

HAWASSI-VBM2

User Manual



by
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Preamble

Waves are fascinating, important and challenging.

The importance can be substantiated from some well-known observations:

- Half of the world population lives less than 150 km from the coast
- The sea is a relatively easy medium for transport of people and goods (half of all the world crude oil and increasingly more natural gas) and for intercontinental telecommunication through cables
- Ocean resources of food and minerals are only at the start of discovery, profits from wind parks and harvesting of wave energy in coastal areas is expanding.

Therefore, a sustainable and safe development of the oceanic and coastal areas is of paramount importance. Nowadays that means that for the design of harbours, breakwaters and ships, calculations are performed with increasingly more accurate and fast simulation tools. Tools that are, packaged in software, based on the basic physical laws that describe the properties of waves, the wave-ship interaction, the forces on structures, etc.

HAWASSI software is aimed to contribute to extend the accuracy, capability and speed of existing numerical methods and software using applied-mathematical modelling methods that are at the basis.

A basis with a rich history that is fascinating and challenging. Starting in the 18th century with Euler who generalized Newton's law for fluids, in the 19th century Airy 'solved' the problem to describe small amplitude surface water waves. In that same century, many renowned scientists like Scott Russel, Stokes, Boussinesq, Rayleigh and Korteweg & De Vries investigated the nonlinear aspects of finite amplitude waves. As much as possible without the need to fully calculate the internal fluid motion; started with Boussinesq in an approximative way, this was formulated accurately in the 1960-1970's by Zakharov and Broer by providing the Hamiltonian form of the dynamic equations.

HAWASSI software is based on these last findings, with methods for making the principal description into a practical (numerical) modelling and implementation tool.

The first release of the software deals with wave propagation, but the developers are in the process to extend the capabilities to include coupled wave-ship interactions, amongst others, in later releases.

We sincerely hope that the use of the software, just as the design of it has been, will be fascinating and challenging for students and academicians as well as for practitioners; from both groups we hope to receive comments and suggestions for further improvements and extensions in a way that can be profitable for both sides.

*Let nature tell its secrets
Listen to the physics in its mathematical language
Restrain from idealization
Only then models will serve us in abundance*

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The software has been developed over the past years in collaboration with the University of Twente, Netherlands, with additional financial support of Netherlands Technology Foundation STW and Royal Netherlands Academy of Arts and Sciences KNAW.

By downloading and using the software you agree that Yayasan AB is not liable for any loss or damage arising out of the use of the Software. Although much care is taken to arrive at trustful results of simulations with HAWASSI, Yayasan AB cannot be held responsible for any result of simulations obtained with the software, or consequential actions or calculations that are based on the results, e.g. because of possible bugs, wrong use of the software, or other causes.

1 Introduction

This document is the Manual of HAWASSI-VBM2 software that serves as a guide for using and running the software.

HAWASSI-VBM2 simulates phase resolved waves in 2 Horizontal Directions (long and short crested waves), as appear in wave tanks, coastal and oceanic areas, harbors, with flat and varying bathymetry, and with (partially) reflecting walls and damping zones.

Section 2 describes briefly the mathematical background and dispersive qualities of the code, together with some features of the software; it is advised to read this Section before continuing to the rest of the manual¹. Section 3 provides a step-by-step installation procedure of the software. The full description of the software, regarding GUIs and input/output parameters, is given in detail in Section 4. Section 5 starts with a short tutorial for getting ready to use the software (without the need to know all the information from section 4), in particular to show how to deal with test cases that are provided in successive subsections.

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DEMO-version with restricted functionality

The Demo-version of HAWASSI-VBM2 has restricted functionality and facilities:

- Only 1 parabolic vertical profile
- Only linear
- Non-depth dependence mesh generator
- No internal flow calculations
- No comparison with external (measurement) data

Full functionality and facilities under licence

- Licence for *University Thesis Projects*
- **Research Licence** for extending capabilities and/or functionalities
- **Licence for companies / commercial use**, tailor made on demand; all proceeds will be used at Foundation Yayasan AB for improving/extending the software

Visit www.hawassi.labmath-indonesia.org for further information,
or send email to licence@hawassi.labmath-indonesia.org

¹ Users with limited experience in mathematical-physical wave modelling may consult the service booklet [1] **Water Wave Modelling & Simulation, with Introduction to HAWASSI-software, YAB LabMath**

2 Description of HAWASSI-VBM2

2.1 Introduction HAWASSI-VBM2

The purpose of this section is to provide the user relevant background information of HAWASSI-VBM2 and to give some general advice in choosing the basic input for the computations.

HAWASSI - VBM is a software package for the simulation of realistic waves in wave tanks (1HD – 1 Horizontal Dimension), oceanic and coastal areas, harbor etc (2HD – 2 Horizontal Dimensions).

The acronym of HAWASSI stands for

Hamiltonian Wave-Ship-Structure Interaction.

HAWASSI -VBM is a finite element implementation of the **Variational Boussinesq Model** (VBM). Presently the code is for simulation of wave-structure interactions; coupled wave-ship interaction is foreseen in future releases.

VBM is a Boussinesq-type model, first introduced by Klopman et al 2005, that is derived via the variational formulation for surface water waves. The model has been further developed to have tailor-made dispersion properties (based on the problem to be solved) with accuracy up to $kh \approx 15$ or more (see Adytia & Groesen 2012). The interior fluid motion is modelled by a combination of a few (Airy-type) depth profiles; this makes it possible to optimize the dispersion properties depending on the specific case to be simulated. Nonlinear effects are accounted for in a weakly nonlinear way that is sufficient for most applications. The model is called the Optimized Variational Boussinesq Model (OVBM) which is the mathematical model behind the HAWASSI – VBM.

Underlying Modeling Methods

HAWASSI-VBM is based on the following principles

- The free surface dynamics of the irrotational flow of inviscid, incompressible fluid is governed by a set of Hamilton equations for the surface elevation η and the potential ϕ at the surface
- By approximating the kinetic energy functional $K(\phi, \eta)$ explicitly as an expression in η , and ϕ , the simulation of the interior flow can be avoided, the Boussinesq character of the codes.
- The way of approximating $K(\phi, \eta)$ is based on Dirichlet's principle for the boundary-value problem in the fluid domain. By restricting the set of competing functions in the minimization, an approximation of $K(\phi, \eta)$ is obtained. The variational derivative $\delta_\phi K(\phi, \eta) = \partial_N \Phi$ is the corresponding consistent approximation of the Dirichlet-to-Neumann operator.
- The (approximate) Hamilton system conserves the (approximate) positive definite total energy exactly, avoiding sources of instability.
- The time dynamics is explicit, no CFL-conditions are required. Time stepping is done with matlab odesolver code, with automatic variable time step.

In VBM the interior flow is approximated by using a linear combination of vertical Airy profiles, characterized by the values of wave numbers κ_m . The choice of these values determines the dispersion

relation. Given the spectrum of the influx signal (or initial profile) of the case under investigation, the values of κ_m are optimized for best performance for the relevant frequency interval. Therefore, VBM can have excellent, tailor-made, dispersive properties; deep water waves can be simulated just as well as infragravity waves.

Numerical Implementation

A Finite Element method using piece-wise linear splines can deal with the first order differentiations that appear in the approximate Kinetic Energy. In addition to two scalar dynamic equations for ϕ and η , a system of elliptic equations has to be solved for the amplitudes of the Airy functions.

Advice

Non-experienced users are suggested to start using the software with the test cases that are provided in order to understand the input requirements and to explore the various possibilities of output from the simulation.

2.2 Model features

HAWASSI-VBM2 accounts for the following physical phenomena of waves in 2 HD (horizontal directions), long and short-crested waves

- Wave propagation, dispersion, diffraction, refraction and shoaling
- Nonlinear wave-wave interactions

Features of the software include

- The quality of dispersion is optimized for specific wave problem to be simulated, which makes it possible to simulate deep ocean waves or very short waves ($kh \approx 15$ or more) and infragravity waves
- Various method for wave influx
- Use of efficient damping zones and (partially reflecting) walls

Facilities of the software include

- GUI (Graphical User Interface) for making a depth dependent unstructured mesh in a given geometry with sea and or wall boundaries, and for input of wave characteristics and model parameters
- GUI for post-processing of the output of the wave simulation
- Time partitioned simulation is possible to reduce (computer) hardware requirements
- Project examples with harmonic and irregular waves above bathymetry in simple as well as complicated geometries such as harbours.

Simulation results of the model have been compared with series of experiments in laboratories (see the references in Section 6).

2.3 Relation to other Boussinesq-type wave models

HAWASSI-VBM is a phase-resolving model where individual waves (wave components) in the energy spectrum are resolved with their phases and amplitudes. This type of model is typically used for studying wave propagation in a small area, such as in a harbor or near coasts. Other Boussinesq-type models that are adopted by commercial software are based on Madsen & Sørensen [1992] (MIKE21-Boussinesq Wave by DHI) and Nwogu [1993] (BOUSS2D, SMS by Aquaveo). Both models have dispersion accuracy up to $kh \approx 3.14$, which implies that it is possible to simulate waves with wavelength more than 2 times the depth. The dispersive quality of HAWASSI-VBM compared with these other two Boussinesq models is illustrated in Figure 2-1

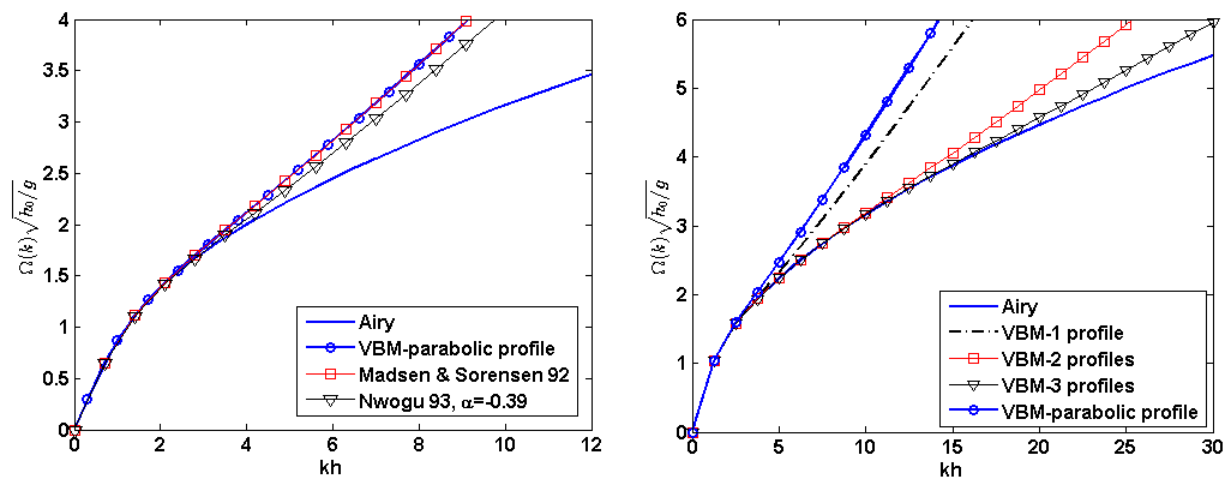


Figure 2-1. Dispersion relation comparison of Boussinesq-type models by Madsen & Sørensen [1992], Nwogu [1993], VBM with parabolic profile by Klopman et al [2010] with the Airy linear theory dispersion relation (left) as function of kh . In the right plot a comparison of dispersion relations for VBM with 1, 2, 3 Airy profiles and parabolic profile with the Airy linear theory.

2.4 Units, coordinate system and computational grid

The HAWASSI-VBM2 expects all quantities that are given by the user to be expressed in S.I unit: m, kg, s. (meter, kilogram, second). As a consequence, the wave height and water depth are in m, wave period in s, etc. HAWASSI-VBM2 only operates in a Cartesian coordinate system.

3 Installing HAWASSI-VBM software

The HAWASSI-VBM installer includes both HAWASSI-VBM2 as well as HAWASSI-VBM1 (there is a separate manual for VBM1); the installation process will automatically install both codes. HAWASSI-VBM software is programmed under the MATLAB environment; therefore the software needs the MATLAB Compiler Runtime (MCR) installer. MCR will install MATLAB Runtime Libraries on the computer so that compiled MATLAB applications can run on PC-machines that do not have MATLAB installed. The installation of HAWASSI-VBM can be done in two main steps; the installation of MCR and the installation of HAWASSI-VBM itself.

3.1 System requirements

HAWASSI-VBM (v.1.1) can run on Windows operating system with 64bit architecture. The minimum memory (RAM) required is 2GB (4GB RAM or more is advised).

3.2 First step: Installing MCR

HAWASSI-VBM package (v.1.1) requires MCR installer for **MATLAB version R2013b (8.2)** for Windows operating system 64bit. The MCR installer can be downloaded from the MATLAB website: <http://www.mathworks.com/products/compiler/mcr/> ; after downloading the MCR, install it by double clicking the installer and following the instruction in the installation wizard.

3.3 Second step: Installing HAWASSI-VBM

After the installation of the MCR is done, the installation of HAWASSI-VBM1 and 2 is performed by double clicking the installer of HAWASSI-VBM: '**setup_HAWASSI_VBM_v1.1.exe**' and follow the instructions in the installation wizard. During the installation process a *copyright and non-liability agreement* should be accepted to be able to proceed.

After the installation is finished, start HAWASSI-VBM (VBM1 or VBM2) from the shortcut on the Desktop. In the Main-GUI that appears, under 'Help' go to 'Licence Activation' and load '*licence.lic*'. Closing the software and starting again, the licence will have been activated and the software can run for the licence-period. If a new version is downloaded and installed, the same *licence.lic* file will be valid for the new version until expiration time.

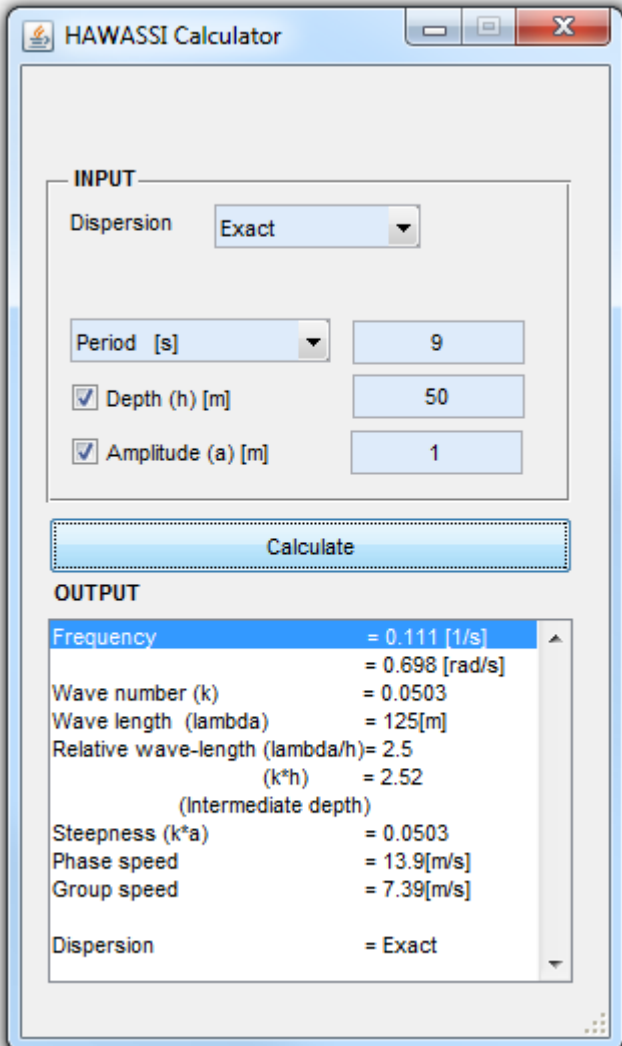
After the installation is finished, the software can be accessed from the shortcut in the Desktop and the Start Menu. Documentation and Test-cases of the HAWASSI-VBM are provided and placed in '*My Document / HAWASSI_VBM*'.

4 GUI's of HAWASSI-VBM2

For ease of operation, HAWASSI-VBM2 software includes two interfaces or GUI's, Graphical User Interfaces, namely the **Main GUI** for the input model and a **Post-Processing GUI** for the wave simulation output. The GUI's act as an input-output manager.

There is a simple **Wave-Calculator** that expects as input the period, frequency or wave length of a harmonic wave and the depth, and will then calculate all wave-relevant quantities; by also specifying the amplitude, the calculated steepness is added. The calculator can be accessed by clicking 'Tool' → 'Wave Calculator'.

Figure 4-1 Wave Calculator



INPUT	
Dispersion	Exact
Period [s]	9
<input checked="" type="checkbox"/> Depth (h) [m]	50
<input checked="" type="checkbox"/> Amplitude (a) [m]	1
Calculate	
OUTPUT	
Frequency	= 0.111 [1/s]
Wave number (k)	= 0.698 [rad/s]
Wave length (lambda)	= 125[m]
Relative wave-length (lambda/h)	= 2.5
(k*h)	= 2.52
(Intermediate depth)	
Steepness (k*a)	= 0.0503
Phase speed	= 13.9[m/s]
Group speed	= 7.39[m/s]
Dispersion	= Exact

4.1 Main GUI

Choosing the wave model characteristics, wave parameters, the domain and input signal and profile are managed in the main GUI (Figure 4-2). Details of each input in the main GUI will be explained in detail in the next sub-sections.

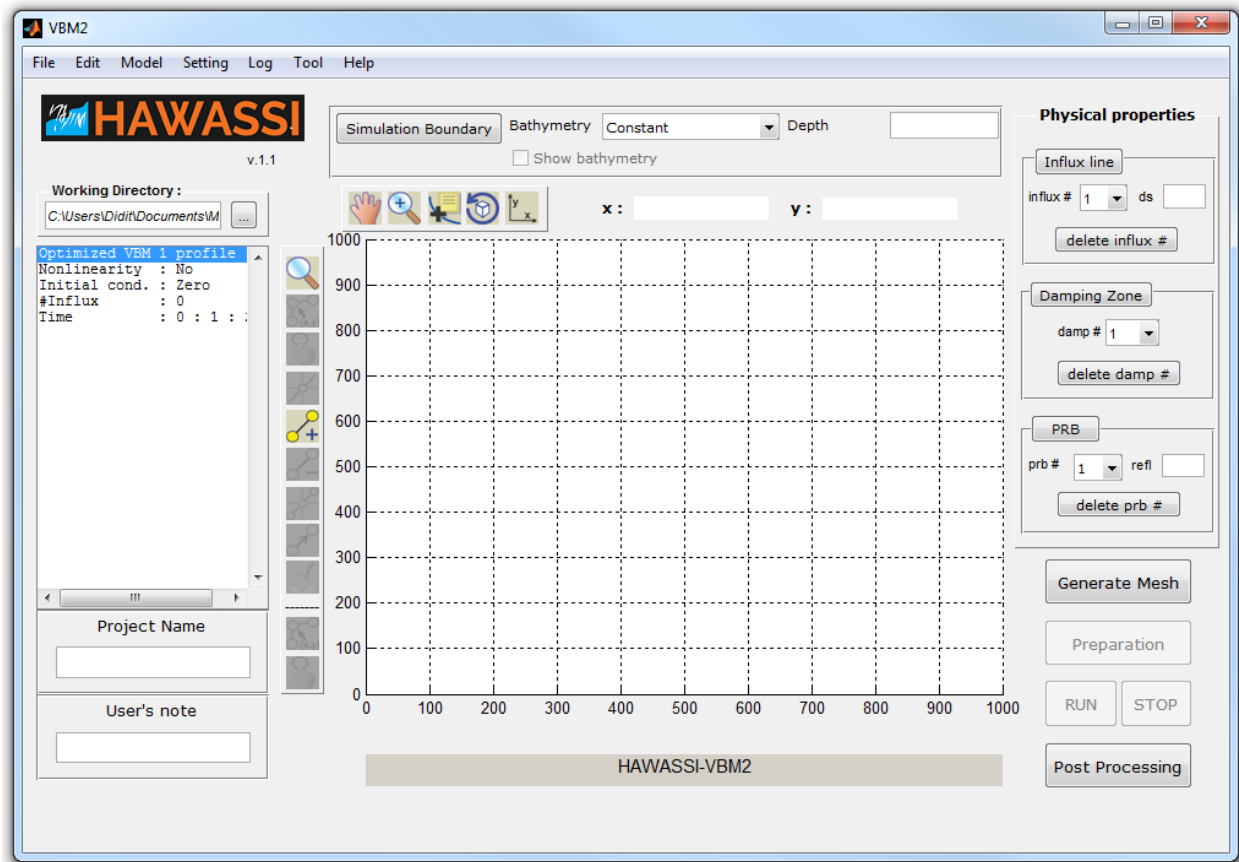



Figure 4-2 The main GUI of HAWASSI-VBM2

4.1.1 Working Directory

To get started with HAWASSI-VBM2, the user should first specify the working directory for the software. This can be done by clicking  button and choose a location or folder.

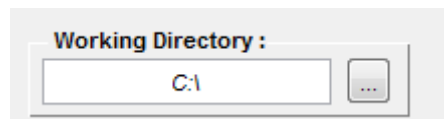


Figure 4-3 Choosing working directory

In the specified directory/folder, the software will create new folder: ‘**Output**’ when the directory does not contain the folder yet. If the folder already exists, it will keep and use the folder. **All** output files will be stored in the ‘Output’ folder.

4.1.2 Project Name & User’s Note

After specifying the working directory, the user should specify Project Name and (if wanted) User’s note. The User note will be printed in the log-file, which is stored as ‘./Output/LOG_[ProjectName].log’.

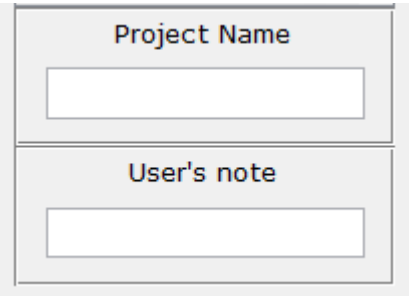


Figure 4-4 Project name & User’s note

4.1.3 Wave Model Characteristics

HAWASSI-VBM2 comes with two main versions, the non-dispersive model Shallow Water Equation (SWE) and various variants of the dispersive model, the VBM.

There are 5 sub-options of VBM as choices which vertical profile(s) to be used, which will determine the *dispersive quality of the model* as illustrated in **Figure 2-1**. The user can select the model to be used under ‘Model’ → ‘Type’ → ‘SWE’ or ‘VBM’ (see **Figure 4-5**).

In the (Optimized-)VBM, the software will calculate automatically the optimized wave number κ to be used in the Airy profile, based on the problem to be solved (signaling problem and/or initial value problem). In the User-defined VBM, the user can freely choose frequencies (related to the wave numbers) to be used as input in the Airy profile. When this option is selected, there will be a pop-up menu asking for the custom values in [Hz], as shown in **Figure 4-6**.

Suggestion : For inexperienced users a trial-simulation with VBM parabolic profile will give an idea how the dispersive waves will propagate. If the model’s dispersion quality is too poor for the waves to be simulated, the Optimized VBM with 1 profile, and after that with 2 profiles can be tried.

Warning:

1. The more Airy profiles are used, the more computation time will be needed. For rather simple waves, simulations with 2 profiles will approximately cost 1.5 times more CPU time than needed for 1 Airy profile. For complicated waves (very steep, broad spectrum) the calculation time may be longer.

2. The **User-defined option of VBM is recommended only for advanced users** who know and understand the (energy) spectrum of the wave to be simulated, and the effect of their choices, i.e. how the choice of the frequencies in the Airy functions of VBM may affect the results.

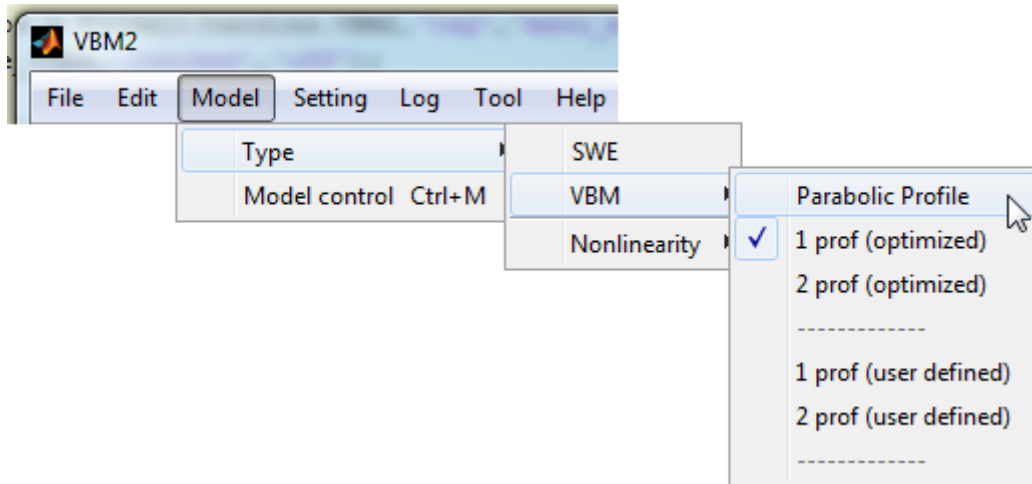


Figure 4-5 Choosing model type

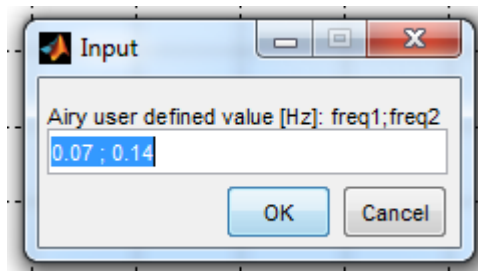


Figure 4-6. Pop-up menu for Airy user-defined value [Hz]

The option to include **nonlinear terms** in the mathematical model is given in the option under 'Model' → 'Type' → 'Nonlinearity' → 'weakly nonlinear', see Figure 4-7. In the current version of HAWASSI-VBM2, the weakly nonlinear VBM is used (see Adytia & Van Groesen [2012] for further details). For relevant applications that are given in 'Test Cases', the weakly nonlinear version is sufficiently accurate to describe wave phenomena with a good match when compared with experimental data.

When using the nonlinear simulation, the length of a **nonlinear adjustment zone** has to be prescribed (in number of wave lengths) in order to prevent spurious oscillations, see Fig 4-7.

Suggestion : It is suggested to do first a linear simulation before any nonlinear simulation. Besides the fact that a linear simulation is faster than a nonlinear one, more important is that the linear results represents in many cases already 80-90% of the wave characteristics to be simulated (except for cases with very strong nonlinearities). Having studied the output of the linear simulation, the differences caused by nonlinear effects can be better investigated.

Warning : The nonlinear calculation will cost at least 2 times the CPU time of the linear calculation. Just as for the choice of the number of Airy profiles, the CPU time will vary depending on the complexity of the waves to be simulated.

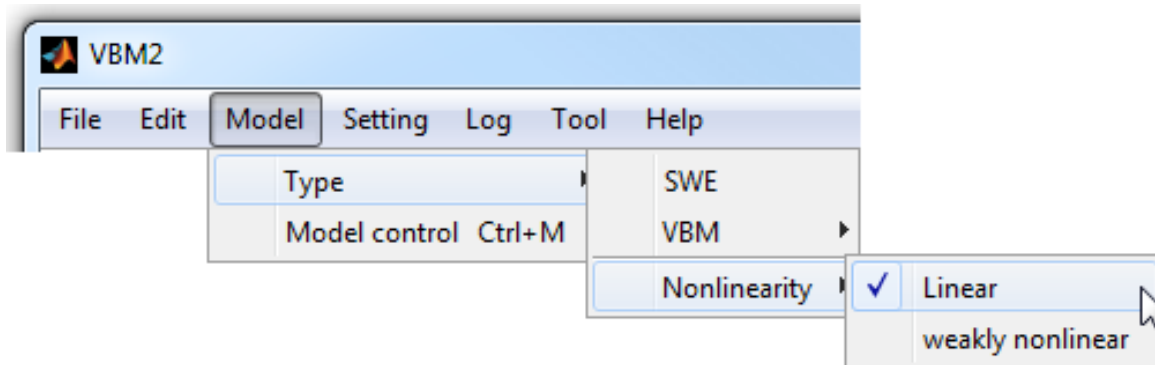


Figure 4-7 Specification of Linear or Nonlinear simulation

4.1.4 Model Control

An independent GUI so-called ‘Model Control’ is provided to specify Initial Conditions and Time Signal information to be used for the simulation, as shown in Figure 4-8. The GUI can be called manually by clicking ‘Model’→’Model control’.

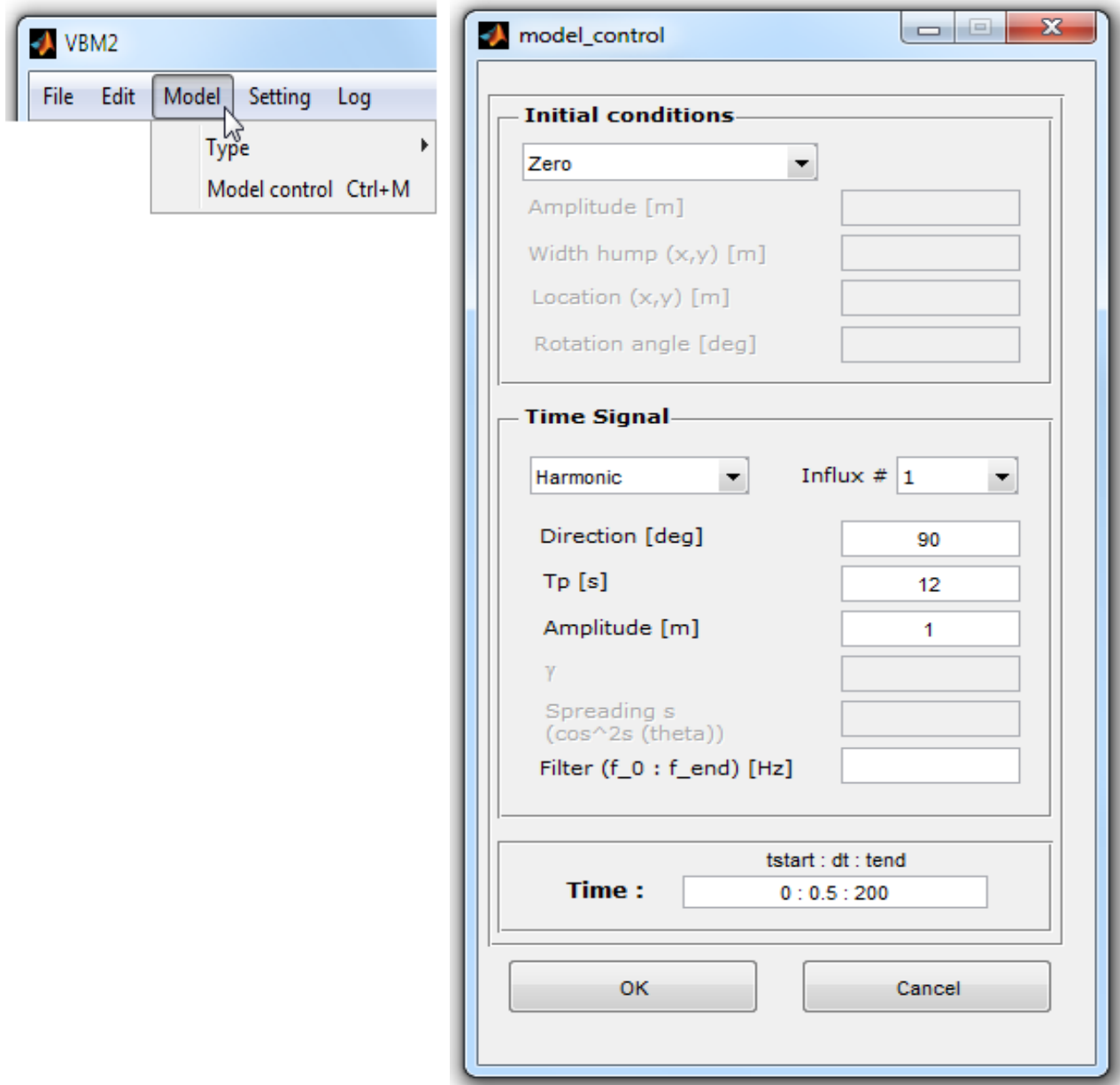


Figure 4-8 Model Control

4.1.5 Initial Conditions

In the ‘Model Control’ GUI, Initial conditions (for the surface elevation η and the surface potential ϕ) have to be specified, as shown in Figure 4-9. Choosing option ‘Zero’ means that the surface elevation η and surface potential ϕ have initial value zero: flat water surface at rest. Initial conditions can be specified with the option ‘User defined’; the user will then be asked to click the file-name of the (prepared) initial conditions through a dialog box. The data format for the user-defined initial conditions is illustrated in Table 4-1. The data should consist of four columns: the first column specifies the discretization of the horizontal x -coordinate, the second specifies the discretization of the horizontal y -coordinate, the third and

fourth columns are the data of η and ϕ , respectively. If only three columns are specified, this will be interpreted as zero initial condition for ϕ (no velocity).

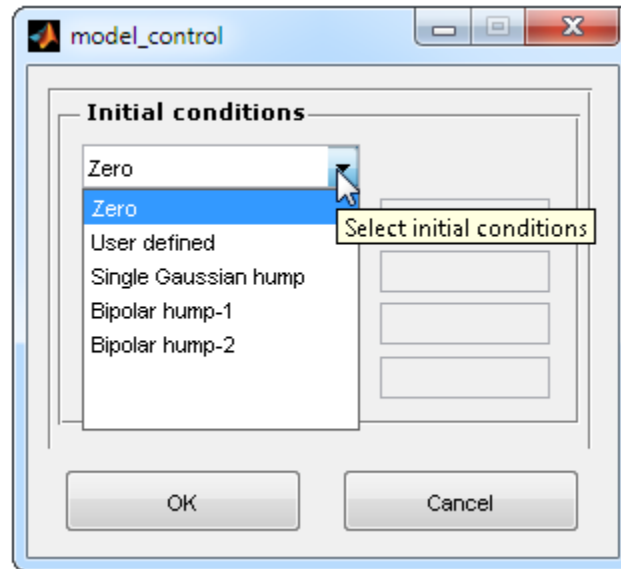


Figure 4-9 Initial condition for wave elevation

Table 4-1 Data format for user-defined initial conditions

% x	y	$\eta(x, y)$	$\phi(x, y)$
x_1	y_1	$\eta(x_1, y_1)$	$\phi(x_1, y_1)$
x_2	y_2	$\eta(x_2, y_2)$	$\phi(x_2, y_2)$
\vdots			\vdots
x_n	y_n	$\eta(x_n, y_n)$	$\phi(x_n, y_n)$

Other options of initial conditions are ‘Single Gaussian hump’, ‘bipolar hump-1’ and ‘bipolar hump-2’; for these options additional parameters have to be specified, such as the amplitude, the width, the center location of the initial profile and the rotation angle; see Figure 4-10 -Figure 4-13.

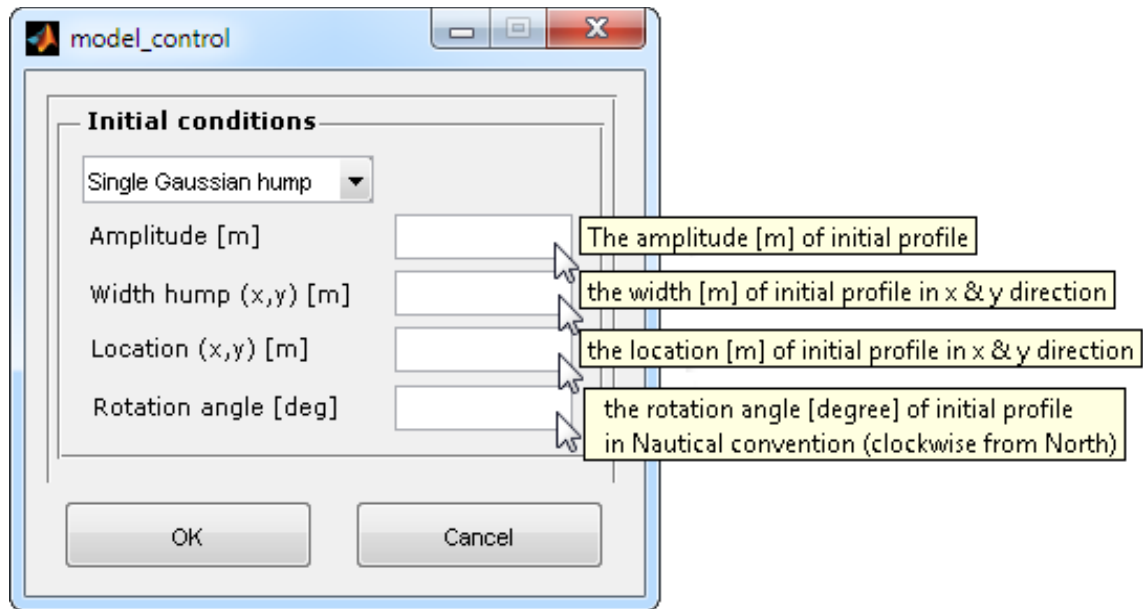


Figure 4-10 Initial condition for single gaussian hump

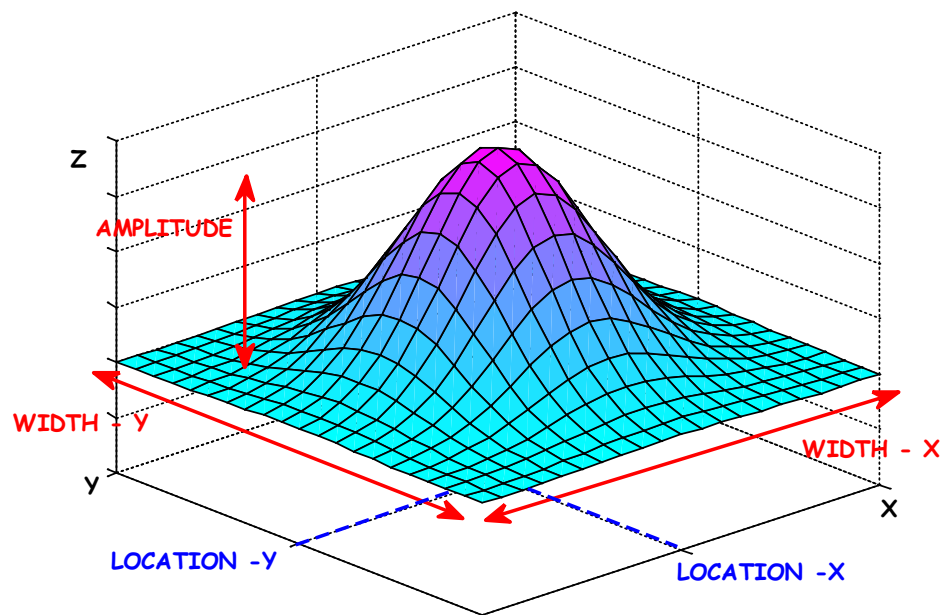


Figure 4-11 Single Gaussian hump

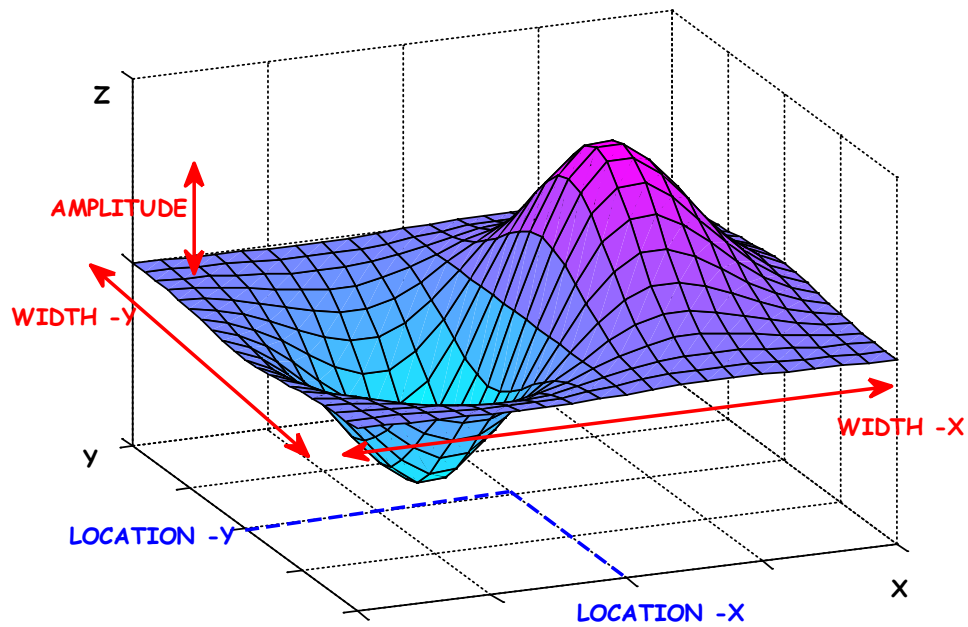


Figure 4-12 Bipolar hump-1

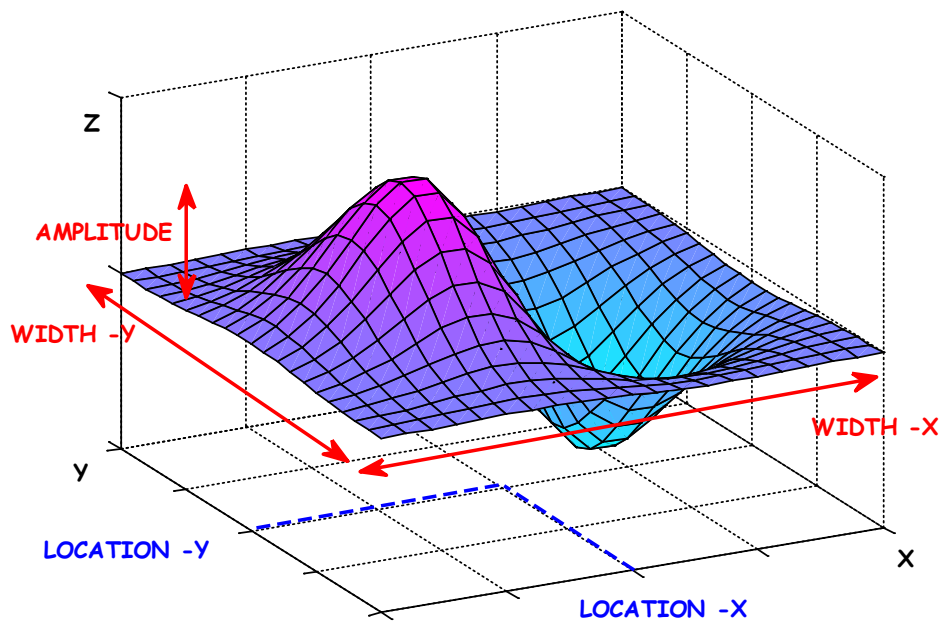


Figure 4-13 Bipolar hump-2

4.1.6 Time Signal

In HAWASSI-VBM2, when dealing with a signaling problem, an embedded wave influxing method is used (see Liam et al. [2014]). Instead of generating influx from a boundary, an influx signal is generated in the computational domain from a line in the interior of the domain.

Provided that the boundary of the domain is already made, the following steps will create an influx line:

1. Click 'Influx line' button under the 'Physical properties' panel (Figure 4-14)
2. Put two points as the ends of the influx line (Figure 4-14)
3. Specify the distance between points ('ds') (Figure 4-15)

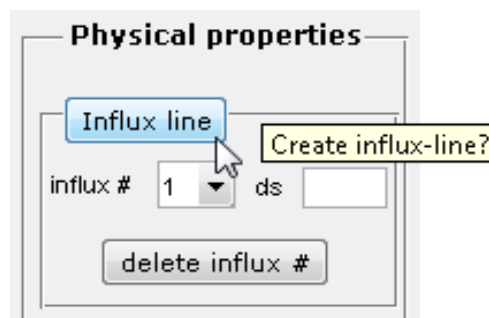


Figure 4-14 Influx line controller

To have a point on the shoreline/boundary line:

Put the (starting) point outside the domain, the point will be projected automatically on to (nearest) the shoreline

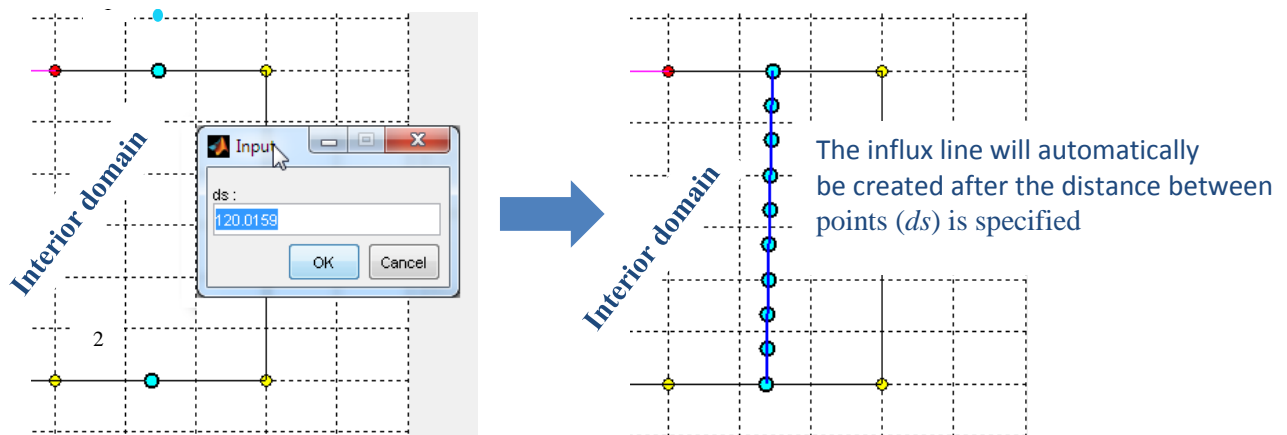


Figure 4-15 Creating influx line

In the ‘Model Control’ GUI, a time signal dialog will be active if there is an influx line in the domain (after the mesh is generated). There are four type of influx signal that can be chosen by the user; a harmonic signal, a signal with JONSWAP type of spectra, a user defined signal, and a signal with 2D Spectrum input (2D SWAN-spectrum format), see Figure 4-16.

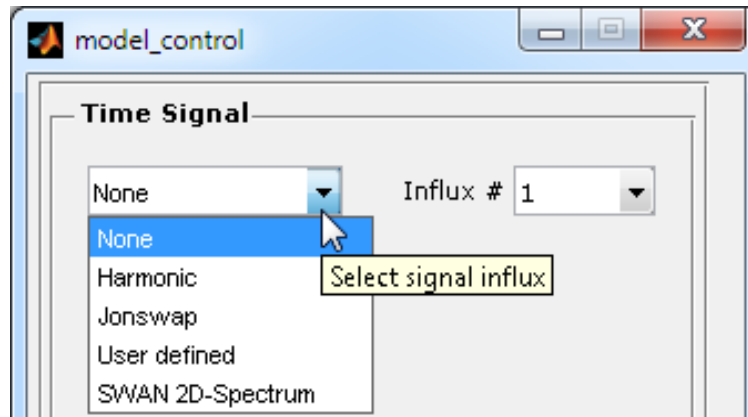


Figure 4-16 Influx signal option

For the option ‘Harmonic’ the user needs to specify the (main) wave direction (in Nautical convention; clockwise from North direction), the wave period T_p , and the amplitude Amp , see Figure 4-17 .

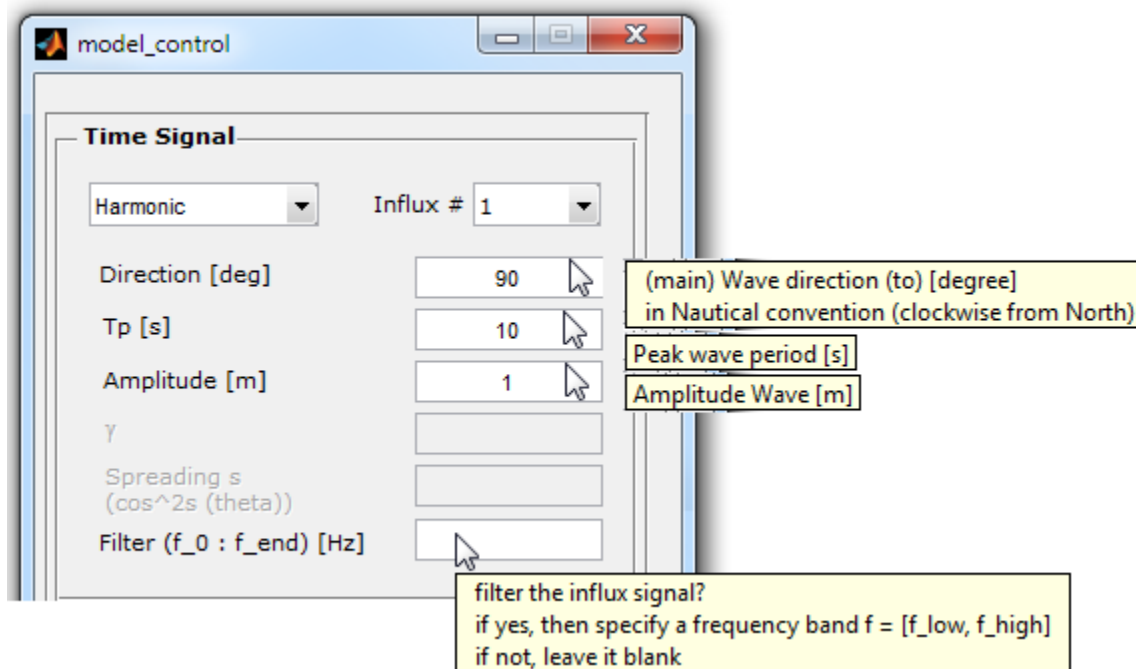


Figure 4-17 Signal parameters for harmonic signal

For the option ‘Jonswap’, the user has to specify; the main wave direction (in Nautical convention; clockwise from North direction), the peak wave period T_p , the significant wave height H_s , Jonswap parameters such as gamma and directional spreading s , see Figure 4-18.

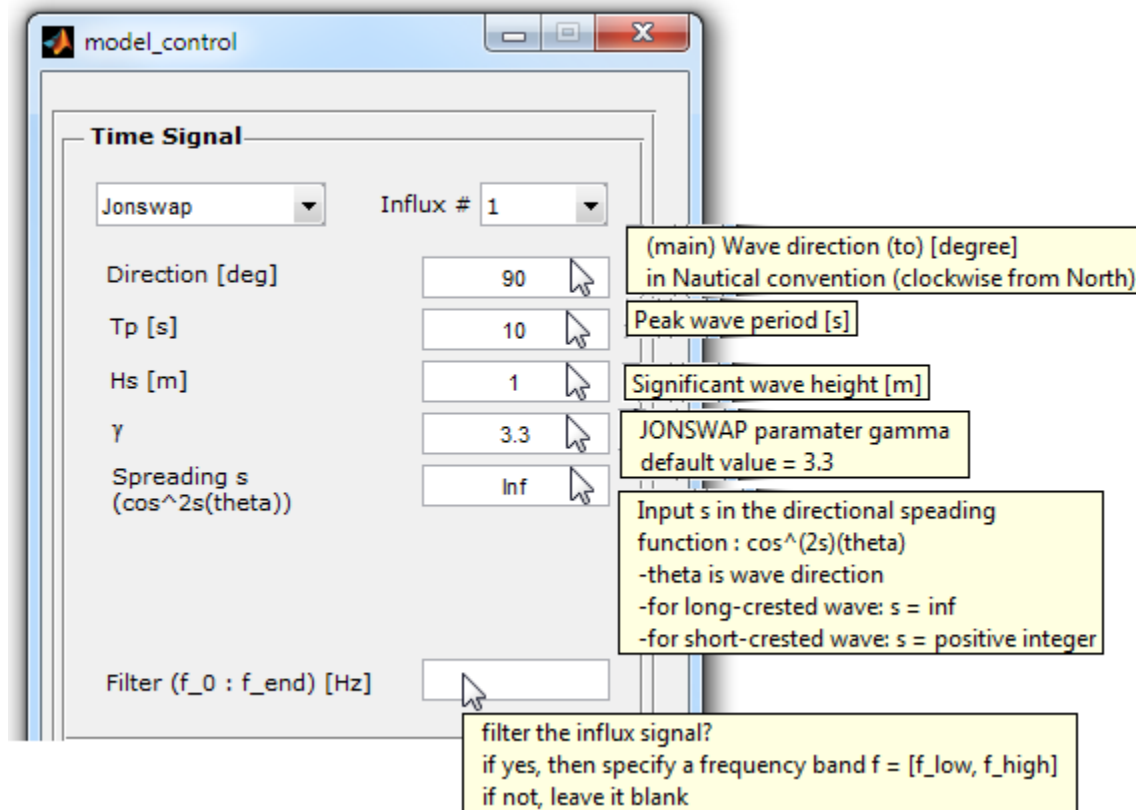


Figure 4-18 Signal parameters for Jonswap option

For the option ‘User defined’, the user should locate the data file of the signal influx (in ASCII-file) through a pop-up dialog box. User-defined signal data need to have a format as show in Table 4-2. The first box has to be filled by **0**. The other boxes in the first row are the data position with respect to the first point. The first column is the time information. The column below data position is the signal data at the corresponding point. The example of user-defined signal can be found in test cases folders under the name ‘INFLUX_[Project_Name].txt’, see Figure 4-19.

After the simulation is finished, the input signal of the simulation has been saved (by default) in the output folder: ‘/Output/[Project_name]/INFLUX_[Project_name].txt’.

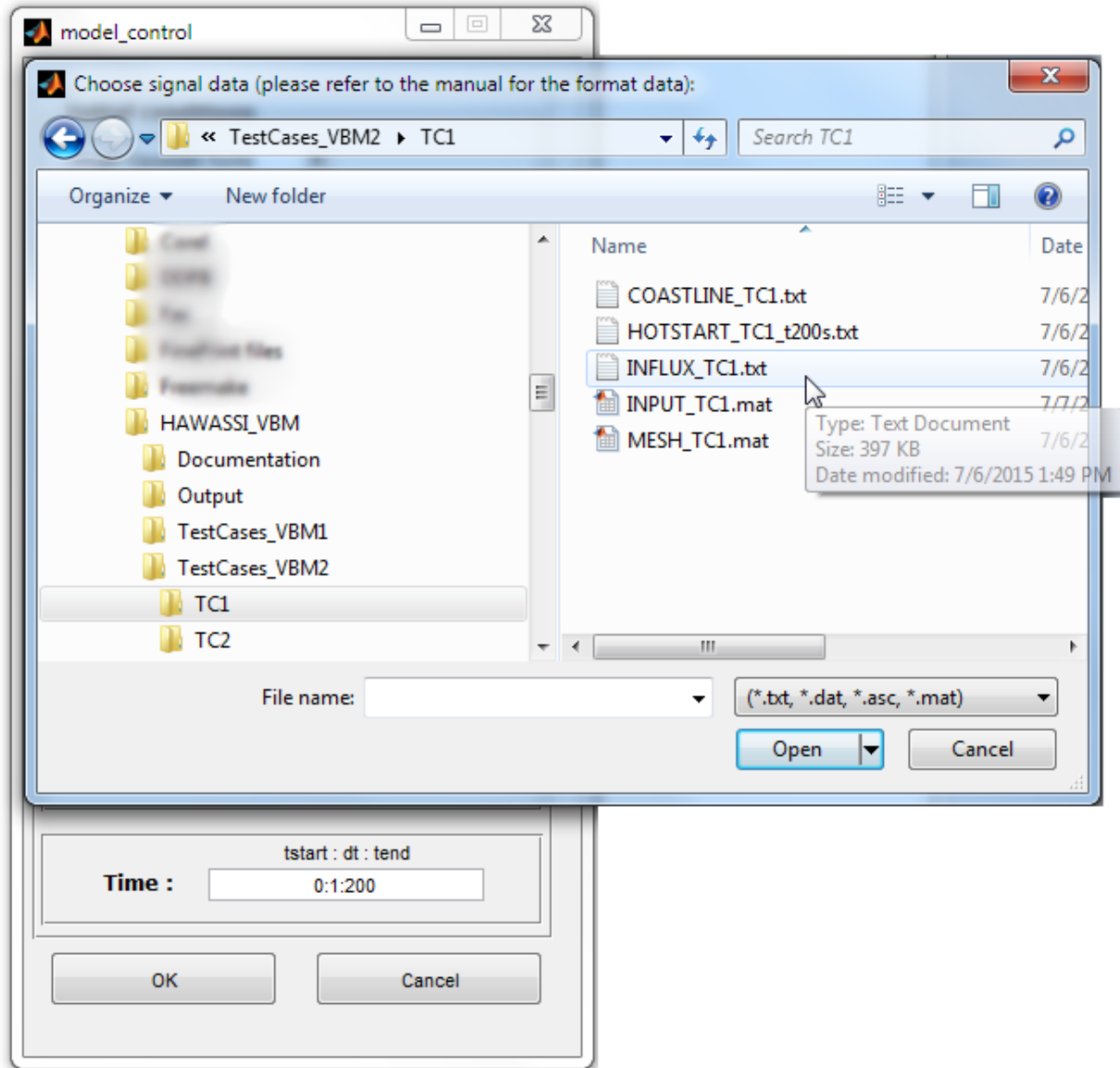


Figure 4-19 Location of 'User defined' influx signal

Table 4-2 User-defined influx data format

0	s_1	s_2	...	s_m
t_1	$\eta_{(1,1)}$	$\eta_{(1,2)}$...	$\eta_{(1,m)}$
t_2	$\eta_{(2,1)}$	$\eta_{(2,2)}$...	$\eta_{(2,m)}$
\vdots	\vdots	\vdots		\vdots
t_n	$\eta_{(n,1)}$	$\eta_{(n,2)}$...	$\eta_{(n,m)}$

Note: The ‘User-defined’ signal data will be interpolated along the influx line. Therefore for long crest wave, the data can also be defined only at the start and at the end point. If the provided input data is shorter than the length of the influx signal or the influx line (so, either in space or time) the missing information will be substituted with zero’s.

For the option ‘SWAN 2D-Spectrum’, the user should choose the 2D spectrum file. The data format of ‘SWAN 2D Spectrum’ can be seen in **Appendix I**, and an example file of SWAN 2D Spectrum can be found in ‘/UserInput_VBM2/InfluxSignal/SWAN_SPEC2D_02.sp2’. After the data file has been chosen, the user should specify the type of SWAN simulation mode that is used when generating SWAN 2D spectrum; **N** for *Nonstationary* or **S** for *Stationary*, see Figure 4-20.

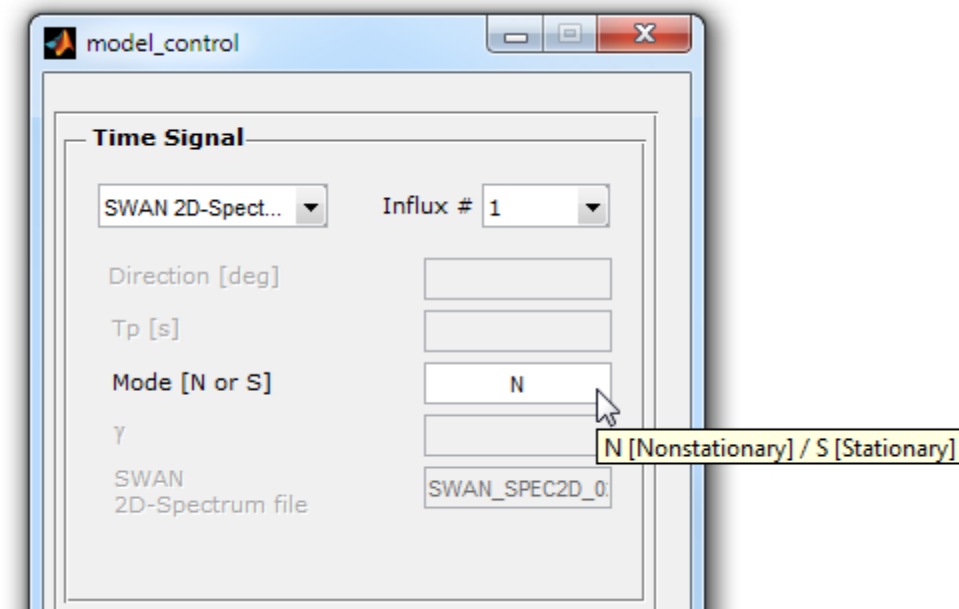


Figure 4-20 Signal SWAN 2D spectrum

Time Interval for Soft Start

For the option ‘User defined’ or ‘SWAN 2D-spectrum’, the user has to specify a time interval for soft start in an input dialog, see Figure 4-21. This time interval is used as time duration to ramp the signal such that the signal is smoothly influxed into the domain of computation. The default value is 10s. For the other option; ‘Harmonic’ and ‘Jonswap’, the time interval for soft start is automatically set to be 3 times the (peak) period.

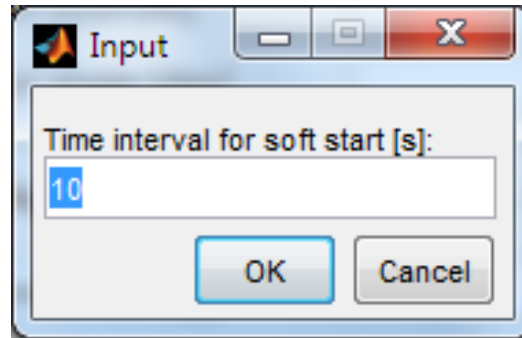


Figure 4-21 Time interval for soft start

Nonlinear Adjustment zone

When a signal is influxed into a nonlinear wave model, the nonlinearity may produces undesirable spurious modes on the generated waves (see Liam et al. [2014]), a phenomenon that is well known in wave maker theory. The appearance of spurious modes can also be expected when using the generation method of HAWASSI-VBM2. In order to avoid the generation of spurious modes, the nonlinear terms can be smoothly introduced into the computation domain, in the downstream direction from the influx location. HAWASSI-VBM2 provides this facility: the length of a so-called **nonlinear adjustment zone** can be prescribed (The length has to be specified related to the peak wavelength), see Figure 4-22.

Advice: For nonlinear simulations the length of ‘Nonlinear adjustment’ should be at least 2 peak wavelengths. For influxing rather high waves (with respect to the depth), the length should be more than 2 peak wavelengths.

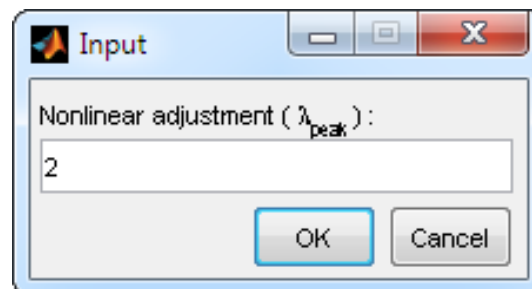


Figure 4-22 Nonlinear adjustment for nonlinear model

4.1.7 Simulation Time

The time interval for the simulation can be specified in the box 'Time' in the 'Model Control GUI' (Figure 4-23). 'tstart' is the starting time of the simulation (should be a non-negative value), 'dt' is the output time discretization for the simulation (should be a positive value) and 'tend' is the ending time of the simulation. All values should be in seconds. Time discretization 'dt' is not the time discretization for calculation of the time integration; HAWASSI-VBM uses automatic internal time-stepping in the matlab-odesolver.

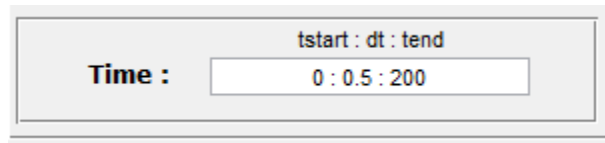


Figure 4-23 Time control of simulation

4.1.8 Simulation Boundary, Bathymetry and Boundary Conditions

4.1.8.1 Simulation Boundary

The simulation boundary defines the boundary of the computational domain. The user can create and/or edit the boundary points by using available tools in the main GUI of HAWASSI-VBM2, see Figure 4-25. When these tools are not active, the user can activate them by clicking 'Edit' → 'Scatter module'.

For loading an existing simulation boundary, the user should click 'Simulation Boundary' button in the main GUI; the user should then locate the (scatter) data of coastline. The data format of the coastline is illustrated in

Table 4-3.

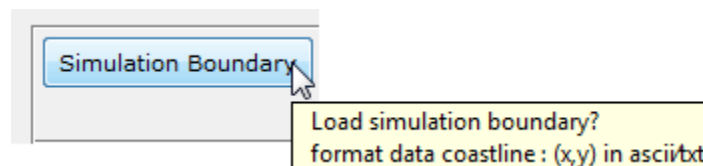


Figure 4-24 Load simulation boundary data

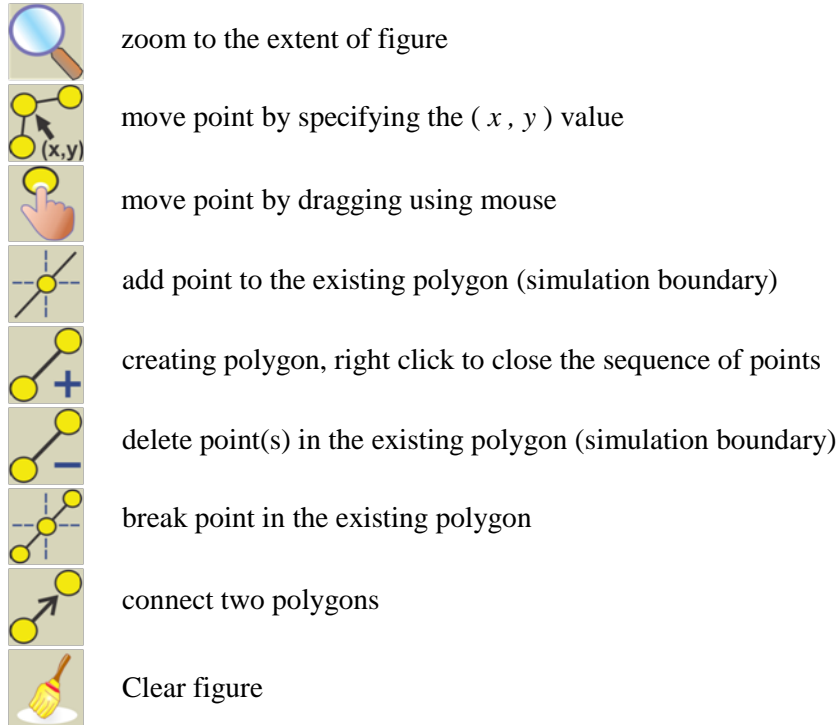


Figure 4-25 Tools for editing/creating the boundary points

Table 4-3 Coastline data format

% x	y
x_1	y_1
x_2	y_2
\vdots	\vdots
x_n	y_n

4.1.8.2 Bathymetry

The software provides two options for choosing bathymetry type: flat bottom or custom bathymetry that is defined in a scatter data (x,y,z) . For flat bottom the depth should be specified in the ‘Depth’ box, see Figure 4-26.

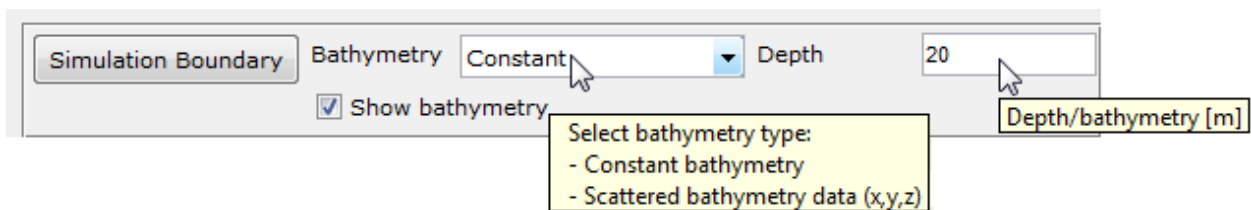


Figure 4-26 Simulation boundary and Bathymetry option

For the bathymetry option ‘Scatter data (x, y, z)’, the data input has to be located through a (pop-up) dialog box. The data should consist of three columns: the first and second column for x - and y -coordinate, the third column for the depth (should be > 0) at (x, y), see Table 4-4 below.

Table 4-4 Bathymetry data format

% x	y	$h(x, y)$
x_1	y_1	$h(x_1, y_1)$
x_2	y_2	$h(x_2, y_2)$
\vdots		\vdots
x_n	y_n	$h(x_n, y_n)$

Note: Bathymetry information should cover the whole area inside the coastline.

4.1.8.3 Boundary Conditions

Two types of **boundary** that are used in the software are **damping zone’s** and **partial reflective boundaries (PRB)**, see Figure 4-27 and Figure 4-29. The purpose of the damping zone (sponge-layer) is to absorb outgoing waves without reflecting or disturbing the waves in the rest of the computation domain. The efficiency of the damping zone is determined by the length of the damping and its damping. The length of damping-zone should be at least 2 times the simulated peak wavelength; a shorter length may create reflection.

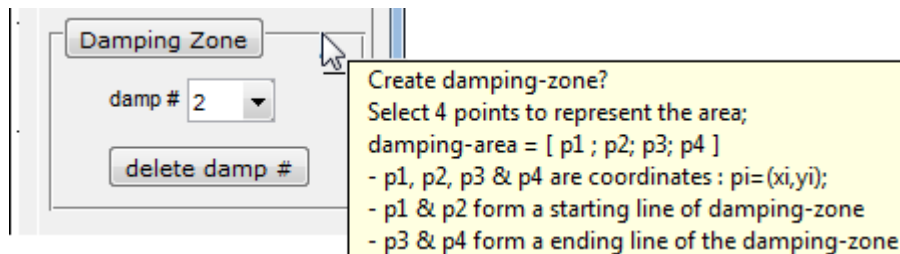


Figure 4-27 Damping Zone controller

After the boundary of the domain has been made, a **damping zone** can be created in the computation domain:

1. Click ‘Damping Zone’ button in the ‘Physical properties’ panel (Figure 4-27)
2. Put four points that cover the area of the damping zone. The first two points create a line that indicate the beginning of the damping zone area (dash line) (Figure 4-28)

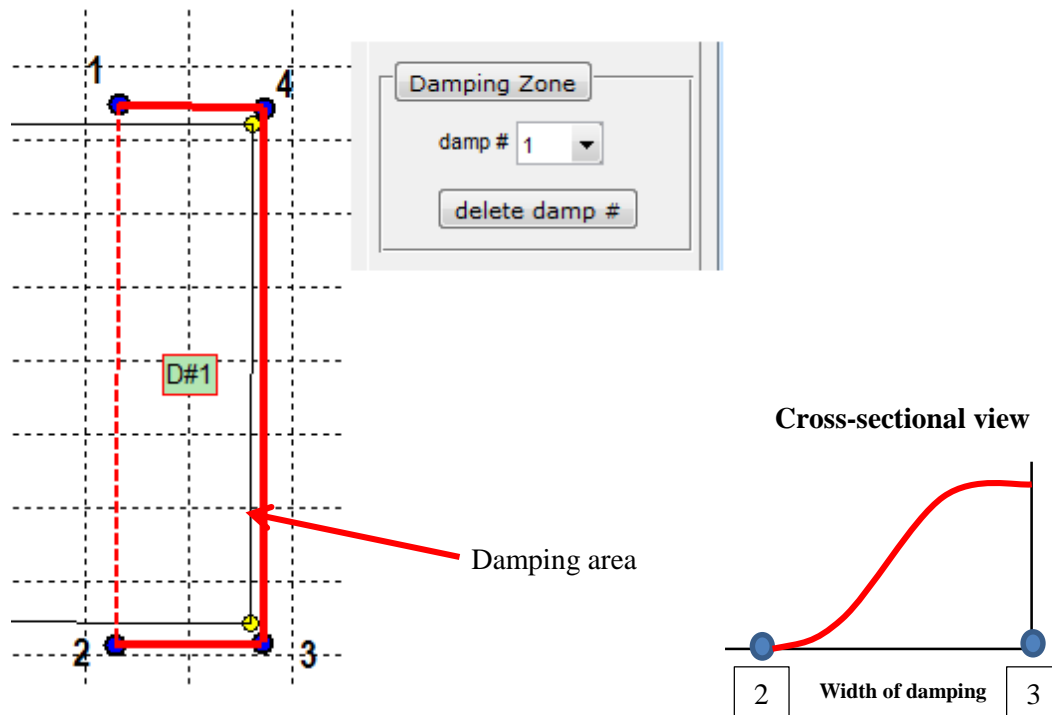
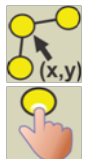


Figure 4-28 Creating damping zone

For editing the boundary point position, select 'Edit' → 'Physical properties module' (Fig.4-24). Two tools for editing points will be activated, as shown below:



move point by specifying the (x, y) value

move point by dragging using mouse

Advice To avoid reflection from the damping-zone, the width of damping-zone should be at least 2 times the peak wavelength.

Warning: Be sure that the influx line is not (partly) inside a damping-zone.

A modified Sommerfeld boundary condition is used to model *partial reflective boundary conditions* in HAWASSI-VBM2. For this boundary a reflection coefficient $C_R \in [0, 1]$ has to be specified.

For $C_R = 1$ the boundary acts as a fully reflecting wall, for $C_R=0$ as a transparent boundary condition so that the out-going wave will be fully transmitted. Partially reflecting boundaries, by setting for instance $C_R=0.6$, let the wave height of the outgoing wave be reflected for 60% and transmitted for 40% from the initial wave height; this applies for *all* wave frequencies.

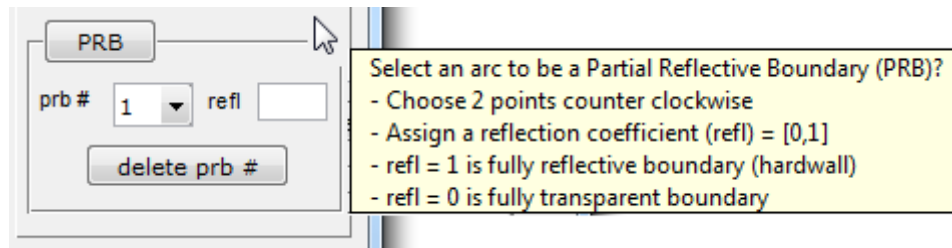


Figure 4-29 Partial Reflective Boundary (PRB) controller

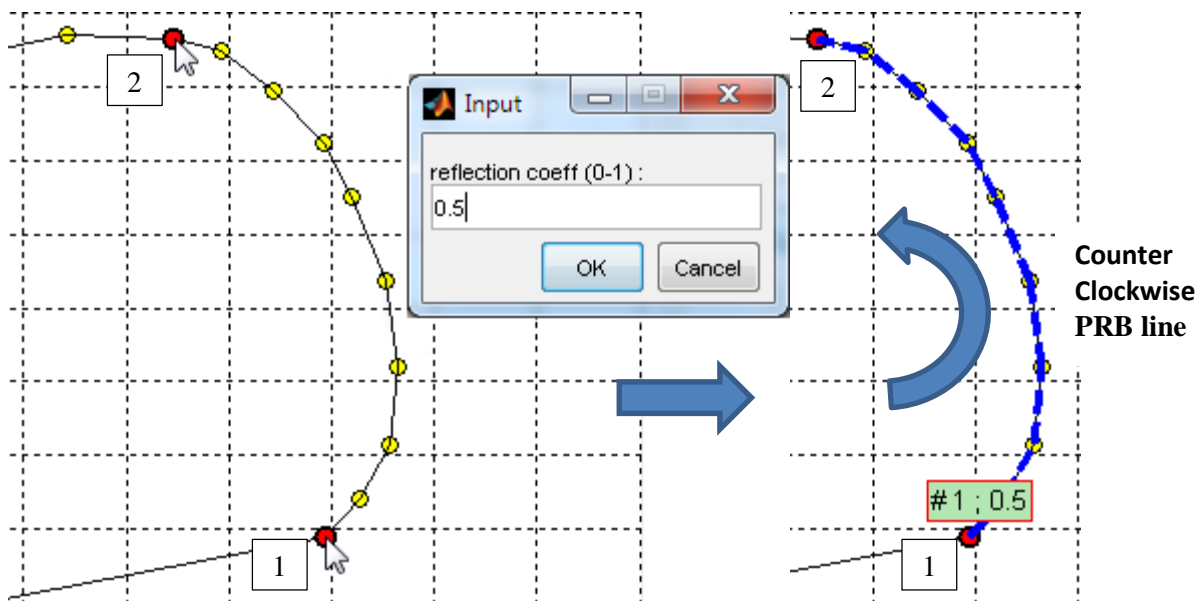


Figure 4-30 Creating Partial reflective boundary (PRB)

The following steps are to specify a partial reflective boundary (PRB) condition at part of the domain boundary:

1. Click 'PRB' button in the 'Physical Properties' panel (Figure 4-29)
2. Select two points at the coastline (boundary line) that will mark the area of PRB. The area is in a counter clockwise direction, from the first point until the second point. The reflection coefficient is in the range of 0 to 1 (1 for full reflection), see Figure 4-30.

*If the user does not specify a boundary condition at (part of) the boundary line, the software will treat that part as a **fully reflecting** boundary condition (hard wall conditions).*

Warning: When PRB of HAWASSI-VBM2 (v.1.1) is used with $C_R=0$ (fully transmitted), not all wave frequencies may be transmitted perfectly; short waves ($kh > \pi$) may be partly reflected (less than 10%).

4.1.9 Mesh Generation

HAWASSI-VBM2 (v.1.1) uses an unstructured triangular mesh. The mesh generator is based on the algorithm of *Distmesh - A simple Mesh Generator in MATLAB* that was introduced by Persson and Strang [2004]. The mesh generator is designed to create a depth dependent mesh that is finer in shallower areas where the wave length becomes shorter such that roughly the same number of points per wave length are taken in the whole domain. An illustration of a depth dependent mesh is shown in Figure 4-31.

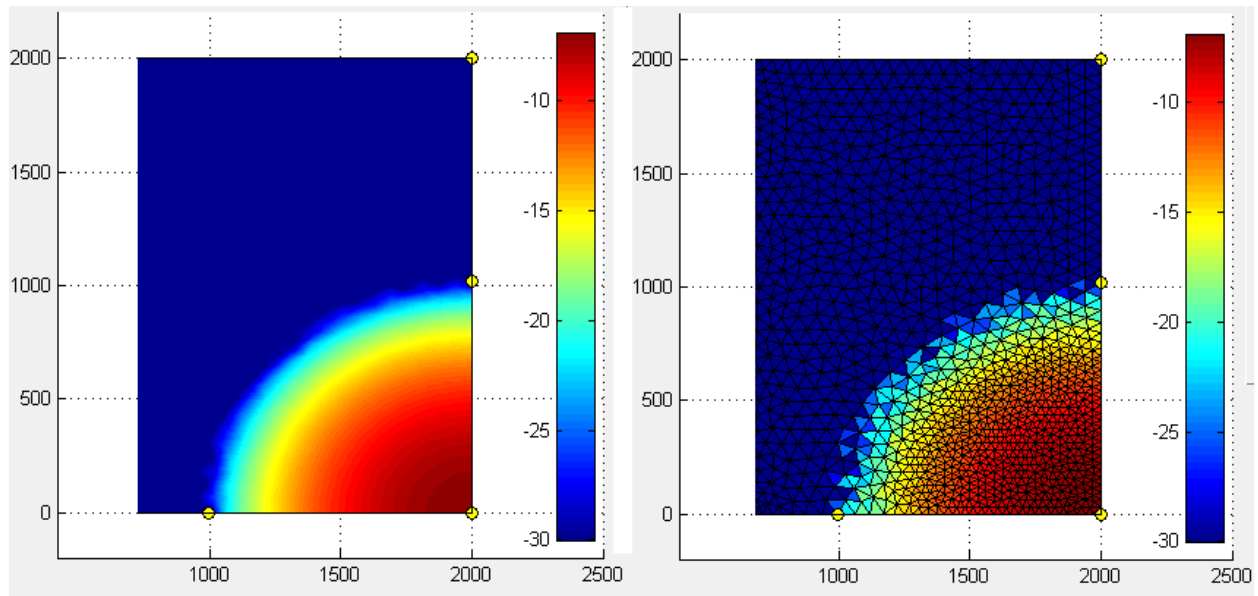


Figure 4-31 Illustration of depth dependence mesh. Colorbar indicates the water depth [m].

After the user has designed/loaded simulation boundary, influx line and bathymetry, the mesh can be created by clicking ‘Generate Mesh’ button in the main GUI, see Figure 4-32. A pop-up dialog box so-called ‘mesh properties’ will appear for asking mesh parameters as shown in Figure 4-33.

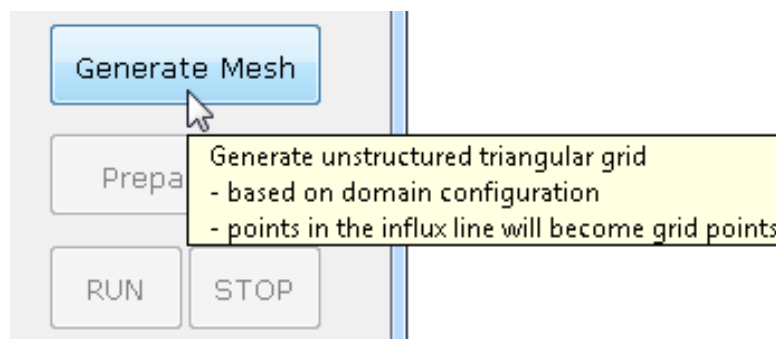


Figure 4-32 Generate mesh

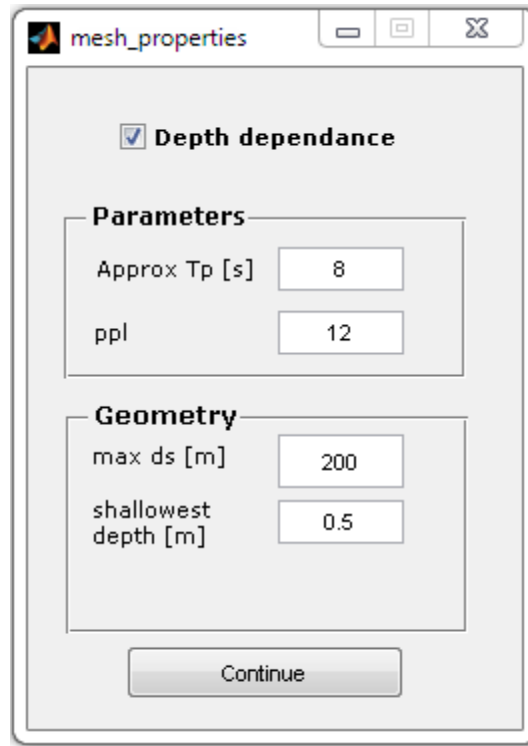


Figure 4-33 Mesh properties dialog box

The depth dependent mesh is activated when the check box ‘Depth dependence’ is checked; otherwise, the mesh size will only be determined by ‘max ds’ value (maximum allowable grid size) under the ‘Geometry’ panel.

‘Shallowest depth’ is the value of the shallowest depth in the bathymetry. As an illustration, when the user loads a bathymetry data that contains topography/land (the depth is negative value), the mesh generator will limit the smallest depth values with the ‘Shallowest depth’ value. The value should be a positive number.

If ‘Depth dependence’ is chosen, the user has to specify mesh size parameters in the ‘Parameters’ panel: ‘Approx Tp’ for the (approximate peak period) of the waves to be simulated, and ‘ppl’ as abbreviation for *point per-wavelength*, denotes the number of points (in the mesh) to represent a (peak) wavelength.

Warning :

1. Changing the project name after creating the mesh will cause the output of simulation be stored in the different output folder.
2. Mesh size can become very small if the depth (bathymetry) is very shallow at some parts, which may lead to longer computation times.
3. ‘Shallowest depth’ should be a positive value, which means that the bathymetry data should only contain positive depth values and does not has topography/land (negative depth value). If topography/land is included in the bathymetry data, the software will automatically only take the depth values and replaces the topography/land data by ‘Shallowest depth’ value.

4.1.10 Advanced Settings

HAWASSI-VBM2 provides an additional GUI so-called ‘**Advanced Settings**’ to change given standard settings that are used in the simulation. The **Advanced Settings** interface can be called by clicking the menu ‘Setting’ → ‘Advanced Settings’ (see Figure 4-34 and Figure 4-35). Physical parameters that can be changed in Advanced Settings GUI are the value for the gravitational acceleration g [m/s^2], fluid density ρ [kg/m^3].

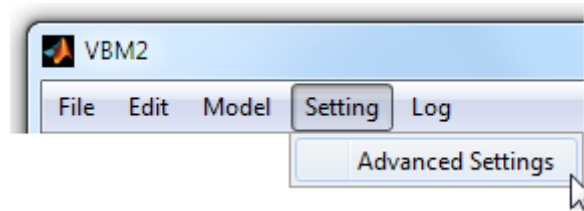



Figure 4-34 Calling Advanced Settings GUI

In the ‘Advanced Settings’ it is also possible to modify settings in the ‘Time-Stepping’ such as ‘**Time partition**’, ‘**Hotstart**’, ‘**Save signal influx**’ and ‘**Split Output Data**’ (see Figure 4-35).

‘Time partition’ is an option to divide the simulation/calculation into several steps (the default is 1) to reduce memory (RAM) requirements, see Figure 4-36. This facility is useful especially when dealing with long time simulations or when solving a large problem. When the ‘Split Output Data’ option is checked, the calculated data will be divided into the number of time partitions and stored as ‘/Output/[ProjectName]/DATA_[ProjectName]_iter[i].mat’, with i denoting the i -th partition. The data of the i -th iteration will be directly saved into the hard-disk after the i -th iteration is finished. If it is unchecked (by default), the simulation data will be saved as one file, named as ‘/Output/[ProjectName]/DATA_iter1.mat’.

For saving the last state of the surface elevation η and surface potential ϕ at the end of a specific time partition (saving done as a *.txt ASCII file), the option ‘**Hotstart**’ should be checked (is default). The option ‘**Save signal influx**’ is created to save the influx signal (if it is a signaling problem) as a *.txt (ASCII) file in the folder ‘/Output/[ProjectName]/’; the option is checked by default.

To save all information that have been configured in the ‘Advanced Settings’ GUI, click ‘Save’; to cancel all changes click .

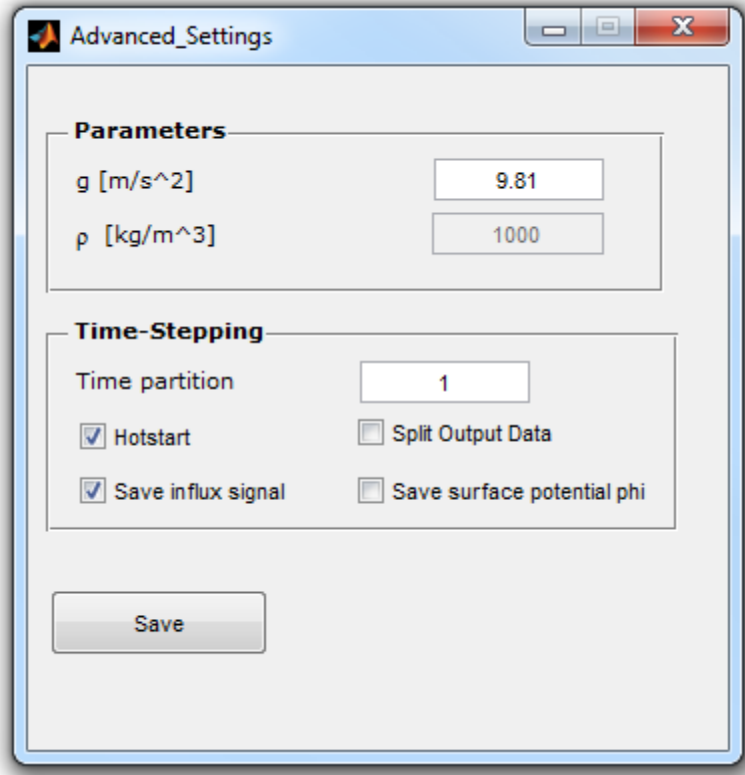


Figure 4-35 Advanced Settings GUI

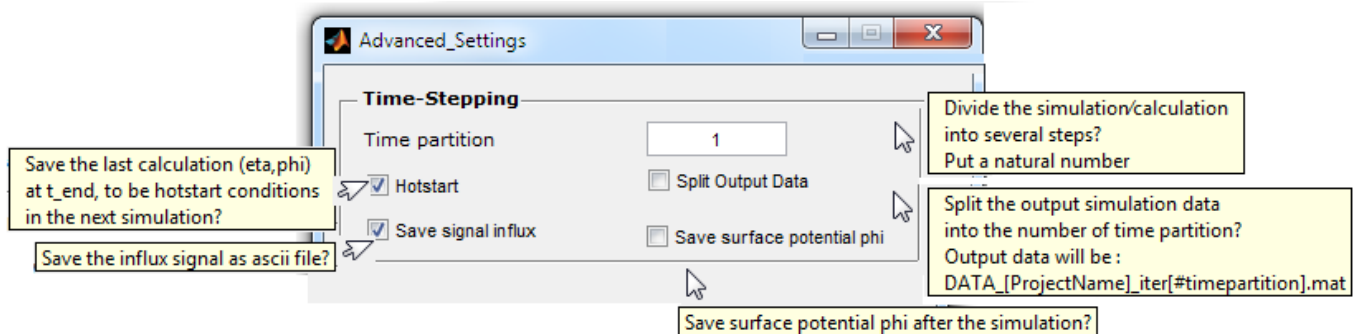


Figure 4-36 Time-stepping parameters in the Advanced Settings

4.1.11 Running Simulation

After all parameters and input have been set, the user can start the simulation. Three main steps can be distinguished:

1. **Preparation :**

After the 'Preparation' button is pressed, the software extracts all input data from the Main GUI, the Model Control GUI and the Advanced Settings GUI. The input data will be checked and processed. An overview of the input and numerical setup will be shown to the user via a panel-plot called 'Model Setup'. The panel shows an overview of domain, bathymetry, boundary conditions,

influx location, the influx signal and its amplitude spectrum, the initial condition of the surface elevation η , and the dispersion quality of the model compared to the exact Airy linear theory (see Figure 4-38). The dispersion quality plot is as in Figure 4-39.

2. **RUN :**

The 'RUN' button is enabled after the 'Preparation' phase is finished. RUN will execute the time integration from the numerical setup. When the '**STOP**' button, placed under the RUN button, is pressed, the simulation will terminate and the simulation results until the termination time will be stored. If the calculation is finished, the software will automatically call the Post-Processing GUI, and load the simulation data directly to it.

3. **Post Processing :**

When the 'Post Processing' button is pressed, the Post-Processing GUI will appear. Details of the GUI will be described in Section.0

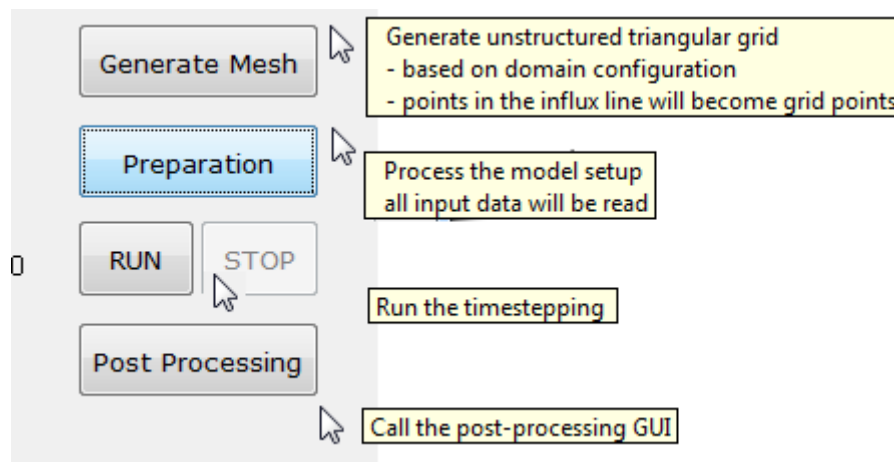


Figure 4-37 Buttons for running the simulation in the main GUI

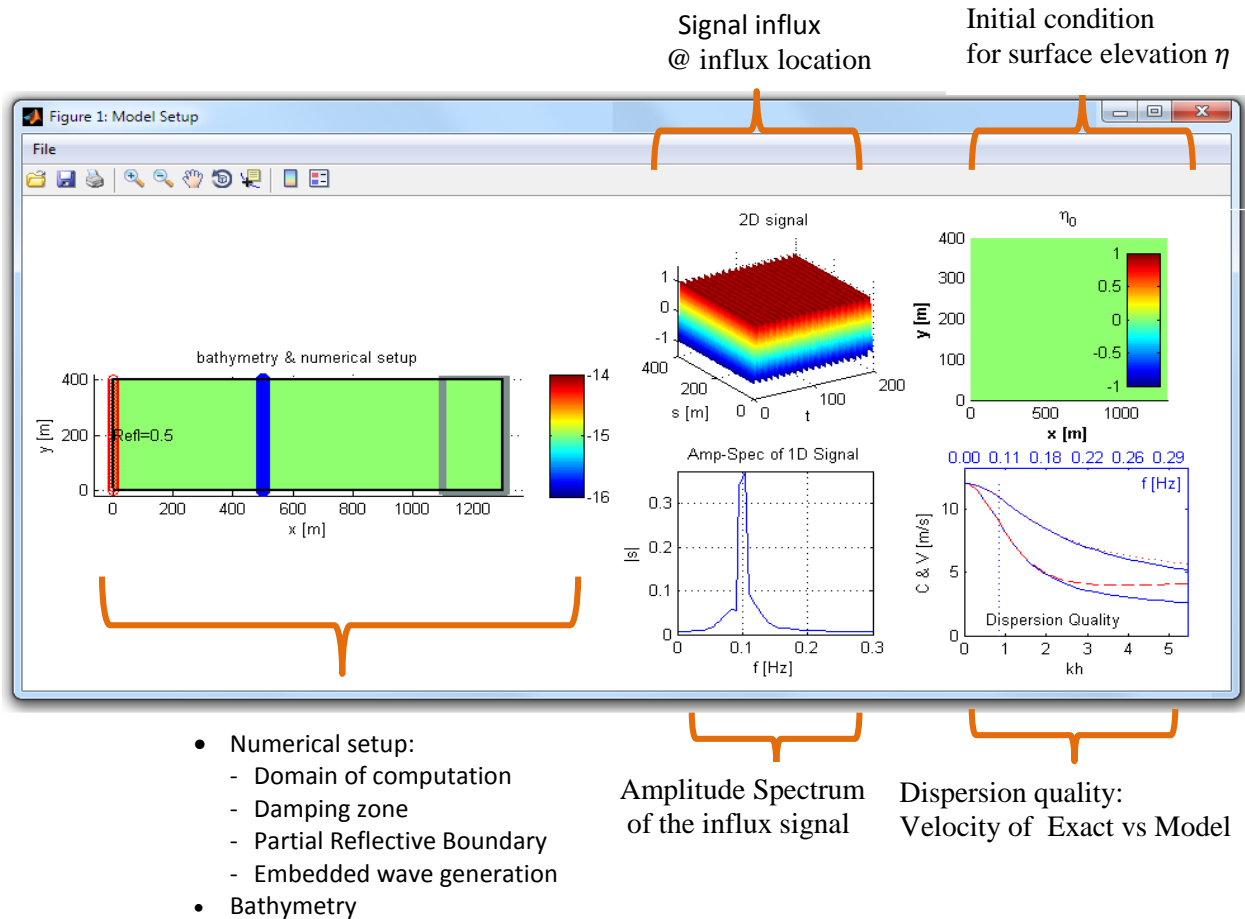


Figure 4-38 Overview of the numerical setup panel showing details of the simulation to be performed

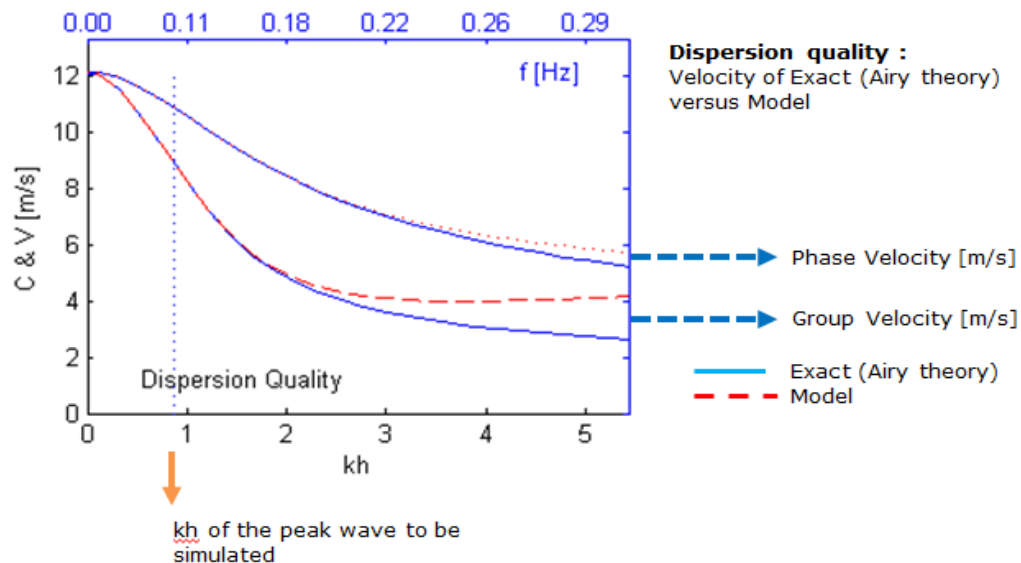


Figure 4-39 Description of Dispersion Quality plot (blue solid for Exact, red dashed for Model set-up)

4.1.12 Output Files

Output files will be stored in the folder ‘[WorkingDirectory]/Output/[ProjectName]/’. A description of all output files is given in Table 4-5.

Table 4-5 Output files/folders

No.	Output Files/Folders	Description
1.	INPUT_[ProjectName].mat	Input data for the simulation, a result from ‘Preparation’
2.	DATA_[ProjectName]_iter[<i>i</i>].mat	Output data from the <i>i</i> -th step of the (partitioned) simulation, a result from ‘RUN’. If the ‘Split Output file’ in the ‘Advanced Settings’ GUI is activated, then the data of simulation will be split into the number of ‘Time Partition’. If the ‘Split Output file’ is not active the iteration is only 1.
3.	LOG_[ProjectName].log	A log-file of the case ‘ProjectName’. If the ‘ProjectName’ is not changed, details of anew simulation will be added with to the existing log-file.
4.	INFLUX_[ProjectName].txt	The influx signal data (*.txt or ASCII-file) that is used in the simulation, only available when the ‘Save influx signal’ in the Advanced Settings GUI was checked.
5.	HOTSTART_[ProjectName]_t[time].txt	The last state of the surface elevation η and surface potential φ at the end of a time partition, only available when the user had checked the ‘Hotstart’ checkbox in the Advanced Settings GUI.
7.	./Output/Anim_GIF/	Is a sub-folder that will contain animation (*.gif) files from the PostProcessing GUI
8.	./Output/Anim3D_GIF/	Is a sub-folder that will contain 3D animation (*.gif) files from the PostProcessing GUI
9.	./Output/Figures/	Is a sub-folder that will contain figure (*.fig & *.png) files from the PostProcessing GUI.
10.	./Output/Frames/	Is a sub-folder that will contain frames (*.png or *.jpg) from Post-Processing GUI.

4.2 Post-Processing GUI

After a simulation is finished the Post-Processing GUI will automatically pop-up and loads the simulation data. The Post-Processing GUI (Figure 4-40) can also be called directly from the Main GUI by pressing the ‘PostProcessing’ button. To load data of previous simulations, select ‘other’ under the simulation data section in the GUI, as illustrated in Figure 4-41.

There are two main panels in the Post-Processing GUI, i.e. Animation and Plotting. Each panel will be described in the next two subsections.

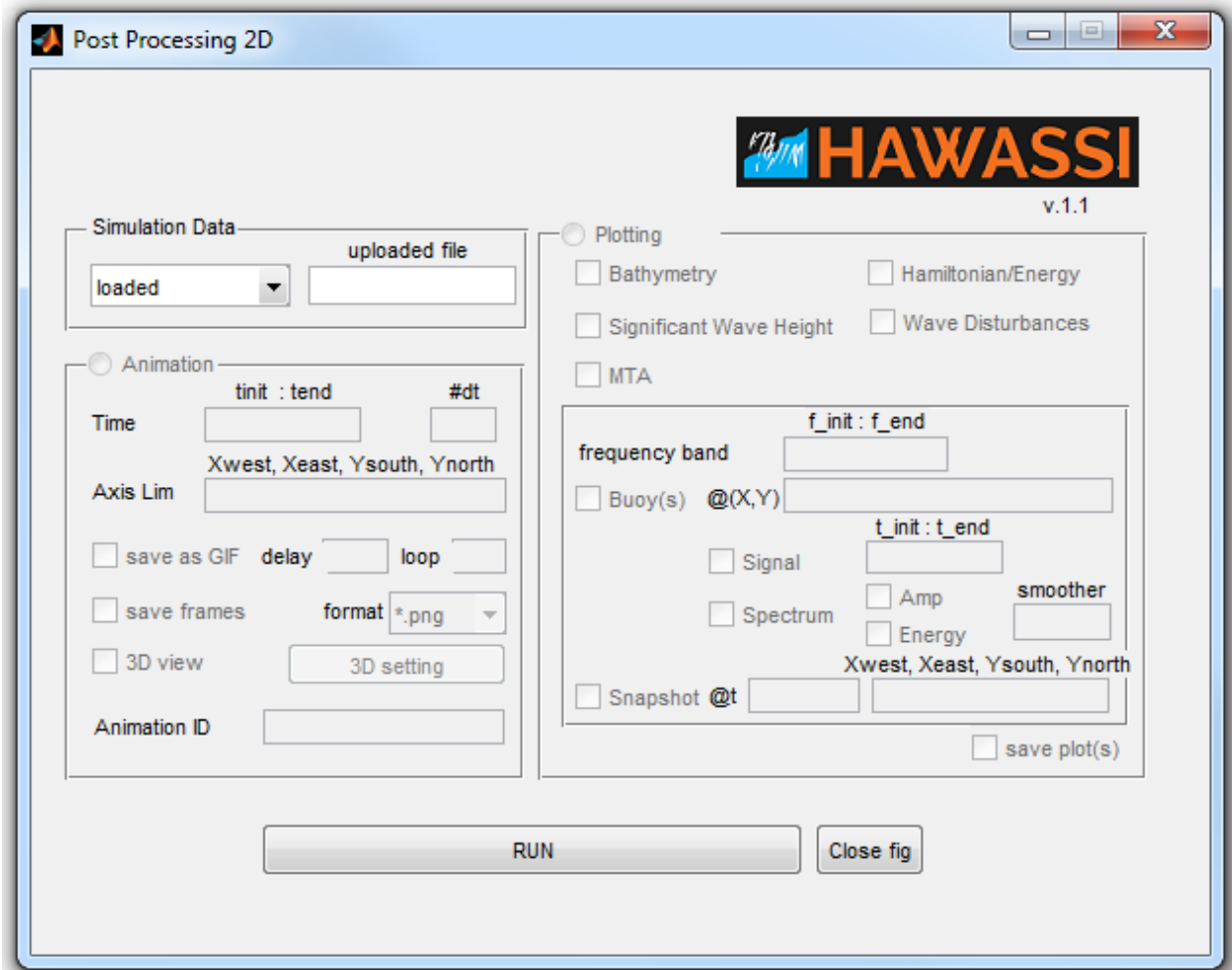


Figure 4-40 Post Processing GUI

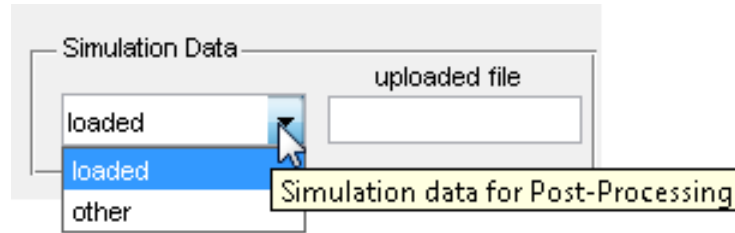


Figure 4-41 Load other simulation data in Post-Processing GUI

4.2.1 Animation

The 'Animation' panel is to show animations of the wave elevation. Information of domain and time interval for the animation is needed. By default these fields are automatically filled based on the uploaded simulation data: the whole area and whole time interval.

A restricted domain for the animation can be specified in 'Axis Lim', see Figure 4-42.

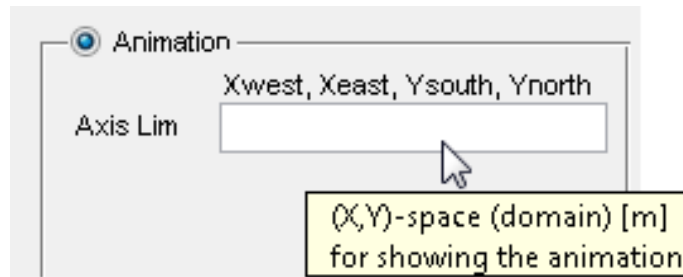


Figure 4-42 Domain for showing the animation

A restricted time interval for the animation can also be specified, and the animation interval-steps: a time step that is a multiple (m) of dt , the value m to be given under '#dt' (Figure 4-43)

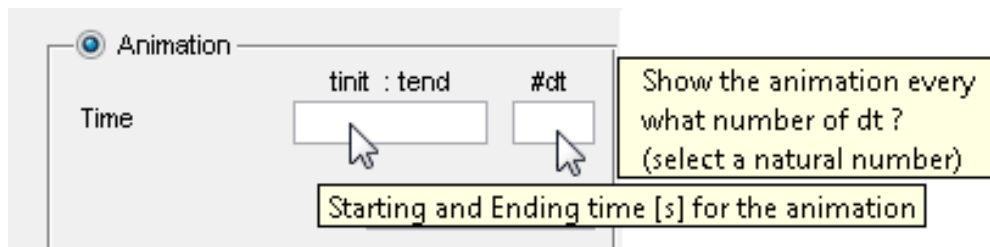


Figure 4-43 Animation time

The animation can be saved as a moving *.GIF-file format by specifying a delay between each frame and the looping of the animation (**Figure 4-44**); the delay information is in seconds and the loop information has to be a natural number.

For making animations in other formats, saving frames, either in PNG or JPG format, can be used afterwards with any existing animation software (**Figure 4-45**). If no specific name is provided in the *animation ID* field, the animation/frames will be saved with ‘anim’ as the default name.

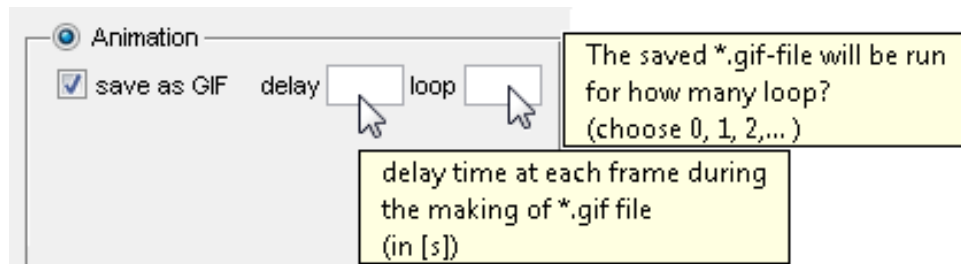


Figure 4-44 Saving animation as GIF

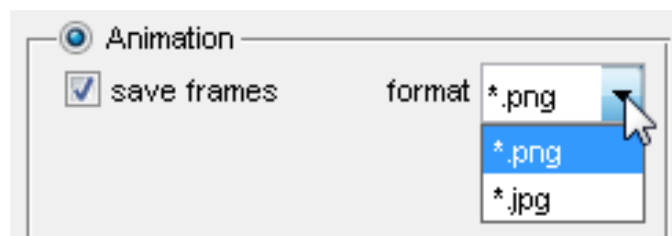


Figure 4-45 Saving all frames in png/jpg format

In HAWASSI-VBM2, the animation result can also be viewed in 3D. Select ‘Animation’ → ‘3D view’. To change the default setting of 3D output, select ‘Animation’ → ‘3D view’ → ‘3D setting’, see Figure 4-47.

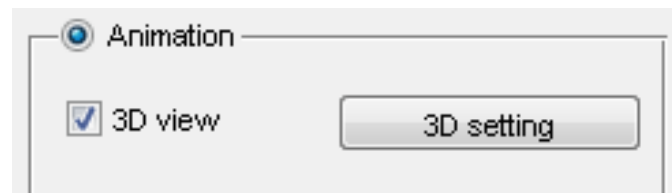


Figure 4-46 View the animation in 3D view

There are three main panels in the 3D setting interface, i.e. ‘Color’, ‘Scale’ and ‘Frame Angle’. The color panel is used to set the color for topography and bathymetry along with the color for wave. The data will be spanned in the given color data. Set the color by specifying the value of red, green and blue component. The user can directly specify the value in the RGB box or through the color selection by clicking the button next to the RGB box. To execute the color change click ‘OK’ button (Figure 4-48).

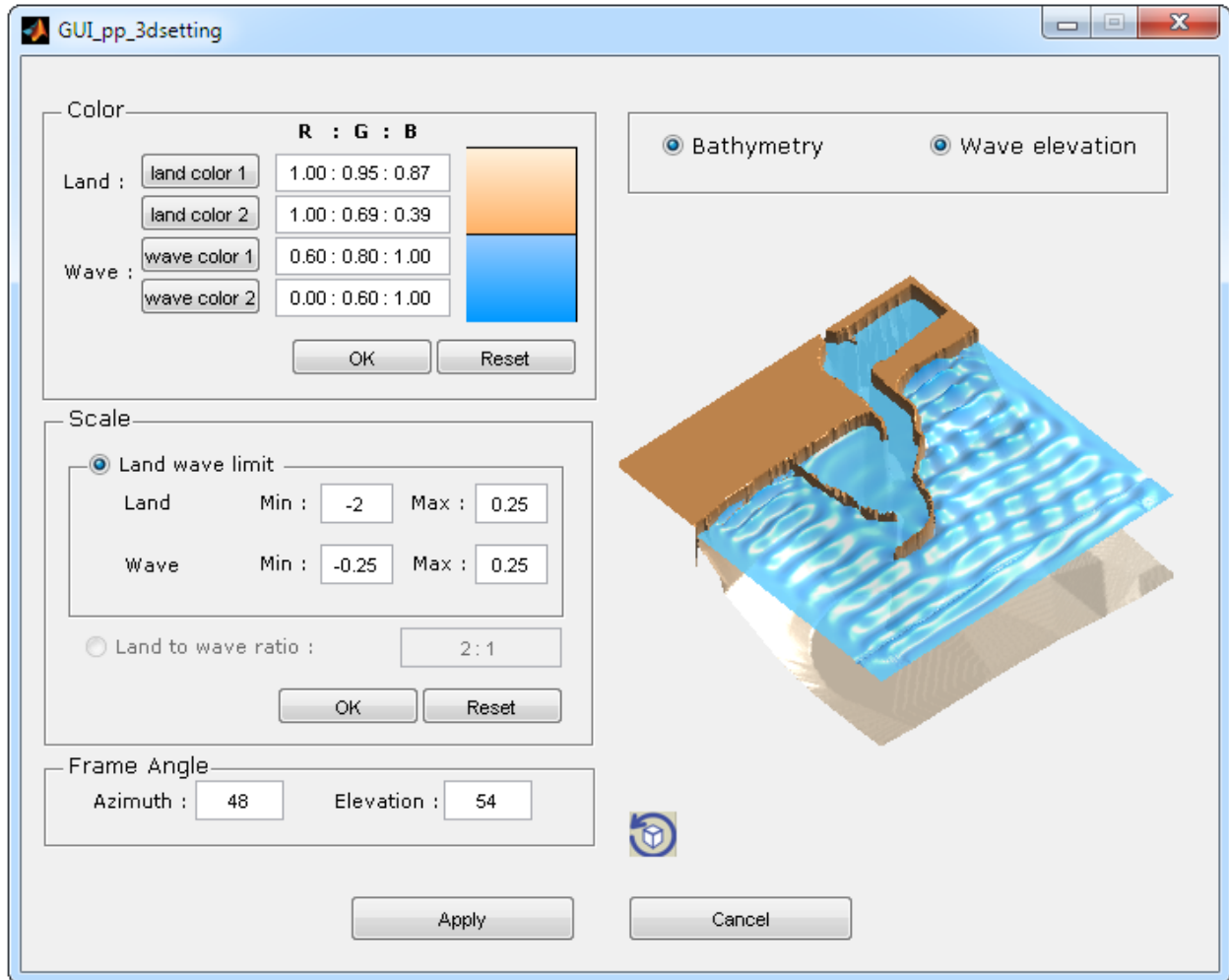



Figure 4-47 3D setting of animation

Using the *Scale* panel, the data can be spanned in the given value range; to execute the change click OK.

For changing the frame angle in 3D view, select button  and then move the cursor to have a frame angle according to wish, showing the azimuth and elevation value after pressing the 'Apply' button to save all setting changes (Fig. 4-48).

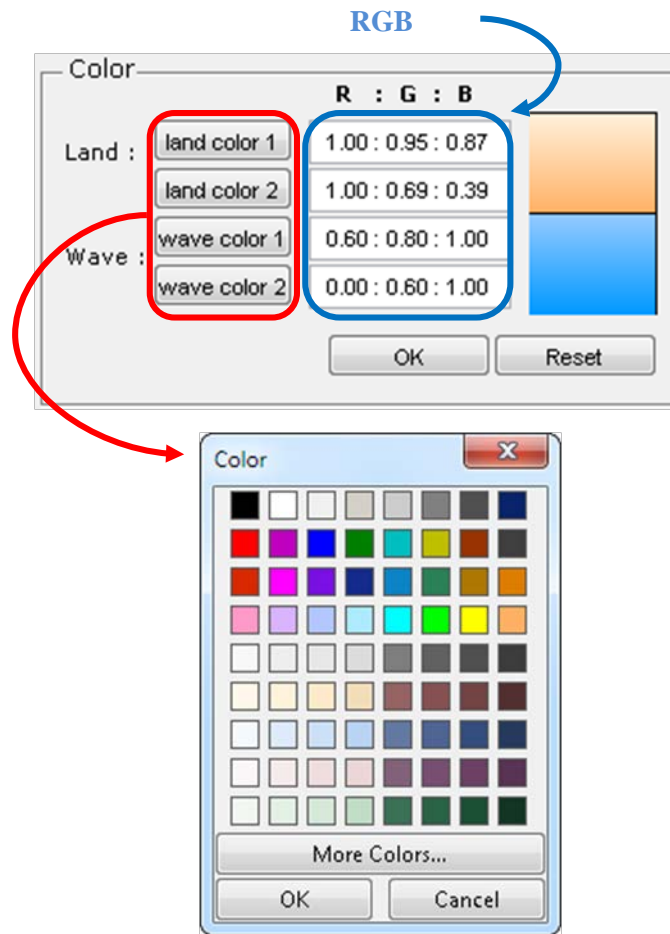


Figure 4-48 Setting land and wave color in 3D setting

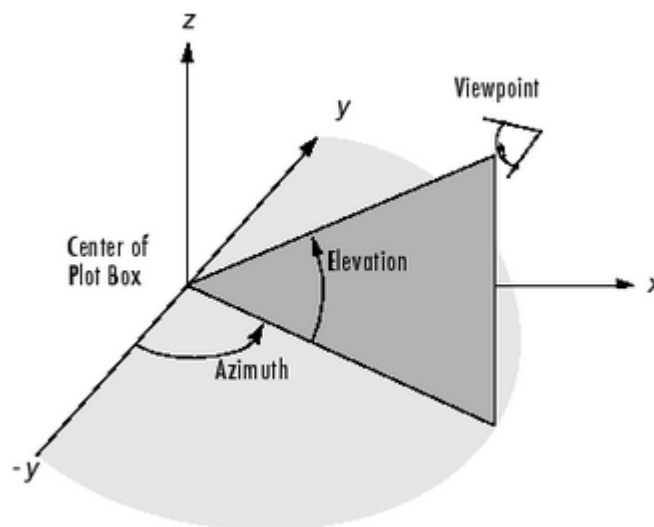


Figure 4-49 Viewpoint with azimuth and elevation

4.2.2 Plotting

The **'Plotting'** panel can produce plots of bathymetry (bottom profile), the significant wave height, Maximum Temporal Amplitude MTA (maximum wave height), Hamiltonian or total wave energy and wave disturbances (normalized significant wave height H_s with respect to the H_s in the influx location), see Figure 4-50.

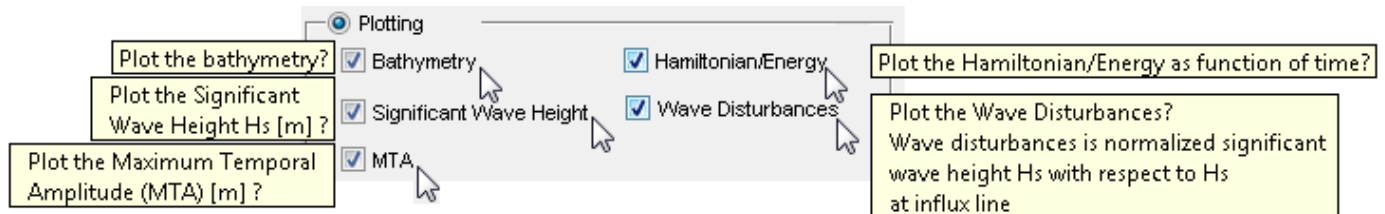


Figure 4-50 Bathymetry, significant wave height H_s , MTA, Hamiltonian/Energy and Wave disturbances

Data at a specific time or at a specific location can be obtained by the option **'Buoys'** and/or **'Snapshot'**.

'Buoy' will give the time signal and/or its spectrum of the elevation at the specified Buoy position inside the computation domain, see Figure 4-51. For the spectrum, the **'frequency band'** option is provided to filter the (extracted) signal information see Figure 4-52.

The **'Snapshot'** option provides capability for the user to take a snapshot of the simulation at a time to be specified and within an interval to be specified, see Figure 4-53.

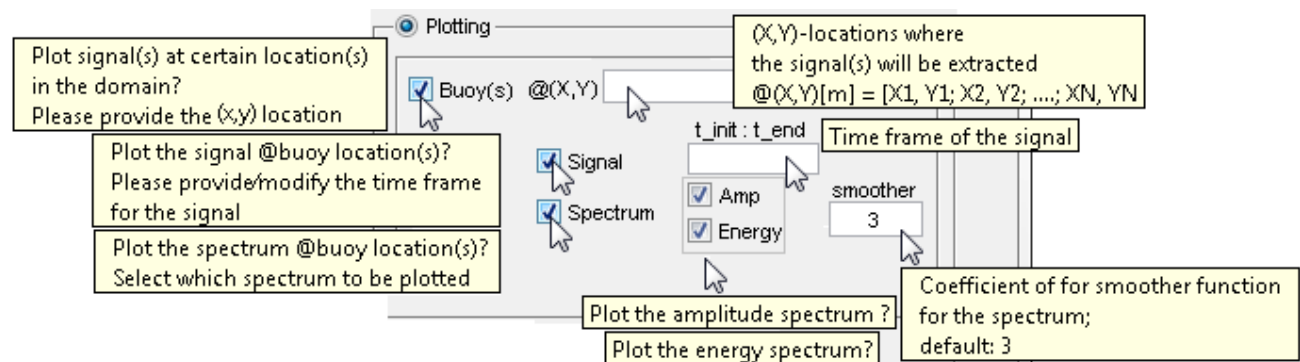


Figure 4-51 Buoy setting option of Plotting

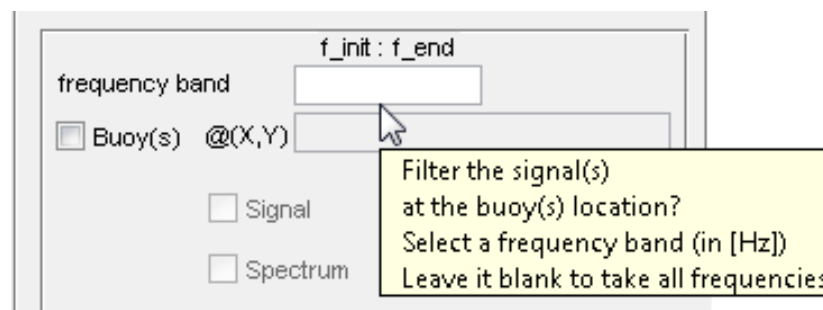


Figure 4-52 Option for filtering the (extracted) signal at (specific) Buoy location(s)

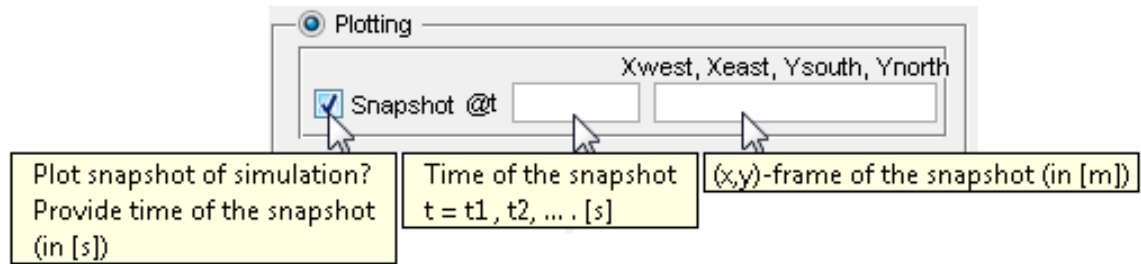


Figure 4-53 Snapshot setting option of Plotting

5 Test cases


HAWASSI-VBM2 provides 6 test cases. The first case is meant for practicing the software such that the user gets a (first) idea how the software works in handling influx signals, boundary conditions and different wave models (SWE & VBM). The second and third test cases are to show the characteristic wave phenomena of diffraction, refraction and shoaling. Understanding such wave phenomena is important as we go further into test cases 4-6 using a harbor layout with real bathymetry where all wave phenomena are expected to happen in a single domain.

For getting started with the practical use of the software, we take the last test case of a realistic harbour as example; after that the test cases are described in successive sections.

5.1 Example of set-up, simulation and post-processing of harbour waves

This section will show how to prepare a domain, generate a mesh and run the simulation in HAWASSI-VBM2 software for the test case of a realistic harbour in Indonesia, test case 6b. This section can be read without knowing the information of Section 4, to which the reader can refer for further details, especially for knowing how to prepare input-data that are provided for this and other test cases.

5.1.1 Getting started the software

To start the software, click the shortcut so-called ‘VBM2’ in the Desktop or in the Start menu. The main GUI of HAWASSI-VBM2 will appear as in Figure 5-1. Instruction of what to do in the next step, is shown the ‘comment box’ panel, see Figure 5-2. After the software is opened, select your ‘Working Directory’ by clicking  button.

It is advised to use ‘C:\Users\[UserName]\Documents\HAWASSI_VBM’ folder as the working directory, see Figure 5-3. Test cases of HAWASSI-VBM2 are stored in this folder, named as ‘TestCases_VBM2’.

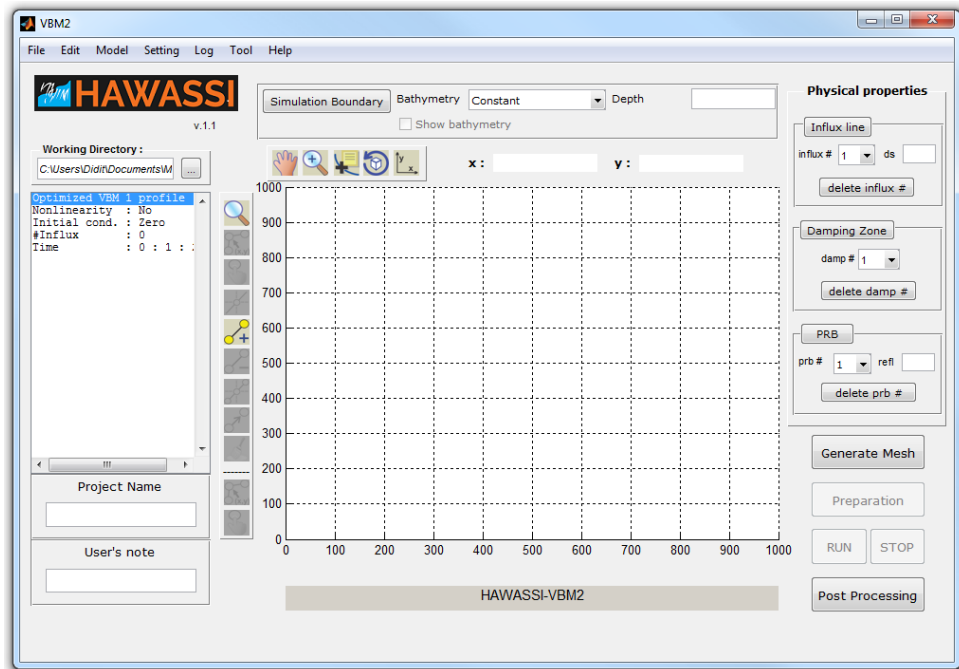


Figure 5-1 Main GUI of GBM2

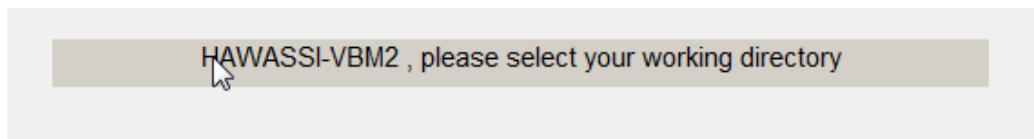


Figure 5-2 'Comment box' panel, showing (short) instruction for running the software

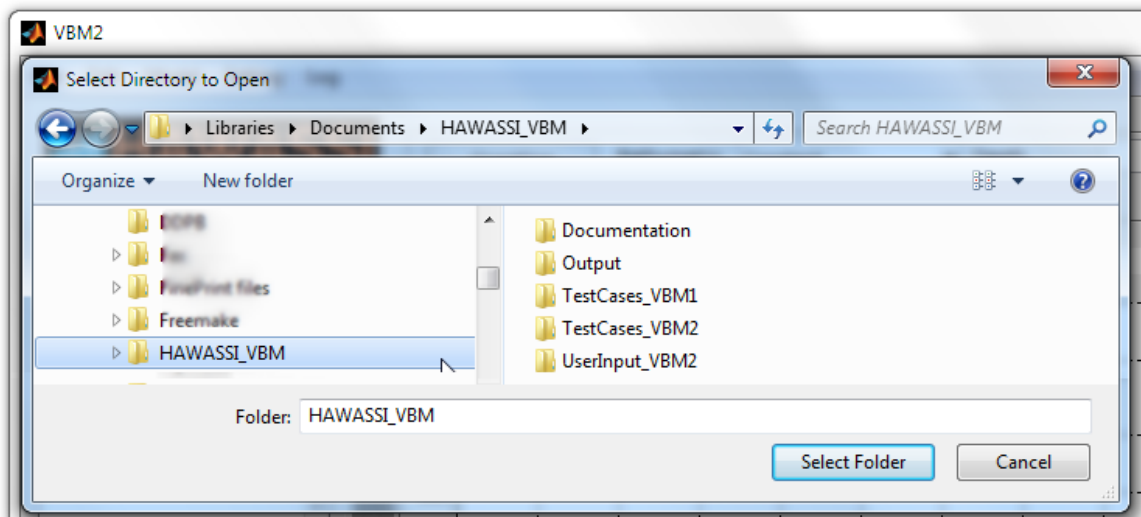


Figure 5-3 Select working directory in 'My Document'

5.1.2 Selecting wave model

HAWASSI-VBM provides two wave model; the non-dispersive Shallow Water Equation (SWE) and the dispersive Variational Boussinesq Model (VBM). By default the chosen model will be the linear Optimized VBM with one vertical profile, see Figure 5-4.

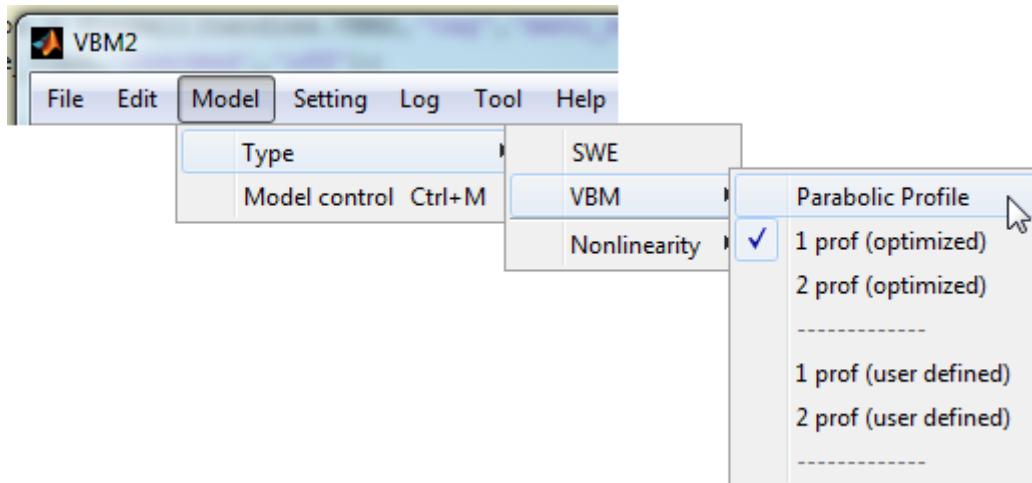


Figure 5-4 Select wave model

5.1.3 Defining the Domain

Start with defining the domain of computation, or in this case the 'Simulation Boundary'. 'Simulation boundary' files have been prepared for each test case. To load the simulation boundary of Test case 6b, click the 'Simulation Boundary' button (Figure 5-5) and locate the file location. After the data is loaded, the simulation boundary will be plotted in the GUI (Figure 5-6). Simulation boundary data includes a list of two-dimensional polylines that is always considered to be closed.

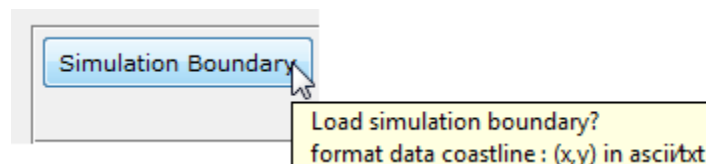


Figure 5-5 Load Simulation boundary data

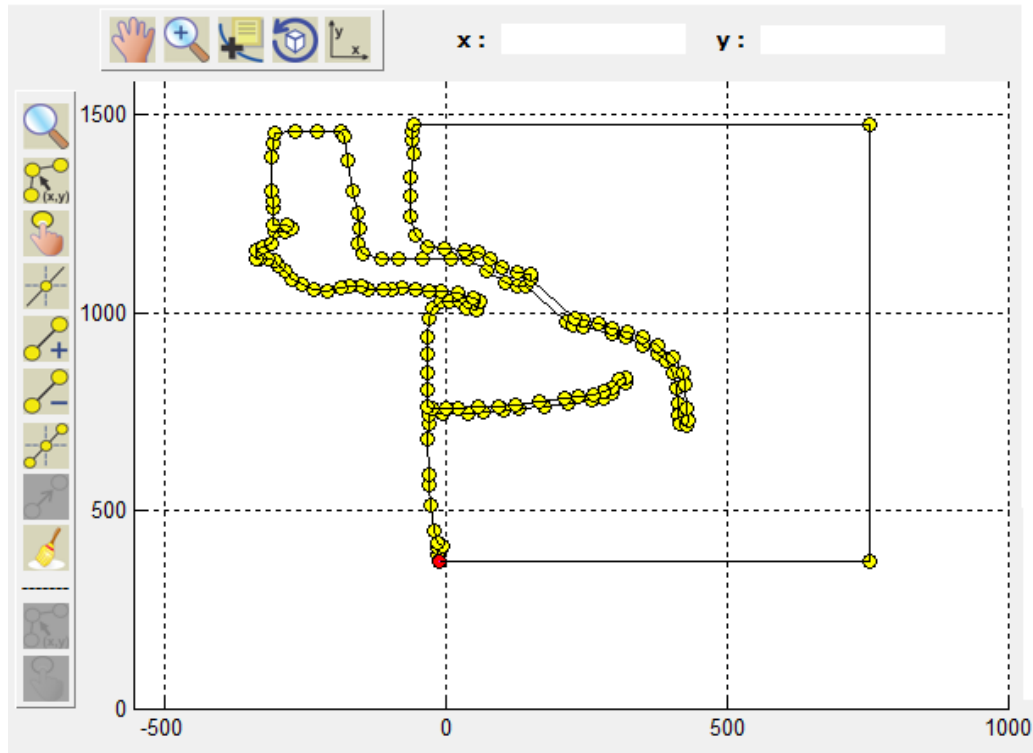


Figure 5-6 Simulation boundary data is loaded

5.1.4 Reading bathymetry file

After the simulation boundary is loaded, the next step is to load the bathymetry data. To that end, click the 'Bathymetry' pop-up menu and select 'Scatter bathymetry data (x,y,z)', see Figure 5-7. Locate and select the bathymetry data.

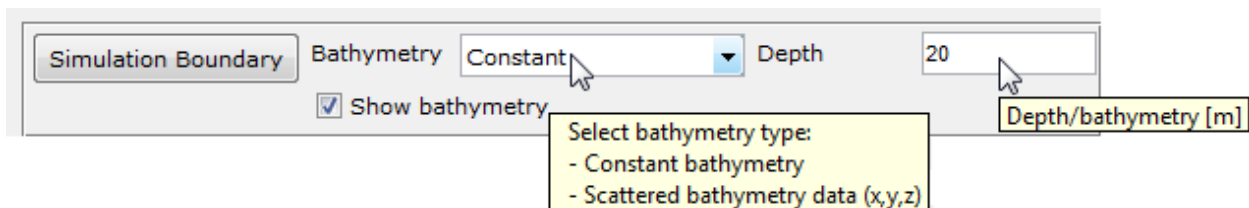


Figure 5-7 Load bathymetry data

5.1.5 Assigning boundary types

Boundary types can be specified by using tools in 'Physical properties' panel, see Figure 5-8. The 'Damping Zone' is used to dissipate/absorb the outgoing waves. The 'Partial Reflective Boundary (PRB)' is used to have a controllable reflection on the boundary.

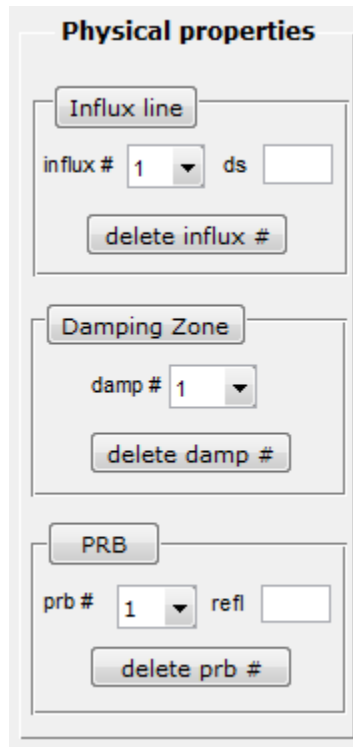


Figure 5-8 Physical properties panel

Activate and choose 'Damping Zone' area in the following steps:

- Click 'Damping Zone' button in 'Physical properties' panel (Figure 5-8)
- Put four points that will become the area of the damping zone; the first two points create a dashed line that indicates the beginning of the 'Damping Zone', see Figure 5-9.
- Put four points in the east position

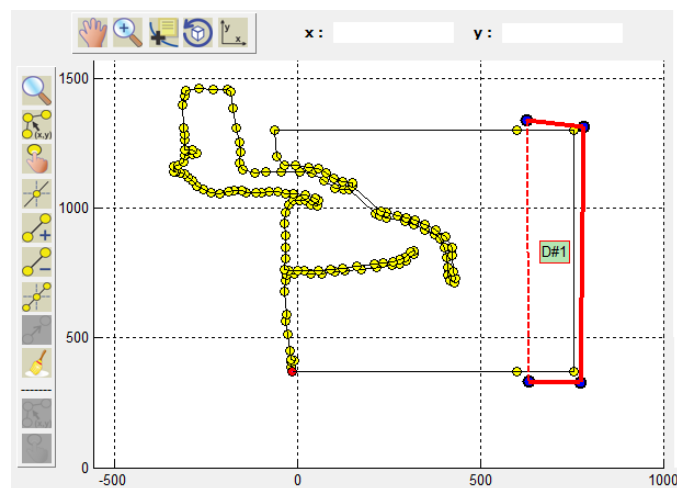



Figure 5-9 Creating 'Damping Zone' in HAWASSI-VBM2

- Editing the damping points can be done by activating ‘physical properties’ module in the ‘Edit’ menu, then select  to edit the points by specifying the (x , y) position.

To have a good damping boundary, the width of the damping zone should cover at least two times the longest wave.

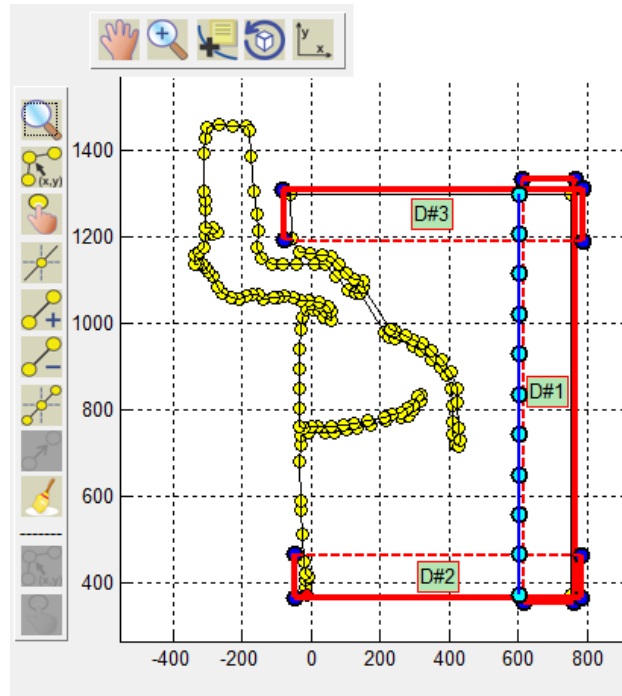


Figure 5-10 Creating 3 ‘Damping Zones’ as transparent boundaries at the sea sides

To select Partial Reflective Boundaries (PRB), the following steps should be done:

1. Click ‘PRB’ button in the ‘Physical properties’ panel (Figure 5-8)
2. Select two points (start and end point) in the coastline data that will mark the boundary line of PRB. The boundary line is in the counter clockwise direction, from start to end point. The reflection coefficient is in the range of 0 to 1, with 1 for full reflection.

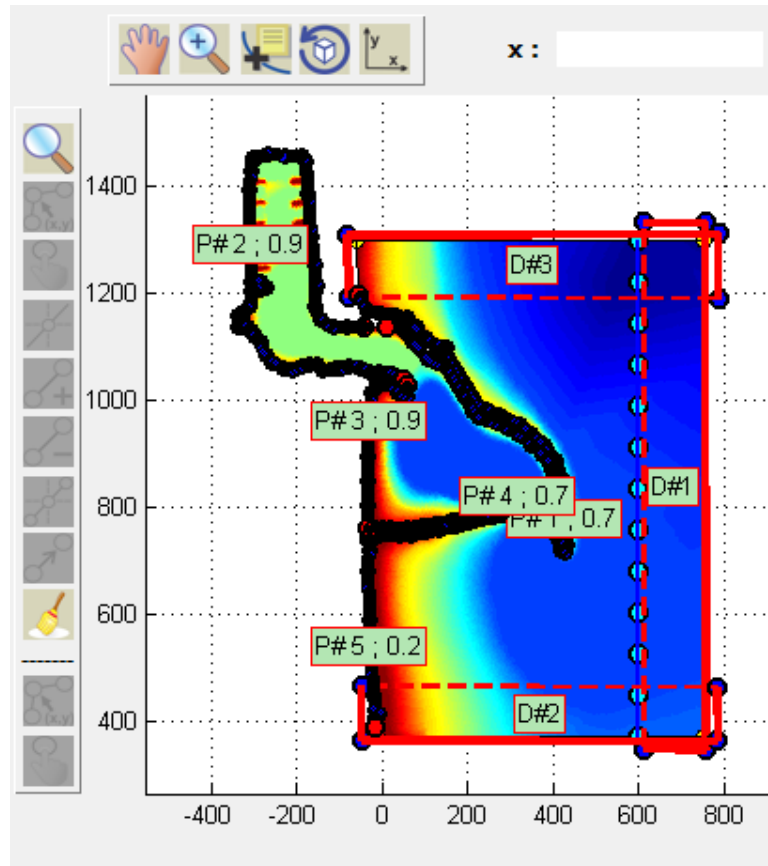



Figure 5-11 Creating PRB's at the land boundaries and harbour walls

5.1.6 Specifying the influx

For influxing waves into the domain of computation, the user needs to define an embedded influx line in the domain and provide the information for the time signal via the following steps:

1. Click 'Influx line' button in the 'Physical properties' panel
2. Put two points that will create a line in the domain; if the point is placed outside the domain it will be **projected** to the closest point on the domain boundary.
 - For editing the influx line position, activate the editing tools by in 'Edit' menu → 'Physical

properties' module, then click  to edit the (starting and ending) points of the influx line by specifying the (x , y) position.

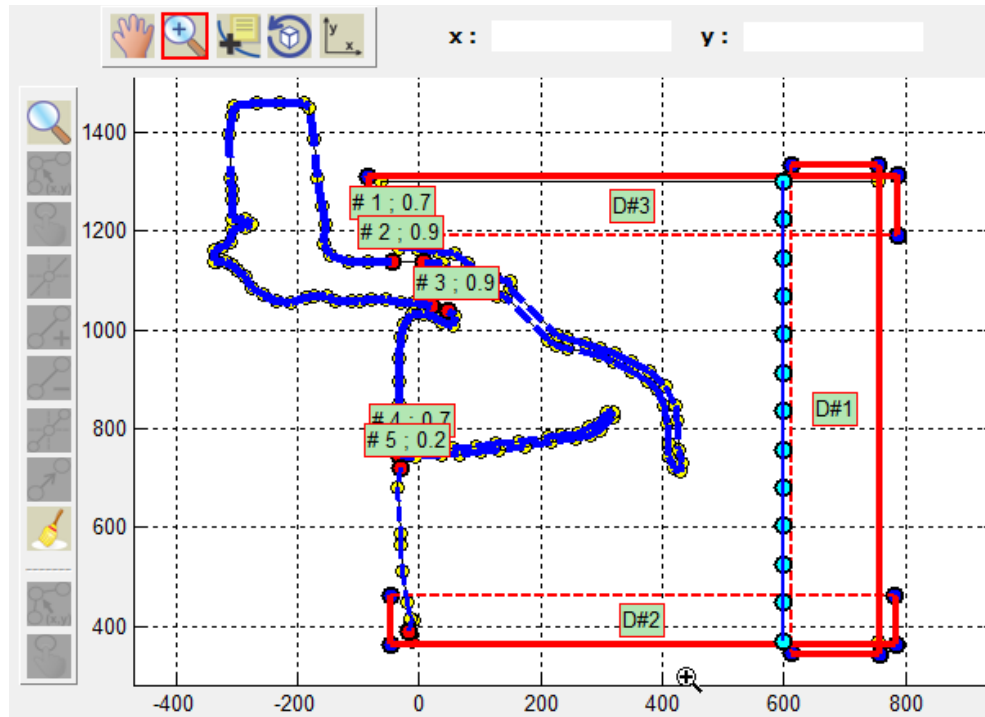


Figure 5-12 Creating influx line

3. Define the influx signal by calling the 'Model Control' GUI; click 'Model' menu → Select 'Model Control' or simply (Ctrl + M).
4. Select *Harmonic* in the 'Time Signal' panel, then set the following signal parameters :
 - Direction : 270 (nautical, counterclockwise from north)
 - Tp : 9
 - Amplitude : 0.25
 - Time : 0:1:300

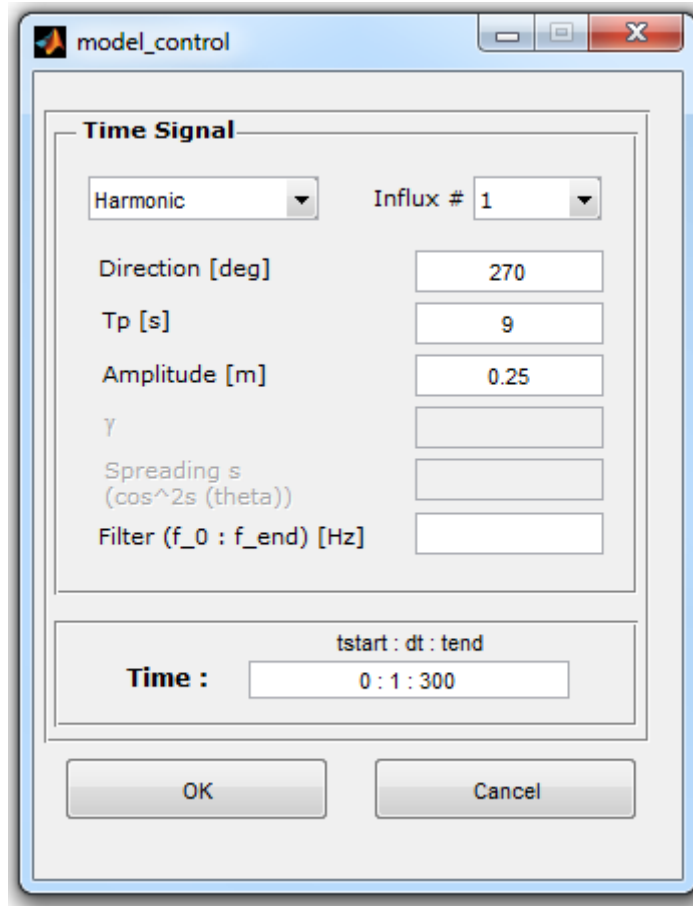


Figure 5-13 Set influx signal parameter in 'Model Control'

5. Click the OK button to close 'Model Control' GUI.

5.1.7 Creating mesh

Now the set-up of the domain, boundary conditions, and wave influx is done, the next step is to create the mesh by clicking 'Generate Mesh' button. After the button is pressed, a pop-up GUI 'Mesh properties', will ask for parameters for the mesh generator. The parameters should be set with the following information:

- Approx Tp : 9
- ppl : 10
- max ds : 200
- shallowest depth : 1
- check **Depth dependence**

The mesh generation process will start after the ‘Save’ button is clicked. A progress bar indicating the progress of the unstructured grid generation is shown in the lower part of the main GUI, **Error! Reference source not found.**, with a result as shown In Figure 5-18.

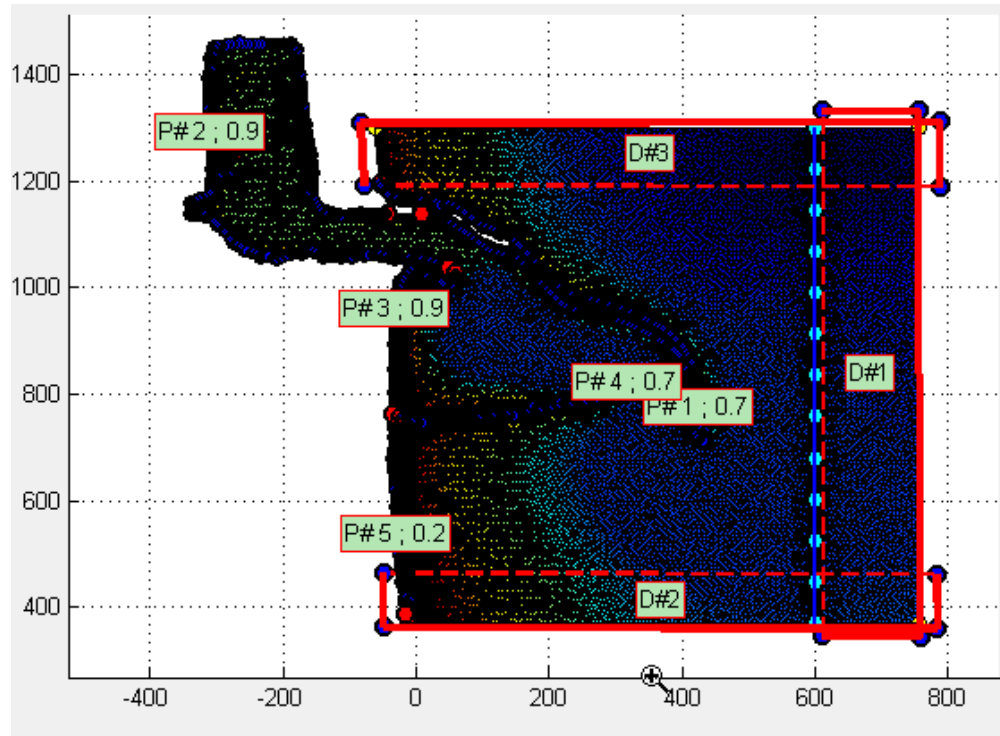


Figure 5-14 Generated mesh

5.1.8 Running the simulation

After the mesh has been created and model data have been specified, the simulation with HAWASSI-VBM2 can be started as follows:

1. Click the ‘Preparation’ button; this gives an overview to check the domain settings and the numerical setup based on the given input, as illustrated in Figure 5-15, .
2. Click the (activated) ‘RUN’ button

After the calculation is finished, there are several new data files created in the folder **Output/[ProjectName]/**, containing detailed information of the performed simulation. Details of names and contents of the files are described in Table 4-5.

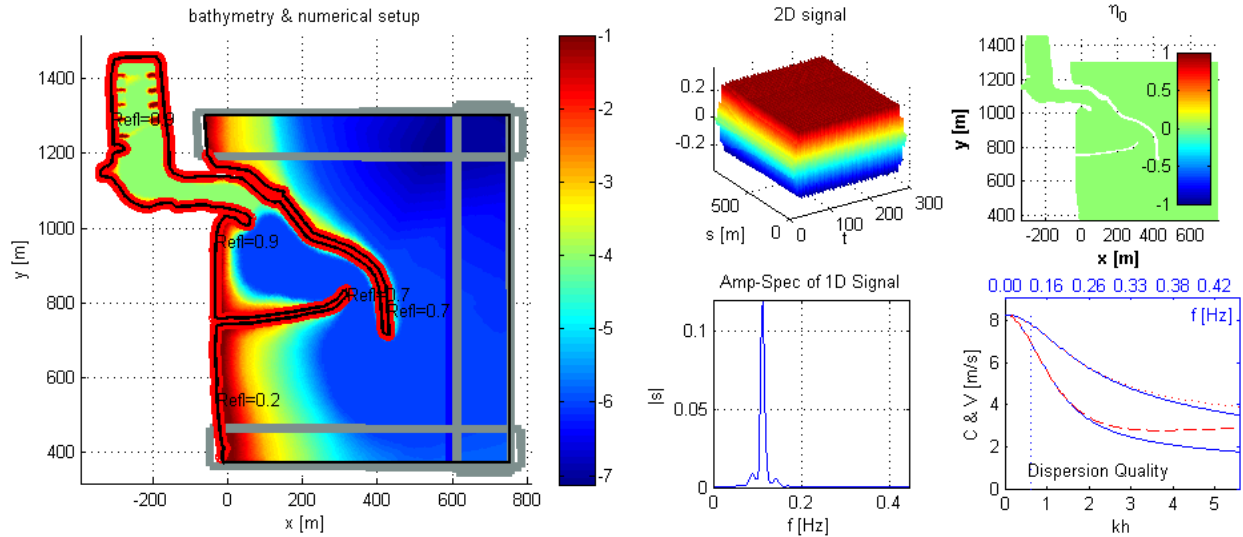


Figure 5-15 Overview of the numerical setup after 'Preparation' is finished

5.1.9 Post processing of the output

After the calculation is finished, the Post processing GUI automatically pops-up (Figure 5-16 Post processing GUI). The GUI can also be used to process existing output data by selecting the option 'Other' in the 'Simulation Data' panel and specifying the file through the dialog box 'Select a mat file'.

To show the animation (2D or 3D) for test case 6b, the following steps have to be done:

1. Activate 'Animation' panel in Post processing GUI
2. Keep the values for time and space at their default values.
3. For running the 2D animation, click the 'RUN' button directly.
4. For running the 3D animation, check the '3D view', and (if desired) adjust the 3D view setting by clicking '3D setting' button. To start the animation, click the 'RUN' button.

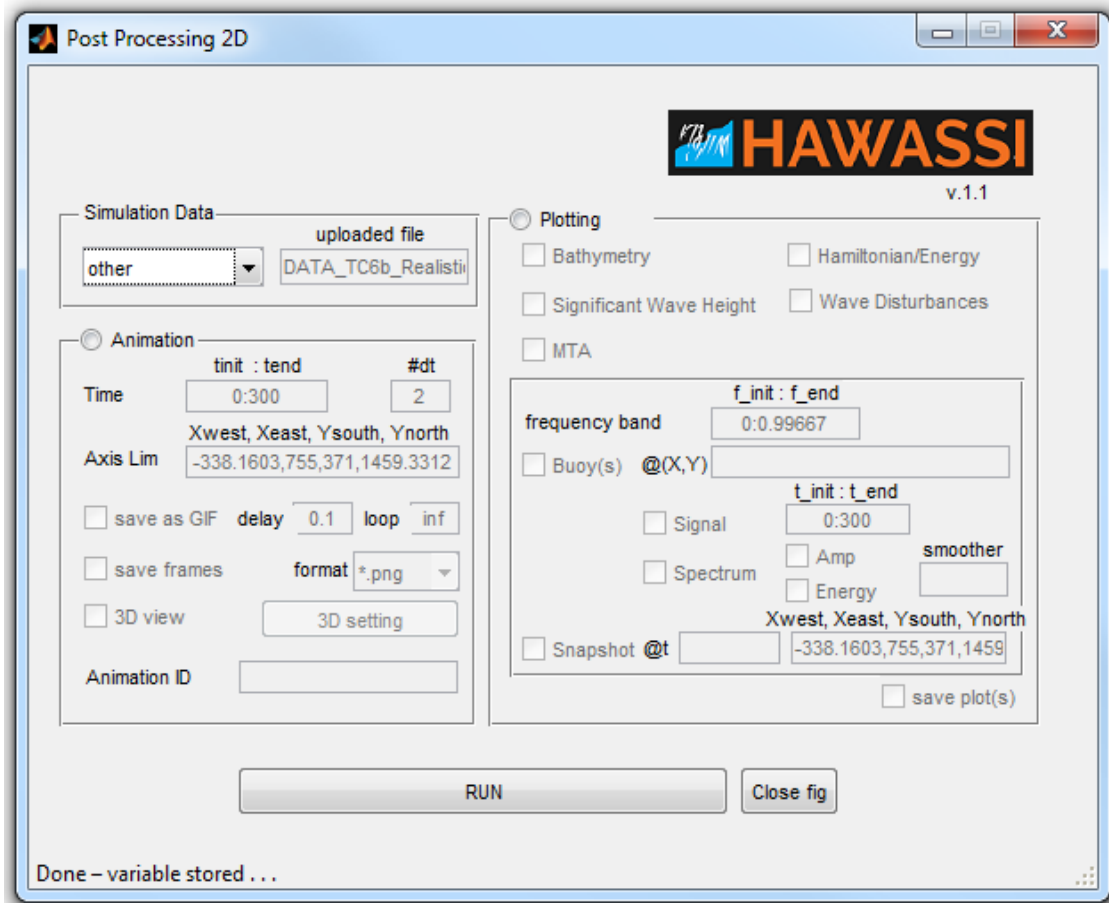


Figure 5-16 Post processing GUI

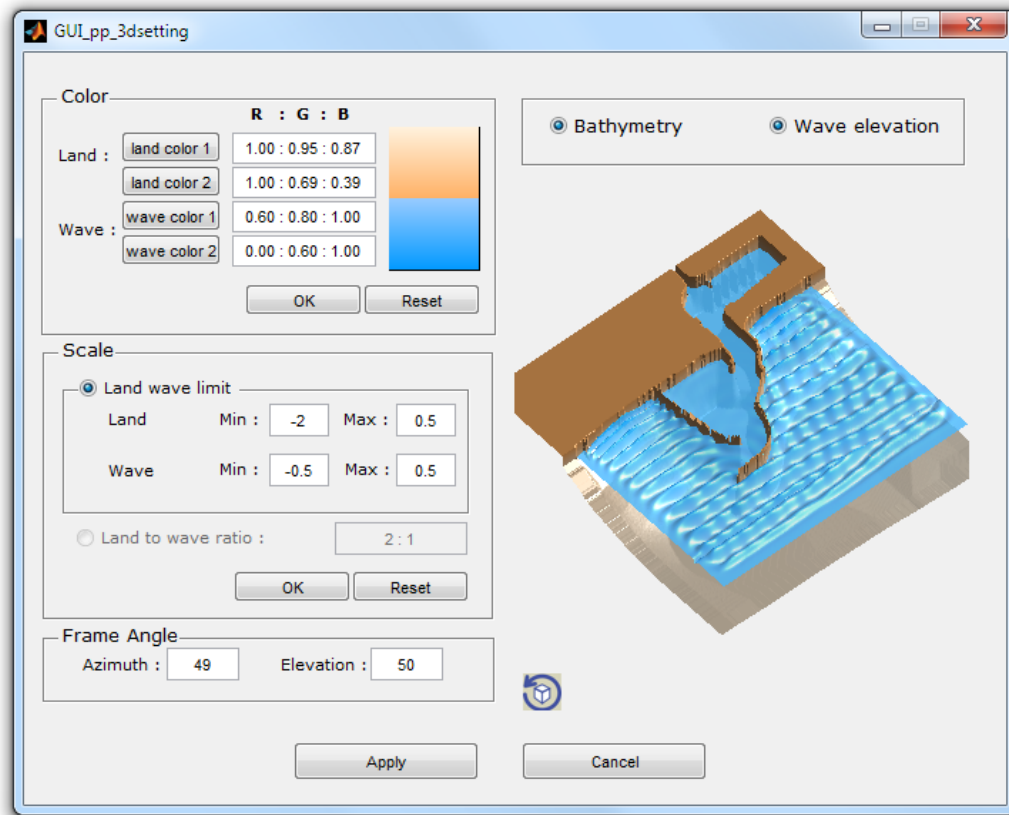


Figure 5-17 GUI for 3D settings

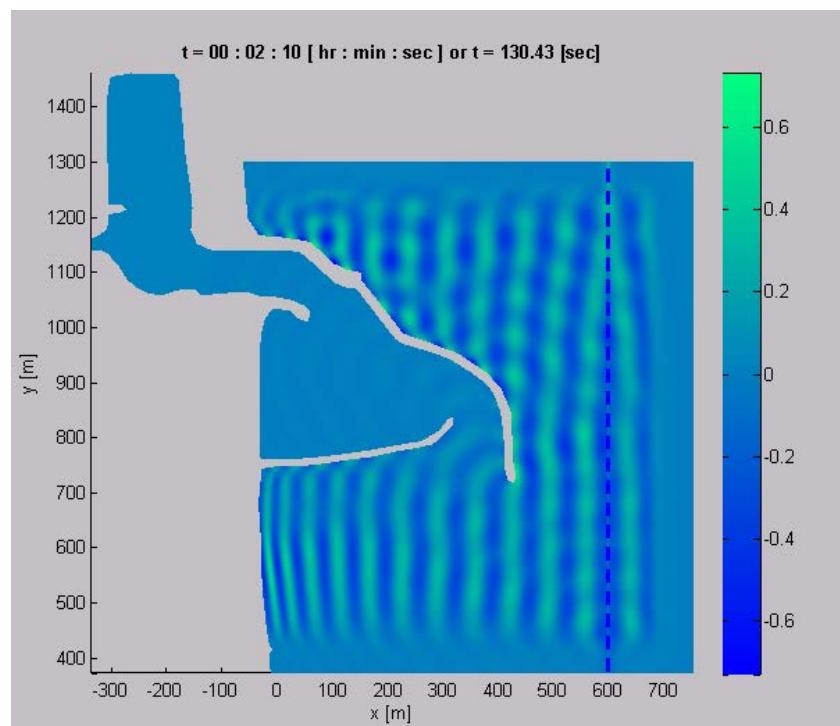


Figure 5-18 2D Animation output

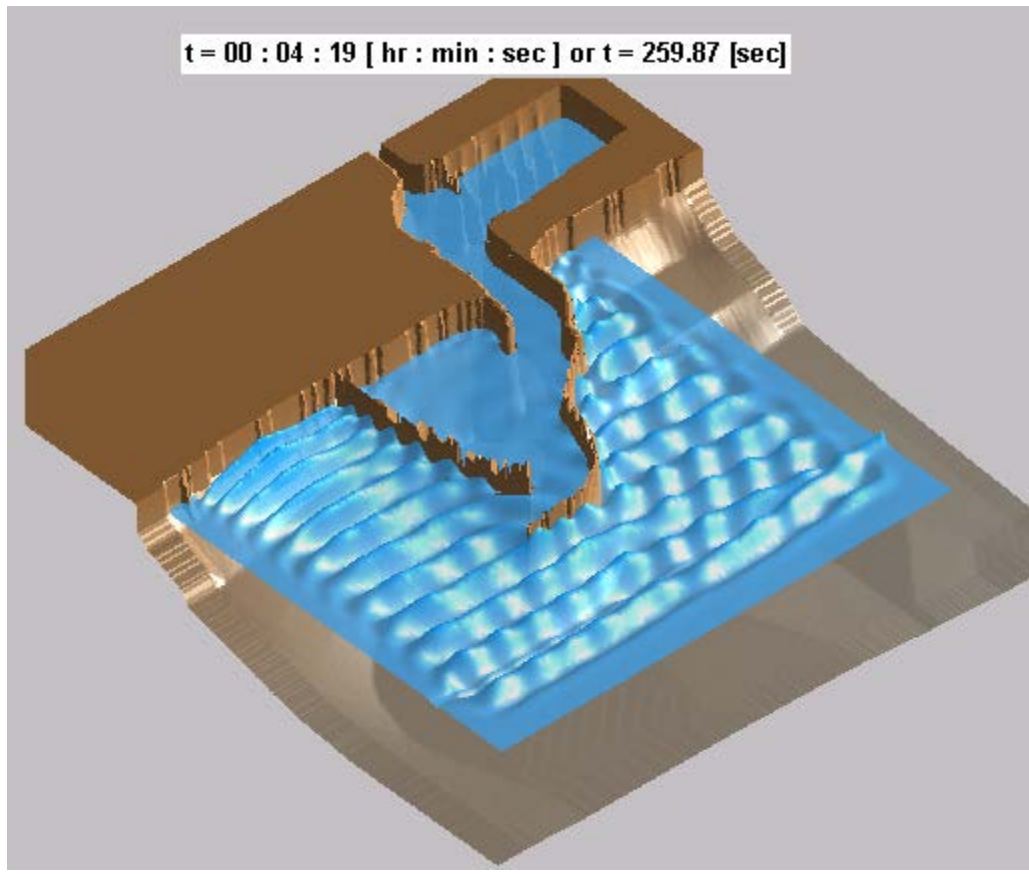


Figure 5-19 3D animation output

5.2 Test Case 1: Wave Propagation above a Flat bottom

This introductory example of waves above a flat bottom is to illustrate wave influxing and effects of damping zones and (partially reflecting) boundaries. Besides that, various types of waves, and the difference in propagation when different wave models are used, can be investigated.

A simple domain configuration, setting for the mesh generator and model control are illustrated in Figure 5-20, Figure 5-21 and Figure 5-22.

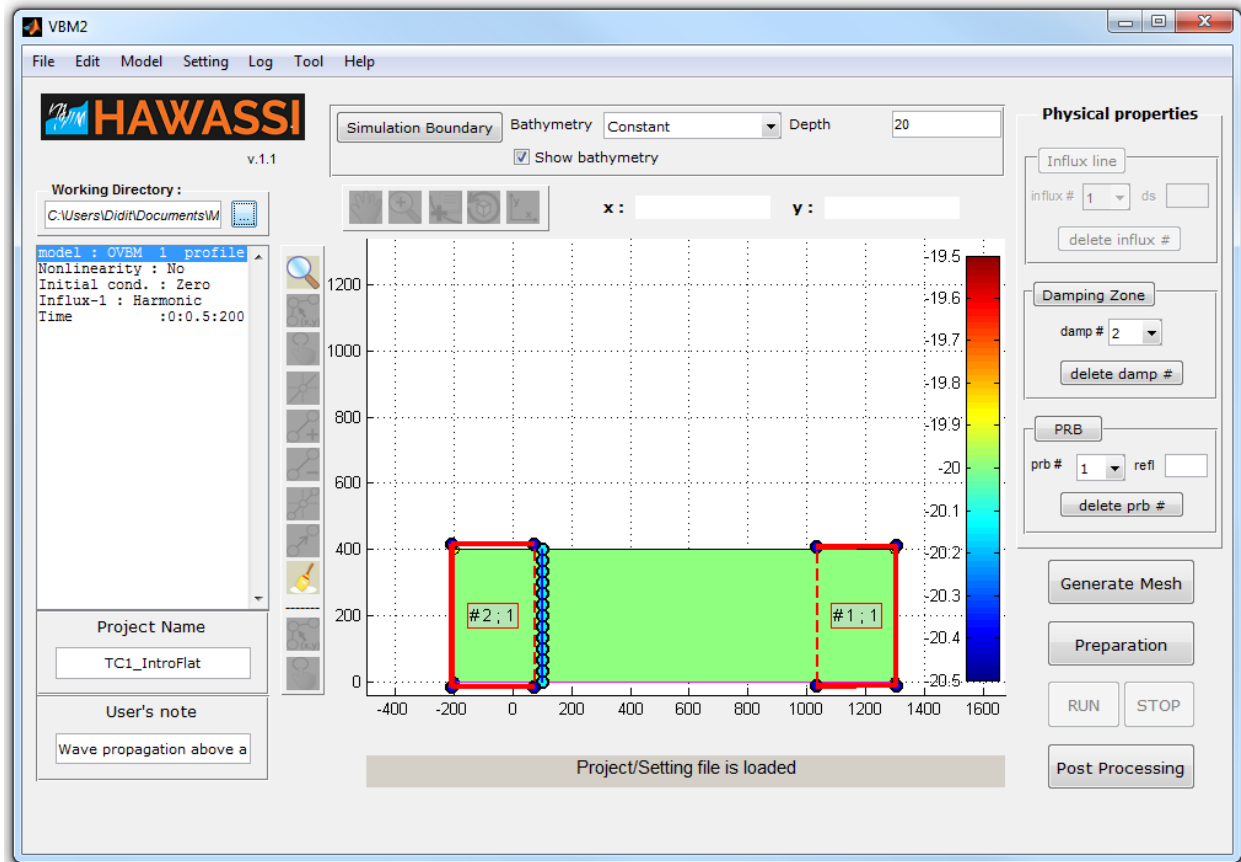


Figure 5-20 Domain settings of test case 1

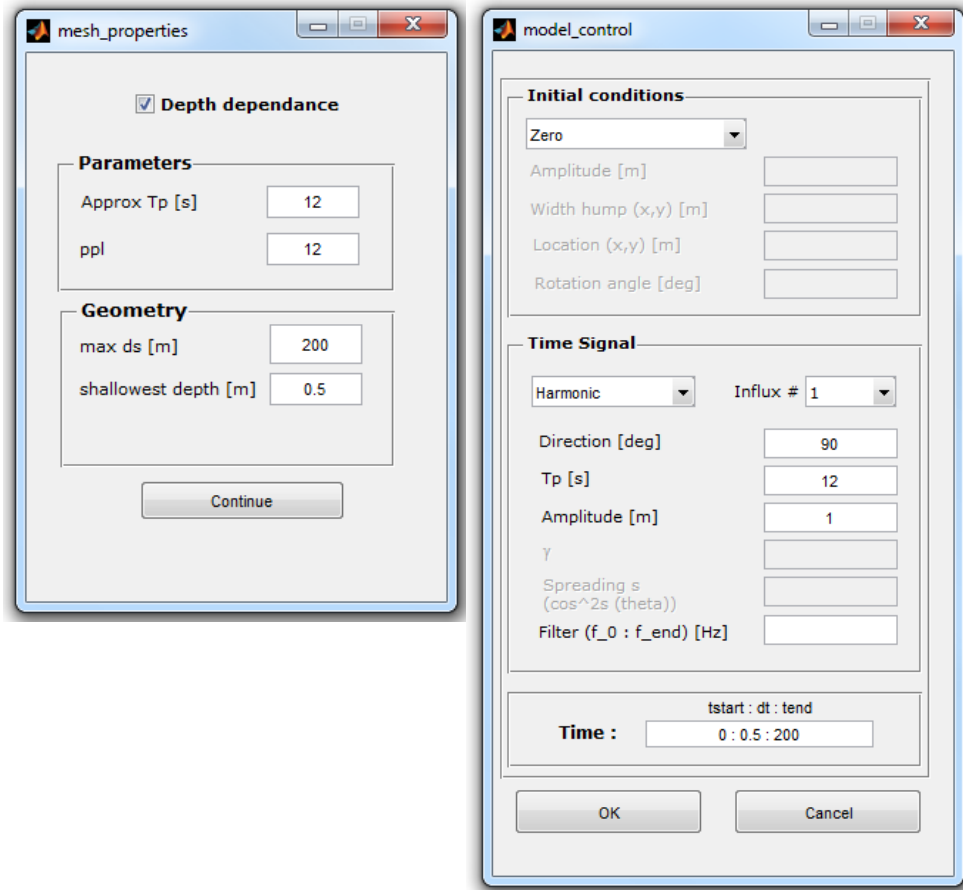


Figure 5-21 Settings for mesh properties and model control for the test case 1

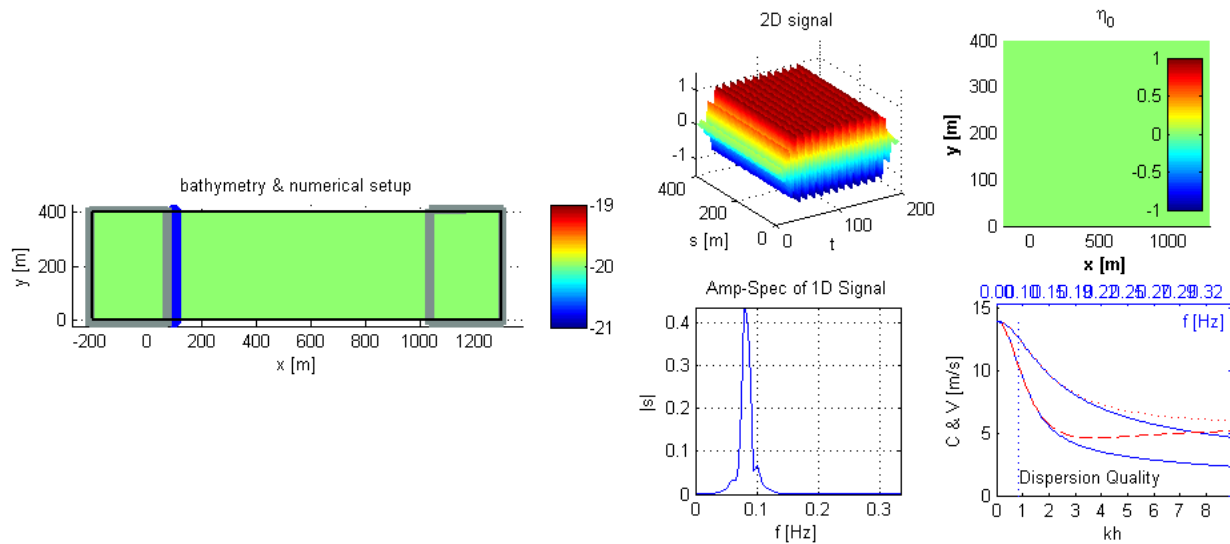


Figure 5-22 Model setup of test case 1 (overview as result of 'Preparation')

Suggestions.

- Look at the log-file to find the calculated wave length. How many points will be in one wavelength for the given dx ? Estimate how many waves you will see, in which interval with the expected amplitude.
- Run the simulation and perform post-processing. Verify if your expectations are correct.
- Perform other simulations for this wave case:
 - See effect of changing grid size, by changing ‘ppl’ parameter in the ‘mesh-properties’, change period (and choose sensible grid-size)
 - Change influx line position, damping zone, boundary values, etc.
 - Perform nonlinear simulations; see effect of increasing the amplitude and explain.
- Change wave type to Jonswap, $H_s=1$; $T_p=12$; $\Gamma=3$. Estimate peak wave length. Activate MTA when plotting animations and snapshots. *NOTE: for comparison of different wave models, the same initial signal has to be used: it has to be loaded from a previous simulation since the parameters alone do NOT specify the Jonswap input signal because phases are added randomly!!*
 - Check performance of linear simulation, using SWE. Observe that propagation is a pure translation.
 - Now use VBM dispersion (parabolic, 1 and 2 profiles) and observe differences (compare outputs by combining them in a single plot).
 - Observe effects of changing Jonswap parameters.
 - Perform non-linear simulations (increasing H_s)

5.3 Test Case 2: Diffraction

Test case 2 is an illustration of the diffraction phenomenon. The configuration is chosen to mimic a semi-analytical solution of the Helmholtz equation. The contour lines that are a result of the VBM simulation shown in in Figure 5-26 illustrate the diffraction; these results are comparable with the semi-analytical solution, see Shore Protection Manual¹ [1984], page 124.

The domain configuration, setting for the mesh generator and model control are illustrated in Figure 5-23, Figure 5-24, and Figure 5-25.

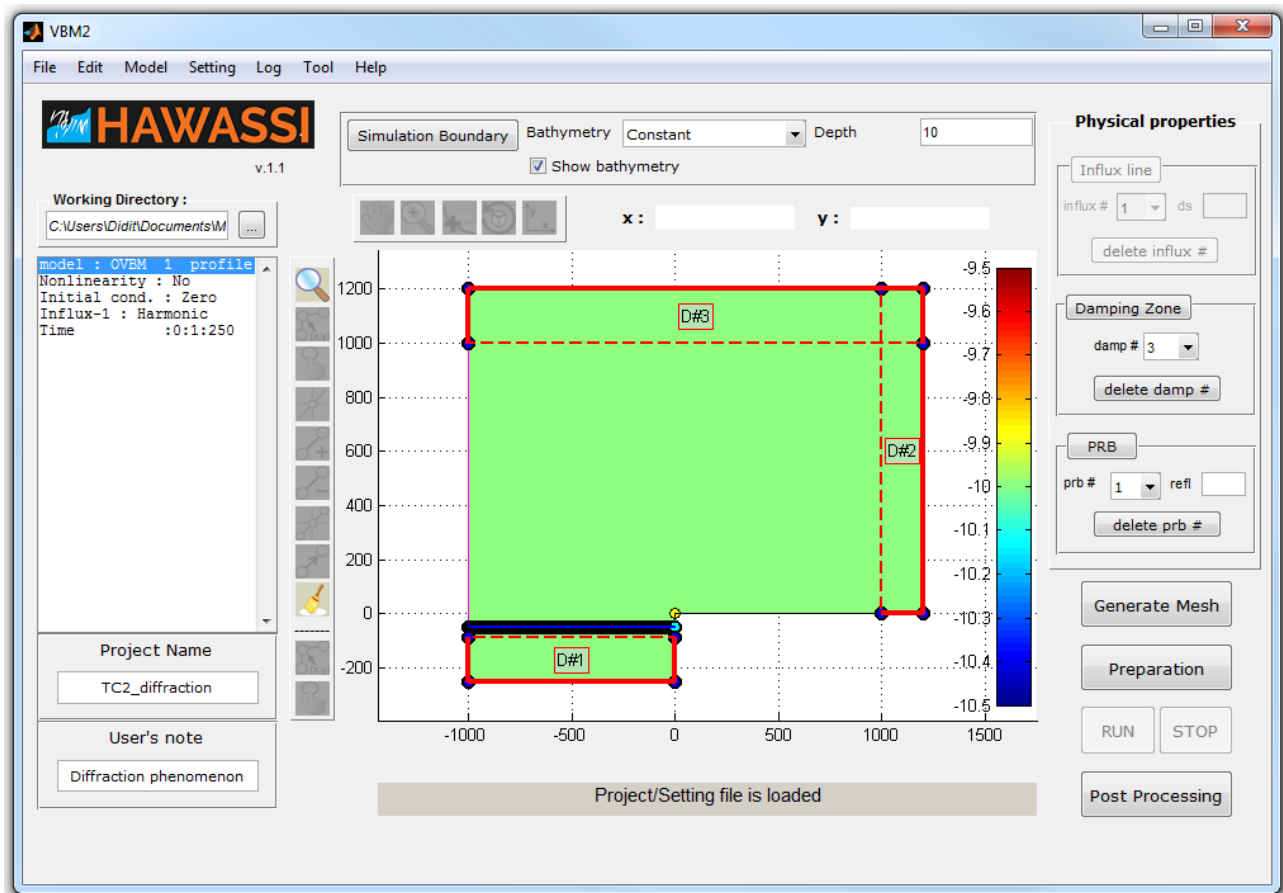


Figure 5-23 Domain settings of test case 2

- ¹ U S Army Corps of Engineers (1984). Coastal Engineering Research Center: Shore Protection Manual vol.1.

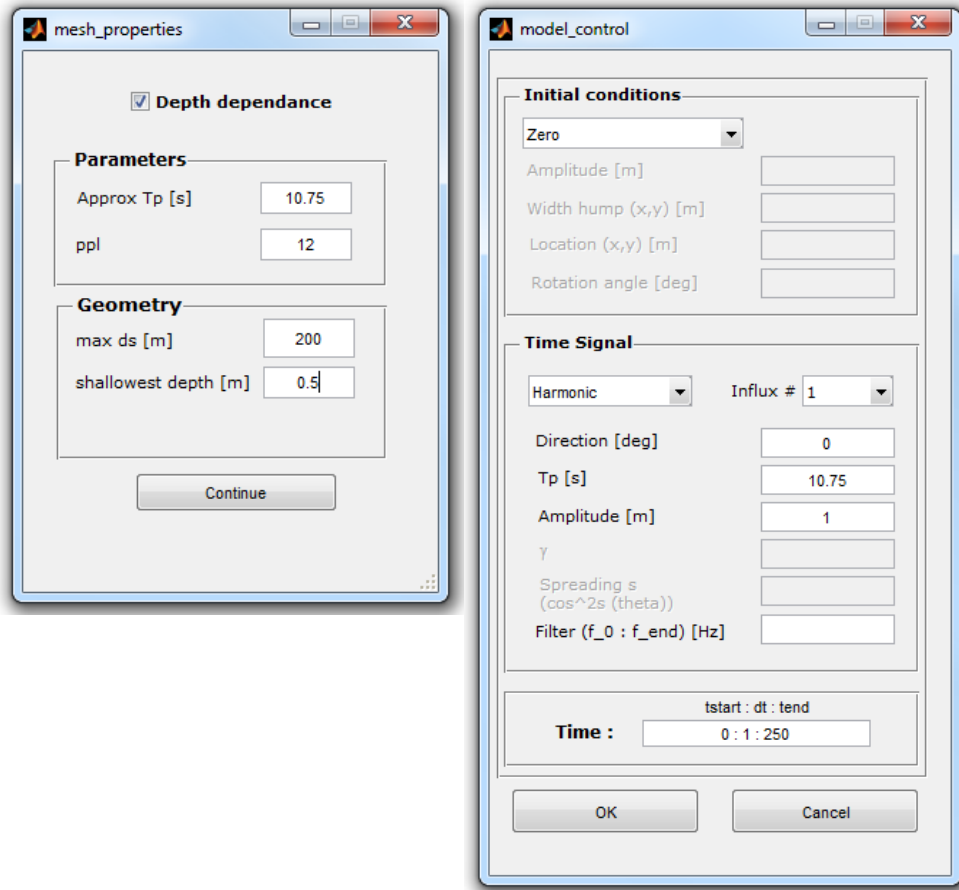


Figure 5-24 Settings for mesh properties and model control for the test case 2

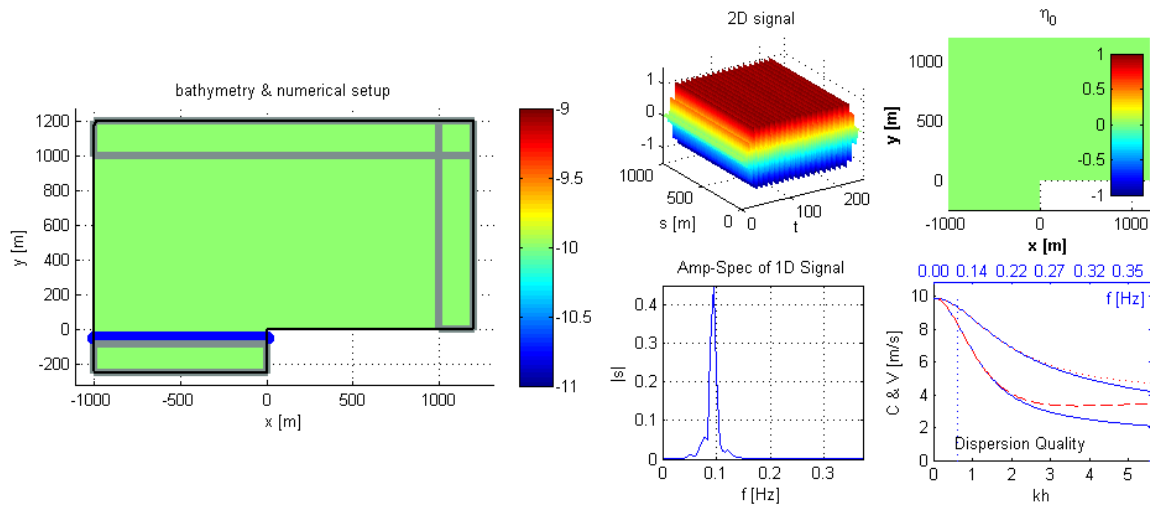


Figure 5-25 Model setup of test case 2

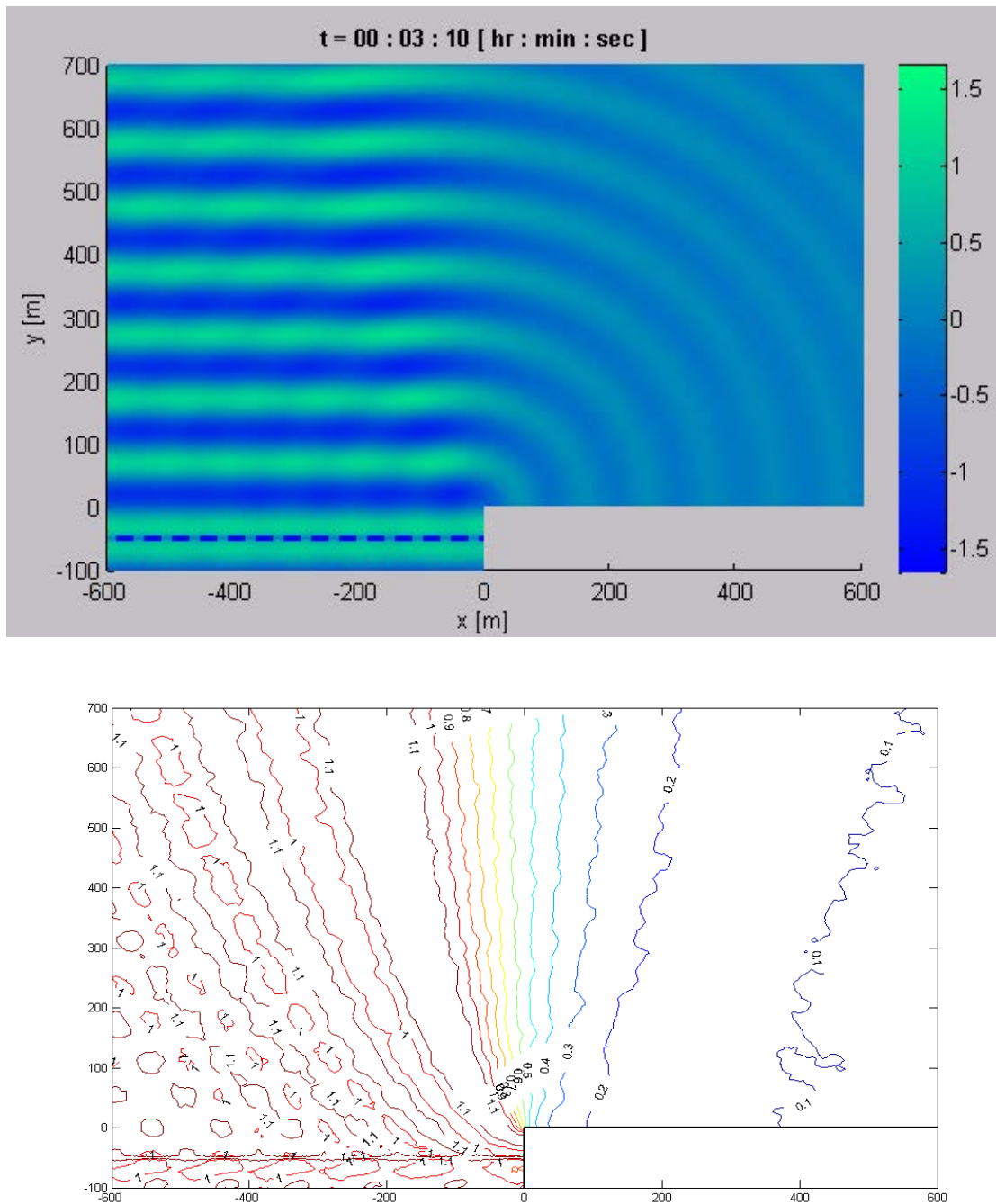


Figure 5-26 The upper plot shows the snapshot of surface elevation and the lower plot shows contour line of the maximum wave height

Observation.

- Look at the diffraction pattern, especially behind the wall.
- Try to investigate the dependence of the diffraction pattern on wavelength.
- Use various influx waves, also Jonswap influx type
- Use various wave models.

5.4 Test Case 3: Refraction

Test case 3 is a continuation of test case 1, now for a bathymetry that includes a shallow part that will show the refraction phenomenon, i.e. the bending of waves towards the shallow area because of reduced speed over shallower areas.

The domain configuration, settings for the mesh generator and model control are illustrated in Figure 5-27, Figure 5-28 and Figure 5-29.

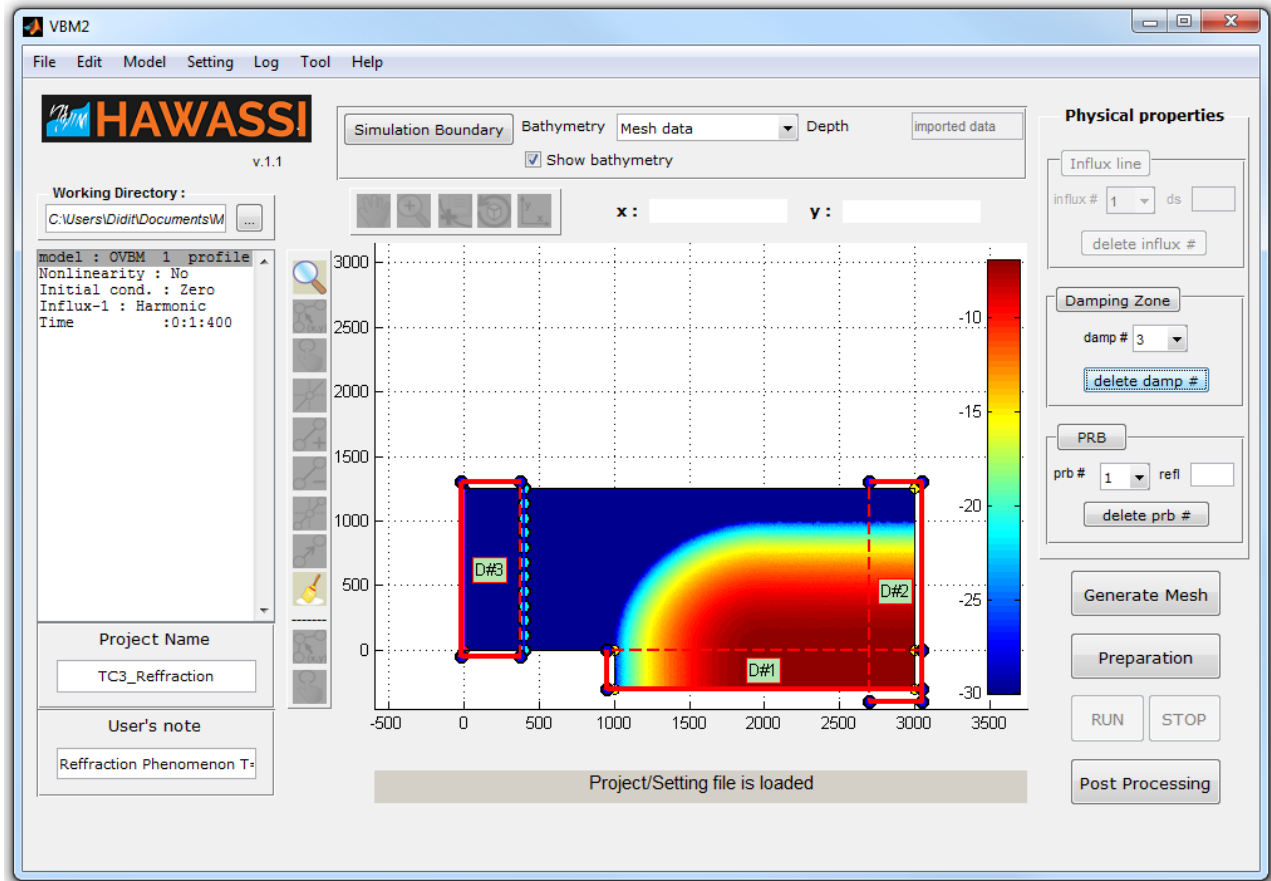


Figure 5-27 Domain settings of test case 3

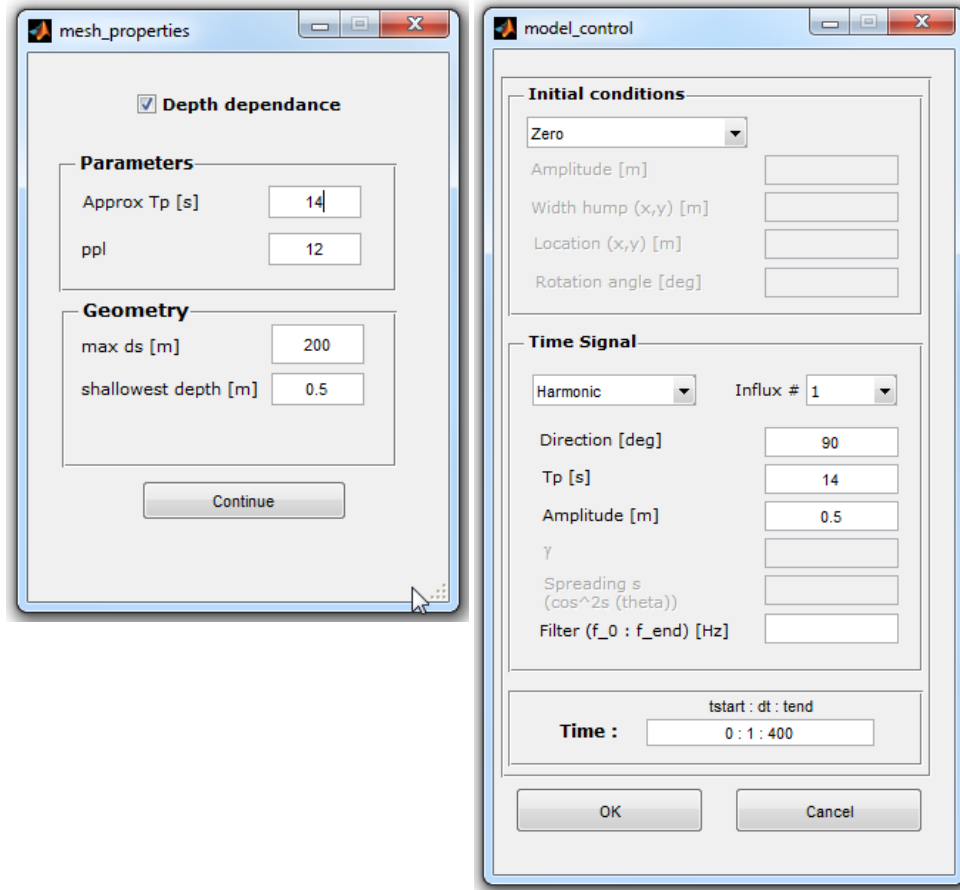


Figure 5-28 Settings for mesh properties and model control for the test case 3

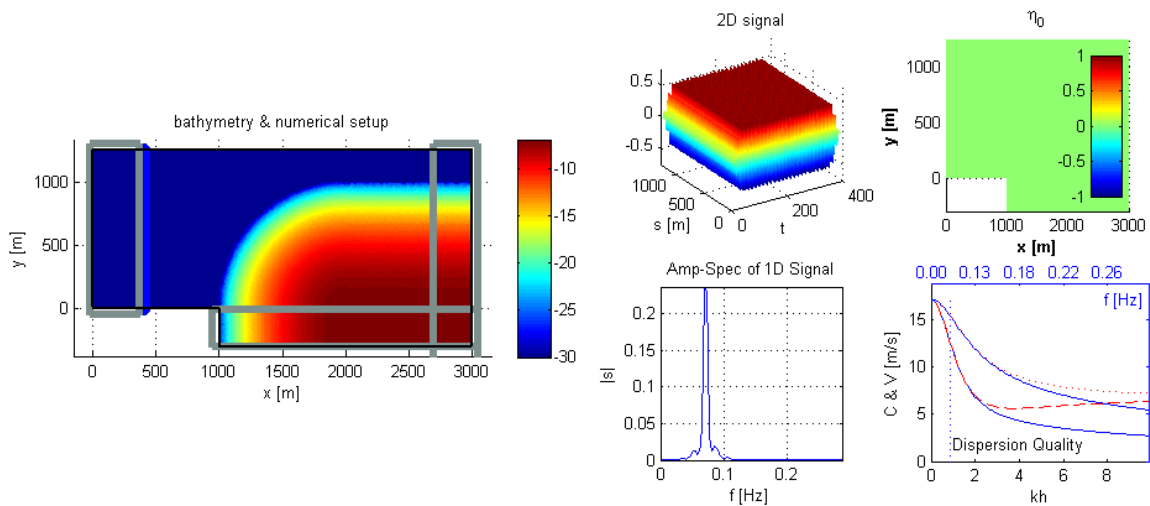


Figure 5-29 Model setup of test case 3

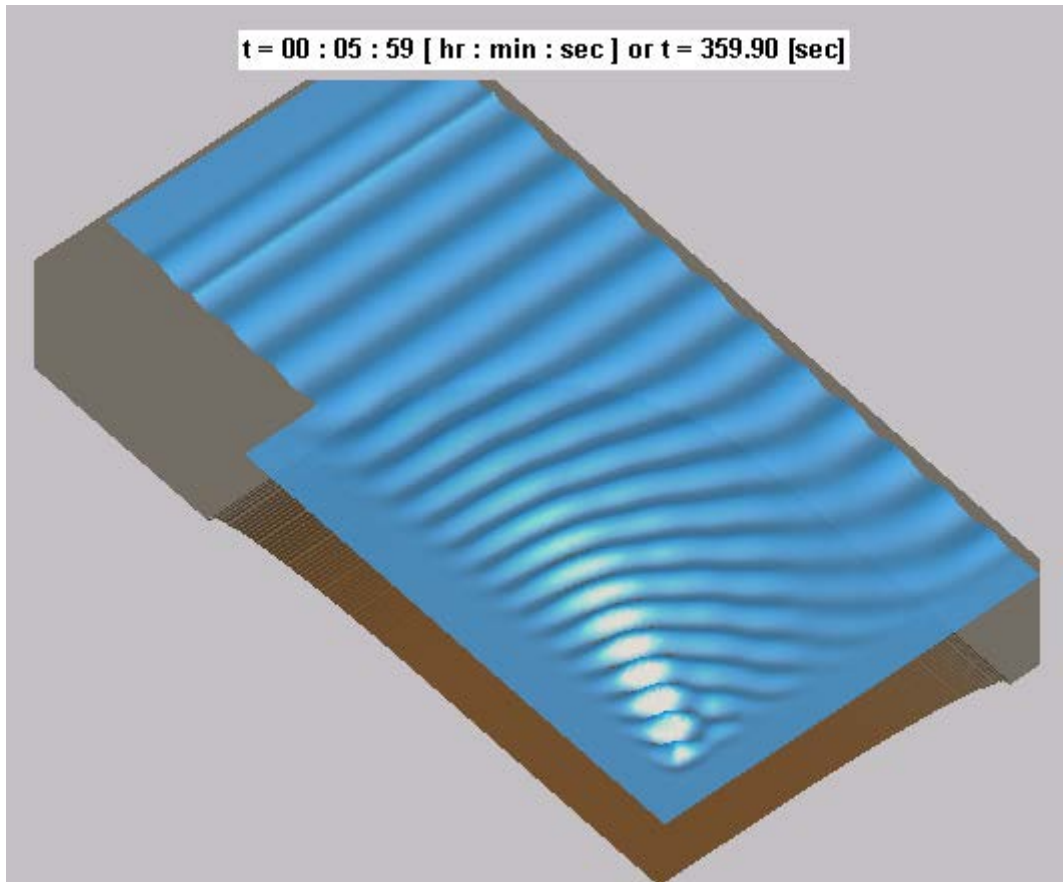


Figure 5-30 Test case 3: Snapshot of surface elevation shows the refraction phenomenon.

Observation

- Observe the amplitude changes above slope
- Reflections are more pronounced for steep slopes
- Investigate effect of different wave lengths.

5.5 Test Case 4: Simple harbour layout

Test case 4 is designed to illustrate standing (resonant) harbour waves in a rectangular basin with influx from part of the boundary. The influxed waves are mainly reflected from the opposite wall and leave the domain (not affecting or hindered by the influx line), but diffraction causes the waves to partly enter the right part of the basin where for specific wave influxes a pattern may develop standing waves. The domain configuration, settings for the mesh generator and model control are illustrated in Figure 5-31, Figure 5-32, and Figure 5-33.

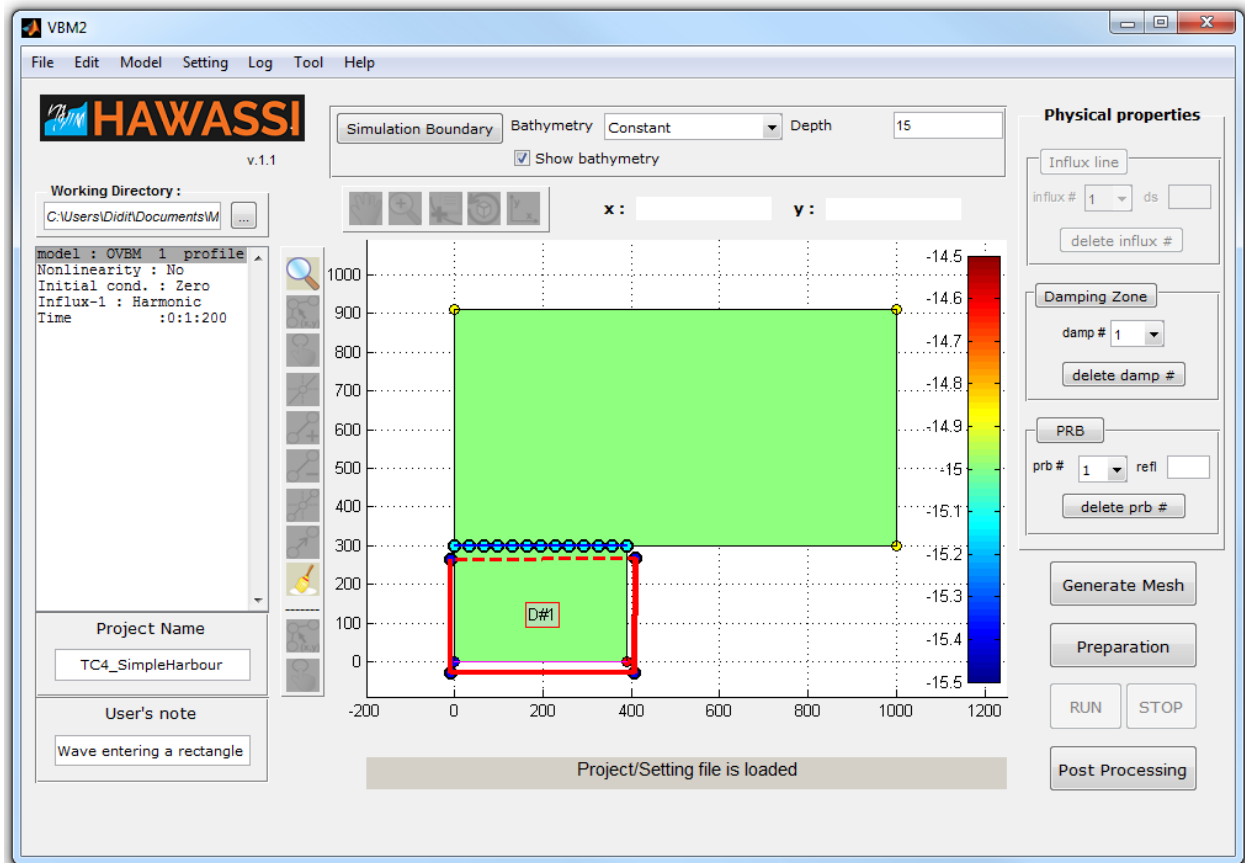


Figure 5-31 Domain settings of test case 4

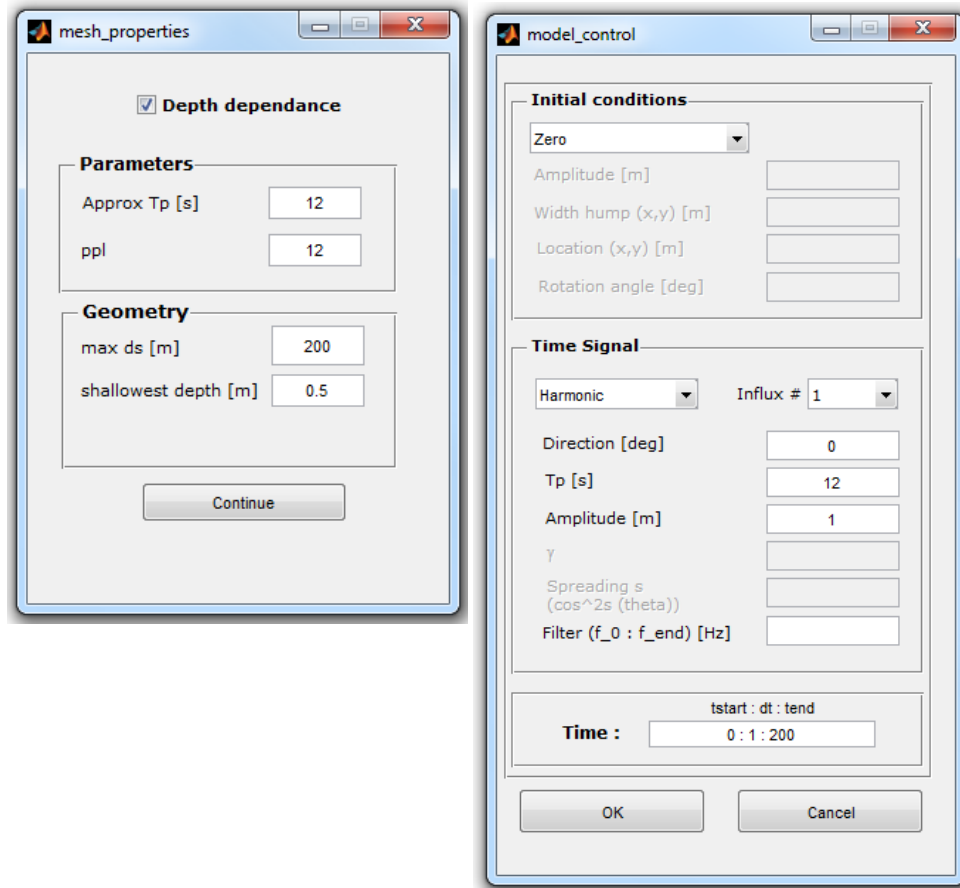


Figure 5-32 Settings for mesh properties and model control for the test case 4

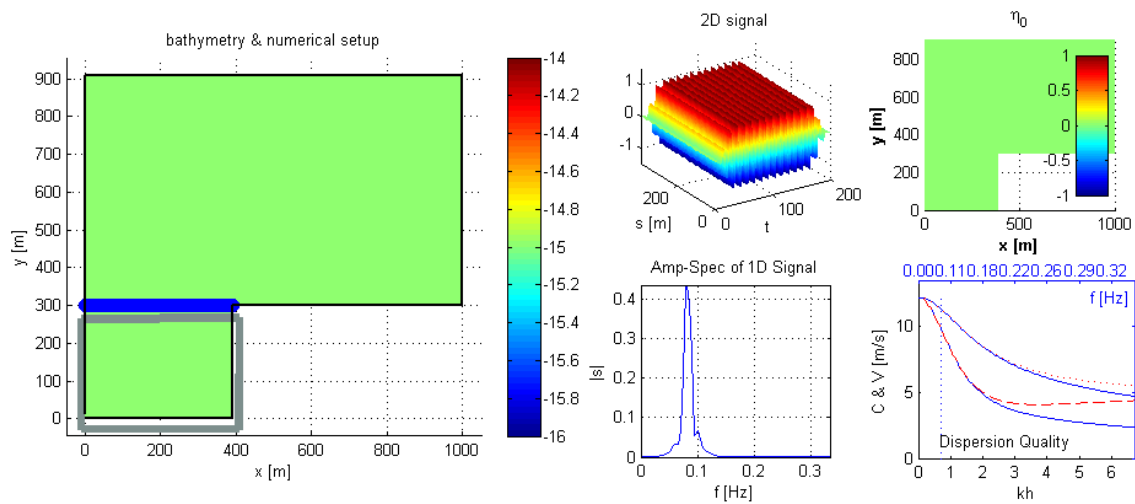


Figure 5-33 Model setup of test case 4

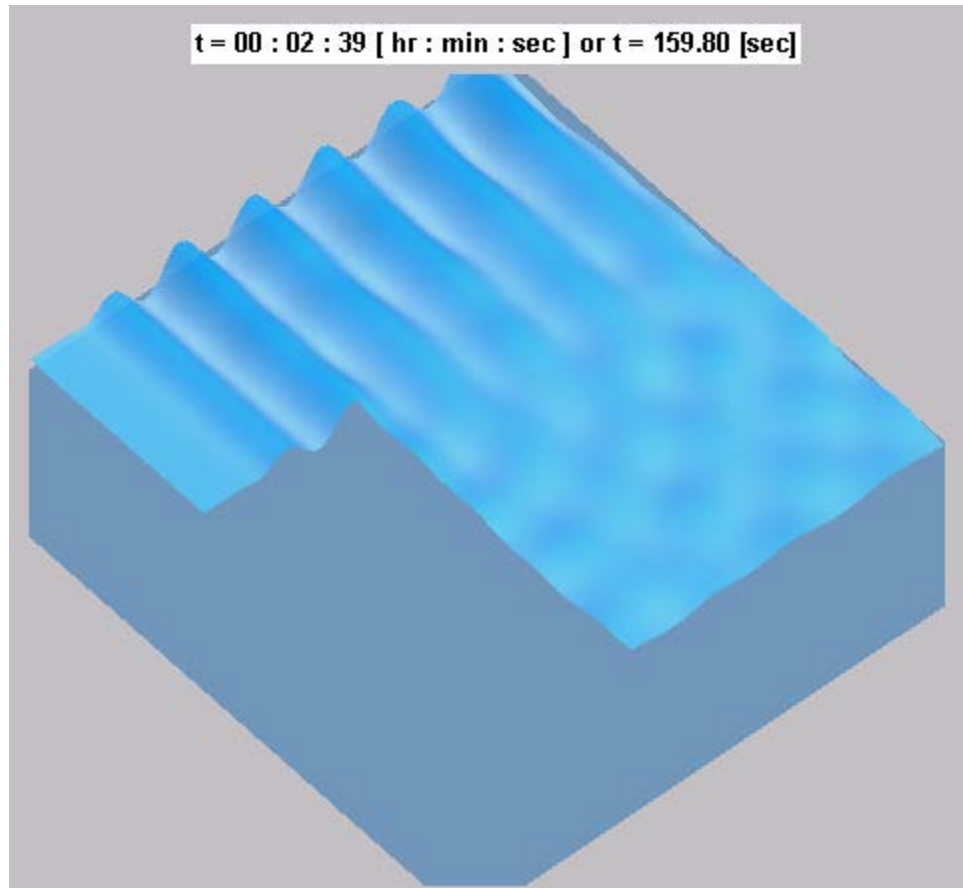


Figure 5-34 Test case 4: Snapshot of surface elevation in a simple harbour layout

Observation

- Compare wave disturbance from harmonic waves of different wavelength
- Compare results of various wave models: 1 and 2 profiles, linear and nonlinear
- Quantify the ‘wave energy’ inside the harbour at one instant; decide from that when, starting from an initially flat sea, the waves have ‘completely’ occupied/filled the harbour
- Any standing waves? (Investigate buoy measurements at (clever) positions to support claims about standing waves.)

Suggestion

- Calculate on paper some simple standing wave patterns for the right side of the basin; estimate the wavelengths that play a role, and perform simulations to investigate the occurrence of such harbour resonances.

5.6 Test Case 5: Simple harbour layout 2

Test case 5 is a harbour with a basin with an oblique basin, all with constant depth. The domain configuration, setting for the mesh generator and model control are illustrated in Figures 5-39, 5-40, 5-41.

A plot of a simulation is shown in Figure 5-38.

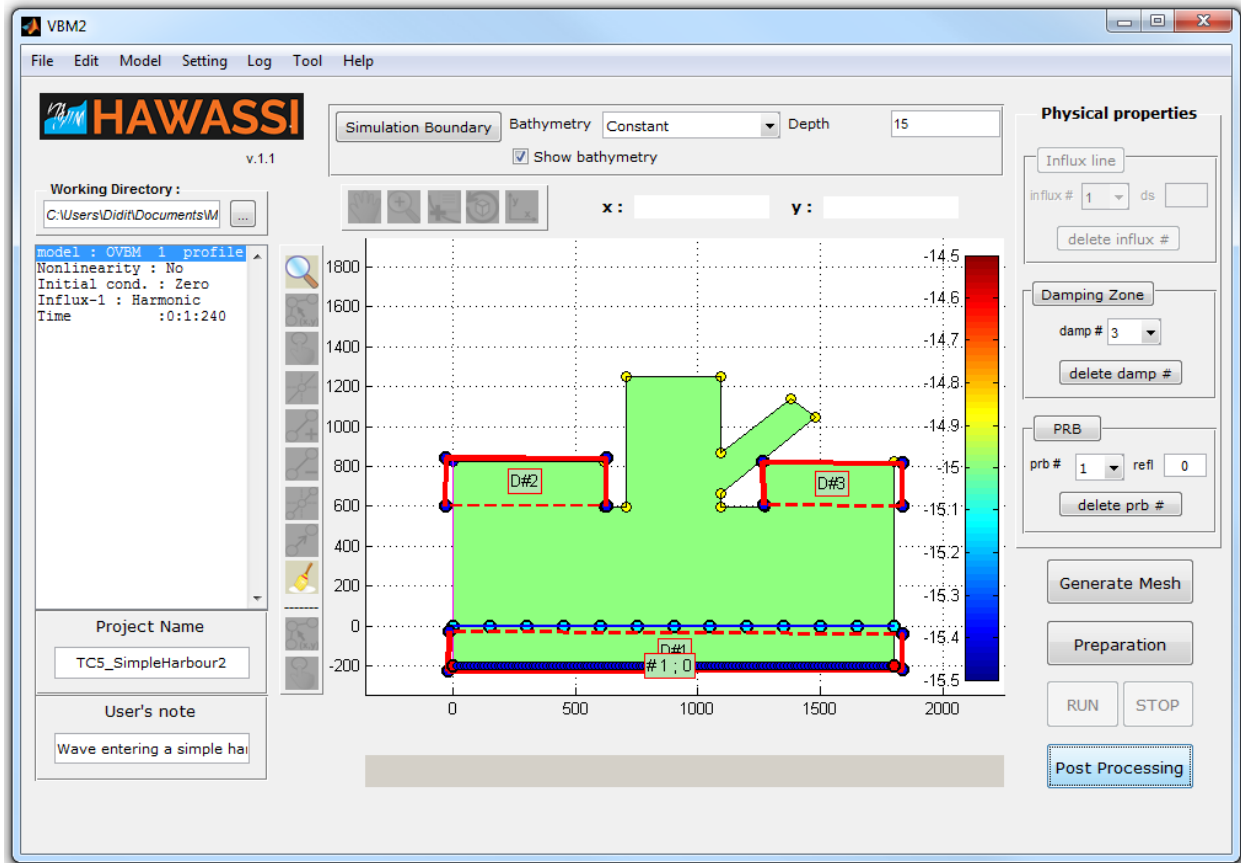


Figure 5-35 Domain settings of test case 5

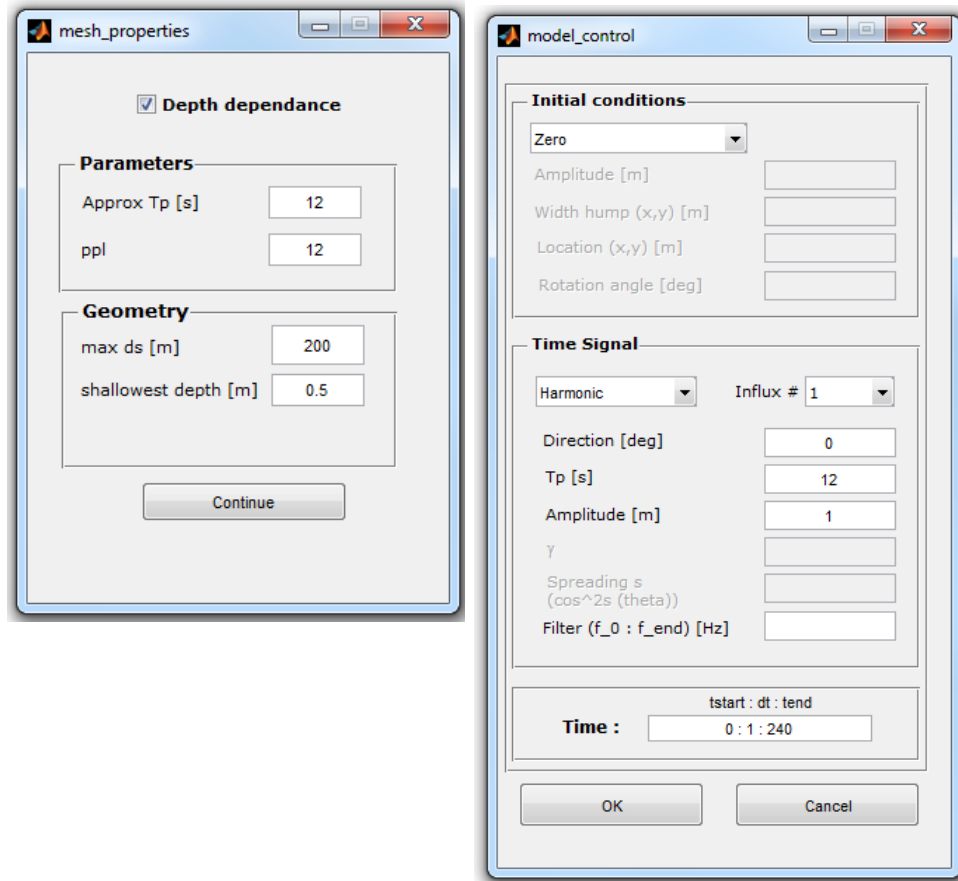


Figure 5-36 Settings for mesh properties and model control for the test case 5

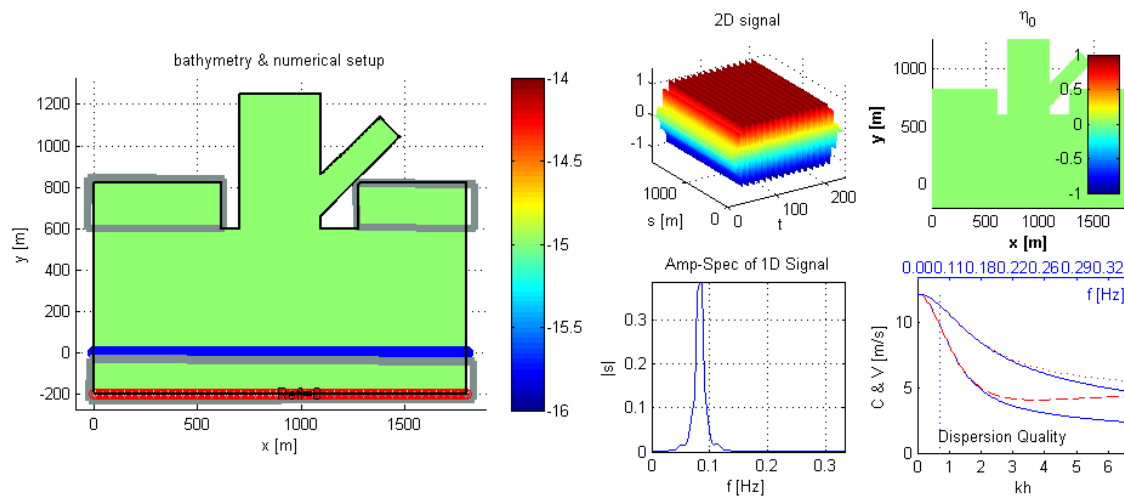


Figure 5-37 Model setup of test case 5

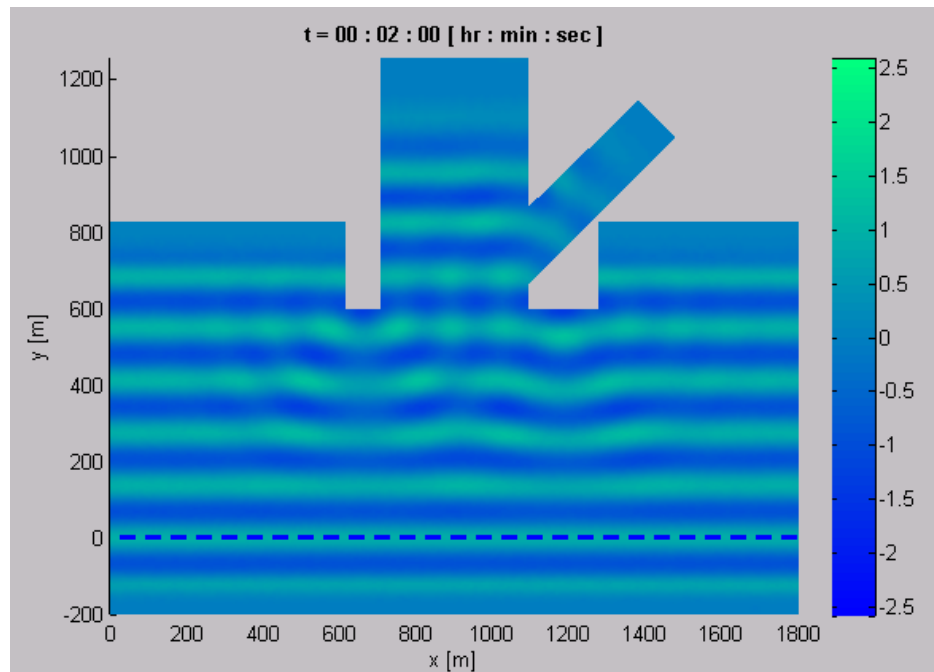


Figure 5-38 Test case 5: Snapshot of surface elevation in a rectangular basin with an internal oblique basin

Observation

- Compare wave disturbance of simulation with long and short crested waves, 1 profile, linear and nonlinear
- Any standing waves? (Be sure the harbour is fully ‘filled’)

Suggestion

- Make simulation with a hot-start
- Perform time-partitioned simulation with 3 intervals

5.7 Test Case 6: Cilacap harbour

Test case 6a and 6b show two realistic breakwater configurations in a fisher harbour at Cilacap (South coast of Jawa, Indonesia). The aim is to show effects that different breakwater configurations will have on the wave disturbance in the inner harbour.

5.7.1 Breakwater configuration -1

The domain configuration (as built in 2006), settings for the mesh generator and model control are illustrated in Figure 5-39, Figure 5-40, and Figure 5-41.

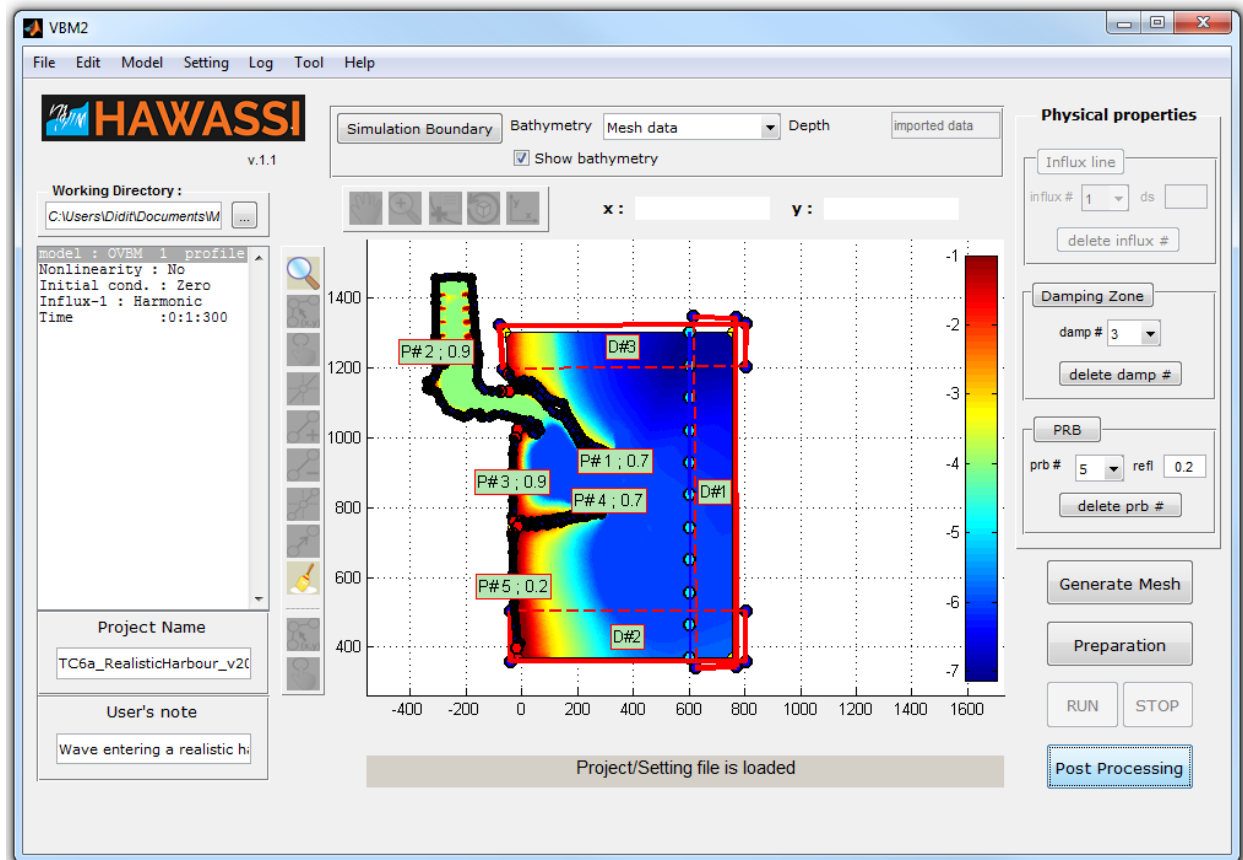


Figure 5-39 Domain settings of test case 6a

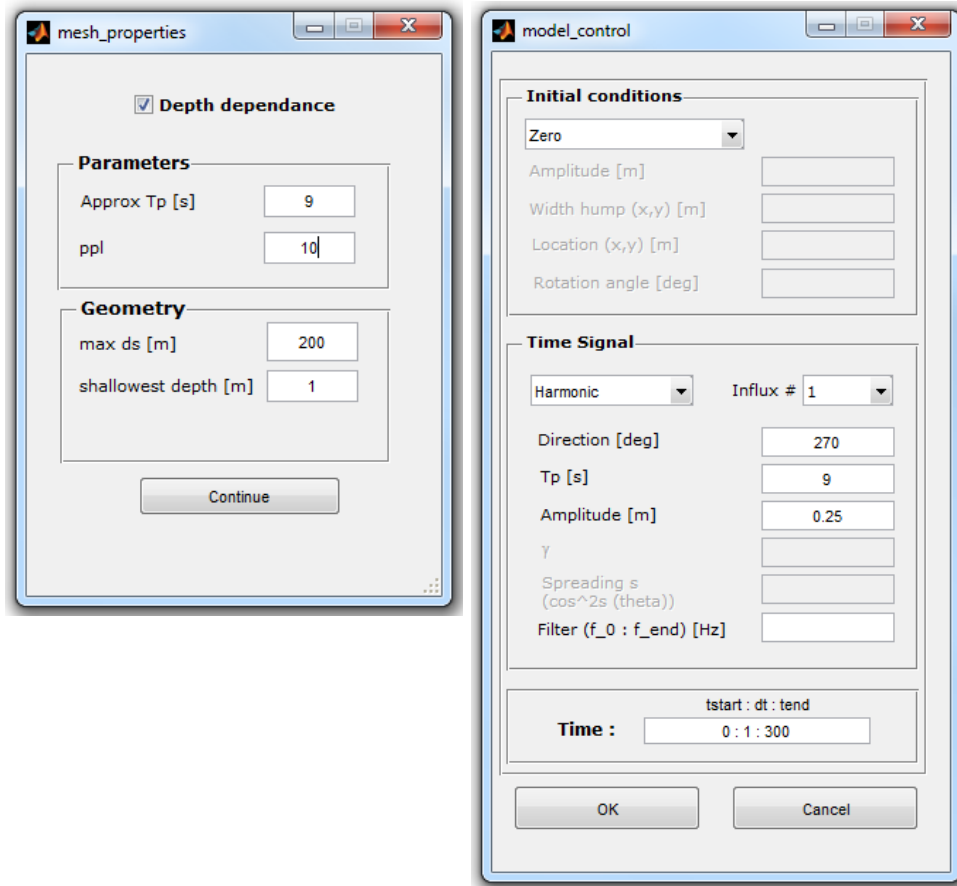


Figure 5-40 Settings for mesh properties and model control for the test case 6a

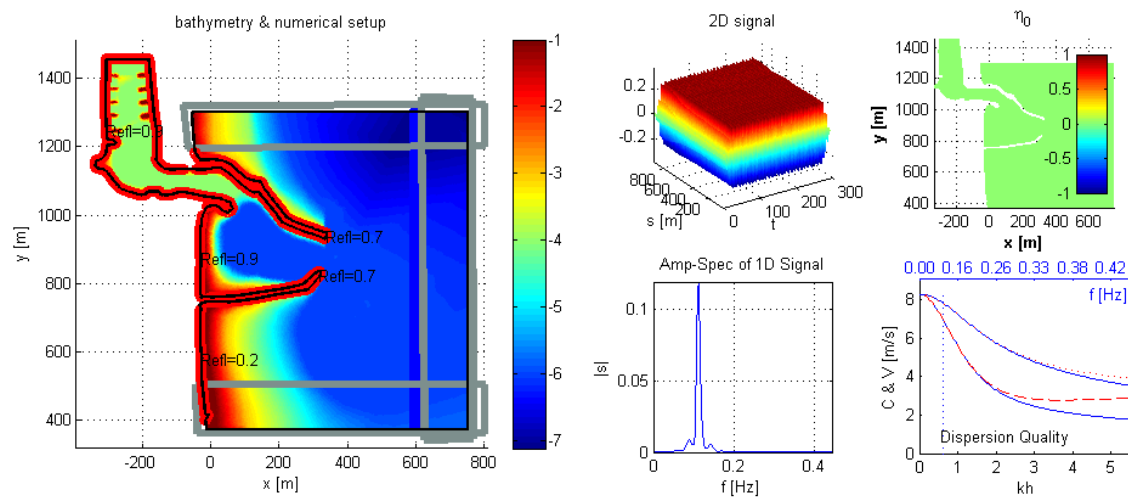


Figure 5-41 Model setup of test case 6a

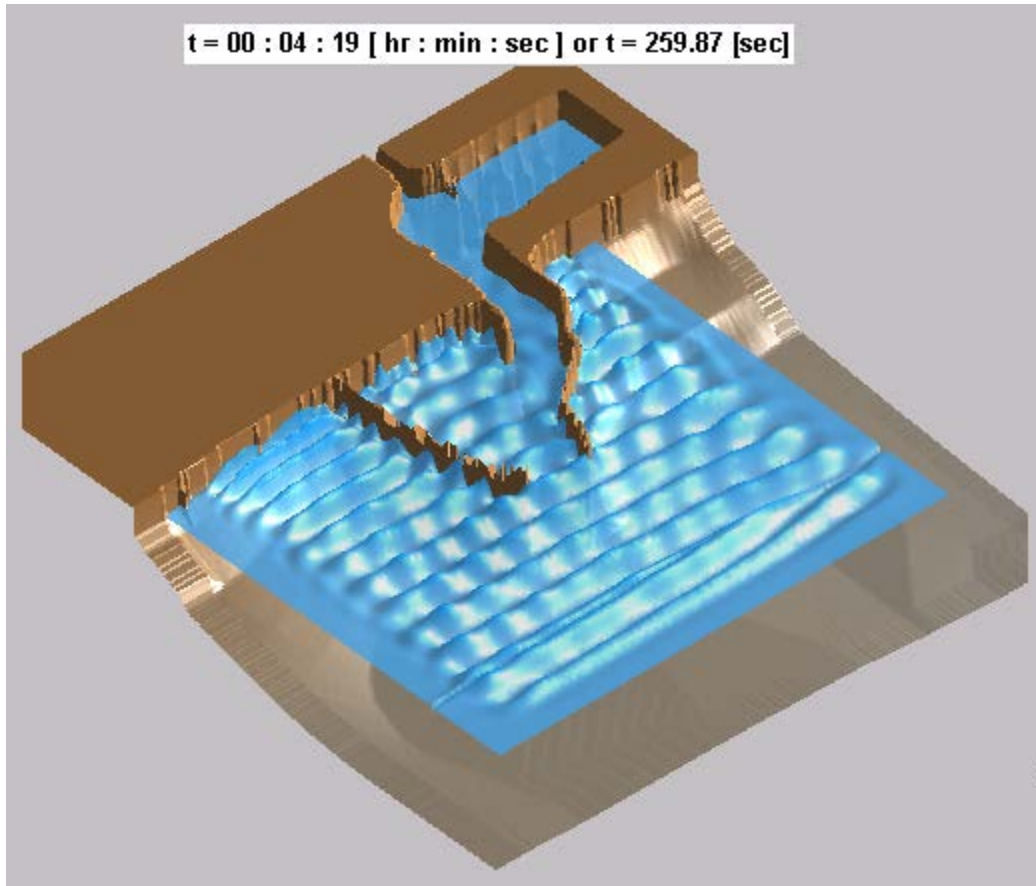


Figure 5-42 Test case 6a: Snapshot of the surface elevation

Observation

- Harbour lay-out in Google Earth (7043'44''S, 109001'32''E) in 2006
- Different type of harbour waves depending on wave type and on (main) incoming direction

Suggestion

- Quantify the 'wave energy' inside the 'fishing harbour' and investigate wave resonances there.
- Compare the wave disturbance caused by long-crested monochromatic and irregular waves, by short crested irregular waves, linear and nonlinear simulations

5.7.2 Breakwater configuration-2

The domain configuration (as built in 2009), settings for the mesh generator and model control are illustrated in Figure 5-43, Figure 5-44, and Figure 5-45.

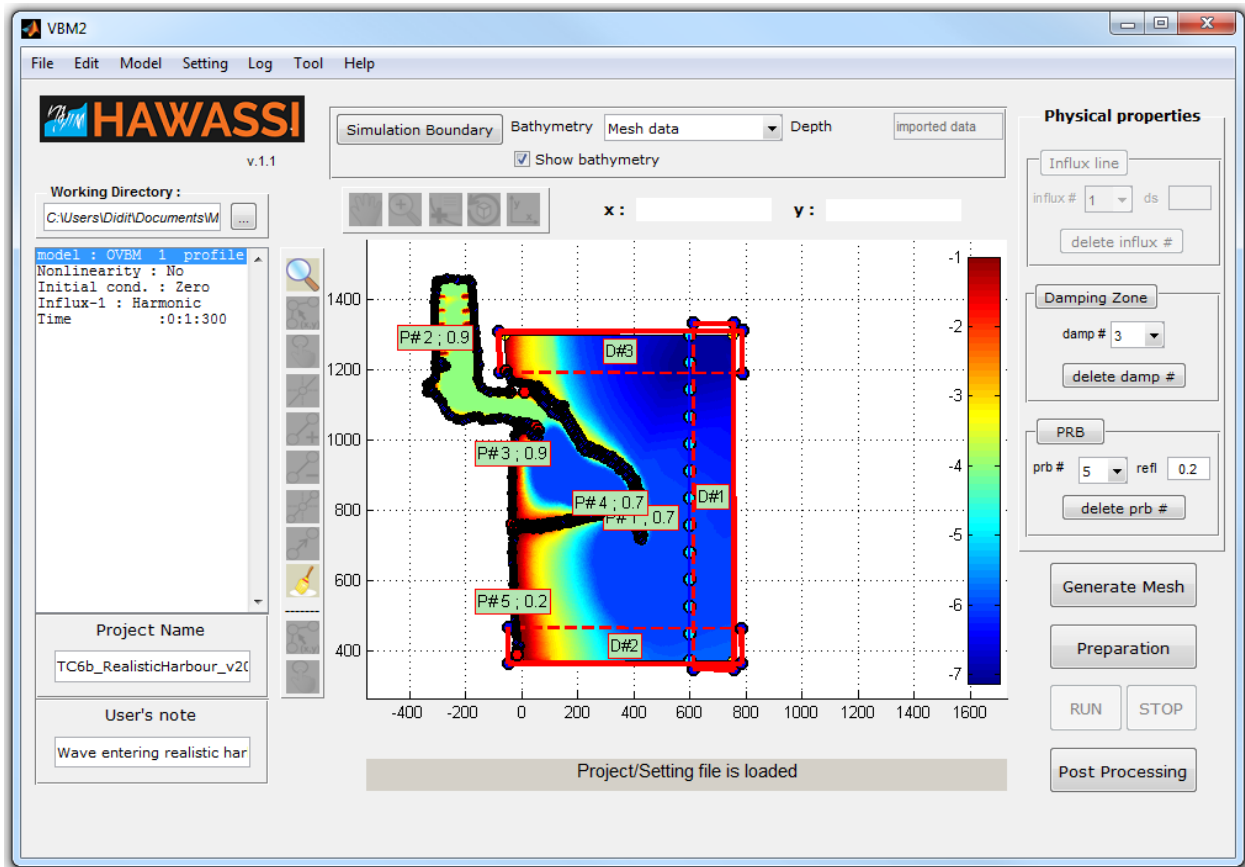


Figure 5-43 Domain settings of test case 6b

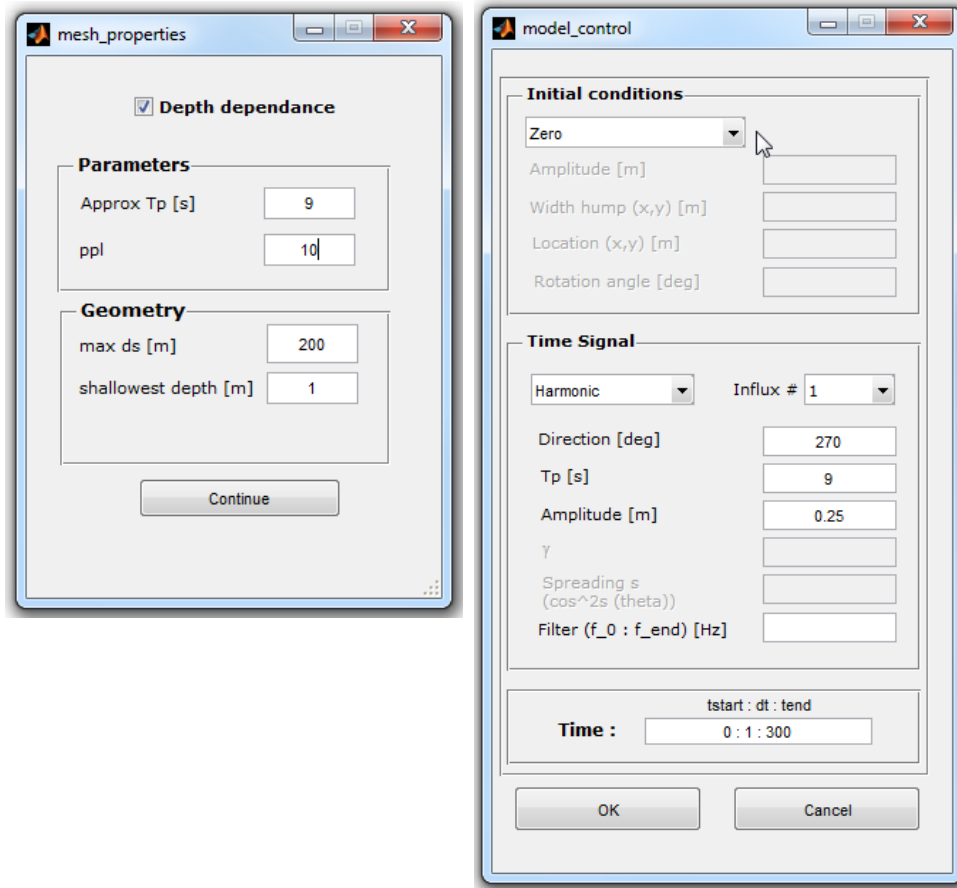


Figure 5-44 Settings for mesh properties and model control for the test case 6b

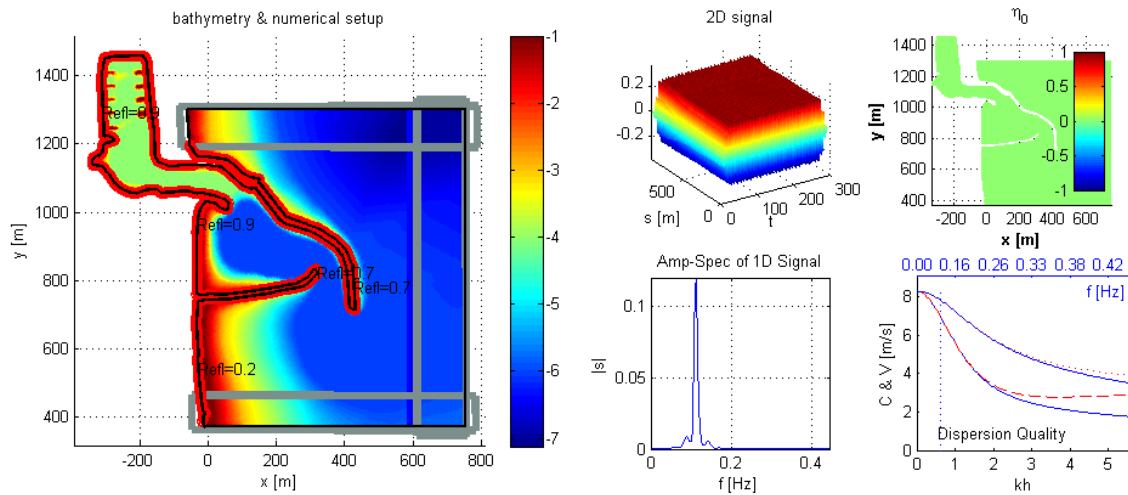


Figure 5-45 Model setup of test case 6b

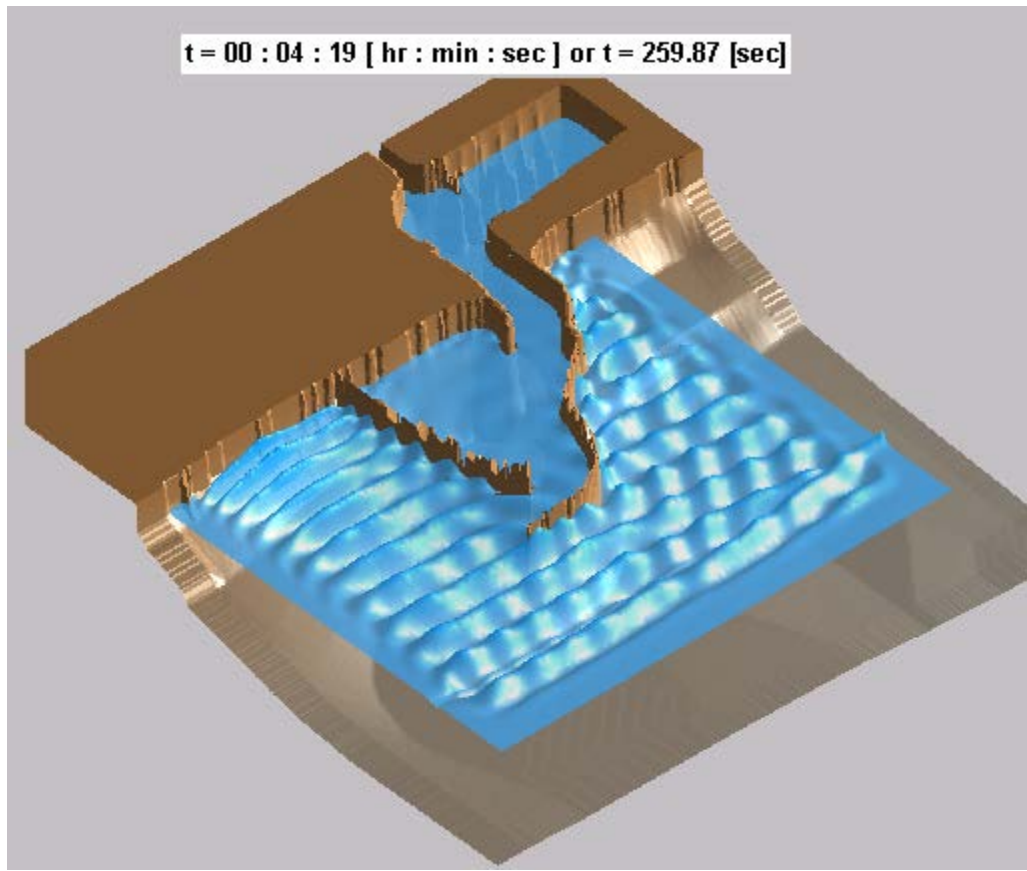


Figure 5-46 Test case 6b: Snapshot of the surface elevation

Observation

- Harbour lay-out in Google Earth (7043'44''S, 109001'32''E) in > 2009
- Different type of harbour waves depending on wave type and on (main) incoming direction

Suggestion

- Quantify the 'wave energy' inside the 'fishing harbour' and investigate wave resonances there.
- Compare (wave disturbance) simulations with long-crested monochromatic and irregular waves, with simulations of short crested irregular waves, linear and nonlinear

6 References

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- Gert Klopman, Brenny van Groesen, Maarten W. Dingemans, A variational approach to Boussinesq modelling of fully non-linear water waves, *Journal Fluid Mechanics* **657** (2010) 36-63
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- E. van Groesen, D. Adytia & Andonowati, Near-coast tsunami waveguiding: phenomenon and simulations, *Natural Hazards and Earth System Sciences*, **8**(2008) 175-185.
- G. Klopman, M. Dingemans & E. Van Groesen, Propagation of wave groups over bathymetry using a variational Boussinesq model, Proceedings *Int. Workshop on Water Waves and Floating Bodies*, (eds: Šime Malenica and Ivo Senjanović), Plitvice, Croatia, April 2007, pp125-128.
- G. Klopman. M. Dingemans & E. van Groesen, A variational model for fully non-linear water waves of Boussinesq type, *Proceedings of 20th International Workshop on Water Waves and Floating Bodies*, Spitsbergen, Norway, 29 May - 1 June 2005

Appendix I

```

SWAN      1                               Swan standard spectral file, version
$ Data produced by SWAN version 41.01
$ Project:'projname'      ;   run number:'runnum'
LOCATIONS                                locations in x-y-space
      1                                number of locations
      22222.22      0.00
RFREQ                                         relative frequencies in Hz
      25                                number of frequencies
      0.0418
      0.0477
      0.0545
      0.0622
      0.0710
      0.0810
      0.0924
      0.1055
      0.1204
      0.1375
      0.1569
      0.1791
      0.2045
      0.2334
      0.2664
      0.3040
      0.3470
      0.3961
      0.4522
      0.5161
      0.5891
      0.6724
      0.7675
      0.8761
      1.0000
CDIR                                         spectral Cartesian directions in degr
      12                                number of directions
      30.0000
      60.0000
      90.0000
      120.0000

```

QUANT

1

VaDens

 $\text{m}^2/\text{Hz}/\text{degr}$

-0.9900E+02

FACTOR

0.675611E-06

[illegible]