978). Numerical estimates of coliform mortality rates under various conditions, *Journal of Water Pollution Control Fed.*, November, 2477-2484.
- Mead, C., and Cooper, A. (1992). Three-dimensional numerical modelling of coastal hydrodynamics and pollutant dispersal, *Conf. Hyd. Env. Mod. Coast., Est. and River Waters*, Ashgate Pub., 31-41.
- Mujeriego, R. (1989). Estudio del saneamiento de las zonas costeras de Cambrils y Vilaseca-Salou, *Int. Rep. Env. Eng. Sec.*, DEHMA, ETSECCPB, UPC, Barcelona, September, (*in spanish*), 152 pg.
- Nadaoka, K. and Hirose, F. (1986). Modelling of diffusion coefficient in the surf zone based on physical process of wave breaking, *Proc. 33rd Japan Conference Coastal Engineering*, 26-30, (*in Japanese*).
- Ozmidov, R. (1990). Diffusion of contaminants in the ocean, *Oceanographic Sciences Library*, Vol.4, Kluwer Academic Publishers, London.
- Redondo, J., Rodríguez, A., Bahía, E., Falqués, A., Gracia, V., Sánchez-Arcilla, A. and Stive, M. J. F. (1994). Image Analysis of Surf-Zone Hydrodynamics, *Proc. Coastal Dynamics 94*, ASCE, (*in press*).
- Sánchez-Arcilla, A., Collado, F. and Rodriguez, A. (1992). Vertically varying velocity field in Q3D nearshore circulation, *Proc. Int. Conf. Coast. Eng.*, ASCE, 2811-2838.
- Rodríguez, A., Sánchez-Arcilla, A., Collado, F., Gracia, V. and Coussirat, M. G. (1994). Waves and currents at the Ebro Delta Surf Zone: measured and modelled *Proc. Int. Conf. Coast. Eng.*, ASCE, (*in press*).
- Sierra, J. P. (1990). Transferencia no lineal de registros de oleaje. Análisis Hidrodinámico, PhD Thesis, ETSECCPB, UPC, Barcelona, (*in spanish*), 310 pg.
- Zeider, R. (1976). Coastal Dispersion of Pollutants, *Jour. Water. Harb. Coast. Eng.*, ASCE, Vol. 102, no. WW2 (May), 235-254.



A5. *Macroturbulence Measurements with Electromagnetic and Ultrasonic Sensors: A Comparison under hight-turbulent Flows.*

Este artículo ha sido aceptado, -sujeto a correcciones en fase de elaboración-, en la revista "Experiments in Fluids" (Springer). Es una versión corregida y aumentada del trabajo previo denominado *Experimental Study of Surf-Zone Macroturbulence and Mixing using DELTA'93 Field data* presentado en la Conferencia Internacional "Coastal Dynamics'95" y publicado por la ASCE (CD'95, ISBN 0-7844-0154-3, pg. 305-316).



Macroturbulence measurements with ElectroMagnetic and UltraSonic Sensors: A Comparison under high-turbulent Flows

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Summary

Experimental results of turbulent flows for both, field and laboratory tests are presented. The spatial and temporal resolution is limited by the measuring instruments which result in “filtering” out the small scales and observing only macroturbulence. The experimental field-results have been obtained during DELTA’93 large-scale surf zone (SZ) experiments in the Ebro Delta, (Spain), under spilling/plunging breaking waves, (Rodriguez et al., 1995b). The field-measurements include several tests across the surf zone with high vertical resolution. The measured turbulent properties are compared with state-of-art macroturbulence characteristics and scale-formulations. Furthermore, a detailed comparison of 2D -Electromagnetic (EMS) and 3D-Ultrasonic measurements has been carried out for hydraulic jumps in a laboratory flume to validate the field measurements and to study the frequency response of EMS.

Key Words

Hydrodynamics, macroturbulence, breaking waves, electromagnetic current meters, ultrasonic sensors, surf zone.

Introduction

To study and model the surf-zone (SZ) turbulence effects on the mean flow and transport processes some basic requirements are the turbulent momentum and mass fluxes, $\langle u'_i u'_j \rangle$, $\langle \rho' i u'_j \rangle$, which need high frequency velocity measurements.

The acquisition of this turbulence data demands special sensors due to very adverse field conditions. A wide range of techniques exists for the direct measurement of point instantaneous velocity, e.g. mechanic impellers (MI), hot-wire and hot-film probes (HFA), electromagnetic current meters (EMS), ultrasonic sensors (US), pressure sensors (VDK) and laser velocimeters (LDA). None of them is

of limitations, (see e.g. the revision by Clifford et al., 1993). For instance, *MI* have poor frequency response and are affected by multidirectional and reversible flows; *HFA* are sensitive to air/particle contamination and are very fragile for field-conditions, *US* are also fragile and sensitive to air bubbles and particles, *LDA* are both complex and sensitive to suspended sediment and air bubbles,- apart from its high cost-, and *EMS* need determination of its frequency response over 20 **Hz** (Clifford et al., 1993), discoidal heads are sensitive to flow separation, and can be affected by external magnetic fields.

Early studies of *SZ* turbulence were carried out in laboratory flumes with *LDA*, -some of the most relevant can be found in Stive (1980), Aono and Hattori (1984), Nadaoka (1986), Okayasu (1989) and Cox et al. (1994). In all of them, there are scale effects affecting the breaking induced turbulence. The second limitation of these laboratory studies is due to the type of waves generated during the experiments, namely “regular” waves , while in nature the waves are mainly irregular. This aspect is essential in the way to define turbulence under breaking waves, as it will be discussed below.

Under field conditions there are less experiments, mainly due to the high complexity and costs involved in *SZ* measurements. The main field measurements of surf-zone turbulence are recent and can be summarized as follows.

Kuznetsov and Speransky (1990) have used special *VDK* pressure sensors (see Kuznetsov and Speransky, 1986 for a description of these sensors) to measure spilling and plunging breaking wave induced turbulence in the Black Sea. Flick and George (1990) have used *HFA* to measure turbulence in the swash zone and George et. al (1994) measured surf-zone turbulence and organized flow with *HFA* and *EMS* in the California coast. Recently preliminary results of macroturbulence and mixing processes using *EMS* and a combination of dye and digital analysis of video images has been presented in Rodriguez et al. (1995a).

In this work, spherical *EMS* have been selected to study the *SZ* macroturbulence due to their characteristics, (e.g. in spite of the minor sensitivity of spherical heads respect to discoidal sensors under 3D unsteady turbulent flows, spherical sensors show a reduced interference). In order to establish the “validity range” of field measurements and estimate a realistic upper frequency response of the *Delft p-S EMS* (Delft Hydraulics, 1993), a laboratory comparison with *US* has been carried out then.

EMS sensors: sensors have been used to measure turbulent velocities and oscillatory flow in marine environments since the 50's. (e.g. Bowden and Fairbain, 1956; Miller and Ziegler, 1964 or Thornton, 1968). The *EMS* is based on Faraday's law of electromagnetic induction measuring the velocity of a conductive liquid moving through a magnetic field. The power supply frequency, jointly with the physical dimensions of the sensor, impose a theoretical upper limit on the instrument sensivity (or frequency response). Their main advantages are robustness, tolerance to particles or air contamination and good frequency response in the range 5-20 **Hz**, (Clifford and French, 1993). The upper limit needs to be verified for each specific *EMS* type; e.g., recent laboratory and field intercomparisons between two standard equipments such as the spherical *Marsh McBirney* (3.8 cm diameter) and the disc-type *Colnbrook/Valeport* (5.5 cm diameter head) have shown 5 **Hz** and 10 **Hz** as valid upper frequencies, (Lane et al. 1993). New Japanese sensors (*Kenek-VM2*) seem to work well up to 20 **Hz** (Kenek, 1996). On the other hand, the Ultrasonic sensors are based on the frequency changes of a sound beam propagating along a flow path. The flow velocity is estimated as:

$$V \equiv C_s^2 \nabla t / 2 L_p \quad (1)$$

where C_s is the sound propagation velocity (typically 1500 m/s), L_p is the length path of the US sensor and ∇t is the difference between travel time in opposing directions. The US have an excellent frequency response (up to 30 Hz), allowing 3D measurements, but are fragile and sensitive to particle/air contamination. For these reasons were selected to measure turbulence only under laboratory conditions. The air-bubbles effects were corrected before the analysis and comparison with EMS series, (see figures 5 and 6.)

Field Experiments in the Ebro Delta-Surf Zone

Significant surveying activities around the Ebro Delta, -in the Spanish Mediterranean coast, figure 1-, has been carried out by LIM-UPC during the last years. Among these activities was the DELTA'93 SZ experiments, from which hydrodynamic data have been obtained and analyzed. This SZ campaign took place along the Trabucador bar, a longshore-uniform and barred sandy beach. The DELTA'93 field campaign was a modest field effort with respect to some large past-experiments (as e.g. DUCK's, EGMOND, KAMCHIYA, LUBIATOWO, NERC or NSTS) or future larger ones (as FANS'96-97 or SANDYDUCK'97). The motivation for this campaign was the lack of detailed 3D data on SZ hydrodynamics in microtidal environments and the preparation of future campaigns such as FANS. The experiments were thus focused on the 3D structure of the flow including different time-scales: e.g. *currents* presented in Rodriguez et al. (1994), *oscillatory flow* studies, in Rodriguez et al. (1996) and *macroturbulence*, presented in this paper. A complete description of DELTA'93 SZ experiments can be seen in Rodriguez et al. (1995b).

The obtained field data include bathymetry, shoreline features, wave data outside and inside the SZ, mean water levels across the SZ, and the associated velocity fields (both horizontal and vertical structure). A movable sledge was used across the beach to register hydro and morphodynamic conditions across the SZ from the shoreline up to 2 m depth, (see figure 2).

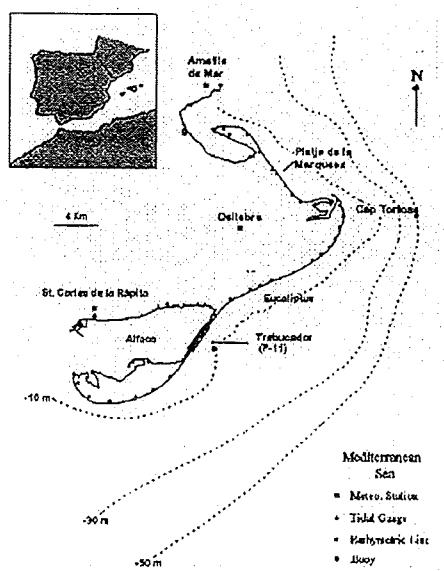


Figure 1: The Ebro Delta area.

The vertical structure of horizontal velocities u, v was measured with six $2D$ -electromagnetic current meters, *Delft Hydraulics p-S* type (4 cm diameter head), mounted on a sledge. The vertical spacing of the *EMS*, range from 0.10 to 0.20 m, starting at 0.10 m above the bottom and up to 0.80 m above the bottom, with an helicoidal distribution and a sampling rate of 20 Hz. The velocity-error was less than 2.5 cm/s (1% of the full-scale range). Simultaneously, the local water level evolution was measured with a vertical step wave-gauge (*Etrometa*) at a sampling rate of 4 Hz.

During DELTA'93 experiments 12 "tests" were carried out, but in this paper only the measurements corresponding to medium-high incident waves are considered for analysis. The incident wave conditions are summarized in table 1 for the 8 selected tests. The root-mean-square wave height H_{rms} and the mean water depth d correspond to short (256 s) "turbulent time-series". The orbital velocities were measured under wave-crests for "total time-series" and the wave-period corresponds to the peak of the power spectra of the total time-series (20 minutes).

Field Test n°	Shore-line Distance (m)	Depth * (m)	Peak Wave Period (s)	H_{rms} * (m)	$U_{orb}^{+ rms}$ (m/s)
F5	40.0	1.13	7.1	0.62	0.61
F6	25.0	0.67	7.1	0.53	0.57
F7	17.0	0.54	8.0	0.43	0.53
F8	45.5	1.35	7.1	0.53	0.44
F9	32.0	0.72	7.1	0.51	0.71
F10	25.0	0.71	7.1	0.40	0.51
F11	21.5	0.63	8.0	0.34	0.52
F12	12.0	0.40	8.0	0.21	0.52

Table 1: Field-experiment conditions (*: for turbulent series)

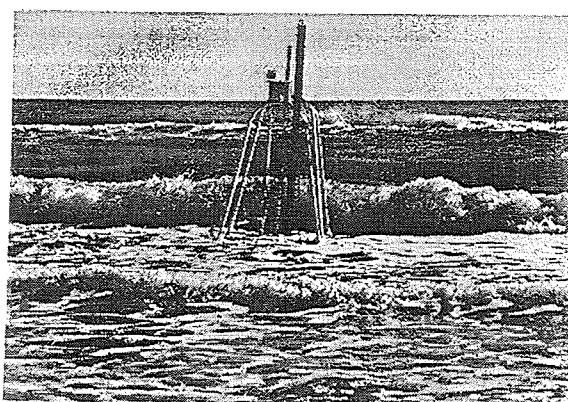


Figure 2: Instrumental Sledge with 6 EMS, 1 WG, 3 OBS, 1 compass and 1 optic-prism.

Data processing

The measured velocity data (20 Hz-raw series) were first debugged removing "noise", -e.g. values greater than 2.5 m/s-, and after that, the $2D$ values were projected into longshore (v) and cross-shore

(u) components using the compass and the topographic surveys. Water level measurements were recorded simultaneously at 4 **Hz** data sampling rate. These η series were also debugged and after that, low frequencies were removed using a high-pass filter with a cut-off frequency of 0.05 **Hz**, (obtaining the oscillations associated to “wind waves”). These water surface data will be further used to split turbulence and oscillatory flow as is described below.

Macroturbulence under breaking waves:

Defining turbulence in the *SZ* is a complex problem due to the overlapping of flow scales, the limitations of the scale range of sensors and those inherent to the processing/filtering technique. These problems are mainly related to “*time*” and “*space*” averaging processes.

“Time” considerations: A clear definition of turbulence in the *SZ* has not been established yet due to the coexistence of various unsteady and irregular flow-scales, and the overlapping of scales in the range between short waves and macroturbulence (large-eddies) generated under breaking waves.

Several methods have been proposed to split turbulence and waves, e.g. *a*) phase averaging (Stive, 1980), *b*) filtering (Nadaoka, 1986), *c*) coherence (Thornton, 1979), or *d*) from dissipation rates (George et al., 1994) but none of them seems to be exempt of disadvantages. For instance *a*) is only valid for regular waves, *b*) in general introduces spurious noise or artificial smoothing near the cut-off frequencies, *c*) for nonlinear waves (with/without turbulence) the coherence is less than unity because of the phase locking or higher modes and since this method also neglects surface correlated turbulence due to plunging breaking waves, and finally *d*) assume strong hypotheses about the stationarity and uniformity of the mean flow.

In this work we propose a *mixed* and practical method based on an accurate numerical filter with a cut-off frequency f_c obtained from the comparison of water-surface and velocity spectra. An efficient band-pass numerical filter, (Karl, 1989), without ripples around the values of the cut-off frequencies was used, (see figure 3).

“Spatial” considerations: For the spatial averaging of *EMS* it has been assumed that the velocity field around the head sensor is “detected” in a volume of scale L' ($L' \cong 3$ head diameter $\cong 0.12$ **m**). This spatial averaging is compatible with a time-scale related to the sampling rate f (20 **Hz**). Since the maximum velocity which advects the turbulent eddies, imposes a limit on the measurable eddies). These scales are thus related as,

$$V_{max} < L' f \cong 0.12 \times 20 = 2.4 \text{ m/s} \quad (2)$$

since the instantaneous measured velocities were less than 2.5 **m/s** in 99.99 % of cases, this V_{max} value allows to detect eddies larger than 0.1 **m** diameter approximately. Then, it can be concluded that after “spatial” and “temporal” averaging, only macroturbulence fluctuations can be detected from *EMS* data.

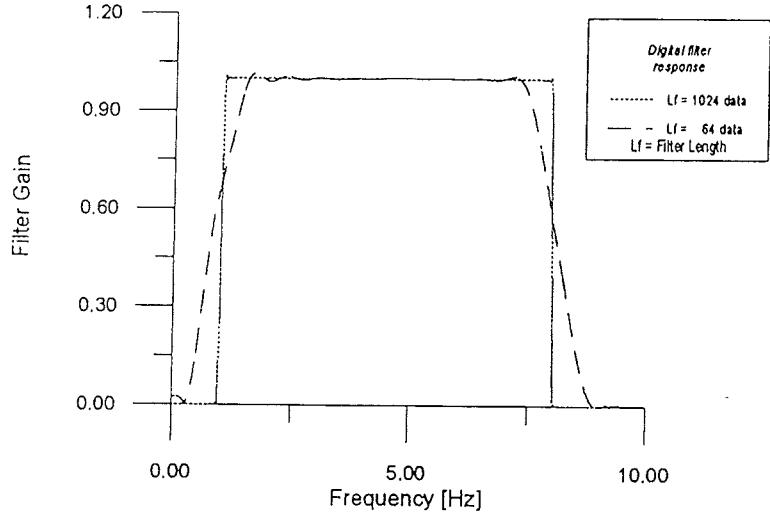


Figure 3: Gain Signal of the Numerical Filter used to split macroturbulence from oscillatory flow.
A filter length of 1024 data was used in all tests.

To carry out the filtering, two frequencies has to be defined. The upper one is the so called Nyquist frequency, equal to half of the sampling frequency, $f_N = 20/2 \text{ Hz}$. The other one is the lower cut-off frequency f_c and was determined as follows.

- i.) The water-surface energy spectrum, $S\eta(f)$ is computed by a classic *FFT* method.
- ii.) The $S\eta(f)$ is transformed into the surface-induced velocity spectrum S_{u-t} , using a linear transfer function, (*LTF*) Hu^2 , based on linear wave theory.
- iii.) The spectra of the measured $S_{u-m}(f)$ and filtered $S_{u-t}(f)$ velocity, are computed by a classic *FFT* method.
- iv.) The f_c is defined as the value for which the spectrum of the measured velocity (S_{u-m}) does not fall off while the “theoretical” spectra associated to the orbital motion (S_{u-t}) falls off rapidly, see test 6 spectra as an example (figure 4), where two values of f_c have been selected to study the sensitivity of turbulent characteristics to f_c , ($f_c(6a) = 1.11 \text{ Hz}$ and $f_c(6b) = 1.29 \text{ Hz}$).

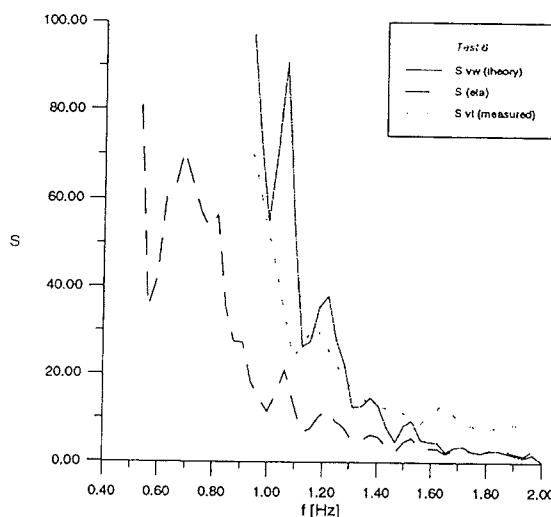


Figure 4: Determination of cut-off frequencies for test 6.

Macro-Turbulence characteristics

Macroturbulent Intensities: the horizontal turbulent intensities u', v' were obtained as the r.m.s. values of the filtered velocities,

$$u' = \sqrt{(1/n \sum_{i=1}^n U_i^2)} \quad (3)$$

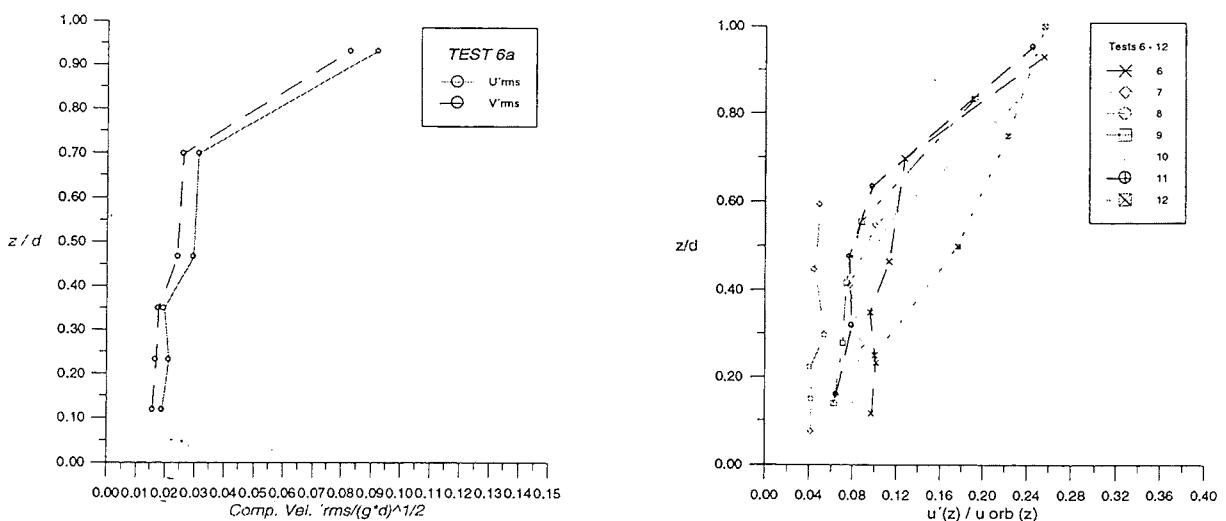
where U is the filtered velocity and n the length of the measured series, ($n = 4096$).

The obtained horizontal *MT*-intensities (u', v') show values similar to previous studies in the middle and lower water column (around 0.01 of wave celerity C). Near the wave-trough and free surface, *MT*-intensities can increase up to 0.1 C . These upper values are in correspondence with the range of available laboratory data and are larger than the field measurements reported by George et al. (1994).

Inside the surf zone all intensities (tests 5-11) show a *parabolic* trend, which seems not to be sensitive to the cut-off frequency used to define the *SZ* macroturbulence. A different trend has been found near the swash zone (test 12), where the intensities show higher values and a *linear* profile. Figure 5 shows the Froude scaled components for test 6, and figure 6 the cross-shore variation of u' scaled with the measured orbital velocity under wave-crests.

Horizontal shear-stress:

The vertical distribution of horizontal shear-stresses $\langle u'v' \rangle$ is shown in figure 7. It can be seen that $\langle u'v' \rangle$ is very important in the upper third of the water column, where the horizontal momentum transfer is expected to be vertically-anisotropic and higher near the water surface. This point is important for numerical models, where the adopted eddy viscosity profile should have a consistent vertical distribution where a realistic diffusion is required.



Figures 5 and 6: (left) Macroturbulent Intensities for both horizontal components u' and v' of test 6 and (right) $u'(z)$ for all tests

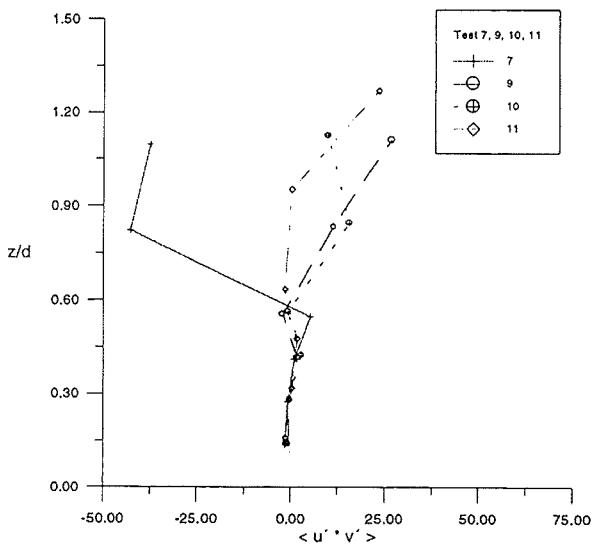


Figure 7: Vertical structure of horizontal shear-stresses $\langle u'v' \rangle$ for tests 7,9,10 and 11.

Macroturbulent-Isotropy:

In order to study the horizontal macroturbulence isotropy, the u' and v' MT-intensities were compared (see figures 5 and 6). It was found that, in general, there is evidence of a small horizontal anisotropy between the parallel and perpendicular directions with respect to the mean wave-propagation direction. This anisotropy is almost uniform in the water column.

During field experiments the *EMS*-2D sensors measured only horizontal components, which means that, for 3D considerations the z-component should be estimated.

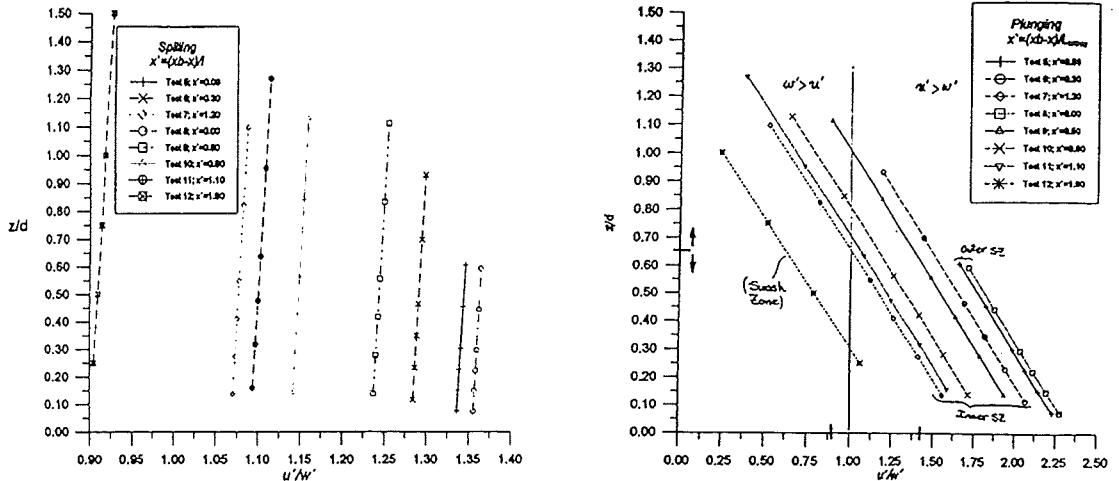
The vertical turbulent intensity, w' , was thus obtained using the detailed 2DV laboratory measurements obtained using an *ALD* in laboratory by Aono and Hattori (1984) and Nadaoka (1986). These data were used to generate empirical functions F of the type:

$$u'/w'(z) = \beta_1 + \beta_2 z/d + \beta_3 (x - x_b)/L \quad (4a)$$

where x is the cross-shore coordinate, x_b means the mean breaking point position and L is the wave length. The functions F_s (spilling) and F_p (plunging) were used to evaluate the relation $u'/w'(z)$ for all field experiments. The β -values fitted for the spilling-breaking function, F_s , were:

$$\beta_1 = 1.35, \beta_2 = -0.24, \text{ and } \beta_3 = 0.02 \quad (4b)$$

and the results are shown in figures 8 and 9.



Figures 8 and 9: Functions F_s and F_p for all tests.

Figure 10 is presented to illustrate the degree of SZ anisotropy, where, the arrows indicate the similarity of the measurements with typical values for “plane-wake turbulence” reported by Townsend (1976) and Stive and Wind (1982):

$$u'^2 / 2K = 0.43; \quad v'^2 / 2K = 0.31; \quad w'^2 / 2K = 0.26$$

where K is the turbulent kinetic energy (see definition below).

In order to estimate the turbulence isotropy parameter A , ($\varepsilon = A (u' v' w') / \mathcal{L}$), expression 6 is used, where \mathcal{L} is the *integral turbulent length scale*, according to Tennekes and Lumley (1972) and ε is the energy dissipation rate.

$$A(z) = 0.5 C_D (u'^2 v'^2 w'^2)^{3/2} / u' v' w' \quad (6)$$

For isotropic turbulence a value of $A = 0.42$, is obtained. In some of our SZ experiments (3 out of 8) a constant value of $A(z)$ near 0.30 was found.

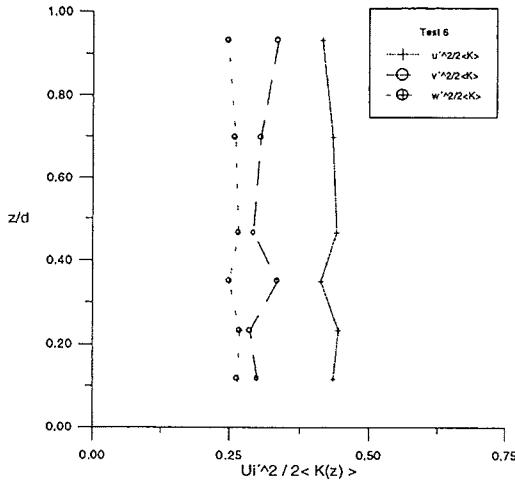


Figure 10: Macroturbulence Anisotropy for test 6.

Macroturbulent Kinetic energy K :

The MT -kinetic energy was estimated as:

$$K(z) = \frac{1}{2} (u'^2 + v'^2 + w'^2) \quad (7)$$

where the horizontal intensities were measured and the vertical component w' was estimated using the function F_S .

The vertical distributions of K shows a similar trend to that of MT intensities, with an important increase near the water surface, where the source of macroturbulence is located. Figure 11 shows the obtained results for all tests. Important differences can be observed between values in the outer (test 8), inner SZ (other tests) and swash zone (test 12). A strong increase in K values appears at z/d around $2/3$, except near the swash zone where the profile is quasi-linear.

Integral Length Scale \mathcal{L}

The determination of the turbulent length-scales \mathcal{L} is important to estimate the eddy viscosity V_t which is in turn used for modeling hydrodynamics, sediment transport and pollutant dispersion inside the surf zone.

Previous studies have estimated this SZ turbulent Length-scale as shown in table 2:

$\mathcal{L} =$	Source-data	Reference
0.2-0.3 d	Laboratory-surf zone	Svendsen, 1987,
H_{rms}	---	McKee Smith et al., 1993
0.43 d	Field-swash zone	Flick and George, 1990
0.25 d	Field-surf zone	George et al., 1994
0.04 d	Laboratory-outer SZ	Cox et al., 1994
0.12 d	Laboratory-middle SZ	Cox et al., 1994
0.18 d	Laboratory-inner SZ	Cox et al., 1994

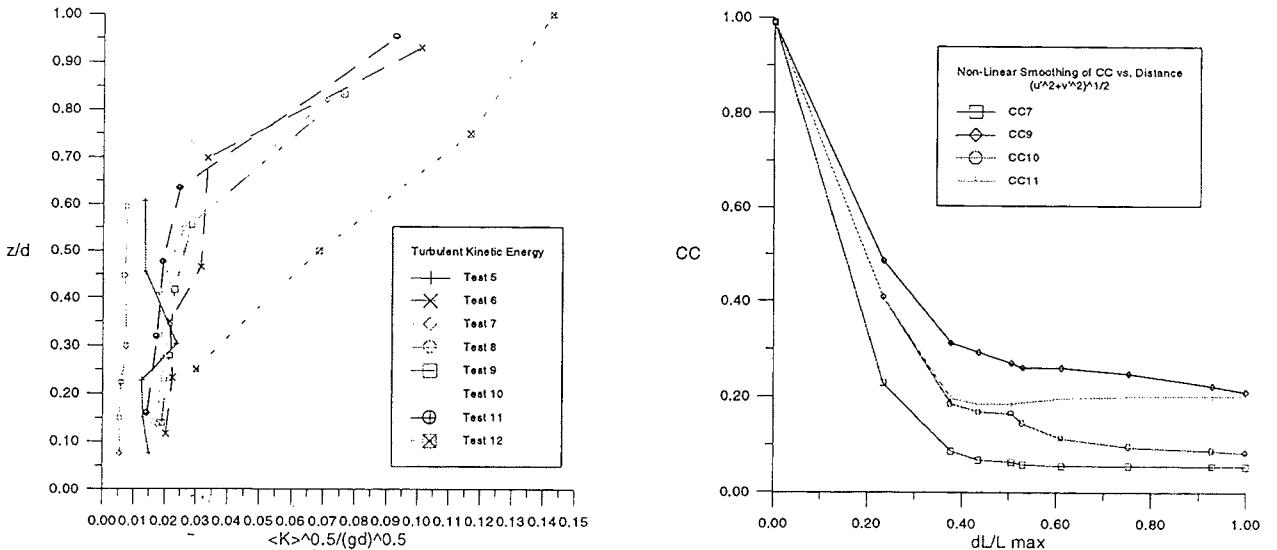
Table 2: “state of art” estimations of \mathcal{L} in the surf-zone.

In this work, the classical definition of the Integral length-scale of the turbulence \mathcal{L} (Tennekes and Lumley, 1972) is taken:

$$\mathcal{L} = \int_0^{L_{max}} CC(\mathbf{u}'_i - \mathbf{u}'_{i+dl}) dl \quad (8)$$

where the horizontal turbulent velocity ($u' = (u'^2 + v'^2)^{1/2}$) cross-correlation coefficients (CC) were computed with different spatial (dl) and temporal lags.

The spatial lags were fixed and obtains from the separation of the 6 EMS (16 values between 0.2 and $L_{max} = 1.2$ m) and the temporal lag was determined by the maximum correlation between $T = \pm 1 / f_c$. The experimental curves of CC were smoothed before the application of a numerical quadrature, see figure 12 where the results for tests 7,9,10 and 11 are shown. The experimental values found for tests 5-12 are shown in table 3.



Figures 11 and 12: Kinetic energy K for all tests, and Curves for Integral length scales for tests 7,9,10 and 11.

Field test	ℓ / d	f_c (Hz)	SZ Location
5	0.34	1.15	Outer SZ
6	0.28	1.11	Middle SZ
7	0.24	1.27	Middle SZ
8	0.30	1.17	Outer SZ
9	0.45	1.31	Middle SZ
10	0.33	1.38	Middle SZ
11	0.44	1.33	Inner SZ
12	0.58	1.17	Inner SZ

Table 3: Dimensionless turbulent scales ℓ / d and Cut-off frequencies.

The test-11 value is of the same order of that reported by Flick and George (1990) near the swash zone.

From these experimental values a multiple regression was obtained using the *r.m.s.* wave-height dimensionless with the water depth, and the Froude-scaled *r.m.s.* orbital-velocity, as independent variables,

$$\ell / d = \alpha_1 + \alpha_2 H_{rms}/d + \alpha_3 U_{orb}/C \quad (9)$$

where C is the local wave celerity. The results are shown in figure 13 and table 4.

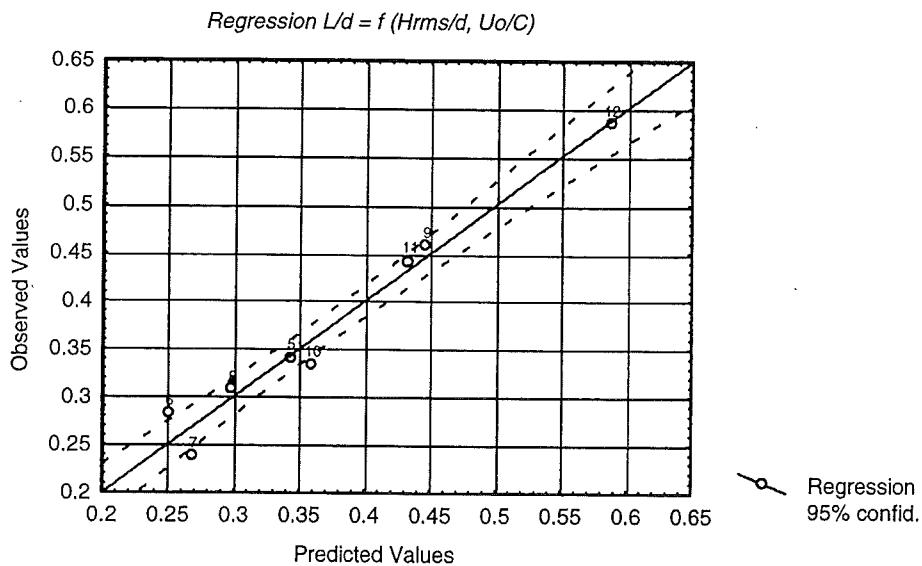


Figure 13: Multiple Regression for dimensionless Integral Length scale ℓ / d

Length scale	α_1	α_2	α_3	R^2 (Adj.)
ℓ / d	0.286	-0.837	2.820	0.9545

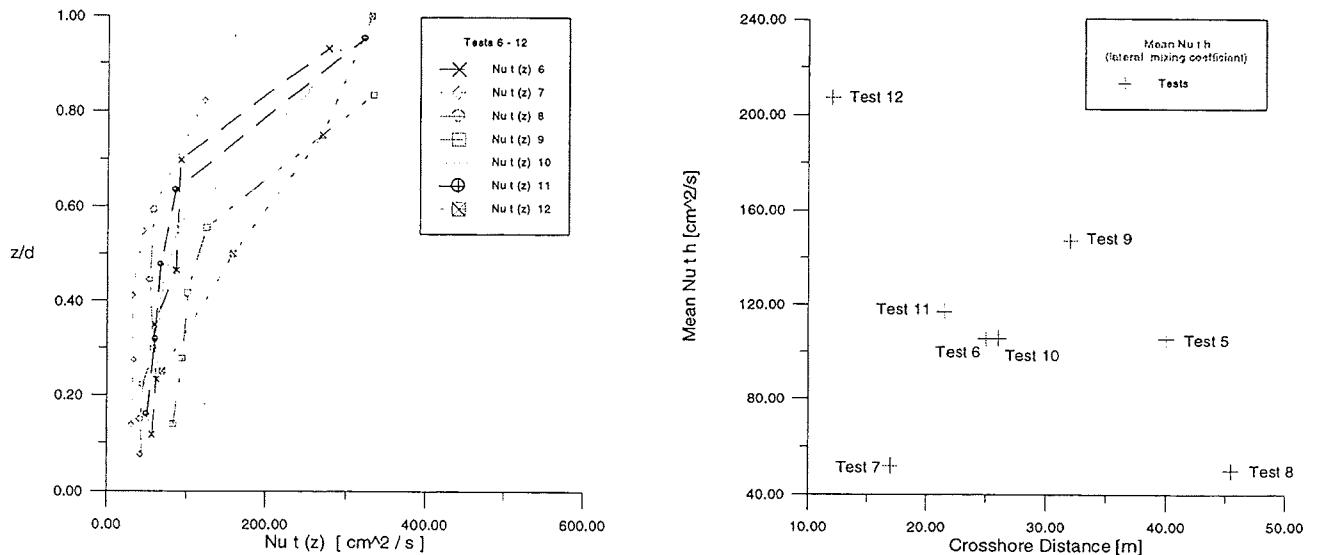
Table 4: Multiple regression parameters for Turbulent Length-Scale in the Surf Zone

Eddy viscosity:

The eddy viscosities were estimated as:

$$v_t(z) = C'_\mu K^{1/2}(z) \quad \ell \quad (10)$$

where a C'_μ value was 0.5 according to Rodi (1984). Figure 14 shows the vertical distributions for various tests.



Figures 14 and 15: Vertical and cross-shore distribution of eddy viscosity for all tests

Macroturbulent Dissipation ϵ :

The energy dissipation rate was estimated as

$$\epsilon(z) = C_D K^{3/2}(z) / \ell \quad (11)$$

were $C_D = 0.16$ according to Rodi (1984). Figure 16 shows the vertical structure of ϵ for various tests.

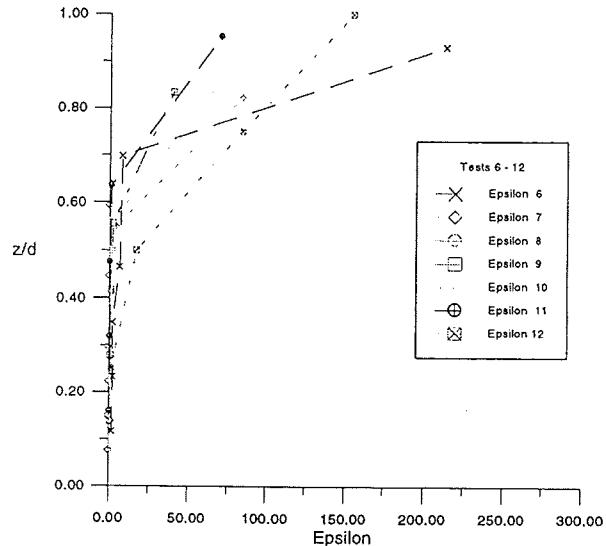


Figure 16: Vertical distribution of ϵ for tests 6-11.

These results show a similar trend to that obtained in previous studies or the estimated with semi-empirical formulations used in numerical models. For all tests the values computed with Thornton (1970) or Battjes (1983) formulations were larger (about twice) than the depth-averaged measured values, (see figure 15).

Laboratory Measurements

To examine the frequency response of the *Delft p-S EMS* a comparison with a *SonTec-3D Ultrasonic* velocimeter was carried out in a tilting flume (0.6 m depth, 0.6 m width, 20 m length) under various high turbulence flows, see figure 17. The experimental laboratory conditions are summarized in table 5. All tests were performed with fresh water at 22° C, and a time-series of 120 s, with a sampling rate of 25 Hz and a steady discharge. The sensors were deployed 1 m downstream of a movable gate (gate 1) combining different positions of a second one at the end of the flume (gate 2). All test were performed with a steady discharge of 0.09956 m³/s. Various turbulent intensities were generated by using a coarse grid up-stream of gate 1, and downstream of a steady hydraulic-jump.

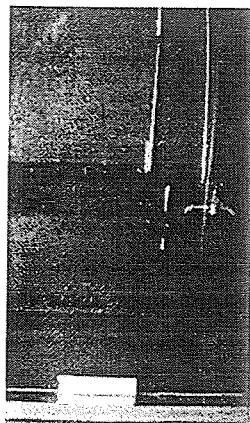


Figure 17: Delft 2D P-s EMS and SonTec 3D US in the flume tests, the horizontal-white mark is 10 cm length.

Lab. Test num.	Mean Flow (m/s)	Water depth (m)	Z- EMS (m)	Z- US (m)	Volume - US (cm ³)	Experimental Conditions
L0	0.474	0.350	0.155	0.186	12.65	q-uniform flow
L1	0.750	0.295	0.155	0.186	12.63	gate1-8, gate2-a
L2	0.795	0.278	0.155	0.186	12.61	gate1-8, gate2-b
L3	0.885	0.250	0.155	0.186	12.63	gate1-8, gate2-c
L4	0.980	0.225	0.155	0.186	12.59	gate1-8, gate2-d
L5	1.020	0.217	0.155	0.185	12.53	gate1-8, gate2-e
L6	0.980	0.225	0.155	0.185	12.53	gate1-8, gate2-f
L7	0.980	0.225	0.155	0.181	12.12	gate+coarse grid
L9	1.230	0.180	0.095	0.126	6.64	gate + hyd.jump
L10	1.260	0.175	0.095	0.126	6.64	hydraulic jump

Table 5: Summary of Laboratory-experimental Conditions (Tilting-flume)

Comparison of EMS and US Results:

Statistical and spectral analyses have been used to compare the performance of the sensors. The investigated *EMS* capabilities are the dumping (or smoothing) in the turbulent signal, and a limit for the frequency response.

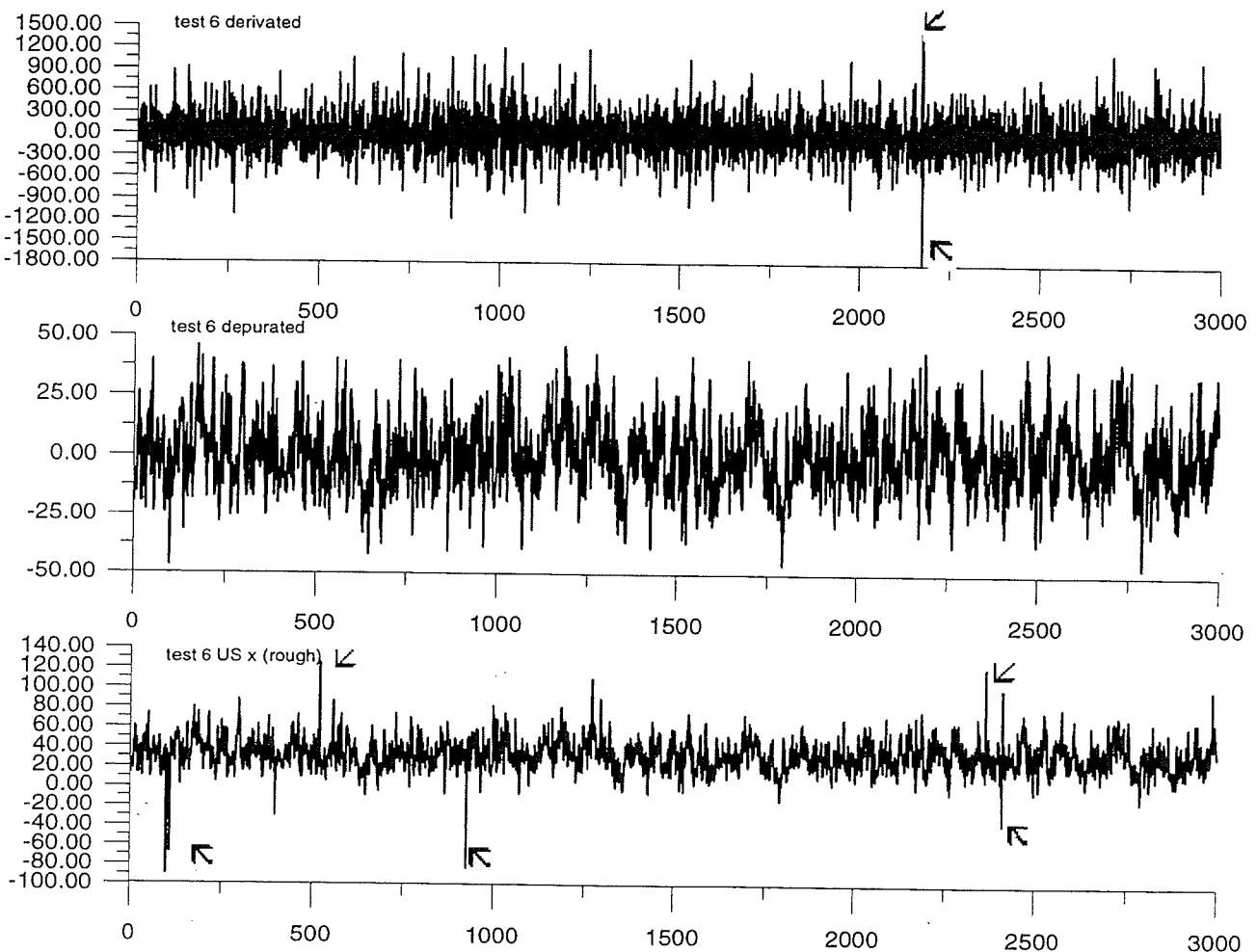
Variable	Statistical Analysis (sample size: 3000 data)					τ : Time Integral Scale (s)
	Mean (cm/s)	Range	Std. Deviation	Skewness	Kurtosis ***	
Ux- EMS 0	33.1	13.0	2.0	-0.24	0.09	--
Ux-SonTec0	29.6	16.4	2.7	-0.11	-0.33	--
Ux- EMS 1	36.5	17.3	2.6	0.12	-0.27	0.82
Ux-SonTec1	30.8	27.4	4.2	-0.07	-0.20	0.43
Ux- EMS 2	40.6	21.7	3.6	-0.14	-0.02	1.03
Ux-SonTec2	34.5	29.9	5.1	-0.25	-0.27	0.68
Ux- EMS 3	45.6	27.6	4.2	0.10	-0.05	0.73
Ux-SonTec3	40.7	37.1	6.1	-0.07	-0.21	0.57
Ux- EMS 4	50.4	38.4	6.0	-0.14	-0.02	0.64
Ux-SonTec4	46.3	49.6	8.3	-0.11	-0.21	0.38
Ux- EMS 5	49.9	39.4	6.2	0.02	-0.23	0.78
Ux-SonTec5	48.0	52.1	8.4	-0.13	-0.37	0.39
Ux- EMS 6	38.4	48.6	7.2	0.30	0.02	0.43
Ux-SonTec6	33.6	92.4	14.4 *	-0.27	0.07	0.24
Ux- EMS 7	45.2	15.9	2.4	0.29	0.16	0.30
Ux-SonTec7	32.2	39.3	6.5	0.06	-0.14	0.17
Ux- EMS 9	72.6	51.3	7.2	-0.37	0.64	0.43
Ux-SonTec9	55.9	87.7	16.1 *	0.09	-0.24	0.22
Ux- EMS 10	83.4 **	48.0 **	9.5 **	-0.30	-0.19	0.52
Ux-SonTec10 ..	56.0 *	111.9 *	22.2*	-0.09	0.46	0.18

Table 6: Statistical Parameters and Int. Time Scales of *EMS* and *US* Velocity Time-series
(*: doubtful values from *US* due to air bubbles).

(**: underestimated values from *EMS* due to values out of scale-range of $\pm 1\text{m/s}$)

(***: modified values, taking zero as the value of a normal distribution.)

Previously to the statistical and spectral analyses of the velocity series, a debugging of *US* data was carried out to remove the “noise” due to air bubbles. Down-stream of the gate or the hydraulic jump, air bubbles were entrained into the flow, (see figures 18 and 19b). The effects were analyzed using two methods, namely removing “unlikely” velocity values, as in figure 6b, greater than 3 times the standard deviation; and secondly removing values corresponding to “unlikely” accelerations as can be seen in figure 18.



Figures 18 and 19a-b: Acceleration (upper) and Velocity time series for test 6.
Arrows show the air bubbles distortion in the *US* measurements. Lower figure is the raw time series and the central one is the debugged velocity time series.

The “dumping” in the *EMS*-turbulence measurements, defined as $S = 1 - u'_{ems} / u'_{us}$, was estimated by comparison of turbulent Intensities from the *US* and *EMS* for various levels of turbulence. The turbulence level is related to the turbulence Intensity and it ranged from 2 to 22 cm/s.

The trend for the *EMS*-dumping is presented in figure 20, with values of S between 25 % - 57 % within a u'_{ems} range between 2.0 and 9.5 cm/s

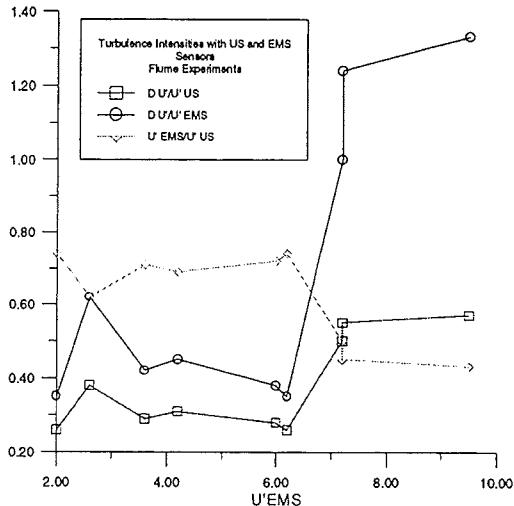


Figure 20: “Dumping” for turbulence Intensities measured with *EMS* and *US*.

The best fitting was obtained using a reciprocal linear regression:

$$u'_{us} / u'_{ems} = \gamma_1 u'_{us} + \gamma_2 \quad (12)$$

with $\gamma_1 = 1.140$, $\gamma_2 = 0.055$ and $R^2 = 0.828$.

To study the limit of the *EMS* frequency range the following procedure was used.

Spectral Analysis:

Previously to the power-spectra computations, a numerical IDFT¹-type band-pass filter, -with a band of 0.1-10.0 Hz, and a length of 1024 data-, was used to eliminate undesired frequencies, (Karl, 1989). Figure 3 shows an example of the accurate gain signal without ripples near the cut-off frequencies. The spectra $S(f)$ were next computed using a FFT²-technique (Gómez, 1993). Velocity time series were detrended using a simple linear regression tapered with a Welch window prior to applying *FFT*. The raw spectra have been calculated over series of 2048 data-points grouped in subseries of 1024 records 50 % overlapped. The associated spectral variance was 33 % and the spectral resolution of 0.024 Hz.

Dimensionless Spectra: $S'(f)$

To compare *EMS* and *US* frequency-responses dimensionless Spectra: $S'(f)$ have been computed for each experiment (“ i ”),

$$S'(f) = S(f) / (\sigma_i^2 / \tau_i) \quad (13)$$

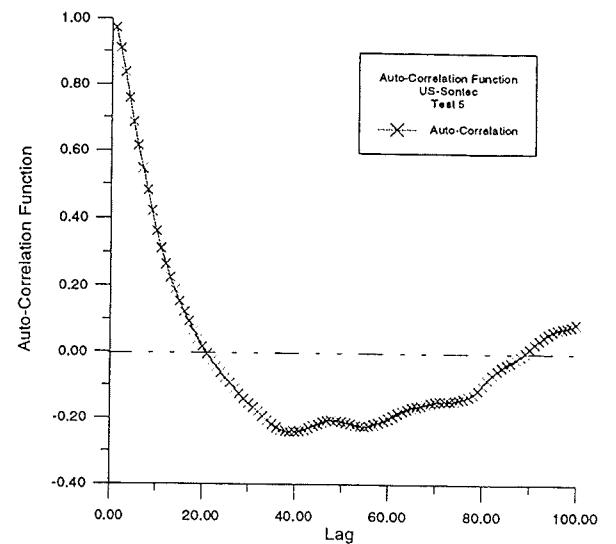
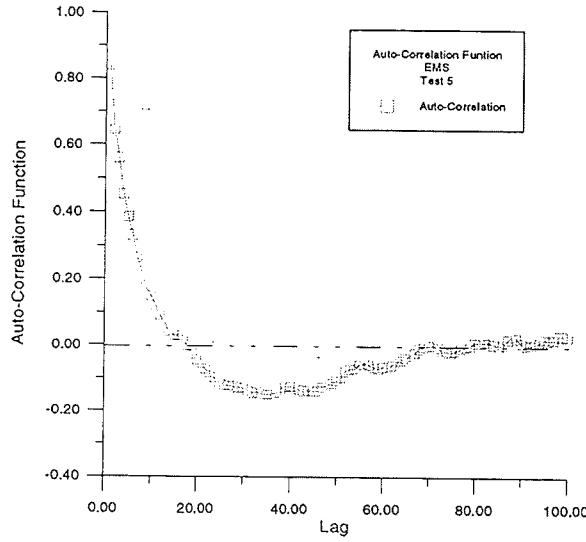
¹IDFT: Inverse Discrete Fourier Transform.

²FFT: Fast Fourier Transform.

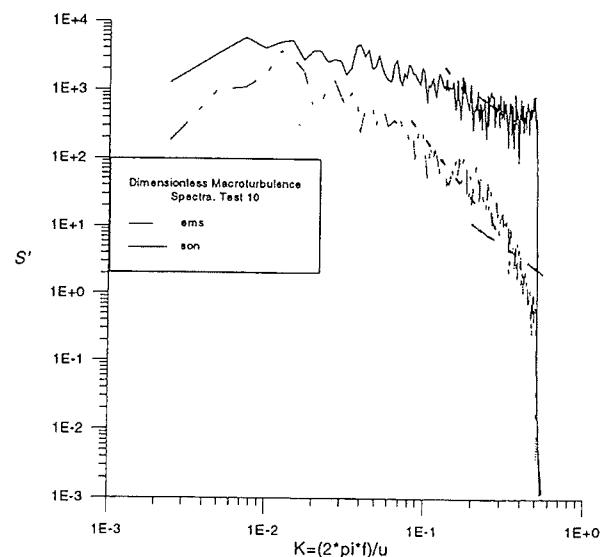
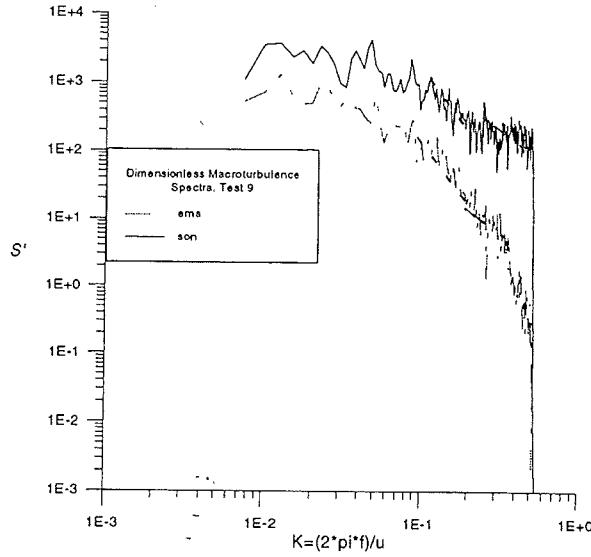
where σ^2 is the variance of the velocity time-series and τ is the Turbulent Integral Time-scale (see e.g. Tennekes and Lumley, 1972) defined as

$$\tau = \int_0^\infty \rho(\tau) d\tau \quad (14)$$

and computed numerically from the Auto-Correlation Function ($\rho(\tau) = \langle u'(t) u'(t+\tau) \rangle / \sigma^2$) of each time series, see figures 21 a, b as example, and table 6.



Figures 21a, b: Auto-Correlation Functions of turbulent velocities for test 5
used to obtain the Turbulent Integral time-scales τ of EMS and US time series.



Figures 22a, b: Dimensionless spectra of turbulent EMS and US measurements for test 9 and 10

Conclusions

General remarks

The developed methodology appears to work successfully even though there are still some difficulties to define exactly what the spatial averaging around the *EMS* is.

The identification of different flow modes, e.g. splitting up between macroturbulence (high frequency) and wave motion (oscillatory flow) needs to be done carefully due to the non-negligible dependence on the filtering technique.

The proposed methodology to detect a cut-off frequency between macroturbulence and irregular wave motion seems to work inside the surf zone, but near the shore line (in the swash zone) the difference between the measured and the theoretical spectrum becomes "puzzy" due to the high values of the Linear Transfer Function.

Analysis of Field results:

A non-homogeneous vertical structure for turbulence in the surf zone, has been observed. This suggests the necessity of depth-varying models for a proper description of *SZ* hydrodynamics. The V_t ($3D$) values show a parabolic vertical distribution except near the swash zone where it seems to be linear. This change is probably due to the higher entrainment of surface-induced turbulence.

The local equilibrium assumption for *SZ* turbulence seems to be confirmed, since ε is only important in the upper third of the water column, showing that the energy is mainly dissipated where it is produced.

The experimental values of *MT*-Isotropy in 3 out of 8 tests have shown a distribution very similar to the one reported by Townsend (1976) corresponding to "plane-wake" turbulence. For the other tests no clear relation could be detected. In all tests the value of the empirical coefficient A , was independent of depth, with a value around 0.3 (note that the theoretical value of A for homogeneous and isotropic turbulence is 0.42).

The macroturbulent (*MT*) intensities and the *MT*-turbulent kinetic energy appears to decrease with depth at a higher rate than the oscillatory flow (*r.m.s.* measured velocities). This implies that the total kinetic energy not uniform is distributed in the water column for the different hydrodynamic scales (turbulence, waves and currents) inside the surf zone (*SZ*).

Some practical expressions for *SZ* -turbulence parameters have been obtained:

- a) Eq. 9, which allows to estimate the turbulent length scale inside the surf zone, is more general than the state of art common estimations for this scale (see table 2).
- b) Simple relations (F_s and F_p , eq. 6) have also been obtained to estimate horizontal/vertical turbulent ratios for both "spilling" and "plunging" breaking waves, using existing detailed laboratory data.

It seems that in the inner *SZ* the *MT* horizontal eddies are more important than $3D$ or vertical ones. This finding is supported by the small differences between horizontal components of *MT*-intensity and the lower values for the vertical one. Additionally a change in the large-eddy structure with

depth could also be detected from the vertical distribution of the kurtosis, with values greater than 3 (“Gaussian” turbulence) in the upper half of the water column and lower values near the bottom.

In the outer and inner SZ the *MT* kinetic energy is almost constant in the lower half of the water column, showing an abrupt increase near the surface where the turbulent source is located. Near the swash-zone (test 12) the vertical distribution becomes quasi-linear, probably due to the entrainment of the surface-induced turbulence.

Comparison of EMS and US:

High frequencies appear to be poorly measured by *EMS*, with a practical limit for the used *EMS* (Delft ems p-s) around 2.7 Hz where most of the dimensionless *EMS* spectra of the *EMS* have shown a break-line. The separation frequency between *US* and *EMS* spectra has been completely found around 3 Hz.

The rates of dumping of turbulent intensities (u'_{EMS}/u'_{US}) between both types of velocimeters were smaller for high turbulence flows (around 40%), increasing for lower turbulence to levels up to 70%. This is reasonable due to the greater sensitivity and resolution of the ultrasonic velocimeter. This behavior shows an abrupt change around a value of $u'_{US} \approx 10 \text{ cm/s}$.

To obtain more general conclusions, additional measurements are quite obviously necessary.

Acknowledgments

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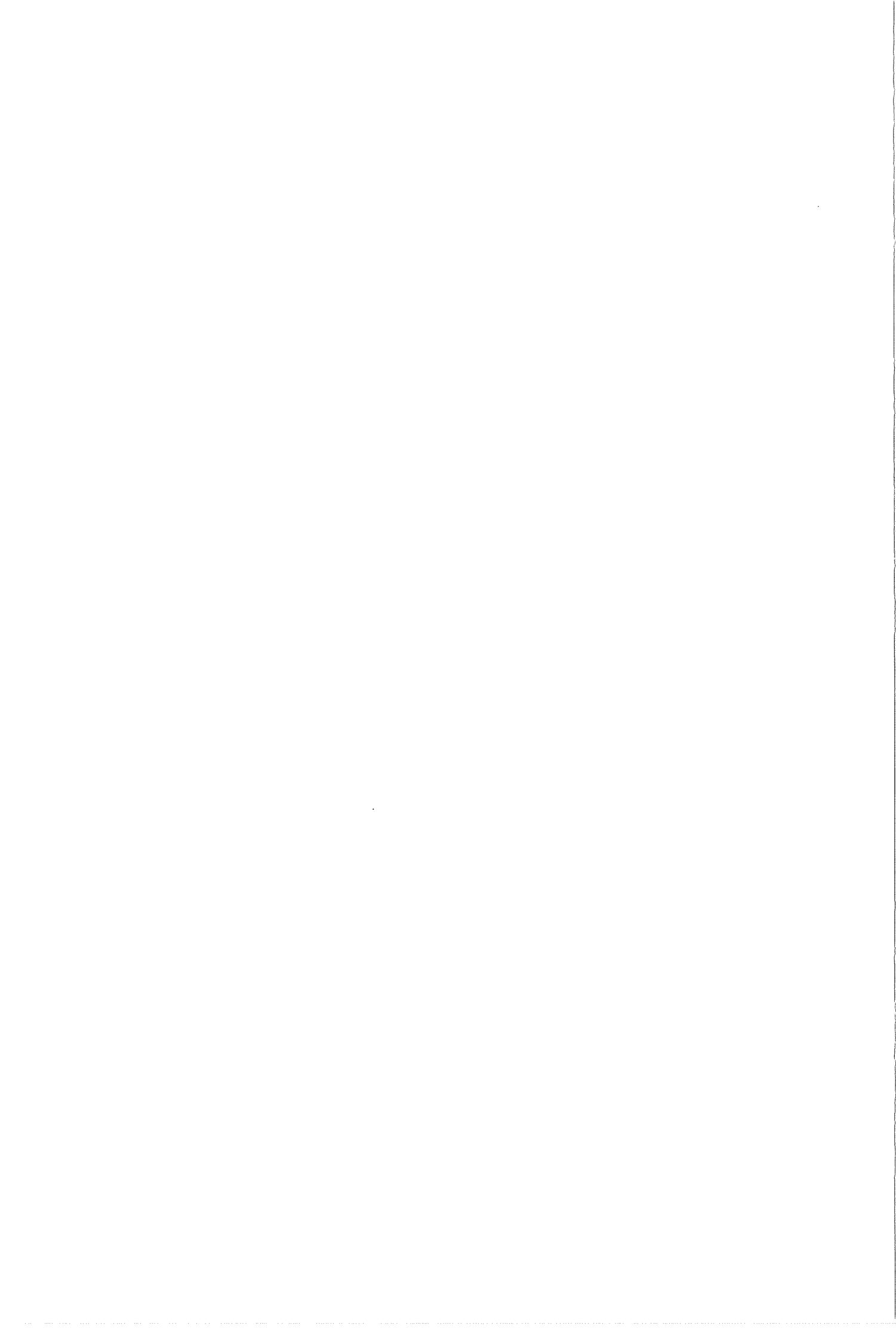
References

- Aono,T. and Hattori,M. 1984: Experimental study on the spatial characteristics of turbulence due to breaking waves, 30th J. Conf. Coastal Eng., JSCE, 25-29, (in Japanese).
- Battjes,J. 1983: Surf zone turbulence, 20th IAHR Cong., Moscow.
- Clifford,N.; French,J. and Hardisty,J. 1993: Turbulence: Perspectives on Flow and Sediment Transport, John Wiley & Sons, N.Y., USA
- Clifford,N. and French,J. 1993: Monitoring and modeling turbulent flows, in “Turbulence: Perspectives on Flow and Sediment Transport”, Ed. Clifford, et al. , John Wiley & Sons, N.Y., USA
- Bowden,K. y Fairbairn,L. 1956: Measurements of turbulence fluctuations and Reynolds stresses in a tidal current, Proc. Royal Soc. of London, A 237, 422-438.

- Cox,D.; Kobayashi,N. and Okayasu,A. 1994: Vertical variation of fluid velocities and shear stress in surf zones, Proc. ICCE, ASCE, 98-112.
- Deguchi,I.; Sawaragi,T. and Ono,M. 1992: Longshore current and lateral mixing in the surf zone, Proc. ICCE, ASCE, 2642-2654.
- Delft Hydraulics, 1993: P.-E.M.S. Programmable electromagnetic liquid velocity meter, User's manual, August, 52 pp.
- Gómez,J. 1993: Sistema de análisis espectral de olas escalares "V-SAS", LIM-UPC Rep., Vers. 1., Bcn, Spain, 19 pp, (in Spanish).
- Flick,R. and George,R. 1990: Turbulence scales in the surf and swash, Proc. ICCE, ASCE, 557-569.
- George,R.; Flick,R. and Guza,R. 1994: Observations of turbulence in the surf zone, JGR, 99, C1, 801-810.
- Karl,J. 1989: An Introduction to Digital Signal Processing, Academic Press Inc, London.
- Kenek, Co. 1996: "Ultra-small detector; Electromagnetic Current Meter, catalog, 10 pp.
- Kuznetsov,S. y Speransky,N. 1986: Dynamic characteristics of the VDK sensor as velocity meter, Oceanology, (Academy of Sciences USSR), translation of AGU, Vol. 26, 2, 248-253, USA.
- Kuznetsov,S. and Speransky,N. 1990: Turbulence in shoaling and breaking waves, in "Modern Processes of Sedimentation on Shelf", Edit. Nauka, Moscow, Russia.
- Lane,S.; Richards,K. and Warburton, J. 1993: Comparison between high frequency velocity records obtained with spherical and discoidal electromagnetic current meters, in "Turbulence: Perspectives on Flow and Sediment Transport", Ed. Clifford, et al. , John Wiley & Sons, N.Y., USA
- Miller, R. and Ziegler,J. 1968: The internal velocity field in breaking waves, Proc. ICCE, ASCE, 103-122.
- Nadaoka,K. 1986: A Fundamental Study on Shoaling and Velocity Field Structure of Water Waves in the Nearshore Zone, Ph.D. Thesis, Tokyo Institute of Technology, (Tech. Rep. 36), 125 pp, Japan.
- Okayasu,A. 1989: Characteristics of Turbulence Structure and Undertow in the Surf Zone, Ph.D. Thesis, Univ. of Tokyo, Japan.
- Rodi, W. 1984: Turbulence Models and Their Application in Hydraulics, IAHR, Delft, NT.
- Rodriguez,A.; S.Arcilla,A.; Collado,F.; Gracia,V.; Cousirat,M. y Prieto,J.: Waves and currents in the Ebro Delta Surf Zone: measuments and modelling, Proc.Int.Conf.Costal.Eng., ASCE, (2542-2556), 1994.
- Rodriguez,A.; S.Arcilla,A.; Gómez,J.and Bahia,E. 1995a: Study of macroturbulence and mixing using Delta'93 field data, Proc. Coastal Dynamics, ASCE, Gdansk, Poland.
- Rodriguez,A., S.Arcilla,A. and Mösso,C. 1995b: DELTA'93: Experimental study of surf-zone hydrodynamics at the Ebro Delta, Proc. MAST G8M Workshop, Sept., Gdansk, Poland.
- Rodriguez,A.; S.Arcilla,A.; Redondo,J.; Bahia,E. and Sierra,J. 1995c: Measurement and modeling of pollutant dispersion in the nearshore region, J. Water Science and Technology, IAWQ, 32, 9/10, 12 pp.

- Rodríguez,A., S.Arcilla,A.; Mösso,C. and Mercader,B. 1996: Comparación entre medidas y teorías para el flujo oscilatorio en la zona de rompientes, Ingeniería Hidráulica de México, (in Spanish), in press.
- Smith,J.M.; Larson,M. and Kraus,N. 1993: Longshore current on a barred beach: field measurements and calculation, JGR, 98, C12, 22.717-22.731.
- Stive,M.J.F. 1980: Velocity and pressure field of spilling breakers, Proc. ICCE, ASCE, 547-566.
- Stive,M.J.F. and Wind,H. 1982: A study of radiation stress and set-up in the nearshore region, Coastal Engineering, 6, 1-25.
- Svendsen,I. 1987: Analysis of surf zone turbulence, JGR, 92, 5115-5124.
- Tennekes,H. y Lumley,J. 1972: A First Course in Turbulence, MIT Press, USA.
- Thornton,E. 1968: A field investigation of sand transport in the surf zone, Proc. ICCE, ASCE, 335-351.
- Thornton,E. 1970: Variation of longshore currents in the surf zone, Proc. ICCE, ASCE, 291-308.
- Thornton,E. 1979: Energetics of breaking waves within the surf zone, JGR, 84, 4931-4938.
- Townsend,A. 1976: The Structure of Turbulent Shear Flow, Cambridge University Press, Cambridge, UK.





Estudio Experimental de la Hidrodinámica de Zona de Rompientes

ANEXO B

**-Recopilación de Antecedentes de Experimentos de Campo
en la Zona de Rompientes-**

Andrés Rodriguez

Agosto de 1996



RECOPILACION DE ANTECEDENTES DE EXPERIMENTOS DE CAMPO EN LA ZONA DE ROMPIENTES

A continuación se describen las principales características de los experimentos de campo centrados en el estudio de la hidrodinámica costera, y en particular de la zona de rompientes (ZR). Este Anexo completa la información del Capítulo 2 de la Tesis, donde se presentan además las conclusiones de la revisión bibliográfica.

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a) Campañas Australianas:

a.1) **Eastern Beach:** (Wright et al. 1986).

Instituciones: Universidad de Sydney, Oficina de Investigación Naval, Instituto de Ciencia Marina de Virginia y Universidad de Florida (EEUU).

Fecha: las medidas se realizaron en Mayo de 1981.

Lugar y características de la playa:

La playa donde se realizaron las medidas se denomina "Eastern" y esta situada en la costa de Gippsland, Victoria (sudeste de Australia) frente al Mar de Tasmania, ver figura 2.a.1. Las principales características de esta playa son: playa de arena ($D_{50} = 0,3\text{mm}$) con uniformidad longitudinal, micromareas, existencia de una zona de rompientes disipativa-reflexiva con un sistema surco-barra estable.

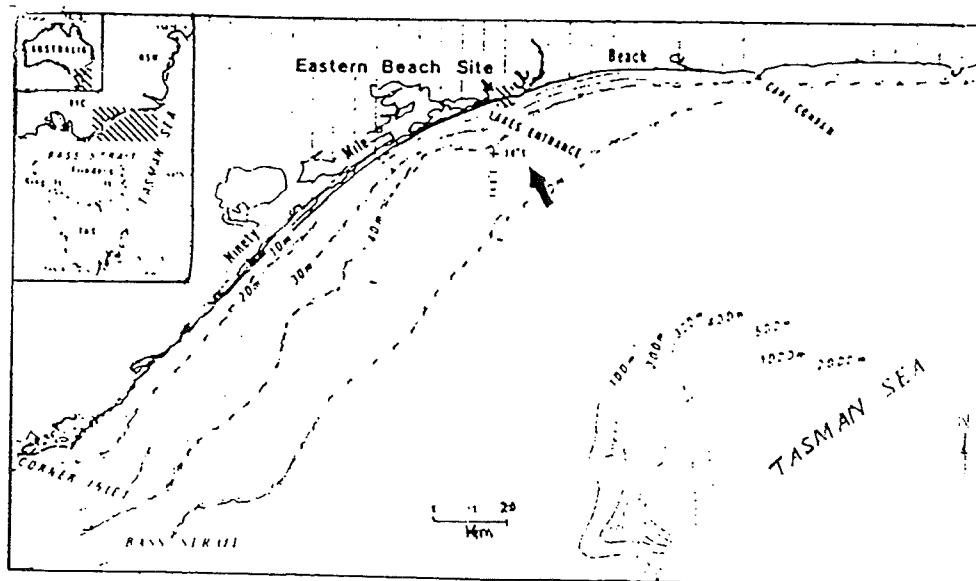


Figura 2.a.1: Localización de la Campaña de "Eastern" (Wright et al. 1986)

Objetivos: Obtener datos de campo que permitan estudiar la morfodinámica de playas con sistemas de surco-barra.

Metodología:

La batimetría se obtuvo mediante topografía convencional en la playa y ZR hasta 4

m de profundidad y se completó con una ecosonda para profundidades mayores. En la zona de trabajo se realizaron 6 perfiles perpendiculares a la playa separados 50 *m* entre sí.

Se midieron las corrientes de fondo cercanas a la costa en dos puntos con 10 y 20 *m* de calado mediante sendos CEM colocados a 1 *m* del fondo. La frecuencia de muestreo fue de 0,5 Hz durante 15 minutos cada hora. Los instrumentos fueron colocados sobre trípodes (220 Kg) apoyados en el fondo marino. Mediante teoría lineal y a partir del espectro de estas velocidades se obtuvieron alturas significantes y períodos de pico.

Los datos de oleaje en aguas profundas (90 *m*) se midieron a 80 *Km* de la costa en una plataforma petrolera.

En la zona de rompientes se midieron niveles y velocidades en varios puntos (ver figura 2.a.2.) mediante sensores de presión y correntímetros de rotor.

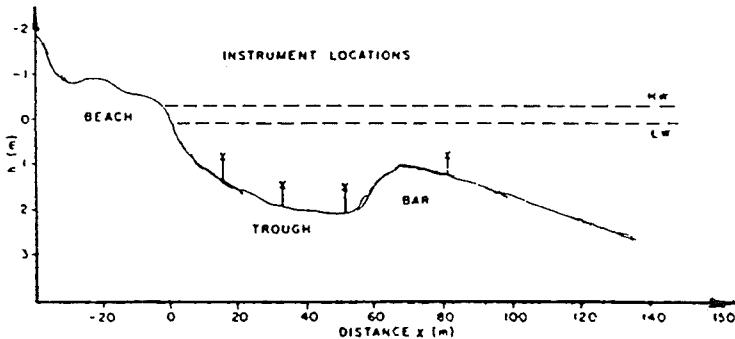


Figura 2.a.2: Distribución de los sensores a lo largo del perfil de playa (Wright et al. 1986)

Los niveles se obtuvieron por simple conversión hidrostática de la presión. Las velocidades horizontales se midieron mediante correntímetros colocados en dos ejes ortogonales dentro de tubos horizontales con una frecuencia de muestreo entre 0,66 y 1 Hz. La distribución típica de los correntímetros en la vertical fue de 5, 20, 45, y 90 cm desde el fondo.

Para soporte de los sensores se utilizaron mástiles con una base plana de 50 Kg de peso y la transmisión de datos a tierra se realizó vía cable hasta el vehículo con el equipo de adquisición.

También se midió el perfil vertical de transporte sólido mediante un muestreador

de succión desarrollado por Nielsen (1984) y la descripción en planta de la circulación fue completada utilizando trazadores.

El proceso y análisis de los datos incluyó la obtención de vectores instantáneos y medios de velocidad, análisis espectral y cros-espectro para determinar las componentes de las distintas frecuencias de velocidades y oscilaciones de la superficie. Los datos de altura y velocidad fueron separados y analizados en cuatro escalas temporales denominadas: oleaje incidente (T entre 12 y 17 s), subarmónicos ($T/2$), ondas infragravitatorias (T mayor a 30 s) y corrientes medias.

Resumen de resultados:

Algunas de las conclusiones de este trabajo fueron que los estados morfodinámicos denominados "sistema surco-barra" (en sus dos variantes "barra longitudinal" y "barra rítmica") estaban favorecidos por la combinación de alturas de rotura moderadas y oscilaciones de marea pequeñas. El proceso característico "surco-barra" estaba dominado por los movimientos oscilatorios a la frecuencia del oleaje incidente a lo ancho de toda la zona de rompiente. En este tipo de zonas de rompiente el oleaje fue la principal fuente de producción tanto de sedimento en suspensión como de turbulencia en la capa límite del fondo. Las ondas estacionarias y de borde con frecuencias infragravitatorias fueron secundarias en términos energéticos, pero importantes para la determinación de los patrones de circulación y transporte de sedimentos, y por lo tanto de influencia en la topografía resultante. La presencia de la barra suprimió la existencia de frecuencias bajas (inferiores a las correspondientes a las ondas estacionarias) y favoreció la aparición de frecuencias que entraban en resonancia con la topografía coincidiendo los nodos con la posición del surco y los antinodos con la barra. Las barras de estos sistemas tuvieron una alta movilidad, no así el perfil de la playa.

Otras Campañas australianas son:

a.2) **Moruya-Broulee-Bracken Beaches:** (Wright et al., 1979)

Institución: Universidad de Sydney

Fechas y duración: 1971-1977, 1 o 2 días más batimetrías periódicas.

Lugar y área: Playas Moruya, Broulee y Bracken (Australia).

Mediciones: Batimetría, Olas, Corrientes y Características de los Sedimentos.

a.3) **Cable Beach:** (Wright et al., 1982)

Institución: Universidad de Sydney

Fecha y duración: 1980, 20 días.

Lugar y área: Playa Cable, Broome (Australia occidental), 600 m x 1.500 m.

Mediciones: Batimetría, Olas, Corrientes, Transporte y Características de los Sedimentos.

a.4) **Bracken Beach:** (Black y Rosenberg, 1991).

Institución: Intituto Victoriano de Estudios Marinos.

Fecha: 1989.

Lugar y área: Playa Bracken (Australia), un transecto.

Mediciones: Olas, Corrientes, Mareas, Transporte y Características de los Sedimentos.

b) Campañas Británicas:

Los principales experimentos británicos son los realizados en el programa denominado B-BAND:

b.1) **B-BAND:** British Beach and Nearshore Dynamics, (Russell et al., 1991; Foote et al., 1992 y Davidson et al., 1992).

Instituciones: Univ. de Gales, IMS Univ. de Plymouth Univ. de Hull (RU), Natural and Enviromental Research Council (RU-NERC).

Objetivos: el principal objetivo de este programa fue mejorar el conocimiento de la dinámica de la zona de rompientes incluyendo hidrodinámica, morfodinámica y las repuestas de la playa.

Lugares y áreas: los experimentos fueron realizados en varias playas macromareales: a): LLangennith (playa disipativa), b): Spurn Head (intermedia), c): Teignmouth (playa reflexiva), y d): Seaton (RU). Ver figura 2.b.1.

Fechas y duración: El programa tiene una duración de tres años (1990/93). Los experimentos se realizaron en: a): 1990 durante 13 días; b): 1991 y d): 1992.

Medidas en varios puntos localizados en un transecto de 200 m y un área de 40 x 40 m. Ver figura 2.b.2.

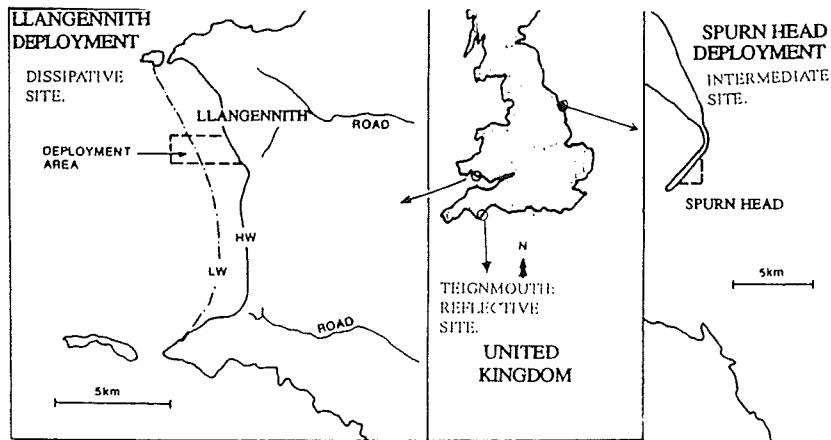


Figura 2.b.1: Playas medidas en B-BAND, (Davidson et al. 1992)

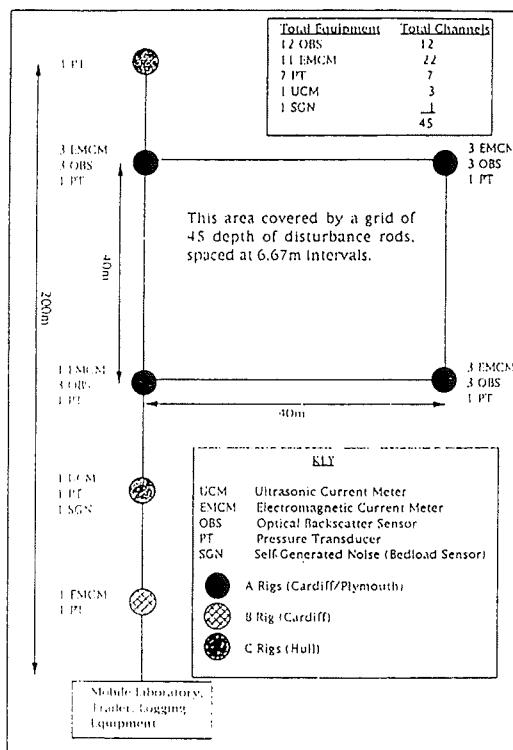


Figura 2.b.2: Sensores y su distribución típica en la zona de trabajo de B-BAND, (Davidson et al. 1992)

La metodología empleada (puntos fijos en una playa con gran carrera de marea)

es equivalente a ir desplazando un trineo o medir con varias torres (excepto cuando la playa no tiene una pendiente constante).

Mediciones e instrumental: Las medidas incluyeron Batimetría, Olas y niveles mediante 7 sensores de presión, Velocidades con 11 CEM y un sensor ultrasónico 3D, Características y Transporte de Sedimentos mediante 12 OBS y un sensor de transporte de fondo ultrasónico (SGN)

La mayoría del instrumental fue concentrado en los vértices del cuadrado de medición ($40 \times 40 m$). Los CEM fueron colocados en series de 3 correspondientes a las siguientes alturas: 0,1-0,25-0,63 m. Los OBS se colocaron a 0,04-0,1-0,25 m. El instrumental fue conectado a la base terrestre mediante 200 m de cable. La frecuencia de muestreo fue de 2Hz y la longitud de las series temporales de 17,07 minutos (2048 datos).

Hay numerosas campañas británicas que no ha sido tan completas como las BBAND pero que son de interés. Una de las primeras en que específicamente se midió la hidrodinámica dentro de la ZR es,

b.2) playa de Saunton, (Devon, RU): (Huntley y Bowen, 1974).

Se midieron en uno y tres puntos con CEM a 0,2 m y 0,4 m del fondo respectivamente. Se utilizaron 3 trípodes instrumentados con un CEM y un sensor de presión cada uno (ver figuras 2.b.3 y 2.b.4). Con un punto llegaron a cubrir un transecto de 120 m gracias a la carrera de marea.

Otras campañas son:

b.3) Pendine-Carmarthen: (Jago y Hardisty, 1984).

Fecha y duración: 1968 y 1970, durante 1 mes.

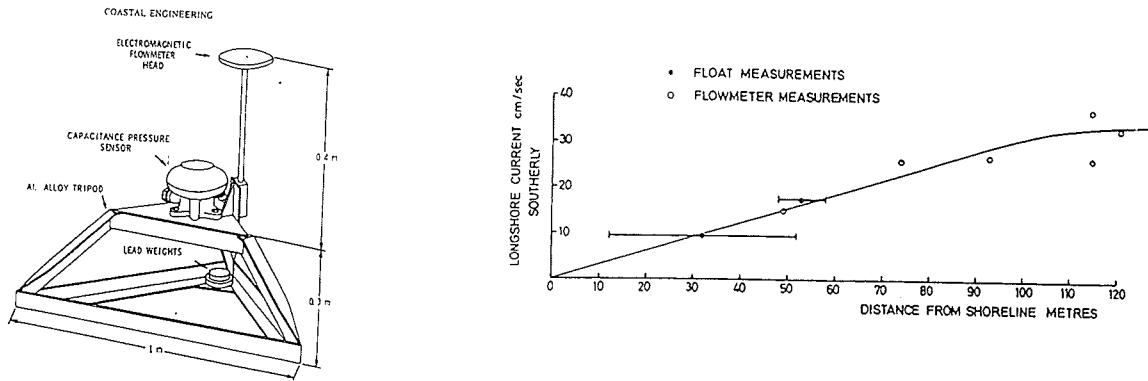
Lugar y área: Playa Pendine sands, en la bahía de Carmarthen, en un área de 8 x 1,5 Km.

Mediciones: Batimetría, Olas, Corrientes y Transporte de Sedimentos.

b.4) Maplin Sands, Estuario del Támesis : (Owen y Thorn, 1978; Soulsby, 1988).

Institución: Hydraulics Research, HR (Wallingford)

Fechas: 1973 a 1975.



Figuras 2.b.3 y 2.b.4: Sistema de medición y distribución en la playa, (Huntley y Bowen, 1974).

Lugar y área: Playa de Maplin Sands, en el estuario exterior del Támesis, en un transecto.

Mediciones: Batimetría, Olas, Corrientes, Mareas, Características y Transporte de Sedimentos.

b.5) Boscombe Pier: (Owen y Thorn, 1978, Soulsby, 1988).

Institución: Hydraulics Research, HR (Wallingford)

Fechas: 1977 y 1978, durante los dos años.

Lugar y área: Boscombe Pier, en Bournemouth, (RU), en un transecto.

Mediciones: Olas, Corrientes, Mareas, Características y Transporte de Sedimentos.

b.6) Isla de Wight (Stable) : (Humphery,J., 1987 y Soulsby, 1988).

Instituciones: Proudman Oceanographic Laboratory e Hydraulic Research (RU).

Fechas y duración: del 11-24 Octubre de 1986.

Lugar y área: Playa Stable, bahía Freshwater, en la isla de Wight, en un punto fijo que

al avanzar la marea cubre un transecto. Se trata de una playa estable de grava.

Mediciones: Con un sistema integrado de medición denominado STABLE (ver figura 2.b.5).

- . Olas: con un sensor de presión e intervalos de medición de 15 minutos durante el ciclo de marea,
- . Corrientes: con tres CEM (2D y 3D) a 0,1 - 0,4 y 0,8 m del fondo a 4 Hz.
- . Características, Concentraciones y Transporte de Sedimentos con dos OBS.

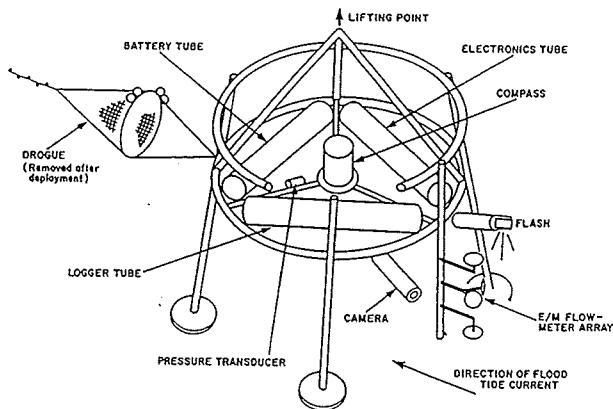


Figura 2.b.5: Sistema de medición STABLE, (Soulsby, 1988).

b.7) LLangenith : (Russell, 1990 y Russell, 1993).

Institución: University College of Swansea.

Fechas: 1988, algunos días durante el verano y el invierno.

Lugar y área: Playa de LLangenith en la bahía de Rhossili, en un punto fijo de un transecto que al avanzar la marea cubre un rango 100 m.

Mediciones:

- . Olas: con un sensor de presión,
- . Corrientes: con un CEM,
- . Características, Concentraciones y Transporte de Sedimentos: con dos OBS.

c) Campañas Canadienses:

c.1) **Bahía de Nottawasaga:** (Greenwood y Sherman, 1984; Bauer y Greenwood, 1990 y Greemwood, Osborne y Bowen, 1991).

Instituciones: Universidad de Toronto, Universidad de Dalhousie y C-COAST (Canadian Coastal Sediment Transport Programme).

Fechas: Mayo-Junio de 1980, Junio de 1986 y 1987/88.

Lugar y características de las playas:

La mayoría de las mediciones analizadas se realizaron en la Bahía de Nottawasaga, Ontario. Las mediciones de 1980 se realizaron en la playa de "Wendake" en un área de 150 x 60 m. Las de 1986 en playa de "Wymbolwood" en un área de 150 x 60 m durante 2 meses; y las de 1987/88 se realizaron en la playa de "Bluewater" en un transecto de 220 m, ver figura 2.c.1.

Se trata de playas sin mareas con una longitud de "fetch" limitada (84 Km) que presentaron dos barras durante las mediciones. La pendiente media fue de 0,015 y la granulometría varió entre 0,71 mm en la costa y 0,13 mm a 300 m aguas adentro.

Objetivos:

En la campaña de "Wendake" en 1980 el pricipal objetivo fue medir las características del oleaje y las corrientes longitudinales inducidas en la zona de rompientes.

En las mediciones de "Wymbolwood" en 1986 el objetivo fue identificar y medir la estructura vertical del flujo transversal a la costa ("undertow") y sus mecanismos impulsores ("wave set-up"), relacionándolos con la batimetría.

Finalmente, en las mediciones de "Bluewater" en 1987/88 el objetivo fue estudiar el rol del flujo oscilatorio y las corrientes en el transporte transversal de sedimentos.

Metodología:

La batimetría en la zona de trabajo se midió convencionalmente con perfiles cada

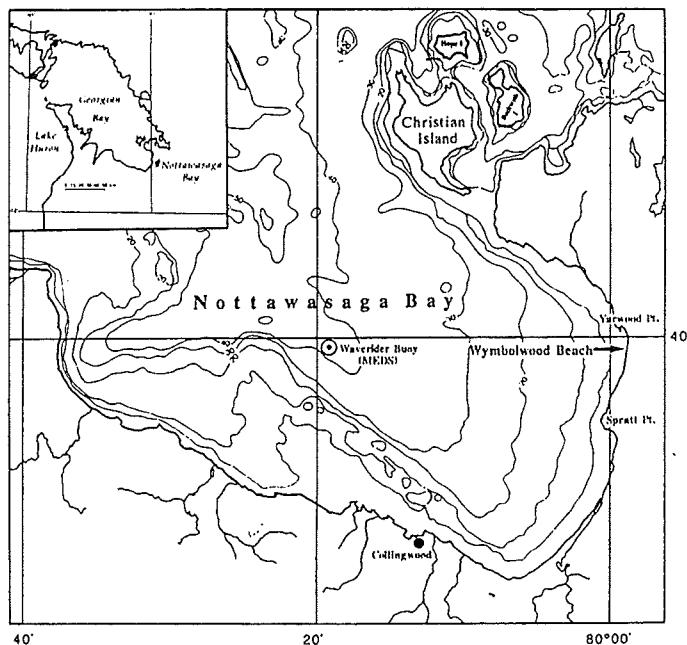


Figura 2.c.1: Localización de las Campañas en la Bahía de Nottawasaga: playas "Wendake", "Wymbolwood", y "Bluewater", (Greenwood y Osborne, 1990)

30 m.

El oleaje incidente se midió con una boya localizada aproximadamente a 40 m de profundidad, (fig. 2.c.1.), y en la zona de rompientes con varios sensores resistivos distribuidos transversalmente a la costa.

Las velocidades fueron medidas mediante CEM y las concentraciones de sedimento con OBS. La distribución de los equipos se muestran en las figuras 2.c.2., 2.c.3. y 2.c.4.

Las frecuencias de muestreo fueron de 2,0-2,38-4,0 Hz y las longitudes de las series 9-21-60 minutos para las mediciones en Wendake, Wymbolwood, y Bluewater respectivamente.

La orientación y verticalización de los CEM se realizó con un compás sumergible (que permite alcanzar una precisión de 1° aproximadamente) y con un nivel esférico.

Resumen de resultados:

En las mediciones de corriente longitudinal:

Se encontró que en el efecto de la barra es incrementar las velocidades en la zona exterior y reducirlas en la zona interior de la ZR, respecto a las esperables en un perfil sin barra.

En la comparación entre los datos medidos y los modelos de Longuet-Higgins y Ebersole-

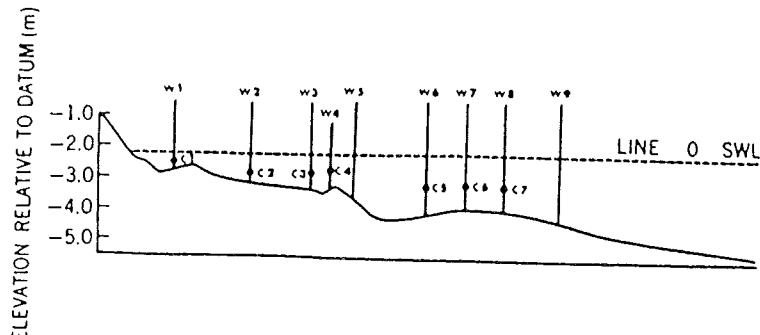


Figura 2.c.2: Distribución de los sensores para medir el perfil transversal de la corriente longitudinal: 9 wg y 7 cem, "Wendake'80" (Greenwood y Sherman, 1986)

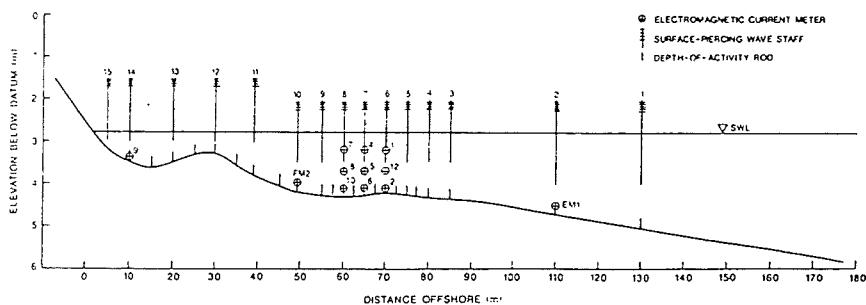


Figura 2.c.3: Distribución de los sensores para medir la estructura vertical del "undertow": 15 wg y 12 cem, "Wymbolwood'86" (Greenwood y Osborne, 1990)

Dalrymple el primero da resultados razonables si el perfil es suave, mientras que si la barra es significativa el segundo da mejores resultados.

La presencia de las barras se manifiesta también con un incremento aparente de la viscosidad turbulenta (horizontal) al aumentar los gradientes transversales de la velocidad longitudinal.

En las mediciones de corriente transversal:

Se encontraron asimetrías importantes en el flujo: velocidades medias "undertow" del orden de 20 cm/s hacia "offshore" y asimetrías (tercer momento normalizado por el desvío standard) hacia costa de +60.

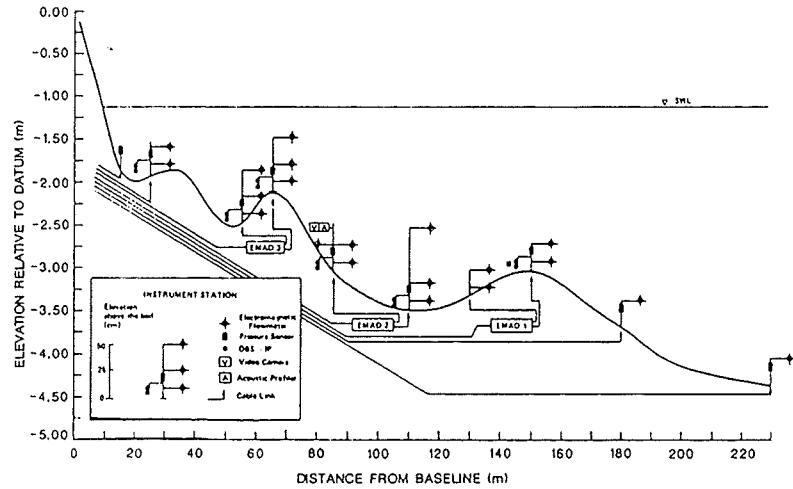


Figura 2.c.4: Distribución de los sensores para estudiar estructura 3D de corrientes y transporte transversal: 9 sens.presión, 12 obs y 19 cem, "Bluewater'87/88" (Greenwood et al. 1991)

La tendencia vertical del flujo medio es creciente hacia el fondo mientras que el flujo oscilatorio (estimado por el desvío estandar de $u(t)$) varía en sentido opuesto.

El "set up" fue ajustado satisfactoriamente con un polinomio de cuarto orden, y mostró correlaciones altas con el "undertow" y la altura de ola.

Otras Campañas canadienses de interés son:

c.2) Bahía Kouchibouguac: (Greenwood y Mittler, 1984).

Institución: Universidad de Toronto

Fecha: 1978.

Lugar: Bahía Kouchibouguac, New Brunswick

Mediciones: Batimetría, Olas, Corrientes, Transporte de Sedimentos y Meteorología.

c.3) Pointe Sapin: (Bowen et al., 1986; Willis, 1987).

Institución: C^2S^2 Canadian Coastal Sediment Study (CCSS-NERC)

Fecha y duración: 1983, 23 días.

Lugar y área: Pointe Sapin, New Brunswick, en un área de 500 x 300 m.

Mediciones: Meteorología, Batimetría, Olas, Corrientes, Mareas, Transporte y Características de los Sedimentos.

c.4) **Stanhope Lane:** (Bowen et al., 1986; Willis, 1987).

Institución: C^2S^2 (CCSS-NERC)

Fecha y duración: 1984, 36 días.

Lugar y área: Stanhope Lane, Prince Edward Island, en un transecto.

Mediciones: Batimetría, Olas, Corrientes, Transporte y Características de los Sedimentos.

c.5) **Queensland Beach:** (Greenwood et al., 1990).

Institución: C-COAST

Lugar y área: Playa de Queensland, Bahía de Sta. Margarita, Nva. Escocia, en un transecto de 220 m.

Mediciones: Olas, Corrientes, Mareas y Transporte de Sedimentos.

c.6) **Stanhope Lane:** (Van Hardenberg et al., 1991).

Institución: C-COAST

Fecha: 1989.

Lugar y área: Stanhope Lane, Prince Edward Island, en un transecto.

Mediciones: Olas, Corrientes, Mareas y Transporte de Sedimentos.

c.7) **Queensland Beach:** (Vincent et al., 1991).

Lugar y área: Playa de Queensland, Bahía de Sta. Margarita, Nva. Escocia, en un transecto de 100 m.

Mediciones: Olas, Corrientes, y Transporte de Sedimentos.

d) Campañas Españolas:

d.1) **Suances:** (Huntley et al. 1994)

El único antecedente publicado conocido que incluya la ZR en el litoral español es el trabajo dirigido por D.Huntley y M.Losada en el estuario de Suances.

Instituciones: realizado por la Universidad de Cantabria y el Instituto de Estudio Marinos de Plymouth (RU). En este experimento participó también personal del LIM-UPC con el objeto de adquirir experiencia en este tipo de mediciones.

Fecha: Dicho experimento se realizó durante Noviembre de 1991.

Lugar: Suances, en la costa Cantábrica cerca de Santander, ver localización en la figura 2.d.1.

Objetivo: Las mediciones tuvieron por objeto estudiar la interacción de olas y corrientes en la desembocadura del río Besaya.

Metodología: Se midieron velocidades mediante tres correntímetros electromagnéticos bidimensionales (CEM) Valeport (2 esféricos y uno de anillo), niveles con un sensor de presión, y turbidez con un "optical back-scatter" (OBS). Se midieron series de 17 minutos de longitud con 2 Hz como frecuencia de muestreo. El sistema de medición era alimentado mediante baterías y es relativamente complejo de instalar y operar. Los sensores fueron colocados en una estructura metálica fija de forma piramidal que se clavó en el fondo durante la marea baja.

Resumen de resultados: dicho experimento ha sido presentado recientemente por Huntley et al. (1994) donde se describen las ondas transversales de baja frecuencia encontradas dentro del estuario y su relación con los grupos de olas.

d.2) **El Saler:** (e.g. Medina,J. y Serra,J., 1993; Santás, 1994; Santás y De la Peña, 1995).

Otro estudio español reciente es la campaña realizada en "EL Saler" (Valencia), realizado por el CEPYC-CEDEX en las costas de Valencia en el marco del proyecto MAST II-G8M. Dicha campaña incluye levantamientos batimétricos detallados en un tramo de playa de 2 KM incluyendo 21 perfiles transversales medidos hasta 12 m de profundidad con una periodicidad mensual. Las medidas incluyeron

RIA DE SAN MARTIN DE LA VEGA O DE SUANCES

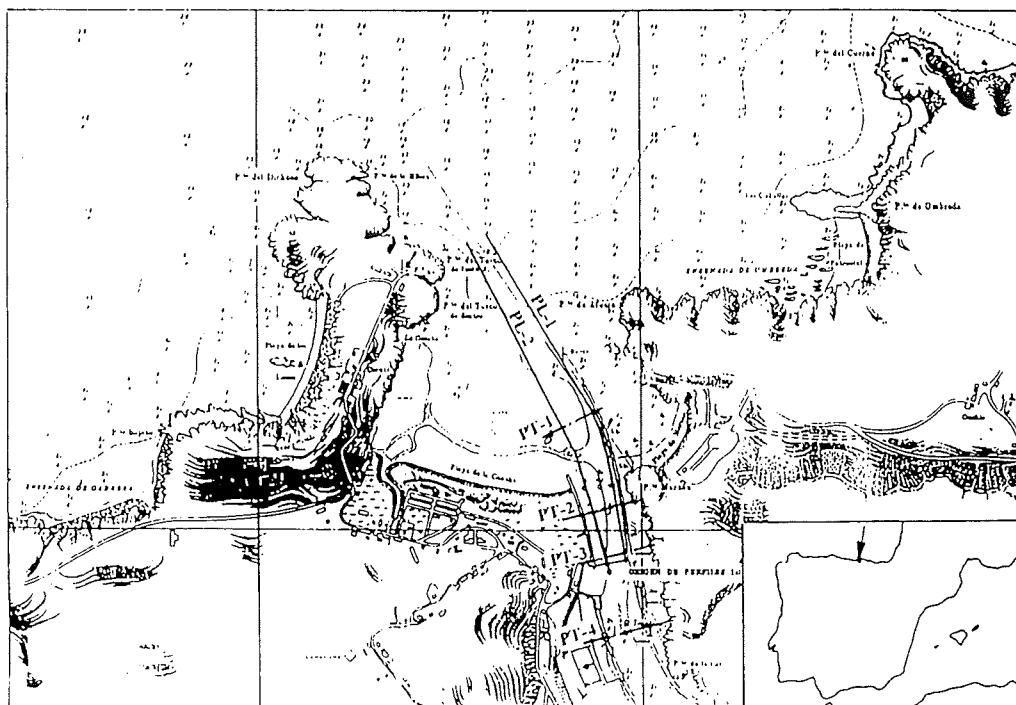


Figura 2.d.1: Localización de la Campaña de Suances (Huntley et al. 1994)

características granulométricas del sedimento (en playa seca, orilla y sumergida), y mediciones hidrodinámicas con un trípode a 10 m de profundidad instrumentado en forma autónoma con un CEM y un sensor de presión, y una boya direccional de oleaje fondeada a 50 m de profundidad. Como ambos sensores fueron ubicados fuera de la zona de rompientes no se describirá en detalle esta campaña.

Recientemente se han realizado tambien medidas en la costa Cantábrica, incluyendo la ZR, (Vidal, 1995). Dichos experimentos han sido realizados por el grupo de la Universidad de Cantabria bajo la dirección del Dr. M.Losada, (no se conoce la publicación de los resultados de dichos experimentos).

e) Campañas Francesas:

El único experimento francés en la ZR conocido es:

e.1) Arcachon: (Bellesort, 1988).

Institución: SOGREAH

Fechas: Noviembre de 1983 y Mayo de 1984.

Lugar y área: Arcachon en la costa de Aquitania, (Francia). las medidas se realizaron en un muelle de 800 m que permite alcanzar profundidades de 11 m. Se trata de una playa arenosa (pendiente 1:67) y $D_{50} = 0,35 \text{ mm}$.

Mediciones: Olas, Mareas (rango de 3-6 m), Características y Transporte de los Sedimentos en varias posiciones del transecto. El experimento estuvo centrado en el estudio del sedimento en suspensión bajo rotura del oleaje.

Se mencionan también otros trabajos experimentales en la zona costera.

e.2) Dunkirk : (Latteux, 1988).

Instituciones: Laboratorio Nacional de Hidráulica (LNH).

Fechas: Varios períodos entre 1960 y 1977.

Lugar y características: Dunkirk, costa del Mar del Norte. Se mide en las vecindades de un puerto exterior para supertanques, antes y después de la construcción del puerto. Se trata de una zona con numerosos bancos de arena poco profundos sometida a intensas mareas y oleaje.

Metodología y Medidas:

- . Olas con 7 sensores de presión en el fondo cubriendo un área de $15 \times 5 \text{ Km}$ paralelo a la costa, series de 20 minutos durante marea alta.
- . Corrientes: con 17 correntímetros 3 m sobre el fondo, cubriendo un área de $30 \times 10 \text{ Km}$ paralelo a la costa, durante 2 semanas.
- . Las medidas incluyeron levantamientos batimétricos periódicos, y transporte de sedimentos con diversas técnicas.

No se describen más detalles por no tratarse de una playa con medidas dentro de la ZR.

e.3) Contentin: (Levoy y Antoine, 1991; Levoy et al., 1995).

Instituciones: Universidad de Caen (Programa ROMIS).

Fechas: 1991-1993, durante 4 días al mes.

Lugar y características: Península de Contentin, en la bahía de las Islas del Canal, (Canal de la Mancha). Se mide en un área de 80 x 50 Km. Se trata de una zona con una batimetría compleja con playas de arena y afloramientos rocosos. La dinámica costera es muy activa (variaciones de la línea de orilla en algunos puntos de 5 m/año) e intensa hidrodinámica (mareas de 15 m y velocidades de 3 m/s).

Metodología: los experimentos incluyeron "Medidas Regionales" y "Medidas Locales":

"Medidas Regionales": realizadas durante tres años.

Corrientes con correntímetros electromagnéticos a 5 m bajo el nivel medio en marea baja. Olas con una boya direccional más sensores de presión coincidentes con los CEM, y Mareas: con tres sensores. Las medidas incluyeron levantamientos batimétricos periódicos, y mediciones meteorológicas en dos estaciones.

"Medidas Locales": realizadas en 10 puntos durante 4 días al mes. Olas y corrientes con 4 CEM. Las medidas incluyeron levantamientos batimétricos, fotos aéreas, mediciones meteorológicas, y transporte de sedimentos incluyendo la ZR mediante trampas de sedimentos multidireccionales y trazadores fluorescentes.

e.4) Bas Champs : (Bellesort, 1988).

Institución: SOGREAH

Fechas y duración: 1965-1966, durante 6 meses.

Lugar y área: Playas Bas Champs (Francia).

Mediciones: Olas, Corrientes, Mareas, Meteorología, Características y Transporte de los Sedimentos.

f) Campañas Holandesas:

f.1) Egmond:1981 (e.g. Derks, 1982-84; Derks y Stive, 1984; Reinalda, 1988; De Vriend et al. 1988).

Instituciones: TOW, Rijkswaterstaad (Dept. de Obras Públicas), Universidad Tecnológica de Delft y Laboratorio Delft Hydraulics.

Fechas: Mayo y Junio de 1981, y de Septiembre de 1982 a Enero de 1983.

Lugar y características de la playa:

Costa de Egmond, Mar del Norte, Holanda, (figura 2.f.1), en un transecto de 250 m en 1981 y en un área de 100 m x 2,5 Km en 1982-83. Las principales características de la playa de Egmond son: playa de arena longitudinalmente uniforme con una zona de rompientes disipativa y con influencia de mareas.

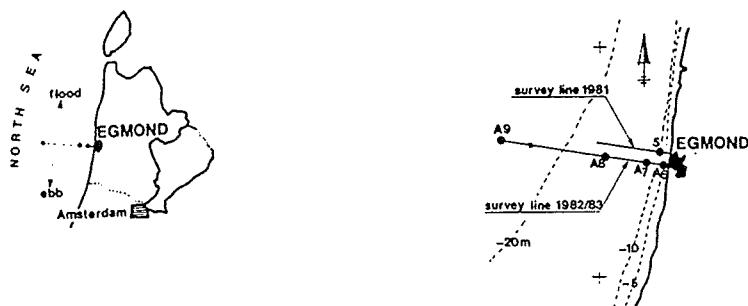


Figura 2.f.1: Localización de la Campaña de Egmond, (Reinalda, 1988)

Objetivos: Obtención de datos de olas, corrientes y transporte de sedimentos para estudiar la hidráulica y morfodinámica costera; estudiar el funcionamiento de distintos sensores de oleaje, niveles, corrientes y transporte sólido, dentro y fuera de la ZR bajo distintas condiciones; verificar el funcionamiento del sistema de adquisición y análisis de datos in situ como la logística empleada y finalmente la adquisición de experiencia en Campañas de medidas.

Metodología:

Se midieron condiciones de calma en la primera fase (1981) y temporales durante la segunda fase (1982/83).

La lista de variables medidas incluye: elevaciones de la superficie libre, niveles medios, velocidades instantáneas dentro de la ZR, velocidades medias fuera de la ZR, concentraciones de arena en suspensión dentro de la ZR, topografía, granulometría, viento, temperatura del agua y dirección del oleaje.

Para medir la lista de variables anterior se utilizaron numerosos sensores que se detallan en figura 2.f.2. Los sensores dentro de la ZR se colocaron en una estructura metálica fija tipo muelle perpendicular a la costa. La distribución de los sensores

Measured quantity	Type of instrument			Number	
	Brand	Principle	Size	1981	1982/1983
mean current velocity	NBA Flachsee	prop./compass prop./compass		1 -	4 1
instantaneous flow velocity	Marsh McBirney Colnbrook Vektor Akwa ASTM SIMRAD HC 100 NSW	EM EM ac.(travel time) ac.(Doppler) ac.(travel time) EM	3.8 cm 11 cm 24 cm 1-3 cm 19 cm 5,5 cm	2 1 2 1 1 -	5 1 2 2 - 1
mean water level	Vega OTT XX rec. TPD rec. DAG 6000	press. sensor float float press. meter		- 1 - -	1 - 1 2
inst. water surface elevation	Plessey Datawell	wave staff wave rider		3 1	6 3
wave direction	videorec./poles	visual	10x30 m 100x100 m	1 -	- 1
sand concentration	ASTM DELFT HYDRAULICS	ac.(backscatter) suction id.	1-3 cm 16 cm 1.3. cm	1 4 -	2 - 5
bottom comp.	samplers	sieving			
bottom level	special HF standard stadar	echo-sounding echo-sounding levelling	4 cm/1 MHz - -	- 1 1	4 1 1
water temp.	temp. sensors	el. resistance	1 cm	-	4
wind speed	Thies	prop./vane		1	1

Figura 2.f.2: Mediciones y equipos utilizados (de Vriend et al. 1988)

correspondientes a las dos fases puede verse en la figura 2.f.3.

Un aspecto interesante fue la completa comparación de sensores que se realizó. Concretamente se pudieron comparar ocho tipos de correntímetros, tres

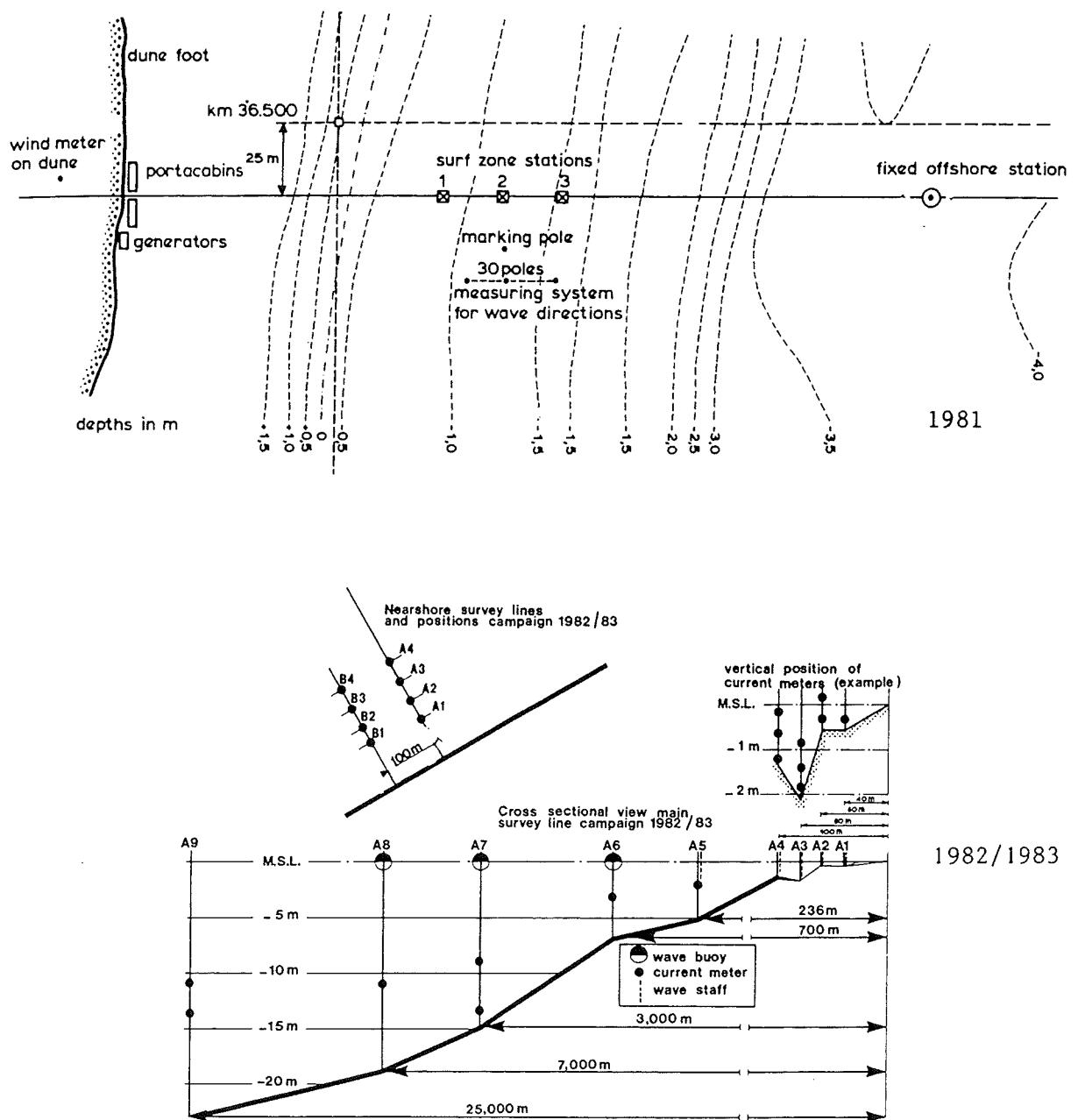


Figura 2.f.3: Colocación de los sensores (Reinalda, 1988)

electromagnéticos y tres acústicos dentro de la ZR, y dos correntímetros de rotor con brújula fuera de la ZR. Los 6 primeros se usaron para medir velocidades "instantáneas" mientras que los de rotor se utilizaron para medir corrientes. Se compararon además

seis tipos de sensores de nivel, dos para medir la elevación de la superficie "instantánea" (una boyas y un sensor resistivo), y cinco para medición de niveles medios (dos tipos de presión, uno resistivo y dos tipos de flotador).

Las series medidas tuvieron una duración entre 30 minutos y 13 horas. La frecuencia de muestreo fue muy alta, (133 datos por segundo) como consecuencia de las características del equipo de adquisición de datos utilizado.

Para medir sedimentos en suspensión se utilizó un sistema de muestreo por succión y un sensor de transporte de sedimento acústico (ASTM) capaz de medir concentraciones instantáneas. Para medir la dirección del oleaje incidente se utilizaron imágenes de video.

Resumen de resultados:

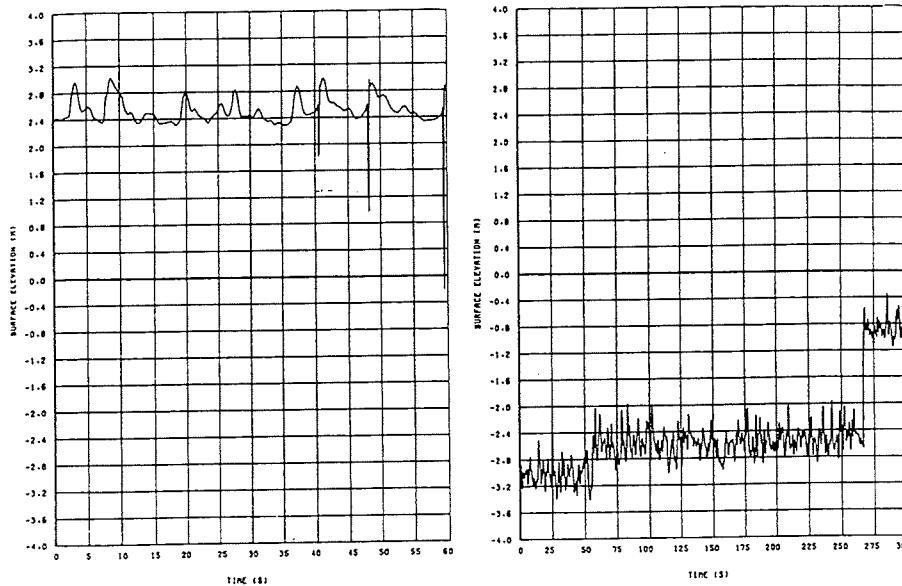
Básicamente hay dos tipos de resultados en estas campañas, por un lado los referidos a la metodología empleada y por otro el análisis de los datos medidos. En este punto el interés está centrado principalmente en la metodología y técnicas experimentales empleadas. Los referidos al análisis de fenómenos físicos se pueden ver en los trabajos sobre propagación de oleaje de Battjes y Stive (1984) características de velocidades de baja frecuencia por Gerritsen y van Heteren (1984) corrientes inducidas por olas y transporte de sedimentos por Boer et al. (1984) ó cinemática y direcciones del oleaje por van Heteren y Stive (1984).

Respecto de la medición de elevaciones de la superficie se encontró que las boyas "Data Well" utilizadas fueron muy fiables con excepción de cortos intervalos durante temporales severos donde las boyas pudieron quedar invertidas.

Con referencia a los sensores resistivos ("Plessey W.S.") su comportamiento fue bastante insatisfactorio como se puede ver en las figuras 2.f.4-5 dado que experimentaron picos espúreos o cambios de señal arbitrariamente. Dos complicaciones adicionales fueron la alta variabilidad que mostraron sus coeficientes de calibración a lo largo de los 4 meses de experimentos y la perturbación que producía la tubería de protección de los hilos conductores (una reducción del 10% en el valor de $H_{1/3}$ medido).

Los sensores de presión ("Vega" y "DAG 6000") mostraron ser adecuados para la medición de niveles medios, pero no aptos para seguir en forma fiable las oscilaciones de la superficie libre a frecuencias mayores a 0,5 Hz. En el rango de 1 a 2 m de profundidad la presión no fue hidrostática por lo que fue necesaria una corrección hidrodinámica.

Los correntímetros electromagnéticos ("Marsh McBirney") y los acústicos o ultrasónicos ("Vector Akwa") fueron comparados agrupándolos en pares a una distancia



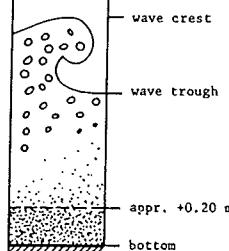
Figuras 2.f.4-5: Ejemplo de comportamiento anómalo en los sensores de altura resistivos (Reinalda, 1988)

horizontal de 2,5 m. Esto se realizó tanto para los pares iguales como para los de tipo diferente mediante la comparación directa de las señales, el espectro cruzado de la dos velocidades, y el espectro cruzado de la velocidad y la superficie libre. Las diferencias entre los dos tipos de sensores fueron del mismo orden que las correspondientes a los sensores del mismo tipo. Por lo que se pudo determinar una equivalencia, a primer orden, de los dos tipos de correntímetros.

En la figura 2.f.6 se resume el comportamiento de los diferentes tipos de correntímetros bajo distintas condiciones de medición.

El lector interesado en ampliar la información sobre estas campañas puede consultar los trabajos de Derks y Stive (1984), de Vriend et al. (1988) y Reinalda (1988).

Otras campañas holandesas de interés son:



VERTICAL POSITION		CONDITIONS		PERFORMANCE OF CURRENT METERS			
		Marsh Mc Birney	Colnbrook	NSH	VEKTOR AKVA	ASTM	
• air bubbles	+	+	-		-		
• instruments above waterlevel	+	-	-	?	-	?	
• air bubbles	+++	+	+++	+++	+++	+++	
	+++	+	+++	+++	+++	+++	
	+++	+	+++	+++	+++	+++	
• sand particles	+++	+	+++	+++	+++	+++	
	+++	+	+++	+++	+++	+++	
• sand particles	-	-	?	+++	+++	+++	
	-	-	?	+++	+++	+++	

HORIZONTAL POSITION		CONDITIONS				
distance between instruments	synchronization of magnetic field	Marsh Mc Birney	Colnbrook	NSH		
more than 0.50 m	not relevant	+	+	?		
between 0.20 - 0.50 m	yes	+	?	?		
	no	-	*	?		

+++ good performance
 + + } no optimum performance
 + bad performance
 ? unknown performance

Figura 2.f.6: Comparación del funcionamiento de los distintos correntímetros (Reinalda, 1988)

f.2) Egmond: (Van Rijn y Kroon, 1991; Kroon, 1991; Kroon, 1992 y Kroon, 1994).

Estos experimentos fueron realizados cerca de la misma playa de Egmond por la Universidad de Utrecht durante Octubre y Noviembre de 1990, y han sido publicadas recientemente por A. Kroon (1994).

En esta campaña se utilizó una plataforma móvil equipada con 3 CEM, 2 OBS, un sensor de alturas capacitivo y un sistema de 8 tubos de succión para medir transporte en suspensión, ver figura 2.f.6.

La frecuencia de muestreo de todos los sensores fue de 4 Hz y las series de tiempo fueron medidas durante 20 y 40 minutos. Si bien estos experimentos estuvieron centrados en los aspectos morfodinámicos más que en la hidrodinámica, se midieron olas y corrientes dentro de la ZR analizándose las propiedades del flujo oscilatorio y de la ondas de baja frecuencia con miras a su influencia en el transporte de sedimentos.

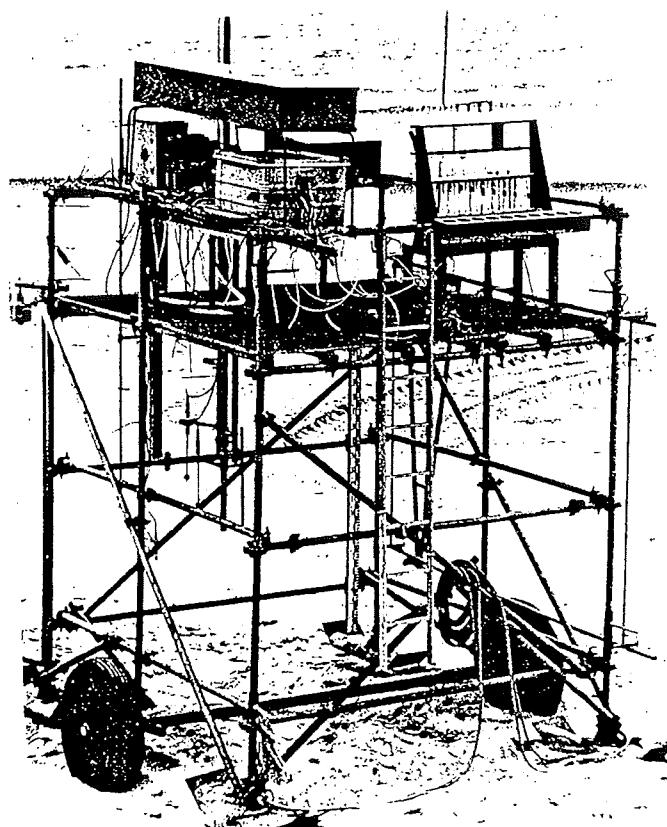


Figura 2.f.7: Plataforma móvil y colocación de los sensores (Kroon, 1994).

f.3) Eastern Sheldt: (Van Rijn, 1991)

Institución: VESSEM

Fecha: 1983.

Lugar y área: Un transecto en el estuario de Eastern Sheldt (Holanda)

Mediciones: Olas, Corrientes, Características y Transporte de Sedimentos.

g) Campañas Japonesas:

Japón junto con los EEUU es uno de los países que más esfuerzos ha realizado en campañas de medidas costeras. Una de las primeras es la realizada en "North Akashi", Miyazu, donde se midieron el transporte de sedimentos, cambios batimétricos y condiciones meteorológicas (Ishara et al., 1958). Experimentos más completos se

realizaron, poco después cerca del puerto de Kashima entre 1962 y 1966. En estos experimentos se midieron Olas, Corrientes, Batimetría, Características y Transporte de sedimentos, (Sato y Tanaka, 1966).

Las principales campañas japonesas son:

g.1a) NERC (Nearshore Environment Research Centre): **Ajigaura y Oarai**, (Horikawa y Hattori, 1987; Kraus et al., 1981; Sasaki y Horikawa, 1978; Uda y Hashimoto, 1983, y Watanabe, 1988).

Instituciones: Japanese Nearshore Environment Research Centre, NERC. Los Institutos: Pub.Works Res., Cent.Res.Elect.Power Indust. y Port Harbour Research. Las Universidades: de Tokio, Chuo, Yokohama, Metropolitana de Tokio, Tsukuba y Tohoku.

Fechas y duración: 1978-1984, con 6 series de 2 a 4 semanas cada una.

Lugares y áreas: 2 Playas en la costa del Pacífico.

a) Playa de Ajigaura: playa arenosa rectilínea y pendiente 1:40. Se midió en transecto (muelle) de 200 m de longitud que permitió alcanzar profundidades de 5 m.

b) Playa de Oarai: se trata de una playa arenosa afectada por obras costeras con una pendiente de 1:60. Las medidas se realizaron en varios transectos.

Mediciones: (Ver figuras 2.g.1 y 2.g.2)

. Olas: con 5 sensores ultrasónicos a 6 m de profundidad en una línea paralela a la costa de 100 m; 4 sensores de presión a 3 m de profundidad en una línea de 400 m; 15 sensores capacitivos en la ZR en un área de 400 x 150 m. Filmación y fotogrametría del oleaje con cámaras aéreas.

. Corrientes: con 12 CEM, uno a 3 m de profundidad y los restantes en la ZR coincidiendo con los sensores de altura. Medidas Lagrangianas con trazadores (boyas, paneles pintados y colorantes) seguidos desde helicóptero, globo o torre.

. Características y Transporte de Sedimentos: mediante trazadores fluorescentes, diversos tipos de trampas, OBS y sensores ultrasónicos, (ver figura 2.g.3).

Batimetría: Medida mediante vehículo anfibio radiocontrolado, ecosonda y topografía convencional. Las medidas se realizaron hasta los 6 m de profundidad y al menos dos veces durante cada campaña.

También se midieron las condiciones meteorológicas.

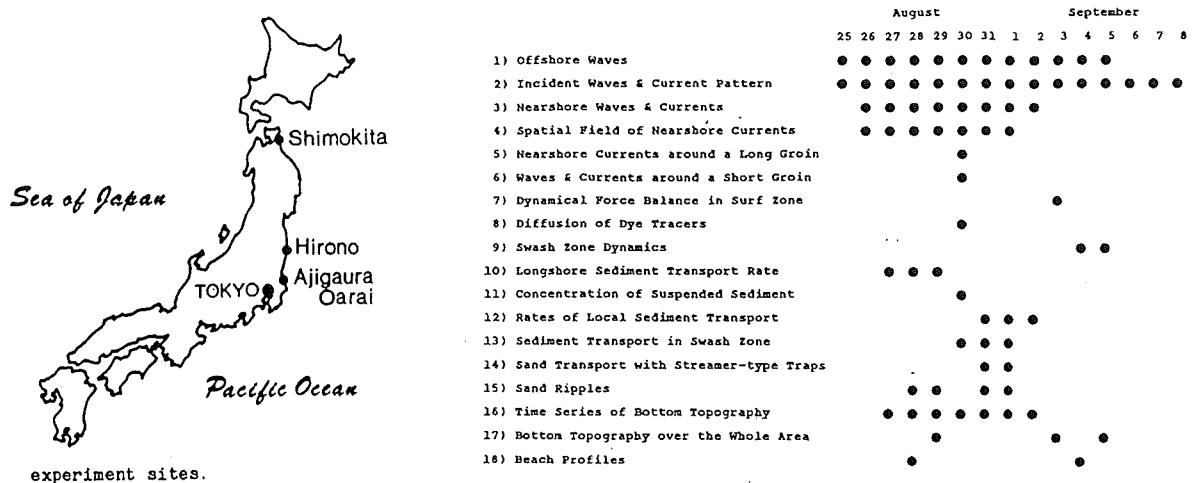


Figura 2.g.1: Mediciones en Oarai-1981, (Watanabe, 1988).

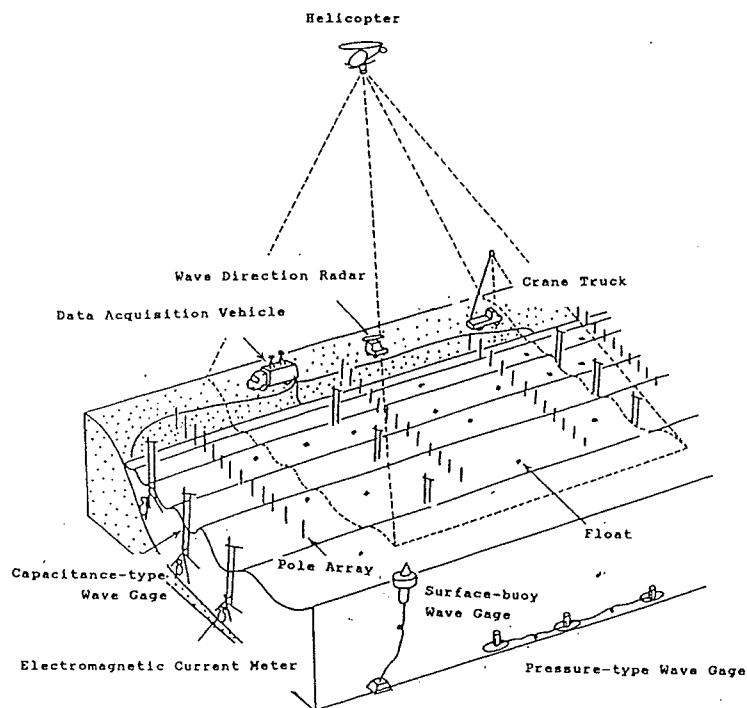


Figura 2.g.2: Instrumental en la playa de Oarai, (Watanabe, 1988).

Otros experimentos del programa NERC son:

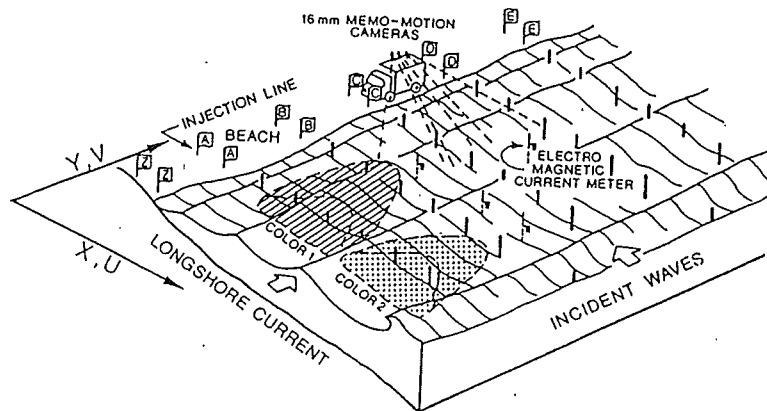


Figura 2.g.3: Mediciones del transporte de sedimentos con trazadores multicolores, (Kraus et al., 1981).

g.1b) NERC, Ajigaura'78-79; Shimokita; Hirono y Oarai 80-82: (a): Sasaki et al., 1976 ; b): Kraus et al., 1982)

Instituciones:

(a): INA Co., Univ.Tokio, Univ.Metropol.Tokio.

(b): Public Works Research Institute, Minist. of Construct., INA Co., Science Research Fun. of Minist. of Education, Yokohama Univ., NERC.

Fechas: a): 1976 y b): 1978-1982.

Lugar y área: Playas en la costa Ibaraki, norte del Japón (O.Pacífico): a): Ajigaura y b): Ajigaura, Shimokita, Hirono y Oarai; en un área de 100 m x 5 Km.

Mediciones:

(a): Batimetría, Campo de alturas de ola, nivel medio, características de la ZR y Corrientes superficiales mediante fotografías y filmación aérea ("Stereo-backs").

(b): Batimetría, Olas, Corrientes, Características y Transporte de Sedimentos.

Experiment	Median grain size d_{50} (mm)	Sorting coef. $(d_{75}/d_{25})^{1/2}$	Specific gravity	Composition	Nearshore beach slope	Comments
AJIGAURA 78	0.23	1.1 (estimated)	2.65	quartz	1/50 to 1/70	Coast is 9 km long with no significant structures; Ajigaura 78 performed near south headland, Ajigaura 79 performed near middle of coast
AJIGAURA 79	0.27	1.1 (estimated)	2.65	quartz	1/50 to 1/70	
SHIMOKITA	0.18	1.06	3.13	quartz heavy minerals	1/40 to 1/60	Long coast (38 km) with uniform contours
HIRONO - 1	0.59	1.69	2.67	quartz sand & pebbles	1/10	Pocket beach
HIRONO - 2	0.59	1.69	2.67	quartz sand & pebbles	1/10	Same location as Hirono 1
OARAI 80	0.25	1.09	2.79	quartz	1/50 to 1/70	Near large groin and behind harbor breakwater
OARAI 81	0.24	1.16	2.79	quartz	1/50 to 1/70	Same location as Oarai 80
OARAI 82	0.25	1.05	2.79	quartz	1/30 to 1/40	Behind harbor breakwater and 2 km south of Oarai 80; beach slope steep due to erosion

Figura 2.g.4: Características de las 4 playas, (Kraus et al., 1982).

g.2) Ogata: (Kawata et. al., 1990)

Institución: Universidad de Kyoto.

Fecha y duración: 1988/89 y 90: durante los meses de invierno.

Lugar y área: Costa de Lioka, en una playa de arena con numerosas obras (diques perpendiculares paralelos a la playa) e intensa actividad morfodinámica natural y artificial. Las medidas se tomaron en un área de 300 x 300 m.

Mediciones:

- . Batimetría medida tres veces en el área de 300 x 300 m,
- . Olas: medidas en 3 estaciones localizadas a 6 Km mar-adentro,
- . Corrientes: medidas con CEM en las mismas posiciones,
- . Características y el Transporte de Sedimentos: con trazadores fluorescentes.

g.3) HORF - Kashima: (Nadaoka et al., 1988; Kuriyama, 1991; Nakamura y Katoh, 1992 y Kuriyama y Ozaki, 1993)

ITEM	AJIGAURA		SHINOKITA		HIRONO 1980		OARAI	OARAI	OARAI
	1978	1979	1979		13 Nov	14 Nov	1980	1981	1982
Longshore stations	12	13	17		18	18	18	18	20
Grid length alongshore (m)	130; 210	130	255		300	200	130	175	100
Offshore stations	6	7 & 9	8		5	5	7	9	12
Offshore spacing (m)	10	7.5	10		4	4	8	10	3
Width of surf zone (m)	60	52.5	80		20	20	56	90	36
Spatial Samplings	4	2	3		3	3	2	2	2
Start of sampling after injection (min)	15, 30 70, 120	30, 120	30 120, 180	45 105, 165	60 120, 180	90, 180	90, 180	90, 180	60, 180
Temporal Samplings	-	13	12	-	16	19	30	-	-
Sampling interval (min)	-	15	15	-	15	15	10	-	-
Number of lines	-	2	2	-	1	1	1	-	-
Distance from injec. line to sampling line (m)	-	10, 20	10, 20	-	8	15	15	-	-
Number of tracer colors	2	3	2	1	1	3	3	4	
Outer Colors	green	orange	green	-	-	orange	orange	orange	
Mid	-	red	-	red	-	red	red	blue, red	
Inner	red	green	red	-	-	green	green	green	
Amount of tracer inj'd for each color (kgf)	100,100	100,100,100	150,150	50	60	50, 40, 40	27,27,27	1.5 per color	
Wave measurement*	stereo photos direct sighting	PWG 16mm	16mm	16mm	16mm	16 mm PHG;CWG	CWG;PWG 16mm	16 mm	
Current measurement*	floats	EMCM (5) floats	EMCM (3) floats	EMCM (2) floats	EMCM (3) floats	EMCM (3) floats	EMCM (2) floats	EMCM (3) floats	

*) PWG (CWG) = pressure (capacitance) wave gage; 16mm = 16mm memo-motion camera;
EMCM = electromagnetic current meter (numbers in parenthesis give number of meters used)

Figura 2.g.5: Resumen de los experimentos, (Kraus et al., 1982).

Institución: HORF, Hazaki Oceanographical Research Facility, Port and Harbour Research Institute.

Fechas y duración: a) 12-26 Septiembre de 1988; b) 13-31 de Julio de 1989; c) 9-28 de febrero de 1990 y d) 25 Junio - 10 de Julio de 1990.

Lugar y área: Kashima, en un muelle de 427 m, figuras 2.g.6 y 2.g.7. La playa es aproximadamente rectilínea, con una barra longitudinal, ocasionales ondulaciones longitudinales y una pendiente media de 1:60. Las mareas son menores a 2 m.

Mediciones:

En las campañas (a) y (b) : se midió en detalle cerca de la línea de rotura bajo diversas condiciones de oleaje, en la (c) : en el medio de la ZR durante un temporal, y en la (d) : tanto en las proximidades de la rotura como en el medio de la ZR. En varios casos se observó la existencia de "rip-currents".

Batimetría: mediciones diarias del perfil expuesto (al sur del muelle) cada 5 m hasta 500 m de la orilla. En los perfiles restantes (separados 11 m) las mediciones llegaron

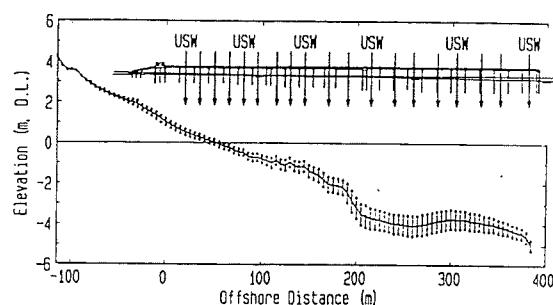
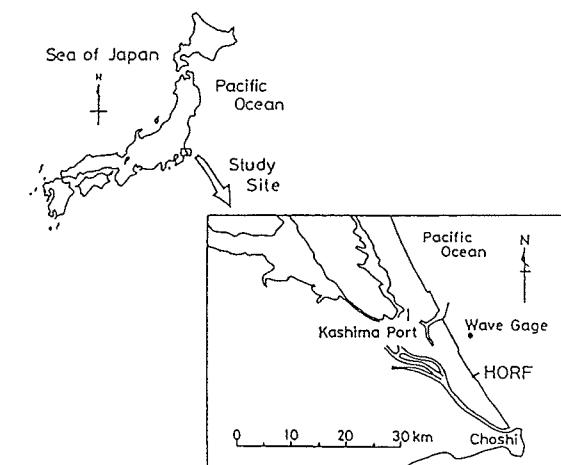


Figura 2.g.6: Localización y vista lateral de HORF señalando los puntos de medición, (Kuriyama y Ozaki, 1993).

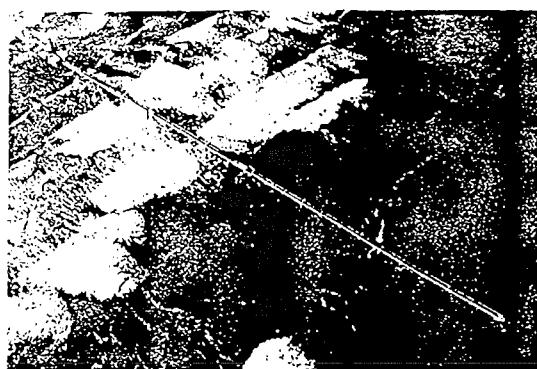


Figura 2.g.7: Vista aérea del muelle HORF, (Nakamura y Kato, 1992).

hasta 200 m de la costa.

Olas: Las olas "off-shore" se midieron con un sensor ultrasónico 7 Km al norte de HORF a 23 m de profundidad. Varios puntos a lo largo del muelle con sensores ultrasónicos ("USW" en la figura 2.g.6 y 2.g.9). Se observaron adicionalmente propiedades del oleaje en rotura como: fracción de olas rotas, posición de la línea de rotura y tipo de rotura.

Corrientes: con un CEM en cada punto de medida coincidiendo con los sensores de olas. También se realizaron numerosas mediciones con trazadores (boyas lastradas) a lo largo del muelle. Estos trazadores y la comparación de sus medidas con las de los CEM se muestra en las figuras siguientes.

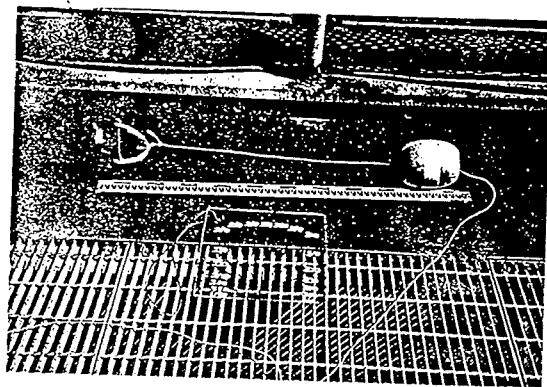


Figura 2.g.8: Flotadores para mediciones Lagrangianas de la corriente, (Kuriyama y Ozaki, 1993).

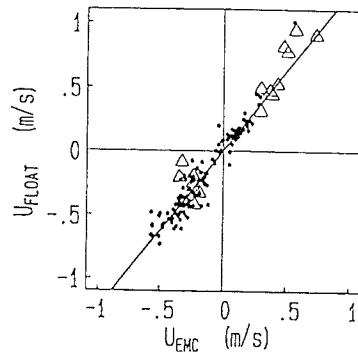
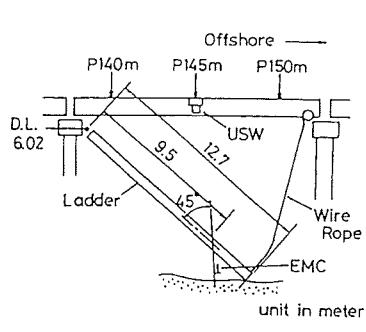


Figura 2.g.9: Localización de los CEM y USW, y comparación entre medidas Eulerianas y Lagrangianas de la corriente longitudinal, (Kuriyama y Ozaki, 1993).

La comparación entre los CEM y los trazadores arrojó una relación: $V_{cem} = 0,81V_{boya}$. El hecho de que las boyas sobreestimen la corriente se puede deber a que el arrastre hidrodinámico del "roller" sobre la boyas en la superficie tiene una componente paralela la costa que contribuye a incrementar la velocidad.

Las series temporales medidas con los CEM y USW tuvieron una duración de 20 minutos con una frecuencia de muestreo de 2 Hz. De estos experimentos se han obtenido numerosos y completos perfiles transversales de la corriente longitudinal, que a pesar de no tener resolución vertical, constituyen uno de los experimentos de campo con más resolución en perfiles barrados. Dichos datos han sido modelados recientemente por Kuriyama (1994). Como ejemplo se muestran en las figuras siguientes los datos de corriente, batimetría y "decay" medidos.

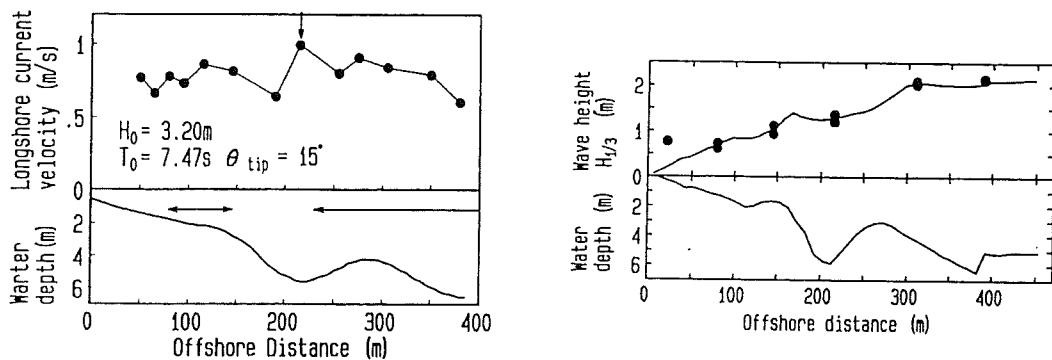


Figura 2.g.10: Distribución transversal de la corriente longitudinal y la altura de ola, las flechas horiz. indican la zona de rotura, (Kuriyama y Ozaki, 1993).

Otras Campañas japonesas de interés son:

g.4) Naka: (Greenwood y Mittler, 1984)

Institución: Univ. de Toronto (Canadá).

Fechas: 1980-1981.

Lugar y área: Costa de Ibaraki, Playa Naka en un área de 100 x 150 m.

Mediciones: Batimetría, Olas, Corrientes, y Transporte de Sedimentos.

g.5) **Lioka:** (Uda et. al., 1991)

Fecha y duración: 1987, durante 7 meses.

Lugar y área: Costa de Lioka, en una playa de arena con numerosas obras (diques perpendiculares paralelos a la playa) e intensa actividad morfodinámica natural y artificial. Las medidas se tomaron en un área de 300 x 300 m.

Mediciones:

Batimetría medida tres veces en el área de 300 x 300 m; Olas medidas en 3 estaciones localizadas a 6Km mar-adentro; Corrientes medidas con CEM en las mismas posiciones. También se realizaron medidas de las Características y el Transporte de Sedimentos (con trazadores fluorescentes).

g.6) **Ehime :** Bashinji y 5 playas. (a): Ifuku y Kakinuma, 1982; b): Ifuku y Kakinuma, 1988; Ifuku, 1988)

Institución: Univ. de Ehime, (Japón).

Fechas y duración: a): 1978 durante 7 días, y b): 1982 y 1984, durante 3 meses cada vez.

Lugar y área:

a): 5 Playas: Chuyo, Akita, Hiez, Nishikinohama y Takahama. La primera es una playa rocosa y las 4 restantes de arena.

b): Costa de Ehime, Playa Bashinji en dos transectos.

Mediciones: a): Batimetría (ecosonda), Olas (sensores de presión), Características de los Sedimentos y formas de fondo con hidrocámaras. Estos experimentos (a) 5 playas) estuvieron orientados al estudio de la rugosidad de fondo bajo olas sin rotura.

b): Batimetría, Olas, Corrientes, Mareas, Características y Transporte de Sedimentos.

h) Campañas Norteamericanas:

Estados Unidos es un país con larga tradición en medidas en zonas costeras. Los primeros intentos conocidos de medir la hidrodinámica en ZR son los realizados por el Instituto Scrips en las playas de California en 1936 y 1937, seguidos por Caldwell

(1956) en la Bahía Anaheim, (California); o Moore y Cole (1960) que midieron en Cabo Thompson, Alaska.

Dorrestein midió en 1961 en la Playa Fernandina, en las costas de Florida, utilizando un muelle transversal para medir el oleaje incidente y 6 sensores de nivel a través de la ZR para medir el "set up" inducido por el oleaje.

En 1966 Ingle midió la distribución transversal de la corriente longitudinal, la batimetría, características del oleaje incidente, y niveles a través de la zona de rompientes en la playa de "Trancas" en las costas de California, (Ingle, 1966; Thornton, 1970).

h.1) **La Jolla (1) Torrey Pines:** (Guza y Thornton, 1978; Thornton, 1979).

Instituciones: US Office of Naval Research, Jet Propulsion Laboratory, Naval Postgraduate School (Monterrey) y Scrips Inst. Oceanography (La Jolla).

Fecha: Marzo de 1977.

Lugar: Playa "Torrey Pines", La Jolla - California.

Medidas: se midieron corrientes longitudinales, oleaje y batimetría. Dicha playa es longitudinalmente uniforme, con efectos de marea (rango de 2m), arena de $D_{50}=0,1$ mm, rotura tipo "spilling" y pendientes entre 1:40 y 1:150

El oleaje fue medido mediante 5 sensores de presión distribuidos a lo largo de 400 m en una paralela a la costa (9 m de profundidad). Las velocidades (horizontales y verticales) fueron medidas mediante 6 CEM distribuidos como se muestra en la figura siguiente. La frecuencia de muestreo fue de 64 Hz y los datos almacenados a 2 Hz. Los niveles se midieron mediante sensores capacitivos que se colocaron junto con los CEM en torres metálicas de 4 m de altura clavadas en la arena durante la bajamar. Las medidas se presentan en la figura 2.h.1b.

A pesar de que esta campaña fue relativamente pequeña (frente a las de mayor envergadura descriptas más adelante) se obtuvieron algunas conclusiones interesantes además que permitieron acumular experiencia para los experimentos de gran escala. Por ejemplo se puso de manifiesto la alta variabilidad espacial y temporal que suelen presentar las corrientes longitudinales, lo cual obliga a disponer de una alto número de sensores para obtener una descripción fiable de la estructura hidrodinámica. Un ejemplo de esta variabilidad espacial y temporal se puede ver en la figura 2.h.2 donde la máxima separación entre CEM es de 14 m.

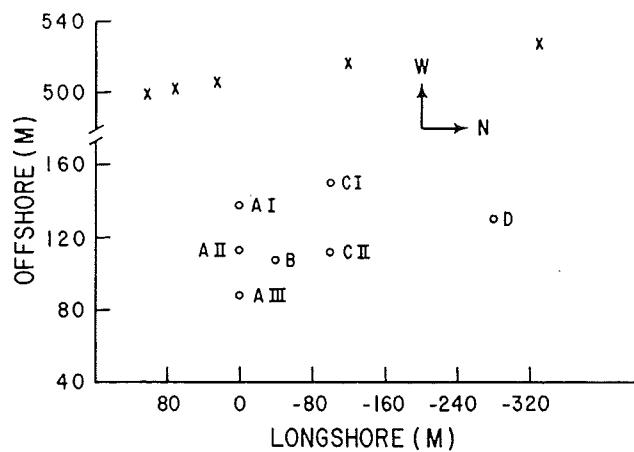


Figura 2.h.1a: Distribución espacial de equipos en "Torrey Pines": "x" sensor de presión, "o" CEM, (Guza y Thornton, 1978)

Run	Distance Across SurfZone, %	Beach Slope, $\tan \beta$	Mean Water Depth h , cm	Relative Flow Meter Elevation from Bottom, z/h	Frequency of Peak Coherence		Surf Variance σ_u^2, m^2	Velocity Variance m^2/s^2	Surface Parameter ξ	Wave-Induced Velocity Intensity $\sigma_w/\sigma_u, \%$
					f_0, h_s	$\gamma_{u*}^*(f_0)$				
Carmel River										
May 29, 1975	0*	0.14	145	0.33	0.079	0.78	0.036	1.12	0.25	0.84
May 10, 1976	0.3†	0.12	46	0.33	0.087	0.82	0.008	1.78	0.19	0.81
Torrey Pines										
March 16, 1977	0.3	0.007	136	0.35	0.070	0.90	0.045	0.16	85	0.90
March 17, 1977	0.3	0.009	176	0.28	0.077	0.85	0.059	0.15	74	0.88
March 18, 1977	0.1	0.009	180	0.25	0.084	0.84	0.043	0.26	75	0.81
March 21, 1977	0.1	0.010	153	0.33	0.070	0.83	0.036	0.16	39	0.87
March 21, 1977	0.5	0.009	96	0.15	0.070	0.79	0.017	0.08	30	0.87
March 23, 1977	0.1	0.016	151	0.44	0.070	0.91	0.041	0.18	16	0.91
March 23, 1977	0.5	0.016	62	0.35	0.070	0.86	0.008	0.07	6.9	0.90

0 = break point.

*Average breaker location.

†Positive number indicates shoreward of breakpoint.

‡Negative number indicates outside surf zone.

Figura 2.h.1b: Resumen de medidas en "Torrey Pines", (Thornton, 1979)

Otra conclusión de este trabajo fue que la resolución temporal de medición (2 Hz) no garantizó una buena estimación del tensor de radiación (componente S_{xy}). Cuyo cálculo a partir de las velocidades oscilatorias fue además, altamente sensible a los errores en la orientación de los CEM ya que errores de orientación de $\pm 2^\circ$ fueron suficientes para impedir el cálculo correcto de S_{xy} .

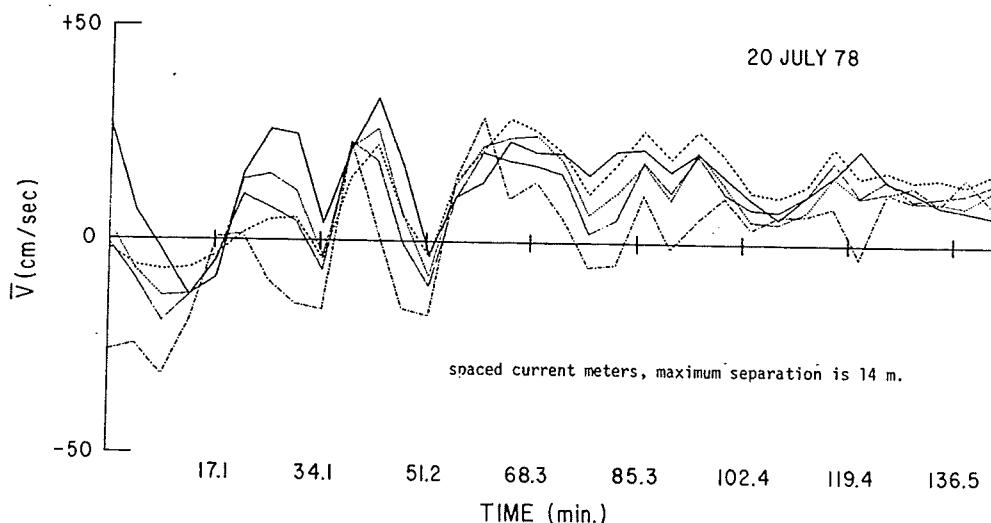


Figura 2.h.2: Series de 5 de los 6 CEM utilizados con un promediado temporal en 256 s, (Guza y Thornton, 1978)

h.2) La Jolla (2) y (3): (2) Flick y George, 1990; (3) George et al., 1994

Instituciones: California Dept. of Boating and Waterways y Scrips Institution of Oceanography.

Fecha y duración: (2): algunos días durante Marzo de 1990 y (3): una semana en Marzo y Abril de 1992.

Lugar y área: Playa Scrips, cercana a La Jolla, California, en un transecto.

Mediciones: niveles, olas y velocidades con alta resolución (temporal y espacial).

En Marzo de 1990 Flick y George miden en una playa cercana a La Jolla (California), velocidades, niveles y temperatura mediante instrumental convencional (CEM, sensores de presión, sensores de altura resistivos, termistores, etc.) y anemómetros de placa caliente (APC). Este trabajo es interesante porque se utilizó instrumental no convencional como son los APC para estudiar las escalas turbulentas en la zona de "swash" y la zona de rompientes interior ("inner surf-zone").

Los sensores de presión se utilizaron para tener un registro cualitativo de la superficie libre y correlacionarla con las señales de los APC. Estos sensores suavizan las oscilaciones de la superficie ya que las fluctuaciones de alta frecuencia se amortiguan con la profundidad.

El comportamiento de los sensores resistivos fue insatisfactorio por su alta sensibilidad a la existencia de partículas e impurezas que se adherían a los hilos. Los sensores térmicos fueron utilizados para permitir la calibración de los APC.

Las mediciones de 1990 estuvieron orientadas a estudiar las escalas turbulentas en la zona de "swash" y rompientes interior, mientras que las de 1992 estudian con mayor profundidad la turbulencia generada por la rotura del oleaje. En este último trabajo proponen además un nuevo método para separar turbulencia de flujo oscilatorio basado en la disipación, el espectro del número de onda y en las hipótesis de Taylor (que asumen "turbulencia congelada").

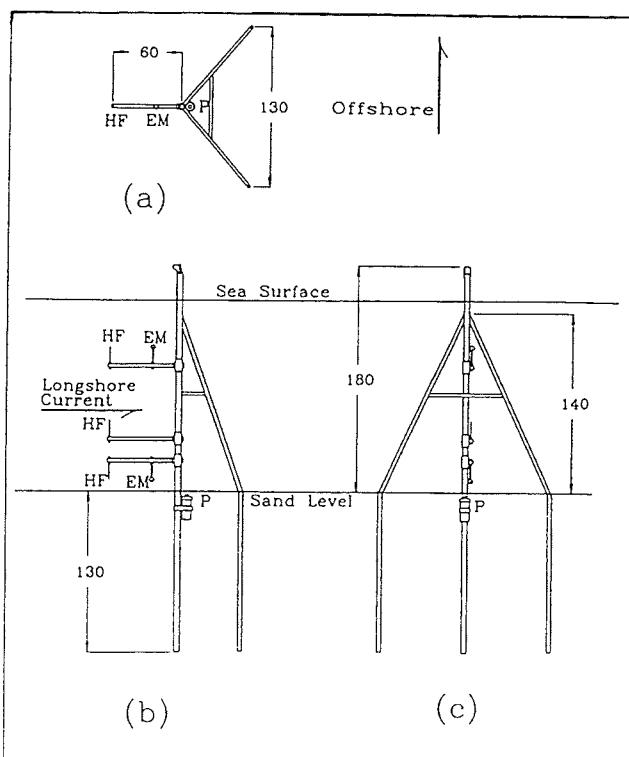


Figura 2.h.3: Trípode con dos CEM, tres APC y un sensor de presión, (George et al. 1994).

Experimentos de "gran escala":

En la costa Este se destacan las Campañas "DUCK-82", "DUCK-85", "SUPERDUCK", y "DELILAH" y "DUCK94". En la costa Oeste el programa "NSTS" (I, II y III). Este último se ha realizado en dos playas: "Torrey Pines" cerca de La Jolla y "Leadbetter" cerca de Santa Bárbara, ambas en California.

h.3) NSTC-1 Torrey Pines: (Seymour y Duan, 1978; Gable, 1979; Seymour y Gable, 1980; Guza y Thornton, 1980; Thornton y Guza, 1981; Seymour, 1983; Seymour, 1988).

Institución: National Oceanic and Atmospheric Administration.

Fechas y duración: 20 días (27/10/78 al 06/1/78)

Lugar y área: Playa de Torrey Pines, en un área de 500 x 500 m. Se trata de una playa barrada longitudinalmente uniforme, con mareas de 2,2 m, y pendiente 1:43.

Mediciones: ver figura 2.h.4a.

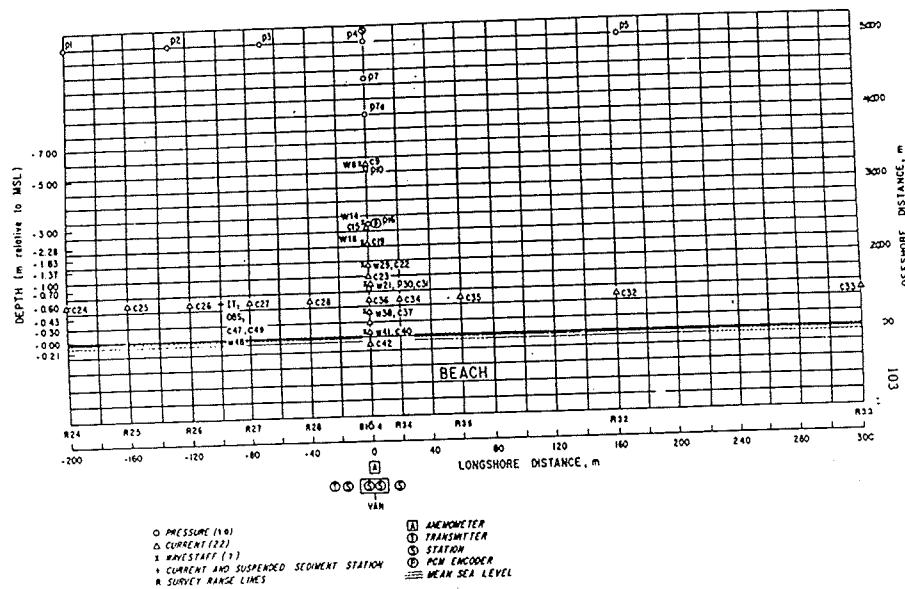


Figura 2.h.4a: Distribución del instrumental en NSTC-1 Torrey Pines, (Seymour, 1988).

Olas: con 10 sensores de presión y 7 sensores de altura dentro de la ZR y una DWR.

- . Corrientes: con 22 CEM, más unos trípodes con un CEM y un sensor de presión cada uno para medir "rip-currents".

Las medidas incluyeron Batimetrías, "run-up", Mareas y SWL, Meteorología, características y transporte de sedimentos, y el uso de fotografías y trazadores.

h.4.) **NSTS-2 Leadbetter:** (Gable, 1981; Thornton y Guza, 1986; Guza et al., 1986; Dean et al., 1987, Seymour, 1988).

Institución: National Oceanic and Atmospheric Administration.

Fechas y duración: 1979-1980, durante 30 días más 14 meses de mediciones de transporte de sedimentos.

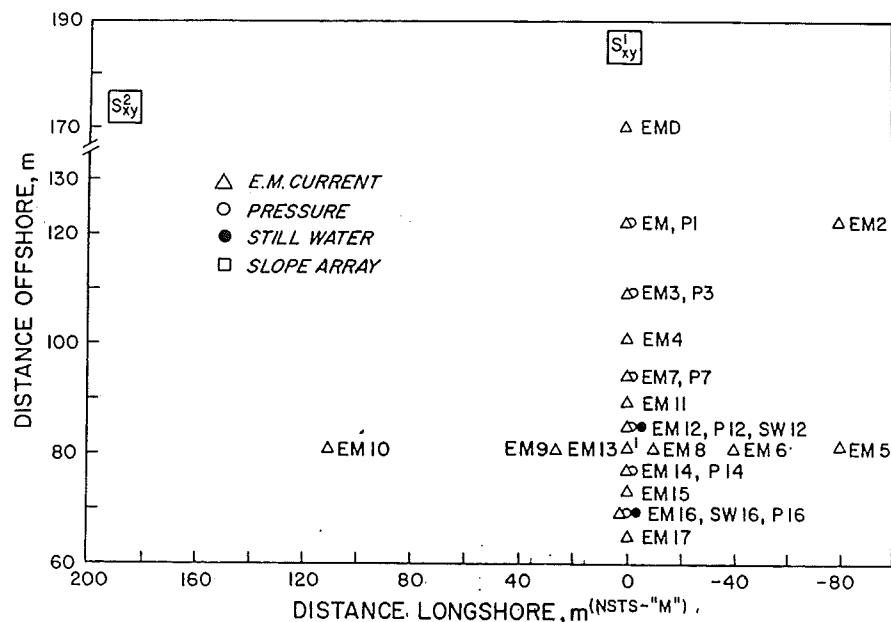
Lugar y área: Playa de Leadbetter, Santa Bárbara, California. En un transecto de 170 m y 200 m a lo largo de la costa. Se trata de una playa abierta de arena y longitudinalmente uniforme con una estrecha ZR. La pendiente varió entre 1:33 y 1:16.

Mediciones: ver figuras 2.h.4 b y c.

- . Olas: con 18 sensores de presión y 5 sensores de altura resistivos en la ZR y la zona de "swash".
- . Mareas: con un mareógrafo en el puerto de Sta. Bárbara y un sensor de presión.
- . Corrientes: con 24 CEM, más unos adicionales en trípodes para medir "rip-currents".
- . Batimetrías: en 5 transectos cada 50 m medidos diariamente durante la marea baja; en 9 líneas longitudinales, dos campañas con barco y ecosonda antes y después de los experimentos intensivos.

Las medidas incluyeron "run-up", SWL en dos puntos, meteorología, temperatura de agua, características y transporte de sedimentos de fondo as con sensores acústicos, en suspensión con trampas y 5 OBS, y el uso de fotografías y trazadores de arena fluorescente.

El tercer experimento NSTS-3 se realizó en 1981 en una playa de Virginia con una duración de 5 meses y estuvo orientada a la medición del transporte de sedimentos, olas y batimetrías, (ver Seymour, 1987).



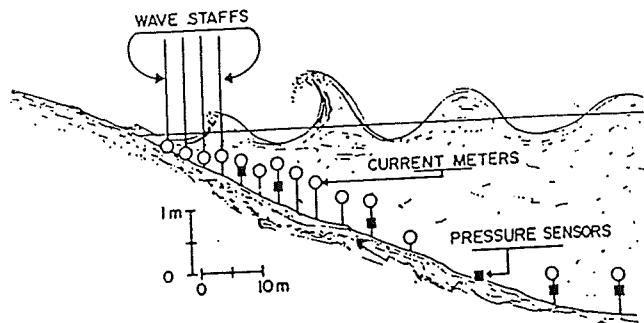


Figura 2.h.4c: Distribución del instrumental a lo largo del perfil en NSTS-2, (Thornton y Guza, 1986).

- . Olas: 1 DWR a 6 Km de la costa (20 m de profundidad) y 7 sensores de altura en la ZR.
- . Corrientes: 4 CEM
- . Batimetría general con 15 perfiles de 300 m cada 23 m mediante el CRAB ("coastal research amphibious buggy", ver Birkemeier y Mason, 1984).
- . Otros: Meteorología, viento, y fijación de la línea de orilla con cámaras en el muelle.

Además de las medidas en el muelle FRF, se midió a 457 m al N de la FRF en la ZR con un trineo:

- . Batimetría local mediante prismas ópticos en un trineo y sensores infrarrojos desde tierra.
- . Olas: mediante un sensor de presión en un trineo.
- . Corrientes: mediante tres (seis en algunos casos) CEM a 0,5 - 1,0 y 1,75 m del fondo. Con una frecuencia de 2 Hz y un tiempo de adquisición de 34,1 minutos.
- . Transporte de sedimentos con 1 OBS.

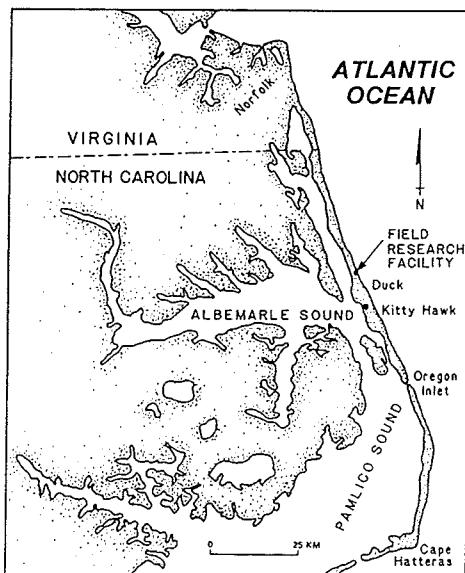


Figura 2.h.5a: Localización de la estación FRF, Duck, del CERC, (Kraus et al., 1989).

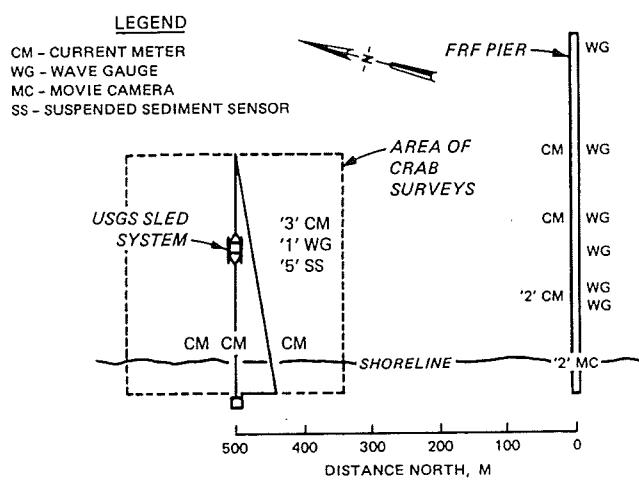


Figura 2.h.5b: Esquema de los experimentos Duck-82, (Mason et al., 1984).

h.6.) **FRF-DUCK'85** : (Mason et al., 1987; Hubertz et al., 1987; Birkemeier et al.,

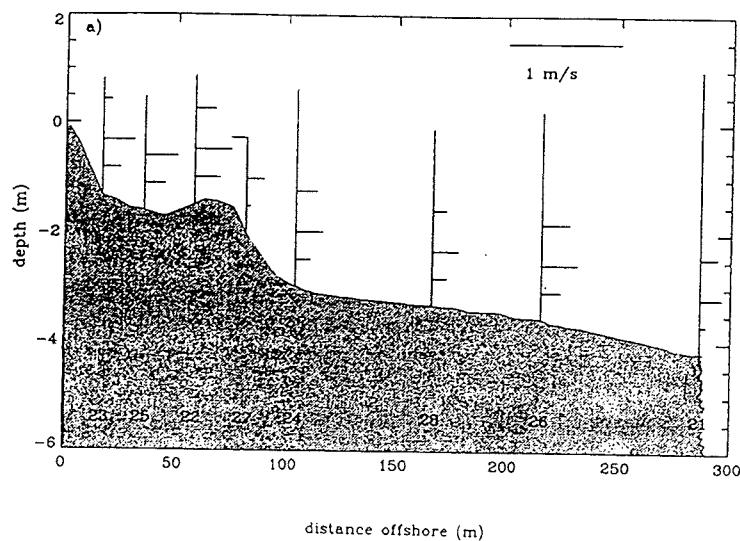


Figura 2.h.5c: Perfil transversal, posiciones del trineo y "undertow", (Haines y Sallenger, 1994).

1988; Kraus et al., 1989)

Instituciones: Field Research Facility FRF, y Coastal Engineering Research Center, CERC.

Fechas y duración: 19 días en Septiembre y 11 días en Octubre, 1985. - Entre el 26 y 27 de Septiembre el huracán Gloria pasó por la FRF.

Lugar y área: Playa de Duck, Carolina del Norte, en la FRF y 500 al N del muelle. La zona cubierta fue de 1 Km a lo largo de la costa y en un transecto de 500 m, ver figura 2.h.6.

Mediciones: ver figura 2.h.7.

- . Olas: 2 DWR a 20 y 10 m de profundidad, 5 sensores de presión en la ZR, numerosos postes ("photopoles") para obtener mediante fotografías las alturas, 4 sensores de presión en sendos trípodes.
- . Corrientes: 5 CEM más 4 trípodes con un correntímetro para medir el "undertow". Varios CEM en un trineo, y un radar para medir corrientes superficiales.
- . Sedimentos: 5 OBS coincidentes con los CEM, 2 más en dos de los cuatro trípodes, numerosas trampas y arena coloreada.
- . Batimetría general con 20 perfiles de 1 Km cada 25 m mediante el CRAB, más

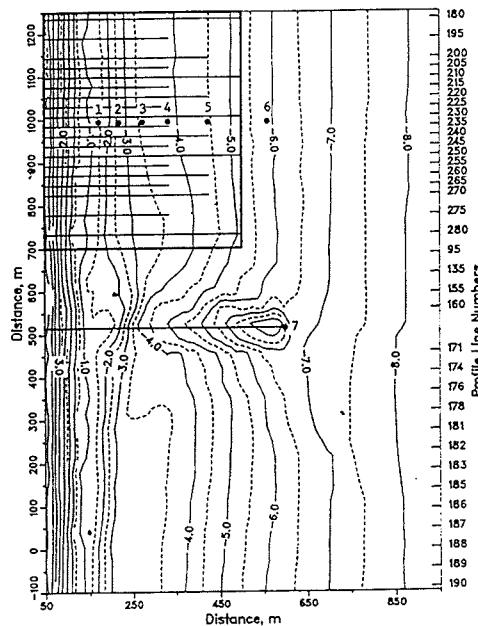


Figura 2.h.6: Batimetría distribución del instrumental en los experimentos Duck-85, (Birkemeier et al., 1988).

Instrument Description	Number	Type	Figure 3 Location Number	Water Depth m	Sensor Location		
					Alongshore m	Cross-shore m	Elevation m
Atmospheric Pressure	616	A		565.0	12.2	4.60	
Air Temperature	624	T		565.0	12.2	4.60	
Wind Speed	672	S	7	513.3	600.0	18.55	
Wind Direction	673	D	7	513.3	600.0	17.71	
Water Level	1	H	7	513.3	600.0	0.00	
Cross-Shore Pipe 1	701	P	1	-1.4	993.3	173.9	-1.33
	709	U			993.9	174.9	-0.86
	719	V			993.9	174.9	-0.86
Cross-Shore Pipe 2	711	P	2	-2.6	993.6	220.1	-1.69
	729	U			993.0	220.7	-1.24
	739	V			993.0	220.7	-1.24
Cross-Shore Pipe 3	721	P	3	-3.7	993.9	273.8	-3.55
	749	U			993.9	273.8	-2.26
	759	V			993.9	273.8	-2.26
Cross-Shore Pipe 4	731	P	4	-4.0	994.5	333.2	-3.49
	769	U			994.5	333.2	-2.26
	779	V			994.5	333.2	-2.26
Cross-Shore Pipe 5	741	P	5	-4.5	993.9	424.7	-4.11
	789	U			993.9	424.7	-2.36
	799	V			993.9	424.7	-2.36
	141	W			993.9	619.0	-5.50
Vertical Current Meter Array	SD25-1	U	6	-6.1	994.0	560.0	-5.40
	SD25-1	V			994.0	560.0	-5.40
	SD25-2	U			994.0	560.0	-3.96
	SD25-2	V			994.0	560.0	-3.96
	SD25-3	U			994.0	560.0	-2.51
	SD25-3	V			994.0	560.0	-2.51
Nearshore Waverider	640	W		-9.0	515.0	977.0	0.00
Offshore Waverider	630	W		-18.0	515.0	6000.0	0.00

Figura 2.h.7: Instrumental en los experimentos Duck-85, (Birkemeier et al., 1988).

numerosos levantamientos de detalle.

- Otros: Meteorología y viento.

h.7.) SUPERDUCK : (Crowson et al., 1988; Byrnes, 1989; Birkemeier et al., 1989, Rosati et al., 1990)

Instituciones: Field Research Facility FRF, y Coastal Engineering Research Center, CERC.

Fechas y duración: 22 días en Septiembre y 22 días en Octubre, 1986.

Lugar y área: Playa de Duck, Carolina del Norte, en la FRF y 500 al N del muelle. La zona cubierta fue de 600 m a lo largo de la costa. Ver figura 2.h.8.

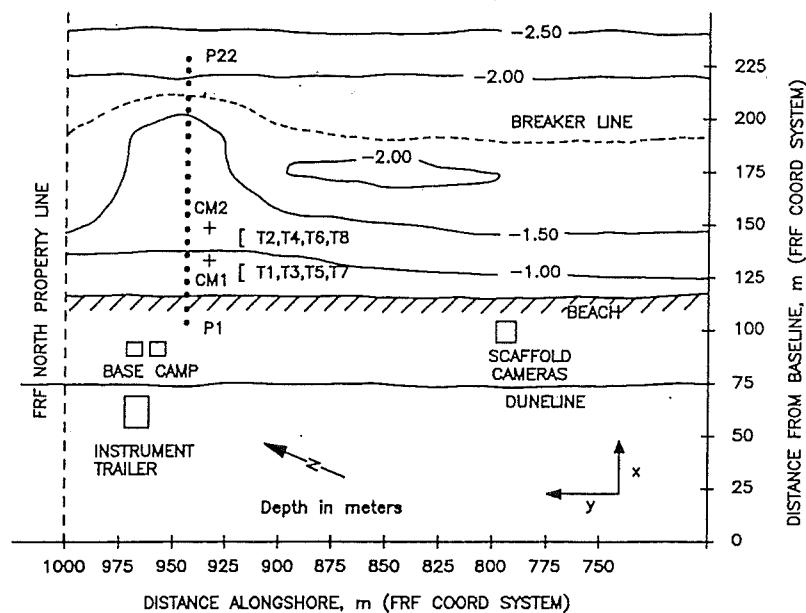


Figura 2.h.8: Esquema y batimetría durante los experimentos SUPERDUCK, (Rosati et al., 1990).

Mediciones:

- . Medidas hidrodinámicas continuas en la FRF: 5 sensores de altura y un sensor direccional de oleaje.
- . Olas: 10 sensores de presión de registro continuo en una línea paralela a la costa a 8 m de profundidad, 7 sensores de presión en un transecto perpendicular de 1,3 a 3,25 m de profundidad.
- . Corrientes: 10 CEM coincidiendo con la línea a 8 m de los sensores de presión, un trípode al S del transecto con un sensor de presión y un CEM.
- . Sedimentos: 5 OBS coincidentes con los CEM, 2 más en dos de los cuatro trípodes, numerosas trampas y arena coloreada.

- . Batimetria general con 20 perfiles de 600 m cada una semana en Octubre y diariamente en Septiembre, (23 en total), mediante el CRAB, más numerosos levantamientos de detalle.
- . Otros: Meteorología y viento, temperatura y densidad del agua, ángulo de incidencia del oleaje y ancho de la ZR mediante filmaciones.

Se realizaron además 30 experimentos por parte de numerosas instituciones:

- i) Medidas en condiciones de calma: transporte de sedimentos en suspensión mediante trampas portables (PST) ocasionalmente con uno o dos CEM. Filmación del oleaje mediante 22 postes ("photopoles") incados en la ZR y comparación de las filaciones con las medidas de dos sensores resistivos y dos de presión. Medidas de "rip-currents" mediante trípodes portátiles con dos CEM y un sensor de presión (PUV).
- ii) Medidas en temporales: Ondas infragravitatorias mediante video y 10 CEM distribuidos transversalmente en la ZR para medir el espectro del número de onda. Respuesta del perfil mediante un arreglo transversal de 7 sensores de presión y 7 sondas tipo sonar. Efecto conjugado del viento y el oleaje impulsando la circulación cercana a la costa mediante un trineo dotado con un anemómetro, 3 CEM, varios sensores de presión (dos diferenciales y uno absoluto) para medir gradientes del tensor de radiación. Gradiente longitudinal de presión mediante 7 sensores a lo largo de 27 Km. Dos trípodes PUV a 7 y 12 m de profundidad con dos CEM y un sensor de presión cada uno. Para estudiar la dinámica de la plataforma ("inner-shelf") se utilizaron dos trípodes PUV fuera de la ZR con 5 OBS cada uno y un radar que permitía medir el espectro direccional del número de onda desde la ZR hasta 4 Km de la costa. Medidas del transporte de sedimentos con trazadores fluorescentes y filmación submarina.
- iii) Medidas continuas: 3 grupos de trampas de sedimentos fuera de la Zr (a 11 m de profundidad y logarítmicamente equi-espaciadas). En uno de los grupos se agregó un trípode PUV. Dos estaciones meteorológicas completas. Medidas con radar hasta 40 Km de la costa. Dos sensores Doppler para medir batimetrías, uno remoto y otro para las medidas cerca de la costa. Sensores de presión de alta presión para determinar la dirección de propagación del oleaje. Finalmente también se midieron micro-sismos de baja frecuencia para compararla con los espectro de energía marina medidos.

h.8.) **DELILAH:** "Duck Experiment on Low-frequency and Incident-band Longshore and Across-shore Hydrodynamics", (Birkemeier et al., 1991; Scott et al., 1991; Smith et al., 1992; Smith et al., 1993)

Instituciones: Field Research Facility FRF, y Coastal Engineering Research Center, CERC.

Fechas y duración: del 1 al 21 de Octubre de 1990

Lugar y área: Playa de Duck, Carolina del Norte, en la FRF. La zona cubierta fue de 400 x 200 m. Ver figura 2.h.9.

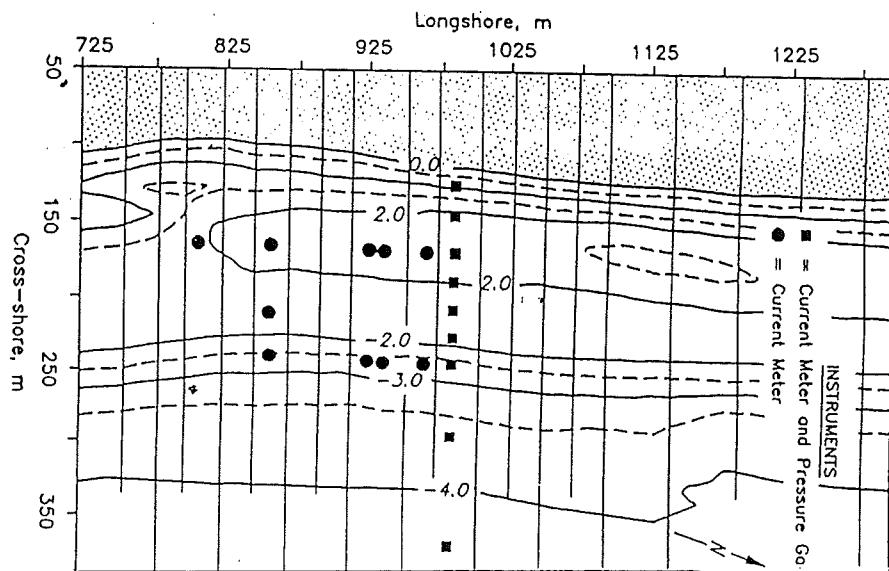


Figura 2.h.9: Instrumental y batimetría durante los experimentos DELILAH
(Smith et al., 1993).

Mediciones:

- . Medidas hidrodinámicas continuas en la FRF
- . Olas: 15 sensores de presión en un conjunto para medir oleaje direccional a los 8 m de profundidad, varios sensores de presión en un transecto a través de la ZR, dos sensores de altura en un trineo. También se utilizaron imágenes de video para medir "set-up" y ondas largas en la línea de orilla (e.g. Lippmann y Holman, 1992).
- . Corrientes: 9 CEM coincidiendo con la línea de los sensores de presión en la ZR, un trípode al S del transecto con un sensor de presión y un CEM.
- . Batimetría general mediante el CRAB, más numerosos levantamientos de detalle.

- . Otros: Meteorología, ángulo de incidencia del oleaje y ancho de la ZR mediante filmaciones, dos anemómetros (uno en el trineo).

Es uno de los conjuntos de datos de campo más completos para validar modelos morfodinámicos 2DV (CPM) incluyendo eventos de erosión, sedimentación, formación y migración de barras. Estas medidas han permitido el estudio del transporte de sedimentos producido por las distintas componentes del flujo (e.g. Howd et al. 1991 y Scott et al. 1991).

También de utilidad para modelos hidrodinámicos Q3D ya que dispone de medidas de la distribución transversal de la corriente longitudinal (e.g. Smith et al. 1993; Church y Thornton, 1993) y del "undertow" (e.g. Smith et al. 1992).

h.9.) **DUCK94:** (Birkemeier y Thornton, 1994; Birkemeier y Hathaway, 1996);

Instituciones: Field Research Facility FRF, y Coastal Engineering Research Center, CERC.

Fechas y duración: del 9 al 19 de Agosto y del 3 al 21 de Octubre de 1994.

Lugar y área: Playa de Duck, Carolina del Norte, en la FRF. La zona cubierta fue de

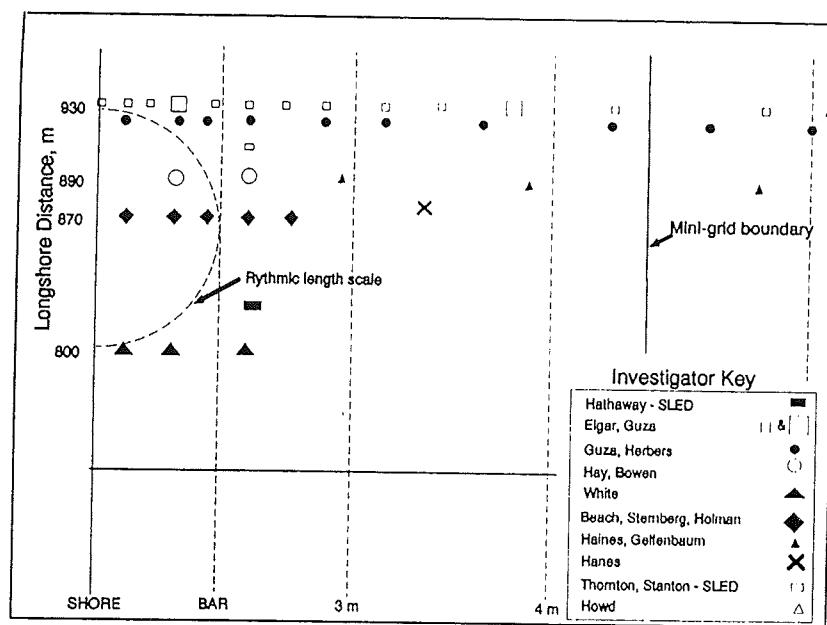


Figura 2.h.10: Distribución del instrumental durante los experimentos DUCK'94, (Birkemeier y Thornton, 1994).

1000 x 350 m.

Se trata del último y mayor experimento realizado a la fecha de esta tesis, como dato ilustrativo de la envergadura de esos experimentos se menciona que durante las mediciones de Octubre'94 el número de participantes osciló entre 70 y 100 personas. Su principal objetivo ha sido afinar el diseño de los experimentos de mayor escala "SANDYDUCK", (-ver Birkemeier y Hathaway, 1996), incluyendo medidas de los siguientes tópicos: morfología, transporte de sedimentos a pequeña y media escala, "shoaling", rotura y circulación costera, y zona de "swash".

Sus primeros resultados han sido publicados recientemente: estructura vertical de la corriente longitudinal y formas de fondo (Thornton et al., 1995), turbulencia y formas de fondo (Stanton y Thornton, 1996), estructura horizontal de la corriente longitudinal (Fedderse et al. 1996), evolución de sistemas de barras (Gallagher et al. 1996), y patrones de rotura mediante análisis de imágenes de video (Lippmann y Thornton, 1996).

Estos experimentos "DUCK'94" fueron a su vez planeados en base a los resultados de los anteriores ("DELILAH"), de donde se obtuvieron las siguientes conclusiones para su diseño:

- . La separación transversal de los trípodes de medición debe ser de 10 a 15 m para

poder describir adecuadamente divergencias del transporte de sedimentos.

- . La influencia de las mareas es de orden 1, por lo cual las medidas hidrodinámicas deben ser continuas.
- . Dentro de la ZR la importancia del flujo medio, las ondas largas y las olas de viento fue del mismo orden, por lo cual todas estas escalas deben ser estudiadas y consideradas en el cálculo del transporte de sedimentos.
- . El transporte de sedimentos fue mayoritariamente por suspensión.
- . Los efectos tridimensionales son importantes, por lo cual deben tenerse en cuenta las variaciones longitudinales .

Mediciones: Ver la distribución de los equipos en la figura 2.h.10.

- . Medidas hidrodinámicas continuas en la FRF
- . Batimetría
- . Olas
- . Corrientes

También en los EEUU se han realizado otras campañas de menor envergadura como las siguientes:

h.10.) **Del Monte, Monterrey:** (Thornton et al., 1976; Thornton, 1979)

Institución: Naval postgraduate School, Monterrey, California.

Fechas y duración: Varios días entre Abril de 1973 a Marzo de 1975.

Lugar y área: Playa Del Monte cerca de Monterrey, se trata de una playa de arena ($D_{50} = 0.2\text{mm}$), con pendientes entre 1:14 y 1:40, roturas tipo "spilling" o "plunging".

Mediciones: ver figuras 2.h.11a-b y 2.h.12.

Las mediciones incluyeron Batimetría, Olas mediante tres sensores capacitivos de 2,5, m montados en tres torres , Corrientes y Características de los Sedimentos.

Campañas en las costas del Lago Michigan:

h.11.) **Lago Michigan - Ludington:** ((a): Meadows, 1976; (b): Allender et al., 1978;

Antecedentes de Campo

Run	Distance Across SurfZone, %	Beach Slope, $\tan \beta$	Mean Water Depth h , cm	Relative Flow Meter Elevation from Bottom, z/h	Frequency of Peak Coherence f_s, h_s	Peak Coherence $\gamma_{uu}^*(f_s)$	Surf Elevation Variance σ_u^2, m^2	Velocity Variance m^2/s^2	Surface Parameter ξ	Wave-Induced Velocity Intensity $\sigma\bar{u}/\sigma_u, \%$
Del Monte										
April 12, 1973	0	0.03	186	0.26	0.067	0.79	0.025	0.22	4.7	0.82
May 23, 1974	-0.1‡	0.03	148	0.36	0.125	0.94	0.029	0.17	6.9	0.84
March 4, 1975	0	0.07	125	0.46	0.061	0.94	0.048	0.93	0.67	0.85
March 4, 1975	0.1	0.07	45	0.24	0.067	0.94	0.026	0.69	0.49	0.80
March 5, 1975	-0.1	0.06	167	0.35	0.078	0.87	0.017	0.27	0.69	0.80
March 5, 1975	0	0.06	108	0.31	0.084	0.93	0.023	0.32	0.82	0.81
March 6, 1975	-0.1	0.04	130	0.28	0.084	0.95	0.015	0.15	2.0	0.82
March 8, 1975	0	0.04	115	0.49	0.092	0.94	0.015	0.18	2.0	0.90
March 8, 1975	0.1	0.04	62	0.66	0.092	0.92	0.018	0.35	2.2	0.76
March 9, 1975	0.4	0.03	102	0.39	0.061	0.84	0.020	0.28	4.4	0.70
March 9, 1975	0.5	0.03	67	0.70	0.061	0.83	0.013	0.36	3.6	0.64

0 = break point.

*Average breaker location.

†Positive number indicates shoreward of breakpoint.

‡Negative number indicates outside surf zone.

Figura 2.h.11a: Resumen de medidas en "Del Monte", (Thornton, 1979)
(ver figura 2.h.1b)

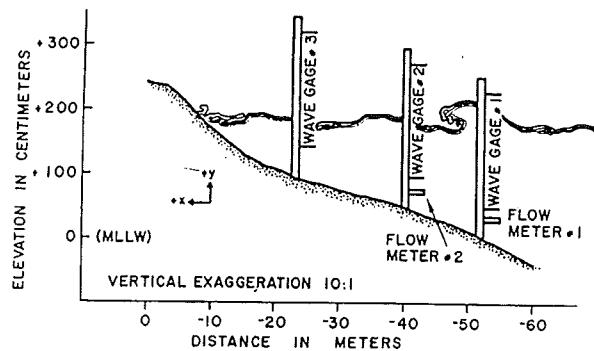


Figura 2.h.11b: Localización de instrumentos, (Thornton et al., 1976)

(c): Rosati et al., 1991)

Instituciones: (a): Purdue University, (b): Argonne National Laboratory (Illinoils), y
(c): CERC y Oregon State University

Fechas y duración: 1976 y, (b): durante dos temporales en Noviembre de 1977 y Abril de 1978; (c): Septiembre de 1988 durante 8 días.

Lugar y área:

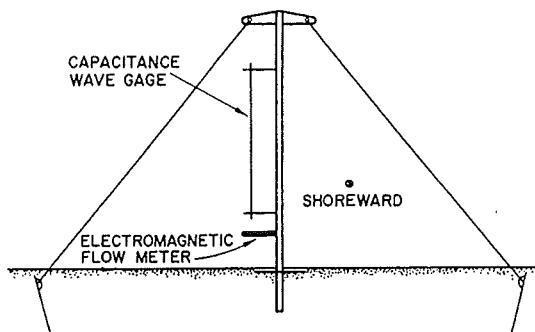


Figura 2.h.12: Esquema de una torre de medición, (Thornton et al., 1976)

- (a): Costa este del Lago Michigan, se trata de una playa multibarrada realizándose las medidas en un transecto de 30 m con una pendiente 1:40, ver figura 2.h.13.
- (b): Costa oeste del lago, en la Playa de Zion. Se trata de una playa con dos barras longitudinales realizándose las medidas en un transecto de 300 m mediante un trineo, ver figura 2.h.14.
- (c): Playa de Ludington, en la costa este del lago, en un área de 100 x 200 m, ver figura 2.h.15.

Mediciones:

- (a) : Batimetría, Olas con 8 sensores, Corrientes en tres torres y tres puntos de la vertical mediante correntímetros de molinete entubados.
- (b) : Batimetría: medidas detalladas antes y después del temporal con perfiles cada 20 m. Olas: mediante una DWR a 20 m de profundidad a 4 Km de la costa, un sensor de presión a 4,4 m de profundidad frente al transecto de medición. Dentro de la ZR las olas se midieron con 4 sensores resistivos fijos y otro en un trineo, a 10 Hz en series de 5 y 17 minutos cada tres horas. Las corrientes se midieron desde el trineo con dos correntímetros de molinete entubados en series de 5 minutos cada tres horas y una frecuencia de 10 Hz. Adicionalmente se utilizaron manchas de trazadores vertidas desde el trineo y fotografías aéreas. Las condiciones meteorológicas se midieron en una torre en la playa.

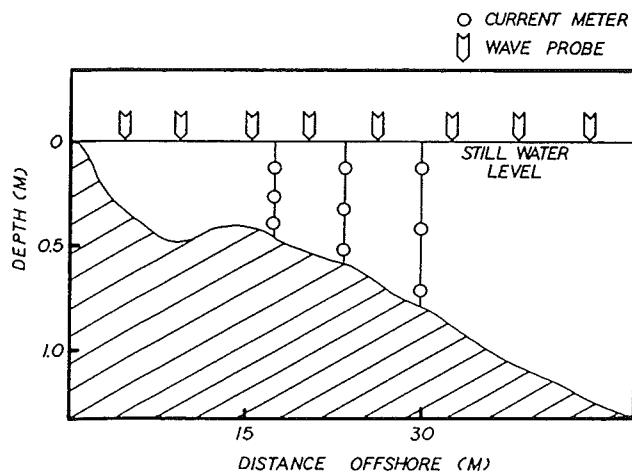


Figura 2.h.13: Esquema de medición en el Lago Michigan caso (a), (Meadows, 1976)

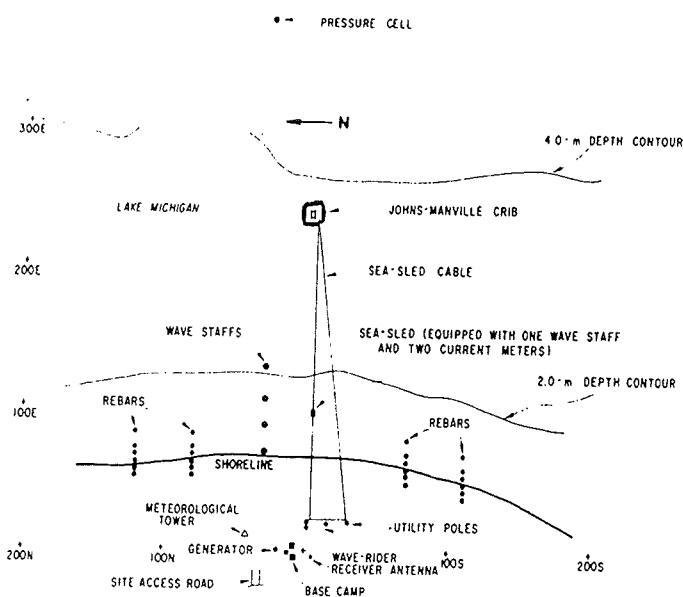


Figura 2.h.14: Esquema de medición en el Lago Michigan caso (b), (Allender et al., 1978)

- (c) Con el objeto de estudiar el transporte de sedimentos en suspensión se midieron: La batimetría con perfiles cada 15 m al comienzo y final de los experimentos. Las olas con un sensor direccional a 10 m de profundidad y 3 sensores de presión en la ZR. Las corrientes mediante dos CEM a 20 cm del fondo coincidiendo con los sensores de presión. Las Características y el Transporte de Sedimentos fueron medidas en detalle mediante numerosas trampas PST y OBS.

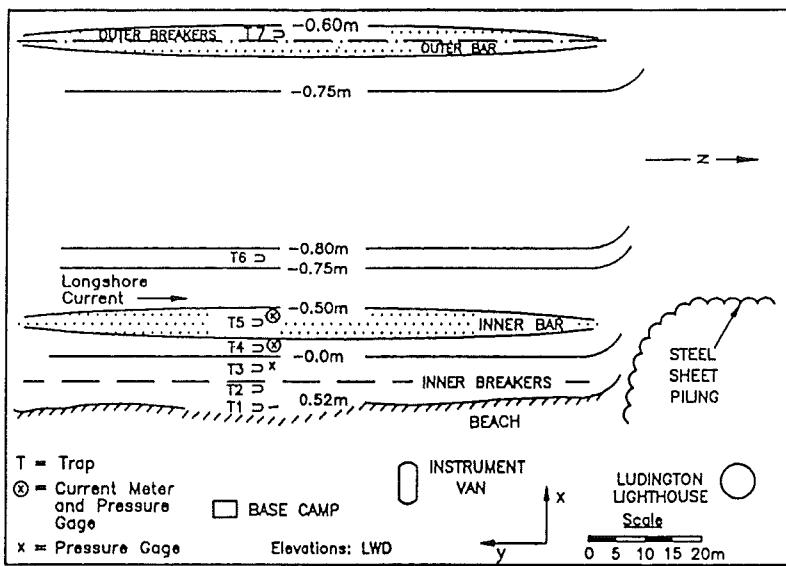


Figura 2.h.15: Esquema de medición en el Lago Michigan caso (c), (Rosati et al., 1991)

i) Campañas Polacas : (Druet et al., 1976; Basinski, 1980 y Owczarczyk, 1989; Antsyferov et al., 1990).

Las principales campañas Polacas han sido realizadas en la estación de Lubiatowo (ver figura 2.i.1) en la costa del mar Báltico.

Instituciones: CMEA, Academia Polaca de Ciencias, Instituto de Hidroingeniería, IBW PAN. Los experimentos se realizaron conjuntamente con varios países del COMECON.

Fechas y duración: Se realizaron experimentos en: a) 1974, b) 1976 y c) 1983; con una duración de 36, 53 y 5 días respectivamente.

Lugar y características de la playa: Se trata de un ambiente micromareal con una playa en mar abierto situada 80 Km al NE de Gdańsk, en la costa del mar Báltico. La playa es de arena fina, rectilínea y con tres barras paralelas a la costa estables. Las áreas medidas han variado desde un transecto en la línea de torres (ver figura), a 6 Km a lo largo de la costa con un área de 1 Km².

Objetivos: Los objetivos de la estación son realizar medidas sistemáticas (desde 1971-72) de las condiciones meteorológicas, hidrodinámicas y morfodinámicas en la zona costera incluyendo la Zona de Rompientes. Dichas medidas son utilizadas para la caracterización de los procesos físicos costeros y la validación de modelos numéricos.

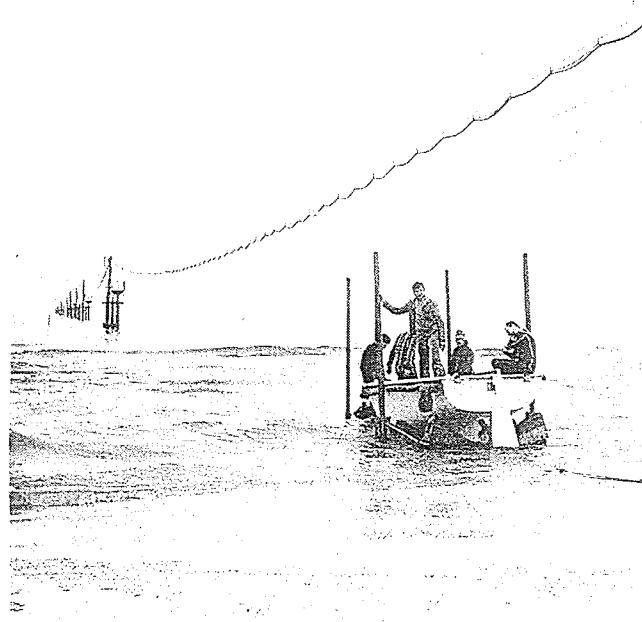


Figura 2.i.1: Vista de la estación de Lubiatowo, (IBW PAN'95)

Metodología:

Como se muestra en la figura correspondiente la estación consta además de la base terrestre permanente, de una serie de torres metálicas que se extienden en un transecto perpendicular a la playa de $0,75 \text{ Km}$ hasta una profundidad de $6-7 \text{ m}$. Dichas torres soportan además de instrumental fijo (correntímetros, etc), un cable carril desde el cual se pueden medir variaciones batimétricas y las variables puntuales en la posición deseada (olas, etc).

Las mediciones han y continúan utilizando diverso equipo, entre los cuales hay instrumentos poco frecuentes en los países occidentales. Por ejemplo, las olas son medidas con: radar, sensores de contacto (WG), sensores capacitivos-resistivos, sensores de presión, "sonda Glukhovsky". El "run up" es medido con sensores de contacto. Las velocidades con correntímetros de rotor ("BVP"), de presión ("VDK"), y trazadores.

i) las investigaciones hidrodinámicas miden: niveles medios, olas, corrientes, oscilaciones de la línea de orilla ("swash" y "run-up"), oscilaciones de baja frecuencia, difusión y dispersión, y aparatos extractores de energía del oleaje.

ii) las investigaciones morfodinámicas miden: transporte de sedimentos en suspensión y fondo mediante trampas y trazadores radioactivos y luminosos. Levantamientos batimétricos periódicos orientados al estudio de macroformas y

evolución a largo plazo. Desde 1983 se mide mensualmente el perfil transversal, y anualmente un tramo de 3 Km paralelo a la costa.

j) Campañas rusas y de países ex-soviéticos :

j.1) **Anapa y Krimea, Mar Negro-1/2:** (Longinov, 1963; Antsyferov et al., 1990)

Fechas: a) 1950-1955 y b) 1965-1970.

Lugar y área: Playas a) cerca de la presa de Anapa, y b) costa de Krimea.

a) La estación de Anapa costaba de tres torres portantes de un cable-carril desde donde se efectuaban las mediciones. La longitud del transecto cubierto era de 200 m alcanzando profundidades de 4 m. Ver figura 2.j.1.

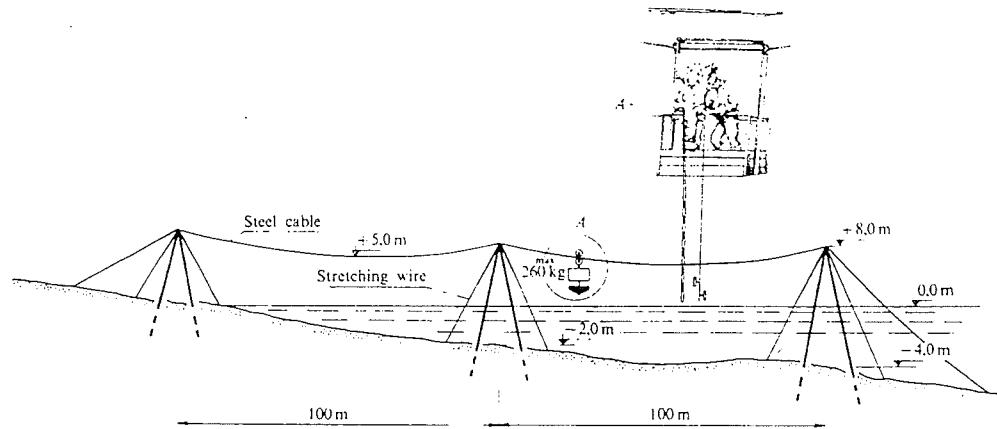


Figura 2.j.1: Esquema de la estación de Anapa en el Mar Negro, (Antsyferov et al., 1990).

b) La estación de Krimea consistía en un muelle de caballete de 1,3 m de ancho apoyado en torres espaciadas 12 m desde donde se efectuaban las mediciones. La longitud del transecto cubierto fue de 370 m alcanzando profundidades de 6 m.

Mediciones: Batimetría, Olas, Corrientes y Características de los Sedimentos.

j.2) **Kamchiya, Mar Negro-3/4 :** (Antsyferov et al., 1990)

Instituciones: 15 instituciones de 5 países. Algunas son:

Alemania Oriental: Institute de Investigación Marina, (Warnemünde) y Universidad Karl Marx, (Leipzig).

Bulgaria: Instituto de Investigación Marina y Oceanología; Academia de Ciencias de Bulgaria, Universidad de Sofía.

Polonia: Academia de Ciencias de Polonia, Intituto de Hidroingeniería, (Gdansk), Universidad de Gdansk y Universidad de Varsovia.

Rumania: Academia de Ciencias de Rumania e Instituto de Investigación Marina, (Costanta).

Rusia: Instituto Shirshov de Oceanología, Instituto de Problemas Hídricos, Academia de Ciencias de la URSS (Moscú y Gelendjik).

Otros: Academia de Ciencias de Ucrania, (Sevastopol); Academia de Ciencias de Lituania, (Vilnius) y Academia de Ciencias de Estonia, (Tallin).

Fechas y duración: a) 1977, b) 1978 y c) 1979.

Lugar y área: En Shkorpilovty cerca de la desembocadura del río Kamchiya, en las costa del mar Negro. Ver figura 2.j.2a.

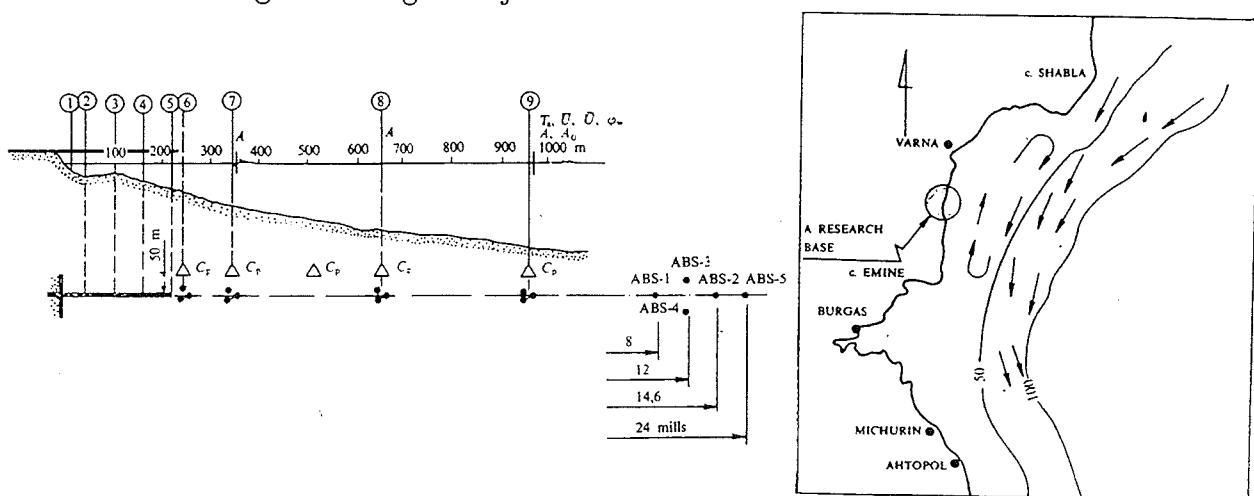


Figura 2.j.2a: Vista lateral y superior de la estación de Kamchiya en el Mar Negro, (Antsyferov et al., 1990).

Mediciones: Batimetría, Olas, Corrientes y Características de los Sedimentos, ver figuras 2.j.2a-d. La estación de 6 m fue destruida durante un severo temporal en 1979. Las medidas en el muelle y las torres fueron complementadas con cinco boyas aguas afuera,

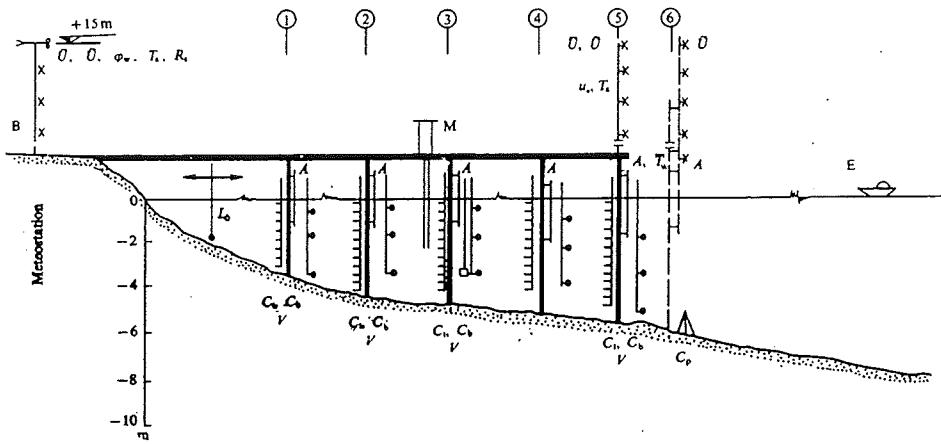


Figura 2.j.2b: Detalle del muelle e instrumental de la estación de Kamchiya, (Antsyferov et al., 1990).

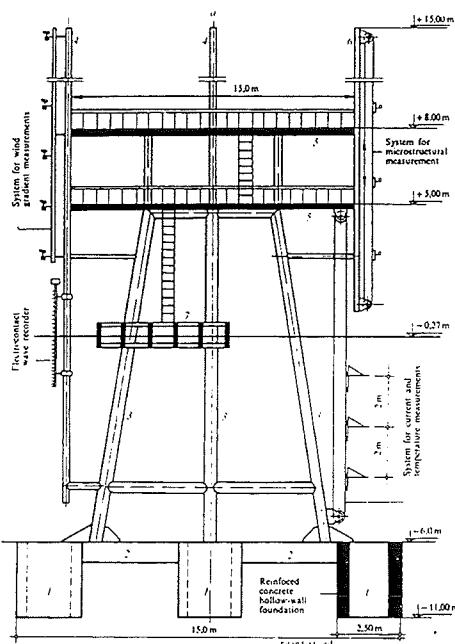


Figura 2.j.2c: Detalle de la torre a 6 m de profundidad en la estación de Kamchiya, posición 6 en la fig. 2.j.2a, (Antsyferov et al., 1990).

representadas como ABS-1, ... ABS-5, en figura 2.j.2a; y campañas oceanográficas periódicas.

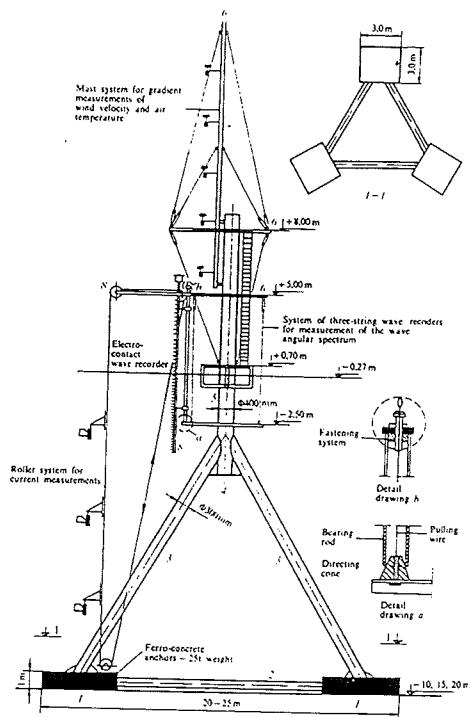


Figura 2.j.2d: Detalle de las torres a 10,15 y 18 m de profundidad en la estación de Kamchiya, posiciones 7,8 y 9 en la fig. 2.j.2a, (Antsyferov et al. 1990).

Los resultados de estas campañas se concentraron en el estudio de: *a*) propiedades del oleaje de viento, *b*) velocidades orbitales y flujo máscico y *c*) transporte de sedimentos en suspensión. Estos resultados teóricos y experimentales han sido publicados por Antsyferov et al. (1990).

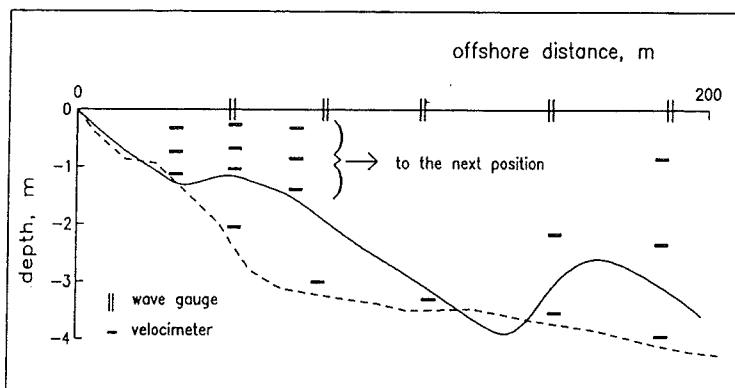
j.3) **Donuzlav-Kamchiya, Mar Negro-3** : (Kuznetsov y Speranski, 1990; Speranski, 1994a; Speranski, 1994b y Speranski, 1995).

Instituciones: Shirshov Inst. de Oceanología de Moscú, Inst. de Oceanología de Bulgaria.

Fechas: 1979-1988

Lugares y características de las playas: Playas rectilíneas de arena en el Mar Negro (1. "Donuzlav" en Crimea, (Ucrania) y 2. "Shcorpilovksi" en la desembocadura del río Kamchiya (Bulgaria)). Ambas playas tienen arenas finas con $D_{50} = 0,2\text{mm}$ con una pendiente del fondo de 1:50 entre los 0 y 5 m. La primera presenta un perfil bi-barrado mientras que la segunda no tiene barras, como se observa en la figura 2.j.3.

Objetivos: estudiar la hidrodinámica de la ZR. En aspectos relacionados a la turbulencia, flujo oscilatorio, flujo másico, y "undertow".



Beach profiles at "Donuzlav" (solid line) and "Shcorpilovsci" (dashed line) facilities.

Figura 2.j.3: Distribución de los sensores, (Speranski'94b).

k) Campañas Sudafricanas:

Los principales experimentos sudafricanos fueron realizados dentro del programa CAESAR "Coastal Area Environmental and Sediment Applied Research": (Swart, 1988).

k1) Río Sondangs: (Swart, 1984)

Institución-denominación: Council Scientific Indust. Research CSIR, CAESAR PE1

Fechas y duración: 1983, durante 5 días.

Lugar y área: Cerca del río Sondangs en la Bahía de Algoa, en un área de 200 x 100 m. Se trata de una playa arenosa con barras y canales.

Mediciones: Batimetrías en 1 Km de costa hasta 1 m bajo el nivel mínimo de marea baja, Olas con una DWR a 10 m de profundidad, y medidas directas dentro de la ZR con 7 WG, Corrientes con drogas, colorantes y fotos aéreas, Características y Transporte de los Sedimentos. Ver figura 2.k.1.

k2) Walker Bay a-b: (Swart, 1988)

Institución-denominaciones: Council Scientific Indust. Research CSIR, CAESAR: WB1

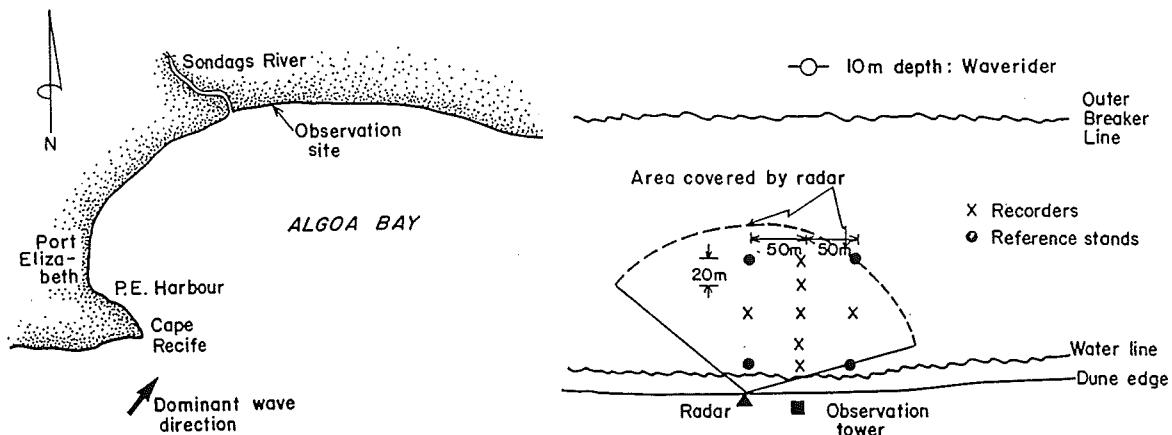


Figura 2.k.1: Distribución de los sensores en CAESAR PE1 (Swart, 1988).

y WB2

Fechas y duración: 1986 durante 4 y 9 días respectivamente.

Lugar y área: Bahía Walker, en áreas de 700 m en la línea de orilla y 700 x 75 m.

Mediciones: Batimetrías en 1 Km de costa hasta 1 m bajo el nivel mínimo de marea baja, Olas con una DWR a 10 m de profundidad, y medidas directas dentro de la ZR con 7 WG, Corrientes con drogas, colorantes y fotos aéreas, Características y Transporte de los Sedimentos. Ver figuras 2.k.2. y 2.k.3.

k3) Walker Bay c-d: (c: Schoonees, 1991 y d: Coppoolse et al., 1992)

Institución-denominaciones: Council Scientific Indust. Research CSIR, CAESAR: 3 y 4

Fechas y duración: 1987 y 1990, durante 7 y días respectivamente.

Lugar y área: Bahía Walker, en áreas de c: en dos transectos, uno paralelo a la orilla de 150 m y otro perpendicular de 100 m; d: en un transecto perpendicular. Se trata de una playa arenosa con una ZR de 500 m y un rango de mareas de 1,5 m.

Mediciones: c: Batimetrías hasta 1 m bajo el nivel mínimo de marea baja en 4 ocasiones, y un levantamiento hidrográfico hasta 6 m de profundidad. Las series temporales se midieron desde 1,5 h antes del ascenso de la marea, durante 3 h cada media hora. Las Olas se midieron con una DWR y medidas directas dentro de la ZR con numerosos sensores resistivos y de presión. Las Corrientes se midieron con CEM. Se tomaron fotos

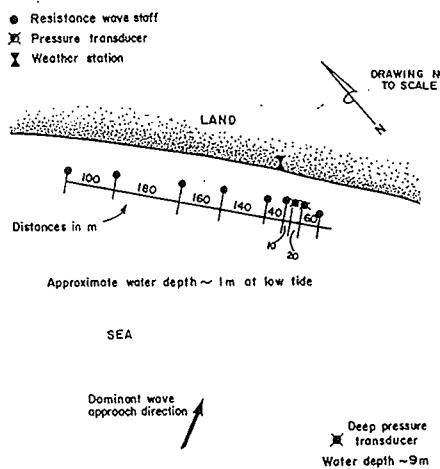


Figura 2.k.2: Distribución de los sensores en CAESAR WB1 (Swart, 1988).

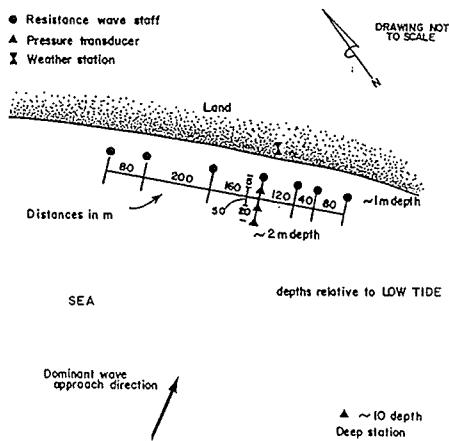


Figura 2.k.2: Distribución de los sensores en CAESAR WB2 (Swart, 1988).

aéreas, y medidas meteorológicas. También se midieron Características y Transporte de los Sedimentos en suspensión (medio e instatáneo). Ver figura 2.k.3.

Mediciones: *d*: Batimetrías periódicas apoyadas con diversas técnicas mediante el uso de un helicóptero. Las series temporales se midieron durante 3 h desde el comienzo de cada

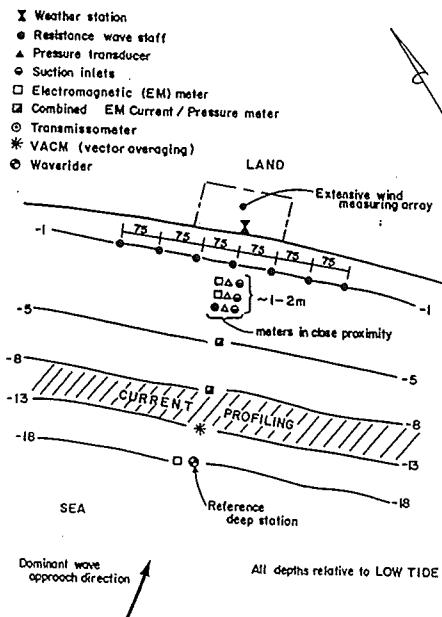


Figura 2.k.3: Distribución de los sensores en CAESAR WB3 (Swart, 1988).

marea. Se desplegaron sensores de presión y CEM en la ZR (profundidades menores a 1,5 m) y sensores de presión y correntímetros a 5 y 10 m. Una DWR a 20 m de profundidad. Adicionalmente se utilizaron dos plataformas móviles (transportadas con el helicóptero) en distintos puntos. Estas plataformas estaban provistas con sensores de altura, CEM y sensores de concentración, se midieron 56 posiciones con éxito durante 25 minutos cada una.

1) Otras Campañas:

11) Campaña internacional **NOURTEC** : Mar de Norte (Hoekstra et al., 1994; Van Vessem et al., 1994).

Instituciones: Estos recientes experimentos han sido realizados conjuntamente por Alemania, Holanda, Dinamarca en sendos sitios escogidos en cada uno de los países intervenientes, bajo el auspicio del programa MAST-2. Intervienen: por Dinamarca: Danish Coastal Authority; por Holanda: Univ. Utrecht, Rijkwaterstaat y por Alemania: Coastal Research Station.

Fecha y duración: Los experimentos fueron planeados durante 1992, e iniciados en 1993, teniendo una duración prevista de 3 años.

Lugares y áreas: Tres sitios en el Mar del Norte: el la península de Jutland en Dinamarca occidental (área: 7 x 1,5 Km), en la isla de Terschelling en Holanda (área: 15 x 2 Km), y en la isla de East Frisian Waden en Alemania (área: 2 Km x 500 m). Ver figura 2.1.1.

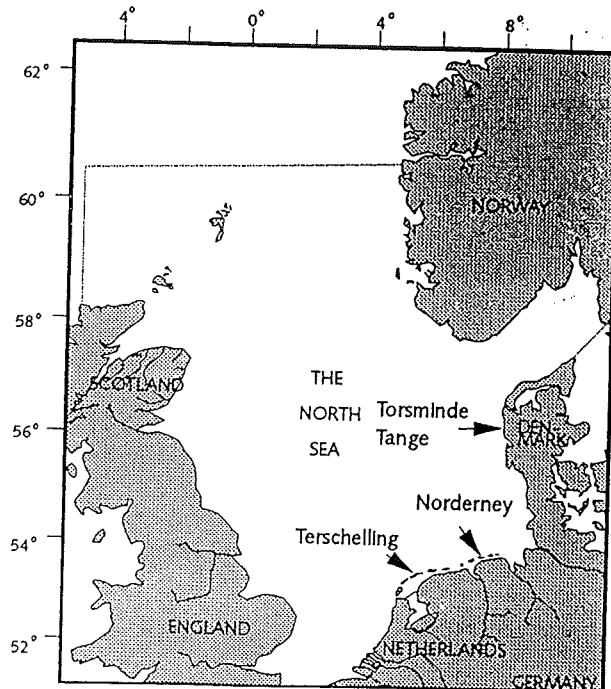


Figura 2.1.1: Sitios de medición de los experimentos NOURTEC, (Hoekstra et al., 1994).

Objetivos: estudiar y explicar la factibilidad, la efectividad y el diseño óptimo de técnicas de regeneración de playas bajo distintas condiciones ambientales.

Mediciones: en todos los experimentos se miden Batimetría, Olas, Corrientes, Mareas, Meteorología Transporte y Características de los Sedimentos.

12) **Mar del Plata:** (Atlántico Sur) (Caviglia et al., 1991)

Institución: Univ. Mar del Plata. Fecha y duración: , 13 meses.

Lugar y área: Mar del Plata, (Argentina).

Mediciones: Batimetría, Olas, Transporte y Características de los Sedimentos.

13) **Kaergaad Plantation:** (DHI, 1984)

Institución: Danish Hydraulic Institute (DHI, Dinamarca).

Fecha y duración: 1982-83 durante 6 meses.

Lugar y área: Kaergaad Plantation (Din.), en un área de 1500 x 40 m.

Mediciones: Batimetría, Olas, Corrientes, Mareas, Características de los Sedimentos y Meteorología.

14) **Sylt** : (Dette, 1985; Oelerinch, 1990; Dette y Oelerinch, 1992)

Institución: Leichtweiß Institute (Alemania).

Fecha y duración: 1987-91.

Lugar y área: Costa oeste de la Isla Sylt en el Mar del Norte. Se trata de una playa rectilínea de arena con barras longitudinales. Es un ambiente expuesto a altos niveles de energía (oleaje y mareas). La erosión de la playa es de aproximadamente 1m al año.

Mediciones: Batimetrías periódicas, Olas y Corrientes en 4 estaciones con sensores de presión y CEM, y una boya direccional (DWR) a 14 m de profundidad. Las mareas se midieron con 11 sensores de presión en 5 posiciones y dos mareógrafos en los extremos de la isla. Características de los Sedimentos en una zona hasta 600 m mar adentro y Transporte de sedimentos con trazadores luminosos. Las condiciones Meteorológicas se midieron en dos estaciones.

15) **Kokkino Limanaki, Linoperamata y Rio** : (Moutzouris, 1988)

Institución: LHW, Univ. Tec. de Atenas (Grecia). Fecha y duración: 1986-87, durante varios períodos.

Lugares: Playas de Kokkino Limanaki, Linoperamata (Creta) y Rio en el Egeo. Se trata de ambientes micromareales con playas de arenas gruesas y gravas.

Mediciones: Batimetrías periódicas, Olas, Corrientes, Características de los Sedimentos.

16) **Costa de Taichung, Taiwan**: (Chang y Hwang, 1994/95)

Instituciones: Instituto de Puertos y Tecnología Marina, y National Science Council, Taiwan. Fecha y duración: 1992/93, durante varios períodos.

Lugar: Playa de Taichung, (medio Oeste de Taiwan), se trata de un ambiente mareal (carrera de marea de 4,6 m), con playas de arena con una pendiente de aproximadamente

1/80.

Mediciones: Batimetrías periódicas, Viento, Olas, Corrientes, Características y transporte de Sedimentos en suspensión. Se utilizaron tres pilas, la primera en la orilla de bajamar, y las otras dos a 200 y 450 m de la primera, respectivamente (ver figura 2.1.2). En cada pila interior se colocaron dos OBS y un sensor de presión. Las velocidades se midieron mediante CEM.

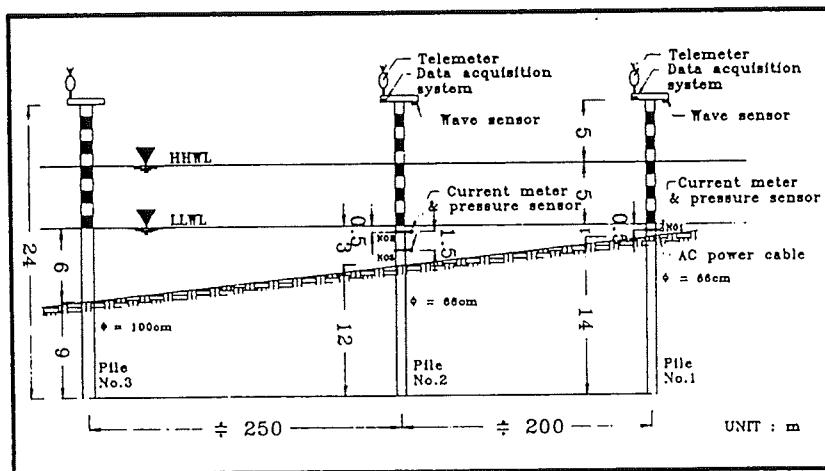


Figura 2.1.2: Esquema de medición, (Chang y Hwang, 1995).

Referencias Bibliográficas

Allen,H.; Bauer,B.; Pauty,N. y Carter,R. y (1991): *Process variation across a barred, tidal nearshore*, Proc. Coastal Sediments, ASCE, 498-511.

Allender,J.; Ditmars,J.; Harrison,W. y Paddock,A. (1978): *Comparison of model and observed nearshore circulation*, ICCE, ASCE, 810-827.

Antsyferov,S.; Belberov,Z. y Massel,S. Eds. (1990): *Dynamical Processes in Coastal Regions*, Pub.House Bulg.Ac.of Sciences, Sofía, 190 pg.

Bakker,W. y de Vroeg,H. (1988): *Coastal modelling and coastal measurements in the Netherlands*, Proc. of seminar on Prototype measurements to validate numerical models of coastal processes, Sogreah, Francia, 5-25.

Basinski,T. (1980): *Proceedings of the international investigations LUVIATOWO'76: hydrodynamical and lithodinamical processes in the marine coastal zone*, Academia Polaca de Ciencias, Inst. de Hidroingeniería, Hidrotechnical translations, Pol.Sc.Publ., Varsovia.

Bauer,B. y Greenwood,B. (1990): *Modification of a linear bar-trough system by a standing edge wave*, Marine Geology, 92, 177-204.

Bellessort,B. (1988): *Field measurements of sediment transport carried out in France*, Eds. de Graaw,A. y Hamm,L., Proc. of seminar on Prototype measurements to validate numerical models of coastal processes, Sogreah, Francia, 26-49.

Birkemeier,W. y Mason,C. (1984): *The CRAB: A unique nearshore surveying vehicle*, Journal of Surveying, ASCE, 110, 1-7.

Birkemeier,W.; Strider,J.; Baron,C. y Hathaway,K. (1988): *Field data from the DUCK 85 field experiment for the evaluation of nearshore numerical models*, Proc. of seminar on Prototype measurements to validate numerical models of coastal processes, Sogreah, Francia, 50-75.

Birkemeier,W.; Baron,C; Leffler,M.; Hathaway,K.; Miller,H. y Strider,J. (1989): *SUPERDUCK nearshore processes experiment data summary*, CERC Field Research Facility, CERC, Misc. Paper CERC 89-16.

Birkemeier,W. (1991): *SAMPSON and DELILAH at the FRF*, CERCular, CERC, Vol. CERC-91-1, Marzo.

Birkemeier,W. y Thornton,E. (1994): *The DUCK'94 nearshore experiment*, Coastal Dynamics, ASCE, 815-821.

Birkemeier,W. y Hathaway,K. (1996): *DELILAH, DUCK'94 and SundyDuck: three nearshore field experiments*, Book of Abstracs ICCE, ASCE, 414-415.

Black,K. y Rosenberg,M. (1991): *Suspended sediment load at three time scales*, Proc. Coastal Sediments, ASCE, 313-327.

Boer,S.; de Vriend,H.; y Wind,H. (1984): *A mathematical model for the simulation of morphological processes in the coastal area*, ICCE, ASCE, 14 pg.

Bowen,A.; Chartrand,D.; DanielM.; Glodowsky,C.; Piper,D.; Readshaw,J.; Thibault,J.; y Willis,D. (1984): *Canadian Coastal Sediment Study*, Informe Final, Nat.Res.Counc.Canada, Div.Eng.Mec., Hid.Lab.Tec.Rep., Rep. TR-HY-013, 96 pg.

Byrnes,M. (1989): *SUPERDUCK beach sediment experiment, report 1, data summary, and initial observations*, CERC, Misc. Paper CERC 89-18.

Caldwell,J. (1956): *Wave action and sand movement near Anaheim bay, California*, US Army, Beach Erosion Broad, Tech. Memorandum 68, EEUU.

Caviglia,F.; Pousa,J. y Lanfredi,N. (1991): *A determination of the energy flux constant from dredge records*, Jour. Coastal Research, 7, (2), 543-549.

Chang,C. y Hwang,C. (1994): *Waves, currents and sediment transport in the surf zone of a mildly sloping beach*, Basic Research, No. 6, Inst.Harbour Marin.Tech., Taichung, Taiwan.

Chang,C. y Hwang,C. (1995): *Studies on wave, current and suspended sediment characteristics at the surf zone*, Coastal Dynamics, ASCE, 728-738.

Church,J. y Thornton,E. (1992): *Effects of wave induced turbulence within a longshore current model*, Coastal Engineering, 20, 1-18.

Coppoolse,R.; Schoonees,J.; Smith,G.y Mocke,G. (1992): *Hydrodynamics and sediment concentrations at Walker bay*, ICCE, ASCE, 3026-3039.

Crowson,R.; Birkemeier,W.; Klein,H. y Miller, H. (1988): *SUPERDUCK nearshore processes experiment: summary of studies, ERC field research facility*, Technical report CERC-88-12, CERC.

Davidson,M.; Russell,P.; Huntley,D.; Hardisty,J. y Cramp,A. (1992): *An overview of the British Beach and Nearshore Dynamics (B-BAND) Programme*, ICCE, ASCE, 1987-2000.

Dean,R.; Berek,E.; Bodge,K. y Gable,C. (1987): *NSTS measurements of total longshore transport*, Proc. Coastal Sediment, ASCE, 625-667.

De Vriend,H.; Reinalda,R. y Derks,H. (1988): *The Egmond field data and their use for the validation of mathematical models*, Proc. of seminar on Prototype measurements to validate numerical models of coastal processes, Sogreah, Francia, 134-151.

Derks,H. (1982-1984): *Field campaign at the Egmond coast*, Partes I,II,III,IV,V,VI,VI y VII, Informes de Delft Hydraulics, Series R1597, (en holandés).

Derks,H. y Stive,M. (1984): *Field investigations in the TOW study programme for coastal sediment transport in The netherlands*, ICCE, ASCE, 1830-1845.

Dette,H. (1985): *About the feasibility of in-situ measurements with respect to longshore transport*, Proc. European Workshop on Coastal Zones, Atenas, Octubre, 1-15.

Dette,H.; y Oelerich,K. (1992): *Data sets from prototype and field measurements*, MAST G6M Workshop, Pisa, 1-3.

Dette,H.; Newe,J. y Wu,Y. (1994): *Field and prototipe measurements for numerical coastal modelling*, Coastal Dynamics, ASCE, 129-142.

DHI (1984): *North sea approach: monitoring of sedimentation in a dredged trench, Final Report*, Informe del Danish Hydraulic Institute, Horsholm, Agosto.

Druet,T.; Hupfer,P. y Shadrin,I. (1976): *Properties and transformation of hydrodynamical processes in coastal zone of non-tidal sea*, Informe R2a del Instituto Morski Rybaki, Gdynia, Polonia.

Flick,R. y George,R. (1990): *Turbulence scales in the surf and swash*, ICCE, ASCE, 557-569.

Feddersen,F.; GuzamR.; Elgar,S. y Herbers,T. (1996): *Cross-shore structure of longshore currents during Duck94*, Book of Abstracts ICCE, ASCE, 418-419.

Foote,Y.; Huntley,D.; Davidson,M.; Russel,P., Hardisty,J. y Cramp,A. (1992): *Incident wave groups and long waves in the nearshore zone*, ICCE, ASCE, 974-989.

Gable,C. (1979): *Report on data from the Nearshore Sediment Transport Study experiment at Torrey Pines beach, California, Nov.-Dec. 1978*, Institute of Marine Resources Ref. nro.79-8.

Gable,C. (1981): *Report on data from the Nearshore Sediment Transport Study experiment at Leadbetter beach, California, Jan.Feb., 1980*, Institute of Marine Resources Ref. nro.80-5.

Gallaher,E.; Elgar,S. y Guza,R. (1996): *Obsrvations and predictions of sand bar motion*, Book of Abstracts ICCE, ASCE, 78-79.

George,R.; Flick,R. y Guza,R. (1994): *Observations of turbulence in the surf zone*, JGR, 99, C1, 801-810.

Gerritsen,F. y Van Heteren,J. (1984): *The effect of low frequency oscillations on coastal morphology*, ICCE, ASCE, 14 pg.

Greenwood,B. y Mittler (1984) *Sediment flux and equilibrium slopes in a barred nearshore*, Marine Geology, 60, 79-98.

Greenwood,B. y Sherman,D.(1984): *Waves, currents, sediment flux and morphological response in a barred nearshore system*, Marine Geology, 60, 31-61.

Greenwood,B. y Sherman,D.(1986): *Longshore current profiles and lateral mixing across the surf zone of a barred nearshore*, Coastal Engineering, 10, 149-168.

Greenwood,B. y Osborne,P. (1990): *Vertical and horizontal structure in cross-shore flows: an example of undertow and wave set-up on a barred beach*, Coastal Engineering, 14, 543-580.

Greenwood,B.; Osborne,P.; Bowen,A.; Hazen,D. y Hay,A. (1990): *Nearshore sediment flux and bottom boundary dynamics: The Canadian Coastal Sediment transport Programme (C-COAST)*, ICCE, ASCE, 2227-2240.

Greenwood,B.; Osborne,P. y Bowen,A. (1991): *Measurements of suspended sediment transport: prototype shorefaces*, Coastal Sediments, ASCE, 284-299.

Guza,R. y Thornton,E. (1978): *Variability of longshore currents*, ICCE, ASCE, 756-775.

Guza,R. y Thornton,E. (1980): *Local and shoaled comparisons of sea surface elevations, pressures and velocities*, JGR, 85, 1524-1530.

Guza,R.; Thornton,E. y Christensen,N. (1986): *Observationns of steady longshore currents in the surf zone*, JPO, 16(11), 1959-1969.

Haines,J. y Sallenger,A. (1994): *Vertical structure of mean cross-shore currents across a barred surf zone*, JGR, 99, C7, 14223-14242. 1166-1179.

Hoekstra,P.; Houwman,K.; Kronn,A.; Van Vessem,P. y Ruessink,B. (1994): *The Nourtec experiment of Terschelling: Process-oriented monitoring of a shoreface nourishment (1993-1996)*, ICCE, ASCE, 1166-1179.

Hotta,S.; Mizuguchi,M. e Isobe,M. (1981): *Observation of of long period waves in the nearshore zone*, Coastal Eng. in Japan, Vol. 24, 41-76.

Horikawa,K. y Hattori,M. (1987): *The neashore enviromental research centre project*, Proc.

Referencias

Coastal Sediments'87, ASCE, 756-771.

Horikawa,K., Ed. (1988): *Neashore Dynamics and Coastal Processes*, University of Tokio press, Tokio.

Howd,P.; Bowen,T.; Holman,R. and Oltman-Shay,J. (1991): *Infragravity waves, longshore currents and linear sand bar formation*, Proc. Coastal Sediments, ASCE, 72-84.

Hubertz,J.; Long,C.; Rivers,P. y Brown,W. (1987): *DUCK'85 nearshore waves and currents experiment, data summary report*, CERC, Misc. Paper CERC 87-3.

Humphery,J. (1987): *STABLE - un instrument for studing current structure and sediment transport in the benthic boundary layer*, Proc. Electronics for Ocean Technology, Edimburgo, IERE, Londres.

Huntley,D. y Bowen,A. (1974): *Field measurements of nearshore velocities*, ICCE, ASCE, 538-557.

Ifuku,M. y Kakinuma,T. (1982): *Bottom friction factors off five japanese coasts*, Coastal Eng. in Japan, Vol. 25, 37-49.

Ifuku,M. y Kakinuma,T. (1988): *Suspended sediment concentration in the surf zone*, ICCE, ASCE, 1661-1675.

Ishihara,T.; Iwaski,Y. y Murakami,M. (1958): *On the investigation of beach erosion along the north coast of Akashi Strait*, Coastal Eng. in Japan, Vol. 1, 97-109.

Jago,C. y Hardisty,J. (1984): *Sedimentology and morphodynamics of a macrotidal beach, Pendine sands, SW Wales*, Marine geology, 60, 123-154.

Kawata,Y.; Yoshioka,H. y Tsuchiya,Y. (1990): *The in-situ measurements of sediment transport and bottom topography changes*, ICCE, ASCE, 2332-2345.

Kraus,N.; Farinato,R. y Horikawa,K. (1981): *Field experiments on longshore sand transport in the surf zone*, Coastal Eng. in Japan, 24, 71-194.

Kraus,N.; Isobe,M.; Igarashi,H.; Sasaki,T. y Horikawa,K. (1982): *Field experiments on longshore sand transport in the surf zone*, ICCE, ASCE, 969-988.

Kraus,N.; Gingerich,K. y Rosati,J. (1989): *DUCK85 surf zone sand transport experiment*, Technical report CERC-89-5 , 70 pg., EEUU.

Kroon,A. (1991): *Suspended sediment concentrations in a barred nearshore zone*, Proc. Coastal Sediments, ASCE, 328-341.

Kroon,A. (1994): *Sediment Transport and Morphodynamics of the Beach and Nearshore Zone Near Egmond, The Netherlands*, Tesis Doctoral, Universidad de Utrecht, 275 pg., Holanda.

Kuriyama,Y. y Ozaki,Y. (1993): *Longshore current distribution an a bar-trough beach -Field measurements at HORF and numerical model*, Report Port and Harbour Research Institute, Vol. 32, Nro. 3, 3-37.

Kuriyama,Y. (1994): *Numerical model for longshore current distribution on a bar-trough beach*, ICCE, ASCE, 2237-2251.

Kuznetsov,S. y Speransky,N. (1990): *Turbulence in shoaling and breaking waves*, en "Modern Processes of sedimentation on shelf", Editorial Nauka, Moscu.

Latteux,B. (1988): *Field measurements carried out for the design of the new outer-harbour of Dunkirk*, Eds. de Graaw,A. y Hamm,L., Proc. of seminar on Prototype measurements to validate numerical models of coastal processes, Sogreah, Francia, 76-88.

Levoy,F. y Avoine,J. (1991): *Quantitative approaches to coastal sediment processes*, Coastal Sediments, ASCE, 14 pg. (publ. separada de los Proc.).

Levoy,F.; Monfort,O. y Rousset,H. (1995): *Sediment transport under wave-current interaction on macro-tidal beaches*, Coastal Dynamics, ASCE, 727-741.

Lippmann,T. y Holman,R. (1992): *Wave group modulations in cross-shore breaking patterns*, ICCE, ASCE, 14 pg.

Lippmann,T. y Thornton,E. (1996): *Observations of surf zone wave breaking during Duck94*, Book of Abstracts ICCE, ASCE, 720-721.

Losada,M.A.; Huntley,D.; Stapleton,K.; Medina,R. y Vidal,C. (1994): *Field measurements in a tidal river estuary on the Cantabrian coast, Spain*, Coastal Dynamics, ASCE, 143-157.

Longinov,V. (1963): *Coastal Zone Dynamics at Nontidal Seas*, Nauka, Moscu, (en ruso).

Mason,C.; Sallenger,A.; Holan,R. y Birkemeier,W. (1984): *DUCK82 - A coastal storm processes experiment*, ICCE, ASCE, 1913-1928.

Mason,C.; Birkemeier,W. y Howd,P. (1987): *Overview of DUCK85 nearshore processes experiment*, Proc. Coastal Sediments, ASCE, 818-833.

Meadows,G. (1976): *Time dependent fluctuations in the longshore currents*, ICCE, ASCE, 660-680.

Medina,J. y Serra,J. (1993): *Beach monitoring program of "El Saler"*, Proc. Workshop on Natural Hazards, Bcna., 8-11 Junio, 14 pg.

Moore,G. y Cole,J. (1960): *Coastal processes in the vicinity of Cape Thompson, Alaska*, Report US Geological Survey, Trace Elements Investigations, Rep. 753, EEUU.

Moutzouris (1988): *Wave-induced distribution of sediment size-related parameters on the nearshore sea bed*, Eds. de Graaw,A. y Hamm,L., Proc. of seminar on Prototype measurements to validate numerical models of coastal processes, Sogreah, Francia, 89-99.

Nadaoka,K.; Ueno,S. e Igashari,T. (1988): *Field observation of the three dimensional large-scale eddies and sediment suspension in the surf zone*, Coastal Eng. in Japan, 31, 2, 277-288.

Nakamura,S. y Katoh,K. (1992): *Generation of infragravity waves in breaking process of wave groups*, ICCE, ASCE, 990-1003.

Nielsen,P. (1984): *Field measurements of time-averaged suspended sediment concentrations under waves*, Coastal Engineering, 8, 51-72.

Oelerich,J. (1990): *Zur berechung des kstenparallen santranportes*, Informe del Instituto Leichtweiß, Heft 108, 179-422, (en alemán).

Oelerich,J.; Otay,E. y Sraube J. (1992): *Pressure and velocity response in random sea approach, measurements and comparisons*, Book of Abstracts, ICCE, ASCE.

Owczarczyk,A.; Strzelecki,M; Szpilowski,St. y Wierzchnicki,R. (1989): *New application of a radioactive tracer method for sediment movement measurements in the nearshore zone*, Isotopeopenpraxis, Vol. 25, No. 8, 330-334.

Owen,M. y Thorn,M. (1978): *Effect of waves on sand transport by currents*, ICCE, ASCE, 1675-1687.

Reinalda, R. (1988): *Measurements in the nearshore zone at Egmond, The Netherlands*, Report on invest. H246, Delft Hydraulics, 43 pg., Holanda.

Rosati,J.; Gingerich,K. y Kraus,N. (1989): *SUPERDUCK surf zone sand transport experiment*, Technical report CERC-90-10, 70 pg., EEUU.

Rosati,J.; Gingerich,K.; Kraus,N.; Smith,J.M. y Beach,R. (1991): *Longshore sand transport rate distributions measured in Lake Michigan*, Proc. Coastal Sediments, ASCE ,156-169.

Rosati,J.; Hamilton,D.; Fowler,J. y Smith,JM. (1995): *Design of a Laboratory Facility for Longshore Sediment Transport Research*, Coastal Dynamics, ASCE ,771-782.

Russell,P. (1990): *Field Studies of Suspended Sand Transport on a High Energy Dissipative Beach*, Tesis Doctoral, Universidad de Gales, RU.

Russell,P.; Davidson,M.; Huntley,D.; Cramp,A.; Hardisty,J. y Llyod,G. (1991): *The british beach and nearshore dynamics (B-BAND) programme*, Coastal Sediments, ASCE, 371-384.

Russell,P. (1991): *Mechanisms for beach erosion during storms*, Continental Shelf Research, Vol.13, Nro.11, 1243-1265

Sallenger,A.; Howard,P.; Fletcher,C. y Howd,P. (1983): *A system for measuring bottom profile, waves and currents in the high-energy nearshore environment*, Marine Geology, 64, 237-257.

Sasaki,T. (1974): *Field Investigations of Nearshore Currents on a Gently Sloping Bottom*, Tesis doctoral, 240 pg., Univ. de Tokio, Japón, en japonés.

Sasaki,T.; Horikawa,K. y Hotta,S. (1976): *Nearshore current on a gently sloping beach*, ICCE, ASCE, 626-644.

Sasaki,T. y Horikawa,K. (1978): *Observation of nearshore current and edge waves*, ICCE, ASCE, 791-805.

Sato,S. y Tanaka,N. (1966): *Fied investigation on sand drift at Port Kashima facing the Pacific Ocean*, ICCE, ASCE, 595-614.

Scott,K.; Thornton,E. y Birkemeier,W. (1991): *Mean currents and sediment transport at DELILAH*, Proc. Coastal Sediments, ASCE, 477-488.

Schoonée,J. (1991): *Field measurements of suspended sediment concentrations in the surf zone*, Euromech 262, Sand Transport in Rivers Estuaries and the Sea, Editado por Soulsby,R. y Bettes,R.; Balkema.

Seymour,R. y Duane,D. (1978): *The Nearshore Sediment Transport Study*, ICCE, ASCE, 1555-1562.

Seymour,R. y Gable,C. (1980): *Nearshore Sediment Transport Study experiments*, ICCE, ASCE, 1402-1415.

Seymour,R. (1983): *The Nearshore Sediment Transport Study*, JWW, ASCE, 109, 1, 79-85.

Seymour,R. (1987): *An assessment of NSTS*, Proc. Coastal Sediments'87, ASCE, 642-651.

Seymour,R. (1988): *The Nearshore Sediment Transport Study data sets*, Proc. of seminar on Prototype measurements to validate numerical models of coastal processes, Sogreah, Francia, 100-109.

Smith,J.M.; Svendsen,I. y Putrevu,U. (1992): *Vertical structure of the nearshore current at Delilah: measured and modeled*, ICCE, ASCE, 2825-2838.

Smith,J.M.; Larson,M. y Kraus,N. (1993): *Longshore current on a barred beach: field measurements and calculation*, JGR, 98, C12, 22.717-22.731.

Sonu,C. (1972): *Fied observation of nearshore circulation and meandering currents*, JGR, 77, nro.18, 3232-3247.

Soulsby,R. (1988): *UK field data for coastal models and processes*, Proc. of seminar on Prototype measurements to validate numerical models of coastal processes, Sogreah, Francia, 110-117.

Speranski,N. (1994a): *On some hydrodynamic effects found in large scale experiments*, Coastal Dynamics'94, ASCE, 784-793.

Speranski,N. (1994b): *Measurements of mass-transport and undertow-flow in field conditions*, Proc. Litoral'94 (Eurocoast), Sept., Lisboa, Portugal, 577-585.

Speranski,N. (1995): *Field measurements of vertical velocity in breaking waves*, Book of abstracts Coastal Dynamics'95, ASCE, Gdansk, 201-202.

Stanton,T. y Thornton,E. (1996): *Reynolds stress and small-scale morphology measurements during Duck94*, Book of Abstracts ICCE, ASCE, 420-421.

Swart,D. (1984): *Sediment dynamics field experiment: Sunday's River*, ICCE, ASCE, 1371-1385.

Swart,D. (1988): *CAESAR- Coastal Area Enviromental and sediment Applied Research: surf zone experiments in South Africa*, Proc. of seminar on Prototype measurements to validate numerical models of coastal processes, Sogreah, Francia, 118-133.

Thornton,E. (1979): *Energetics of breaking waves within the surf zone*, JGR, Vol. 84, c(, 4931-4938.

Thornton,E.; Galvin,J.; Bub,F. y Richardson,D. (1976): *Kinematics of breaking waves*, ICCE, ASCE, 461-476.

Thornton,E. y Guza,R. (1986): *Surf zone longshore currents and random waves: field data and models*, JPO, Vol. 16, July, 1165-1178.

Thornton,E.; Soares,C.; y Stanton, (1995): *Vertical profiles of longshore currents and bed shear stress*, I.C.Coastal Dynamics, ASCE, Gdansk, 449-459.

Uda,T. y Hashimoto,H. (1983): *Field investigation of nearshore circulation by a remote sensing technique*, Coastal Eng. in Japan, 26, 209-218.

Uda,T.; Naito,K. y Kanda,Y. (1991): *Field experiment on sand bypass off the Lioka coast*, Coastal Eng. in Japan, 34, 2, 295-221.

Van Hardenberg,B.; Hay,A.; Sheng,P. y Bowen,A. (1991): *Field measurements of the vertical structure of suspended sediment*, Proc. Coastal Sediments, ASCE, 300-312.

Van Heteren,J. y Stive,M. (1984): *Wave kinematics and directionality in the surf zone*, ICCE, ASCE, 70-81.

Van Rijn,L. (1991): *Data Base: sand concentration profiles and sand transport for currents and/or waves*, Informe de Delft Hydraulics, H1148-04/05.

Van Rijn,L. y Kroon,A. (1992): *Sand concentration profiles in the surf zone near Egmond, The Netherlands*, Proc. MAST G6M Workshop, Pisa, Mayo, 3.12.

Van Vessem,P.; Van de Kree,J., Mulder,J.; Lastrup,C. y Niemeyer,H. (1994): *Design of a shoreface nourishment NOURTEC experiment at Terschelling, The Netherlands*, ICCE, ASCE, 2886-2900.

Vidal,C. (1995), *comunicación personal*, Valencia.

Vincent,C.; Hanes,D.; y Bowen,A. (1991): *Acoustic measurements of suspended sand on the shoreface and the control of concentration by bed roughness*, Marine Geology, 96, 1-18.

Walton,T. (1993): *Ocean city, Maryland, wave run*, Journal of Coastal Research, 9(1), 1-10.

Wallace,H. (1993): *Coastal sand transport and morphodynamics: A review of field data*, Report SR 355 (issue A), Abril, Hydraulic Research, 50 pg., R.U.

Watanabe,A. (1988): *Field measurements in the Nearshore Environment Research Center Project in Japan*, Proc. of seminar on Prototype measurements to validate numerical models of coastal processes, Sogreah, Francia, 152-163.

Willis,D. (1987): *The canadian coastal sediment study: an overview*, Proc. Coastal Sediments, ASCE, 682-693

Wright,L.; Chappel,J.; Thom,B.; Bradshaw,M. y Cowell,P. (1979): *Morphodynamics of reflective and dissipative beach and inshore systems: Southeastern Australia*, Marine Geology, 32, 105-140.

Wright,L.; Nielsen,P.; Short,A. y Green,M. (1982): *Morphodynamics of a macrotidal beach*,

Referencias

Marine Geology, 50, 97-128.

Wright,L.; Nielsen,P. y List, J. (1986): *Morphodynamics of a bar-trough surf zone*, Marine Geology, 70, 251-285.

Estudio Experimental de la Hidrodinámica de Zona de Rompientes

ANEXO C

-Datos obtenidos en las Campañas Delta'93-

Andrés Rodriguez

Marzo de 1995



Estudio Experimental de la Hidrodinámica de Zona de Rompientes

ANEXO C

-Datos obtenidos en las Campañas *Delta'93*-

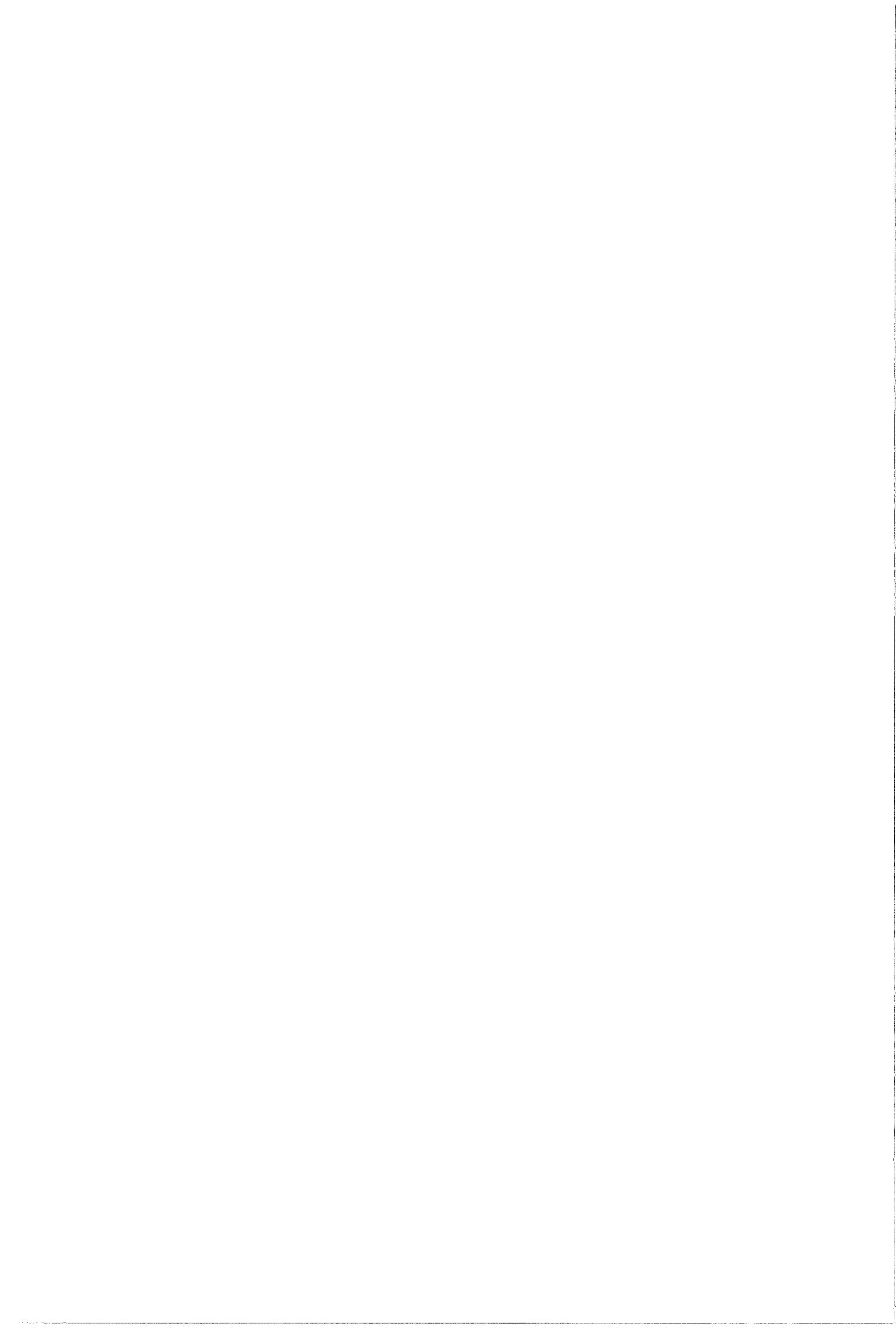
Contenido:

- C1. Topografía**
- C2. Olas fuera de la Zona de Rompientes**
- C3. Olas de viento en la Zona de Rompientes**
- C4. Velocidades y Niveles en la Zona de Rompientes**

- C4.1. Flujo Medio**
- C4.2. Flujo Oscilatorio**
- C4.3. Flujo Macroturbulento**

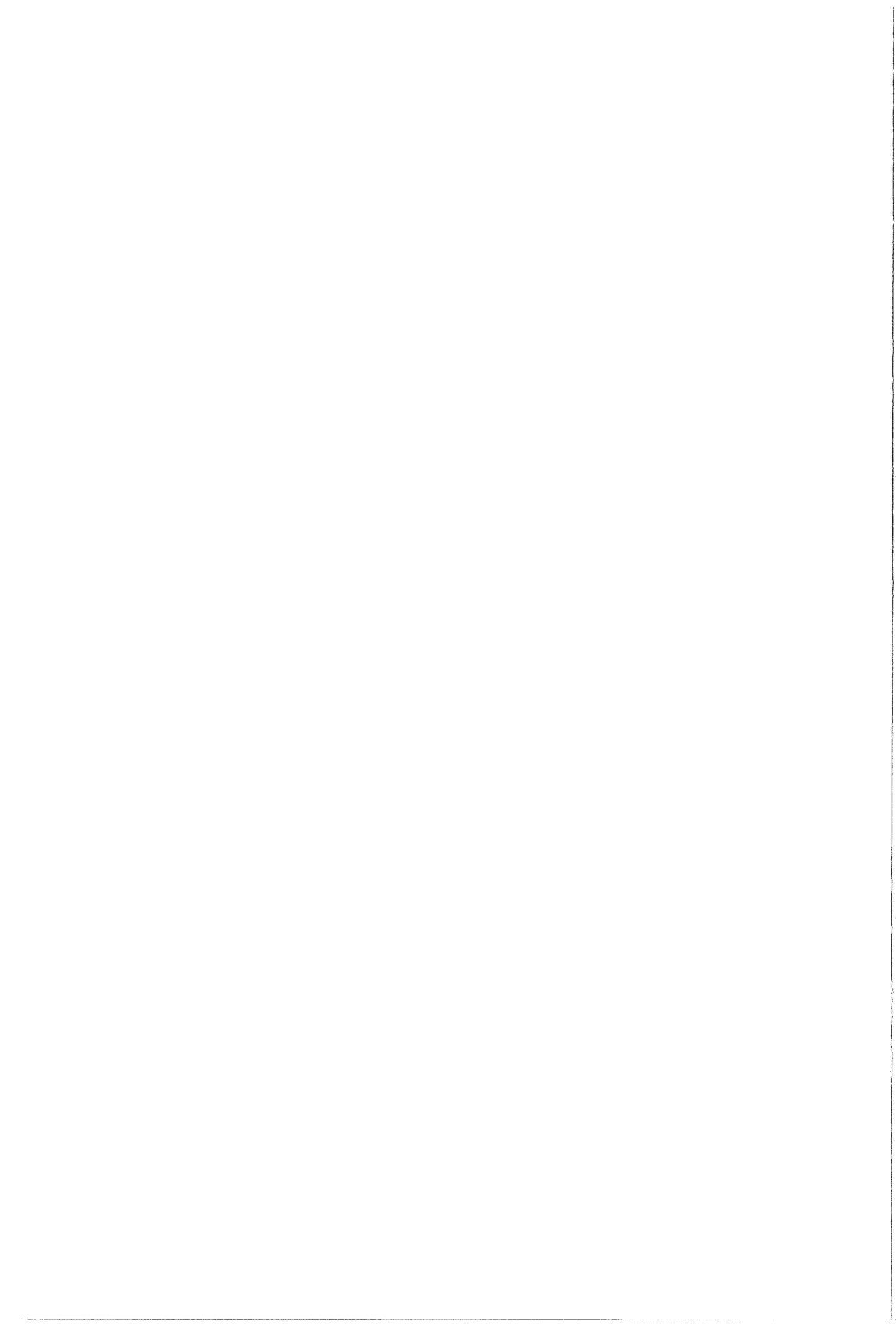
- C5. Imágenes de Video**

- C6. Meteorología**



C1. Topografía¹

¹ Nota: Este trabajo ha sido realizado por Vicente Gracia, del Área de Morfodinámica del LIM-UPC.



I. Introducción

En este apartado se presenta la base topográfica realizada en los alrededores del perfil P11, en la barra del Trabucador, utilizada como soporte básico para el estudio de los distintos fenómenos hidrodinámicos y sedimentarios de la zona. A continuación se describen los trabajos realizados en las dos campañas de toma de datos realizadas en mayo (caso I) y diciembre (casos II a V) de 1993. El instrumental utilizado ha sido siempre el mismo, una estación total tipo SOKKIA SET5/SET5S.

II. Campaña de mayo de 1993 (caso I)

1. Determinación de un sistema de coordenadas sobre el que referenciar todos los puntos. Para ello se escogió el poste de cableado eléctrico más próximo al perfil P-11 como centro de coordenadas (marcado con pintura fluorescente amarilla). El eje X se tomó positivo hacia el sur en la dirección que presentan los postes eléctricos. El eje Y se tomó positivo hacia el este (dirección hacia el mar).
2. Determinación de una cota de referencia y cálculo del error de la medida. Todos los puntos se han referenciado con respecto a la marca de cota 2.7 m que existe en todos los postes eléctricos. La cota de referencia del poste 11S se tomó dos veces. En la tabla 1 se presentan los resultados obtenidos.
3. Determinación de las coordenadas X, Y, Z de los puntos de referencia de las imágenes de video de los trazadores, tabla 2. Las coordenadas en X, Y, de los puntos C y Cdyes corresponden a la proyección de la cámara con respecto al plano de referencia, para hallar la verdadera coordenada en z debe sumarse 18 m a C y 19 m a Cdyes, que es la distancia vertical existente entre la cámara y el suelo (tomados mediante el uso de una cinta métrica). En la figura 1 se presenta un esquema en planta de los puntos de referencia de las imágenes de video.
4. Determinación de 3 perfiles topográficos normales a la costa, de norte a sur (perfil norte, centro y sur), tablas 3 a 5, con el objeto de observar la morfología existente en la zona. En la figura 2 se presenta un esquema en planta de los distintos puntos de cada perfil. En las figuras 3, 4 y 5 se muestran los distintos perfiles. En la figura 6 se da una visión tridimensional de la zona sujeta al levantamiento topográfico.
5. Determinación de las coordenadas X, Y, Z de los puntos de referencia de las imágenes de video para la determinación de las características de la linea de orilla, tabla 6. Las coordenadas en X, Y, de los puntos C y Cdyes corresponde a la proyección de la cámara con respecto al plano de referencia, para hallar la verdadera coordenada en z debe sumarse 18 m a C y 19 m a Cdyes, que es la distancia vertical existente entre la cámara y el suelo (tomados mediante el uso de una cinta métrica). En la figura 7 se presenta un esquema en planta de los puntos de referencia usados en las tomas de video para la caracterización morfodinámica.

III. Campaña de diciembre de 1993 (casos II a V)

1. Sobre el sistema de coordenadas definido en la campaña de mayo de 1993 se realizan un total de 31 perfiles topográficos, de los cuales 17 corresponden al día 13 de diciembre de 1993 en situación de calma (ver figura 8) y 14 al día 17 de diciembre de 1993 en situación de tormenta (ver figura 9). Todos los puntos se referencian a la marca de cota -2.7 m existente en los postes eléctricos. En las tablas 7 a 38 se indican las coordenadas obtenidas en cada perfil, mientras que en la figura 10 se comparan entre ellos.
2. Determinación de las coordenadas X, Y, Z de los puntos referencia de las imágenes de video (tabla 39 y figura 11).
3. Determinación de las coordenadas X, Y, Z de las posiciones del trineo (ver tabla 40 y figura 12).
4. Determinación de las coordenadas X, Y, Z de las posiciones de las trampas de sedimento (ver tabla 41 y figura 12).
5. Determinación de la posición de la barra exterior en la zona de interés de muestreo del trineo correspondiente al día 12 de diciembre de 1993 (situación de calma).
6. El perfil central P000 se corresponde con el perfil del hito P-11.

LISTA DE TABLAS

REFERENCIAS								
H	V	INCL	BASE	COTA	COM	X	Y	Z
399,848	99,790	120,152	120,151	0,396	11S	120,151	-0,287	0,000
201,456	99,806	122,662	122,661	0,374	11N	-122,629	-2,805	-0,023
399,854	99,794	120,160	120,159	0,389	11S	120,159	-0,276	-0,008

Tabla 1. Referencias del sistema de coordenadas utilizado. H ángulo horizontal; V ángulo vertical; INCL distancia al punto en metros; BASE distancia horizontal al punto en metros; COTA distancia vertical al punto (con respecto del teodolito) en metros; COM comentarios: 11S poste eléctrico sur, 11N poste eléctrico norte; X coordenada longitudinal en metros; Y coordenada transversal en metros; Z coordenada vertical con respecto a la referencia 2.7 en metros.

VIDEO POINTS								
H	V	INCL	BASE	COTA	COM	X	Y	Z
95,140	99,568	38,476	38,475	0,261	On	2,934	38,363	-2,135
45,938	99,810	58,556	58,556	0,175	Os	43,961	38,681	-2,222
44,106	99,136	31,630	31,627	0,429	C	24,335	20,200	-1,967
45,474	99,280	32,881	32,879	0,372	Cdyes	24,842	21,539	-2,024
121,034	100,838	100,887	100,878	-1,328	Bn	-32,727	95,422	-3,724
52,810	100,654	144,619	144,611	-1,486	Bs	97,644	106,668	-3,882

Tabla 2. Puntos de referencia utilizados en las imágenes de video. H ángulo horizontal; V ángulo vertical; INCL distancia al punto en metros; BASE distancia horizontal al punto en metros; COTA distancia vertical al punto (con respecto del teodolito) en metros; COM comentarios: Os posición de orilla sur, On posición de orilla norte, C posición de la cámara durante la primera toma de imágenes, Cdyes posición de la cámara durante la segunda toma de imágenes (corresponde al vertido de los trazadores), Bn posición de barra norte, Bs posición de barra sur; X coordenada longitudinal en metros; Y coordenada transversal en metros; Z coordenada vertical con respecto a la referencia 2.7 en metros.

PERFIL NORTE								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>COTA</i>	<i>COM</i>	<i>X</i>	<i>Y</i>	<i>Z</i>
305,392	92,100	19,057	18,910	2,359		1,600	-18,843	-0,038
307,532	91,190	14,122	13,987	1,948		1,651	-13,889	-0,448
314,840	93,160	5,244	5,214	0,562		1,204	-5,073	-1,834
92,824	97,872	12,545	12,538	0,419		1,410	12,458	-1,977
96,846	98,750	24,317	24,312	0,477		1,204	24,282	-1,919
98,338	99,342	37,321	37,319	0,386		0,974	37,306	-2,011
98,476	100,140	44,439	44,439	-0,098	SHLN	1,064	44,426	-2,494
98,420	100,140	44,456	44,456	-0,098		1,103	44,442	-2,494
98,828	100,734	57,029	57,025	-0,658		1,050	57,016	-3,054
98,660	101,156	62,108	62,098	-1,128		1,307	62,084	-3,524
98,680	101,536	68,503	68,483	-1,653		1,420	68,468	-4,049
98,446	101,324	74,418	74,402	-1,548		1,816	74,380	-3,944
98,614	101,062	81,139	81,128	-1,353		1,766	81,108	-3,750
98,704	100,920	87,254	87,245	-1,261		1,776	87,227	-3,657
98,860	100,752	93,264	93,257	-1,102		1,670	93,243	-3,498
99,390	100,862	99,316	99,307	-1,345		0,952	99,302	-3,741
99,394	100,880	99,348	99,339	-1,373		0,946	99,334	-3,770
99,536	101,002	107,608	107,595	-1,694		0,784	107,592	-4,090

Tabla 3. Puntos de referencia utilizados en el perfil norte. *H* ángulo horizontal; *V* ángulo vertical; *INCL* distancia al punto en metros; *BASE* distancia horizontal al punto en metros, *COTA* distancia vertical al punto (con respecto del teodolito) en metros; *COM* comentarios; *SHLN* línea de orilla; *X* coordenada longitudinal en metros; *Y* coordenada transversal en metros; *Z* coordenada vertical con respecto a la referencia 2.7 en metros.

PERFIL CENTRO		<i>INCL</i>	<i>BASE</i>	<i>COTA</i>	<i>COM</i>	<i>X</i>	<i>Y</i>	<i>Z</i>
<i>H</i>	<i>V</i>							
361,352	95,790	34,815	34,739	2,301		28,532	-19,818	-0,096
368,828	95,646	32,095	32,020	2,193		28,258	-15,059	-0,203
390,572	98,690	27,962	27,956	0,575		27,650	-4,125	-1,821
16,624	99,042	28,064	28,061	0,422		27,110	7,245	-1,974
31,226	98,948	30,366	30,362	0,502		26,782	14,302	-1,895
39,640	98,956	32,944	32,940	0,540		26,758	19,210	-1,856
58,388	99,222	41,225	41,222	0,504		25,066	32,725	-1,893
68,604	100,188	58,730	58,730	-0,173	SHLN	27,804	51,731	-2,570
76,404	100,754	62,716	62,712	-0,743		22,715	58,453	-3,139
78,172	101,174	67,361	67,350	-1,242		22,643	63,429	-3,638
81,248	101,500	74,185	74,164	-1,748		21,531	70,970	-4,144
81,872	101,356	78,166	78,148	-1,665		21,954	75,001	-4,061
83,728	101,130	83,668	83,655	-1,485		21,150	80,937	-3,881
85,692	100,896	89,770	89,761	-1,263		20,004	87,504	-3,660
86,622	100,746	96,585	96,578	-1,132		20,146	94,454	-3,528
88,022	100,816	104,218	104,209	-1,336		19,492	102,370	-3,732
87,918	100,830	103,482	103,473	-1,349		19,520	101,615	-3,745
89,598	100,964	107,978	107,966	-1,635		17,563	106,528	-4,031

Tabla 4. Puntos de referencia utilizados en el perfil centro. *H* ángulo horizontal; *V* ángulo vertical; *INCL* distancia al punto en metros; *BASE* distancia horizontal al punto en metros; *COTA* distancia vertical al punto (con respecto del teodolito) en metros; *COM* comentarios: *SHLN* línea de orilla; *X* coordenada longitudinal en metros; *Y* coordenada transversal en metros; *Z* coordenada vertical con respecto a la referencia 2.7 en metros.

PERFIL SUR								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>COTA</i>	<i>COM</i>	<i>X</i>	<i>Y</i>	<i>Z</i>
381,200	97,852	61,964	61,929	2,090		59,248	-18,024	-0,306
384,816	97,736	60,938	60,899	2,167		59,175	-14,388	-0,230
399,194	99,416	58,111	58,109	0,533		58,104	-0,736	-1,863
13,442	99,298	58,234	58,230	0,642		56,937	12,204	-1,754
26,284	99,270	61,006	61,002	0,700		55,876	24,476	-0,697
36,248	99,622	65,516	65,515	0,389		55,179	35,320	-1,993
42,304	100,104	69,468	69,468	-0,113	SHLN	54,686	42,839	-2,510
51,656	100,556	78,819	78,816	-0,688		54,263	57,162	-3,085
56,282	100,984	83,932	83,922	-1,297		53,207	64,899	-3,694
60,462	101,238	89,601	89,584	-1,742		52,129	72,855	-4,139
63,822	101,142	96,998	96,982	-1,740		52,195	81,739	-4,136
66,424	100,818	101,637	101,629	-1,306		51,149	87,819	-3,702
69,420	100,688	110,337	110,331	-1,192		50,983	97,845	-3,589
71,388	100,800	116,910	116,901	-1,469		50,788	105,292	-3,865

Tabla 5. Puntos de referencia utilizados en el perfil sur. *H* ángulo horizontal; *V* ángulo vertical; *INCL* distancia al punto en metros; *BASE* distancia horizontal al punto en metros; *COTA* distancia vertical al punto (con respecto del teodolito) en metros; *COM* comentarios: *SHLN* línea de orilla; *X* coordenada longitudinal en metros; *Y* coordenada transversal en metros; *Z* coordenada vertical con respecto a la referencia 2.7 en metros.

PUNTOS DE MORFODINAMICA								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>COTA</i>	<i>COM</i>	<i>X</i>	<i>Y</i>	<i>Z</i>
17,758	99,946	142,250	142,250	0,121	Os1	136,752	39,167	-2,276
39,798	100,110	73,417	73,417	-0,127	Os2	59,532	42,965	-2,523
46,026	99,820	58,591	58,591	0,166	Os3	43,934	38,765	-2,231
45,492	99,292	32,897	32,895	0,366	Cdyes	24,848	21,556	-2,030
95,036	99,530	38,500	38,499	0,284	On4	2,999	38,382	-2,112
109,118	99,714	40,482	40,482	0,182	On5	-5,778	40,067	-2,214
147,212	99,632	52,176	52,175	0,302	On6	-35,243	38,473	-2,095
166,578	99,734	75,546	75,545	0,316	On7	-65,372	37,864	-2,081

Tabla 6. Puntos de referencia utilizados en las imágenes de video para la determinación de las características morfodinámicas. *H* ángulo horizontal; *V* ángulo vertical; *INCL* distancia al punto en metros; *BASE* distancia horizontal al punto en metros; *COTA* distancia vertical al punto (con respecto del teodolito) en metros; *COM* comentarios: *Os_n* posición de orilla sur (_n número de orden), *On_n* posición de orilla norte (_n número de orden), *Cdyes* posición de la cámara durante la segunda toma de imágenes (corresponde al vertido de los trazadores); *X* coordenada longitudinal en metros; *Y* coordenada transversal en metros; *Z* coordenada vertical con respecto a la referencia 2.7 en metros.

PERFIL 0.3								
H	V	INCL	BASE	X	Y	COTA	COM	Z0
194,970	98,340	91,342	91,311	-91,026	-7,207	2,381		2,455
198,600	98,770	90,287	90,270	-90,248	-1,985	1,744		1,818
202,300	99,315	89,820	89,815	-89,756	3,244	0,966		1,040
208,960	99,390	90,162	90,158	-89,266	12,647	0,864		0,937
218,650	99,295	92,428	92,422	-88,485	26,690	1,024		1,097
224,020	99,420	94,728	94,724	-88,061	34,898	0,863		0,936
226,630	99,440	96,136	96,132	-87,844	39,050	0,846		0,919
228,100	99,705	96,760	96,759	-87,485	41,335	0,448		0,522
230,430	99,805	98,224	98,224	-87,215	45,183	0,301	SHLN	0,374
233,060	100,105	100,121	100,121	-86,921	49,688	-0,165		-0,092
237,010	100,185	103,492	103,492	-86,490	56,833	-0,301		-0,227
241,420	100,265	107,899	107,898	-85,855	65,352	-0,449		-0,376
244,050	100,350	111,520	111,518	-85,870	71,152	-0,613		-0,540
246,910	100,355	115,346	115,344	-85,422	77,507	-0,643		-0,570
250,565	100,485	121,116	121,112	-84,876	86,396	-0,923		-0,849
253,355	100,600	126,178	126,172	-84,394	93,793	-1,189		-1,116
256,095	100,750	132,321	132,312	-84,187	102,074	-1,559		-1,486

Tabla 7. Puntos obtenidos en el perfil P0.3 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL 0.2								
H	V	INCL	BASE	X	Y	COTA	COM	Z0
187,895°	97,410	60,723	60,673	-59,579	-11,467	2,470		2,543
191,220	98,115	60,101	60,075	-59,504	-8,259	1,779		1,853
194,990	98,575	59,856	59,841	-59,656	-4,704	1,340		1,413
197,160	98,690	59,860	59,847	-59,788	-2,669	1,232	REFESTA	1,305
201,735	99,130	59,525	59,519	-59,497	1,622	0,813		0,887
207,750	99,145	59,560	59,555	-59,114	7,232	0,800		0,873
213,275	99,120	60,600	60,594	-59,282	12,544	0,838		0,911
222,923	99,040	63,169	63,162	-59,111	22,255	0,953		1,026
229,495	99,120	65,944	65,938	-58,987	29,468	0,912		0,985
236,285	99,195	69,662	69,656	-58,645	37,587	0,881		0,954
239,295	99,520	71,745	71,743	-58,505	41,524	0,541		0,614
241,885	99,640	74,078	74,077	-58,614	45,296	0,419		0,492
244,010	99,850	76,043	76,043	-58,584	48,481	0,179	SHLN	0,252
247,680	100,125	79,489	79,489	-58,218	54,122	-0,156		-0,083
250,830	100,255	83,557	83,556	-58,308	59,849	-0,335		-0,261
254,000	100,285	88,011	88,010	-58,202	66,017	-0,394		-0,321
257,090	100,390	92,461	92,459	-57,707	72,240	-0,566		-0,493
260,125	100,580	98,683	98,679	-57,845	79,947	-0,899		-0,826
262,180	100,665	103,345	103,339	-57,843	85,634	-1,080		-1,006
264,120	100,720	107,840	107,833	-57,608	91,155	-1,220		-1,146

Tabla 8. Puntos obtenidos en el perfil P0.2 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla, REFESTA referencia estaca; X ccordenada x en metros; Y ccordenada y en metros; Z0 ccordenada en z respecto a la referencia 2.7 en metros.

PERFIL 0.15								
H	V	INCL	BASE	X	Y	COTA	COM	Z0
180,255	96,210	47,372	47,288	-45,032	-14,433	2,819		2,892
186,240	96,480	46,050	45,980	-44,910	-9,861	2,545		2,618
191,905	97,470	45,120	45,084	-44,720	-5,717	1,793		1,866
195,425	97,695	44,889	44,860	-44,744	-3,221	1,625		1,698
198,730	98,440	44,729	44,716	-44,707	-0,892	1,096	REFESTA	1,169
210,515	98,870	45,001	44,994	-44,382	7,398	0,799		0,872
227,520	98,735	48,534	48,524	-44,061	20,329	0,964		1,038
238,265	98,775	53,119	53,109	-43,801	30,034	1,022		1,095
247,235	99,039	59,113	59,106	-43,570	39,940	0,892		0,966
249,510	99,455	61,005	61,003	-43,466	42,802	0,522		0,596
251,470	99,635	62,966	62,965	-43,483	45,539	0,361		0,434
254,590	99,865	66,302	66,302	-43,383	50,138	0,141	SHLN	0,214
257,390	100,185	69,517	69,517	-43,132	54,518	-0,202		-0,129
262,082	100,330	76,882	76,881	-43,132	63,642	-0,399		-0,325
265,020	100,335	81,973	81,972	-42,808	69,906	-0,431		-0,358
268,180	100,570	89,375	89,371	-42,833	78,438	-0,800		-0,727
271,165	100,730	97,319	97,313	-42,585	87,500	-1,116		-1,043
273,070	100,810	104,638	104,630	-42,952	95,407	-1,331		-1,258
275,265	100,905	110,798	110,787	-41,970	102,529	-1,575		-1,502

Tabla 9. Puntos obtenidos en el perfil P0.2 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla, REFESTA referencia estaca; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL 0.1								
H	V	INCL	BASE	X	Y	COTA	COM	Z0
175,245	95,345	32,549	32,462	-30,039	-12,307	2,378		2,451
180,800	96,210	31,649	31,593	-30,167	-9,384	1,883		1,956
190,613	96,720	30,626	30,585	-30,253	-4,494	1,577		1,650
197,020	97,455	30,384	30,360	-30,326	-1,421	1,214		1,288
203,180	98,190	30,382	30,370	-30,332	1,516	0,864	REFESTA	0,937
226,475	98,405	33,835	33,824	-30,941	13,665	0,848		0,921
243,305	98,390	39,826	39,813	-30,952	25,042	1,007		1,080
250,990	98,640	44,965	44,955	-31,290	32,278	0,961		1,034
256,860	98,845	50,026	50,018	-31,359	38,967	0,908		0,981
259,120	99,415	52,583	52,581	-31,491	42,107	0,483		0,556
260,225	99,635	54,175	54,174	-31,688	43,940	0,311		0,384
261,985	99,635	56,545	56,544	-31,794	46,759	0,324		0,397
264,170	100,155	59,378	59,378	-31,682	50,219	-0,145	SHLN	-0,071
266,200	100,195	62,968	62,968	-31,883	54,299	-0,193		-0,120
266,860	100,310	64,376	64,375	-32,018	55,848	-0,313		-0,240
269,360	100,320	69,047	69,046	-31,963	61,202	-0,347		-0,274
271,000	100,355	73,127	73,126	-32,171	65,669	-0,408		-0,335
273,955	100,510	81,816	81,813	-32,545	75,062	-0,655		-0,582
275,660	100,735	87,540	87,534	-32,658	81,214	-1,011		-0,937
276,740	100,775	92,577	92,570	-33,075	86,460	-1,127		-1,054
277,770	100,855	98,221	98,212	-33,602	92,285	-1,319		-1,246
278,815	100,905	104,697	104,686	-34,197	98,943	-1,488		-1,415

Tabla 10. Puntos obtenidos en el perfil P0.1 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla, REFESTA referencia estaca; X ccordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL 0.05								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
198,225°	96,645	15,255	15,234	-15,228	-0,425	0,804	REFESTA	0,877
148,990	91,110	21,090	20,885	-14,532	-15,000	2,936	DUNA	3,009
152,595	91,630	19,791	19,620	-14,427	-13,297	2,595		2,668
165,010	93,420	17,213	17,121	-14,600	-8,943	1,776		1,849
177,480	95,405	15,848	15,807	-14,828	-5,476	1,143		1,216
198,010	96,595	15,268	15,246	-15,239	-0,476	0,816	REFESTA	0,889
243,935	97,425	19,326	19,310	-14,891	12,294	0,781		0,855
260,785	97,740	26,337	26,320	-15,207	21,483	0,935		1,008
261,655	98,185	35,640	35,626	-20,184	29,356	1,016		1,089
277,450	98,680	43,949	43,940	-15,241	41,212	0,911		0,984
277,835	99,400	46,502	46,500	-15,865	43,710	0,438		0,512
280,890	99,890	52,172	52,172	-15,427	49,839	0,090	SHLN	0,163
280,695	100,275	57,803	57,802	-17,261	55,165	-0,250		-0,176
285,175	100,400	70,584	70,583	-16,288	68,677	-0,443		-0,370
286,675	100,490	76,495	76,493	-15,894	74,823	-0,589		-0,516
287,620	100,710	83,384	83,379	-16,112	81,807	-0,930		-0,857
288,605	100,845	91,571	91,563	-16,302	90,100	-1,215		-1,142
289,285	100,920	97,583	97,573	-16,345	96,194	-1,410		-1,337

Tabla 11. Puntos obtenidos en el perfil P0.05 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla, REFESTA referencia estaca; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL 0									
H	V	INCL	BASE	X	Y	COTA	COM	Z0	
347,750	98,350	34,579	34,567	23,564	25,291	0,896	*		
302,000	94,000	7,753	7,719	0,242	7,715	0,730		0,803	
301,305	96,410	14,067	14,045	0,288	14,042	0,793		0,866	
301,200	96,945	19,243	19,221	0,362	19,217	0,923		0,996	
301,110	97,420	25,621	25,600	0,446	25,596	1,038		1,111	
301,085	97,755	29,352	29,334	0,500	29,329	1,035		1,108	
301,090	98,190	34,281	34,267	0,587	34,262	0,975		1,048	
300,990	98,455	38,275	38,264	0,595	38,259	0,929		1,002	
301,025	98,570	41,805	41,794	0,673	41,789	0,939		1,012	
301,030	99,145	43,041	43,037	0,696	43,031	0,578		0,651	
300,975	99,750	47,124	47,124	0,722	47,118	0,185	SHLN	0,258	
300,925	100,130	53,812	53,812	0,782	53,806	-0,110		-0,037	
300,975	100,324	60,219	60,218	0,922	60,211	-0,306		-0,233	
300,960	100,405	70,270	70,269	1,060	70,261	-0,447		-0,374	
300,960	100,675	78,794	78,790	1,188	78,781	-0,835		-0,762	
300,905	100,845	87,449	87,441	1,243	87,432	-1,161		-1,087	
300,890	100,930	95,165	95,155	1,330	95,146	-1,390		-1,317	

Tabla 12. Puntos obtenidos en el perfil P0 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X ccordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -0.05								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
398,620	96,850	15,097	15,079	15,075	0,327	0,747	REFESTA	0,820
45,965	94,010	21,425	21,330	16,008	-14,097	2,013		2,086
33,340	94,905	18,346	18,287	15,836	-9,145	1,467		1,540
12,850	96,455	15,825	15,800	15,480	-3,168	0,881		0,954
398,855	96,915	15,122	15,104	15,102	0,272	0,733	REFESTA	0,806
380,515	96,895	15,364	15,346	14,633	4,624	0,749		0,822
398,400	97,395	18,953	18,937	18,931	0,476	0,775		0,849
339,965	97,595	25,264	25,246	14,828	20,433	0,954		1,027
330,600	97,840	31,928	31,910	14,754	28,294	1,083		1,156
324,520	98,390	38,527	38,515	14,470	35,693	0,974		1,047
321,570	98,550	43,620	43,609	14,494	41,129	0,993		1,067
321,265	98,665	44,413	44,403	14,558	41,949	0,931		1,005
319,940	99,520	46,807	46,806	14,422	44,528	0,353		0,426
318,575	99,765	50,187	50,187	14,436	48,066	0,185	SHLN	0,259
316,100	100,345	56,912	56,911	14,240	55,101	-0,308		-0,235
314,920	100,270	60,887	60,886	14,139	59,222	-0,258		-0,185
313,370	100,345	67,471	67,470	14,066	65,988	-0,366		-0,292
311,755	100,520	75,611	75,608	13,882	74,323	-0,618		-0,544
310,500	100,760	83,649	83,643	13,733	82,508	-0,999		-0,925
309,640	100,825	89,227	89,220	13,458	88,199	-1,156		-1,083
309,065	100,925	94,765	94,755	13,447	93,796	-1,377		-1,304

Tabla 13. Puntos obtenidos en el perfil P-0.05 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla, REFESTA referencia estaca; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -0.1								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
0,150	97,875	29,748	29,731	29,731	-0,070	0,993	REFESTA	1,066
35,492	95,255	35,242	35,144	29,823	-18,594	2,624	DUNA	2,698
31,025	95,505	34,142	34,057	30,092	-15,948	2,409	DUNA	2,482
26,015	95,835	33,112	33,041	30,321	-13,129	2,165	DUNA	2,238
19,925	96,820	31,780	31,740	30,198	-9,773	1,587	DUNA	1,660
14,455	97,295	30,770	30,742	29,953	-6,920	1,307	DUNA	1,380
398,490	98,080	29,913	29,899	29,891	0,709	0,902	REFESTA	0,975
372,765	98,420	32,372	32,362	29,446	13,426	0,803		0,877
354,675	98,330	38,145	38,132	28,869	24,912	1,001		1,074
348,140	98,285	41,693	41,678	28,597	30,319	1,123		1,196
343,640	98,075	45,093	45,072	28,533	34,891	1,363		1,437
340,575	98,480	47,754	47,740	28,409	38,368	1,140		1,213
338,180	98,815	49,708	49,699	28,051	41,026	0,925		0,998
336,270	99,405	52,105	52,103	28,104	43,873	0,487		0,560
335,050	99,655	53,858	53,857	28,176	45,899	0,292		0,365
333,125	99,620	56,148	56,147	27,914	48,716	0,335	SHLN	0,408
330,740	100,355	59,801	59,800	27,766	52,963	-0,333		-0,260
328,515	100,255	63,944	63,943	27,693	57,636	-0,256		-0,183
326,685	100,305	67,156	67,155	27,332	61,341	-0,322		-0,248
324,755	100,375	71,952	71,951	27,278	66,579	-0,424		-0,351
323,015	100,345	76,541	76,540	27,072	71,592	-0,415		-0,342
320,910	100,555	82,768	82,765	26,698	78,340	-0,722		-0,648
319,555	100,555	87,598	87,595	26,485	83,495	-0,764		-0,690
318,385	100,820	93,532	93,524	26,635	89,651	-1,205		-1,131
316,885	100,890	99,664	99,654	26,122	96,170	-1,393		-1,320

Tabla 14. Puntos obtenidos en el perfil P0 el día 13 de diciembre de 1993. *H* ángulo horizontal; *V* ángulo vertical; *INCL* distancia inclinada al punto en metros; *COTA* distancia vertical del punto (con respecto del teodolito) en metros; *COM* comentarios: *SHLN* línea de orilla; *X* coordenada x en metros; *Y* coordenada y en metros; *Z0* coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -0.15								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
19,975	96,500	46,954	46,883	44,594	-14,470	2,580		2,653
15,205	97,570	46,340	46,306	44,992	-10,955	1,768		1,842
9,275	98,590	45,620	45,609	45,126	-6,621	1,010		1,084
399,825	98,975	45,030	45,024	45,024	0,124	0,725	REFESTA	0,798
392,420	98,260	45,526	45,509	45,187	5,406	1,244		1,317
367,000	98,680	49,771	49,760	43,223	24,654	1,032		1,105
361,190	98,420	54,127	54,110	44,363	30,981	1,343		1,416
357,520	98,425	56,253	56,236	44,174	34,801	1,392		1,465
354,990	98,840	58,191	58,181	44,236	37,793	1,060		1,134
354,315	99,055	58,443	58,437	44,025	38,427	0,867		0,941
352,255	99,350	60,664	60,661	44,386	41,348	0,619		0,693
350,610	99,625	61,644	61,643	44,004	43,168	0,363		0,436
347,840	99,570	64,579	64,578	44,088	47,186	0,436		0,509
344,870	100,160	67,783	67,783	43,916	51,632	-0,170		-0,097
344,100	100,290	68,791	68,790	43,932	52,935	-0,313		-0,240
340,675	100,305	73,960	73,959	44,104	59,370	-0,354		-0,281
337,345	100,400	79,151	79,149	43,813	65,917	-0,497		-0,424
334,440	100,375	85,098	85,097	43,823	72,945	-0,501		-0,428
331,015	100,660	93,801	93,796	43,909	82,883	-0,972		-0,899
328,825	100,745	100,333	100,326	43,890	90,217	-1,174		-1,101
326,540	100,865	106,881	106,871	43,274	97,718	-1,452		-1,379

Tabla 15. Puntos obtenidos en el perfil P0 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN linea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -0.2								
H	V	INCL	BASE	X	Y	COTA	COM	Z0
335,375	100,750	115,741	115,733	61,051	98,321	-1,364		-1,290
336,450	100,720	112,465	112,458	60,928	94,523	-1,272		-1,199
337,575	100,635	108,982	108,977	60,651	90,539	-1,087		-1,014
339,755	100,520	103,250	103,247	60,365	83,761	-0,843		-0,770
341,295	100,380	99,523	99,521	60,123	79,308	-0,594		-0,521
343,125	100,365	96,082	96,080	60,221	74,866	-0,551		-0,478
344,715	100,295	93,353	93,352	60,309	71,256	-0,433		-0,359
346,915	100,305	89,778	89,777	60,332	66,482	-0,430		-0,357
348,150	100,450	87,234	87,232	59,864	63,448	-0,617		-0,543
350,095	100,470	84,621	84,619	59,924	59,745	-0,625		-0,551
351,705	100,380	82,455	82,454	59,844	56,721	-0,492		-0,419
352,910	100,250	81,209	81,208	59,987	54,739	-0,319		-0,246
354,620	100,085	79,009	79,009	59,772	51,670	-0,105		-0,032
357,275	99,555	76,611	76,609	59,994	47,641	0,536		0,609
359,730	99,640	74,445	74,444	60,040	44,012	0,421		0,494
360,720	99,545	73,597	73,595	60,025	42,582	0,526		0,599
361,825	99,285	72,646	72,641	59,968	40,996	0,816		0,889
365,245	98,990	70,276	70,267	60,053	36,484	1,115		1,188
368,950	98,999	67,783	67,775	59,872	31,761	1,066		1,139
375,565	99,095	64,851	64,844	60,126	24,282	0,922		0,995
378,005	99,145	63,803	63,797	60,027	21,606	0,857		0,930
391,075	99,275	60,868	60,864	60,267	8,505	0,693		0,766
395,275	99,275	60,267	60,263	60,097	4,469	0,686	REFESTA	0,760
398,820	98,935	59,954	59,946	59,935	1,111	1,003		1,076
2,370	98,675	60,003	59,990	59,948	-2,233	1,249		1,322
7,010	98,375	60,567	60,547	60,181	-6,654	1,546		1,619
10,900	98,065	61,093	61,065	60,172	-10,404	1,857		1,930
14,205	97,630	61,871	61,828	60,295	-13,682	2,303		2,376
18,985	97,405	63,022	62,970	60,190	-18,501	2,568		2,641

Tabla 16. Puntos obtenidos en el perfil P-0.2 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -0.3								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
199,245	99,710	120,334	120,333	-120,324	-1,427	0,548	D(-1,0)	0,784
168,110	96,115	35,680	35,614	89,086	-18,530	2,176		2,412
171,260	96,130	34,860	34,796	89,014	-16,607	2,118		2,353
187,300	98,400	31,347	31,337	89,608	-7,637	0,788		1,023
196,780	98,800	30,497	30,492	89,871	-2,969	0,575	REFESTA	0,810
229,458	98,800	34,569	34,563	89,396	14,001	0,652		0,887
247,810	98,775	43,176	43,168	88,768	28,029	0,831		1,066
256,000	99,060	50,257	50,252	88,292	37,292	0,742		0,978
260,740	99,425	52,640	52,638	89,881	41,515	0,475		0,711
261,990	100,185	58,183	58,183	87,613	46,690	-0,169		0,066
264,150	100,675	61,451	61,448	87,521	50,532	-0,652		-0,416
266,000	100,890	64,934	64,928	87,273	54,459	-0,908		-0,672
266,840	100,800	67,067	67,062	86,951	56,741	-0,843		-0,607
267,975	100,555	68,804	68,801	87,155	58,851	-0,600		-0,364
269,570	100,495	72,768	72,766	86,852	63,183	-0,566		-0,330
271,740	100,510	79,328	79,325	86,256	70,210	-0,635		-0,400
273,230	100,575	84,313	84,310	85,907	75,538	-0,762		-0,526
274,865	100,675	90,360	90,355	85,570	81,977	-0,958		-0,723
276,440	100,825	95,682	95,674	85,720	87,770	-1,240		-1,004
277,235	100,900	101,000	100,990	84,976	93,175	-1,428		-1,192

Tabla 17. Puntos obtenidos en el perfil P-0.3 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -1.0								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
73,630	83,105	5,903	5,696	122,617	-6,642	1,548	DUNA	1,784
334,285	91,965	4,494	4,458	122,611	2,400	0,566		0,801
303,205	97,715	18,755	18,743	121,267	17,292	0,673		0,909
299,440	98,265	35,205	35,192	120,014	33,764	0,959		1,195
299,380	98,910	37,161	37,156	119,962	35,727	0,636		0,872
298,860	99,360	41,137	41,135	119,587	39,701	0,414		0,649
298,560	100,275	48,273	48,273	119,232	46,833	-0,209	SHLN	0,027
298,290	100,890	53,789	53,784	118,880	52,337	-0,752		-0,516
298,170	100,880	58,160	58,154	118,653	56,703	-0,804		-0,568
298,020	100,865	63,472	63,466	118,350	62,008	-0,862		-0,627
297,890	100,570	66,308	66,305	118,127	64,842	-0,594		-0,358
297,735	100,890	70,913	70,906	117,802	69,434	-0,991		-0,756
297,645	100,670	76,392	76,388	117,499	74,909	-0,804		-0,568
297,525	100,715	80,817	80,812	117,183	79,324	-0,908		-0,672
297,475	100,785	86,637	86,630	116,889	85,135	-1,068		-0,833
297,395	100,900	91,147	91,138	116,596	89,635	-1,289		-1,053

Tabla 18. Puntos obtenidos en el perfil P-1.0 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios; SHLN línea de orilla; X ccordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -1.5								
H	V	INCL	BASE	X	Y	COTA	COM	Z0
13,115	98,080	61,587	61,559	180,581	-14,019	1,857		2,093
7,205	98,875	60,750	60,741	180,676	-8,287	1,073		1,309
0,205	99,390	60,374	60,371	180,695	-1,621	0,578	REFESTA	0,814
384,890	99,415	62,280	62,277	180,855	13,216	0,572		0,808
373,200	98,860	66,778	66,767	181,262	25,857	1,196		1,431
369,880	99,150	68,500	68,494	181,294	29,784	0,915		1,150
362,595	99,520	73,541	73,539	181,530	39,338	0,554		0,790
358,000	100,270	77,657	77,656	181,685	46,169	-0,329		-0,094
355,745	100,525	80,087	80,084	181,825	49,867	-0,660		-0,425
353,350	100,455	82,668	82,666	181,771	53,871	-0,591		-0,355
350,525	100,400	86,895	86,893	182,271	59,507	-0,546		-0,310
347,675	100,450	90,926	90,924	182,226	65,170	-0,643		-0,407
345,250	100,520	95,029	95,026	182,322	70,588	-0,776		-0,541
343,070	100,615	99,186	99,181	182,421	75,909	-0,958		-0,723
340,840	100,715	103,790	103,783	182,429	81,723	-1,166		-0,930
339,325	100,760	107,380	107,372	182,511	86,103	-1,282		-1,046

Tabla 19. Puntos obtenidos en el perfil P-1.5 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN lnea de orilla; X ccordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -2.0								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
7,670	98,885	120,466	120,448	239,898	-15,903	2,110		2,345
3,045	99,670	119,275	119,273	239,461	-7,130	0,618		0,854
399,415	99,810	118,766	118,765	239,084	-0,336	0,354	(-1,-2)	0,590
399,410	99,815	118,774	118,773	239,092	-0,326	0,345		0,581
391,150	99,700	119,018	119,017	238,193	15,065	0,561		0,796
381,985	99,475	121,595	121,591	237,079	32,523	1,003		1,238
379,230	99,720	122,958	122,957	236,795	37,980	0,541		0,776
376,415	99,865	124,576	124,576	236,448	43,676	0,264		0,500
375,025	99,970	125,720	125,720	236,493	46,638	0,059		0,295
372,000	100,185	127,898	127,897	236,049	53,029	-0,372	SHLN	-0,136
369,520	100,290	129,972	129,971	235,681	58,450	-0,592		-0,357
367,165	100,335	132,110	132,108	235,247	63,729	-0,695		-0,460
365,000	100,420	134,504	134,501	235,005	68,850	-0,887		-0,652
363,035	100,490	137,020	137,016	234,884	73,735	-1,055		-0,819
360,760	100,565	139,870	139,864	234,450	79,427	-1,241		-1,006
360,790	100,565	139,728	139,722	234,372	79,291	-1,240		-1,005
358,610	100,645	143,090	143,083	234,217	85,182	-1,450		-1,214

Tabla 20. Puntos obtenidos en el perfil P-2.0 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -2.5								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
199,305°	99,300	120,147	120,140	-120,133	-1,312	1,321	D(-3,-2)	1,307
198,485	99,260	60,136	60,132	299,102	-2,779	0,699	REFESTA	0,685
183,195	97,765	62,472	62,434	298,946	-17,638	2,193	DUNA	2,179
194,105	99,215	60,497	60,492	298,984	-6,942	0,746		0,732
198,490	99,280	60,145	60,141	299,093	-2,774	0,680		0,666
215,710	99,130	61,980	61,974	299,120	13,791	0,847		0,833
228,990	98,020	66,925	66,893	299,141	28,071	2,081		2,067
236,510	99,090	71,639	71,632	299,046	37,517	1,024		1,010
241,400	99,740	75,522	75,521	299,110	44,375	0,308		0,294
243,910	100,010	77,783	77,783	299,214	48,148	-0,012	SHLN	-0,026
246,110	100,190	80,064	80,064	299,252	51,703	-0,239		-0,253
248,610	100,540	83,304	83,301	299,042	56,255	-0,707		-0,721
251,370	100,630	86,957	86,953	299,069	61,446	-0,861		-0,875
253,635	100,505	90,281	90,278	299,128	66,027	-0,716		-0,730
255,925	100,395	94,273	94,271	299,041	71,218	-0,585		-0,599
258,875	100,495	99,820	99,817	299,128	78,356	-0,776		-0,790
261,100	100,610	105,997	105,992	298,407	85,465	-1,016		-1,030
263,360	100,720	110,484	110,477	299,086	91,331	-1,250		-1,264

Tabla 21. Puntos obtenidos en el perfil P-2.5 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X ccordenada x en metros; Y coordenada y en metros; Z coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -3.0								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
88,810	90,285	10,718	10,593	361,069	-11,778	1,629		1,615
301,965	95,170	9,351	9,324	359,505	7,972	0,709		0,695
301,160	97,560	27,584	27,564	359,719	26,211	1,057		1,043
299,315	97,950	37,007	36,988	358,819	35,638	1,191		1,177
299,150	98,785	43,808	43,800	358,632	42,448	0,836		0,822
299,040	99,510	47,796	47,795	358,496	46,441	0,368		0,354
298,290	100,155	53,971	53,971	357,767	52,603	-0,131	SHLN	-0,146
299,110	100,370	56,180	56,179	358,432	54,826	-0,327		-0,341
299,385	100,910	62,792	62,786	358,610	61,435	-0,898		-0,912
299,670	100,980	67,746	67,738	358,866	66,389	-1,043		-1,057
299,785	100,950	73,949	73,941	358,967	72,592	-1,103		-1,118
299,605	100,065	77,626	77,626	358,735	76,276	-0,079		-0,093
299,730	100,460	82,978	82,976	358,865	81,627	-0,600		-0,614
299,110	100,575	89,432	89,428	357,967	88,072	-0,808		-0,822
298,890	100,675	94,878	94,873	357,563	93,510	-1,006		-1,020

Tabla 22. Puntos obtenidos en el perfil P-3.0 el día 13 de diciembre de 1993. *H* ángulo horizontal; *V* ángulo vertical; *INCL* distancia inclinada al punto en metros; *COTA* distancia vertical del punto (con respecto del teodolito) en metros; *COM* comentarios: *SHLN* línea de orilla; *X* ccordenada x en metros; *Y* coordenada y en metros; *Z0* coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -3.5								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
399,970	99,080	60,221	60,215	419,432	-1,320	0,870	REFESTA	0,856
9,530	98,090	61,022	60,995	419,529	-10,445	1,831		1,816
40,480	98,675	60,387	60,374	407,792	-37,202	1,257		1,243
399,950	99,070	60,238	60,232	419,449	-1,301	0,880	REFESTA	0,866
397,680	99,305	60,233	60,229	419,406	0,846	0,658		0,643
381,805	99,290	62,546	62,542	419,222	16,285	0,698		0,683
370,285	98,930	67,013	67,004	419,053	28,803	1,126		1,112
368,255	99,115	67,962	67,955	418,897	31,151	0,945		0,931
358,110	99,340	75,399	75,395	418,870	44,759	0,782		0,768
354,660	99,620	78,354	78,353	418,524	49,855	0,468		0,454
350,460	100,120	83,541	83,541	418,715	57,296	-0,157	SHLN	-0,172
349,215	100,275	85,387	85,386	418,845	59,769	-0,369		-0,383
347,220	100,455	87,665	87,663	418,439	63,286	-0,627		-0,641
344,360	100,595	92,531	92,527	418,598	69,611	-0,865		-0,879
342,385	100,435	96,065	96,063	418,552	74,199	-0,656		-0,671
342,050	100,365	97,100	97,098	418,790	75,328	-0,557		-0,571
339,435	100,325	101,655	101,654	418,235	81,419	-0,519		-0,533
337,035	100,400	107,457	107,455	418,262	88,431	-0,675		-0,689
334,785	100,510	103,407	103,404	412,947	87,000	-0,828		-0,843
332,705	100,580	119,777	119,772	418,076	102,964	-1,091		-1,105

Tabla 23. Puntos obtenidos en el perfil P-3.5 el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios; SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

BARRA EXTERIOR								
H	V	INCL	BASE	X	Y	COTA	COM	Z0
297,050	100,675	139,873	139,865	17,085	165,006	-1,483	1	-1,053
299,670	100,630	141,034	141,027	22,833	166,316	-1,396	2	-0,966
301,215	100,650	130,007	130,000	26,045	155,268	-1,327	3	-0,897
305,615	100,660	139,817	139,809	35,879	164,557	-1,449	4	-1,019
309,200	100,640	141,517	141,510	43,943	165,326	-1,423	5	-0,993
312,840	100,625	144,981	144,974	52,606	167,327	-1,423	6	-0,993
316,685	100,615	149,381	149,374	62,266	169,564	-1,443	7	-1,013
321,305	100,605	153,230	153,223	73,889	170,014	-1,456	8	-1,026
323,950	100,610	153,139	153,132	79,824	167,714	-1,467	9	-1,037
326,725	100,858	158,316	158,302	88,083	169,848	-2,134	10	-1,704
328,090	100,590	160,368	160,361	92,047	170,294	-1,486	11	-1,056
329,290	100,610	157,325	157,318	93,417	166,250	-1,507	12	-1,077
329,260	100,750	154,366	154,355	92,036	163,628	-1,819	13	-1,389
326,610	100,735	151,640	151,630	85,114	163,867	-1,751	14	-1,321
323,875	100,750	149,175	149,165	78,203	164,089	-1,757	15	-1,327
321,270	100,740	146,550	146,540	71,618	163,728	-1,703	16	-1,273
316,960	100,770	142,455	142,445	61,065	162,711	-1,723	17	-1,293
313,555	100,810	140,600	140,589	53,273	162,705	-1,789	18	-1,359
307,455	100,835	137,741	137,729	39,656	162,077	-1,807	19	-1,377
303,505	100,830	137,086	137,074	31,107	162,158	-1,787	20	-1,357
300,215	100,738	137,510	137,501	24,028	162,791	-1,594	21	-1,164
296,520	100,730	138,566	138,557	15,994	163,641	-1,589	22	-1,159
292,525	100,850	138,277	138,265	7,367	162,604	-1,846	23	-1,416
292,310	100,720	139,750	139,741	6,725	164,014	-1,581	24	-1,151
289,980	100,800	139,866	139,855	1,642	163,418	-1,758	25	-1,328
286,830	100,755	141,006	140,996	-5,397	163,281	-1,672	26	-1,242
284,885	100,760	142,295	142,285	-9,902	163,585	-1,699	27	-1,269
282,720	100,775	143,322	143,311	-14,860	163,356	-1,745	28	-1,315
279,800	100,755	145,496	145,486	-21,828	163,515	-1,725	29	-1,295
272,900	100,685	152,850	152,841	-39,551	164,492	-1,645	30	-1,215
270,290	100,730	155,219	155,209	-46,269	163,903	-1,780	31	-1,350
269,530	100,530	164,126	164,120	-52,023	170,969	-1,366	32	-0,936
281,770	100,570	163,397	163,390	-22,587	182,028	-1,463	33	-1,033
275,410	100,595	161,366	161,359	-37,224	174,762	-1,508	34	-1,078
278,540	100,635	158,577	158,569	-28,882	174,936	-1,582	35	-1,152

<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
278,540	100,635	158,577	158,569	-28,882	174,936	-1,582	35	-1,152
282,725	100,630	155,596	155,588	-18,140	175,186	-1,540	36	-1,110
286,840	100,660	155,143	155,135	-8,277	177,123	-1,608	37	-1,178
291,080	100,665	154,636	154,628	1,969	178,403	-1,615	38	-1,185
294,725	100,690	155,089	155,080	10,729	179,839	-1,681	39	-1,251
298,910	100,685	154,329	154,320	20,922	179,589	-1,661	40	-1,231
300,710	100,680	151,886	151,877	25,258	177,159	-1,622	41	-1,192
304,120	100,695	152,294	152,285	33,412	177,257	-1,663	42	-1,233
309,945	100,695	151,575	151,566	47,145	175,012	-1,655	43	-1,225
311,595	100,675	153,064	153,055	51,287	175,815	-1,623	44	-1,193
315,835	100,665	155,861	155,852	61,931	176,347	-1,628	45	-1,198
319,450	100,660	158,798	158,789	71,326	176,727	-1,646	46	-1,216

Tabla 24. Puntos obtenidos en la barra exterior el día 13 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada z respecto a la referencia 2.7 en metros.

PERFIL 0.3								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
226,825	99,755	98,353	98,352	-89,750	40,227	0,379		0,487
233,630	100,160	104,031	104,031	-89,850	52,435	-0,261	SHLN	-0,153
234,910	100,240	105,738	105,737	-90,234	55,120	-0,399		-0,290
235,135	100,330	106,034	106,033	-90,290	55,593	-0,550		-0,441
237,180	100,290	108,093	108,092	-90,176	59,600	-0,492		-0,384
239,780	100,360	110,837	110,835	-89,892	64,837	-0,627		-0,519
242,925	100,395	115,339	115,337	-90,097	72,007	-0,716		-0,607
245,710	100,420	119,615	119,612	-90,082	78,692	-0,789		-0,681
248,000	100,600	124,418	124,412	-90,693	85,166	-1,173		-1,064
250,060	100,690	127,724	127,716	-90,224	90,394	-1,384		-1,276
251,595	100,750	131,051	131,042	-90,310	94,953	-1,544		-1,436

Tabla 25. Puntos obtenidos en el perfil P0.3 el día 17 de diciembre de 1993. *H* ángulo horizontal; *V* ángulo vertical; *INCL* distancia inclinada al punto en metros; *COTA* distancia vertical del punto (con respecto del teodolito) en metros; *COM* comentarios; *SHLN* línea de orilla; *X* coordenada x en metros; *Y* coordenada y en metros; *Z0* coordenada en z respecto a la referencia 2.7 en metros.

PERFIL 0.2								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
237,625	99,560	72,053	72,051	-59,830	40,147	0,498		0,606
244,730	100,175	78,306	78,306	-59,759	50,602	-0,215	SHLN	-0,107
247,210	100,335	81,275	81,274	-59,932	54,896	-0,428		-0,319
247,450	100,465	81,747	81,745	-60,071	55,441	-0,597		-0,489
248,850	100,400	82,910	82,908	-59,674	57,557	-0,521		-0,413
249,225	100,590	83,573	83,569	-59,807	58,369	-0,775		-0,666
251,815	100,425	87,193	87,191	-59,871	63,386	-0,582		-0,474
254,160	100,495	91,250	91,247	-60,171	68,597	-0,710		-0,601
256,615	100,455	95,629	95,627	-60,240	74,267	-0,683		-0,575
259,590	100,715	101,071	101,065	-59,930	81,379	-1,135		-1,027
262,065	100,795	106,795	106,787	-59,933	88,382	-1,334		-1,225
263,130	100,850	109,711	109,701	-60,041	91,812	-1,465		-1,357

Tabla 26. Puntos obtenidos en el perfil P0.2 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL 0.1								
H	V	INCL	BASE	X	Y	COTA	COM	Z0
258,870*	99,500	52,535	52,533	-31,628	41,946	0,413		0,521
265,050	100,305	61,220	61,219	-31,946	52,223	-0,293	SHLN	-0,185
268,345	100,505	67,191	67,189	-32,049	59,053	-0,533		-0,425
270,560	100,550	72,249	72,246	-32,232	64,658	-0,624		-0,516
272,260	100,650	76,939	76,935	-32,473	69,746	-0,786		-0,677
273,165	100,555	80,173	80,170	-32,802	73,152	-0,699		-0,591
275,420	100,700	87,009	87,004	-32,764	80,599	-0,957		-0,848
276,820	100,910	93,689	93,679	-33,361	87,538	-1,339		-1,231
277,670	100,935	97,436	97,425	-33,476	91,493	-1,431		-1,323

Tabla 27. Puntos obtenidos en el perfil P0.1 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL 0								
H	V	INCL	BASE	X	Y	COTA	COM	Z0
298,855	99,315	43,539	43,536	-0,783	43,529	0,468		0,577
298,770	100,260	53,296	53,296	-1,030	53,286	-0,218	SHLN	-0,109
298,670	100,515	51,086	51,084	-1,067	51,073	-0,413		-0,305
298,630	100,710	67,088	67,084	-1,444	67,068	-0,748		-0,640
298,630	100,850	71,885	71,879	-1,547	71,862	-0,960		-0,852
298,630	100,590	75,391	75,388	-1,622	75,370	-0,699		-0,590
298,805	100,755	82,124	82,118	-1,541	82,104	-0,974		-0,866
298,740	100,910	87,116	87,107	-1,724	87,090	-1,245		-1,137
298,790	100,975	89,888	89,877	-1,708	89,861	-1,377		-1,268

Tabla 28. Puntos obtenidos en el perfil P0 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -0.1		<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
<i>H</i>	<i>V</i>							
227,725	99,820	97,473	97,473	31,950	39,693	0,276		0,578
232,160	100,040	100,630	100,630	32,263	47,273	-0,063		0,239
236,260	100,345	104,075	104,073	32,680	54,697	-0,564		-0,261
238,095	100,415	106,207	106,205	32,573	58,400	-0,692		-0,390
241,875	100,460	110,130	110,127	33,174	65,900	-0,796		-0,493
243,675	100,565	112,074	112,070	33,609	69,567	-0,995		-0,692
244,520	100,605	113,343	113,338	33,589	71,528	-1,077		-0,775
246,030	100,605	115,590	115,585	33,659	75,051	-1,098		-0,796
247,285	100,495	117,106	117,102	34,065	77,771	-0,911		-0,608
249,460	100,610	120,563	120,557	34,357	83,094	-1,155		-0,853
250,730	100,780	123,396	123,387	34,083	86,815	-1,512		-1,209

Tabla 29. Puntos obtenidos en el perfil P-0.1 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios; SHLN línea de orilla; X ccordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -0.2								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
237,460	99,765	71,992	71,992	60,440	38,532	0,266		0,568
241,140	99,760	75,180	75,179	60,304	43,844	-0,283		0,586
245,415	100,365	78,822	78,821	60,723	50,153	-0,452		-0,149
248,095	100,565	82,006	82,003	60,630	54,797	-0,728		-0,425
250,130	100,685	84,506	84,501	60,695	58,446	-0,909		-0,607
250,980	100,555	85,597	85,594	60,739	60,021	-0,746		-0,444
252,105	100,585	87,247	87,243	60,707	62,269	-0,802		-0,499
252,955	100,610	89,190	89,186	60,254	64,495	-0,855		-0,552
254,950	100,730	91,760	91,754	60,680	68,296	-1,052		-0,750
257,200	100,650	95,628	95,623	60,771	73,388	-0,976		-0,674
258,695	100,560	97,512	97,508	61,405	76,267	-0,858		-0,555
259,200	100,555	99,456	99,452	60,861	78,291	-0,867		-0,564
261,485	100,780	104,238	104,230	61,042	84,303	-1,277		-0,975
263,205	100,900	108,190	108,179	61,223	89,181	-1,529		-1,227

Tabla 30. Puntos obtenidos en el perfil P-0.2 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -0.3								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
259,450	99,565	52,904	52,903	88,860	41,102	0,361		0,664
263,225	100,470	57,640	57,638	88,850	46,859	-0,426	SHLN	-0,123
265,390	100,750	61,268	61,264	88,634	51,004	-0,722		-0,419
267,970	100,945	66,052	66,045	88,479	56,433	-0,980		-0,678
270,055	100,345	70,694	70,693	88,284	61,589	-0,383		-0,081
270,530	100,815	72,254	72,248	88,061	63,217	-0,925		-0,622
271,180	100,630	72,889	72,885	88,444	64,117	-0,721		-0,419
272,145	100,680	75,520	75,516	88,327	66,975	-0,807		-0,504
273,415	100,760	79,330	79,324	88,153	71,081	-0,947		-0,644
274,440	100,645	83,207	83,203	87,809	75,159	-0,843		-0,540
275,805	100,705	87,973	87,968	87,691	80,264	-0,974		-0,672
276,845	100,845	92,155	92,147	87,543	84,692	-1,223		-0,921
278,245	101,015	97,314	97,302	87,717	90,248	-1,551		-1,249

Tabla 31. Puntos obtenidos en el perfil P-0.3 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -1.0								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
301,390	99,430	40,751	40,749	121,214	39,313	0,365		0,667
301,230	99,595	40,890	40,889	121,114	39,455	0,260		0,563
301,190	100,500	45,377	45,376	121,172	43,941	-0,356	SHLN	-0,054
301,215	100,800	50,578	50,574	121,289	49,138	-0,636		-0,333
300,960	101,000	52,230	52,224	121,111	50,791	-0,820		-0,518
301,225	100,940	56,915	56,909	121,419	55,471	-0,840		-0,538
300,780	101,120	62,935	62,925	121,095	61,494	-1,107		-0,805
301,280	100,760	65,430	65,425	121,639	63,985	-0,781		-0,479
301,335	100,680	70,654	70,650	121,805	69,207	-0,755		-0,452
301,200	100,680	75,765	75,761	121,752	74,320	-0,809		-0,507
301,285	100,815	82,626	82,619	121,992	81,175	-1,058		-0,755
300,915	100,930	86,372	86,363	121,565	84,927	-1,262		-0,959
301,050	101,025	91,559	91,547	121,834	90,108	-1,474		-1,172

Tabla 32. Puntos obtenidos en el perfil P-1.0 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X ccordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -1.5								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
399,370	99,870	118,651	118,651	238,969	-0,253	0,242	D(-1,-2)	0,545
360,970	99,520	70,535	70,533	178,011	39,157	0,532		0,834
360,895	99,675	70,586	70,585	178,006	39,255	0,360		0,663
354,465	100,240	75,706	75,705	177,476	48,222	-0,285	SHLN	0,017
350,335	100,435	79,915	79,913	177,128	54,782	-0,546		-0,244
347,610	100,605	83,226	83,222	176,921	59,587	-0,791		-0,488
345,250	100,695	86,188	86,183	176,552	63,887	-0,941		-0,638
344,035	100,595	87,196	87,192	175,939	65,725	-0,815		-0,512
341,900	100,680	90,988	90,983	175,975	70,551	-0,972		-0,669
340,140	100,615	93,562	93,558	175,482	74,142	-0,904		-0,601
337,780	100,705	98,160	98,154	175,214	79,944	-1,087		-0,784
336,030	100,835	102,679	102,670	175,378	85,234	-1,347		-1,044
333,875	100,910	105,928	105,917	174,061	89,846	-1,514		-1,212

Tabla 33. Puntos obtenidos en el perfil P-1.5 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X ccordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -2.0								
H	V	INCL	BASE	X	Y	COTA	COM	Z0
220,420	99,840	120,757	120,757	244,655	36,725	0,303		0,714
224,095	100,040	125,166	125,166	242,946	44,902	-0,079	SHLN	0,332
228,055	100,265	128,766	128,765	242,790	53,578	-0,536		-0,125
229,220	100,425	130,228	130,225	242,506	56,347	-0,869		-0,459
229,185	100,435	130,419	130,416	242,303	56,367	-0,891		-0,480
230,905	100,410	143,373	143,370	232,448	65,550	-0,923		-0,513
232,340	100,455	156,230	156,226	222,755	74,645	-1,117		-0,706
233,215	100,400	157,092	157,089	223,064	76,943	-0,987		-0,576
235,365	100,410	159,657	159,654	223,606	82,850	-1,028		-0,617
238,380	100,570	166,177	166,170	222,377	92,872	-1,488		-1,077

Tabla 34. Puntos obtenidos en el perfil P-2.0 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X ccordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -2.5								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
234,800	99,245	72,637	72,632	297,205	36,407	0,861		1,272
242,880	100,125	79,888	79,888	296,812	48,484	-0,157	SHLN	0,254
247,080	100,415	84,913	84,911	296,522	55,877	-0,554		-0,143
250,195	100,520	89,720	89,717	296,008	62,286	-0,733		-0,322
251,030	100,660	91,813	91,808	295,394	64,612	-0,952		-0,541
253,095	100,740	94,968	94,962	295,448	68,984	-1,104		-0,693
254,450	100,790	97,290	97,283	295,436	72,078	-1,207		-0,796
255,565	100,680	99,340	99,334	295,413	74,756	-1,061		-0,650
256,905	100,845	102,187	102,178	295,248	78,299	-1,356		-0,946
257,940	100,600	104,022	104,017	295,423	80,782	-0,980		-0,570
259,305	100,655	106,700	106,694	295,601	84,280	-1,098		-0,687
260,135	100,830	110,447	110,438	294,529	88,135	-1,440		-1,029
261,605	100,865	114,424	114,413	294,357	92,880	-1,555		-1,144
262,155	100,890	116,937	116,926	293,767	95,519	-1,635		-1,224

Tabla 35. Puntos obtenidos en el perfil P-2.5 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -3.0								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
296,415	99,360	43,846	43,844	356,785	42,426	0,441		0,852
296,735	99,975	48,784	48,784	356,752	47,372	0,019	SHLN	0,430
296,240	100,660	55,222	55,219	355,994	53,775	-0,572		-0,162
296,245	101,030	58,978	58,970	355,777	57,520	-0,954		-0,543
296,245	101,240	64,912	64,900	355,427	63,439	-1,264		-0,853
296,235	101,185	68,812	68,800	355,187	67,332	-1,281		-0,870
296,235	100,720	71,337	71,332	355,037	69,860	-0,807		-0,396
296,195	100,690	76,225	76,221	354,700	74,736	-0,826		-0,415
296,250	100,675	81,046	81,041	354,482	79,553	-0,859		-0,449
296,165	100,670	84,958	84,953	354,139	83,451	-0,894		-0,483
296,140	100,780	89,216	89,209	353,847	87,697	-1,093		-0,682
296,160	100,900	96,066	96,056	353,463	94,534	-1,358		-0,947
296,050	100,960	103,422	103,410	352,841	101,863	-1,560		-1,149

Tabla 36. Puntos obtenidos en el perfil P-3.0 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios; SHLN línea de orilla; X ccordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -3.5								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
358,325	99,575	76,166	76,164	419,672	45,026	0,508		0,919
354,165	99,995	80,208	80,208	419,555	51,538	0,006	SHLN	0,417
349,480	100,430	86,485	86,483	419,904	60,302	-0,584		-0,173
346,765	100,625	90,531	90,527	419,931	65,833	-0,889		-0,478
344,875	100,720	93,885	93,879	420,082	70,158	-1,062		-0,651
342,895	100,640	97,285	97,280	419,951	74,673	-0,978		-0,567
341,715	100,685	99,860	99,854	420,101	77,826	-1,074		-0,664
341,000	100,670	101,049	101,043	419,922	79,455	-1,063		-0,653
340,000	101,000	103,737	103,724	420,221	82,567	-1,629		-1,219
339,385	100,840	105,018	105,009	420,152	84,198	-1,386		-0,975
338,780	100,765	106,532	106,524	420,203	86,016	-1,280		-0,869
337,670	100,805	109,154	109,145	420,133	89,241	-1,380		-0,969
336,195	100,630	113,170	113,164	420,182	94,014	-1,120		-0,709
335,020	100,665	116,540	116,534	420,173	97,994	-1,217		-0,807
333,615	100,795	121,221	121,212	420,323	103,355	-1,514		-1,103

Tabla 37. Puntos obtenidos en el perfil P-3.5 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PERFIL -4.0								
<i>H</i>	<i>V</i>	<i>INCL</i>	<i>BASE</i>	<i>X</i>	<i>Y</i>	<i>COTA</i>	<i>COM</i>	<i>Z0</i>
199,305	99,815	120,177	120,176	-120,169	-1,312	0,349	D(-3,-2)	0,760
376,185	99,625	128,304	128,302	478,682	45,536	0,756		1,167
375,860	99,910	128,478	128,478	478,604	46,210	0,182	SHLN	0,592
373,500	100,180	130,733	130,732	478,822	51,513	-0,370		0,041
371,105	100,290	132,966	132,965	478,755	56,951	-0,606		-0,195
368,820	100,455	135,265	135,262	478,613	62,283	-0,967		-0,556
366,310	100,590	137,581	137,575	478,009	68,106	-1,275		-0,864
364,375	100,680	140,556	140,548	478,363	73,261	-1,501		-1,091
362,990	100,655	142,128	142,120	478,026	76,698	-1,462		-1,052
362,130	100,595	143,570	143,564	478,156	79,104	-1,342		-0,931
361,275	100,370	145,239	145,237	478,438	81,650	-0,844		-0,433
359,250	100,385	148,395	148,392	478,269	87,283	-0,897		-0,487
357,145	100,490	152,301	152,296	478,326	93,603	-1,172		-0,761
355,995	100,530	154,759	154,754	478,485	97,305	-1,288		-0,878
352,970	100,500	158,838	158,833	476,681	105,604	-1,247		-0,837
351,770	100,555	163,122	163,116	477,755	110,741	-1,422		-1,011
350,290	100,625	166,391	166,383	477,438	115,765	-1,634		-1,223

Tabla 38. Puntos obtenidos en el perfil P-4.0 el día 17 de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM comentarios: SHLN línea de orilla; X ccordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

POSICION BANDERAS								
H	V	INCL	BASE	X	Y	COTA	COM	Z0
277,435	95,700	9,560	9,538	20,253	34,237		PC	1,075
205,970	99,460	64,729	64,727	-40,878	31,352		PN	0,979
236,620	97,540	15,992	15,980	10,155	33,985		B1	1,048
261,270	99,845	23,684	23,684	10,028	44,726		B2	0,488
288,425	99,720	19,330	19,330	20,069	44,302		B3	0,515
289,635	99,785	21,536	21,536	20,073	46,542		B6	0,503
290,540	101,075	24,493	24,490	19,938	49,511		B7	0,016
321,150	99,755	20,072	20,072	30,110	44,266		B4	0,507
339,760	94,900	11,714	11,676	30,391	34,764		B5	1,367
262,150	101,265	117,067	117,044	-41,996	122,251		BN	
300,220	101,460	101,426	101,399	23,914	126,690		BC	
333,000	101,230	114,850	114,829	80,457	125,035		BS	

Tabla 39. Posiciones de las banderas para los registros de video frontales. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM número de orden: *ni*: posición inicial, *nf*: posición final; X ccordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2,7 en metros.

POSICION TRINEO							
H .	V	INCL	BASE	X	Y	COTA	COM
341,910	100,715	90,274	90,268	78,789	96,695		1
308,295	100,820	62,546	62,541	31,690	87,302		2
307,645	100,705	58,972	58,968	30,628	83,835		3
306,365	100,420	48,493	48,492	28,404	73,541		4
297,850	100,890	62,667	62,661	21,448	87,916		5
285,485	100,385	49,180	49,179	12,448	73,198		6i
284,485	100,535	48,289					6f
283,240	100,360	41,243	41,242	12,831	65,113		7i
283,115	100,415	41,110					7f
301,725	100,240	68,196	68,196	25,411	93,462		8i
301,700	100,250	67,956					8f
300,520	100,410	54,479	54,478	24,009	79,767		9i
300,300	100,475	53,591					9f
300,030	100,450	48,663	48,662	23,587	73,953		10i
299,985	100,460	48,139					10f
300,450	100,435	44,233	44,232	23,877	69,522		11
299,535	100,115	34,703	34,703	23,310	59,993		12

Tabla 40. Posiciones del trineo obtenidas durante los días 15 de diciembre de 1993 (posiciones 1 a 4) y 16 de diciembre de 1993 (posiciones 5 a 12). H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM número de orden: *ni*: posición inicial, *nf*: posición final; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

PST								
H	V	INCL	BASE	X	Y	Z	COM	Z0
297,500	101,130	41,022	41,016	21,954	66,275	-0,728	1	-0,298
291,470	101,625	56,283	56,265	16,048	81,051	-1,436	2	-1,006
273,950	101,320	54,573	54,561	1,856	75,348	-1,131	3	-0,701
266,890	101,620	63,119	63,099	-7,793	80,046	-1,606	4	-1,176
258,790	101,380	53,398	53,385	-8,630	67,877	-1,157	5	-0,727
264,440	101,405	60,940	60,925	-8,725	76,956	-1,345	6	-0,915
259,375	101,125	61,067	61,057	-12,808	74,333	-1,079	7	-0,649
251,510	101,235	53,496	53,486	-13,349	63,998	-1,038	8	-0,608
250,567	101,180	46,678	46,670	-9,141	58,584	-0,865	9	-0,435
254,620	101,335	54,540	54,528	-12,096	66,542	-1,144	10	-0,714
257,345	101,260	61,545	61,533	-14,648	73,521	-1,218	11	-0,788
261,510	101,360	64,703	64,688	-13,207	78,512	-1,382	12	-0,952
269,175	101,560	65,094	65,074	-6,728	82,885	-1,595	13	-1,165
259,055	101,345	44,264	44,254	-2,976	60,703	-0,935	14	-0,505
264,525	101,410	48,618	48,606	-2,141	66,544	-1,077	15	-0,647
268,560	101,305	57,194	57,182	-3,542	75,640	-1,172	16	-0,742
273,725	101,515	63,276	63,258	-1,809	83,237	-1,506	17	-1,076

Tabla 41. Posiciones de las medidas de sedimentos durante los días 15 (posiciones 1 a 3) y 16 (posiciones 4 a 17) de diciembre de 1993. H ángulo horizontal; V ángulo vertical; INCL distancia inclinada al punto en metros; COTA distancia vertical del punto (con respecto del teodolito) en metros; COM número de orden: n_i : posición inicial, n_f : posición final; X coordenada x en metros; Y coordenada y en metros; Z0 coordenada en z respecto a la referencia 2.7 en metros.

LISTA DE FIGURAS

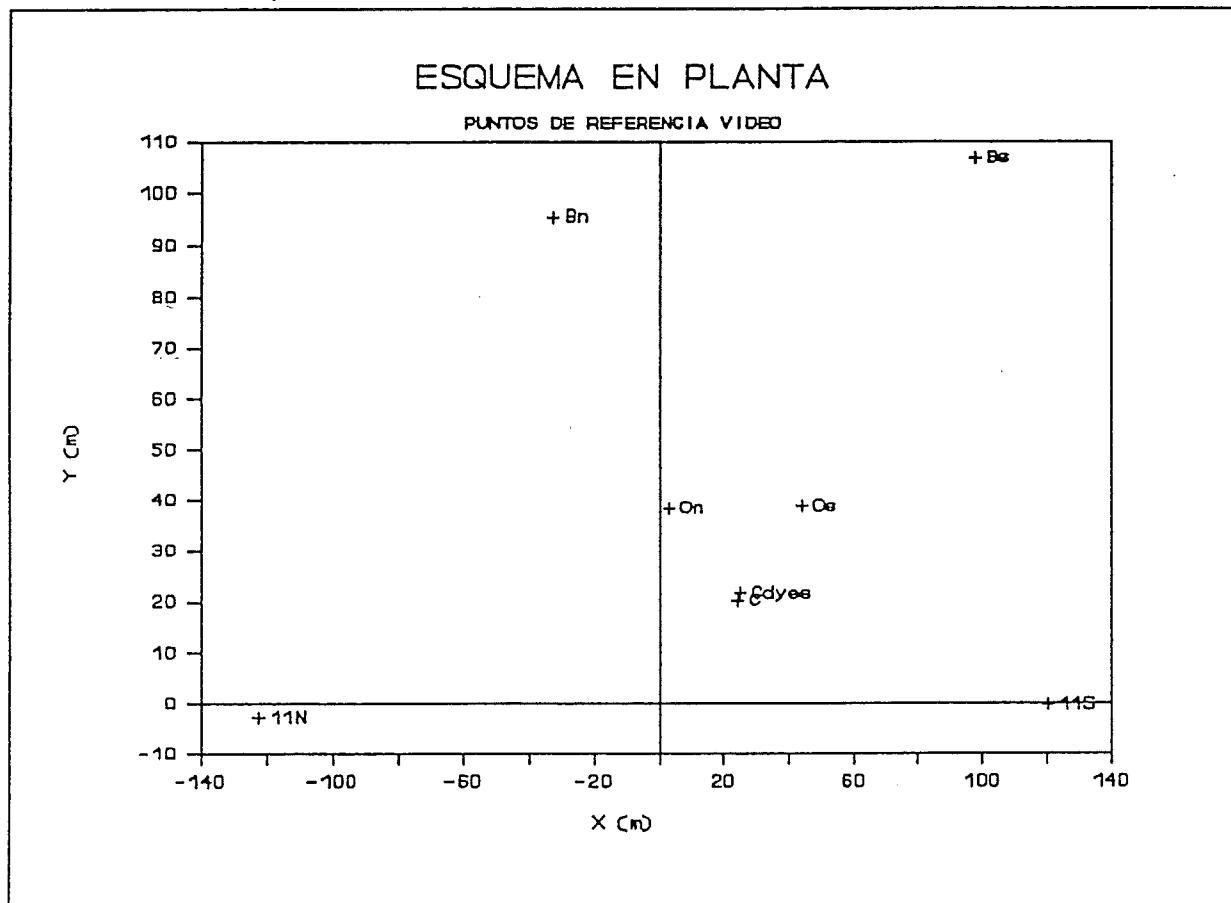


Figura 1. Esquema en planta de los puntos de referencia tomados durante las imágenes de video para la caracterización de los trazadores.

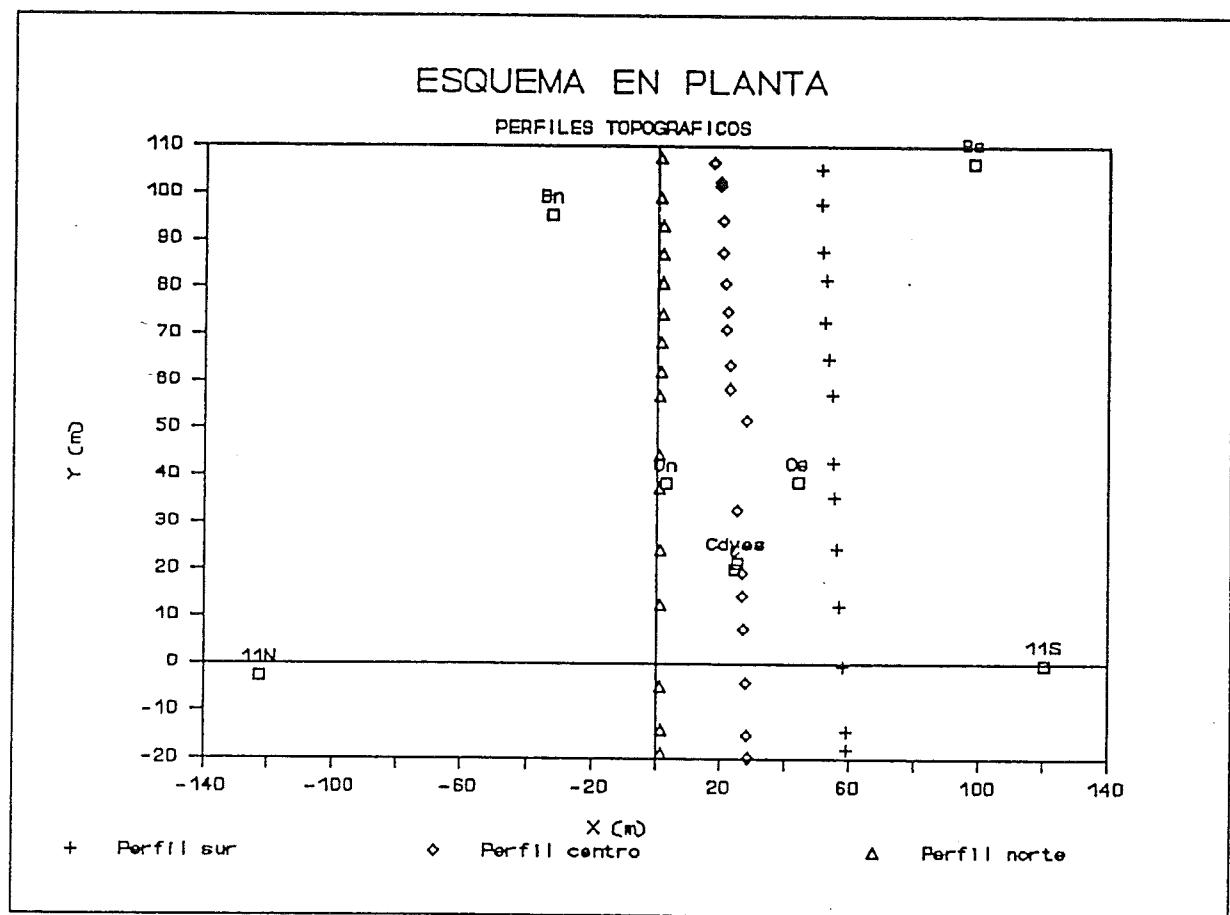


Figura 2. Esquema en planta de los puntos de los perfiles norte, centro y sur.

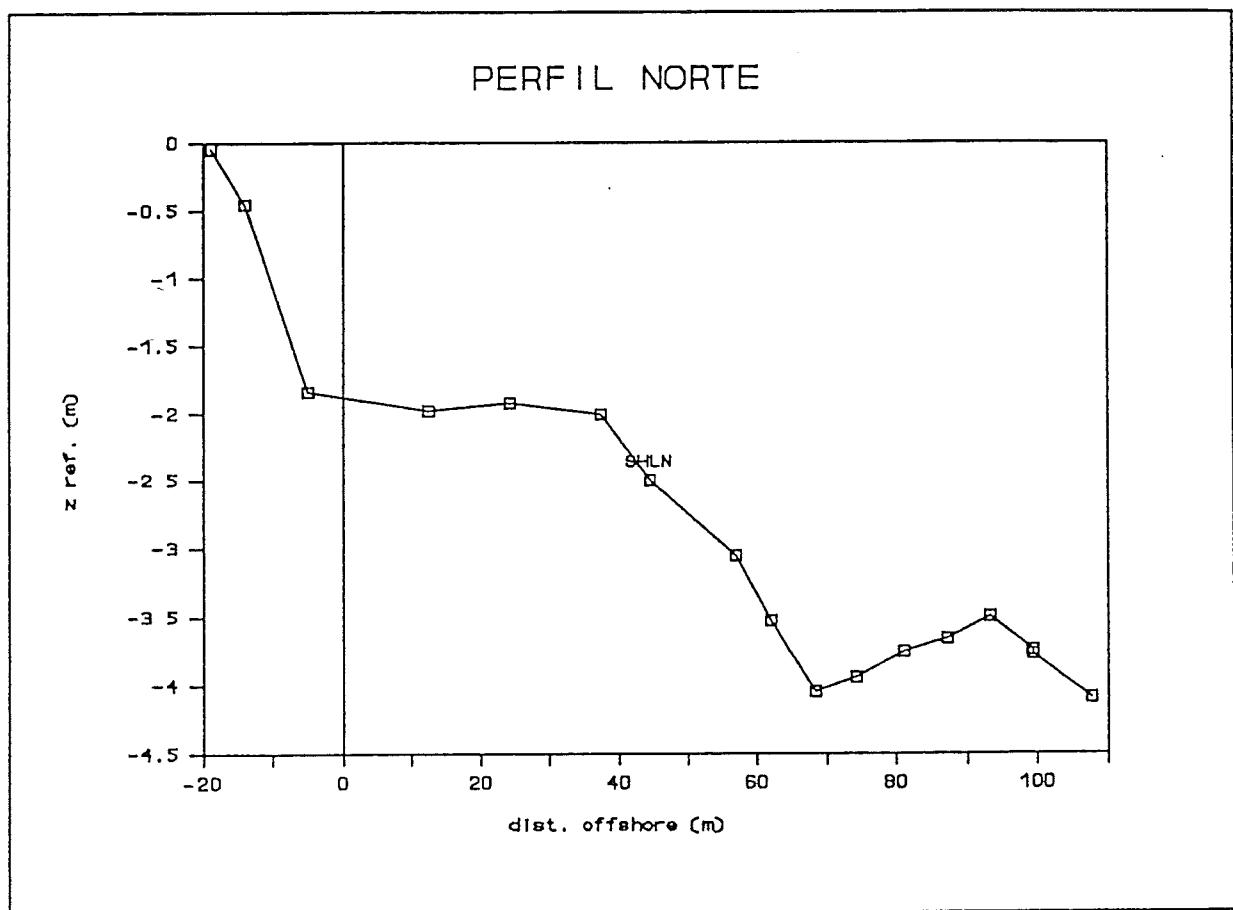


Figura 3. Perfil norte

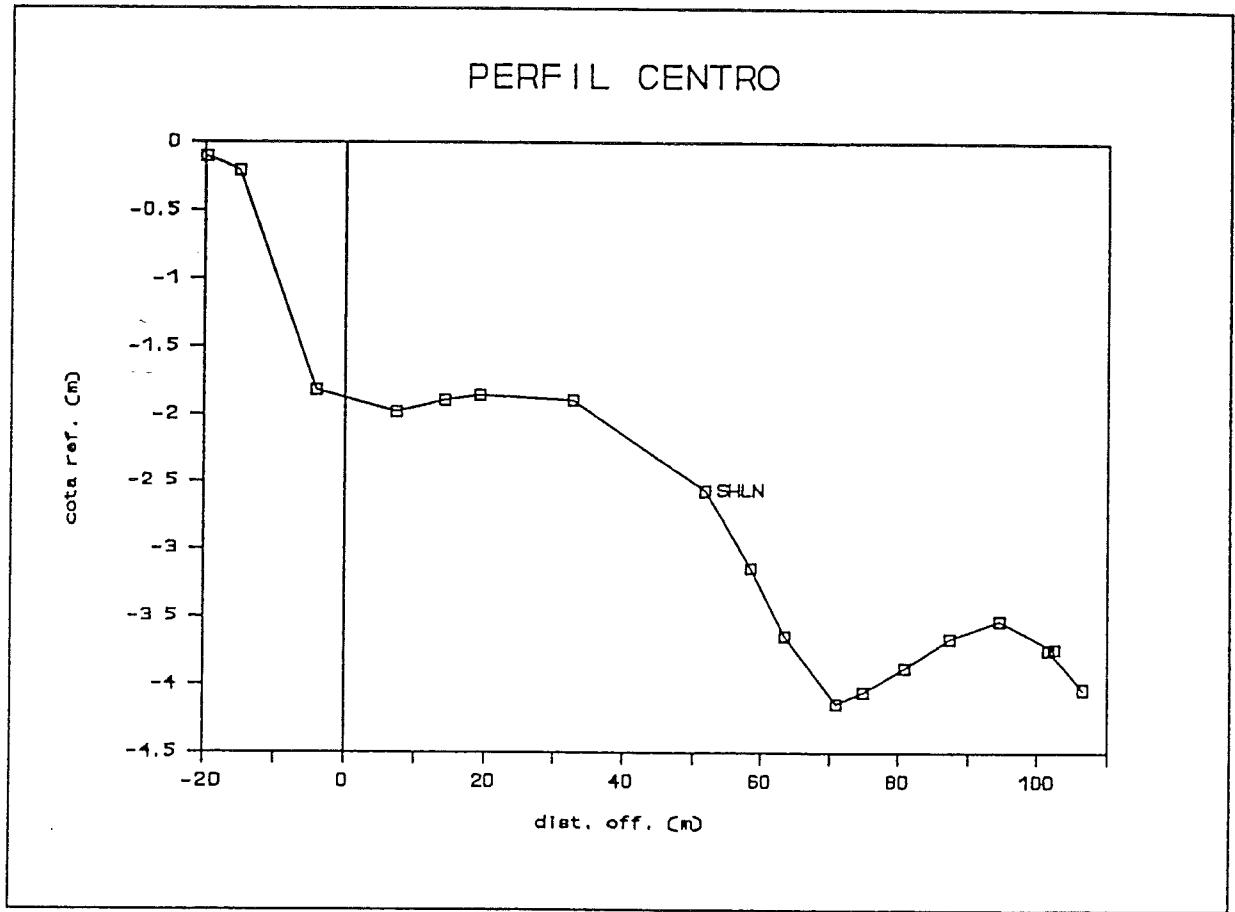


Figura 4. Perfil centro

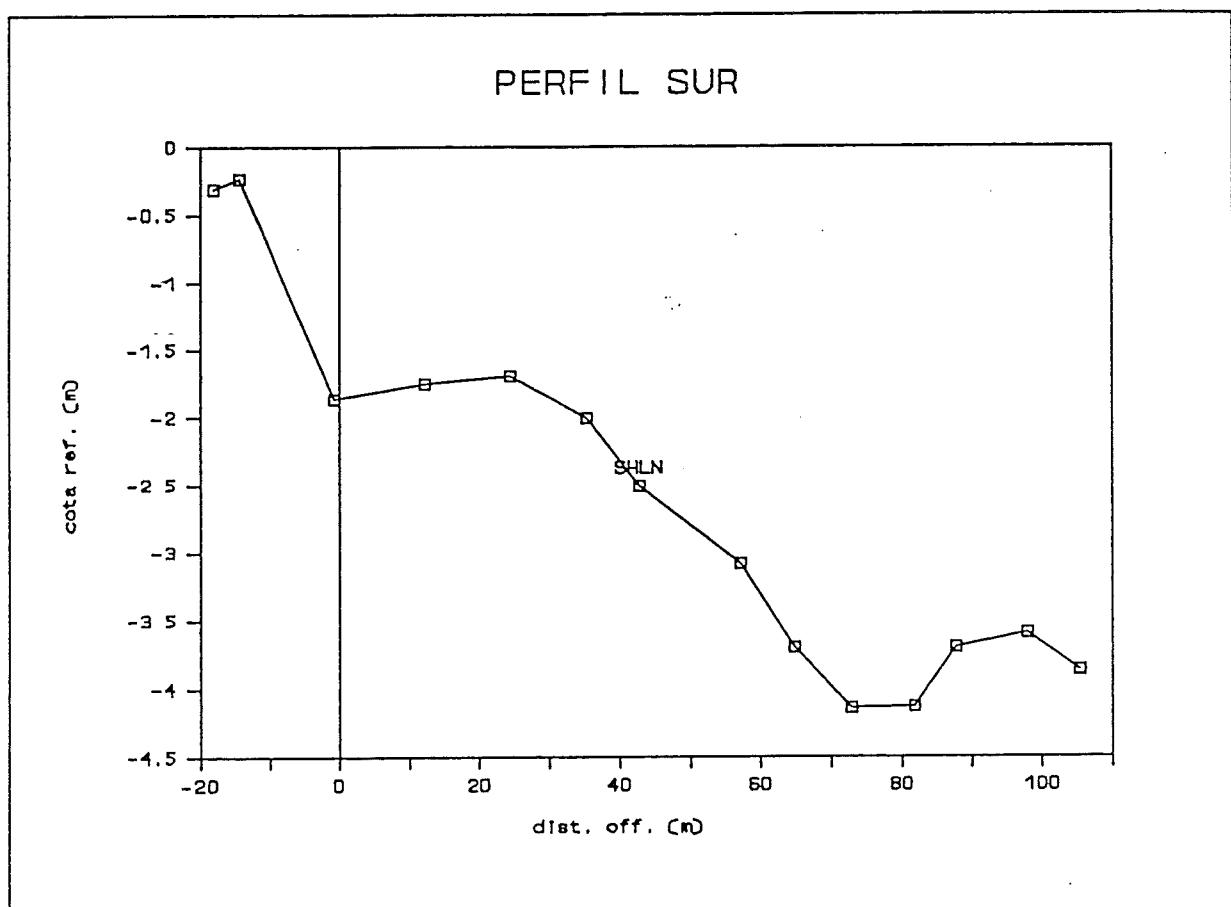
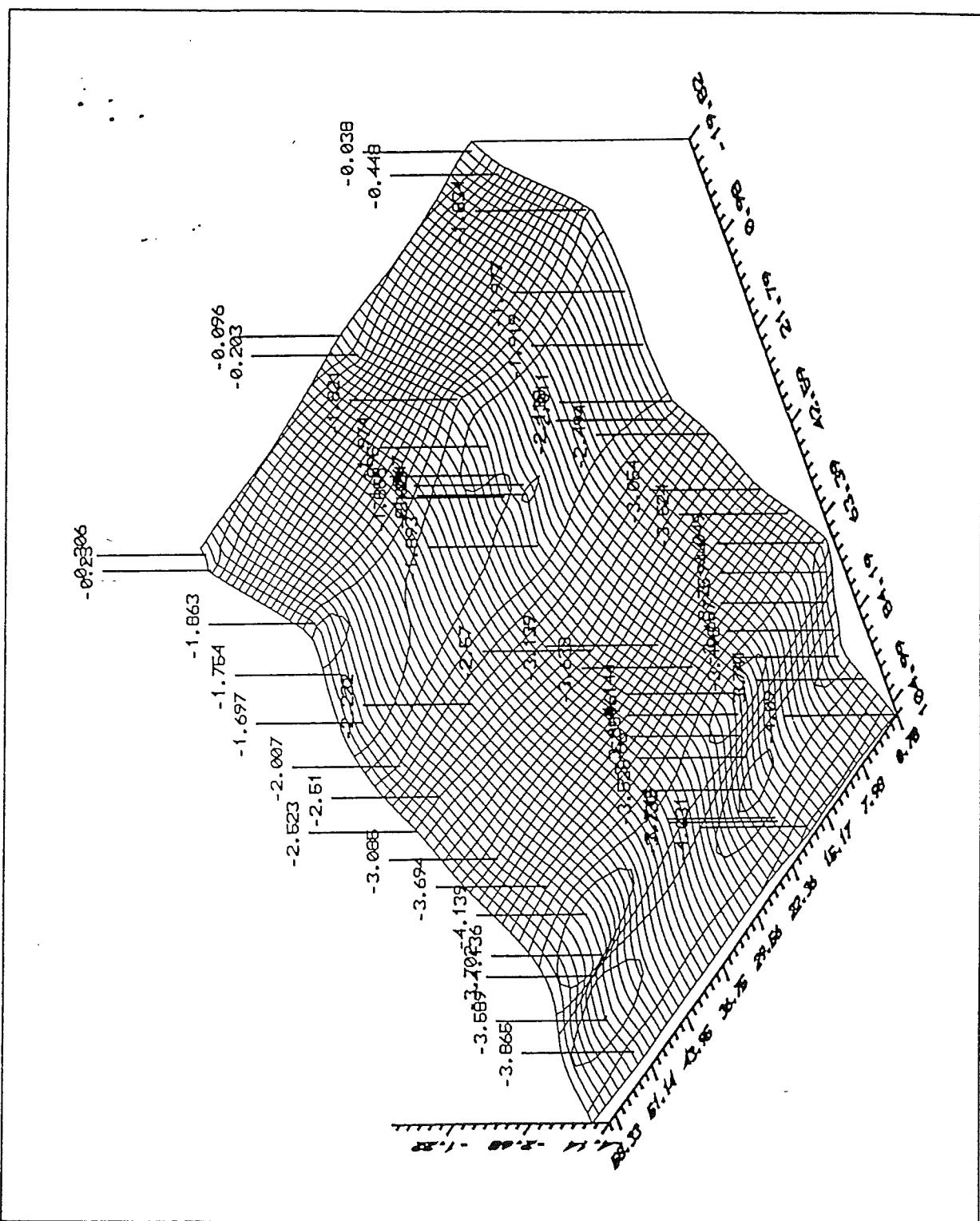


Figura 5. Perfil sur.



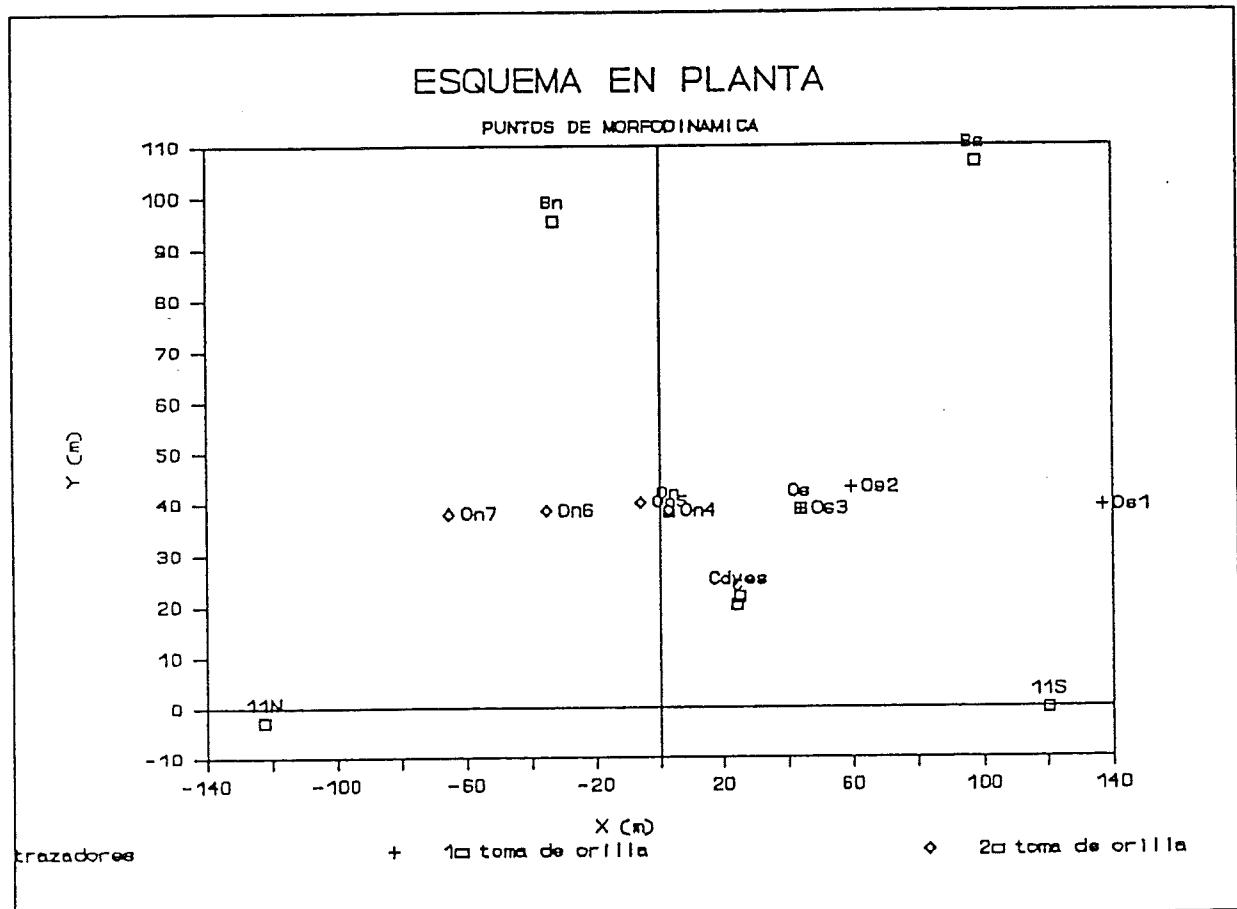


Figura 7. Esquema en planta de los puntos de referencia tomados durante las imágenes de video para la caracterización morfodinámica de la playa.

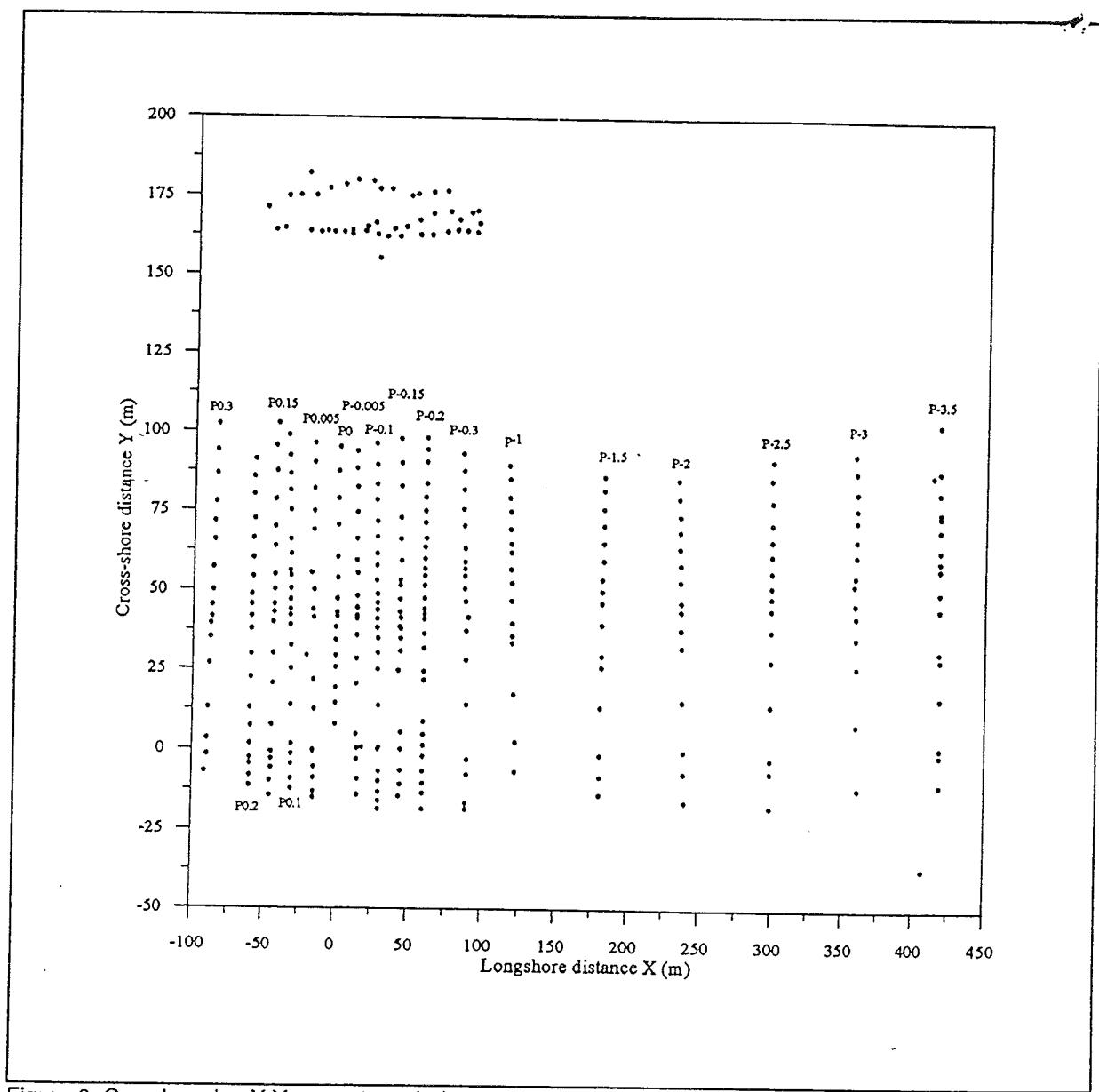


Figura 8. Coordenadas X,Y en metros de los perfiles topográficos realizados el día 13/12/1993.

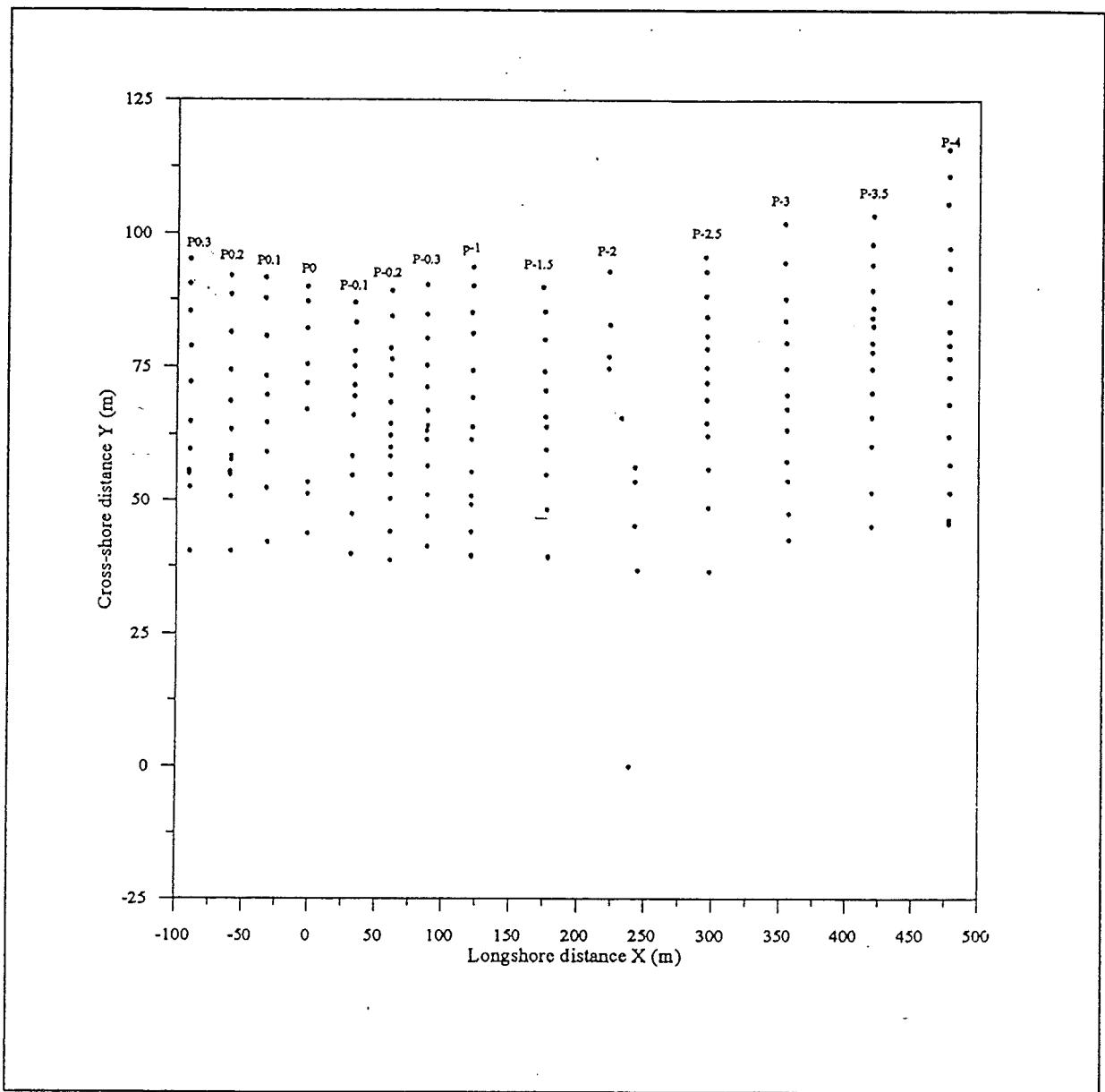


Figura 9. Coordenadas X,Y en metros de los perfiles topográficos realizados el día 17/12/1993.

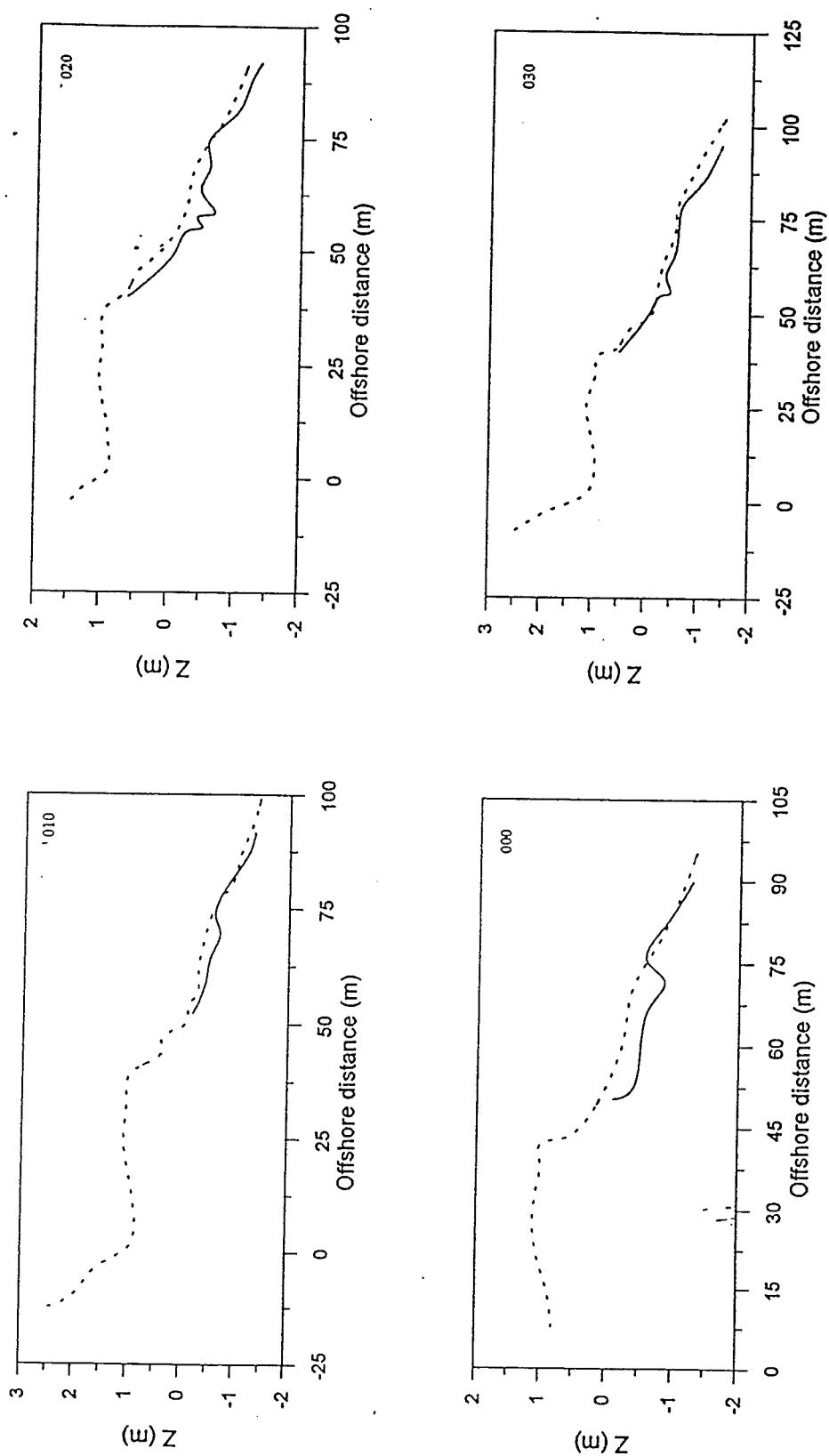
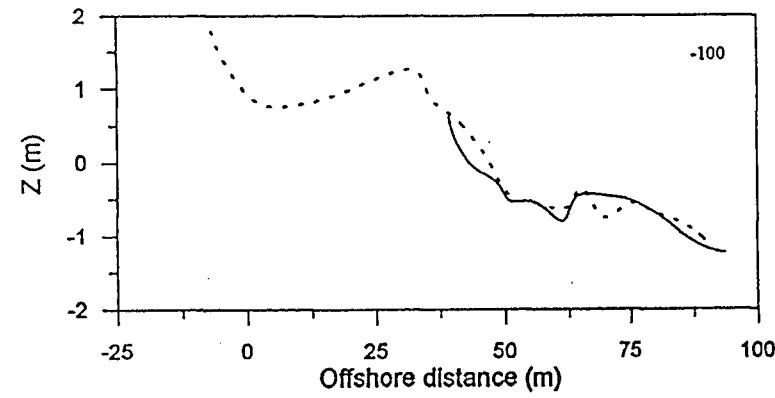
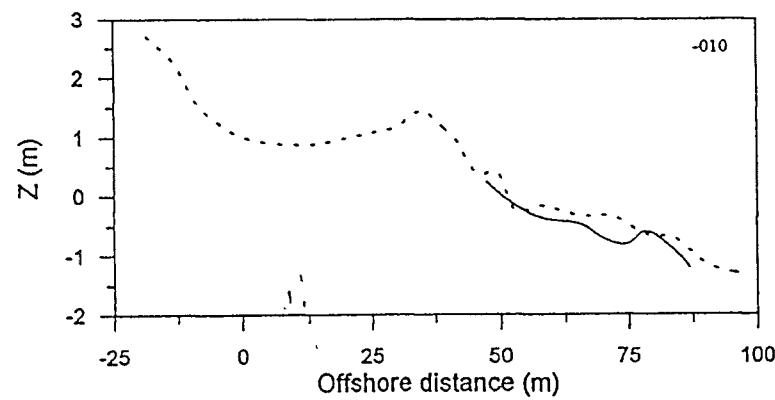
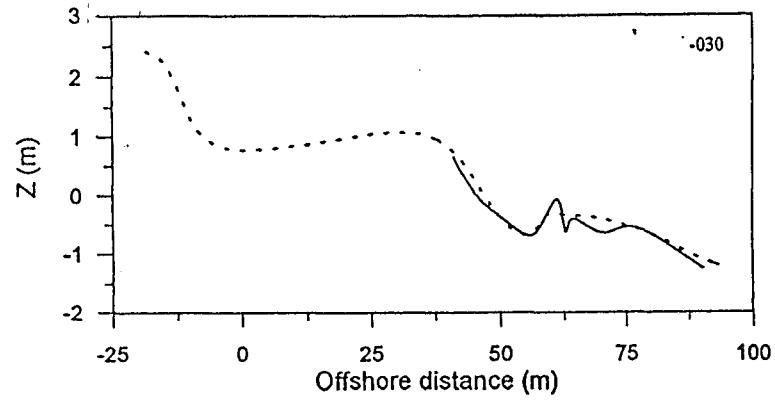
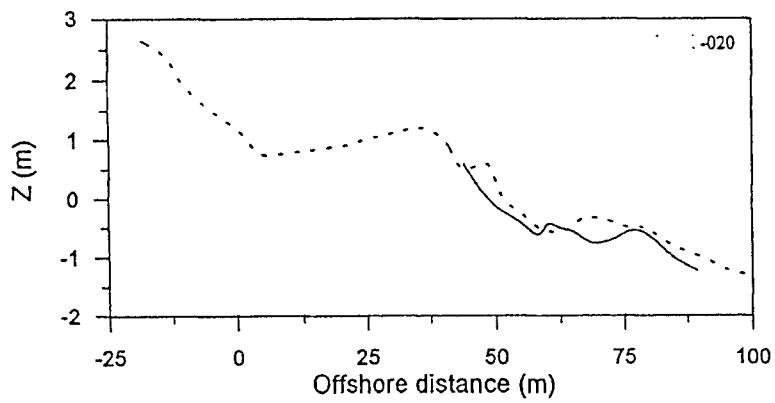


Figura 10. Perfiles topográficos

Figura 10. Perfiles topográficos



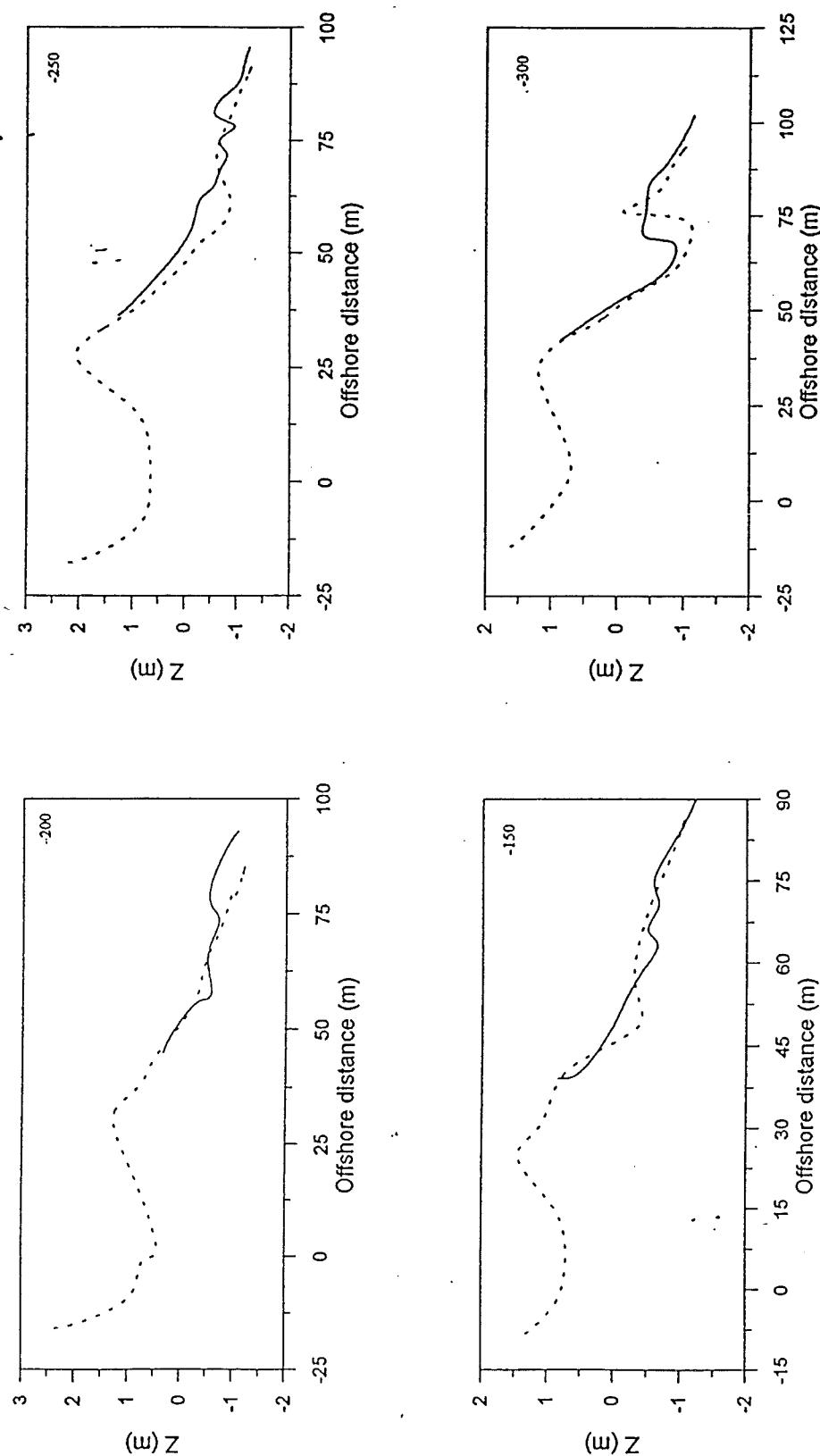


Figura 10. Perfiles topográficos

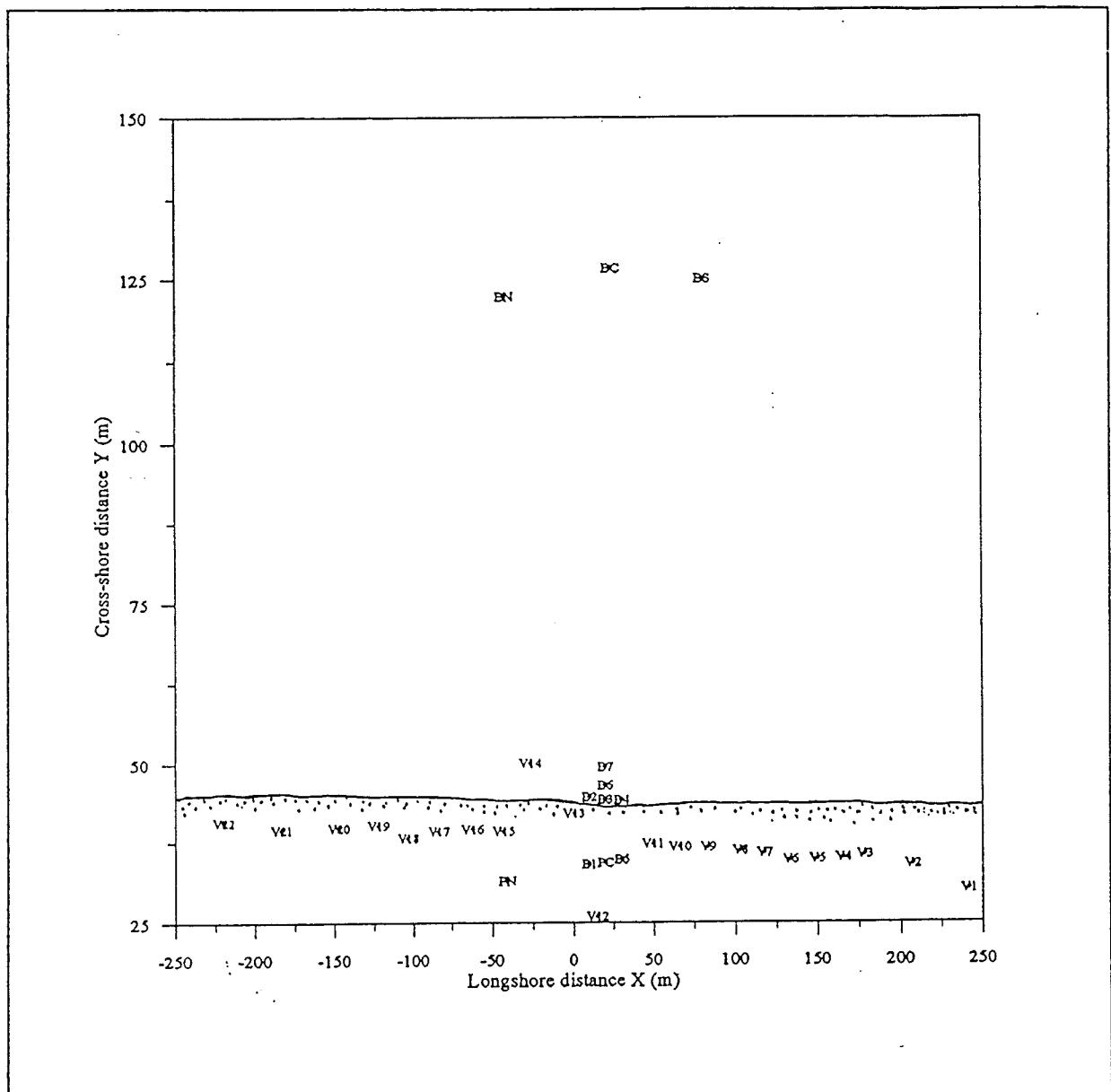


Figura 11. Coordenadas X,Y en metros de los puntos de referencia del vídeo.

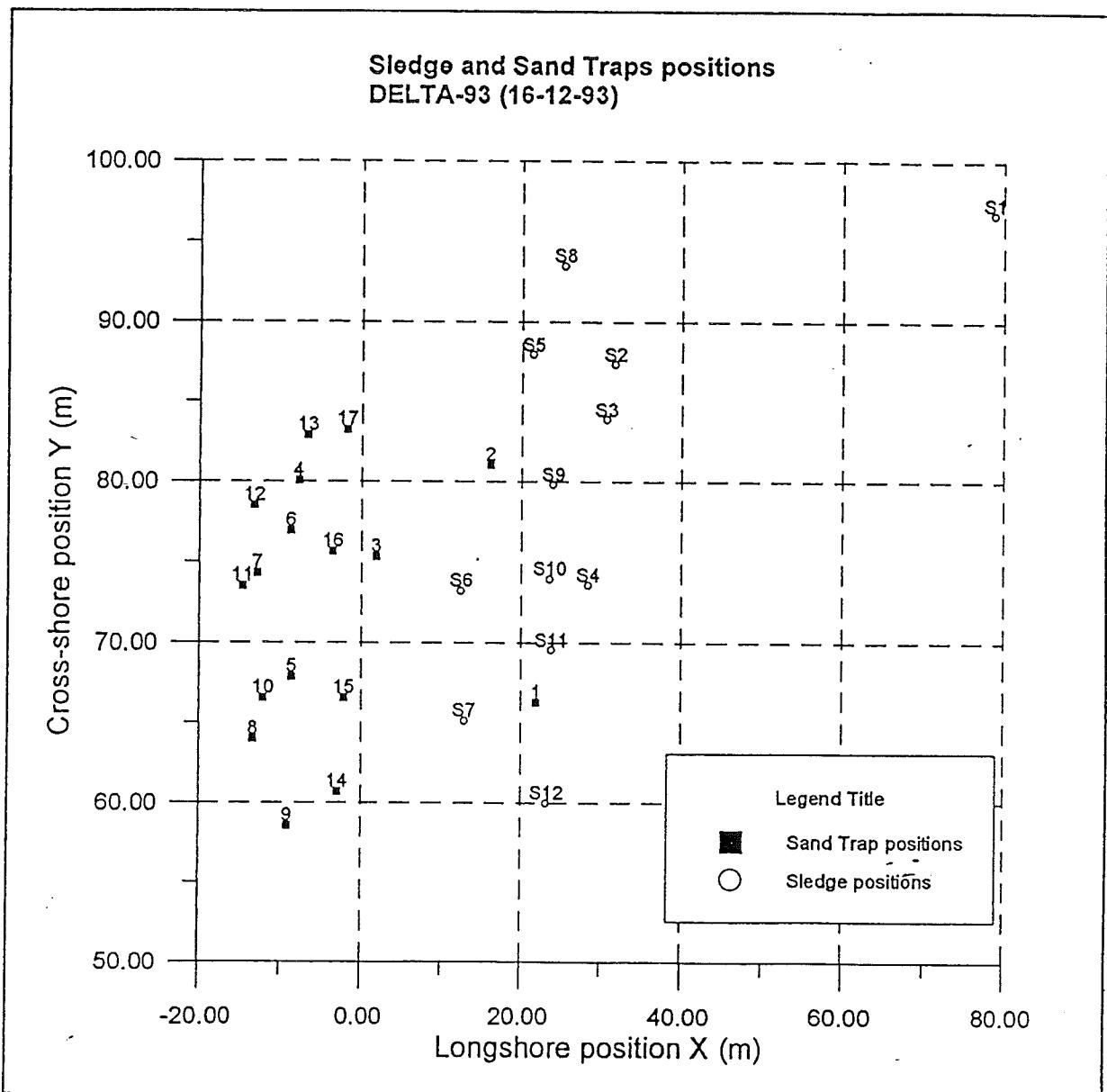
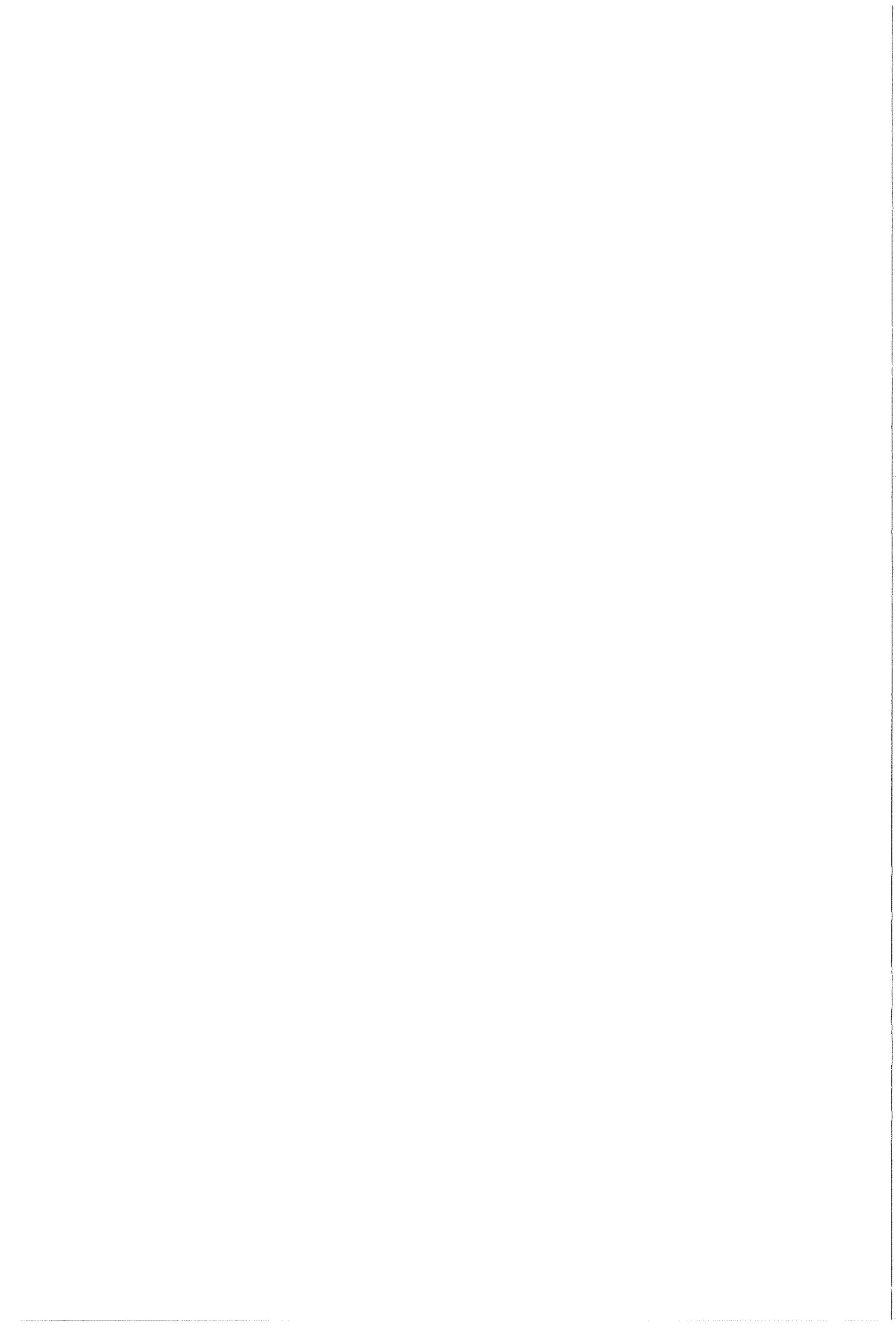
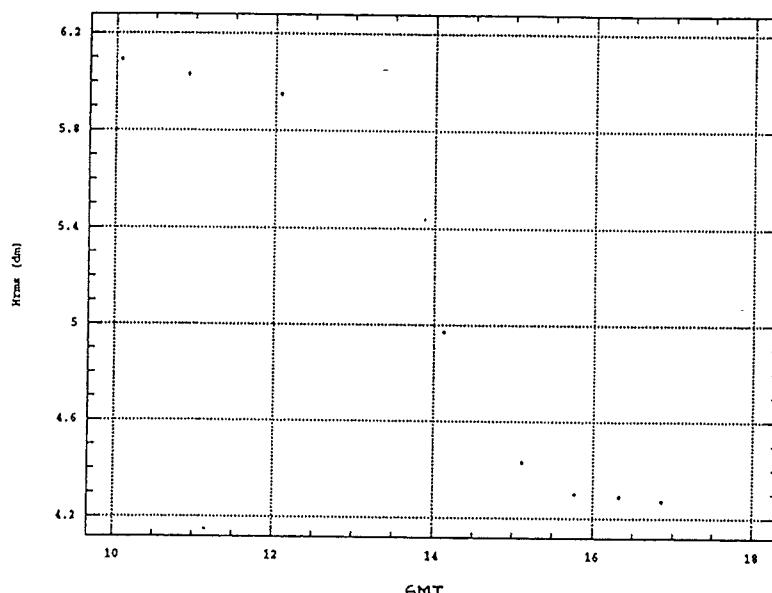


Figura 12. Coordenadas X,Y en metros de las posiciones del trineo y las trampas de sedimento.

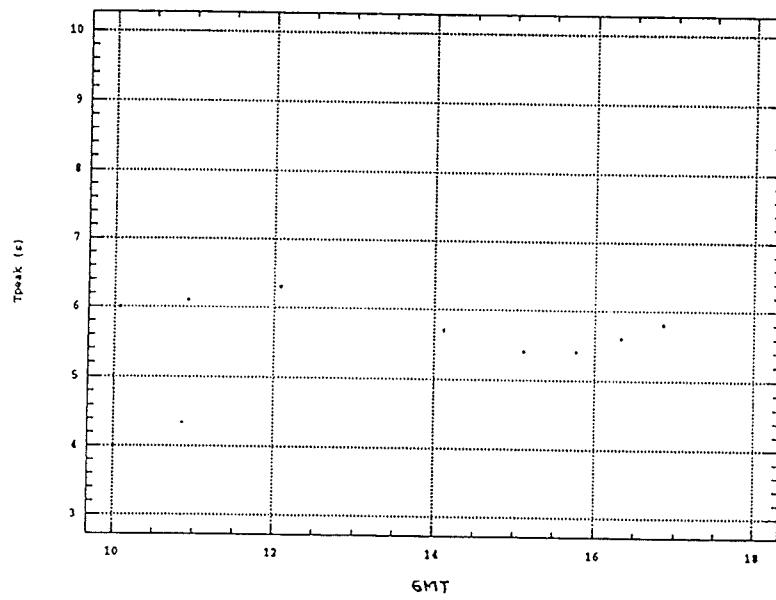
C2. Olas fuera de la ZR (*DWR*)



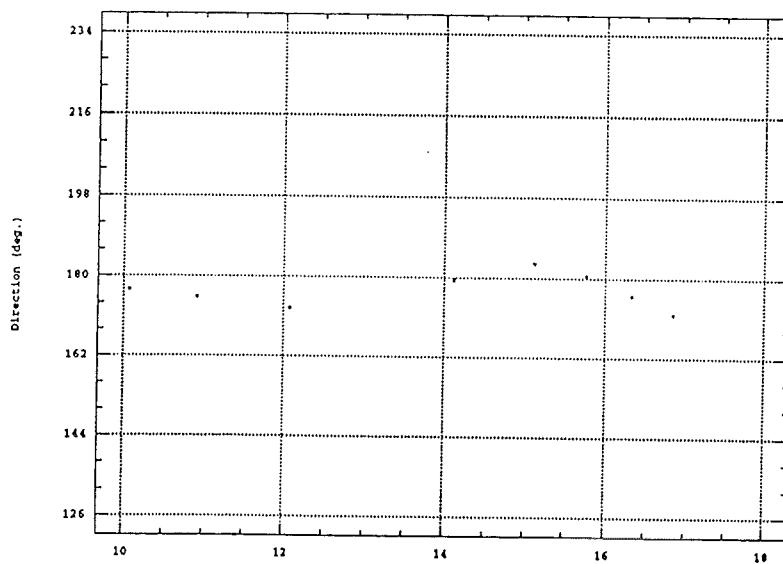
Measured Hrms vs time at 1500 m offshore
16/12/93, Delta Ebro, P11



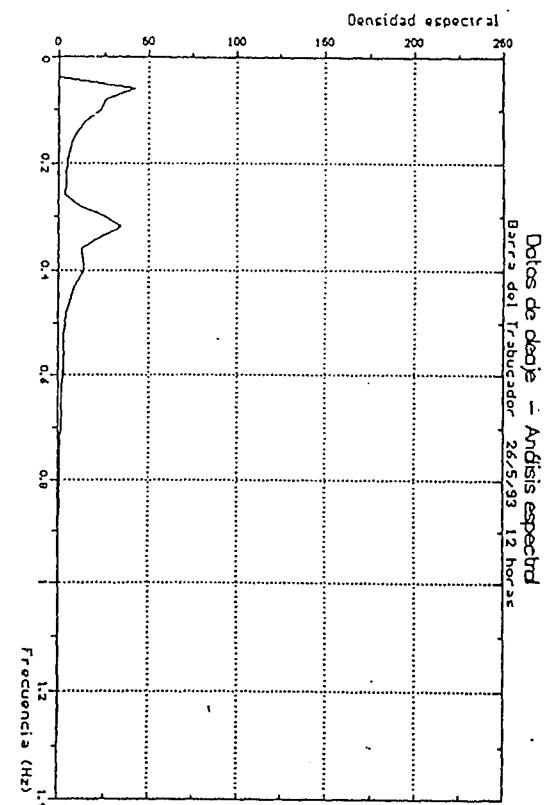
MeasuredTp vs time at 1500 m offshore
16/12/93, Delta Ebro, P11



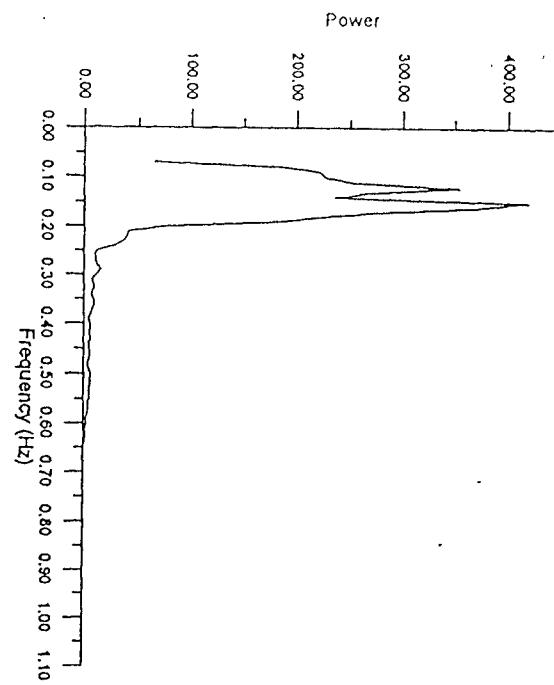
Measured Teta vs time at 1500 m offshore
16/12/93, Delta Ebro, P11



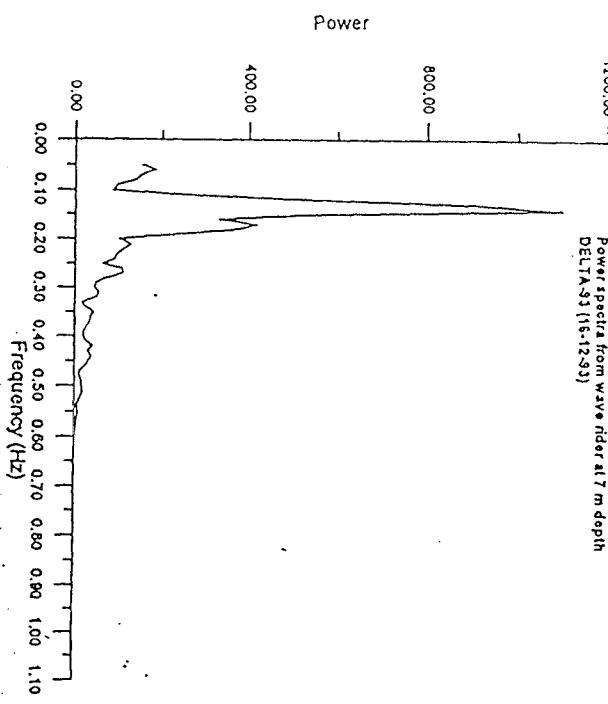
Directional Wave Rider position



Power spectrum from wave rider at 7 m depth
DELTA-33 {16-12-93}



Power spectra from wave rider at 7 m depth
DELTA-33 {16-12-93}



Power spectra from wave rider at 7 m depth
DELTA-33 {16-12-93}

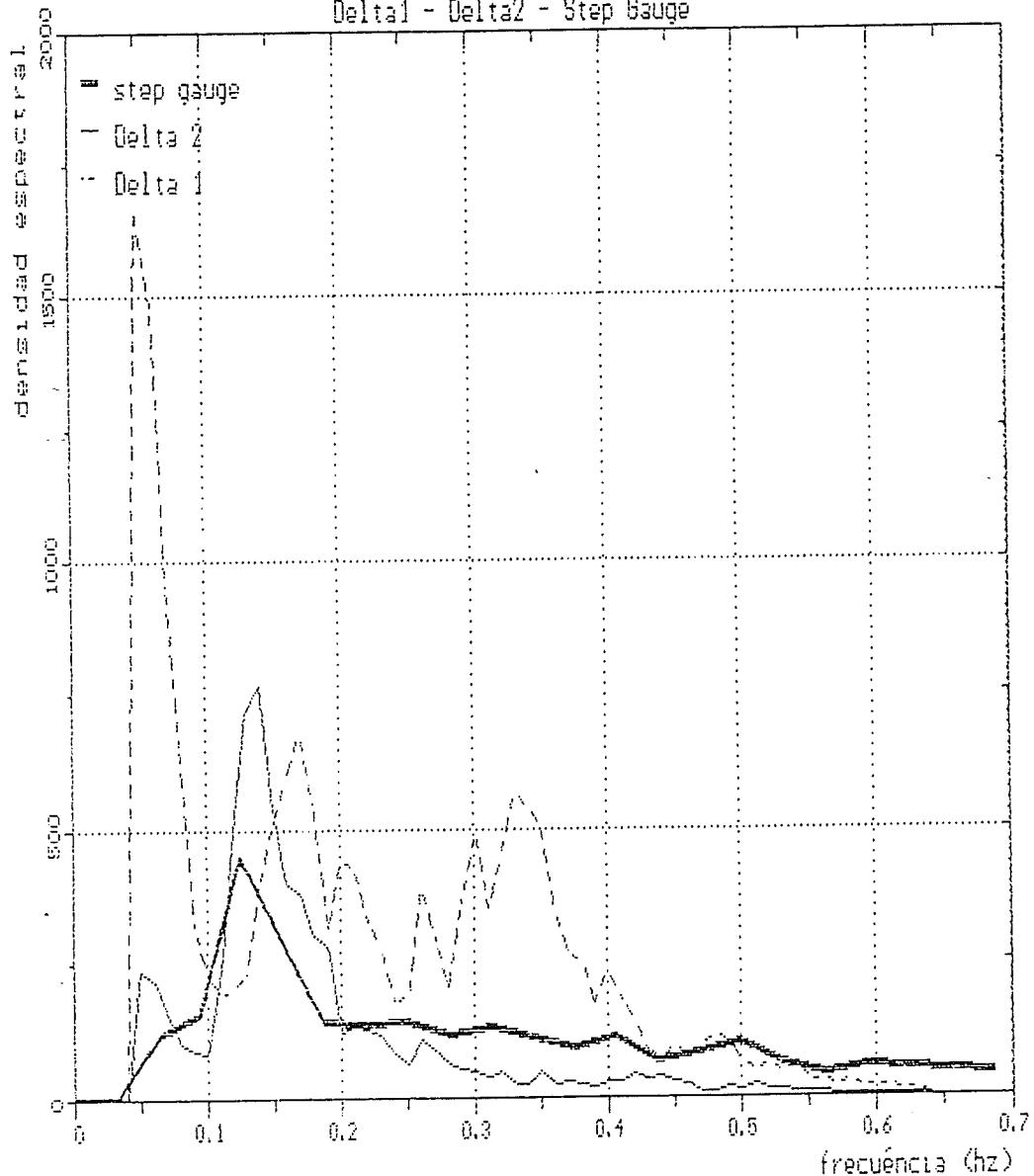
Comparación de Espectros de Energía del oleaje

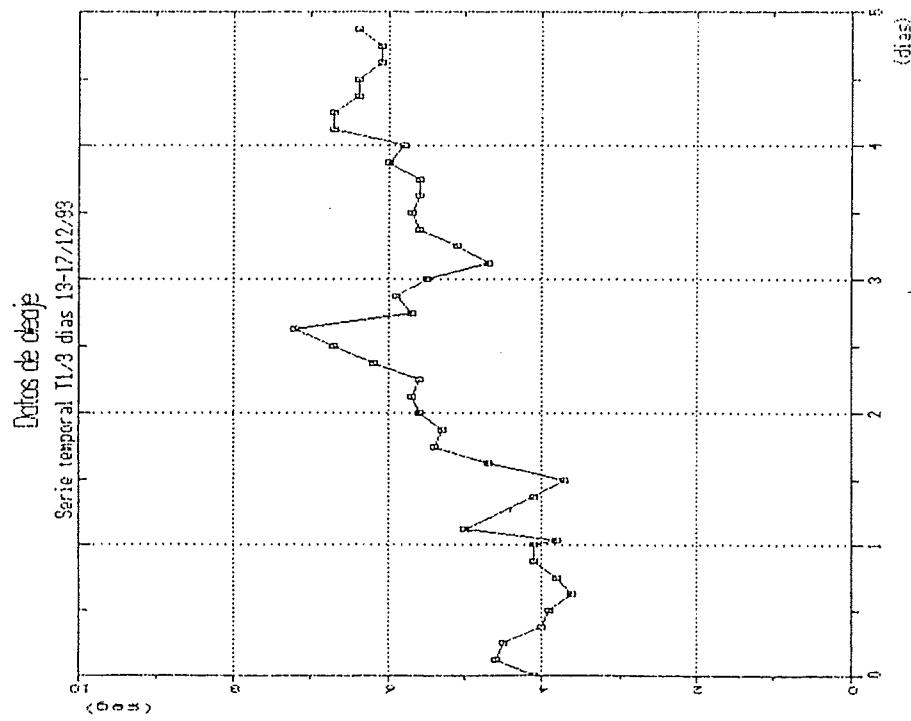
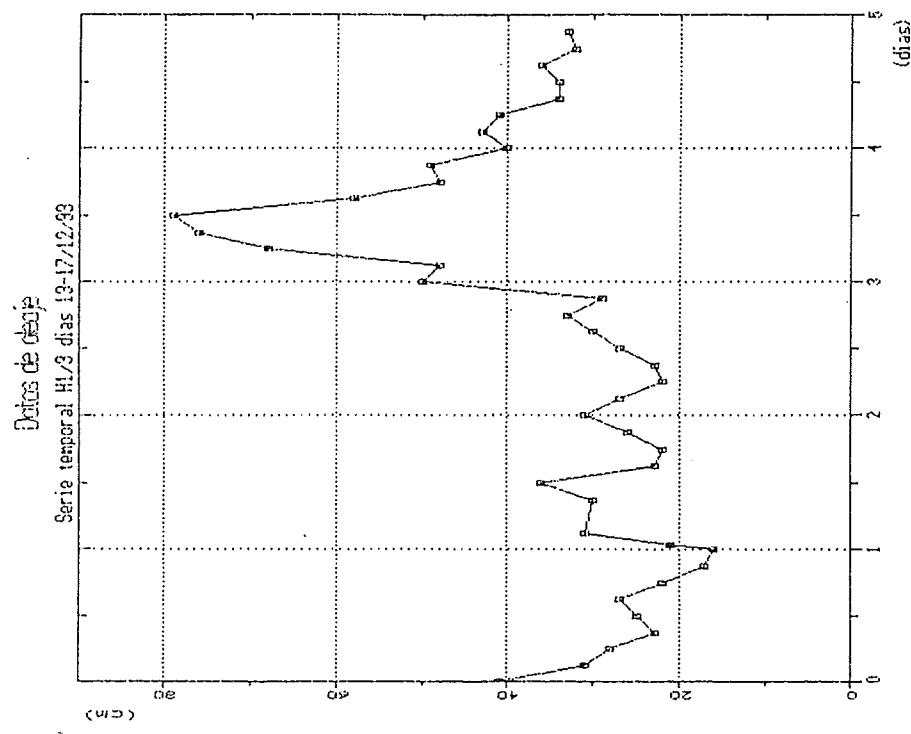
Día: 16/12/93, Case IV, Boyas Trabucador, Cap Tortosa y WG

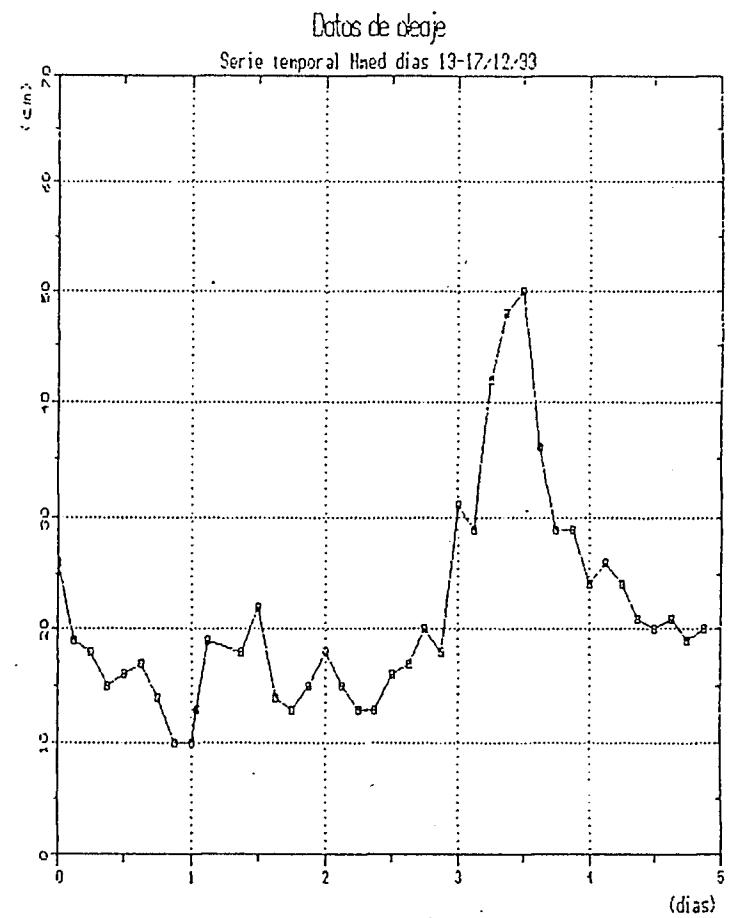
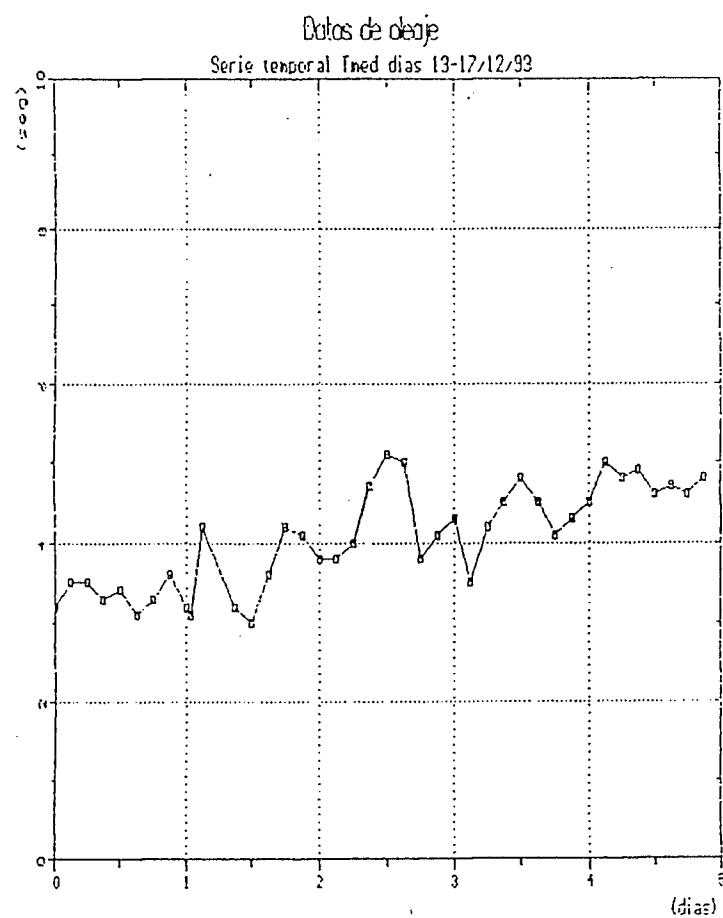
$T_{Trab} : 12161520$, $T_{Cap\ Tort.} : 12161517$, $T_{wg} : Test\ 10$

ANÁLISIS ESPECTRAL DE OLEAJE

Delta1 - Delta2 - Step Gauge

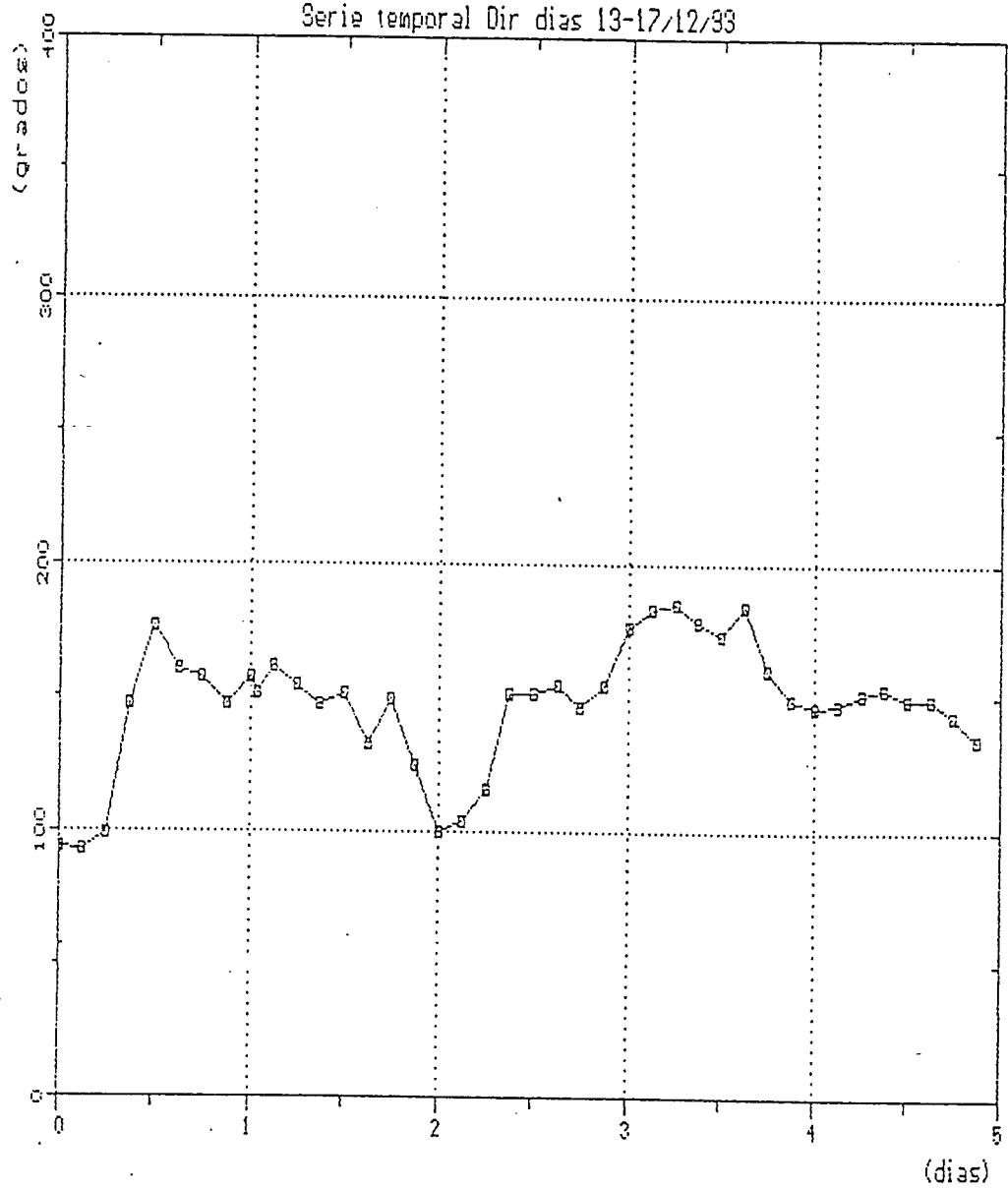


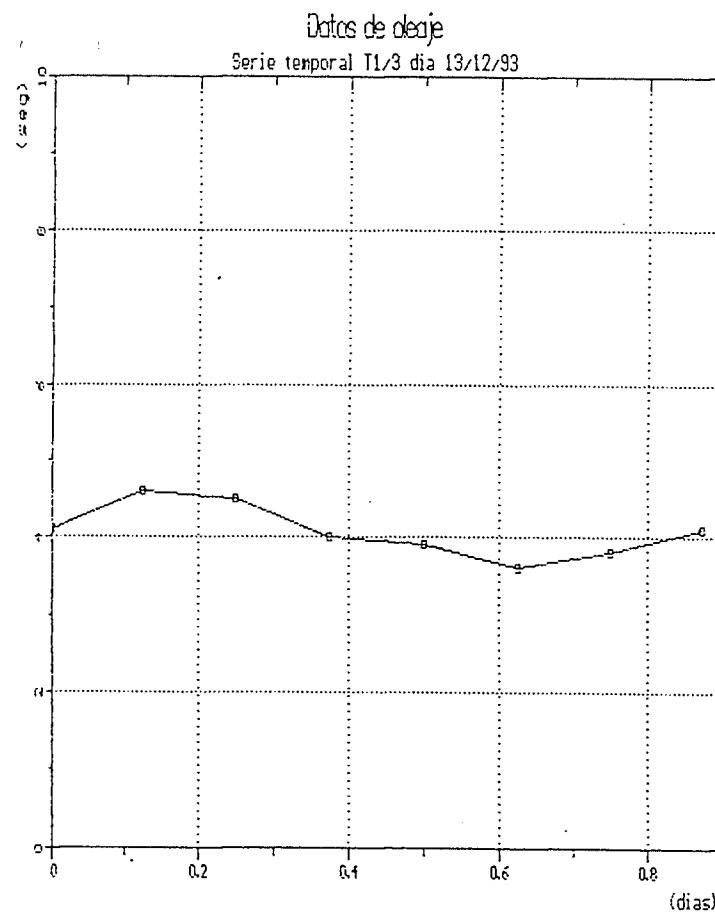
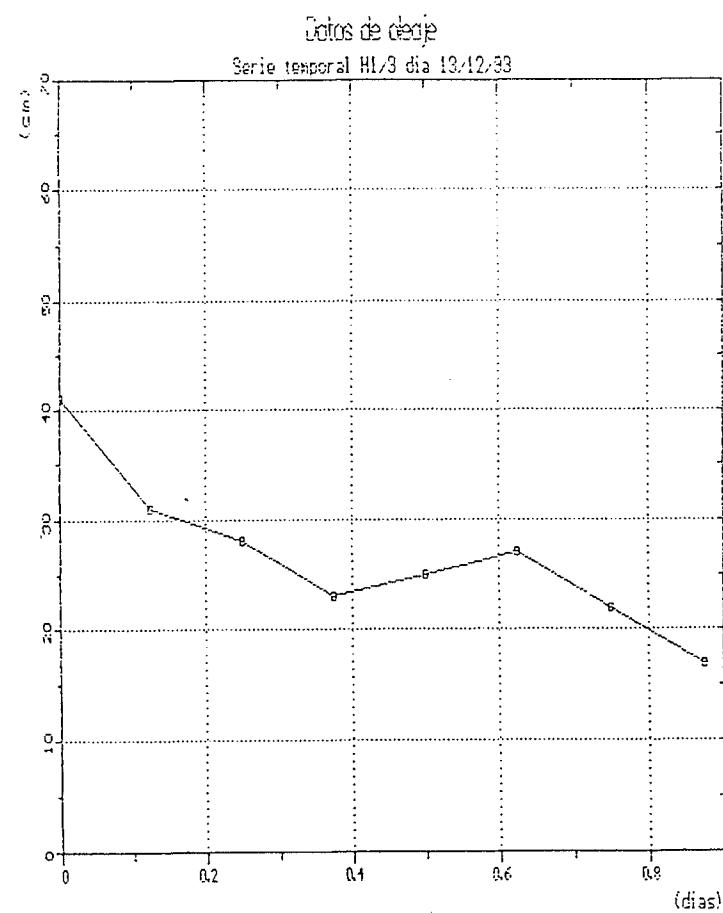




Datos de oleaje

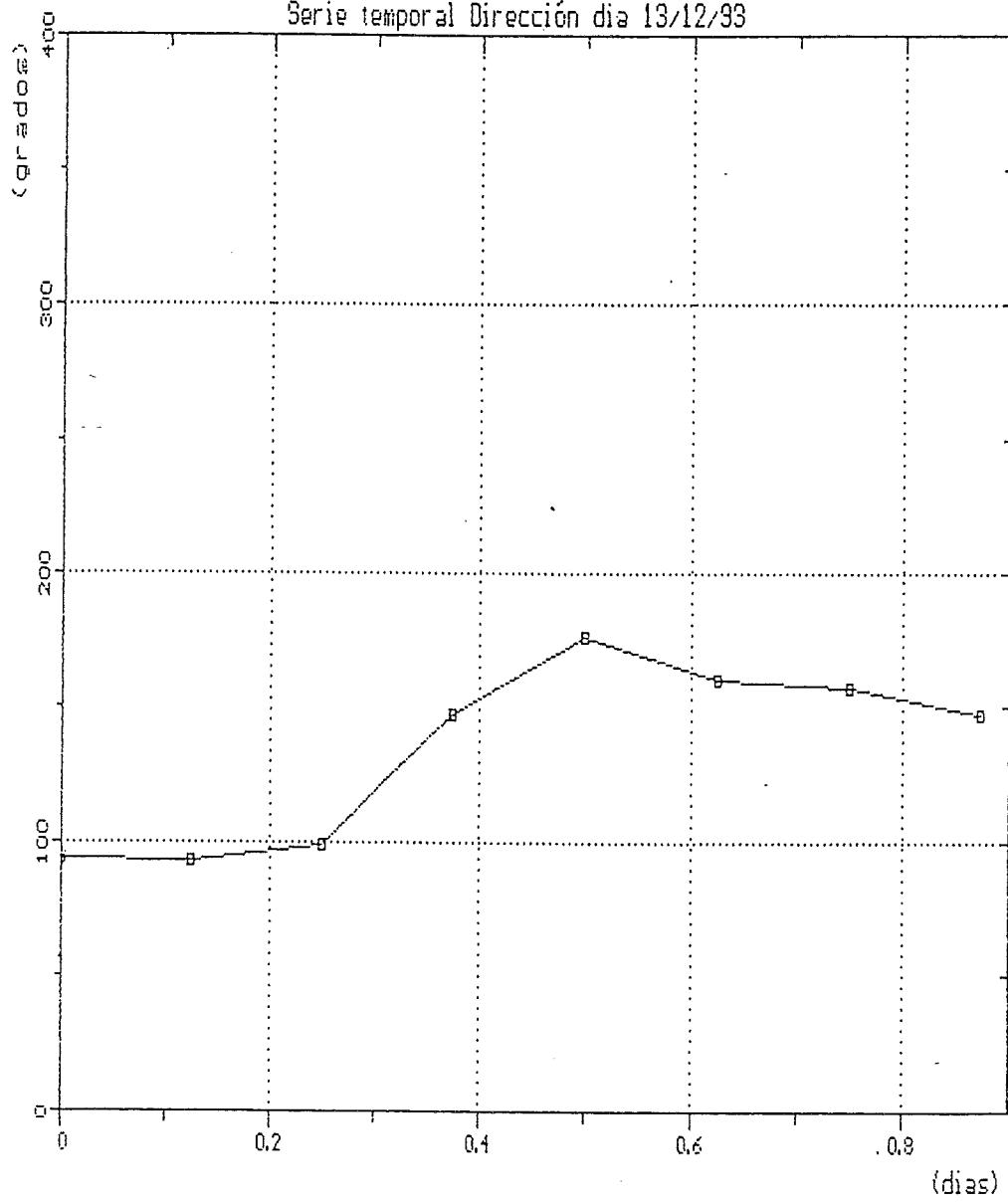
Serie temporal Dir días 13-17/12/93

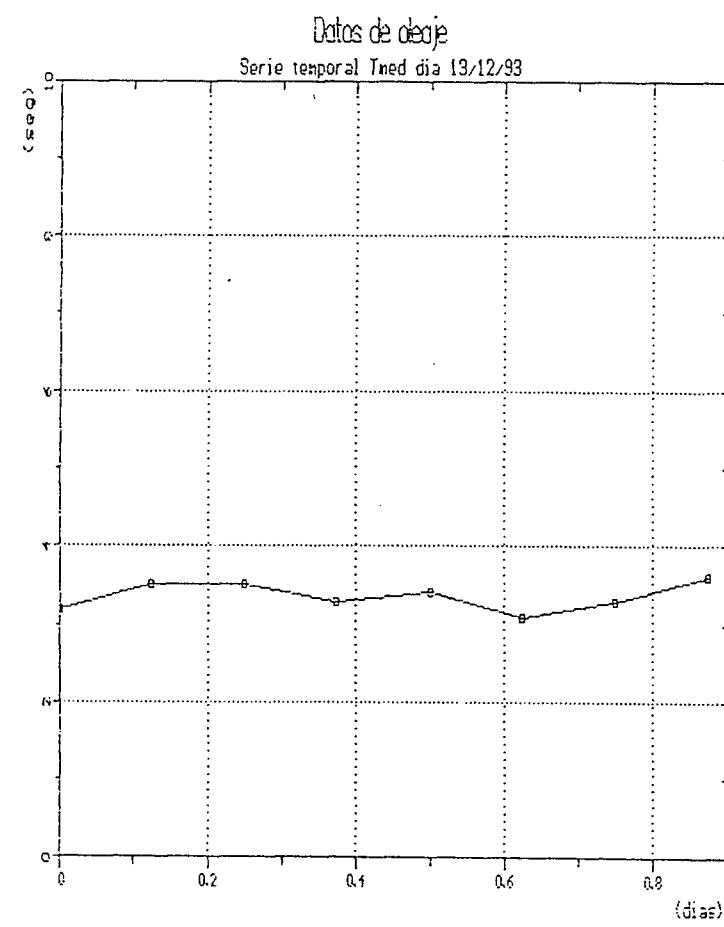
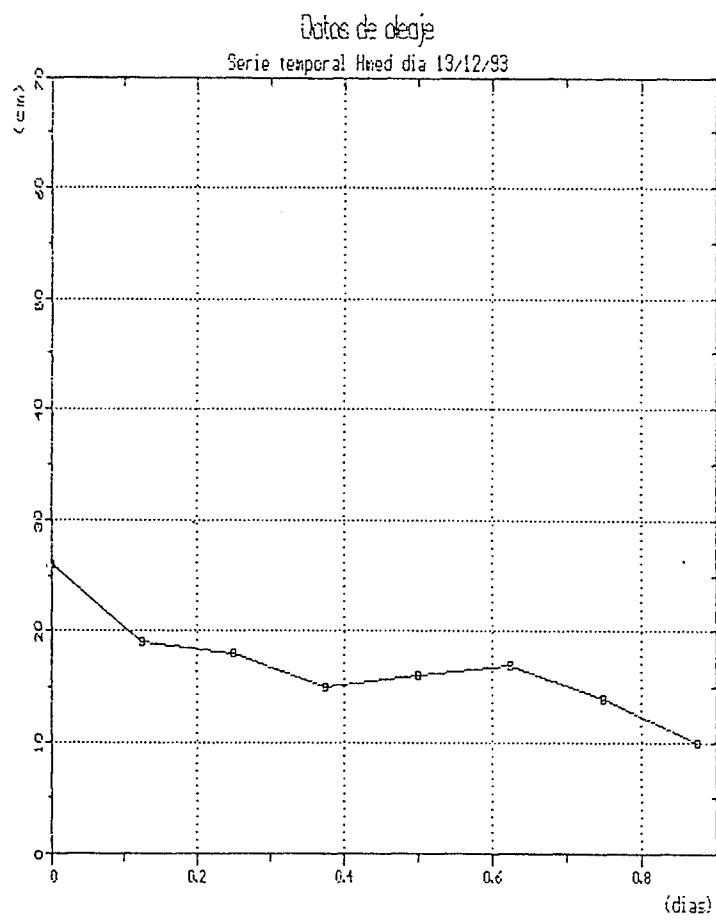


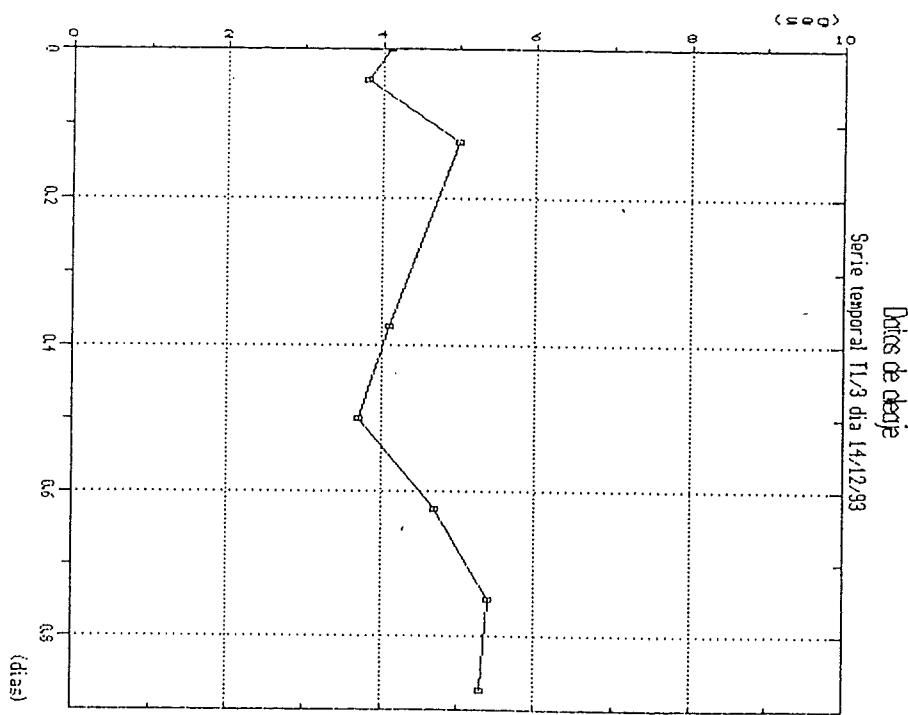
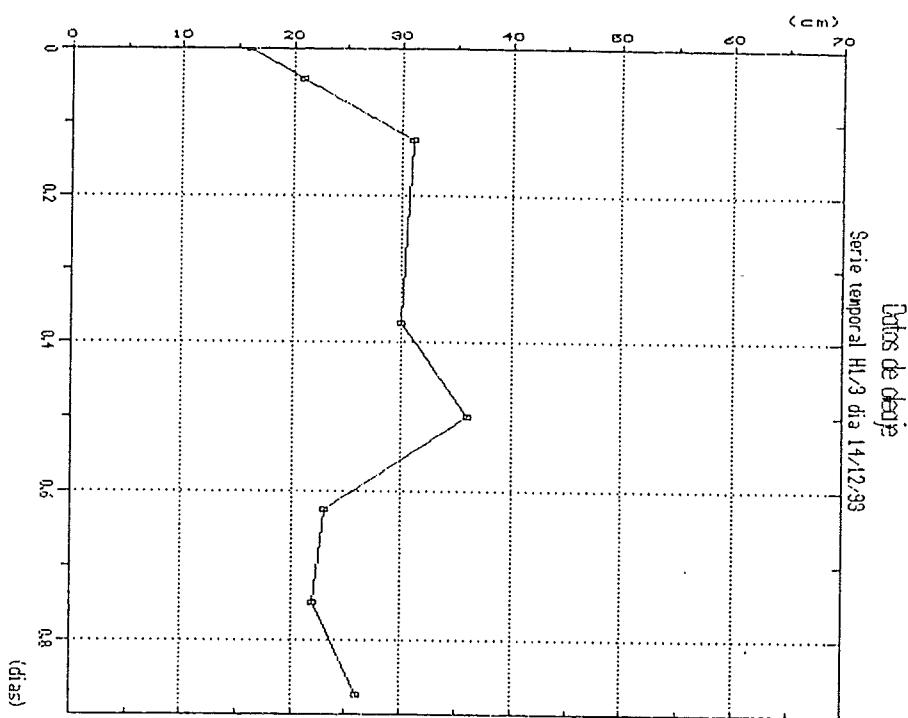


Datos de oleaje

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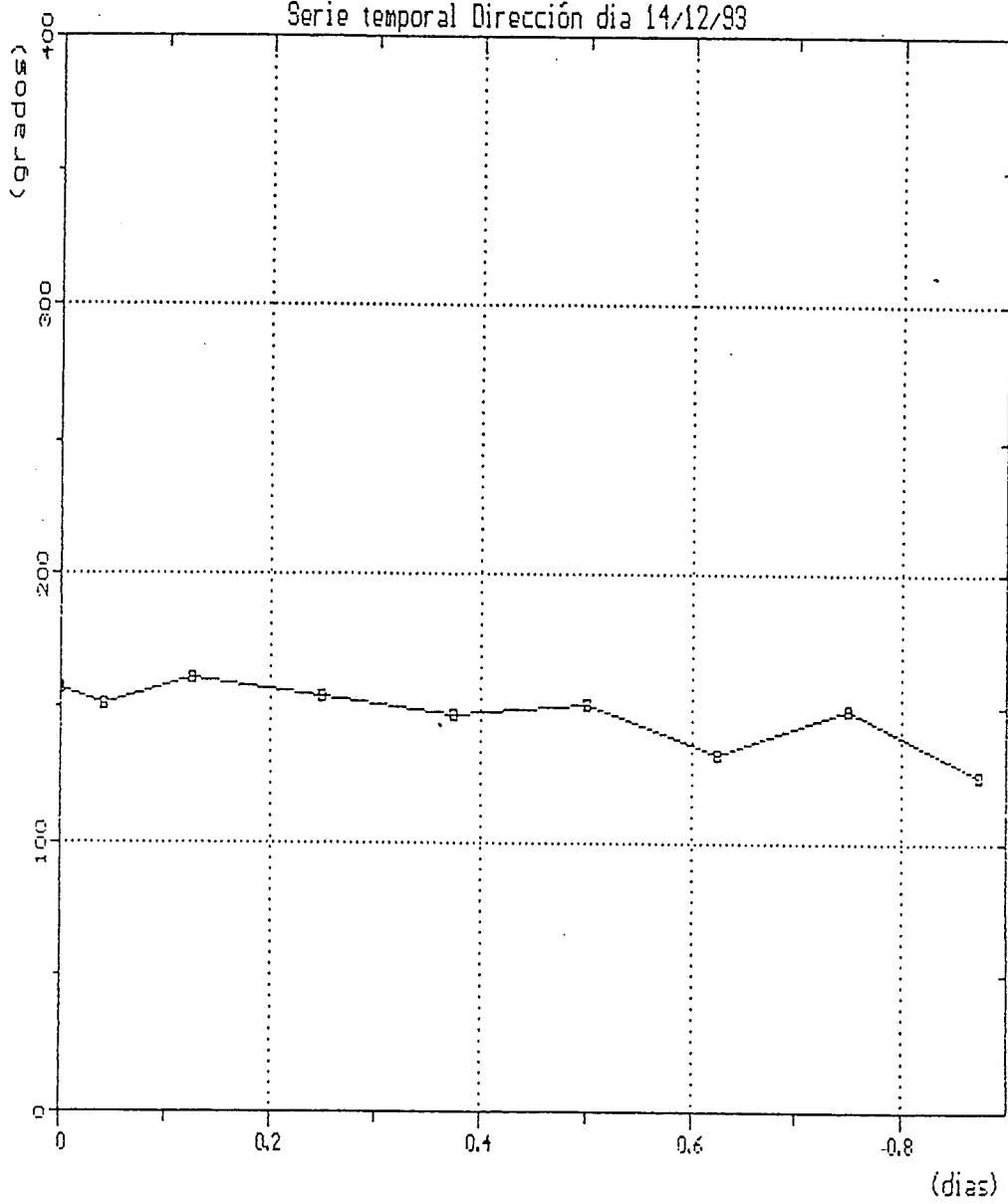


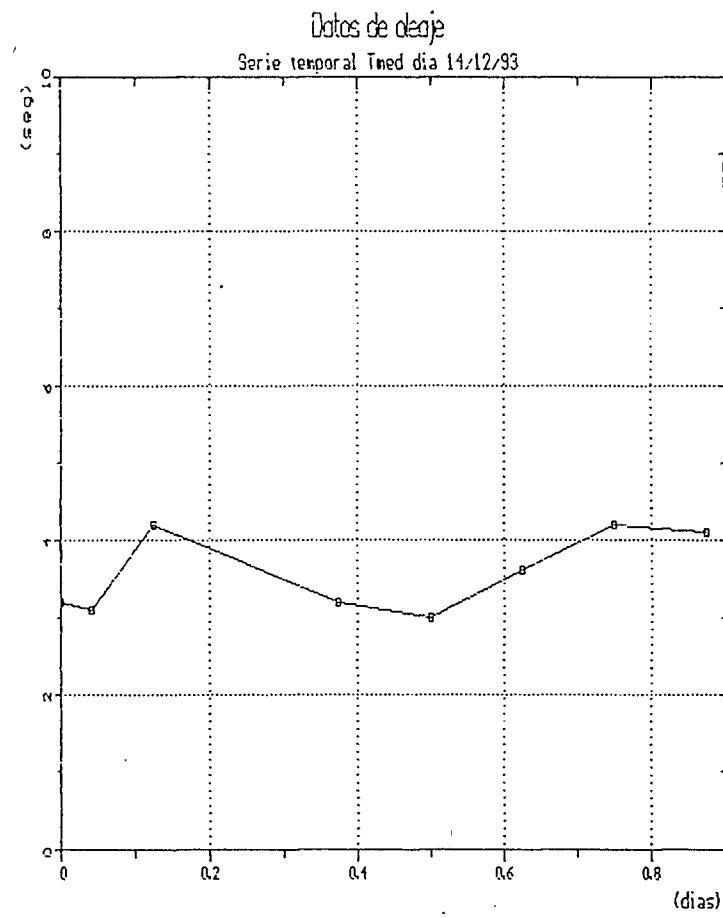
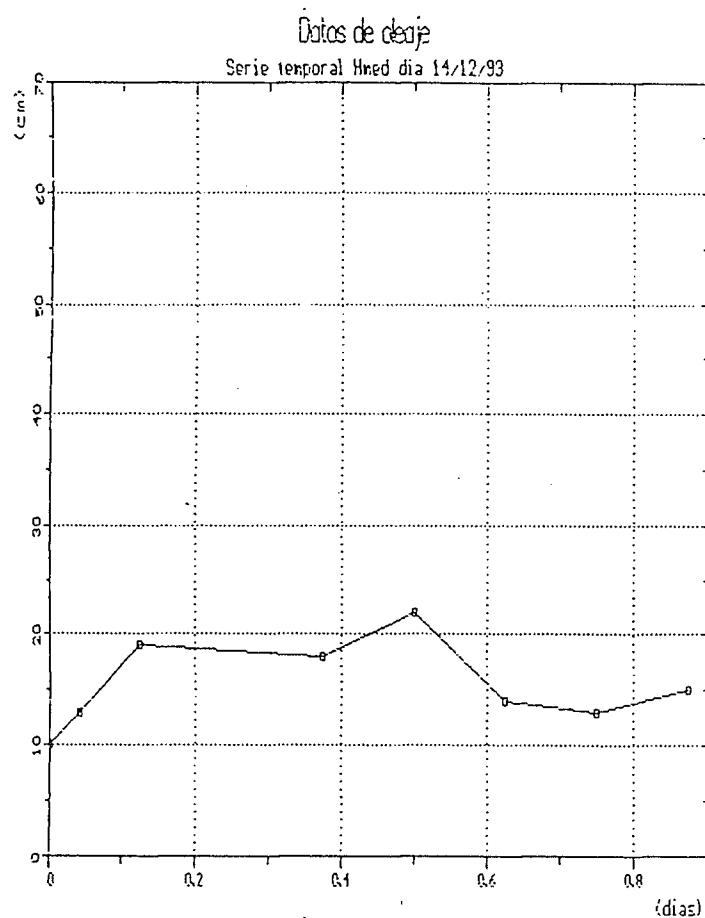


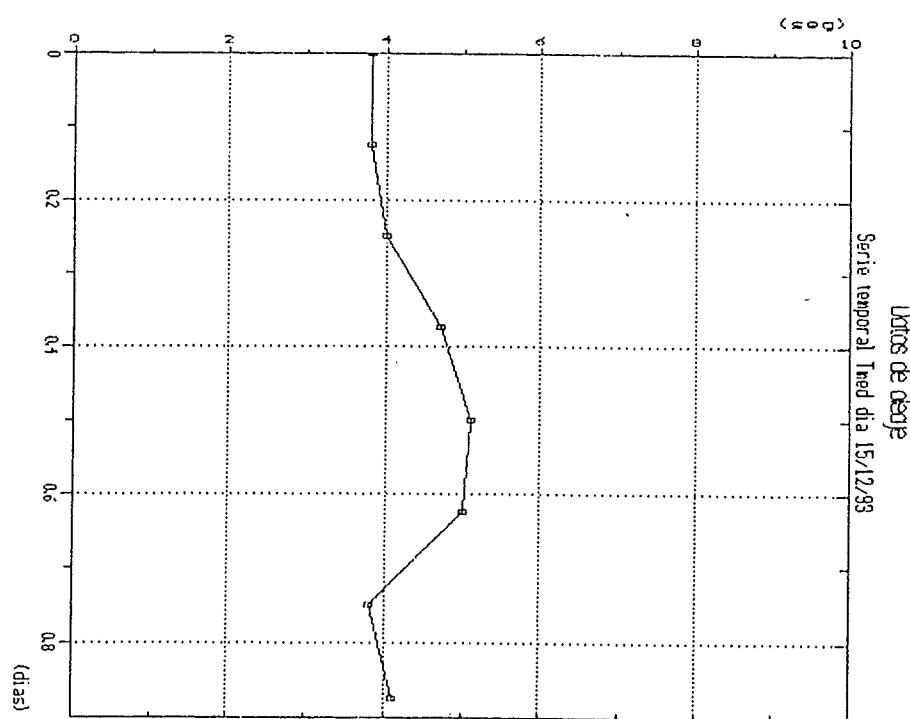
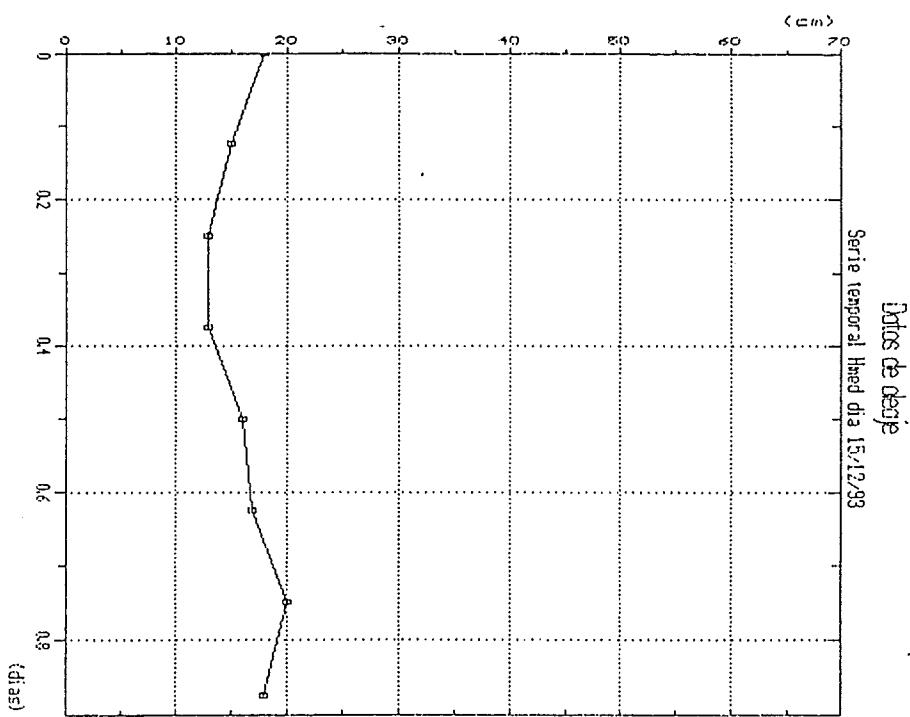


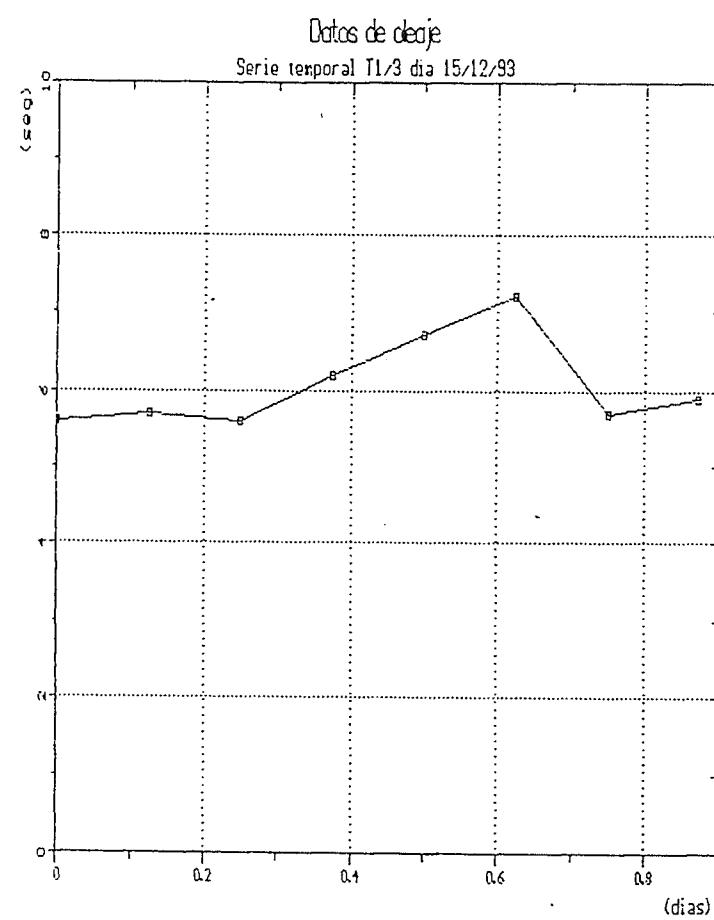
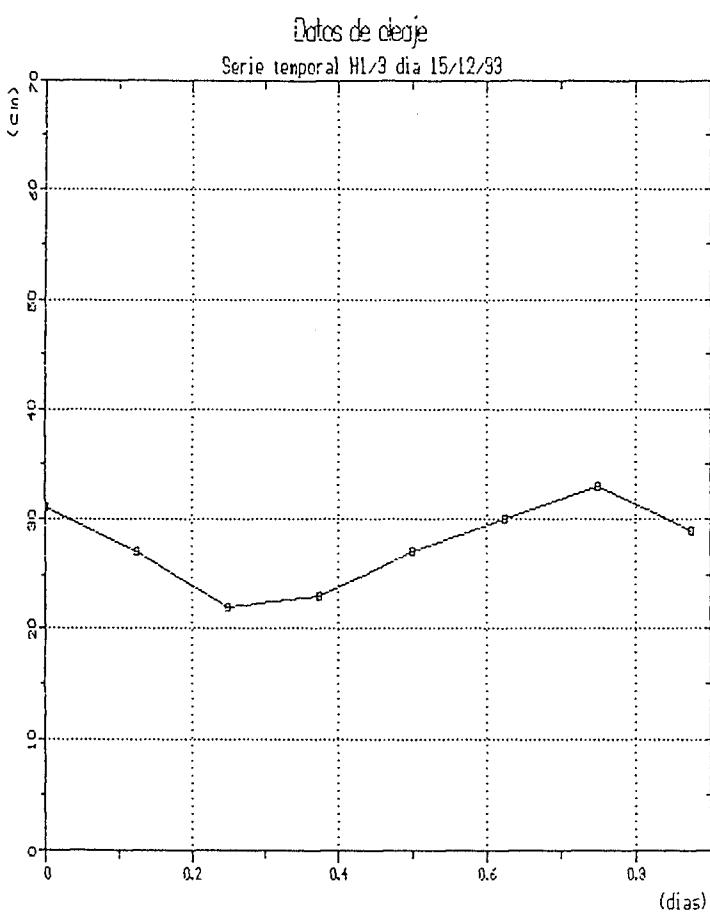
Datos de oleaje

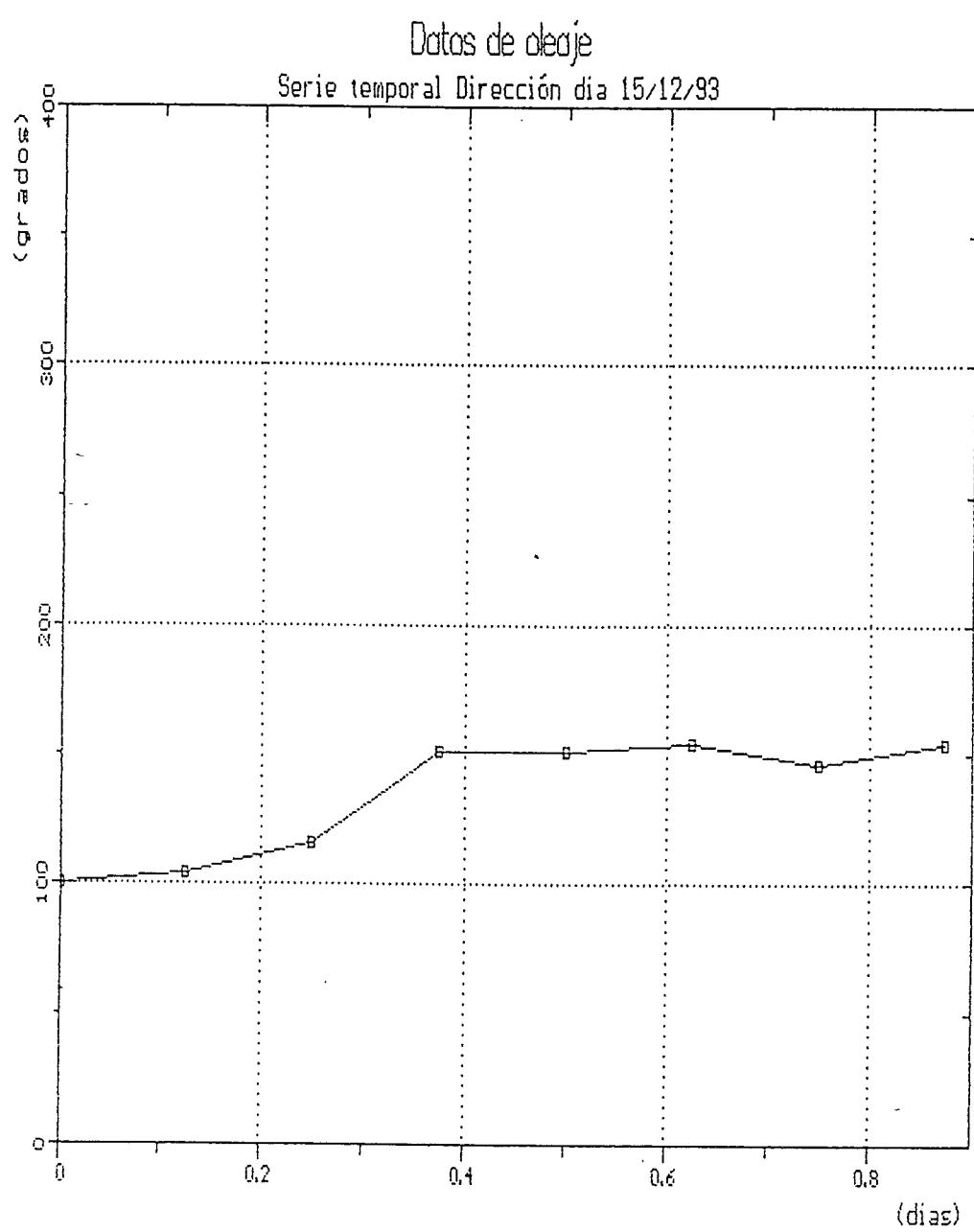
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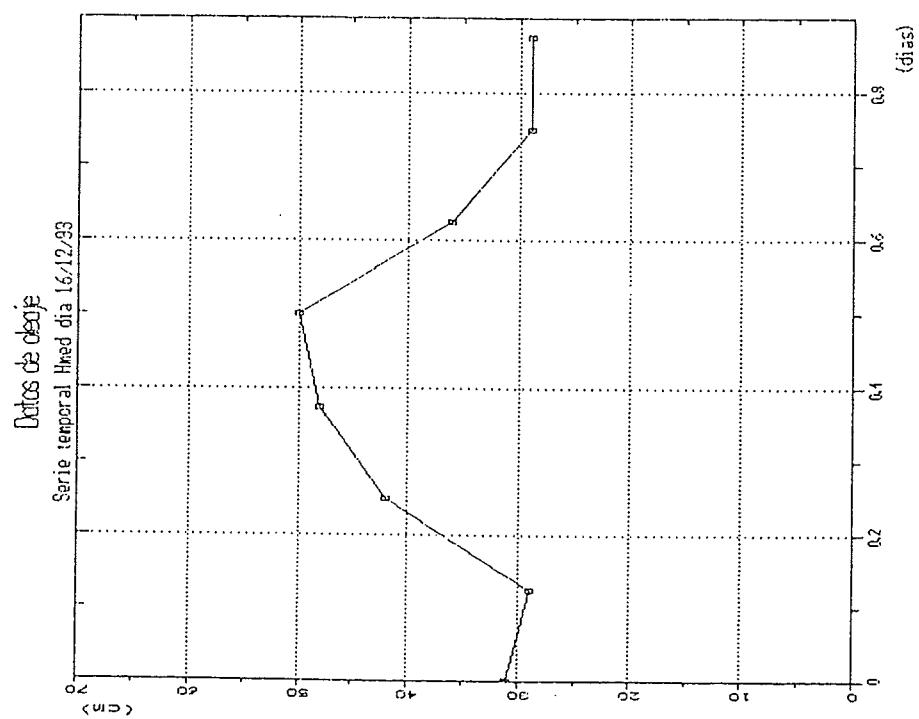
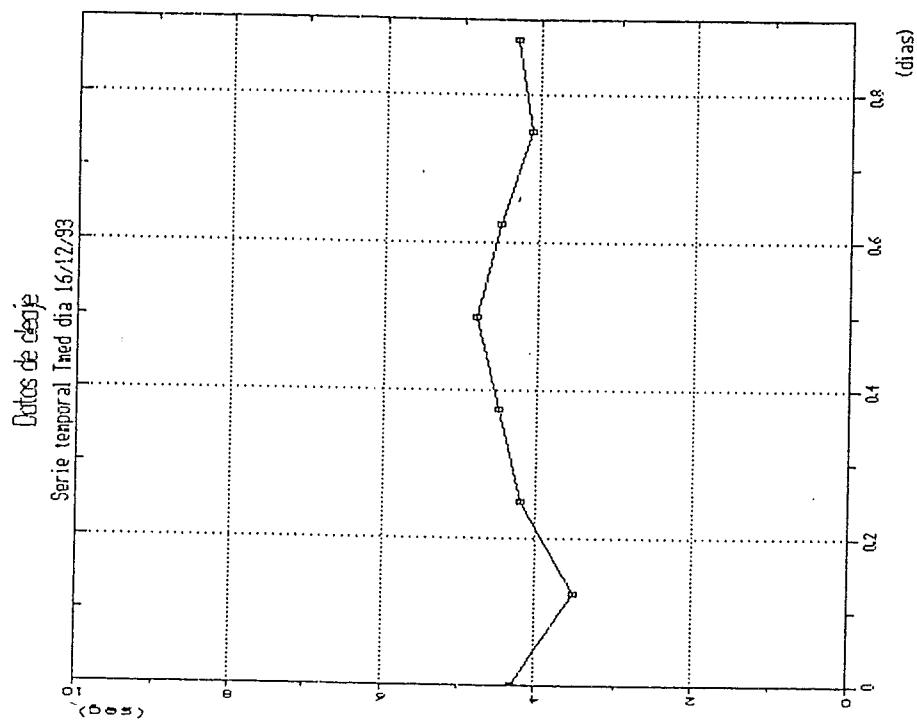


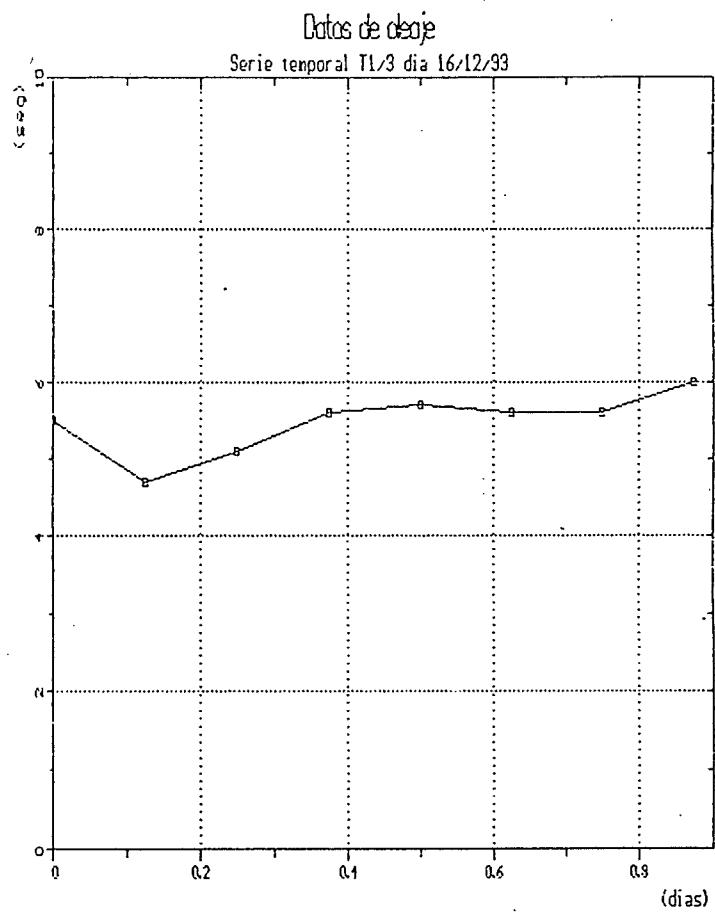
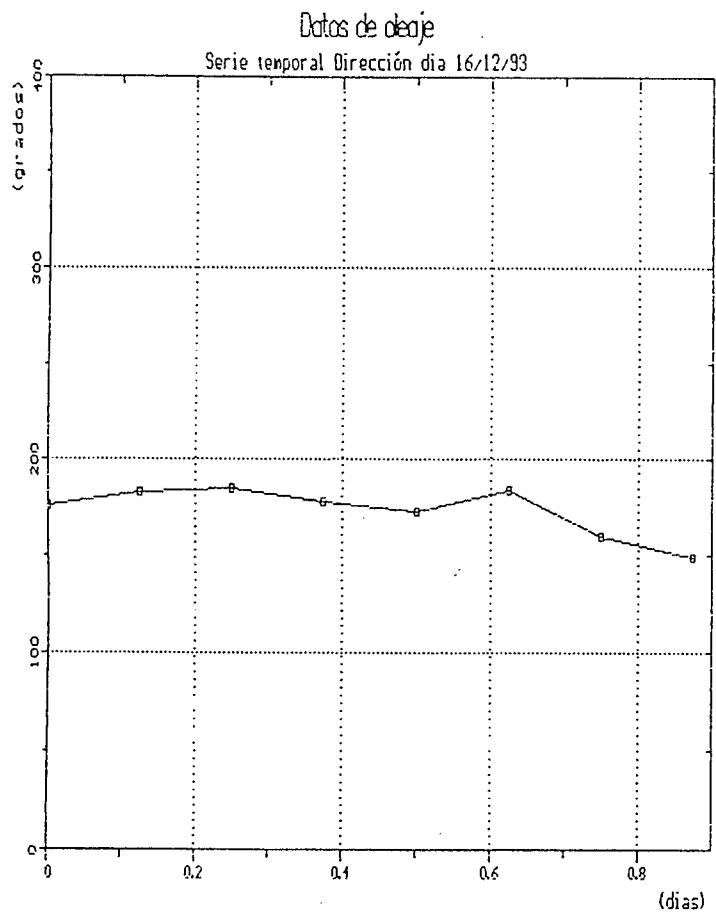


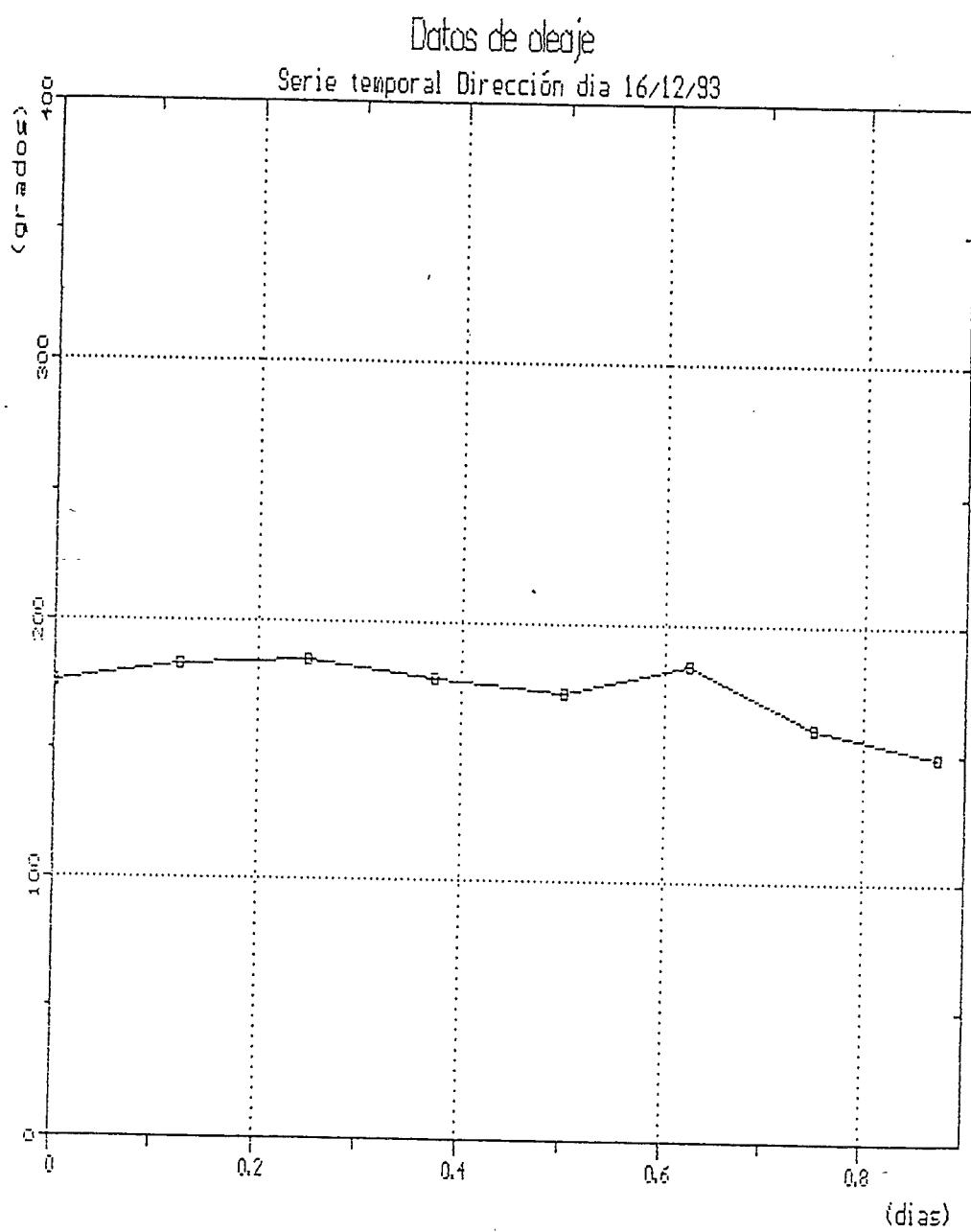


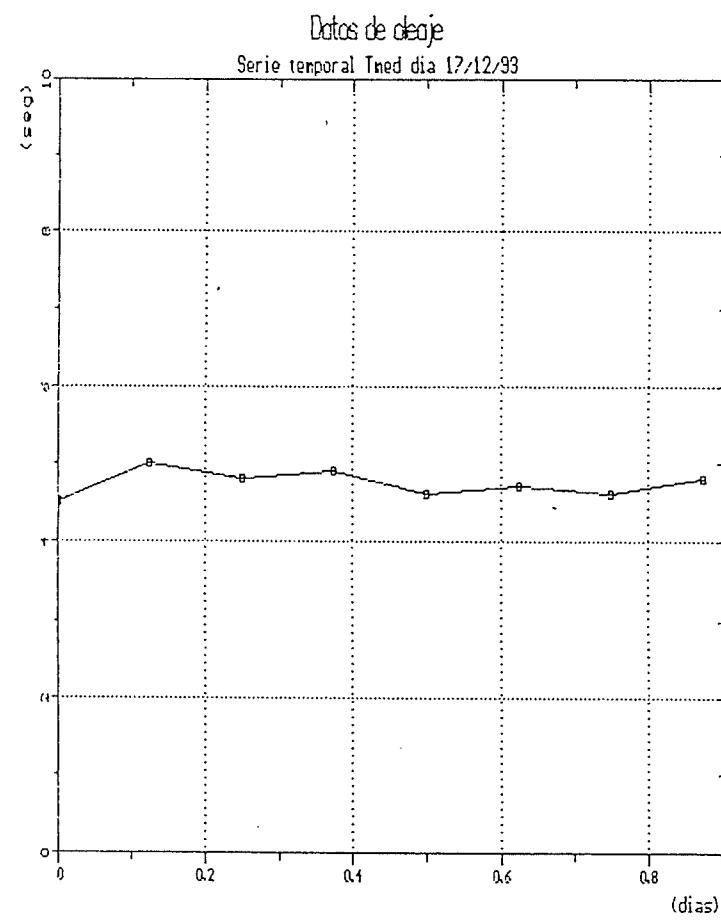
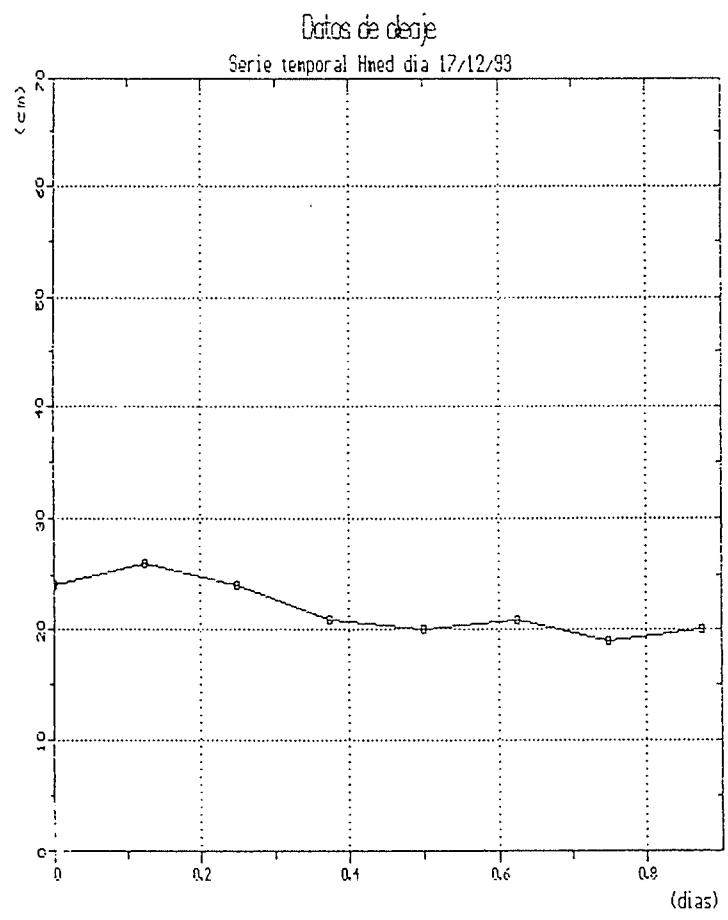


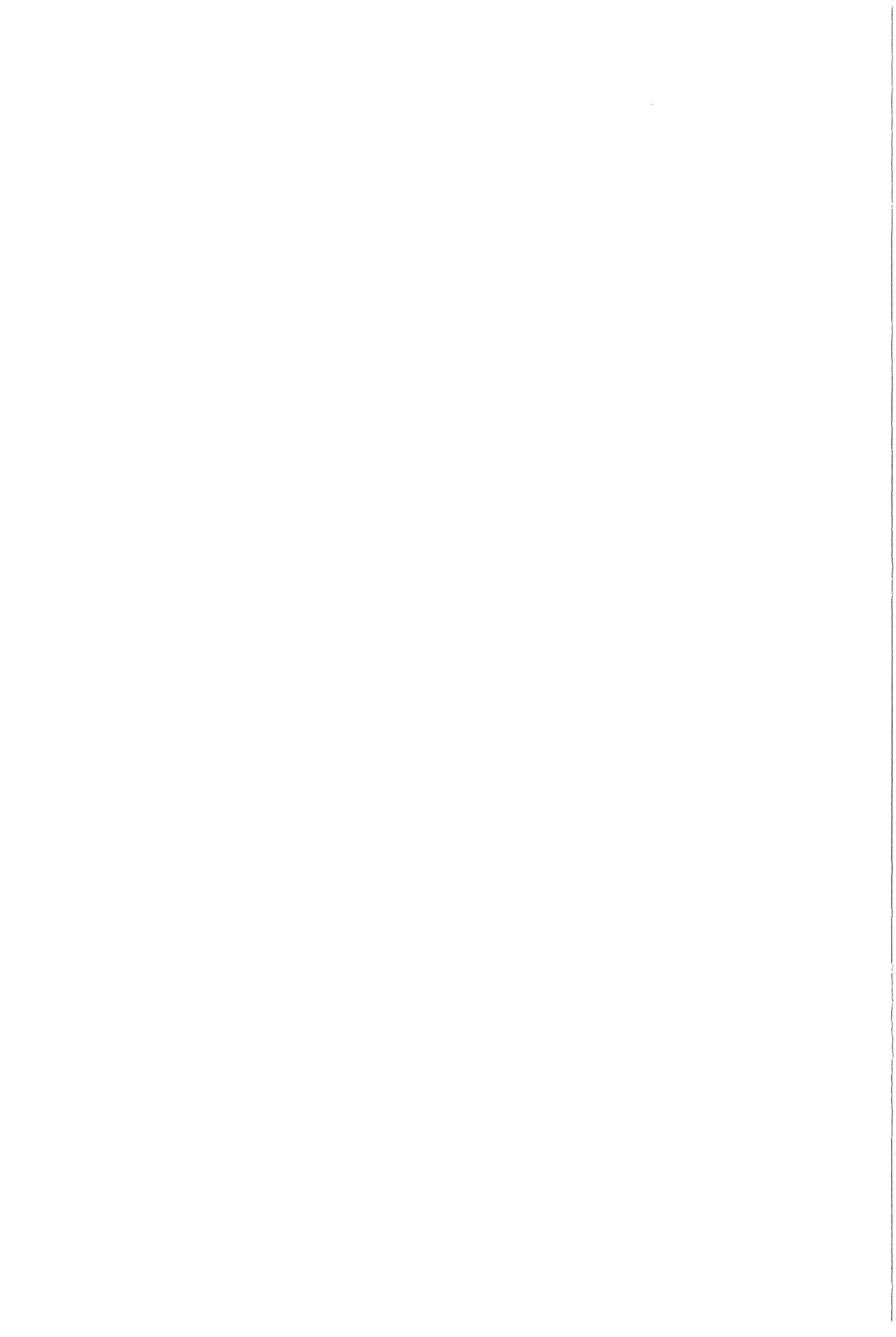






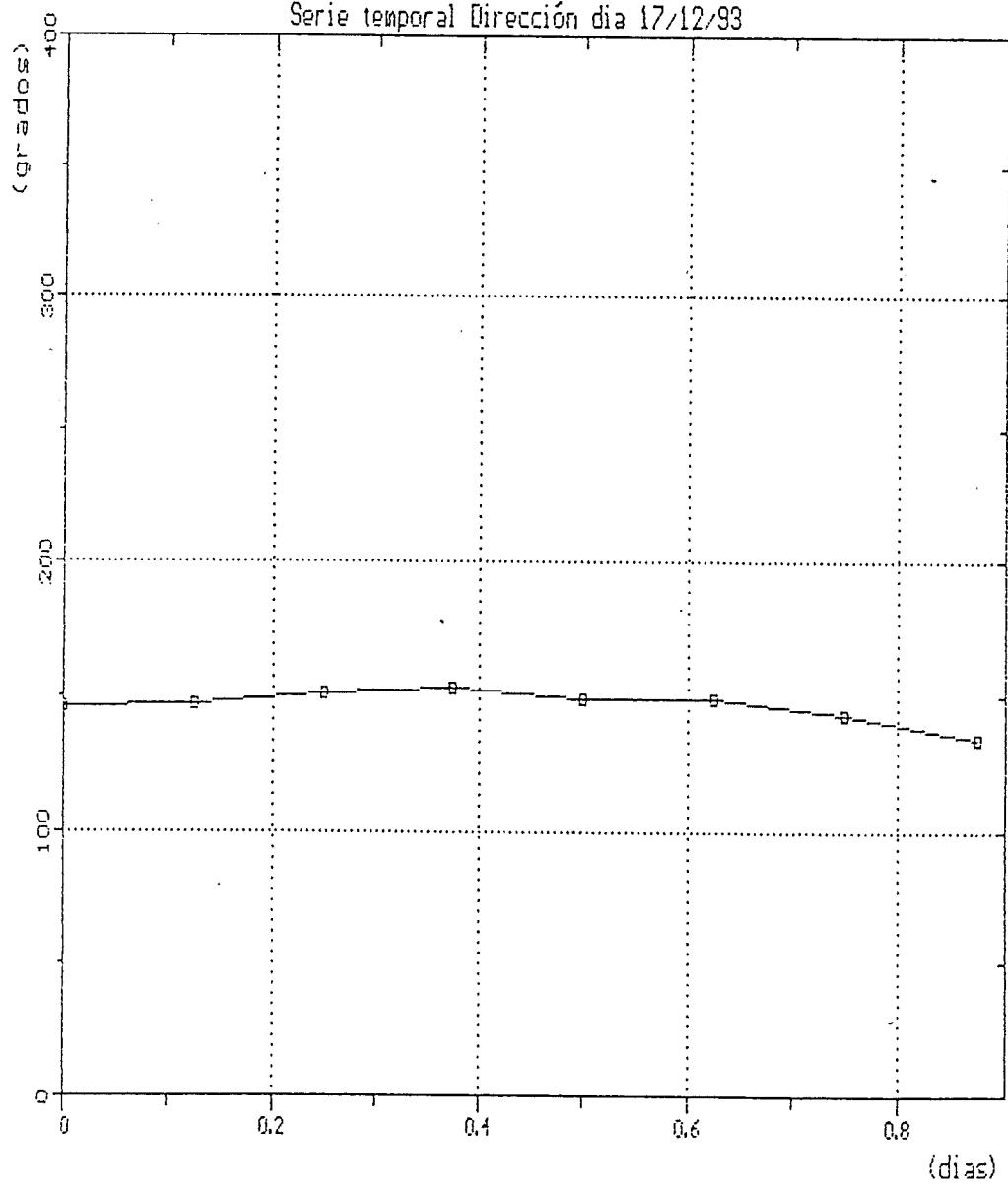


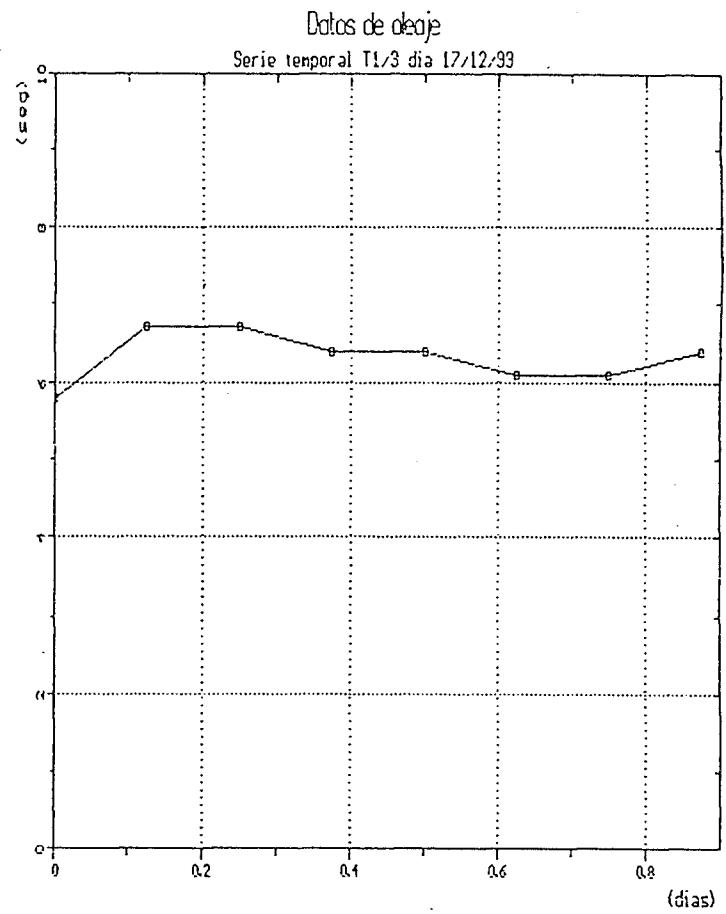
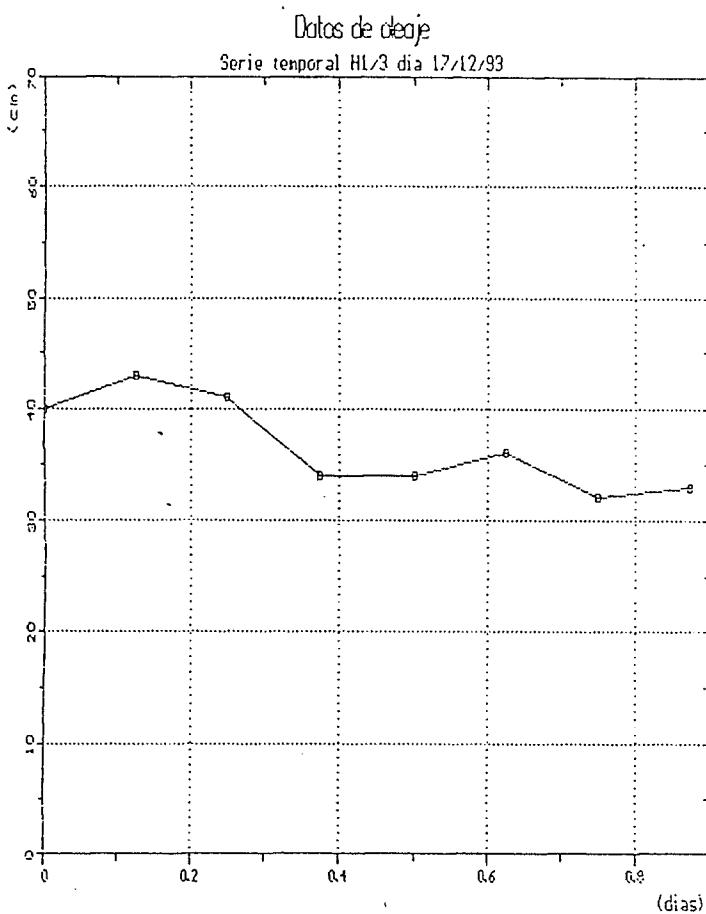


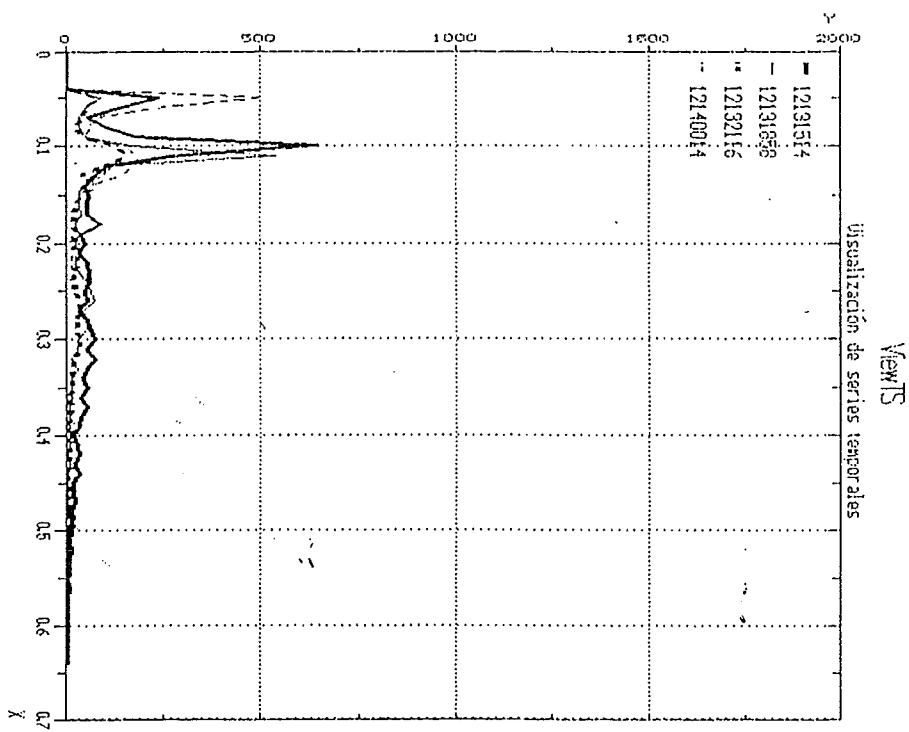
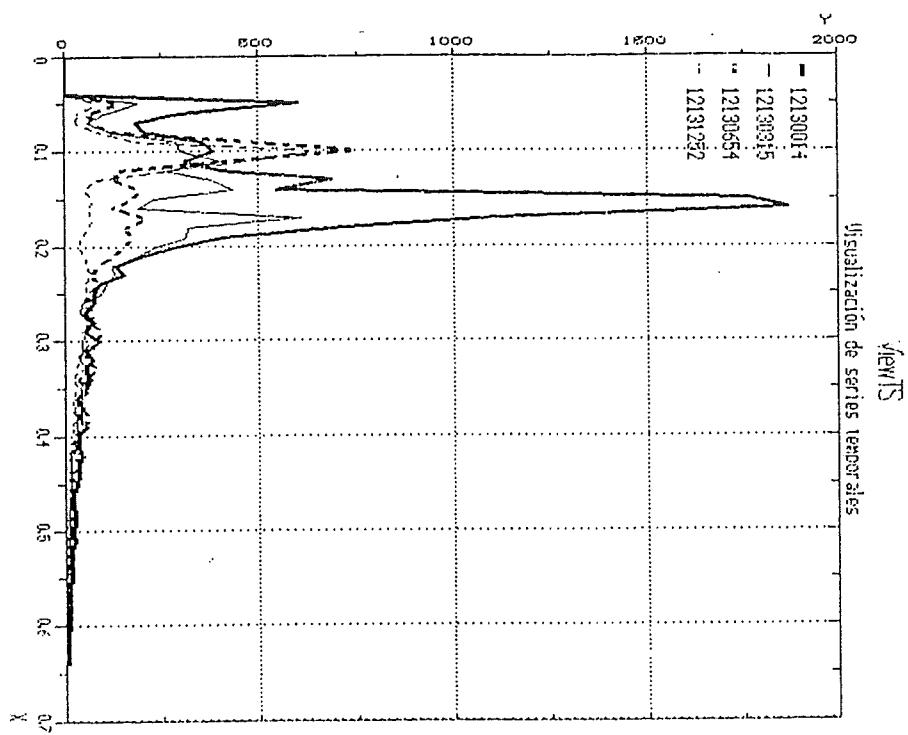


Datos de oleaje

Serie temporal Dirección dia 17/12/93

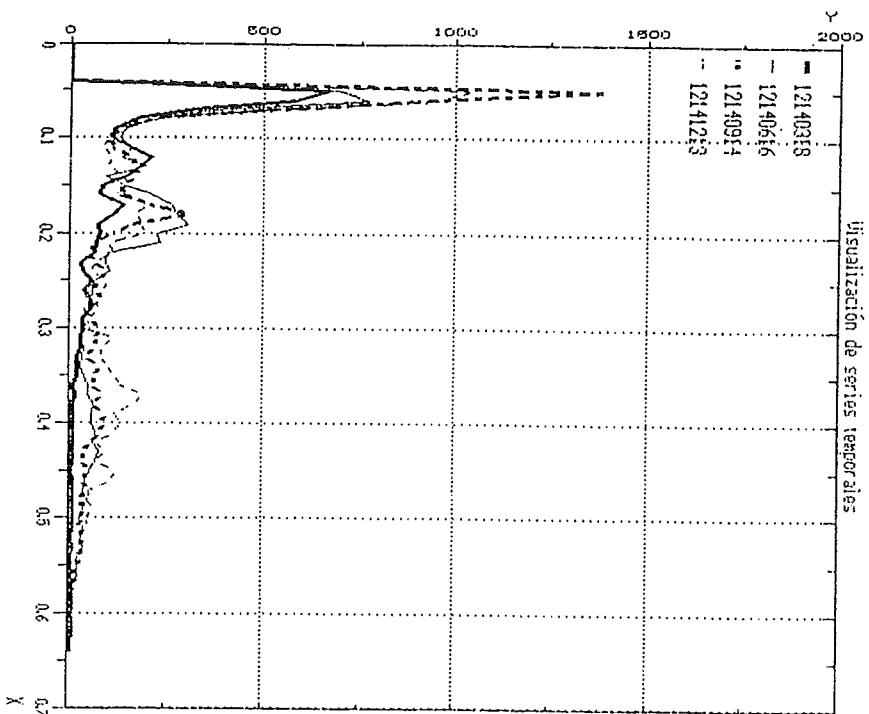






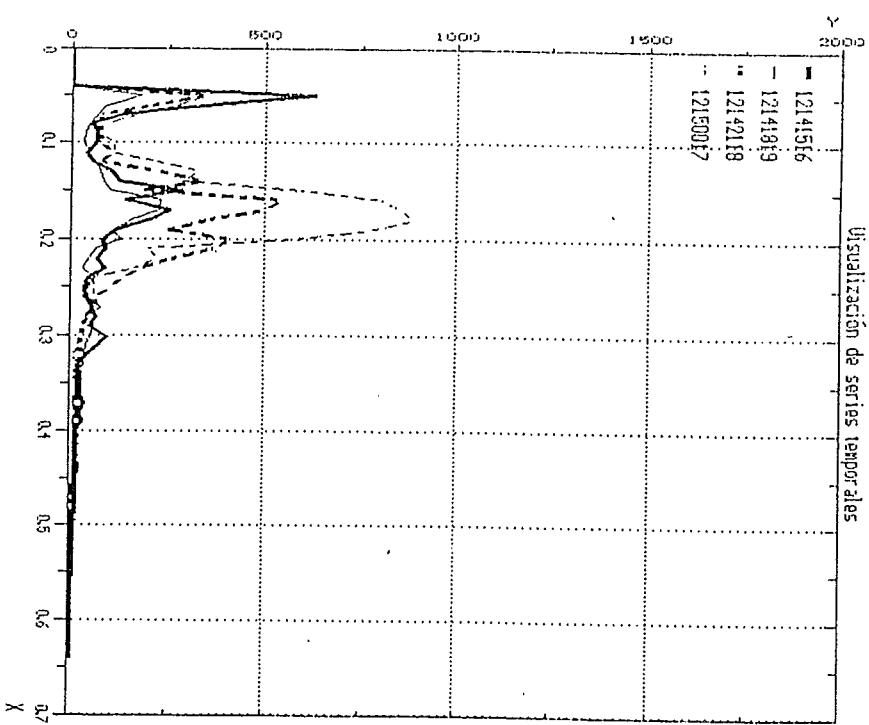
VENT3

Visualización de series temporales



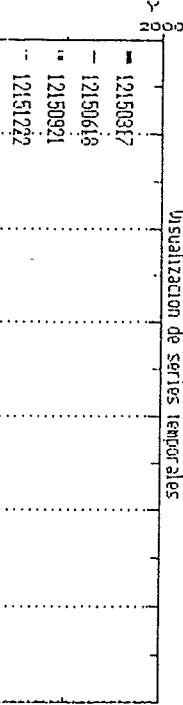
VENT3

Visualización de series temporales



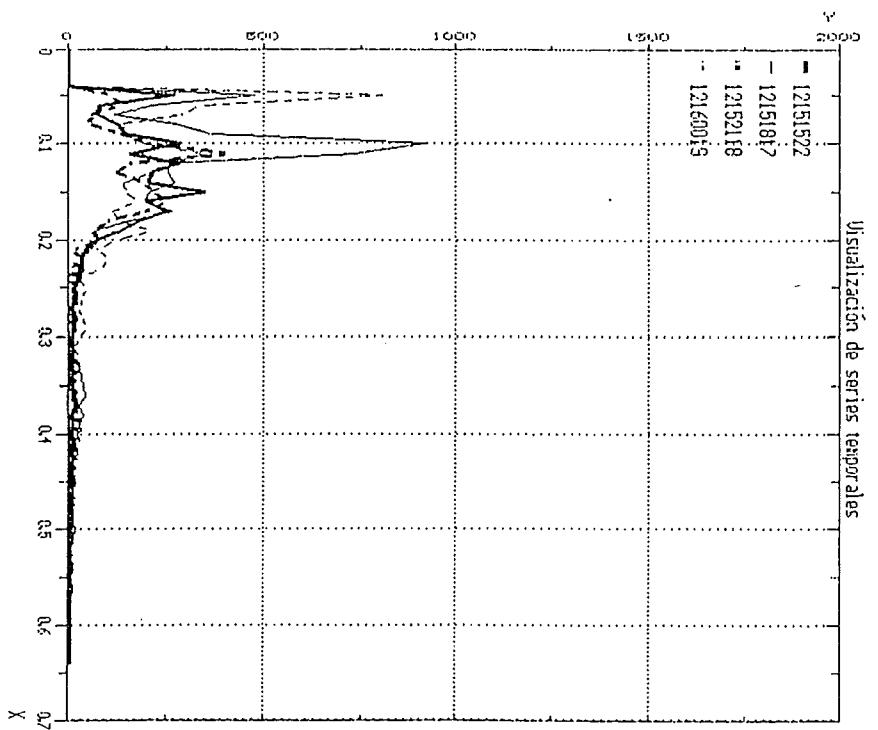
ViewTS

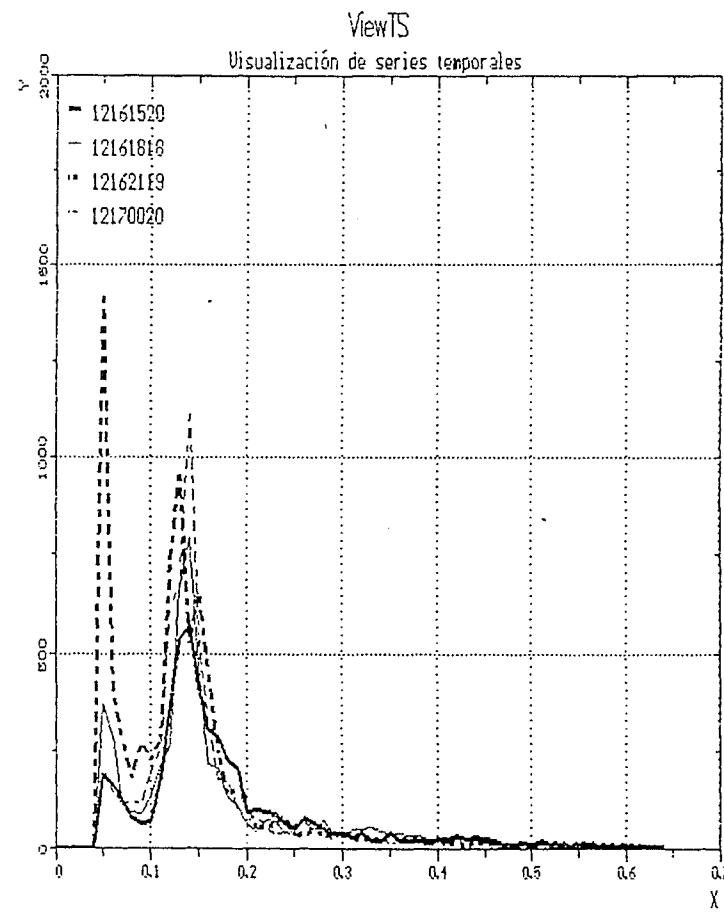
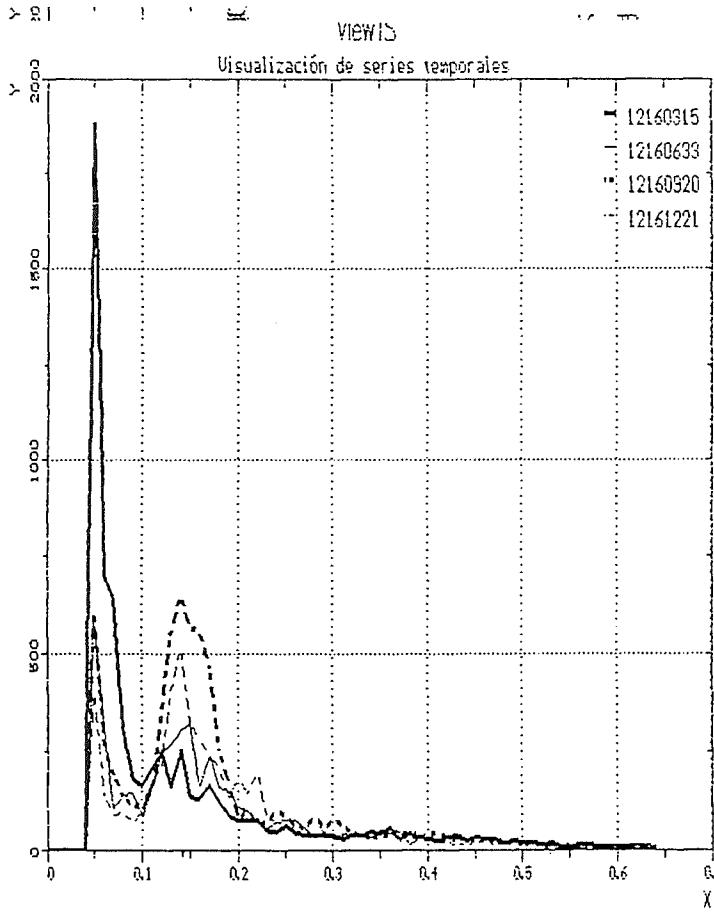
Visualización de series temporales

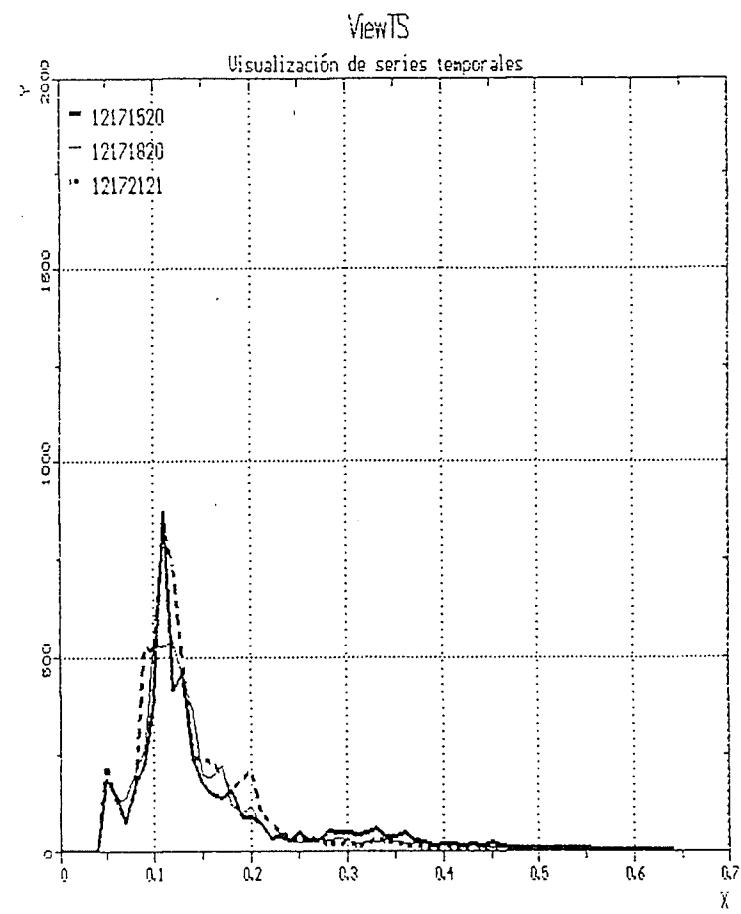
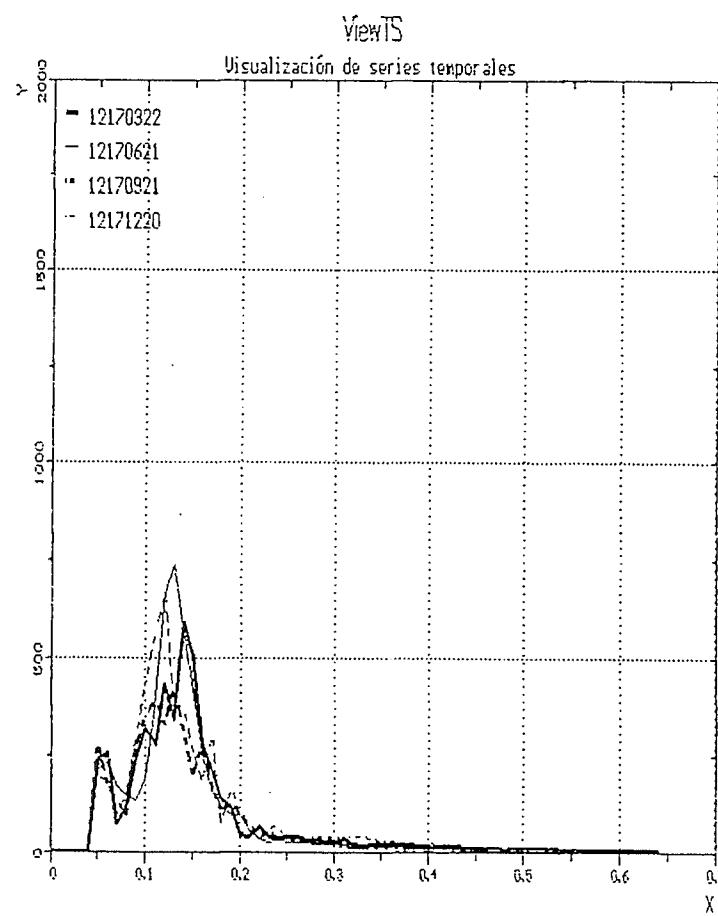


ViewTS

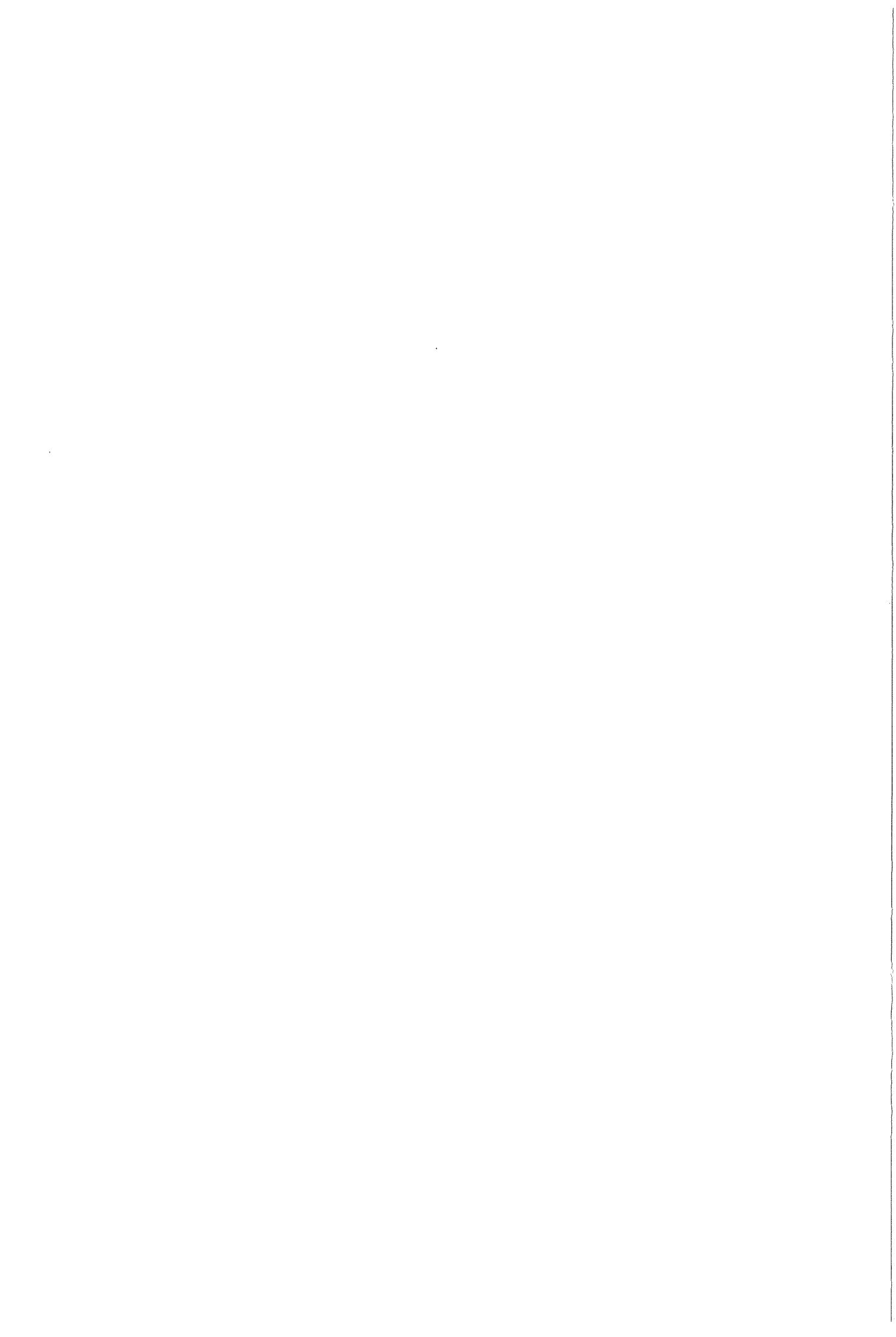
Visualización de series temporales



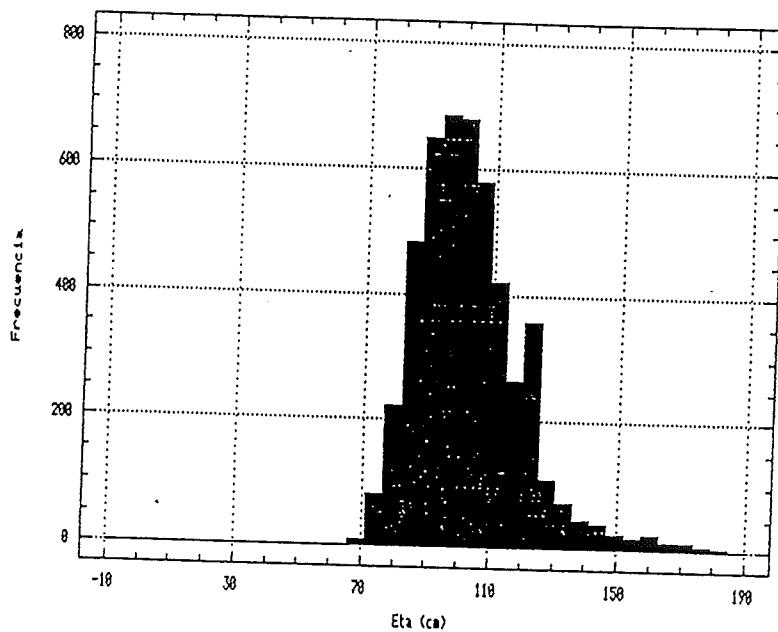




C3. Olas de viento en la ZR (WG)



Histograma de Frecuencias de altura
Delta Ebro, PII, 16/12/93, V5



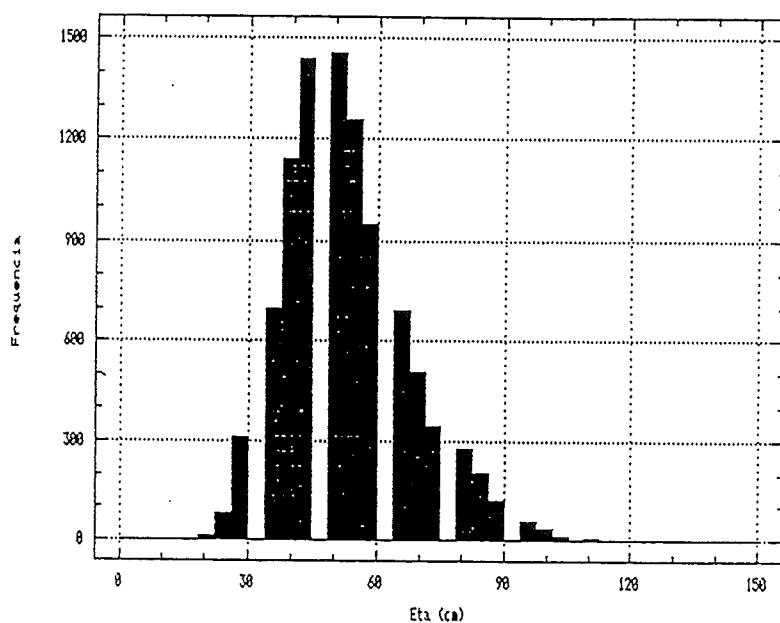
Variable: W5.var1

Sample size	4798.
Average	102.240517
Median	100.
Mode	95.
Geometric mean	100.954613
Variance	280.136428
Standard deviation	16.737277
Standard error	0.241632
Minimum	5.
Maximum	180.
Range	175.
Lower quartile	80.
Upper quartile	110.
Interquartile range	20.
Skewness	1.164678
Standardized skewness	32.935193
Kurtosis	2.325142
Standardized kurtosis	32.87562
Coeff. of variation	16.370483

Press Esc, Cursor keys or Page Number:

1Help 2Edit 3Savscr 4Prtscr 5Prtopt 6Go 7Vars 8Cmd 9Device 10Quit
INPUT 4/12/94 12:07 STATGRAPHICS Plus 5.2 Page 1.1 of 2.1
Display STATS

Histograma de Frecuencias de altura
Delta Ebro; PII; 16/12/93; V6



Variable: W6.var1

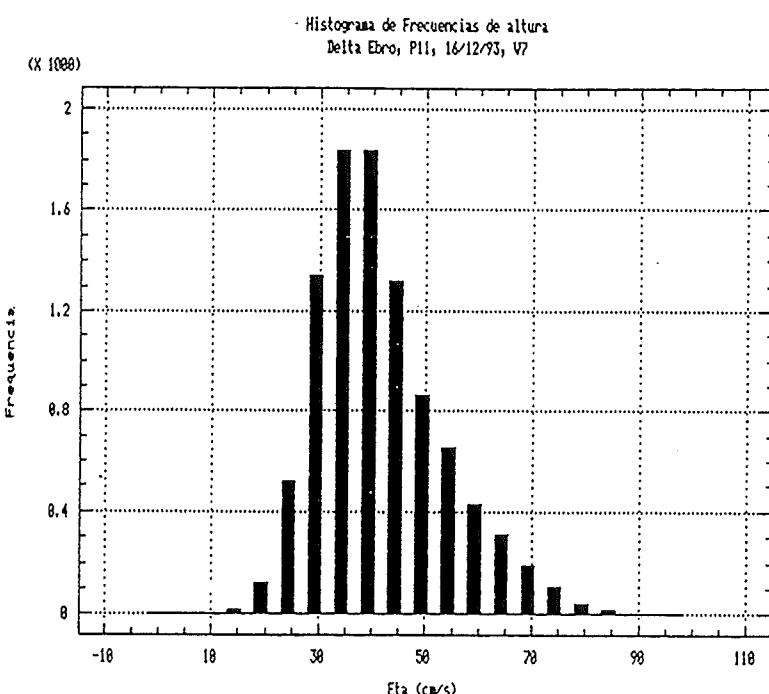
Sample size	9597.
Average	53.434928
Median	50.
Mode	50.
Geometric mean	51.527456
Variance	213.369384
Standard deviation	14.607169
Standard error	0.149107
Minimum	20.
Maximum	135.
Range	115.
Lower quartile	45.
Upper quartile	60.
Interquartile range	15.
Skewness	0.730874
Standardized skewness	29.230375
Kurtosis	0.52607
Standardized kurtosis	10.519755
Coeff. of variation	27.336369

Press Esc, Cursor keys or Page Number:

2Edit 3Savscr 4Prtscr 5Prtptopt 6Go

7Vars 8Cnd

Page 1.1 of 2.1
9Device 10Quit

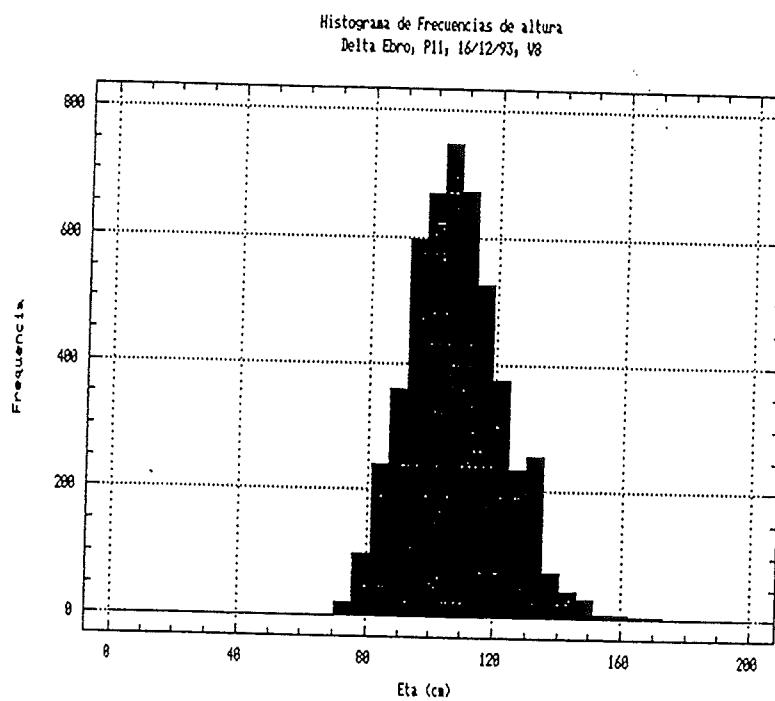


Variable: W7.var1

Sample size	9594.
Average	42.082864
Median	40.
Mode	35.
Geometric mean	40.49914
Variance	140.722102
Standard deviation	11.862635
Standard error	0.12111
Minimum	3.
Maximum	90.
Range	87.
Lower quartile	35.
Upper quartile	50.
Interquartile range	15.
Skewness	0.783989
Standardized skewness	31.349776
Kurtosis	0.492026
Standardized kurtosis	9.837446
Coeff. of variation	28.188753

Press Esc, Cursor keys or Page Number:

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9Device 10Quit

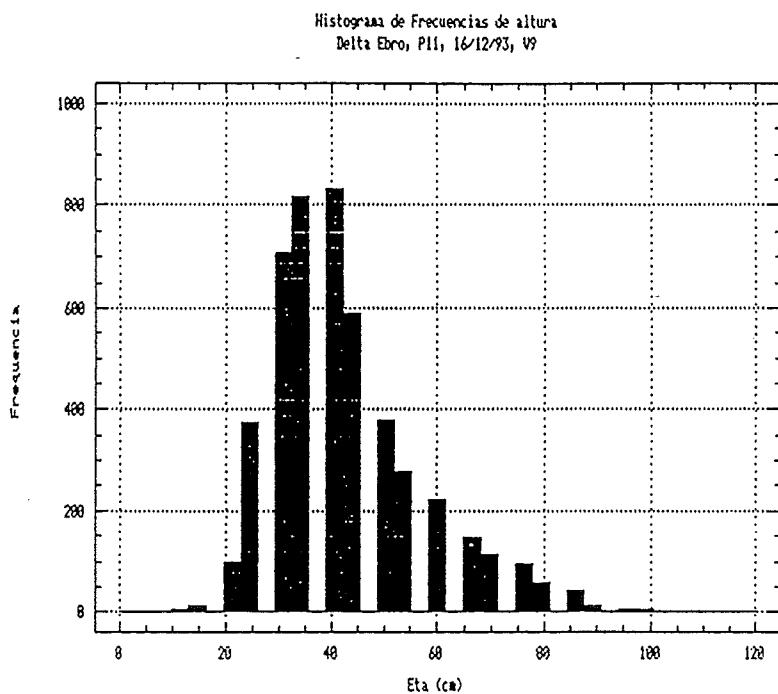


Variable: WAV8.var1

Sample size	4964.
Average	107.092063
Median	105.
Mode	105.
Geometric mean	106.120866
Variance	215.081388
Standard deviation	14.665653
Standard error	0.208154
Minimum	45.
Maximum	185.
Range	140.
Lower quartile	95.
Upper quartile	115.
Interquartile range	20.
Skewness	0.667389
Standardized skewness	19.19639
Kurtosis	1.034898
Standardized kurtosis	14.883591
Coeff. of variation	13.694435

Press Esc, Cursor keys or Page Number:

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Device 10Quit



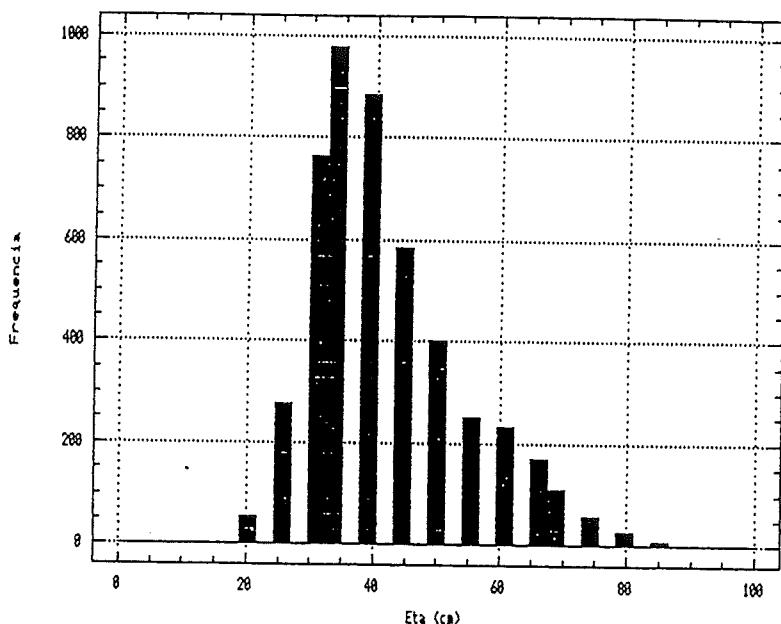
Variable: WAV9.var1

Sample size	4793.
Average	42.545379
Median	40.
Mode	40.
Geometric mean	40.386884
Variance	202.346907
Standard deviation	14.224869
Standard error	0.205468
Minimum	10.
Maximum	110.
Range	100.
Lower quartile	35.
Upper quartile	50.
Interquartile range	15.
Skewness	1.029521
Standardized skewness	28.098014
Kurtosis	1.114585
Standardized kurtosis	15.751118
Coeff. of variation	33.434582

Press Esc, Cursor keys or Page Number:

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Histograma de Frecuencias de altura
Delta Ebro, Pl1, 16/12/93, V10



Variable: W10.var1

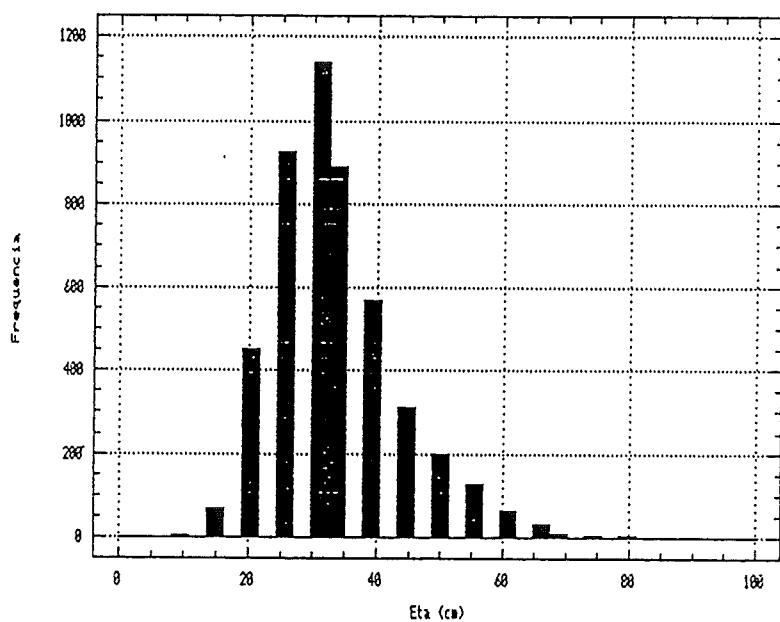
Sample size	4795.
Average	41.736184
Median	40.
Mode	35.
Geometric mean	40.115525
Variance	146.698221
Standard deviation	12.111904
Standard error	0.174911
Minimum	15.
Maximum	85.
Range	70.
Lower quartile	35.
Upper quartile	50.
Interquartile range	15.
Skewness	0.878659
Standardized skewness	24.839287
Kurtosis	0.436483
Standardized kurtosis	6.169582
Coeff. of variation	29.020153

Press Esc, Cursor keys or Page Number:

1Help 2Edit 3Savscr 4Prtscr 5Prttopt 6Go 7Vars 8Cmd 9Device 10Quit
INPUT 4/12/94 12:11 STATGRAPHICS Plus 5.2

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Display STATS

Histograma de Frecuencias de altura
Delta Ebro; PII; 16/12/93; VII



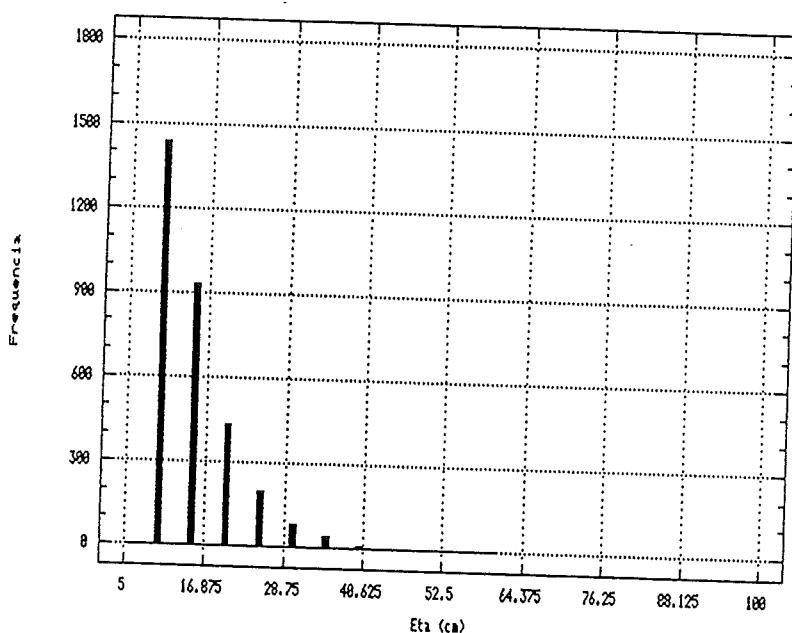
Variable: W11.var1

Sample size	4796.
Average	33.279817
Median	30.
Mode	30.
Geometric mean	31.88458
Variance	99.855784
Standard deviation	8.992787
Standard error	0.144294
Minimum	10.
Maximum	80.
Range	70.
Lower quartile	25.
Upper quartile	40.
Interquartile range	15.
Skewness	0.937156
Standardized skewness	26.495737
Kurtosis	1.206786
Standardized kurtosis	17.059414
Coeff. of variation	30.026568

Press Esc, Cursor keys or Page Number:

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Histograma de Frecuencias de altura
Delta Ebro, PII, 16/12/93, VI12

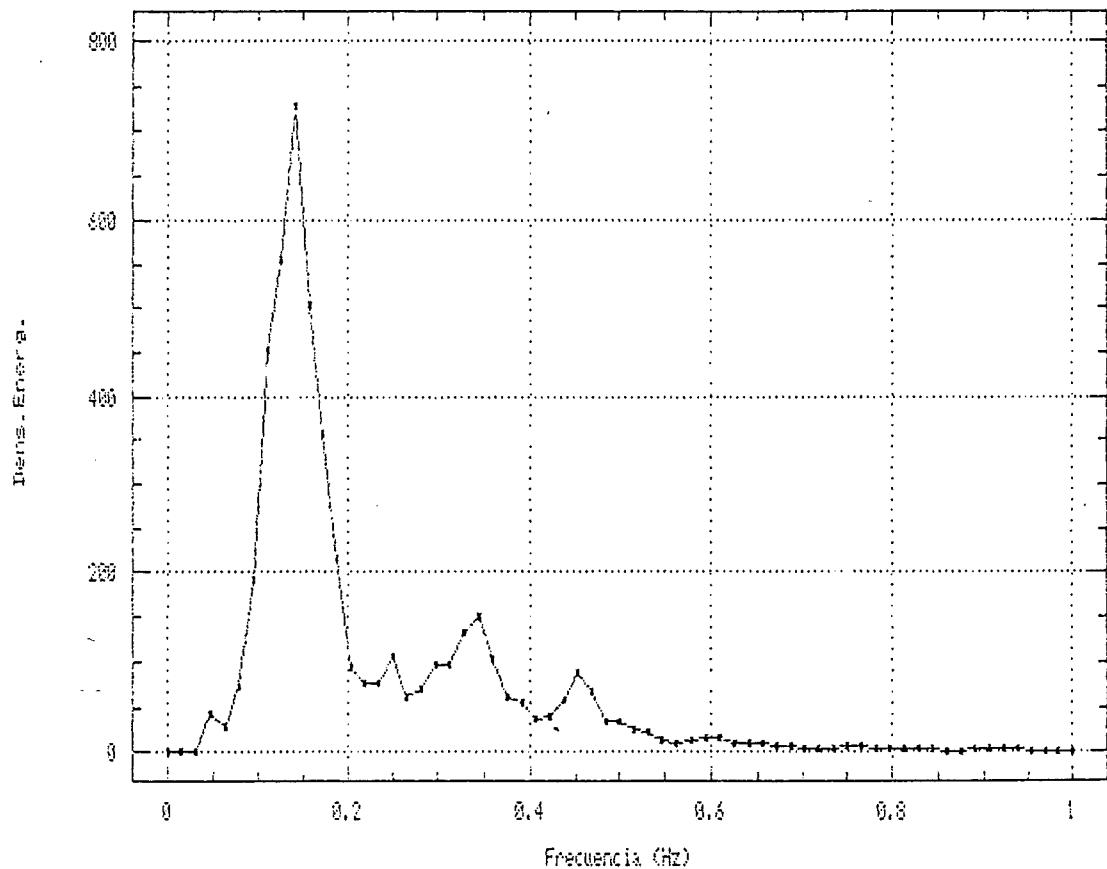


Variable: W12.var1

Sample size	4793.
Average	11.421865
Median	10.
Mode	5.
Geometric mean	9.740144
Variance	45.134597
Standard deviation	6.718229
Standard error	0.09704
Minimum	5.
Maximum	45.
Range	40.
Lower quartile	5.
Upper quartile	15.
Interquartile range	10.
Skewness	1.265977
Standardized skewness	35.781117
Kurtosis	1.785521
Standardized kurtosis	25.23266
Coeff. of variation	58.819016

Press Esc, Cursor keys or Page Number:

Espectro de Energía del Oleaje
Delta Ebro; 15/12/93; Pil, VI



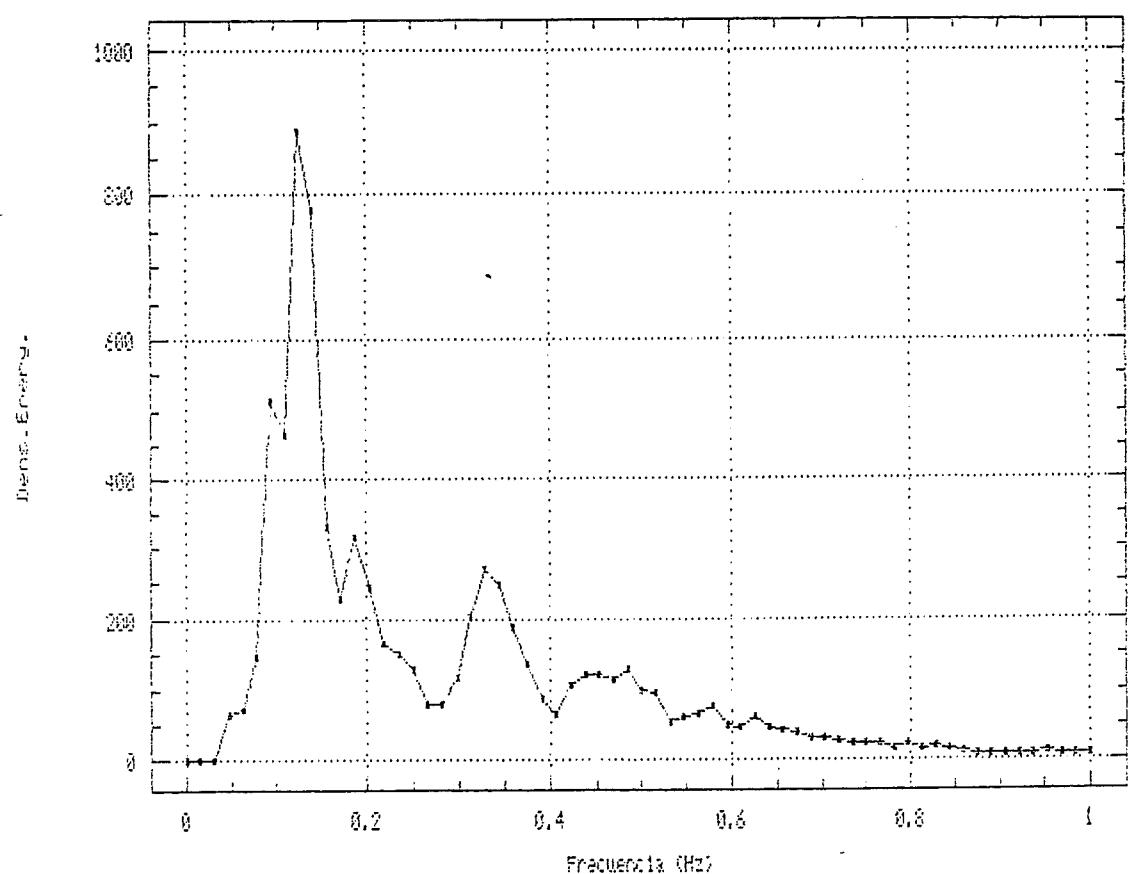
12151213.wav

N M Dt fc Ventana
4096 256 0.250000 0.040000 Welch

M(0) M(1) M(2) M(3) M(4) M(-1) M(-2)
78.008339 19.045244 8.478764 7.221485 9.191481 466.352142 3540.590820

Hs Tz Tc Tp Tp(mom.) Eps
35.364262 3.033222 0.960447 7.111111 11.081033 0.948545

Espectro de Energía del Oleaje
Delta Ebro, 15/12/93, Pl1, V2



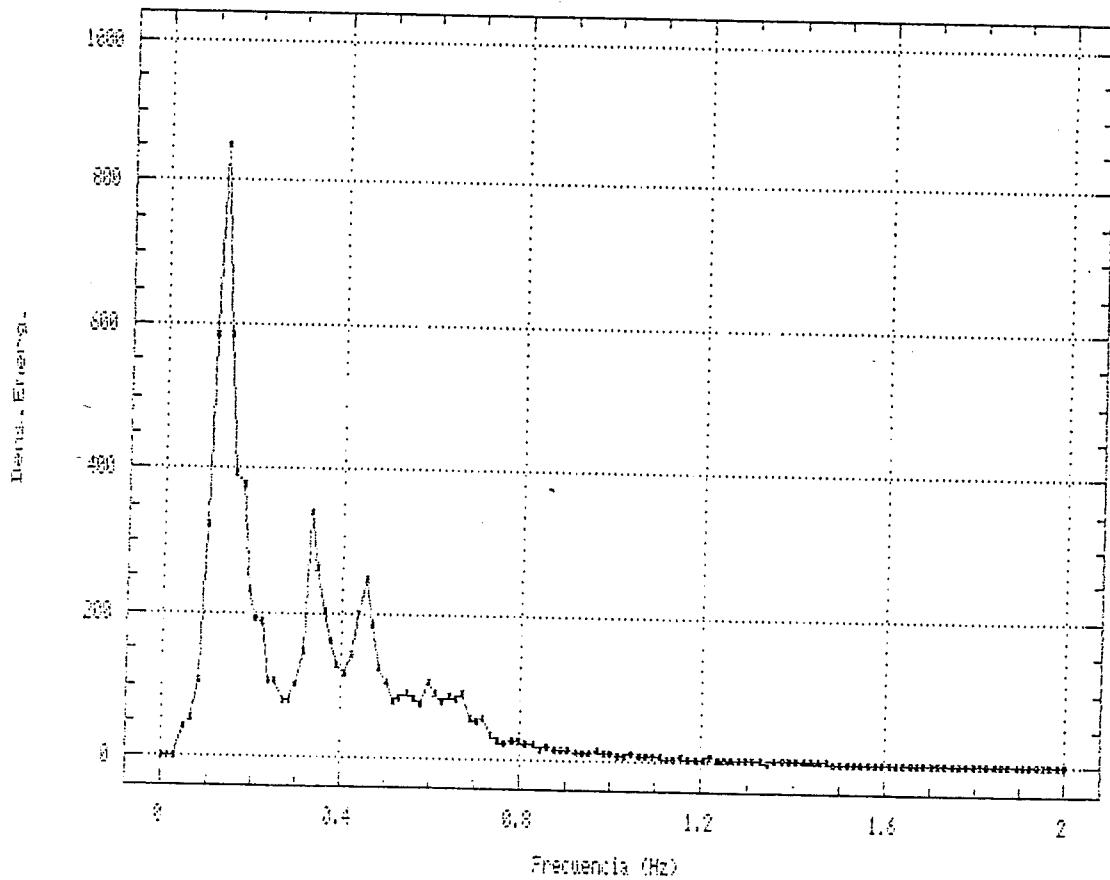
12151459.wav

N	M	Dt	fc	Ventana
4096	256	0.250000	0.040000	Welch

M(0)	M(1)	M(2)	M(3)	M(4)	M(-1)	M(-2)
121.999016	36.507133	18.712181	15.132127	16.980015	666.005188	5136.329

Hs	Tz	Tc	Tp	Tp(mom.)	Eps
44.225449	2.553383	1.049768	8.000000	12.598475	0.911578

Espectro de Energía del Oleaje
Delta Ebro, 15/12/93, P11, v3

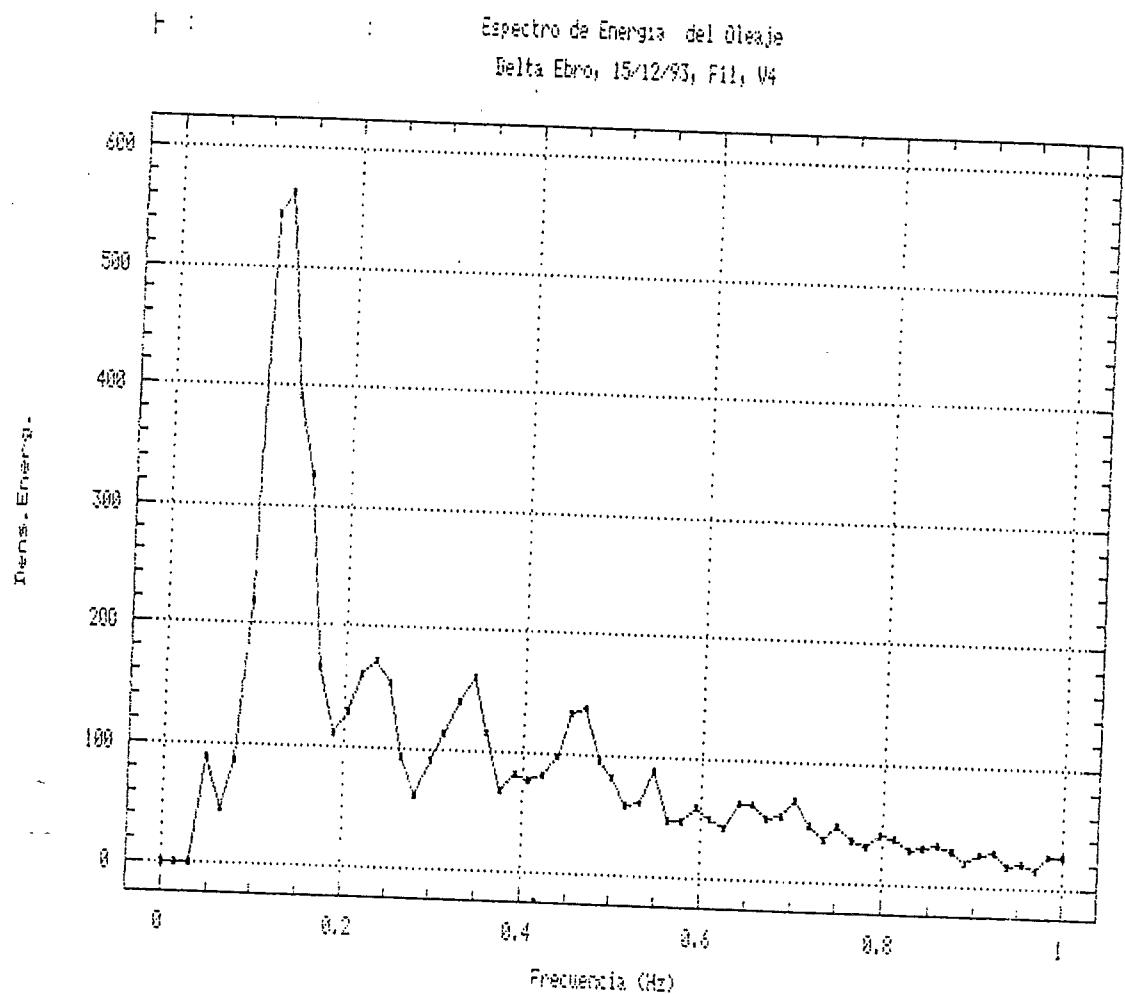


12151627.wav

N	M	Dt	fc	Ventana
4096	256	0.250000	0.040000	Welch

M(0)	M(1)	M(2)	M(3)	M(4)	M(-1)	M(-2)
132.735901	45.829742	25.792534	21.395113	23.752527	640.339294	4536.127930

Hs	Tz	Tc	Tp	Tp(mom.)	Eps
46.130512	2.268544	1.042058	8.000000	11.799291	0.888255

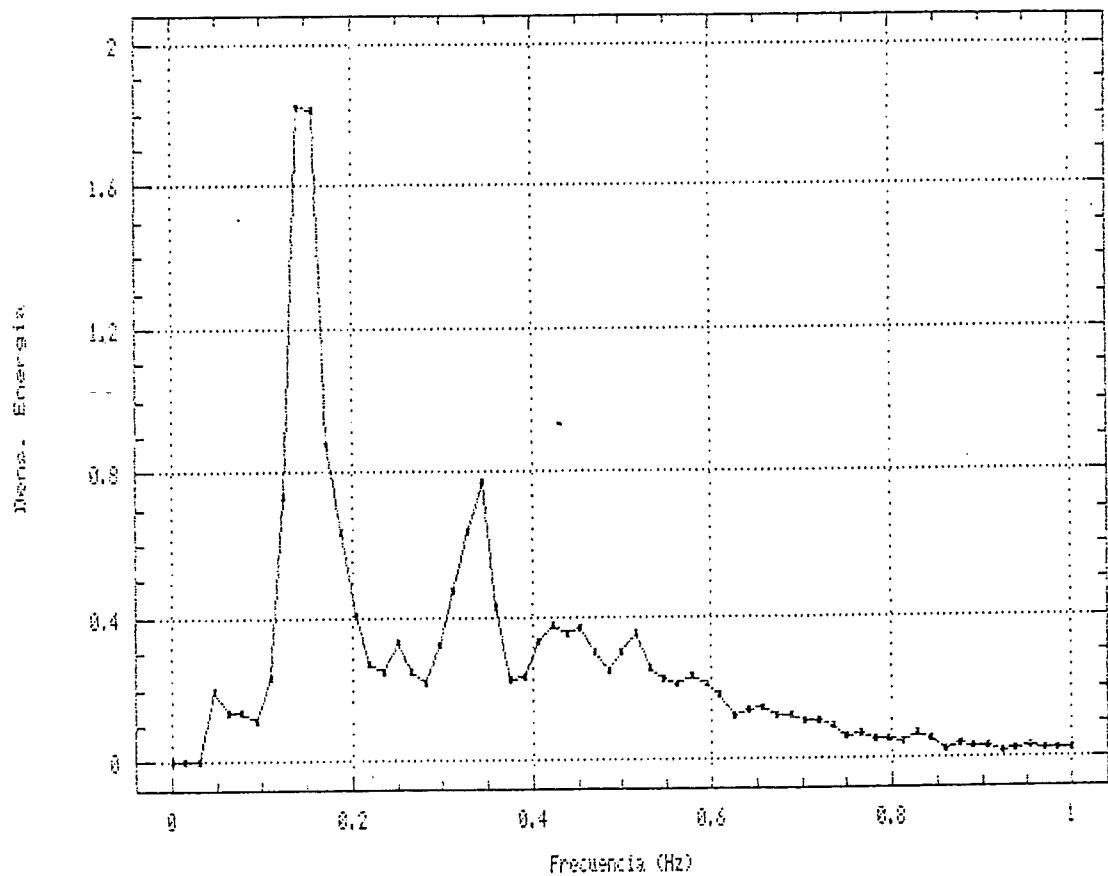


12151705.wav

N	M	Dt	fc	Ventana		
4096	256	0.250000	0.040000	Welch		
M(0)	M(1)	M(2)	M(3)	M(4)	M(-1)	M(-2)
101.392281	39.460453	26.571836	25.460096	30.459713	488.341919	3765.280518
Hs	Tz	Tc	Tp	Tp(mom.)	Eps	
40.317772	1.953402	0.934002	8.000000	14.452721	0.878283	

Espectro de Energía del Oleaje
Delta Ebro, 16/12/93, PII, V5

(X 1000)



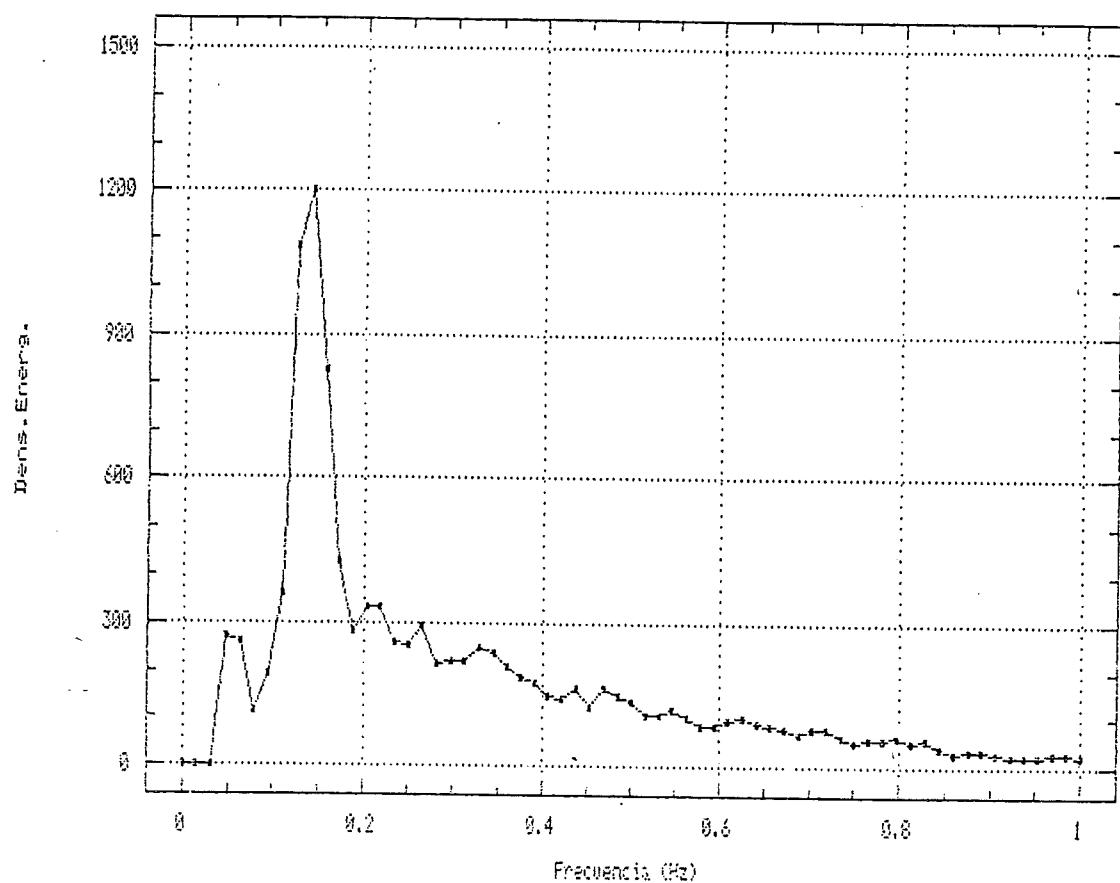
12161004.wav

N	M	Dt	fc	Ventana
4096	256	0.250000	0.040000	Welch

M(0)	M(1)	M(2)	M(3)	M(4)	M(-1)	M(-2)
275.005920	97.677200	53.284073	42.012108	44.459377	1214.190796	8141.112793

Hs	Tz	Tc	Tp	Tp(mom.)	Eps
66.399544	2.271812	1.094755	7.111111	10.514604	0.876234

Espectro de Energía del Oleaje
Delta Ebro, 16/12/93, P11, V6



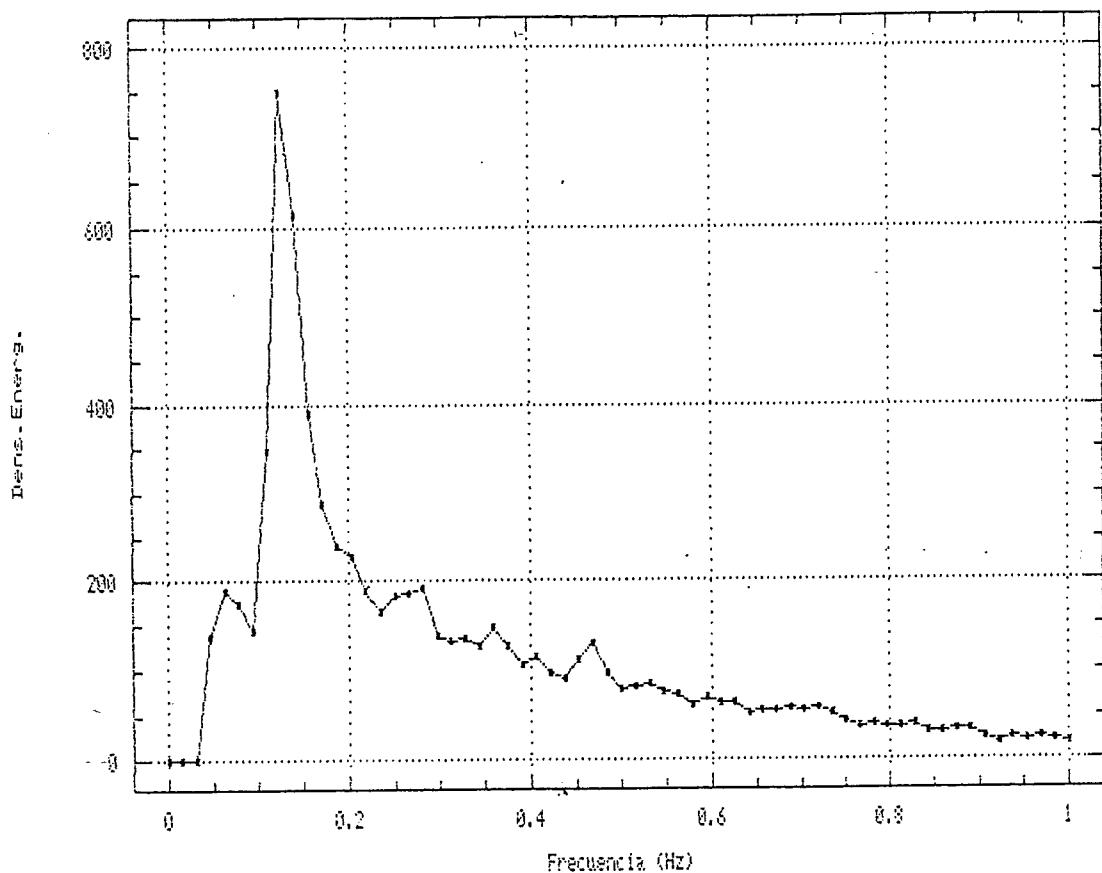
12161055.wav

N M Dt fc Ventana
4096 256 0.250000 0.040000 Welch

M(0) M(1) M(2) M(3) M(4) M(-1) M(-2)
184.350143 63.865070 37.842255 33.074528 37.323288 943.865906 7820.608887

Hs Tz TcTpTp(mom.)Eps
54.364552 2.207157 1.006928 7.111111 14.696605 0.889872

Espectro de Energía del Oleaje
Delta Ebro, 16/12/93, P11, V7



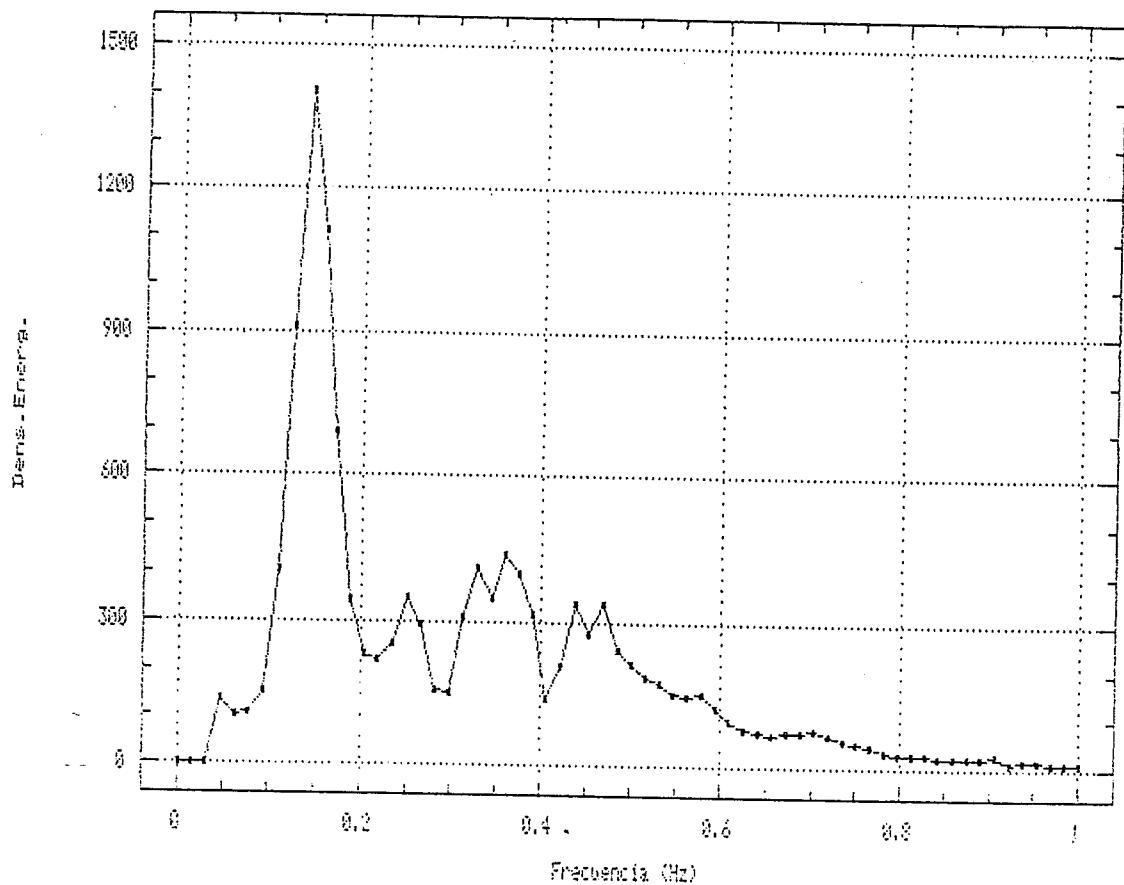
12161205.wav

N M Dt fc Ventana
4096 256 0.250000 0.040000 Welch

M(0) M(1) M(2) M(3) M(4) M(-1) M(-2)
116.486122 42.621048 27.119680 25.248144 29.882025 581.673218 4689.134766

Hs Tz TcTpTp(mom.)Eps
43.214664 2.072501 0.952659 8.000000 14.728837 0.888092

Espectro de Energía del Oleaje
Delta Ebro, 16/12/93, P11, V8



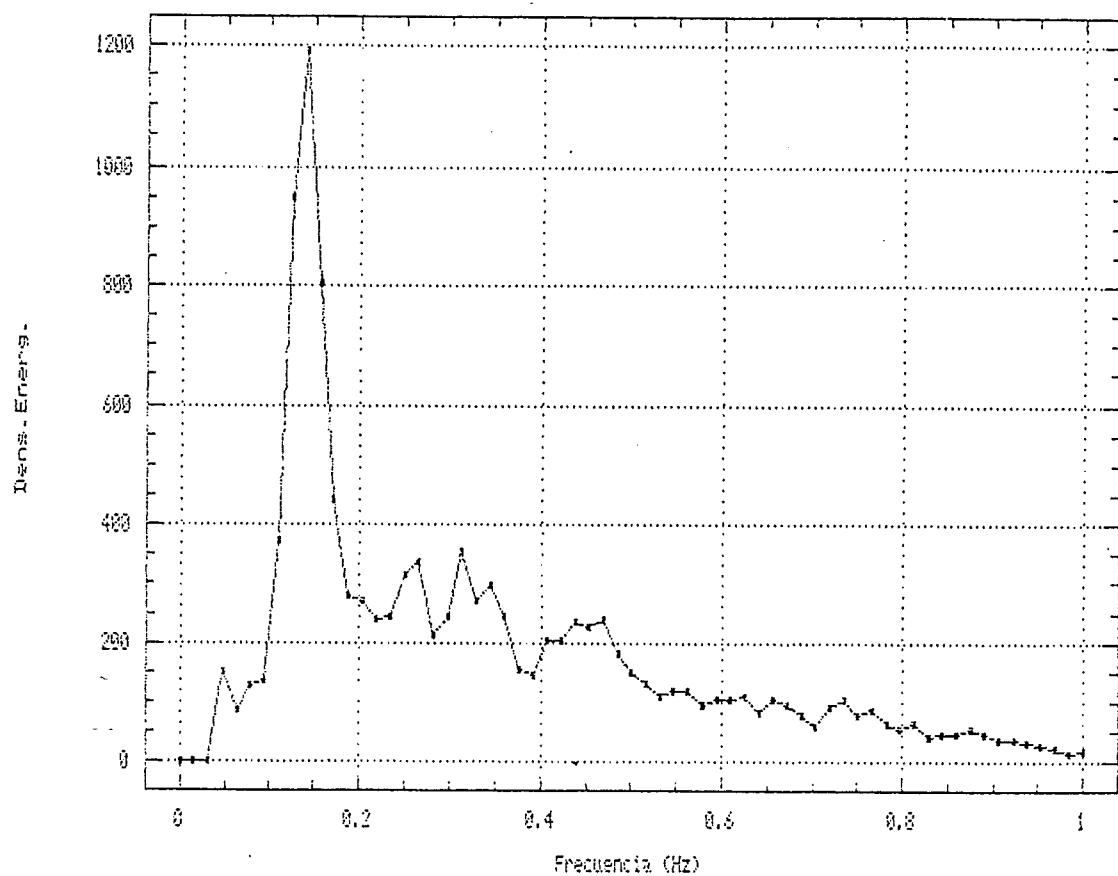
12161407.wav

N M Dt fc Ventana
4096 256 0.250000 0.040000 Welch

M(0) M(1) M(2) M(3) M(4) M(-1) M(-2)
208.759842 69.479973 35.299980 26.014837 26.148689 971.392578 6675.446269

Hs Tz TcTpTp(mom.)Eps
57.851691 2.431847 1.161663 7.111111 10.642558 0.878481

Espectro de Energía del Oleaje
Delta Ebro, 16/12/93, PII, V9



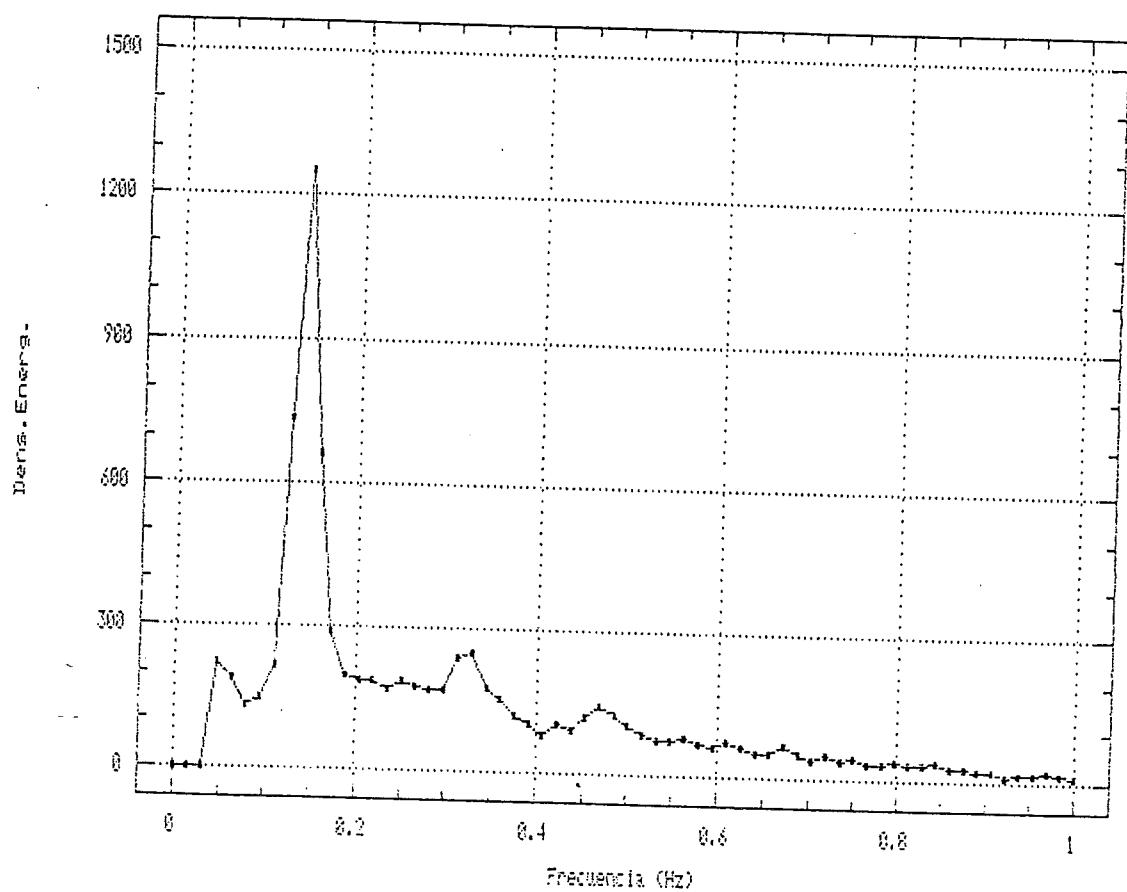
12161507.wav

N M Dt fc Ventana
4096 256 0.250000 0.040000 Welch

M(0) M(1) M(2) M(3) M(4) M(-1) M(-2)
189.512314 70.726982 43.262390 37.962006 42.470692 862.111023 6093.134277

Hs Tz Tc Tp Tp(mom.) Eps
55.120453 2.092972 1.009277 7.111111 11.999165 0.876049

Espectro de Energía del Oleaje
Delta Ebro, 16/12/93, P11, V10



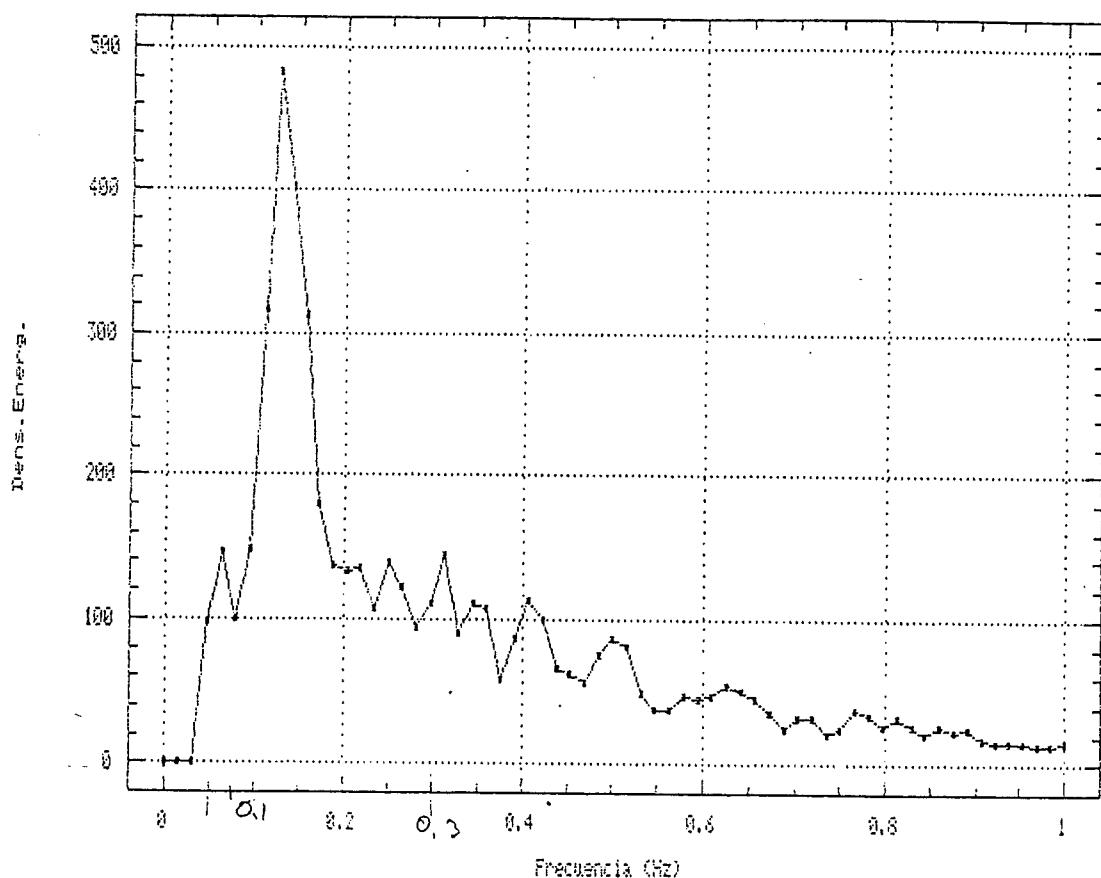
12161546.wav

N	M	Dt	fc	Ventana
4096	256	0.250000	0.040000	Welch

M(0)	M(1)	M(2)	M(3)	M(4)	M(-1)	M(-2)
138.768707	46.699558	27.549128	24.364241	27.936077	734.501099	6183.242188

Hs	Tz	Tc	Tp	Tp(mom.)	Eps
47.167171	2.244357	0.993050	7.111111	14.994982	0.896786

Espectro de Energía del Oleaje
Delta Ebro, 16/12/93, PII, VII



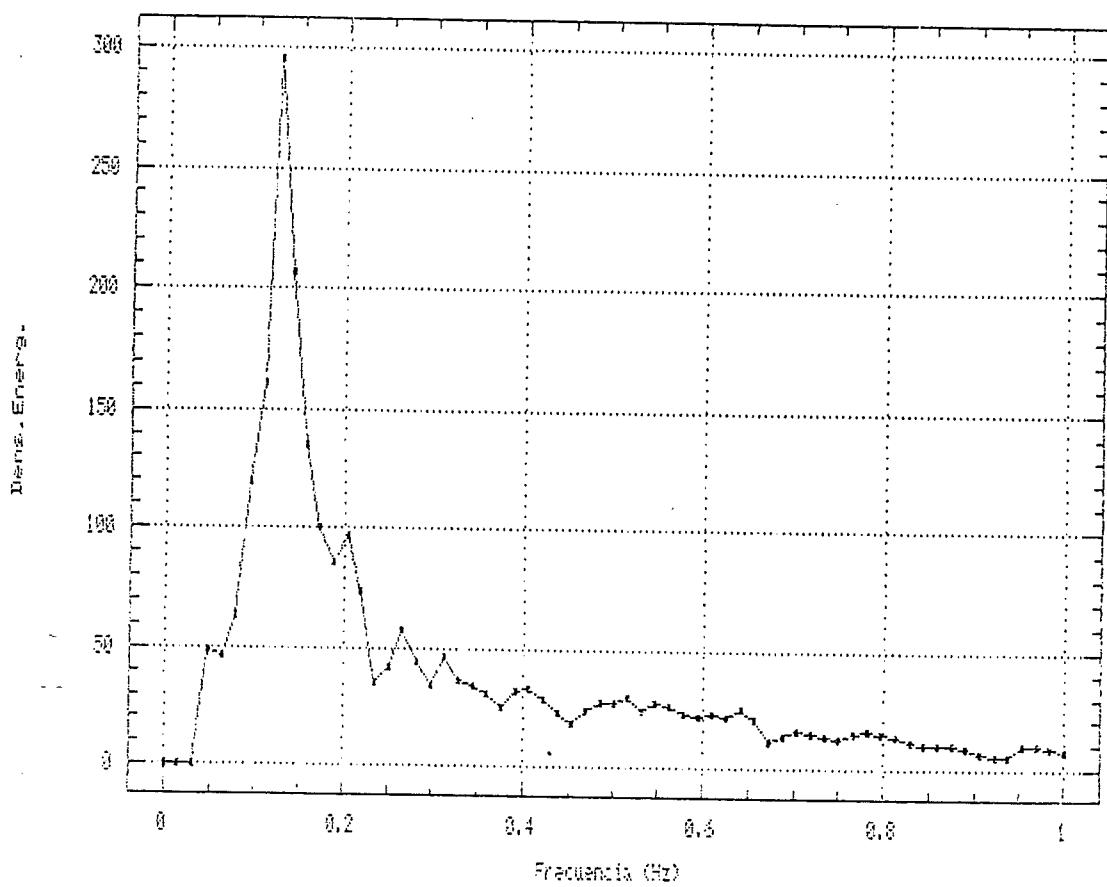
12161620.wav

N M Dt fc Ventana
4096 256 0.250000 0.040000 Welch

M(0) M(1) M(2) M(3) M(4) M(-1) M(-2)
88.716393 32.872425 21.622229 20.742476 25.013889 452.510651 3771.807861

Hs Tz Tc Tp Tp(mom.) Eps
37.713428 2.025591 0.929736 8.000000 15.753373 0.888439

Espectro de Energía del Oleaje
Delta Ebro, 16/12/93, P11, V12

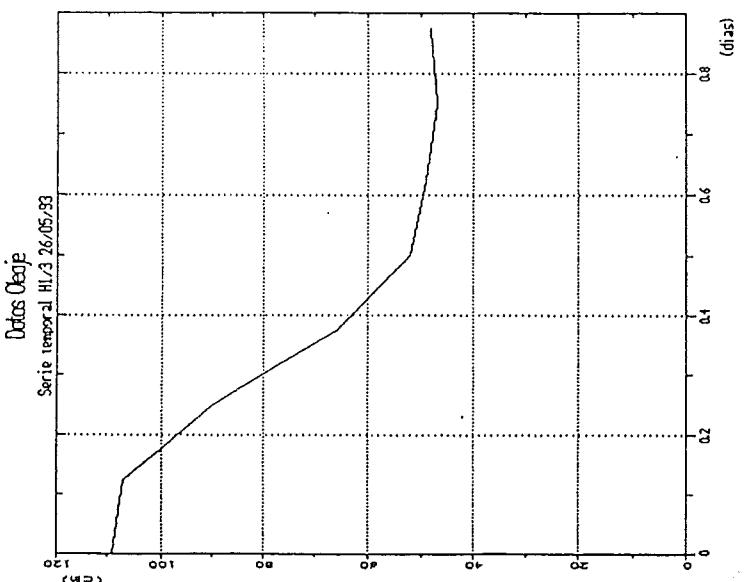
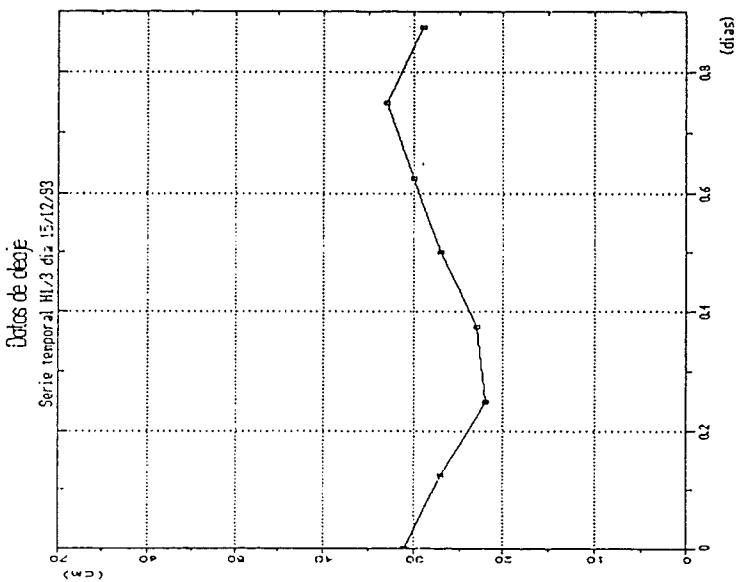
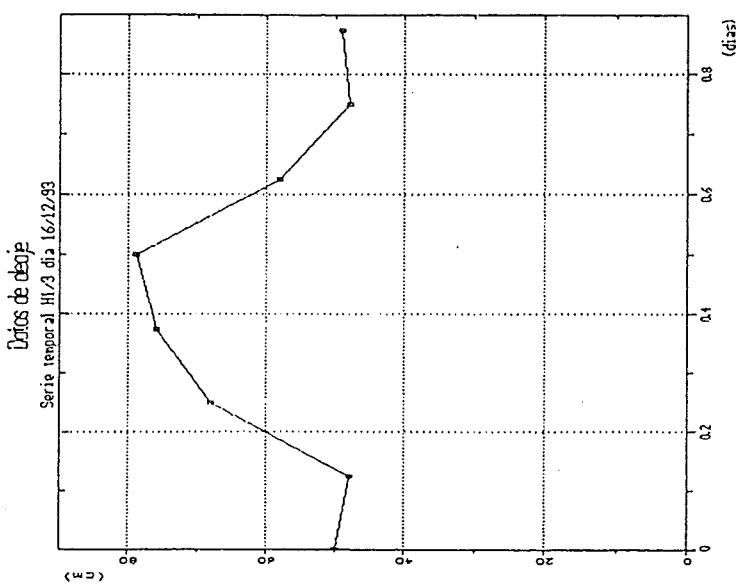


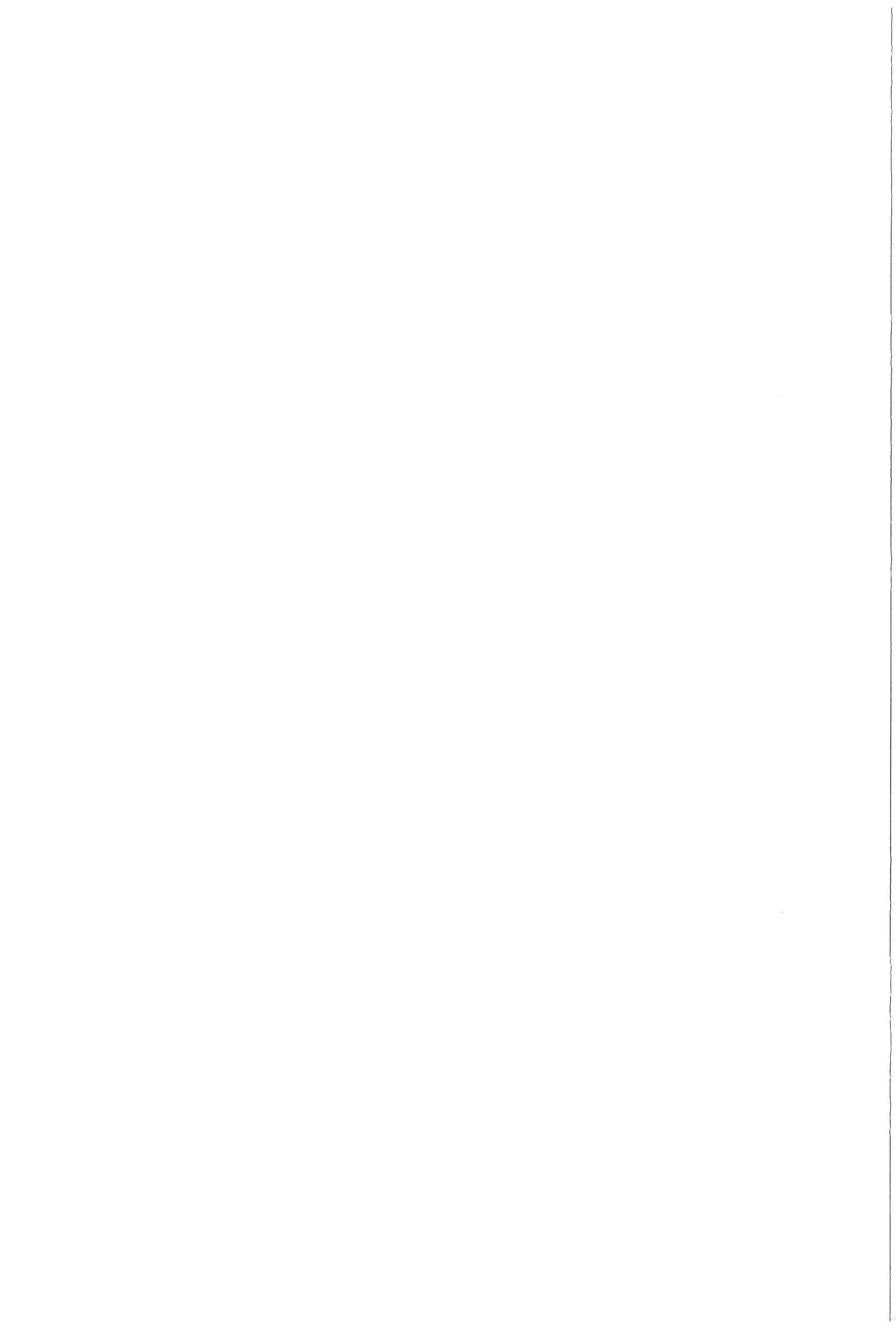
12161651.wav

N M Dt fc Ventana
4096 256 0.250000 0.040000 Welch

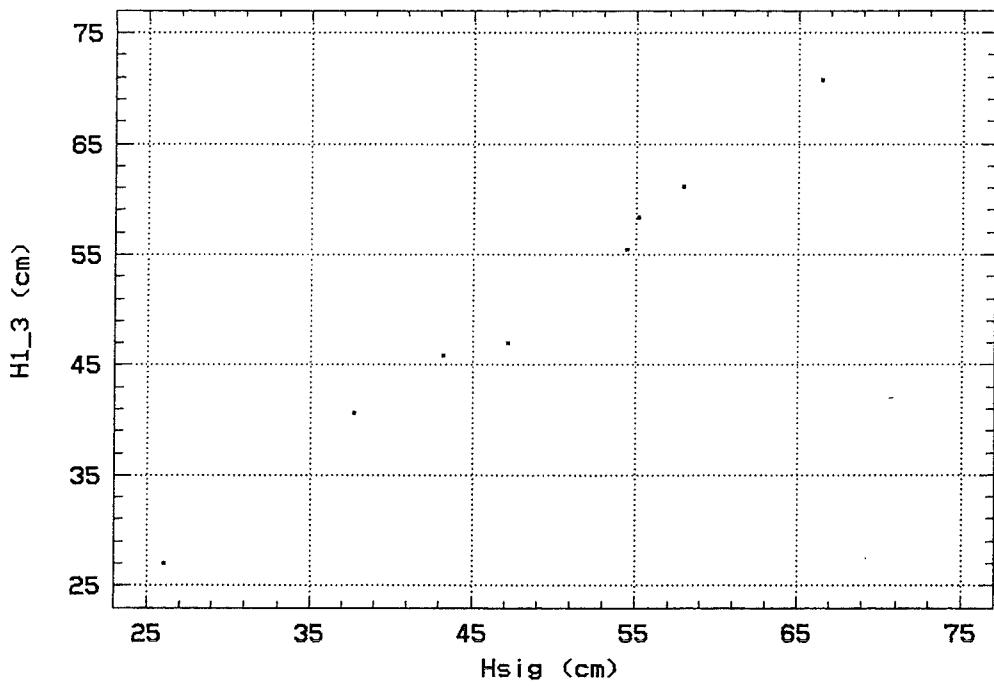
M(0) M(1) M(2) M(3) M(4) M(-1) M(-2)
42.293133 15.682526 11.244204 11.888738 15.421818 227.176392 1919.137207

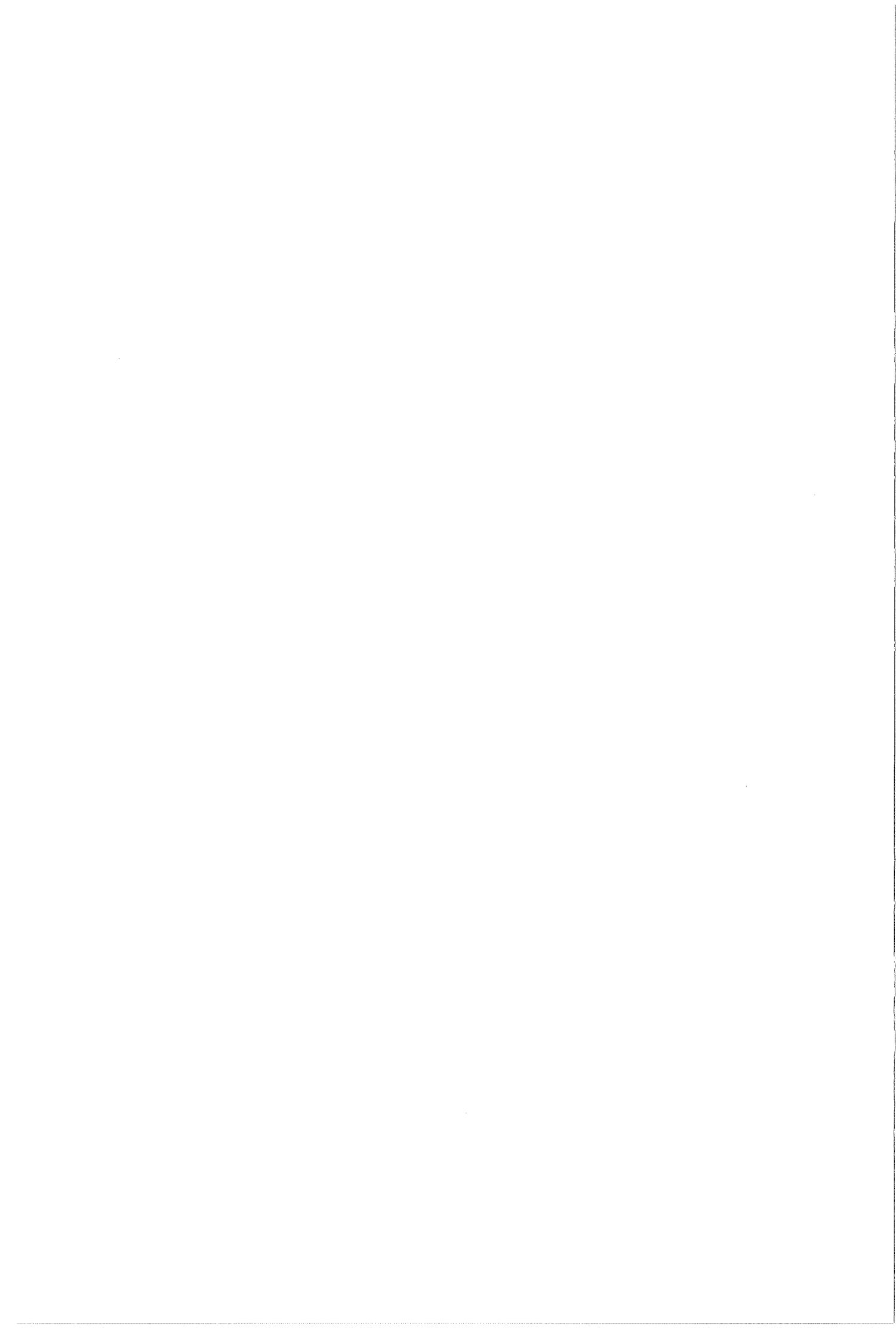
Hs Tz TcTpTp(mom.)Eps
26.039282 1.939414 0.853879 8.000000 16.826056 0.897862



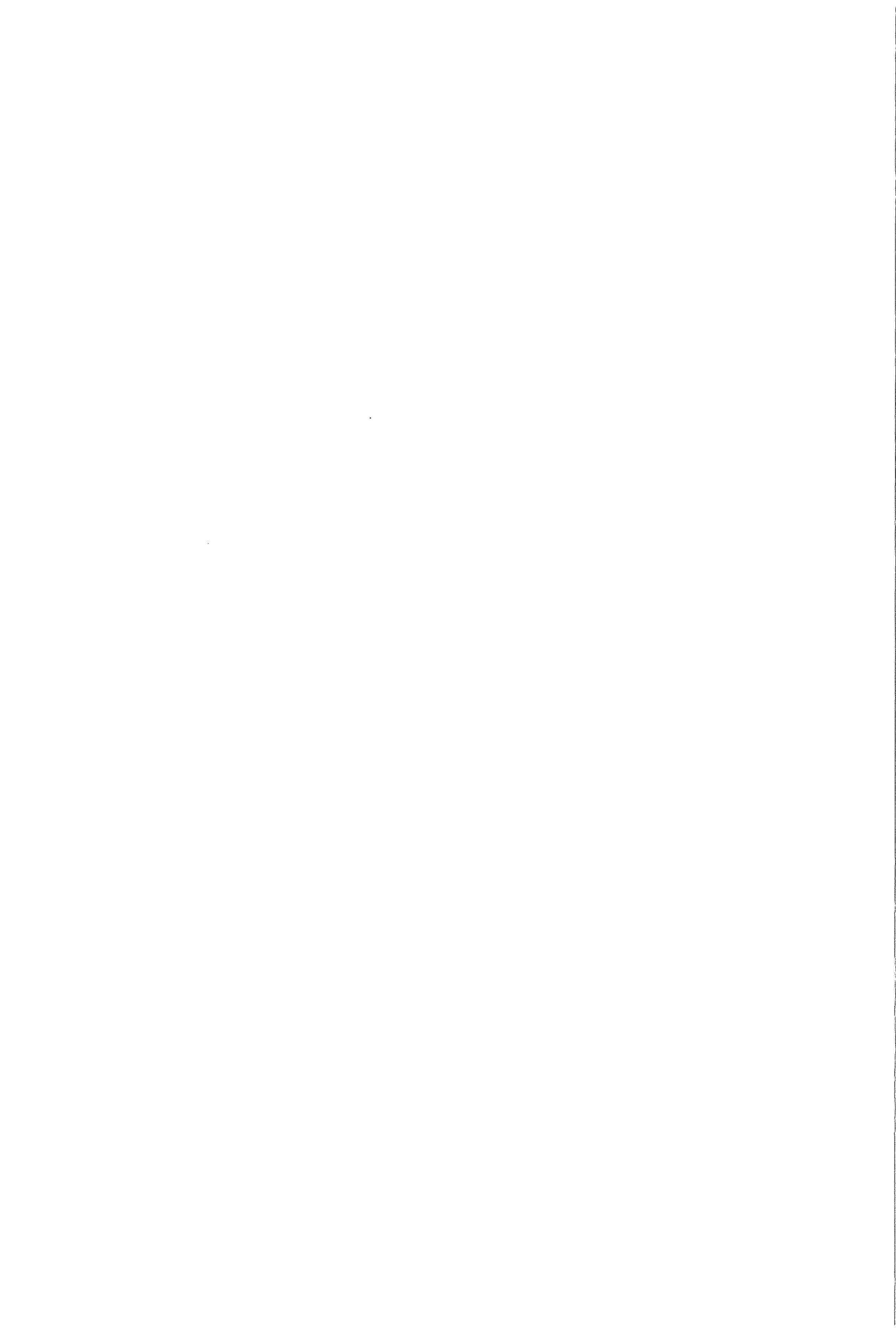


Hsig vs H1_3



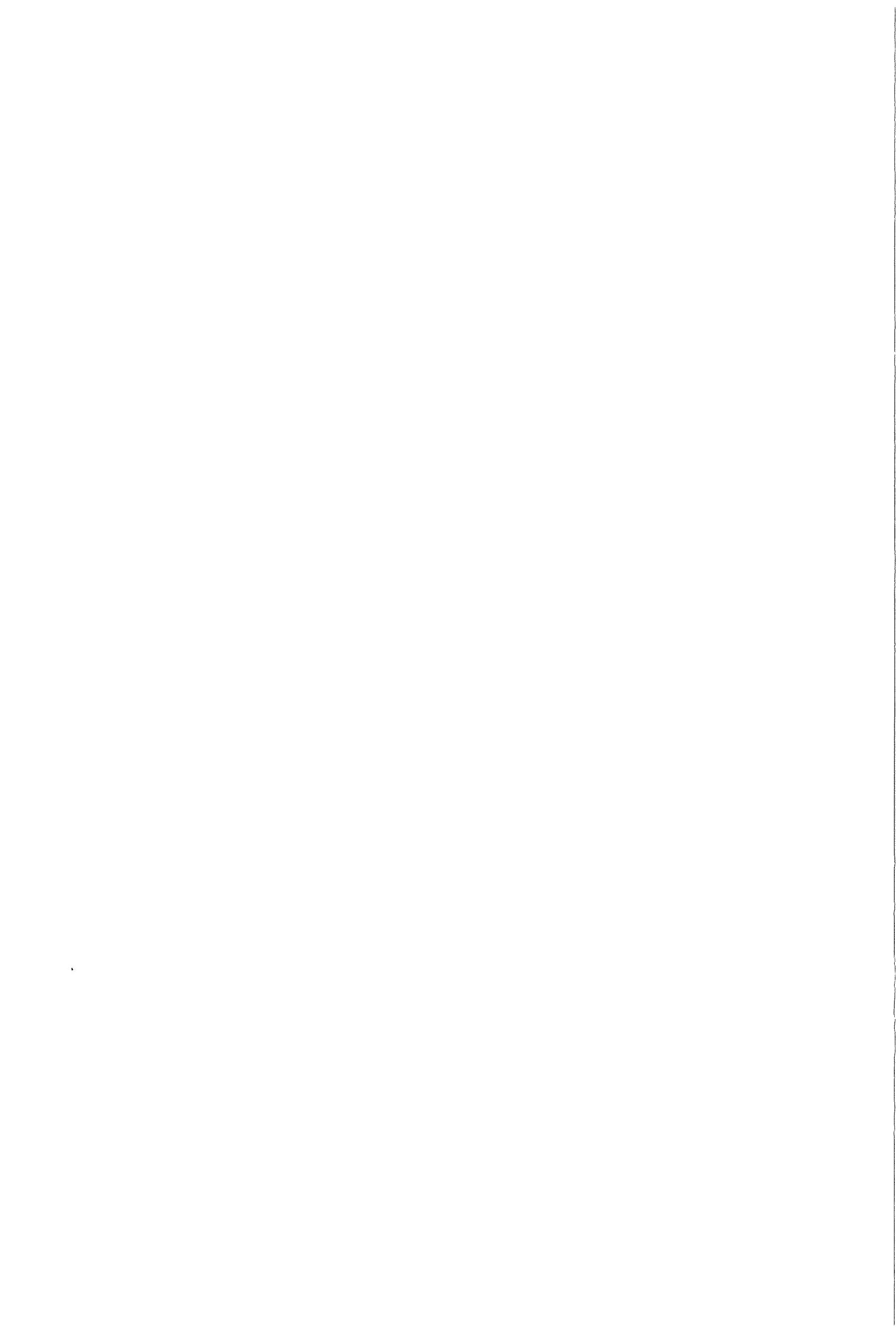


C4. Velocidades y Niveles en la Zona de Rompientes



C4.1.

Flujo Medio

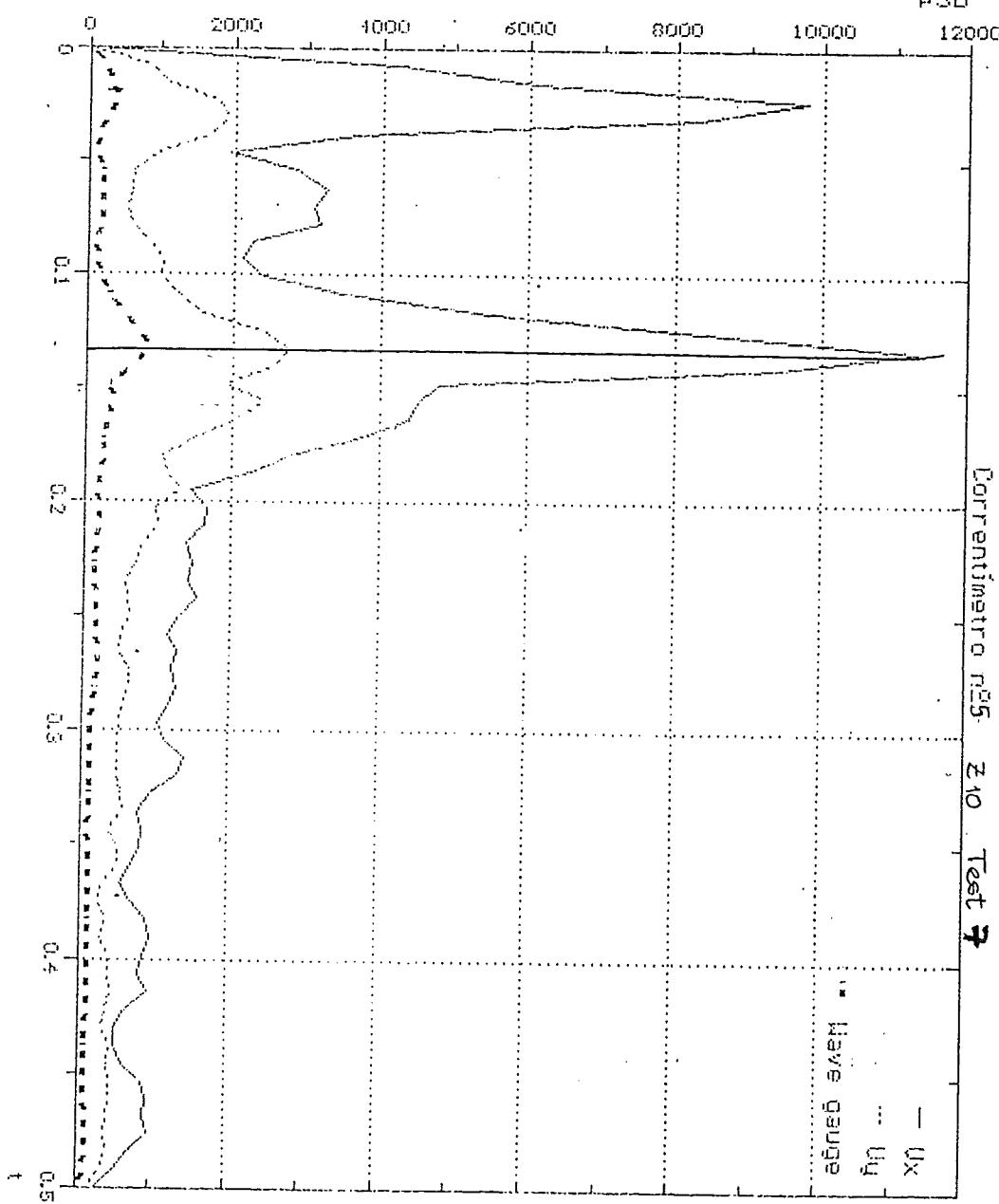


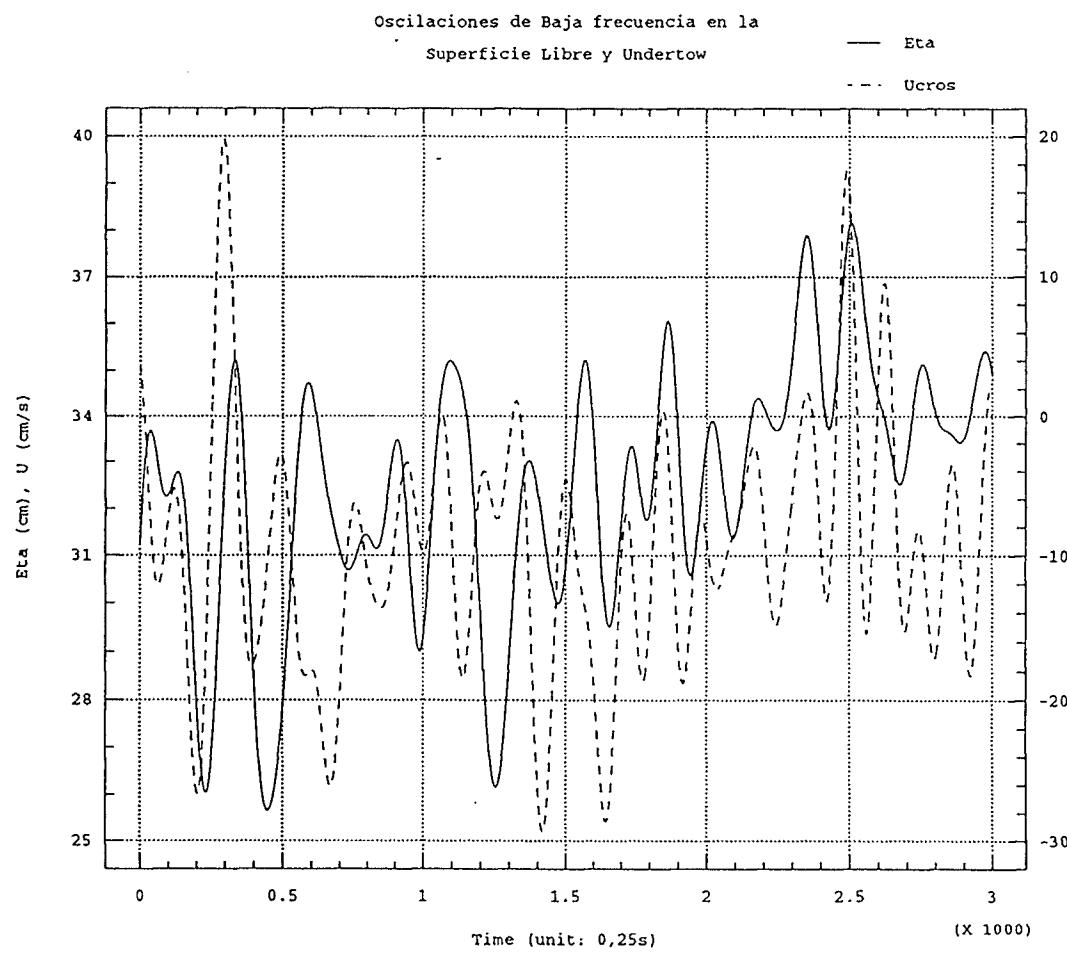
Velocidades dia 18-12-93 12:05

Correntímetro nº5 z=10 Test 7

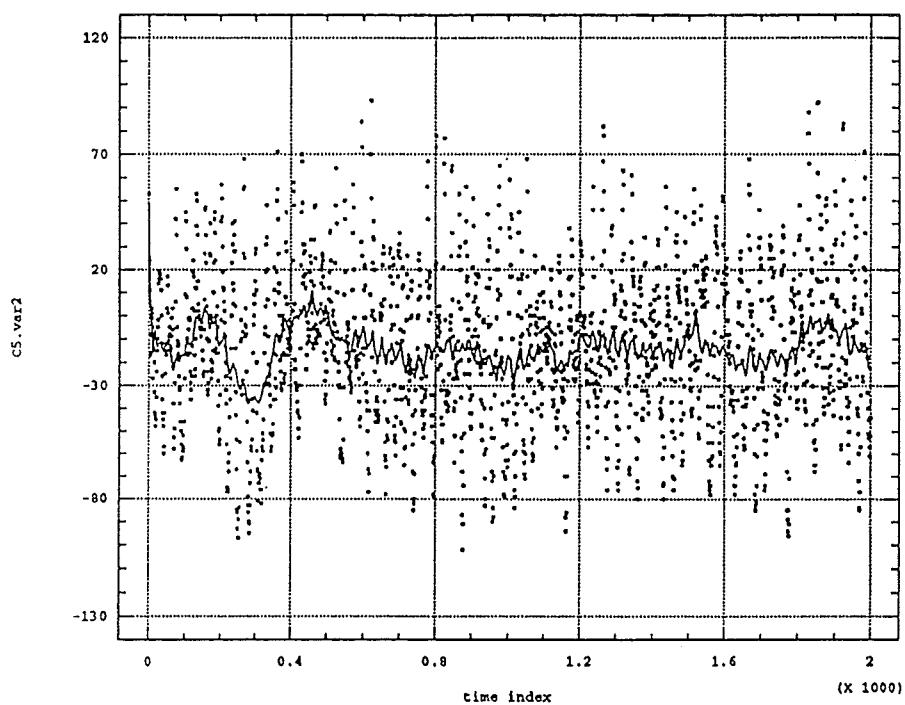
PSD

— U_x
... U_y
* Wave gauge

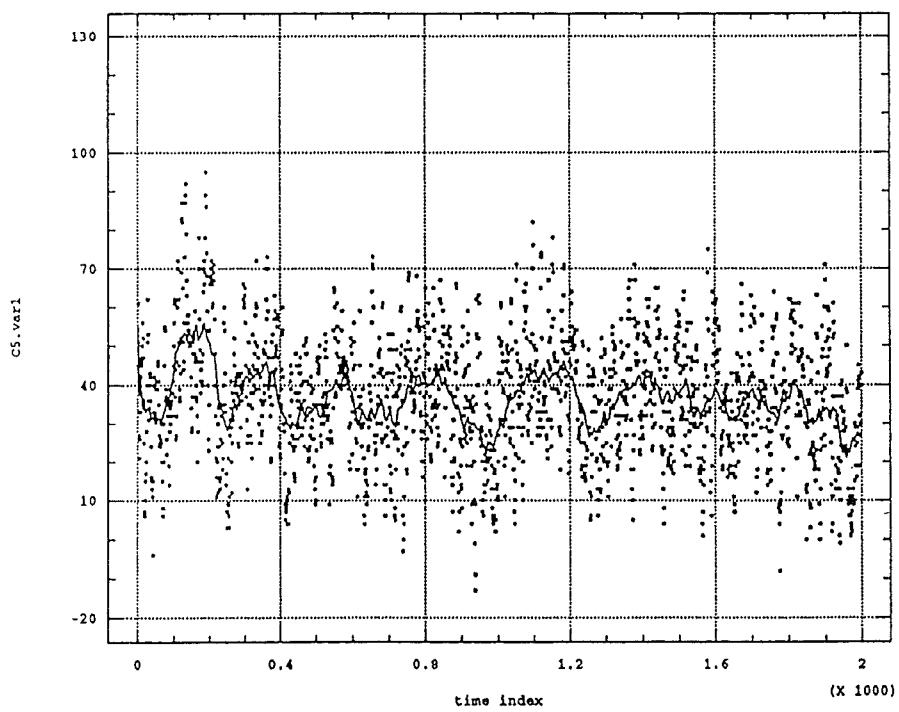




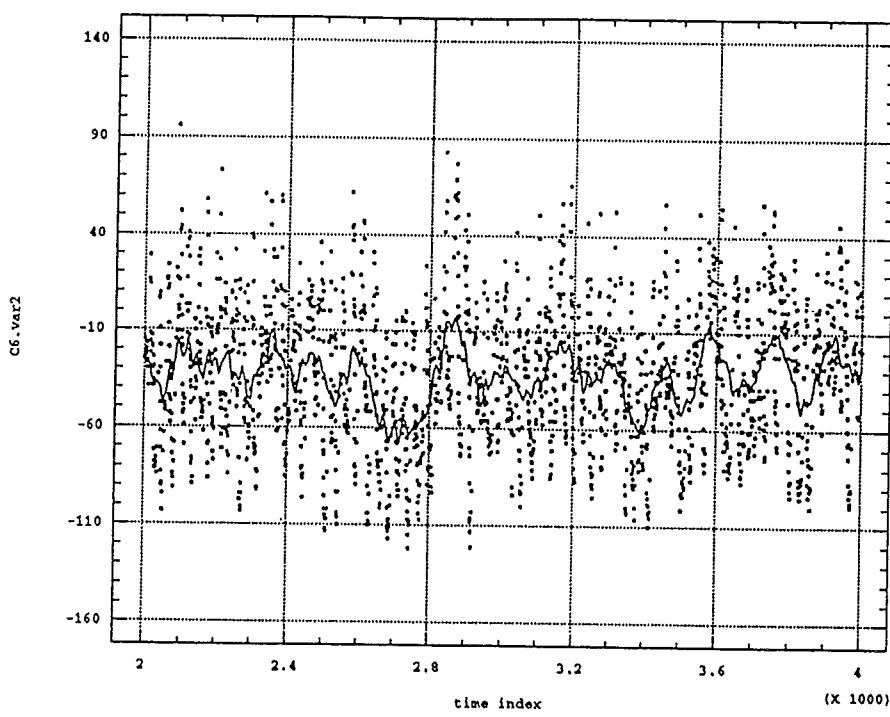
Moving Average of 65 Terms
Undertow oscillation



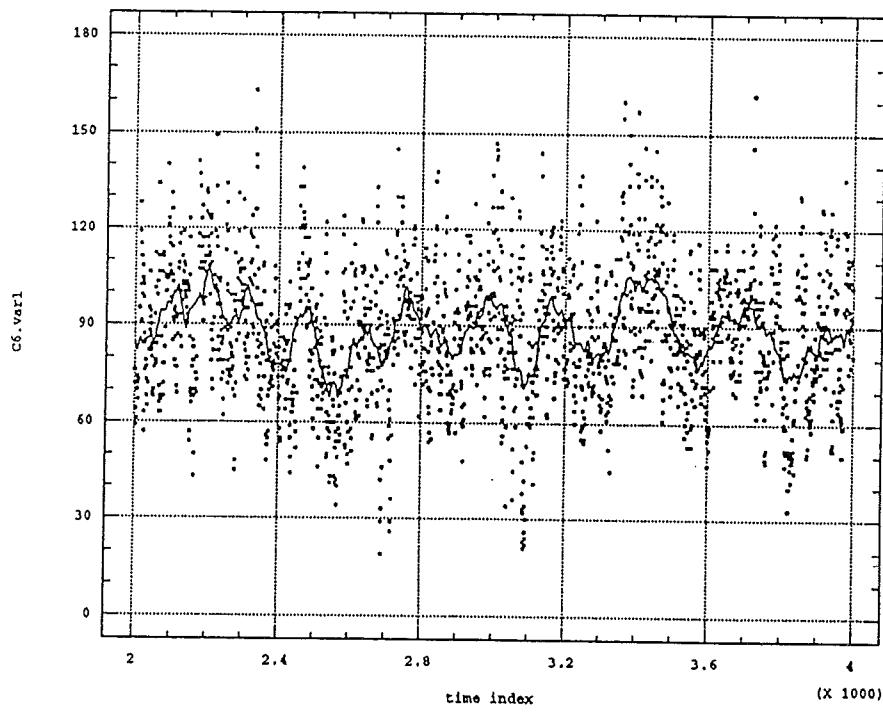
Moving Average of 65 Terms



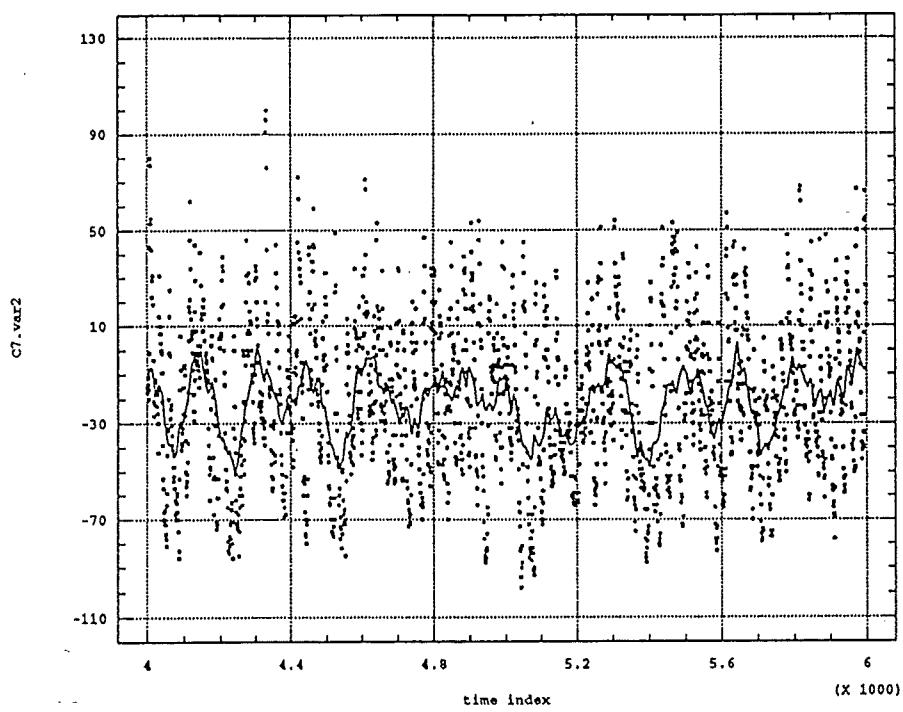
Moving Average of 65 Terms
Undertow oscillation



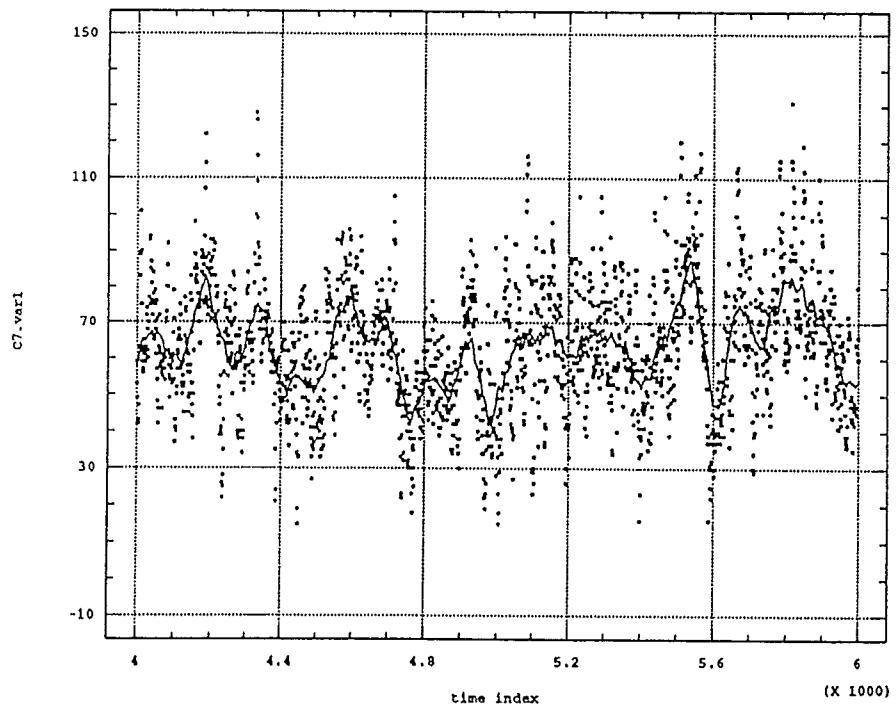
Moving Average of 65 Terms



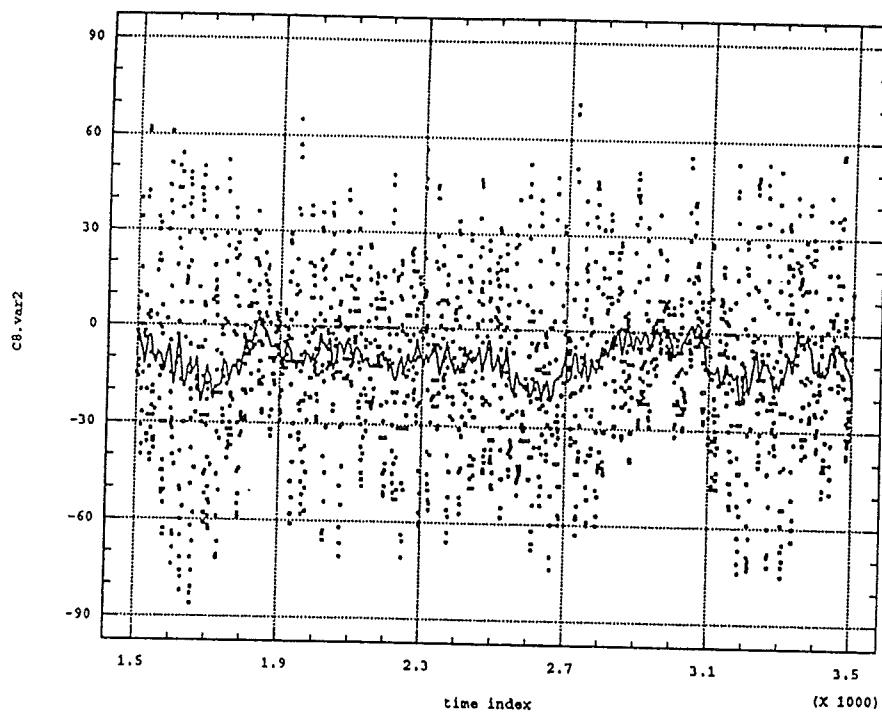
Moving Average of 65 Terms
Undertow oscillation



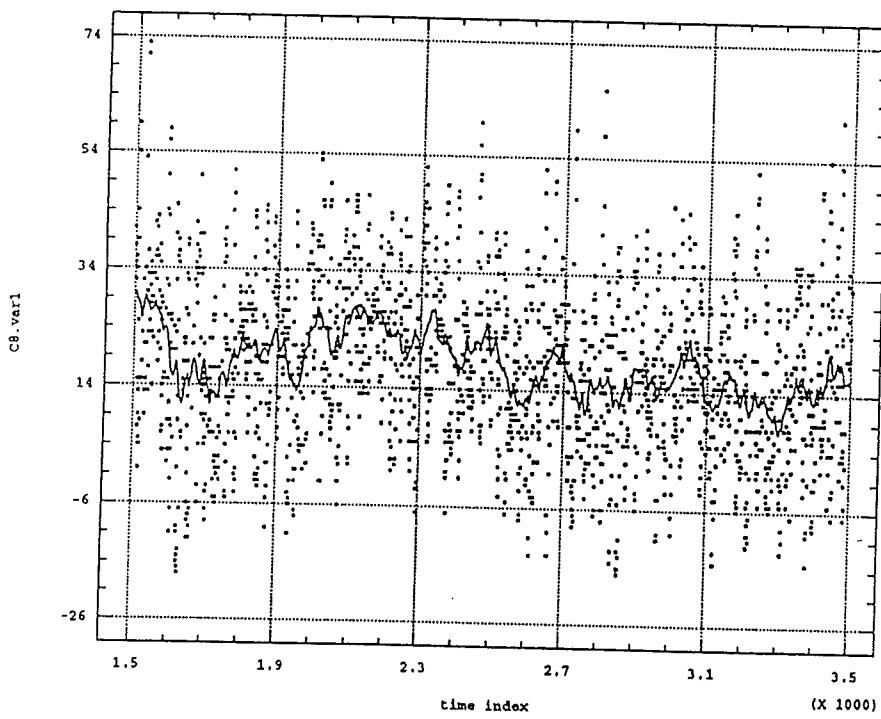
Moving Average of 65 Terms

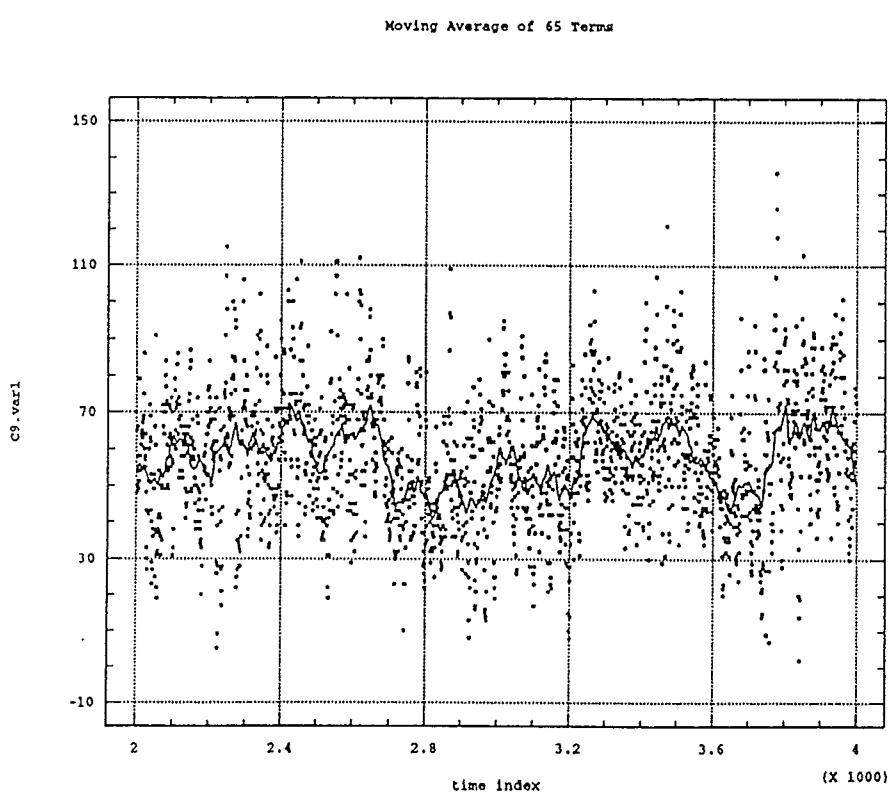
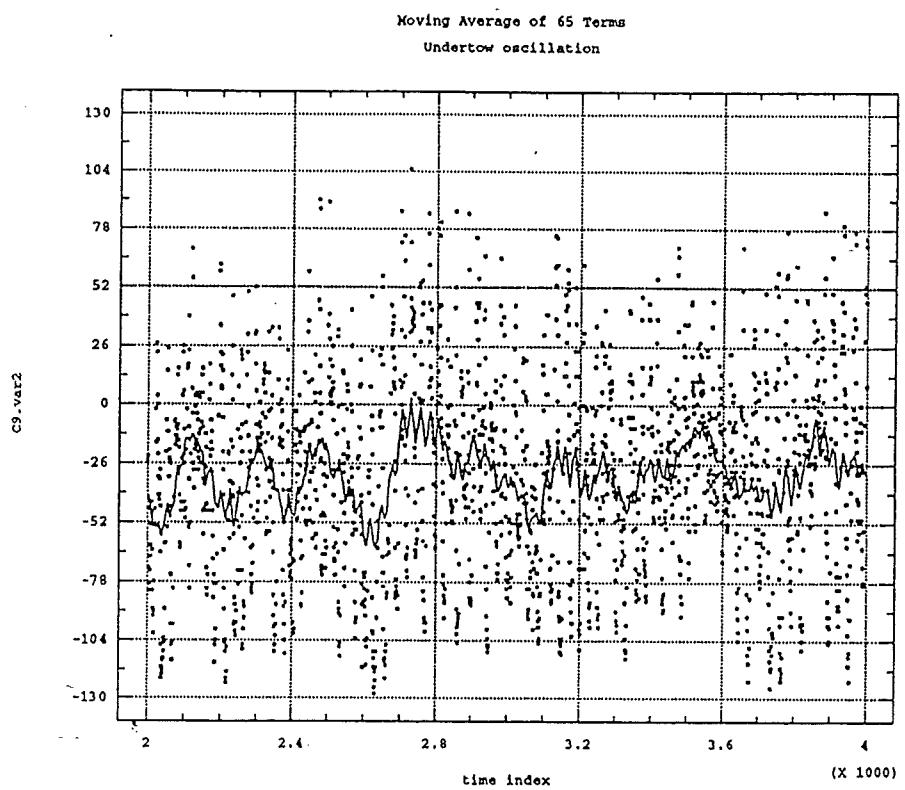


Moving Average of 65 Terms
Undertow oscillation

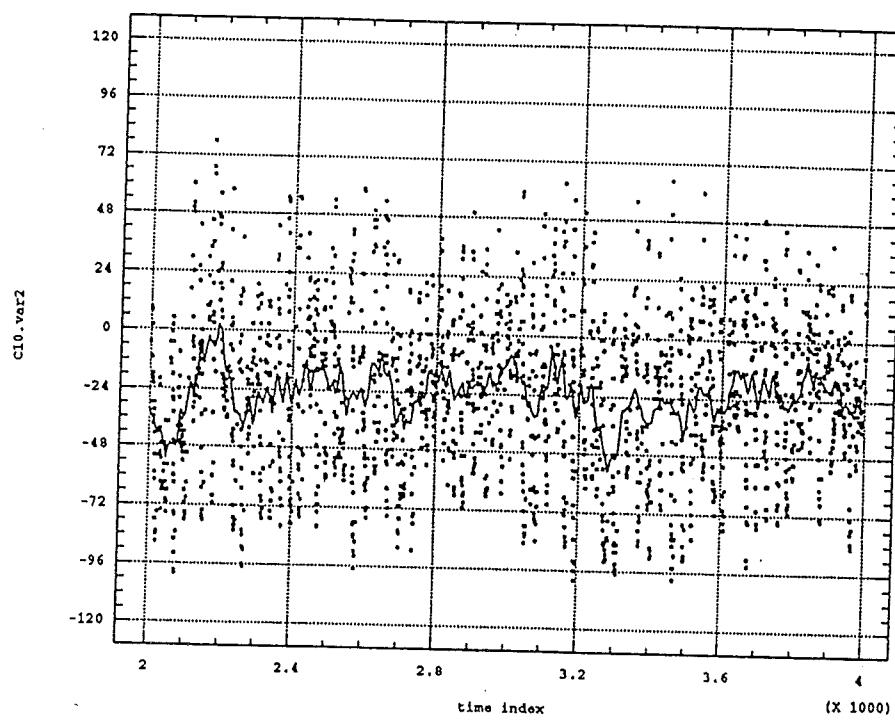


Moving Average of 65 Terms

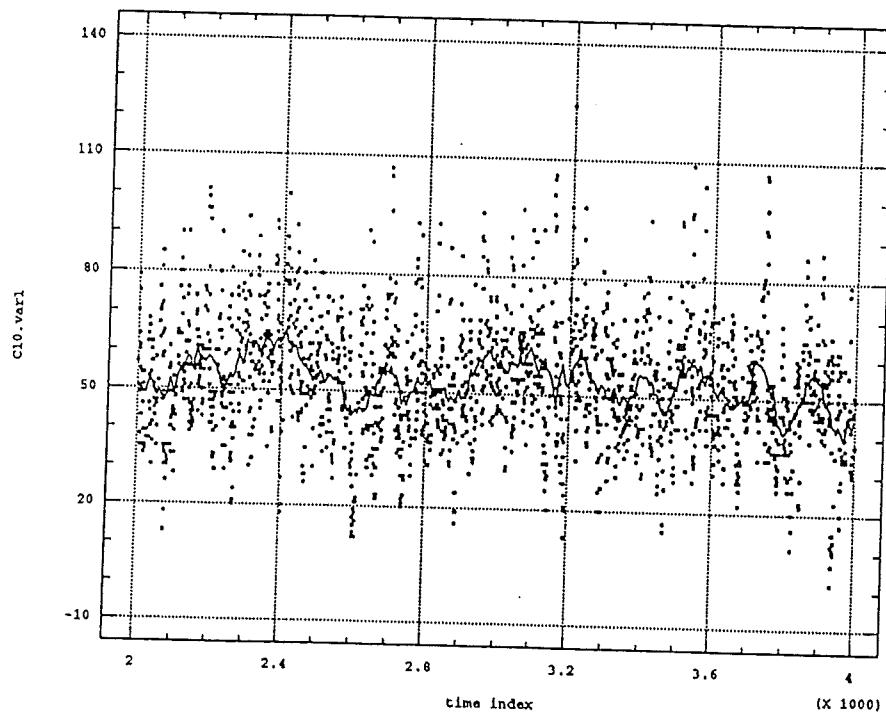


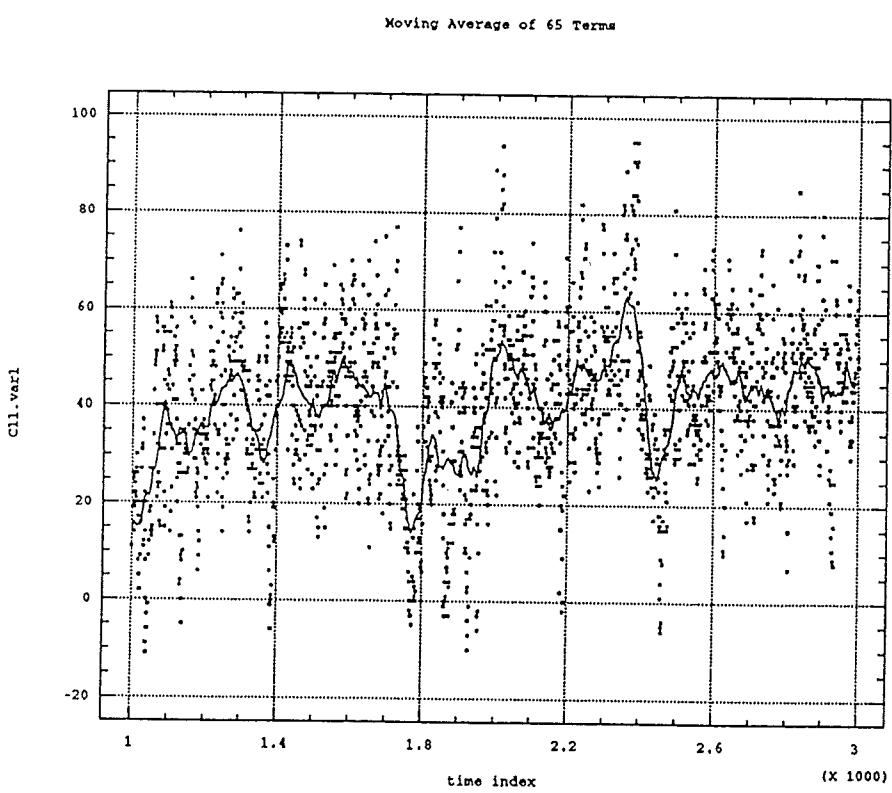
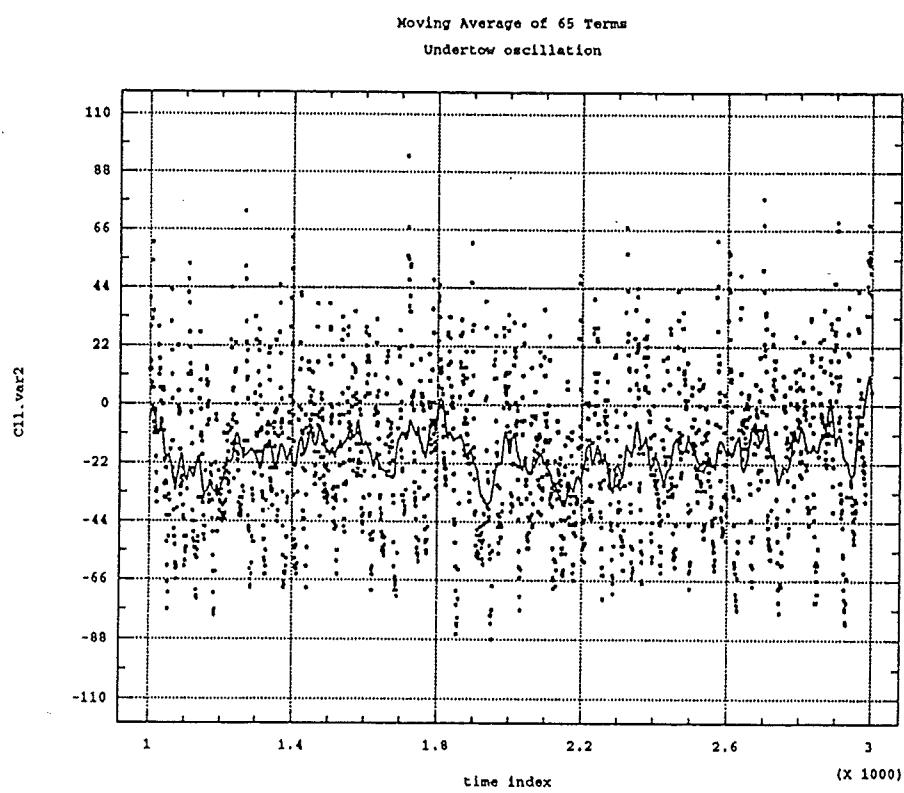


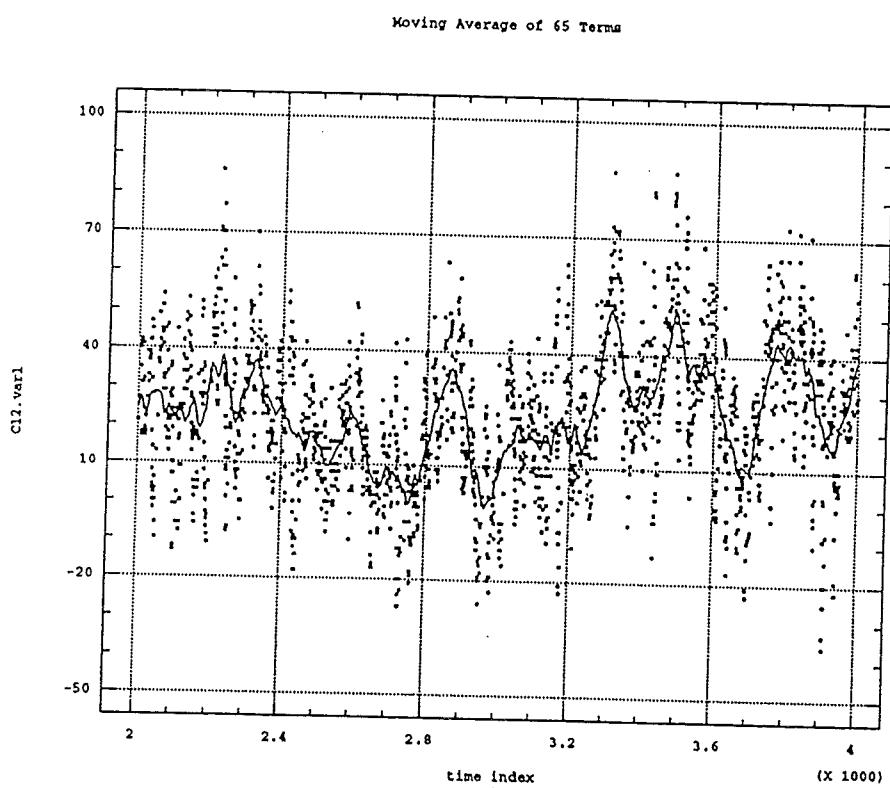
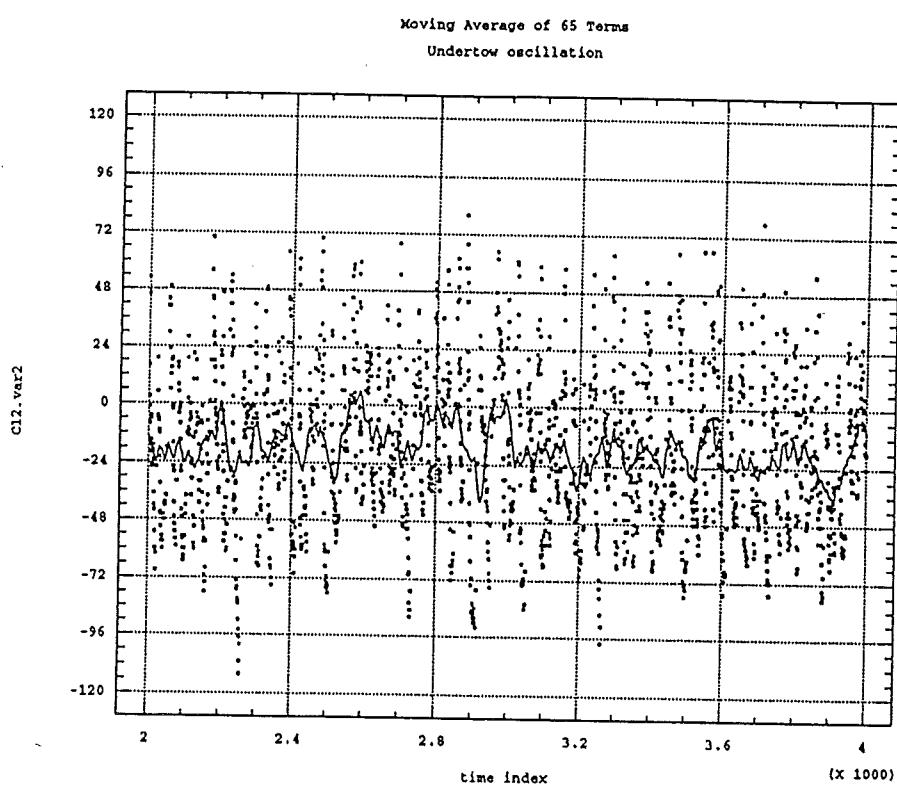
Moving Average of 65 Terms
Undertow oscillation



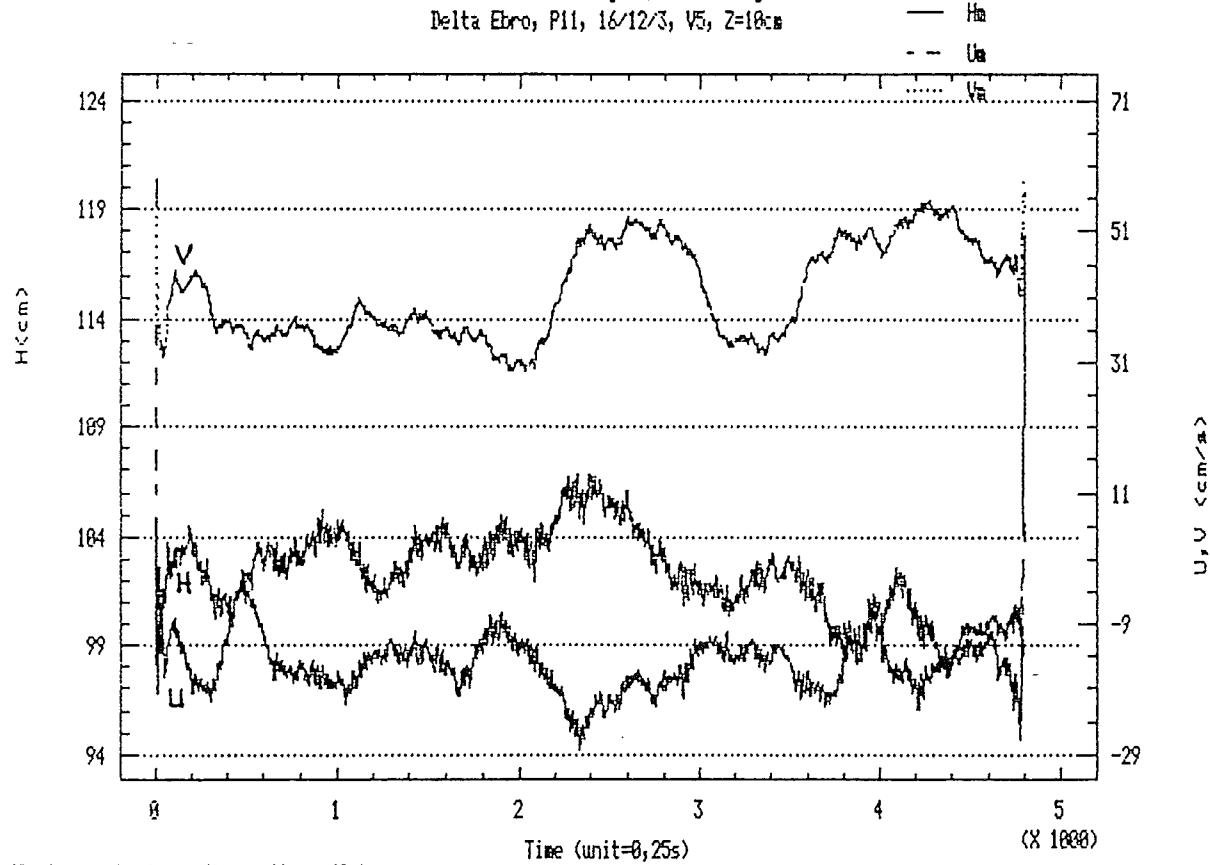
Moving Average of 65 Terms





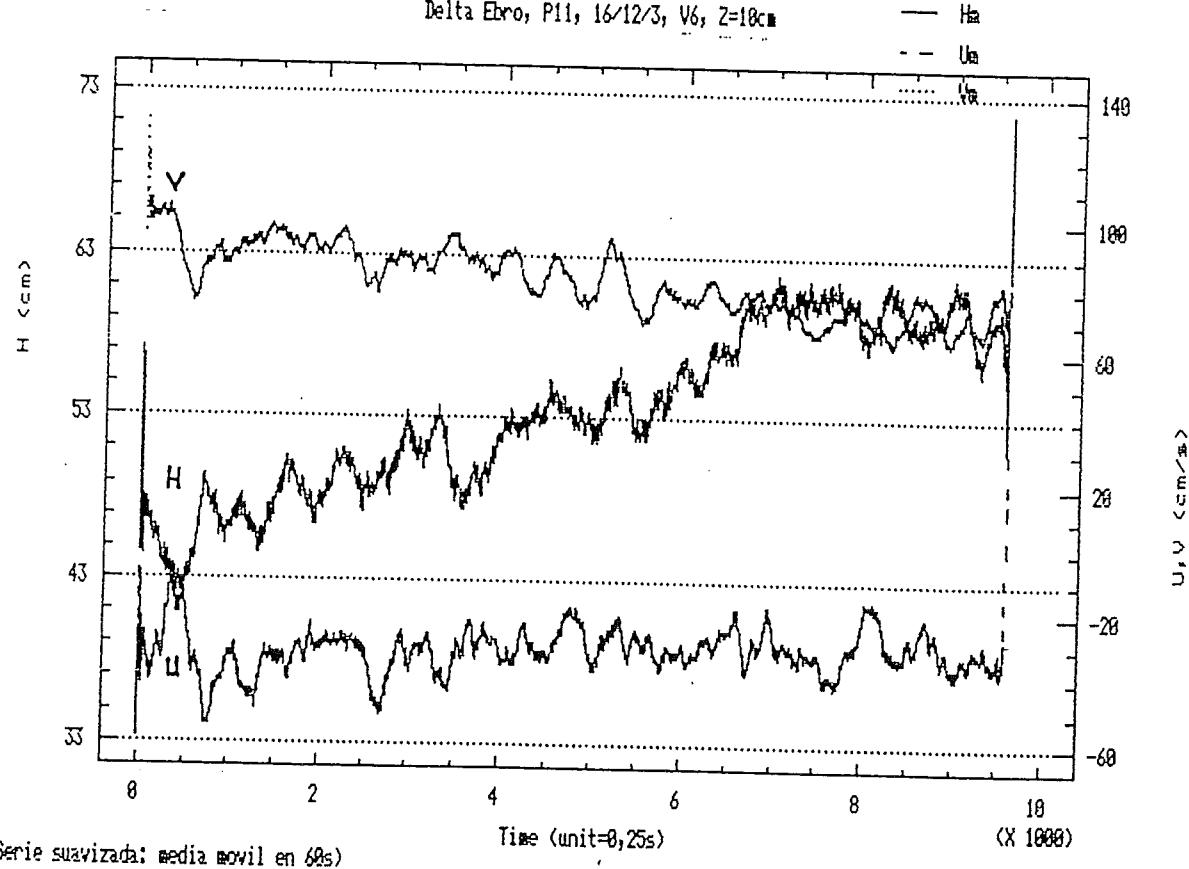


Evolucion del MLL y Corrientes U y V
Delta Ebro, P11, 16/12/3, V5, Z=10cm

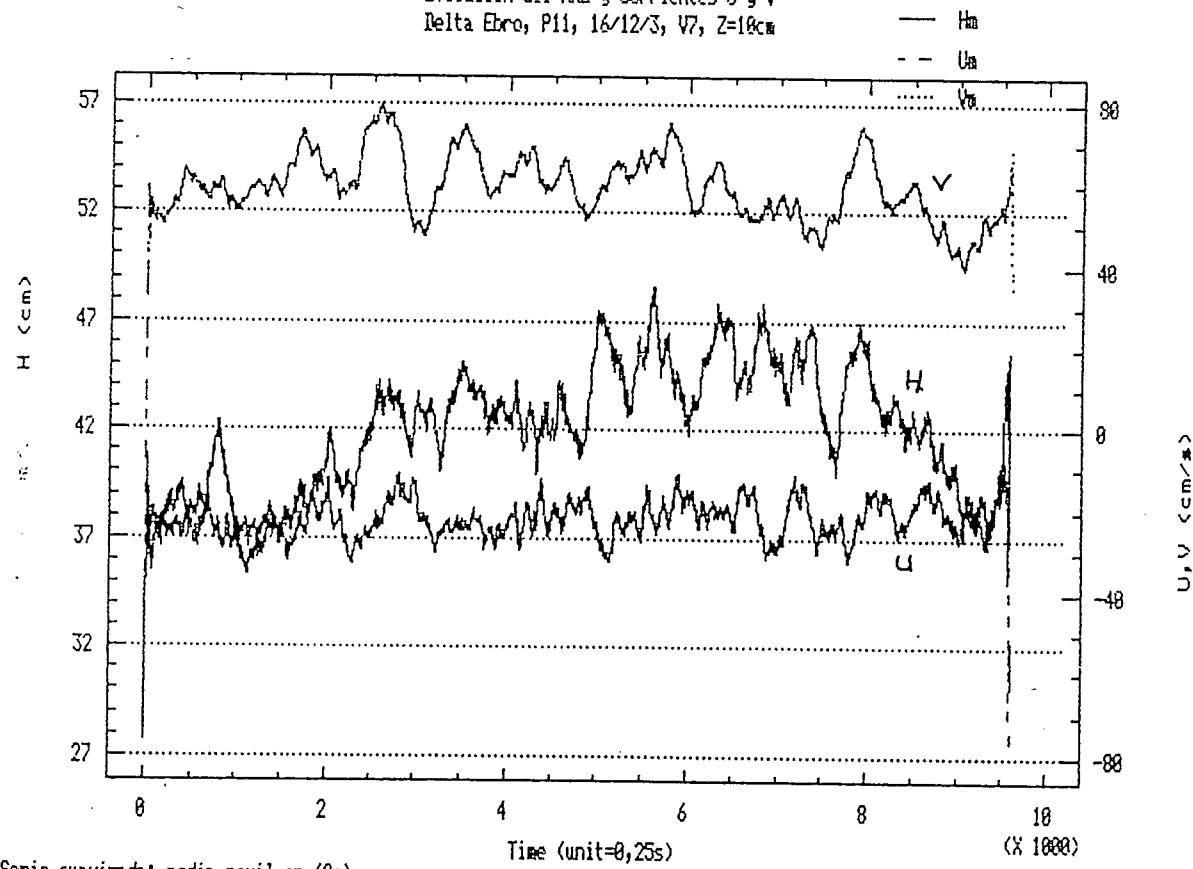


(Serie suavizada: media móvil en 60s)

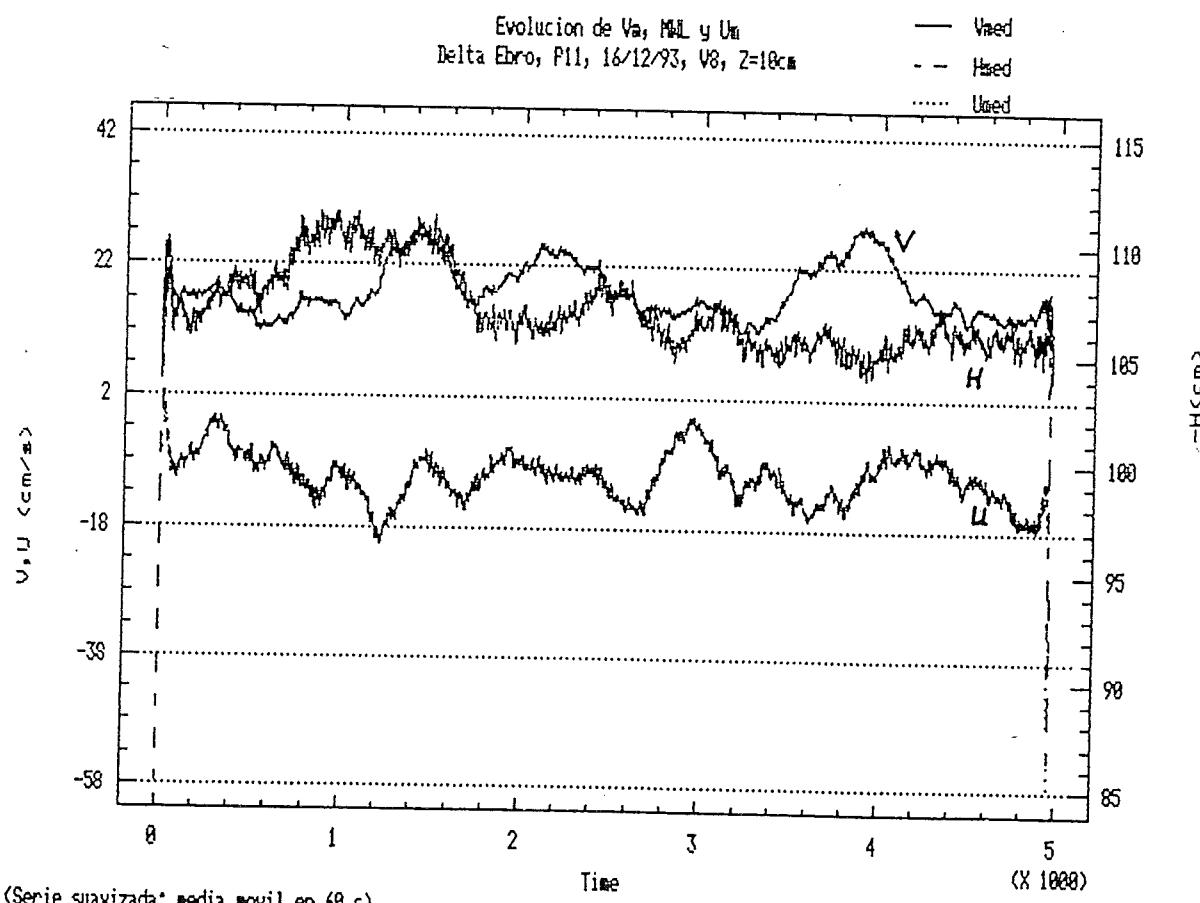
Evolucion del MLL y Corrientes U y V
Delta Ebro, P11, 16/12/3, V6, Z=10cm

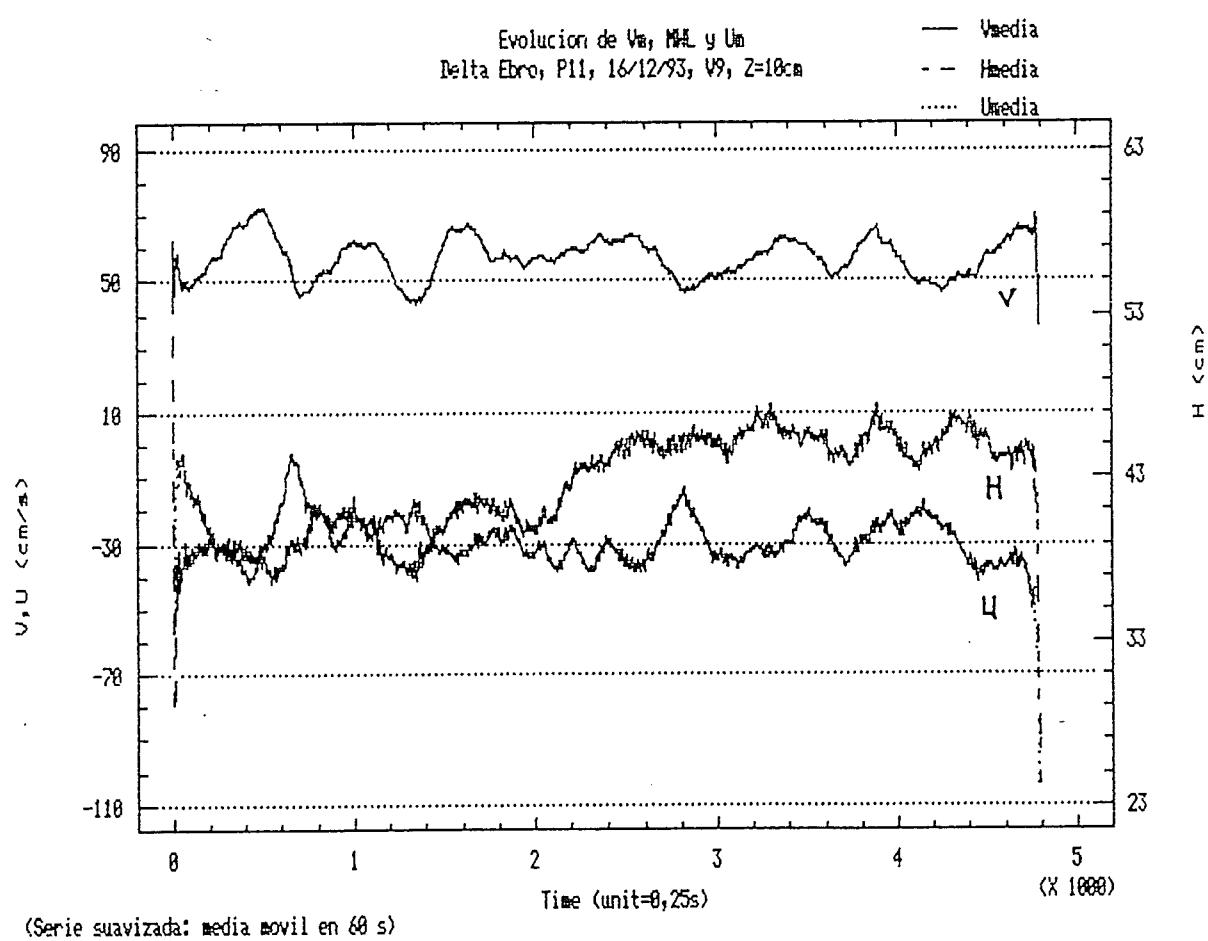


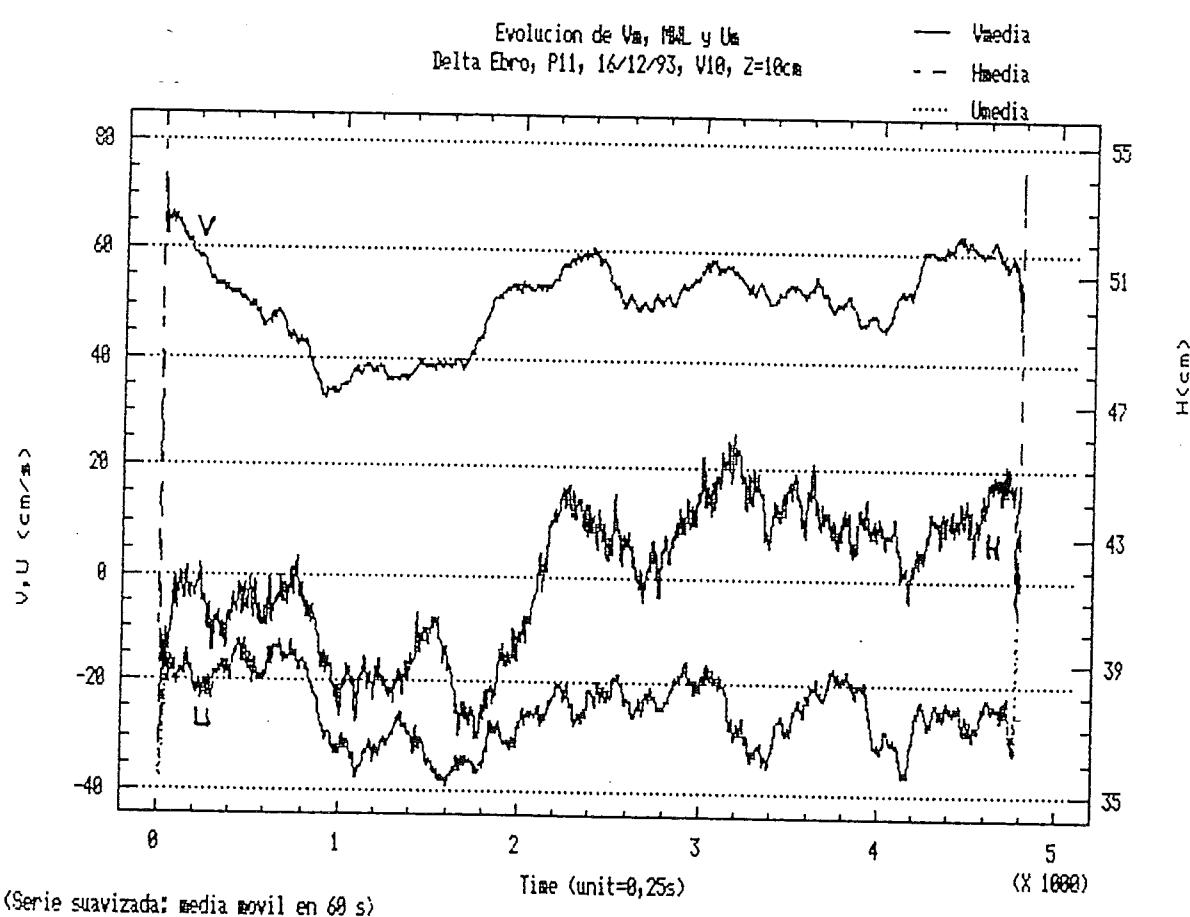
Evolucion del MLL y Corrientes U y V
Delta Ebro, P11, 16/12/83, V7, Z=10cm

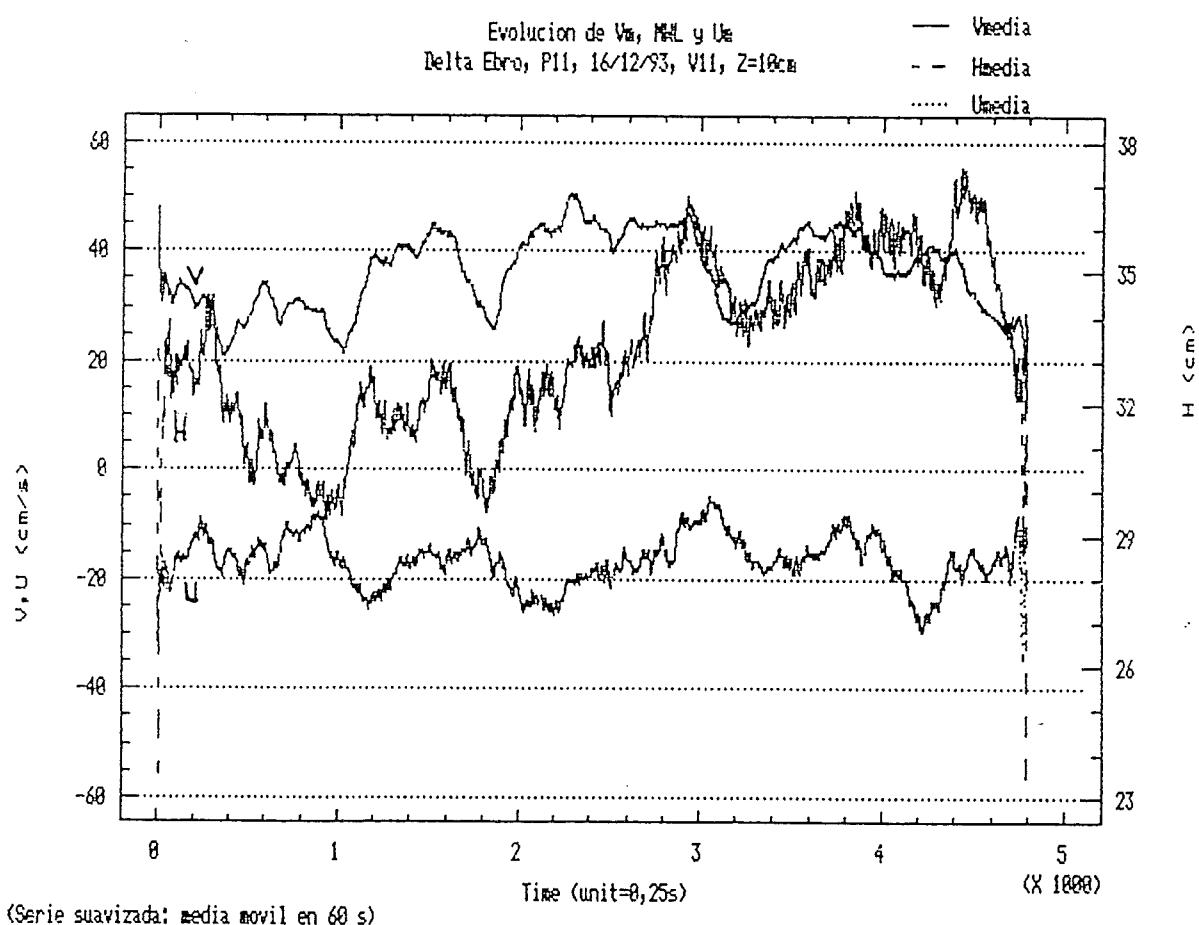


Evolucion de V_a , H_{ed} y U_{ed}
Delta Ebro, P11, 16/12/93, V8, Z=10cm



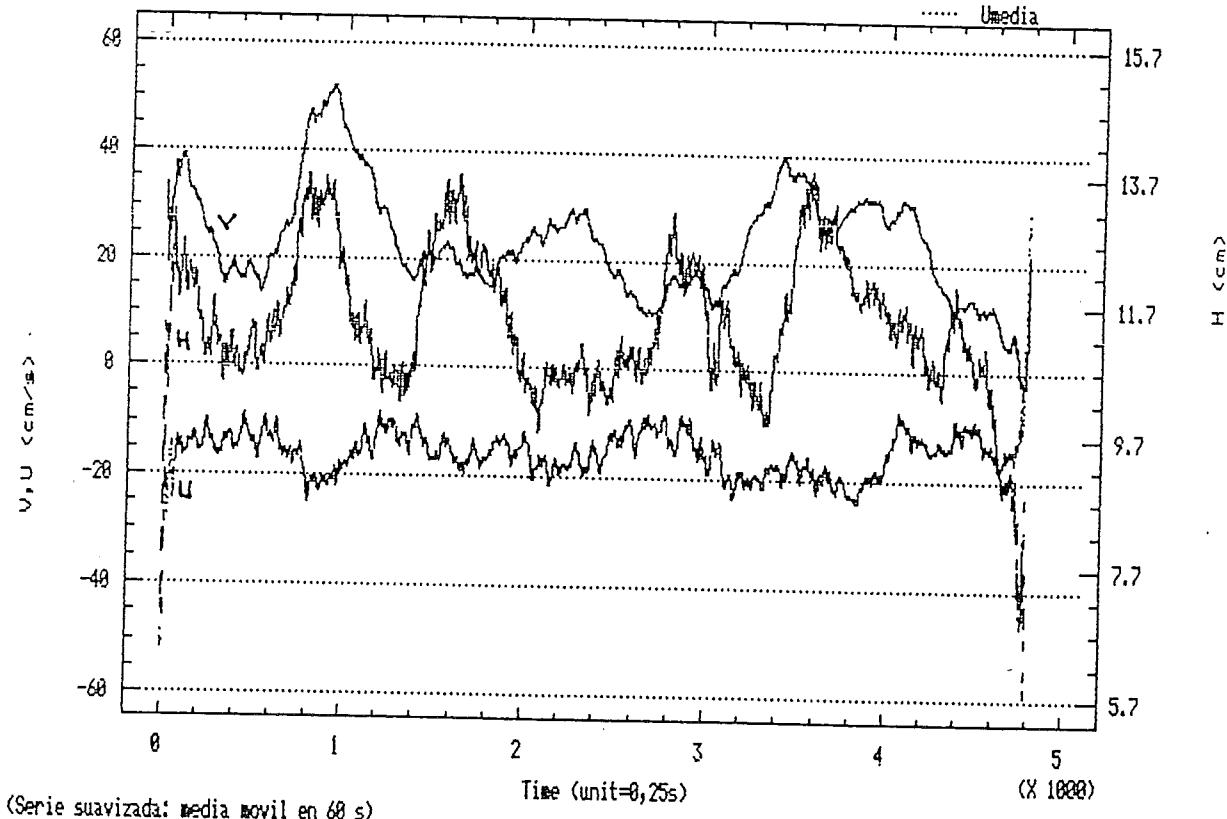




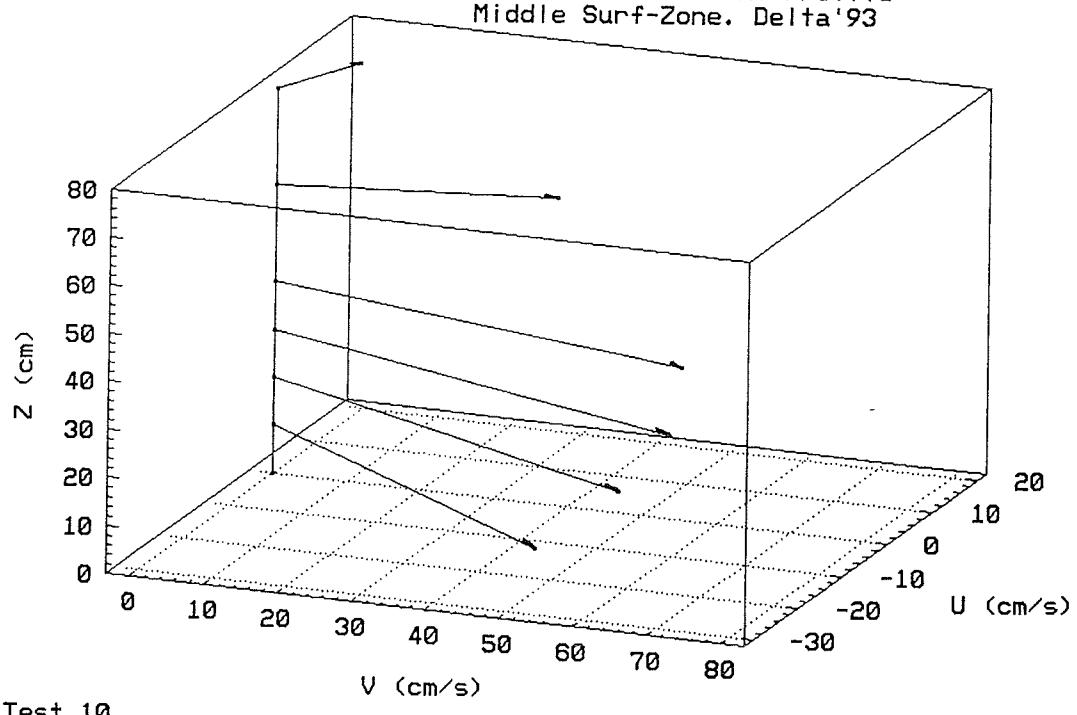


Evolucion de Va, M₁L y U_a
Delta Ebro, P11, 16/12/93, V12, Z=18cm

— Va media
- - M₁L media
.... U_a media

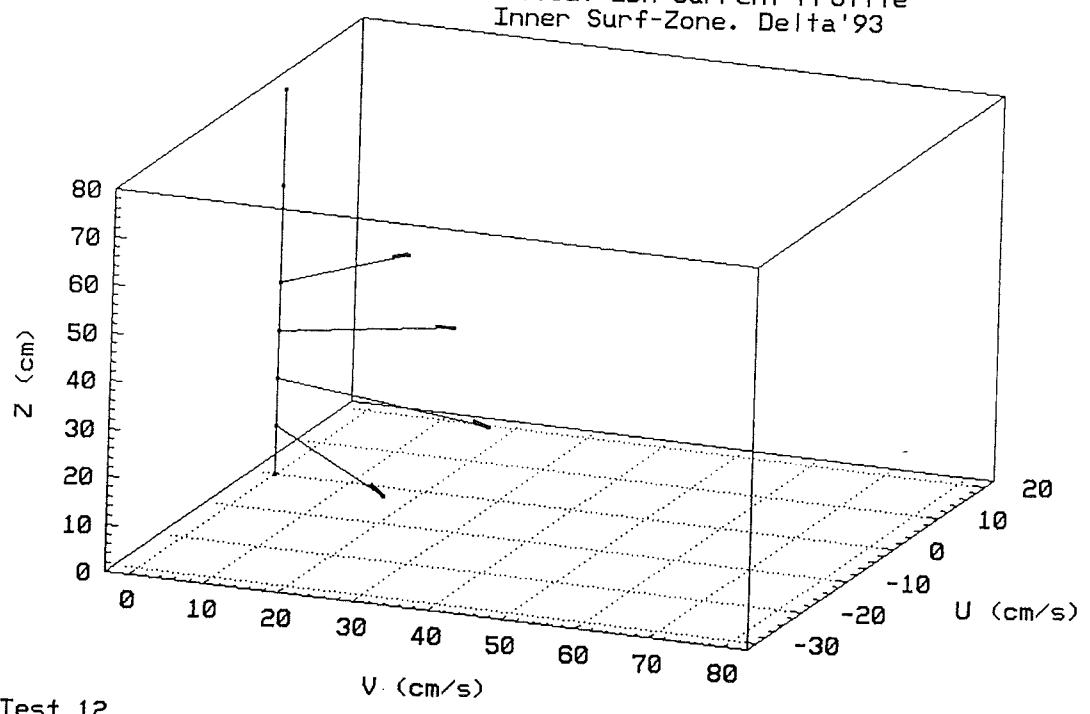


Vertical 2DH Current Profile
Middle Surf-Zone, Delta'93



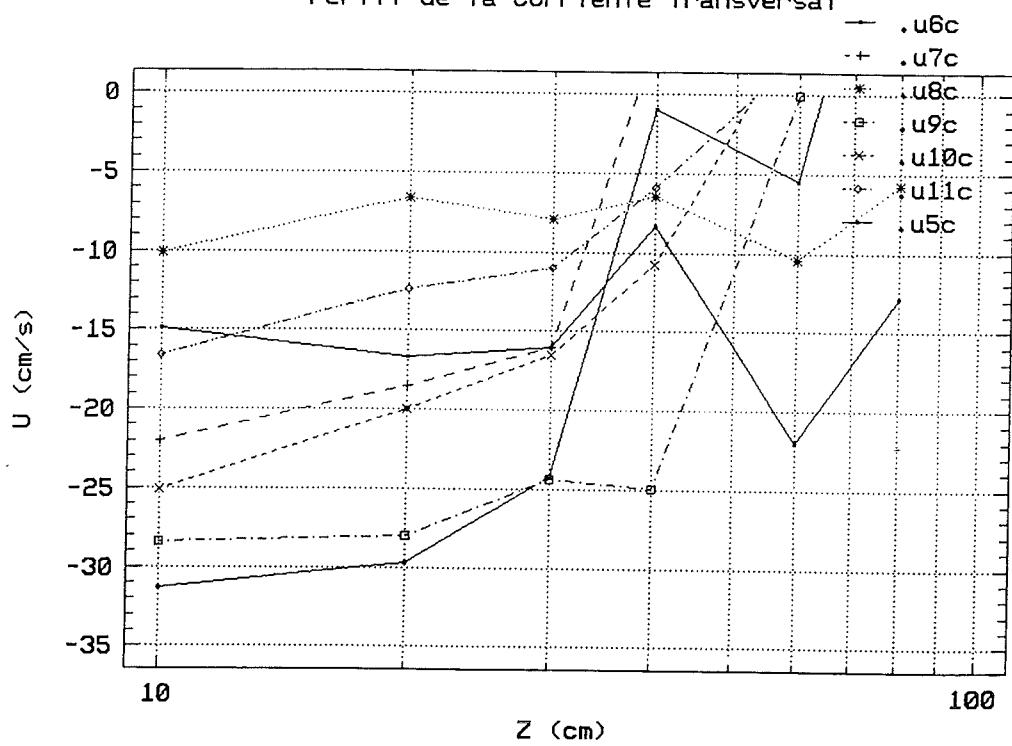
Test 10

Vertical 2DH Current Profile
Inner Surf-Zone. Delta'93



Test 12

Perfil de la Corriente Transversal



Regression Analysis - Linear model: $Y = a+bX$

Dependent variable: VVERT.logz4

Independent variable: VVERT.v5c

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	-1.12069	0.678924	-1.65068	0.24059
Slope	0.0521839	0.0143166	3.645	0.06771

Analysis of Variance

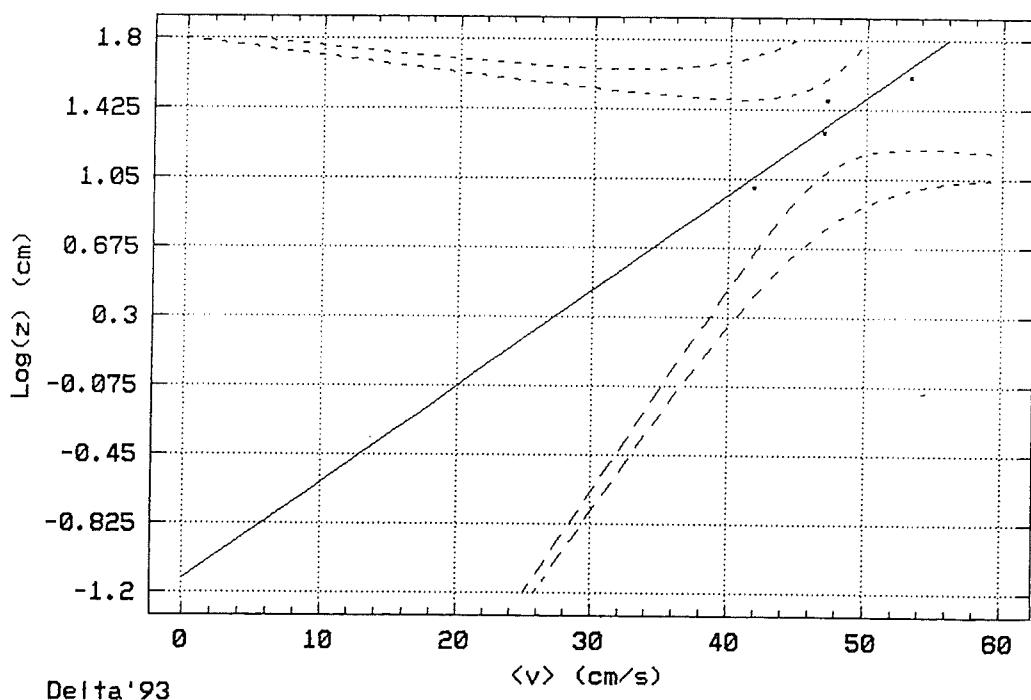
Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	0.177686	1	0.177686	13.28605	0.06771
Residual	0.0267478	2	0.0133739		

Total (Corr.) 0.2044340 3
 Correlation Coefficient = 0.932288
 Stnd. Error of Est. = 0.115646 R-squared = 86.92 percent

Press ENTER to continue.

1Help 2Edit 3Savscr 4Prtscr 5 6Go 7Vars 8Cmd 9Device 10Quit
 INPUT 12/12/96 07:34 STATGRAPHICS Plus 5.2

Ajuste de perfil logaritmico a $\langle v \rangle(z)$
 Caso III, Test 5, $\langle v \rangle$ media en 300 s



Delta'93

Regression Analysis - Linear model: $y = a + bx$

Dependent variable: VVERT.logz4

Independent variable: VVERT.v6c

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	-3.52044	1.17616	-2.99316	0.09584
Slope	0.0567895	0.0137149	4.14071	0.05367

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	0.183078	1	0.183078	17.14544	0.05367
Residual	0.0213559	2	0.0106779		

Total (Corr.) 0.2044340

Correlation Coefficient = 0.946328

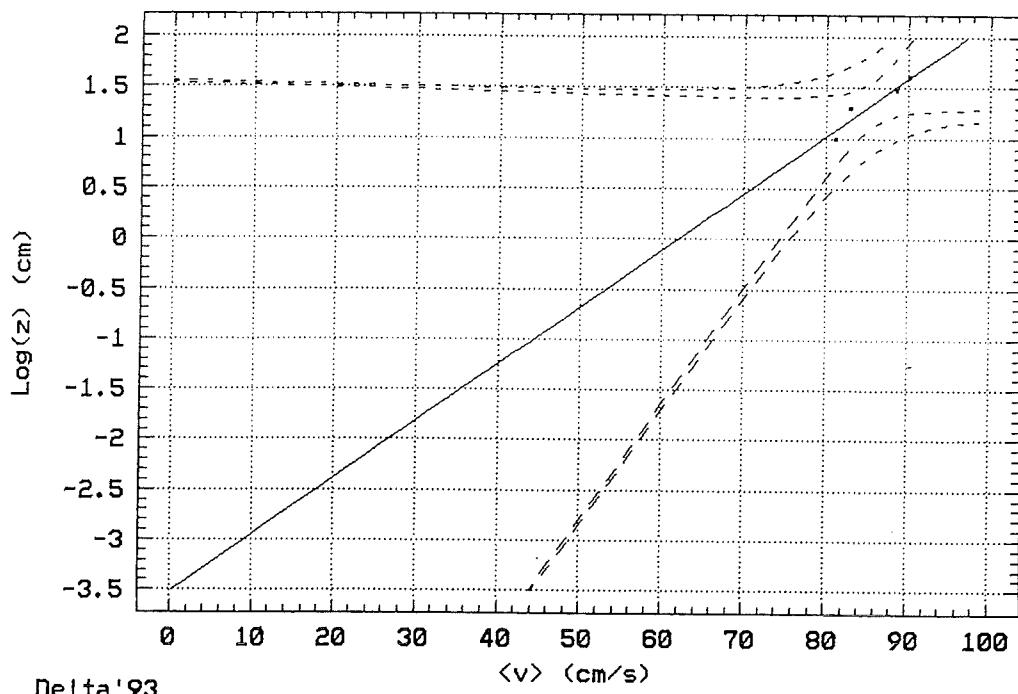
Stnd. Error of Est. = 0.103334

R-squared = 89.55 percent

Press ENTER to continue.

1Help 2Edit 3Savscr 4Prtscr 5 6Go 7Vars 8Cmd 9Device 10Quit
INPUT 12/12/96 07:23 STATGRAPHICS Plus 5.2

Ajuste de perfil logaritmico a $\langle v \rangle(z)$
Caso III, Test 6, $\langle v \rangle$ media en 300 s



Delta '93

Regression Analysis - Linear model: $Y = a+bX$

Dependent variable: VVERT.logz4

Independent variable: VVERT.v7c

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	-1.98876	0.943202	-2.10852	0.16950
Slope	0.0518873	0.0146512	3.54151	0.07131

Analysis of Variance

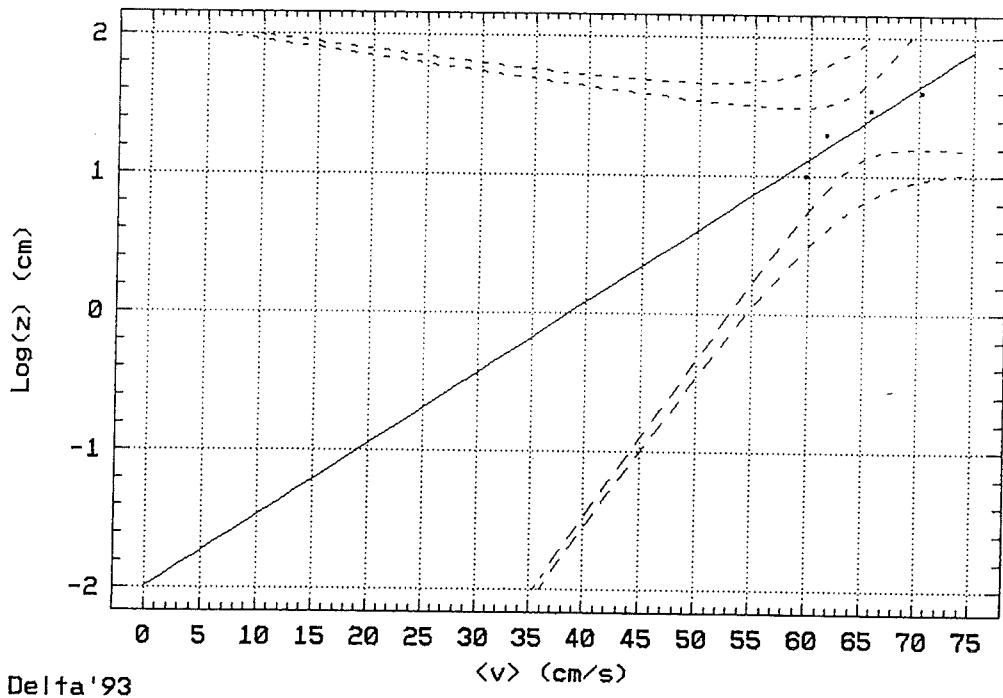
Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	0.176318	1	0.176318	12.54232	0.07131
Residual	0.0281157	2	0.0140579		

Total (Corr.) 0.2044340 3
 Correlation Coefficient = 0.928693
 Stnd. Error of Est. = 0.118566 R-squared = 86.25 percent

Press ENTER to continue.

1Help 2Edit 3Savscr 4Prtscr 5 6Go 7Vars 8Cmd 9Device 10Quit
 INPUT 12/12/96 07:28 STATGRAPHICS Plus 5.2

Ajuste de perfil logarítmico a $\langle v \rangle(z)$
 Caso III, Test 7, $\langle v \rangle$ media en 300 s



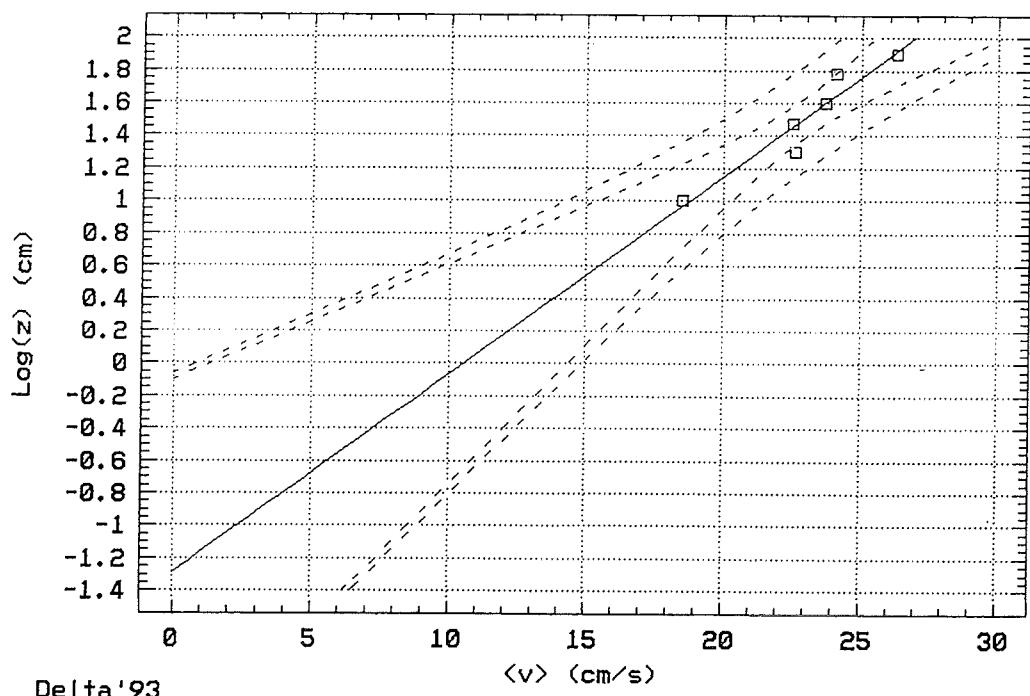
Regression Analysis - Linear model: $Y = a + bX$

Dependent variable: VVERT.logz6		Independent variable: VVERT.v8c		
Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	-1.28737	0.428078	-3.00733	0.03965
Slope	0.121897	0.0185553	6.56939	0.00278
Analysis of Variance				
Source	Sum of Squares	Df	Mean Square	F-Ratio Prob. Level
Model	0.493836	1	0.493836	43.15687 0.00278
Residual	0.0457712	4	0.0114428	
Total (Corr.)	0.5396068	5		
Correlation Coefficient = 0.956649			R-squared = 91.52 percent	
Stnd. Error of Est. = 0.106971				

Press ENTER to continue.

1Help 2Edit 3Savscr 4Prtscr 5 6Go 7Vars 8Cmd 9Device 10Quit
 INPUT 12/12/96 07:07 STATGRAPHICS Plus 5.2 Display REG

Ajuste de perfil logaritmico a $\langle v \rangle(z)$
 Caso IV, Test 8, $\langle v \rangle$ media en 300 s



Delta '93

Regression Analysis - Linear model: $Y = a + bX$

Dependent variable: VVERT.logz3

Independent variable: VVERT.v9c

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	-2.9321	1.04755	-2.79901	0.21845
Slope	0.0695481	0.0173638	4.00534	0.15576

Analysis of Variance

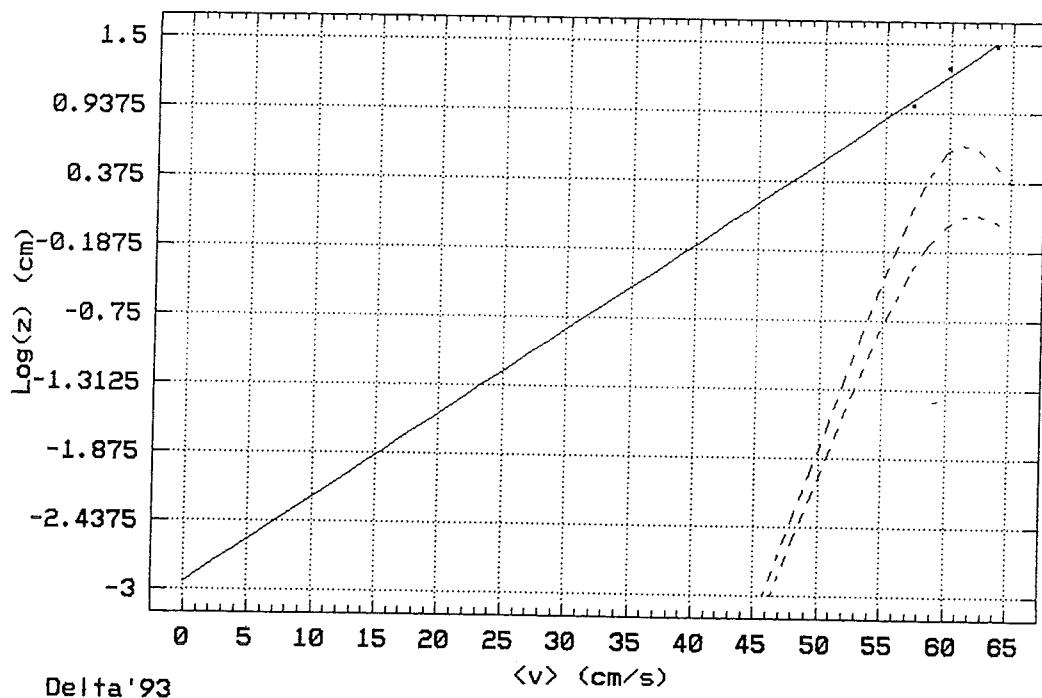
Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	0.109541	1	0.109541	16.04276	0.15576
Residual	0.0068280	1	0.0068280		

Total (Corr.) 0.1163687 2
 Correlation Coefficient = 0.970219
 Stnd. Error of Est. = 0.082632 R-squared = 94.13 percent

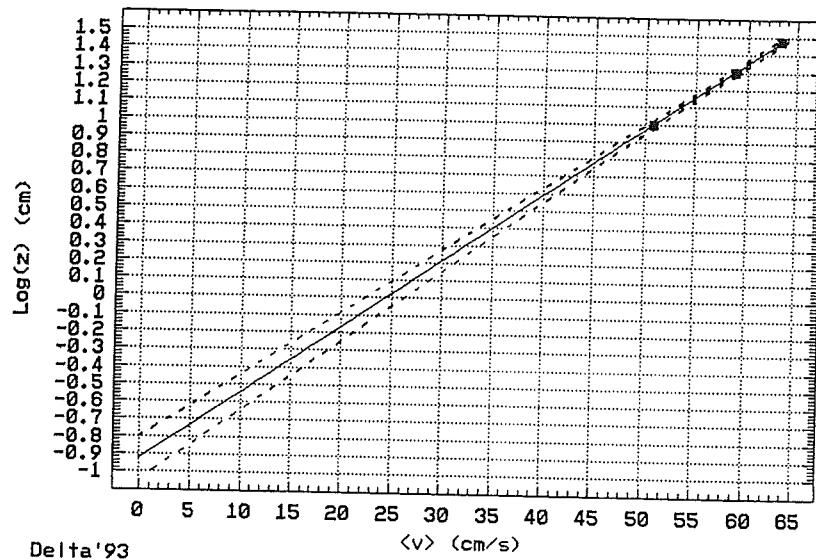
Press ENTER to continue.

1Help 2Edit 3Savscr 4Prtscr 5 6Go 7Vars 8Cmd 9Device 10Quit
 INPUT 12/12/96 07:42 STATGRAPHICS Plus 5.2

Ajuste de perfil logarítmico a $\langle v \rangle(z)$
 Caso IV, Test 9, $\langle v \rangle$ media en 300 s



Ajuste de perfil logarítmico a $\langle v \rangle(z)$
 Caso IV, Test 10, $\langle v \rangle$ media en 300 s



Regression Analysis - Linear model: $Y = a + bX$

Dependent variable: VVERT.logz3

Independent variable: VVERT.v10cc

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	-0.922269	0.00962092	-95.8608	0.00664
Slope	0.0378313	0.000166161	227.678	0.00280

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	0.116	1	0.116	51837.42	0.00280
Residual	0.0000022	1	0.0000022		

Total (Corr.) 0.1163687 2
 Correlation Coefficient = 0.99999
 Stnd. Error of Est. = 0.00149828 R-squared = 100.00 percent

Press ENTER to continue.

1Help 2Edit 3Savscr 4Prtscr 5 6Go 7Vars 8Cmd 9Device 10Quit
 INPUT 12/12/96 07:46 STATGRAPHICS Plus 5.2

Regression Analysis - Linear model: $Y = a + bX$

Dependent variable: VVERT.logz3

Independent variable: VVERT.v11cc

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	-0.601164	0.374099	-1.60697	0.35437
Slope	0.0436054	0.00872108	5	0.12567

Analysis of Variance

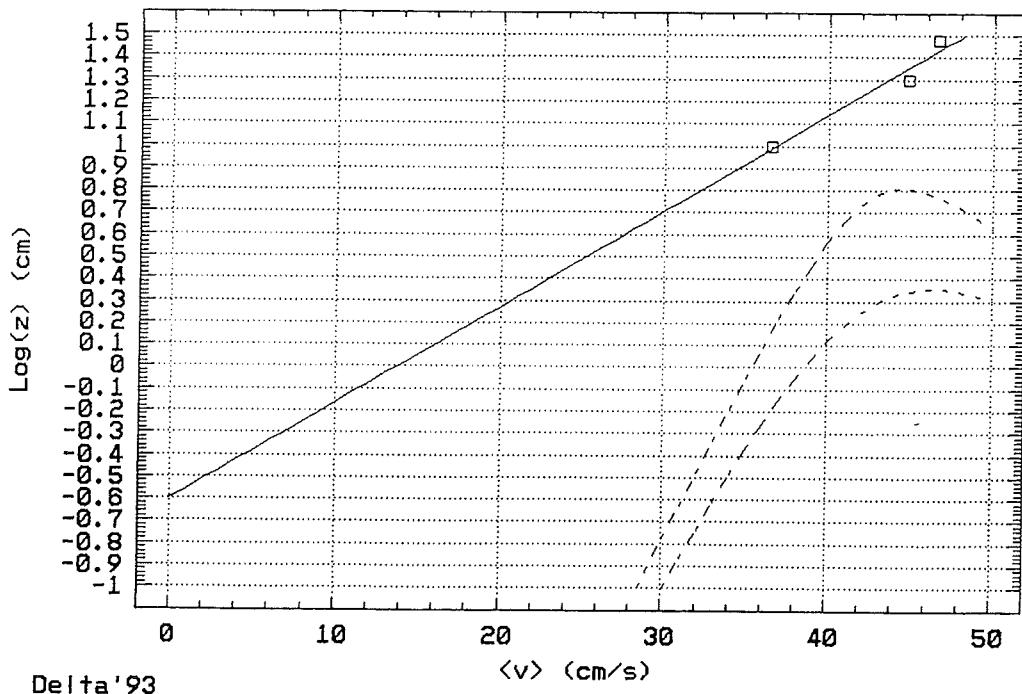
Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	0.111893	1	0.111893	25.00000	0.12567
Residual	0.0044757	1	0.0044757		

Total (Corr.) 0.1163687 2
 Correlation Coefficient = 0.980581 R-squared = 96.15 percent
 Stnd. Error of Est. = 0.0669008

Press ENTER to continue.

1Help 2Edit 3Savscr 4Prtscr 5 6Go 7Vars 8Cmd 9Device 10Quit
 INPUT 12/12/96 07:53 STATGRAPHICS Plus 5.2 Display

Ajuste de perfil logaritmico a $\langle v \rangle(z)$
 Caso IV, Test 11, $\langle v \rangle$ media en 300 s



CALCULO DE PARAMETROS DE LA CAPA LIMITE PARA W+C
sin considerar formas de fondo

TEST: 5 iteraciones: 9.000000
eta: 0.000000E+00 lambda: 0.000000E+00
fc: 4.917194E-03 fwc: 6.502608E-03
nro.movilidad 189.918500 nro. Shields: 0.000000E+00
Kn: 6.250000E-04 Kw: 3.506095E-03
u*: 1.869061E-02 u*wc: 2.493550E-02
delta: 2.036731E-02 delta/d: 1.578861E-02
angW-C: 86.445980 nu-tbl: 8.399915E-06

TEST: 6 iteraciones: 7.000000
eta: 0.000000E+00 lambda: 0.000000E+00
fc: 4.262209E-03 fwc: 6.602458E-03
nro.movilidad 168.476900 nro. Shields: 0.000000E+00
Kn: 6.250000E-04 Kw: 1.233523E-03
u*: 3.759450E-02 u*wc: 4.156032E-02
delta: 2.589561E-02 delta/d: 3.082811E-02
angW-C: 89.616340 nu-tbl: 1.067757E-05

TEST: 7 iteraciones: 7.000000
eta: 0.000000E+00 lambda: 0.000000E+00
fc: 4.703144E-03 fwc: 6.533855E-03
nro.movilidad 144.441800 nro. Shields: 0.000000E+00
Kn: 6.250000E-04 Kw: 1.555534E-03
u*: 2.840923E-02 u*wc: 3.262034E-02
delta: 2.432598E-02 delta/d: 3.525504E-02
angW-C: 89.057120 nu-tbl: 1.003089E-05

TEST: 8 iteraciones: 10.000000
eta: 0.000000E+00 lambda: 0.000000E+00
fc: 5.906344E-03 fwc: 7.083158E-03
nro.movilidad 98.708310 nro. Shields: 0.000000E+00
Kn: 6.250000E-04 Kw: 7.539548E-03
u*: 8.171056E-03 u*wc: 1.323341E-02
delta: 1.399904E-02 delta/d: 1.044704E-02
angW-C: 89.520990 nu-tbl: 5.776187E-06

TEST: 9 iteraciones: 10.000000
eta: 0.000000E+00 lambda: 0.000000E+00
fc: 5.240568E-03 fwc: 6.262825E-03
nro.movilidad 256.785400 nro. Shields: 0.000000E+00
Kn: 6.250000E-04 Kw: 2.450910E-03
u*: 2.747073E-02 u*wc: 3.403183E-02
delta: 2.493509E-02 delta/d: 3.587782E-02
angW-C: 84.938740 nu-tbl: 1.028184E-05

TEST: 10 iteraciones: 7.000000
eta: 0.000000E+00 lambda: 0.000000E+00
fc: 4.766925E-03 fwc: 6.806956E-03
nro.movilidad 133.117600 nro. Shields: 0.000000E+00
Kn: 6.250000E-04 Kw: 1.646824E-03
u*: 2.605911E-02 u*wc: 3.031606E-02
delta: 2.066078E-02 delta/d: 2.994317E-02
angW-C: 88.168580 nu-tbl: 8.520827E-06

TEST: 11 iteraciones: 8.000000
eta: 0.000000E+00 lambda: 0.000000E+00
fc: 5.482635E-03 fwc: 6.556186E-03

nro.movilidad 140.615700 nro. Shields: 0.000000E+00
Kn: 6.250000E-04 Kw: 2.532390E-03
u*: 1.975331E-02 u*wc: 2.476354E-02
delta: 2.100921E-02 delta/d: 3.501535E-02
angW-C: 87.351390 nu-tbl: 8.664379E-06

CALCULO DE PARAMETROS DE LA CAPA LIMITE PARA W+C
considerando formas de fondo sin transporte

TEST: 5 iteraciones: 9.000000
eta: 1.244681E-03 lambda: 7.607625E-02
fc: 2.189350E-02 fwc: 6.637239E-02
nro.movilidad 189.918500 nro. Shields: 0.000000E+00
Kn: 1.149080E-01 Kw: 2.774904E-01
u*: 3.638737E-02 u*wc: 5.261591E-02
delta: 6.677718E-02 delta/d: 5.176526E-02
angW-C: 86.445980 nu-tbl: 2.909027E-05

TEST: 6 iteraciones: 7.000000
eta: 1.463168E-03 lambda: 7.647293E-02
fc: 1.966789E-02 fwc: 6.303320E-02
nro.movilidad 168.476900 nro. Shields: 0.000000E+00
Kn: 1.006619E-01 Kw: 1.454685E-01
u*: 7.873226E-02 u*wc: 8.927716E-02
delta: 7.579573E-02 delta/d: 9.023302E-02
angW-C: 89.616340 nu-tbl: 3.261027E-05

TEST: 7 iteraciones: 7.000000
eta: 2.026557E-03 lambda: 8.676130E-02
fc: 2.104019E-02 fwc: 5.455752E-02
nro.movilidad 144.441800 nro. Shields: 0.000000E+00
Kn: 8.513681E-02 Kw: 1.371428E-01
u*: 5.870885E-02 u*wc: 6.899524E-02
delta: 6.945529E-02 delta/d: 1.006598E-01
angW-C: 89.057120 nu-tbl: 2.978479E-05

TEST: 8 iteraciones: 10.000000
eta: 3.011246E-03 lambda: 7.957665E-02
fc: 1.962988E-02 fwc: 5.126944E-02
nro.movilidad 98.708310 nro. Shields: 0.000000E+00
Kn: 5.702411E-02 Kw: 2.311259E-01
u*: 1.307079E-02 u*wc: 2.412521E-02
delta: 4.030976E-02 delta/d: 3.008191E-02
angW-C: 89.520990 nu-tbl: 1.739075E-05

TEST: 9 iteraciones: 10.000000
eta: 8.283308E-04 lambda: 7.536001E-02
fc: 3.171203E-02 fwc: 7.598411E-02
nro.movilidad 256.785400 nro. Shields: 0.000000E+00
Kn: 1.607707E-01 Kw: 2.909664E-01
u*: 6.603399E-02 u*wc: 8.371593E-02
delta: 8.888522E-02 delta/d: 1.278924E-01
angW-C: 84.938740 nu-tbl: 3.882863E-05

TEST: 10 iteraciones: 8.000000
eta: 2.010972E-03 lambda: 7.751670E-02
fc: 2.059265E-02 fwc: 5.720856E-02
nro.movilidad 133.117600 nro. Shields: 0.000000E+00
Kn: 7.786407E-02 Kw: 1.313161E-01
u*: 5.246479E-02 u*wc: 6.301002E-02
delta: 5.895254E-02 delta/d: 8.543847E-02
angW-C: 88.168580 nu-tbl: 2.535778E-05

TEST: 11 iteraciones: 9.000000
eta: 2.101351E-03 lambda: 8.690543E-02
fc: 2.500750E-02 fwc: 5.398384E-02

nro.movilidad 140.615700 nro. Shields: 0.000000E+00
Kn: 8.270068E-02 Kw: 1.662744E-01
u*: 4.102910E-02 u*wc: 5.288751E-02
delta: 6.210507E-02 delta/d: 1.035084E-01
angW-C: 87.351390 nu-tbl: 2.672304E-05

CALCULO DE PARAMETROS DE LA CAPA LIMITE PARA W+C
considerando formas de fondo y transporte de sedimentos

TEST: 5 iterac.: 9.000000 ind.: 4.000000
eta: 1.244681E-03 lambda: 7.607625E-02
fc: 6.090032E-03 fwc: 8.821833E-03
nro.movilidad 189.918500 nro. Shields: 8.377147E-01
Kn: 1.841392E-03 Kw: 8.144532E-03
u*: 2.084726E-02 u*wc: 2.775040E-02
delta: 2.418769E-02 delta/d: 1.875014E-02
angW-C: 86.445980 nu-tbl: 9.990616E-06

TEST: 6 iterac.: 7.000000 ind.: 4.000000
eta: 1.463168E-03 lambda: 7.647293E-02
fc: 5.340689E-03 fwc: 8.921472E-03
nro.movilidad 168.476900 nro. Shields: 7.515311E-01
Kn: 1.797284E-03 Kw: 3.195520E-03
u*: 4.221948E-02 u*wc: 4.652219E-02
delta: 3.019137E-02 delta/d: 3.594211E-02
angW-C: 89.616340 nu-tbl: 1.246353E-05

TEST: 7 iterac.: 7.000000 ind.: 4.000000
eta: 2.026557E-03 lambda: 8.676130E-02
fc: 5.917266E-03 fwc: 8.824477E-03
nro.movilidad 144.441800 nro. Shields: 6.373116E-01
Kn: 1.808606E-03 Kw: 3.909578E-03
u*: 3.201095E-02 u*wc: 3.658937E-02
delta: 2.854931E-02 delta/d: 4.137580E-02
angW-C: 89.057120 nu-tbl: 1.178715E-05

TEST: 8 iterac.: 10.000000 ind.: 4.000000
eta: 3.011246E-03 lambda: 7.957665E-02
fc: 7.522054E-03 fwc: 1.030926E-02
nro.movilidad 98.708310 nro. Shields: 5.088049E-01
Kn: 2.130961E-03 Kw: 1.787782E-02
u*: 9.158636E-03 u*wc: 1.493415E-02
delta: 1.738640E-02 delta/d: 1.297493E-02
angW-C: 89.520990 nu-tbl: 7.192463E-06

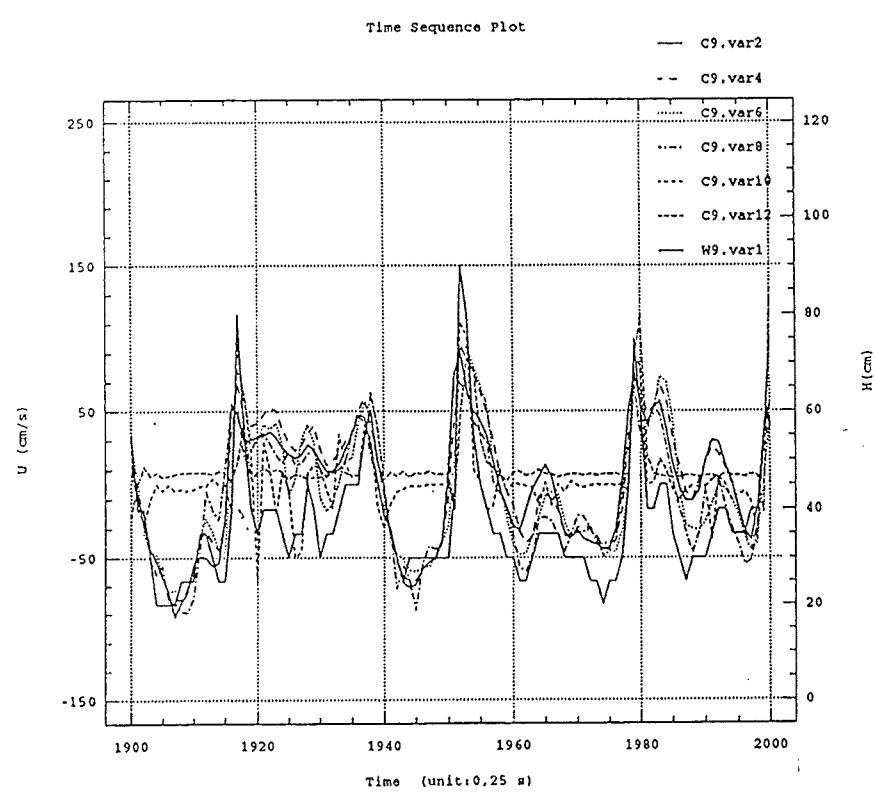
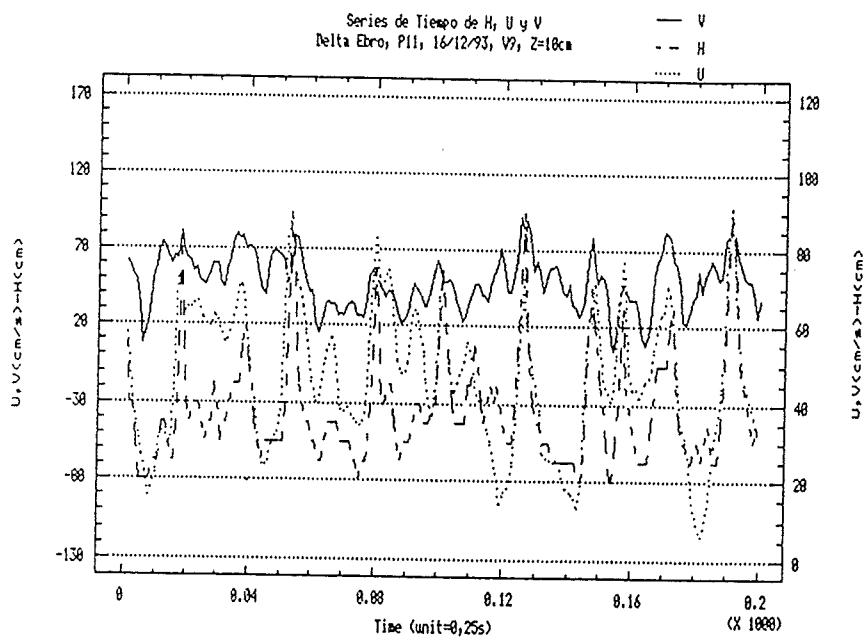
TEST: 9 iterac.: 9.000000 ind.: 4.000000
eta: 8.283308E-04 lambda: 7.536001E-02
fc: 6.776593E-03 fwc: 8.731291E-03
nro.movilidad 256.785400 nro. Shields: 1.121034
Kn: 2.071701E-03 Kw: 6.469993E-03
u*: 3.144515E-02 u*wc: 3.869919E-02
delta: 3.005859E-02 delta/d: 4.324977E-02
angW-C: 84.938740 nu-tbl: 1.241259E-05

TEST: 10 iterac.: 7.000000 ind.: 4.000000
eta: 2.010972E-03 lambda: 7.751670E-02
fc: 6.001753E-03 fwc: 9.291721E-03
nro.movilidad 133.117600 nro. Shields: 6.184456E-01
Kn: 1.813918E-03 Kw: 4.124444E-03
u*: 2.935838E-02 u*wc: 3.401674E-02
delta: 2.434881E-02 delta/d: 3.528813E-02
angW-C: 88.168580 nu-tbl: 1.005662E-05

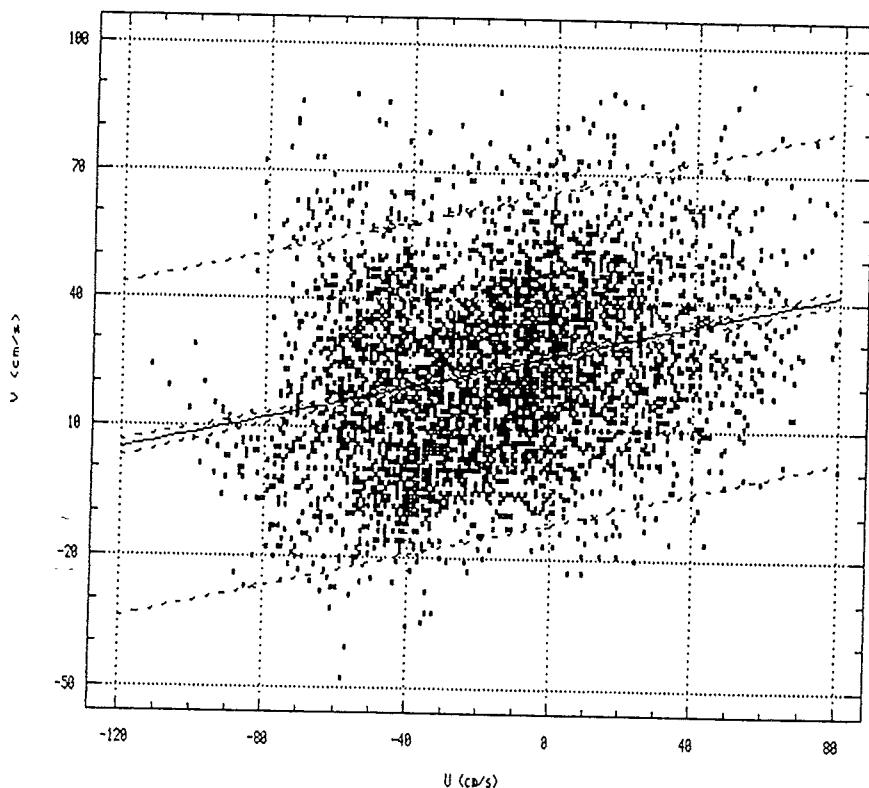
TEST: 11 iterac.: 8.000000 ind.: 4.000000
eta: 2.101351E-03 lambda: 8.690543E-02
fc: 6.904669E-03 fwc: 8.875728E-03

nro.movilidad 140.615700 nro. Shields: 6.240333E-01
Kn: 1.817650E-03 Kw: 5.966407E-03
u*: 2.230094E-02 u*wc: 2.779006E-02
delta: 2.488834E-02 delta/d: 4.148057E-02
angW-C: 87.351390 nu-tbl: 1.027896E-05

C4.2. Flujo Oscilatorio



Componente Longitudinal vs Transversal
Delta Ebro, PII, 16/12/93, VI12, Z:10ca



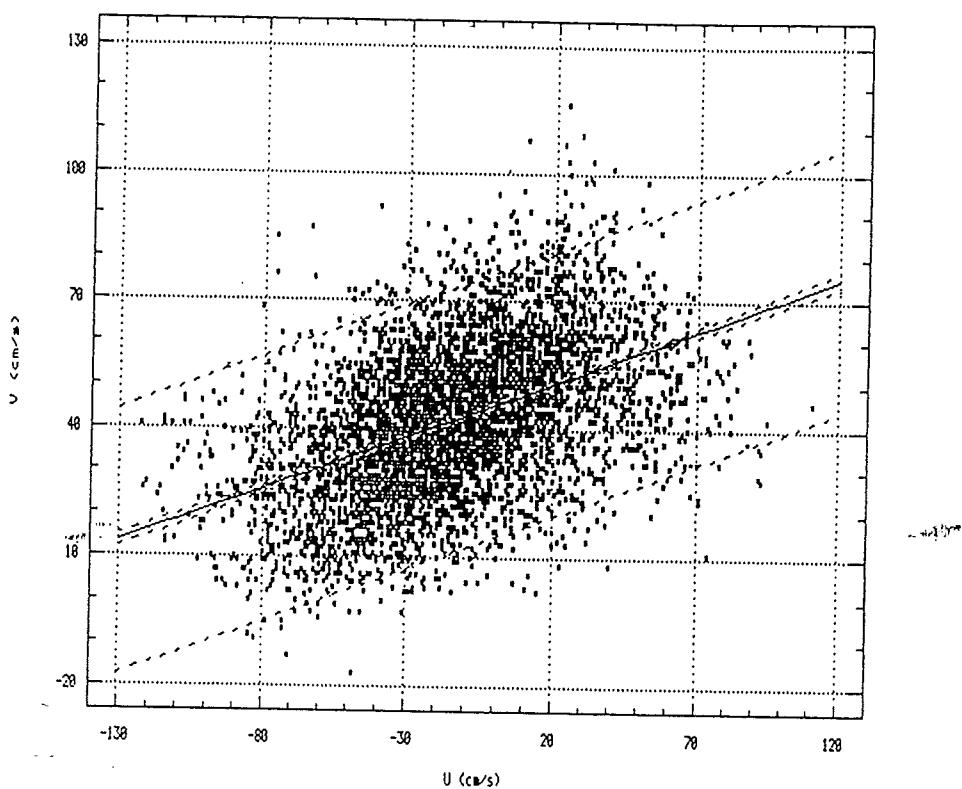
Regression Analysis - Linear model: $Y = a + bX$

Dependent variable: C12.var1		Independent variable: C12.var2		
Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	26.7359	0.31673	84.4123	0.00000
Slope	0.184892	0.00887931	20.8228	0.00000
Analysis of Variance				
Source	Sum of Squares	Df	Mean Square	F-Ratio Prob. Level
Model	169061.31	1	169061.31	433.6 0.00000
Residual	1868073.4	4791	389.9	
Total (Corr.)	2037134.7	4792		
Correlation Coefficient = 0.288079			R-squared = 8.30 percent	
Stnd. Error of Est. = 19.7462				

Press ENTER to continue.
 1Help 2Edit 3Savscr 4Prtscr 5 6Go 7Vars 8Cmd 9Device 10Quit
 INPUT 4/12/94 11:20 STATGRAPHICS Plus 5.2 Display REG

Componente longitudinal vs transversal

Delta Ebro, PII, 16/12/93, V5



Regression Analysis - Linear model: $Y = a + bX$

Dependent variable: C5.var1		Independent variable: C5.var2		
Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	45.4909	0.247676	183.672	0.00000
Slope	0.245765	0.00656884	37.4137	0.00000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	347669.11	1	347669.11	1399.8	0.00000
Residual	1191197.4	4796	248.4		

Total (Corr.) 1538866.5 4797

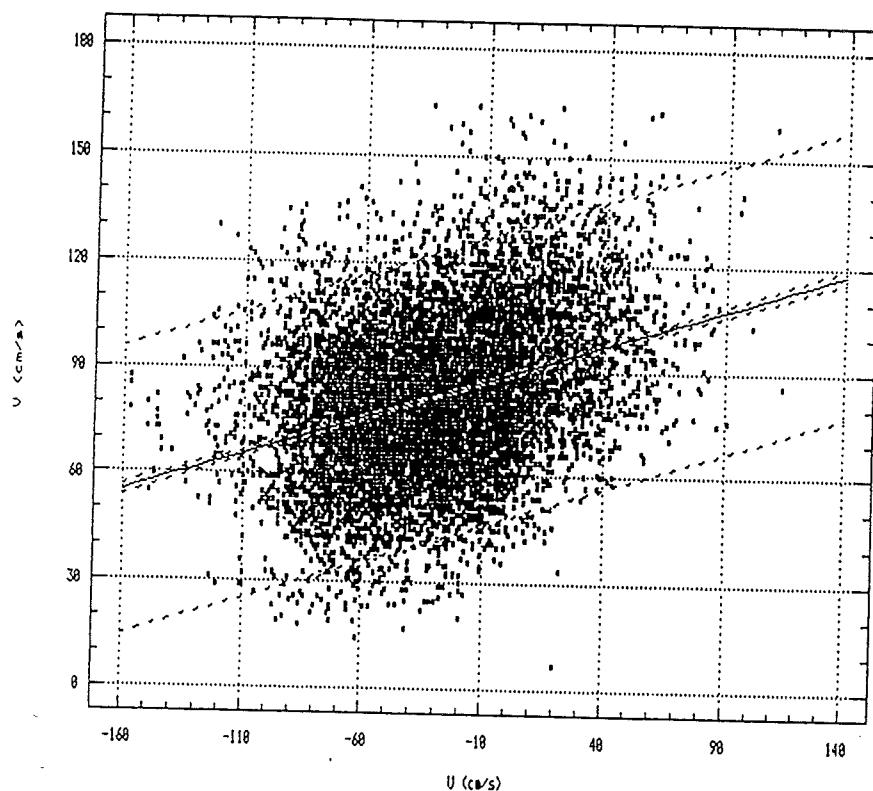
Correlation Coefficient = 0.475316
Stnd. Error of Est. = 15.7599

R-squared = 22.59 percent

Press ENTER to continue.

1Help 2Edit 3Savscr 4Prtscr 5 6Go 7Vars 8Cmd 9Device 10Quit
INFUT 4/12/94 11:27 STATGRAPHICS Plus 5.2 Display REG

Componente longitudinal vs transversal
Delta Ebro, Pla, 16/12/93, V6, Z:10 cm

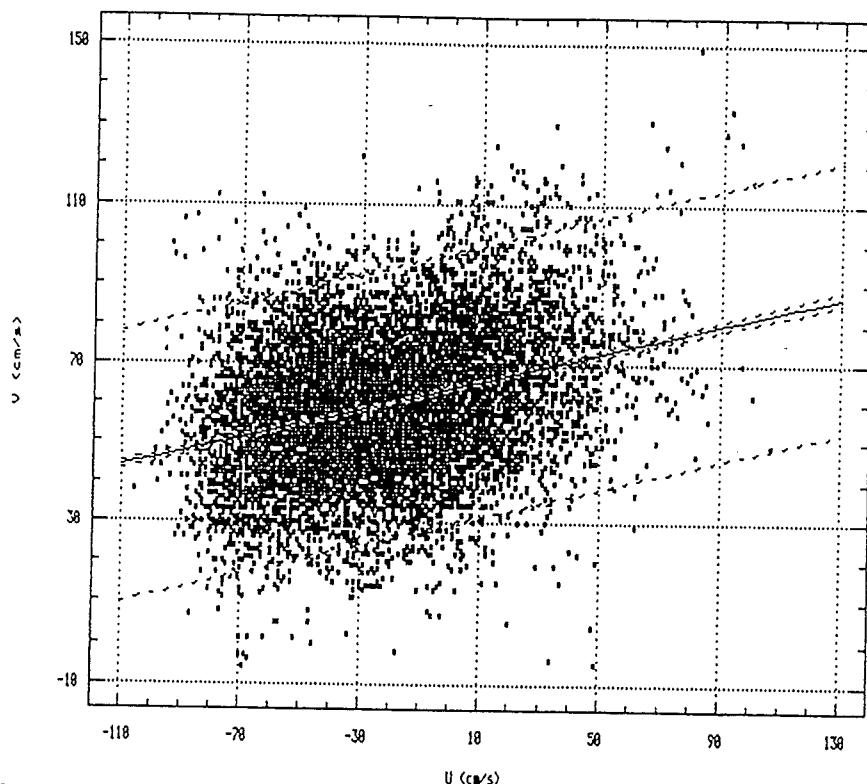


Regression Analysis - Linear model: $Y = a + bX$

Dependent variable: C6.var1		Independent variable: C6.var2		
Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	88.6839	0.2769	320.275	0.00000
Slope	0.209222	0.00574817	36.398	0.00000
Analysis of Variance				
Source	Sum of Squares	Df	Mean Square	F-Ratio Prob. Level
Model	562830.25	1	562830.25	1324.8 0.00000
Residual	4076311.3	9595	424.8	
Total (Corr.)	4639141.5	9596		
Correlation Coefficient = 0.348313			R-squared = 12.13 percent	
Stnd. Error of Est. = 20.6116				

Press ENTER to continue.
 1Help 2Edit 3Savscr 4Prtscr 5 6Go 7Vars 8Cmd 9Device 10Quit
 INPUT 4/12/94 11:34 STATGRAPHICS Plus 5.2 Display REG

Componente longitudinal vs transversal
Delta Ebro, PII, 16/12/93, V7, Z:10 ca



Regression Analysis - Linear model: $Y = a + bX$

Dependent variable: C7.var1

Independent variable: C7.var2

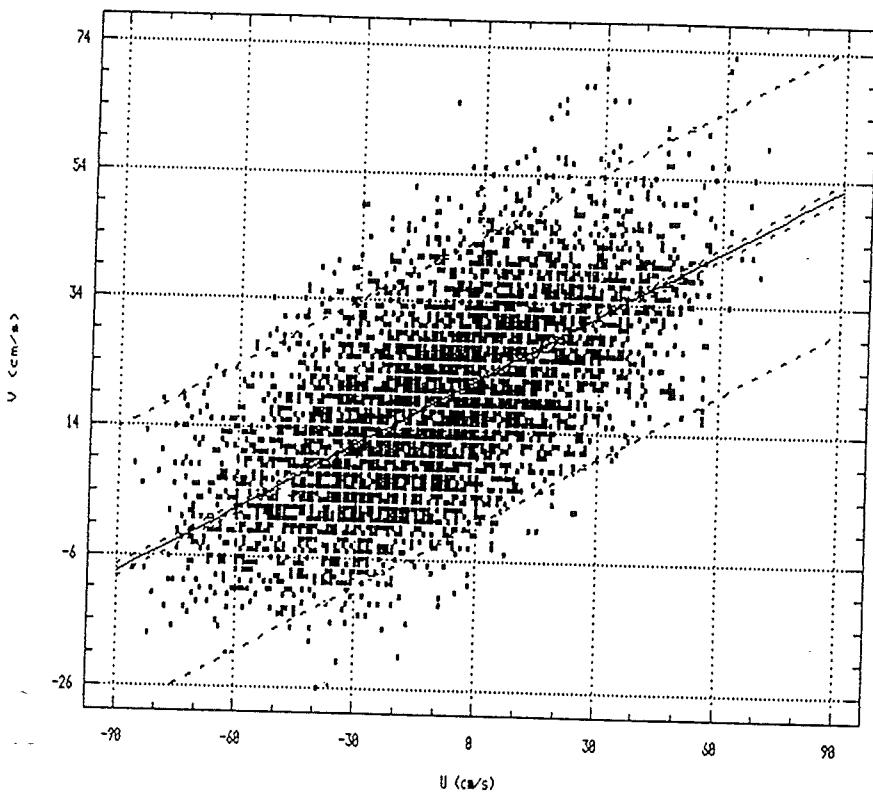
Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	63.5954	0.214658	296.265	0.00000
Slope	0.179148	0.00544445	32.9047	0.00000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	329340.92	1	329340.92	1082.7	0.00000
Residual	2917685.9	9592	304.2		
Total (Corr.)	3247026.9	9593			
Correlation Coefficient = 0.318478				R-squared = 10.14 percent	
Stnd. Error of Est. = 17.4407					

Press ENTER to continue.
 1Help 2Edit 3Savscr 4Frtscr 5 6Go 7Vars ,8Cmd . 9Device 10Quit
 INPUT 4/12/94 11:40 STATGRAPHICS Plus 5.2 Display REG

Componente longitudinal vs transversal
Delta Ebro; PII, 16/12/93, V8, Z=10 cm



Regression Analysis - Linear model: $Y = a + bX$

Dependent variable: C8.var1

Independent variable: C8.var2

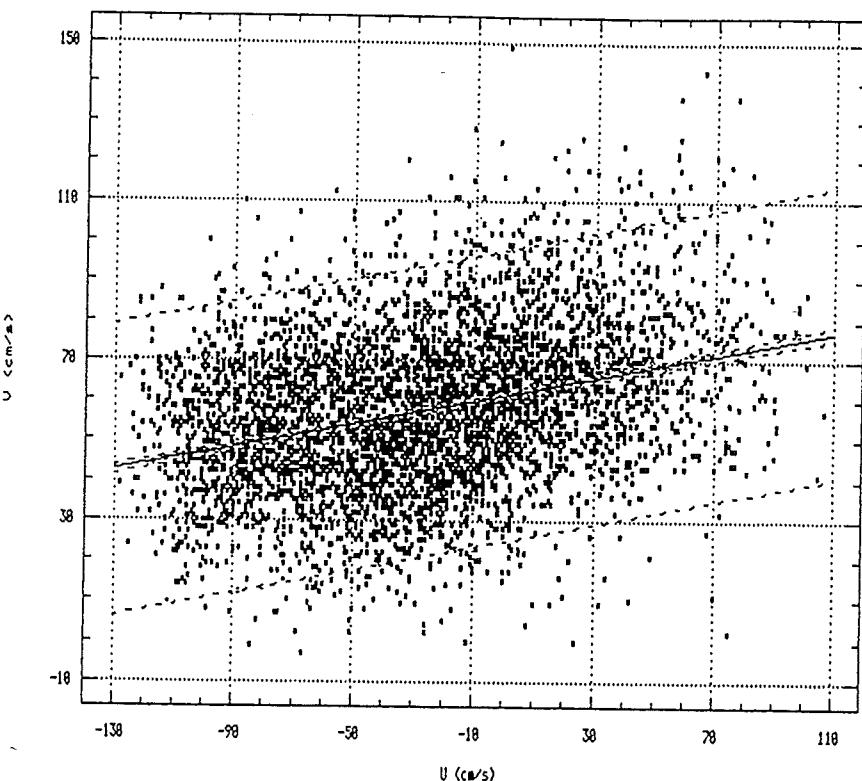
Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	21.944	0.170927	128.382	0.00000
Slope	0.339244	0.00583288	58.1607	0.00000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	432218.60	1	432218.60	3382.7	0.00000
Residual	633888.61	4961	127.77		
Total (Corr.)	1066107.2	4962			
Correlation Coefficient = 0.636724				R-squared = 40.54 percent	
Stnd. Error of Est. = 11.3037					

Press

Componente longitudinal vs transversal
Delta Ebro, PII, 16/12/93, V9, Z:10 cm



Regression Analysis - Linear model: $Y = a + bX$

Dependent variable: C9.var1

Independent variable: C9.var2

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	61.2016	0.315344	194.078	0.00000
Slope	0.144182	0.00584219	24.6794	0.00000

Analysis of Variance

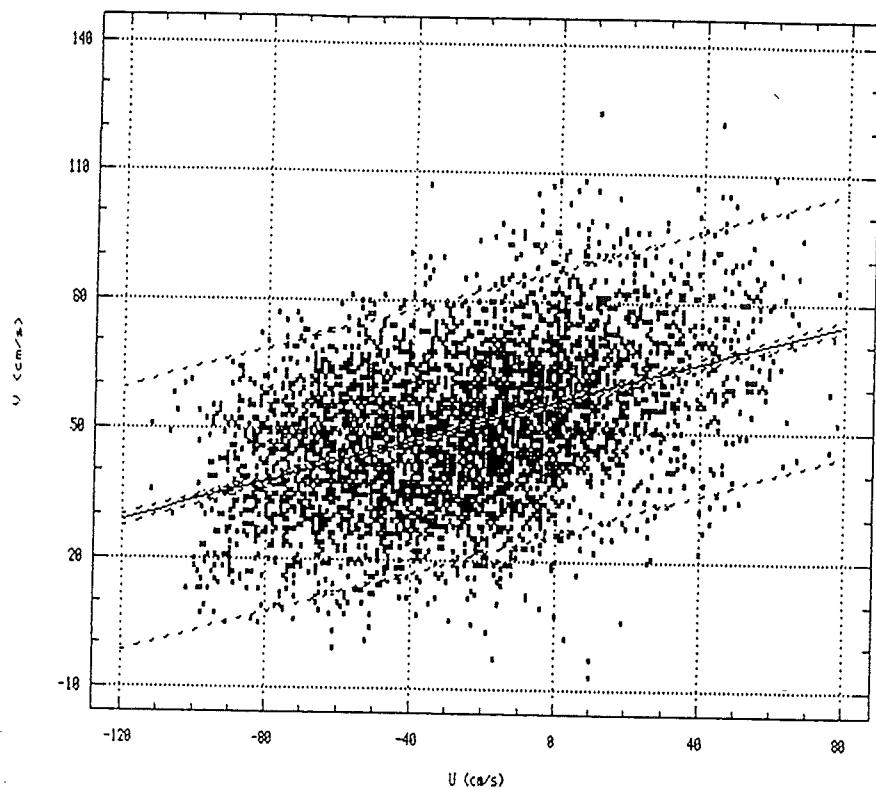
Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	209852.36	1	209852.36	609.1	0.00000
Residual	1650365.0	4790	344.5		
Total (Corr.)	1860217.4	4791			

Correlation Coefficient = 0.335873
Stnd. Error of Est. = 18.5619 R-squared = 11.28 percent

Press ENTER to continue.

Regresion de C10.i.10 en C10.c.10

Delta Ebro; PII, 16/12/222

Regression Analysis - Linear model: $Y = a + bX$

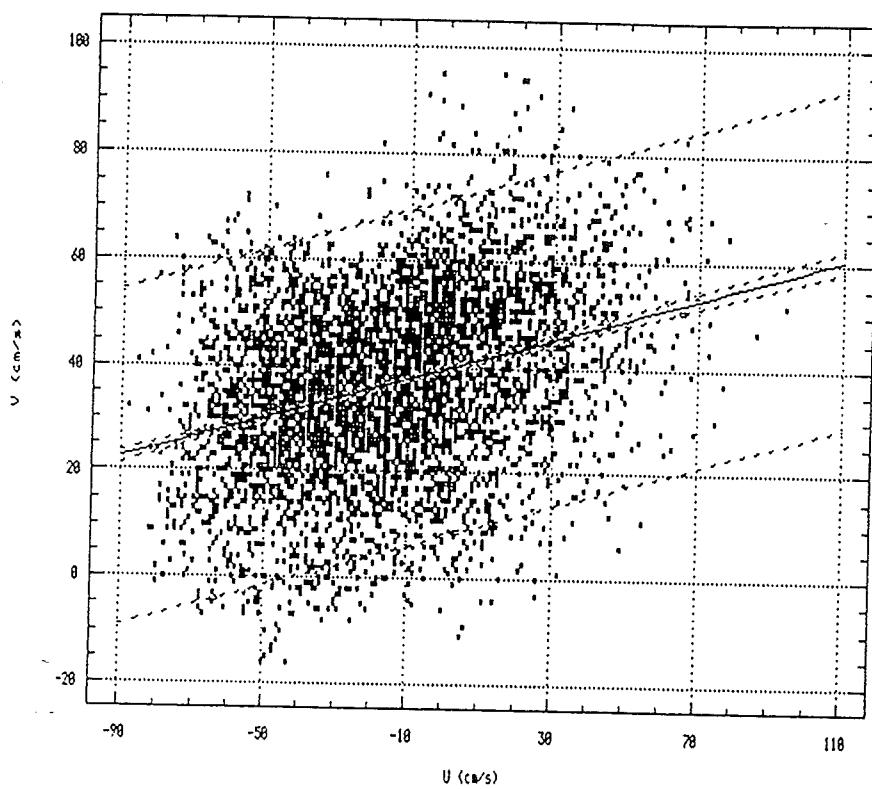
Dependent variable: C10.var1		Independent variable: C10.var2		
Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	56.6564	0.278475	203.453	0.00000
Slope	0.232287	0.00656368	35.3898	0.00000
Analysis of Variance				
Source	Sum of Squares	Df	Mean Square	F-Ratio Prob. Level
Model	302158.69	1	302158.69	1252.4 0.00000
Residual	1156101.2	4792	241.3	
Total (Corr.)	1458259.9	4793		
Correlation Coefficient = 0.455198			R-squared = 20.72 percent	
Stnd. Error of Est. = 15.5324				

Press ENTER to continue.

1Help	2Edit	3Savscr	4Prtscr	5 6Go	7Vars	8Cmd	9Device	10Quit
INPUT	4/12/94	10:52	STATGRAPHICS Plus 5.2			Printer		REG

Regresion de C11.I.10 en C11.c.10

Delta Ebro; PII, 16/12/93

Regression Analysis - Linear model: $Y = a + bX$

Dependent variable: C11.var1

Independent variable: C11.var2

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	39.7161	0.267009	148.744	0.00000
Slope	0.190695	0.00779816	24.4538	0.00000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	156078.66	1	156078.66	598.0	0.00000
Residual	1250482.8	4791	261.0		
Lack-of-fit	38935.172	159	244.875	0.94	0.70411
Pure error	1211547.6	4632	261.6		
Total (Corr.)	1406561.4	4792			
Correlation Coefficient = 0.333114			R-squared = 11.10 percent		
Stnd. Error of Est. = 16.1557					

Press ENTER to continue.

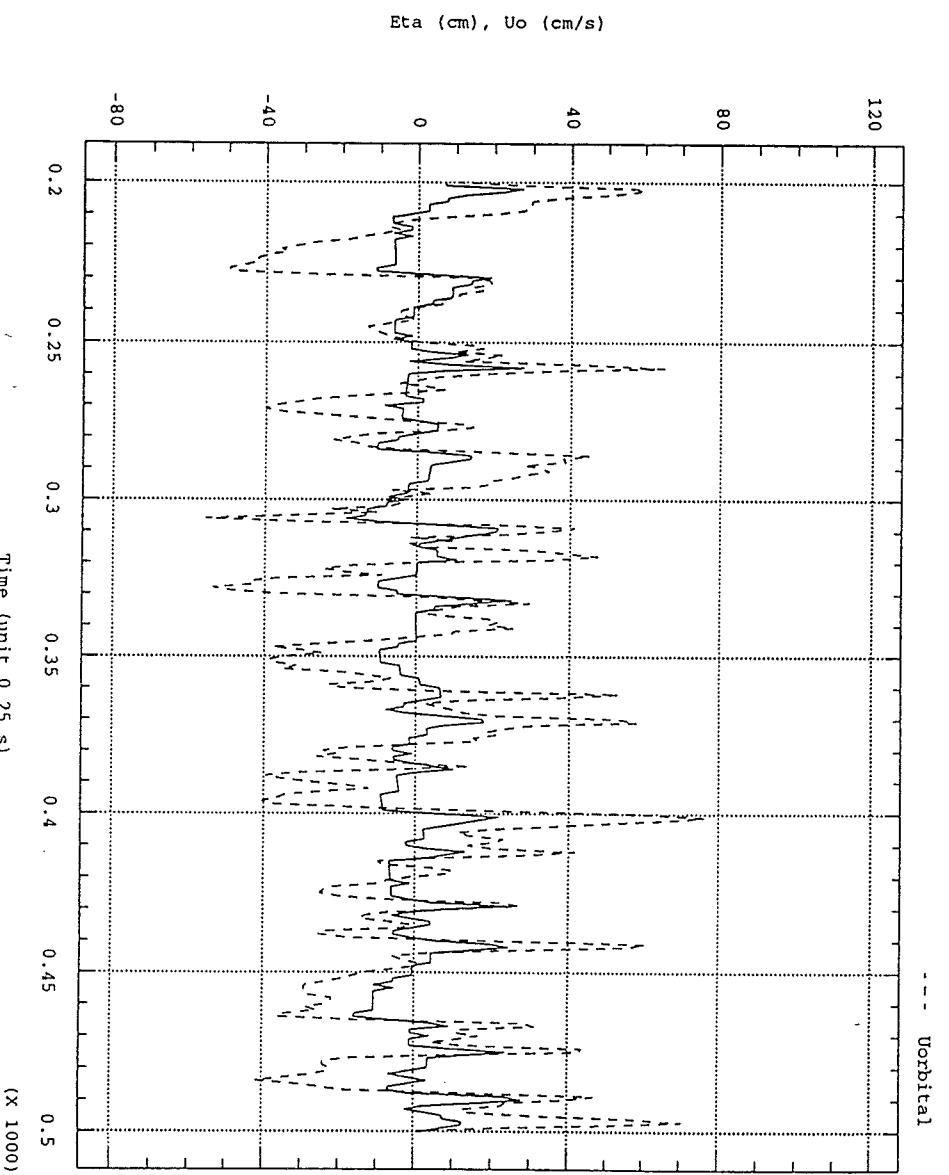
1Help 2Edit 3Savscr 4Prtscr 5 6Go 7Vars 8Cmd 9Device 10Quit
 INPUT 4/12/94 11:19 STATGRAPHICS Plus 5.2 Display REG

vorbital y Superficie libre

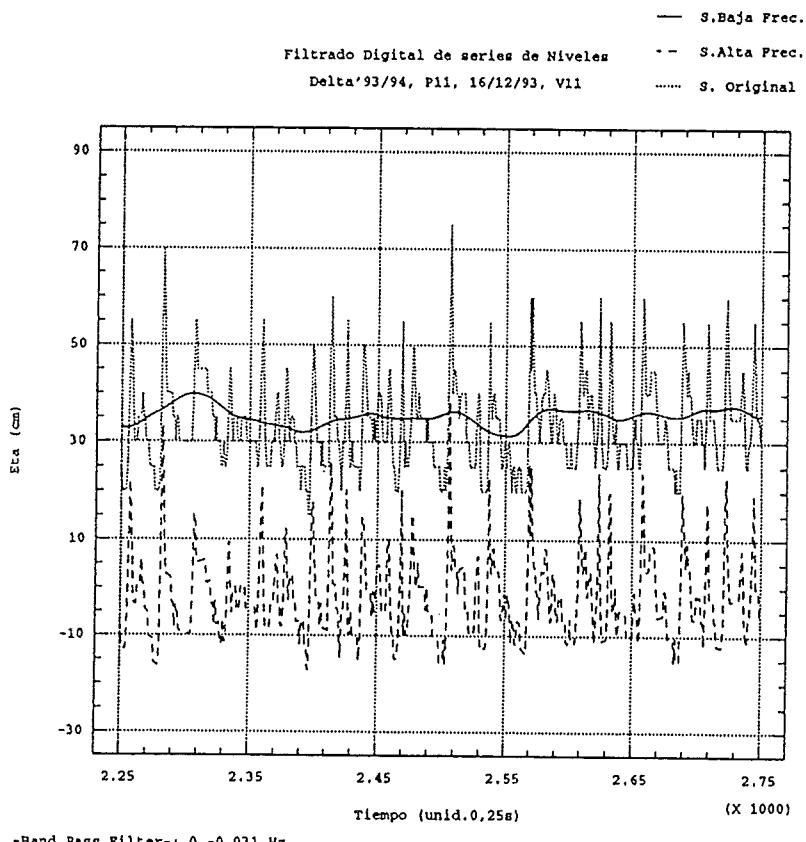
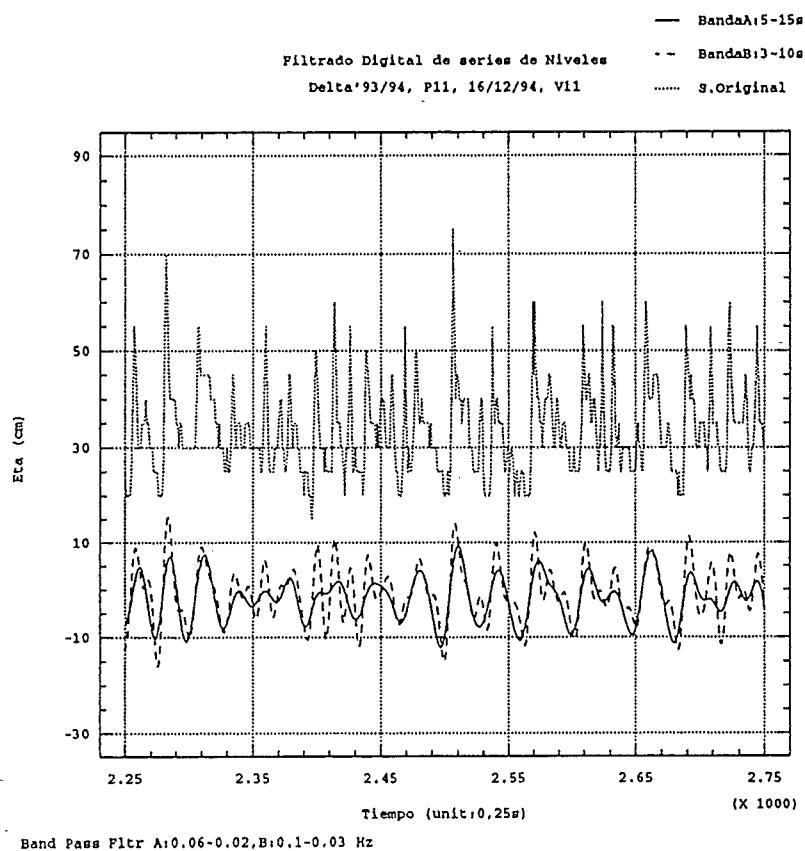
Test 11. Z=10 cm

Eta

Uorbital



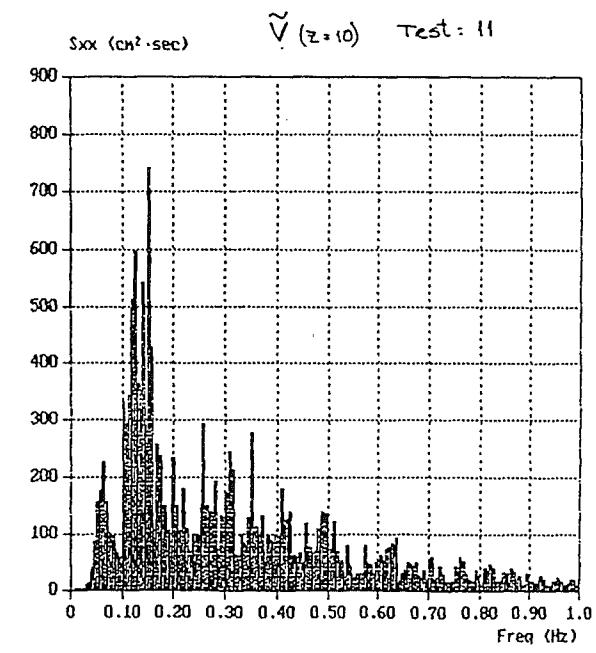
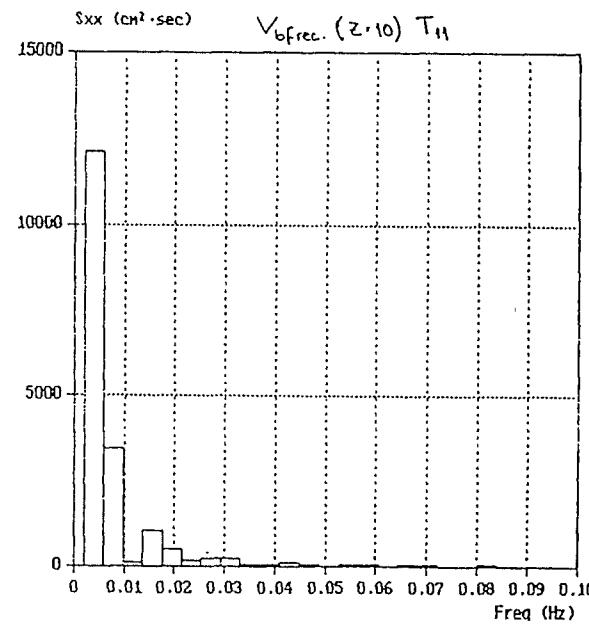
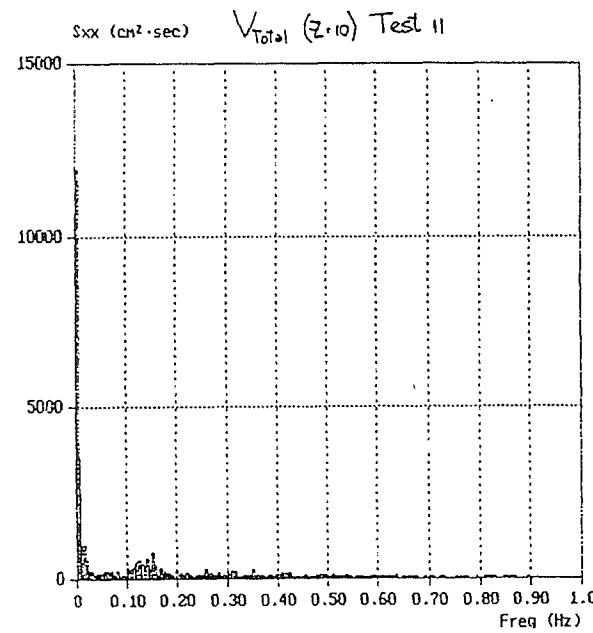
Serie proyectada y filtrada



Peak frequency = 0.003906 Hz Area under curve = 72.767410 cm²
 Peak value Sxx = 12083.201172 cm²·sec 1st order moment = 0.968108 cm²·Hz
 2nd order moment = 0.304583 cm²·Hz²

Peak frequency = 0.003906 Hz Area under curve = 157.417923 cm²
 Peak value Sxx = 11942.379883 cm²·sec 1st order moment = 31.501087 cm²·Hz
 2nd order moment = 19.774954 cm²·Hz²

Peak frequency = 0.152344 Hz Area under curve = 83.709450 cm²
 Peak value Sxx = 738.398193 cm²·sec 1st order moment = 30.339581 cm²·Hz
 2nd order moment = 19.399290 cm²·Hz²



CALCULO DE VELOCIDADES ORBITALES BAJO CRESTA y SENO
 (Hrms)

```

c1 = sqrt(g*d), c2 = SQRT(G*(d+(cresta-mwl)))
UWTR = c1 * ETATR / d
UWCR1 = c1 * ETACR / d
UWCR2 = c1 * ETACR / ( d + etacr )
UWCR3 = c1 * ( ETACR / d - ( ETACR / d ) **2.)
UWCR4 = c2 * ETACR / d
UWCRL = pi * h / T*cos(0)*cosh(k*(d+z))/(sinh(k*d))
UWCRS2 = STOKES 2o ORDEN bajo cresta
UWTRS2 = STOKES 2o ORDEN bajo seno
UCRMTF = 2*pi/T*cosh(k*zb(j))/sinh(k*dm)*ETACR
UTRMTF = 2*pi/T*cosh(k*zb(j))/sinh(k*d)*ETATR
ur1 = H * L**2./d**3.
ur2 = H/(K**2.*d**3.)
ur3 = g*H*T**2./d**2.
    
```

test, d(m), L(m), C1(m/s), C2, Ctl, Ur1, Ur2, Ur3, K

5	1.29	24.86	3.56	3.88	3.50	111.41	2.82	115.33	.25
6	.80	19.71	2.80	3.15	2.77	243.48	6.17	248.73	.32
7	.69	20.66	2.60	2.91	2.58	348.32	8.82	353.42	.30
8	1.34	25.32	3.63	3.89	3.56	90.06	2.28	93.35	.25
9	.69	18.39	2.61	3.01	2.59	338.63	8.58	344.97	.34
10	.68	18.20	2.58	2.91	2.56	292.79	7.42	298.15	.35
11	.60	19.29	2.43	2.73	2.41	406.42	10.29	411.58	.33
12	.38	15.38	1.93	2.18	1.92	659.94	16.72	665.23	.41

**CALCULO DE LA VELOCIDAD ORBITAL BAJO CRESTA: UWCR
(Hrms)**

cem, UWCR1, UWCR2, UWCR3, UWCR4, UCRMTF, UWCRL Test

5

1	.68	.57	.55	.75	1.40	.52
2	.68	.57	.55	.75	1.43	.52
3	.68	.57	.55	.75	1.48	.52
4	.68	.57	.55	.75	1.52	.52
5	.68	.57	.55	.75	1.62	.52
6	.68	.57	.55	.75	1.74	.53

6

1	.75	.59	.55	.84	1.15	.55
2	.75	.59	.55	.84	1.20	.55
3	.75	.59	.55	.84	1.26	.55
4	.75	.59	.55	.84	1.32	.55
5	.75	.59	.55	.84	1.47	.56
6	.75	.59	.55	.84	1.67	.57

7

1	.66	.52	.49	.73	1.06	.50
2	.66	.52	.49	.73	1.12	.50
3	.66	.52	.49	.73	1.18	.50
4	.66	.52	.49	.73	1.25	.50
5	.66	.52	.49	.73	1.42	.51
6	.66	.52	.49	.73	1.65	.51

8

1	.55	.47	.46	.59	1.36	.44
2	.55	.47	.46	.59	1.40	.44
3	.55	.47	.46	.59	1.44	.44
4	.55	.47	.46	.59	1.48	.44
5	.55	.47	.46	.59	1.57	.45
6	.55	.47	.46	.59	1.68	.45

9

1	.86	.65	.58	.99	1.09	.62
2	.86	.65	.58	.99	1.14	.62
3	.86	.65	.58	.99	1.20	.62
4	.86	.65	.58	.99	1.27	.63
5	.86	.65	.58	.99	1.44	.63
6	.86	.65	.58	.99	1.67	.64

10

1	.69	.54	.50	.77	1.05	.52
2	.69	.54	.50	.77	1.11	.52
3	.69	.54	.50	.77	1.17	.52
4	.69	.54	.50	.77	1.24	.52
5	.69	.54	.50	.77	1.42	.53
6	.69	.54	.50	.77	1.65	.54

11

1	.63	.50	.47	.71	1.01	.47
---	-----	-----	-----	-----	------	-----

2	.63	.50	.47	.71	1.08	.47
3	.63	.50	.47	.71	1.15	.47
4	.63	.50	.47	.71	1.23	.48
5	.63	.50	.47	.71	1.43	.48
6	.00	.00	.00	.00	.00	.00
					12	
1	.52	.41	.38	.59	.84	.39
2	.52	.41	.38	.59	.93	.39
3	.52	.41	.38	.59	1.04	.39
4	.52	.41	.38	.59	1.17	.39
5	.00	.00	.00	.00	.00	.00
6	.00	.00	.00	.00	.00	.00

CALCULO DE LA VELOCIDAD ORBITAL BAJO SENO: UWTR
(Hrms)

cem, UWTR, UTRMTF, UWTRL, Test

5

1 -.38 -.37 -.52
2 -.38 -.37 -.52
3 -.38 -.37 -.52
4 -.38 -.37 -.52
5 -.38 -.37 -.52
6 -.38 -.38 -.53

6

1 -.37 -.37 -.55
2 -.37 -.37 -.55
3 -.37 -.37 -.55
4 -.37 -.37 -.55
5 -.37 -.37 -.56
6 .00 .00 .00

7

1 -.35 -.35 -.50
2 -.35 -.35 -.50
3 -.35 -.35 -.50
4 -.35 -.35 -.50
5 .00 .00 .00
6 .00 .00 .00

8

1 -.37 -.35 -.44
2 -.37 -.36 -.44
3 -.37 -.36 -.44
4 -.37 -.36 -.44
5 -.37 -.36 -.45
6 -.37 -.36 -.45

9

1 -.41 -.40 -.62
2 -.41 -.40 -.62
3 -.41 -.40 -.62
4 -.41 -.40 -.63
5 .00 .00 .00
6 .00 .00 .00

10

1 -.37 -.36 -.52
2 -.37 -.36 -.52
3 -.37 -.36 -.52
4 -.37 -.37 -.52
5 .00 .00 .00
6 .00 .00 .00

11

1 -.32 -.32 -.47

2	-.32	-.32	-.47
3	-.32	-.32	-.47
4	-.32	-.32	-.48
5	.00	.00	.00
6	.00	.00	.00

12

1	-.25	-.25	-.39
2	-.25	-.25	-.39
3	-.25	-.25	-.39
4	.00	.00	.00
5	.00	.00	.00
6	.00	.00	.00

```

1*****
High Order Fourier Theory (M.M. Riemecker & J.D. Fenton'81)
Case: III, Test: 5, Hrms
*****
0
0
Mean waterdepth      h   :    1.290000
Wave period          T   :    7.100000
Wave height          H   :    .469000
Mean Eulerian velocity Ce  :    .000000
Number of Fourier components N  :    16
Maximum relative error eps  :    1.00D-08
Water density         rho : 1020.000000
Gravitational acceleration g   :    9.810000
Nr. of hor. velocity levels nvel :    7

0Number of iterations     nit  :    11
Maximum relative error   eps  :    1.37D-12
0
0Wave speed            c   :    3.811205
Wave number            k   :    .232198
Wave length            L   :    27.059553
Crest surface elevation ac  :    .384442
Trough surface elevation at  :   -.084558
Ratio                  ac/at :    4.546503
Still water depth       d   :    1.276510
0Mean kinetic energy    Ek  :    99.930532
Mean potential energy   Ep  :    92.782831
Ratio                  Ek/Ep :    1.077037
Radiation stress        Sxx : 259.804142
Mean wave momentum      I   :    52.440391
Mean energy flux        F   :    701.890444
0Crest bed velocity     ubc :    .796103
Trough bed velocity     ubt :   -.224626
Ratio                  ubc/ubt :    3.544120
RMS value of bed velocity ub,rms :    .324355
Std.deviation of bed velocity s(ub) :    .324355
0Crest surface velocity usc :    1.148925
Trough surface velocity uft :   -.224822
Mean Eulerian velocity Ce  :    .000000
Mean mass transport velocity Cm  :    .039854
0Surface stream function value Q  :    4.865042
Total head              R   :    2.035693
Momentum flux           S   : 27298.105709
1*****
0
0

```

Moments and central moments of the bed velocity.
(normalized with std. deviation of bed velocity)

	Central Moment	Moment
Odd moments |	|	
< u |u|^0 > |	.000000	.000000
< u |u|^1 > |	.486163	.486163
< u |u|^2 > |	1.342435	1.342435
< u |u|^3 > |	3.115922	3.115922

< u |u|^4 >	7.029137	7.029137
-------------	----------	----------

Even moments		
< |u|^1 >	.813821	.813821
< |u|^2 >	1.000000	1.000000
< |u|^3 >	1.675782	1.675782
< |u|^4 >	3.335262	3.335262
< |u|^5 >	7.174734	7.174734

Std. deviation of bed velocity s(ub): .324356

0

0

0

Horizontal velocities under wave crest and trough at different elevations

Elevation	Crest	Trough	Std.	First Fourier components			
	Value	Value	Dev.	1	2	3	4
-.4900	.8664	-.2247	.3387	.3828	.2467	.1318	.0623
-.6900	.8350	-.2247	.3323	.3799	.2396	.1238	.0560
-.8900	.8132	-.2246	.3278	.3779	.2346	.1182	.0517
-.9900	.8057	-.2246	.3263	.3772	.2328	.1162	.0502
-1.0900	.8003	-.2246	.3252	.3767	.2316	.1148	.0492
-1.1900	.7972	-.2246	.3246	.3764	.2309	.1140	.0485
-1.2800	.7961	-.2246	.3244	.3763	.2306	.1137	.0483

Mean Eulerian velocity at all elevations : .0000

0

0

0

Phase	Surface elevation			Cosine Fourier components			
	Time	X	Elevation	i	Elevation	Streamfunction	
.000	.0000	.0000	.3844	0	.000000	-3.811205	
11.250	.2219	.8456	.3251	1	.146975	1.693770	
22.500	.4437	1.6912	.2052	2	.100952	.588375	
33.750	.6656	2.5368	.0970	3	.060410	.233707	
45.000	.8875	3.3824	.0218	4	.033903	.094063	
56.250	1.1094	4.2281	-.0246	5	.018612	.037063	
67.500	1.3313	5.0737	-.0515	6	.010218	.013970	
78.750	1.5531	5.9193	-.0666	7	.005671	.004911	
90.000	1.7750	6.7649	-.0749	8	.003198	.001546	
101.250	1.9969	7.6105	-.0794	9	.001835	.000397	
112.500	2.2188	8.4561	-.0818	10	.001071	.000054	
123.750	2.4406	9.3017	-.0831	11	.000636	-.000022	
135.000	2.6625	10.1473	-.0839	12	.000386	-.000025	
146.250	2.8844	10.9929	-.0842	13	.000242	-.000014	
157.500	3.1062	11.8386	-.0844	14	.000160	-.000007	
168.750	3.3281	12.6842	-.0845	15	.000119	-.000002	
180.000	3.5500	13.5298	-.0846	16	.000053	-.000001	

0

High Order Fourier Theory (M.M. Rienecker & J.D. Fenton'81)

Case: III, Test: 6, Hrms

0

0

Mean waterdepth h : .800000
Wave period T : 7.100000
Wave height H : .384000
Mean Eulerian velocity Ce : .000000
Number of Fourier components N : 16
Maximum relative error eps : 1.00D-08
Water density rho : 1020.000000
Gravitational acceleration g : 9.810000
Nr. of hor. velocity levels nvel : 7

0 Number of iterations nit : 14
Maximum relative error eps : 5.63D-15

0

0 Wave speed c : 3.165786
Wave number k : .279537
Wave length L : 22.477080
Crest surface elevation ac : .338255
Trough surface elevation at : -.045745
Ratio ac/at : 7.394352
Still water depth d : .790056
0 Mean kinetic energy Ek : 50.829006
Mean potential energy Ep : 45.528791
Ratio Ek/Ep : 1.116415
Radiation stress Sxx : 129.138093
Mean wave momentum I : 32.111461
Mean energy flux F : 294.486283
0 Crest bed velocity ubc : .822006
Trough bed velocity ubt : -.150263
Ratio ubc/ubt : 5.470451
RMS value of bed velocity ub,rms : .276552
Std.deviation of bed velocity s(ub) : .276552
0 Crest surface velocity ufc : 1.305109
Trough surface velocity uft : -.150266
Mean Eulerian velocity Ce : .000000
Mean mass transport velocity Cm : .039352
0 Surface stream function value Q : 2.501147
Total head R : 1.314714
Momentum flux S : 11305.921694

0

0

Moments and central moments of the bed velocity
(normalized with std. deviation of bed velocity)

	Central Moment	Moment
Odd moments |		
< u |u|^0 > |	.000000	.000000
< u |u|^1 > |	.618310	.618310
< u |u|^2 > |	1.877581	1.877581
< u |u|^3 > |	5.046318	5.046318

$\langle u | u |^4 \rangle$ | 13.531105 | 13.531105

Even moments |		
$\langle |u|^1 \rangle$ | .742601 | .742601		
$\langle |u|^2 \rangle$ | 1.000000 | 1.000000		
$\langle |u|^3 \rangle$ | 2.077084 | 2.077084		
$\langle |u|^4 \rangle$ | 5.151497 | 5.151497		
$\langle |u|^5 \rangle$ | 13.586850 | 13.586850		

Std. deviation of bed velocity $s(ub)$: .276870

0

0

0-----

Horizontal velocities under wave crest and trough at different elevations

Elevation	Crest	Trough	Std.	First Fourier components			
				Value	Value	Dev.	1	2	3	4
.0000	1.0330	-.1503	.3116	.2819	.2351	.1785	.1263
-.2000	.9348	-.1503	.2953	.2789	.2255	.1634	.1092
-.4000	.8704	-.1503	.2847	.2767	.2187	.1529	.0975
-.5000	.8489	-.1503	.2812	.2759	.2164	.1493	.0935
-.6000	.8338	-.1503	.2788	.2754	.2147	.1467	.0907
-.7000	.8250	-.1503	.2773	.2751	.2137	.1452	.0890
-.7900	.8220	-.1503	.2769	.2750	.2134	.1447	.0885

Mean Eulerian velocity at all elevations : .0000

0-----

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0-----

0-----

Surface elevation | Cosine Fourier components

Phase	Time	X	Elevation		i	Elevation	Streamfunction
.000	.0000	.0000	.3383	|	0	.000000	-.3.165786
11.250	.2219	.7024	.2354	|	1	.085605	1.008375
22.500	.4438	1.4048	.0993	|	2	.071062	.420438
33.750	.6656	2.1072	.0200	|	3	.053987	.212838
45.000	.8875	2.8096	-.0176	|	4	.038791	.112958
56.250	1.1094	3.5120	-.0340	|	5	.027047	.060515
67.500	1.3313	4.2145	-.0409	|	6	.018623	.032211
78.750	1.5531	4.9169	-.0438	|	7	.012807	.016863
90.000	1.7750	5.6193	-.0449	|	8	.008861	.008608
101.250	1.9969	6.3217	-.0454	|	9	.006200	.004244
112.500	2.2188	7.0241	-.0456	|	10	.004406	.001997
123.750	2.4406	7.7265	-.0457	|	11	.003195	.000878
135.000	2.6625	8.4289	-.0457	|	12	.002381	.000347
146.250	2.8844	9.1313	-.0457	|	13	.001842	.000110
157.500	3.1063	9.8337	-.0457	|	14	.001503	.000013
168.750	3.3281	10.5361	-.0457	|	15	.001316	-.000022
180.000	3.5500	11.2385	-.0457	|	16	.000628	-.000014

0-----

High Order Fourier Theory (M.M. Riemecker & J.D. Fenton'81)

Case: III, Test: 7, Hrms

0

0

Mean waterdepth h : .700000
Wave period T : 8.000000
Wave height H : .305000
Mean Eulerian velocity Ce : .000000
Number of Fourier components N : 16
Maximum relative error eps : 1.00D-08
Water density rho : 1020.000000
Gravitational acceleration g : 9.810000
Nr. of hor. velocity levels nvel : 7

0 Number of iterations nit : 15
Maximum relative error eps : 2.78D-15
0
0 Wave speed c : 2.956872
Wave number k : .265618
Wave length L : 23.654973
Crest surface elevation ac : .272676
Trough surface elevation at : -.032324
Ratio ac/at : 8.435596
Still water depth d : .693408
0 Mean kinetic energy Ek : 29.395304
Mean potential energy Ep : 26.478484
Ratio Ek/Ep : 1.110158
Radiation stress Sxx : 75.768558
Mean wave momentum I : 19.882705
Mean energy flux F : 160.314190
0 Crest bed velocity ubc : .737765
Trough bed velocity ubt : -.113957
Ratio ubc/ubt : 6.474083
RMS value of bed velocity ub,rms : .229550
Std.deviation of bed velocity s(ub) : .229550
0 Crest surface velocity ufc : 1.100561
Trough surface velocity uft : -.113957
Mean Eulerian velocity Ce : .000000
Mean mass transport velocity Cm : .027847
0 Surface stream function value Q : 2.050317
Total head R : 1.148307
Momentum flux S : 8652.272491

0

0

Moments and central moments of the bed velocity
(normalized with std. deviation of bed velocity)

	Central Moment	Moment
Odd moments |		
< u |u|^0 > |	.000000	.000000
< u u ^1 >	.663356	.663356
< u u ^2 >	2.110086	2.110086
< u u ^3 >	6.058076	6.058076

< u u ^4 >	17.486337	17.486337
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Even moments	
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< u ^1 >	.710537	.710537
< u ^2 >	1.000000	1.000000
< u ^3 >	2.271828	2.271828
< u ^4 >	6.136343	6.136343
< |u|^5 >	17.524376	17.524376

Std. deviation of bed velocity s(ub): .230018

0
0
0-----

Horizontal velocities under wave crest and trough at different elevations

Elevation	Crest Value	Trough Value	Std. Dev.	1	2	3	4	First Fourier components
.1000	.9666	-.1140	.2646	.2180	.1918	.1574	.1222	
-.1000	.8587	-.1140	.2480	.2159	.1847	.1452	.1069	
-.3000	.7892	-.1140	.2376	.2144	.1797	.1367	.0964	
-.4000	.7663	-.1140	.2342	.2138	.1779	.1338	.0929	
-.5000	.7503	-.1140	.2319	.2134	.1767	.1317	.0903	
-.6000	.7409	-.1140	.2305	.2132	.1759	.1305	.0888	
-.6900	.7378	-.1140	.2300	.2131	.1757	.1301	.0883	

Mean Eulerian velocity at all elevations : .0000

0

0
0-----

Surface elevation | Cosine Fourier components

Phase	Time	X	Elevation	i	Elevation	Streamfunction
.000	.0000	.0000	.2727	0	.000000	-2.956872
11.250	.2500	.7392	.1778	1	.061408	.816372
22.500	.5000	1.4784	.0632	2	.053041	.353848
33.750	.7500	2.2177	.0051	3	.042473	.189256
45.000	1.0000	2.9569	-.0185	4	.032243	.107203
56.250	1.2500	3.6961	-.0273	5	.023660	.061796
67.500	1.5000	4.4353	-.0305	6	.017031	.035700
78.750	1.7500	5.1745	-.0317	7	.012151	.020498
90.000	2.0000	5.9137	-.0321	8	.008658	.011626
101.250	2.2500	6.6530	-.0322	9	.006198	.006477
112.500	2.5000	7.3922	-.0323	10	.004480	.003523
123.750	2.7500	8.1314	-.0323	11	.003291	.001855
135.000	3.0000	8.8706	-.0323	12	.002475	.000935
146.250	3.2500	9.6098	-.0323	13	.001929	.000443
157.500	3.5000	10.3491	-.0323	14	.001582	.000192
168.750	3.7500	11.0883	-.0323	15	.001390	.000077
180.000	4.0000	11.8275	-.0323	16	.000664	.000022

0-----

High Order Fourier Theory (M.M. Rienecker & J.D. Fenton'81)

Case: IV, Test: 8, Hrms

0

0

Mean waterdepth h : 1.340000
Wave period T : 7.100000
Wave height H : .408000
Mean Eulerian velocity Ce : .000000
Number of Fourier components N : 16
Maximum relative error eps : 1.00D-08
Water density rho : 1020.000000
Gravitational acceleration g : 9.810000
Nr. of hor. velocity levels nvel : 7

0 Number of iterations nit : 9
Maximum relative error eps : 5.32D-15

0

0 Wave speed c : 3.809843
Wave number k : .232281
Wave length L : 27.049885
Crest surface elevation ac : .324775
Trough surface elevation at : -.083225
Ratio ac/at : 3.902367
Still water depth d : 1.329064
0 Mean kinetic energy Ek : 80.951637
Mean potential energy Ep : 76.319540
Ratio Ek/Ep : 1.060693
Radiation stress Sxx : 213.823332
Mean wave momentum I : 42.496050
Mean energy flux F : 572.196514
0 Crest bed velocity ubc : .689047
Trough bed velocity ubt : -.219006
Ratio ubc/ubt : 3.146243
RMS value of bed velocity ub,rms : .295037
Std.deviation of bed velocity s(ub) : .295037
0 Crest surface velocity ufc : .941069
Trough surface velocity uft : -.219403
Mean Eulerian velocity Ce : .000000
Mean mass transport velocity Cm : .031092
0 Surface stream function value Q : 5.063527
Total head R : 2.084238
Momentum flux S : 28712.552518

0

0

Moments and central moments of the bed velocity
(normalized with std. deviation of bed velocity)

	Central Moment	Moment
Odd moments |	|	|
< u |u|^0 > |	.000000	.000000
< u |u|^1 > |	.446459	.446459
< u |u|^2 > |	1.208979	1.208979
< u |u|^3 > |	2.714875	2.714875

$\langle u | u|^4 \rangle = 5.875024$

—
—

Even moments |

$< u|^1>$	.829667	.829667
$< u|^2>$	1.000000	1.000000
$< u|^3>$	1.589904	1.589904
$< u|^4>$	2.981306	2.981306
$< u|^5>$	6.063269	6.063269

Std. deviation of bed velocity s_{ub} : .295037

0

0

0

Horizontal velocities under wave crest and trough at different elevations

Elevation | Crest Trough Std. | First Fourier components

	Value	Value	Dev.	1	2	3
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-.5400	.7410	-.2192	.3064	.3608	.2125	.1015	.0425
-.7400	.7179	-.2191	.3013	.3581	.2064	.0953	.0382
-.9400	.7017	-.2190	.2978	.3562	.2021	.0910	.0352
-.9900	.6987	-.2190	.2971	.3558	.2013	.0902	.0347
-1.0400	.6961	-.2190	.2966	.3555	.2006	.0895	.0342
-1.1400	.6922	-.2190	.2957	.3550	.1995	.0884	.0335
-1.3300	.6891	-.2190	.2950	.3546	.1986	.0875	.0329

Mean Eulerian velocity at all elevations : .0000

0

0

0

Surface elevation				Cosine Fourier components			
Phase	Time	X	Elevation	i	Elevation	Streamfunction	

.000	.0000	.0000	.3248	|	0	.000000	-3.809843
11.250	.2219	.8453	.2849	|	1	.140026	1.601274
22.500	.4438	1.6906	.1962	|	2	.088489	.513113
33.750	.6656	2.5359	.1060	|	3	.047887	.184478
45.000	.8875	3.3812	.0363	|	4	.024226	.066656
56.250	1.1094	4.2265	-.0108	|	5	.011995	.023400
67.500	1.3313	5.0719	-.0405	|	6	.005946	.007775
78.750	1.5531	5.9172	-.0584	|	7	.002983	.002366
90.000	1.7750	6.7625	-.0690	|	8	.001522	.000621
101.250	1.9969	7.6078	-.0752	|	9	.000790	.000117
112.500	2.2188	8.4531	-.0787	|	10	.000417	-.000002
123.750	2.4406	9.2984	-.0808	|	11	.000224	-.000016
135.000	2.6625	10.1437	-.0820	|	12	.000122	-.000011
146.250	2.8844	10.9890	-.0826	|	13	.000068	-.000005
157.500	3.1063	11.8343	-.0830	|	14	.000040	-.000002
168.750	3.3281	12.6796	-.0832	|	15	.000027	-.000000
180.000	3.5500	13.5249	-.0832	|	16	.000011	.000000

0

High Order Fourier Theory (M.M. Rienecker & J.D. Fenton'81)

Case: IV, Test: 9, Hrms

0

0

Mean waterdepth h : .700000
Wave period T : 7.100000
Wave height H : .399000
Mean Eulerian velocity Ce : .000000
Number of Fourier components N : 16
Maximum relative error eps : 1.00D-08
Water density rho : 1020.000000
Gravitational acceleration g : 9.810000
Nr. of hor. velocity levels nvel : 7

0 Number of iterations nit : 17
Maximum relative error eps : 5.95D-12
0
0 Wave speed c : 3.050660
Wave number k : .290087
Wave length L : 21.659686
Crest surface elevation ac : .359763
Trough surface elevation at : -.039237
Ratio ac/at : 9.168982
Still water depth d : .690027
0 Mean kinetic energy Ek : 47.333567
Mean potential energy Ep : 41.527573
Ratio Ek/Ep : 1.139811
Radiation stress Sxx : 116.709384
Mean wave momentum I : 31.031689
Mean energy flux F : 260.204783
0 Crest bed velocity ubc : .870125
Trough bed velocity ubt : -.135109
Ratio ubc/ubt : 6.440163
RMS value of bed velocity ub,rms : .269759
Std.deviation of bed velocity s(ub) : .269759
0 Crest surface velocity ufc : 1.527261
Trough surface velocity uft : -.135109
Mean Eulerian velocity Ce : .000000
Mean mass transport velocity Cm : .043462
0 Surface stream function value Q : 2.105039
Total head R : 1.178048
Momentum flux S : 9023.754163

0

0

Moments and central moments of the bed velocity
(normalized with std. deviation of bed velocity)

	Central Moment	Moment
Odd moments |		
< u |u|^0 > |	.000000	.000000
< u |u|^1 > |	.661989	.661989
< u |u|^2 > |	2.101948	2.101948
< u |u|^3 > |	6.020056	6.020056

< u | u|^4 > | 17.330403 | 17.330403

Even moments |		
< |u|^1 > | .711663 | .711663		
< |u|^2 > | 1.000000 | 1.000000		
< |u|^3 > | 2.264751 | 2.264751		
< |u|^4 > | 6.099032 | 6.099032		
< |u|^5 > | 17.368883 | 17.368883		

Std. deviation of bed velocity s(ub): .272030

0
0
0-----

Horizontal velocities under wave crest and trough at different elevations

Elevation	Crest	Trough	Std.	First Fourier components				
				Value	Value	Dev.	1	2
.1000	1.1977	-.1351	.3218	.2594	.2307	.1923	.1521	
-.1000	1.0412	-.1351	.2977	.2564	.2207	.1750	.1302	
-.3000	.9423	-.1351	.2827	.2543	.2136	.1630	.1154	
-.4000	.9100	-.1351	.2779	.2536	.2111	.1588	.1103	
-.5000	.8876	-.1351	.2746	.2530	.2093	.1559	.1068	
-.6000	.8745	-.1351	.2727	.2527	.2083	.1542	.1047	
-.6900	.8702	-.1351	.2720	.2526	.2079	.1536	.1040	

Mean Eulerian velocity at all elevations : .0000

0

0
0-----

Phase	Time	X	Elevation	Cosine Fourier components			
				i	Elevation	Streamfunction	
.000	.0000	.0000	.3598	0	.000000	-3.050660	
11.250	.2219	.6769	.2134	1	.074779	.888795	
22.500	.4438	1.3537	.0700	2	.065217	.388363	
33.750	.6656	2.0306	.0029	3	.053073	.210231	
45.000	.8875	2.7075	-.0237	4	.041219	.120815	
56.250	1.1094	3.3843	-.0336	5	.031156	.070723	
67.500	1.3313	4.0612	-.0372	6	.023261	.041487	
78.750	1.5531	4.7381	-.0385	7	.017336	.024173	
90.000	1.7750	5.4149	-.0390	8	.012995	.013902	
101.250	1.9969	6.0918	-.0391	9	.009854	.007849	
112.500	2.2188	6.7687	-.0392	10	.007597	.004327	
123.750	2.4406	7.4455	-.0392	11	.005984	.002314	
135.000	2.6625	8.1224	-.0392	12	.004844	.001191	
146.250	2.8844	8.7992	-.0392	13	.004059	.000583	
157.500	3.1063	9.4761	-.0392	14	.003548	.000270	
168.750	3.3281	10.1530	-.0392	15	.003260	.000125	
180.000	3.5500	10.8298	-.0392	16	.001583	.000040	

0

```

1*****
High Order Fourier Theory (M.M. Rienecker & J.D. Fenton'81)
Case: IV, Test: 10, Hrms
*****
0
0
Mean waterdepth      h   :    .680000
Wave period          T   :    7.100000
Wave height          H   :    .333000
Mean Eulerian velocity Ce  :    .000000
Number of Fourier components N  :    16
Maximum relative error eps  :    1.00D-08
Water density         rho : 1020.000000
Gravitational acceleration g   :    9.810000
Nr. of hor. velocity levels nvel :    7

0Number of iterations nit  :    15
Maximum relative error eps  :    1.52D-14
0
0Wave speed          c   :    2.942769
Wave number          k   :    .300722
Wave length          L   :    20.893663
Crest surface elevation ac  :    .296859
Trough surface elevation at  :   -.036141
Ratio                ac/at :    8.213857
Still water depth     d   :    .671923
0Mean kinetic energy Ek  :    35.672468
Mean potential energy Ep  :    31.819691
Ratio                Ek/Ep :    1.121082
Radiation stress      Sxx :    90.436311
Mean wave momentum     I   :    24.244147
Mean energy flux       F   :    191.978550
0Crest bed velocity   ubc :    .779049
Trough bed velocity   ubt :   -.128268
Ratio                ubc/ubt :    6.073613
RMS value of bed velocity ub,rms :    .249583
Std.deviation of bed velocity s(ub) :    .249583
0Crest surface velocity ufc :    1.240473
Trough surface velocity uft :   -.128269
Mean Eulerian velocity Ce  :    .000000
Mean mass transport velocity Cm  :    .034954
0Surface stream function value Q  :    1.977314
Total head            R   :    1.124556
Momentum flux         S   :    8267.680810
*****
0
0

```

Moments and central moments of the bed velocity
 (normalized with std. deviation of bed velocity)

	Central Moment	Moment
Odd moments |		
< u |u|^0 >	.000000	.000000
< u |u|^1 >	.646748	.646748
< u |u|^2 >	2.019903	2.019903
< u |u|^3 >	5.652145	5.652145

$\langle u | u |^4 \rangle$ | 15.856994 | 15.856994

Even moments		
$\langle |u|^1 \rangle$	.722937	.722937
$\langle |u|^2 \rangle$	1.000000	1.000000
$\langle |u|^3 \rangle$	2.195112	2.195112
$\langle |u|^4 \rangle$	5.739713	5.739713
$\langle |u|^5 \rangle$	15.900965	15.900965

Std. deviation of bed velocity $s(ub)$: .250210

0
0
0-----

Horizontal velocities under wave crest and trough at different elevations

Elevation	Crest Value	Trough Value	Std. Dev.	First Fourier components			
				1	2	3	4
.1200	1.0640	-.1283	.2950	.2450	.2149	.1754	.1353
-.0800	.9283	-.1283	.2733	.2420	.2048	.1586	.1148
-.2800	.8422	-.1283	.2599	.2398	.1978	.1470	.1009
-.3800	.8139	-.1283	.2555	.2391	.1953	.1430	.0962
-.4800	.7944	-.1283	.2525	.2385	.1936	.1402	.0929
-.5800	.7829	-.1283	.2508	.2382	.1925	.1385	.0909
-.6700	.7791	-.1283	.2502	.2381	.1922	.1379	.0902

Mean Eulerian velocity at all elevations : .0000

0

0
0-----

Surface elevation | Cosine Fourier components

Phase	Time	X	Elevation	|	i	Elevation	Streamfunction
.000	.0000	.0000	.2969	|	0	.000000	-2.942769
11.250	.2219	.6529	.1943	|	1	.068376	.808432
22.500	.4438	1.3059	.0723	|	2	.058432	.346651
33.750	.6656	1.9588	.0086	|	3	.046161	.182580
45.000	.8875	2.6117	-.0187	|	4	.034595	.101536
56.250	1.1094	3.2646	-.0295	|	5	.025135	.057308
67.500	1.3313	3.9176	-.0336	|	6	.017985	.032314
78.750	1.5531	4.5705	-.0352	|	7	.012814	.018039
90.000	1.7750	5.2234	-.0358	|	8	.009158	.009900
101.250	1.9969	5.8763	-.0360	|	9	.006604	.005304
112.500	2.2188	6.5293	-.0361	|	10	.004828	.002753
123.750	2.4406	7.1822	-.0361	|	11	.003599	.001369
135.000	2.6625	7.8351	-.0361	|	12	.002755	.000640
146.250	2.8844	8.4881	-.0361	|	13	.002187	.000271
157.500	3.1063	9.1410	-.0361	|	14	.001825	.000094
168.750	3.3281	9.7939	-.0361	|	15	.001624	.000019
180.000	3.5500	10.4468	-.0361	|	16	.000780	-.000000

0-----

High Order Fourier Theory (M.M. Rienecker & J.D. Fenton'81)

Case: IV, Test: 11, Hrms

0

0

Mean waterdepth h : .600000
Wave period T : 8.000000
Wave height H : .266000
Mean Eulerian velocity Ce : .000000
Number of Fourier components N : 16
Maximum relative error eps : 1.00D-08
Water density rho : 1020.000000
Gravitational acceleration g : 9.810000
Nr. of hor. velocity levels nvel : 7

0 Number of iterations nit : 15
Maximum relative error eps : 5.84D-15
0
0 Wave speed c : 2.755247
Wave number k : .285055
Wave length L : 22.041978
Crest surface elevation ac : .240155
Trough surface elevation at : -.025845
Ratio ac/at : 9.292246
Still water depth d : .594599
0 Mean kinetic energy Ek : 20.911859
Mean potential energy Ep : 18.778119
Ratio Ek/Ep : 1.113629
Radiation stress Sxx : 53.715785
Mean wave momentum I : 15.179661
Mean energy flux F : 106.075734
0 Crest bed velocity ubc : .699279
Trough bed velocity ubt : -.098103
Ratio ubc/ubt : 7.128027
RMS value of bed velocity ub,rms : .207706
Std.deviation of bed velocity s(ub) : .207706
0 Crest surface velocity ufc : 1.045662
Trough surface velocity uft : -.098102
Mean Eulerian velocity Ce : .000000
Mean mass transport velocity Cm : .024803
0 Surface stream function value Q : 1.638266
Total head R : .989120
Momentum flux S : 6417.113373

0

0

Moments and central moments of the bed velocity
(normalized with std. deviation of bed velocity)

	Central Moment	Moment
Odd moments |		
< u |u|^0 >	.000000	.000000
< u |u|^1 >	.687393	.687393
< u |u|^2 >	2.249563	2.249563
< u |u|^3 >	6.716582	6.716582

$\langle u | u|^4 \rangle$ | 20.238031 | 20.238031

Even moments |

$< u|^1>$	.691545	.691545
$< u|^2>$	1.000000	1.000000
$< u|^3>$	2.392663	2.392663
$< u|^4>$	6.782510	6.782510
$< u|^5>$	20.268524	20.268524

Std. deviation of bed velocity s_{ub} : .208534

0

8

8

Horizontal velocities under wave crest and trough at different elevations

Elevation | Crest Trough Std | First Fourier components

	Value	Value	Dev.	1	2	3
--	-------	-------	------	---	---	---

.2000	1.0069	-.0981	.2531	.1902	.1739	.1510	.1255
.0000	.8580	-.0981	.2312	.1881	.1665	.1378	.1080
-.2000	.7657	-.0981	.2179	.1866	.1614	.1286	.0960
-.3000	.7359	-.0981	.2137	.1861	.1596	.1255	.0920
-.4000	.7153	-.0981	.2108	.1857	.1583	.1232	.0891
-.5000	.7033	-.0981	.2091	.1855	.1575	.1219	.0874
-.5900	.6993	-.0981	.2085	.1854	.1573	.1215	.0868

Mean Eulerian velocity at all elevations : .0000

0

0

U

Surface elevation				Cosine Fourier components			
Phase	Time	X	Elevation	i		Elevation	Streamfunction
.000	.0000	.0000	.2402	0		.000000	-2.755247
11.250	.2500	.6888	.1463	1		.049492	.659878
22.500	.5000	1.3776	.0449	2		.043697	.292131
33.750	.7500	2.0664	-.0008	3		.036091	.161123
45.000	1.0000	2.7552	-.0174	4		.028377	.094686
56.250	1.2500	3.4441	-.0231	5		.021586	.056857
67.500	1.5000	4.1329	-.0249	6		.016091	.034337
78.750	1.7500	4.8217	-.0255	7		.011871	.020689
90.000	2.0000	5.5105	-.0257	8		.008730	.012369
101.250	2.2500	6.1993	-.0258	9		.006439	.007305
112.500	2.5000	6.8881	-.0258	10		.004790	.004242
123.750	2.7500	7.5769	-.0258	11		.003617	.002411
135.000	3.0000	8.2657	-.0258	12		.002795	.001334
146.250	3.2500	8.9546	-.0258	13		.002234	.000716
157.500	3.5000	9.6434	-.0258	14		.001872	.000378
168.750	3.7500	10.3322	-.0258	15		.001670	.000211
180.000	4.0000	11.0210	-.0258	16		.000802	.000078

0

High Order Fourier Theory (M.M. Rienecker & J.D. Fenton'81)

Case: IV, Test: 12, Hrms

0

0

Mean waterdepth h : .380000
Wave period T : 8.000000
Wave height H : .184000
Mean Eulerian velocity Ce : .000000
Number of Fourier components N : 6
Maximum relative error eps : 1.00D-06
Water density rho : 1020.000000
Gravitational acceleration g : 9.810000
Nr. of hor. velocity levels nvel : 1

0 Number of iterations nit : 15
Maximum relative error eps : 5.79D-10

0

0 Wave speed c : 1.973921
Wave number k : .397887
Wave length L : 15.791364
Crest surface elevation ac : .115030
Trough surface elevation at : -.068970
Ratio ac/at : 1.667828
Still water depth d : .365285
0 Mean kinetic energy Ek : 29.241171
Mean potential energy Ep : 27.592520
Ratio Ek/Ep : 1.059750
Radiation stress Sxx : 82.687839
Mean wave momentum I : 29.627506
Mean energy flux F : 113.950296
0 Crest bed velocity ubc : .456383
Trough bed velocity ubt : -.344278
Ratio ubc/ubt : 1.325624
RMS value of bed velocity ub,rms : .353738
Std.deviation of bed velocity s(ub) : .353738
0 Crest surface velocity ufc : .645537
Trough surface velocity uft : -.344416
Mean Eulerian velocity Ce : .000000
Mean mass transport velocity Cm : .076438
0 Surface stream function value Q : .721043
Total head R : .584969
Momentum flux S : 2198.400822

0

0

Moments and central moments of the bed velocity
(normalized with std. deviation of bed velocity)

	Central Moment	Moment
Odd moments |	|	
< u |^0 > |	.000000	.000000
< u |^1 > |	.200460	.200460
< u |^2 > |	.515955	.515955
< u |^3 > |	1.041233	1.041233

CALCULO DE VELOCIDADES ORBITALES BAJO CRESTA y SENO
 (H1/3)

```

c1 = sqrt(g*d), c2 = SQRT(G*(d+(cresta-mwl)))
UWTR = c1 * ETATR / d
UWCR1 = c1 * ETACR / d
UWCR2 = c1 * ETACR / ( d + etacr )
UWCR3 = c1 * ( ETACR / d - ( ETACR / d ) **2.)
UWCR4 = c2 * ETACR / d
UWCRL = pi * h /T*cos(0)*cosh(k*(d+z)/(sinh(k*d))
UWCRS2 = STOKES 21 ORDEN bajo cresta
UWTRS2 = STOKES 21 ORDEN bajo seno
UCRMTF = 2*pi/T*cosh(k*zb(j))/sinh(k*dm)*ETACR
UTRMTF = 2*pi/T*cosh(k*zb(j))/sinh(k*d)*ETATR
ur1 = H * L**2./d**3.
ur2 = H/(K**2.*d**3.)
ur3 = g*H*T**2./d**2.
    
```

test, d(m), L(m), C1(m/s), C2, Ctl, Ur1, Ur2, Ur3, K

5	1.29	24.86	3.56	4.17	3.50	204.39	5.18	211.59	.25
6	.80	19.71	2.80	3.39	2.77	417.17	10.57	426.18	.32
7	.69	20.66	2.60	3.12	2.58	597.86	15.14	606.61	.30
8	1.34	25.32	3.63	4.10	3.56	162.53	4.12	168.47	.25
9	.69	18.39	2.61	3.28	2.59	584.54	14.81	595.48	.34
10	.68	18.20	2.58	3.12	2.56	495.00	12.54	504.07	.35
11	.60	19.29	2.43	2.92	2.41	706.07	17.88	715.04	.33
12	.38	15.38	1.93	2.36	1.92	1164.60	29.50	1173.94	.41

CALCULO DE LA VELOCIDAD ORBITAL BAJO CRESTA: UWCR
 (H1/3)

cem, UWCR1, UWCR2, UWCR3, UWCR4, UCRMTE, UWCR1L, Test

5

1	1.32	.96	.83	1.55	1.42	.95
2	1.32	.96	.83	1.55	1.46	.95
3	1.32	.96	.83	1.55	1.50	.95
4	1.32	.96	.83	1.55	1.54	.95
5	1.32	.96	.83	1.55	1.63	.96
6	1.32	.96	.83	1.55	1.74	.96

6

1	1.30	.89	.70	1.57	1.14	.94
2	1.30	.89	.70	1.57	1.18	.94
3	1.30	.89	.70	1.57	1.23	.95
4	1.30	.89	.70	1.57	1.29	.95
5	1.30	.89	.70	1.57	1.42	.96
6	1.30	.89	.70	1.57	1.58	.97

7

1	1.13	.79	.64	1.35	1.05	.86
2	1.13	.79	.64	1.35	1.10	.86
3	1.13	.79	.64	1.35	1.15	.86
4	1.13	.79	.64	1.35	1.21	.86
5	1.13	.79	.64	1.35	1.36	.87
6	1.13	.79	.64	1.35	1.54	.88

8

1	1.00	.78	.72	1.13	1.36	.80
2	1.00	.78	.72	1.13	1.40	.80
3	1.00	.78	.72	1.13	1.43	.80
4	1.00	.78	.72	1.13	1.47	.80
5	1.00	.78	.72	1.13	1.56	.80
6	1.00	.78	.72	1.13	1.65	.81

9

1	1.50	.95	.64	1.89	1.08	1.07
2	1.50	.95	.64	1.89	1.13	1.07
3	1.50	.95	.64	1.89	1.18	1.08
4	1.50	.95	.64	1.89	1.24	1.08
5	1.50	.95	.64	1.89	1.37	1.09
6	1.50	.95	.64	1.89	1.55	1.11

10

1	1.18	.81	.64	1.42	1.05	.88
2	1.18	.81	.64	1.42	1.10	.88
3	1.18	.81	.64	1.42	1.15	.88
4	1.18	.81	.64	1.42	1.21	.88
5	1.18	.81	.64	1.42	1.36	.90
6	1.18	.81	.64	1.42	1.55	.91

11

1	1.09	.75	.60	1.31	1.00	.82
---	------	-----	-----	------	------	-----

2	1.09	.75	.60	1.31	1.05	.82
3	1.09	.75	.60	1.31	1.11	.82
4	1.09	.75	.60	1.31	1.17	.83
5	1.09	.75	.60	1.31	1.34	.83
6	1.09	.75	.60	1.31	1.55	.85
					12	
1	.97	.64	.48	1.18	.85	.68
2	.97	.64	.48	1.18	.93	.68
3	.97	.64	.48	1.18	1.02	.69
4	.97	.64	.48	1.18	1.13	.69
5	.00	.00	.00	.00	.00	.00
6	.00	.00	.00	.00	.00	.00

CALCULO DE LA VELOCIDAD ORBITAL BAJO SENO: UWTR
(H1/3)

cem, UWTR, UTRMTF, UWTRL, Test

5

1 -.63 -.61 -.95
2 -.63 -.61 -.95
3 -.63 -.61 -.95
4 -.63 -.62 -.95
5 -.63 -.62 -.96
6 -.63 -.63 -.96

6

1 -.63 -.62 -.94
2 -.63 -.62 -.94
3 -.63 -.62 -.95
4 -.63 -.62 -.95
5 -.63 -.63 -.96
6 .00 .00 .00

7

1 -.60 -.59 -.86
2 -.60 -.60 -.86
3 -.60 -.60 -.86
4 -.60 -.60 -.86
5 .00 .00 .00
6 .00 .00 .00

8

1 -.65 -.63 -.80
2 -.65 -.63 -.80
3 -.65 -.63 -.80
4 -.65 -.63 -.80
5 -.65 -.63 -.80
6 -.65 -.64 -.81

9

1 -.68 -.66 -1.07
2 -.68 -.67 -1.07
3 -.68 -.67 -1.08
4 -.68 -.67 -1.08
5 .00 .00 .00
6 .00 .00 .00

10

1 -.61 -.60 -.88
2 -.61 -.60 -.88
3 -.61 -.60 -.88
4 -.61 -.60 -.88
5 .00 .00 .00
6 .00 .00 .00

11

1 -.57 -.56 -.82

2	-.57	-.56	-.82
3	-.57	-.56	-.82
4	-.57	-.56	-.83
5	.00	.00	.00
6	.00	.00	.00
			12
1	-.41	-.40	-.68
2	-.41	-.40	-.68
3	.00	.00	.00
4	.00	.00	.00
5	.00	.00	.00
6	.00	.00	.00

 Case: III, Test: 5, HI/
 High Order Fourier Theory (M.M. Rienecker & J.D. Fenton'81)

 Mean waterdepth h : 1.290000
 Wave period T : 7.100000
 Wave height H : .710000
 Mean Eulerian velocity Ce : .000000
 Number of Fourier components N : 16
 Maximum relative error eps : 1.00D-08
 Water density rho : 1020.000000
 Gravitational acceleration g : 9.810000
 Nr. of hor. velocity levels nvel : 7
 Maximum relative error eps : 7.35D-14
 ONumber of iterations nit : 14
 OWave speed c : 4.024008
 Wave number k : 219919
 Wave length L : 28.570459
 Crest surface elevation ac : .613652
 Through surface elevation at : -0.96348
 Ratio ac/act : 6.369154
 Still water depth d : 1.267096
 OMean kinetic energy Ek : 189.143623
 Ratio EK/Ep : 1.126531
 Radiation stress Sxx : 468.443829
 Mean energy flux F : 1373.513212
 Mean wave momentum I : 94.007569
 RMS value of bed velocity ub,rms : .404759
 Std.deviation of bed velocity s(ub) : .404759
 OCreast surface velocity ufc : 1.946363
 Through surface velocity utf : -2.47620
 Mean Eulerian velocity Ce : .000000
 Mean mass transport velocity Cm : .071445
 OSurface stream function value Q : 5.098807
 Total head R : 2.123663
 Momentum flux S : 29343.808180

Moments and central moments of the bed velocity
 (normalized with std. deviation of bed velocity)

Moment	Central Moment
Odd moments	$\langle u_{\lambda}^{\lambda} \rangle$
Even moments	$\langle u_{\lambda}^{\lambda} \rangle$

0
 0

< u |u|^2 >	1.601709	1.601709
< u |u|^3 >	3.983791	3.983791
< u |u|^4 >	9.768674	9.768674

Even moments

< |u|^1 >	.780350	.780350
< |u|^2 >	1.000000	1.000000
< |u|^3 >	1.860293	1.860293
< |u|^4 >	4.135888	4.135888
< |u|^5 >	9.858742	9.858742

Std. deviation of bed velocity s(ub): .405139

0

0

0-----

Horizontal velocities under wave crest and trough at different elevations

Elevation	Crest Trough Std.			First Fourier components			
	Value	Value	Dev.	1	2	3	4
-.4900	1.2106	-.2476	.4267	.4433	.3256	.2063	.1179
-.6900	1.1576	-.2476	.4170	.4404	.3172	.1949	.1071
-.8900	1.1210	-.2476	.4103	.4383	.3112	.1869	.0996
-.9900	1.1085	-.2476	.4080	.4375	.3091	.1842	.0970
-1.0900	1.0996	-.2476	.4064	.4370	.3076	.1822	.0952
-1.1900	1.0943	-.2476	.4055	.4367	.3067	.1810	.0941
-1.2800	1.0926	-.2476	.4051	.4366	.3064	.1806	.0937

Mean Eulerian velocity at all elevations : .0000

0

0

0-----

Phase	Surface elevation			Cosine Fourier components			
	Time	X	Elevation	i	Elevation	Streamfunction	
.000	.0000	.0000	.6137	0	.000000	-4.024008	
11.250	.2219	.8928	.4485	1	.176047	2.065543	
22.500	.4437	1.7857	.2200	2	.137644	.811871	
33.750	.6656	2.6785	.0696	3	.097315	.379013	
45.000	.8875	3.5713	-.0136	4	.065429	.182831	
56.250	1.1094	4.4641	-.0562	5	.043267	.087776	
67.500	1.3313	5.3570	-.0771	6	.028696	.041167	
78.750	1.5531	6.2498	-.0872	7	.019289	.018597	
90.000	1.7750	7.1426	-.0920	8	.013209	.007976	
101.250	1.9969	8.0354	-.0943	9	.009237	.003186	
112.500	2.2188	8.9283	-.0954	10	.006608	.001148	
123.750	2.4406	9.8211	-.0959	11	.004848	.000350	
135.000	2.6625	10.7139	-.0962	12	.003667	.000073	
146.250	2.8844	11.6067	-.0963	13	.002884	-.000002	
157.500	3.1062	12.4996	-.0963	14	.002388	-.000012	
168.750	3.3281	13.3924	-.0963	15	.002113	-.000008	
180.000	3.5500	14.2852	-.0963	16	.001013	-.000002	

0-----

High Order Fourier Theory (M.M. Rienecker & J.D. Fenton'81)

Case: III, Test: 6, H1/3

0

0

Mean waterdepth h : .800000
Wave period T : 7.100000
Wave height H : .550000
Mean Eulerian velocity Ce : .000000
Number of Fourier components N : 16
Maximum relative error eps : 1.00D-08
Water density rho : 1020.000000
Gravitational acceleration g : 9.810000
Nr. of hor. velocity levels nvel : 7

0 Number of iterations nit : 18
Maximum relative error eps : 3.09D-10

0

0 Wave speed c : 3.343274
Wave number k : .264697
Wave length L : 23.737245
Crest surface elevation ac : .501435
Trough surface elevation at : -.048565
Ratio ac/at : 10.324945
Still water depth d : .785706
0 Mean kinetic energy Ek : 81.483227
Mean potential energy Ep : 69.983725
Ratio Ek/Ep : 1.164317
Radiation stress Sxx : 189.371463
Mean wave momentum I : 48.744571
Mean energy flux F : 474.185706
0 Crest bed velocity ubc : 1.004001
Trough bed velocity ubt : -.152477
Ratio ubc/ubt : 6.584589
RMS value of bed velocity ub,rms : .299897
Std.deviation of bed velocity s(ub) : .299897
0 Crest surface velocity ufc : 2.147753
Trough surface velocity uft : -.152477
Mean Eulerian velocity Ce : .000000
Mean mass transport velocity Cm : .059736
0 Surface stream function value Q : 2.626830
Total head R : 1.374282
Momentum flux S : 12186.246604

0

0

Moments and central moments of the bed velocity
(normalized with std. deviation of bed velocity)

Central Moment	Moment
Odd moments |	|
< u |u|^0 > | .000000	| .000000
< u |u|^1 > | .667185	| .667185
< u |u|^2 > | 2.134427	| 2.134427

$\langle u | u|^3 \rangle$	6.176269	6.176269
$\langle u | u|^4 \rangle$	17.984088	17.984088

Even moments |	|	
$\langle |u|^1 \rangle$	.707354	.707354
$\langle |u|^2 \rangle$	1.000000	1.000000
$\langle |u|^3 \rangle$	2.293202	2.293202
$\langle |u|^4 \rangle$	6.252554	6.252554
$\langle |u|^5 \rangle$	18.020899	18.020899

Std. deviation of bed velocity $s(ub)$: .310045

0
0
0

Horizontal velocities under wave crest and trough at different elevations

Elevation	Crest Value	Trough Value	Std. Dev.	1	2	3	4	First Fourier components
.0000	1.3317	-1.525	.3578	.2920	.2578	.2128	.1665	
-.2000	1.1762	-1.525	.3349	.2892	.2484	.1964	.1458	
-.4000	1.0770	-1.525	.3205	.2872	.2416	.1850	.1316	
-.5000	1.0444	-1.525	.3158	.2865	.2393	.1811	.1267	
-.6000	1.0217	-1.525	.3126	.2860	.2377	.1783	.1233	
-.7000	1.0084	-1.525	.3107	.2857	.2367	.1766	.1213	
-.7900	1.0040	-1.525	.3101	.2856	.2363	.1760	.1206	

Mean Eulerian velocity at all elevations : .0000

0
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0
0

Surface elevation | Cosine Fourier components

Phase	Time	X	Elevation	i	Elevation	Streamfunction
.000	.0000	.0000	.5014	0	.000000	-3.343274
11.250	.2219	.7418	.2551	1	.092946	1.103171
22.500	.4438	1.4836	.0760	2	.082085	.487049
33.750	.6656	2.2254	-.0015	3	.068189	.267949
45.000	.8875	2.9672	-.0314	4	.054480	.157258
56.250	1.1094	3.7089	-.0424	5	.042684	.094424
67.500	1.3313	4.4507	-.0464	6	.033278	.057071
78.750	1.5531	5.1925	-.0478	7	.026084	.034441
90.000	1.7750	5.9343	-.0483	8	.020698	.020655
101.250	1.9969	6.6761	-.0485	9	.016708	.012275
112.500	2.2188	7.4179	-.0485	10	.013769	.007218
123.750	2.4406	8.1597	-.0485	11	.011616	.004202
135.000	2.6625	8.9015	-.0486	12	.010057	.002428
146.250	2.8844	9.6433	-.0486	13	.008959	.001407
157.500	3.1063	10.3850	-.0486	14	.008231	.000840
168.750	3.3281	11.1268	-.0486	15	.007814	.000554
180.000	3.5500	11.8686	-.0486	16	.003837	.000226

0

High Order Fourier Theory (M.M. Rienecker & J.D. Fenton'81)

Case: IV, Test: 8, H1/3

0

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Mean waterdepth h : 1.340000
Wave period T : 7.100000
Wave height H : .610000
Mean Eulerian velocity Ce : .000000
Number of Fourier components N : 16
Maximum relative error eps : 1.00D-08
Water density rho : 1020.000000
Gravitational acceleration g : 9.810000
Nr. of hor. velocity levels nvel : 7

0 Number of iterations nit : 14
Maximum relative error eps : 6.59D-16

0

0 Wave speed c : 3.984818
Wave number k : .222082
Wave length L : 28.292208
Crest surface elevation ac : .513099
Trough surface elevation at : -.096901
Ratio ac/at : 5.295094
Still water depth d : 1.320712
0 Mean kinetic energy Ek : 156.197904
Mean potential energy Ep : 141.923883
Ratio Ek/Ep : 1.100575
Radiation stress Sxx : 395.993864
Mean wave momentum I : 78.396505
Mean energy flux F : 1134.280527
0 Crest bed velocity ubc : .969972
Trough bed velocity ubt : -.248753
Ratio ubc/ubt : 3.899338
RMS value of bed velocity ub,rms : .379622
Std.deviation of bed velocity s(ub) : .379622
0 Crest surface velocity usc : 1.544350
Trough surface velocity uft : -.248866
Mean Eulerian velocity Ce : .000000
Mean mass transport velocity Cm : .057358
0 Surface stream function value Q : 5.262797
Total head R : 2.156661
Momentum flux S : 30457.877869

0

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Moments and central moments of the bed velocity
(normalized with std. deviation of bed velocity)

	Central Moment	Moment
Odd moments |	|	
< u |u|^0 > |	.000000	.000000
< u |u|^1 > |	.517013	.517013
< u |u|^2 > |	1.452635	1.452635

$\langle u | u |^3 \rangle$	3.469196	3.469196
$\langle u | u |^4 \rangle$	8.104351	8.104351

Even moments |

$\langle |u|^1 \rangle$	.800004	.800004
$\langle |u|^2 \rangle$	1.000000	1.000000
$\langle |u|^3 \rangle$	1.751401	1.751401
$\langle u ^4 \rangle$	3.656354	3.656354
$\langle u ^5 \rangle$	8.222513	8.222513

Std. deviation of bed velocity $s(ub)$: .379647

0

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Horizontal velocities under wave crest and trough at different elevations

Elevation	Crest Trough Std.			First Fourier components				
	Value	Value	Dev.	1	2	3	4	
-.5400	1.0588	-.2488	.3970	.4338	.2968	.1711	.0877	
-.7400	1.0191	-.2488	.3892	.4308	.2890	.1614	.0795	
-.9400	.9915	-.2488	.3838	.4287	.2834	.1547	.0738	
-.9900	.9864	-.2488	.3828	.4283	.2824	.1534	.0728	
-1.0400	.9820	-.2488	.3820	.4279	.2815	.1523	.0719	
-1.1400	.9753	-.2488	.3807	.4274	.2801	.1507	.0705	
-1.3300	.9700	-.2488	.3796	.4270	.2790	.1493	.0694	

Mean Eulerian velocity at all elevations : .0000

0

0

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Phase	Time	Surface elevation		Cosine Fourier components				
		X	Elevation	i	Elevation	Streamfunction		
.000	.0000	.0000	.5131	0	.000000	-3.984818		
11.250	.2219	.8841	.4109	1	.172733	2.008461		
22.500	.4438	1.7683	.2330	2	.126667	.742747		
33.750	.6656	2.6524	.0940	3	.082424	.319567		
45.000	.8875	3.5365	.0072	4	.050671	.140351		
56.250	1.1094	4.4207	-.0420	5	.030582	.060664		
67.500	1.3313	5.3048	-.0684	6	.018502	.025253		
78.750	1.5531	6.1889	-.0823	7	.011339	.009915		
90.000	1.7750	7.0731	-.0895	8	.007072	.003566		
101.250	1.9969	7.9572	-.0931	9	.004496	.001111		
112.500	2.2188	8.8413	-.0950	10	.002915	.000254		
123.750	2.4406	9.7254	-.0960	11	.001931	.000004		
135.000	2.6625	10.6096	-.0965	12	.001313	-.000041		
146.250	2.8844	11.4937	-.0967	13	.000927	-.000032		
157.500	3.1063	12.3778	-.0968	14	.000694	-.000017		
168.750	3.3281	13.2620	-.0969	15	.000569	-.000007		
180.000	3.5500	14.1461	-.0969	16	.000265	-.000002		

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High Order Fourier Theory (M.M. Rienecker & J.D. Fenton'81)

Case: IV, Test: 10, H1/3

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Mean waterdepth h : .680000
Wave period T : 7.100000
Wave height H : .470000
Mean Eulerian velocity Ce : .000000
Number of Fourier components N : 16
Maximum relative error eps : 1.00D-08
Water density rho : 1020.000000
Gravitational acceleration g : 9.810000
Nr. of hor. velocity levels nvel : 7

0 Number of iterations nit : 19
Maximum relative error eps : 1.39D-10

0

0 Wave speed c : 3.102834
Wave number k : .285209
Wave length L : 22.030121
Crest surface elevation ac : .431736
Trough surface elevation at : -.038264
Ratio ac/at : 11.283177
Still water depth d : .668545
0 Mean kinetic energy Ek : 56.244336
Mean potential energy Ep : 48.267899
Ratio Ek/Ep : 1.165253
Radiation stress Sxx : 129.017233
Mean wave momentum I : 36.253527
Mean energy flux F : 301.069212
0 Crest bed velocity ubc : .940163
Trough bed velocity ubt : -.129619
Ratio ubc/ubt : 7.253265
RMS value of bed velocity ub,rms : .265368
Std.deviation of bed velocity s(ub) : .265368
0 Crest surface velocity ufc : 1.994983
Trough surface velocity uft : -.129616
Mean Eulerian velocity Ce : .000000
Mean mass transport velocity Cm : .052269
0 Surface stream function value Q : 2.074384
Total head R : 1.174291
Momentum flux S : 8895.161605

0

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Moments and central moments of the bed velocity
(normalized with std. deviation of bed velocity)

	Central Moment	Moment
Odd moments |		
< u |u|^0 > |	.000000	.000000
< u |u|^1 > |	.691119	.691119
< u |u|^2 > |	2.275787	2.275787

< u |u|^3 >	6.851902	6.851902
< u |u|^4 >	20.836746	20.836746

Even moments |		
< |u|^1 >	.688225	.688225
< |u|^2 >	1.000000	1.000000
< |u|^3 >	2.416156	2.416156
< u ^4 >	6.916099	6.916099
< u ^5 >	20.866221	20.866221

Std. deviation of bed velocity s(ub): .277592

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Horizontal velocities under wave crest and trough at different elevations

Elevation	Crest		Trough		Std.		First Fourier components			
	Value	Value	Dev.	Dev.	1	2	3	4		
.1200	1.3814	-.1296	.3394	.2516	.2308	.2016	.1689			
-.0800	1.1660	-.1296	.3088	.2488	.2211	.1839	.1452			
-.2800	1.0342	-.1296	.2904	.2468	.2142	.1717	.1292			
-.3800	.9919	-.1296	.2846	.2461	.2118	.1675	.1237			
-.4800	.9628	-.1296	.2807	.2456	.2101	.1645	.1198			
-.5800	.9458	-.1296	.2784	.2453	.2091	.1627	.1176			
-.6700	.9402	-.1296	.2776	.2452	.2087	.1621	.1168			

Mean Eulerian velocity at all elevations : .0000

0

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0

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Surface elevation | Cosine Fourier components

Phase	Time	X	Elevation	i	Elevation	Streamfunction
.000	.0000	.0000	.4317	| 0	.000000	-.3.102834
11.250	.2219	.6884	.2029	| 1	.073735	.875997
22.500	.4438	1.3769	.0517	| 2	.066343	.393809
33.750	.6656	2.0653	-.0074	| 3	.056539	.222440
45.000	.8875	2.7538	-.0281	| 4	.046443	.134759
56.250	1.1094	3.4422	-.0349	| 5	.037370	.083841
67.500	1.3313	4.1306	-.0372	| 6	.029841	.052676
78.750	1.5531	4.8191	-.0379	| 7	.023877	.033149
90.000	1.7750	5.5075	-.0382	| 8	.019278	.020795
101.250	1.9969	6.1960	-.0382	| 9	.015787	.012966
112.500	2.2188	6.8844	-.0383	| 10	.013164	.008023
123.750	2.4406	7.5729	-.0383	| 11	.011214	.004926
135.000	2.6625	8.2613	-.0383	| 12	.009786	.003009
146.250	2.8844	8.9497	-.0383	| 13	.008773	.001846
157.500	3.1063	9.6382	-.0383	| 14	.008096	.001168
168.750	3.3281	10.3266	-.0383	| 15	.007706	.000810
180.000	3.5500	11.0151	-.0383	| 16	.003786	.000337

0-----

$\langle u | u |^3 \rangle$	1.988496	1.988496
$\langle u | u |^4 \rangle$	3.979522	3.979522

Even moments		
$\langle |u|^1 \rangle$	.856985	.856985
$\langle |u|^2 \rangle$	1.000000	1.000000
$\langle |u|^3 \rangle$	1.439770	1.439770
$\langle |u|^4 \rangle$	2.387154	2.387154
$\langle |u|^5 \rangle$	4.301467	4.301467

Std. deviation of bed velocity $s(ub)$: .328426

0
0
0

Horizontal velocities under wave crest and trough at different elevations

Elevation	Crest Trough Std.			First Fourier components			
	Value	Value	Dev.	1	2	3	4
.2000	1.4417	-.2860	.5222	.0442	-.0760	.5042	.1627
.0000	1.0541	-.2883	.4210	.0437	-.0726	.4574	.1387
-.2000	.8368	-.2879	.3653	.0433	-.0702	.4251	.1225
-.3000	.7705	-.2876	.3484	.0432	-.0693	.4139	.1170
-.4000	.7259	-.2872	.3371	.0431	-.0687	.4060	.1131
-.5000	.7001	-.2870	.3306	.0431	-.0684	.4013	.1108
-.5900	.6918	-.2870	.3284	.0430	-.0683	.3998	.1100

Mean Eulerian velocity at all elevations : .0000

0
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0
0

Phase	Time	X	Elevation	Cosine Fourier components		
				i	Elevation	Streamfunction
.000	.0000	.0000	.3311	0	.000000	-2.663227
11.250	.2500	.6658	.0780	1	.011972	.148217
22.500	.5000	1.3316	-.0348	2	-.019763	-.123048
33.750	.7500	1.9974	-.0673	3	.123820	.517039
45.000	1.0000	2.6632	-.0761	4	.037616	.117609
56.250	1.2500	3.3290	-.0776	5	-.027590	-.068536
67.500	1.5000	3.9948	-.0761	6	.067843	.137786
78.750	1.7500	4.6606	-.0675	7	.041722	.069544
90.000	2.0000	5.3265	-.0353	8	-.020427	-.028177
101.250	2.2500	5.9923	.0763	9	.031518	.035774
112.500	2.5000	6.6581	.3310	10	.037185	.033802
123.750	2.7500	7.3239	.0796	11	-.011764	-.008655
135.000	3.0000	7.9897	-.0343	12	.012683	.007464
146.250	3.2500	8.6555	-.0672	13	.032810	.014890
157.500	3.5000	9.3213	-.0763	14	-.004566	-.001729
168.750	3.7500	9.9871	-.0783	15	.002514	.000811
180.000	4.0000	10.6529	-.0789	16	.015507	.004339

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High Order Fourier Theory (M.M. Rienecker & J.D. Fenton'81)

Casc: IV, Test: 12, H1/3

0

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Mean waterdepth h : .380000
Wave period T : 8.000000
Wave height H : .270000
Mean Eulerian velocity Ce : .000000
Number of Fourier components N : 5
Maximum relative error eps : 1.00D-06
Water density rho : 1020.000000
Gravitational acceleration g : 9.810000
Nr. of hor. velocity levels nvel : 1

0 Number of iterations nit : 14
Maximum relative error eps : 1.11D-10

0

0 Wave speed c : 1.922889
Wave number k : .408447
Wave length L : 15.383112
Crest surface elevation ac : .135302
Trough surface elevation at : -.134698
Ratio ac/at : 1.004478
Still water depth d : .331760
0 Mean kinetic energy Ek : 90.966646
Mean potential energy Ep : 89.879370
Ratio Ek/Ep : 1.012097
Radiation stress Sxx : 264.852318
Mean wave momentum I : 94.614561
Mean energy flux F : 363.970480
0 Crest bed velocity ubc : .675728
Trough bed velocity ubt : -.676127
Ratio ubc/ubt : .999410
RMS value of bed velocity ub,rms : .663480
Std.deviation of bed velocity s(ub) : .663480
0 Crest surface velocity ufc : .705067
Trough surface velocity uft : -.681049
Mean Eulerian velocity Ce : .000000
Mean mass transport velocity Cm : .244104
0 Surface stream function value Q : .637938
Total head R : .590892
Momentum flux S : 2056.585102

0

0

Moments and central moments of the bed velocity
(normalized with std. deviation of bed velocity)

	Central Moment	Moment
Odd moments |	|	
< u |u|^0 > |	.000000	.000000
< u |u|^1 > |	-.004497	-.004497
< u |u|^2 > |	-.009525	-.009525

< u |u|^3 >	- .015242	- .015242
< u |u|^4 >	- .021848	- .021848

Even moments |	|	
< |u|^1 >	.963945	.963945
< |u|^2 >	1.000000	1.000000
< |u|^3 >	1.065741	1.065741
< |u|^4 >	1.154677	1.154677
< |u|^5 >	1.266956	1.266956

Std. deviation of bed velocity s(ub): .661469

0
0
0-----

Horizontal velocities under wave crest and trough at different elevations

Elevation |	Crest	Trough	Std.	|	First Fourier components			
|	Value	Value	Dev.	|	1	2	3	4

-.2800 |	.6767	-.6769	.6627 |	.8728	-.0079	-.3187	.0078
--------	-------	--------	-------	-------	--------	--------	-------

Mean Eulerian velocity at all elevations : .0000

0
1*****

0
0-----

Surface elevation |	Cosine Fourier components					
Phase	Time	X	Elevation |	i	Elevation	Streamfunction

.000	.0000	.0000	.1353 |	0	.000000	-1.922889
36.000	.8000	1.5383	.1261 |	1	.172472	2.160753
72.000	1.6000	3.0766	.1411 |	2	-.004119	-.010125
108.000	2.4000	4.6149	-.1317 |	3	-.066656	-.286659
144.000	3.2000	6.1532	-.1358 |	4	.004421	.005643
180.000	4.0000	7.6916	-.1347 |	5	.029184	.077512

Q

Cnoidal Wave Theory									
Wave Ht	Wave Period	Water Depth	Wave Length	Wave Celer	Energy Density	Energy Flux	Ursell No.	Order	
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m			
0.470	7.100	1.290	26.659	3.755	202.691	725.245	155.600	2	

Vert Coord: -1.190 m
 Wavelen Frac: 0.000
 Water Surf: 0.383 m
 Pressure: 14699.290 n/m^2

Horiz Velocity:	0.712	Vertical
Acceler:	0.000	-0.052 m/s^2

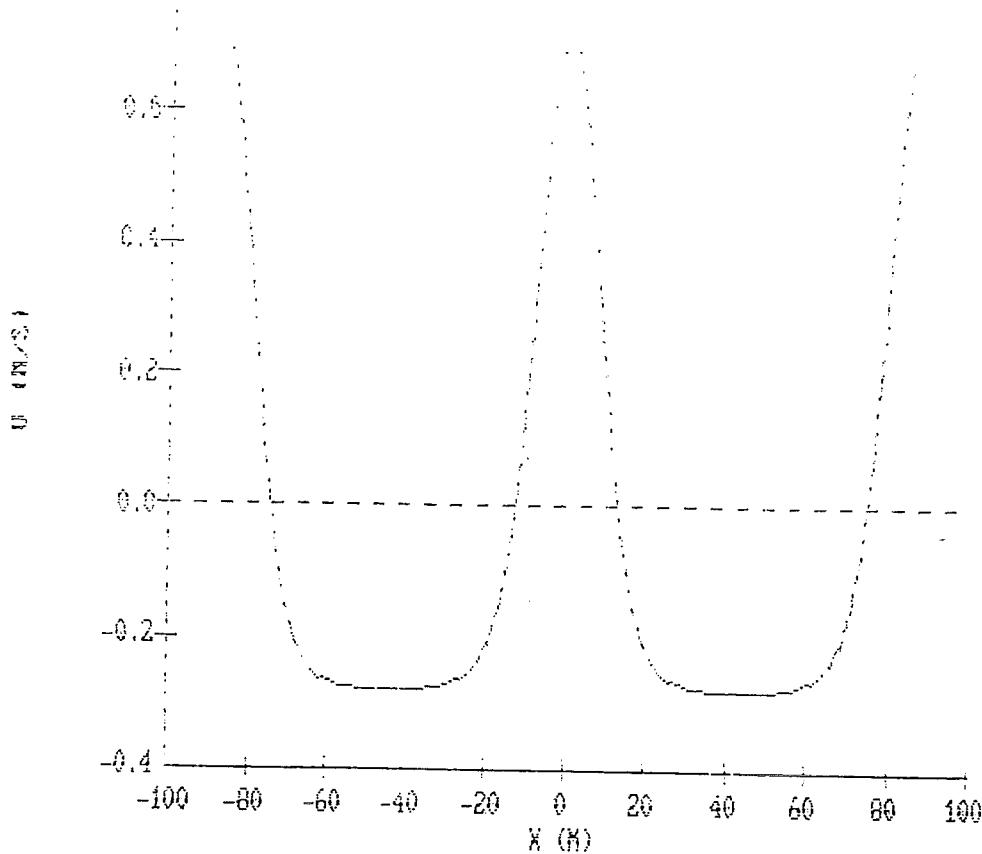
Cnoidal Wave Theory									
Wave Ht	Wave Period	Water Depth	Wave Length	Wave Celer	Energy Density	Energy Flux	Ursell No.	Order	
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m			
0.470	7.100	1.290	26.659	3.755	202.691	725.245	155.600	2	

Vert Coord: -1.190 m
 Wavelen Frac: 0.500
 Water Surf: -0.087 m
 Pressure: 11102.380 n/m^2

Horiz Velocity:	-0.279	Vertical
Acceler:	0.000	0.000 m/s^2

CNOIDAL WAVE THEORY
 Horizontal Velocity

Test 5
 Hrms



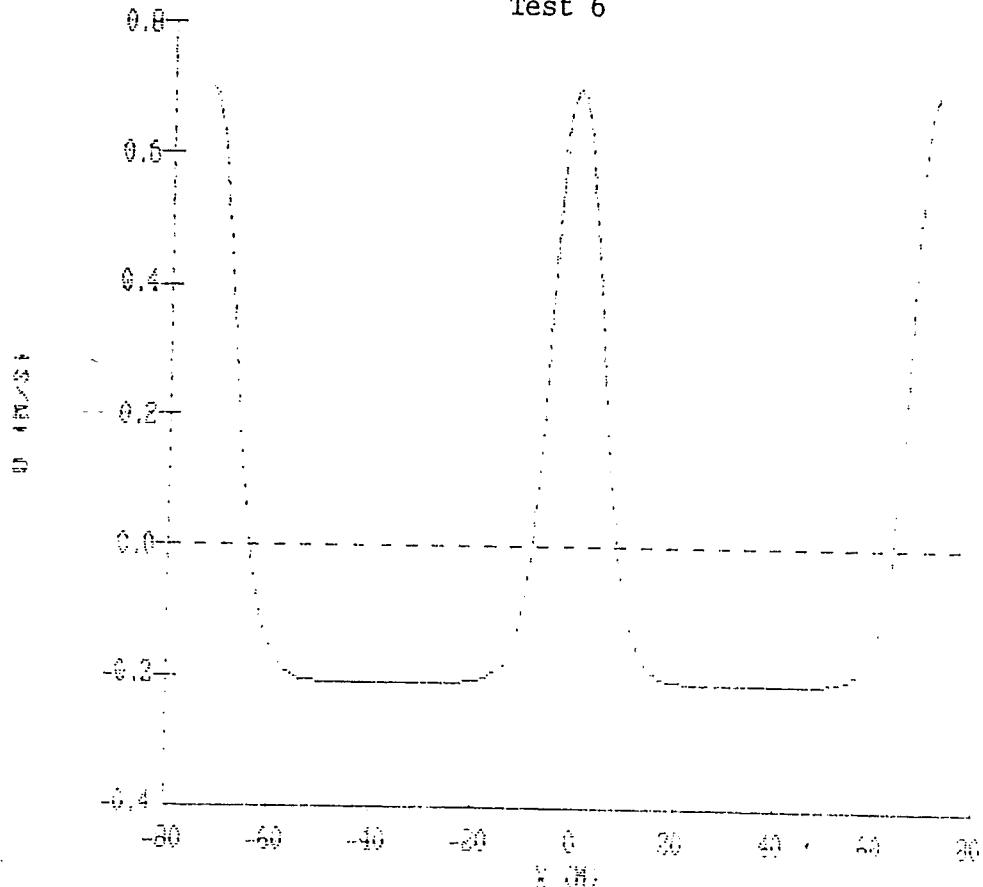
Cnoidal Wave Theory								
Wave Ht	Wave Period	Water Depth	Wave Length	Wave Celer	Energy Density	Energy Flux	Ursell No.	Order
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m		
0.384	7.100	0.800	22.041	3.104	105.222	319.854	364.355	2

Vert Coord: -0.700 m
 Wavelen Frac: 0.000
 Water Surf: 0.336 m
 Pressure: 9262.110 n/m^2

Horiz Velocity:	0.705	Vertical
Acceler:	0.000	-0.068 m/s^2

CNOIDAL WAVE THEORY
Horizontal Velocity

Test 6



Cnoidal Wave Theory								
Wave Ht	Wave Period	Water Depth	Wave Length	Wave Celer	Energy Density	Energy Flux	Ursell No.	Order
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m		
0.380	7.100	0.800	22.016	3.101	103.442	313.943	359.739	2

Vert Coord: -0.700 m
 Wavelen Frac: 0.500
 Water Surf: -0.048 m
 Pressure: 6587.076 n/m^2

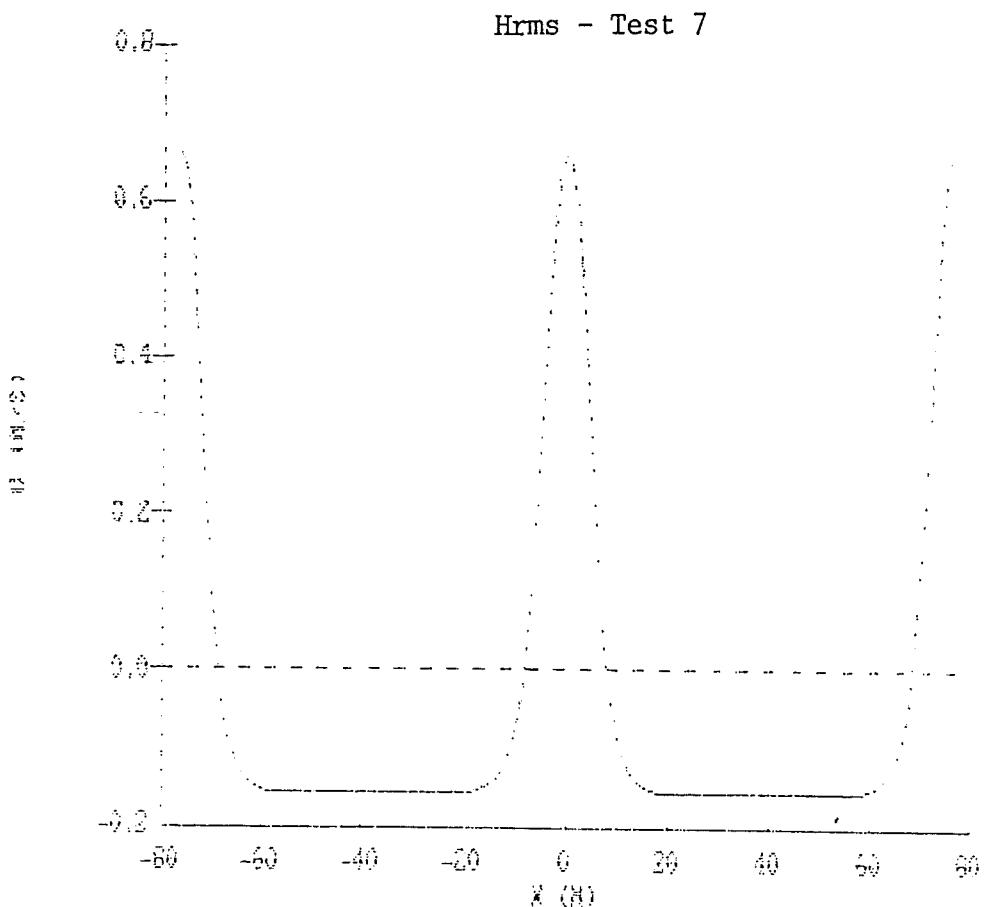
Horiz Velocity:	-0.207	Vertical
Acceler:	0.000	0.000 m/s^2

Cnoidal Wave Theory									
Wave	Wave	Water	Wave	Wave	Energy	Energy	Ursell	Order	
ht	Period	Depth	Length	Celer	Density	Flux	No.		
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m			
0.310	8.000	0.700	23.359	2.920	.61.447	177.201	493.133	2	

Vert Coord: -0.600 m
 Wavelen Frac: 0.000
 Water Surf: 0.276 m
 Pressure: 7943.488 n/m^2

	Horiz	Vertical
Velocity:	0.660	0.000 m/sec
Acceler:	0.000	-0.086 m/s^2

CNOIDAL WAVE THEORY
 Horizontal Velocity



Cnoidal Wave Theory									
Wave	Wave	Water	Wave	Wave	Energy	Energy	Ursell	Order	
ht	Period	Depth	Length	Celer	Density	Flux	No.		
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m			
0.310	8.000	0.700	23.359	2.920	.61.447	177.201	493.133	2	

Vert Coord: -0.600 m
 Wavelen Frac: 0.500
 Water Surf: -0.034 m
 Pressure: 5717.095 n/m^2

	Horiz	Vertical
Velocity:	-0.155	0.000 m/sec
Acceler:	0.000	0.000 m/s^2

Cnoidal Wave Theory								
Wave	Wave	Water	Wave	Wave	Energy	Energy	Ursell	Order
H ₁	Period	Depth	Length	Celer	Density	Flux	No.	
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m		
0.410	7.100	1.340	26.756	3.768	163.793	586.642	121.987	2

Vert Coord: -1.240 m
 Wavelen Frac: 0.000
 Water Surf: 0.325 m
 Pressure: 14899.200 n/m^2

Horiz	Vertical
Velocity: 0.633	0.000 m/sec
Acceler: 0.000	-0.046 m/s^2

Cnoidal Wave Theory								
Wave	Wave	Water	Wave	Wave	Energy	Energy	Ursell	Order
H ₁	Period	Depth	Length	Celer	Density	Flux	No.	
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m		
0.410	7.100	1.340	26.756	3.768	163.793	586.642	121.987	2

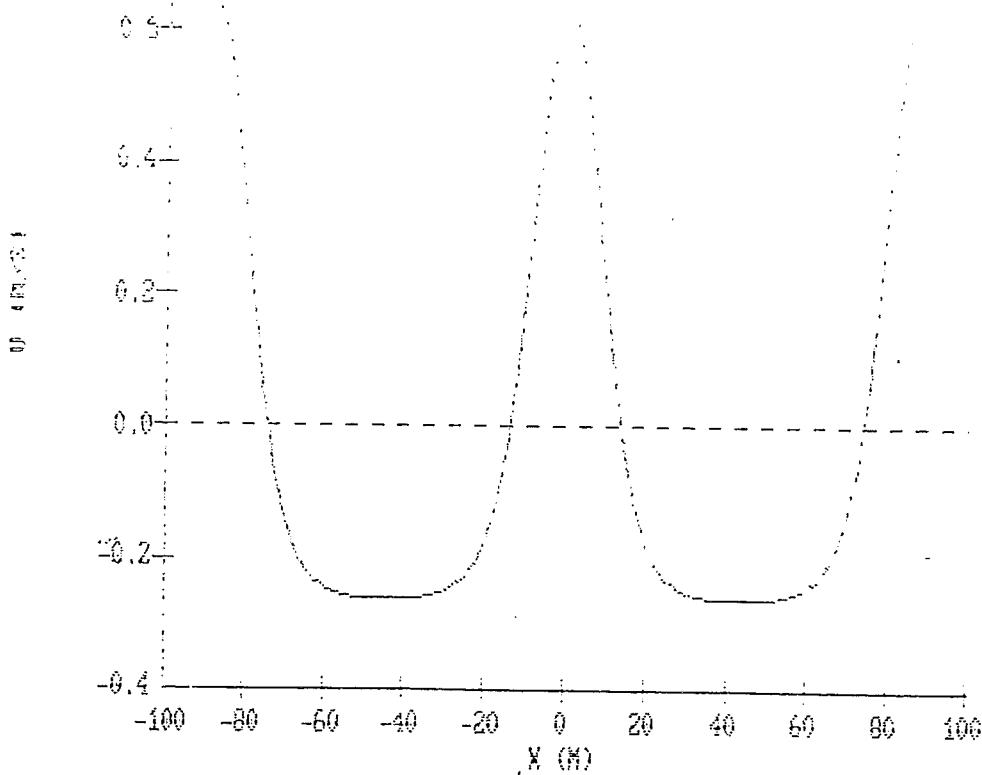
Vert Coord: -1.240 m
 Wavelen Frac: 0.500
 Water Surf: -0.085 m
 Pressure: 11618.790 n/m^2

Horiz	Vertical
Velocity: -0.260	0.000 m/sec
Acceler: 0.000	0.000 m/s^2

CNOIDAL WAVE THEORY

Horizontal Velocity

Test 8
Hrms



Cnoidal Wave Theory								
Wave Ht	Wave Period	Water Depth	Wave Length	Wave Celer	Energy Density	Energy Flux	Ursell No.	Order
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m		
0.400	7.100	0.700	21.154	2.979	101.611	300.835	521.867	2

Vert Coord: -0.600 m
 Wavelen Frac: 0.000
 Water Surf: 0.357 m
 Pressure: 8233.387 n/m^2

Horiz Velocity: 0.716 m/sec
 Acceler: 0.000 m/s^2

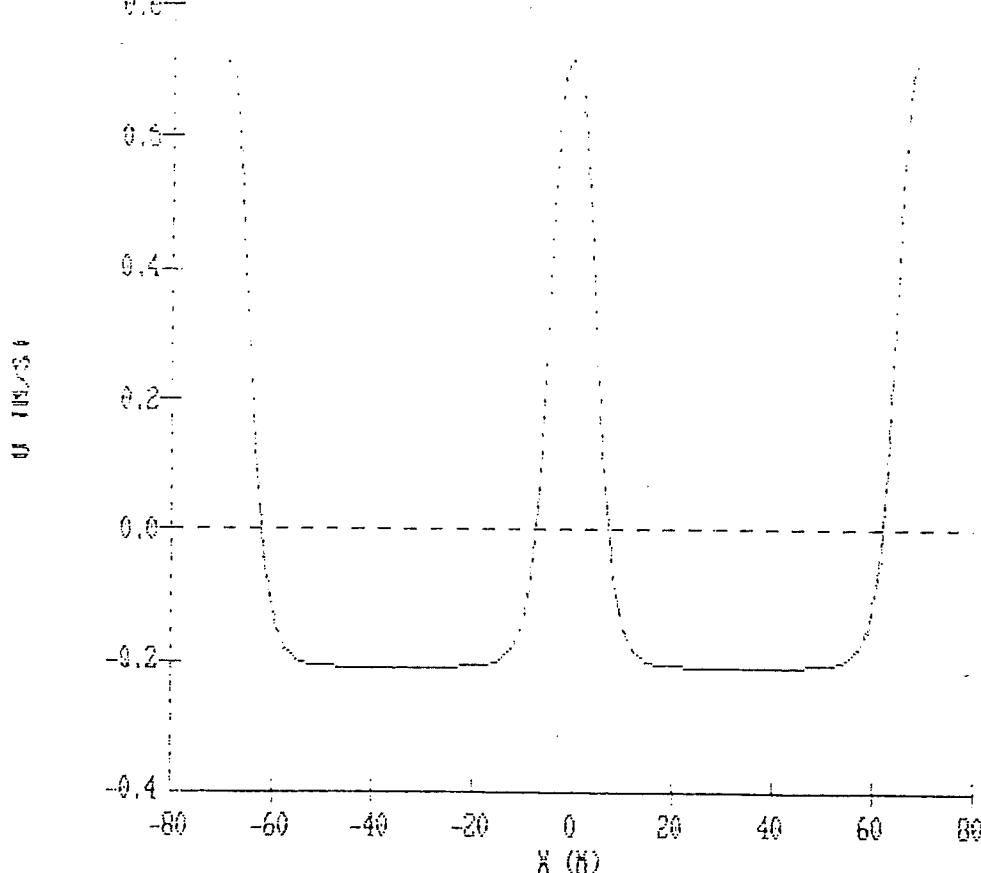
Cnoidal Wave Theory								
Wave Ht	Wave Period	Water Depth	Wave Length	Wave Celer	Energy Density	Energy Flux	Ursell No.	Order
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m		
0.400	7.100	0.700	21.154	2.979	101.611	300.835	521.867	2

Vert Coord: -0.600 m
 Wavelen Frac: 0.500
 Water Surf: -0.043 m
 Pressure: 5659.287 n/m^2

Horiz Velocity: -0.206 m/sec
 Acceler: 0.000 m/s^2

CNOIDAL WAVE THEORY
 Horizontal Velocity

Test 9



Cnoidal Wave Theory								
Wave Ht	Wave Period	Water Depth	Wave Length	Wave Celer	Energy Density	Energy Flux	Ursell No.	Order
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m		
0.330	7.100	0.680	20.482	2.885	72.842	207.054	440.304	2

Vert Coord: -0.580 m
 Wavelen Frac: 0.000
 Water Surf: 0.292 m
 Pressure: 7772.444 n/m^2

Horiz	Vertical
Velocity: 0.668	0.000 m/sec
Acceler: 0.000	-0.077 m/s^2

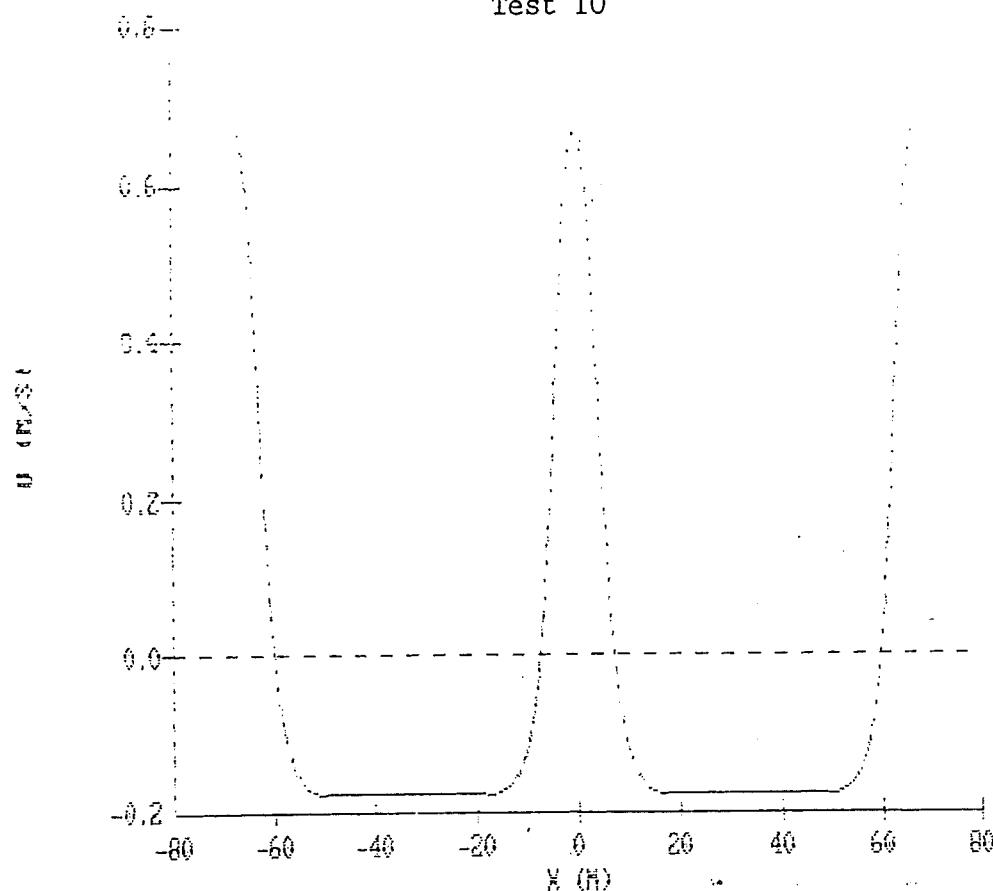
Cnoidal Wave Theory								
Wave Ht	Wave Period	Water Depth	Wave Length	Wave Celer	Energy Density	Energy Flux	Ursell No.	Order
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m		
0.330	7.100	0.680	20.482	2.885	72.842	207.054	440.304	2

Vert Coord: -0.580 m
 Wavelen Frac: 0.500
 Water Surf: -0.038 m
 Pressure: 5480.422 n/m^2

Horiz	Vertical
Velocity: -0.179	0.000 m/sec
Acceler: 0.000	0.000 m/s^2

CNOIDAL WAVE THEORY horizontal Velocity

Test 10



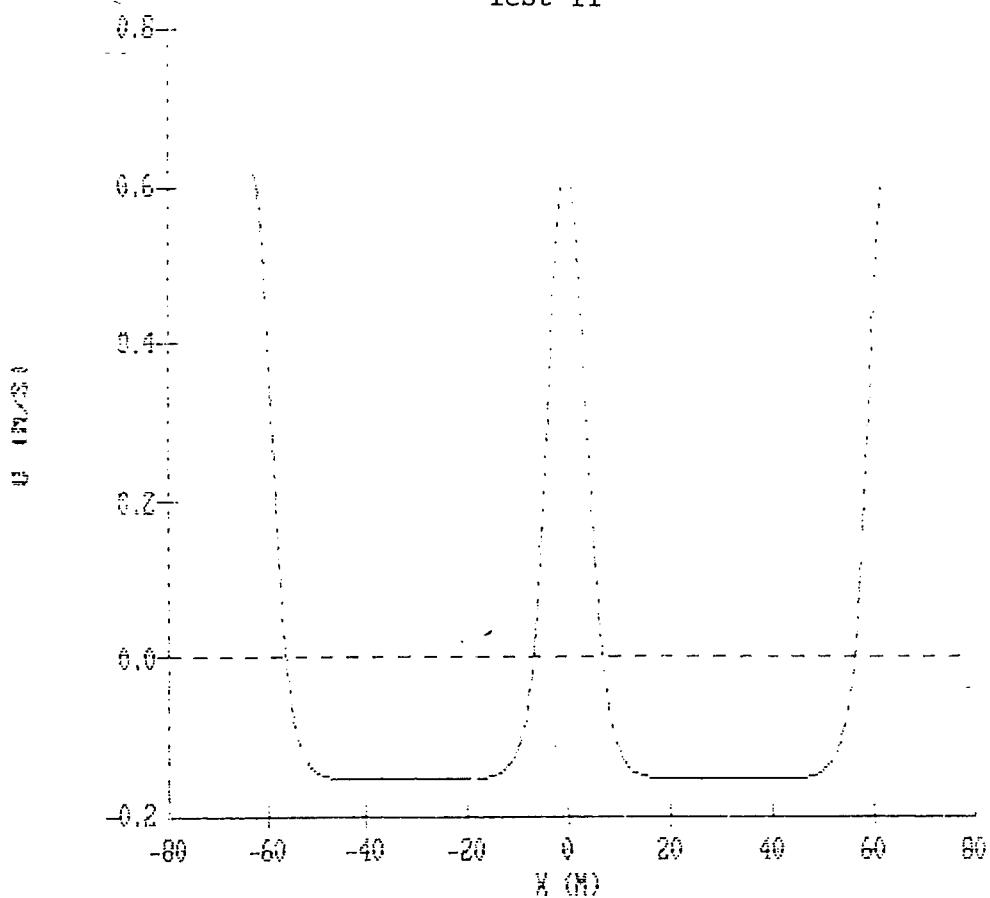
Cnoidal Wave Theory								
Wave Ht	Wave Period	Water Depth	Wave Length	Wave Celer	Energy Density	Energy Flux	Ursell No.	Order
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m		
0.270	7.100	0.600	19.170	2.700	47.859	127.398	459.348	2
Vert Coord: -0.500 m								
Wavelen Frac: 0.000						Horiz Velocity:	0.614	Vertical
Water Surf: 0.239 m						Velocity:	0.000 m/sec	
Pressure: 6677.308 n/m^2						Acceler:	0.000	-0.100 m/s^2

Cnoidal Wave Theory								
Wave Ht	Wave Period	Water Depth	Wave Length	Wave Celer	Energy Density	Energy Flux	Ursell No.	Order
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m		
0.270	7.100	0.600	19.170	2.700	47.859	127.398	459.348	2
Vert Coord: -0.500 m								
Wavelen Frac: 0.500						Horiz Velocity:	-0.151	Vertical
Water Surf: -0.031 m						Velocity:	0.000 m/sec	
Pressure: 4742.693 n/m^2						Acceler:	0.000	0.000 m/s^2

CNOIDAL WAVE THEORY

Horizontal Velocity

Test 11



Cnoidal Wave Theory

Wave Ht	Wave Period	Water Depth	Wave Length	Wave Celer	Energy Density	Energy Flux	Ursell No.	Order
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m		
0.180	8.000	0.380	17.663	2.208	15.722	34.877	1023.447	2

Vert Coord: -0.280 m
 Wavelen Frac: 0.000
 Water Surf: 0.166 m
 Pressure: 3975.868 n/m^2

Horiz Velocity:	0.543	Vertical
Velocity:	0.000	0.000 m/sec
Acceler:	-0.150	m/s^2

Cnoidal Wave Theory

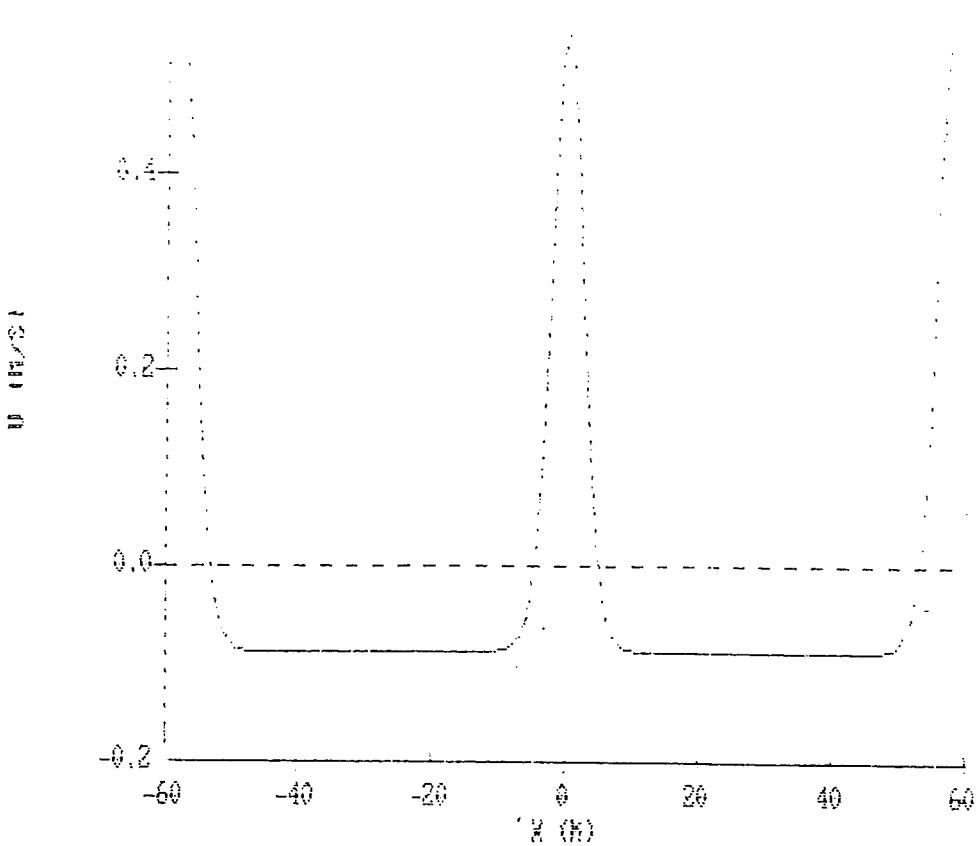
Wave Ht	Wave Period	Water Depth	Wave Length	Wave Celer	Energy Density	Energy Flux	Ursell No.	Order
m	sec	m	m	m/sec	n-m/m^2	n-m/s-m		
0.180	8.000	0.380	17.663	2.208	15.722	34.877	1023.447	2

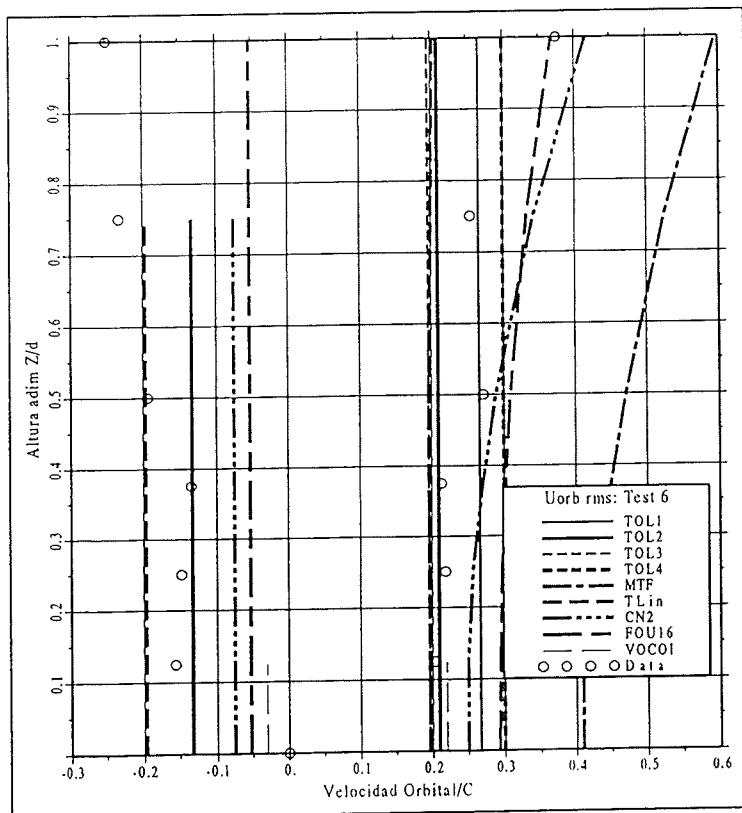
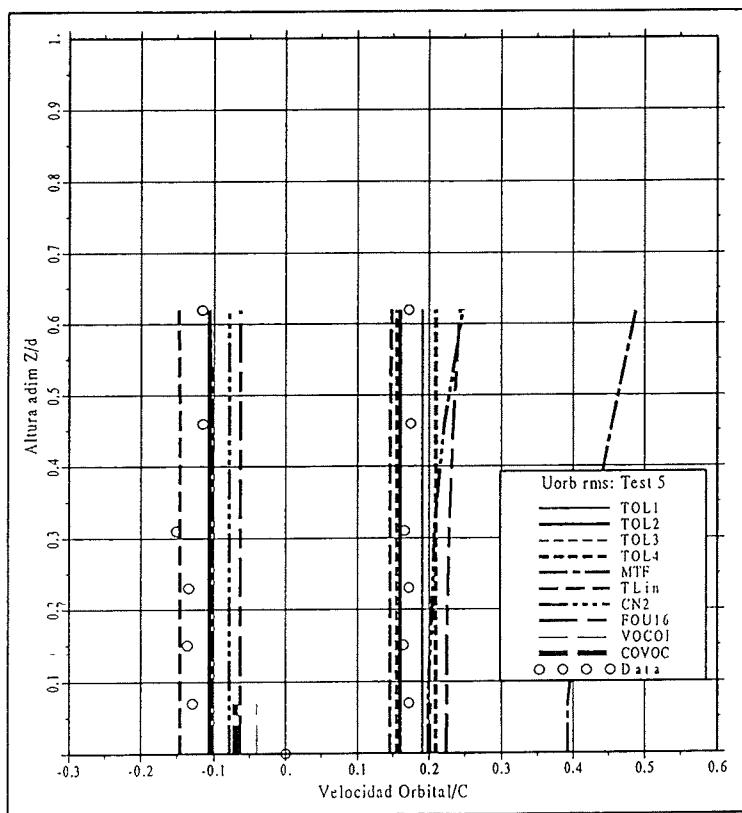
Vert Coord: -0.280 m
 Wavelen Frac: 0.500
 Water Surf: -0.014 m
 Pressure: 2694.620 n/m^2

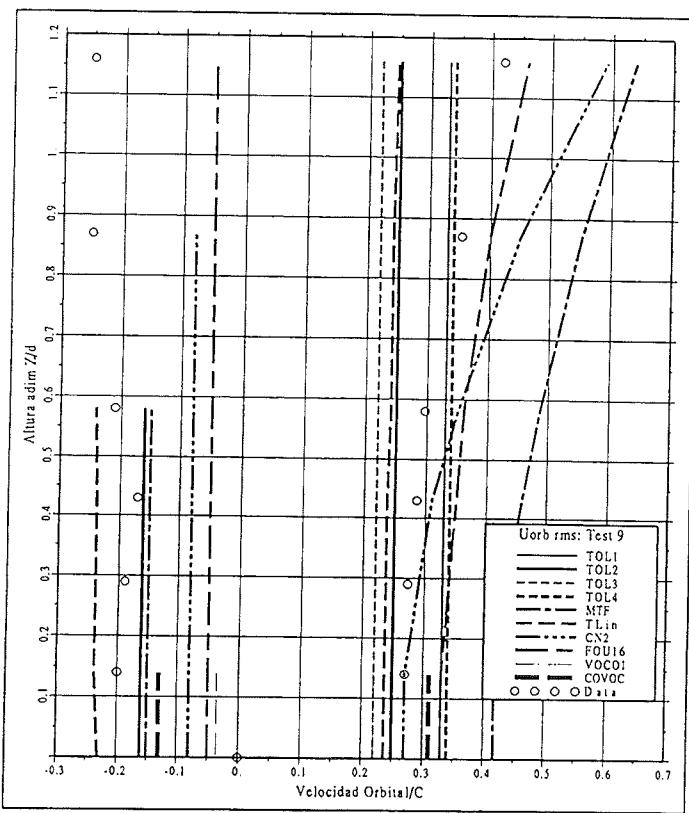
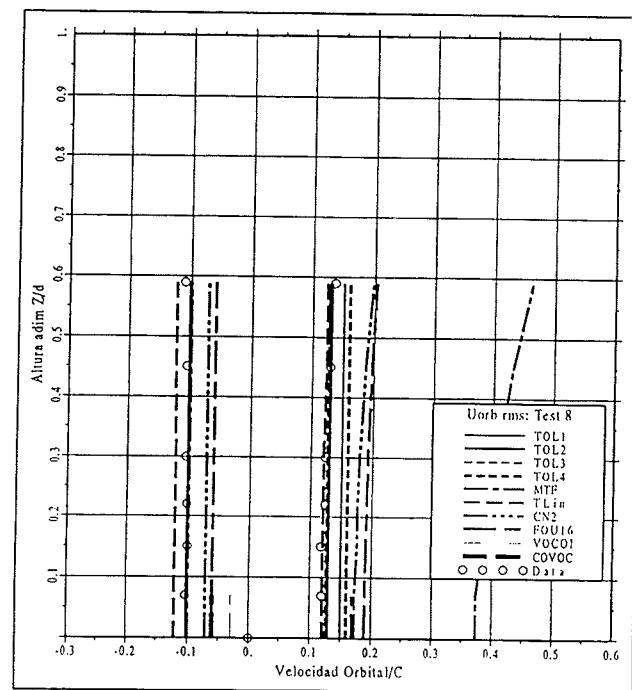
Horiz Velocity:	-0.088	Vertical
Velocity:	0.000	0.000 m/sec
Acceler:	0.000	0.000 m/s^2

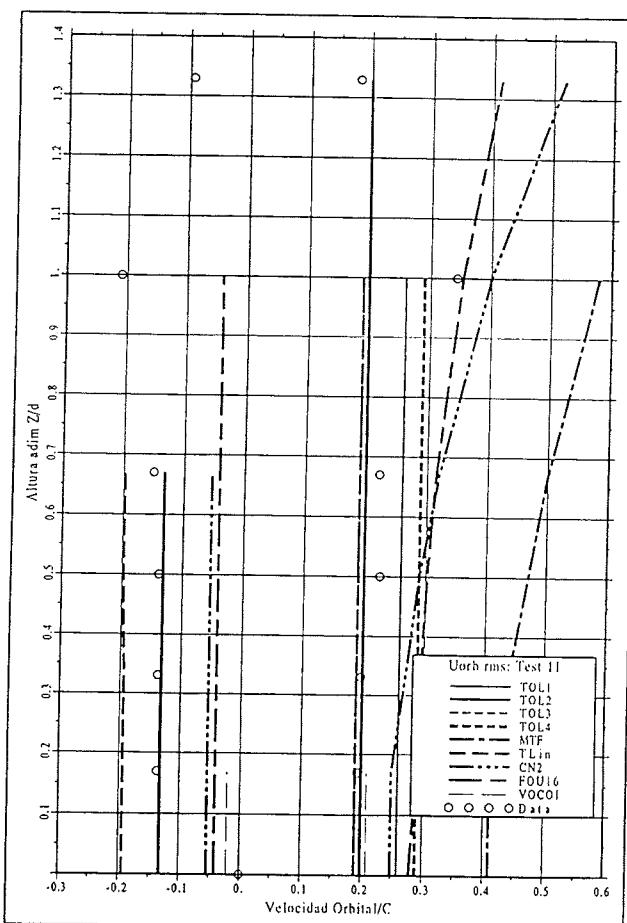
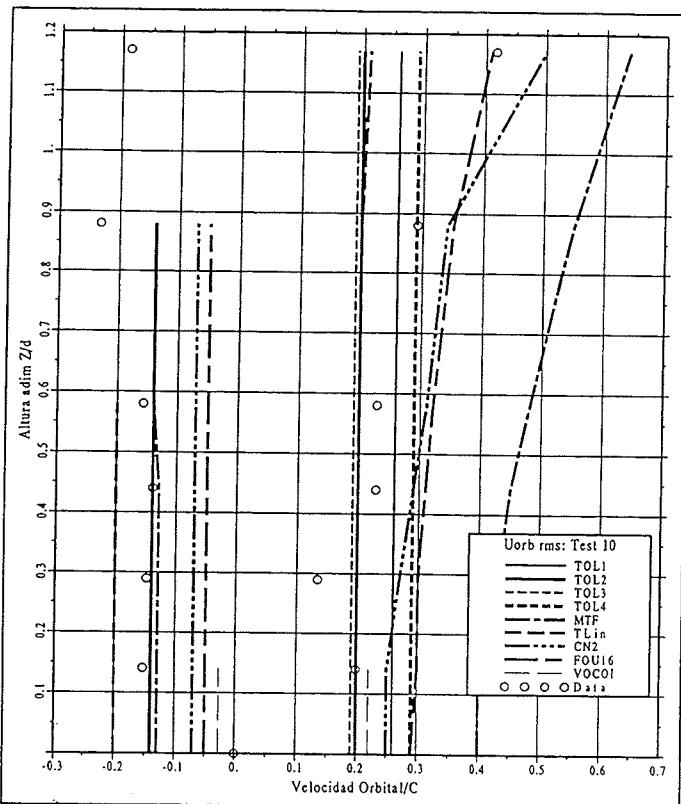
CNOIDAL WAVE THEORY
Horizontal Velocity

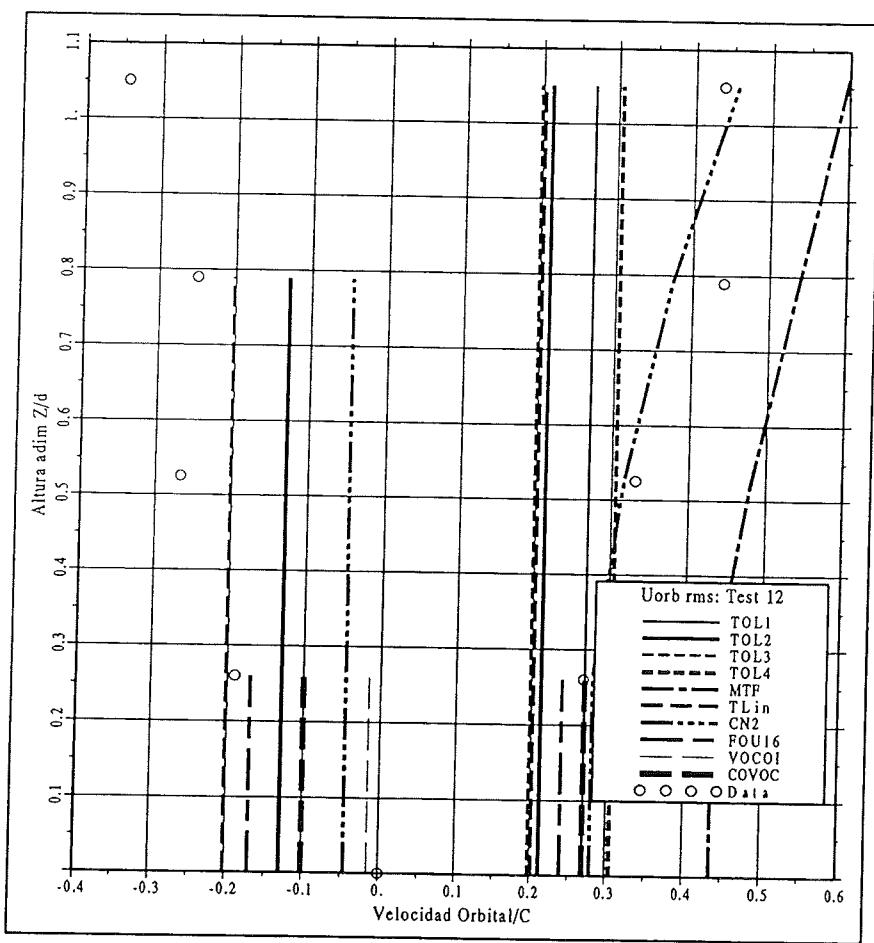
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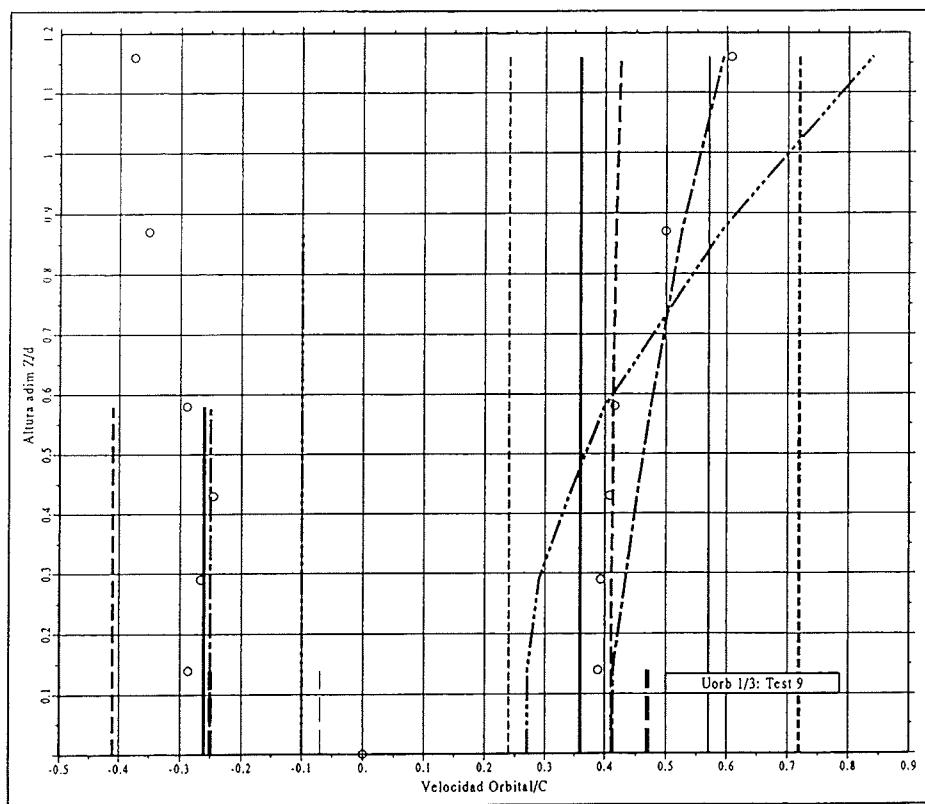
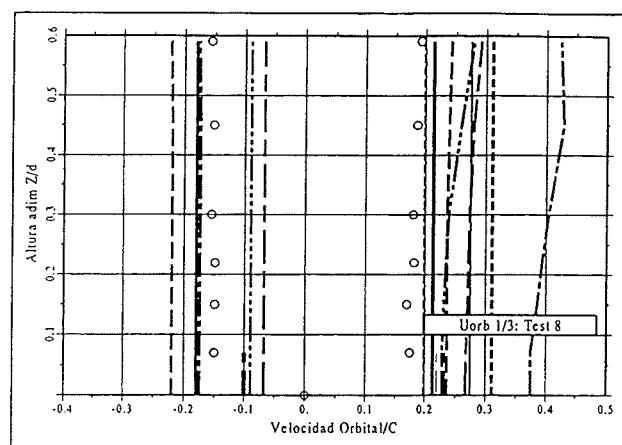


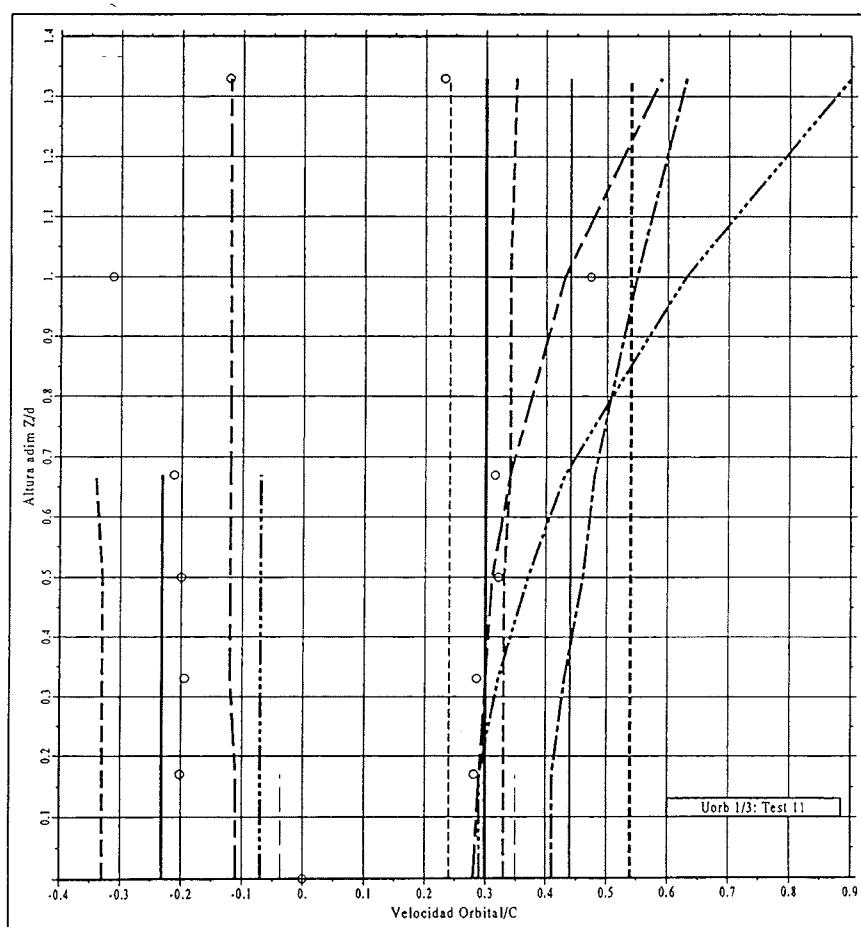
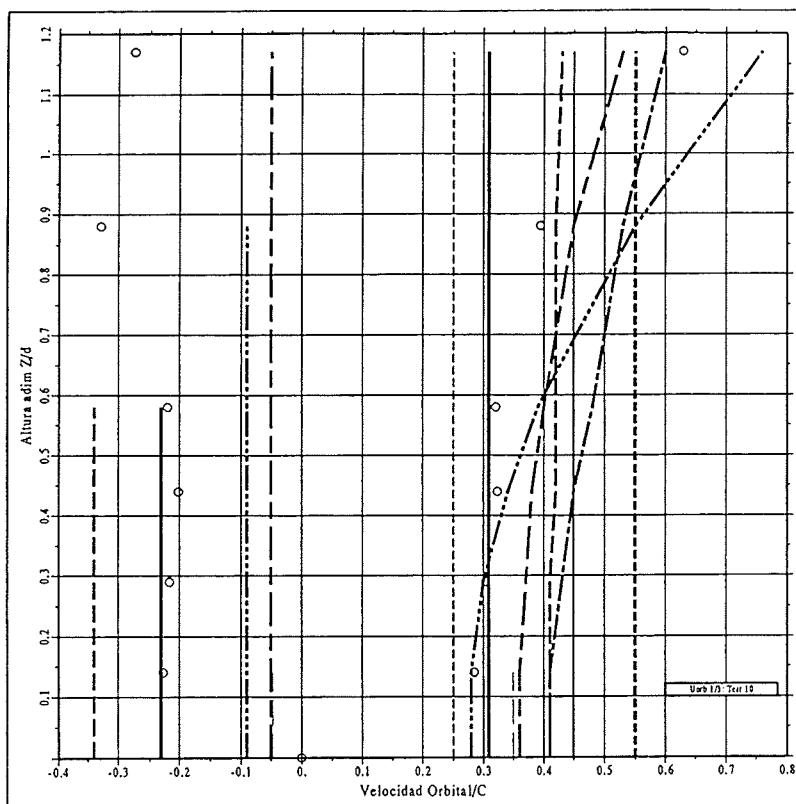


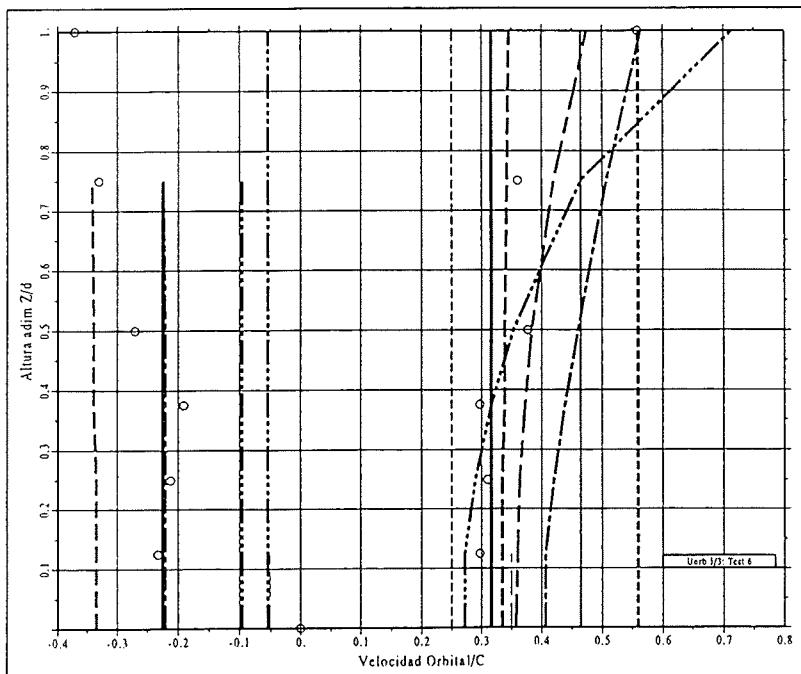
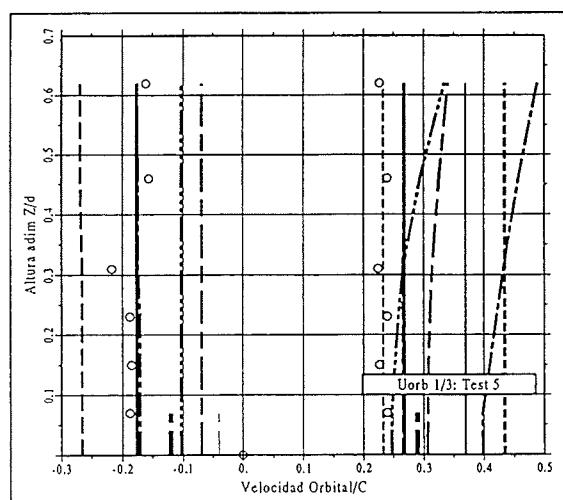


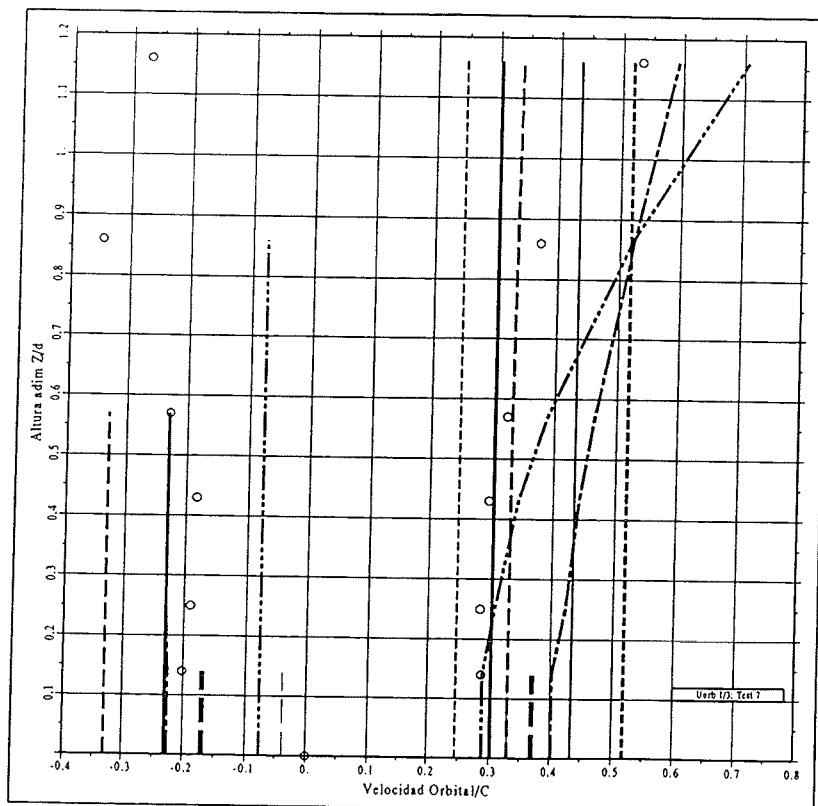
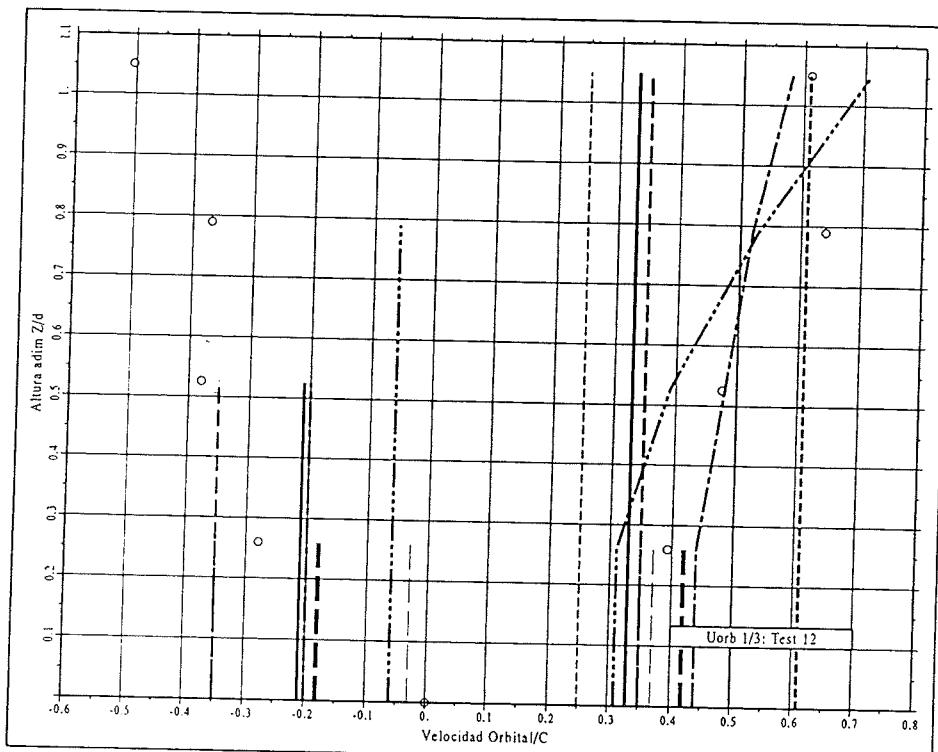


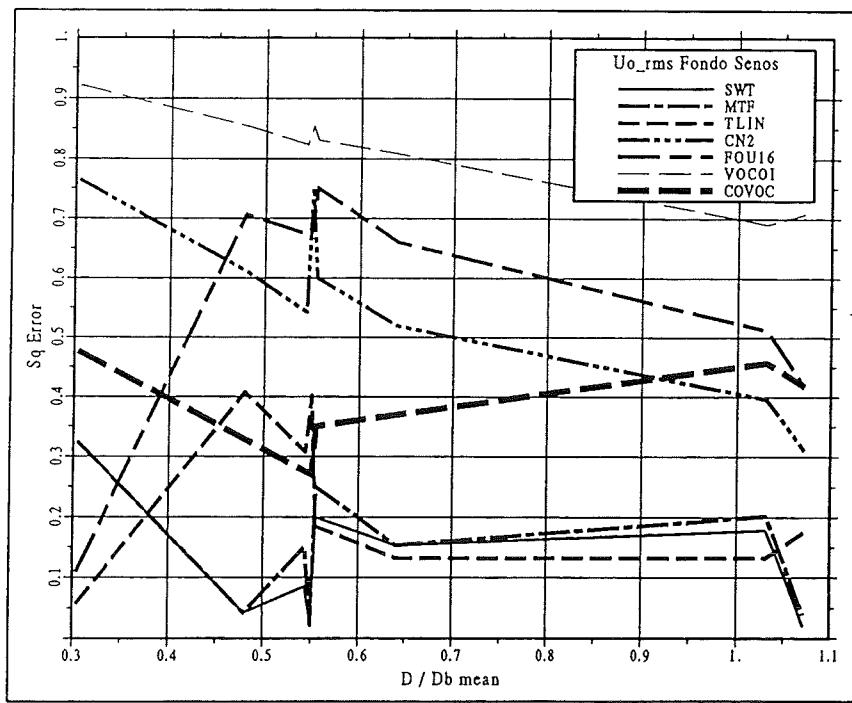
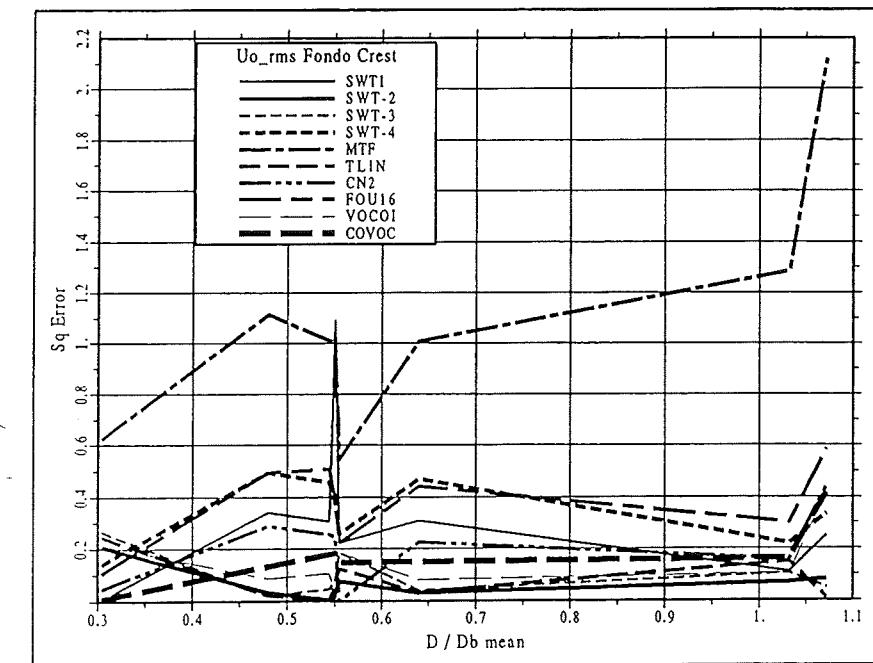


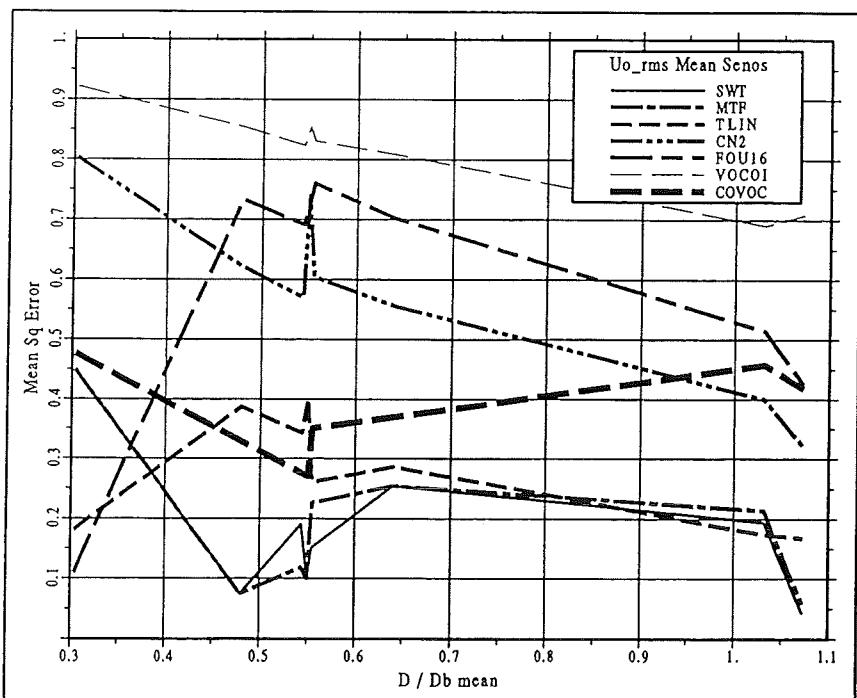
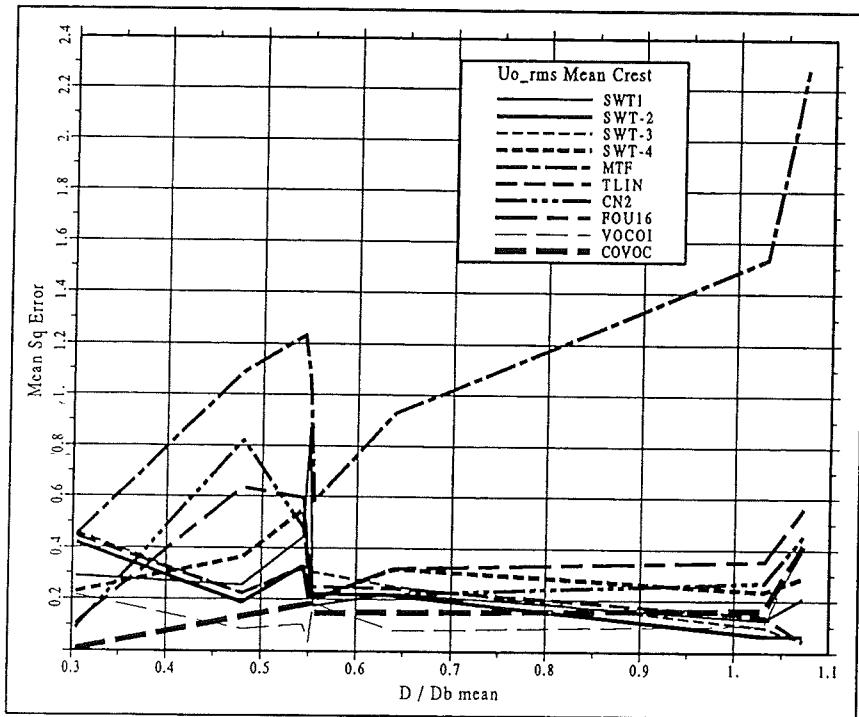


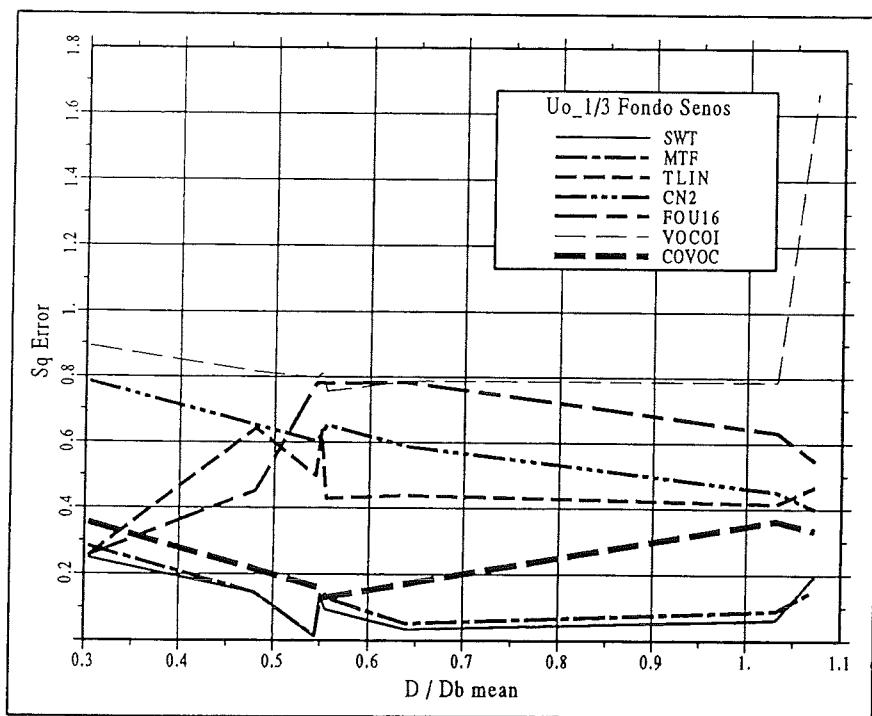
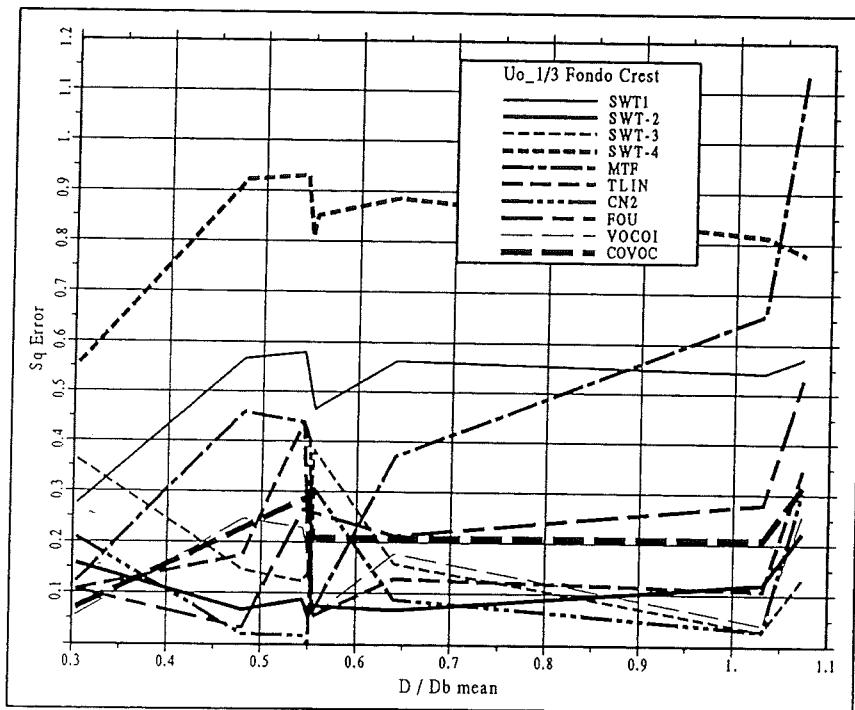


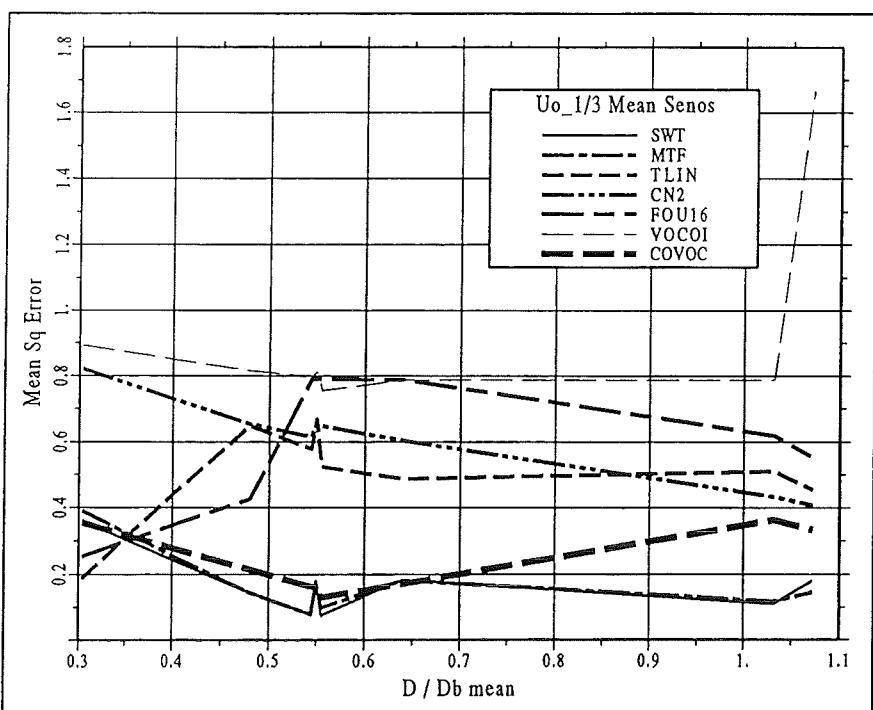
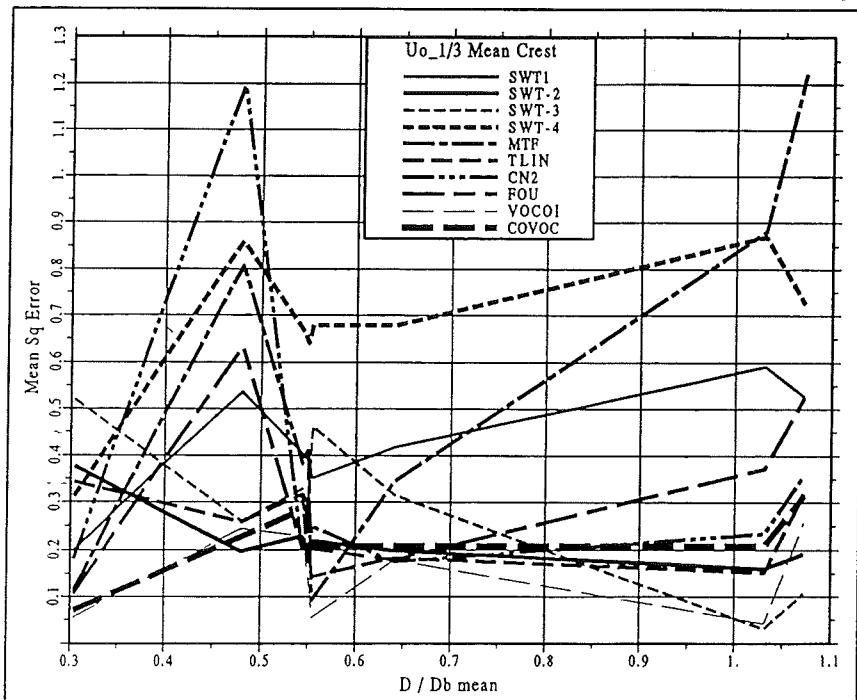






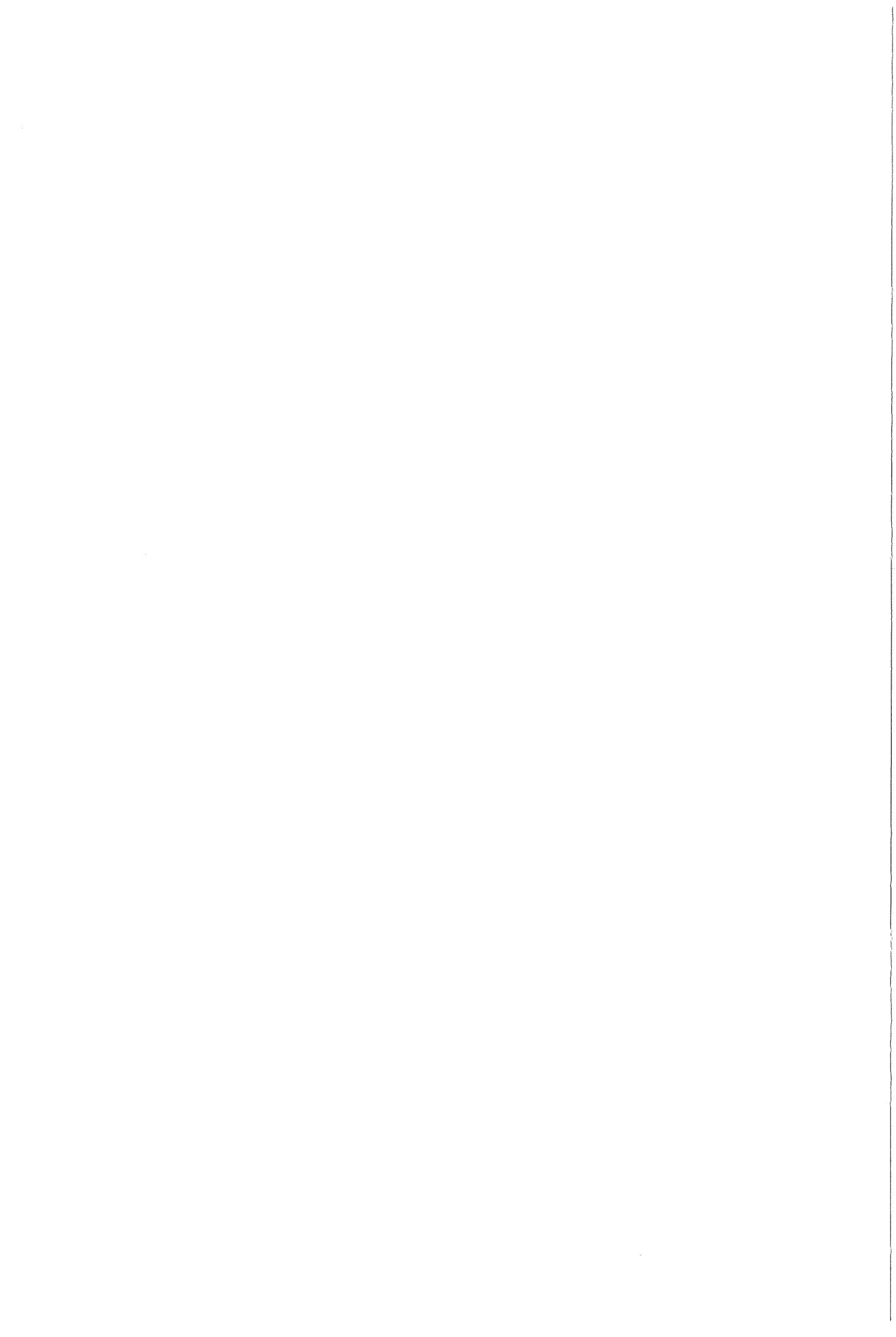




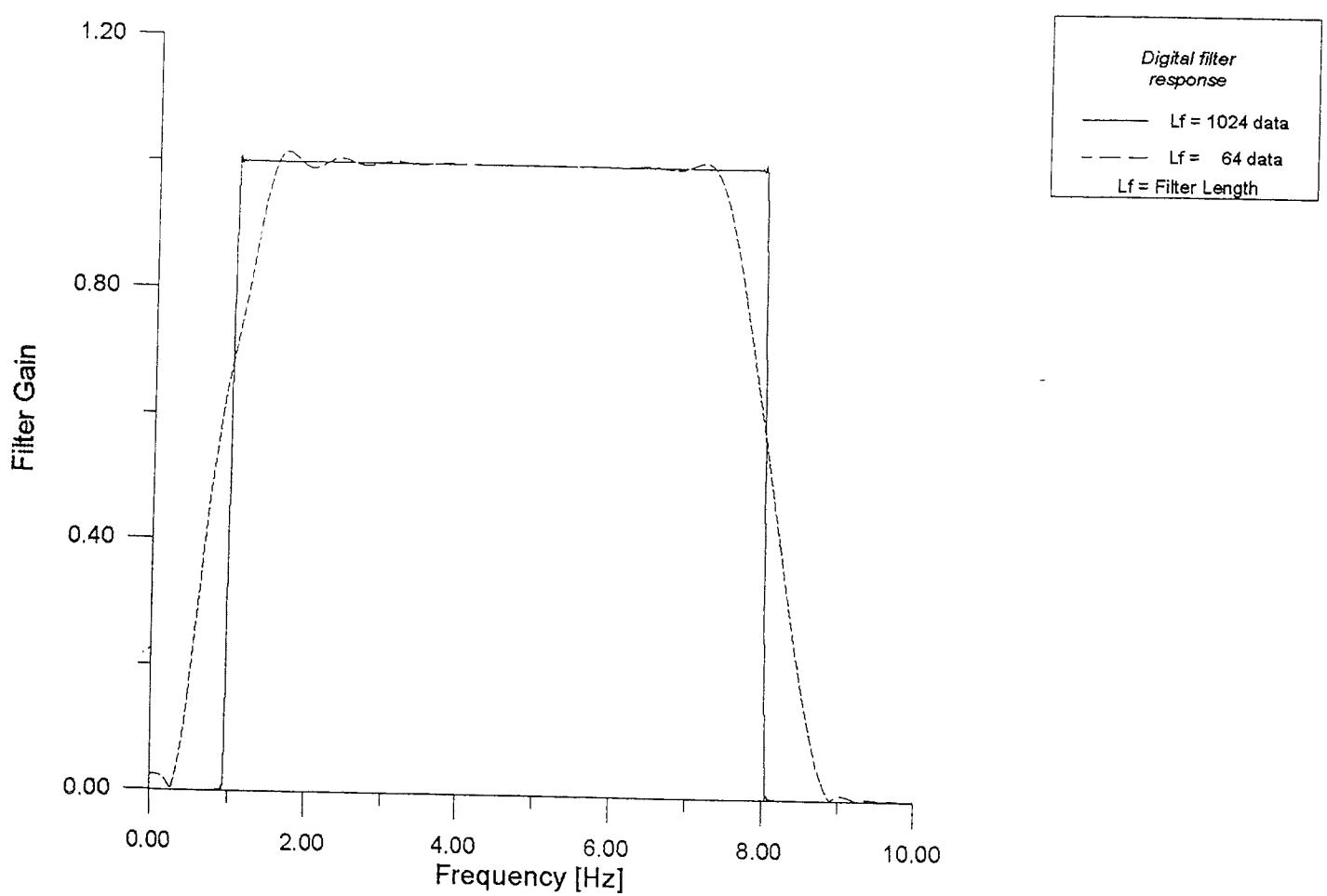
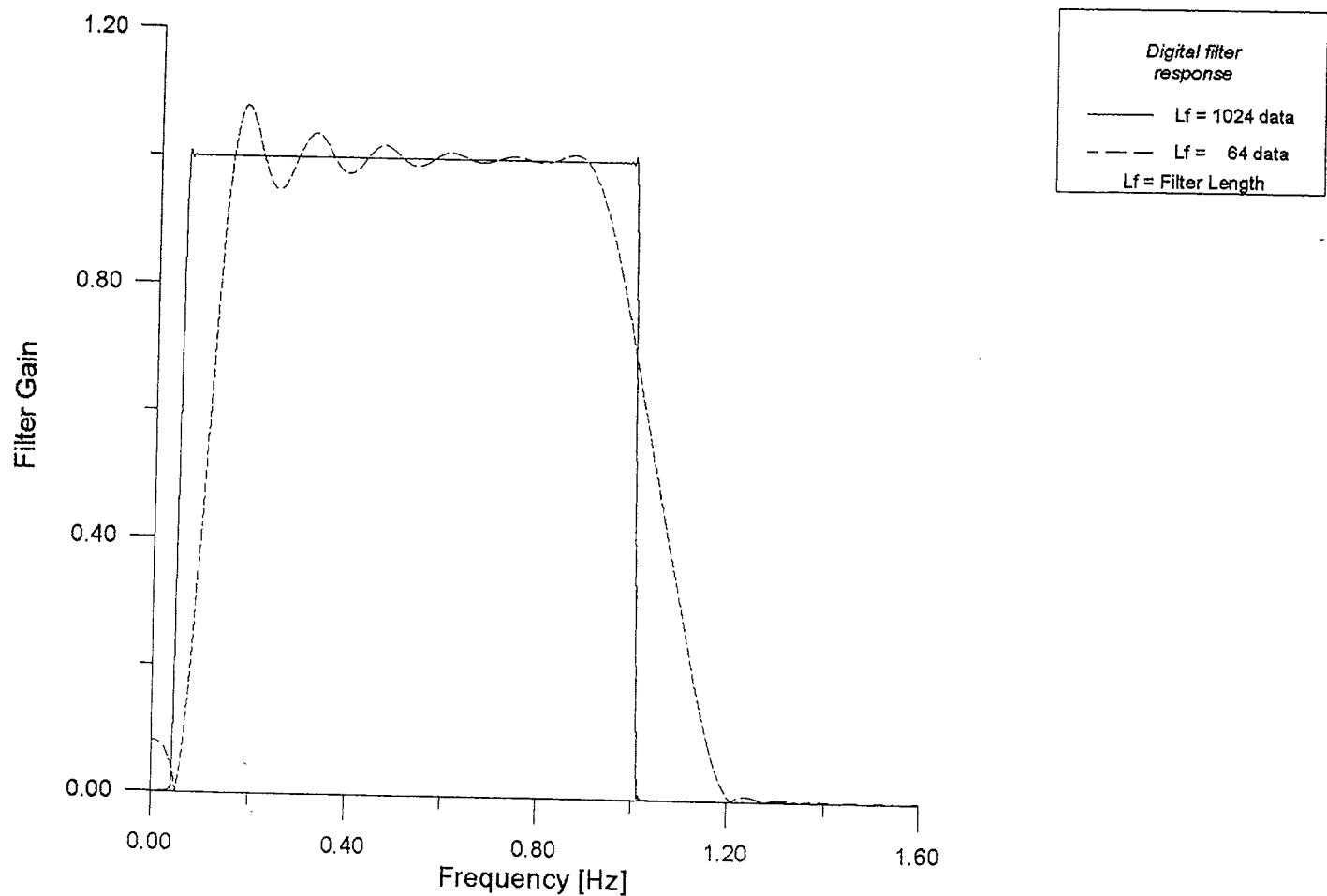


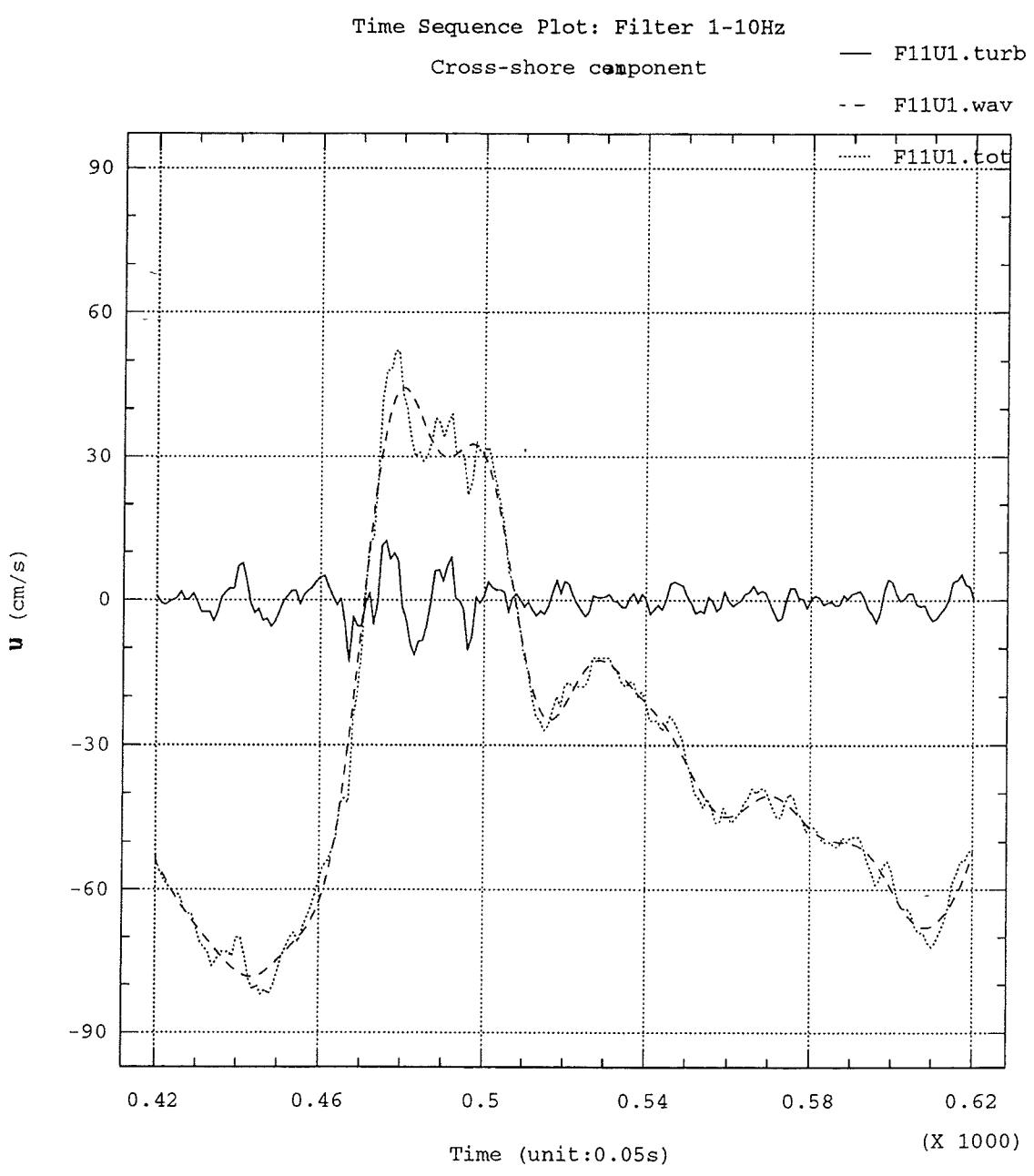
C4.3.

Flujo Macroturbulento

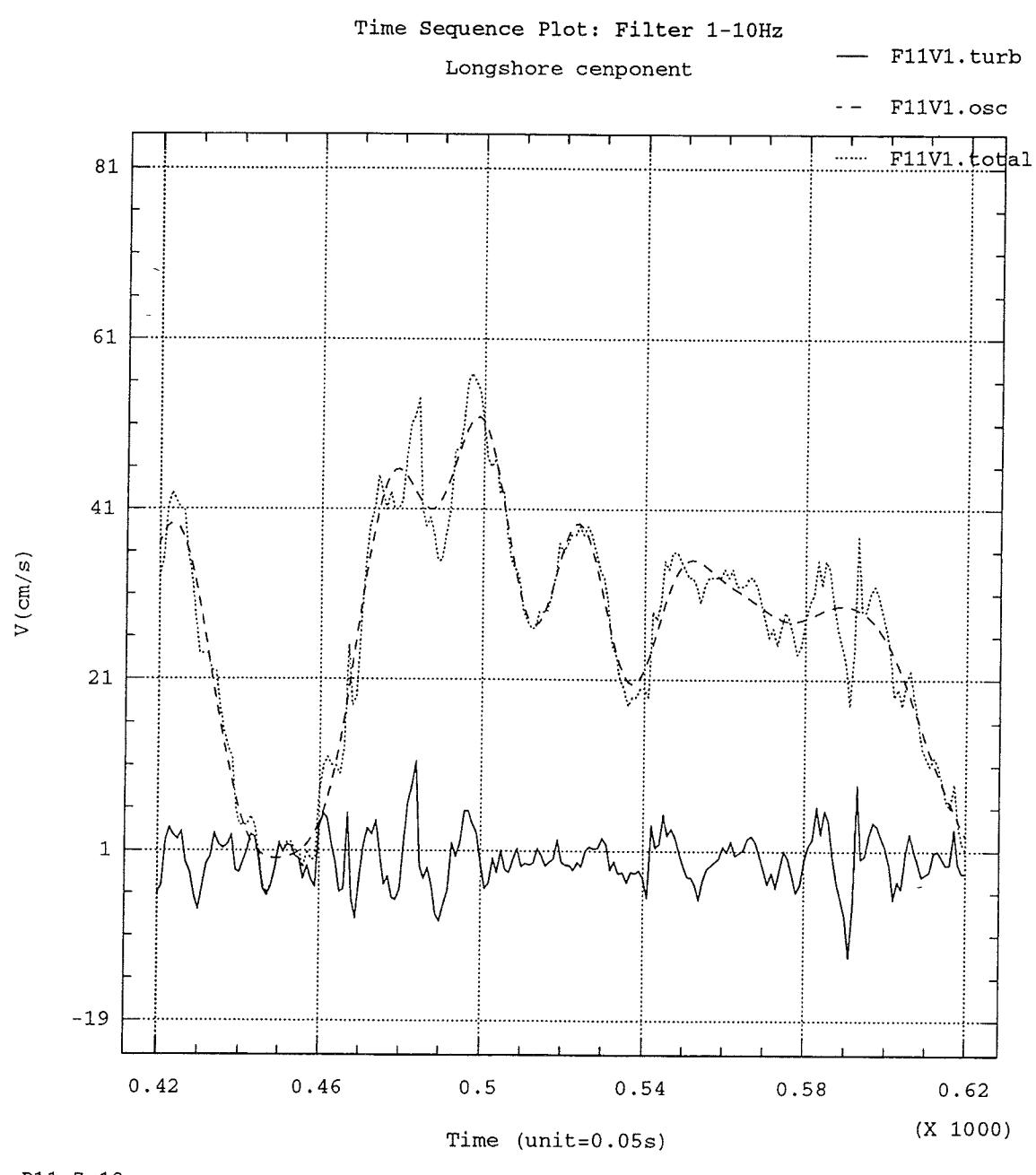


Test 5			
EMC	U'rms	V'rms	W'=U'/ a
1	4.6300	4.8900	3.4644
2	4.2900	3.9400	3.2067
3	4.2600	3.6200	3.1811
4	6.8000	8.6900	5.0727
5	4.6200	3.9000	3.4395
6	4.2300	4.4000	3.1428
Test 6			
EMC	U'rms	V'rms	W'=U'/ a
1	5.5600	4.6100	4.3282
2	6.1700	4.9500	4.7953
3	5.7100	5.1400	4.4306
4	8.6200	7.0100	6.6779
5	9.0700	7.6000	7.0040
6	26.7900	24.0800	20.6216
Test 7			
EMC	U'rms	V'rms	W'=U'/ a
1	4.2100	3.3100	3.9349
2	4.5600	3.8700	4.2523
3	4.2100	3.8000	3.9170
4	6.1500	5.1000	5.7090
5	16.1100	15.3000	14.8874
6	21.0500	19.5100	19.3650
Test 8			
EMC	U'rms	V'rms	W'=U'/ a
1	1.8600	1.8400	1.3721
2	1.8300	1.7300	1.3487
3	1.8800	1.9900	1.3842
4	2.4200	2.5800	1.7801
5	2.1200	2.5200	1.5564
6	2.4600	2.5500	1.8025
Test 9			
EMC	U'rms	V'rms	W'=U'/ a
1	4.4200	4.3700	3.5725
2	5.0400	4.8800	4.0655
3	5.4900	5.0800	4.4197
4	6.7700	6.1500	5.4393
5	17.7100	17.3900	14.1725
6	21.9400	23.0500	17.4883
Test 10			
EMC	U'rms	V'rms	W'=U'/ a
1	3.7500	3.5000	3.2847
2	4.8200	4.2600	4.2126
3	5.0200	4.3900	4.3778
4	6.7900	6.0700	5.9084
5	18.0300	18.9500	15.6208
6	19.9700	16.8700	17.2267
Test 11			
EMC	U'rms	V'rms	W'=U'/ a
1	3.0700	2.8700	2.8057
2	3.7900	3.3200	3.4548
3	4.2000	3.7900	3.8187
4	5.3300	4.8800	4.8336
5	20.3700	17.7300	18.3787
6	11.7200	10.3500	10.5206
Test 12			
EMC	U'rms	V'rms	W'=U'/ a
1	5.1800	3.2900	5.7259
2	11.2200	9.4900	12.3417
3	18.9500	16.7300	20.7428
4	21.5900	24.1300	23.5178
5	8.9400	7.8700	9.6446
6	7.4200	8.2200	7.9286

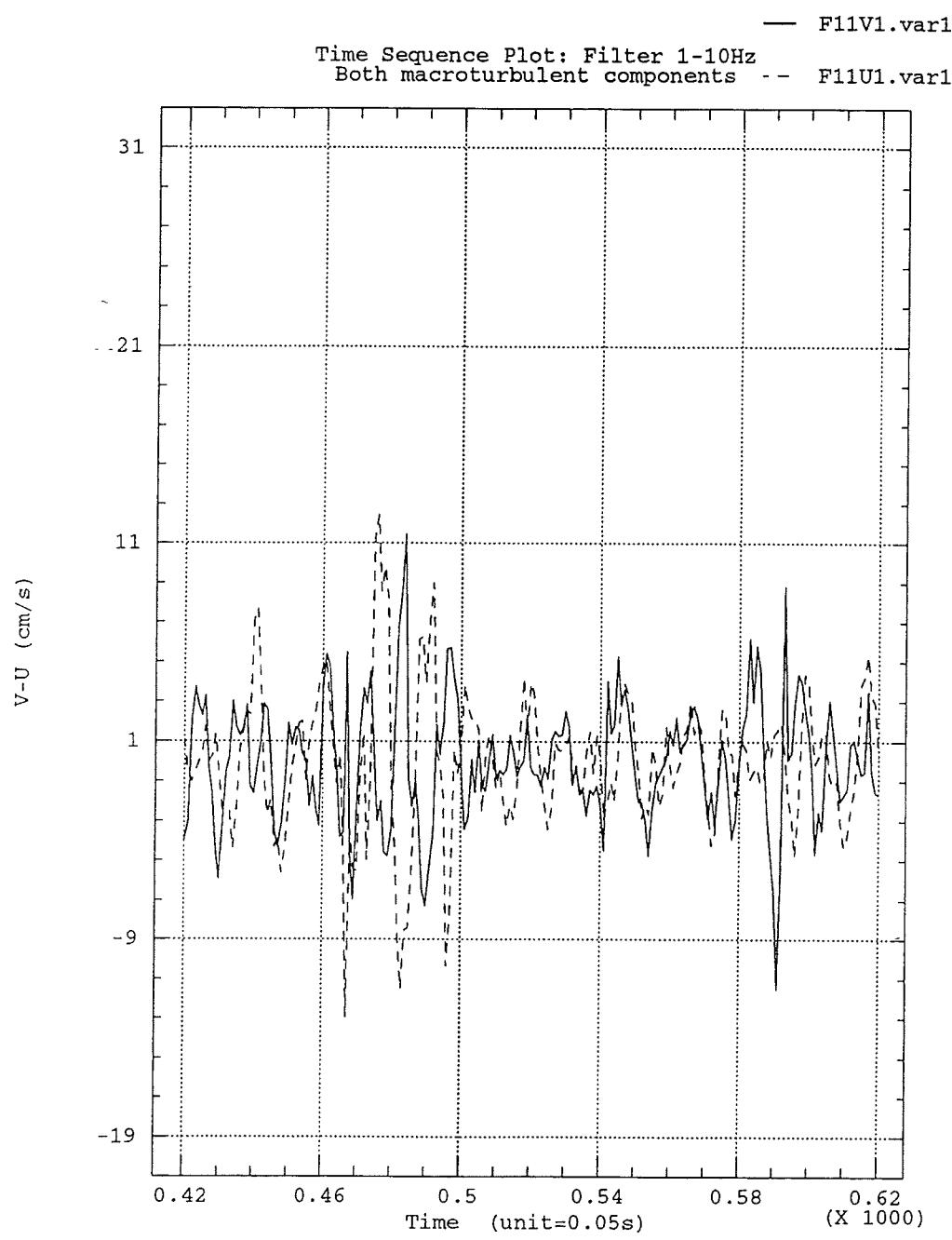




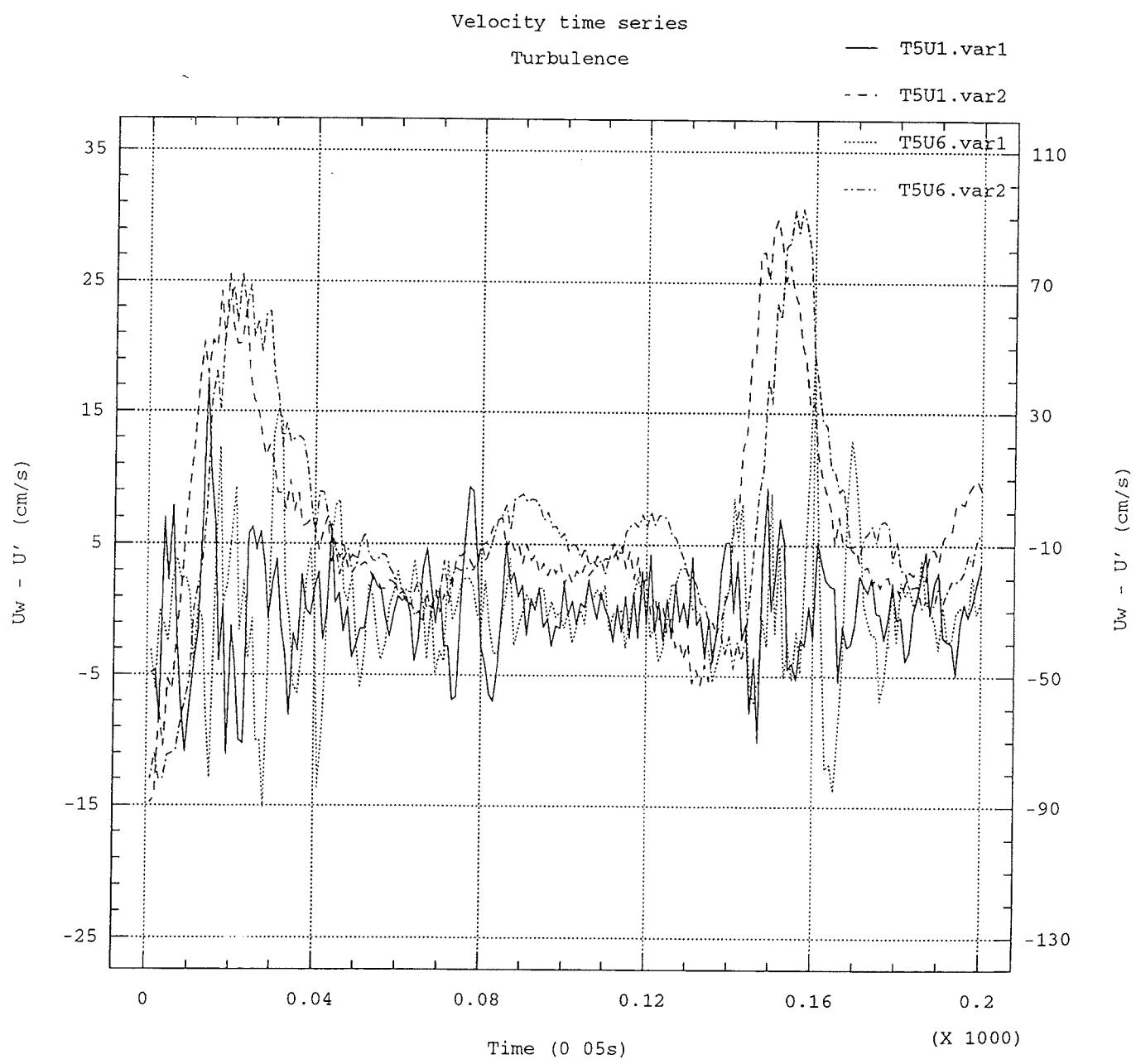
P11, Z=10cm



P11, Z=10cm

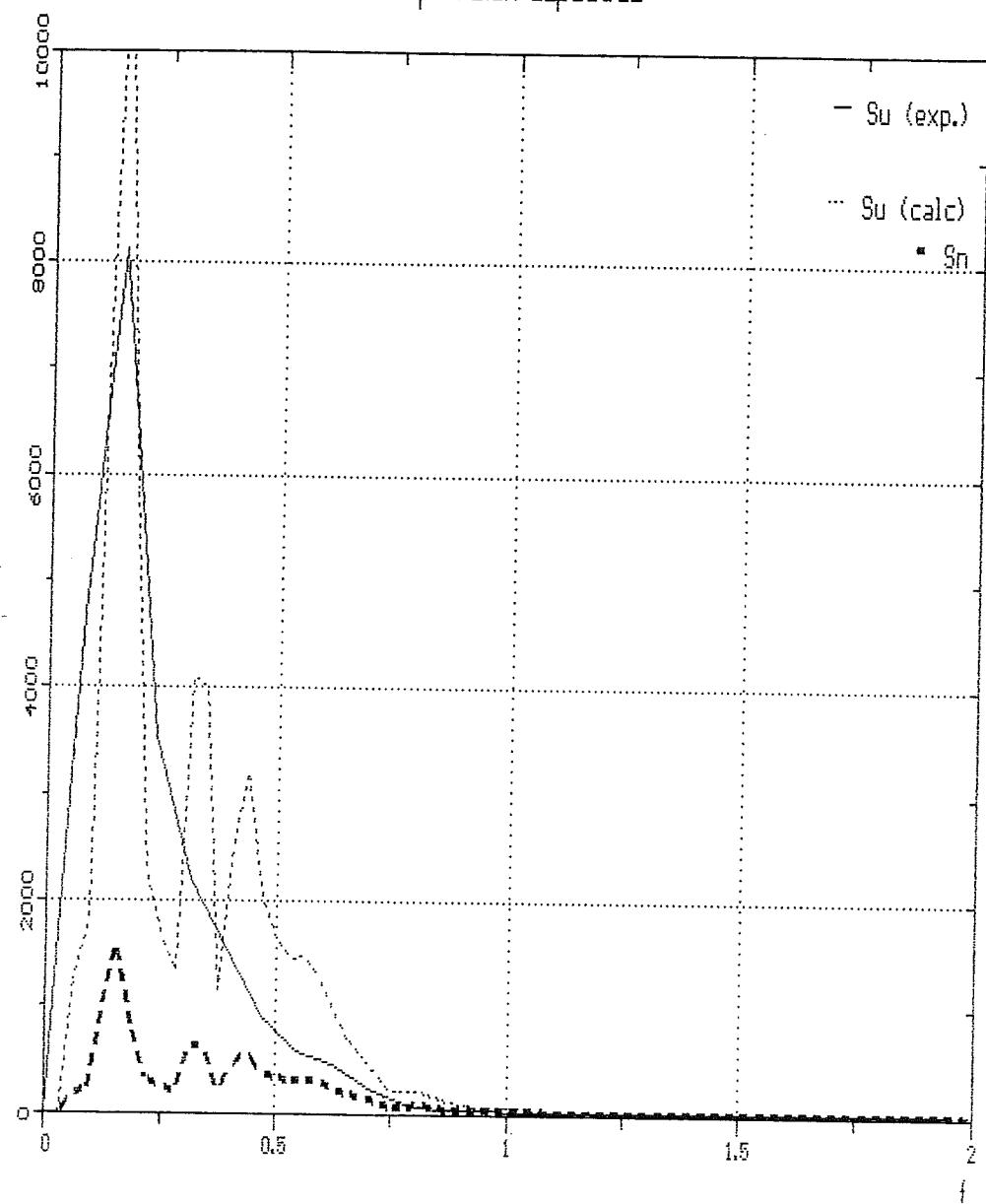


P11, Z=10cm

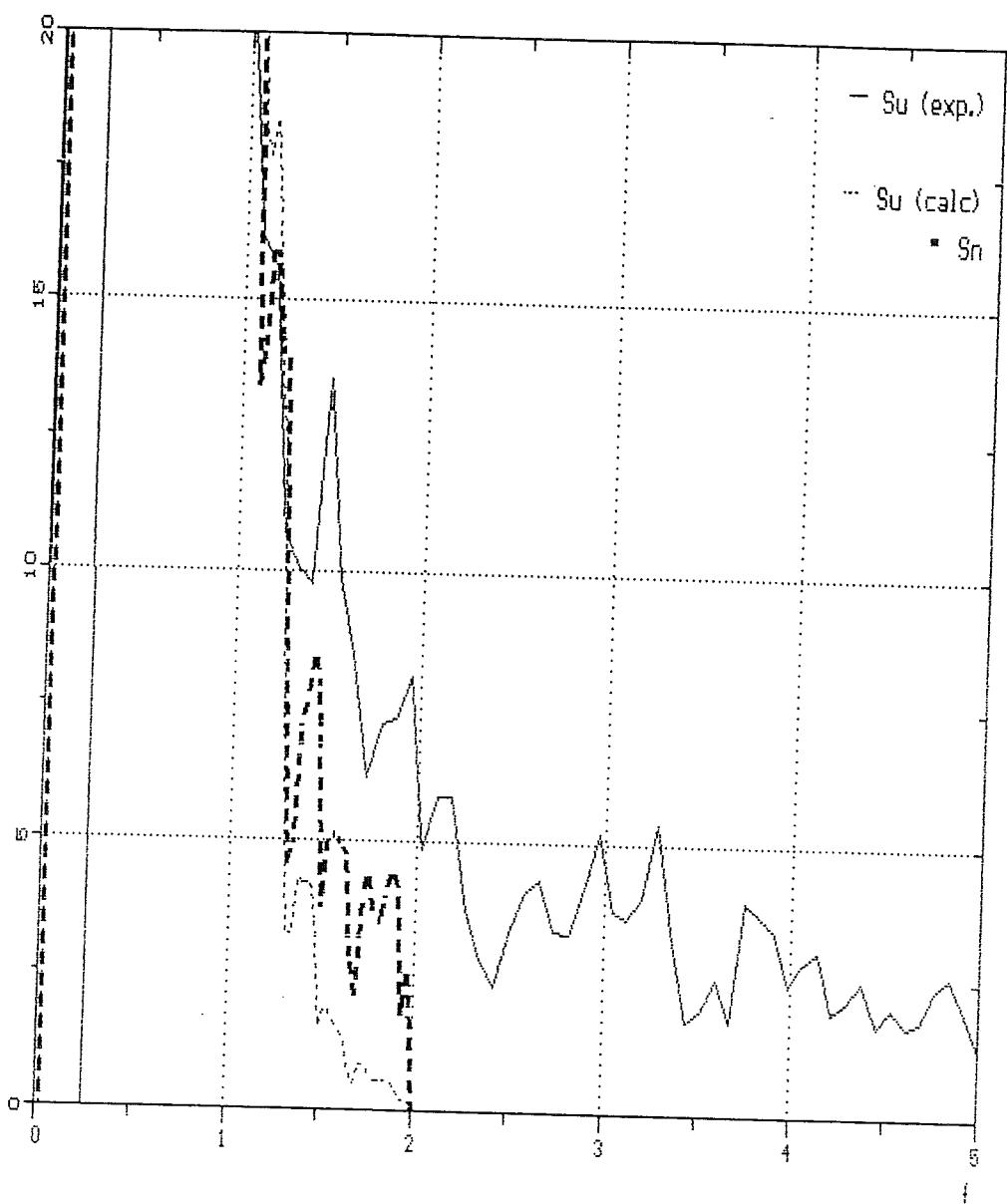


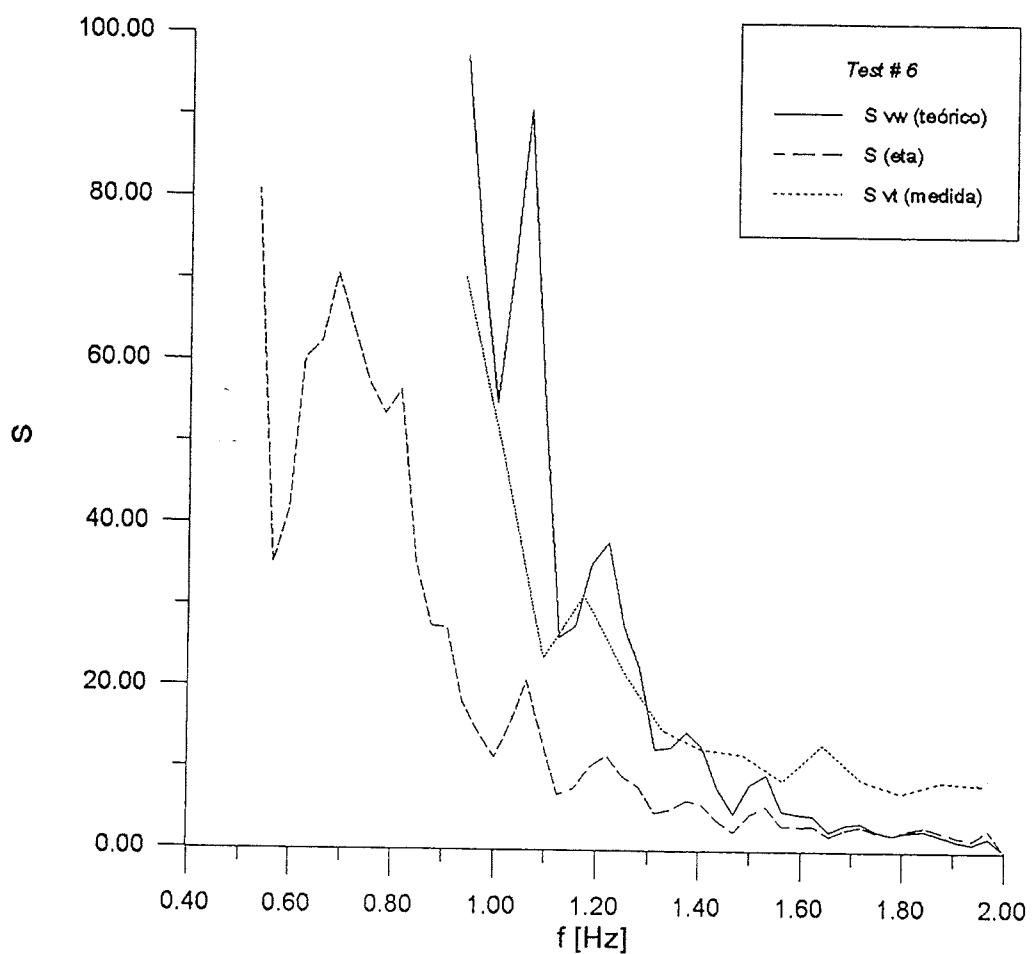
Test 5, $z=10$ cm and $z=80$ cm

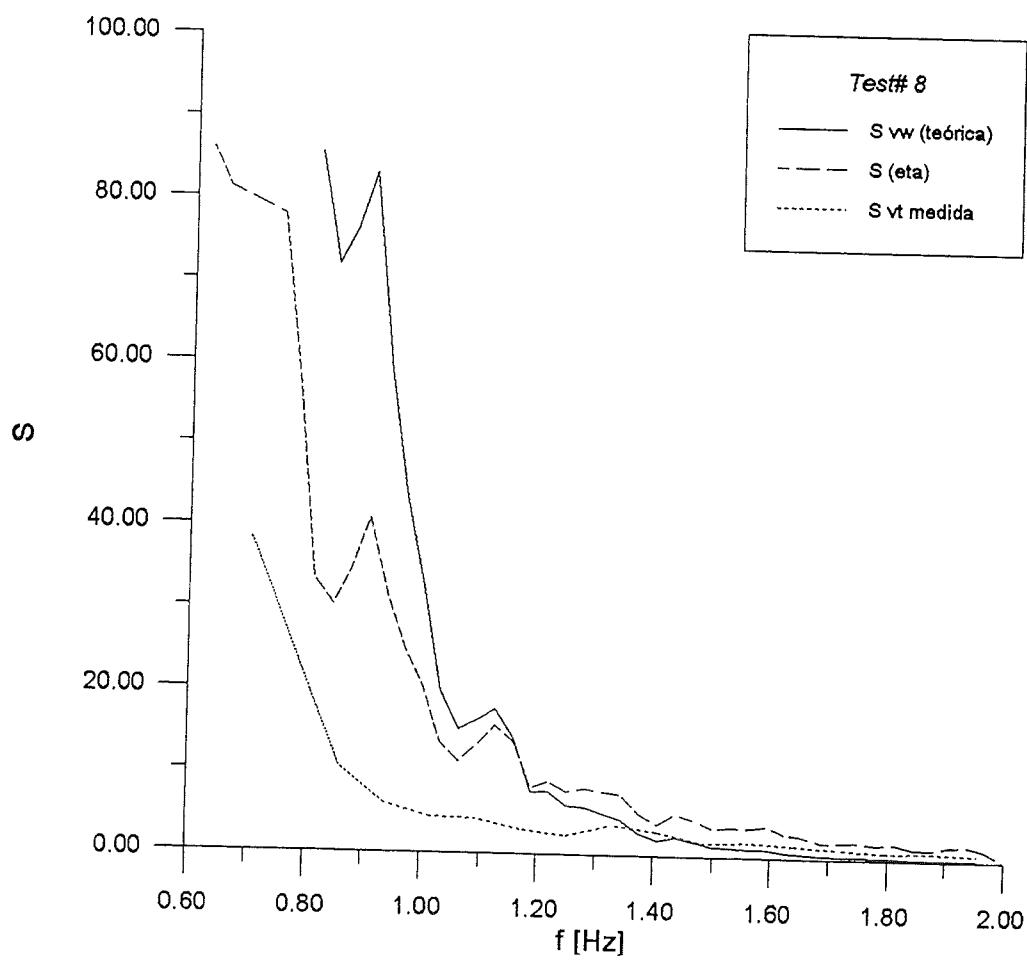
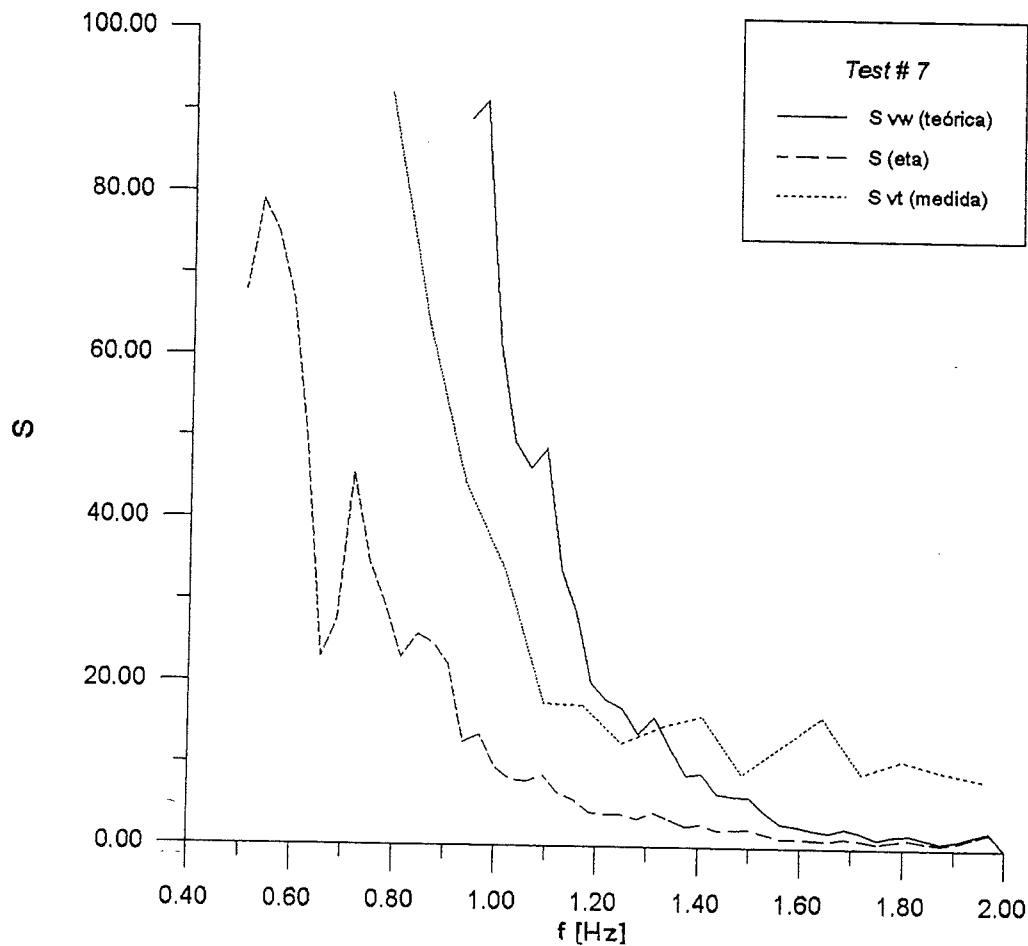
Comparación espectros

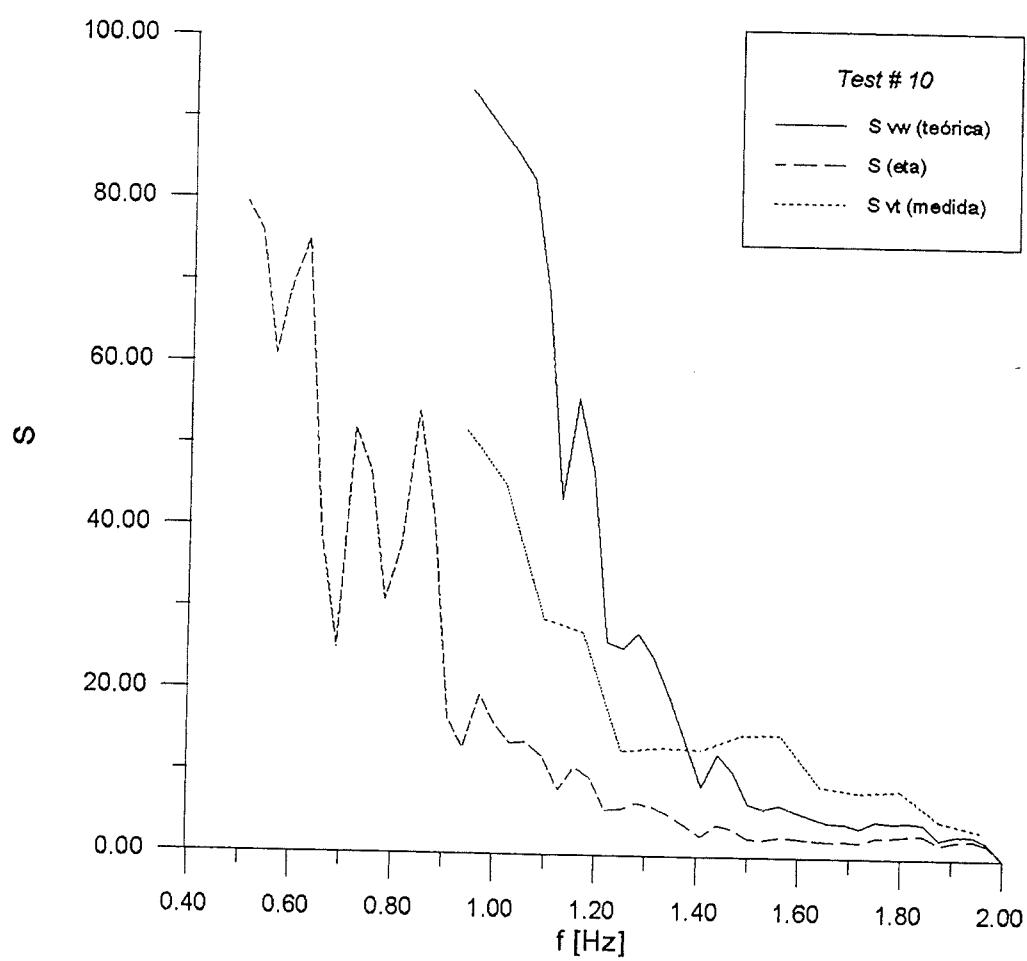
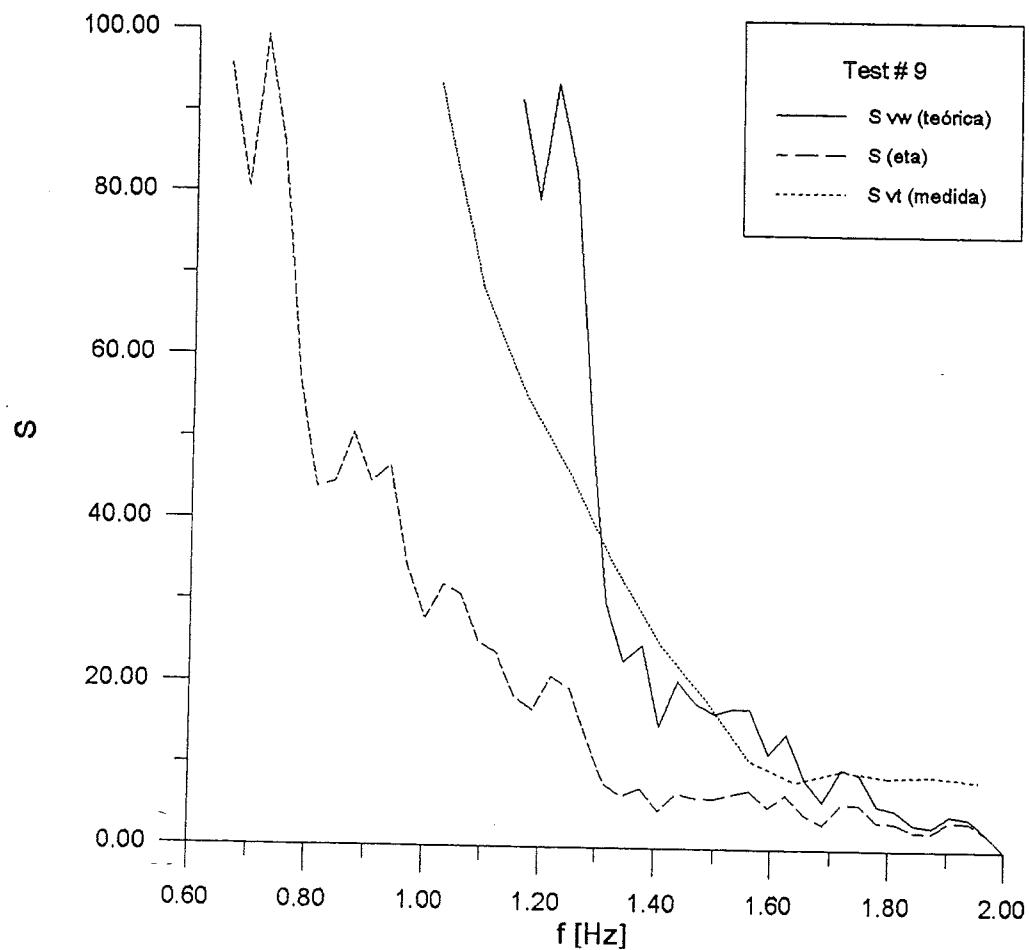


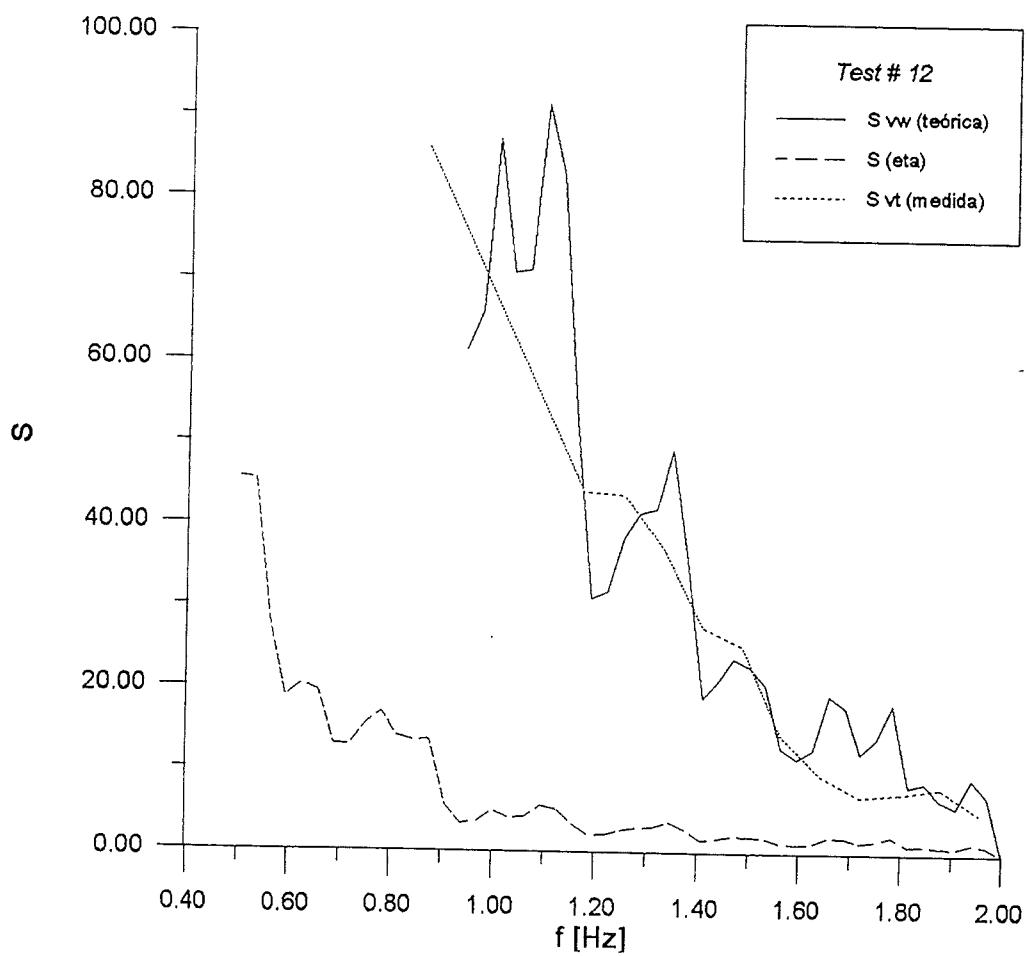
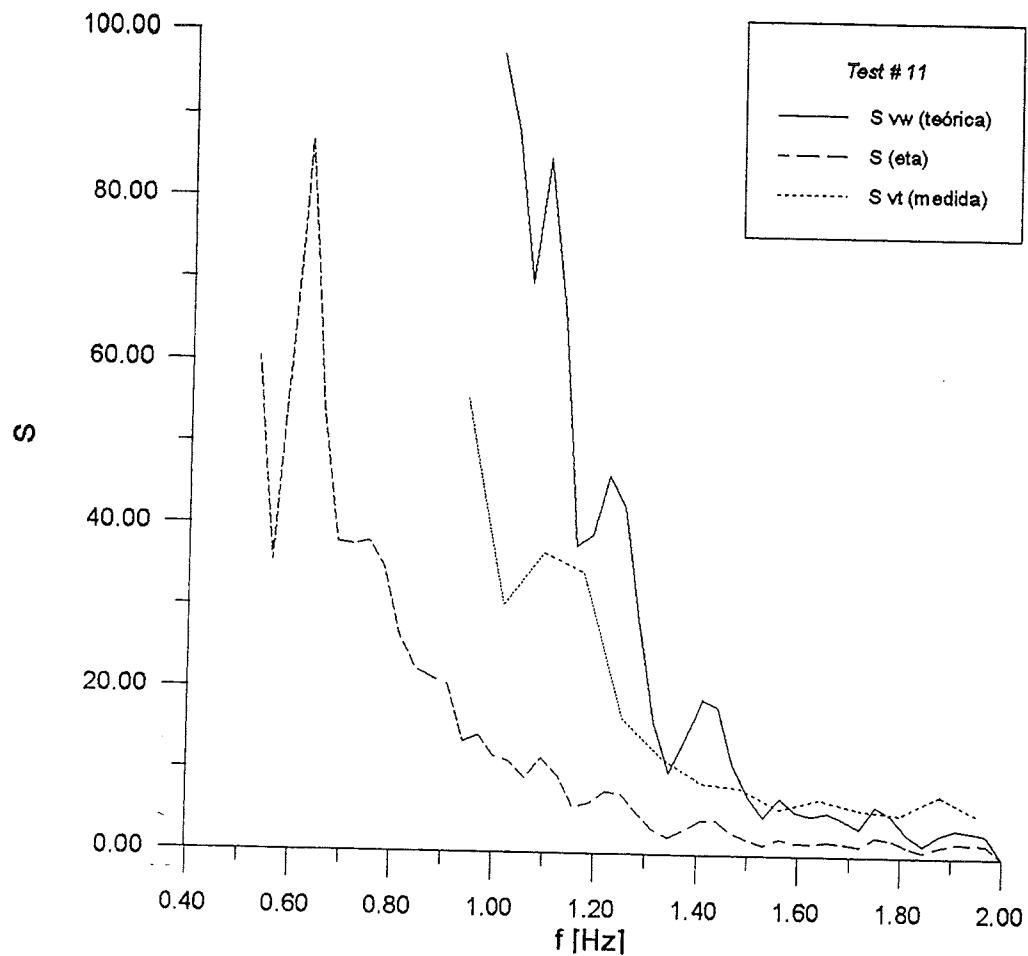
Comparación espectros

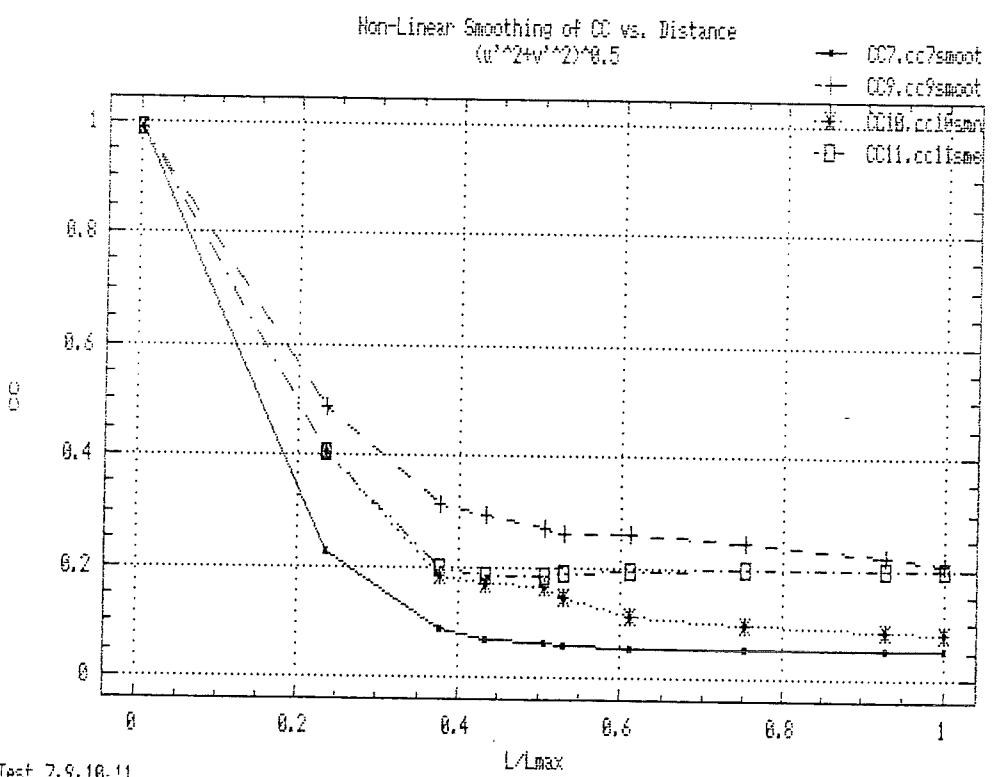
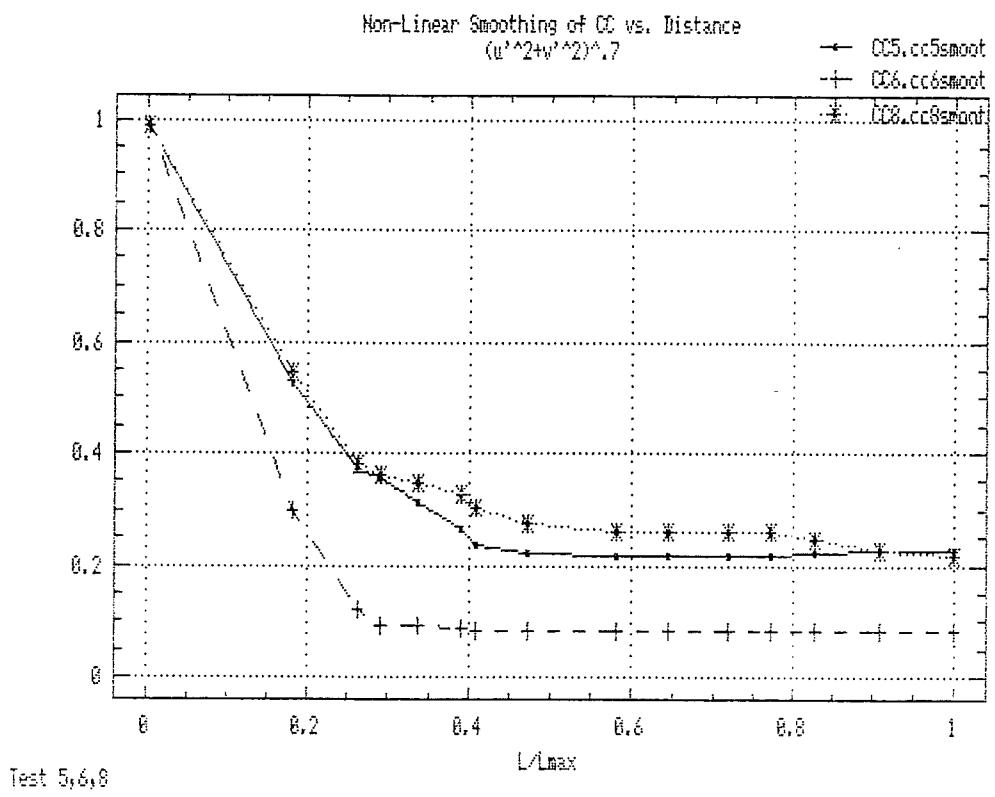


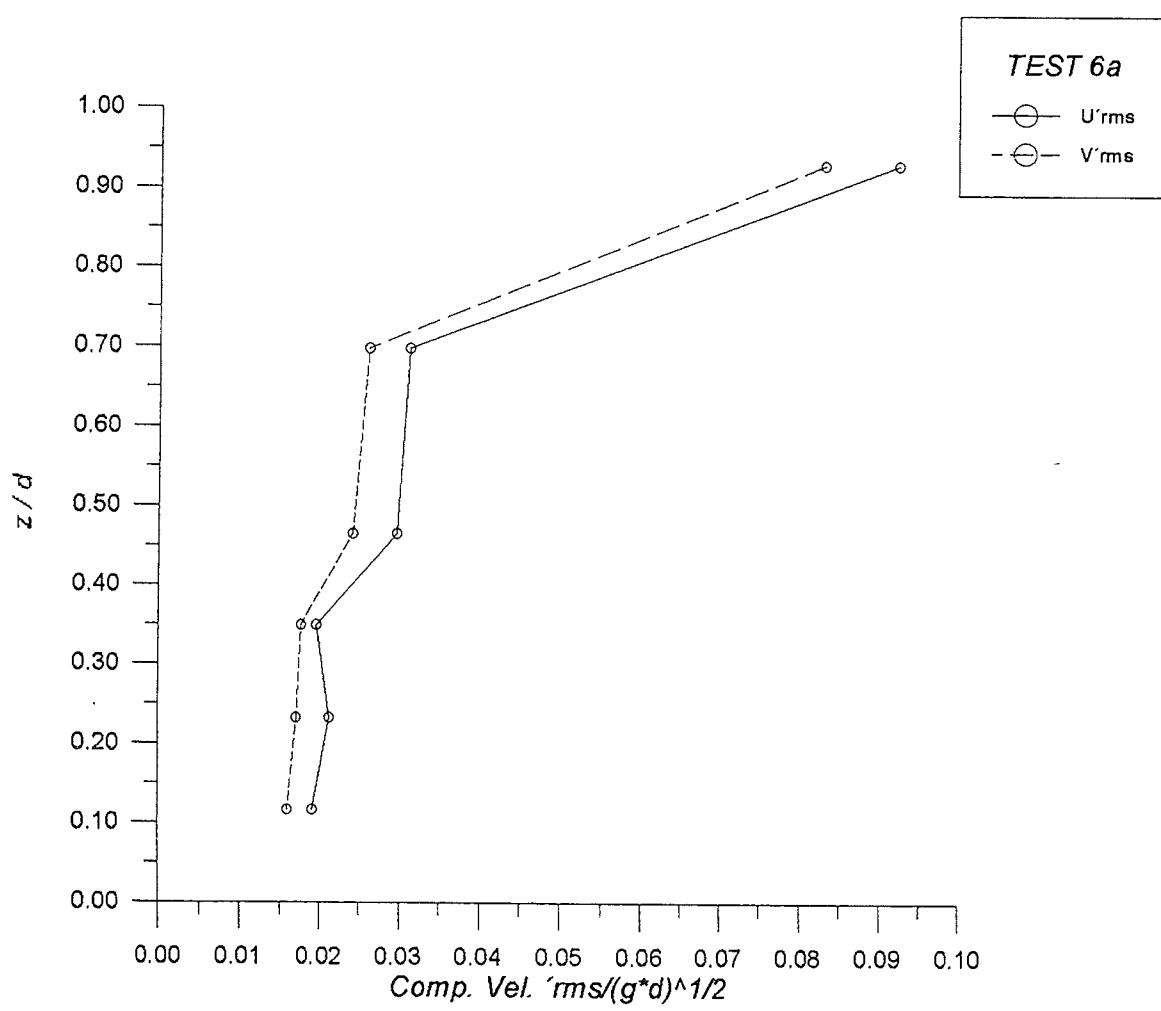
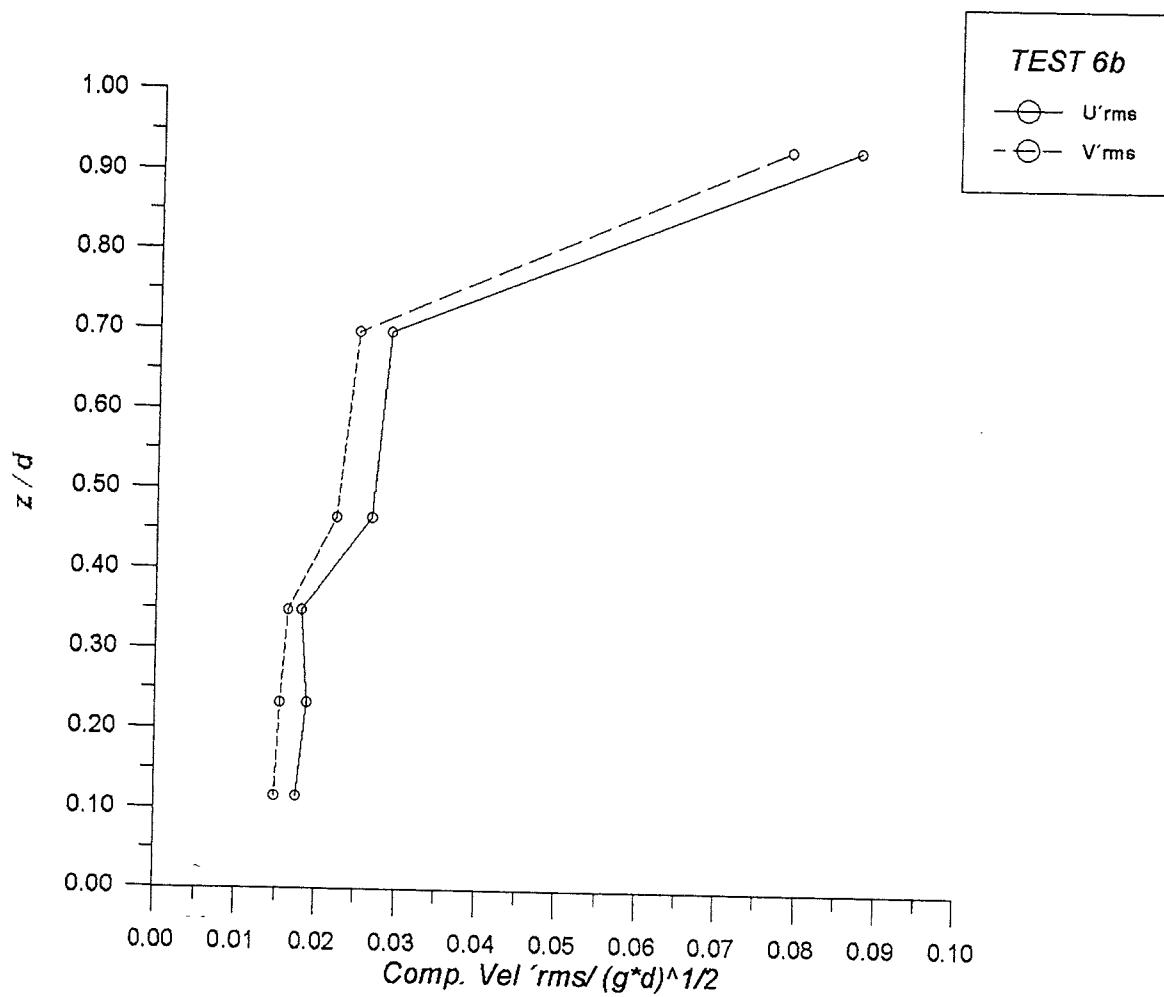


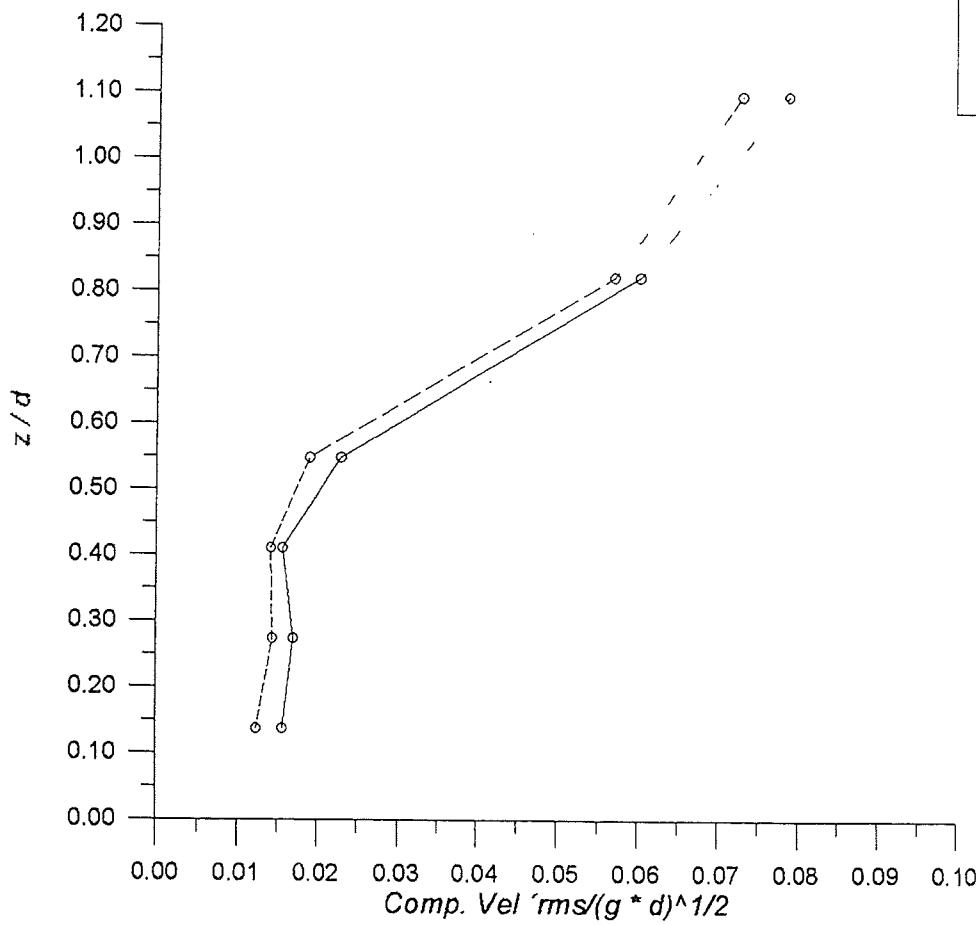
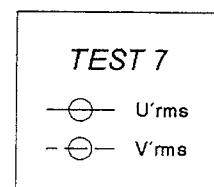
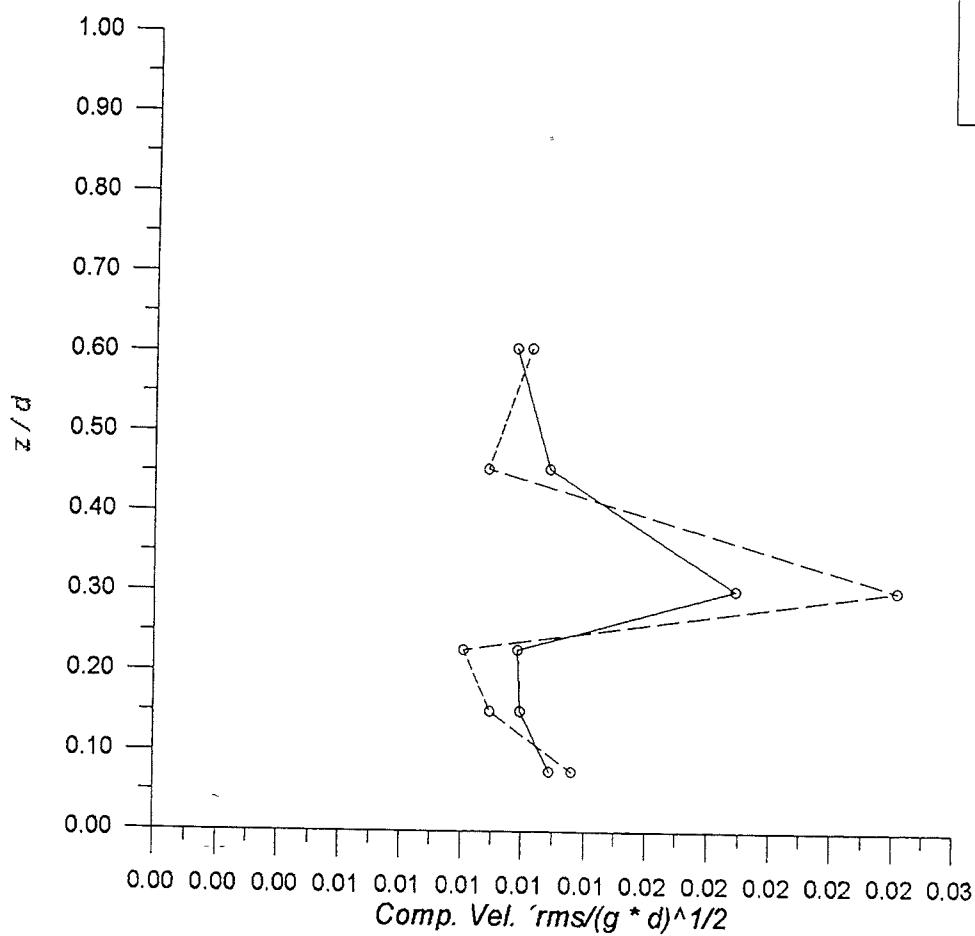
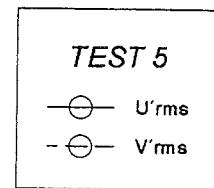


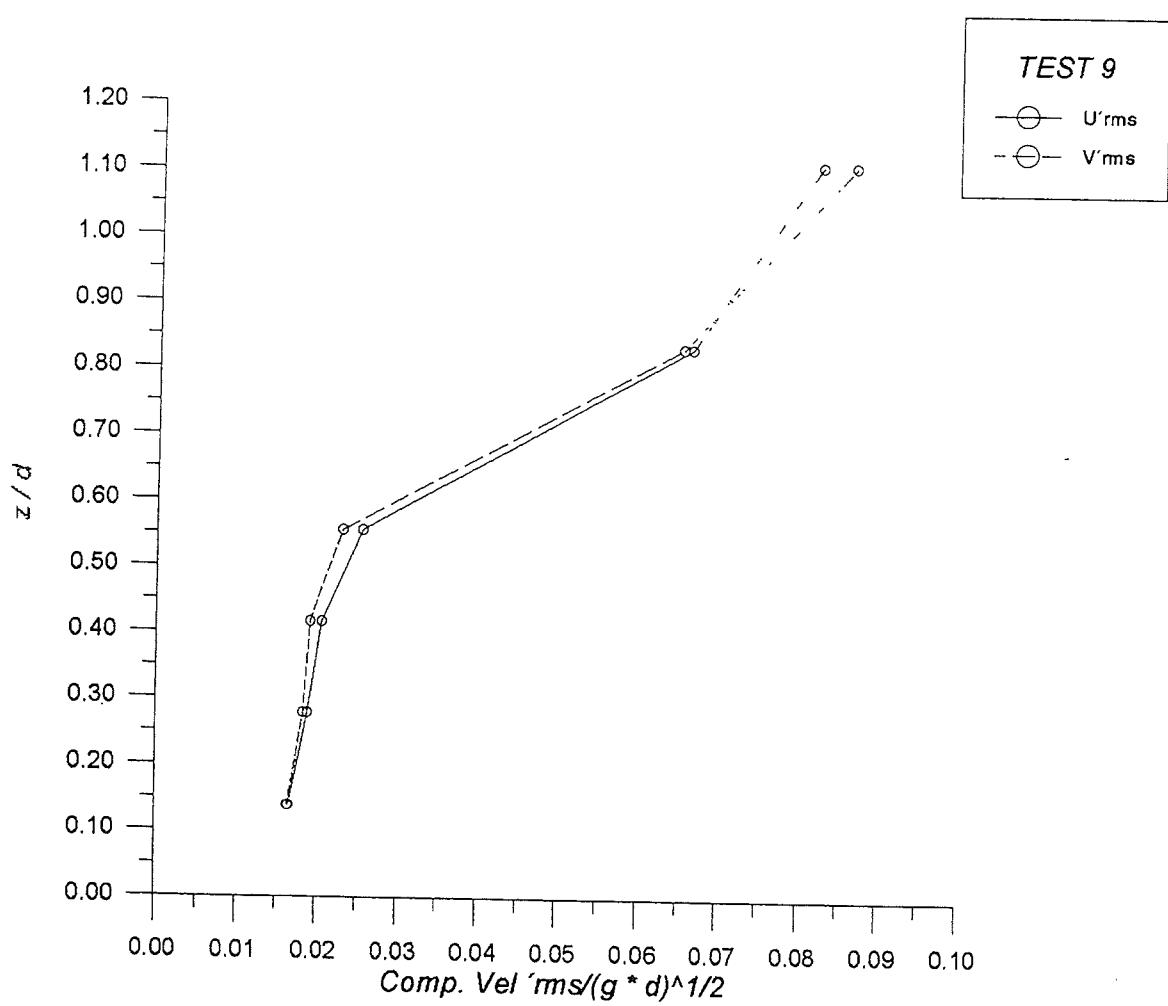
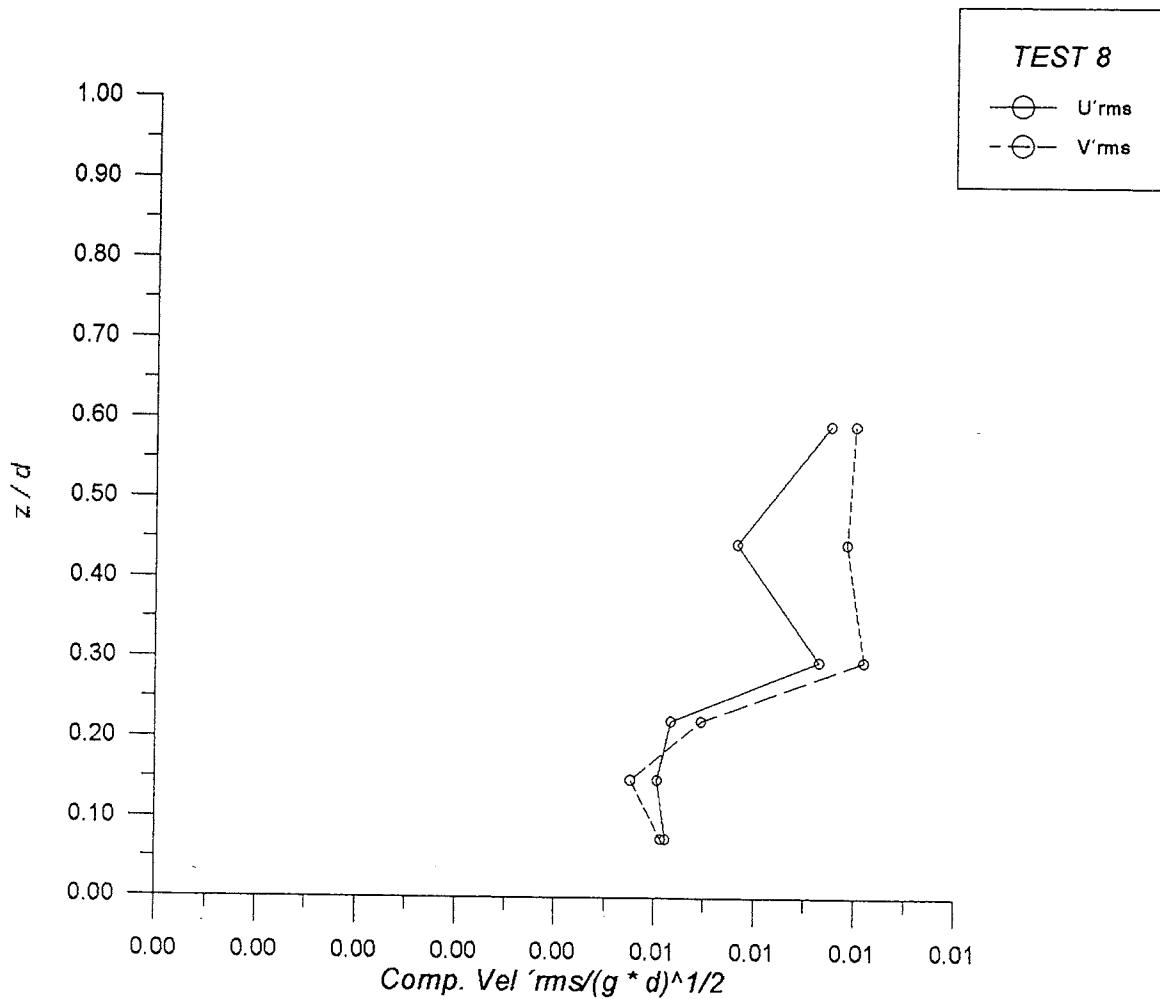


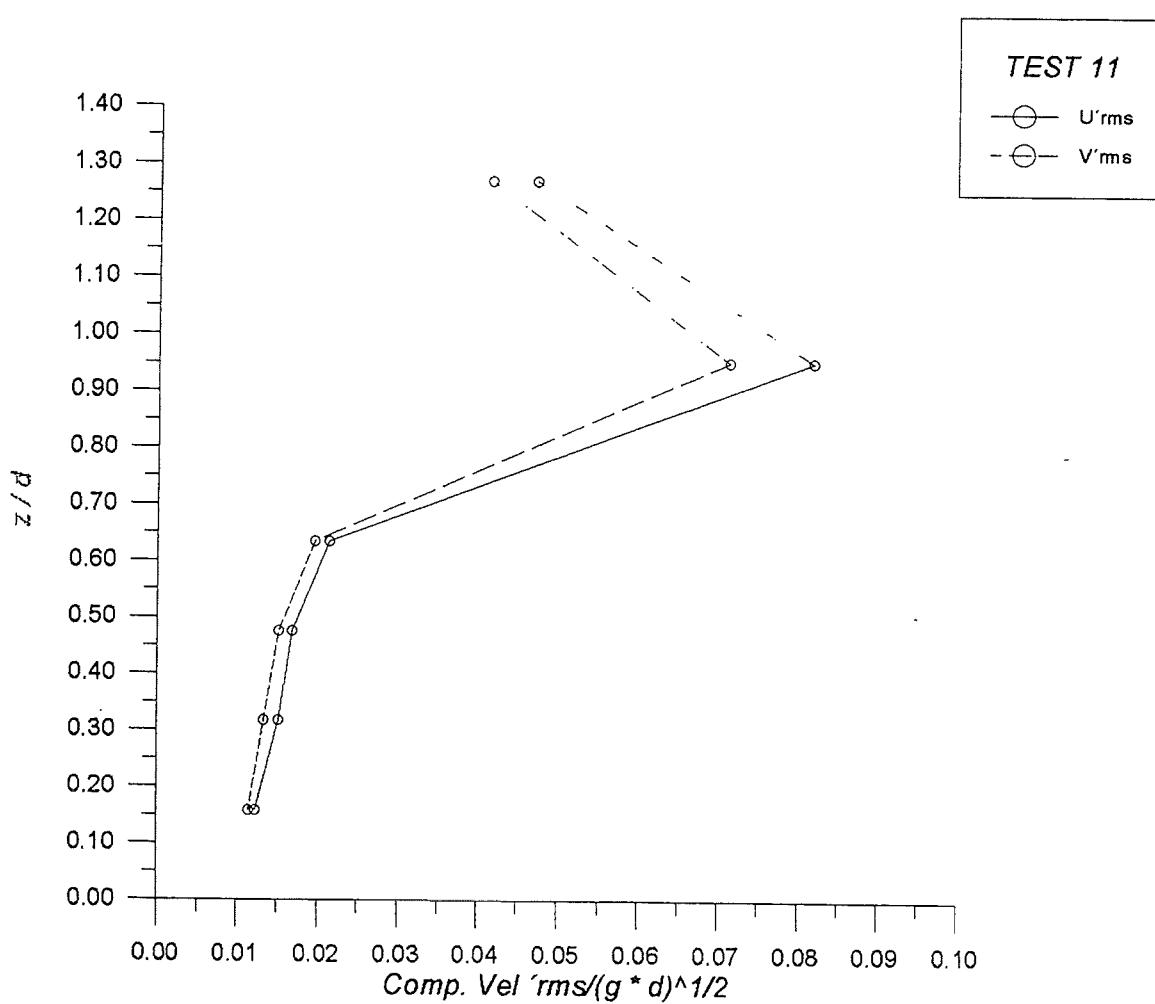
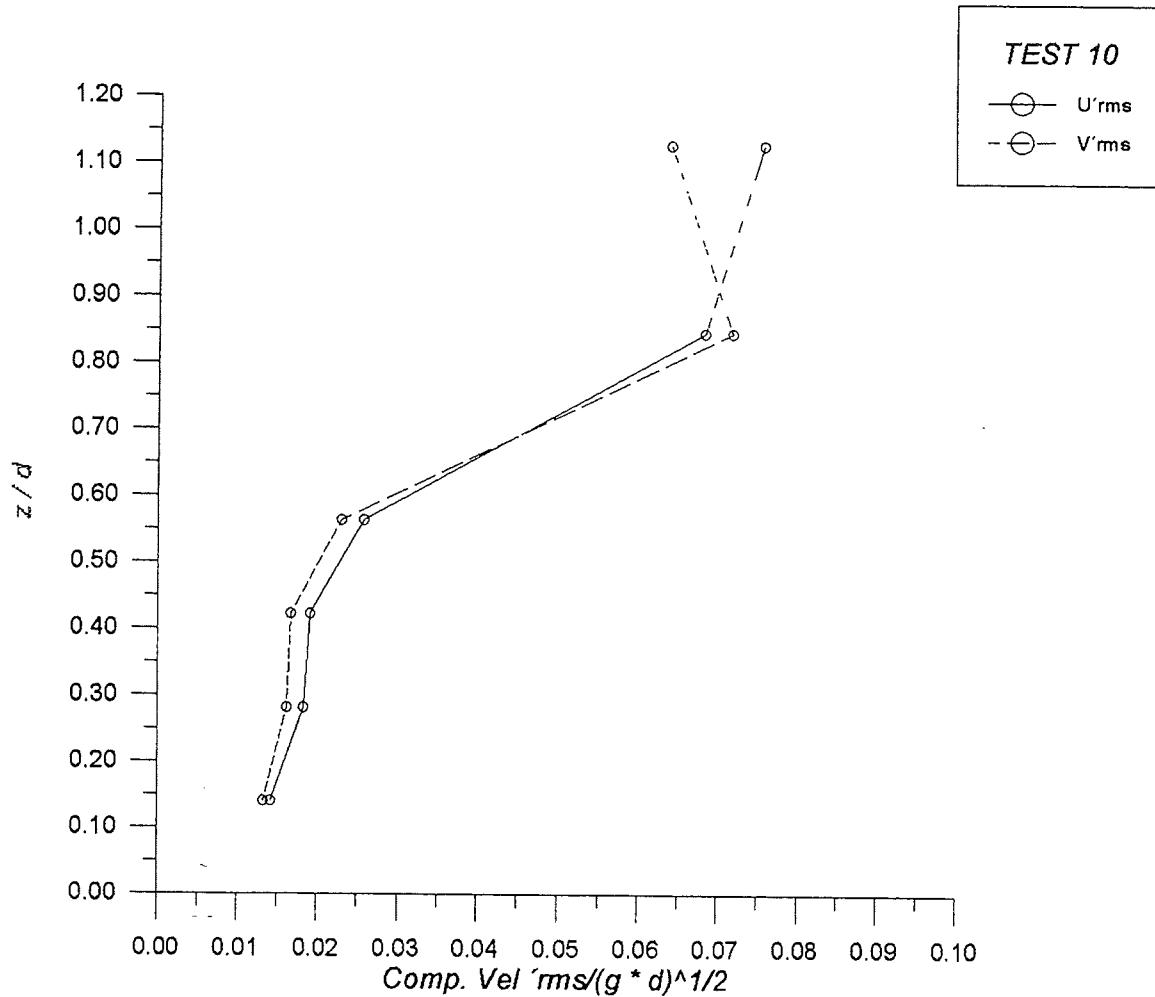


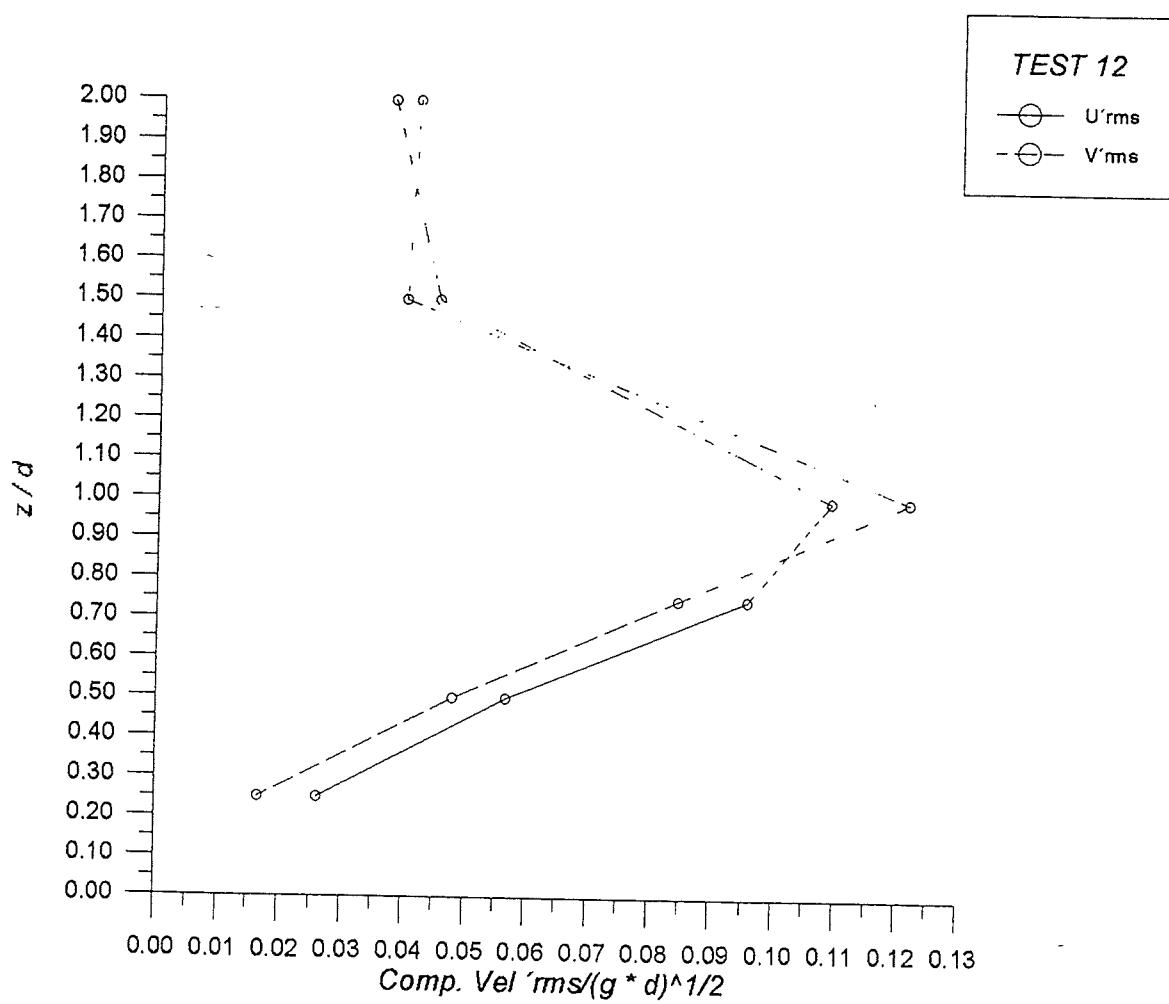




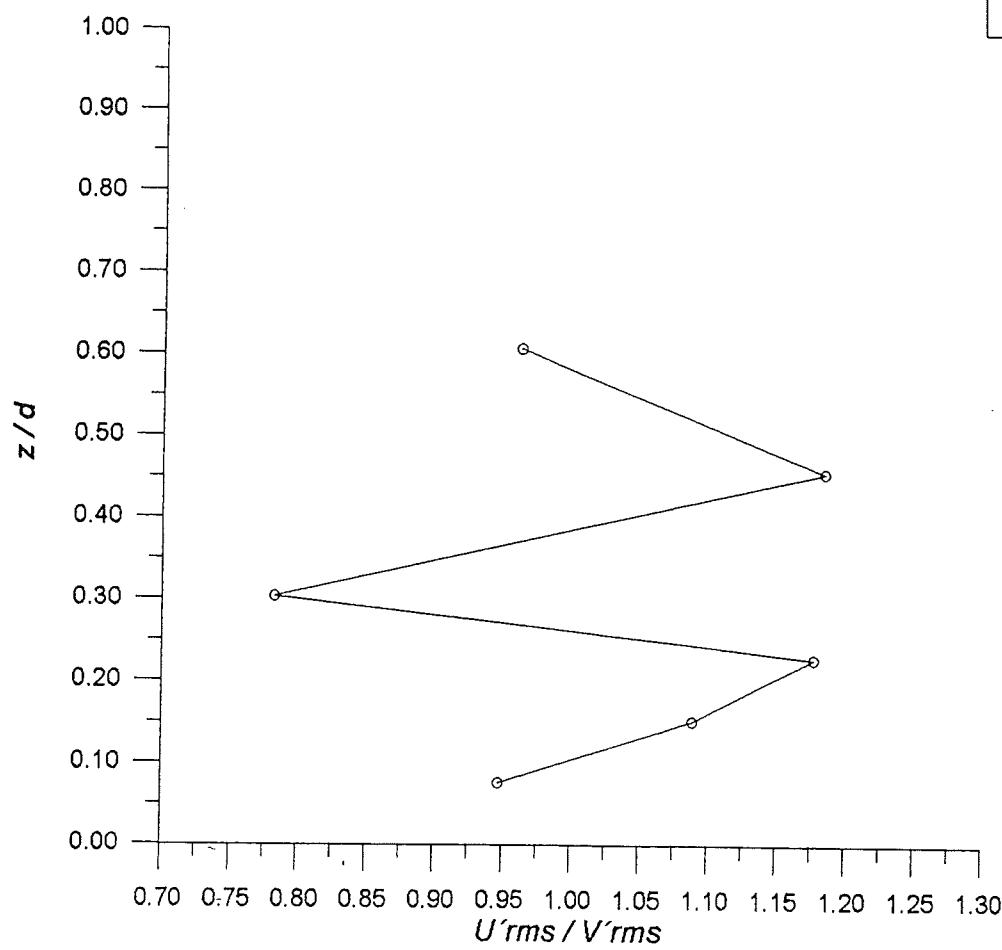




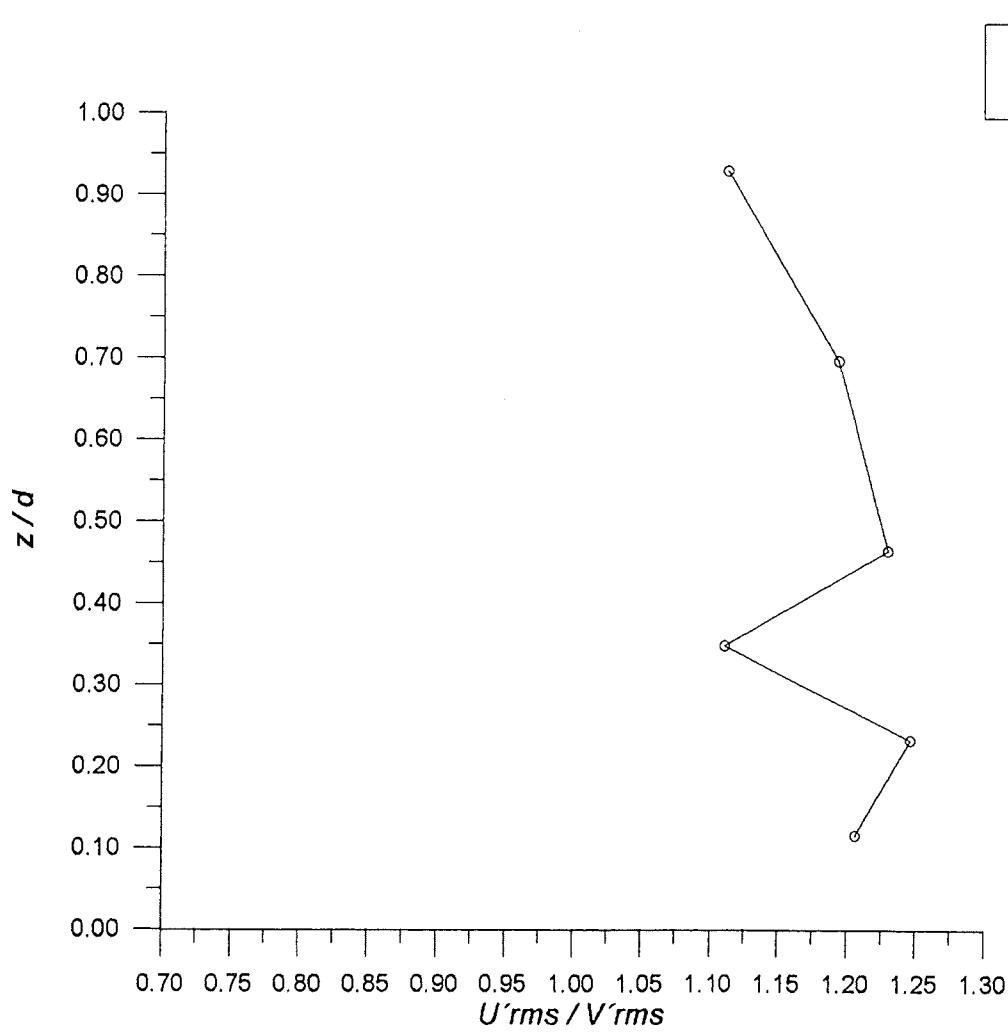




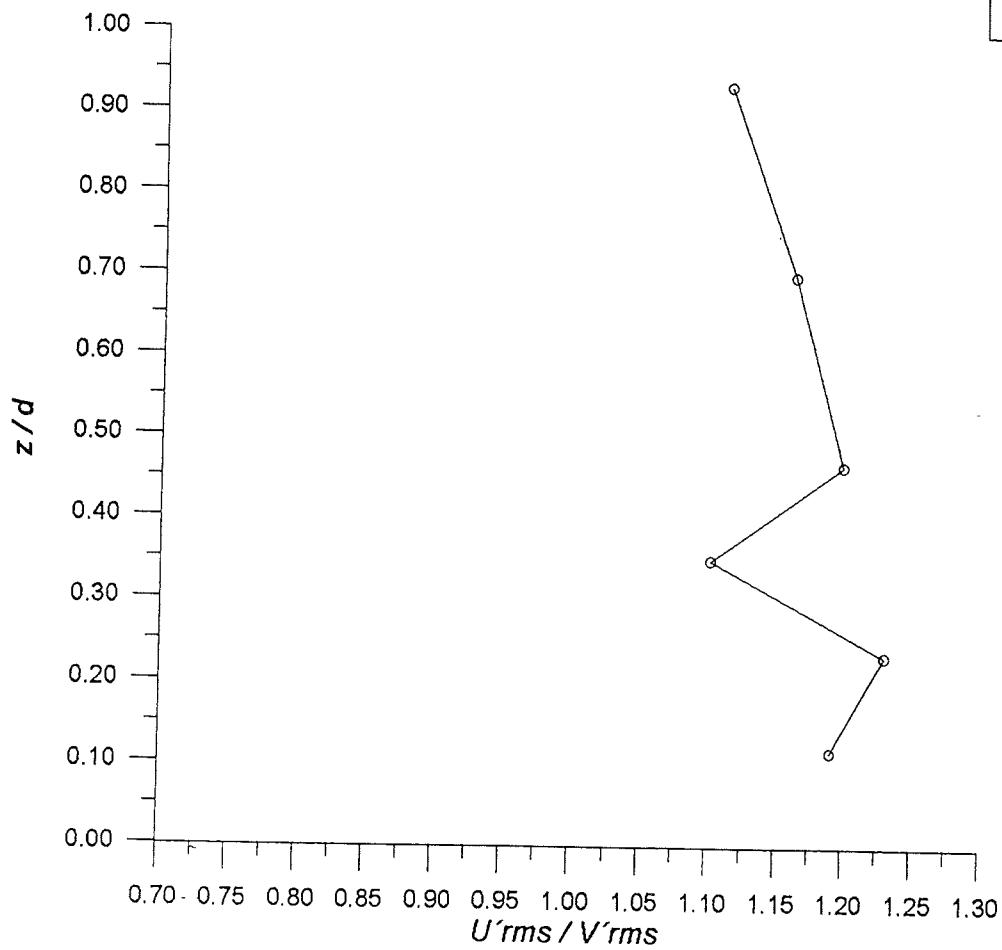
TEST 5



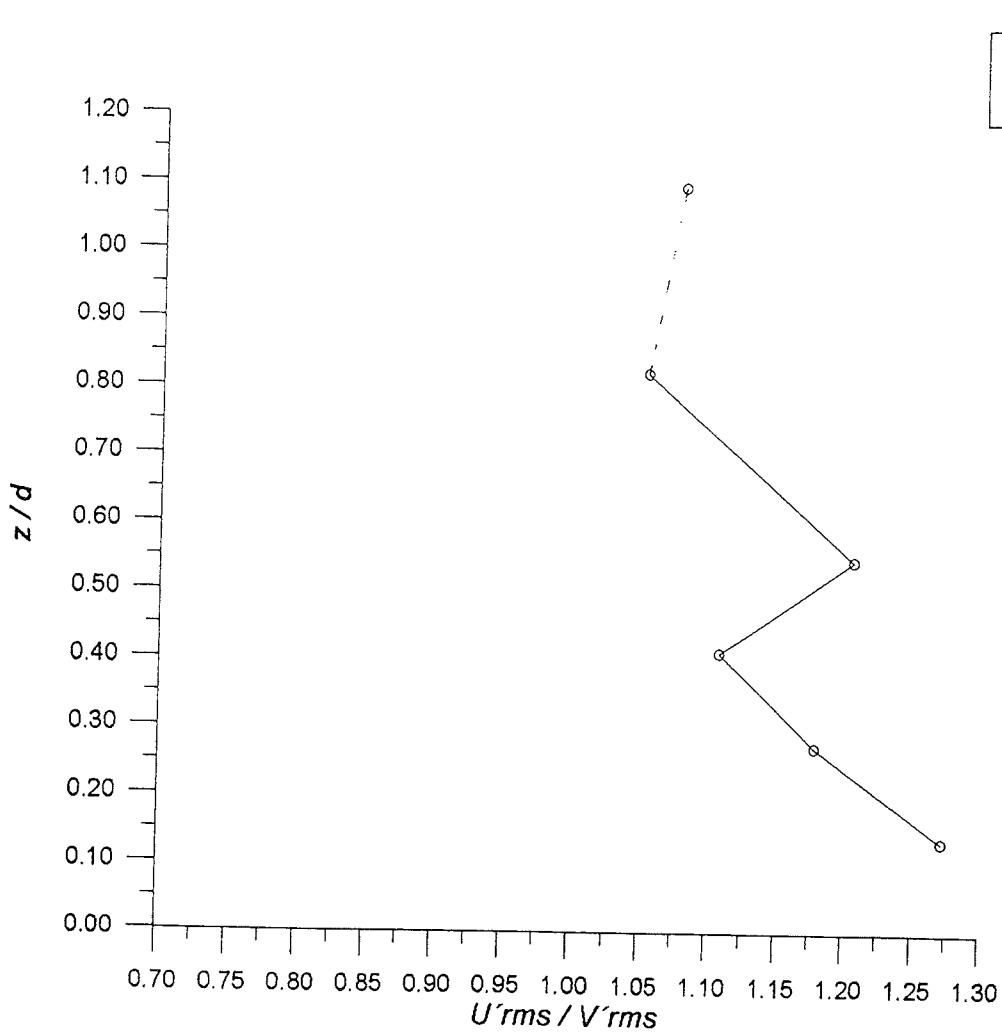
TEST 6a



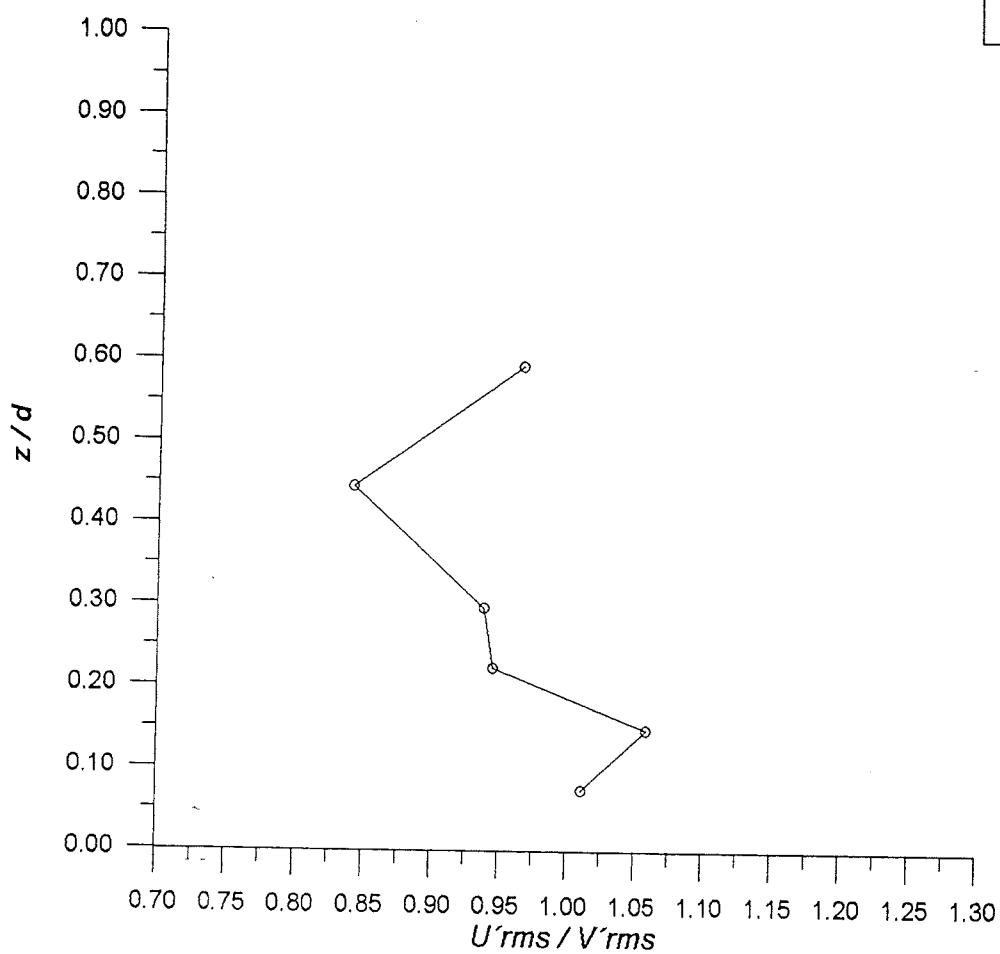
TEST 6b



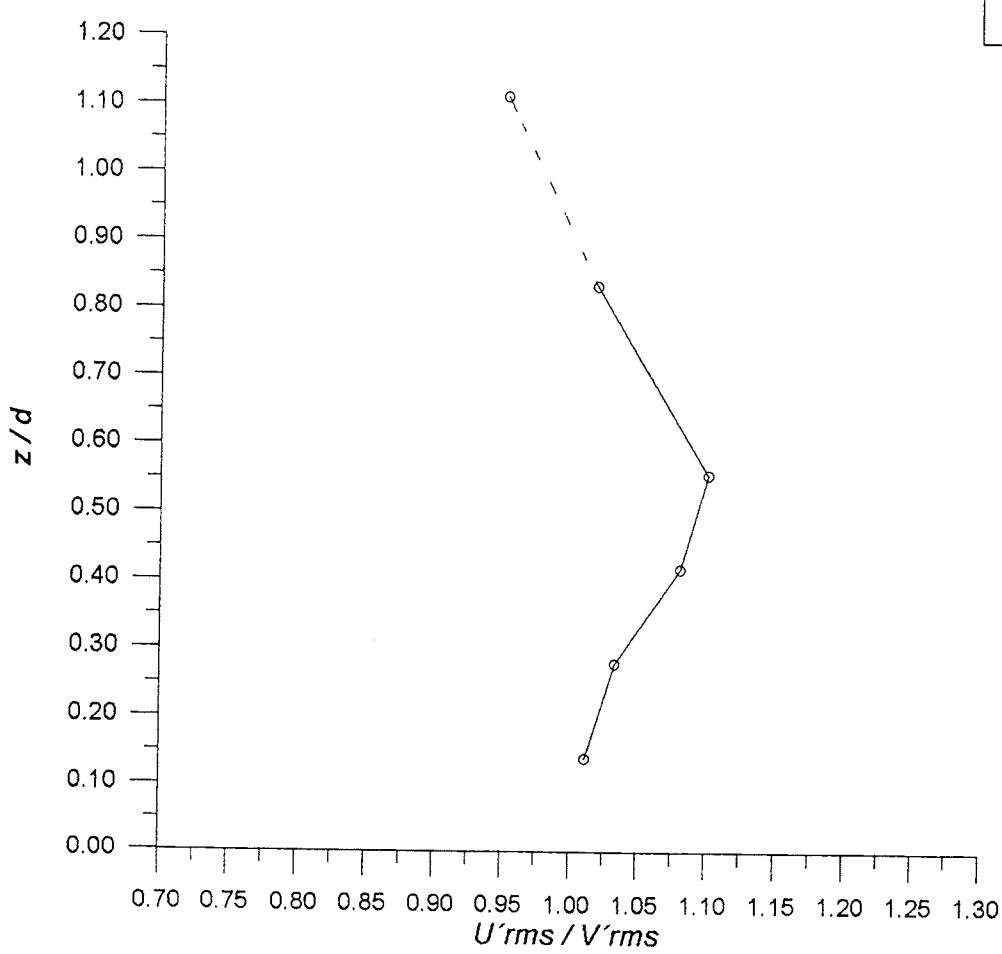
TEST 7



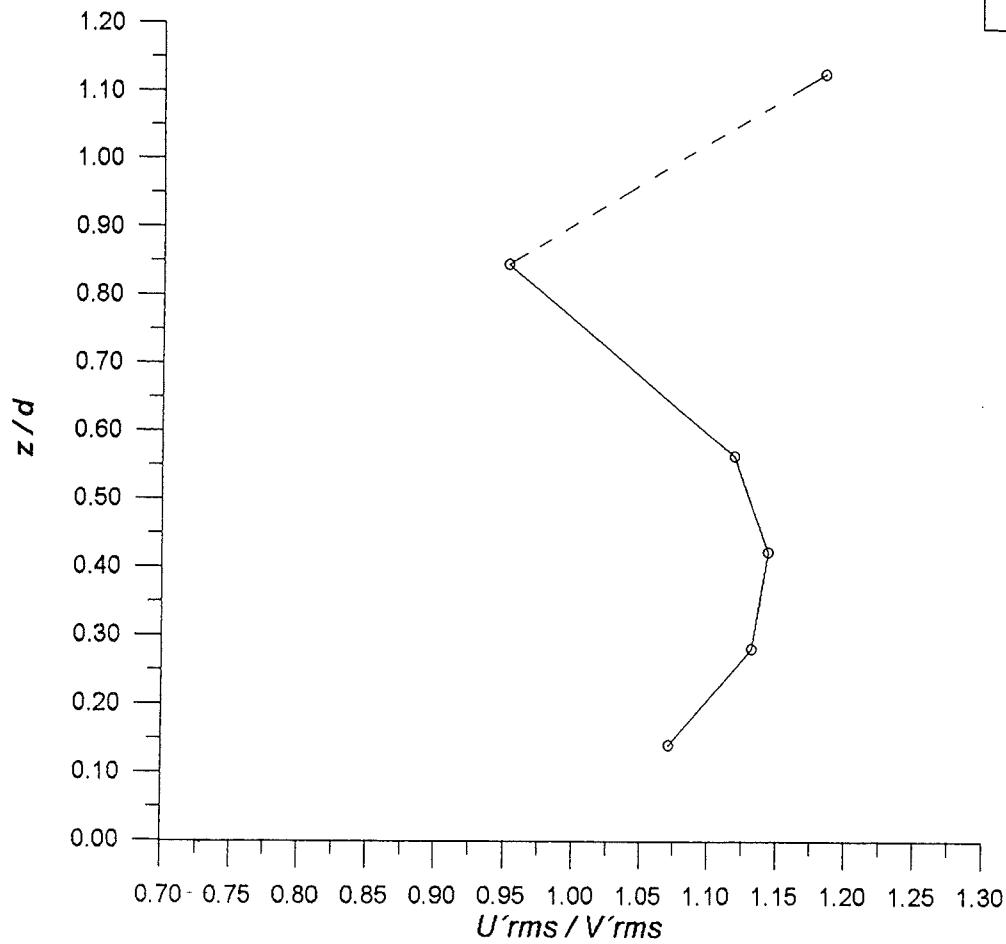
TEST 8



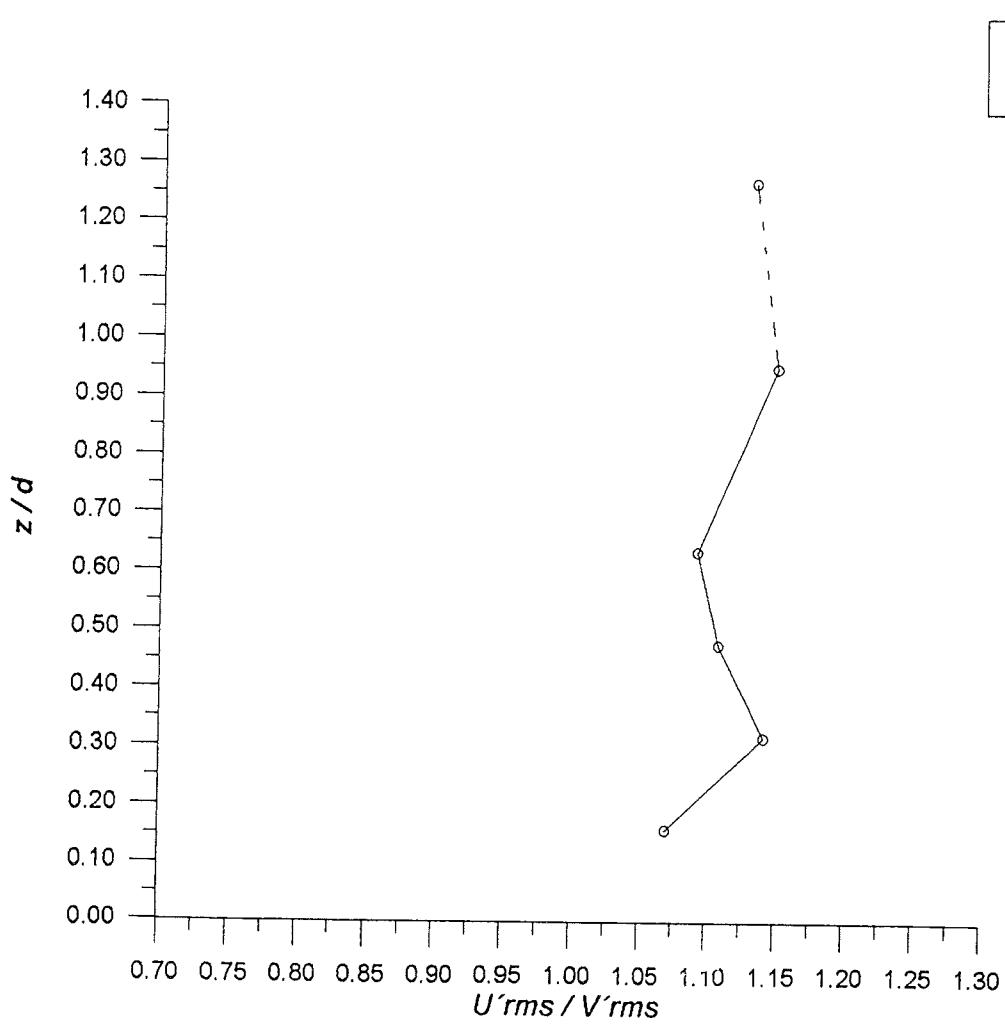
TEST 9



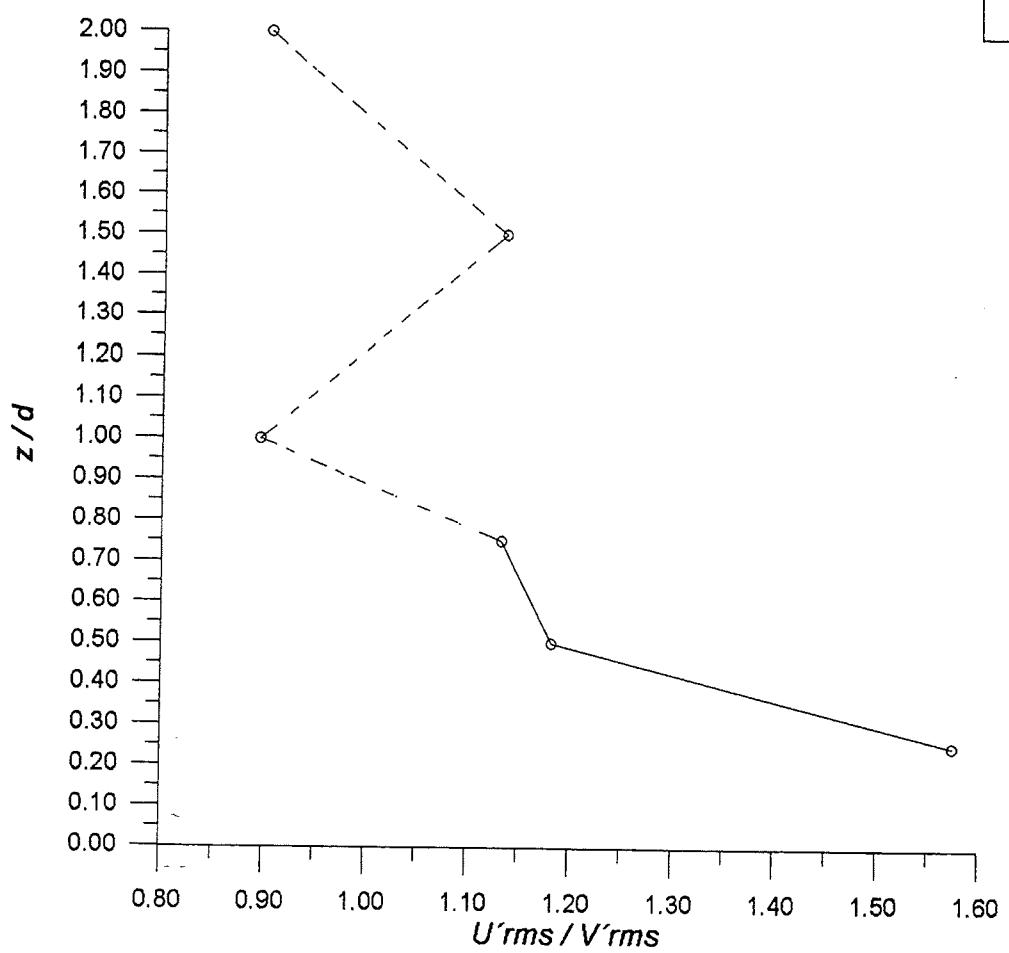
TEST 10

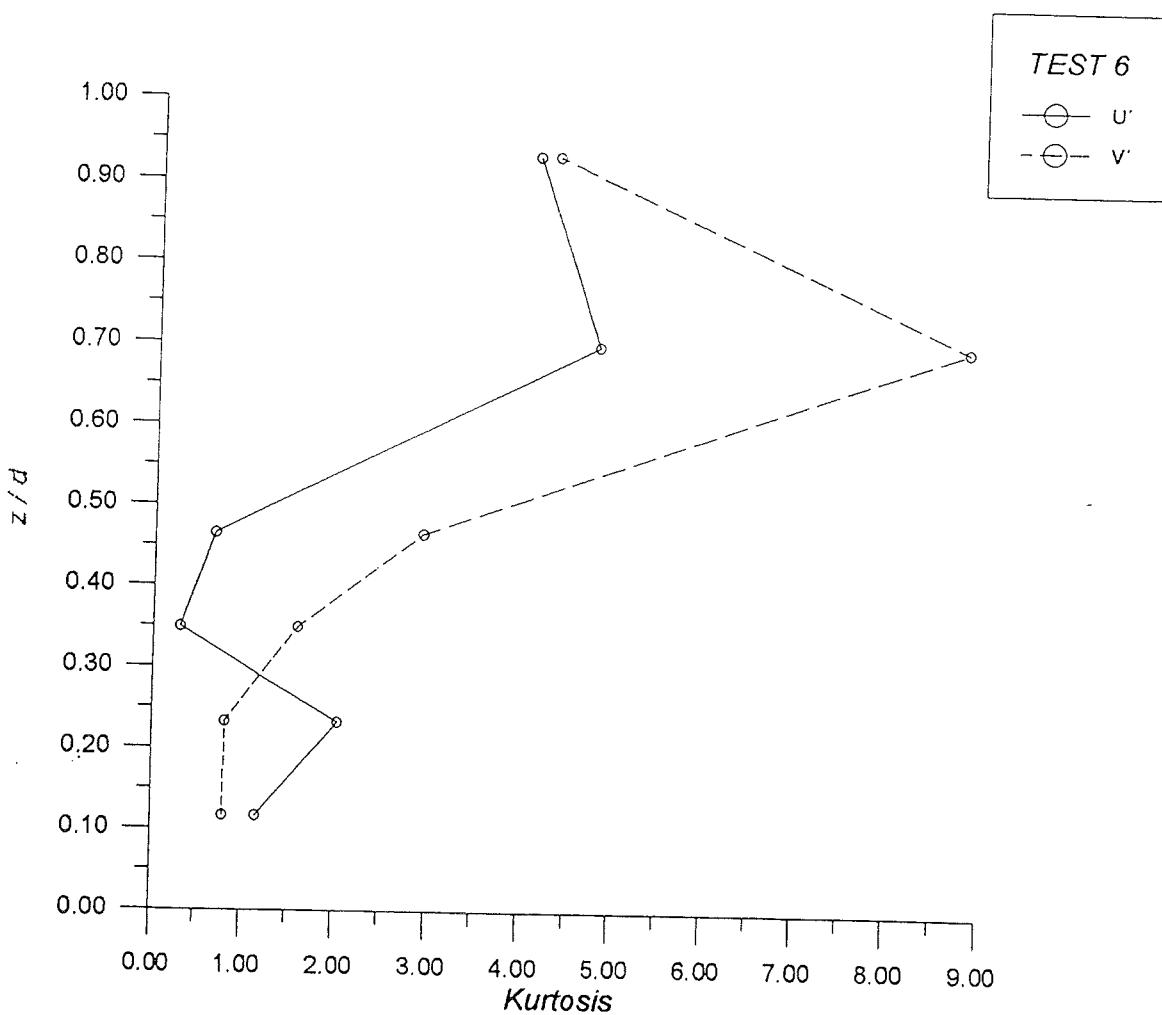
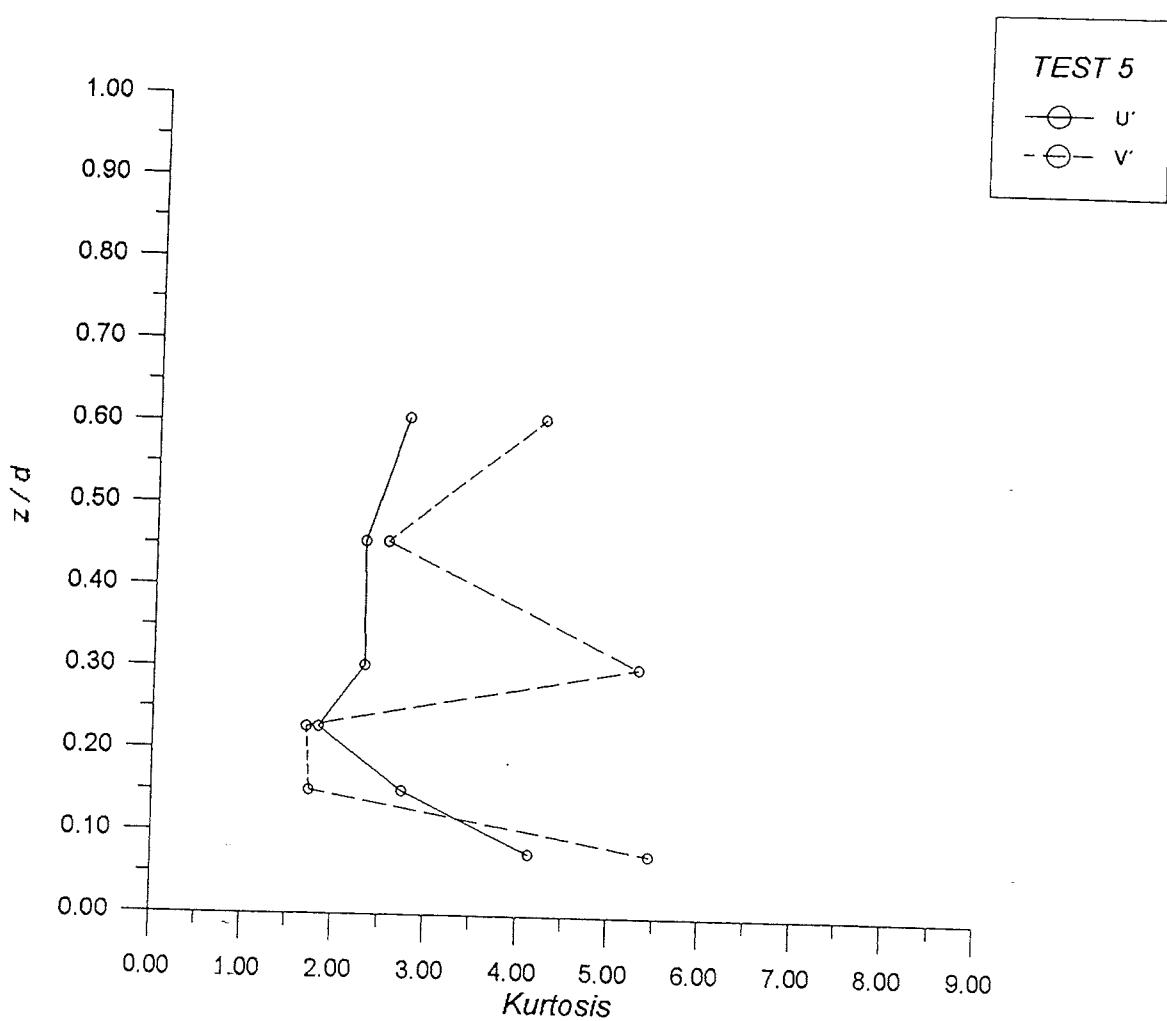


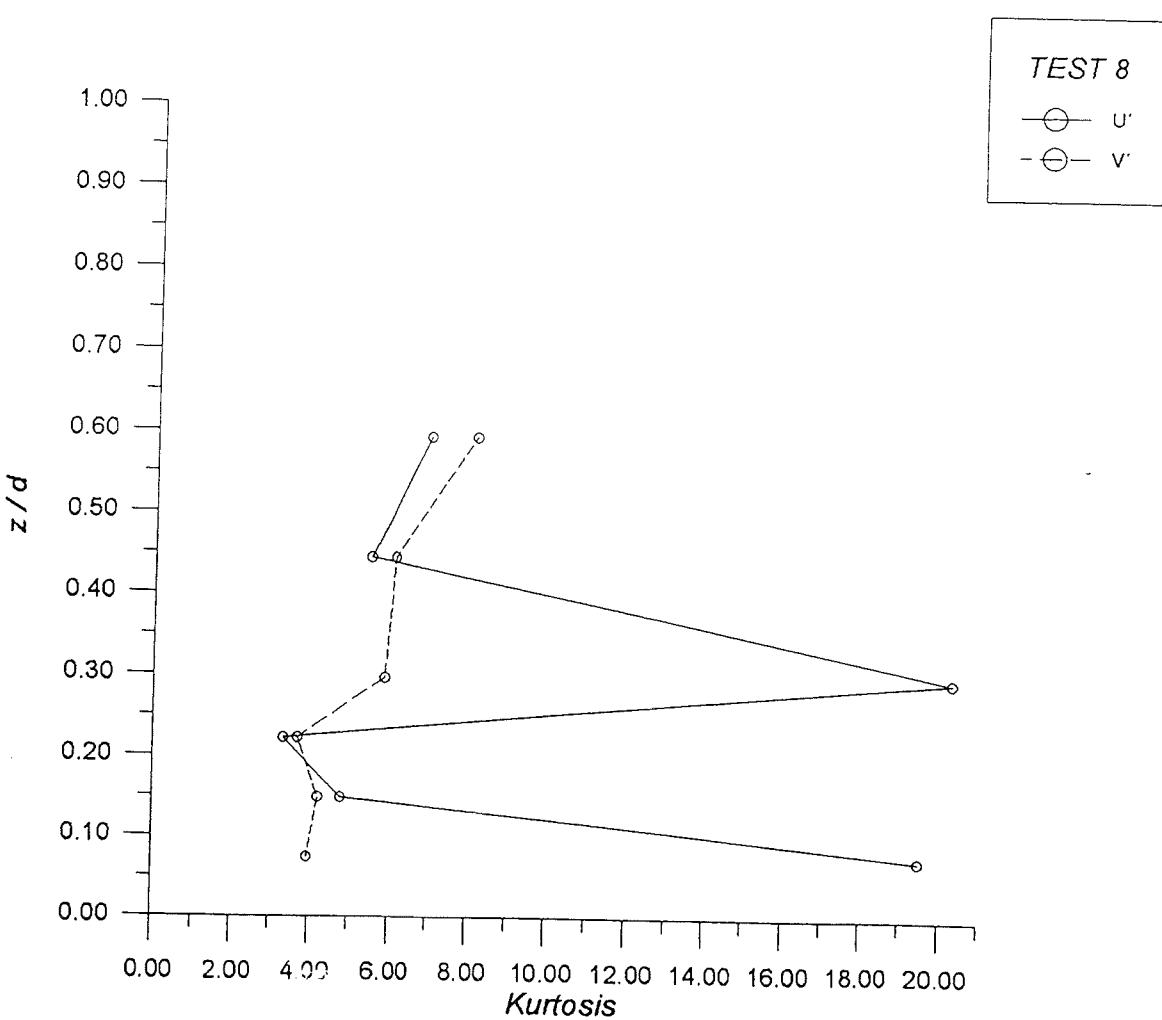
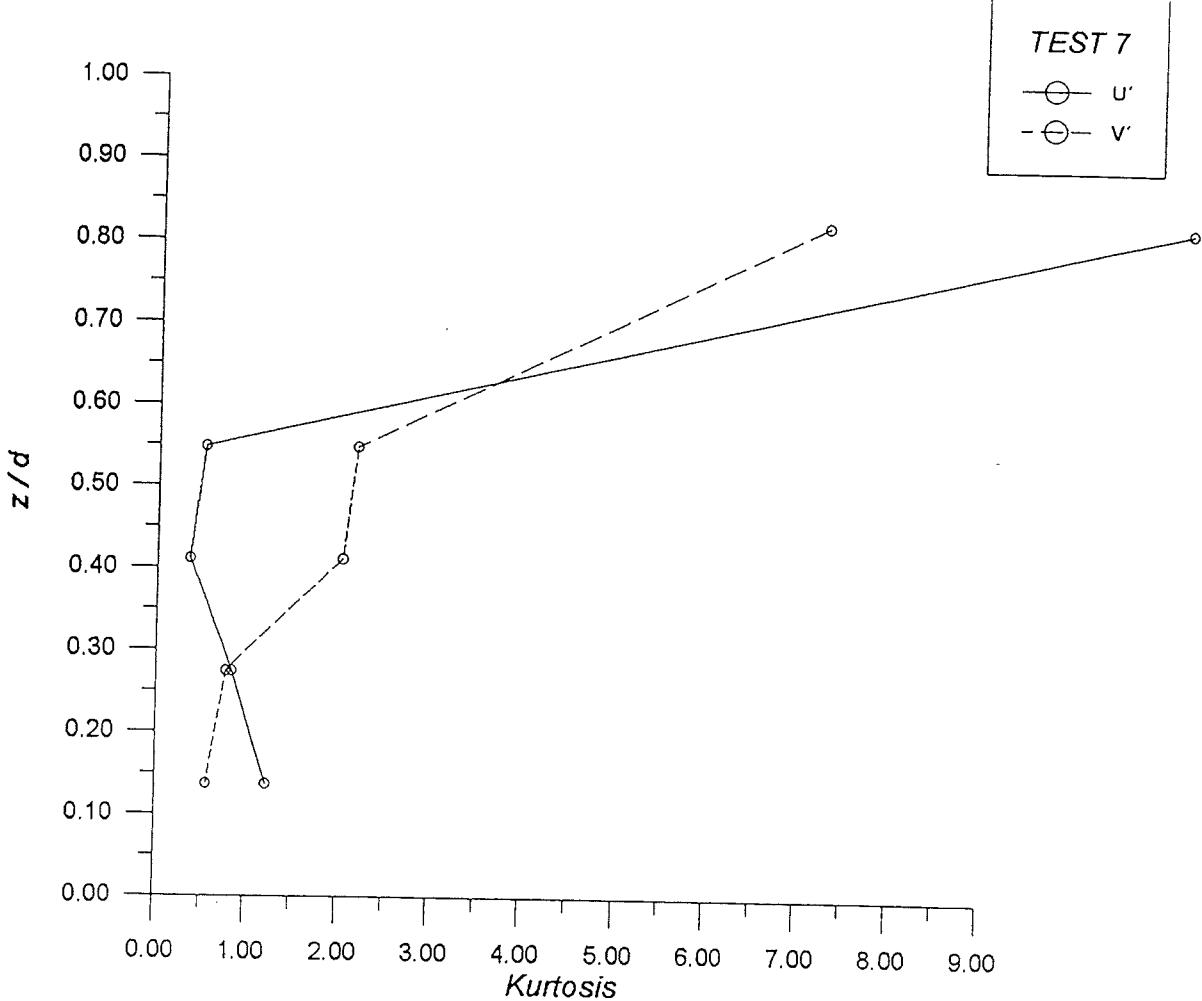
TEST 11

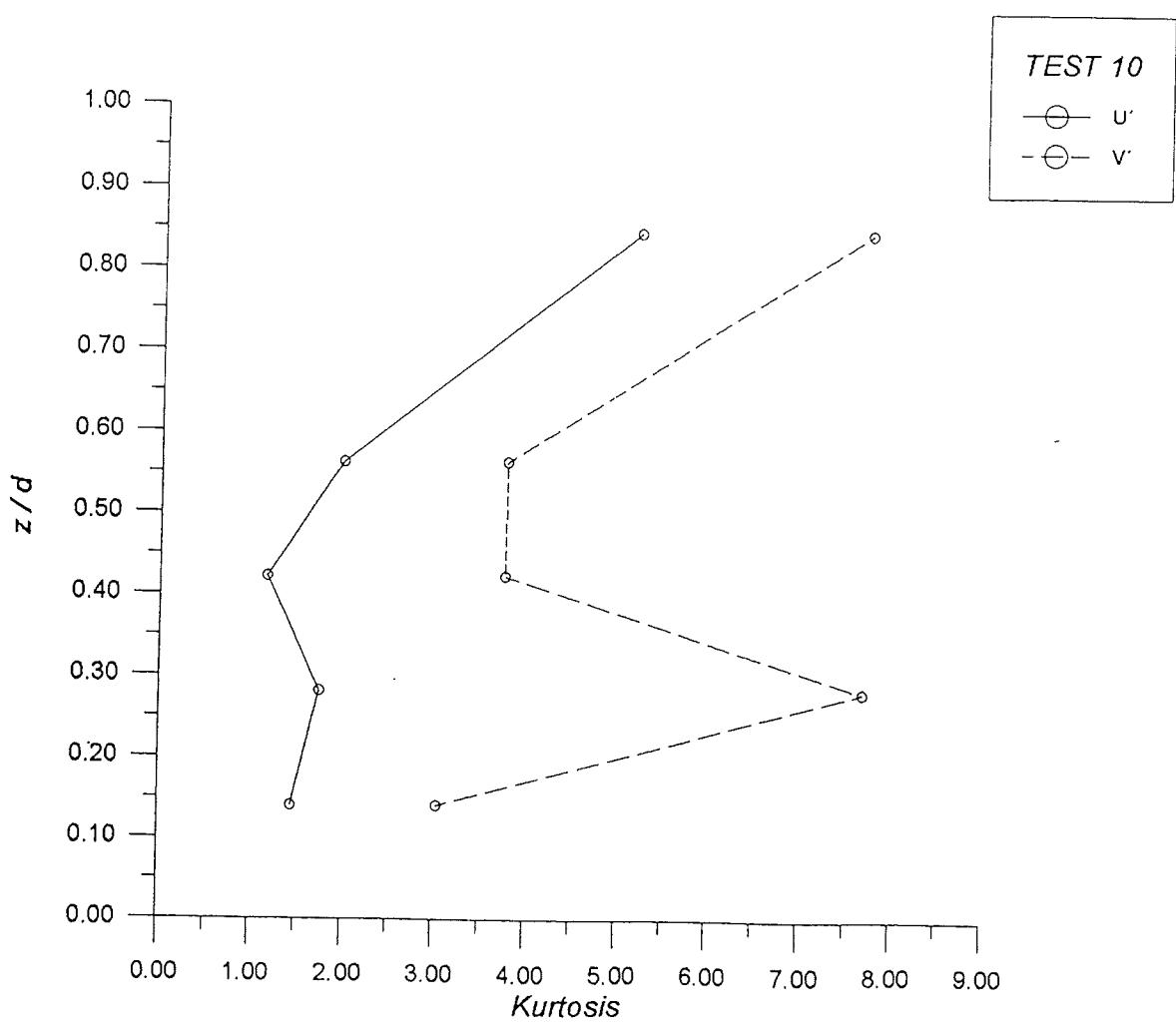
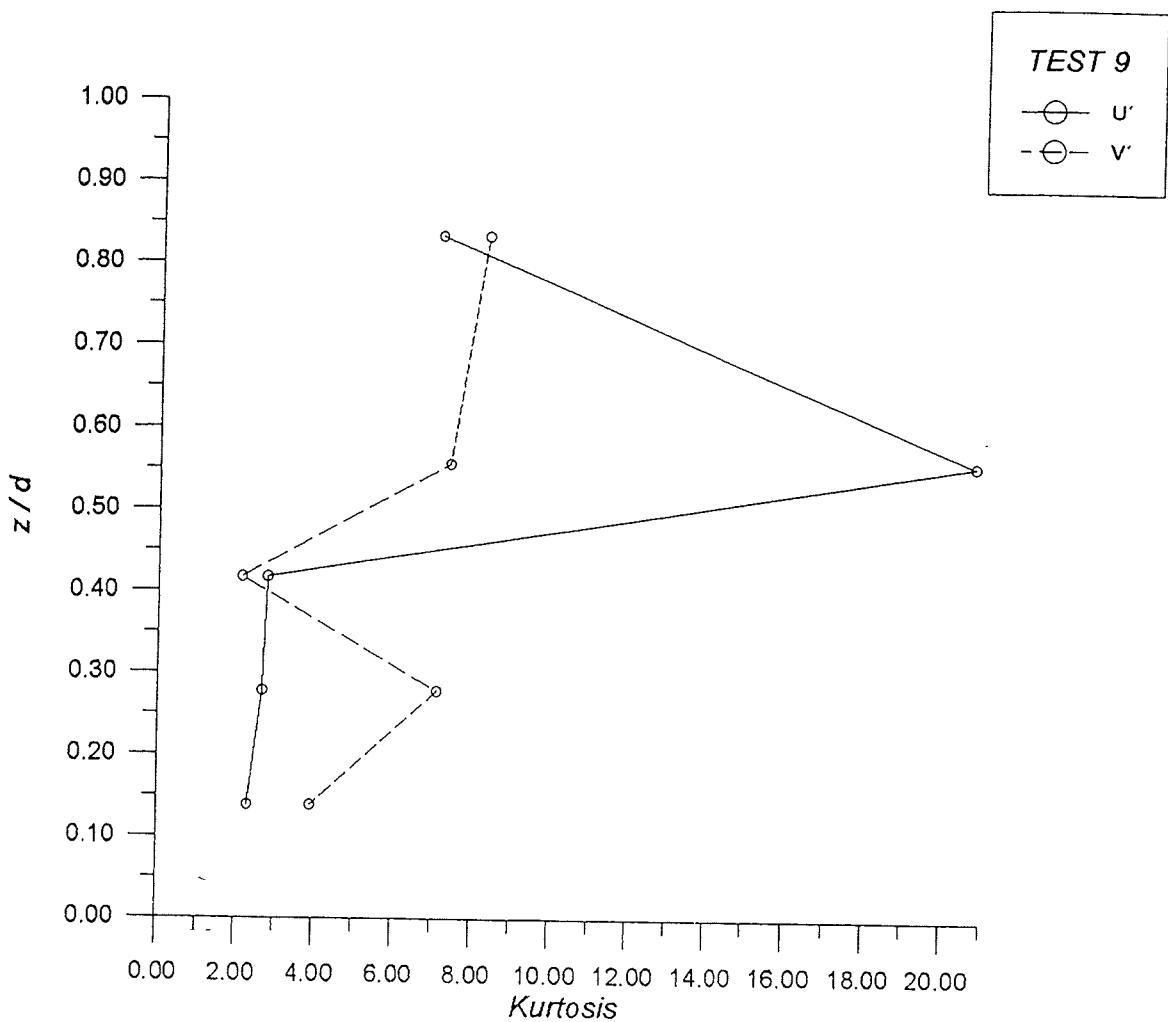


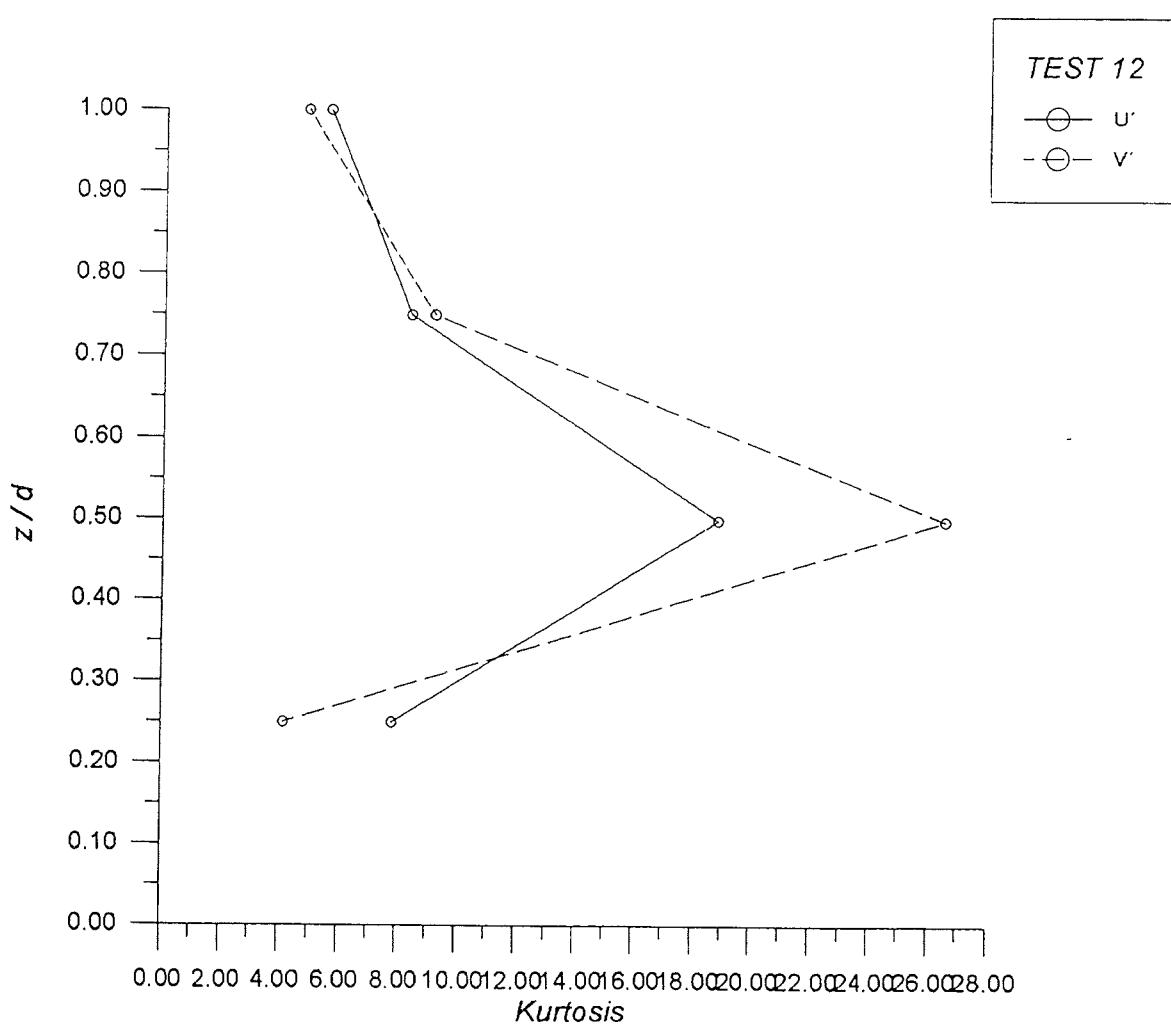
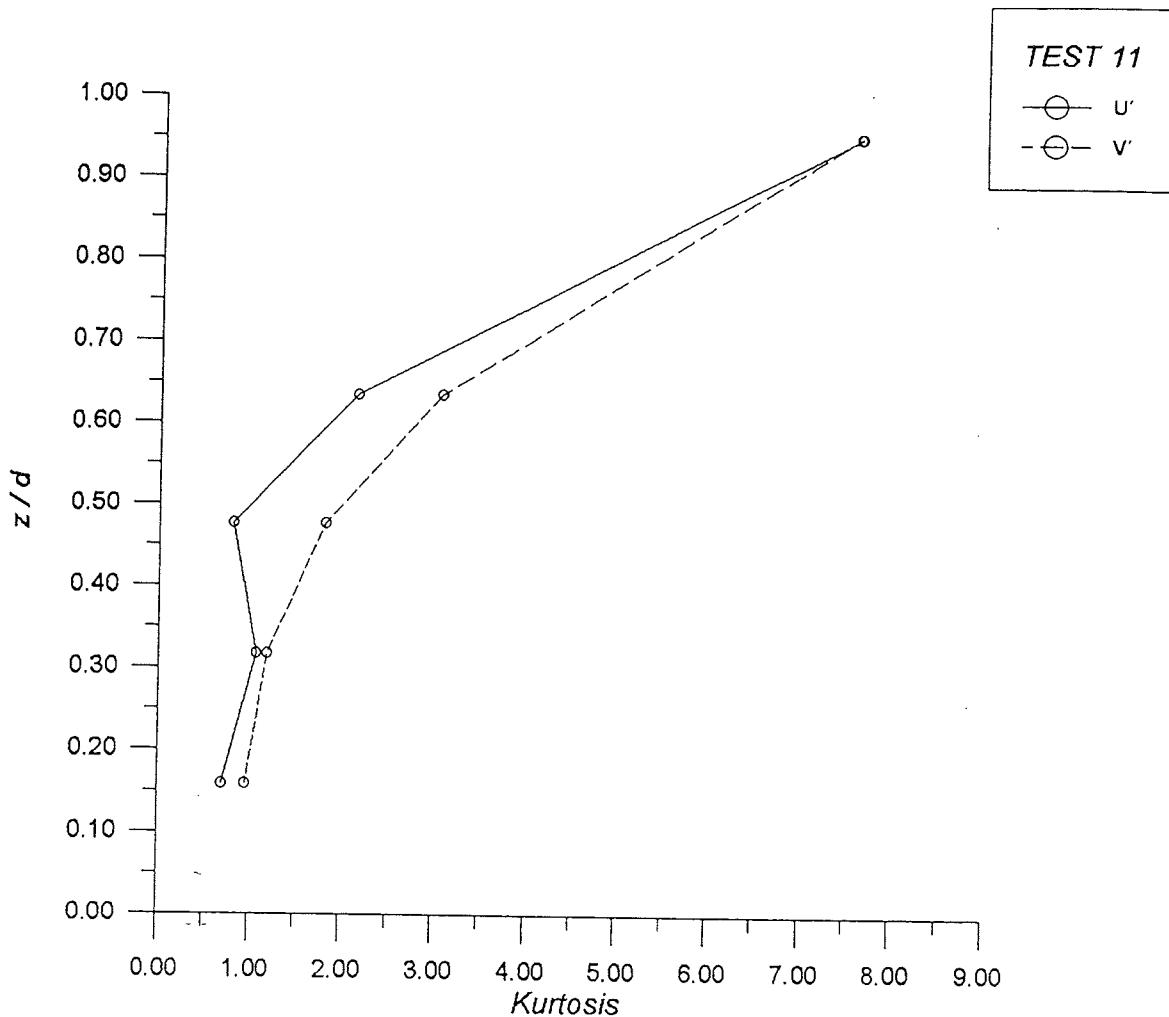
TEST 12

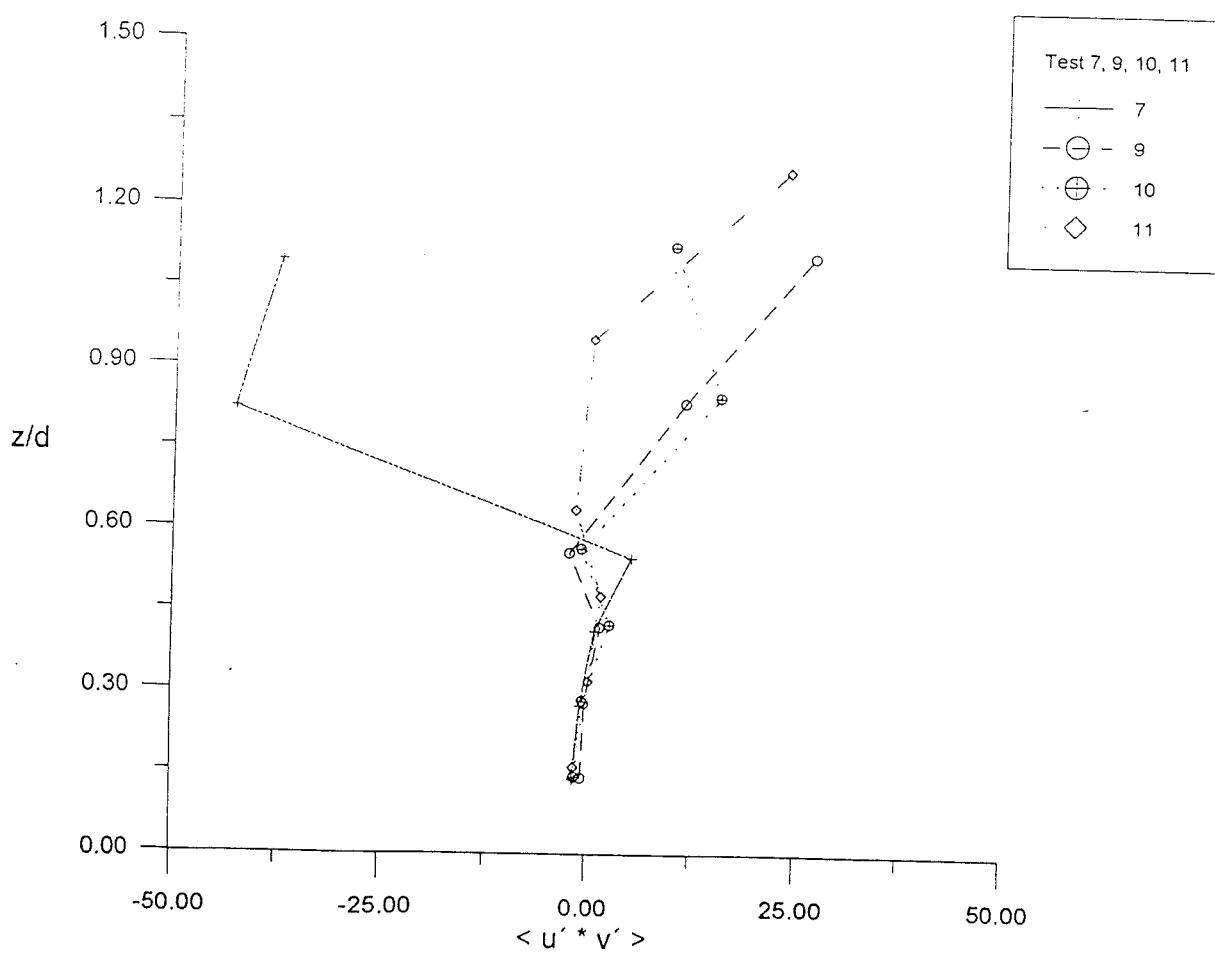
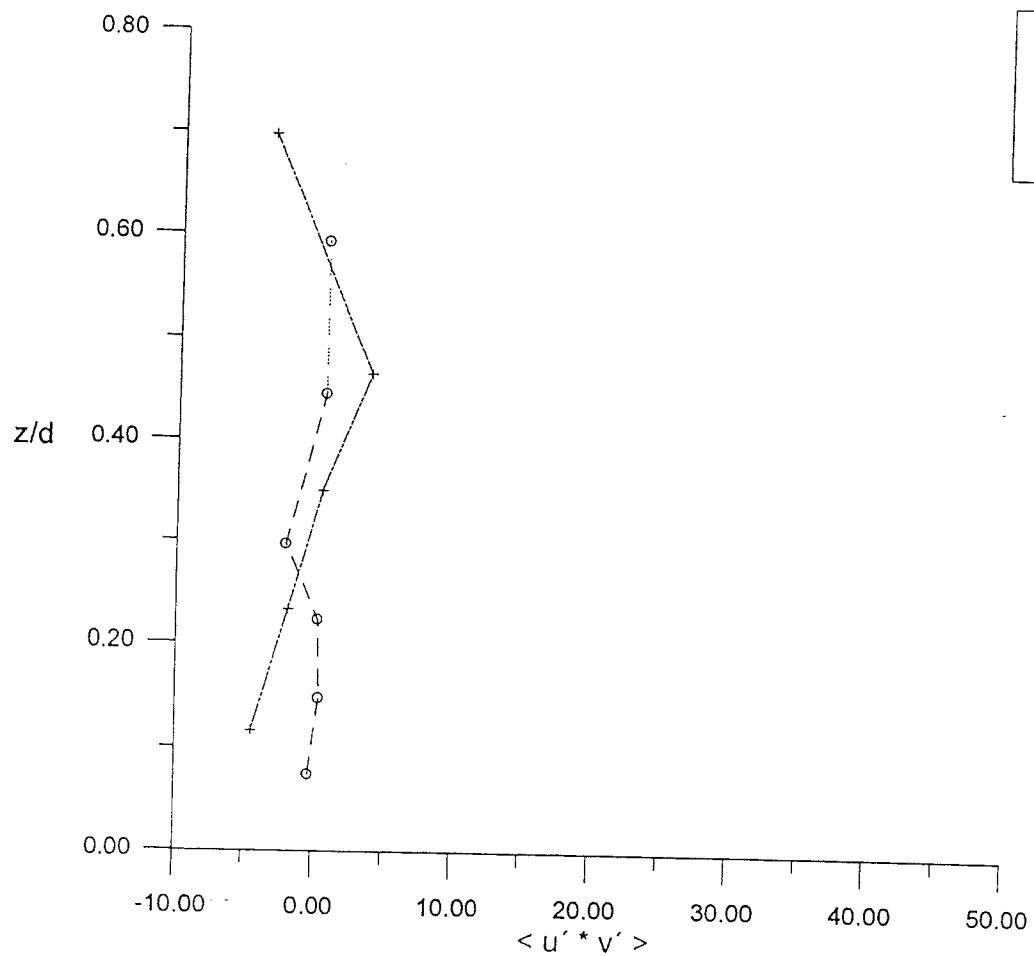


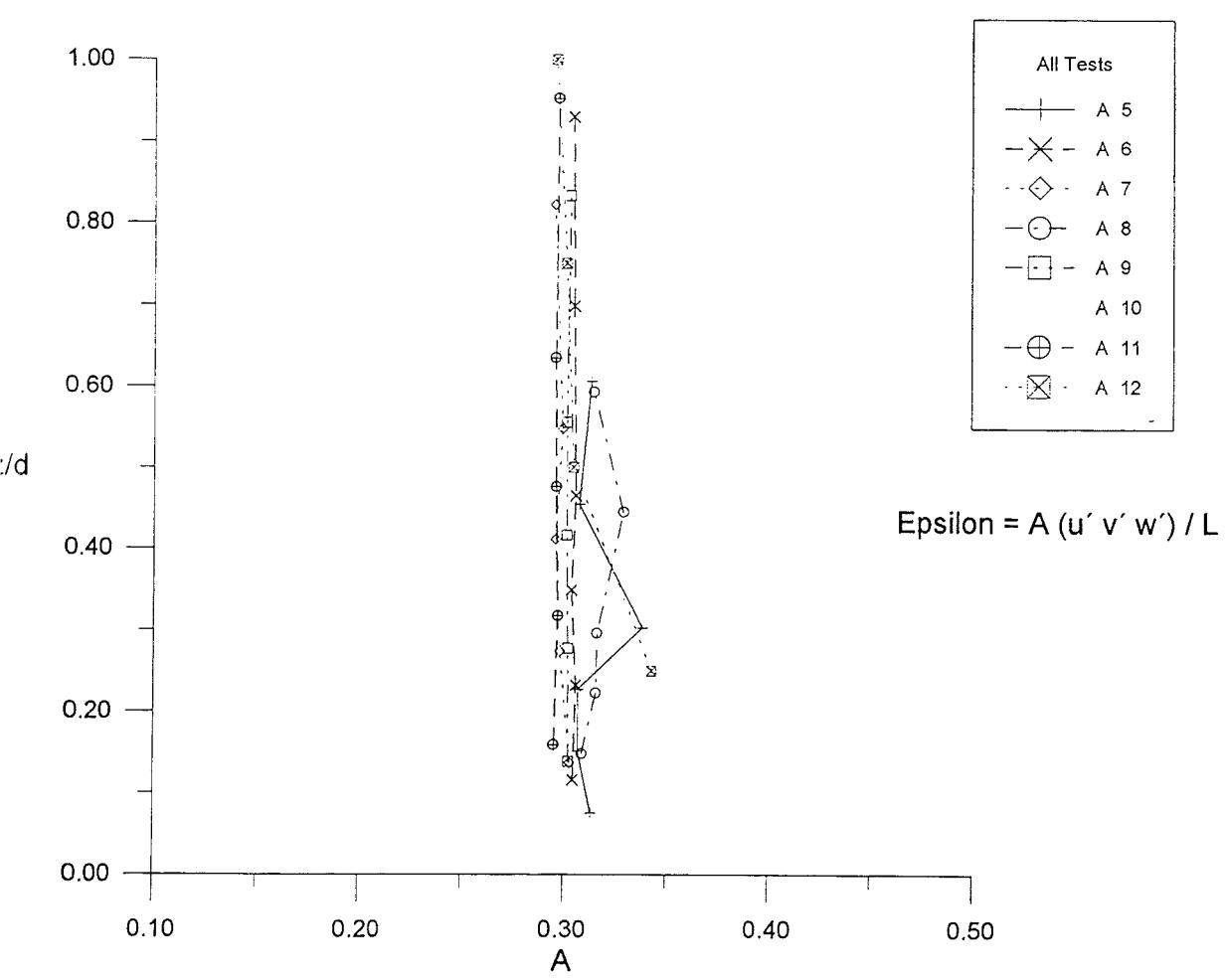
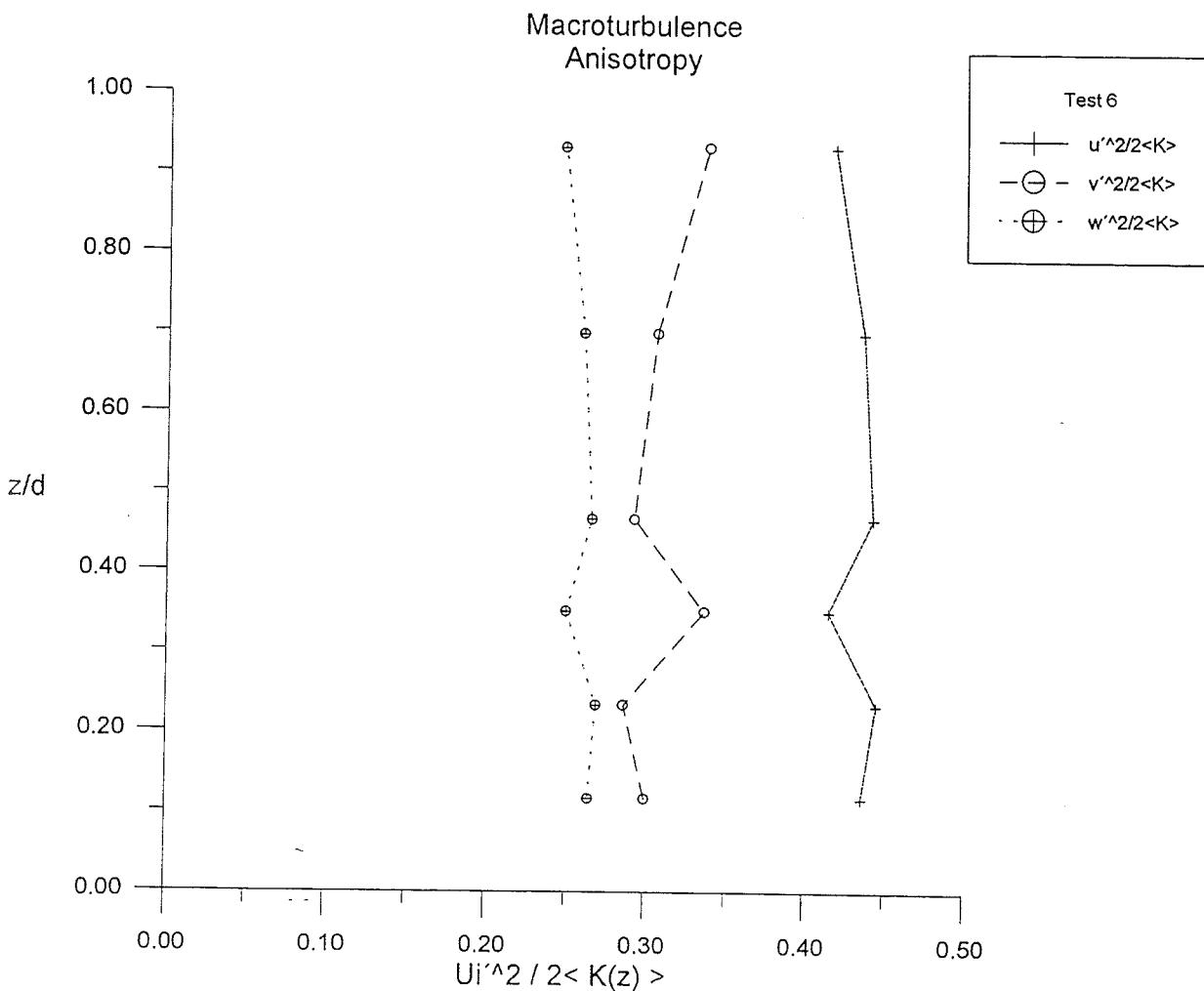


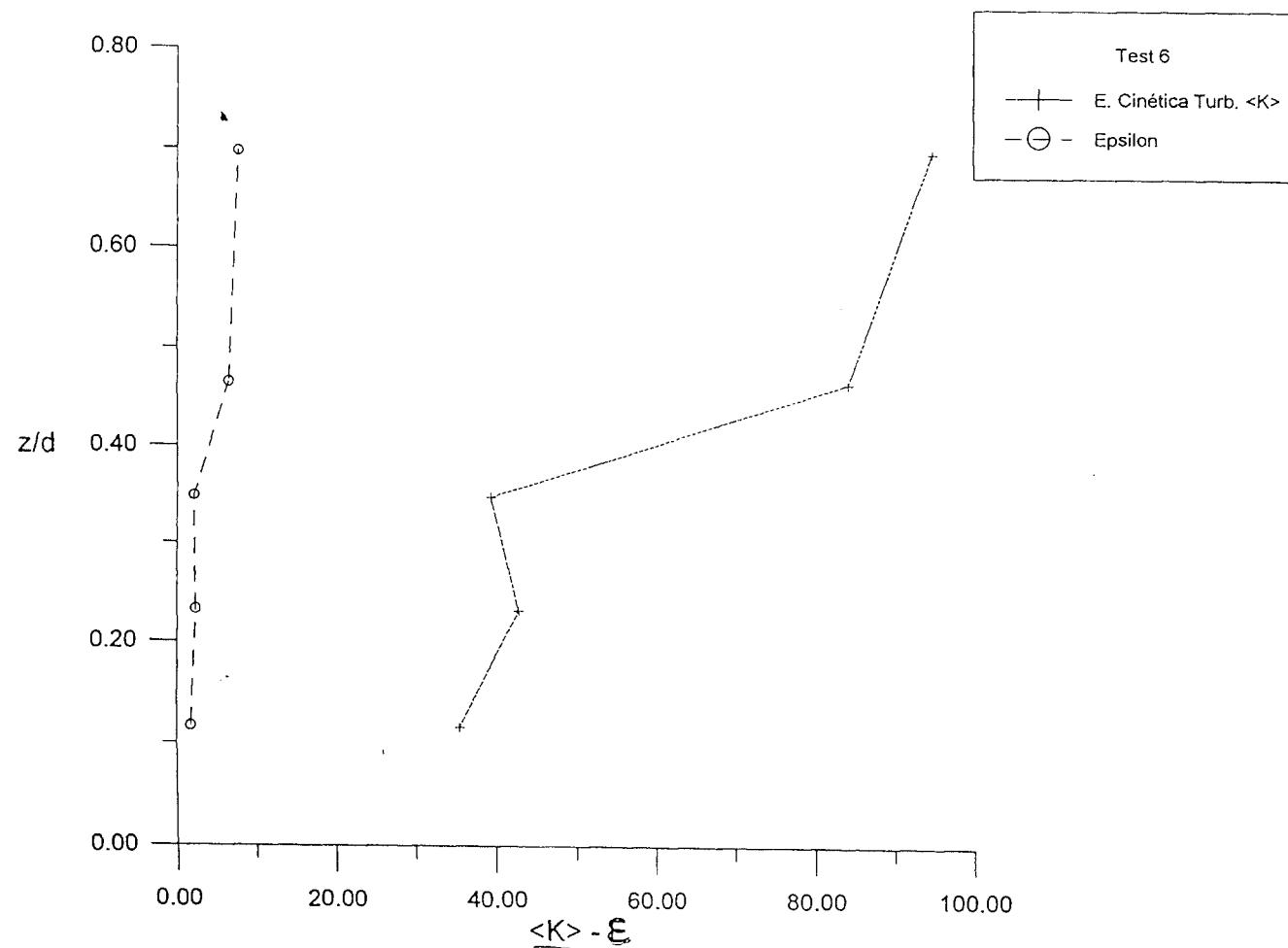


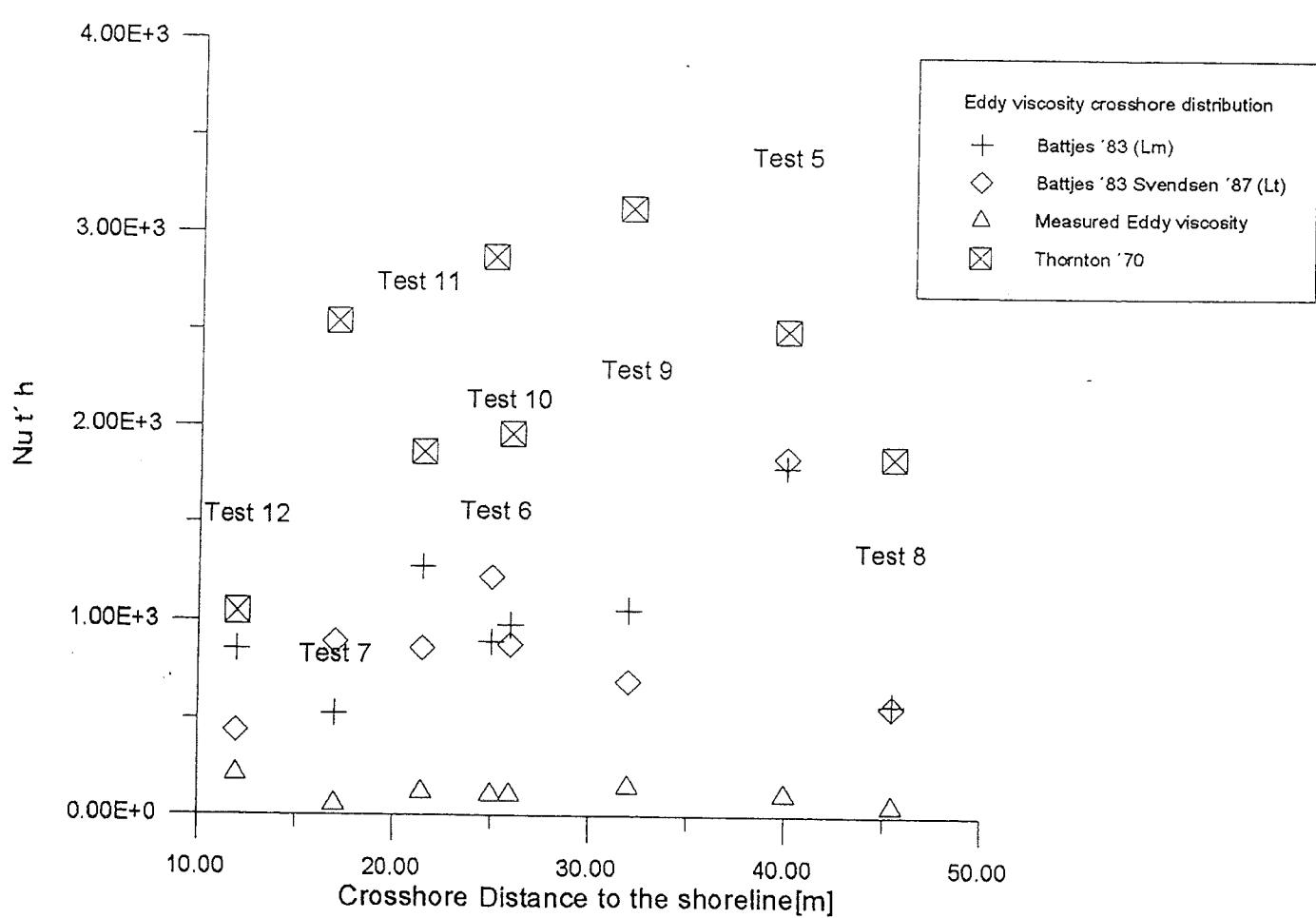
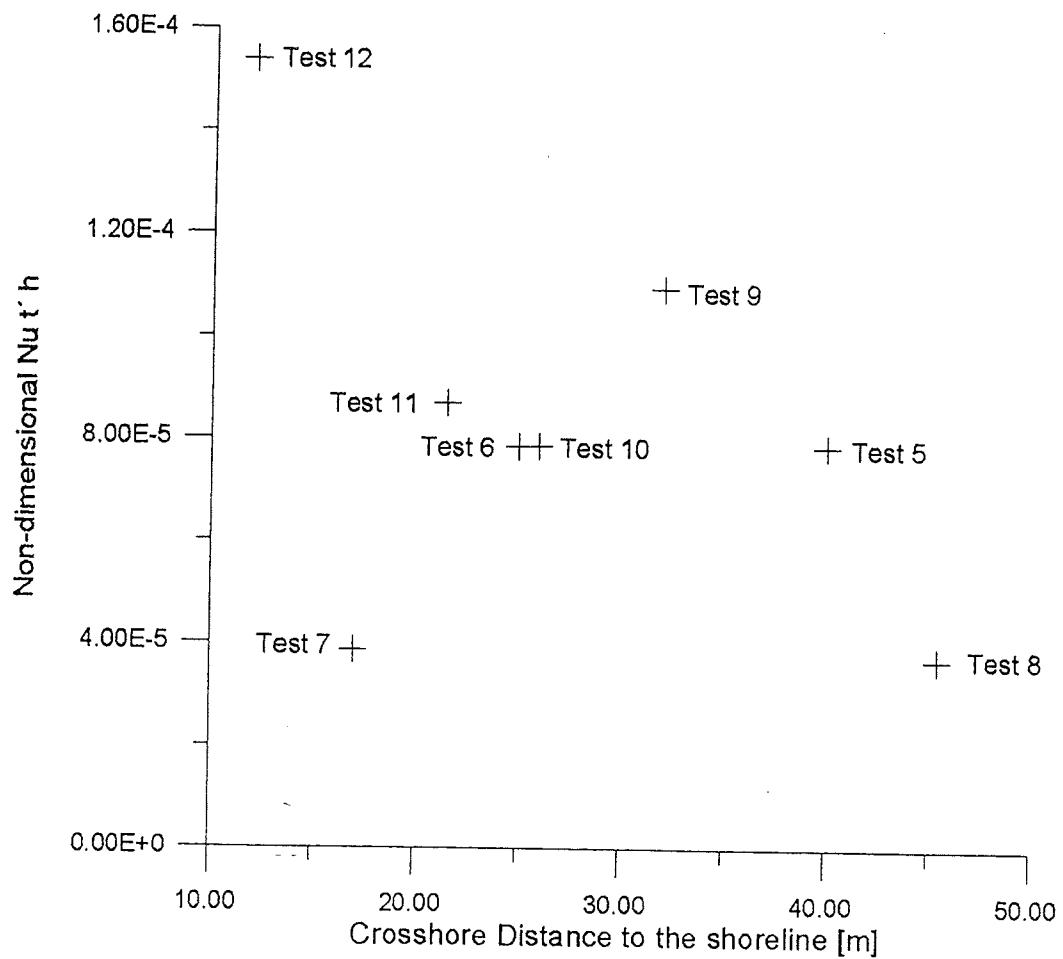


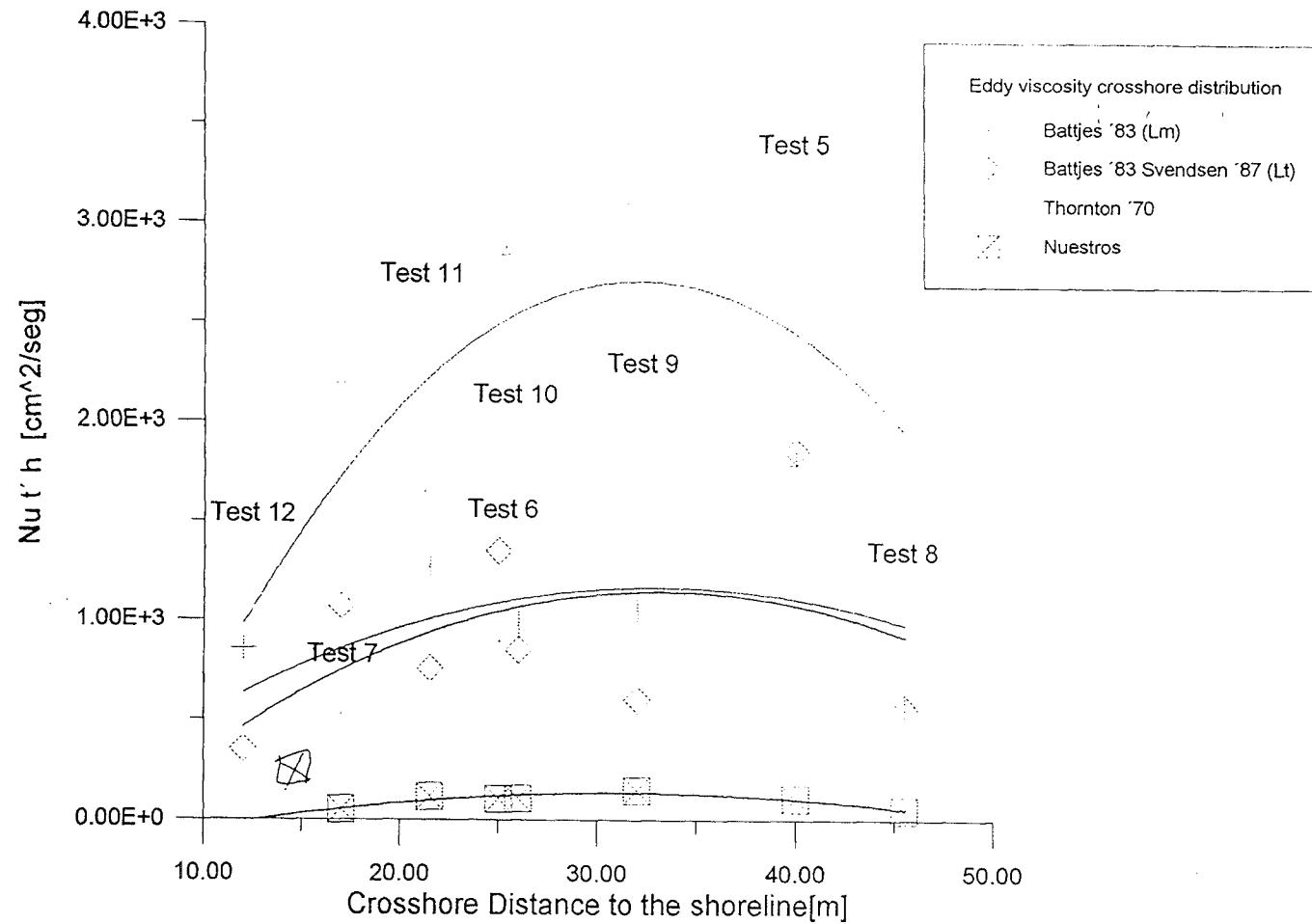


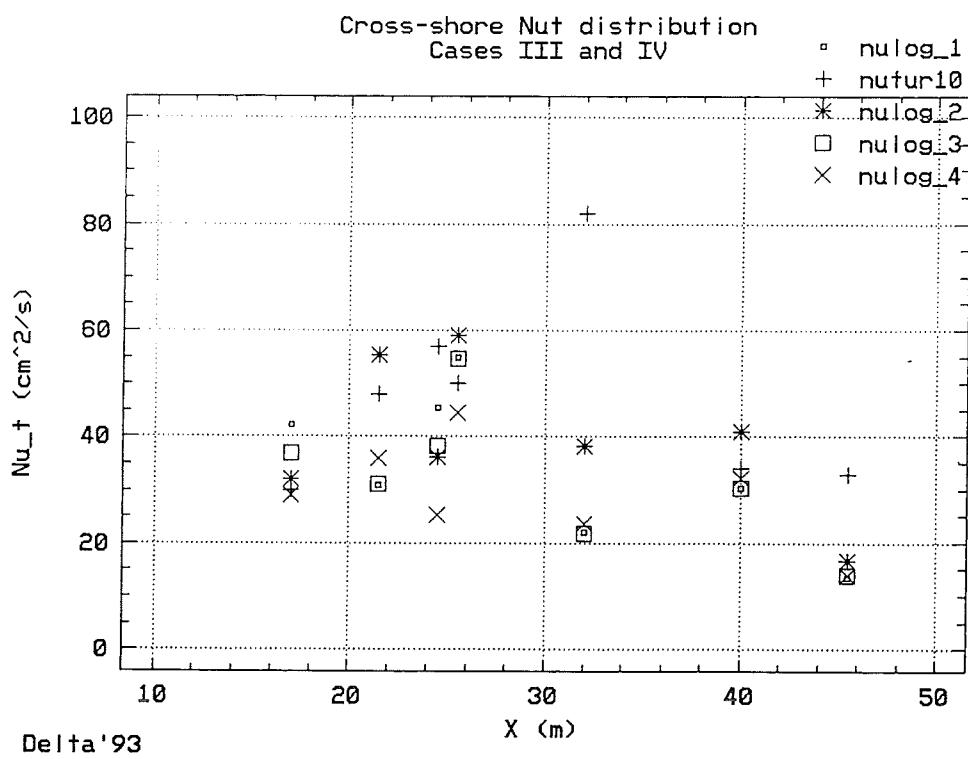
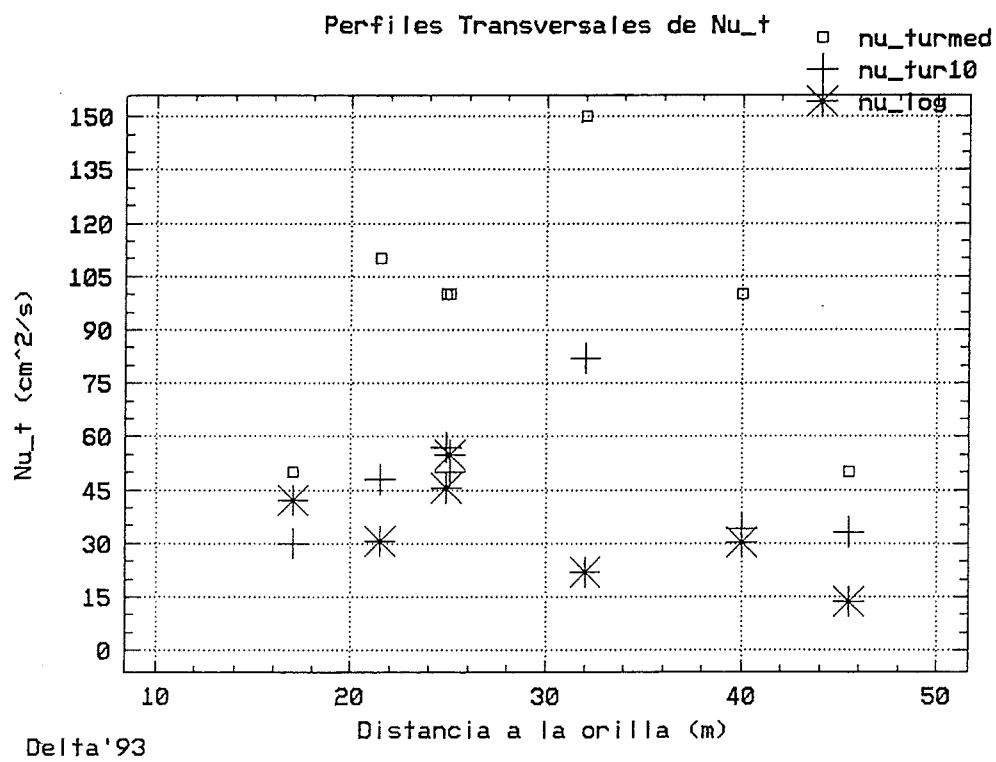








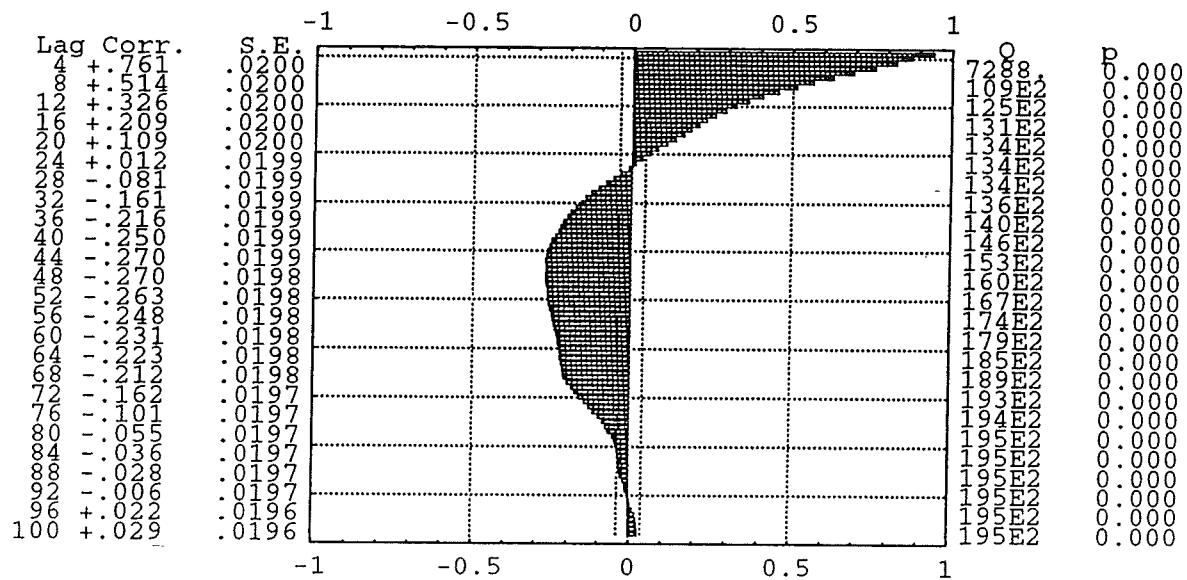




Turbulent Velocities from EMC and SONTEC

Test 1

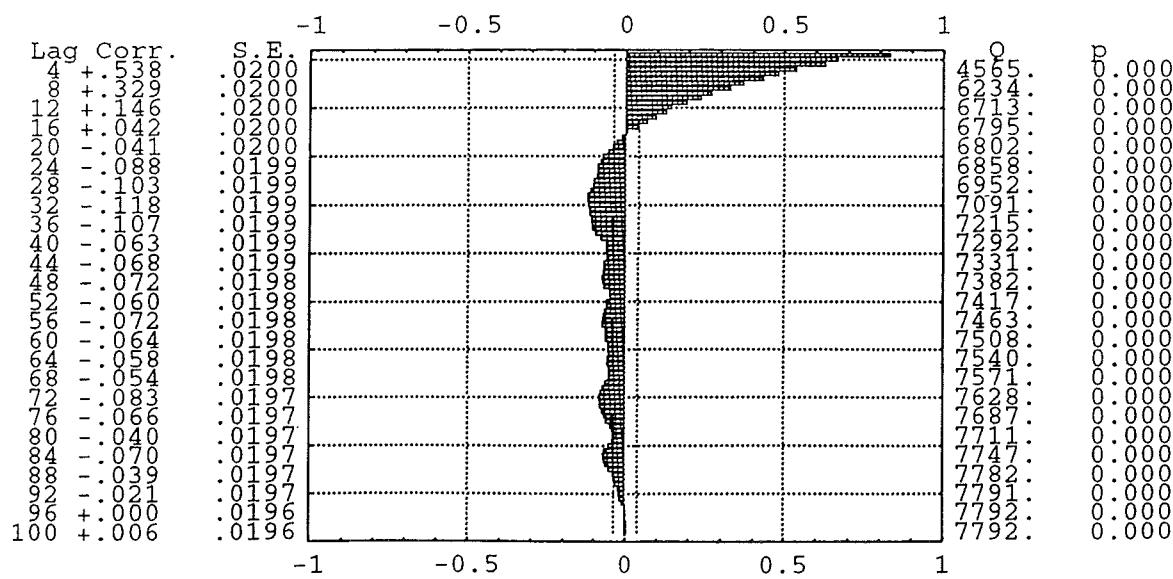
EMC



Turbulent Velocities from EMC and SONTEC

Test 1

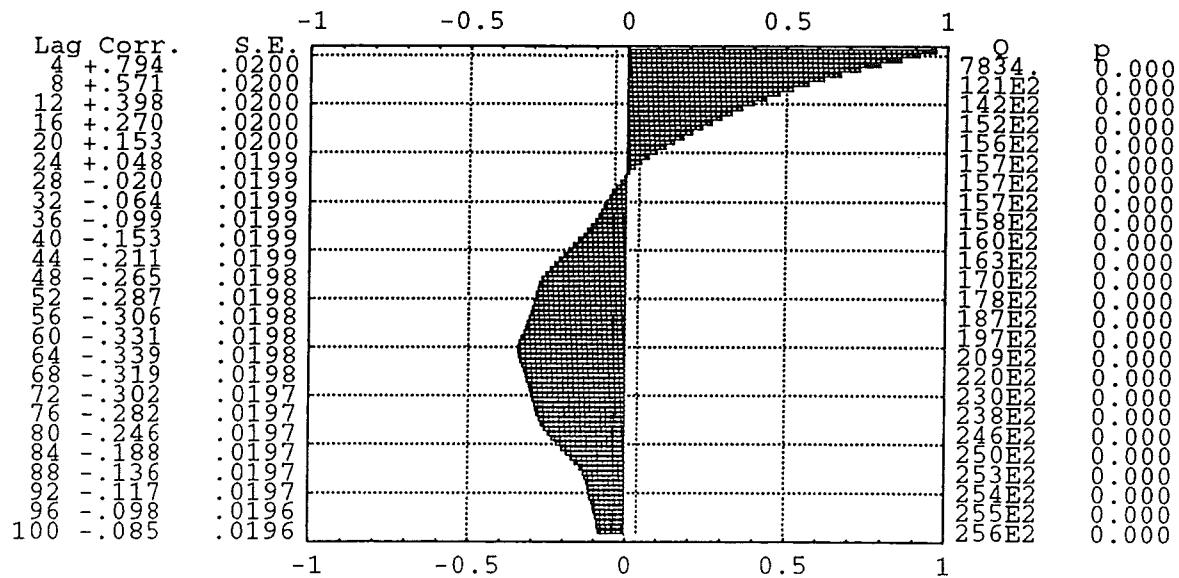
SONTEC



Turbulent Velocities from EMC and SONTEC

Test 2

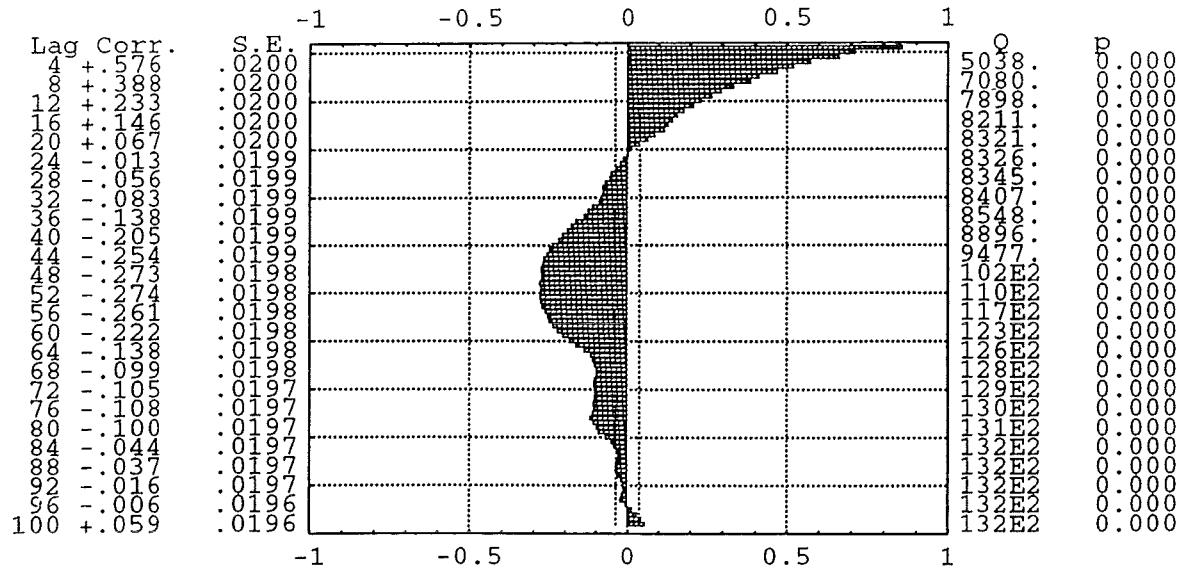
EMC



Turbulent Velocities from EMC and SONTEC

Test 2

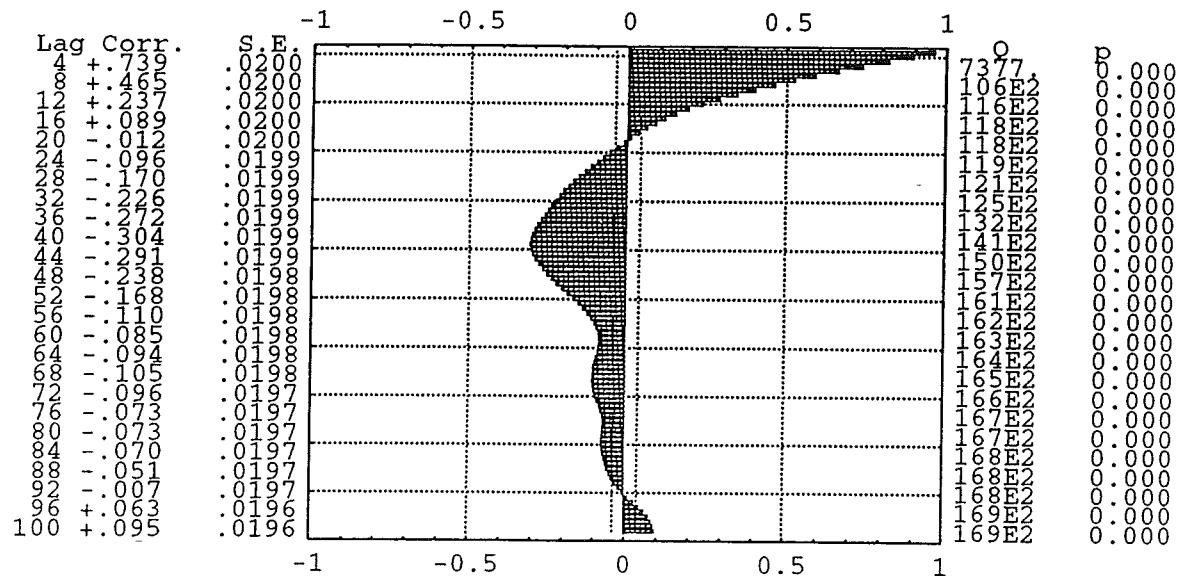
SONTEC



Turbulent Velocities from EMC and SONTEC

Test 3

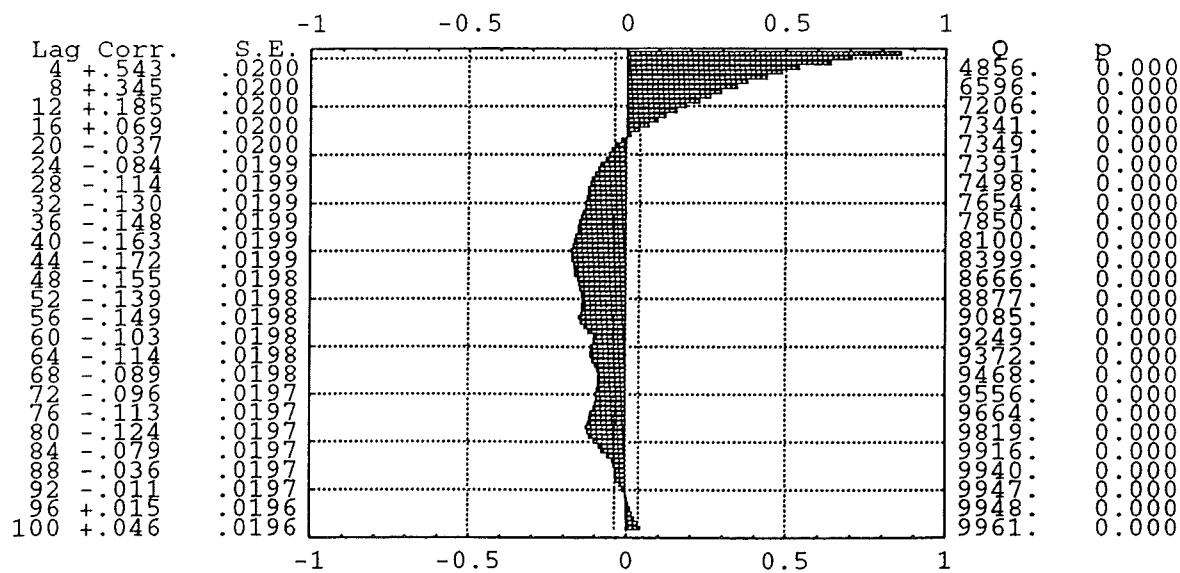
EMC



Turbulent Velocities from EMC and SONTEC

Test 3

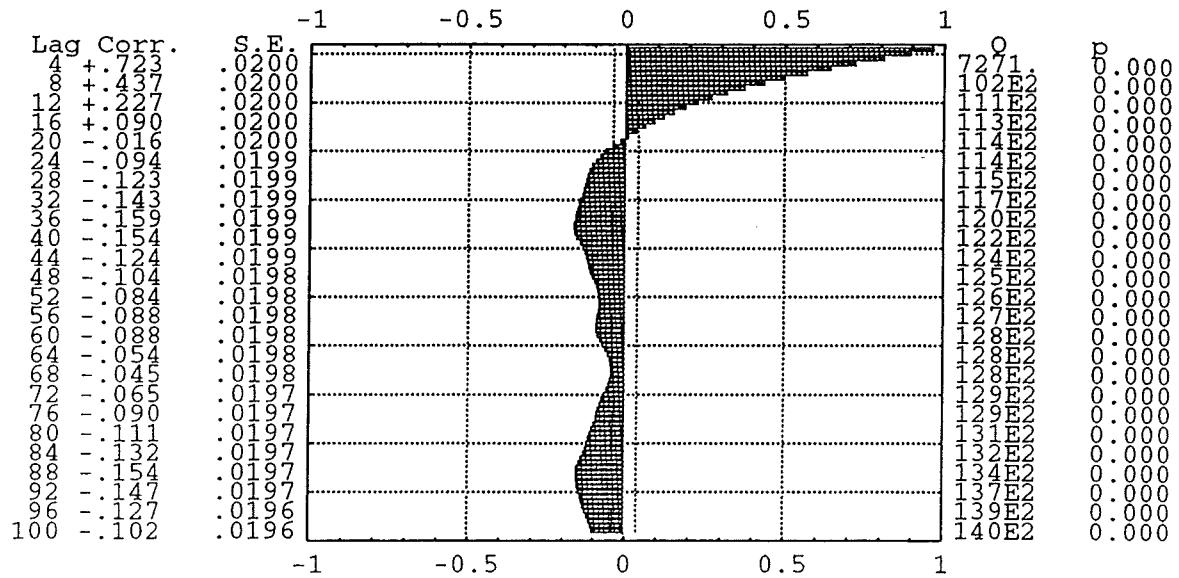
SONTEC



Turbulent Velocities from EMC and SONTEC

Test 4

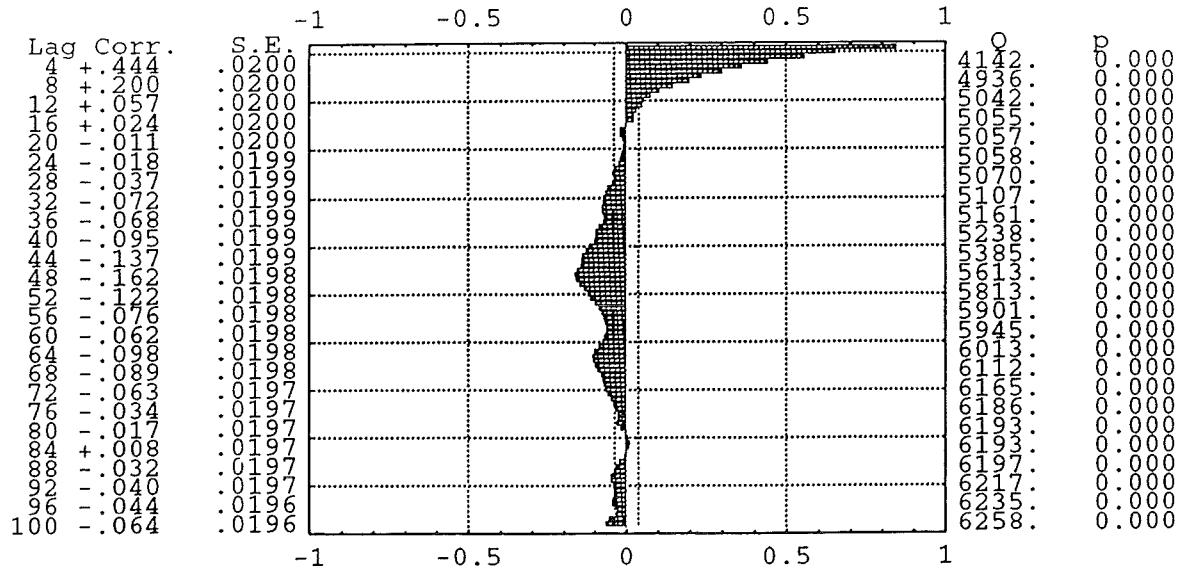
EMC



Turbulent Velocities from EMC and SONTEC

Test 4

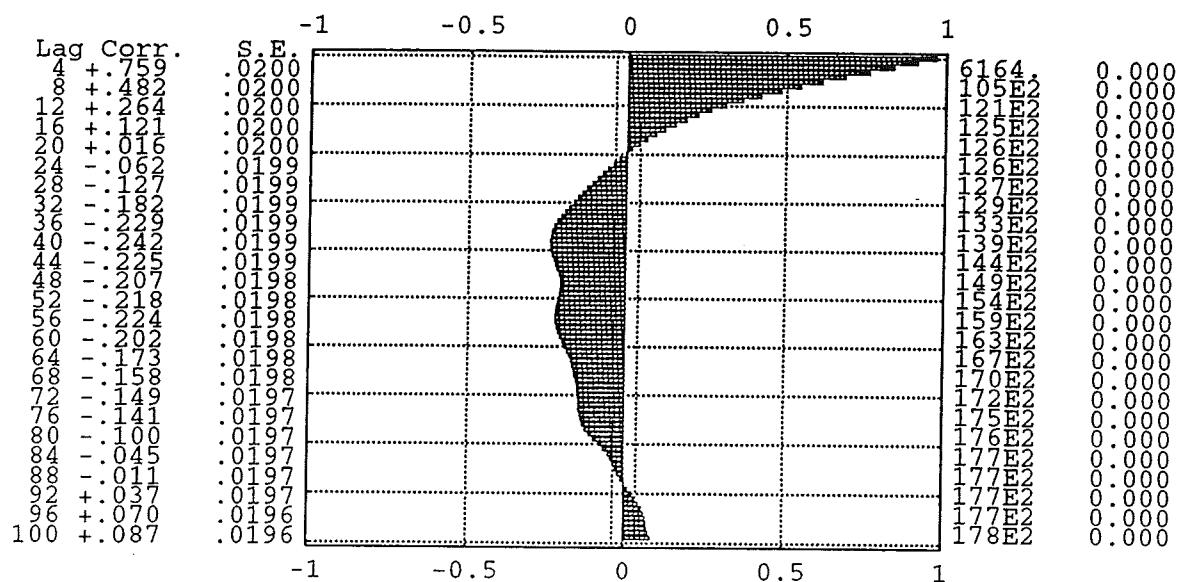
SONTEC



Turbulent Velocities from EMC and SONTEC

Test 5

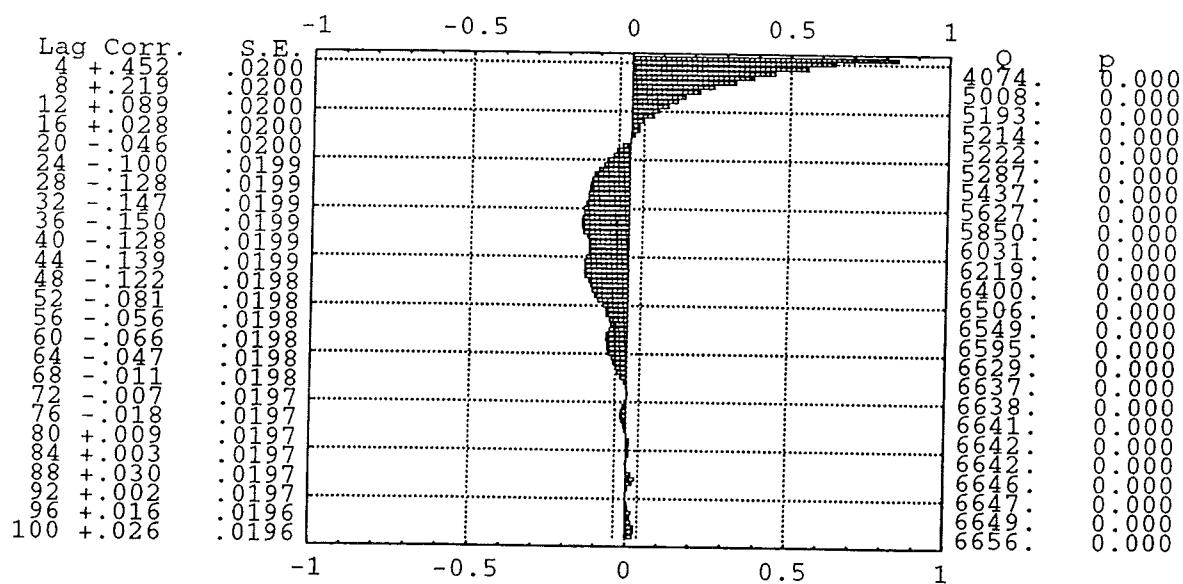
EMC



Turbulent Velocities from EMC and SONTEC

Test 5

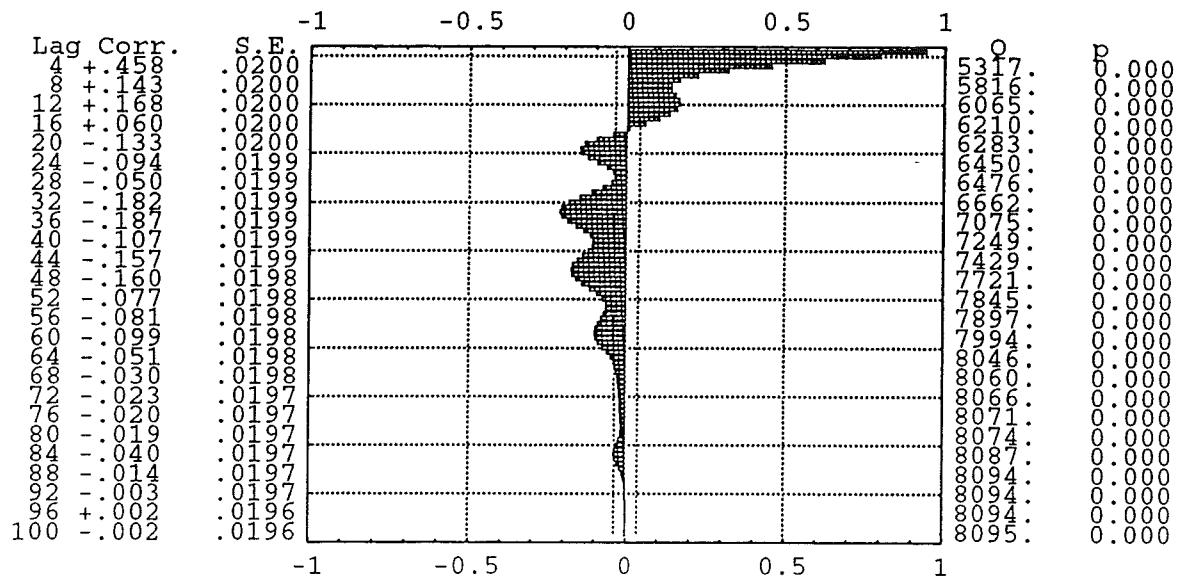
SONTEC



Turbulent Velocities from EMC and SONTEC

Test 6

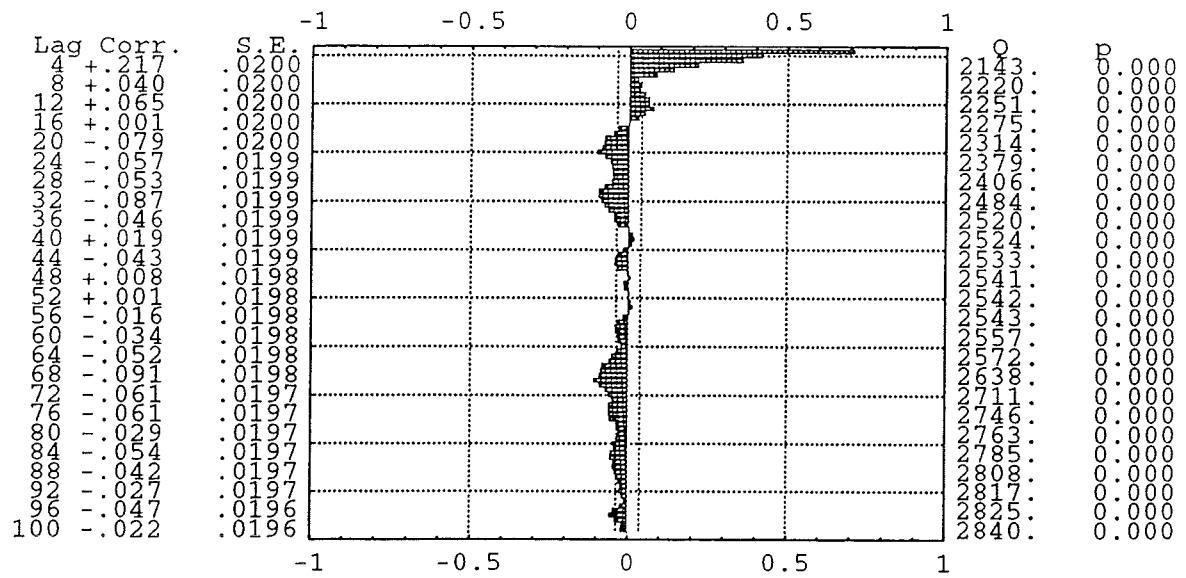
EMC



Turbulent Velocities from EMC and SONTEC

Test 6

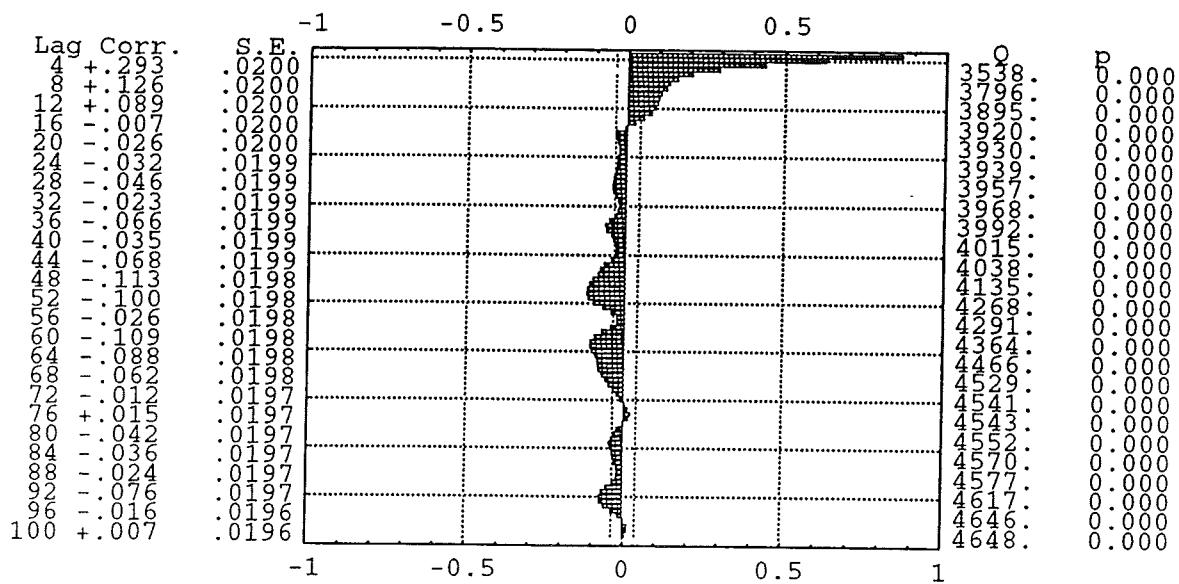
SONTEC



Turbulent Velocities from EMC and SONTEC

Test 7

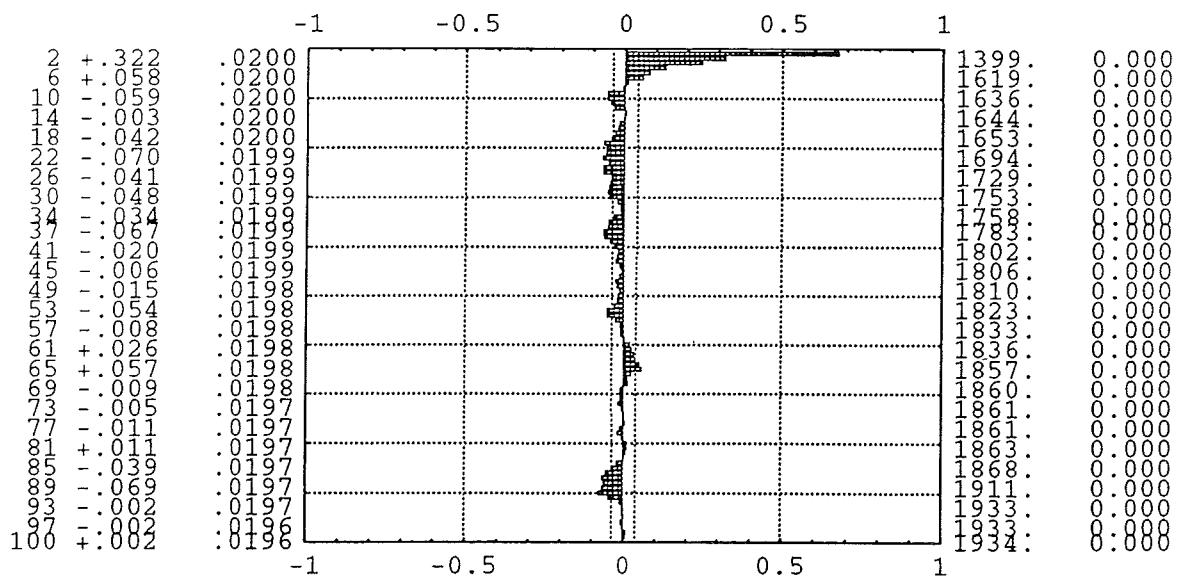
EMC



Turbulent Velocities from EMC and SONTEC

Test 7

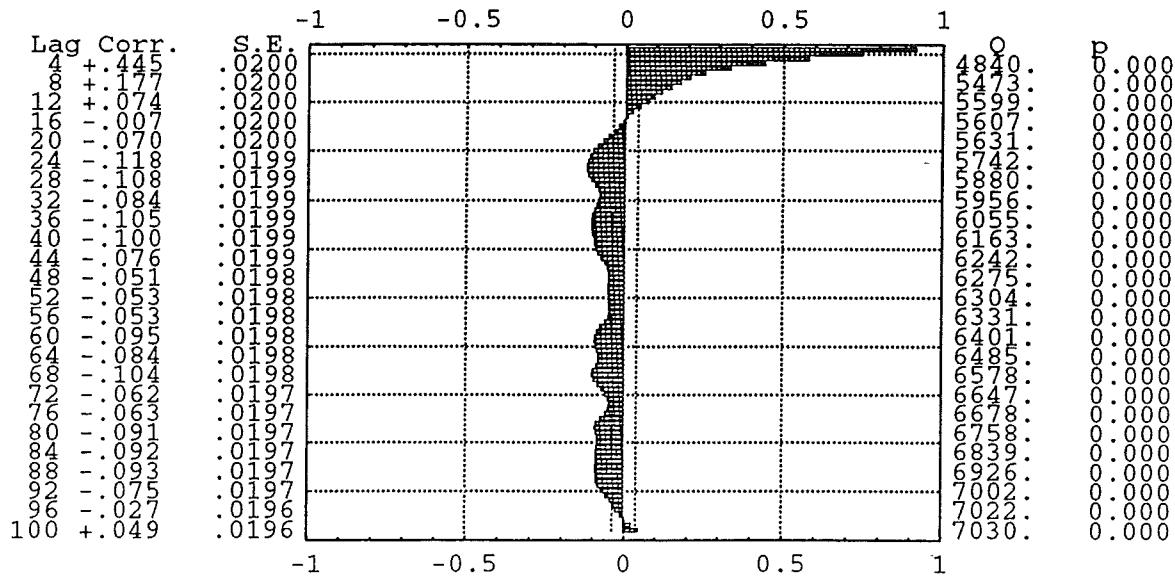
SONTEC



Turbulent Velocities from EMC and SONTEC

Test 9

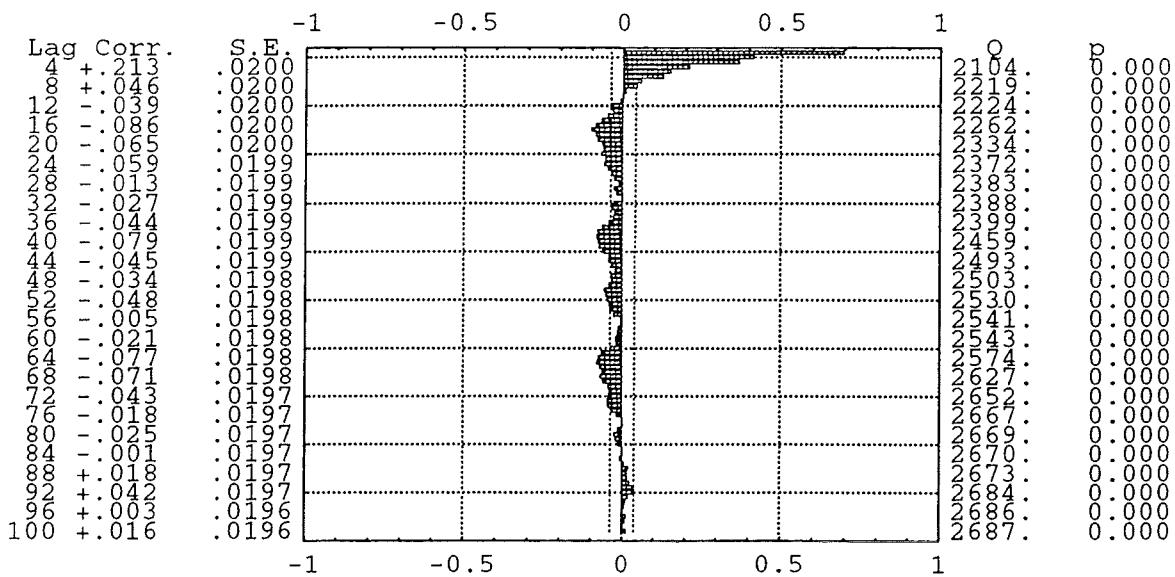
EMC



Turbulent Velocities from EMC and SONTEC

Test 9

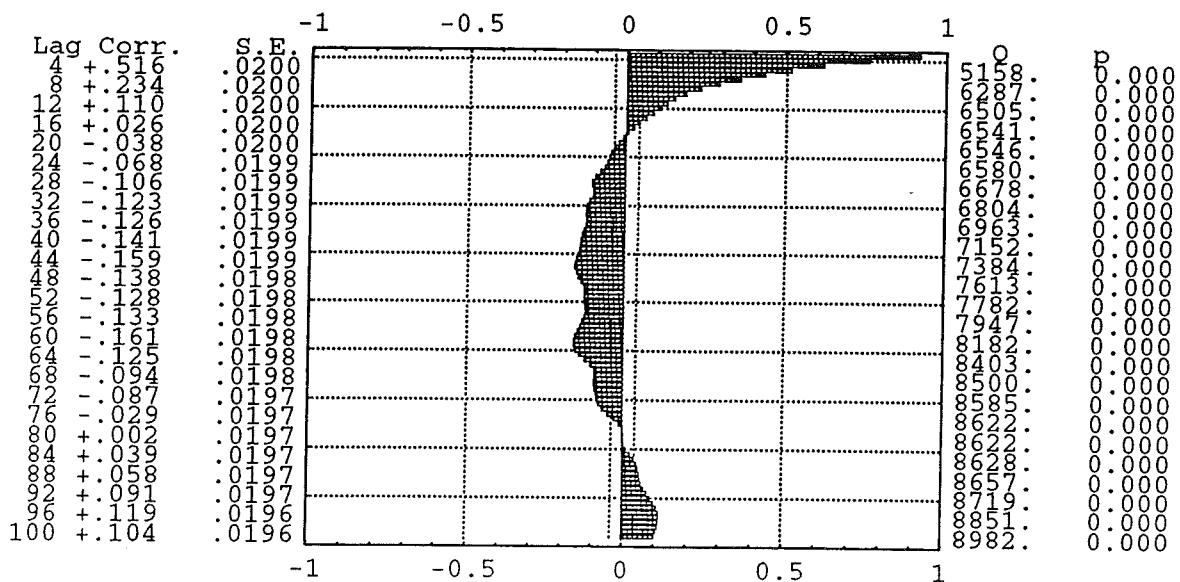
SONTEC



Turbulent Velocities from EMC and SONTEC

Test 10

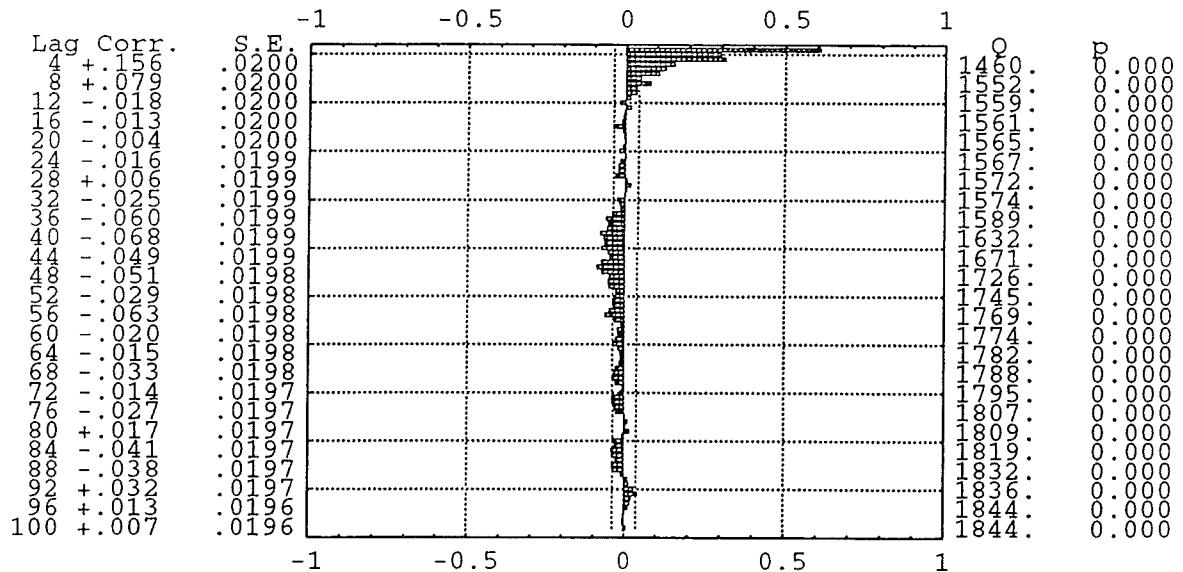
EMC

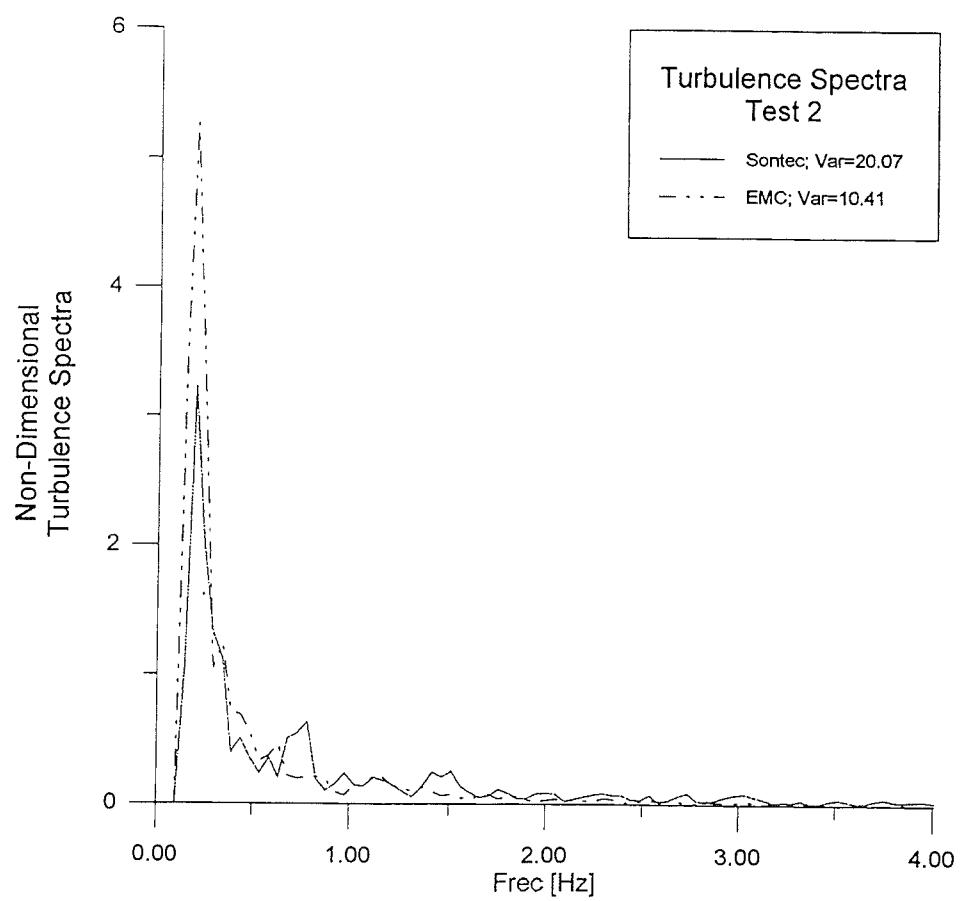
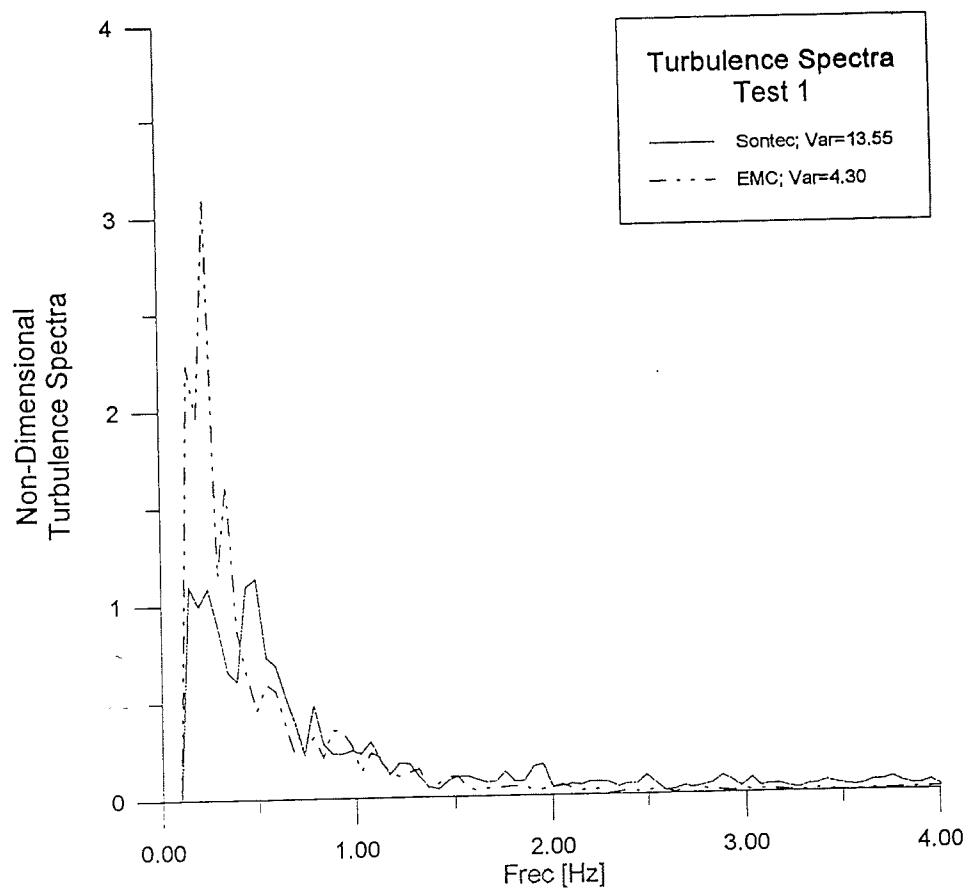


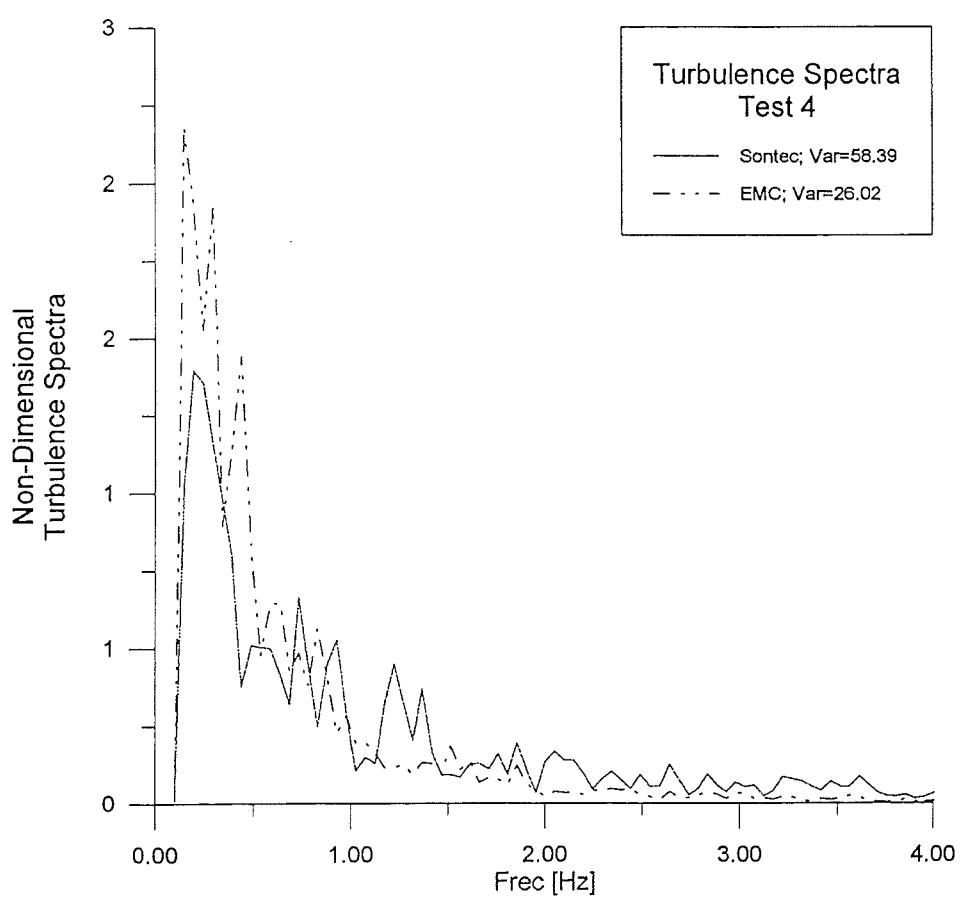
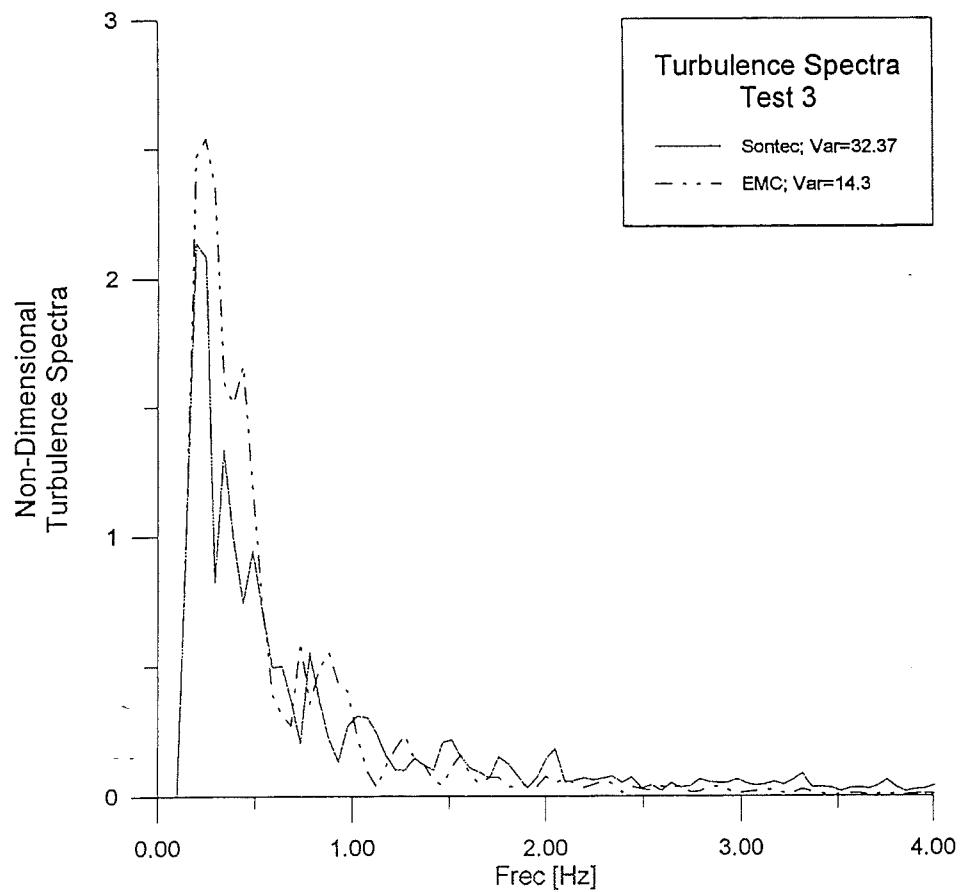
Turbulent Velocities from EMC and SONTEC

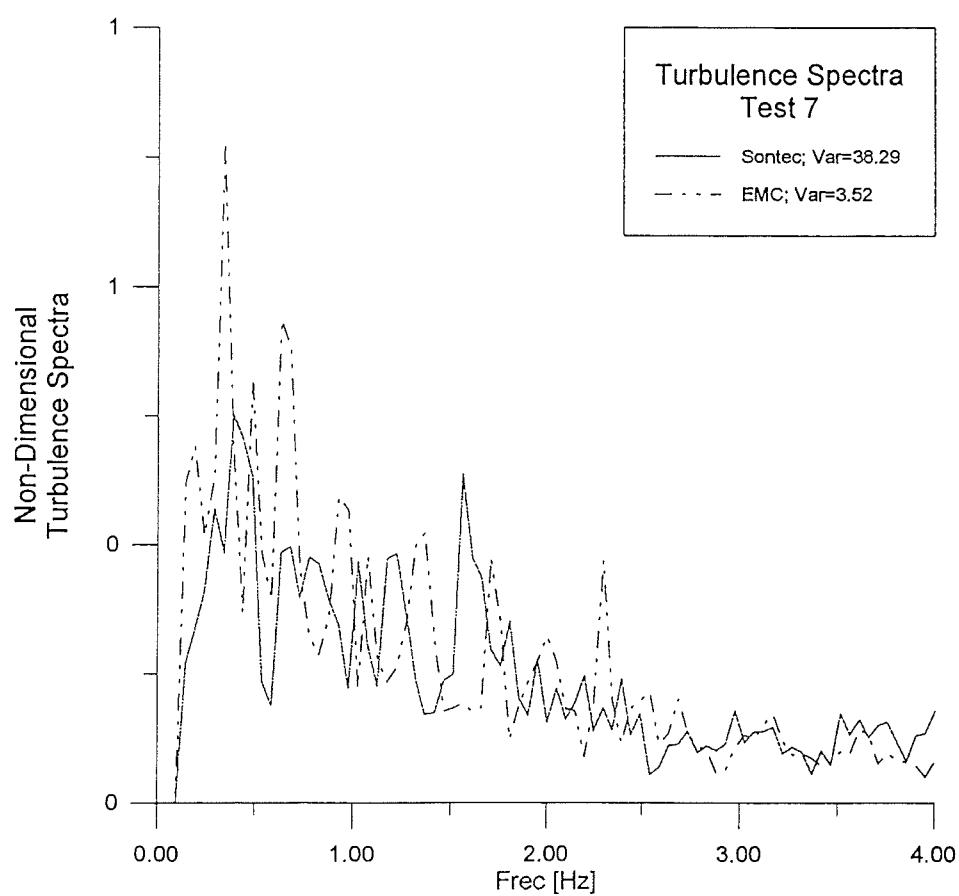
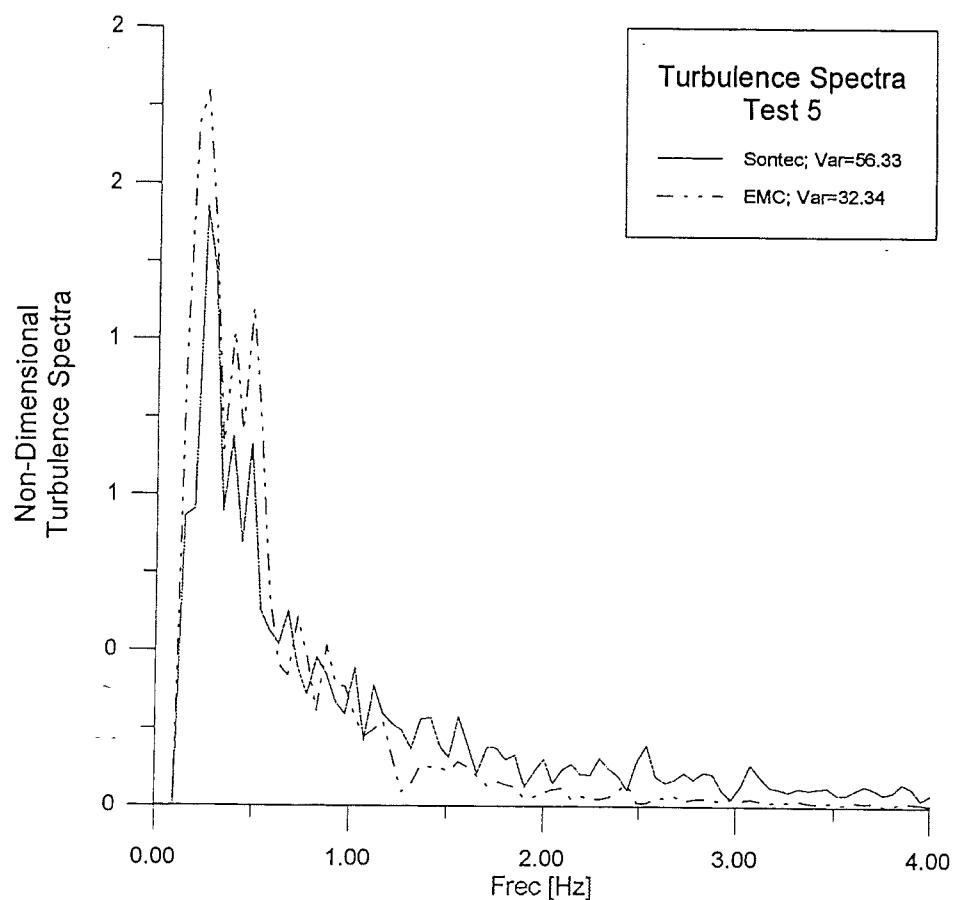
Test 10

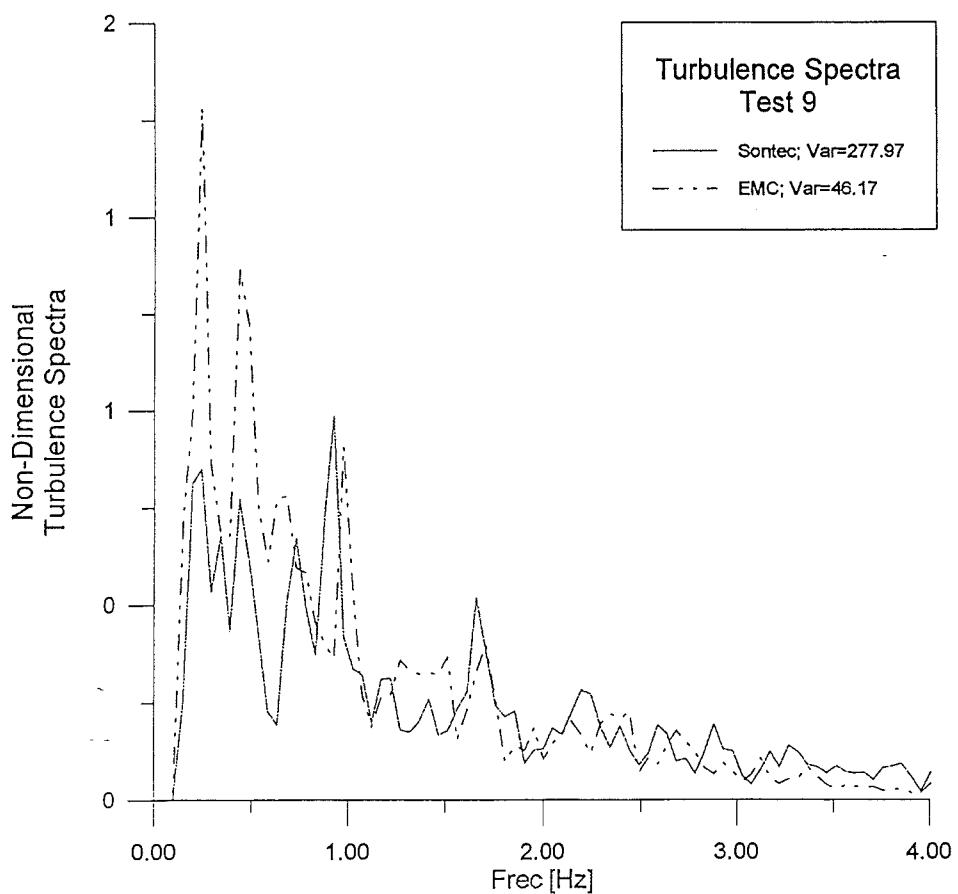
SONTEC

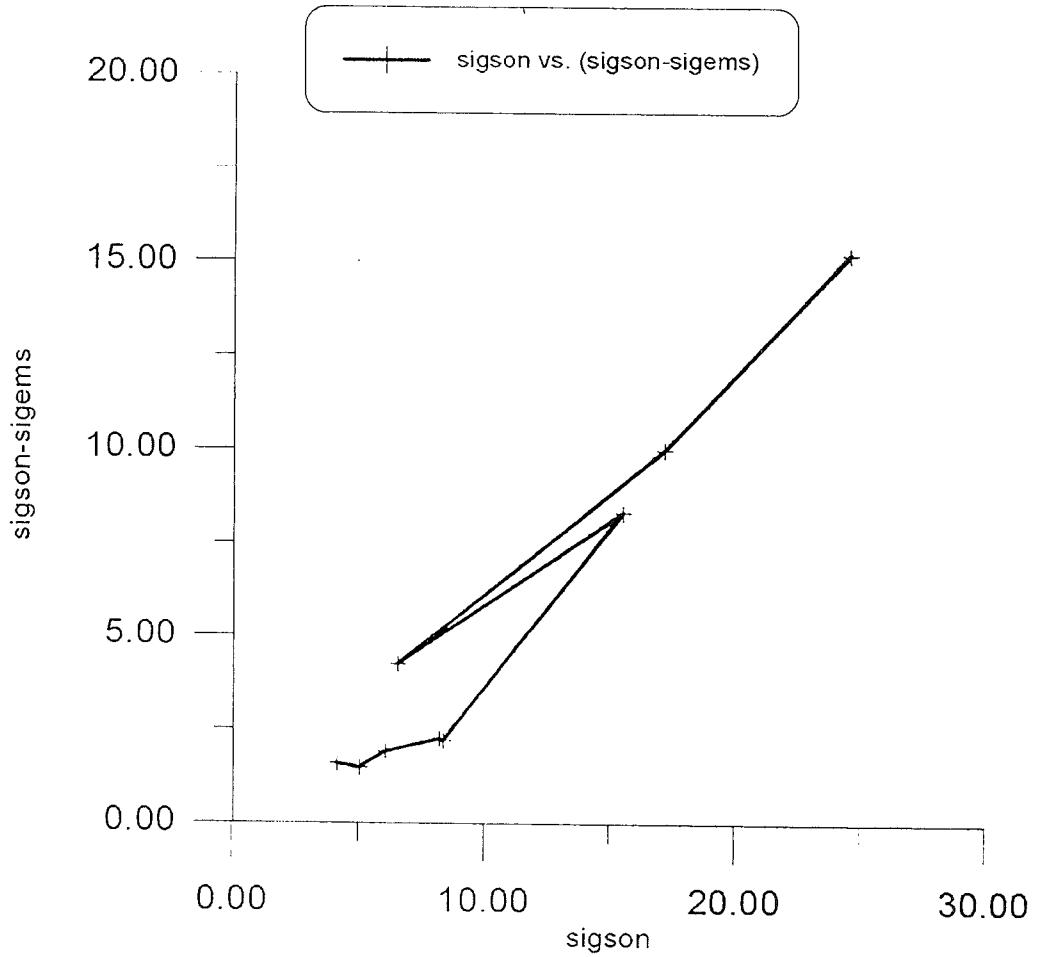
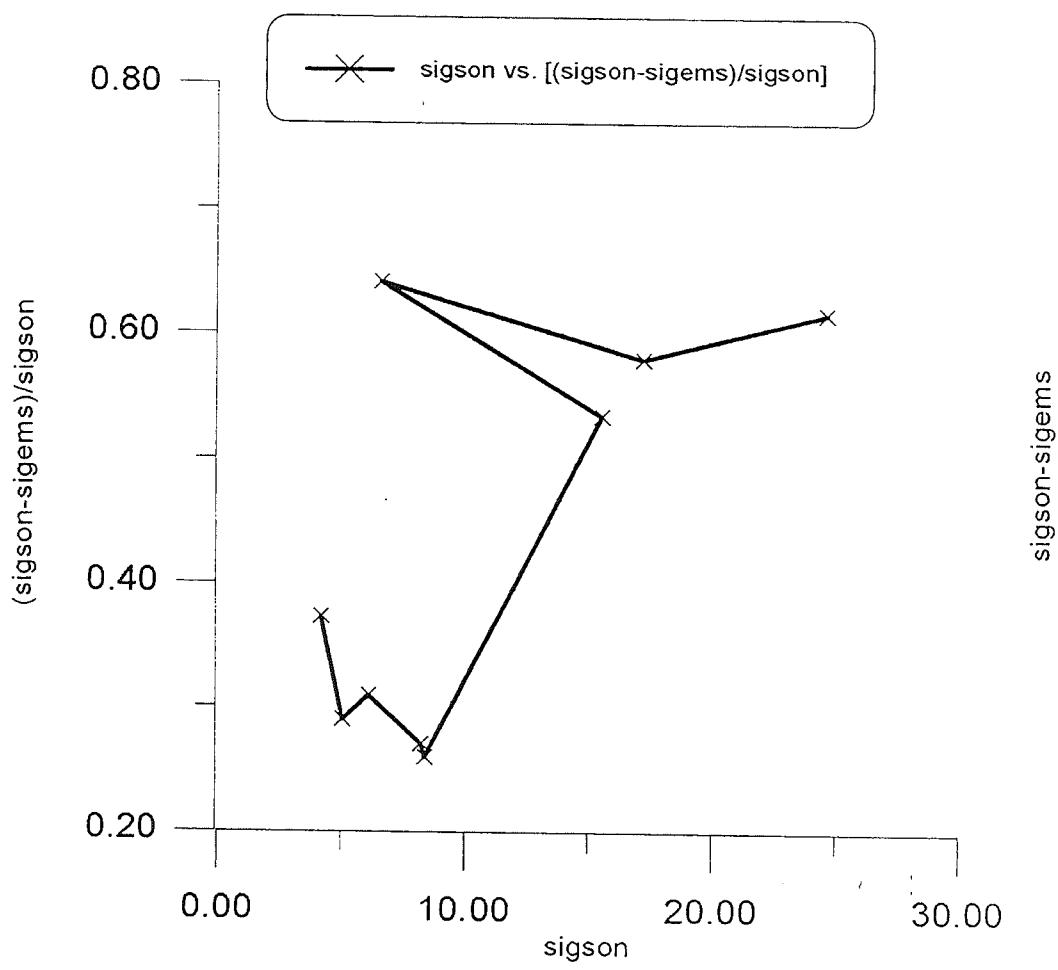




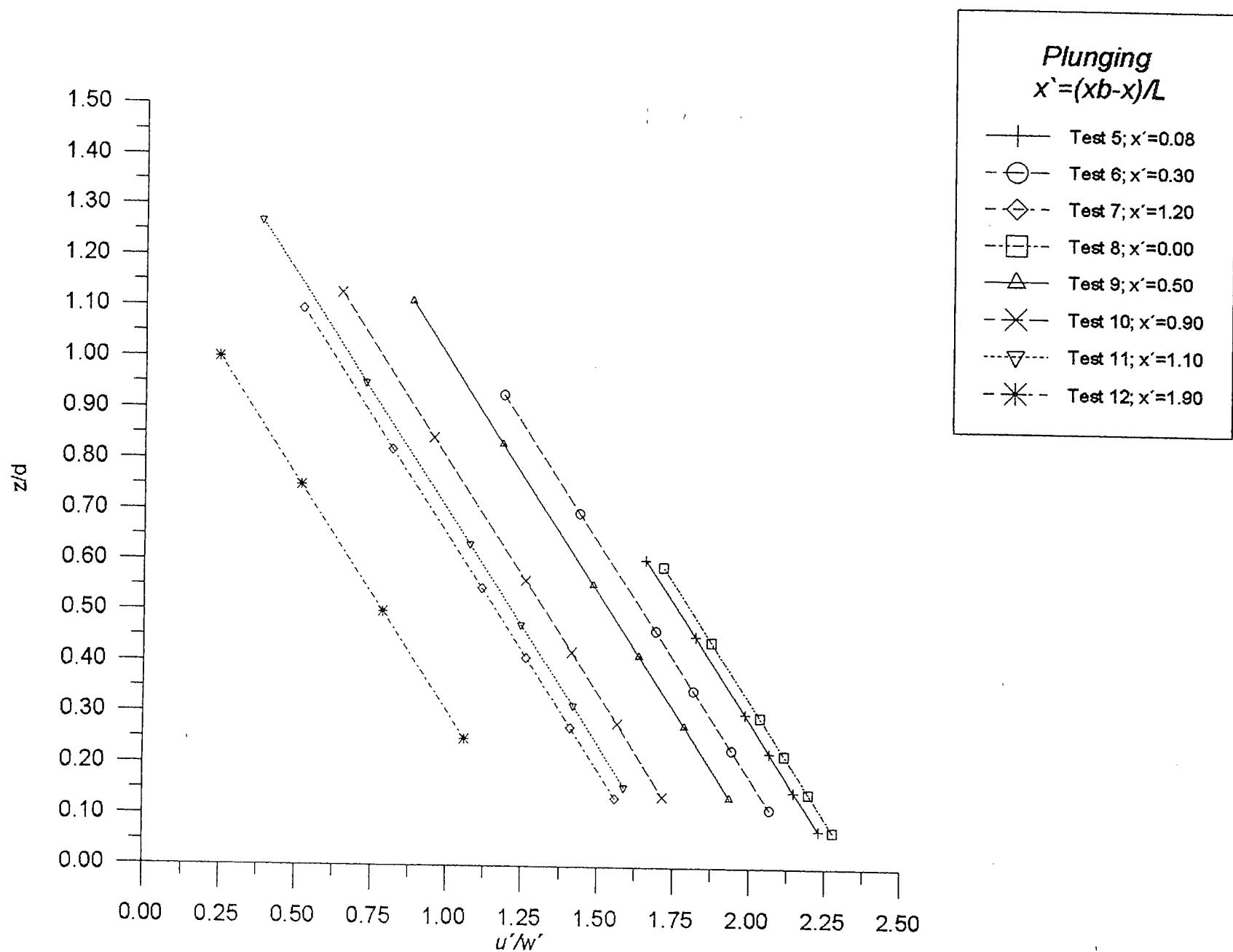


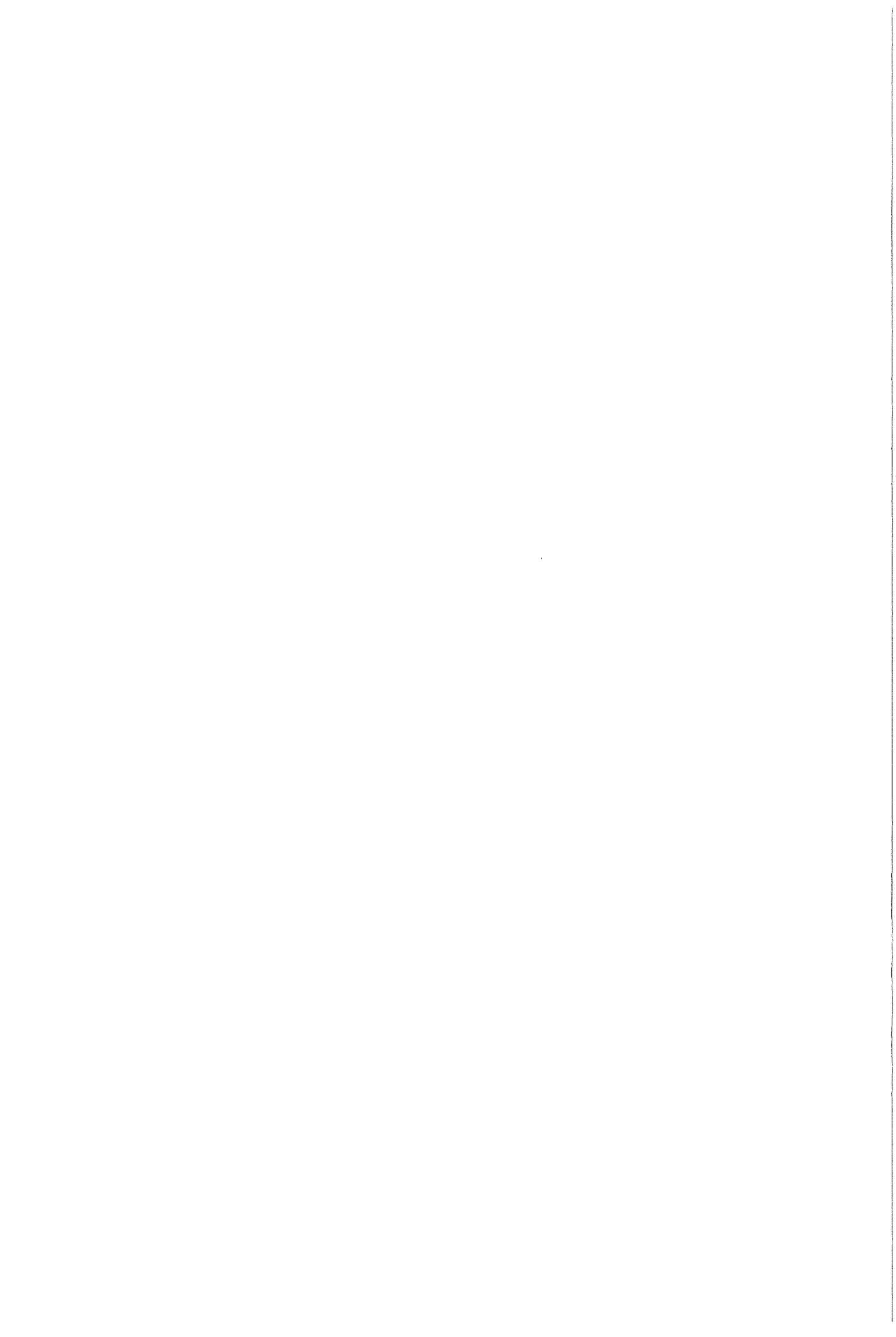




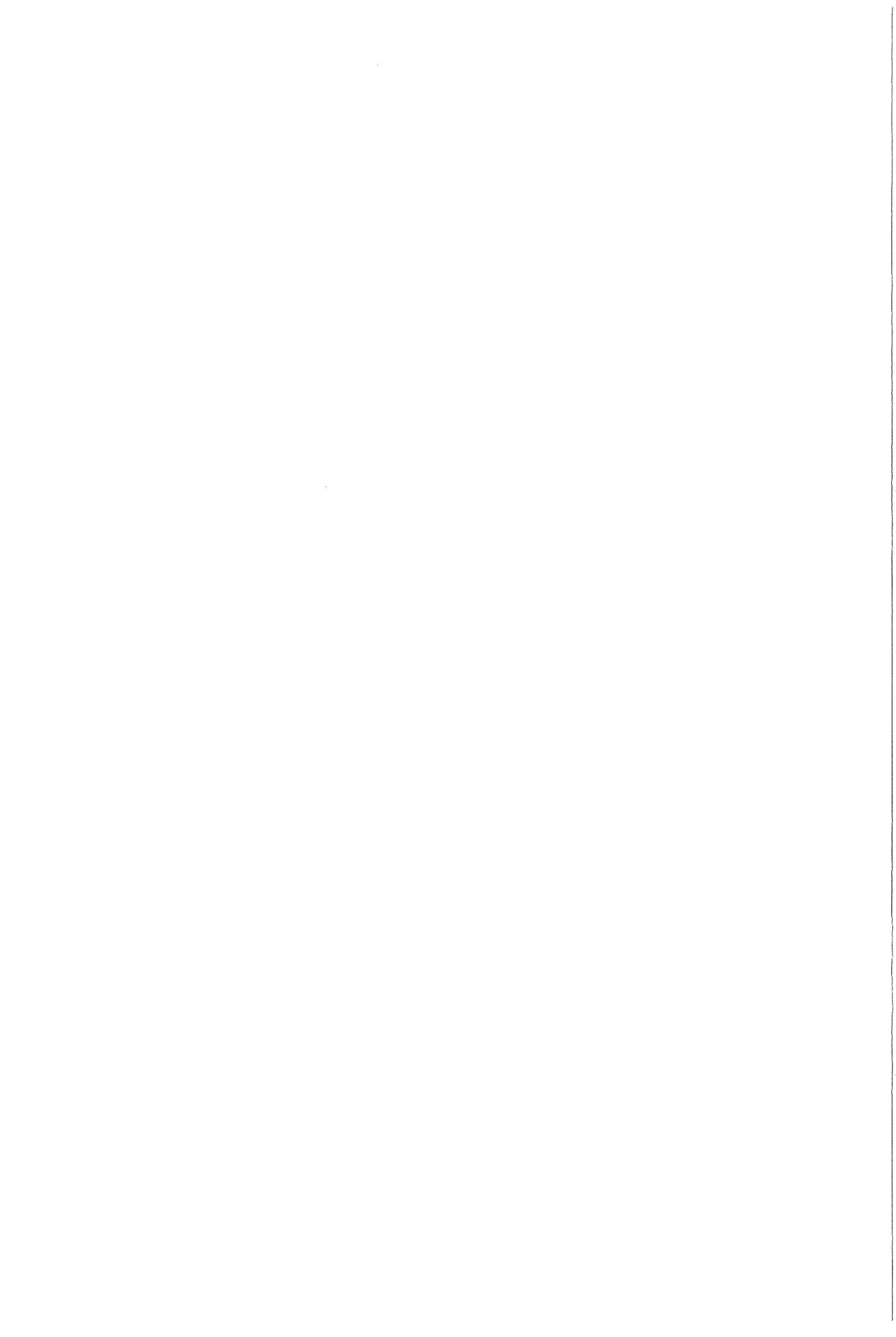


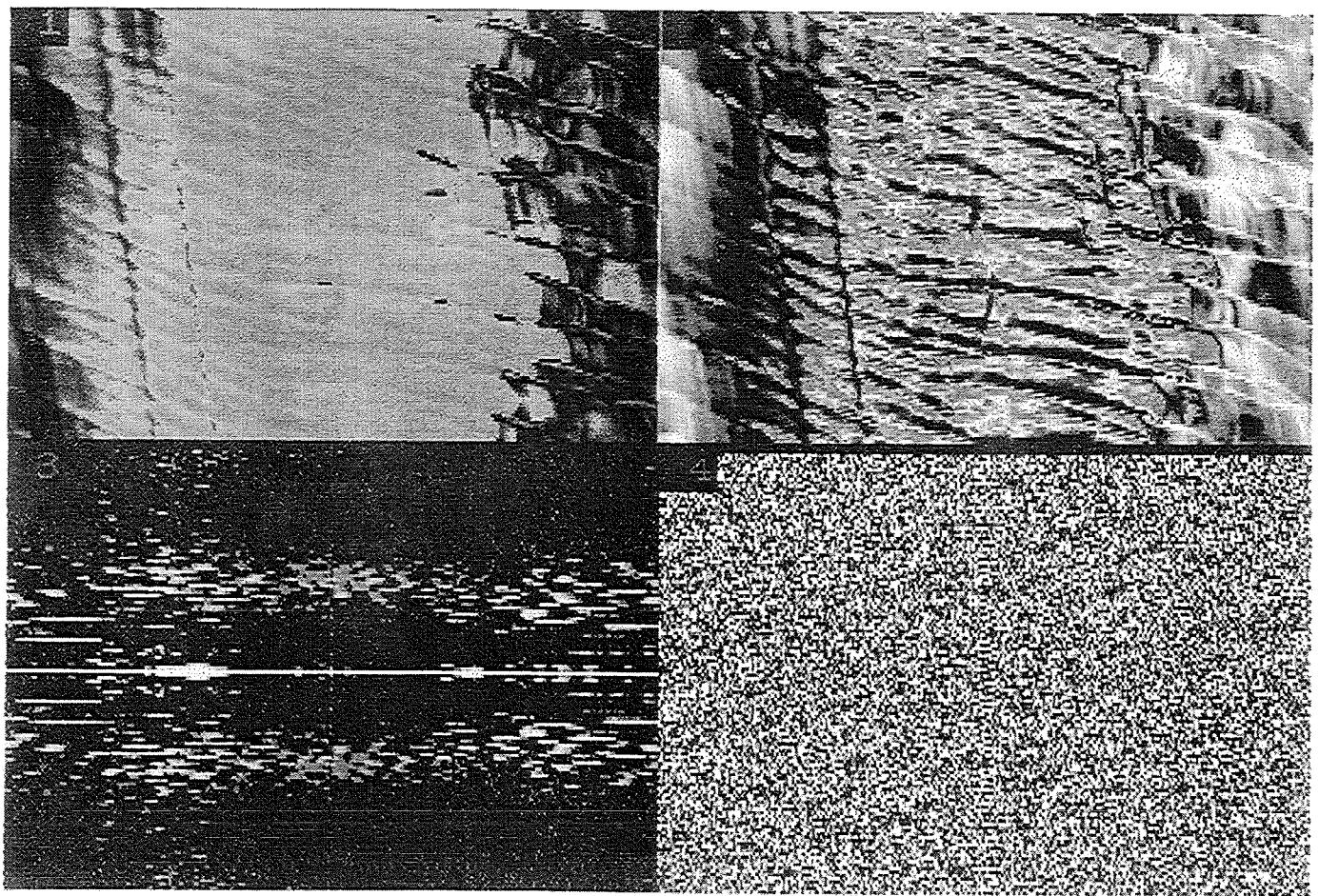
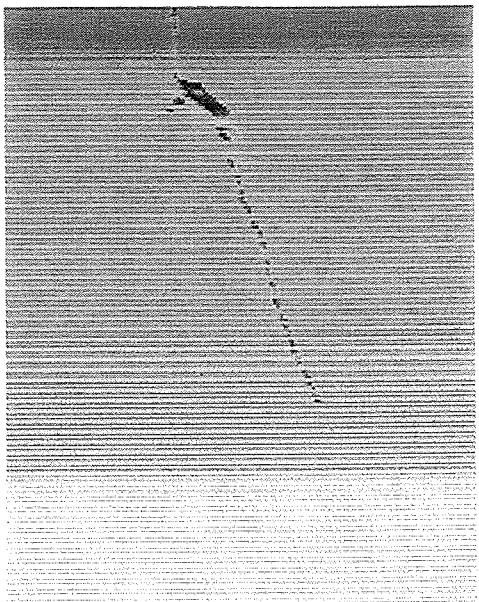
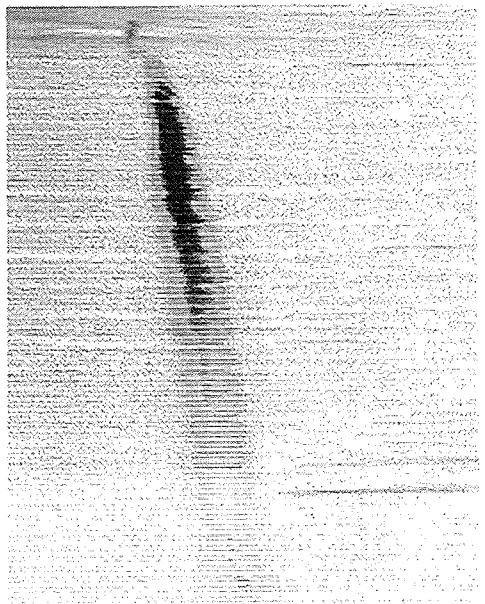




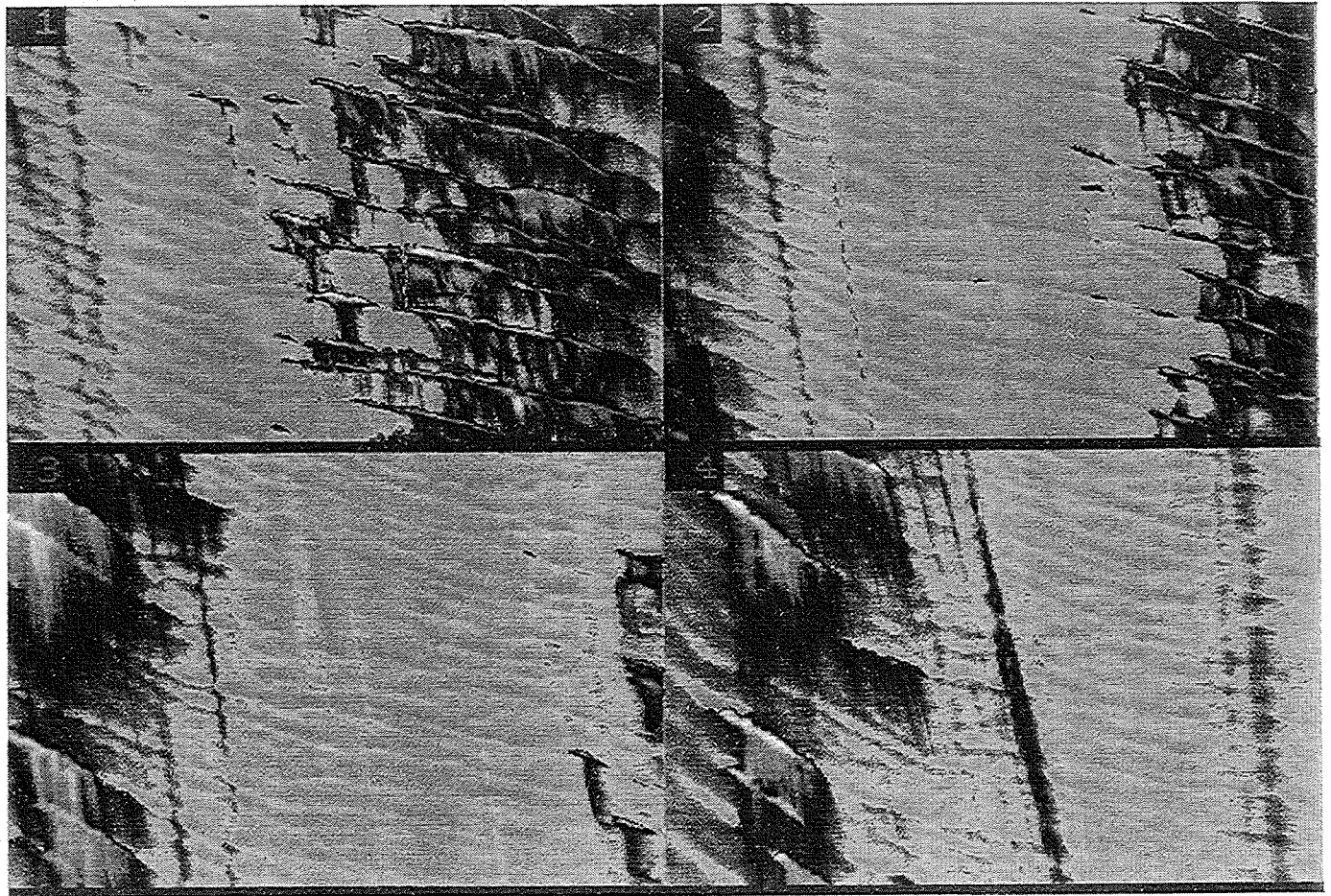


C5. Filmaciones de Video e Imágenes

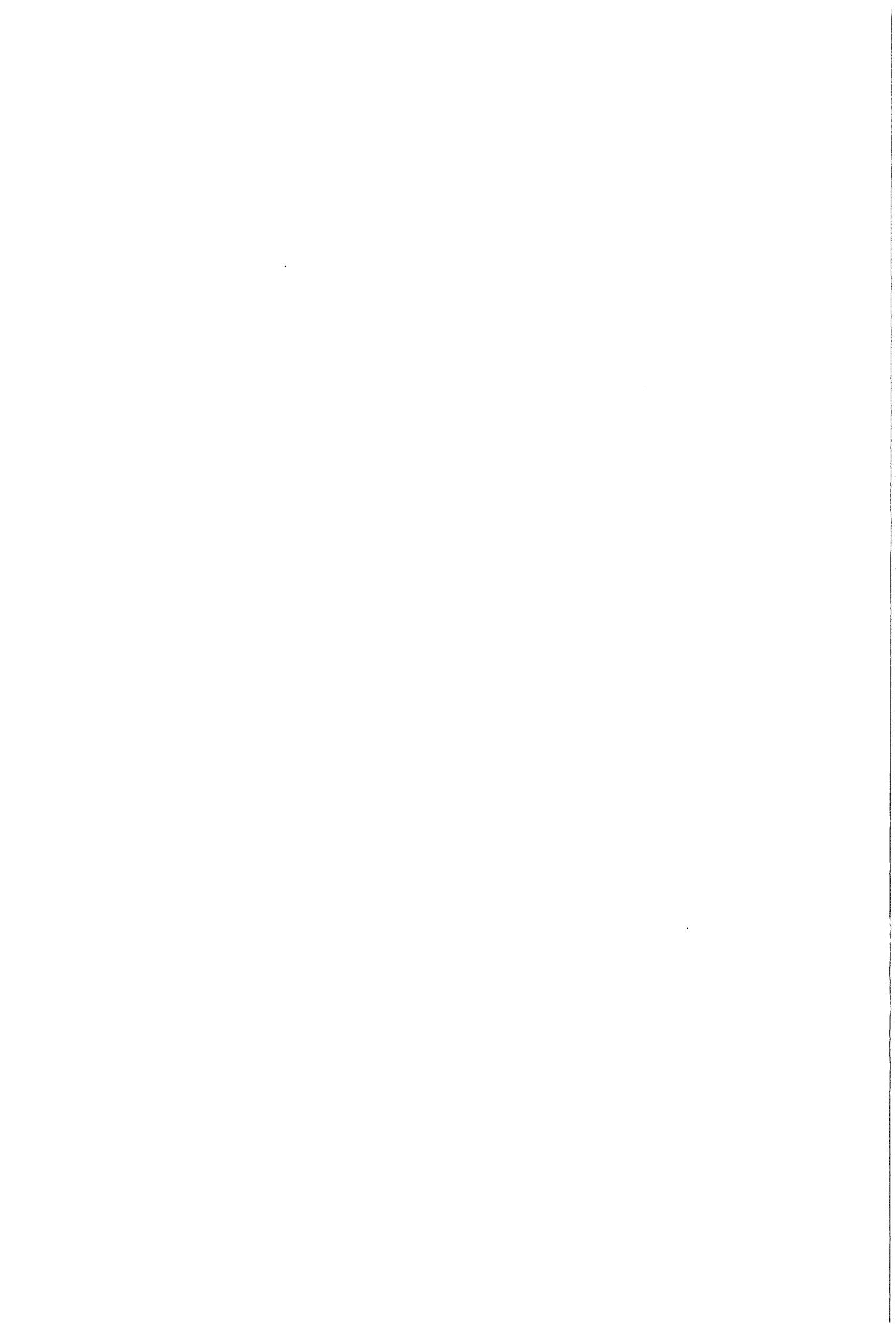


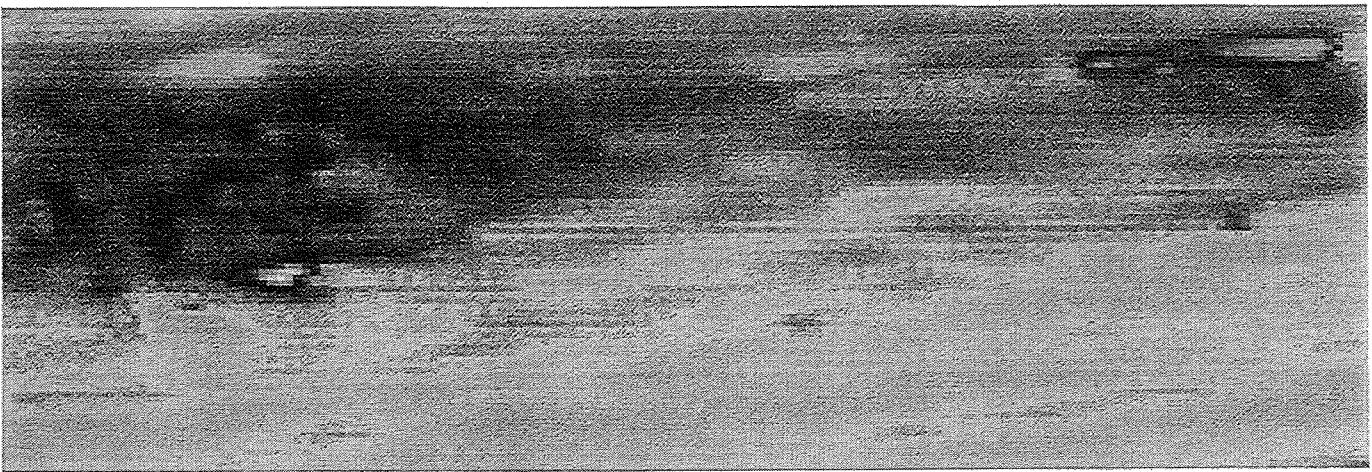




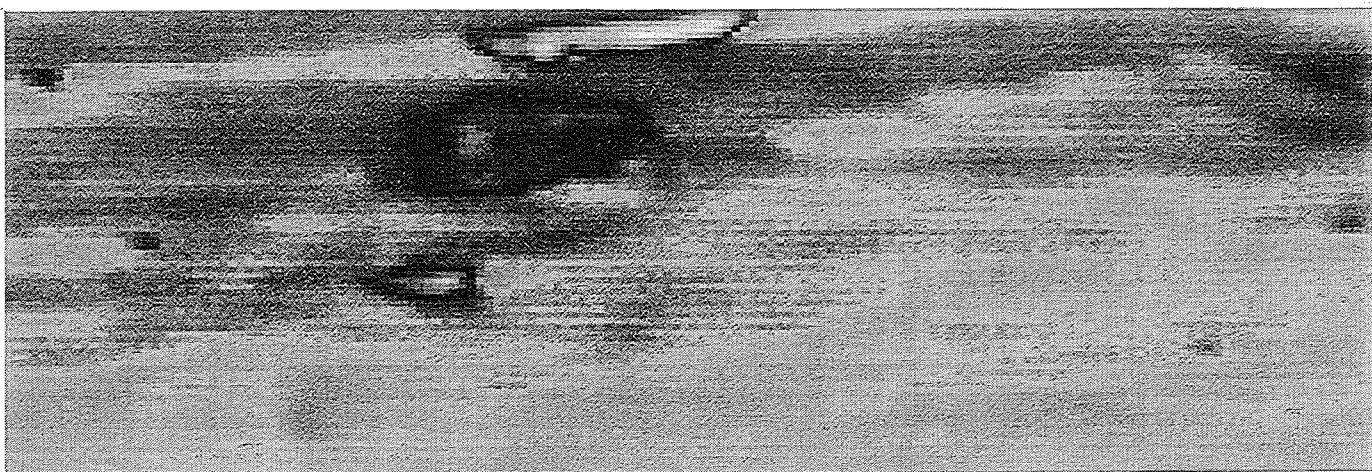


9/11/1993 - C:\IMG\DIGIMAGE\MAN2S.JET

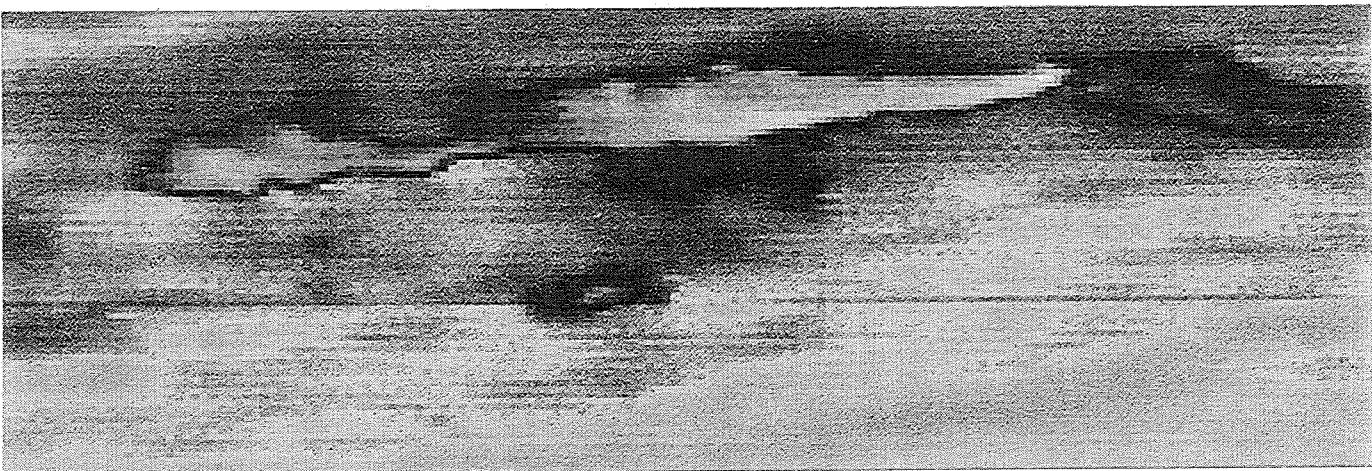




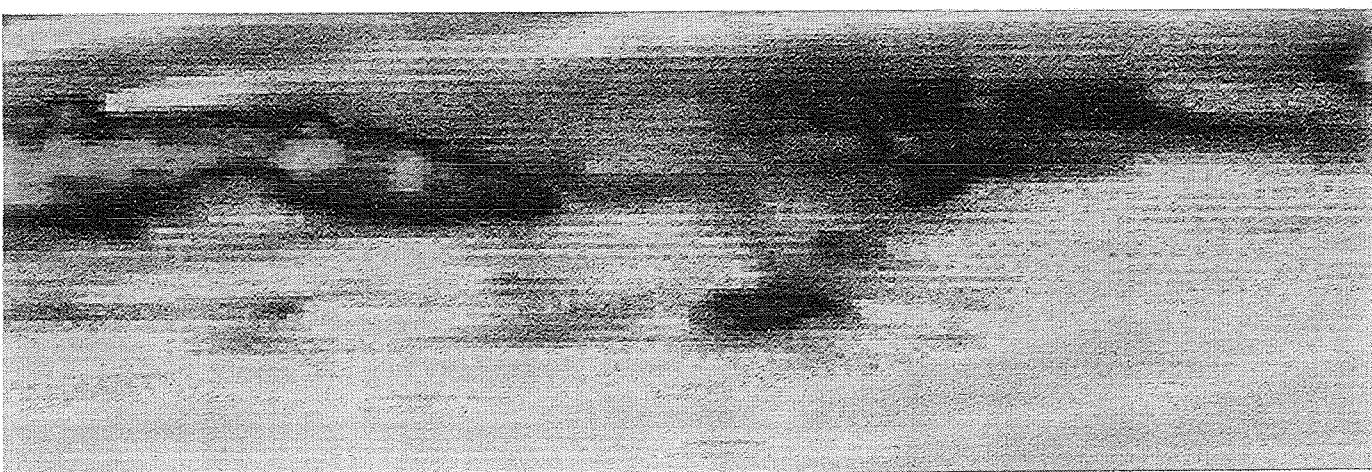
31/08/1993 - C:\IMG\DIGIMAGE\MA1.JET



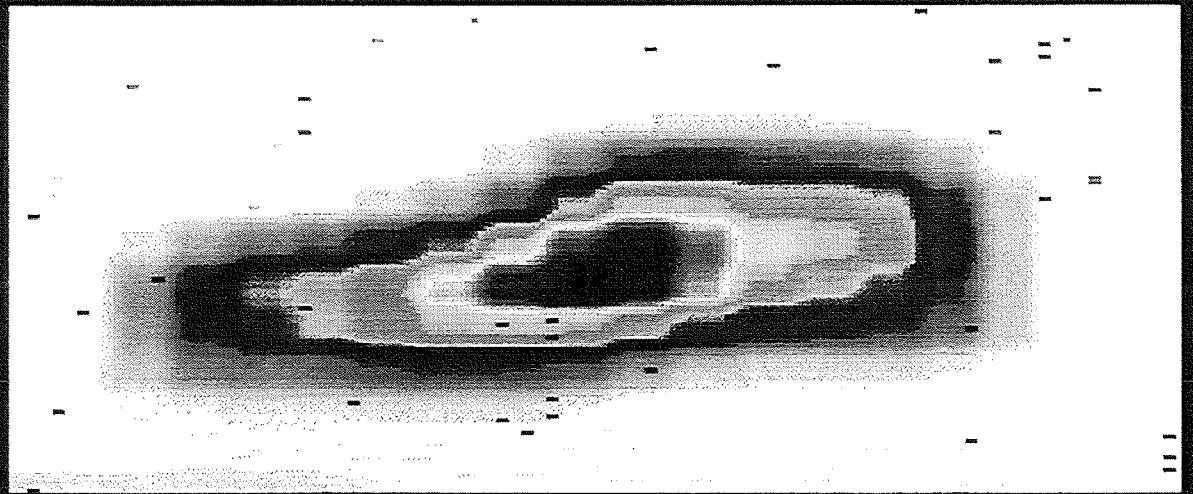
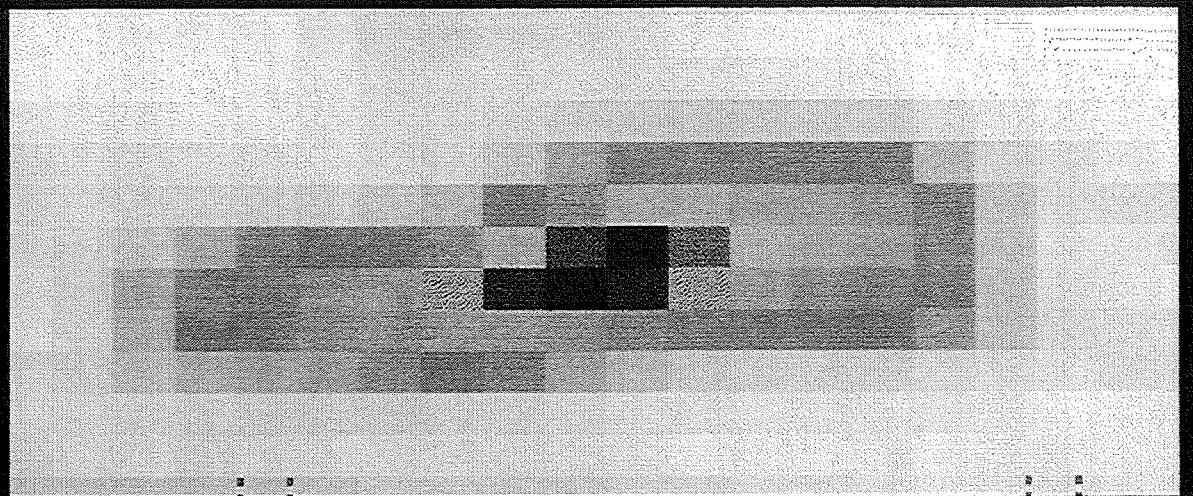
31/08/1993 - C:\IMG\DIGIMAGE\MA2.JET



31/08/1993 - C:\IMG\DIGIMAGE\MA3.JET



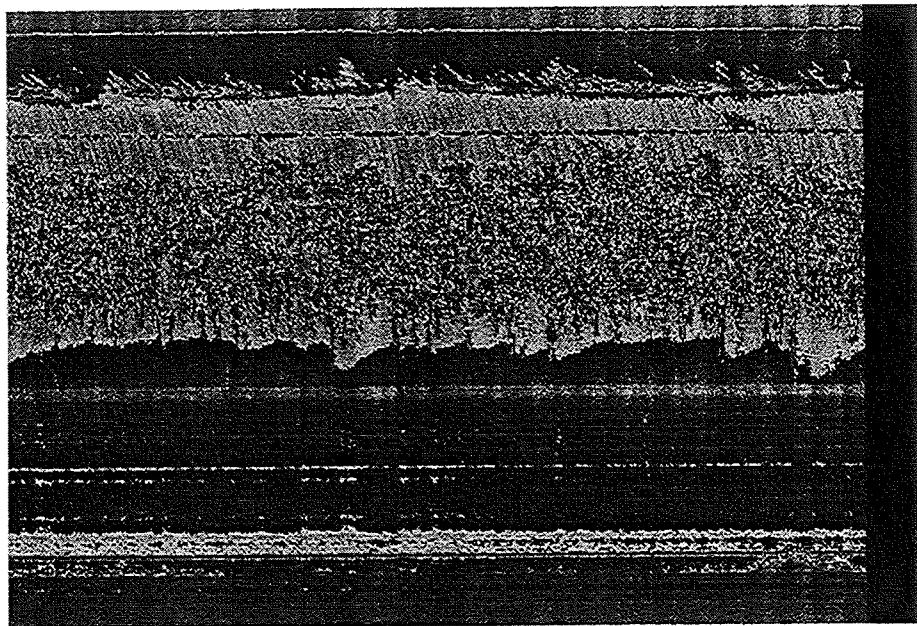
31/08/1993 - C:\IMG\DIGIMAGE\MA4.JET



DigImage: 14/07/1994 - C:\IMG\DIGIMAGE\DATAIMANVE1.JET

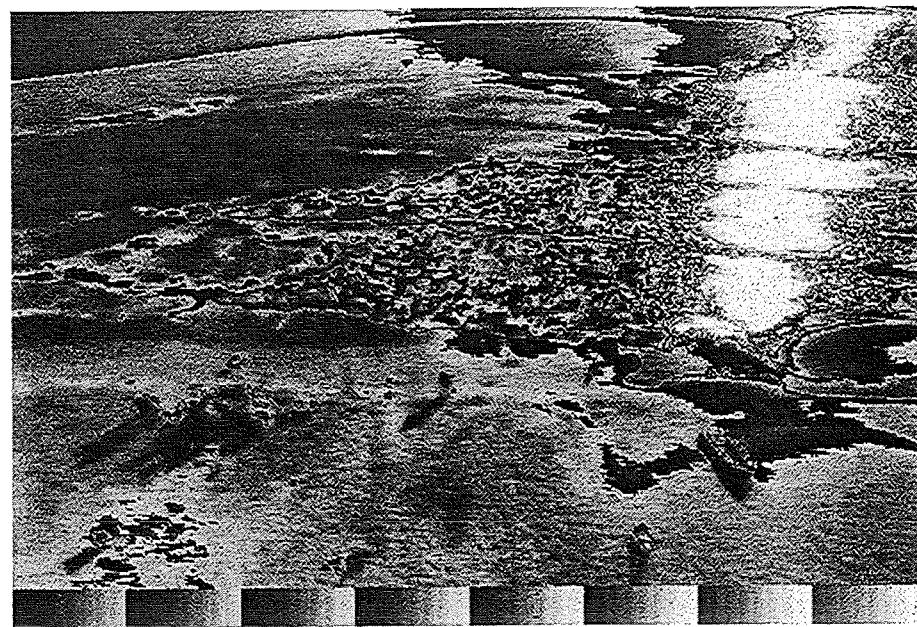


ts.6



DigiImage: 23/09/1994 - C:\IMG\DIGIMAGE\DATA\TS6.JET

pl.16.5

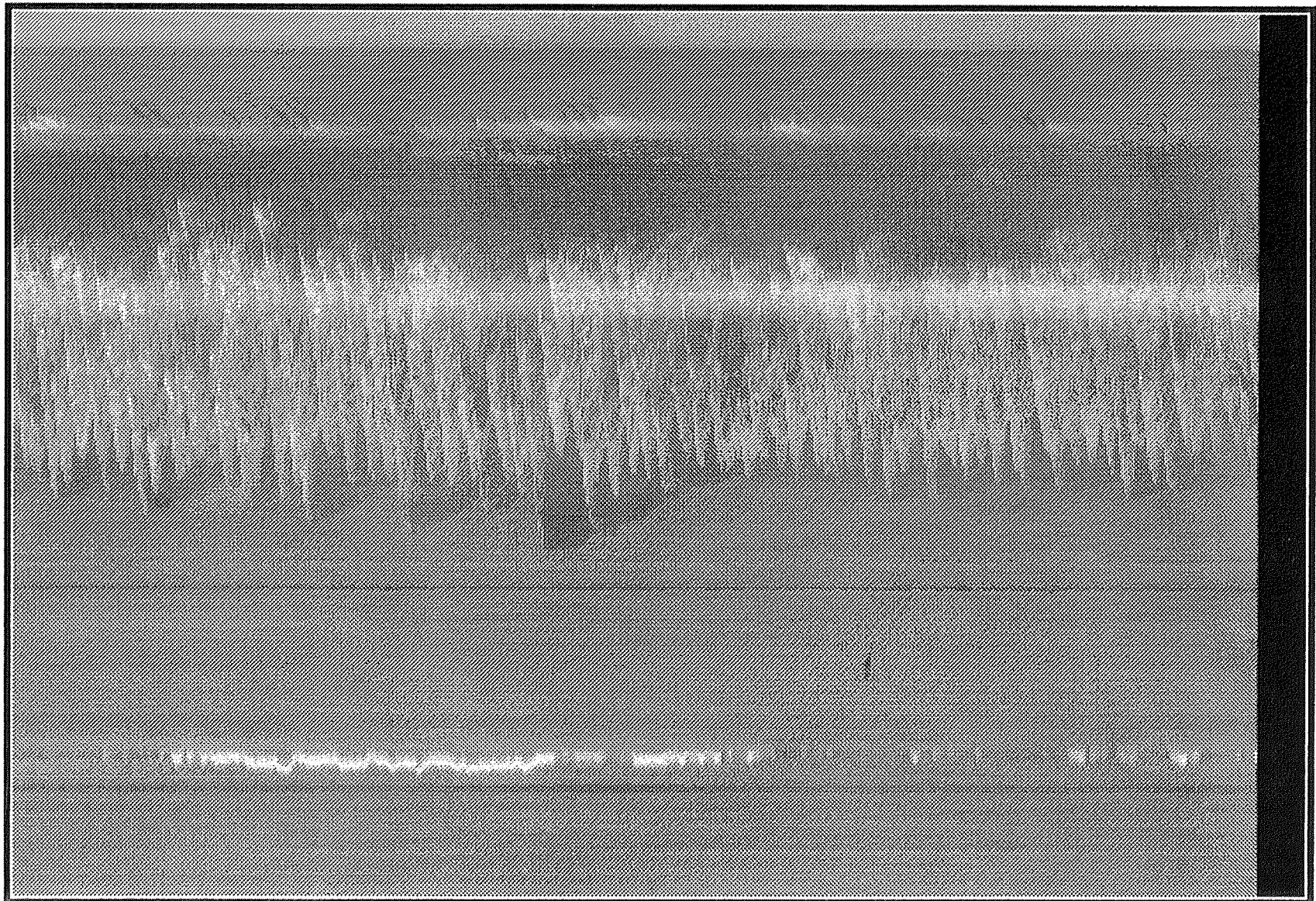


DigiImage: 23/09/1994 - C:\IMG\DIGIMAGE\DATA\PL165.JET



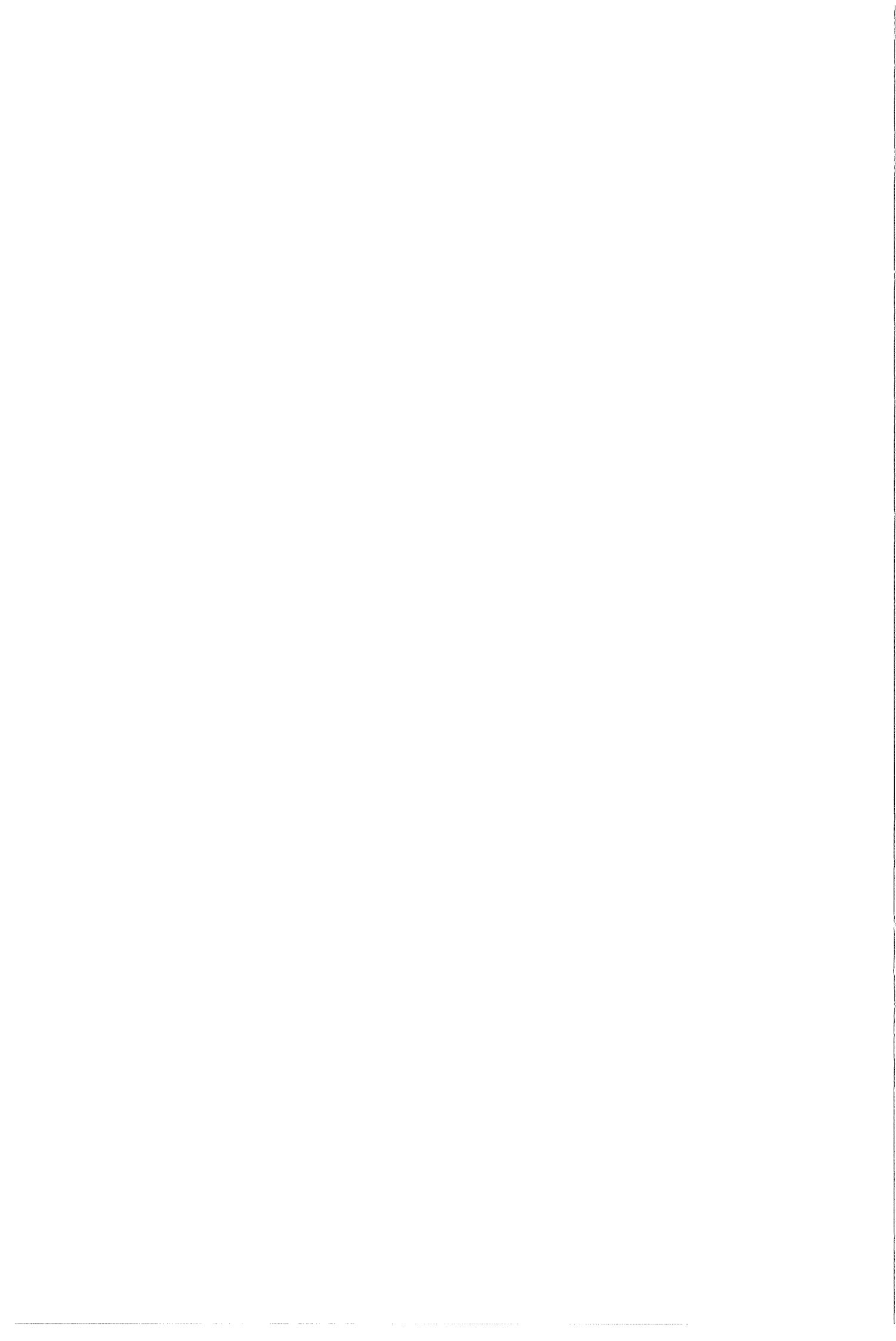
C:\IMG\DIGIMAGE\DATA\PL167.PIC

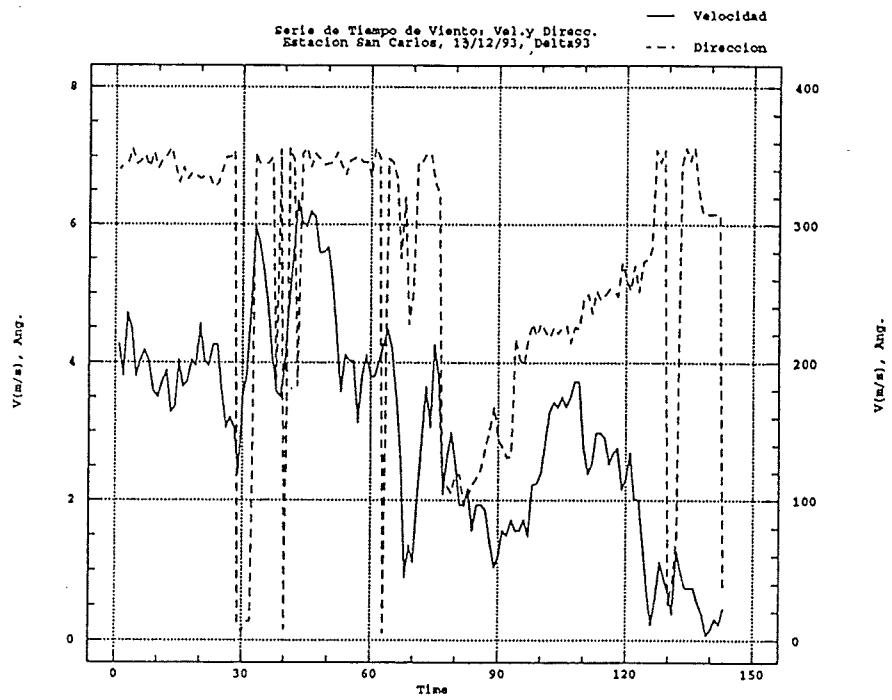




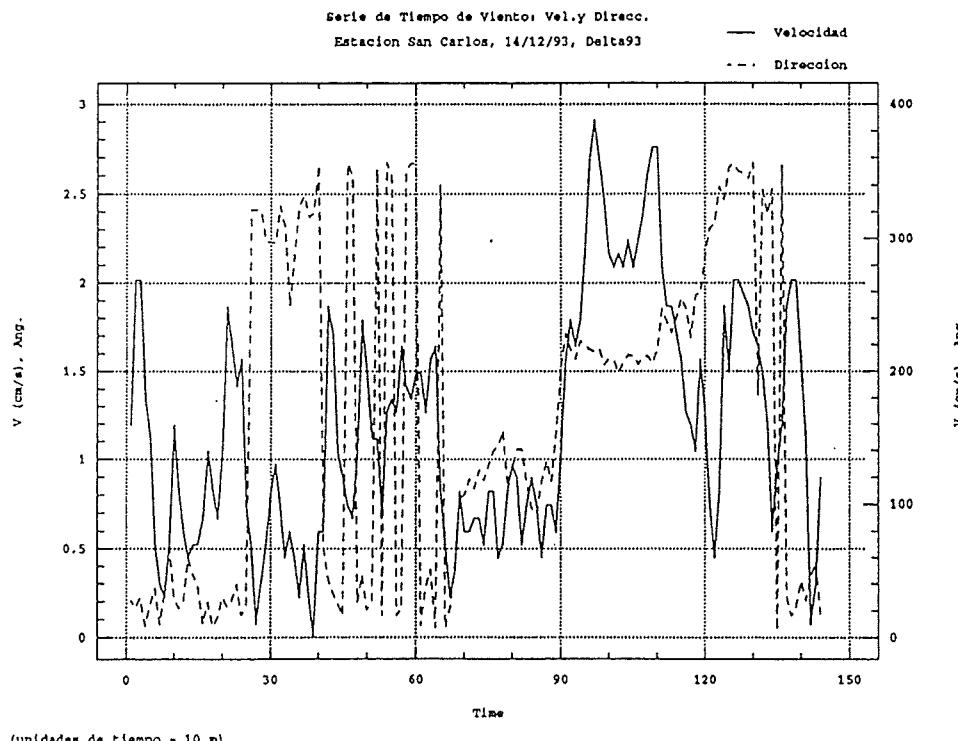


C6. Meteorología



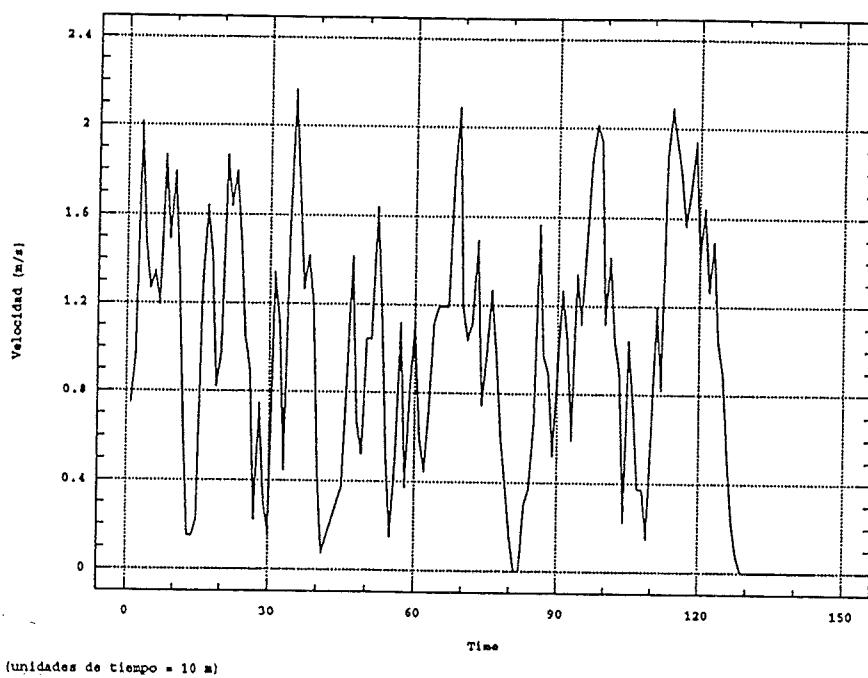


(unidades de tiempo = 10 m)



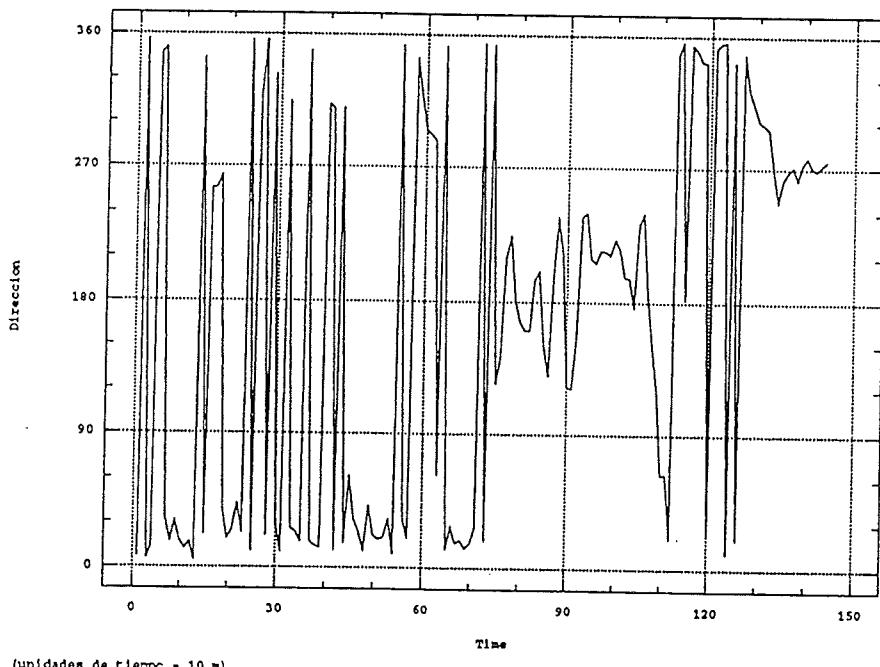
(unidades de tiempo = 10 m)

Serie de Tiempo de Viento: Vel.y Direcc.
Estacion San Carlos, 15/12/93, Delta93



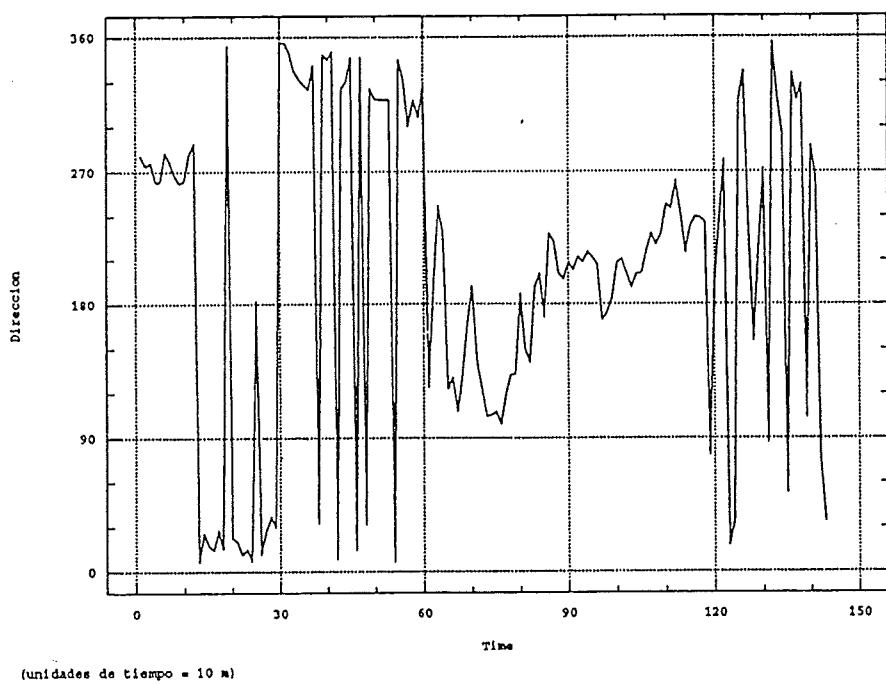
(unidades de tiempo = 10 s)

Serie de Tiempo de Viento: Vel.y Direcc.
Estacion San Carlos, 15/12/93, Delta93



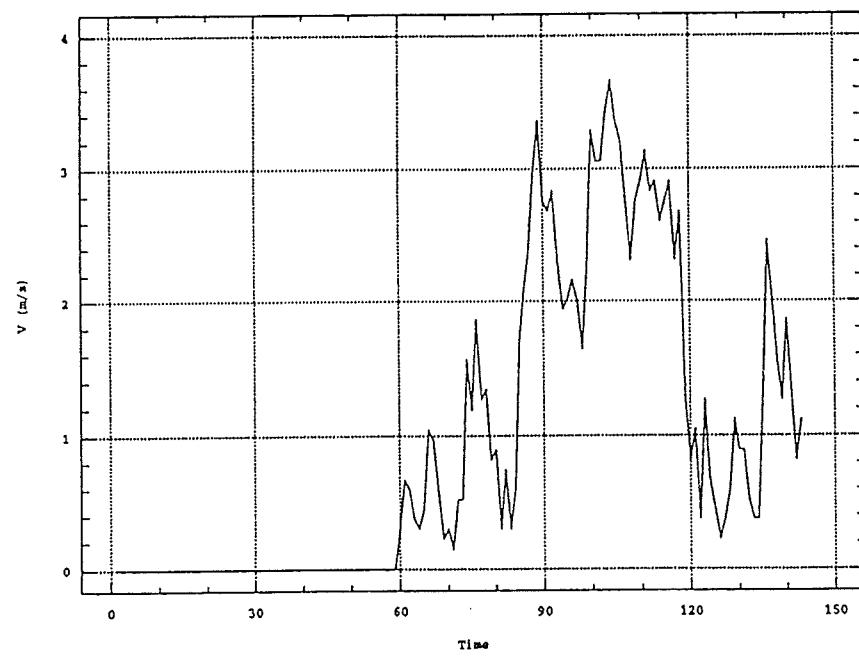
(unidades de tiempo = 10 s)

Serie de Tiempo de Viento: Vel.y Direcc.
Estacion San Carlos, 16/12/93, Delta93



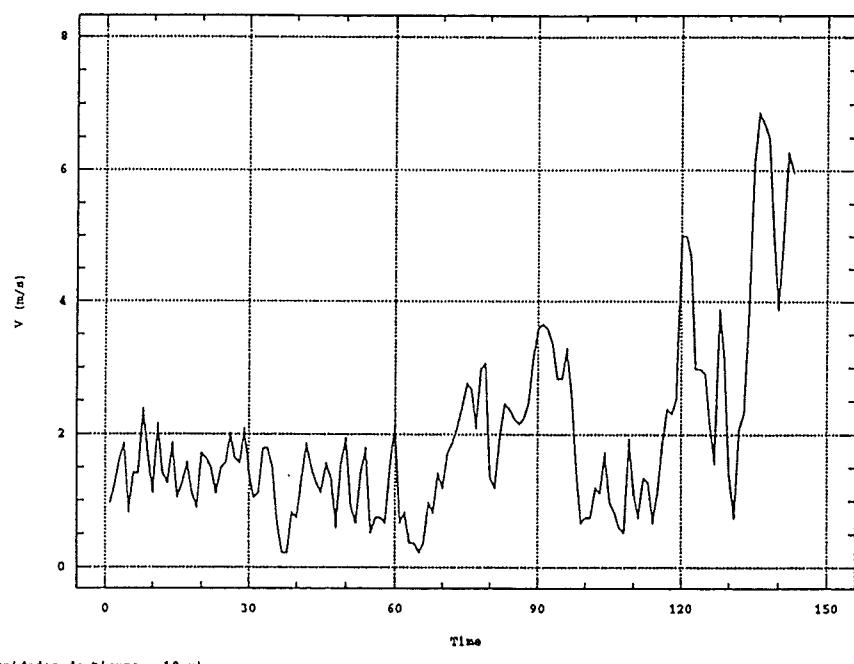
(unidades de tiempo = 10 s)

Serie de Tiempo de Viento: Vel.y Direcc.
Estacion San Carlos, 16/12/93, Delta93

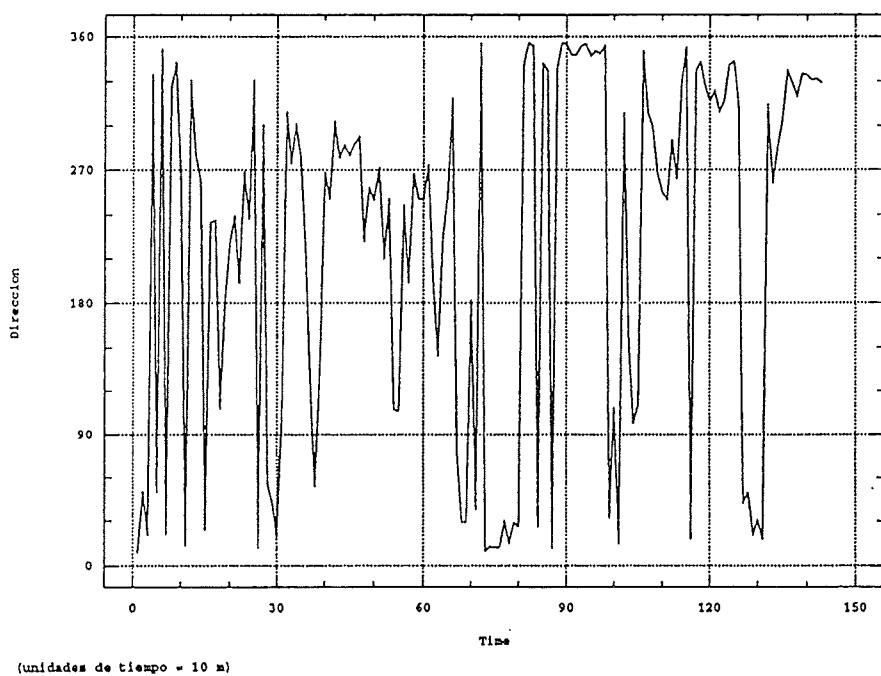


(unidades de tiempo = 10 s)

Serie de Tiempo de Viento: Vel.y Direcc.
Estacion San Carlos, 17/12/93, Delta93



Serie de Tiempo de Viento: Vel.y Direcc.
Estacion San Carlos, 17/12/93, Delta93



TIPO DE CINTA : ESTACION
 FECHA DE LECTURA : 26-11-93 9:20
 LATITUD : 40 43' N
 FECHA DE COMIENZO : 13-12-93 0: 0
 VELOCIDAD DE MUESTREO: 10 MINUTOS
 NUMERO SERIE APARATO : 3014-3

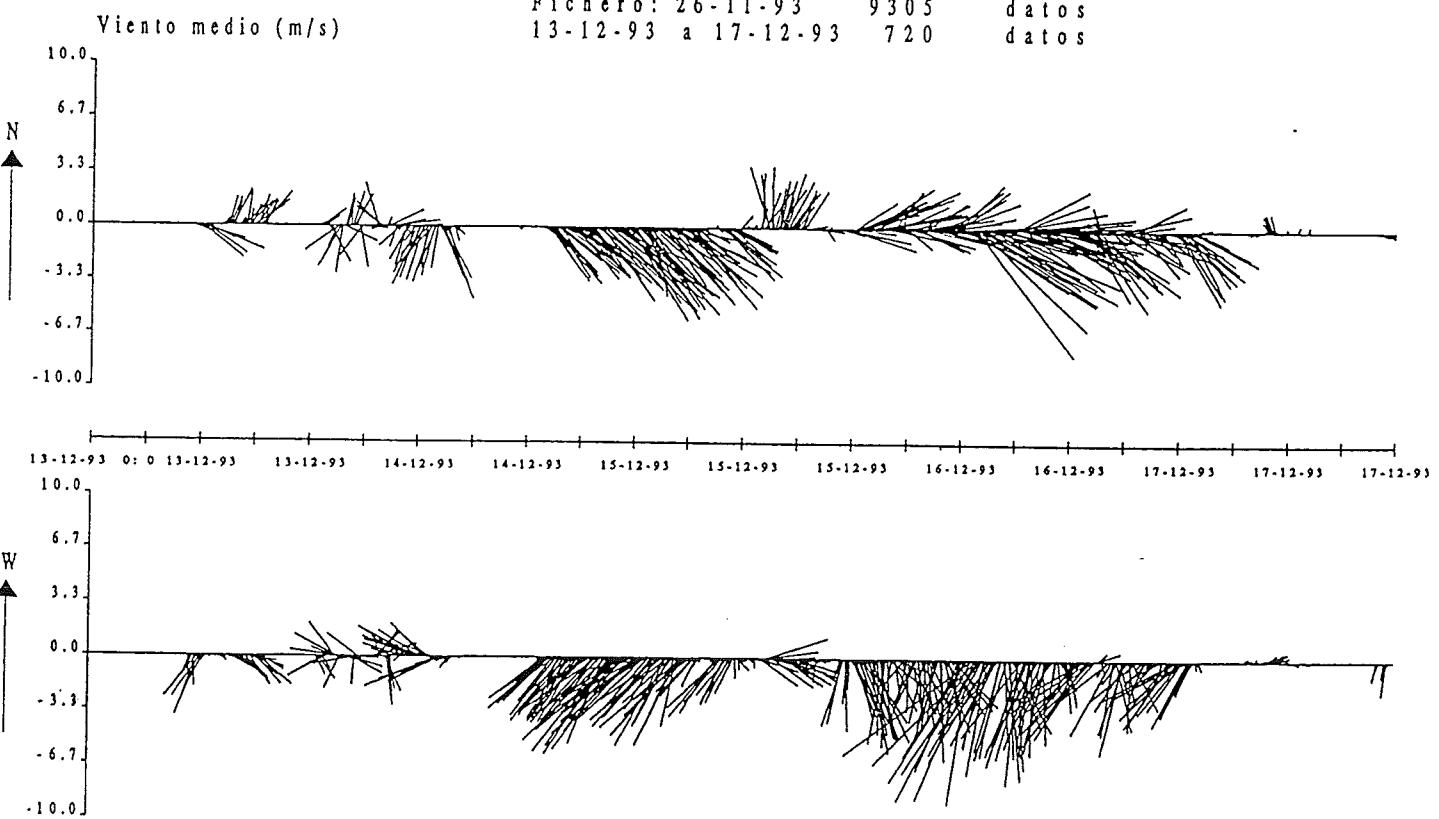
EMPLAZAMIENTO : DELTEBRE
 DATOS TRATADOS : 720
 LONGITUD : 00 45' E
 FECHA FINAL : 17-12-93 23:50
 DECLINACION MAGNETICA: 0.00
 FICHERO : E261193D

	VEL. MAX (m/s)	VEL. MED (m/s)	DIRECCI. (grads)	TEMPERA. (C)	PRESION (mb)
VAL. MIN.	0.000	0.000	5.339	-1.318	1012.537
VAL. MAX.	14.622	9.847	356.782	48.665	1034.292
RANGO	14.622	9.847	351.443	49.983	21.755
MEDIA	3.836	2.115	241.101	48.199	1021.204
VARIANZA	11.311	5.344	7621.223	22.154	37.436
DESVIACION	3.363	2.312	87.300	4.707	6.118
COEF VARIACION	87.671	109.278	36.209	9.765	0.599
COEF ASIMET.	0.469	0.775	-1.286	-10.017	0.642
CURTOSIS	-0.696	-0.441	0.787	98.499	-0.773
PT.ST.MIN	-1.141	-0.915	-2.701	-10.520	-1.417
PT.ST.MAX	3.207	3.345	1.325	0.099	2.139
COVARIANZA	103.130	71.811			
CORRELACION	0.351	0.356			

ESTACION DELTEBRE

Fichero: 26-11-93 9305
13-12-93 a 17-12-93 720

datos
datos



Serie vectorial girada 90.00 grados

12 horas: 2.40 cm

TIPO DE CINTA : ESTACION
 FECHA DE LECTURA : 15-10-93 9:30
 LATITUD : 40 37' N
 FECHA DE COMIENZO : 13-12-93 0:0
 VELOCIDAD DE MUESTREO: 10 MINUTOS
 NUMERO SERIE APARATO : 0821-1

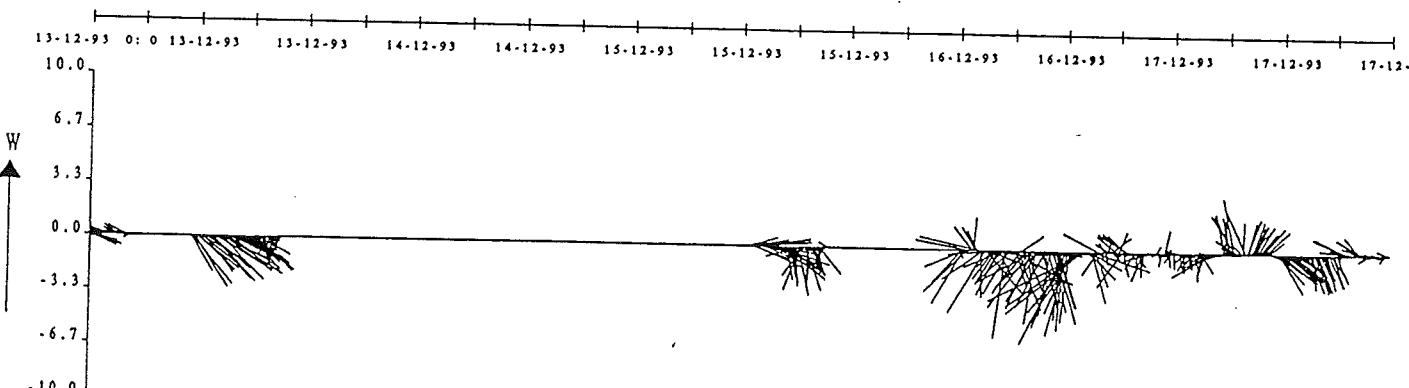
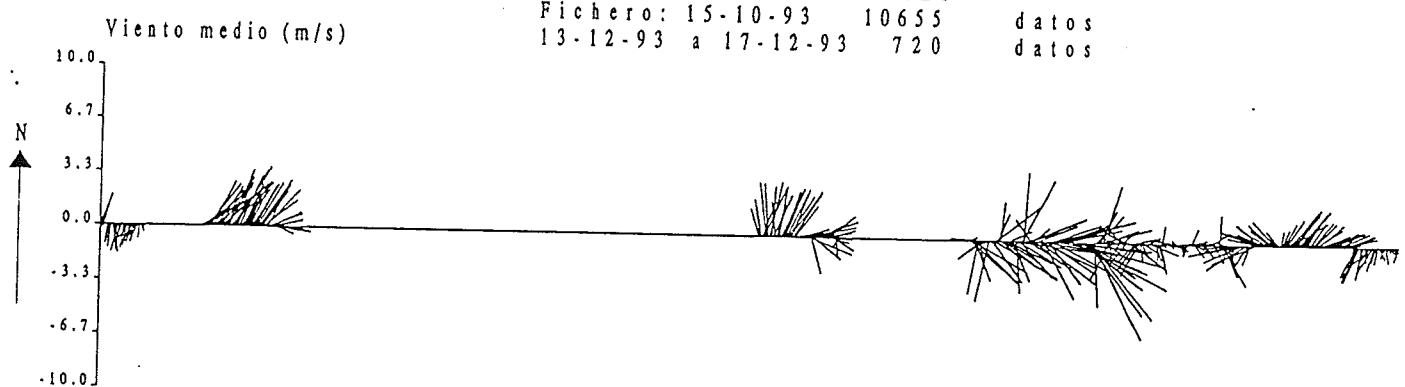
EMPLAZAMIENTO : SAN CARLES
 DATOS TRATADOS : 720
 LONGITUD : 00 16' E
 FECHA FINAL : 17-12-93 23:50
 DECLINACION MAGNETICA: 0.00
 FICHERO : E151093c

	VEL. MAX (m/s)	VEL. MED (m/s)	DIRECCI. (grads)	TEMPERA. (C)	PRESION (mb)
VAL. MIN.	0.000	0.000	4.990	7.811	1005.576
VAL. MAX.	11.041	6.639	356.084	18.410	1026.647
RANGO	11.041	6.639	351.094	10.599	21.071
MEDIA	1.740	1.059	213.926	12.053	1014.712
VARIANZA	5.053	1.830	13493.214	4.550	36.678
DESVIACION	2.248	1.353	116.160	2.133	6.056
COEF VARIACION	129.205	127.725	54.299	17.698	0.597
COEF ASIMET.	1.395	1.156	-0.632	0.908	0.559
CURTOSIS	1.675	0.627	-0.949	0.725	-0.856
PT.ST.MIN	-0.774	-0.783	-1.799	-1.989	-1.508
PT.ST.MAX	4.138	4.126	1.224	2.980	1.971
COVARIANZA	21.238	8.946			
CORRELACION	0.081	0.057			

ESTACION SAN CARLES

Fichero: 15-10-93 10655
13-12-93 a 17-12-93 720

datos
datos



Serie vectorial girada 90.00 grados

12 horas: 2.40 cm

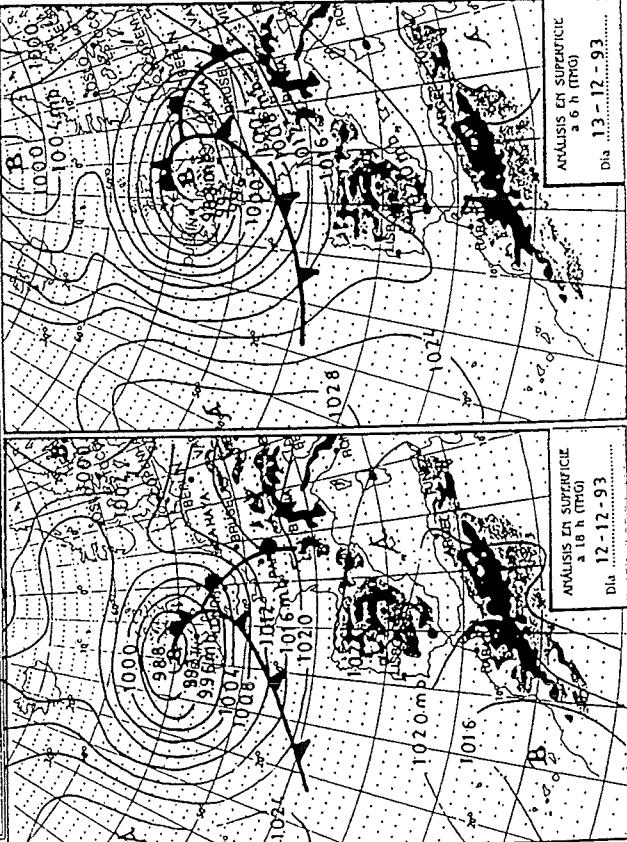
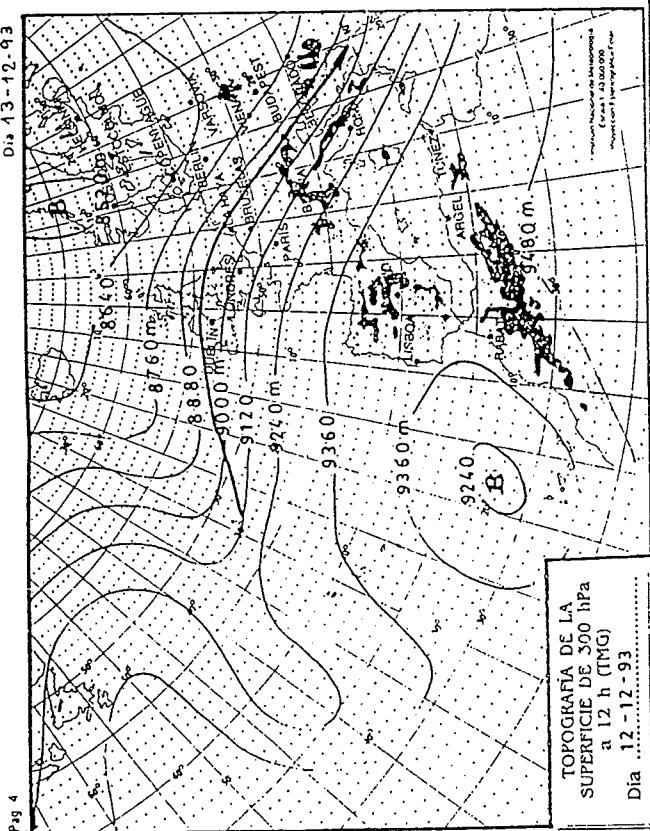
B O L E T I N

Ministerio de Obras Públicas y Transportes

MADRID, LUNES, 13 de DICIEMBRE de 1993 Número 347

Meteorológico

MADRID, LUNES, 13 de DICIEMBRE de 1993 Número 347



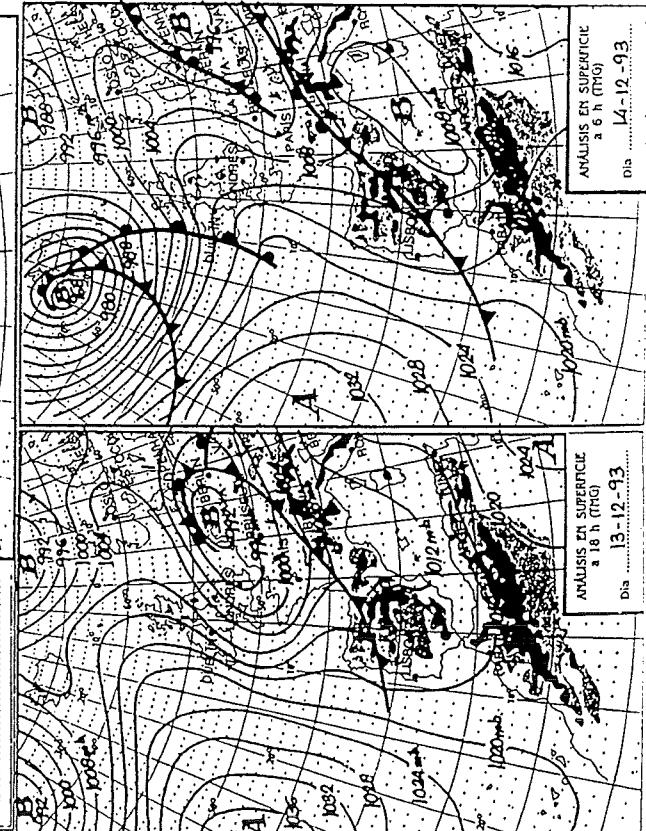
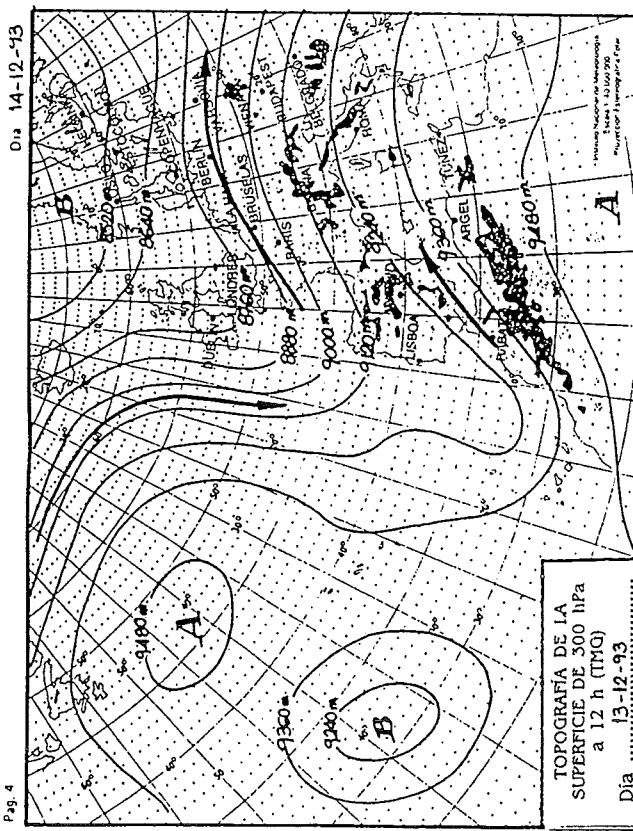
Meteorológico

BOLLETTINO

WICHTIG
Mitschrifte des Oberschul-Pedagogischen Instituts

MADRID, Martes, 14 de Diciembre de 1993 Número 348

14-12-43

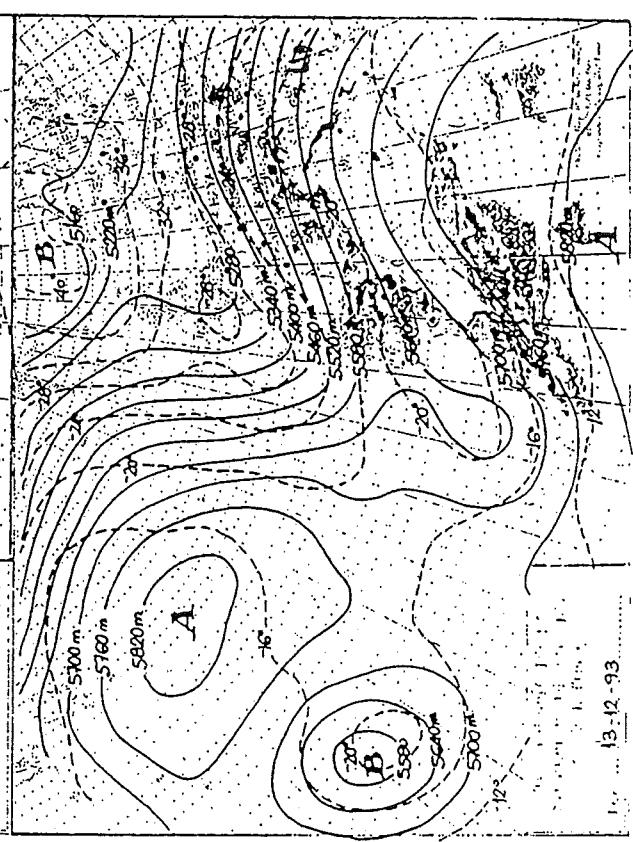
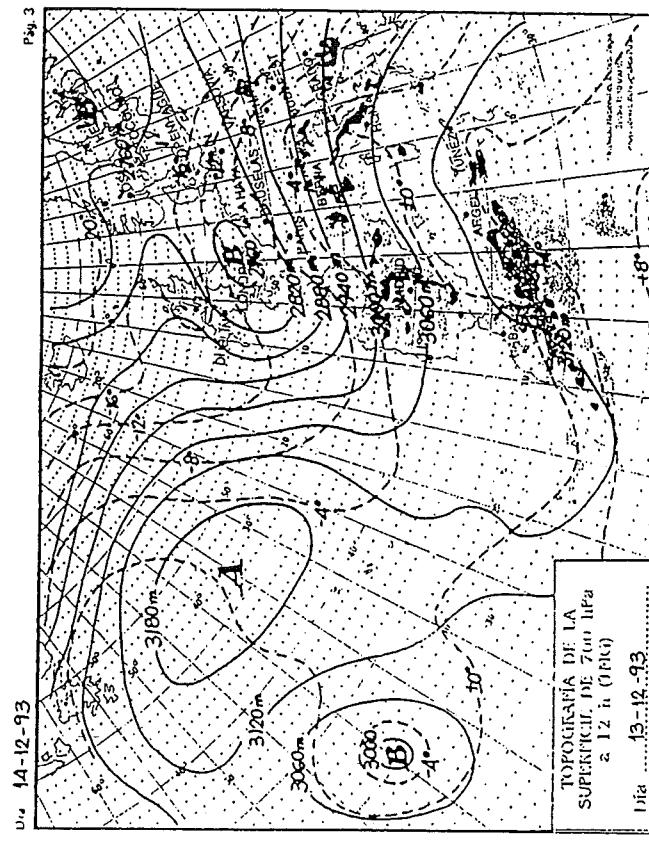
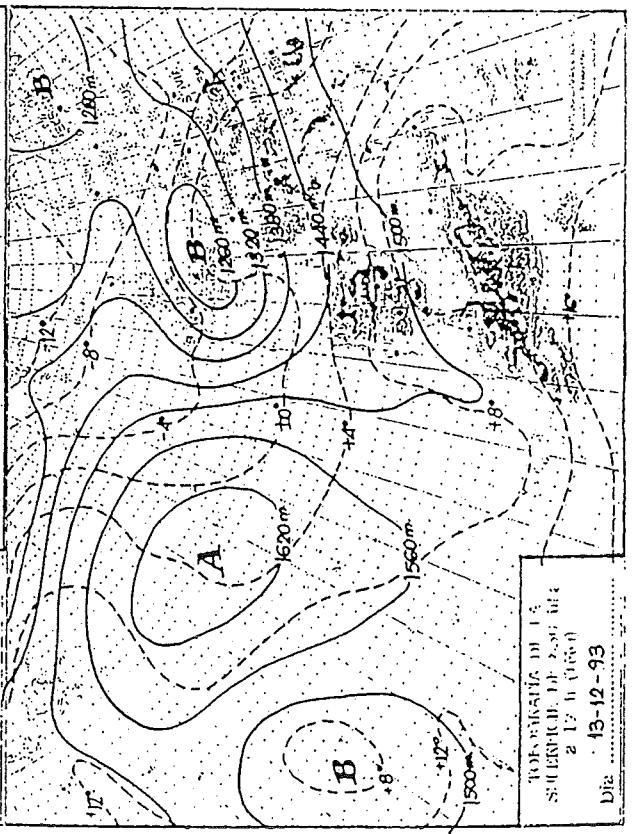
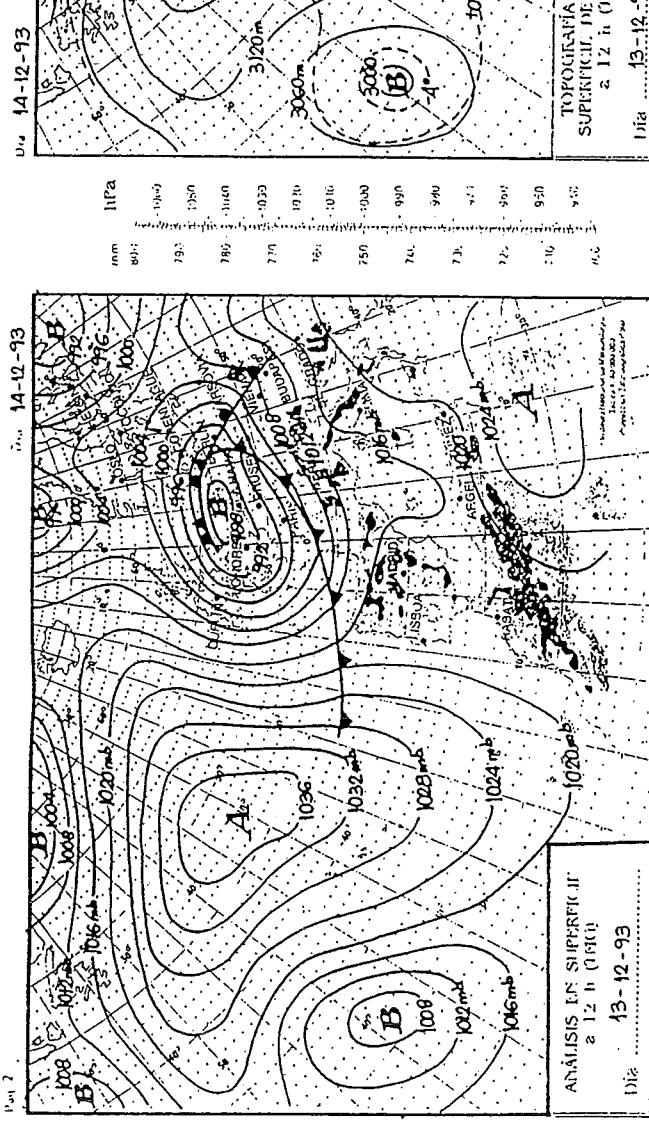


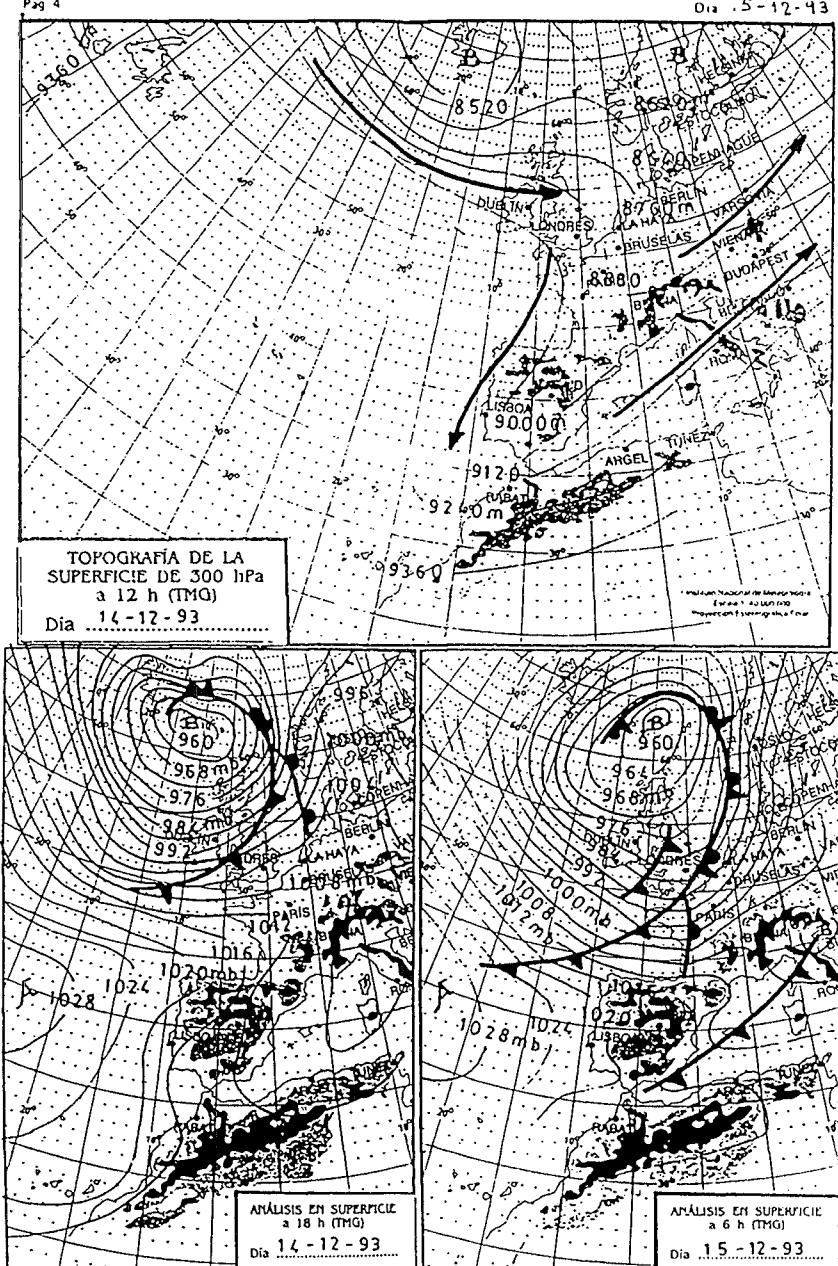
ESTACIONES	PRECIPITAC.			TEMPERAT.			RUMAS DE SOL		
	Mes.	Año	Día	Mín.	Max.	Méd.	Mín.	Méd.	Nubes
ZONA NOROESTE									
La Coruña	131	9	3.0	4.0	0.0		151	91	1
Almería	111	61	15.0	4.0	0.0		151	51	
El Ferrol	111	21	6.0	4.0	0.0		151	7	2.3
Lugo (P. C.)	9	101	3.0	5.0	0.0		151	7	
Santander (C. C.)	101	31	9.0	5.0	0.0		151	7	
Ponferrada	111	11	3.0	5.0	0.0		151	9	
Vigo (A)	9	51	1.0	0.0	0.0		151	7	
Vigo	101	71	7.0	0.0	0.0		141	81	1.4
Orense	71	41	7.0	2.0	0.0		141	81	
Ponferrada	71	21	2.0	1.0			131	91	
Avilés (A)	131	51	9.0	11.0	0.5		151	101	5.2
Gijón	131	61	6.0	8.0	1.4		151	9	3.9
Oviedo	111	41	9.0	8.0	1.4		161	111	
Bilbao (A)	141	61	6.0	8.0	2.3		151	9	
Bilbao (A)	141	81	12.0	5.0	2.3		151	101	2.4
Bilbao (A)	151	71	2.0	4.8	1.0		141	111	
San Sebastián (A)	141	71	2.0	5.0	1.4		141	91	0.6
San Sebastián (A)	181	71	2.0	5.0	1.4		141	91	
Lodón (A)	3	-21	2.0	0.4	0.0		141	61	1.6
Zamora	2	-21	1.0	2.2			111	31	
Palencia	-	-	-	-	-		111	31	1.0
Burgos (A)	-	-	-	-	-		171	91	3.5
Burgos	6	-1	0.2	1.0	1.0		161	131	
Valladolid (A)	6	21	0.6	0.0	0.0		181	101	3.8
Soria	111	01	1.0	7.4			181	131	1.5
Salamanca	-	-	-	-	-		181	131	1.6
Salamanca (A)	111	01	6.0	4.8			181	71	1.5
Ávila	121	01	3.0	6.2			161	111	4.8
Segovia	111	1	1	1			181	131	3.2
Navarra	71	-51	0.5	7.1			181	131	
Madrid-Barrio (C. C.)	111	11	1.8				221	161	
Madrid (C. Univ.)	111	5					171	111	
Madrid (Roble)	-	-	-	-	-		231	171	
Guadalajara	131						61		
Toledo	121	51	2.0	5.1			231	171	
Cuenca	131	51	0.4	3.3			231	161	
Molina de Aragón	131	-11	1.3	8.2			221	161	
Ciudad Real	141	71	1	8.0			221	151	
Albacete (A)	111	61	2.7				211	151	
Córdoba	111	51	3.0	0.7			211	151	
Badajoz (A)	121	1	1	1			211	151	
Vitoria (A)	9	21	2.0	3.9			181	141	5.0
Laredo	51	41	2.0	0.0			171	151	2.0
Pamplona	9	41	1.0	4.0	0.3				
Huesca	141	31	4.0						
Daroca	141	31							
Zaragoza (A)	71	41	6.8						
Zaragoza	121	1	0.0						
Calatayud	121	1	6.6						
Teruel	111	41							

INFORMACION GENERAL

EN GENERAL LOS CIELOS HAN ESTADO POCO NUBOSOS AUMENTANDO A MUY NUBOSOS AL PASO DE UN FRETE FRIO QUE EN LAS ULTIMAS 24 HORAS HA ESTADO ATRAVIESANDO LA PENINSULA. HA HABIDO PRECIPITACIONES, DE NIEVE EN LOS SISTEMAS MONTAÑOSOS DE LA MITAD NORTE. SORIA, AVILA Y SALAMANCA Y DE LLUVIA EN GALICIA, CANTABRICO Y PUNTOS EN AMBIAS CASTILLIAS, DESTACANDO LOS 20 L/M2 EN OVIEDO, 17 EN SANTIAGO Y 14 EN SANTIANDRÍA.

dia ... 4-12-43





Día 5-12-93

BOLETÍN Meteorológico

MOPt
Ministerio de Obras Públicas y Transportes

MADRID, Miércoles, 15 de Diciembre de 1993 Número 349

ESTACIONES	TEMPERAT. Máx. Min.	PRECIPITAC. Día Noche	HORAS DE SOL	ESTACIONES	TEMPERAT. Máx. Min.	PRECIPITAC. Día Noche	HORAS DE SOL
ZONA NOROESTE				CATALUÑA			
La Coruña —	11.1 7.1	0.61 1.01		Lérida —	9.1 1.1	—	0.4
Monteviejo —	9.1 7.1	4.01 2.01		Girona (A) —	12.1 1.1	—	0.7
El Ferrol —	—	—		Barcelona —	10.1 6.1	—	
Lugo (P. C.) —	—	1.01 0.41	1.4	Barcelona (A) —	11.1 5.1	—	
Santiago de C. —	8.1 2.1	5.01 1.01	3.4	Reus (A) —	11.1 4.1	—	0.6
Ponteveda —	10.1 3.1	0.91 2.01	2.0	Tarragona —	11.1 5.1	—	
Vigo (A) —	10.1 3.1	0.21 2.01	6.0	Tortosa —	—		
Vigo —	9.1 6.1	—	1.01 4.6	Montsoriu —	12.1 7.1	0.51	1.0
Orense —	10.1 0.31	—	2.5				
Ponferrada —	8.1 —	—					
ZONA CANTABRICA				LEVANTE			
Avilés (A) —	10.1 4.1	4.01 0.0		Castellón —	12.1 6.1	3.01	0.2
Gijón —	11.1 5.1	3.01 0.21	1.8	Valencia (A) —	13.1 —	5.01	
Oviedo —	7.1 1.1	10.01 0.0	0.9	Valencia —	18.1 7.1	1.01 40.0	1.1
Santander (A) —	12.1 —	5.01 —		Alicante (A) —	17.1 8.1	1.01 22.0	
Santander —	11.1 6.1	5.01 0.21	0.0	Alicante —	17.1 7.1	119.0	
Bilbao (A) —	10.1 4.1	5.01 0.41	0.0	Murcia (A) —	17.1 7.1	1.01 11.0	0.8
San Sebastián —	9.1 5.1	2.01 3.01	0.7	Cartagena —	16.1 9.1	—	
S. Sebastián (A) —	10.1 5.1	4.01 2.01	0.0	San Javier —	17.1 6.1	—	1.1
ZONA DUERO							
León (A) —	5.1 -2.1	—	6.4	SEVILLA (A) —	17.1 4.1	—	
Zamora —	—	0.01	6.4	Córdoba (A) —	12.1 2.1	—	1.4
Palencia —	4.1 -3.1	—	1.01	Jaén —	9.1 3.1	2.01	
Burgos (A) —	3.1 -4.1	—	0.0	Granada (A) —	11.1 —	—	
España —	—	—		Huelva —	14.1 5.1	—	8.3
Valladolid (A) —	—	—		Jerez de la Fron. —	14.1 2.1	3.01	8.1
Valladolid —	—	—		Cádiz —	13.1 8.1	1.01	
Soria —	6.1 -4.1	—	4.5	Tarifa —	13.1 8.1	3.01	6.9
Salamanca —	7.1 -2.1	—	—	Málaga (A) —	16.1 7.1	0.21	4.9
Salamanca (A) —	11.1 -2.1	—	3.3	Almería (A) —	16.1 7.1	—	4.0
Ávila —	2.1 -5.1	0.31	0.5				
Sogovia —	2.1 -2.1	—	0.4	BALEARES			
				IBIZA (A) —	15.1 10.1	3.01	1.8
				Mallorca (A) —	14.1 10.1	1.01	0.0
				Ibiza (A) —	17.1 12.1	0.61	1.9
ZONA GUADIANA							
Navacerrada —	—4.1 -7.1	3.01	0.0	BALEARES			
Madrid/Barajas —	8.1 -2.1	1.01	0.0	STA. C. Tenerife —	20.1 16.1	4.01	5.7
Madrid (C. Univ.) —	8.1 -2.1	—		Tenerife Norte (A) —	13.1 11.1	0.61	5.01
Madrid (Retiro) —	7.1 -1.1	—		Tenerife Sur (A) —	22.1 17.1	—	3.2
Guadalajara —	7.1 -4.1	—		IZALCA —	4.1 —	—	
Toledo —	8.1 0.1	3.01	0.0	LAS PALMAS (A) —	11.1 15.1	—	5.0
Cuenca —	7.1 0.1	7.0	0.0	FUERTEVENTURA (A) —	11.1 15.1	—	6.5
Molina de Aragón —	7.1 -5.1	—	0.0	LANZAROTE (A) —	19.1 16.1	2.01	1.8
Ciudad Real —	8.1 2.1	5.01	0.0	LA PALMA (A) —	11.1 15.1	—	
Albacete (A) —	10.1 4.1	3.0 4.0	0.0	HIERRO (A) —	16.1 10.1	13.01	
Cáceres —	10.1 3.1	—	5.8				
Badajoz (A) —	1.1 2.1	—		CEUTA —	18.1 11.1	9.01	9.01
				MELILLA —	—		
ZONA DEL EBRO / C. TAJO / GUADIANA							
Vitoria (A) —	6.1 -1.1	2.01	0.31 0.2				
Llodio —	8.1 2.1	1.01	1.01				
Llodio (A) —	9.1 -2.1	—	1.2				
Pamplona —	8.1 1.1	0.31	—				
Huesca (A) —	7.1 -1.1	—	1.3				
Daroca —	7.1 -3.1	—	0.6				
Zaragoza (A) —	11.1 1.1	—	4.1				
Zaragoza —	11.1 2.1	—					
Calamocha —	4.1 -1.1	—	0.2				
Teruel —	4.1 -3.1	0.81	0.1				

INFORMACIÓN GENERAL

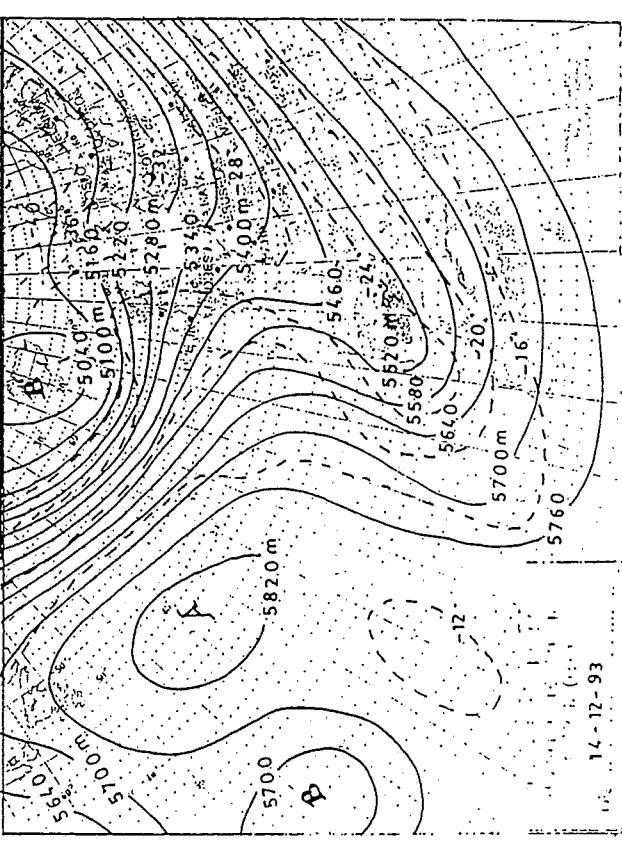
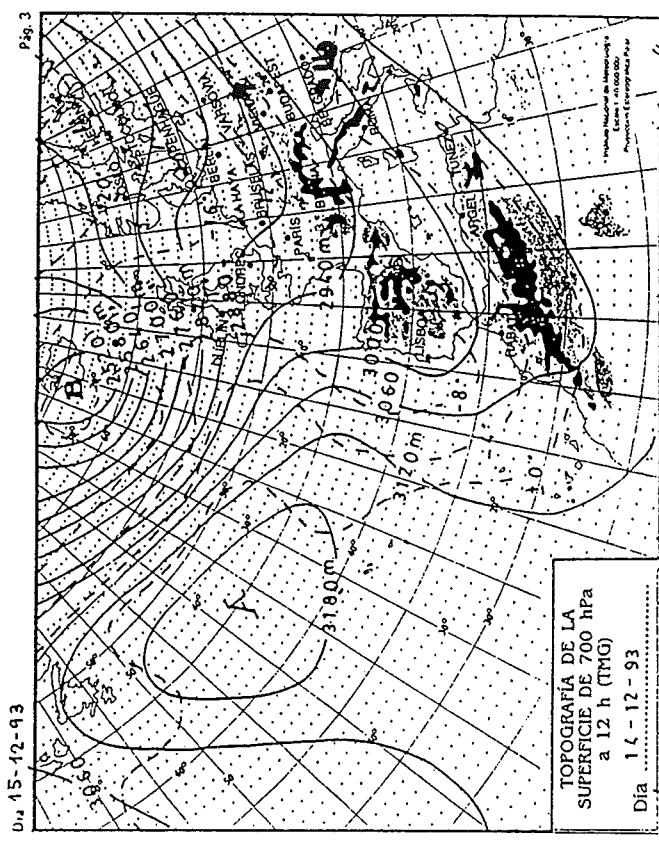
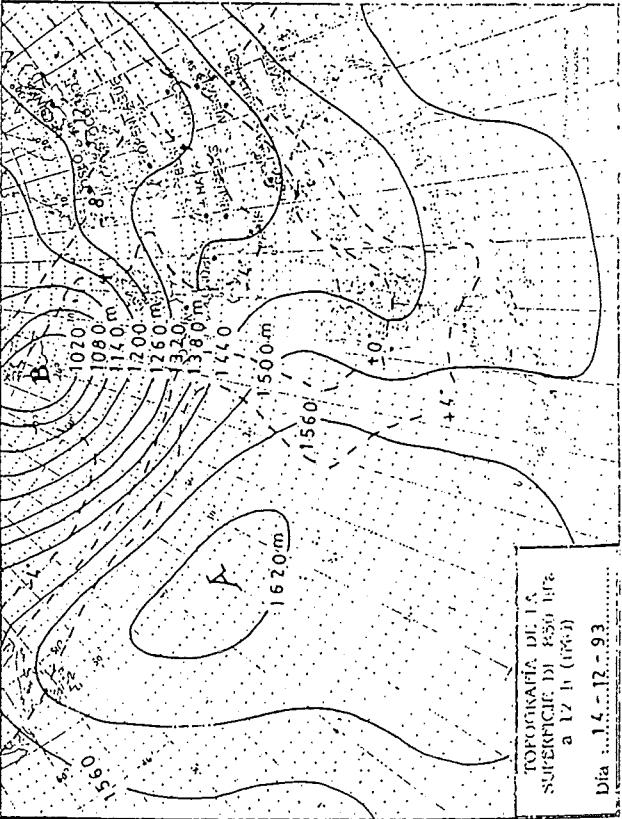
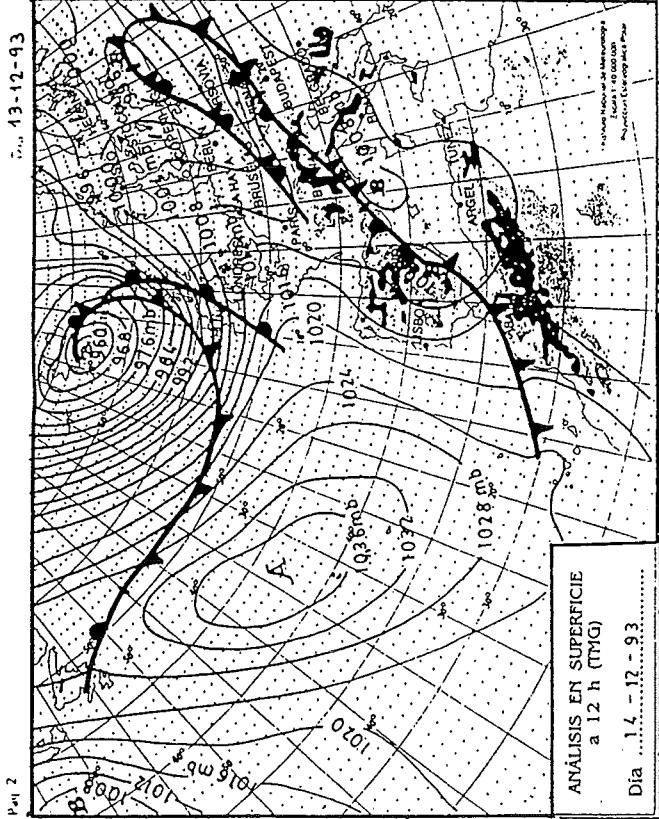
EN LAS ÚLTIMAS 24 HORAS HA LLUVIADO EN GALICIA; COMUNIDADES DEL CANTÁBRICO Y EN LUGARES CE AMBAS CASTILLAS, ALTO EBRO, ARAGÓN, COMUNIDAD VALENCIANA, MURCIANA, CATALUÑA, ANDALUCIA; BALEARES Y CANARIAS; DURANTE LA NOCHE PASADA SE REGISTRARON 40 L/M2 EN ALICANTE (A), 19 EN MURCIA (A) Y 7 EN PALMA (A); NEVO EN LUGARES DE CASTILLA-LEÓN Y SISTEMA CENTRAL.

NOTA: Las temperaturas vienen expresadas en °C, salvo que las precipitaciones lo estén en litros por metro cuadrado de superficie. Si es "precipitación insuficiente", es decir, inferior a 0.1 l/m2.

Las máximas y las precipitaciones de día son de 06 a 18 TMG de ayer.

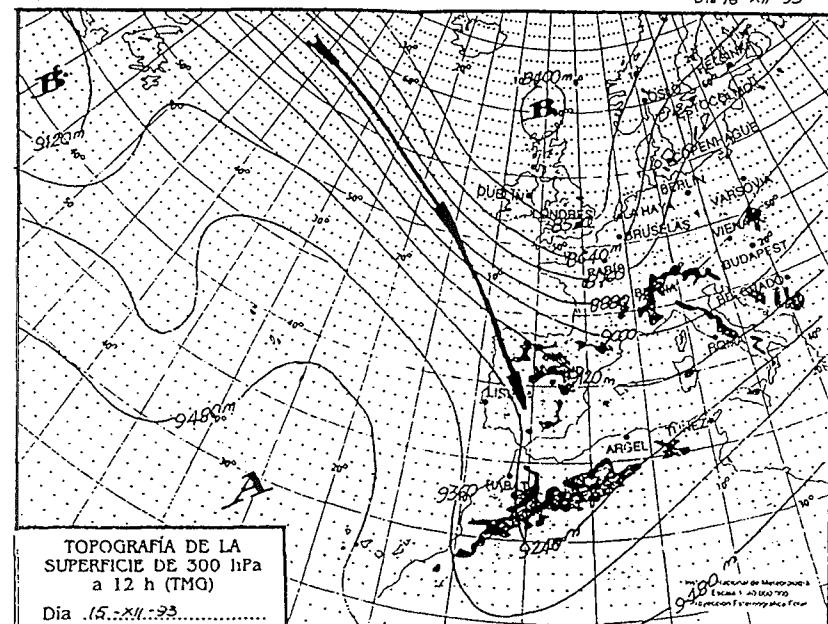
Las mínimas y las precipitaciones de noche son de 18 TMG de ayer.

Las horas de sol se refieren a ayer.



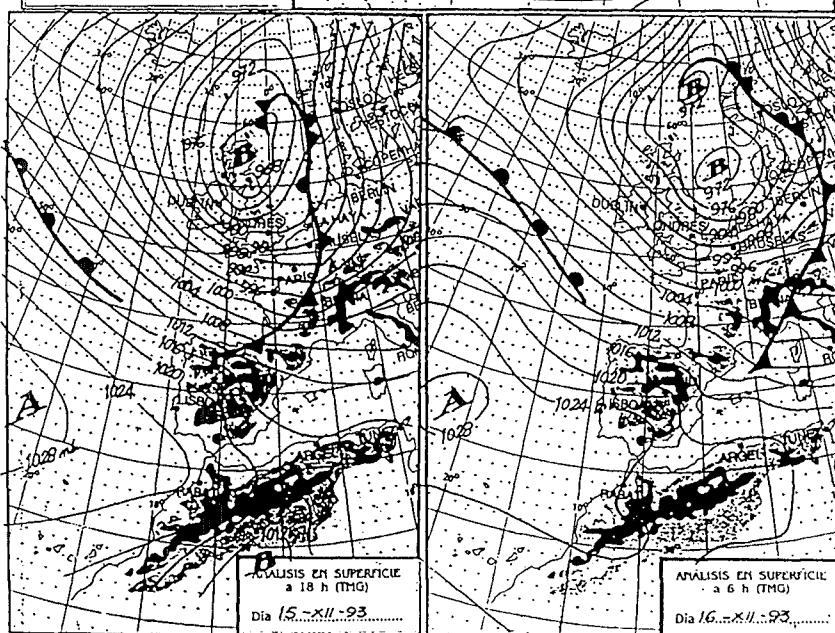
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**TOPOGRAFÍA DE LA
SUPERFICIE DE 300 hPa
a 12 h (TMG)**

Dia 15-11-93



**ANALISIS EN SUPERFICIE
a 18 h (TMG)**

Diá 15 ~ XII - 93

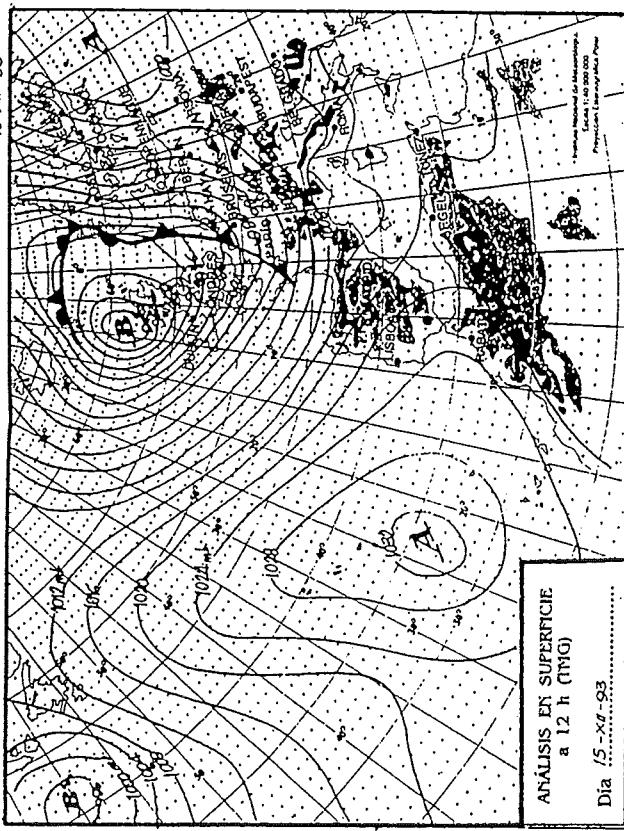
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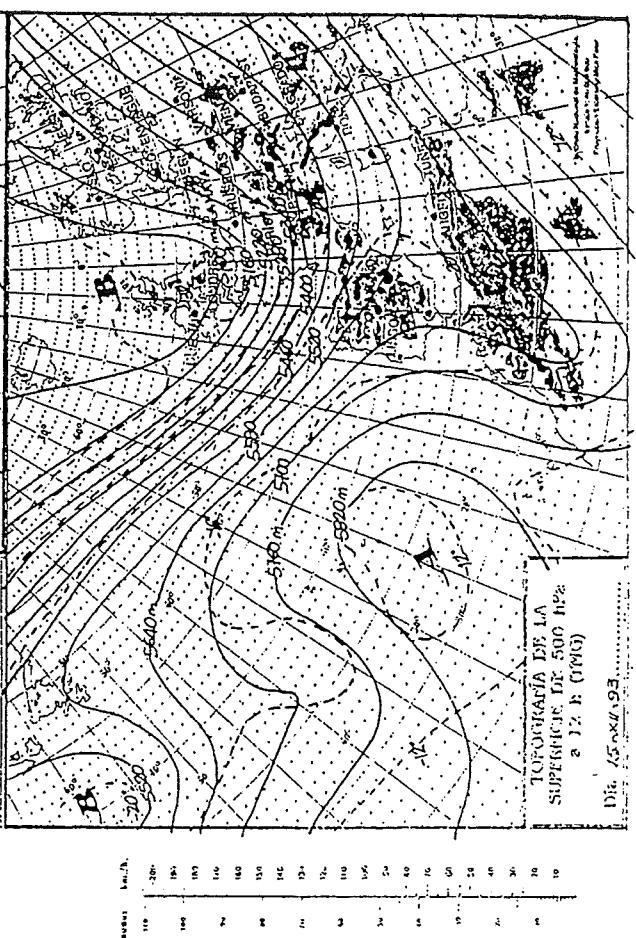
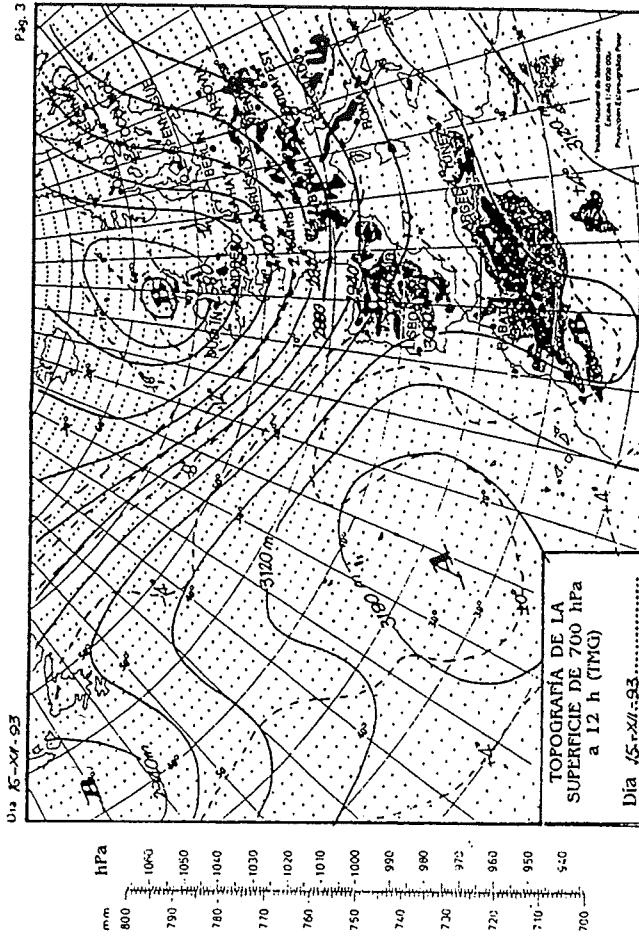
MADRID. Jueves, 16. de Diciembre de 1993 Número 350

DURANTE LAS ULTIMAS 24 HORAS HA ESTADO MUY NUBOSO EN LA VERTIENTE CANTABRICA Y PIRINEOS CON INTERVALOS NUBOSOS EN EL RESTO DE LA MITAD N PENINSULAR, BALEARES Y CANARIAS. HA LLUVIADO DEBILMENTE EN GALICIA, COMUNIDADES CANTABRICAS, PUNTOS DE CASTILLA-LEON, BALEARES Y CANARIAS Y EN FORMA DE NIEVE EN COTAS ALTAS DE LOS SISTEMAS MONTAÑOSOS. LOS VIENTOS HAN SIDO DE COMPONENTE W FLOJOS A MODERADOS EN LA MITAD N PENINSULAR, BALEARES Y AREA DEL ESTRECHO Y MODERADOS DEL NE EN CANARIAS.

Pfig. 2
15-XII-93



Pfig. 3
15-XII-93



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MICOP
Ministerio de Obras Públicas y Transportes

MADRID/VIERNES, 17 DE DICIEMBRE DE 1973 Número 334

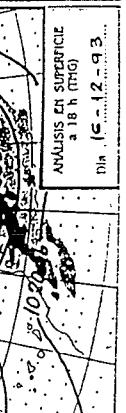
ESTACIONES	TEMPERATURA			PRECIPITAC.	HORAS DE SOL	ESTACIONES	TEMPERATURA			PRECIPITAC.	HORAS DE SOL
	M. M.	M. M.	Día. Noche				M. M.	M. M.	Día. Noche		
ZONA NOROESTE											
La Coruña (A) —	13	11	7.0	0.4			Lérida (A)	15	2		7.9
Monteviejo (—)	11	8	6.0	0.3			Gerona (A)	15	21		8.2
El Ferrol (—)	11	8	6.7	1.0	0.3		Barcelona (A)	16	5		
Lugo (G. C.) —	12	8	3.0	0.3			Tarragona (A)	16	5		7.4
Santiago do C. —	13	10	3.0	2.0	0.7		Tortosa (A)	16	5		7.9
Ponterrodo (—)	12	9	2.0	0.7			Montcada (A)	16	11		
Vigo (A) —	12	9	5.0	2.0	0.7		Cerdanyola (A)	18	11		8.3
Vigo (G.) —	12	11	5.0	2.0	0.8		Montseny (A)	18	11		
Orense (—)	13	7	1.0	0.3	0.4						
Portomarín (—)	11	7	1.0	0.3	0.4						
ZONA NOROESTE											
Avilés (A) —	14	8	1		1.0		Cartagena (A)	18	7		9.0
Colón (—)	15	7	1		1.0		Valencia (A)	16	5		8.8
Ortodoxo (—)	14	7	1		1.0		Alicante (A)	18	9		
Santander (A) —	14	10	1		4.8		Murcia (A)	18	31		9.0
Ribadeo (A) —	13	7	4.0	0.5	1.3		Cartagena (A)	18	4		
Blimea (A) —	13	7	4.0	0.5	1.3		San Javier (A)	18	3		9.3
Ben. Sebastian (A) —	11	9	0.1	2.0	0.0						
& Bobadilla (A) —	12	9	0.1	2.0	0.0						
León (A) —	9	1	1		4.6		Sevilla (A)	13	4		
Zamora (—)	5	1	1		1.6		Córdoba (A)	12	4		0.2
Palencia (—)	10	3	1		0.2		Jérez (A)	12	4		
Burgos (A) —	10	3	1		0.2		Granada (A)	8	1		7.9
Portugalete (A) —	10	3	1		0.2		Huelva (A)	16	4		0.6
Valladolid (A) —	10	3	1		3.8		Jerez de la Frontera (A)	15	9		
Valladolid (—)	10	4	3.5				Cádiz (A)	17	10		7.7
Sozla (—)	8	-3	4.4				Tarifa (A)	18	81		8.6
Balmameca (A) —	10	2	1		1.3		Almería (A)	18	81		8.8
Avila (—)	8	0	1		2.6		Palma de M. (A)	16	21		
Segovia (—)	8	4	0		0.0		Málaga (A)	15	8		7.6
Navafranca (—)	7	-2	1		0.0		Dízana (A)	10	1		
Madrid-Barajas (C. Univ.) —	13	-1	1		7.8		Sit. C. Teide-Tenefire-Norte (A)	19	161		IP
Madrid (Rodrigo) —	12	0	1				Tenefire Sur (A)	22	161		0.4
Grandal (Ara) —	13	1	1		7.9		Isla (A)	6	1		
Tolod (Ara) —	13	1	1		0.0		Las Palmas (A)	15	151		
Ciudad Real (Ara) —	10	1	1		4.0		Fuerteventura (A)	14	14		
Molina de Aragón (Ara) —	8	-1	1		4.0		Lanzarote (A)	19	131		
Albacete (A) —	11	2	1		5.7		La Palma (A)	20	161		
Chelva (A) —	13	4	1		4.1		Hierro (A)	—	1		
Badajoz (A) —	14	—	—				Ceuta (A)	16	101		
Vitola (A) —	10	0	1		0.4		Melilla (A)	16	81		
Lopodio (A) —	13	0	1		0.4						
Pamplona (A) —	11	0	0.3		7.8						
Recoletas (A) —	12	4	0.3		1.6						
Daroca (A) —	10	2	1		4.7						
Zaragoza (A) —	1	4	1		5.7						
Calamocha (A) —	9	1	1		6.5						
Teruel (A) —	10	-1	1		4.2						
					6.5						

INFORMACIÓN GENERAL

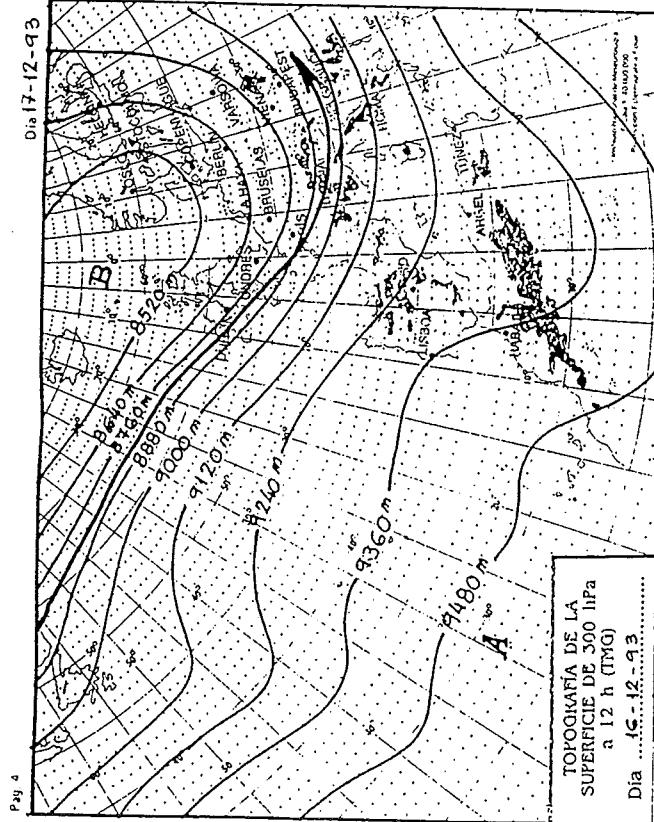
EN LAS ÚLTIMAS 24 HORAS LOS CIELOS HAN ESTADO MUY NUBOSOS CON PRECIPITACIONES DEBILS A MODERADAS, EN GALICIA Y CANTABRICO. NUBOSOS CON ALGUNA PRECIPITACION DEBIL EN ALTO E布RO Y CANARIAS. INTERVALOS NUBOSOS EN LA MEDITERRANEA Y BALEARES. LOS VIENTOS HAN SOSTENIDOS UNA VELOCIDAD MODERADA A FUERTE EN EL NORTE Y AL NOROESTE. LAS TEMPERATURAS NOCTURNAS HAN DESCENDIDO LIGERAMENTE CON HELADAS DEBILES EN PUNTOS DEL INTERIOR.



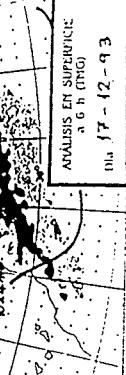
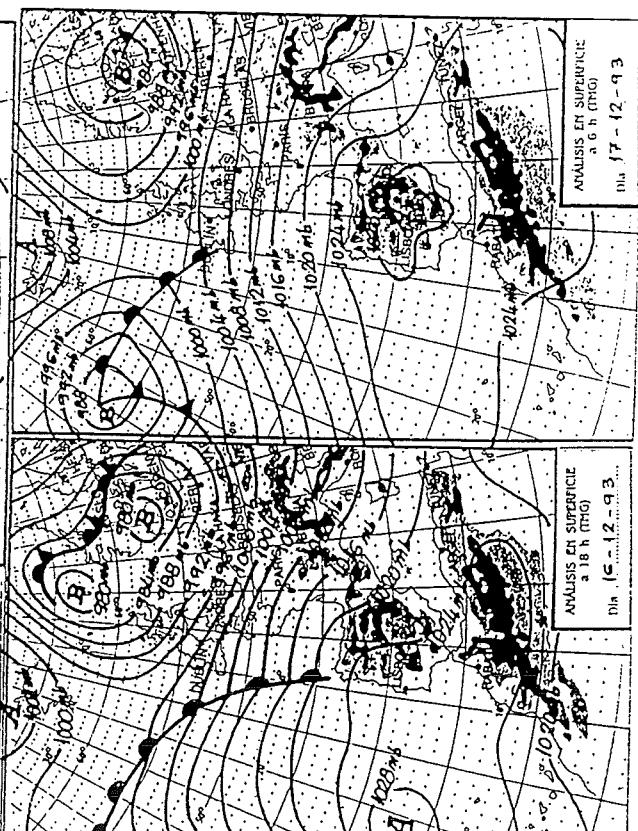
ANALISIS EN SUPERFICIE
a 6 h (TMG)
Día 17 - 12 - 93



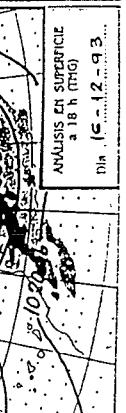
ANALISIS EN SUPERFICIE
a 00 h (TMG)
Día 17 - 12 - 93



TOPOGRAFIA DE LA SUPERFICIE DE 300 mPa
a 12 h (TMG)
Día 17 - 12 - 93



ANALISIS EN SUPERFICIE
a 12 h (TMG)
Día 17 - 12 - 93



ANALISIS EN SUPERFICIE
a 00 h (TMG)
Día 17 - 12 - 93

NOTA: Las temperaturas vienen expresadas en °C, indicando que las precipitaciones lo están en litros por metro cuadrado de superficie. IP = Precipitación Importante. o sea, inferior a 1 l/m².
Las nubes y las precipitaciones de día son de 06 a 18 h.
Las nubes y las precipitaciones de noche son de 18 h a 06 h.
IP = TMG de hor.
Las horas de sol se refieren a IP.

Fig. 2

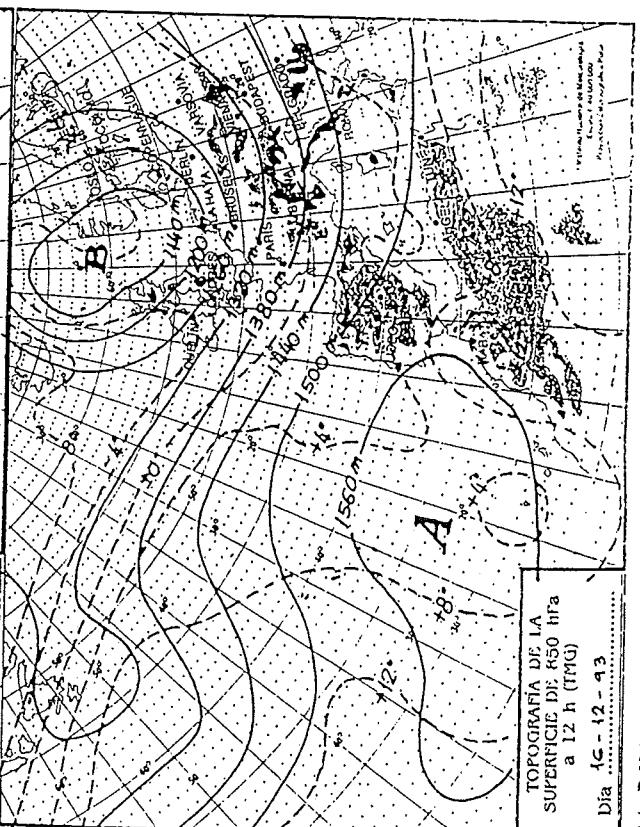
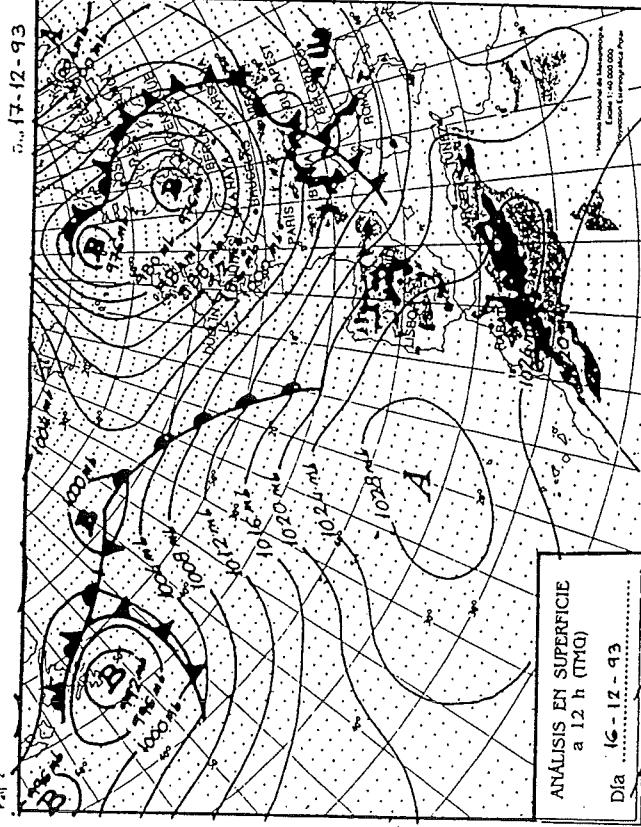


Fig. 3

