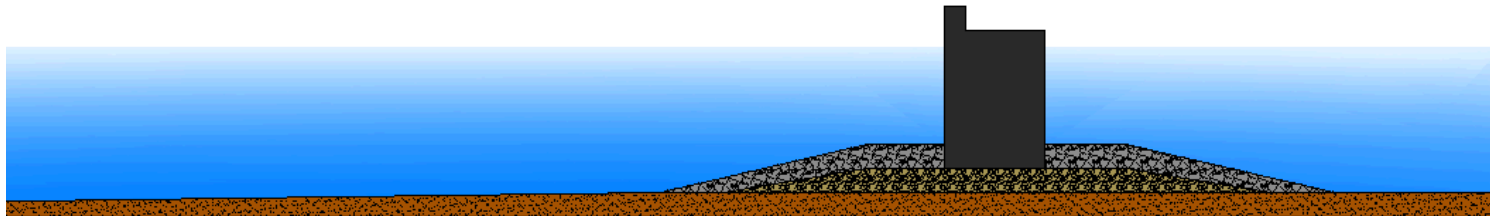


Example 3

Irregular waves interaction with a vertical breakwater



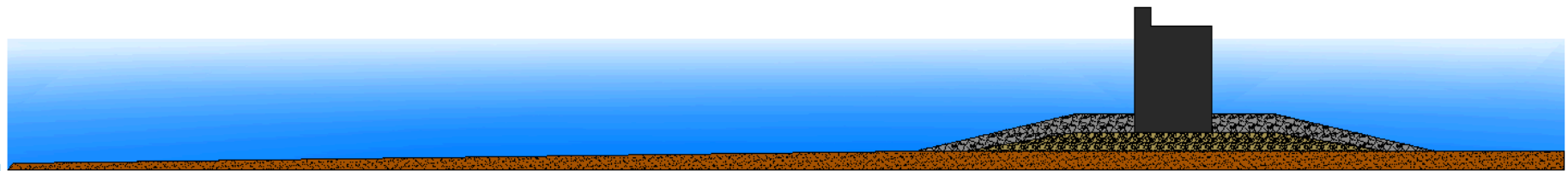
Maria Maza (mazame@unican.es)

Study of a Vertical Breakwater

A vertical breakwater is studied in this example. The breakwater is composed by a vertical caisson disposed over a rubble mound.

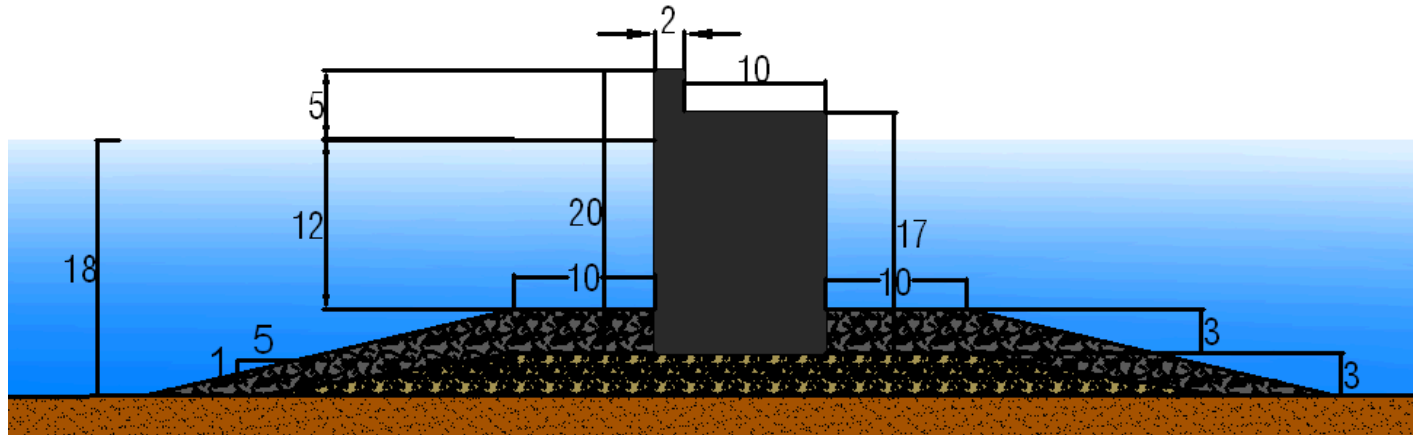
The bathymetry has a uniform 1:100 slope from the wave generation region to the toe of the structure. The seabed is considered horizontal at the breakwater location

The water depth in front of the breakwater is 18m. The submerged berm crest is 12 m deep. The vertical breakwater freeboard is 5 m. The rubble-mound slopes are 5H:1V.



Study of a Vertical Breakwater

The foundation is built by an outer layer made of 5 t quarry stones. The inner layer is formed by quarry material of 0.3 m of nominal diameter.



The purpose of this example is to study the interaction between irregular waves and a vertical breakwater.

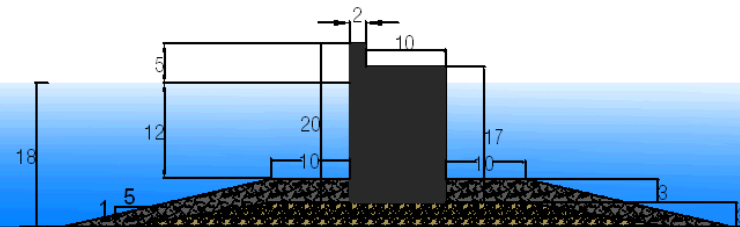
The breakwater is tested considering **irregular waves** with a significant wave height equal to **9m** and a peak wave period of **12s**. Wave energy is distributed following a **Jonswap**-type spectrum with a peak enhancement factor of **3.3**.

Study of a Vertical Breakwater

IH2-VOF model is used to obtain the free surface, horizontal and vertical velocities, pressure and turbulence in the entire domain. Maximum pressure and forces in the structure are calculated. Furthermore, energy spectra and free surface time series in some desired locations are obtained.

- **Objectives:**

- Wave conditions analysis: time series, wave spectra
- Overtopping
- Pressure: stability analysis, forces in the caisson



- Select directory, Select Folder
- Create New Case



STEPS

PREPROCESSING

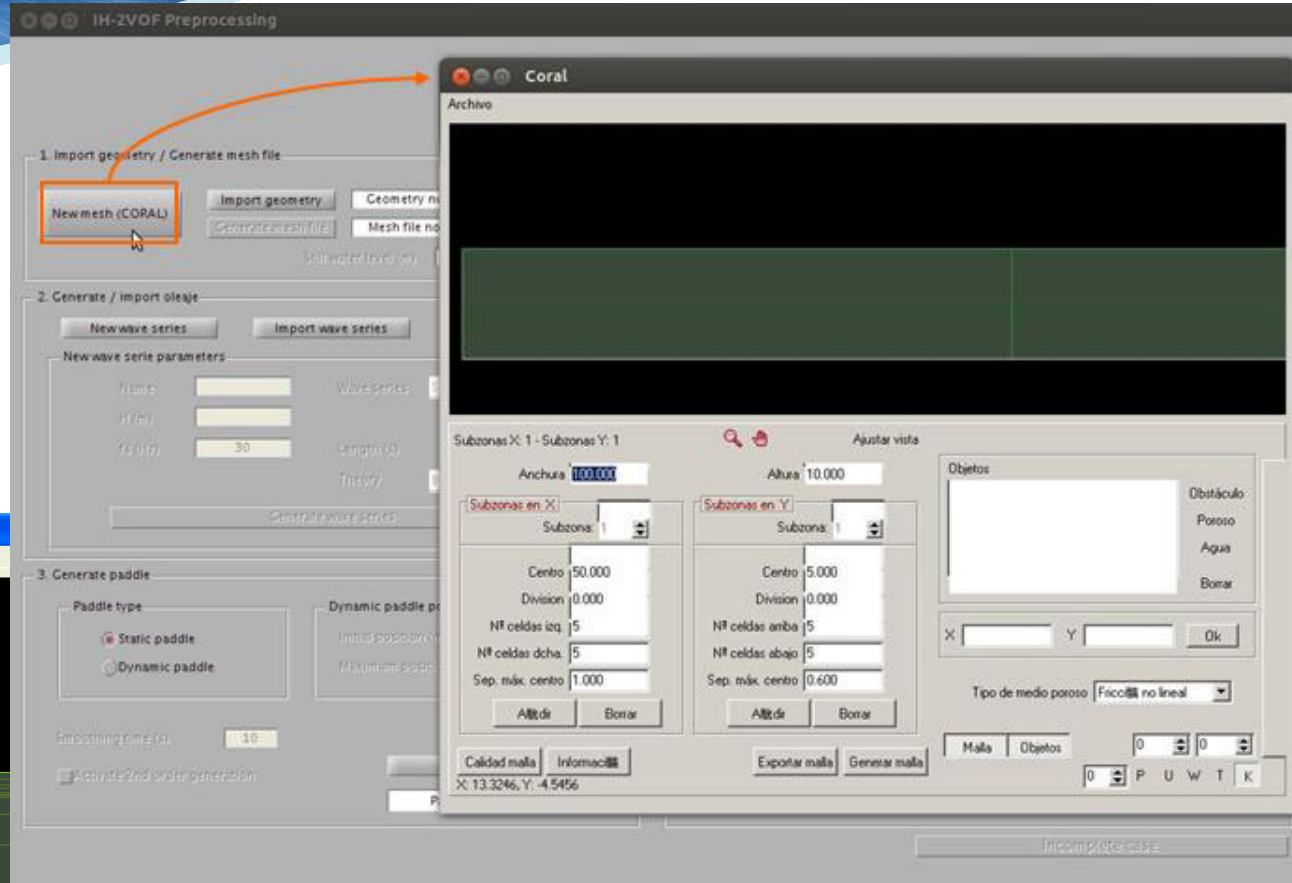
- MESH GENERATION
- SECTION 1: “IMPORT GEOMETRY/GENERATE MESH FILE”
- SECTION 2: “GENERATE/IMPORT WAVE CONDITIONS”
- SECTION 3: “GENERATE PADDLE”
- SECTION 4: “GENERATE INPUT FILE”

POSTPROCESSING

- WAVE GAUGES
- OVERTOPPING
- PRESSURE
- DRAWFAST

MESH GENERATION

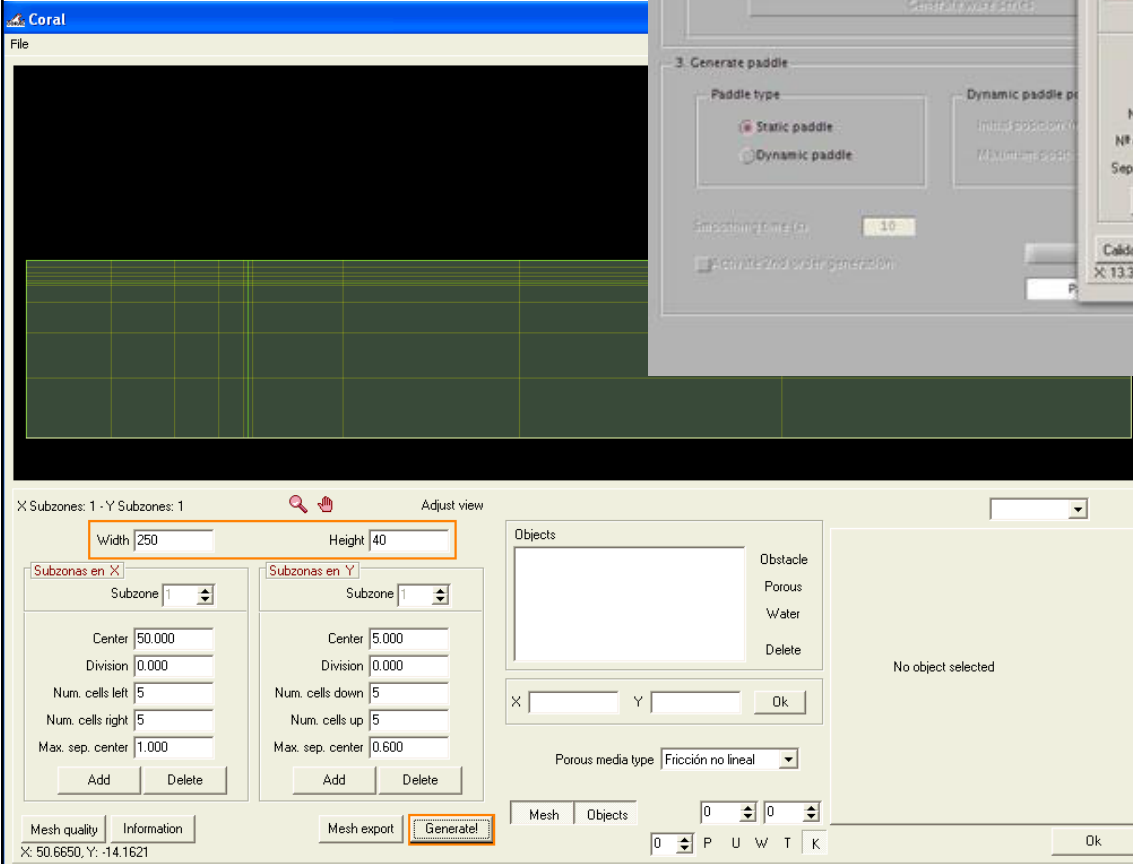
-New mesh (CORAL):
CORAL mesh generator is opened



- Domain specification:

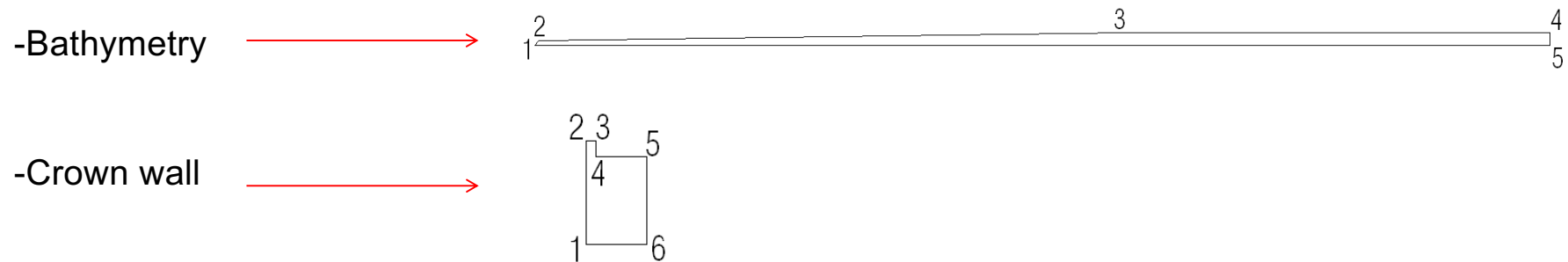
$L = 152\text{m}$, considering around $1.5L$ before the breakwater: **width = 250m**

Rubble mound total height is equal to 25m, considering possible overtopping events: **height = 40m**



MESH GENERATION: Defining the elements

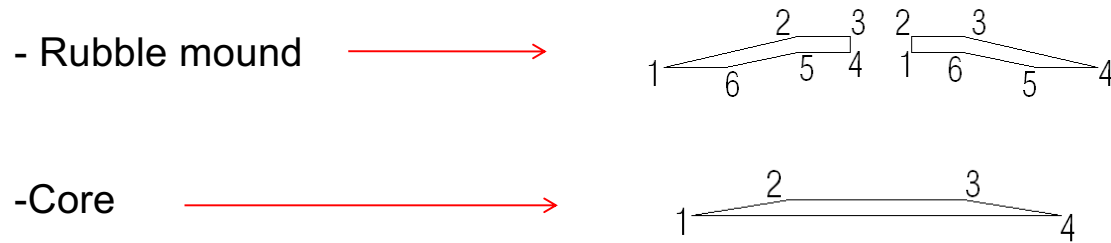
Introduce **obstacles**:



Element	Vertices	X Coordinate	Y Coordinate
Bathymetry	1	-1	-1
	2	-0.8	0
	3	146	2
	4	251	2
	5	251	-1
Caisson	1	181.5	6
	2	181.5	26
	3	184	26
	4	184	23
	5	194	23
	6	194	6

MESH GENERATION: Defining the elements

Introduce **porous media**:



Element	Vertices	X Coordinate	Y Coordinate
Core	1	154	2
	2	172	6
	3	204	6
	4	222	2
Rubble mound 1	1	146	2
	2	172	9
	3	181.5	9
	4	181.5	6
	5	172	6
	6	154	2
Rubble mound 2	1	194	6
	2	194	9
	3	204	9
	4	230	2
	5	222	2
	6	204	6

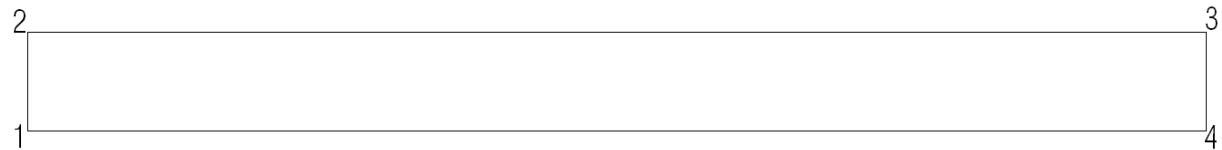
MESH GENERATION: Defining the elements

Introduce porous media properties:

Characteristic	Rubble Mound 1	Rubble Mound 2 & 3
Porosity	0.35	0.45
Linear friction coef.	200	200
Non-Linear friction coef.	0.70	1.00
Added mass coef.	0.34	0.34
D50	0.30	1.25

MESH GENERATION: Defining the elements

Introduce water: →



Element	Vertices	X Coordinate	Y Coordinate
Water	1	-1	-1
	2	-1	20
	3	251	20
	4	251	-1

MESH GENERATION: Spatial discretization

At least 10 cells per wave height! ($H = 9\text{m}$)

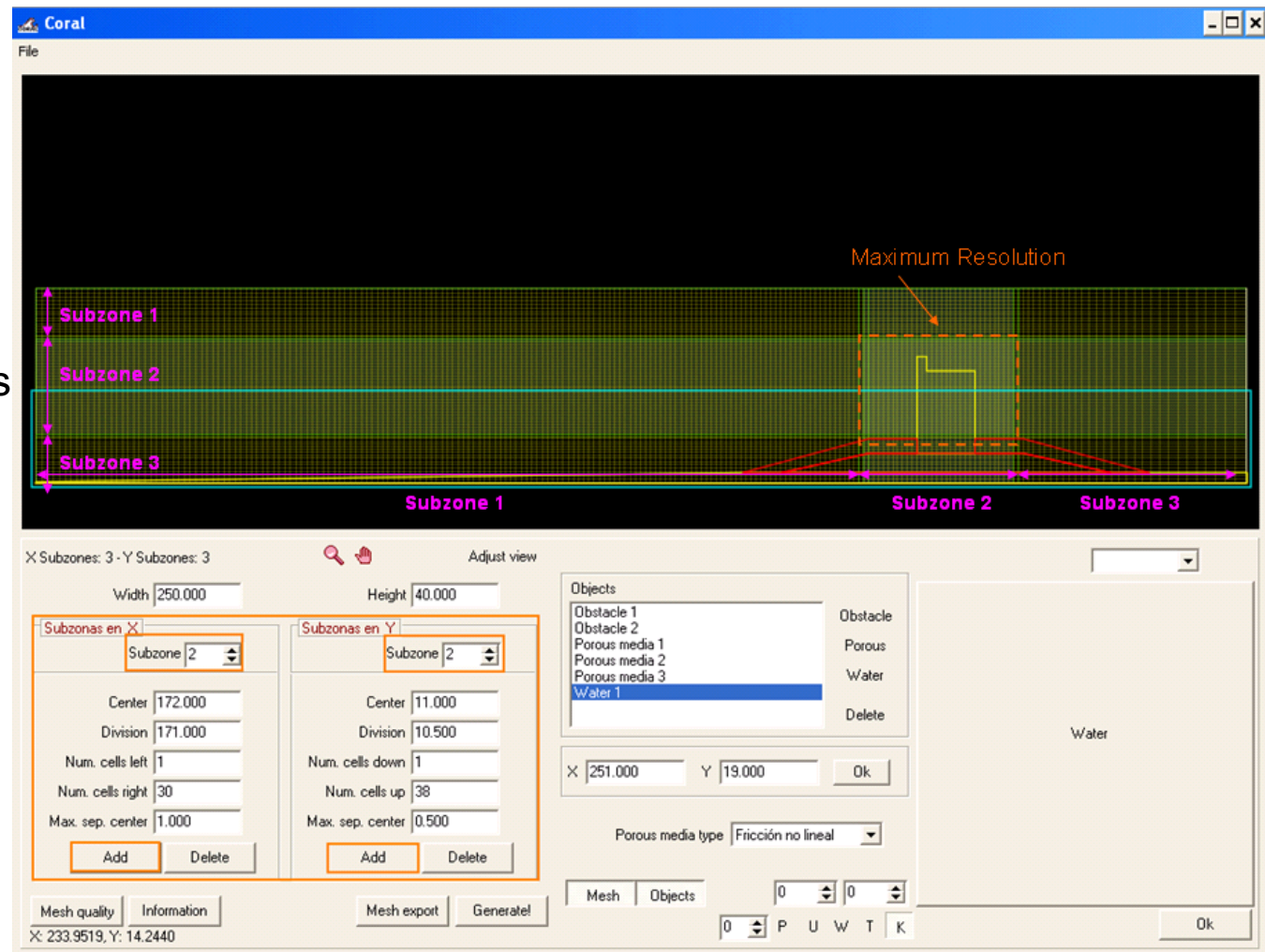
→ $\Delta y = 0.9\text{m}$

Because overtopping events are expected

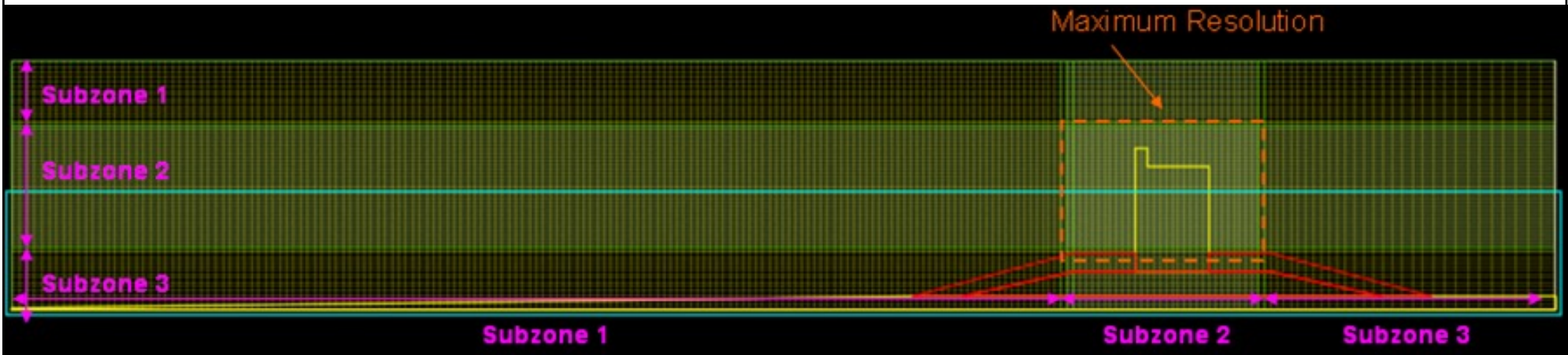
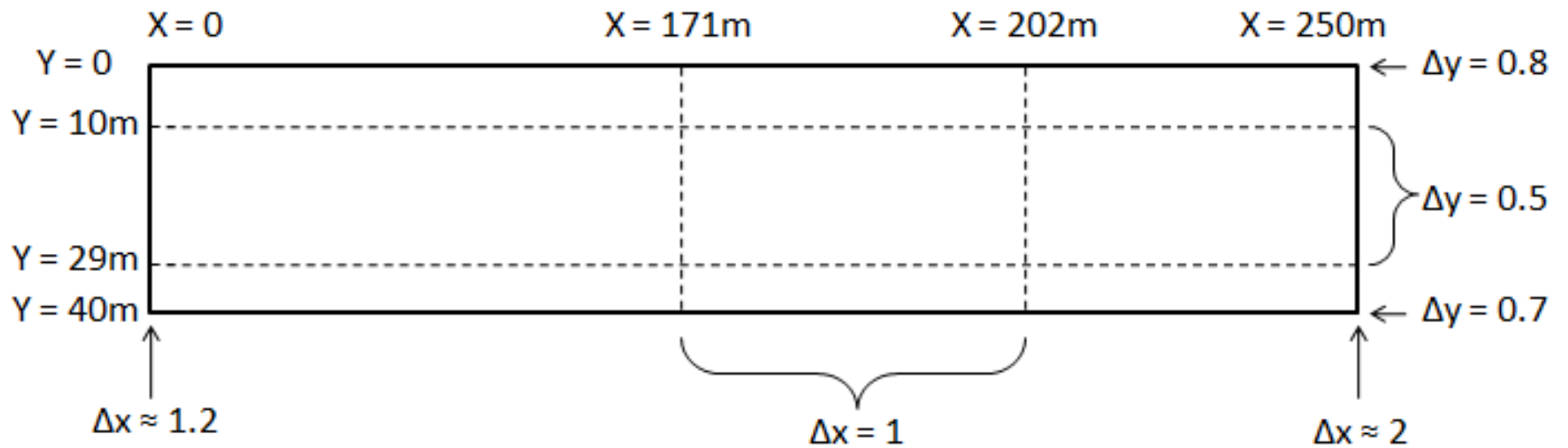
→ $\Delta y = 0.5\text{m}$

Aspect ratio: $\Delta x/\Delta y=2$

→ $\Delta x = 1\text{ m}$



Variable grid system in both the horizontal and the vertical directions : three subzones

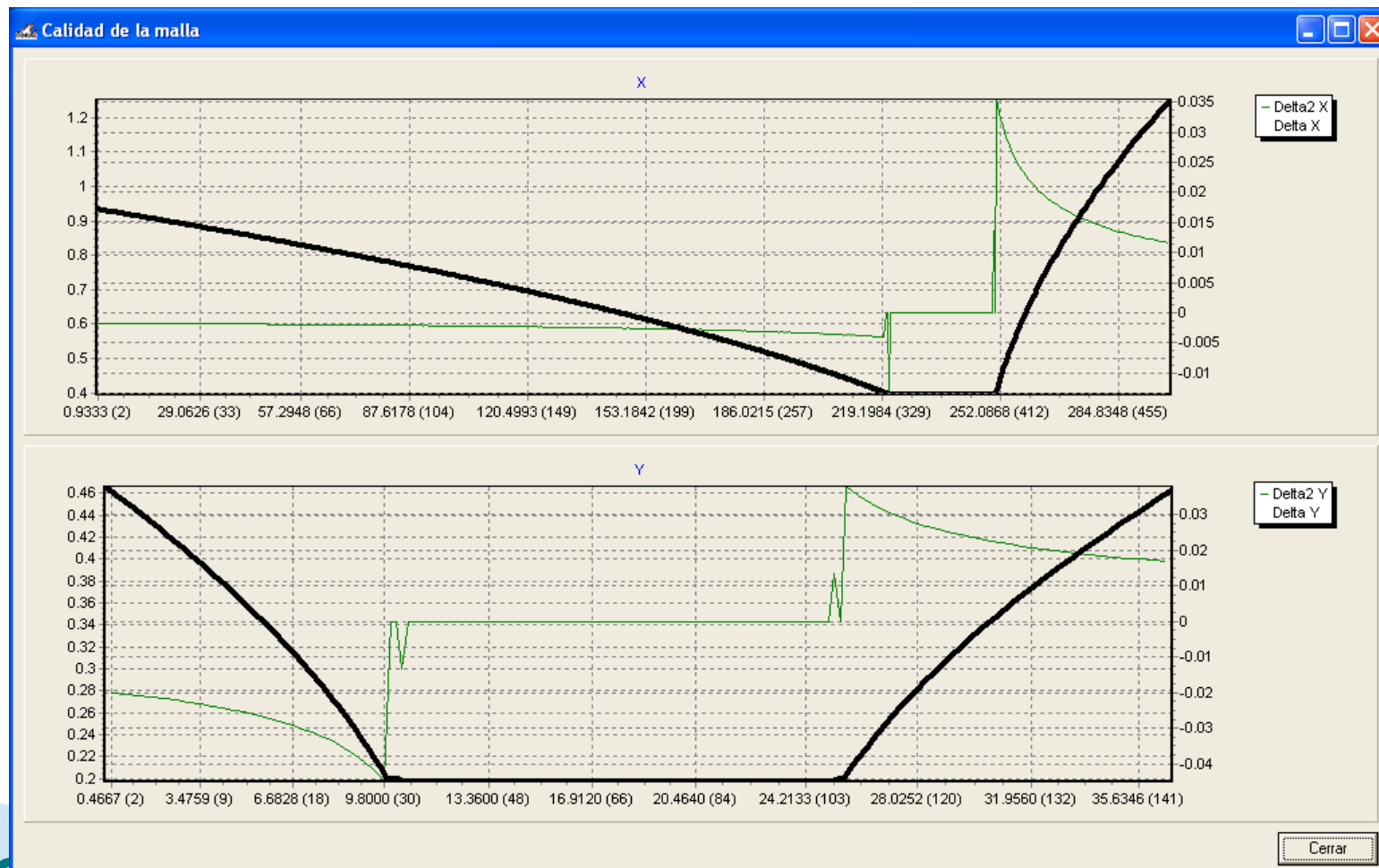


MESH GENERATION: Spatial discretization

	X Direction			Y Direction		
	Subzone 1	Subzone 2	Subzone 3	Subzone 1	Subzone 2	Subzone 3
Center	170.00	172.00	203.00	10.00	11.00	29.50
Division	0.00	171.00	202.00	0.00	10.50	29.00
Num. cells left	155	1	1	15	1	1
Num. cells right	1	31	30	1	36	16
Max. sep. center	1.00	1.00	1.00	0.50	0.50	0.50

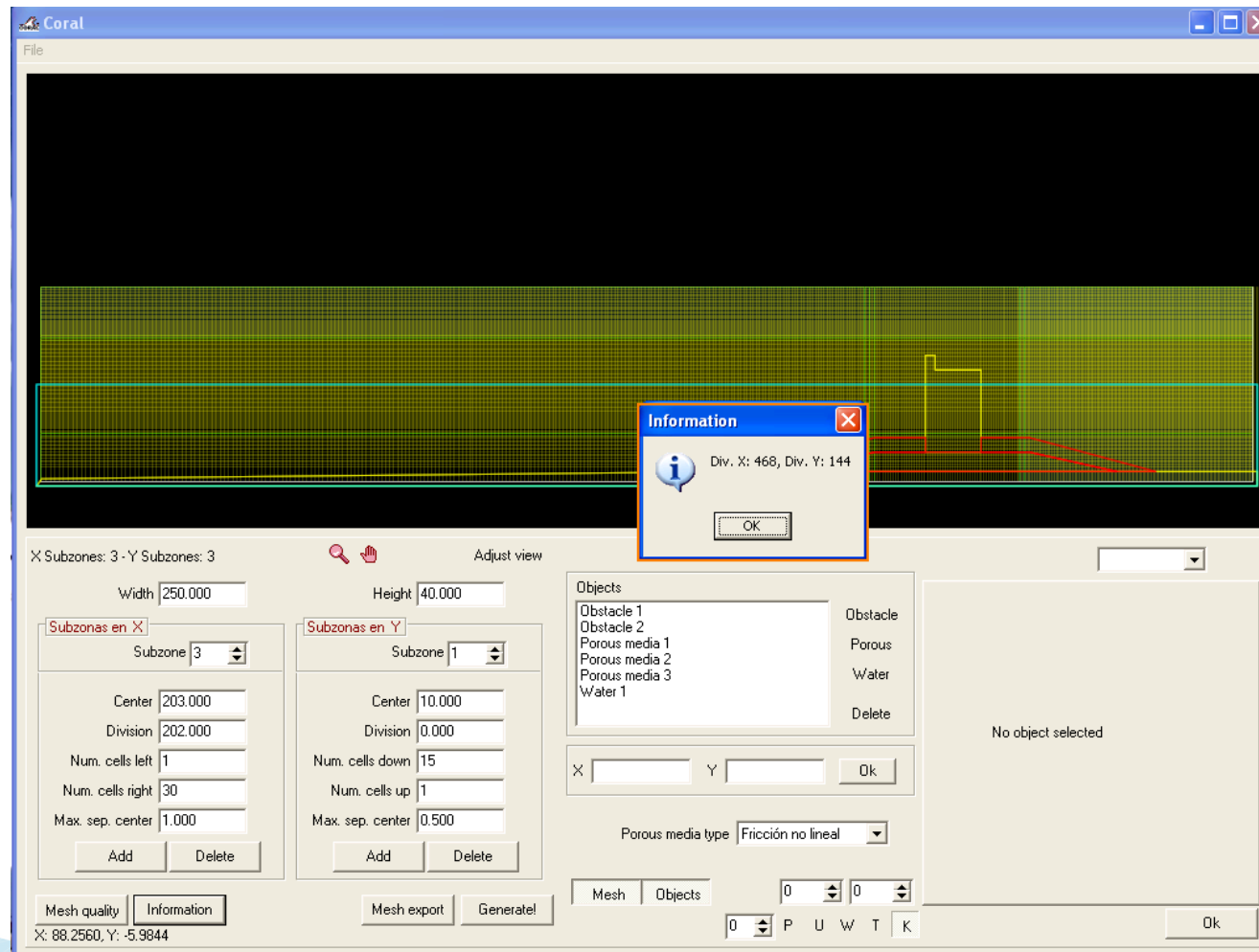
MESH GENERATION: Mesh quality

By pressing button “Mesh quality”:



MESH GENERATION: Mesh info

By pressing button “Information”:



SECTION 1 : “IMPORT GEOMETRY/GENERATE MESH FILE”

-Saving the generated mesh its **“.dat”** file appears in **green** in the GUI

-Mesh characteristics are exported to a **“Mesh.mes”**



SECTION 2 : “GENERATE/IMPORT WAVE CONDITIONS”

-Wave series: Irregular

-Hs = 9m

-Tp = 12s

- Time series 800 s long

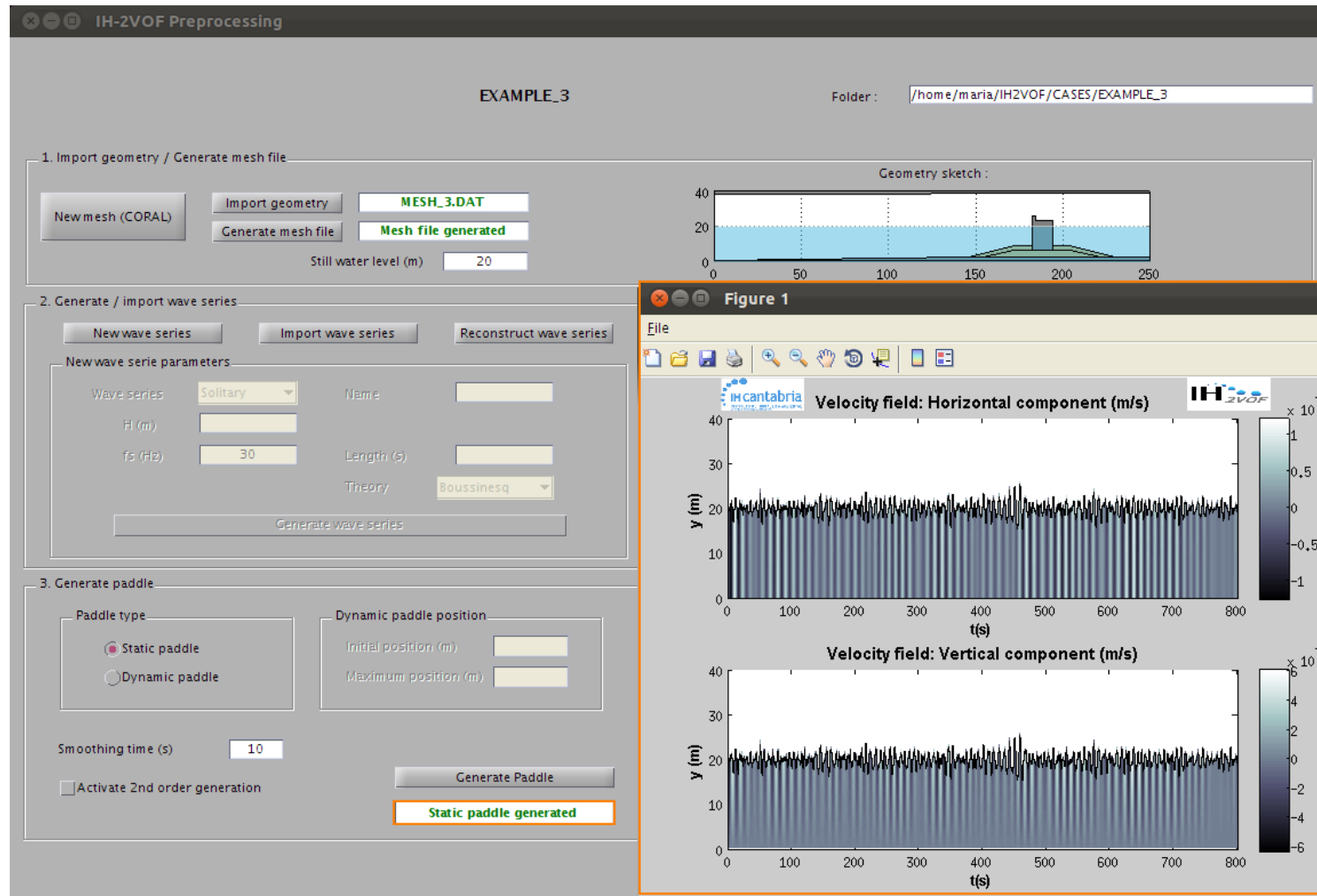
Generate wave series

The screenshot displays the IH-2VOF Preprocessing software interface. The main window shows the 'EXAMPLE_3' project with a folder path of '/hpme/maria/IH2VOF/CASES/EXAMPLE_3'. The '1. Import geometry / Generate mesh file' section includes buttons for 'New mesh (CORAL)', 'Import geometry', and 'Generate mesh file', with 'MESH_EXAMPLE3.DAT' and 'Mesh file generated' displayed. A 'Still water level (m)' field is set to 20. A 'Geometry sketch' plot shows a cross-section of a structure in a channel. The 'Selected wave series' panel is highlighted, showing an 'Irregular' wave series named 'lrr' with 83 waves, a length of 800s, and a sampling frequency of 30 Hz. Key parameters include Hm = 5.72m, Hs = 9.01m, Tm = 9.38s, Ts = 12.21s, and Tp = 13.32s. The '4. Generate input file' section shows simulation length (800s), initial dt (0.005s), and fluid density (1000 kg/m³). Checkboxes for 'Left boundary absorption', 'Right boundary absorption', 'VOF', 'Horizontal velocity', 'Vertical velocity', 'Pressures', and 'Turbulence' are all checked. A 'Sampling frequency (Hz)' field is set to 10. Buttons for 'Wave gauges', 'Fs (Hz)', 'Run-up', 'Pressure', and 'Save input file' are visible. A status bar at the bottom indicates 'Incomplete case'.

The 'Figure 1' window displays several analysis plots: 'Free surface' (k(m) vs Time(s)), 'Wave height histogram' (Num. of waves vs H(m)), 'Wave period histogram' (Num. of waves vs T(sec)), 'JONSWAP Spectrum' (S(m²/s) vs f(Hz)), and 'Wave height vs. Period' (T(s) vs H(m)).

SECTION 3 : “GENERATE PADDLE

-Static wave paddle



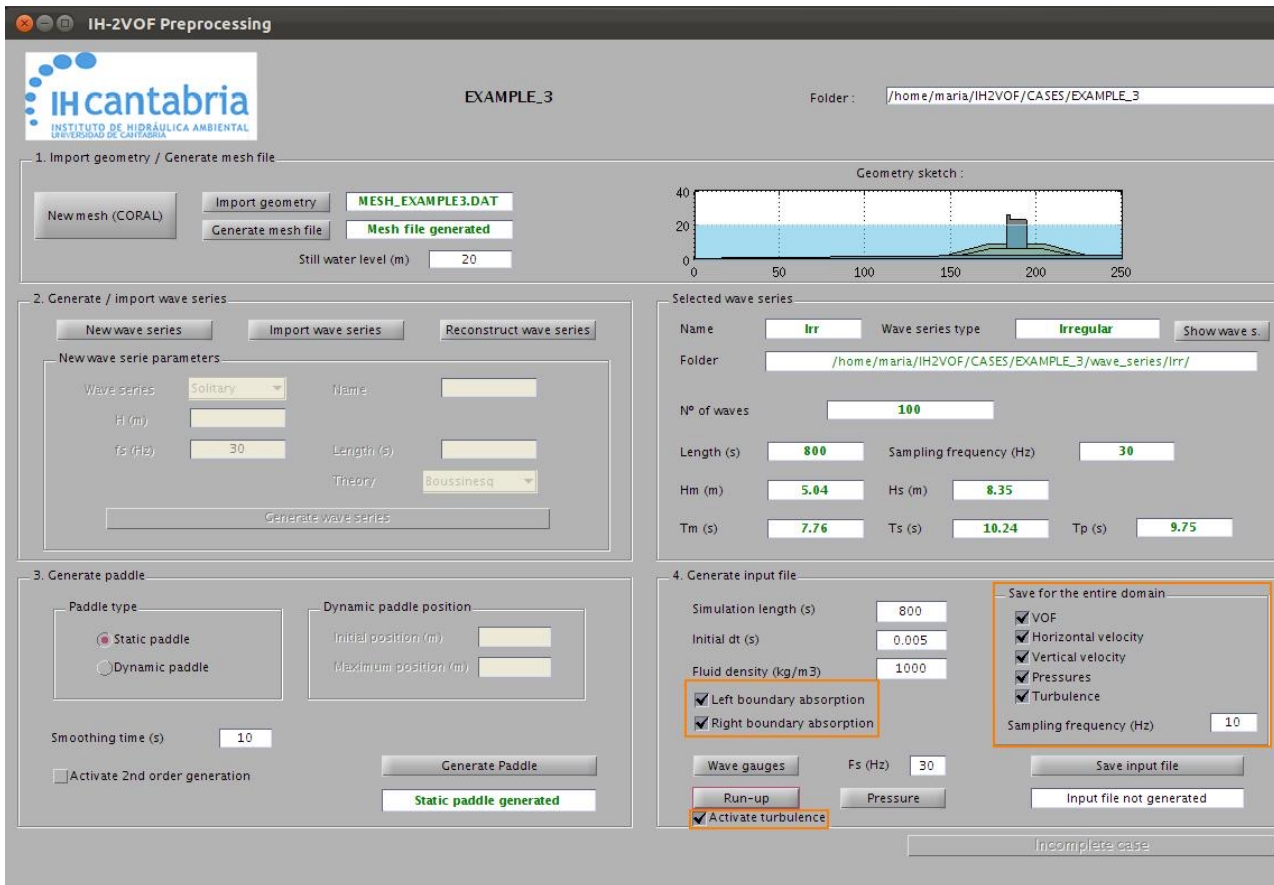
The screenshot displays the IH-2VOF Preprocessing software interface. The main window is titled "IH-2VOF Preprocessing" and shows the "EXAMPLE_3" project. The folder path is "/home/maria/IH2VOF/CASES/EXAMPLE_3".

The interface is divided into three main sections:

- 1. Import geometry / Generate mesh file:** This section includes buttons for "New mesh (CORAL)", "Import geometry", and "Generate mesh file". The "Import geometry" button is highlighted, and the file "MESH_3.DAT" is listed. Below these buttons, the "Still water level (m)" is set to 20. A "Mesh file generated" status message is visible. To the right, a "Geometry sketch" shows a cross-section of a channel with a central paddle structure.
- 2. Generate / import wave series:** This section includes buttons for "New wave series", "Import wave series", and "Reconstruct wave series". Under "New wave serie parameters", the "Wave series" is set to "Solitary", "H (m)" is empty, "fs (Hz)" is 30, "Length (s)" is empty, and "Theory" is "Boussinesq". A "Generate wave series" button is at the bottom.
- 3. Generate paddle:** This section includes "Paddle type" options: "Static paddle" (selected) and "Dynamic paddle". "Dynamic paddle position" fields for "Initial position (m)" and "Maximum position (m)" are empty. "Smoothing time (s)" is set to 10. There is a checkbox for "Activate 2nd order generation" and a "Generate Paddle" button. A "Static paddle generated" status message is highlighted in a yellow box.

Overlaid on the right side of the software interface is a window titled "Figure 1" showing two velocity field plots. The top plot is "Velocity field: Horizontal component (m/s)" and the bottom plot is "Velocity field: Vertical component (m/s)". Both plots show velocity (m/s) on the y-axis (ranging from -1 to 1 for horizontal and -6 to 10 for vertical) versus time (t(s)) on the x-axis (ranging from 0 to 800). The plots show oscillatory behavior over time.

SECTION 4 : “GENERATE INPUT FILE”



The screenshot shows the 'IH-2VOF Preprocessing' software interface. The main window title is 'IH-2VOF Preprocessing'. The interface is divided into four main sections:

- 1. Import geometry / Generate mesh file:** Includes buttons for 'New mesh (CORAL)', 'Import geometry', 'Generate mesh file', and 'Reconstruct wave series'. A 'Mesh file generated' status is shown. A 'Geometry sketch' plot shows a cross-section of a structure in a channel with a water level of 20m.
- 2. Generate / import wave series:** Includes 'New wave series', 'Import wave series', and 'Reconstruct wave series' buttons. Parameters for a 'Solitary' wave series are set: H (m) is empty, T_s (Hz) is 30, Length (s) is empty, and Theory is 'Boussinesq'. A 'Generate wave series' button is present.
- 3. Generate paddle:** Includes 'Paddle type' (Static paddle selected), 'Dynamic paddle position' (Initial position (m) and Maximum position (m) are empty), and 'Smoothing time (s)' set to 10. A 'Generate Paddle' button is present, with a 'Static paddle generated' status.
- 4. Generate input file:** Includes 'Simulation length (s)' set to 800, 'Initial dt (s)' set to 0.005, and 'Fluid density (kg/m³)' set to 1000. Checkboxes for 'Left boundary absorption' and 'Right boundary absorption' are checked. A 'Save for the entire domain' section has checkboxes for 'VOF', 'Horizontal velocity', 'Vertical velocity', 'Pressures', and 'Turbulence', all of which are checked. 'Sampling frequency (Hz)' is set to 10. A 'Save input file' button is present, with an 'Input file not generated' status.

- Simulation length = 200 s

- Initial dt = 0.005 s

- Left and right boundary absorption are activated

- VOF, horizontal and vertical velocity, pressure fields and turbulent intensity are saved

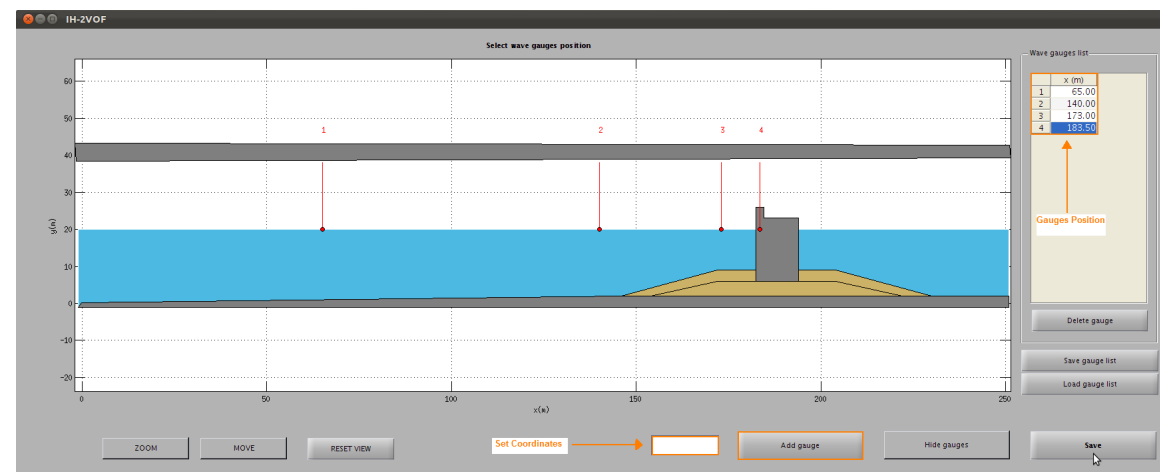
SECTION 4 : “GENERATE INPUT FILE” – *Wave gauges*

Different wave gauges are disposed in the domain to measured the wave conditions and overtopping.

Gauge	X(m)
1	65
2	140
3	173
4	183.5

Press the button Wave gauges - Add gauge

Gauges positions are specified

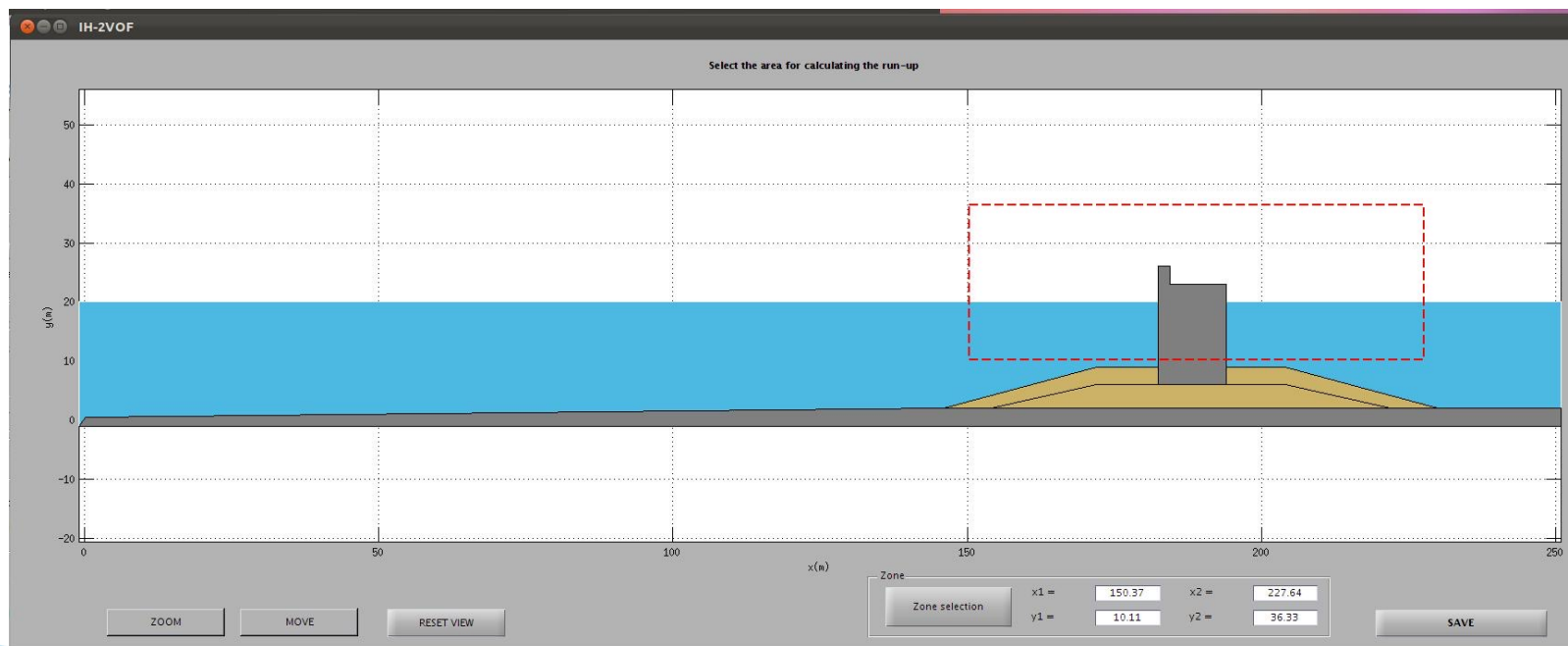


SECTION 4 : “GENERATE INPUT FILE” – *Run-up*

Press the button

Run-up

The area where run-up is calculated is selected specifying two vertices

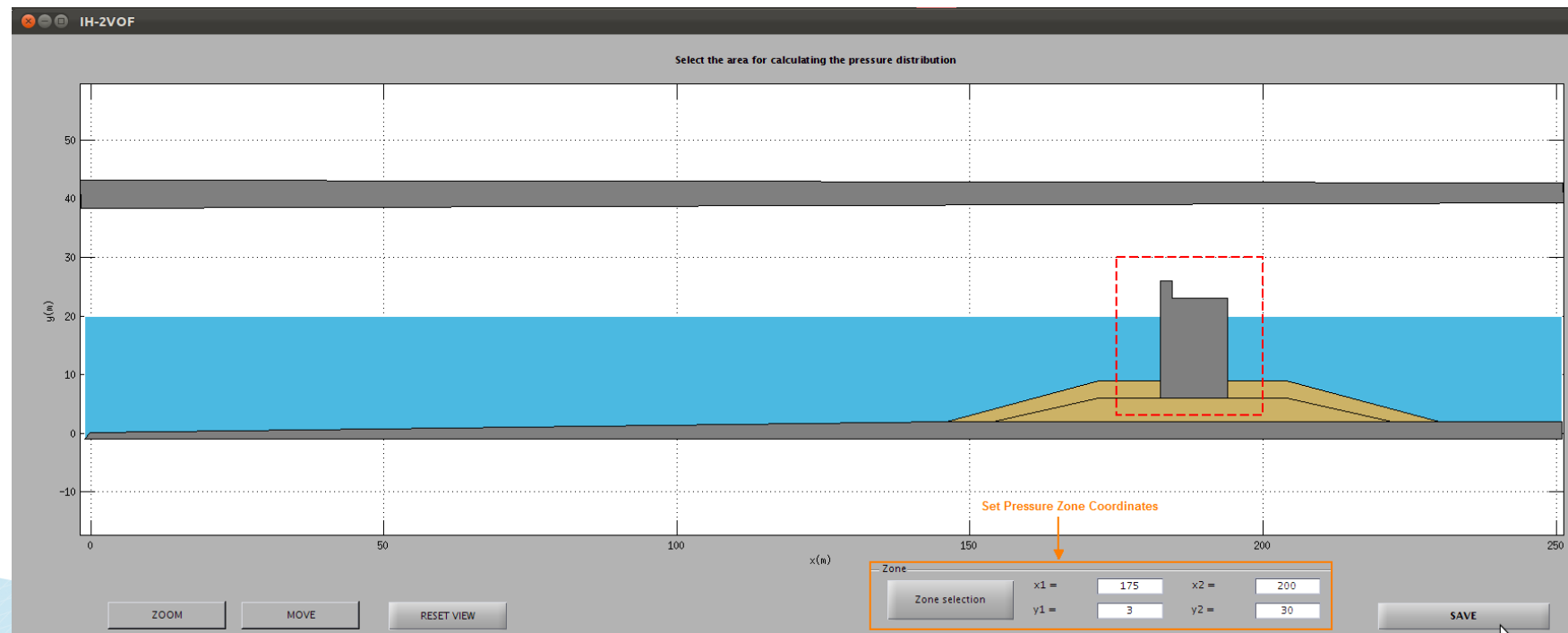


SECTION 4 : “GENERATE INPUT FILE” – Pressure

Press the button

Pressure

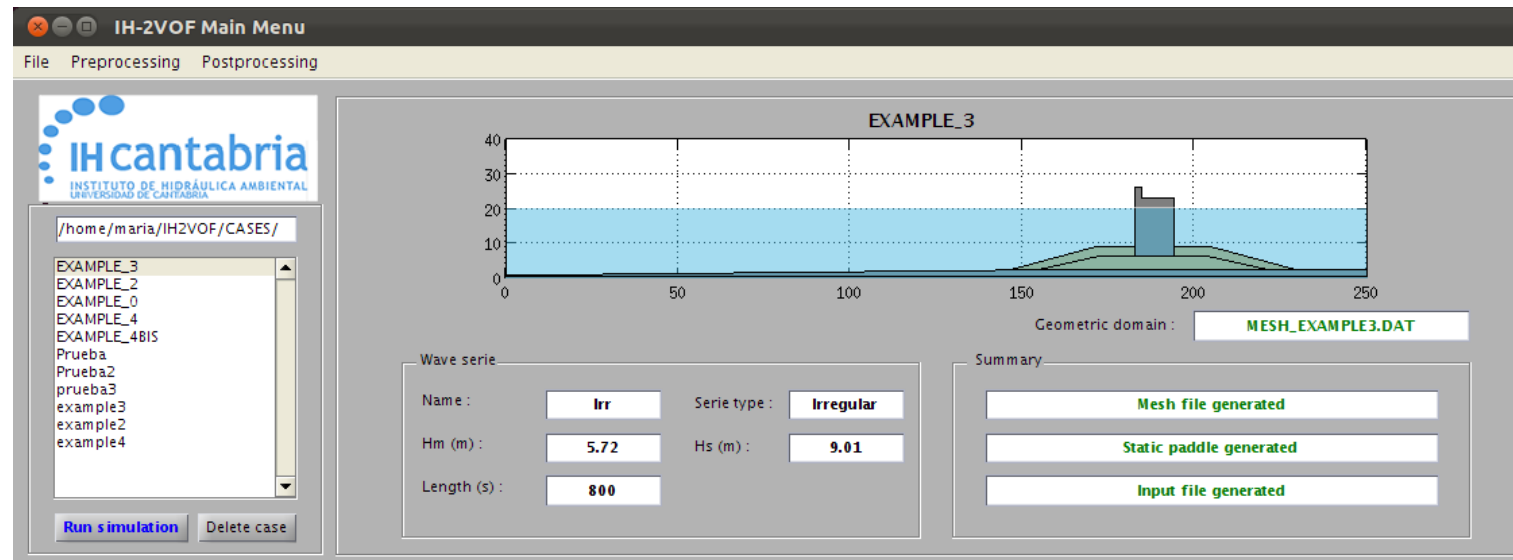
The area where pressure is calculated is selected specifying two vertices



SUMMARY

All the variables are defined
The input file is saved

→ the case is ready to be simulated

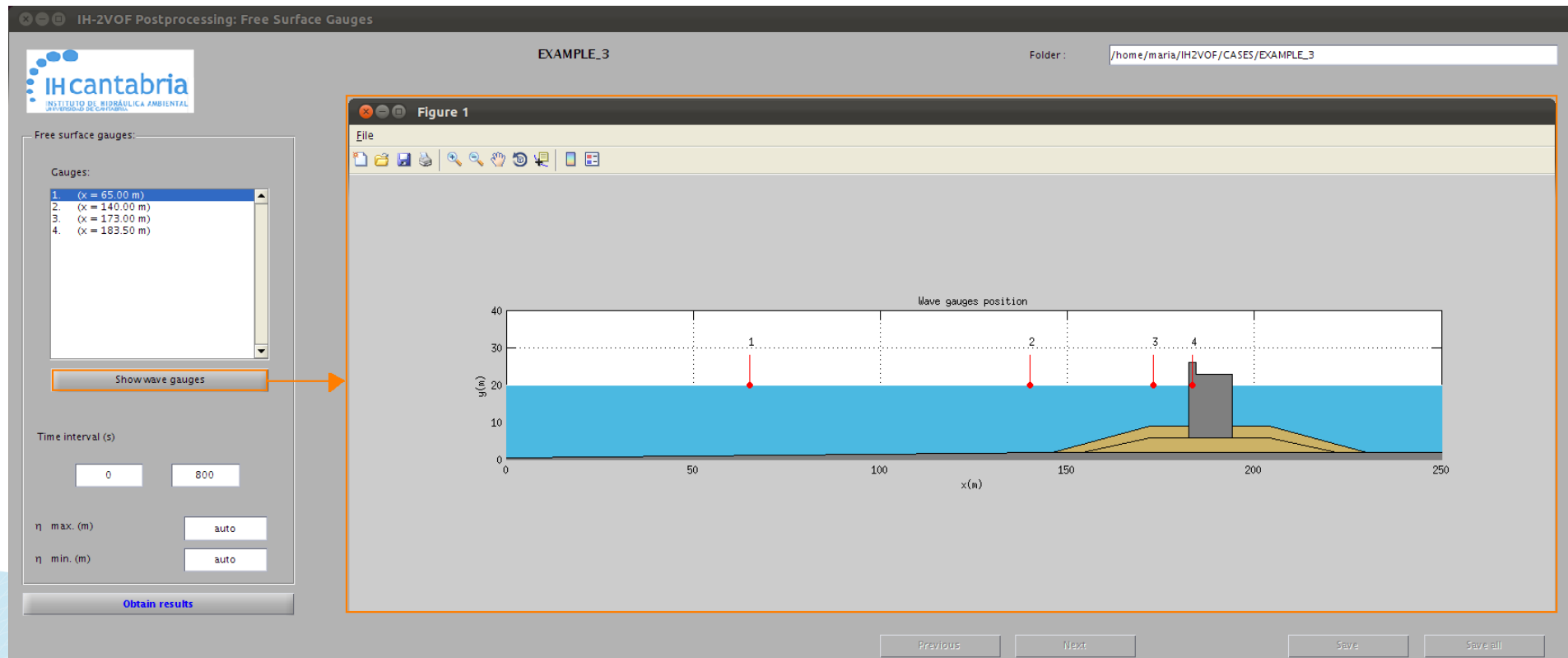


The simulation will start by pressing the button

Run simulation

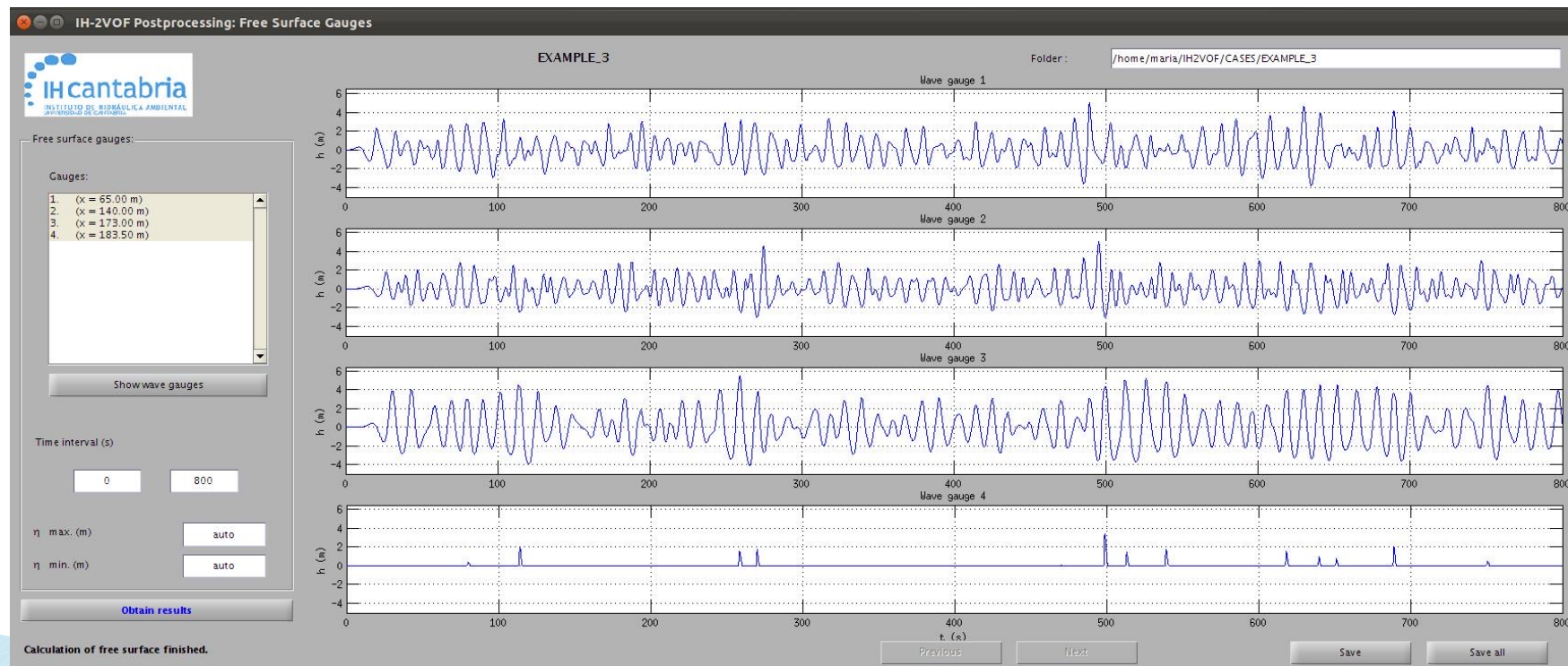
WAVE GAUGES – Show wave gauges

- 4 wave gauges were disposed along the domain.



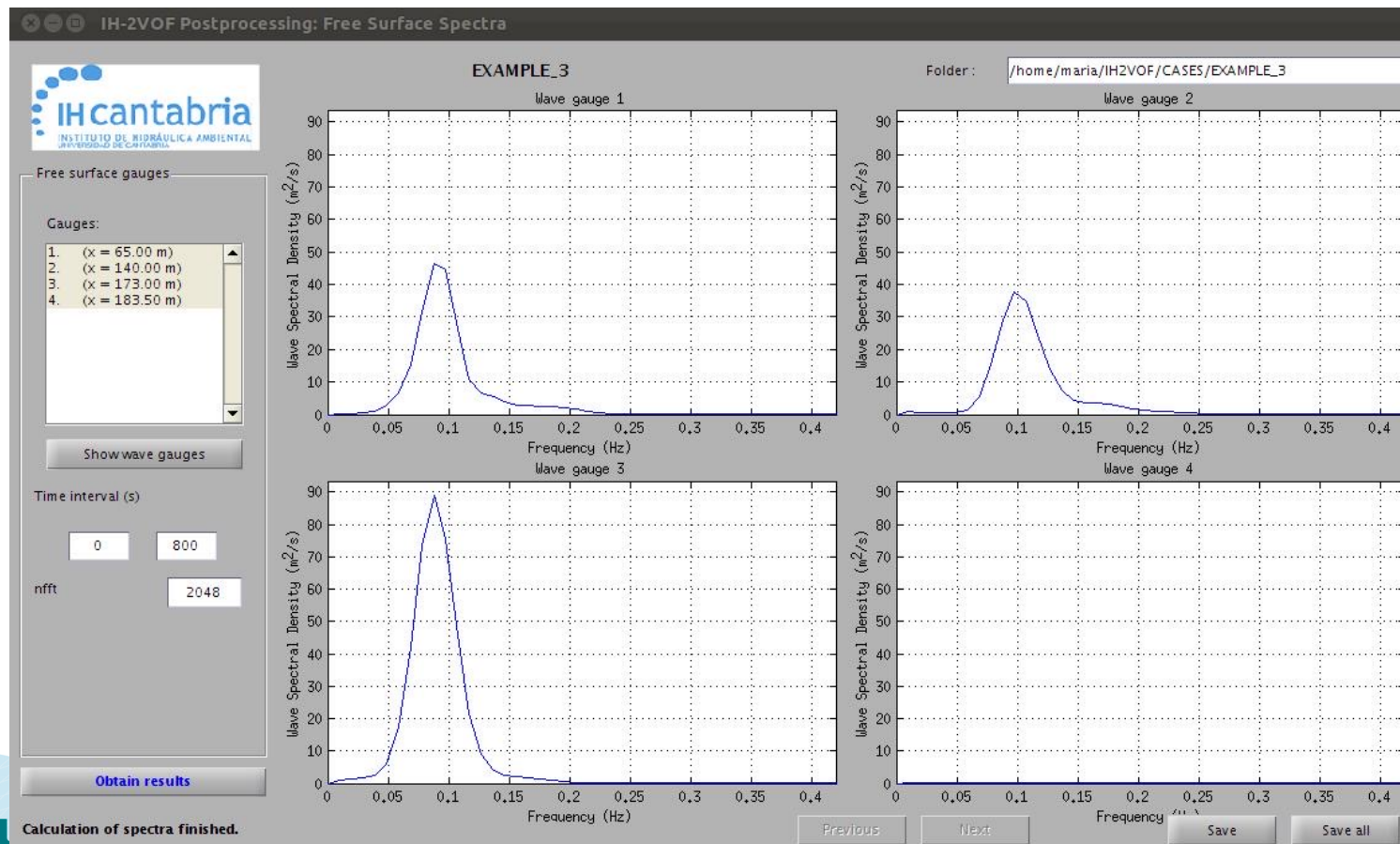
WAVE GAUGES – Time series

-Results of the free surface elevation are obtained by pressing the button

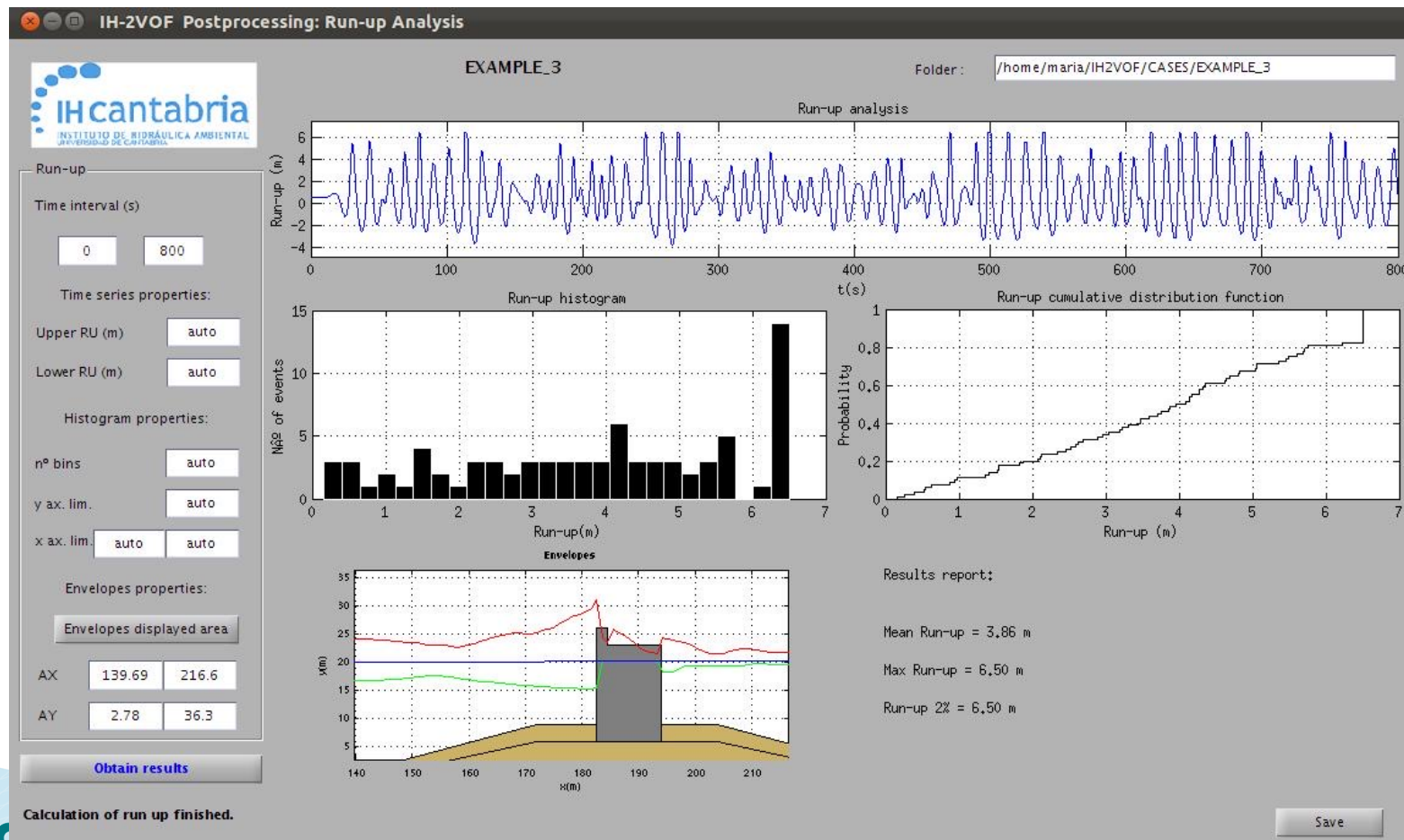


WAVE GAUGES – Spectra

- Energy spectra associated to each one of the selected gauges before the simulation can be obtained



RUN-UP



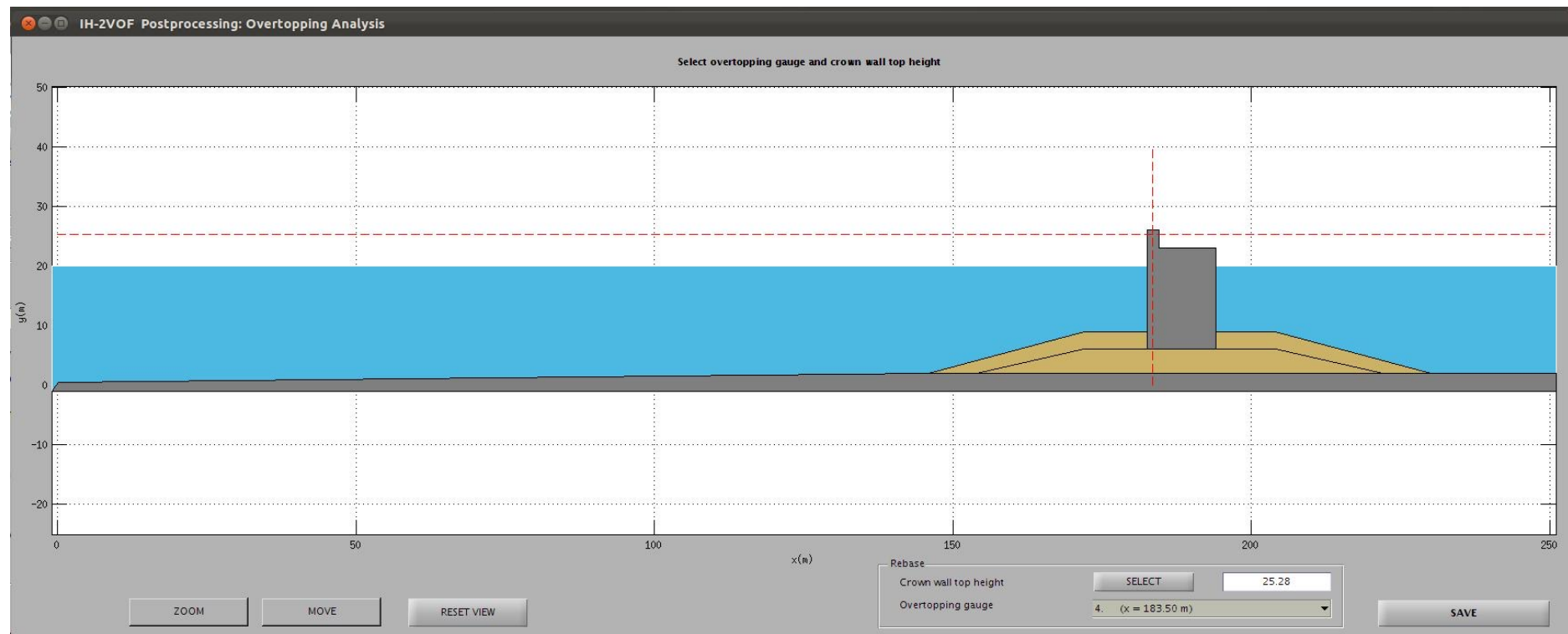
OVERTOPPING

- Select overtopping gauge:

Postprocessing

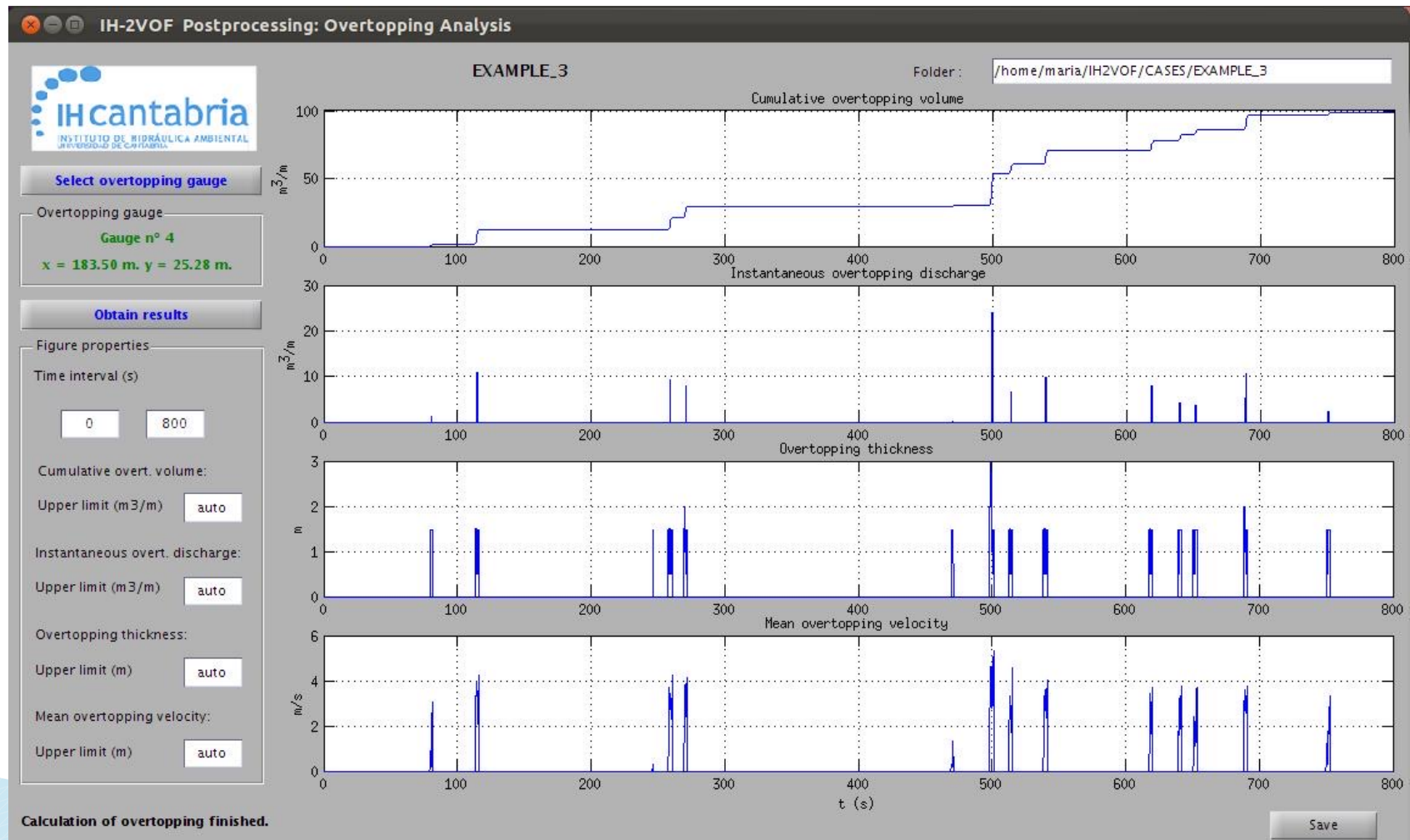


Overtopping Analysis



OVERTOPPING

- Obtain results:



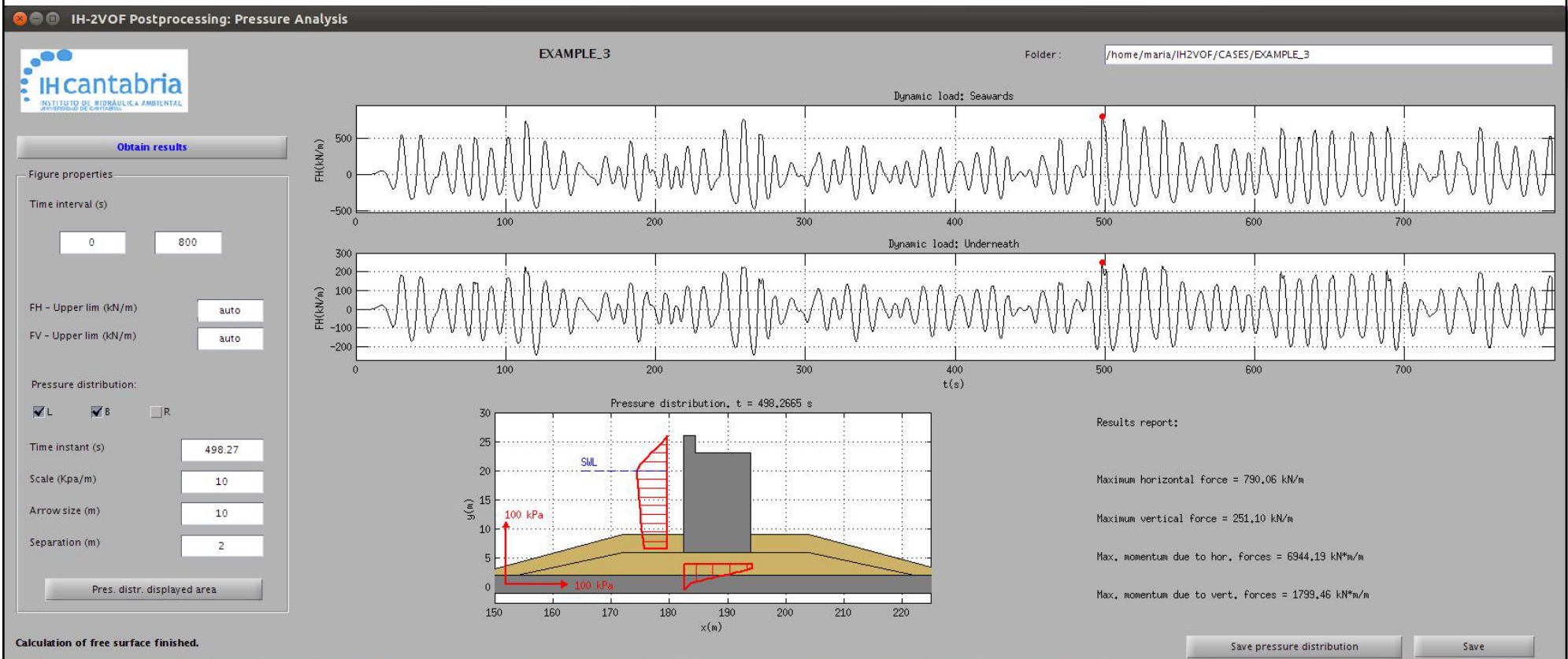
PRESSURE

- The produced pressure over the structure is calculated as well as the maximum forces.

Postprocessing



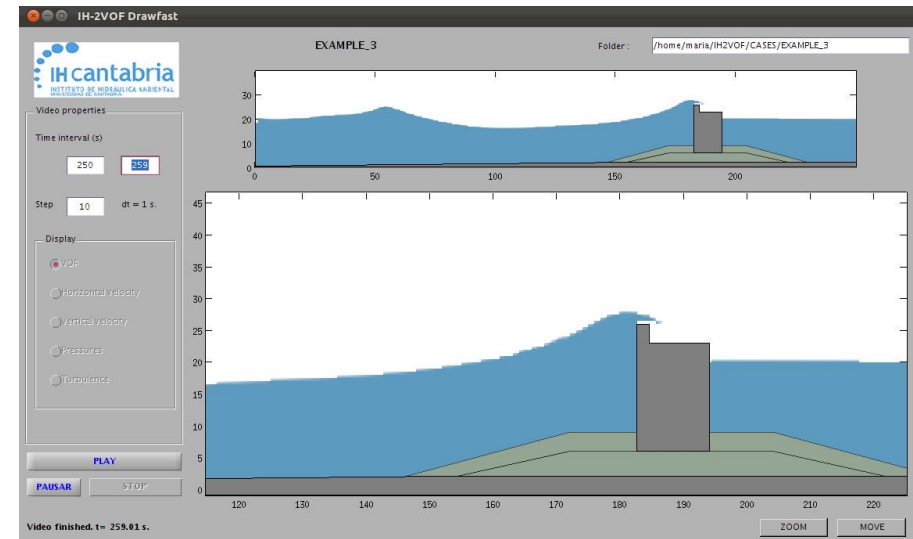
Pressure Analysis



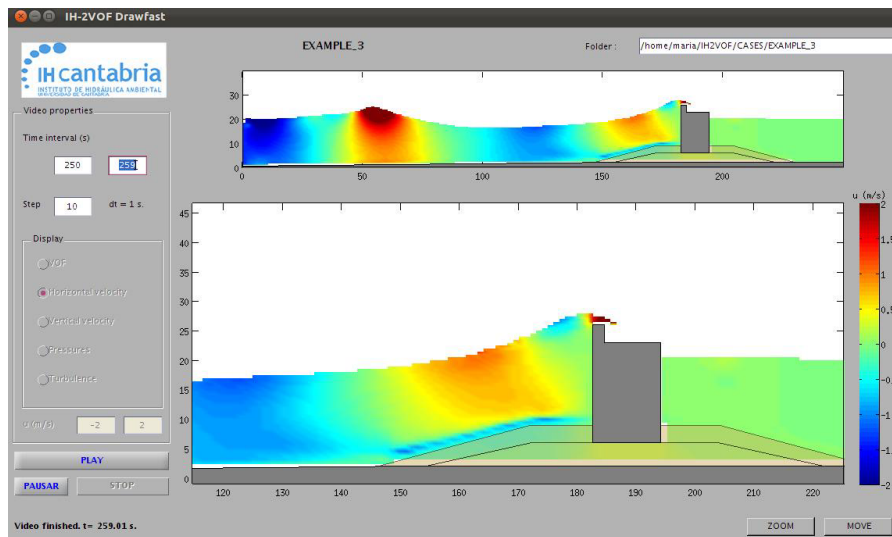
DRAWFAST

The visualization properties: initial time, final time and time step can be chosen, as well as the variable to display.

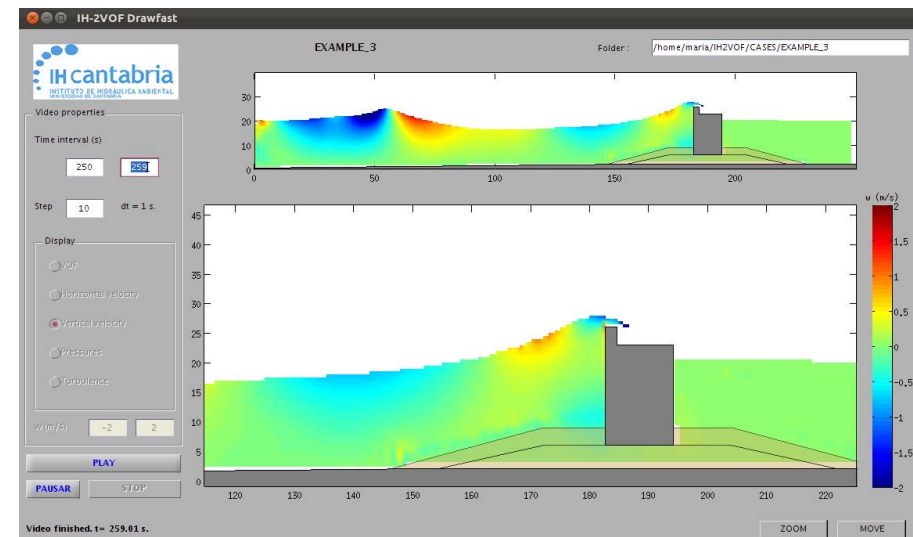
A zoom of the area of interest can be done using zoom controls in the figure below.



VOF drawfast

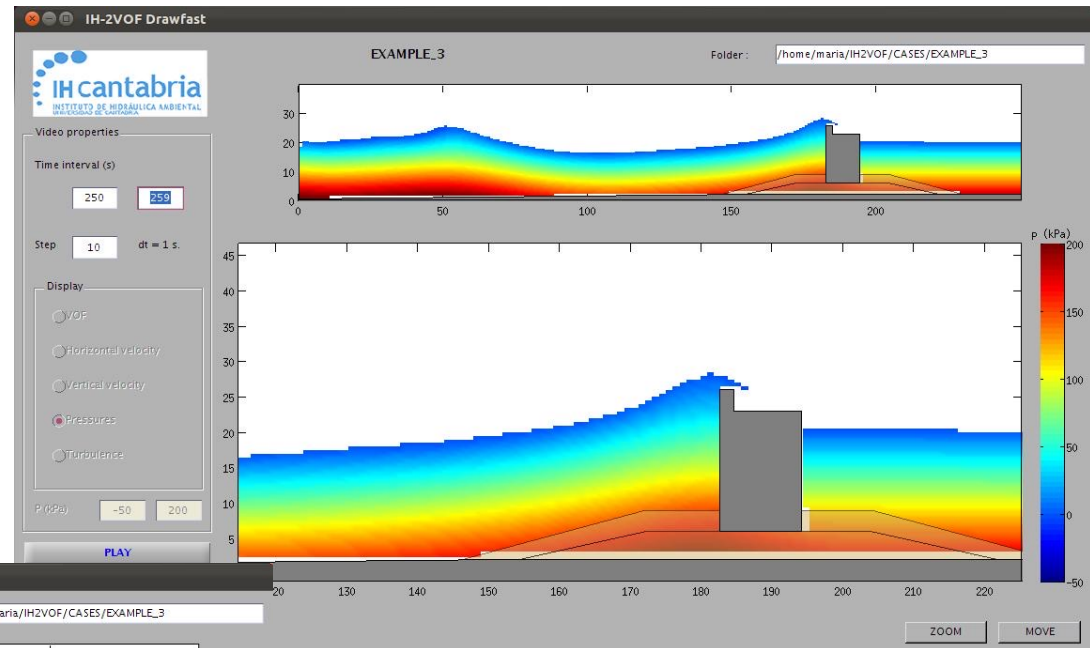


Horizontal Velocity drawfast

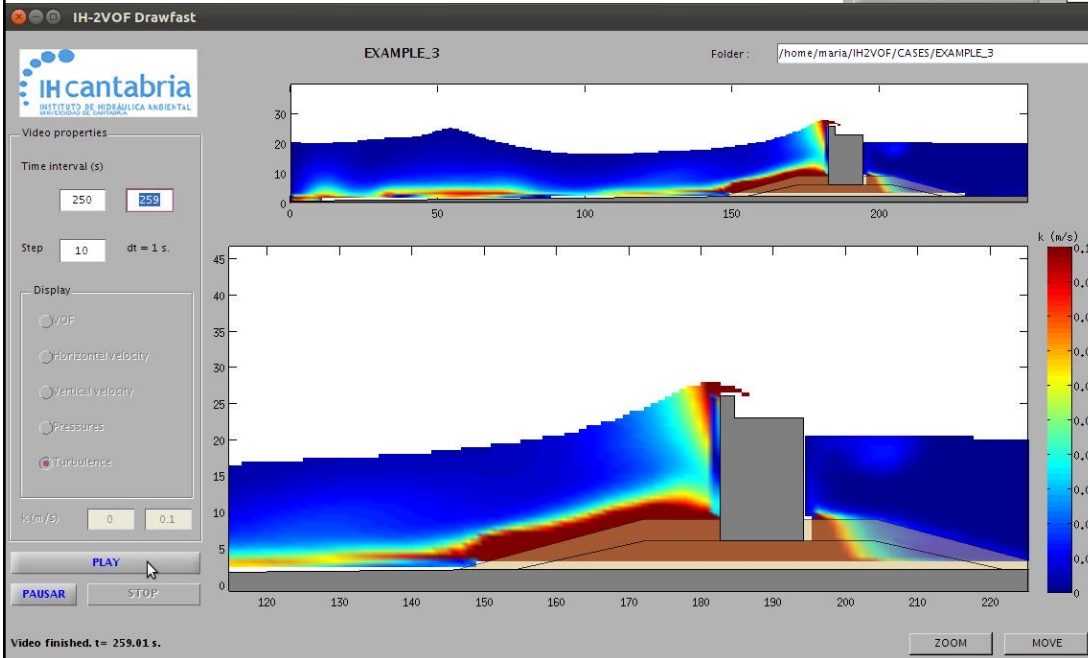


Vertical Velocity drawfast

DRAWFAST



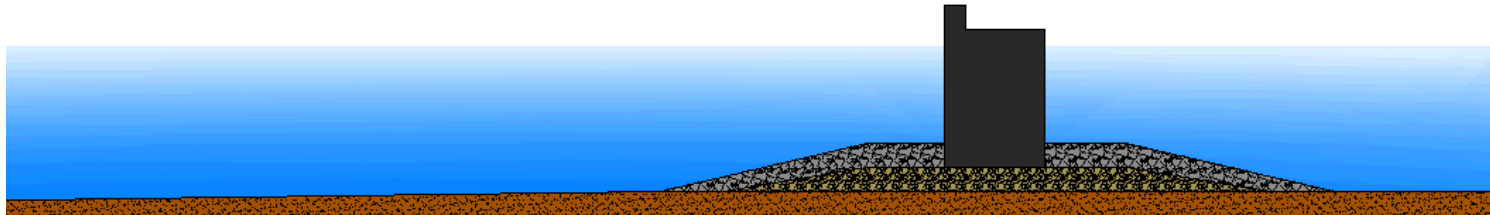
Pressure drawfast



Turbulencedrawfast

Example 3

Irregular waves interaction with a vertical breakwater



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