Prepared for:

Rijkswaterstaat, Rijksinstituut voor Kust en Zee

Bed variability in the surf zone at the storm- and seasonal time scale, mapped by Argus-video techniques

Preliminary results using the SBM-2DH model

Report

November, 2004

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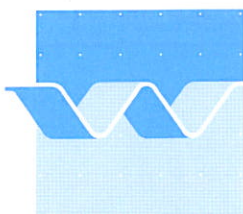
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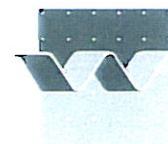
Preliminary results using the SBM-2DH model

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CLIENT:	Rijkswaterstaat Rijksinstituut voor Kust en Zee

TITLE:	Bed variability in the surf zone at the storm- and seasonal time scale, mapped by Argus-video techniques.

ABSTRACT:

Every five year the safety of coastal defence structures along the Dutch coast is evaluated based on model calculations. At present, the surf zone bathymetry measured during the 'summer' season (April-September) is used as an input condition for the models to evaluate safety during design storm conditions. This design storm is most likely to occur during the 'winter' season (October-March) and the question arises whether the summer profile is a correct input condition. In addition, the extent to which the bathymetry evolves during the storm itself is a relevant issue, because this evolution may possibly damp or reinforce the impact of the storm on the coast and its defence structures.

The bathymetric data needed to answer the above questions is not easily obtained with traditional surveying techniques due to the generally rough wave and weather conditions in winter and the sheer impossibility to be physically present in the surf zone during storm events. Consequently, an alternative to these in situ surveying techniques is needed. In this study Argus video imagery in combination with inverse modelling techniques (SBM-2DH model) is used to map the surf zone bathymetry near Egmond aan Zee from September 1999 to June 2001. Next the bed variability at the seasonal- and storm time scale is analysed along a cross-shore transect.

The most important observation with relevance for the 5-yearly evaluations of the coastal safety, is that the outer bar moves farther offshore during the winter period than can be derived from the annual surveys conducted during the summer period. The extent to which cross-shore positions of bars vary through a single storm event can not yet be assessed with sufficient accuracy, nor is the depth over the bar crest. This accuracy can be improved by upgrading the video-interpretation module of SBM-2DH, as well as by improving the calibration based on time series of bed level measurements at single points, such as provided by the ASM-instrument. Moreover, those time series will help build confidence in video-derived observations of bed variability during storm events.

REFERENCES:	Overeenkomst RKZ-1418
	Voortschrijdend Onderzoeksprogramma RIKZ-WL

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1 Introduction

1.1 Background

Every five year the safety of coastal defence structures along the Dutch coast is evaluated based on model calculations. At present, the surf zone bathymetry measured during the 'summer' season (April-September) is used as an input condition for the models to evaluate safety during design storm conditions. This design storm is most likely to occur during the 'winter' season (October-March) and the question arises whether the summer profile is a correct input condition. In fact, bars are likely to be located farther offshore in winter, and consequently have a larger water depth over the crest. This yields a stronger wave attack at the shoreline and possibly the coastal defence structures. In addition, the extent to which the bathymetry evolves during the storm itself is a relevant issue, because this evolution may possibly damp or reinforce the impact of the storm on the coast and its defence structures.

The bathymetric data needed to answer the above questions is not easily obtained with traditional surveying techniques. Summer surveying will not be the problem, but due to the generally rougher wave and weather conditions in winter it may be difficult to survey the surf zone over small enough time intervals. In addition, it is sheer impossible to be physically present in the surf zone during storm events. Consequently, an alternative to these in situ surveying techniques is needed. Argus video imagery in combination with inverse modelling techniques may be such an alternative.

A model that translates information from video images of the surf zone to bathymetry is the Subtidal Beach Mapper model (SBM). This model was originally developed in profile mode by Aarninkhof (2003) (SBM), and was later on extended to area mode (SBM-2DH) (Roelvink et al., 2003). In this study, a state-of-the-art version of SBM-2DH will be applied to gather bathymetric data on the storm- and seasonal time scale. This data will be used to assess whether 'winter' bathymetry differs systematically from the 'summer' bathymetry. Whether SBM-2DH can be used to map bed evolution over a storm event with sufficient accuracy is not yet clear and will be explored in the present study.

1.2 Objectives and approach

The objectives of the present study are two-fold:
- Analyse the difference between summer and subsequent winter surf zone bathymetry using Argus video imagery and the state-of-the-art version of SBM-2DH.
- Explore the possibilities to monitor bed evolution over a storm event using Argus video imagery and the state-of-the-art version of SBM-2DH.

Each topic will be analysed on the basis of a case study using data from the Argus station 'Jan van Speijk' located at the Egmond aan Zee lighthouse. The analysis will focus on the bed evolution along a cross-shore profile located in the centre of the mapped area. Since the

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SBM-2DH model has recently been upgraded, improvements over the version presented in Roelvink et al. (2003) will be briefly discussed in Chapter 2.

The general approach adopted in this analysis is to first calibrate the SBM-2DH model on the annual scale, i.e. to assess suitable parameter settings to obtain realistic bed evolution data over a 1.5 year period. Whether the evolution is realistic is determined by qualitative comparison to 5 traditional bathymetric surveys during the considered period.

For the analysis of seasonal- and storm scale bed level variability the calibrated SBM-2DH model will subsequently be ran over the period between the two nearest traditional bathymetric surveys. For the seasonal variability these are the surveys of March 2000[1] and March 2001. For the storm-related bed variability these are the surveys of September 1999 and March 2000. The degree of similarity between Argus-derived bathymetry and surveyed bathymetry at the end of each period provides a measure for the level of detail allowed in the interpretation of the preceding Argus-derived bed level variability.

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[1] *It appeared that the effect of starting SBM-2DH at a different initial bathymetry than the one used in the calibration run disappeared after only a few images.*

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2 Measuring surf zone bed levels from video imagery

The Argus monitoring system consists of a set of digital video cameras (usually 5, in order to cover a 180° field of view) connected to a computer. Controlled by this computer various types of visual information can be routinely collected, such as time-exposure images or time series of individual image pixels. The visual information usually is an indirect measure of the variable of interest. For example, this study requires bed level measurements, for which we will use time exposure images of the surf zone.

In order to map subtidal bathymetry from time-averaged video images the whiteness (i.e. image intensity value) related to wave breaking is quantitatively scaled to represent wave energy dissipation. This step is referred to as the Video Interpretation Model (VIM). The next step is referred to as the Bathymetry Assessment Model (BAM), which essentially consists of running a hydrodynamic model (flow and waves) in an iterative mode to estimate the underlying bathymetry. This two step procedure is the core of the Subtidal Beach Mapper (SBM) model developed by Aarninkhof (2003) (see Fig. 2.1). The original model was developed in profile mode and restricted to single camera coverage. This implied that the selected cross-shore profile had to be located either in front of the Argus station, such that it was covered by the offshore directed camera, or at a large distance (~ 1.5 km) such that is was covered by a longshore directed camera. At present the SBM model is extended to remove this single camera restriction and allow for the usage of multiple camera wave dissipation information. The extended model is referred to as SBM-2DH and is described in detail by Roelvink et al. (2003). In the following section the procedure to derive bed levels from time exposure images will be briefly explained. Also, recent improvements of the SBM-2DH model formulations and the results of calibration efforts will be summarized.
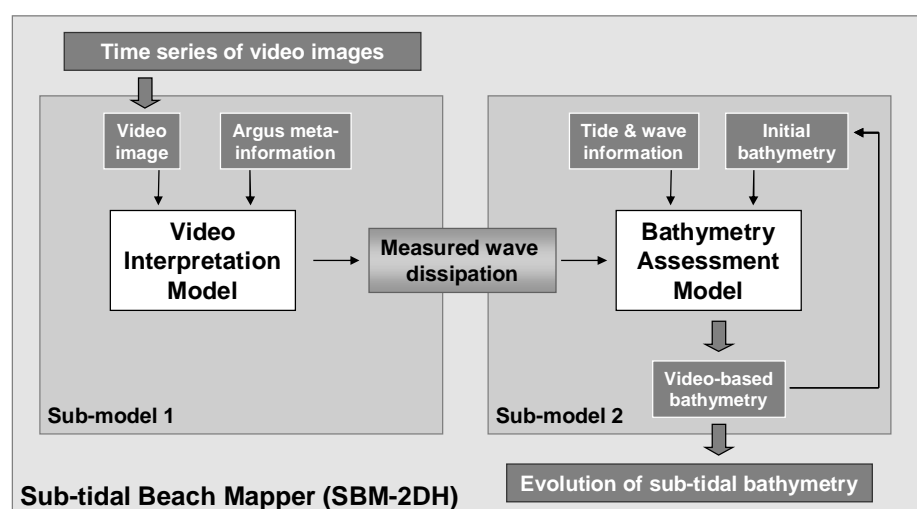

Fig. 2.1: *General layout of the 2DH Subtidal Beach Mapper SBM-2DH*

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2.1 The SBM-2DH model

The first step in the procedure to measure bed levels from video images is to select good-quality, time exposure images with sufficient wave dissipation, i.e. considerable wave breaking occurring over at least one sand bar. For this purpose, 5-camera merges of plan view images were used (Fig. 2.2).
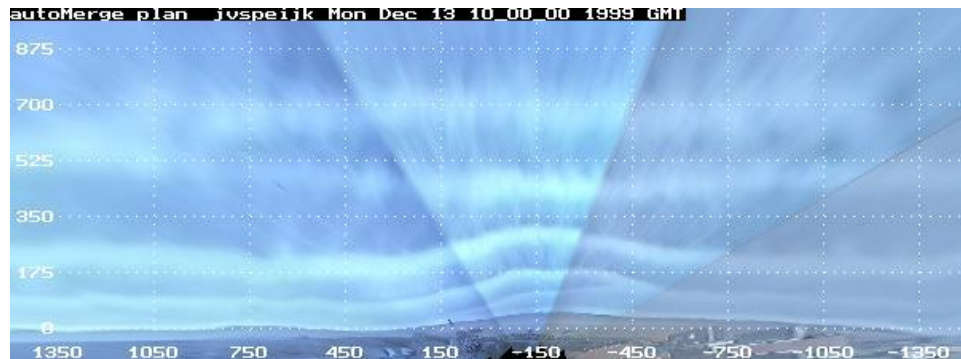

Fig. 2.2: *Merged, plan view image of Egmond station Jan van Speijk dd. 13/12/1999 at GMT 10:00 hr. The bright band at 700 m offshore shows the shoreface nourishment.*

The video interpretation model

To obtain a wave energy dissipation map from a merged plan view video image, to be used with the Bathymetry Assessment Model, a three-step approach is followed. First a background intensity level is removed, because an area with no wave breaking should map to no wave dissipation, hence the video intensity should be set to zero there. This is achieved by determining the average image intensity in the region from 800 m to 1800 m offshore (i.e. well outside the barred zone), for each vertical image line in the oblique image (Fig. 2.3a). Before transforming the oblique image to a plan view image this value is subtracted from each vertical image line.
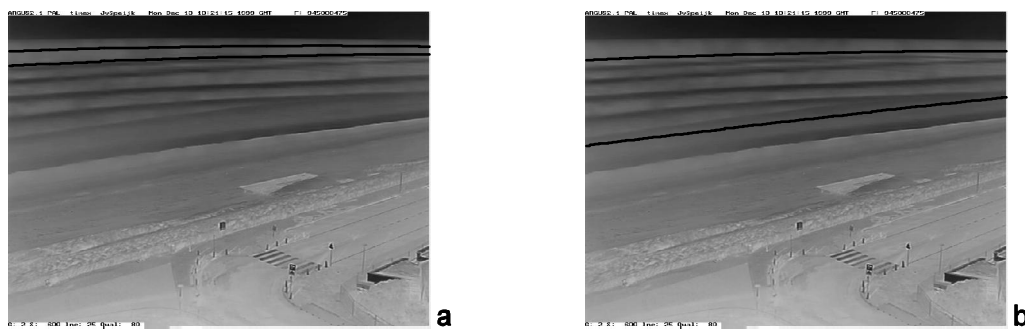

Fig. 2.3: *Visualization of the deep water region used for the cross-camera removal of background illuminations (a) and the surf zone region used for the determination of image contrast (b).*

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To obtain smooth wave dissipation maps covering multiple cameras, we further take into account differences in image contrast levels between cameras, because an area represented by a low contrast image will result in unrealistically low wave dissipation levels in that area. This is achieved by adopting the standard deviation σ_{sz} of surf zone pixel intensities as an indicator for image contrast. An image-specific σ_{sz} is determined from pixel intensities sampled from a nearshore region enclosed by shore-parallel lines at 100 m and 1000 m offshore (Fig. 2.3b). Breaking-induced image intensities collected from different cameras are corrected according to

$$I_{c,i} = \left(\frac{\sigma_{sz,\min}}{\sigma_{sz,i}} \right) I_i \qquad \text{(Eq. 2.1)}$$

where $\sigma_{sz,i}$ is the standard deviation of surf zone pixel intensities of camera i, $\sigma_{sz,min}$ is the minimum σ_{sz} of all cameras involved and I_i is the breaking-induced image intensity map of camera i (after correction for background illuminations) and $I_{c,i}$ is the breaking-induced image intensity map after correction for variable image contrast. The ratio $\sigma_{sz,min}/\sigma_{sz,i}$ typically varies between 0.5 and 1.

Finally, the corrected image intensities are scaled such that they are a quantitatively correct measure of wave energy dissipation. Following Aarninkhof (2003), SBM-2DH relates breaking-induced image intensity patterns I_v to hydrodynamic model-computed dissipation patterns of roller energy. Consequently, the Video Interpretation Model normalizes I_v such that $\iint_{x\,y} I_v dxdy = 1$ and scales the normalized intensity map with the incoming wave energy flux to obtain a video-derived measure of wave dissipation D_o that quantitatively matches the model-computed roller dissipation:

$$D_o(x, y) = \int_y Ec_g \cos(\theta)dy \left(\frac{I_v(x, y)}{\iint_{x\,y} I_v dxdy} \right) \qquad \text{(Eq. 2.2)}$$

In Eq. 2.2, E is the wave energy at the seaward end of the surf zone according to $E = \frac{1}{8}\rho g H_{rms}^2$, c_g is the wave group velocity and Θ is the wave angle of incidence with respect to shore normal. Wave conditions measured at deeper water are transformed to the seaward end of the surf zone with the help of a standard parametric wave model (Battjes and Janssen, 1978) including bottom friction, to account for the modification of wave height and direction due to wave refraction and bottom friction along the deeper part of the coastal profile.

The present version of the Video Interpretation Model does not apply any correction to the image intensity signal to remove the effect of persistent foam drifting at the sea surface. This correction would involve the application of a 2DH version of the Breaker Intensity Model described by Aarninkhof (2003), which is not operational yet. Also, no correction is made for occasionally occurring radial trends in background intensity, i.e. increasing

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background intensity with increasing distance to the camera, e.g. due to hazy conditions. (NB: the term 'radial' refers to the pattern of intensity trends as observed in a plan view image). In cases where this omission leads to a clearly spurious signal at the seaward boundary of the wave dissipation map the observed wave dissipation is forced to zero offshore of 1000 m.

Bathymetry Assessment Model (BAM)

After correction of the video images for the effect of spatially and temporally varying background illuminations and scaling to a quantitative measure of wave dissipation, the video-derived dissipation pattern is compared to a dissipation pattern obtained from running an advanced 2DH wave transformation model across a recent nearshore bathymetry. This may either be a traditionally surveyed bathymetry or a bathymetry determined from a previous image. Updating of the bathymetry is achieved by raising the bottom elevation in areas where the video-measured dissipation exceeds the model-computed dissipation and vice versa. Since the SBM-2DH model can include video data with high resolution in time, it allows for nearly continuous monitoring of surf zone bathymetry.

In the SBM profile model, a wave transformation model was incorporated in the BAM module. Considering the functional demands of BAM on the 2DH wave transformation model in relation to the functionality readily provided by the Delft3D modeling system, it was decided to implement BAM in the existing Delft3D environment rather than re-coding it (Fig. 2.4). The changes to the Delft3D code are limited to a routine ASSIM that reads the observed dissipation maps and interpolates them to a Delft3D grid and to a section in the existing sediment source/sink routine. The implementation in Delft3D is such that the assimilation with ARGUS data can, in principle, be combined with a regular morphological run.
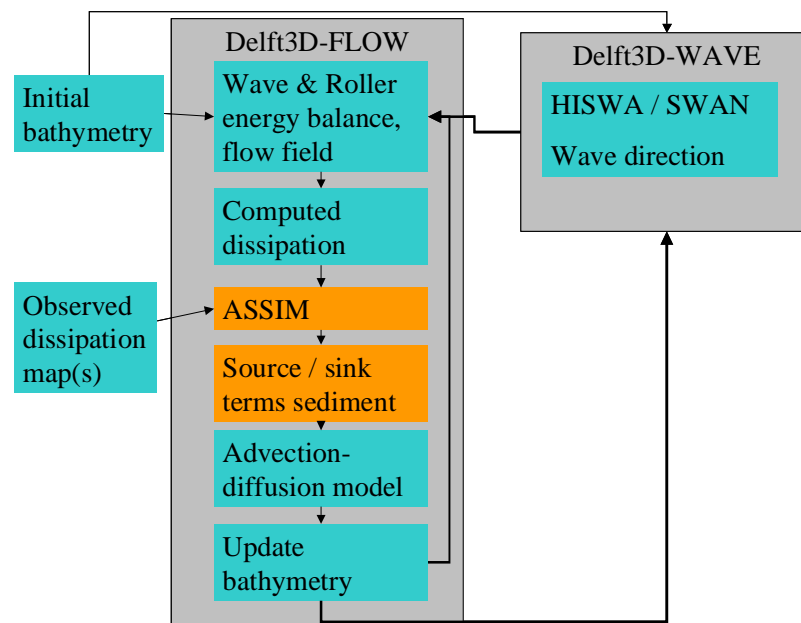

Fig. 2.4: *Flow scheme BAM*

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In 2004 a new model formulation for the breaking coefficient (γ = breaker height-to-depth ratio) was added to Delft3D, reading:

$$\gamma_{RWS} = 0.76kh + 0.29 \tag{Eq.2.3}$$

This empirical relation was derived by Ruessink, Walstra and Southgate (2003) (hence the abbreviation γ_{RWS}) through inverse modelling techniques. They revealed that the free model parameter γ is a locally varying parameter that increases linearly with the product of the local wave number ($k= 2\pi$/wavelength) and water depth (h). This formulation in particular improves the wave transformation modelling across inner bar-trough regions, where errors using a cross-shore constant value for γ are largest.

2.2 On the calibration of SBM-2DH

The SBM-2DH model has a series of free model parameters for which suitable settings need to be found. The suitability of the parameter settings is evaluated by a qualitative comparison of Argus derived bathymetries to 5 traditional bathymetric surveys during the considered period (Table 2.1, note that the first survey is used as input condition for SBM-2DH.)

*Table 2.1: Dates of traditional bathymetric surveys
(pers. comm. E. Biegel and A. de Kruif)*

data source	date
WESP	September 14/15, 1999
WESP	March 30/31, 2000
JARKUS	May 12/16, 2000
WESP	September 21/22/31, 2000
WESP	March 16/20/21/23, 2001
WESP	June 12/19/20/21, 2001

The breaking coefficient γ is the most important hydrodynamic parameter, since it largely determines the spatial pattern of wave dissipation over the nearshore area, hence the pattern of bed level update. In addition, a set of morphological parameters exists that controls the rate at which the bed level is updated per image. These parameters do not affect the overall pattern of bed level update but rather the time scale at which 'erosion' (bed level lowering) and 'accretion' (bed level lifting) occurs. Since we aim for a gradual update of the bathymetry on the basis of a time series of images, instead of over-fitting bathymetry at a single image, calculations for a new bed level are generally ended before an exact fit of calculated and observed dissipation pattern is achieved. Therefore, the parameters affecting the time scale of erosion and accretion do affect the calculated profile changes. The optimal setting of these parameters is related to the time interval between images and the rate of true morphologic change. An in depth analysis on this topic is presented in Aarninkhof (2003).

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In the following, the effect of the newly introduced cross-shore varying breaking coefficient γ on the bed level estimates will be briefly analysed. Also the effect of increasing the number of images to monitor bathymetric change, as compared to Roelvink et al. (2003), will be discussed.

Breaking coefficient (γ)

The value of the breaking coefficient affects the computation of the overall bed level in the following sense. For a given wave height, small values of γ generally lead to relatively deep bed levels in comparison to large values of γ (compare Fig. 2.5, γ=0.5, to Fig. 2.6, γ=0.8). This can be understood from the fact that for γ=0.5 waves do break relatively easily in the hydrodynamic model (as compared to setting of γ=0.8). To match the wave dissipation observed by Argus, the computed bed level needs to be deeper for γ=0.5 than for γ=0.8.

However, due to the fact that the total amount of wave energy to be dissipated over the profile is constant, the full effect of changing γ is slightly more complicated. Rather than simply lowering or raising the profile, with some sort of hinge point at the shoreline, offshore 'erosion' of the profile coincides with nearshore 'accretion' (and vice versa). Close inspection of Fig. 2.5 and 2.6 reveals this effect occurs indeed. The bed levels landward of the inner bar (located near $x=1.028 \times 10^5$ km) respond in the opposite direction to changes in γ as compared to the bed levels seaward of it.
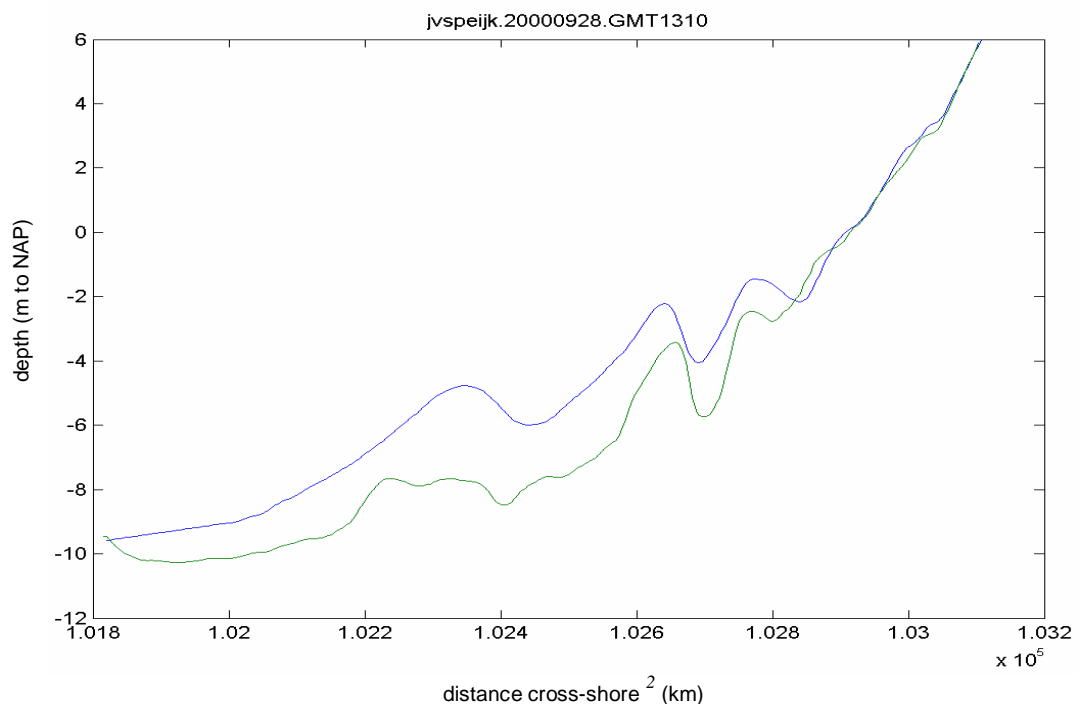

Figure 2.5: Bathymetry measured by WESP (blue line, survey 21/22/31 Sep 2000), and by Argus (green line, 28 Sep 2000) using SBM-2DH after one year of updating the bathymetry from WESP survey Sep 1999), with parameter setting γ = 0.5. (NB: this is the result of a model run using a limited amount of images for evaluating parameter sensitivity)

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[2] *The distance cross-shore is defined according to the Dutch geo-referencing grid ("Rijks Driehoek stelsel"). Tickmarks at 200 m interval.*

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Figure 2.6: Bathymetry measured by WESP (blue line, survey 21/22/31 sep 2000), and by Argus (green line, 28 sep 2000) using SBM-2DH after one year of updating the bathymetry from WESP survey sep 1999, with parameter setting $\gamma = 0.8$. (NB: this is the result of a model run using a limited amount of images for evaluating parameter sensitivity).
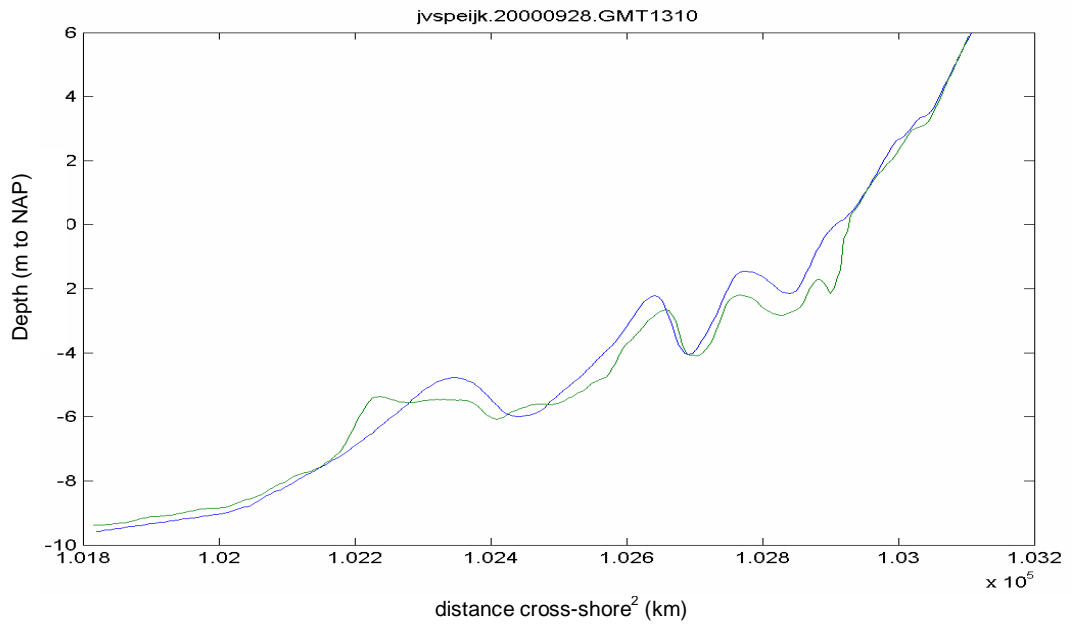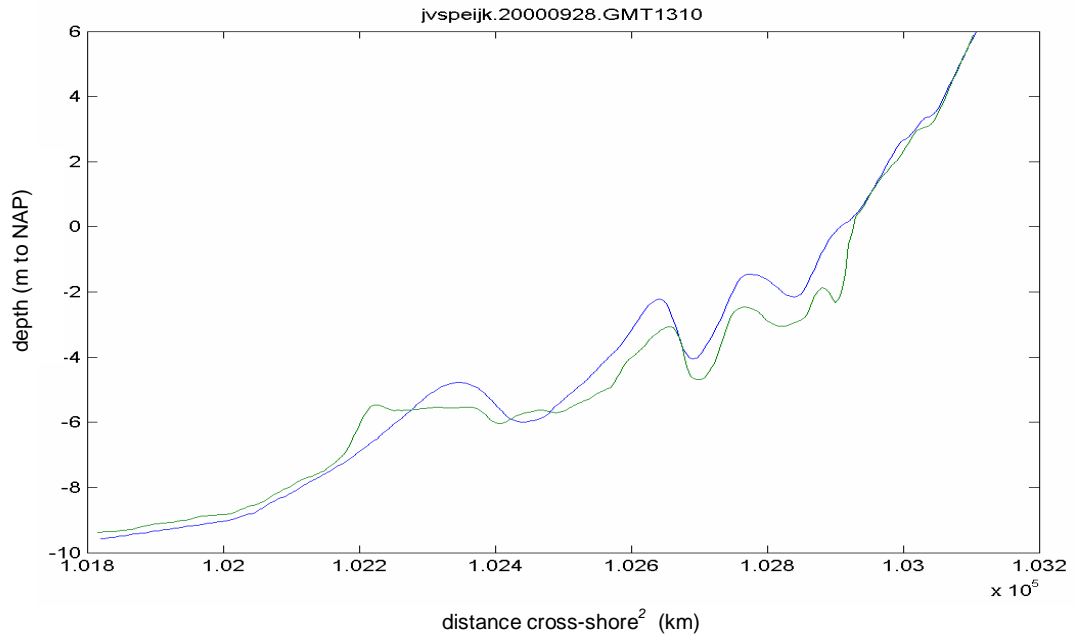

Figure 2.7: Bathymetry measured by WESP (blue line, survey 21/22/31 sep 2000), and by Argus (green line, 28 sep 2000) using SBM-2DH after one year of updating the bathymetry from WESP survey sep 1999, with parameter setting $\gamma = \gamma_{RWS}$. (NB: this is the result of a model run using a limited amount of images for evaluating parameter sensitivity).

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In theory, the cross-shore variable γ setting ($\gamma = \gamma_{RWS}$, see Eq. 2.3) should be the best setting. However, applying the cross-shore variable γ setting produces a somewhat less good approximation of the traditionally surveyed bathymetry than applying a fixed γ value of 0.8 (Fig. 2.7). The better performance for γ=0.8 is probably related to the fact that it counteracts the effects of ignoring the occasional occurrence of radial trends in the background intensity. Since we did not want to be virtually accurate by masking errors in the VIM by setting γ to a rather large (unrealistic) value, we preferred the cross-shore variable γ setting.

Number of images

Increasing the number of images for updating the bathymetry positively affects the overall quality of the bed level monitoring, especially regarding the location and elevation of bar crests (compare Fig 2.8 and 2.9). Note that the unrealistic overestimation of the depth over the inner trough in Fig. 2.9 is corrected over time when sufficient images are used to monitor the subsequent on- and/or offshore movement of the bars (see Fig. 2.10). (NB: the unrealistic trough depth is produced during a storm event where probably a too high level of background intensity was removed in the VIM module, such that the observed dissipation map did not allow for any breaking to occur over the trough.)

Figure 2.8: Bathymetry measured by the WESP (blue line, survey March 16-23, 2001), and by Argus (green line, March 19, 2001) using SBM-2DH and only 12 images for updating the bathymetric change over a period of 1.5 year starting from the September 1999 WESP survey.

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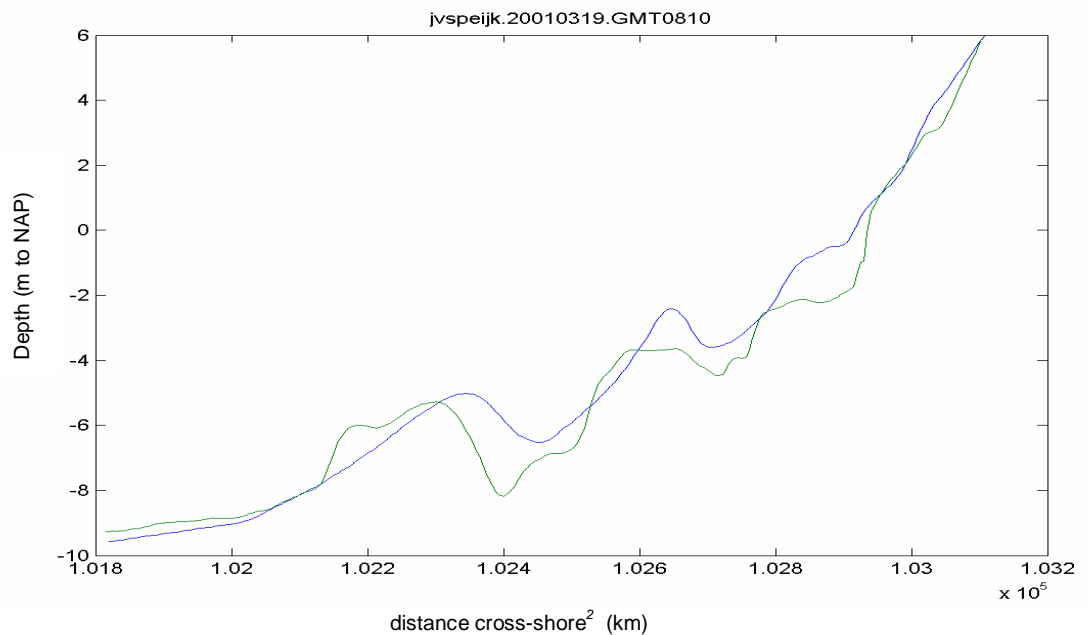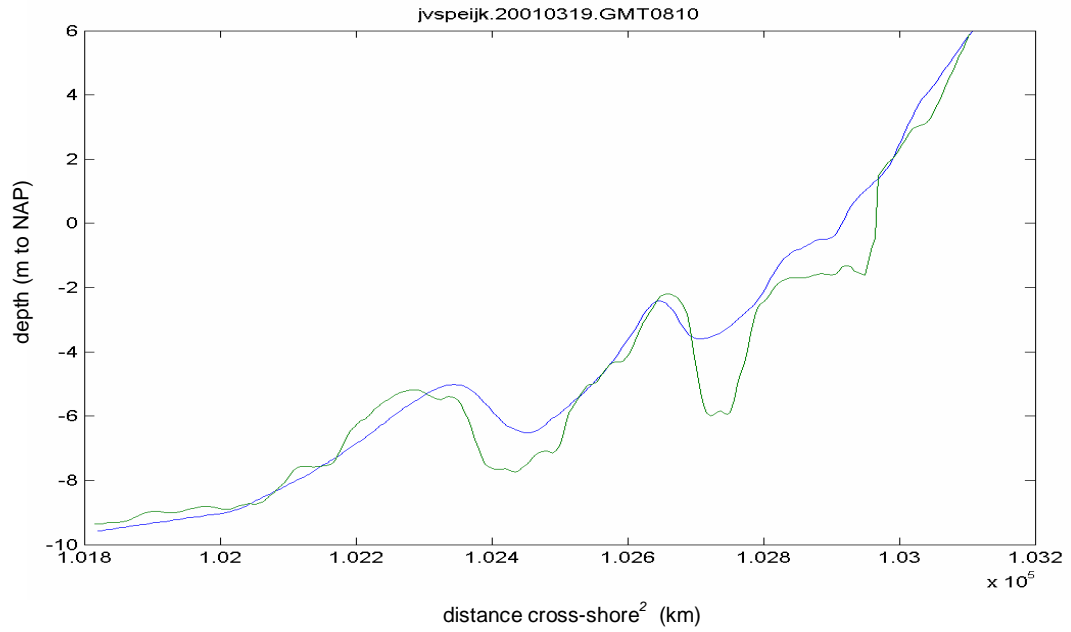*Figure 2.9: Bathymetry measured by the WESP (blue line, survey March 16-23, 2001), and by Argus (green line, March 19, 2001) using SBM-2DH and 71 images for updating the bathymetric change over a period of 1.5 year starting from the September 1999 WESP survey.*
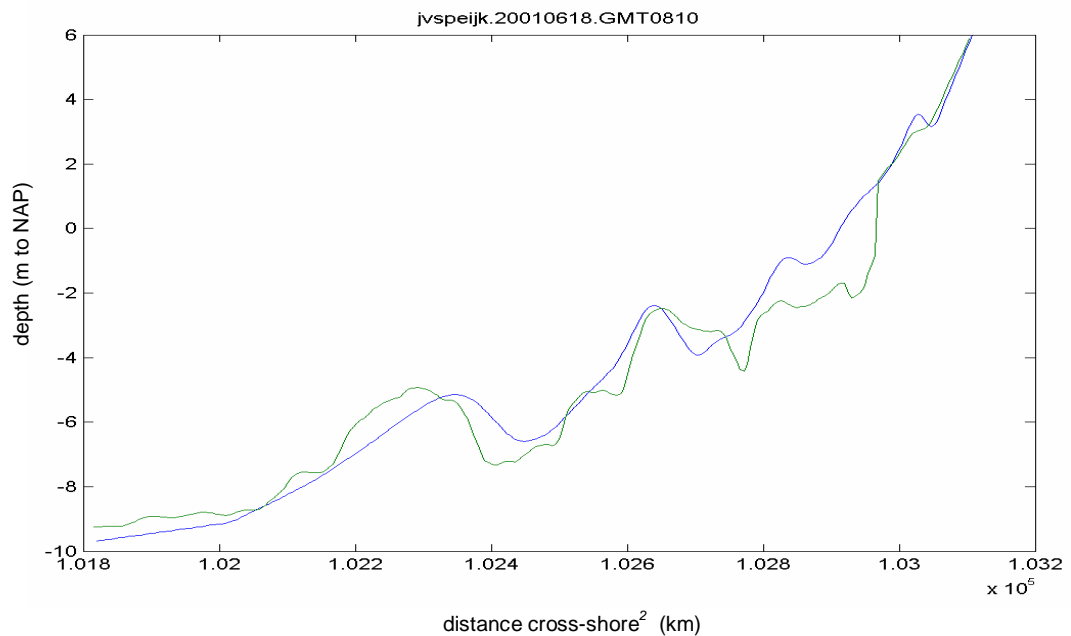

Figure 2.10: Bathymetry measured by the WESP (blue line, survey June 12-21, 2001), and by Argus (green line, June 18, 2001) using SBM-2DH (after updating the bathymetric change over a period of 1.7 year starting from the September 1999 WESP survey).

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Note that if onshore bar movement is large and mapped using images during relatively low wave conditions, the deeper part of the profile is arrested in the SBM model because without wave breaking no adjustment of the bathymetry occurs. This may cause a 'stepped' appearance of the seaward slope of the onshore migrated bar (see Fig. 2.10 middle bar near $x = 1.026 \times 10^5$ km). Also, images with large radial onshore decreasing trends in background intensity, which is currently not corrected for, will produce observed wave dissipation maps with a too large cut-off of wave dissipation. That is, in reality wave breaking occurs on the seaward slope to a larger offshore distance, but this is not correctly represented in the wave dissipation map.

2.3   Seasonal scale bed level measurements

In order to asses whether winter bathymetry differs systematically from summer bathymetry, cross-shore profiles collected in the summer of the year 2000 will be compared to profiles collected in the winter of 2000/2001. Fig. 2.11 shows the wave height variation over this period as well as the timing of the 51 images used for monitoring the seasonal variability in bed level.
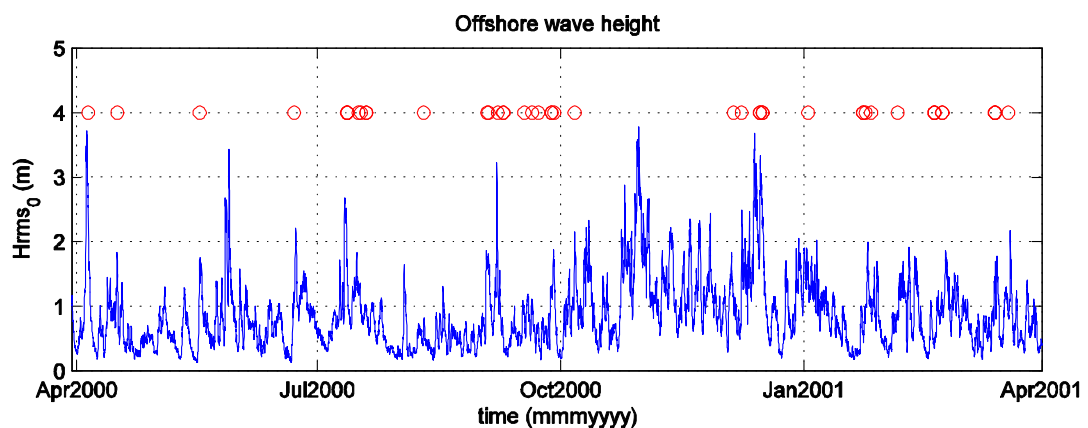

Figure 2.11: Offshore H_{rms} wave height. Red circles indicate selected images used for monitoring seasonal bed level variability with SBM-2DH. Summer observations cover period April 1, 2000 to September 30, 2000; winter observations cover period October 1, 2000 to March 31, 2001.

Fig. 2.12 illustrates the extent to which the Argus derived bathymetry approximates the bathymetry surveyed by the WESP. Obviously, the trough features are far too deep (this anomaly is corrected later on, see Fig 2.10). Qualitatively, the morphology for the inner bar and middle bar zone match reasonably well, i.e. the inner bar moved onshore and evolved into a terrace type feature and the middle bar moved onshore (not only the crest but the complete feature). The mismatch in bar crest position of the outer bar is probably related to the limited number of images that mapped the outer bar position. During a subsequent storm in June 2001, providing good quality images, the position of the outer bar crest mapped by Argus is corrected and then nicely matches the one in the WESP survey.
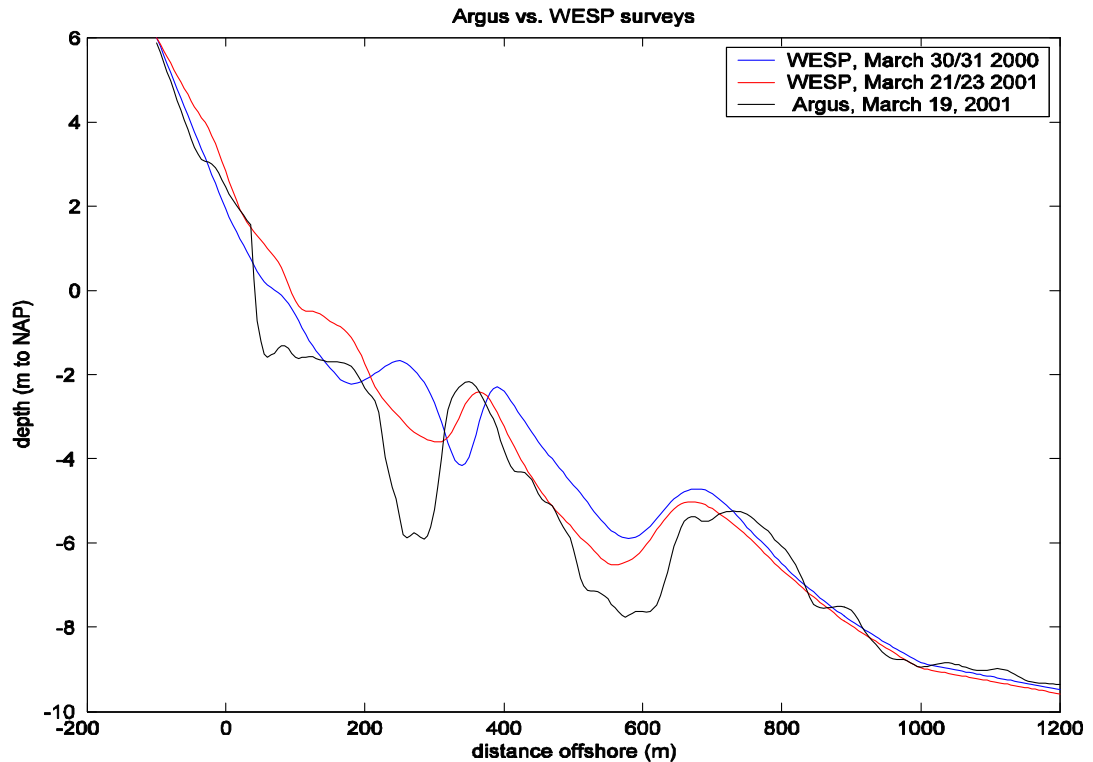
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Figure 2.12: WESP and Argus-based bed level survey in March, 2001, with Argus monitoring starting at March 2000.

2.4   Storm scale bed level measurements

To analyse bed level variability over a storm event, two subsequent storms in the period March 14 to March 19 (year 2000) were selected. This particular period was selected because it occurred close to a traditional bed level survey (March 21-23). This allowed for a relatively good ground truth of the Argus-derived bed level changes.

The wave heights over the considered period are shown in Fig. 2.13, together with the selection of images that were used to map the bed level changes. Due to sun glare in the southwest directed camera, the (merged) images during the rise of the storm of March 14 were rejected for application in SBM-2DH. For the smaller storm of the 18th of March the rise of the storm is covered.

Fig. 2.14 illustrates the extent to which the nearshore bathymetry is approximated by the Argus monitoring technique (note there is an 11 to 12 days difference in survey date). It appears that the full profile as mapped by Argus is located too deep. The locations of the bar crests of the inner and middle bar match those of the WESP survey. The outer bar seems to suffer somewhat from artefacts of the VIM model (stepwise break in seaward slope).

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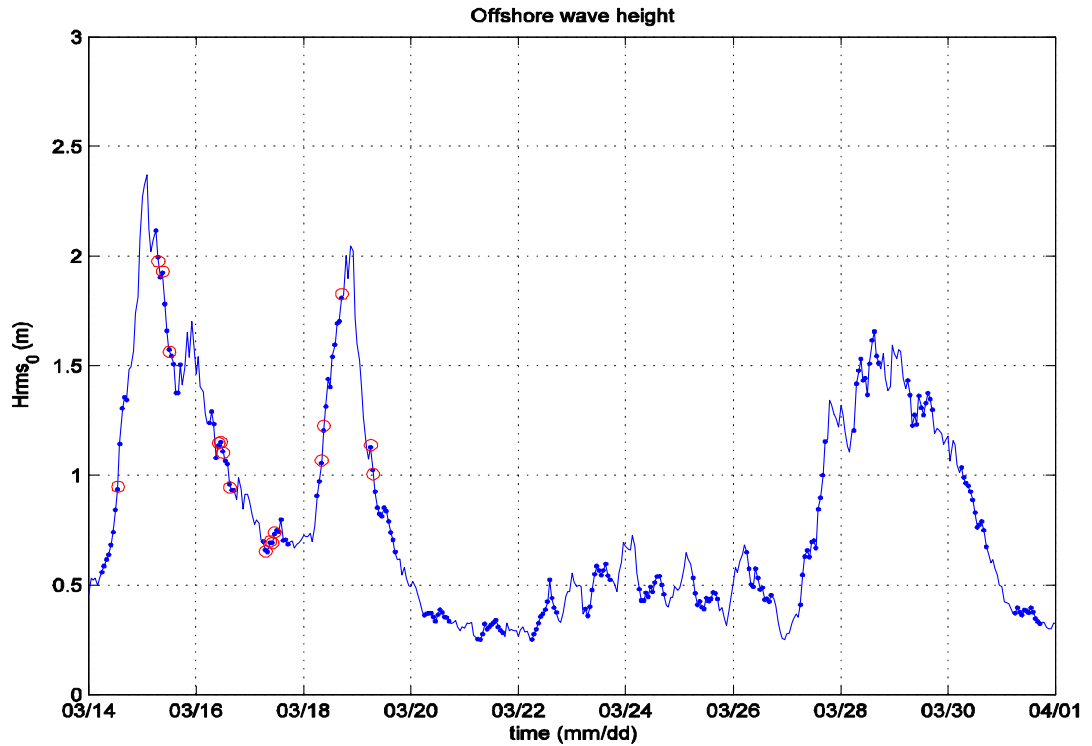Preliminary results using the SBM-2DH model

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Figure 2.13: Offshore H_{rms} wave height. Blue dots represent observations during daylight (6-18 hour). Red circles indicate hours of the selected images used for monitoring bed levels during a storm with SBM-2DH.
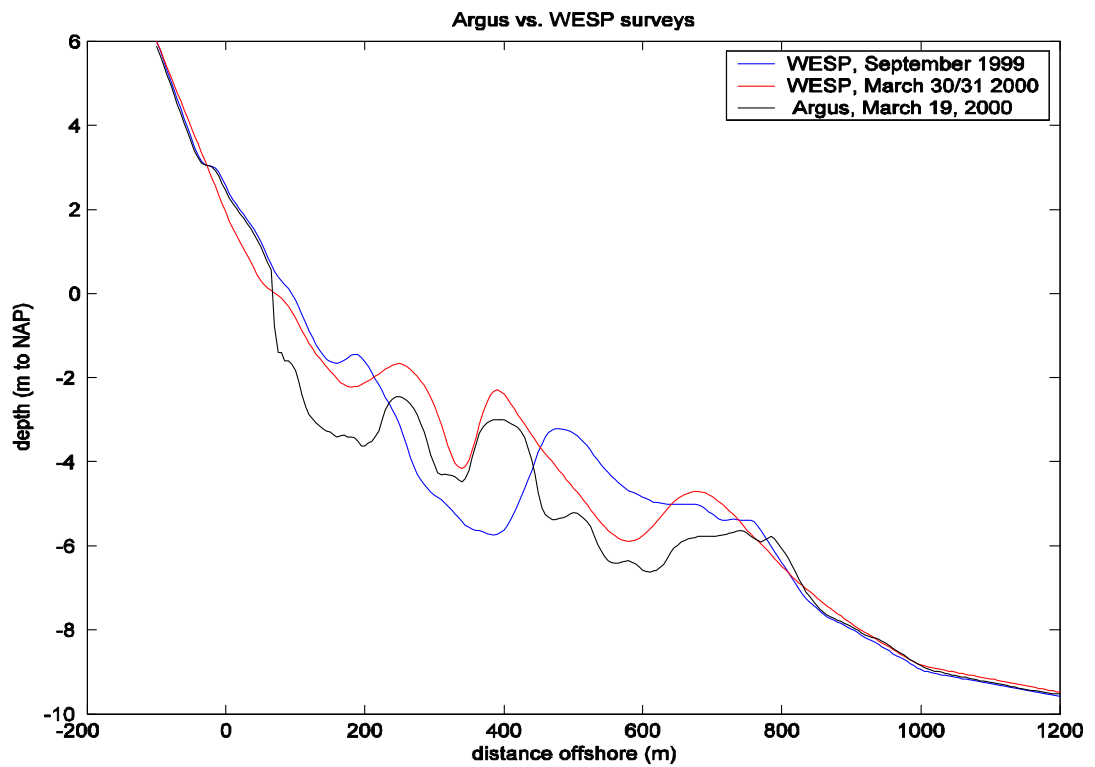

Figure 2.14: WESP and Argus-based bed level survey in March, 2000, with Argus monitoring starting at September 1999.

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2.5   Concluding remarks

The present mapping of the bed level evolution near Egmond over the period September 1999 – March 2001 has improved considerably in comparison to that presented in Roelvink et al (2003). This was achieved by improving the modelling of the breaking coefficient γ as well as by considerably increasing the number of images used to monitor the evolution.

Additional improvement of SBM-2DH bed level mapping can be achieved by developing a method to remove radial trends in background intensity related to the presence of hazy conditions (see Section 2.1). In case of an 'away-from-the-camera' increase in background intensity this may result in spurious offshore dissipation. Currently this is solved at an ad hoc basis by removal of the spurious offshore dissipation (reset to 0, seaward of 1000m from longshore axis Argus coordinate system (~ RSP beach poles)). The related underestimation of wave dissipation in the inner surf zone, however, is not corrected for. This will generally result in too deep inner surf zone bed levels.

Another source of inaccuracy in the present version of SBM-2DH is the occurrence of persistent foam floating at the sea surface, i.e. foam unrelated to energy dissipation in the roller of the breaking wave. Including a correction procedure in the VIM module to remove such persistent foam would further improve the accuracy of SBM-2DH bed level measurements, as was shown by Aarninkhof (2003) for the profile-mode SBM model.

Given the properties of the present version of the SBM-2DH model it is concluded that the location of bar crests can be derived reasonably accurate from Argus imagery, but the depth over bar crests as well as over the bar trough is not yet mapped reliably. This can be improved by improving the Video Interpretation Model (VIM) and by increasing the number of merged images suitable for processing by SBM-2DH. This can probably be achieved by developing a weighting criterion per camera related to the image quality per camera, such that single camera problems (sun glare, water droplets, condensate) do no longer hamper usage of the merged image. After improvement of the VIM module, additional fine-tuning of the morphologic parameter settings may add additional accuracy.

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3 Seasonal scale bed level variability

3.1 Description of Argus-derived profile behaviour

Bar position

Focussing on bar positions it appears that in 'summer' the inner and middle bars are generally located onshore of the March 2000 WESP-survey (Fig. 3.1). Quantifying the bar position in terms of the position of the bar crest it appears that this is related to a net onshore movement of these bars over the summer period (Fig. 3.3, upper and middle panel). Whether the general position of the outer bar crest changes during summer appears less clearly from the Argus surveys, which may partly be related to the fact that the outer bar topography seems to suffer from artefacts induced by the VIM module.

During the 'winter' period the outer bar feature is clearly located offshore of the summer 2000 WESP/Jarkus positions as well as seaward of the end-of-winter-season position in the March 2001 WESP survey (Fig. 3.2). In terms of bar crest position it appears that this is related to the December storms (Fig. 3.3, lower panel and Fig. 2.11). In addition, the bar/terrace feature in the inner nearshore (near 150 m) that is observed in the March 2001 WESP survey is obviously formed during the winter period (Fig. 3.3, upper panel). Fig. 3.3 further reveals that Argus-derived bar crest positions compare remarkably well to those derived from the WESP/Jarkus surveys.

The variability in bar crest position observed in between the dates with ground truth data generally appear to be realistic. It should be kept in mind that in Fig. 3.3 "bar position" is reduced to the position of the shallowest point at the bar. This shallowest point may be more mobile than the bar feature as a whole. Regarding the position of the outer bar crest (Fig. 3.3. lower panel) it should be noted that its position is only updated when images with wave breaking across the outer bar are used. Due to bad quality images (often induced by a single camera) several winter storm images were rejected for bathymetry updates. This explains the stable position of the outer bar after the December 2000 storms. Bathymetry updates based on images of a summer storm in June 2001 reveal the outer bar indeed had moved back onshore.
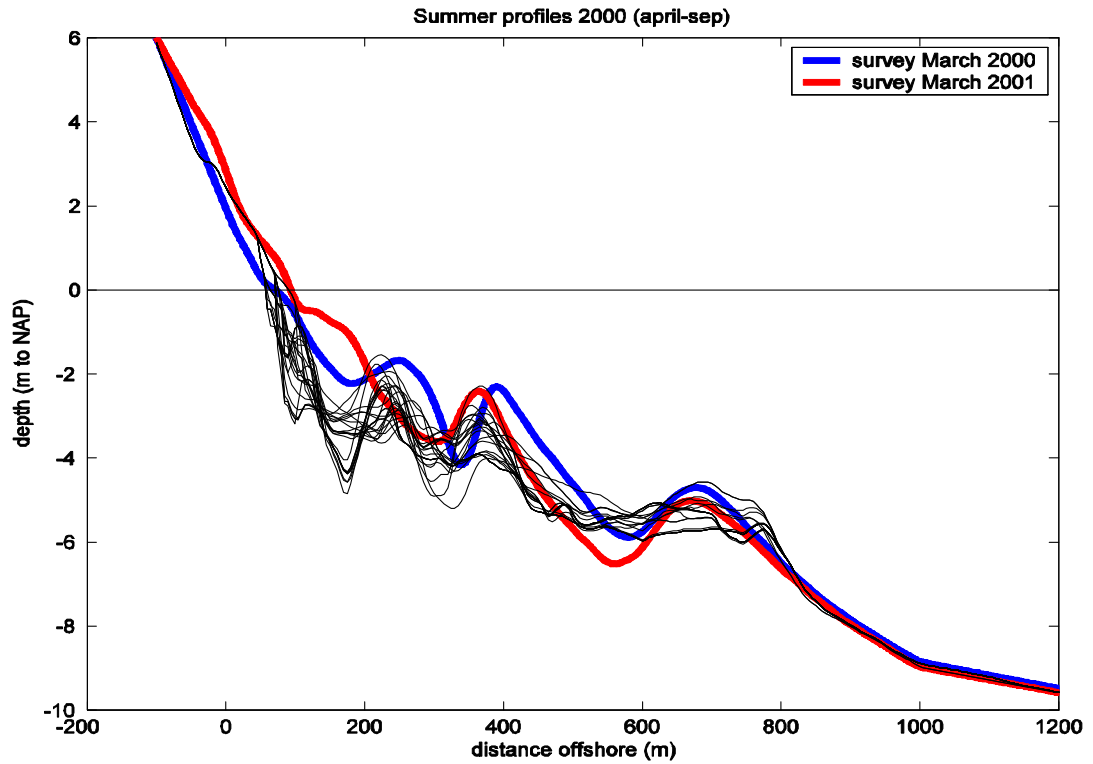
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Figure 3.1: Bed level variability during 'summer' (April-September) as mapped by Argus. For comparison annual bathymetric surveys by the WESP are included.
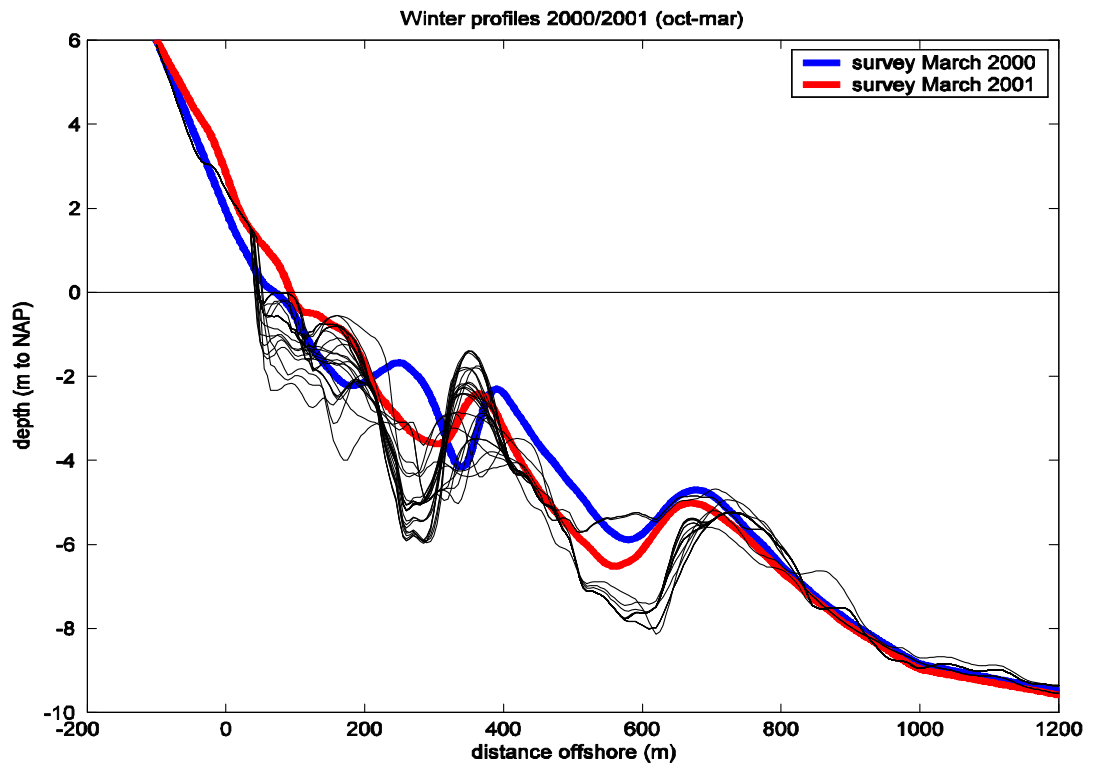

Figure 3.2: Bed level variability during 'winter (October-March) as mapped by Argus. For comparison annual bathymetric surveys by the WESP are included.

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Figure 3.3: Evolution of the position of the crest of the inner, middle and outer bar, based on Argus-derived bathymetries and WESP/Jarkus surveys.

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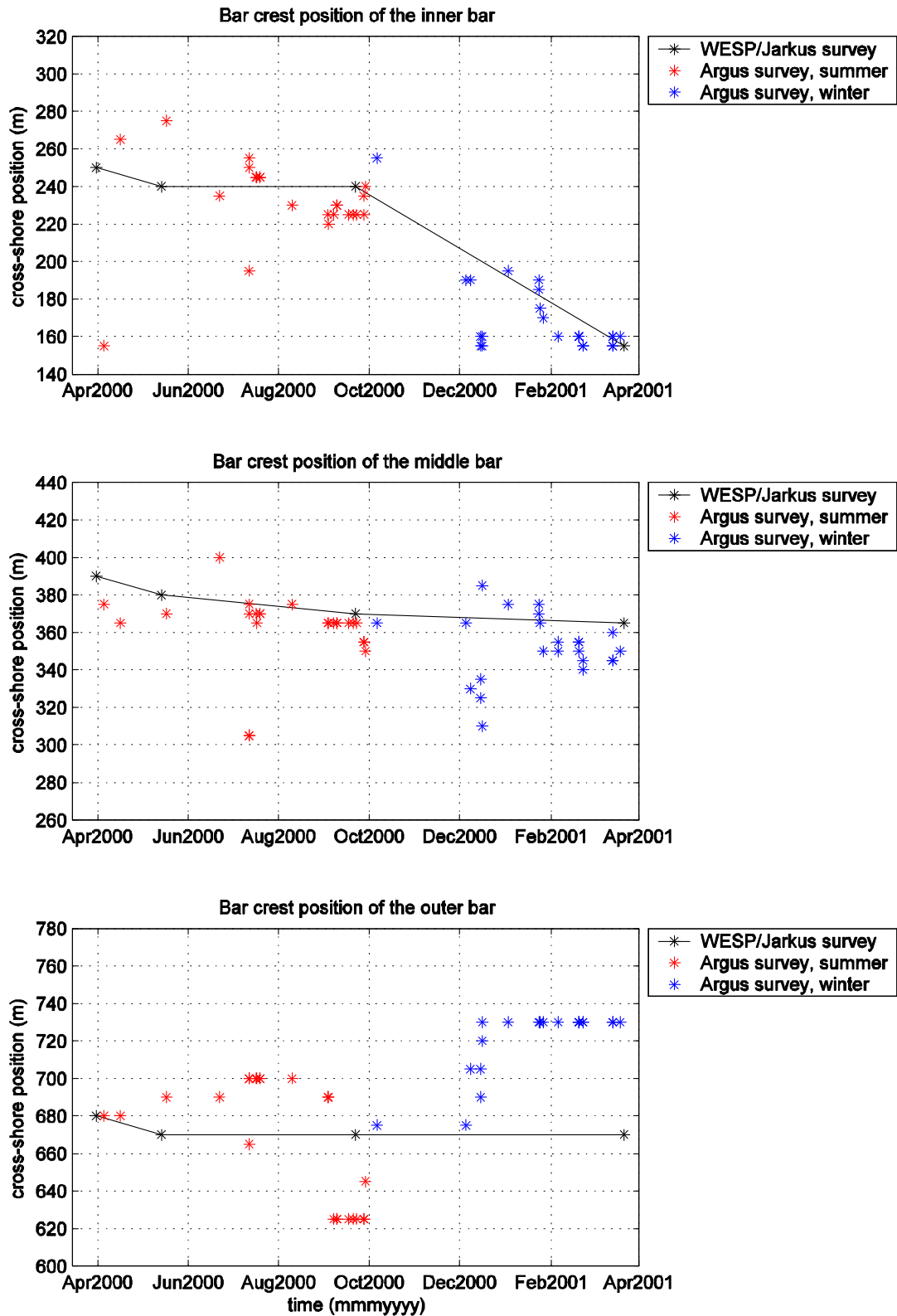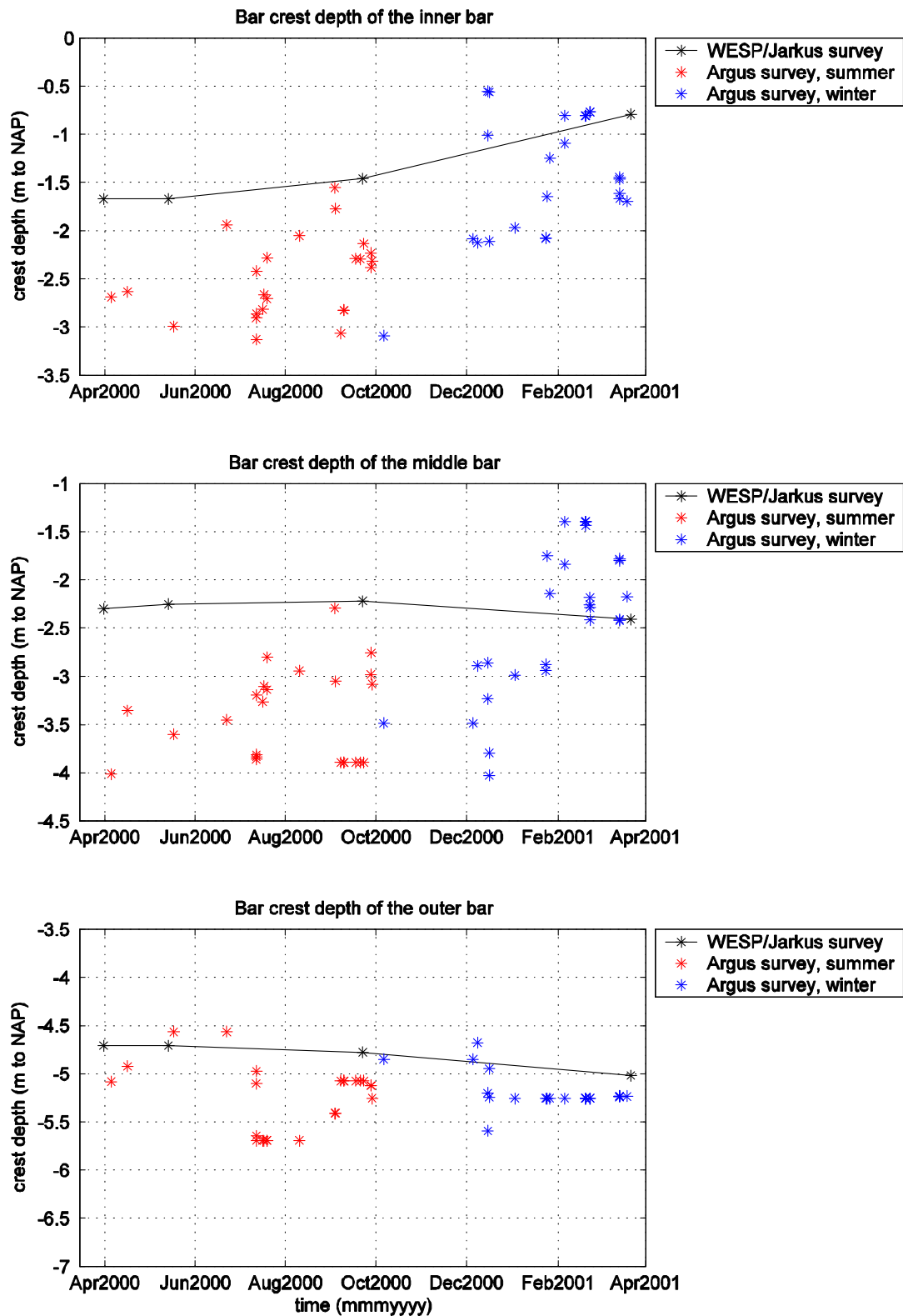Preliminary results using the SBM-2DH model

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Figure 3.4: Evolution of the depth of the crest of the inner, middle and outer bar, based on Argus-derived bathymetries and WESP/Jarkus surveys.

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Bar crest depth

Regarding the depth of the bar crest derived from Argus imagery, it is less clear to what extent the measurements are correct. For instance, Argus-based surveys on dates close to the WESP/Jarkus surveys show that the difference between the two techniques is of order 0.2-0.3 m for the outer bar, which is reasonably close compared to the observed range of fluctuations in depth values (Fig. 3.4, lower panel). Regarding the inner bar the differences between Argus-derived and traditionally-derived data on bar crest depth are larger, but this seems to be related to a systematic offset of order 1 m. Regarding the crest depths of the middle bar the differences between Argus and in situ measurements vary between about 1.7m and 0.3m, without an obvious pattern in the deviations (like the offset occurring for the inner bar).

3.2   Discussion

The general picture arising from the observations presented above is that winter bed levels indeed may differ systematically from those observed during the summer period. This is in line with observations on summer versus winter bed level variability presented by Wijnberg (1995). Wijnberg showed that near Katwijk the bed level variability during the summer period differed considerably from that during the winter period (see Fig. 3.5). During summer, bathymetric changes were generally limited to the inner bar zone (Fig. 3.5. and 3.6), while changes across the outer bar zone generally occurred during the winter period (Fig.3.5 and 3.7).
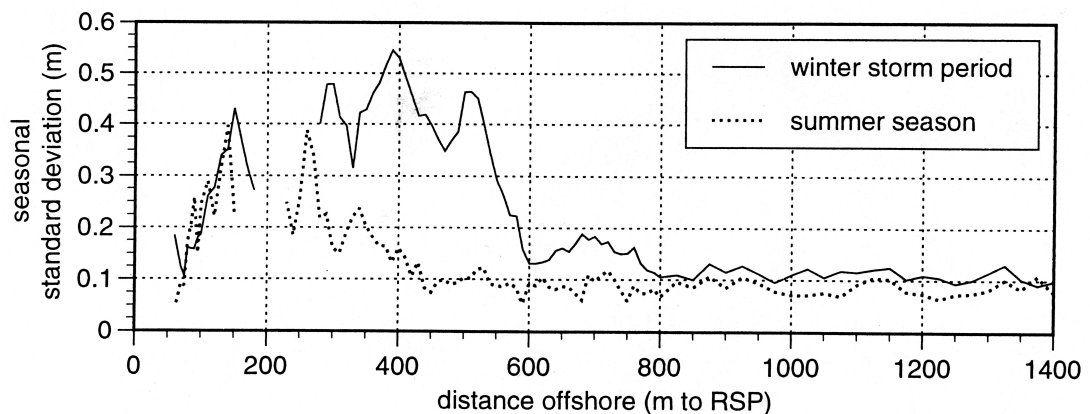

Figure 3.5: Average, seasonal standard deviation of the cross-shore depth measurements at km 84.25 (Katwijk, TAW surveys). The curve of the winter period is averaged over 5 series of 'winter' standard deviations (September-March), viz. the winters of 1979-80, 1980-81, 1981-82, 1982-83, and 1983-84. The curve of the summer period is averaged over 5 series of 'summer' standard deviations (April-August), viz. the summers of 1980, 1981, 1982, 1983, and 1984.

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The observed differences in bar position over the seasons demonstrate that winter topography *can* deviate significantly from the summer topography. Whether it always does, and in what pattern can not be concluded on the basis of this analysis. For instance, the particular pre-winter or pre-summer bar configuration may be relevant as well as the particular storminess of the summer and winter season. To reveal general patterns in seasonal scale variability in surf zone bed levels more data need to be analysed. Note that this may also reveal the extent to which the shoreface nourishment applied in the summer of 1999 influenced the particular pattern of seasonal differences in bar position observed in this study.

At present, the SBM-2DH model seems to be able to monitor the bar crest positions, but not yet the absolute depth over the crest, that is, not as accurate as using the in situ surveying techniques. Note that time series of in situ bed level measurements at a single point near Petten (using an ASM-instrument) revealed that bed level changes of about a meter were observed to occur during a storm in the nearshore (Hordijk 2004).

Supported by the results presented in Aarninkhof (2003), we believe that better accuracy can be achieved by further model improvement. Also the number of suitable images should be increased by developing a method to deal with locally bad quality images (i.e. one out of five cameras giving low quality information, while the others provide good quality information). Also, using detailed in situ observations of bed levels such as provided by the ASM-instrument will both help improve the SBM-2DH model (by providing ground truth data) as well as built confidence in the estimated bathymetries.

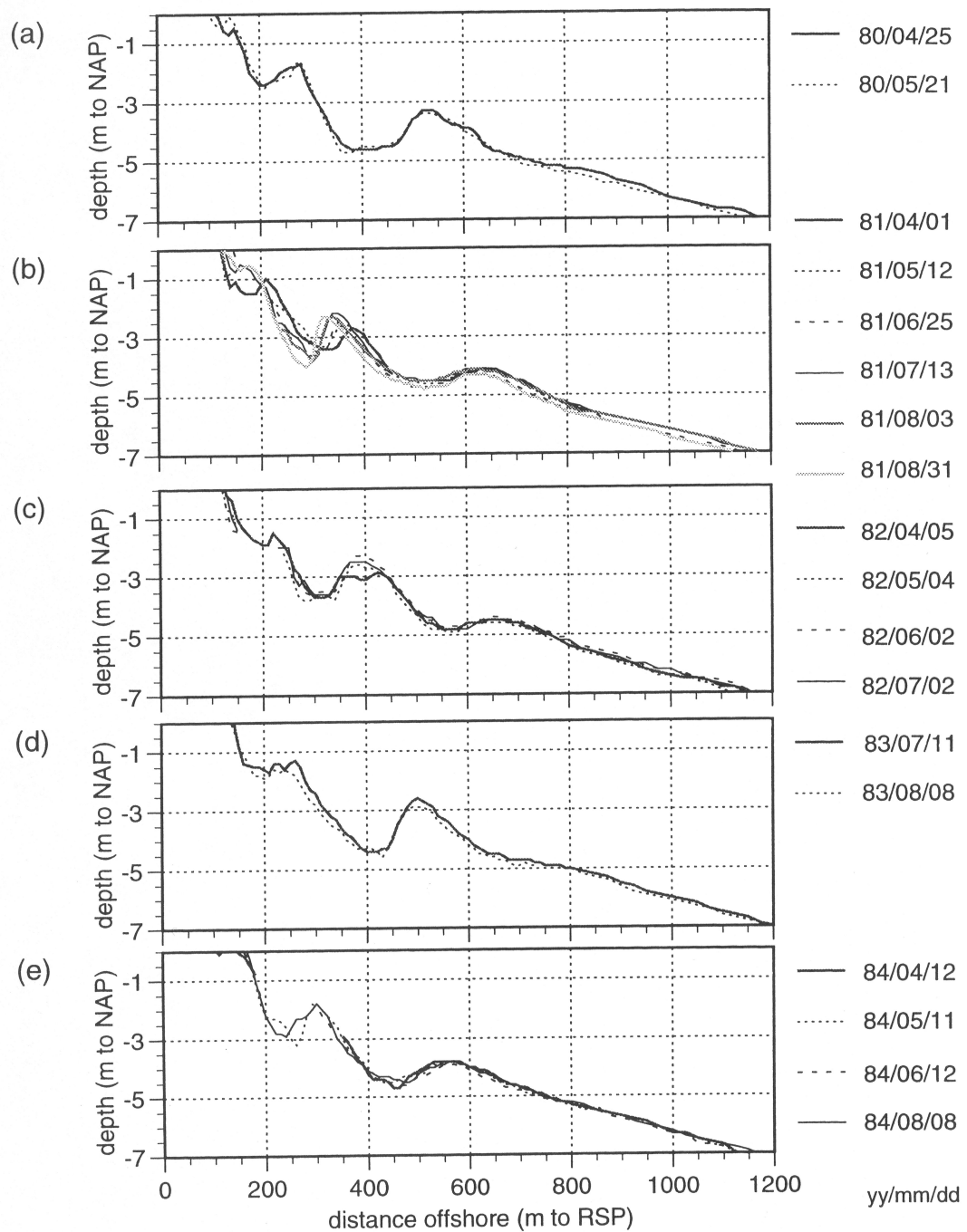Bed variability in the surf zone at the storm- and
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Figure 3.6: Summer period cross-shore profiles near Katwijk (km 84.25, TAW surveys).

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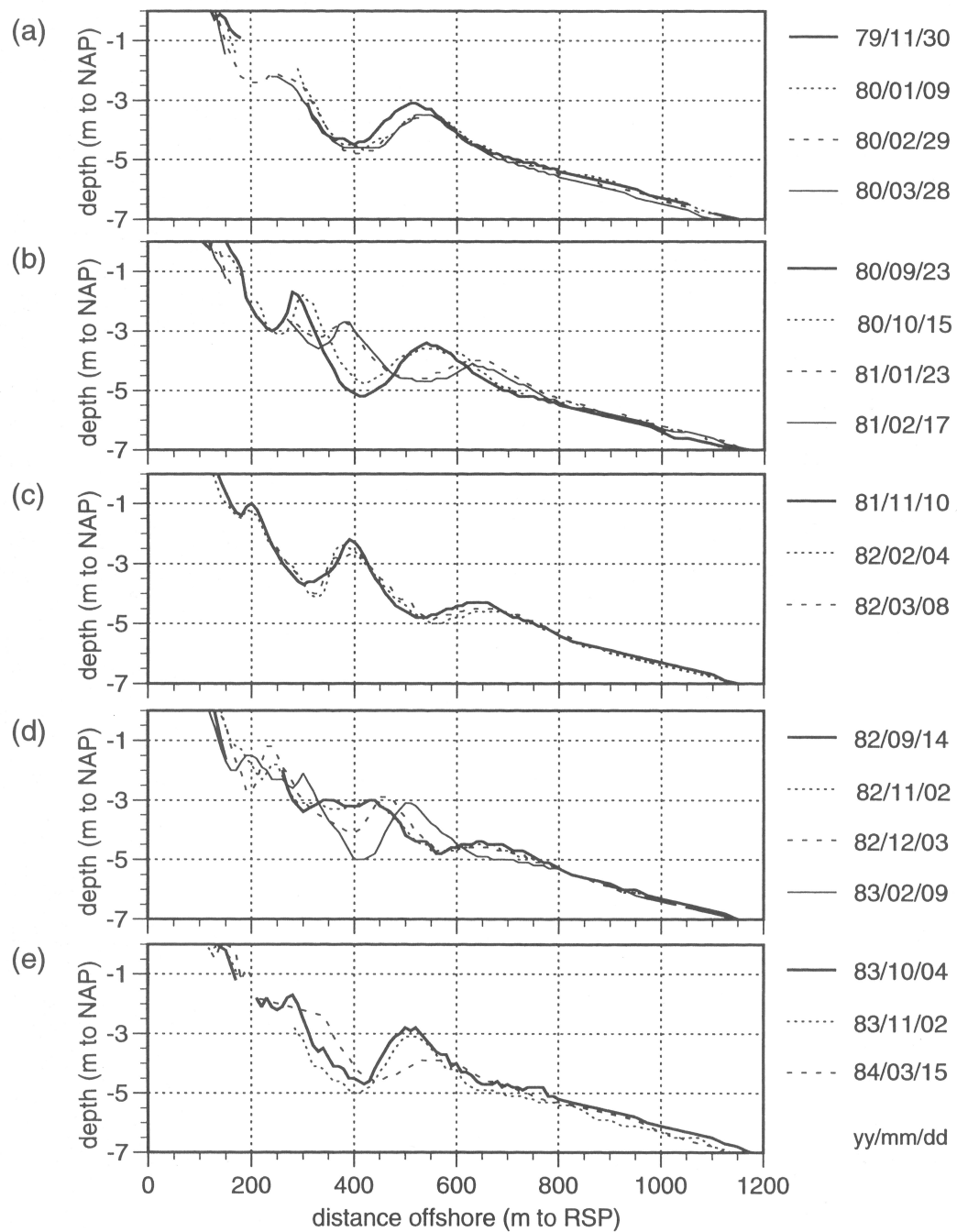
Figure 3.7: Winter period cross-shore profiles near Katwijk (km 84.25, TAW surveys).

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4 Storm scale bed level variability

4.1 Description of Argus-derived profile behaviour

During the rise of the first storm, from March 14 to 15, an overall lowering of the profile is observed (Fig. 4.1). This probably is to some (unknown) extent an artefact of the current set-up of the VIM model (cf. Fig. 2.14). Regarding the bar morphology, in particular the bar crest position, some variability occurs. Due to the bar shape this is more obvious for the middle bar (located near 400m) than the outer bar. During the post-storm period no major changes are mapped.

During the rise of the second storm, on March 18, an inner bar feature develops on the terrace near x= 250m, while the crest of the middle bar moves somewhat onshore. Note that this 'terrace' happens to be in a complicated area where bar bifurcations occur and the inner bar locally merges with the beach (see Fig. 4.2). During the decay of the storm changes are very small.

Table 4.1: Date and time of Argus observations used in monitoring of bed level variability over a storm.

Observation	year	month	day	time
1	2000	03	14	GMT 1308
2	2000	03	15	GMT 0708
3	2000	03	15	GMT 0908
4	2000	03	15	GMT 1208
5	2000	03	16	GMT 1008
6	2000	03	16	GMT 1108
7	2000	03	16	GMT 1208
8	2000	03	16	GMT 1508
9	2000	03	17	GMT 0708
10	2000	03	17	GMT 0908
11	2000	03	17	GMT 1008
12	2000	03	17	GMT 1108
13	2000	03	18	GMT 0808
14	2000	03	18	GMT 0908
15	2000	03	18	GMT 1708
16	2000	03	19	GMT 0608
17	2000	03	19	GMT 0708

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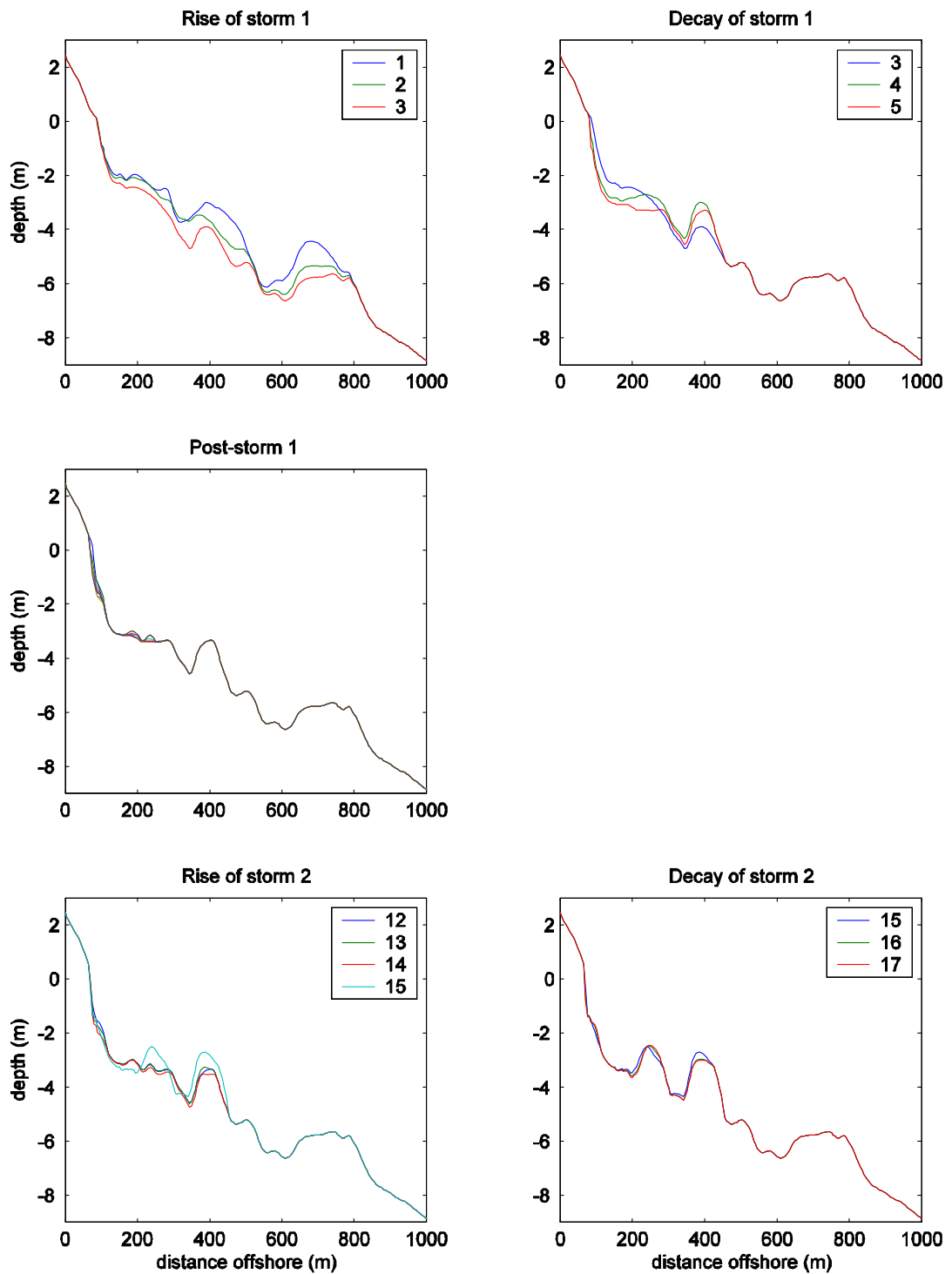
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Figure 4.1: Profile evolution during to subsequent storms, as mapped by Argus. Storm 1 peaks on March 15, 2000; Storm 2 peaks on March 18, 2000. For the date and time related to each observation number see Table 4.1. The panel with post-storm 1 profiles presents observations 5 to 12.
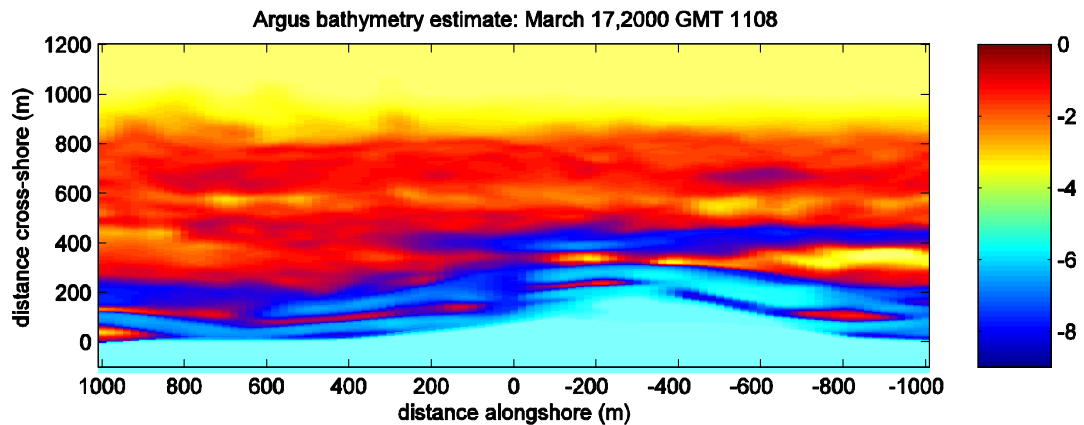
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Figure 4.2: Argus derived bathymetry on March 17, 2000. Cross-shore profiles presented in Fig 4.1 are located at x = 0m.

At present, we can not yet assess to what extent the observed depth variability across bar crests is real or due to shortcomings of the SBM model. Observations of bed level changes in a single point presented by Hordijk (2004) indicate that changes of a meter during a storm event may be realistic.

4.2   Discussion

The results presented in the previous section show that the suitability of the present version of SBM-2DH for monitoring bed evolution over a storm is limited. Changes in bed level occurring over a storm are of comparable magnitude or smaller than the current accuracy of the bed level estimates. This may be improved by upgrading the VIM module, for instance by including a correction for radial background intensity trends and by applying a correction for persistent foam drifting at the water surface (cf. Aarninkhof, 2003).

Further, it should be noted that the calibration of the morphologic parameters in SBM-2DH was based on updating the morphology on a daily to monthly interval. This implied that relatively large morphologic changes per update should be allowed (in particular with monthly intervals). In the case of monitoring the bed evolution over a storm event, hourly updates of the bathymetry are made. Since the number of computational loops for updating the bed is currently fixed (so independent of the time interval between images) the present settings may (and probably do) result in a hyperactive profile. Introducing a link between the time interval between images and the number of bed update loops will probably solve this problem (cf. T_{hist} parameter in Aarninkhof (2003)).

A limitation inherent to the Argus monitoring is that only day time evolution can be monitored. However, to evaluate 'the' bed variability during various stages of a storm-fair weather cycle probably requires a statistical approach, since every storm has its own idiosyncrasies. The incomplete coverage of storm events may then be compensated by the large number of events required for a sound statistical analysis.

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5 Conclusions and recommendations

The most important observation in the above presented case studies with relevance for the 5-yearly evaluations of the coastal safety, is that the outer bar moves farther offshore during the winter period (October-March) than can be derived from the annual surveys conducted during the summer period (April-September). Further, in this particular case study the inner and middle bar moved *on*shore during the winter period. Note, however, that this may be part of a 3D-evolution of the bar morphology in the inner nearshore. The extent to which cross-shore positions of bars vary through a single (winter) storm event can not yet be assessed with sufficient accuracy, nor is the depth over the bar crest.

To analyse bed level variability in more detail using Argus-derived bathymetries requires further improvement of the SBM-2DH model. It is recommended to include a correction for radial trends in background intensity as well for the presence of persistent foam. Further, including a link between the number of bed level update loops in the model and the time interval between subsequent images will reduce the occurrence of 'hyperactive' bathymetry. Since the suggested improvements have already been implemented in the profile-mode version of SBM we are optimistic about the positive effects of these improvements. Time series of bed level measurements at a single point, such as provided by the ASM-instrument, can also contribute to further improvement of the SBM model. Moreover, these observations will help build confidence in video-derived observations of bed variability during storm events.

Notwithstanding the current limitations with respect to the accuracy of the bathymetries currently derived from Argus imagery, it is important to realize that no alternative is available today for monitoring bathymetric change during storm events with comparable temporal and spatial resolution. Moreover, applications that require bathymetric data along a profile line only[3], rather than a complete area, can make use of the profile mode version of SBM, which has the above suggested improvements implemented already.

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[3] *With the limitation that the profile of interest is in the field of view of a single camera.*

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6 References

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