

## EMS wave logger data processing

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Processing data from a pressure gauge

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## EMS wave logger data processing

### Introduction

Waves can be measured in several ways. One way of measuring waves is by measuring the wave pressure at a certain depth using a pressure sensor and calculate the wave information from the pressure record. The EMS wave logger<sup>1</sup> uses a Honeywell MLH 050 PGP 06A pressure sensor. The information is stored by the logger on a SD card. The software in the logger controls the sample durations (from 1 to 30 minutes) and the sample intervals (from 15 min to 3 hours). The sampling rate is fixed to 4 Hz.

### Wave pressure

In a regular, small amplitude wave the instantaneous water level is given by:

$$\eta = a \sin \theta \tag{1}$$

Under a regular, small amplitude wave the pressure is given by:

$$p = -\rho g z + \rho g a \frac{\cosh k(h+z)}{\cosh kh} \sin \theta \tag{2}$$

in which:

- $\eta$  instantaneous water level (m)
- $p$  pressure at the requested location (Pa)
- $\rho$  density of the water ( $\text{kg/m}^3$ )
- $g$  acceleration of gravity ( $\text{m/s}^2$ )
- $z$  depth of the pressure (note: under water  $z$  is negative) (m)
- $a$  amplitude of the wave (m)
- $k$  wave number =  $2\pi/L$
- $\theta$  phase angle of the wave (rad)
- $L$  local wave length (m)

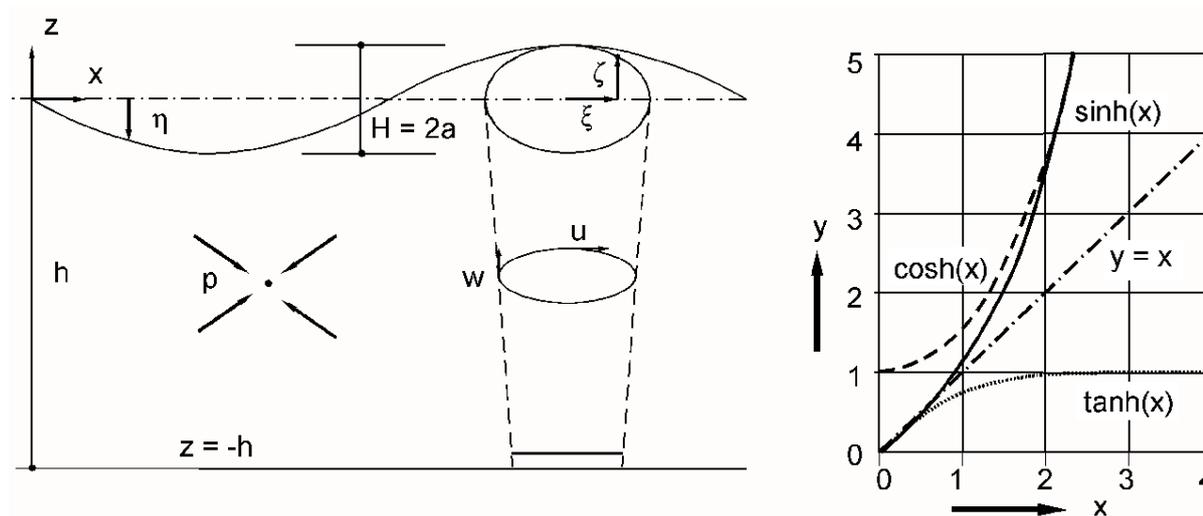


Figure 1: definitions in the wave pressure equation.

When inserting eq. (1) into eq. (2) leads to:

$$p = -\rho g z + \rho g \eta \frac{\cosh k(h+z)}{\cosh kh} \tag{3}$$

<sup>1</sup> The wave logger is produced by Environmental Mapping & Surveying, Durban, South Africa; see also Appendix 1.

In order to do this correct, the density of water needs to be known. This parameter ( $\rho$ ) has to be set in the script. For fresh water  $\rho=1000$ , for sea water one should raise  $\rho$  up to 1030  $\text{kg/m}^3$ .

Subtracting the hydrostatic pressure leads to:

$$\Delta p = \rho g \eta \frac{\cosh k(h+z)}{\cosh kh}$$

$$\eta = \frac{\Delta p}{\rho g} \frac{\cosh kh}{\cosh k(h+z)}$$
(4)

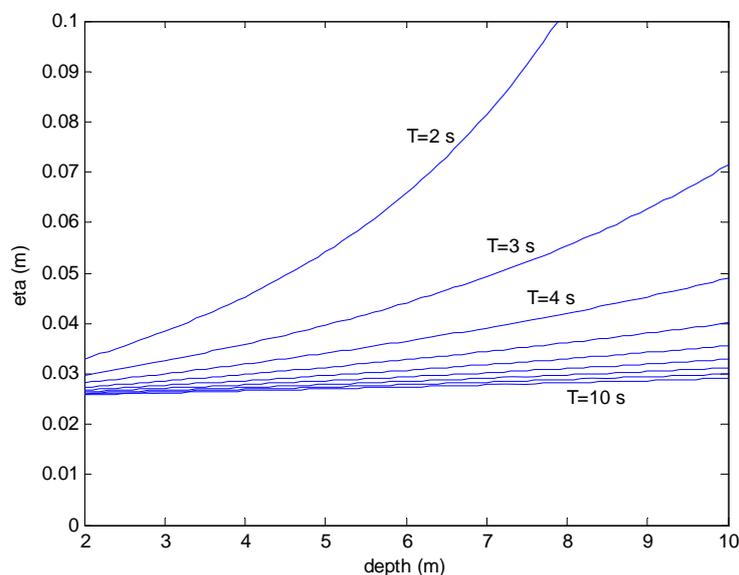
And in case the pressure is measured at the bottom, this reduces to:

$$\eta = \frac{\Delta p}{\rho g} \cosh kh$$
(5)

Eq. (5) can be used to calculate the surface elevation from the pressure record. However, one should realise that this derivation is only valid for regular, small amplitude waves.

In shallow water usually waves cannot be considered small amplitude waves, and second order theory should be applied to describe the water surface elevation. The main difference between first order and higher order waves is the exact shape of the surface. Wave height and wave period are not very different. Because of this, first order wave theory is acceptable for this purpose.

In important drawback of determining wave heights from pressure records is that small, short waves cannot be measured at larger water depths.



*Figure 2: accuracy of the calculated water elevation as a function of water depth and wave period*

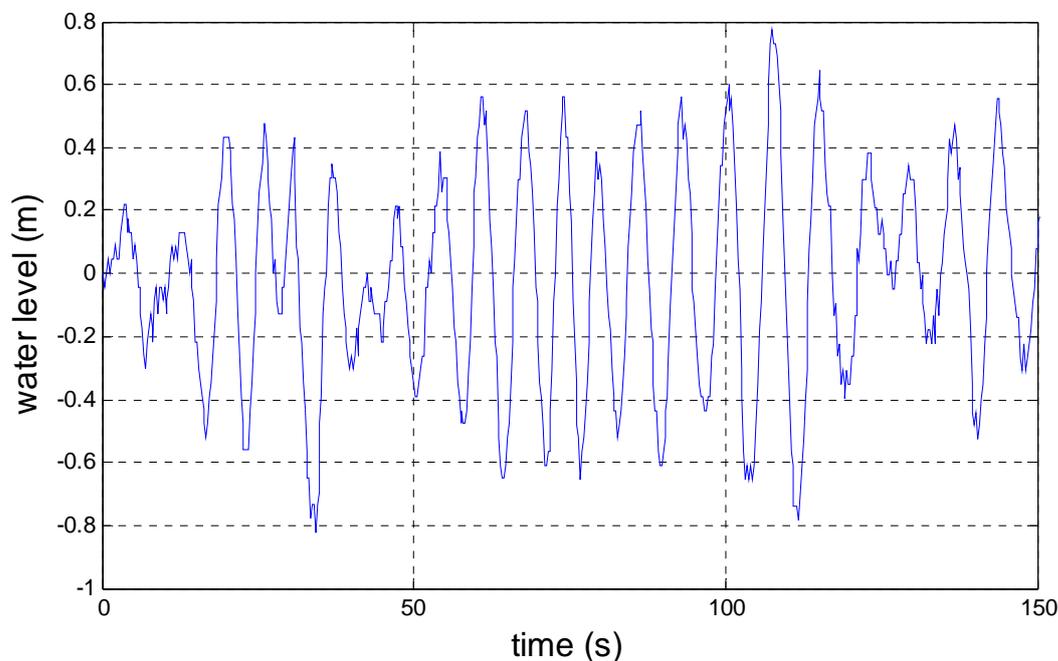
The accuracy of the wave logger is in the order of 250 Pa. In fig. 2. the accuracy of the calculated water elevation is plotted as a function of the water depth and the wave period.

It is clear from the figure that in larger water depths the accuracy decreases significantly for the shorter wave periods. In general one may conclude that up to a water depth of 10 waves with a period of 5 seconds and larger are quite accurate.

### ***Irregular waves (time domain)***

In case of irregular waves the above theory is still valid, but cannot be applied without restrictions.

A real surface record may look like figure 3.



*Figure 3: example of a surface water level record*

As can be seen all individual waves have different periods and heights. To calculate back from a pressure record to a water surface level the individual wave periods should be known. In theory one could split a pressure record into individual waves and then calculate the resulting surface elevation for each individual wave. However this usually leads to large errors with shorter waves. Therefore one can better first calculate the average wave period in the whole record (i.e. the total observation period divided by the number of waves) and use that wave period for the calculation.

When doing so, the short waves in the wave field are not really accounted for. But these waves are also the lower waves, and therefore usually not the most relevant part of the wave height distribution.

For the time domain analysis therefore a surface elevation is generated using eq. (5) and the mean period of the observation time.

With a counting algorithm then the individual waves are distinguished in this generated surface elevation record. To separate the waves the downward crossing method is used. From each wave the height is determined.

In order to calculate the water surface from the pressure record, the period has to be known. The period is included in  $k$  in eq. (2). The program has two methods to do this. In method 1 the average period (observation time/number of waves) is used. In method 2 the period of each individual wave is calculated and used. Method 1 goes wrong with a wide spectrum. Method 2 goes wrong in deep water. Small pressure variations in deep water are translated to huge, ridiculously short waves. This is physically not correct. Therefore the wave steepness is limited to a maximum value for individual waves (this max value is called “steepness” in the Matlab script).

In general method 2 with a correct limitation of the steepness is the preferred method. Also waves which are smaller than a given value ( $H_{\text{minimum}}$ ) are considered not to be real. The value of  $H_{\text{minimum}}$  depends on the accuracy to the pressure sensor and the waterdepth. In shallow water the value of  $H_{\text{minimum}}$  can be very small. In deep water  $H_{\text{minimum}}$  is approx.. 10 cm.

Subsequently the waves are sorted on individual height.

In the Matlab script the array with sorted wave heights is called “Hsorted”. The number of waves found is called “counter”. In this report the following notation is used:

N	Number of waves
$H_i$	individual wave
$H_{\text{mean}}$	average wave height
$H_{\text{rms}}$	root mean square wave height
$H_{1/3}$	Significant wave height

In the next step the time domain variables are determined:

$$H_{\text{mean}} = \frac{1}{N} \sum H_i \quad (6)$$

$$H_{\text{rms}} = \frac{1}{N} \sqrt{\sum H_i^2} \quad (7)$$

$$H_s = H_{1/3} = \frac{1}{N/3} \sum_{\frac{2}{3}N}^N H_i \quad (8)$$

Also are determined the wave height exceeded by 2%, 1% and 0.1% of the waves. These wave heights are determined in three ways:

- Directly from the observations;
- Using a Rayleigh distribution;
- Using the Composite Weibull Distribution according to Battjes and Groenendijk [2000].

With method b a Rayleigh distribution of the waves is assumed. This assumption is usually correct in deep water. For the Rayleigh distribution is valid:

$$\begin{aligned} H_{2\%} &= 1.40H_s \\ H_{1\%} &= 1.50H_s \\ H_{0.1\%} &= 1.85H_s \end{aligned} \quad (9)$$

The equation for the Rayleigh distribution is:

$$P\{\underline{H} > H\} = \exp\left[-1\left(\frac{H}{H_s}\right)^2\right] \quad (10)$$

In shallow water the highest waves in the record are already broken. Therefore the Rayleigh distribution is not valid any more. Battjes and Groenendijk [2000] suggested a approximation of this distribution using:

$$\Pr(\underline{H} \leq H) = \begin{cases} F_1(H) = 1 - \exp\left[-\left(\frac{H}{H_1}\right)^2\right] & H \leq H_{tr} \\ F_2(H) = 1 - \exp\left[-\left(\frac{H}{H_2}\right)^{3.6}\right] & H > H_{tr} \end{cases} \quad (11)$$

Below a transitional value of the wave height ( $H_{tr}$ ), the Rayleigh distribution remains valid. Above this value the exponent in the distribution has a different value (3.6). The values  $H_1$

and  $H_2$  were fitted from measurements and tabulated in the original paper. These values depend on the water depth and the bed slope. Figure 4 below shows the ratio  $H_{x\%}/H_{rms}$  for various values of  $H_{tr}/H_{rms}$ .

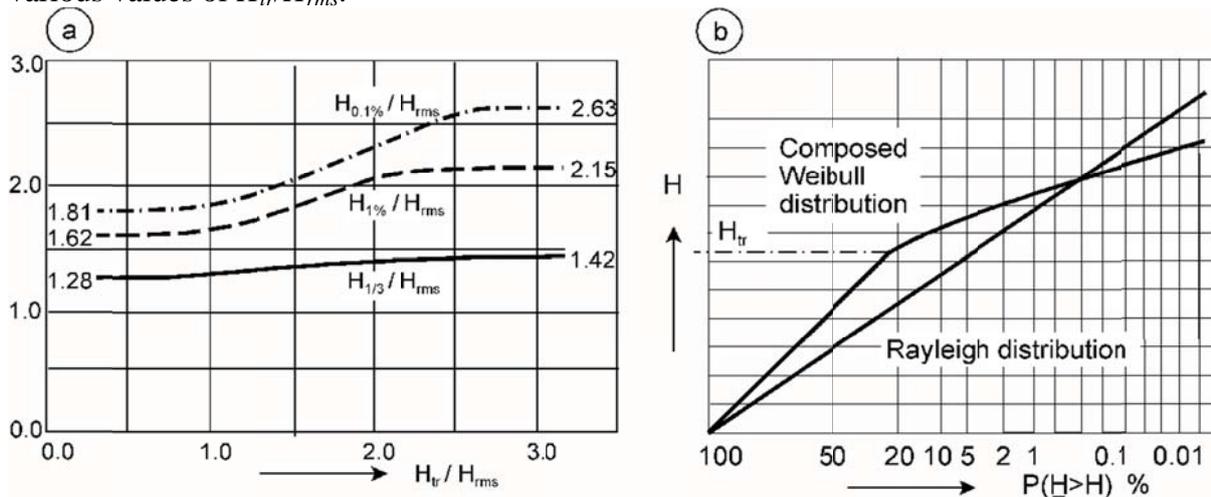


Figure 4: Wave height distribution in shallow water (Battjes/Groenendijk, 2000)

The parameters from the Composite Weibull Distribution are loaded into the script from the matlab script BG.

Note that in case of a limited number of waves in the record (<1000), no observed value of  $H_{0.1\%}$  can be determined. The script gives then as output NaN (Not a Number).

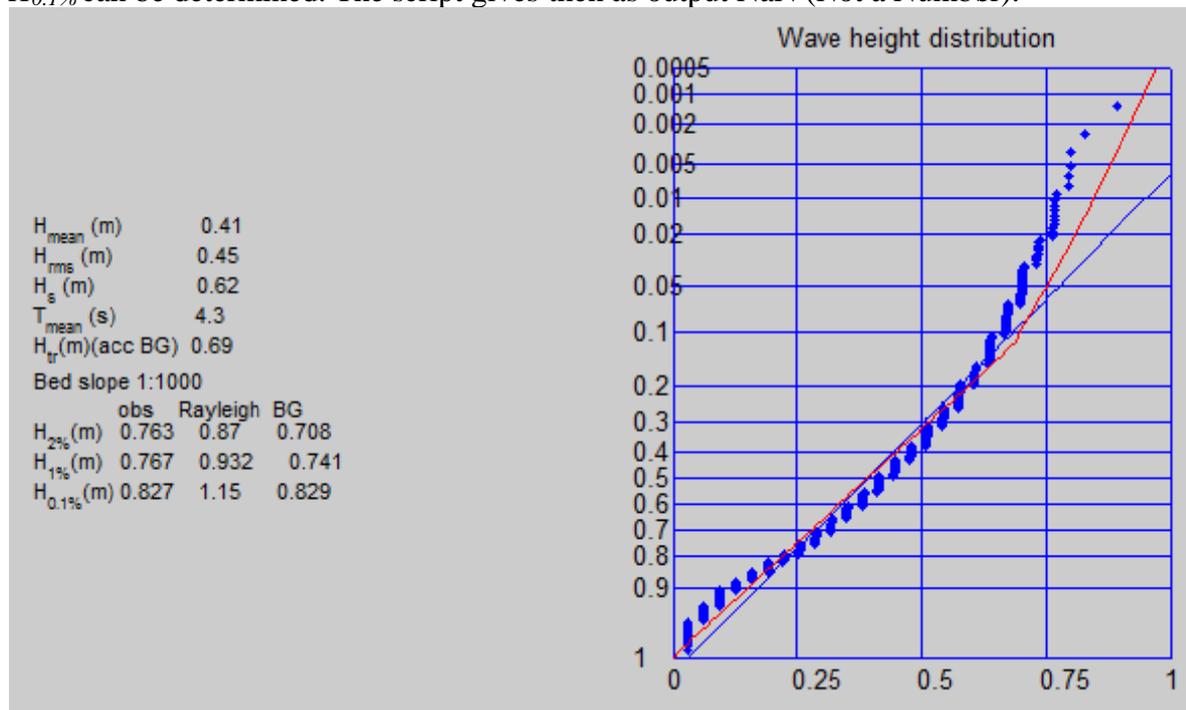


Figure 5: example of the output of a wave height distribution

In the output of the script the blue line is the Rayleigh fit, the red line the Battjes-Groenendijk fit and the blue crosses the observed data. This dataset was observed on a natural beach in very shallow water (1.9 m).

The extreme wave heights in the record are relevant for the design of coastal structures. The stability of armour units depends on the highest values in the record. Assuming a Rayleigh

distribution usually gives a significant overestimation in relatively shallow water, leading to a too heavy structure. Note that with a frequency domain analysis (see below) one cannot determine these highest waves in the record.

### ***Irregular waves (frequency domain)***

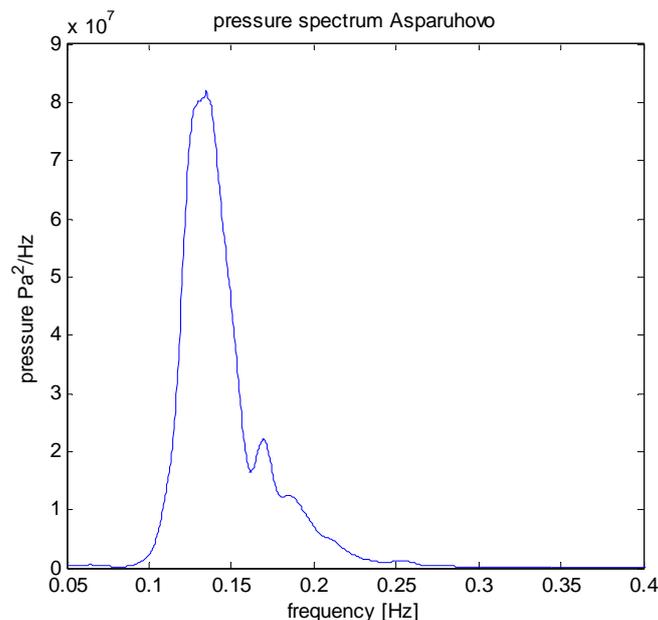
The time domain analysis is not very accurate in determining the periods of the wave. Also it does not give information on the shape of the wave spectrum. Therefore a frequency domain analysis is needed. In principle two methods are possible:

1. Determine the surface elevation of the water and apply spectral analysis on this surface elevation;
2. Determine the spectrum of the pressure and calculate from the pressure spectrum the surface elevation spectrum (wave energy spectrum).

Method 1 is standard in case the surface elevation was measured directly (e.g. with wave buoys or step gauges). However, when applying this method for pressure records, inaccuracies are included because of the fact that the calculated surface elevation is smoothed and does not contain all period information any more.

Therefore for pressure data method 2 is to be preferred.

In the script the pressure record is processed by the script `crosgk`. This script, developed by Klopman of Deltares, determines the power cross spectrum using a Fast Fourier Method. This results in a pressure spectrum:



*Figure 6: A pressure spectrum derived from the pressure data*

A certain degree of smoothing of the spectrum is recommended. This value can be set by changing the parameter  $M$  in the script.  $M=0$  is no smoothing. Practical values for  $M$  are between 20 and 100.

For each frequency bin one can calculate from the pressure value the elevation value (on the vertical axis is the pressure in  $\text{Pa}^2/\text{Hz}$ , in the wave energy spectrum we need  $\text{m}^2/\text{Hz}$ ). This means that the same formula can be used as was applied in the time domain analysis (eq. (5)). Now the exact value for the period is known, because that is given by the number of the frequency bin.

This process results in the energy spectrum:

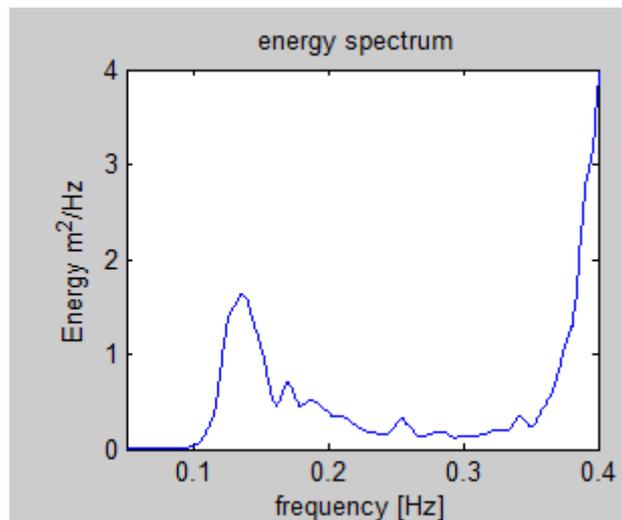


Figure 7: The energy spectrum calculated from the pressure spectrum of figure 6.

It is clear that the peak at the right side of the spectrum is an artefact. It is caused by the fact that a small value of the pressure is multiplied with an extremely high multiplier. This has no physical meaning. The above data were measured on a water depth of 8.5 m. Small variations in the pressure (less than the accuracy of the meter) are interpreted by eq. (5) as being caused by huge waves of very short periods. While in reality these variations are only random noise.

Therefore the spectrum should be cut off in this case at a value of approximately 0.28 Hz (see also figure 6). With the parameters “cutoff” and “high” this is realized. The variable “cutoff” limits the analysis, while “high” only changes the axis of the plot. See figure 8 for the result.

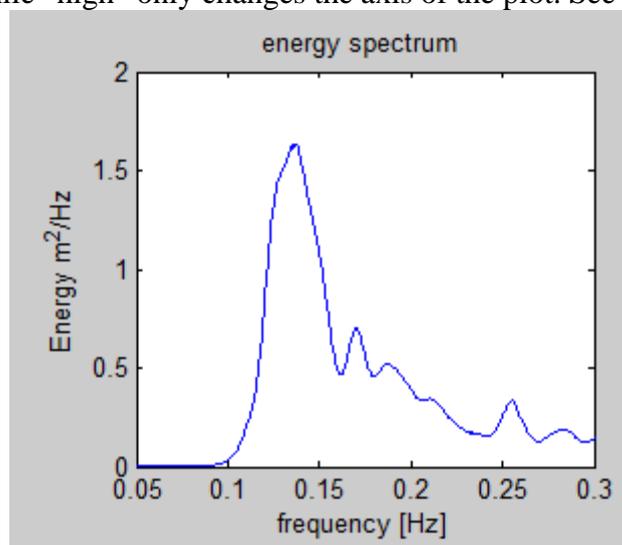


Figure 8: corrected wave energy spectrum using the parameters “cutoff” and “high”

One can determine the values for “cutoff” and “high” by using the plot of the pressure spectrum. This plot is not printed on default, only when the parameter “extraplot” is set to 1. There is also a value “low”. This value should be used for deleting long periodic waves which have nothing to do with the waves to be analysed (e.g. seiches).

From the spectrum various moments are computed. A moment of a spectrum is the product of arm and area. For higher order moments, one raises the arm to a certain power. The zero-th order moment is the area multiplied with the arm to the power zero, which is in fact only the

surface area. The zero-th order moment gives the total energy in the spectrum. The general equation of the moment is:

$$m_n = \int_0^{\infty} f^n S(f) df \quad (12)$$

The zero-th and the 1<sup>st</sup> order moment are:

$$m_0 = \int_0^{\infty} S(f) df \approx \frac{1}{2} \sum_{i=1}^N e_i^2 \quad (13)$$

$$m_1 = \int_0^{\infty} f \cdot S(f) df \approx \frac{1}{2} \sum_{i=1}^N f \cdot e_i^2$$

The script calculates  $m_{-1}$ ,  $m_0$ ,  $m_1$  and  $m_2$ . From these moments the following values are calculated:

$$H_{ms} = \sqrt{8m_0} \quad (14)$$

$$H_{m0} = 4\sqrt{m_0}$$

and

$$T_m = \sqrt{\frac{m_0}{m_2}}$$

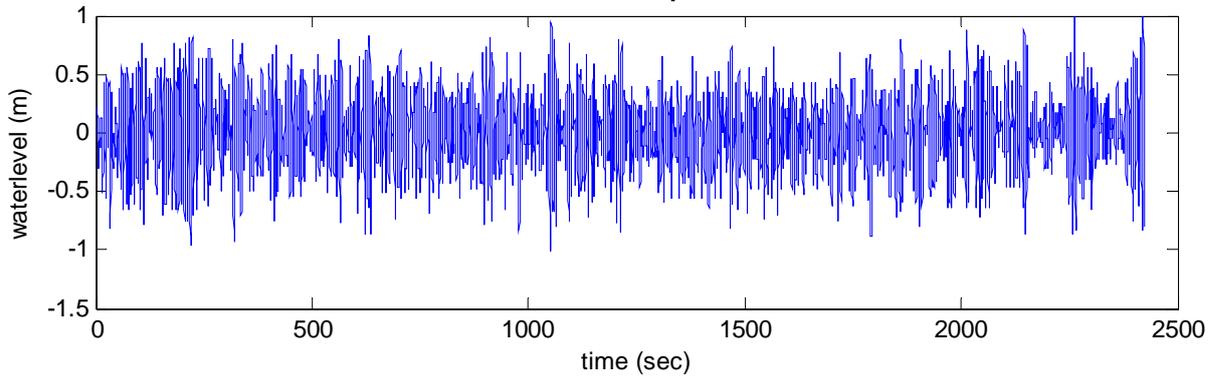
$$T_{0,1} = \frac{m_0}{m_1} \quad (15)$$

$$T_{-1,0} = \frac{m_{-1}}{m_0}$$

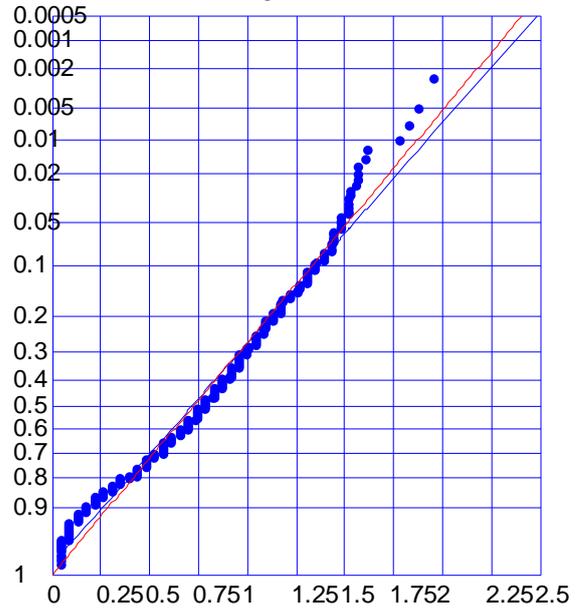
One should expect that  $H_{m0}$  and  $H_{1/3}$  are equal. If this is not the case, one should verify if the settings of the cutoff parameters.

An overview of all standard output of the script is given on the next page.

Time series Asparuhovo



Wave height distribution

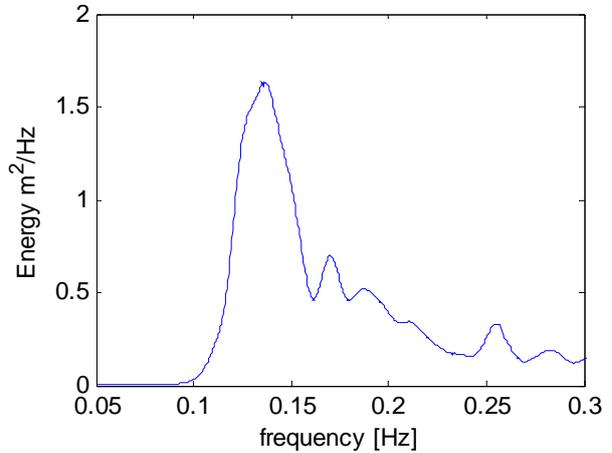


$H_{mean}$ (m)	0.77
$H_{rms}$ (m)	0.87
$H_s$ (m)	1.2
$T_{mean}$ (s)	6.1
$H_{tr}$ (m) (acc BG)	3
Bed slope 1:1000	
	obs Rayleigh BG
$H_{2\%}$ (m)	1.56 1.72 1.73
$H_{1\%}$ (m)	1.61 1.84 1.88
$H_{0.1\%}$ (m)	NaN 2.27 2.3

$H_{rms}$ (m)	1.2
$H_{m0}$ (m)	1.7
$T_m$ (s)	3.5
$T_{m0.1}$ (s)	3.8
$T_{m-1.0}$ (s)	4.8
$T_{peak}$ (s)	2.5

Average depth (m) 8.5  
water density (kgm<sup>3</sup>) 1018

energy spectrum



## Calibration

The pressure sensor of the wave logger has been calibrated in a deep water pit. From this calibration was the following relation found:

$$p = 254V - 43250 \quad (\text{Pa}) \quad (16)$$

In this formula a correction is included for the atmospheric pressure. Variations in the atmospheric pressure have influence on the results, but this effect is very small.

$V$  is the reading from the wavelogger.

The wavelogger has been applied also during one of the Bardex experiments at the large wave flume of Deltares, Netherlands (the Deltaflume). In this flume prototype size waves can be generated. The flume is equipped with standard high performance wave gauges with a very high sampling interval (20 Hz). Appendix 2 shows a comparison of the data from the EMS wavelogger, processed with the TU Delft script and the results from Deltares equipment in the flume.

## User Manual

The data are processed by the Matlab script Wavelogger.m. This script processes files with one observation only. The Wavelogger produces one single datafile with all observations in sequence<sup>2</sup>. The first step in processing is splitting the data from the logger in separate files. This can be done by any program. A nice tool is the program TextSplitter.exe.

Load the output file from the Wavelogger into this program, enter the number of observations and let the program split the datafile into separate chunks of file. When the file is large, this may take several minutes; be patient. The number of observations can be found at the end of the file. The observation number is the number after \$D,.

It is recommended to avoid filenames with an underscore ('\_'), because this symbol makes that letters are printed as subscript in the Matlab script.

All observations from one ensemble should have the same name, and a different number, e.g.: Logger2-012Part1.txt; Logger2-012Part2.txt; Logger2-012Part3.txt;.....etc

Both individual observations as well as a batch of observations can be processed by the Matlab scripts wavelogger.m.

In case of a single observation:

In line 12 and 13 one should set NofFiles and StartFile to 1.

Then in lines 58 to 72 the other input parameters can be set.

In case of processing multiple observations set NofFiles to the number of observations. If one intends to skip the first files (because they do not contain information), set the StartFile to a higher number. This might be useful when the Wavelogger already started to observe before it was placed on its final location.

In case of multiple observations no plots of individual observations are made (like spectra and exceedance lines). In the command window the number of processed files is shown, so one can follow the progress of the calculation.

After completion of all processing the data are written to an outputfile. This file has the same name as the inputfiles of the observations (but without the sequence number) and the extension .mat (e.g. Logger2-012Part.mat)

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<sup>2</sup> Note that this version of the matlab script requires a heading with the following form: \$\$S,1,12:0:3,63,6/7/12. In newer versions of the Wavelogger this header is: \$\$S, BurstIndex,2012-11-01T00:00:00Z,Temp.

One can plot the results with the Matlab script PlotSeries.m. In this script one can set the first point to be plotted (startpunt) and the last point (eindpunt). This means that if one has a record of 600 points and one intends to plot the series from 10 to 595, startpunt=10 and eindpunt=595.

In summary, the following input values can be given in the Matlab script:

Line nr	Variable name	Default value	description
7	Rho	1030	Density of the water (kg/m <sup>3</sup> )
8	g	9.81	Acceleration of gravity (m/s <sup>2</sup> )
9	Avolt	254.1	Calibration value A of the pressure meter (Pa/V)
10	Bvolt	-43250	Calibration value B of the pressure meter (Pa)
11	TanAlfa	0.001	Bed slope in Battjes-Groenendijk calculations
12	NofFiles	1	Number of input files to be processed
13	StartFile	1	First input file to be processed
58	M	25	Smooth factor for the wave spectrum, a low value M=25, high value M=100
60	high	0.4	highest frequency for plots
61	low	0.05	Lowest frequency for plots
62	cutoff	0.08	parameter to eliminate noise from the tail of the spectrum when the spectral value is less than a "cutoff"-fraction of the maximum value, then the spectral value is set to exact zero
66	extraplot	2	extraplot = 0 gives no plots, 1= only summary 2=include pressure, 3=include depth, 4= include pressure
68	method	2	method=1 uses T <sub>m</sub> for calculating wave height from pressure method=2 uses real period per wave
70	steepness	0.03	Maximum allowed wave steepness for individual waves
71	Hminimum	0.10	minimum wave height to be considered
72	interval	0.25	interval is the sample frequency interval of the sensor do not change this value unless another wavelogger is used

## References

BATTJES, J.A., GROENENDIJK, H.W. [2000] Wave height distribution on shallow foreshores, *Coastal Eng. Vol 40, pp 161-182.*

# Appendix 1 Description of the wave logger

## WAVE LOGGER

**The Philosophy...**

- A need for a cost effective wave recording instrument
- A need for an adaptable shallow water wave recorder.
- Simple instrument deployment and recovery.
- Increase spatial resolution of wave dynamics through multiple instrument deployment.
- One-stop-shop approach: instrument, data collection, data processing software, final usable results.

**Right: Non-Directional Wave Logger with acrylic end plate and rugged PVC housing.**

**Physical Properties**

- Size: 500mm X 155mm OD
- Weight: 3 kg
- Material: PVC & Acrylic
- Operating Depth: 20m
- Burst Pressure: 500 psi

**Electrical Features**

- Batteries: 3 X 4.5Ahr 6v
- Operating Voltage: 5v
- Endurance: up to 30 Days
- Operating Current: 30 mA
- Standby Current: 16 mA

**Sampling Properties**

- Sampling Period: 20min \*Programmable
- Sampling Interval: 1 Hr \*Programmable
- Burst Sampling Rate: 4Hz \*Programmable
- Memory: SD Card up to 2GB

**Pressure Transducer**

- Type: Honeywell MHL Series
- Accuracy: ~0.5% FSS
- Resolution: ~5um

**Temperature Sensor**

- Type: Internal
- Accuracy: 0.5 C
- Temp Range: -50 to 150 Deg C

**Wave Parameters**

- No. of Waves per sampling period
- Period
- H1/3
- Maximum Wave Amplitude
- Average Wave Amplitude
- Wave Energy

**Left: Typical deployment mooring with stabilising float and marker buoy.**

**Right: Screenshot of data processing software.**

Above: Sample raw data from actual deployment.

**"We can build It."**

This annex outlines the basic do's and don'ts when operating the unit. It assumes that all necessary care will be taken with the electronics. It must be noted that the system has been designed to be as simple and cost effective as possible and for this reason some of the user error protections that may be found on other devices don't exist here.

### 1. The Pressure Sensor:

The pressure sensor outputs 0.5 to 4.5 volts (full scale 0-50 PSI). At the moment the micro-controller uses a reference voltage of 3.3v. It is therefore not possible to submerge the unit past 15m water depth (on the safe side).

The pressure sensor has been soldered directly to the controller board. If for any reason, the logger is taken apart, make note of the pin outs, reversing the voltage to the sensor will destroy it! The sensor has a stainless steel membrane which is exposed to the water. This hole should be kept clean and no tools should be used remove debris as this will damage the membrane.

Wave logger has a Honeywell MLH pressure sensor. See:

[http://sensing.honeywell.com/index.php?ci\\_id=3108&la\\_id=1&pr\\_id=31550](http://sensing.honeywell.com/index.php?ci_id=3108&la_id=1&pr_id=31550)

MLH 050 PGP 06 A

50 psi psi gage

Flying leads (20 AWG – 6 in)

1/6 in 27 NPT

0.5 Vdc to 4.5 Vdc ratiometric from 5 Vdc excitation

### 2. The SD Card:

All SD cards used should be formatted FAT16. Some SD cards may not work due to speeds and or capacity.

### 3. Data Logging:

The unit will log data to a file called "datalog.txt". This file is created by the unit if it does not exist. If a file is present, it will be appended to. If you would like to deploy the instrument, it is recommended that you remove the existing datalog.txt from the SD card, so that only new data will be written.

The data is only saved to the file when the SD card is closed by the microcontroller at the end of each burst period. Therefore if the green LED is still flashing and power is removed the last burst will NOT be written to the card. There is a push button to close the file at any moment. When pushing the button, all data will be saved and both LEDs go solid.

The device is setup to log once per hour, when the minute variable is 0. The user may only change the number of samples to be recorded (done the menu).

The following file format is used to store data....

Data File Structure

\$S (header), Num (burst number), Time , Temp , Date

This is followed by the data at a rate of 4 Hz.

\$D (header), Num (burst number), Raw ADC Reading

.....

.....

.....

\$E (header), Num (burst number). End Time

#### 4. Indicator LED's:

On startup for 10 seconds:

Green: ON

Orange: ON

Red: ON

In sleep mode between bursts:

Green: OFF

Orange: Blink every 4 seconds

Red: OFF

Recording measurements (Burst):

Green: Blinking rapidly

Orange: OFF

Red: OFF

ERROR SD Card:

Green: OFF

Orange: OFF

Red: ON

#### 6. USB Cable:

The supplied USB cable has a built in FTDI chip, a driver may need to be installed and can be found here: <http://www.ftdichip.com/FTDrivers.htm>. The cable is energized with 5V from the computer USB port, it is therefore necessary to connect the cable to the logger in the correct orientation or damage will result.

The colour of the corresponding wire has been written next to the FTDI pins on the logger.

#### 7. Configuring the Unit:

The device may be configured via the supplied USB cable. Any terminal program may be used to communicate with the device (Hyper Terminal is recommended). The date and time of the unit can be checked and changed and the sampling duration may be changed. Sample intervals are 15 min, 30 min, 60 min and 180 min. So, if 15min chosen, log times will be 0:00, 0:15, 0:30, 0:45. When 180min chosen, log times will be 0:00, 03:00, 06:00, 09:00 etc.

#### Method

- > Remove power to the unit.
- > Plug in the USB cable to the computer.
- > Start Hyper Terminal or some other terminal program.
- > Select to COM port that corresponds with the FDTI USB cable.

##### *Com port settings:*

Baud Rate: 9600.

Data Bits: 8

Parity: None

Stop Bits: 1

Flow Control: None

- > Open the port.
- > Connect the USB FTDI cable to the device (take note of orientation).
- > Connect power to the unit.
- > All three LED should be lit.
- > In the terminal window, text should appear, prompting the user to enter the "M" (capital M) key to enter the setup.
- > Follow the instructions on screen to complete the setup.

Note: the sequence of the above actions is relevant

### **8. The Housing:**

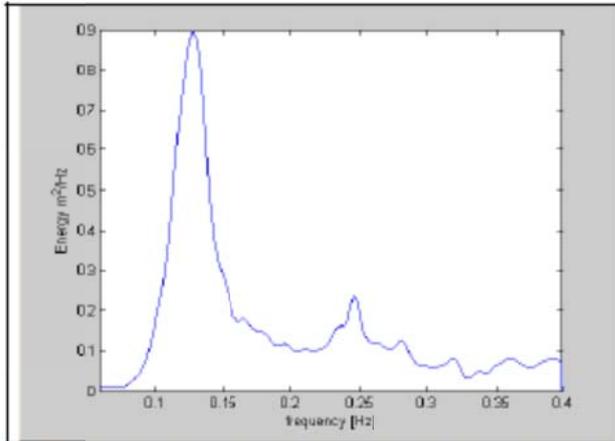
The housing is made from rigid PVC pipe. The fittings have been thermo welded to each other. There is a single o-ring seal for the unit. This o-ring should be kept clean and silicon applied after each deployment. The seal is compressed with the screw on the end cap.

### **9. Batteries:**

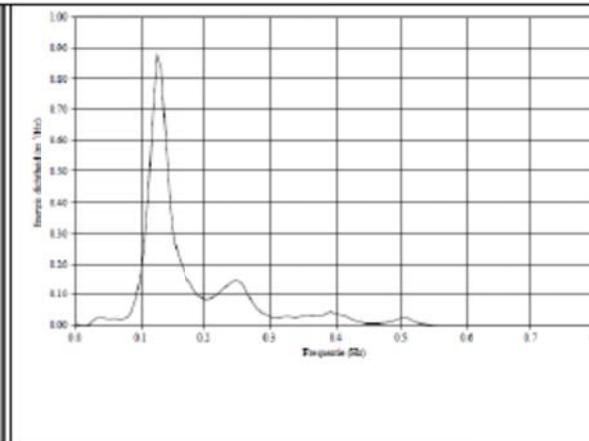
The unit has a 5v step up converter for Li batteries. One D Cell 3.6v Lithium Ion 16500AHr is required. The unit should operate for at least 30 - 40 days on all configurations.

## Appendix 2: Wave logger calibration

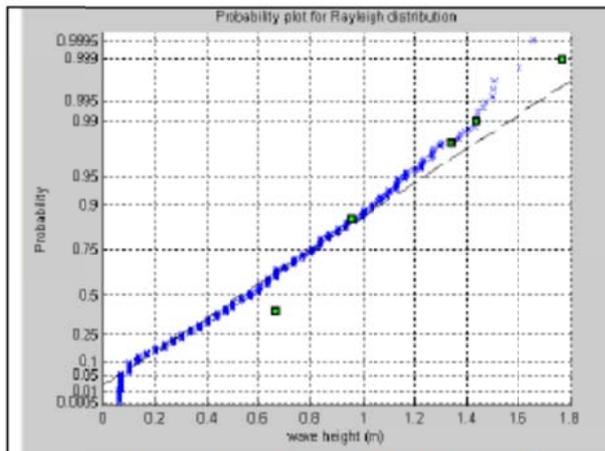
Calibration test EMS wave logger - 7 June 2012 - Deltaflume, Deltares



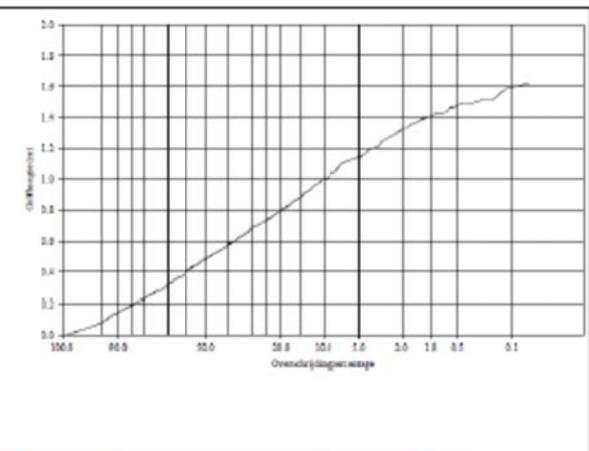
Measured spectrum with EMS wave logger



Measured spectrum according to Deltares equipment



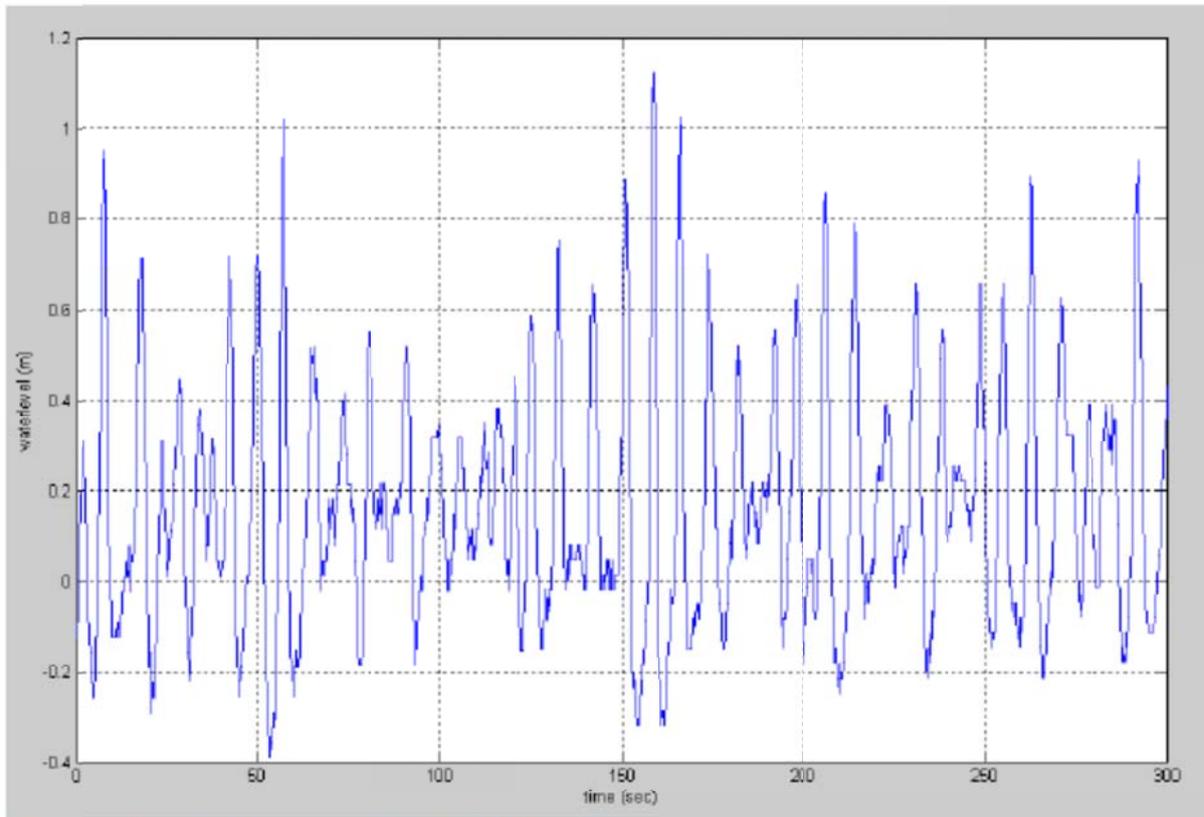
Measured exceedance line with EMS wave logger



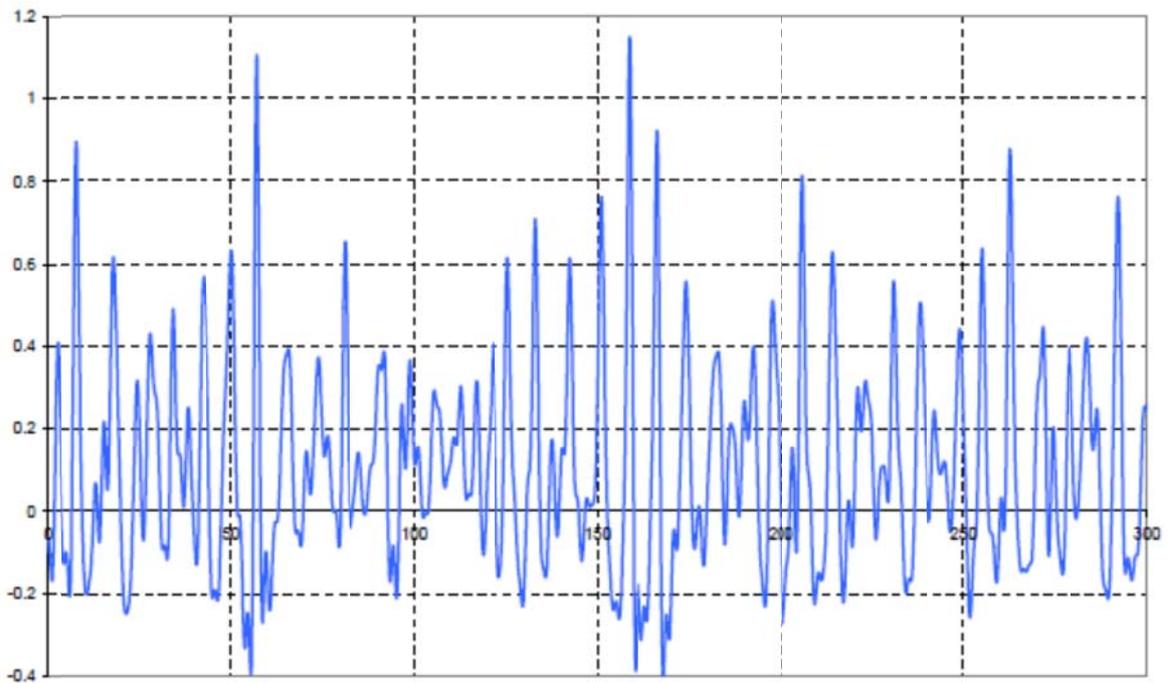
Measured spectrum according to Deltares equipment

measured unit	EMS wave logger	Deltares Equipment
Hm0	0.93	0.93
H1/3	0.96	0.94
H2%	1.34	1.38
Hmax	1.66	1.79
T01	5.47	5.53
T02		4.88
Tm-1,0	6.50	7.90
Tpeak	7.87	7.94
Sampling frequency	4 Hz	20 Hz

Calibration test EMS wave logger - 7 June 2012 - Deltaflume, Deltares



Wave surface elevation measured with EMS wave logger



Wave surface elevation measured with Deltares equipment

The measurements by EMS wave logger and Deltares Equipment were not at exactly the same location.

## Appendix 3: Matlab scripts

### *Wavelogger.m*

```

% Script for processing pressure data from the EMS wavelogger
% Script developed by H.J. Verhagen, Delft University of Technology
% February 2013
clear;
clc;
%define basic variables
Rho=1030;
g=9.81;
Avolt=254.1;      %Calibration value A of the pressure meter
Bvolt=-43250;    %Calibration value B of the pressure meter
TanAlfa = 0.001; %bedslope
NofFiles=1;      % number of files to be processed
StartFile=1;     % first file to be processed
for ii=StartFile:NofFiles
  if (ii==StartFile)
    [FileName,PathName] = uigetfile('*.txt','Select the wavelogger file');
    end;
  if (NofFiles==1)
    fid=fopen([PathName,FileName]);
    [pathstr, heading,ext]=fileparts(FileName);
  else
    if(ii==StartFile)
      [pathstr, heading,ext]=fileparts(FileName);
      heading=heading(1:(length(heading)-1));
      end;
    tellerstring=int2str(ii);
    FileName=[heading,tellerstring,'.txt'];
    fid=fopen([PathName,FileName]);
    end;

    % heading is caption of figures, default heading=FileName
    % if needed assign other value to heading here
    % heading = 'fill in your heading';

HDRS = textscan(fid,'%s %d %s %d %s',1, 'delimiter',' ');
tijd=HDRS{3};
temp=HDRS{4};
date=HDRS{5};
ccc=1;
n=0;

while ccc==1
  DATA = textscan(fid,'%s %d %d d', 'delimiter',' ');
  ccc=strcmpi(DATA{1}, '$D');
  n=n+1;
  %transformation from Volts to pressure using calibration constants Avolt
  %and Bvolt
  %Avolt has dimension Pa/V, Bvolt has dimension Pa
  if (ccc==1) q(n)=Avolt*DATA{3}+Bvolt+0.1;
    end;
end;
n=n-1;      %count number of samples
fclose(fid);
P=double(q');

% additional input data for spectrum
%=====

```

```

M = 50;           % higher values of M give more smoothing of the spectrum
                  % low value for M is 20, high value for M is 100
high = 0.25;     % highest frequency for plots  default high=0.4
low = 0.05;      % lowest frequency for plots  default low =0.05
cutoff=0.10;     % parameter to eliminate noise from the tail of the spectrum
                  % when the spectral value is less than "cutoff" % of the max
                  % value, then the spectral value is set to exact zero;
                  % default = 0.08
extraplot = 2;   % extraplot = 0 gives no plots, 1= only summary
                  % 2=include prssure, 3=include depth, 4= include pressure
method=2;        % method=1 uses Tm for calculating waveheight from pressure
                  % method=2 uses rea period per wave
steepness=0.03; % max allowed wave steepness individual waves, default 0.05
Hminimum=0.10;  % minimum waveheight to be considered default .10 m
interval=.25;   % interval is the sample frequency interval of the sensor
                  % do not change this value unless another wavelogger is used
%=====
if(NofFiles>1)extraplot=0;end; %in case of multiple files plotting
individual
                                %files is blocked
tottime=n*interval; %calculate total duration of observation in sec
ttime=(interval:interval:tottime); %create array with time
time=ttime.';        %change orientation of matrix
% calculate regression coefficients to compensate for change in waterlevel
% during the observations

if (extraplot>3)
    figure;
    plot(time,P);
    xlabel('time (sec)');
    ylabel('pressure (Pa)');
    title(['observed total pressure ',heading]);
end;
BB=polyfit(time,P,1); %regression analysis to determine real waterdepth at
any moment
                                %and correct for hydrostatic pressure
Intercept=BB(2);
Slope=BB(1);
Pwave=P-Intercept-time*Slope;

Pstatic=P-Pwave; %Hydrostatic pressure
Depth=Pstatic/Rho/g;
AverageDepth=mean(Depth);

%Optional figure to plot waterdepth as function of time
if (extraplot>2)
    figure
    plot(time,Depth);
    ylabel('depth (m)');
    xlabel('time (sec)');
    title(['average waterdepth ',heading]);

%Optional figure to plot wave pressure as function of time
    figure
    plot(time,Pwave);
    xlabel('time (sec)');
    ylabel('pressure (Pa)');
    title(['presure variations ',heading]);
end;
%=====
%Time domain analysis
counter=0;
Pmin=0;

```

```

Pmax=0;
period=0;
start=1;
if (method==1)
%loop to find individual pressure waves, needed to find number of waves
%using mean period
for k=1:n-1
    if(Pwave(k+1)*Pwave(k)<0 && Pwave(k+1)<0) %new wave starts at k+1
        counter=counter+1; % counter is number of found waves
        Pmax=0;
        Pmin=0;
    end;
    if(Pwave(k)>Pmax) Pmax=Pwave(k);
    end;
    if (Pwave(k)<Pmin) Pmin=Pwave(k);
    end;
end;
%counter = number of waves found

Tmean=n*interval/counter;
%loop to estimate water level variations
for k=1:n
    period=Tmean;
    L0=g/2/pi*period*period;
    if (Depth(k)/L0 < 0.36)
        L=sqrt(g*Depth(k))*(1-Depth(k)/L0)*period;
    else
        L=L0;
    end;
    eta(k)=(Pwave(k))/Rho/g*cosh(2*pi/L*Depth(k));
end;

%loop to find individual waves from waterlevel record (eta)
counter2=0;
etamax=0;
etamin=0;
for k=1:n-1
    if(eta(k+1)*eta(k)<0 && eta(k+1)<0) %new wave starts at k+1
        counter2=counter2+1;
        H(counter2)=etamax-etamin;
        etamax=0;
        etamin=0;
    end;
    if(eta(k)>etamax) etamax=eta(k);
    end;
    if (eta(k)<etamin) etamin=eta(k);
    end;
end;
% vector H contains all individual waves
% sort H to make exceedance graph
else
eta(1:n)=0;
% Method 2 starts here=====
%loop to find individual pressure waves, needed to find number of waves
%using mean period
for k=1:n-1
    if(Pwave(k+1)*Pwave(k)<0 && Pwave(k+1)<0) %new wave starts at k+1
        counter=counter+1; % counter is number of found waves
        TT(counter)=period;
        L0=g/2/pi*period*period;
        if (Depth(k)/L0 < 0.36)
            L=sqrt(g*Depth(k))*(1-Depth(k)/L0)*period;
        else

```

```

        L=L0;
    end
    H(counter)=(Pmax-Pmin)/Rho/g*cosh(2*pi/L*Depth(k));
    Hunreduced=H(counter);
    Hreduced=H(counter);
    if (H(counter)>steepness*L)
        H(counter)=steepness*L;
        Hreduced=H(counter);
    end;
    if (H(counter)<Hminimum)
        Hreduced=Hminimum;
        counter=counter-1;
    end;
    reduction=Hreduced/Hunreduced;
    for jj=start:k
        eta(jj)=(Pwave(jj))/Rho/g*cosh(2*pi/L*Depth(jj))*reduction;
    end;
    start=k+1;           % remember startpoint for next wave
    Pmax=0;
    Pmin=0;
    period=0;
end;
period=period+interval;
if(Pwave(k)>Pmax) Pmax=Pwave(k);
end;
if (Pwave(k)<Pmin) Pmin=Pwave(k);
end;
end;
end;

% counter = number of waves found
% vector H contains all individual waves
% sort H to make exceedance graph

if (extraplot>0)
    figure;
    subplot(4,1,1);
    plot(time,eta);
    xlabel('time (sec)');
    ylabel('waterlevel (m)');
    title([heading,date,tijd]);
end;
%end waterlevel loop

counter=length(H);
for k=1 : counter
    prob(k)= (counter-k+1)/counter;
end;

Hsorted=sort(H);
Hmean=mean(Hsorted);
Hrms = sqrt(mean(Hsorted.^2)); % rms wave height

from=round(2*counter/3);
to=round(counter);
Hs=mean(Hsorted(from:to)); %H 1/3, or significant wave height

Tsorted=sort(TT);
Tmean=mean(TT);
from=round(2*counter/3);
to=round(counter);

```

```

T3=mean(Tsorted(from:to)); %T 1/3, or significant wave period

%calculation of the H2%
Twopercent=round(counter-counter/50);
if (Twopercent==counter)
    H2percentMeasured=NaN;
else
    H2percentMeasured=Hsorted(Twopercent);
end;
H2percRayleigh=1.4*Hs;
%calculation of the H1%
Onepercent=round(counter-counter/100);
if (Onepercent==counter)
    H1percentMeasured=NaN;
else
    H1percentMeasured=Hsorted(Onepercent);
end;
H1percRayleigh=1.5*Hs;
%calculation of the H0.1%
Onepermille=round(counter-counter/1000);
if (Onepermille==counter)
    H1permilleMeasured=NaN;
else
    H1permilleMeasured=Hsorted(Onepermille);
end;
H1permilleRayleigh=1.85*Hs;

% Compositie weibull ditribution for shallow water
% source: Wave height distributions on shallow foreshores
%         Coastal Engineering, Volume 40, Issue 3, June 2000, Pages 161-182
%         Jurjen A Battjes, Heiko W Groenendijk

Htr=(0.35+5.8*TanAlfa)*AverageDepth; % Transistion wave height acc. to BG
(eq. 8)

H3=Hrms*BG(Htr,3);
H10=Hrms*BG(Htr,10);
H2=Hrms*BG(Htr,0.02);
H1=Hrms*BG(Htr,0.01);
H01=Hrms*BG(Htr,0.001);

%plot Rayleigh graph
if(extraplot>0)
    h = axes('Position',[0 0 1 1],'Visible','off');
    axes('Position',[.45 .40 .45 .30])

    for i=1:counter
        probsorted2(i)=1-i/(counter+1);
    end;
    maxh=1.3*Hsorted(counter);
    step=1;
    if (maxh<5.1) step=0.5;end;
    if (maxh<2.6) step=0.25;end;
    xmark=[0:step:maxh];
    coef=Rayleigh(Hsorted,probsorted2,xmark,Hrms,Htr);
    title('Wave height distribution (m) ');
    string=num2str(Hmean,2);
    str(1) = {'H_{mean} (m) ',string};
    string=num2str(Hrms,2);
    str(2) = {'H_{rms} (m) ',string};
    string=num2str(Hs,2);
    str(3) = {'H_{s} (m) ',string};
    string=num2str(Tmean,2);

```

```

str(4)= {'T_{mean} (s) ',string}};
string=num2str(T3,2);
str(5)= {'T_{1/3} (s) ',string}};
string=num2str(Htr,2);
str(6)= {'H_{tr}(m)(acc BG) ',string}};
string=num2str(1/TanAlfa);
str(7)= {'Bed slope 1:',string}};
str(8)={' obs Rayleigh BG'};
string=num2str(H2percentMeasured,3);
stringB=num2str(H2percRayleigh,3);stringC=num2str(H2,3);
str(9)= {'H_{2%}(m) ',string,' ',stringB,' ',stringC}};
string=num2str(H1percentMeasured,3);
stringB=num2str(H1percRayleigh,3);;stringC=num2str(H1,3);
str(10)= {'H_{1%}(m) ',string,' ',stringB,' ',stringC}};
string=num2str(H1permilleMeasured,3);
stringB=num2str(H1permilleRayleigh,3);;stringC=num2str(H01,3);
str(11)= {'H_{0.1%}(m) ',string,' ',stringB,' ',stringC}};
set(gcf,'CurrentAxes',h)
text(.1,.55,str,'FontSize',8)
end;

%=====
% simple script utilizing croschk (by G. Klopman) to obtain
% spectral estimate
%=====
% data contains the data
% N is the number of samples per data segment (power of 2)
% M is the number of frequency bins over which is smoothed (optional),
% no smoothing for M=1 (default)
% DT is the time step (optional), default DT=1
% DW is the data window type (optional): DW = 1 for Hann window (default)
% DW = 2 for rectangular window
% stats : display resolution, degrees of freedom (optimal, YES=1, NO=0)
%
% Output:
% P contains the (cross-)spectral estimates: column 1= Pxx, 2= Pyy, 3= Pxy
% F contains the frequencies at which P is given load time series

DT = interval;
data = Pwave;
[P,F,dof]=croschk(data,data,length(data),M,DT,1,0);

%recalculatate pressure spectrum to energy spectrum
energy=1:length(F); % length (F) is number of frequency bins
for i=1:length(F)
    energy(i)=0;
end;
m0=0; %zero-th moment
m1=0; %first moment
m2=0; %second moment
m0l=0; %first negative moment {m(-1,0)}
deltaF= F(31)-F(30);

emax=0;
prmax=0; %maximum value of pressure energy
% claculation loop to transform pressure spectrum to energy spectrum and
% to calculate the moments of the spectrum
% low and high frequencies are deleted, range from 200 to 0.2*max
% frequency bin, 200 means f= 200*deltaF, which is approx. 30 seconds
% 0.2*length(F)*deltaF = 0.4, so Tmin - 2.5 seconds

```

```

%loop to determine maximum value of pressure spectrum
for i=50:2000
    if (sqrt(P(i,1))>prmax) prmax=sqrt(P(i,1));
    end;
end;
for i=50:2000
    T=1/F(i);
    pr=sqrt(P(i,1));    %pr=pressure value in pressure spectrum
    L0=1.56*T*T;
    if (AverageDepth/L0<0.36)
        L=sqrt(g*AverageDepth)*(1-AverageDepth/L0)*T;
    else
        L=L0;
    end;
    energy(i)=(pr/(Rho*g)*cosh(2*pi/L*AverageDepth))^2;
    % e=energy density in Hz/m2

    if (pr<cutoff*prmax)
        energy(i)=0;
    end;
    if energy(i)>emax
        emax=energy(i);
        Tpeak=T;
    end;
    m0 =m0 +energy(i)*deltaF;
    m1 =m1 +energy(i)*deltaF*F(i);
    m2 =m2 +energy(i)*deltaF*F(i)^2;
    if (F(i)>0)
        m01=m01+energy(i)*deltaF/F(i);
    end;
end;

Hm0=4*sqrt(m0);    %one may assume Hs = Hm0
Hrmss=sqrt(8*m0);    %root mean square height from spectrum
Tm=sqrt(m0/m2);    %spectral approximation of mean period
T01=m0/m1;    %Period based on first moment
T10=m01/m0;    %Period based on first negative moment

% plot spectrum and print output
if(extraplot>0)
    h = axes('Position',[0 0 1 1],'Visible','off');
    axes('Position',[.45 .05 .45 .20])
    plot(F,energy)
    axis([low high 0 10000])
    axis 'auto y'
    xlabel('frequency [Hz]');
    ylabel ('Energy m^2/Hz');
    title('energy spectrum ');
    string=num2str(Hrmss,2);
    str(1)= {'H_{rms} (m) ',string};
    string=num2str(Hm0,2);
    str(2)= {'H_{m0} (m) ',string};
    string=num2str(Tm,2);
    str(3)= {'T_{m} (s) ',string};
    string=num2str(T01,2);
    str(4)= {'T_{m0,1} (s) ',string};
    string=num2str(T10,2);
    str(5)= {'T_{m-1,0} (s) ',string};
    string=num2str(Tpeak,2);
    str(6)= {'T_{peak} (s) ',string};
    str(7)={' '};
    str(8)={' '};
end;

```

```

string=num2str(AverageDepth,2);
str(9)={['Average depht (m) ',string]};
string=num2str(Rho);
str(10)={['water density (kgm{3}) ',string]};
str(11)={' '};
set(gcf,'CurrentAxes',h)
text(.1,.15,str,'FontSize',8)
end;

%Optional plot pressure spectrum
if (extraplot>1)
figure
plot(F,P(:,1)) % P is pressure2/Hz
axis ([low high 0 1500])
axis 'auto y'
xlabel('frequency [Hz]');
ylabel ('pressure Pa2/Hz');
title(['pressure spectrum ',heading]);
end;

StUitvoer(ii,1)=date;
StUitvoer(ii,2)=tijd;

uitvoer(ii,1)=ii;
uitvoer(ii,2)=AverageDepth;
uitvoer(ii,4)=Hs;
uitvoer(ii,5)=Hm0;
uitvoer(ii,6)=Tmean;
uitvoer(ii,7)=Tm;
uitvoer(ii,8)=Tl0;
uitvoer(ii,9)=Tpeak;
disp(ii);
end;

MeanDepth=0;
for (ii=StartFile:NofFiles)
MeanDepth=MeanDepth+uitvoer(ii,2);
end;
MeanDepth=MeanDepth/(NofFiles-StartFile);
for(ii=StartFile:NofFiles)
uitvoer(ii,3)=uitvoer(ii,2)-MeanDepth;
end;
savefile=([heading, '.mat']);
save (savefile,'StUitvoer','uitvoer');

```

## Rayleigh.m

```

function coef = rayleigh(xi,yi,xmark,Hrms,Htr)
% -----
%     function coef = rayleigh(xi,yi,xmark)
%
% Rayleigh Probability Paper: The paper is marked with probability
% of exceedance [0.002, 0.005, 0.01, 0.05, 0.1:0.1:0.9] (horizontal
% lines associated with these values are drawn). In addition, it draws
% the linear curve fitting for input data points.
%
% xi = horizontal input (physical quantity)
% yi = vertical input (in probability of exceedance)
% xmark = vertical grid lines to be plotted
% coef = slope and intercept of the linear regression line.
x = xmark;
poe = [1:-0.1:0.1, 0.05,0.02,0.01,0.005,0.002,0.001,0.0005]; % prob.of
exceedance
y = sqrt(-log(poe));
n = length(y);
m = length(x);
axis([x(1) x(m) y(1) y(n)]);
dx = abs(x(m)-x(1))/25;
xh = [x(1) x(m)];
% working on horizontal line
for k=1:n,
    yh=[y(k) y(k)];
    line(xh,yh);
    text(x(1)-2*dx,y(k),num2str(poe(k))); % prob. of exceedance
end
% set(gca,'linestyle',':');
% working on vertical line (horizontal scale)
dy=abs(y(n)-y(1))/25;
yv=[y(1),y(n)];
for k=1:m,
    xv=[x(k) x(k)];
    line(xv,yv);
    text(x(k)-dx/4,y(1)-dy,num2str(xmark(k)));
end
axis('off');
% x is wave height
% y is probability (correct numbers)
% z is scaled probability for Rayleigh paper
% plotting data points, convert probabilities for plot
%
zi = sqrt(-log(yi));
hold on
plot(xi,zi, '.')
%
% to draw regression line
%
coef=polyfit(xi,zi,1);
xa = 0.5 * min(xi);
xb = 1.5 * max(xi);
xx = [xa xi xb];
yy = polyval(coef,xx);
plot(xx,yy, '-');
%
H1=BG(Htr/Hrms,1);
H2=BG(Htr/Hrms,2);
xxx=[xmark(1):.01:xmark(m)];
lxxx=length(xxx);
%calculate plot with CWD of Battjes Groenendijk

```

```
for j=1:lxxx
    if (xxx(j)<Htr)
        yyy(j)=1-exp(-power((xxx(j)/(H1*Hrms)),2.0)); %BG 2
    else
        yyy(j)=1-exp(-power((xxx(j)/(H2*Hrms)),3.6)); %BG 3.6
    end;
end;
%convert probabilities to scale for plot
zzz=sqrt(-log(1-yyy));
hold on

plot(xxx,zzz,'r');
```

## ***croschk.m***

```

function [P,F,dof]=croschk(X,Y,N,M,DT,DW,stats);
% CROSKG   Power cross-spectrum computation, with smoothing in the
%         frequency domain
%
% Usage: [P,F]=CROSKG(X,Y,N,M,DT,DW,stats)
%
% Input:
% X   contains the data of series 1
% Y   contains the data of series 2
% N   is the number of samples per data segment (power of 2)
% M   is the number of frequency bins over which is smoothed (optional),
%     no smoothing for M=1 (default)
% DT  is the time step (optional), default DT=1
% DW  is the data window type (optional): DW = 1 for Hann window (default)
%                                     DW = 2 for rectangular window
% stats : display resolution, degrees of freedom (optimal, YES=1, NO=0)
%
% Output:
% P contains the (cross-)spectral estimates: column 1 = Pxx, 2 = Pyy, 3 =
Pxy
% F contains the frequencies at which P is given
%
%
% Gert Klopman, Delft Hydraulics, 1995
%
if nargin < 4,
    M = 1;
end;
if nargin < 5,
    DT = 1;
end;
if nargin < 6,
    DW = 1;
end;
if nargin < 7,
    stats = 1;
end;
df = 1 / (N * DT) ;
% data window
w = [];
if DW == 1,
    % Hann
    w = hanning(N);
    dj = N/2;
else,
    % rectangle
    w = ones(N,1);
    dj = N;
end;
varw = sum (w.^2) / N ;

% summation over segments

nx   = max(size(X));
ny   = max(size(Y));
avgx = sum(X) / nx;
avgy = sum(Y) / ny;
px   = zeros(size(w));
py   = zeros(size(w));

```

```

Pxx = zeros(size(w));
Pxy = zeros(size(w));
Pyy = zeros(size(w));
ns = 0;

for j=[1:dj:nx-N+1],

    ns = ns + 1;

    % compute FFT of signals

    px = X([j:j+N-1]') - avgx;
    px = w .* px ;
    px = fft(px) ;

    py = Y([j:j+N-1]') - avgy;
    py = w .* py ;
    py = fft(py) ;

    % compute periodogram

    Pxx = Pxx + px .* conj(px) ;
    Pyy = Pyy + py .* conj(py) ;
    Pxy = Pxy + py .* conj(px) ;

end;

Pxx = (2 / (ns * (N^2) * varw * df)) * Pxx ;
Pyy = (2 / (ns * (N^2) * varw * df)) * Pyy ;
Pxy = (2 / (ns * (N^2) * varw * df)) * Pxy ;

% smoothing

if M>1,
    w = [];
    w = hamming(M);
    w = w / sum(w);
    w = [w(ceil((M+1)/2):M); zeros(N-M,1); w(1:ceil((M+1)/2)-1)];
    w = fft(w);
    Pxx = fft(Pxx);
    Pyy = fft(Pyy);
    Pxy = fft(Pxy);
    Pxx = ifft(w .* Pxx);
    Pyy = ifft(w .* Pyy);
    Pxy = ifft(w .* Pxy);
end;

Pxx = Pxx(1:N/2);
Pyy = Pyy(1:N/2);
Pxy = Pxy(1:N/2);

% frequencies

F = [];
F = ([1:1:N/2]' - 1) * df;

% signal variance

if DW == 1,
    nn = (ns + 1) * N / 2;
else,

```

```

nn = ns * N;
end;
avgx = sum (X(1:nn)) / nn;
varx = sum ((X(1:nn) - avgx).^2) / (nn - 1);
avgy = sum (Y(1:nn)) / nn;
vary = sum ((Y(1:nn) - avgy).^2) / (nn - 1);
covxy = sum ((X(1:nn) - avgx) .* (Y(1:nn) - avgy)) / (nn - 1);

m0xx = (0.5 * Pxx(1) + sum(Pxx(2:N/2-1)) + 0.5 * Pxx(N/2)) * df;
m0yy = (0.5 * Pyy(1) + sum(Pyy(2:N/2-1)) + 0.5 * Pyy(N/2)) * df;
m0xy = (0.5 * Pxy(1) + sum(Pxy(2:N/2-1)) + 0.5 * Pxy(N/2)) * df;

%disp(['m0x / varx = ' num2str(m0xx./varx) ' ; m0y / vary = '
num2str(m0yy./vary) ' ; m0xy / varxy = ' num2str(real(m0xy)./covxy) ' '])

Pxx = Pxx * (varx / m0xx);
Pyy = Pyy * (vary / m0yy);
Pxy = Pxy * (covxy / real(m0xy));

P = [Pxx, Pyy, Pxy];

% output spectrum characteristics
dof = floor(2*ns*(M+1)/2/(3-DW));
if stats == 1
fprintf('number of samples used : %8.0f\n', nn);
fprintf('degrees of freedom      : %8.0f\n', floor(2*ns*(M+1)/2/(3-DW)));
fprintf('resolution                  : %13.5f\n', (3-DW)*df*(M+1)/2);
end
%
```

**BG.m**

```

function [Hnorm]=BG(Htr,Proba);
% Function developed by H.J. Verhagen, Delft University of Technology
% January 2013

% Input:
% Htr - H transition acc Battjes-Groenendijk (eq 8 in paper)

% Proba code for required exceedance:
%   Proba = 3    ==> H1/3
%   Proba = 10   ==> H1/10
%   Proba = 0.02 ==> H2%
%   Proba = 0.01 ==> H1%
%   Proba = 0.001 ==> H0.1%

% Output Hnorm

% source: Wave height distributions on shallow foreshores
%   Coastal Engineering, Volume 40, Issue 3, June 2000, Pages 161-182
%   Jurjen A Battjes, Heiko W Groenendijk

%table from Battjes groenendijk
% Htr   H1     H2     H1/3   H1/10   H2%    H1%    H0.1%
BGtable=[
0.05    12.193  1.060  1.279  1.466  1.548  1.620  1.813
0.1     7.003   1.060  1.279  1.466  1.548  1.620  1.813
0.15    5.063   1.060  1.279  1.466  1.548  1.620  1.813
0.2     4.022   1.060  1.279  1.466  1.548  1.620  1.813
0.25    3.365   1.060  1.279  1.466  1.548  1.620  1.813
0.3     2.908   1.060  1.279  1.466  1.548  1.620  1.813
0.35    2.571   1.060  1.279  1.466  1.548  1.620  1.813
0.4     2.311   1.060  1.279  1.466  1.548  1.620  1.813
0.45    2.104   1.060  1.279  1.466  1.549  1.620  1.813
0.5     1.936   1.061  1.280  1.467  1.549  1.621  1.814
0.55    1.796   1.061  1.281  1.468  1.550  1.622  1.815
0.6     1.678   1.062  1.282  1.469  1.552  1.624  1.817
0.65    1.578   1.064  1.284  1.471  1.554  1.626  1.820
0.7     1.492   1.066  1.286  1.474  1.557  1.629  1.823
0.75    1.419   1.069  1.290  1.478  1.561  1.634  1.828
0.8     1.356   1.073  1.294  1.483  1.567  1.639  1.835
0.85    1.302   1.077  1.300  1.490  1.573  1.646  1.843
0.9     1.256   1.083  1.307  1.498  1.582  1.655  1.852
0.95    1.216   1.090  1.315  1.507  1.591  1.665  1.864
1       1.182   1.097  1.324  1.518  1.603  1.677  1.877
1.05    1.153   1.106  1.335  1.530  1.616  1.690  1.892
1.1     1.128   1.116  1.346  1.543  1.630  1.705  1.909
1.15    1.108   1.126  1.359  1.558  1.645  1.721  1.927
1.2     1.090   1.138  1.371  1.573  1.662  1.739  1.946
1.25    1.075   1.150  1.381  1.590  1.679  1.757  1.967
1.3     1.063   1.162  1.389  1.607  1.698  1.776  1.988
1.35    1.052   1.175  1.395  1.626  1.717  1.796  2.011
1.4     1.043   1.189  1.399  1.644  1.737  1.817  2.034
1.45    1.036   1.203  1.403  1.664  1.757  1.838  2.058
1.5     1.030   1.217  1.406  1.683  1.778  1.860  2.082
1.55    1.024   1.231  1.408  1.703  1.799  1.882  2.106
1.6     1.020   1.246  1.410  1.721  1.820  1.904  2.131
1.65    1.016   1.261  1.411  1.736  1.841  1.927  2.156
1.7     1.013   1.275  1.412  1.749  1.863  1.949  2.182
1.75    1.011   1.290  1.413  1.759  1.884  1.972  2.207
1.8     1.009   1.305  1.413  1.767  1.906  1.994  2.232
1.85    1.007   1.320  1.414  1.773  1.927  2.017  2.257

```

1.9	1.006	1.334	1.414	1.779	1.949	2.039	2.282
1.95	1.004	1.349	1.415	1.783	1.970	2.062	2.307
2	1.004	1.363	1.415	1.786	1.985	2.084	2.332
2.05	1.003	1.378	1.415	1.789	1.983	2.106	2.357
2.1	1.002	1.392	1.415	1.791	1.982	2.128	2.382
2.15	1.002	1.407	1.415	1.793	1.981	2.150	2.406
2.2	1.001	1.421	1.415	1.795	1.981	2.149	2.430
2.25	1.001	1.435	1.415	1.796	1.980	2.148	2.454
2.3	1.001	1.449	1.415	1.797	1.979	2.148	2.478
2.35	1.001	1.462	1.415	1.797	1.979	2.147	2.502
2.4	1.000	1.476	1.416	1.798	1.979	2.147	2.525
2.45	1.000	1.490	1.416	1.798	1.979	2.147	2.548
2.5	1.000	1.503	1.416	1.799	1.978	2.147	2.571
2.55	1.000	1.516	1.416	1.799	1.978	2.146	2.593
2.6	1.000	1.529	1.416	1.799	1.978	2.146	2.616
2.65	1.000	1.542	1.416	1.799	1.978	2.146	2.629
2.7	1.000	1.555	1.416	1.799	1.978	2.146	2.629
2.75	1.000	1.568	1.416	1.800	1.978	2.146	2.628
2.8	1.000	1.580	1.416	1.800	1.978	2.146	2.628
2.85	1.000	1.593	1.416	1.800	1.978	2.146	2.628
2.9	1.000	1.605	1.416	1.800	1.978	2.146	2.628
2.95	1.000	1.617	1.416	1.800	1.978	2.146	2.628
3	1.000	1.630	1.416	1.800	1.978	2.146	2.628];

```

j=0;
if (Proba==1)      j=2; end;
if (Proba==2)      j=3; end;
if (Proba==3)      j=4; end;
if (Proba==10)     j=5; end;
if (Proba==0.02)   j=6; end;
if (Proba==0.01)   j=7; end;
if (Proba==0.001) j=8; end;
i=round(Htr/0.05);
if (Htr>3)         i=60; end;
if (Htr<.05)      i=1;  end;

if(j==0)
  Hnorm=NaN;
else
  Hnorm=BGtable(i, j);
end;
end

```

## PlotSeries.m

```

[FileName,PathName] = uigetfile('*.mat','Select the datafile to be
plotted');
[pathstr, heading,ext]=fileparts(FileName);
load(FileName);
k=length(uitvoer);
for i=1:k
day(i)=uitvoer(i,1:1)/24;
end;
startpunt=35;
eindpunt=15;
datum=StUitvoer(startpunt,1);
tijd=StUitvoer(startpunt,2);
subplot(3,1,1);
hlines(3)=plot(day(startpunt:k-eindpunt),uitvoer(startpunt:k-
eindpunt,3:3),'b');
xlabel('days');
ylabel('waterlevel (m)');
title(['\bf',heading,datum,tijd,']);
set(hlines(3),'Displayname','tide')
legend('Location','WestOutside')
subplot(3,1,2);
hlines(4)=plot(day(startpunt:k-eindpunt),uitvoer(startpunt:k-
eindpunt,4:4),'b');
hold on;
hlines(5)=plot(day(startpunt:k-eindpunt),uitvoer(startpunt:k-
eindpunt,5:5),'r');
xlabel('days');
ylabel('wave height (m)');
set(hlines(4),'Displayname','H_{1/3}')
set(hlines(5),'Displayname','H_{m0}')
legend('Location','WestOutside')
subplot(3,1,3);
hlines(9)=plot(day(startpunt:k-eindpunt),uitvoer(startpunt:k-
eindpunt,9:9),'b');
hold on;
hlines(8)=plot(day(startpunt:k-eindpunt),uitvoer(startpunt:k-
eindpunt,8:8),'r');
hold on;
hlines(7)=plot(day(startpunt:k-eindpunt),uitvoer(startpunt:k-
eindpunt,7:7),'m');
hold on;
hlines(6)=plot(day(startpunt:k-eindpunt),uitvoer(startpunt:k-
eindpunt,6:6),'g');
set(hlines(6),'Displayname','T_{mean}')
set(hlines(7),'Displayname','T_{m0,2}')
set(hlines(8),'Displayname','T_{m-1,0}')
set(hlines(9),'Displayname','T_{peak}')
legend('Location','WestOutside')
xlabel('days');
ylabel('wve period (s)');

```