GENERATION OF TRIANGULAR FINITE ELEMENT GRIDS USING OPENMeshS

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LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

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PART 1: CONCEPTS AND THEORY

What is a finite element grid?

- Coastal processes are described by partial differential equations
- Because there are no analytical solutions for those equations, they have to be discretized to be solved numerically
- A FE grid is an approach to discretize a continuous domain
- FE discretizations offer a piece-wise continuous description of the variables, with a varying resolution
- Nodes and elements of the grid determine where equations are solved and how spatial gradients are evaluated

What is a finite element grid?

- A finite element grid includes the following information:
  - Location of the nodes
  - Depths at the nodes

Table of nodes

  - Definition of the elements (ordered list of nodes that define each element)

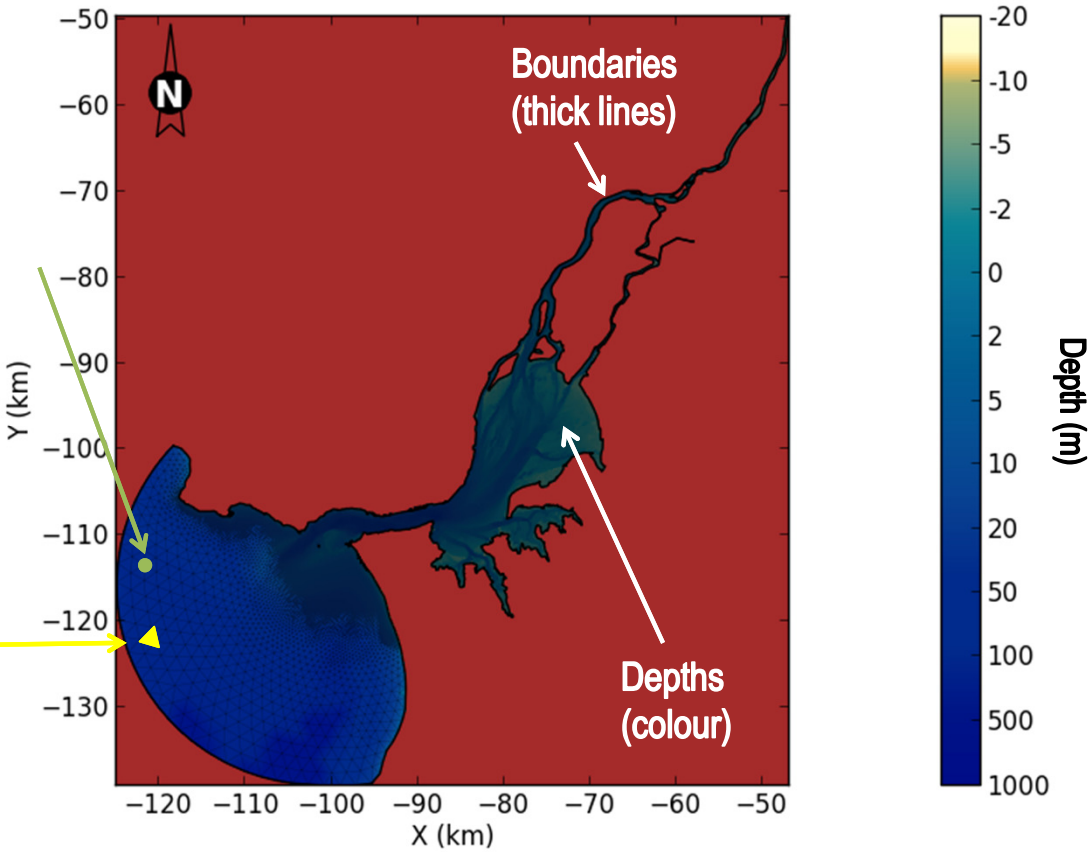
Table of elements

  - Definition of the boundaries

What is a finite element grid?

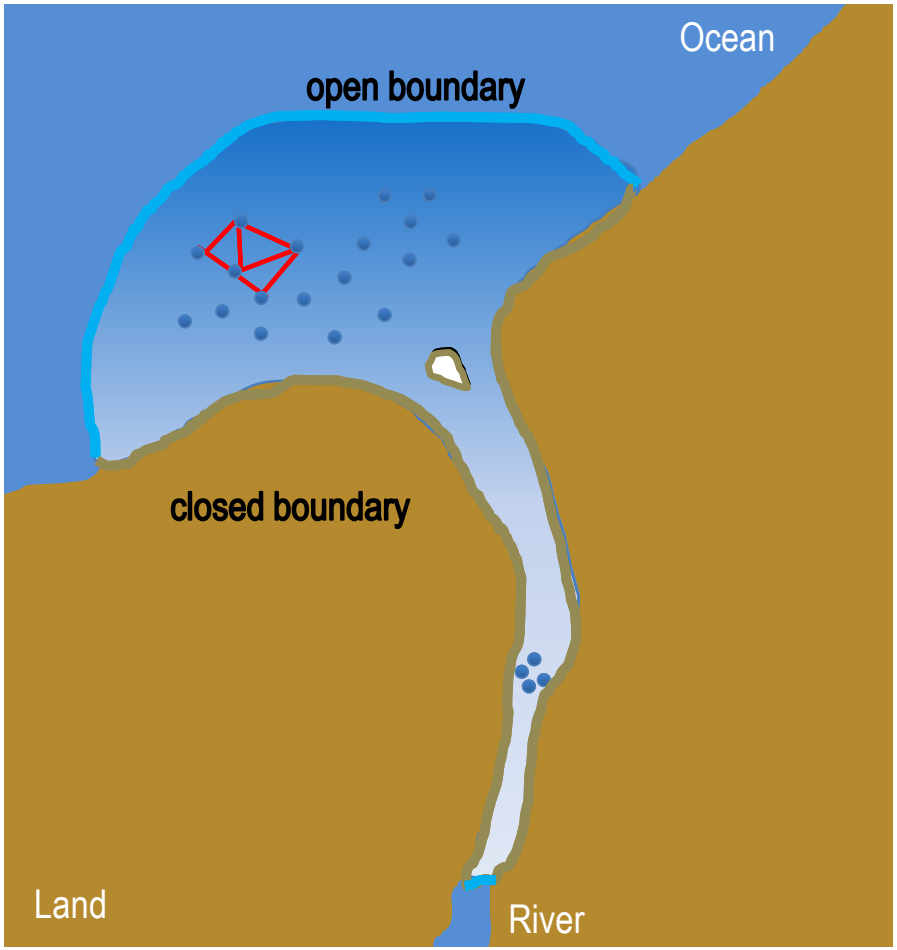
Nodes
(vertices of the triangles)

Elements
(triangles)



Major steps

1. Domain definition
2. Node placement
3. Definition of the triangles
4. Optimization and verification
5. Interpolate the bathymetry
6. Boundary definition

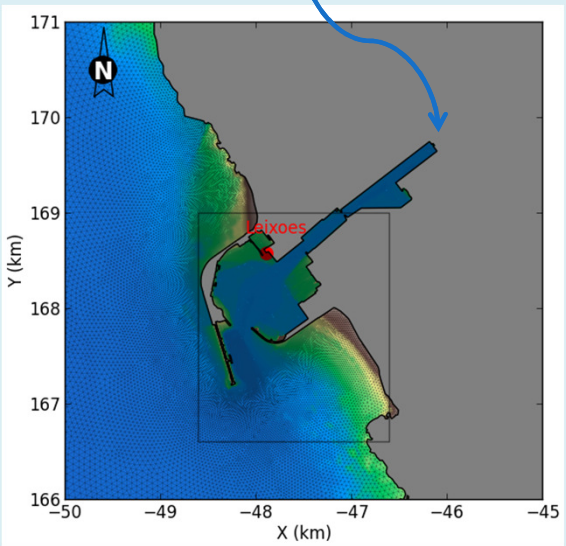


1. Domain definition

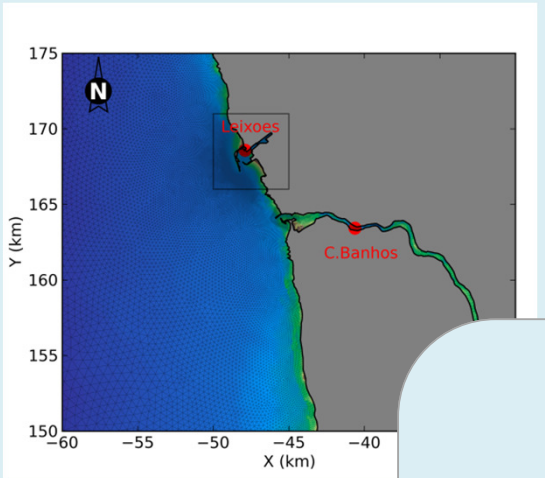
- *Upstream:*
  - *Should extend beyond tidal intrusion*
  - *Often limited by the availability of bathymetry data*
- *Downstream:*
  - *Extend to deep waters, where velocities are small*
  - *Do not place the boundary in areas with strong velocities*
  - *Do not place the boundary in areas affected by the tidal jet*
  - *Make the boundary geometrically simple*

1. Domain definition: example

Upstream boundary limited by data availability



Study region (Leixões harbor)

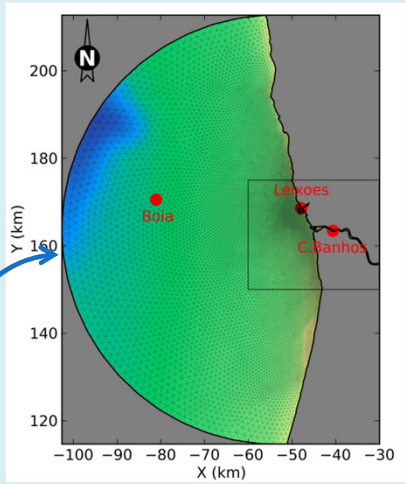


Upstream boundary determined by dam

Douro estuary

Full model domain

Ocean boundary away from the tidal jet and allows the inclusion of wave data in the domain

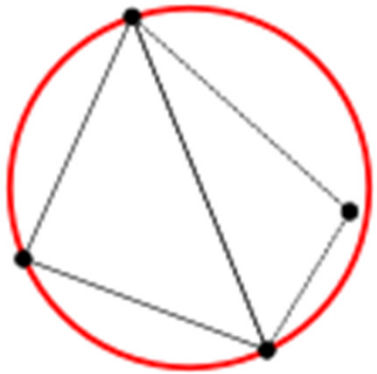


2. Node placement

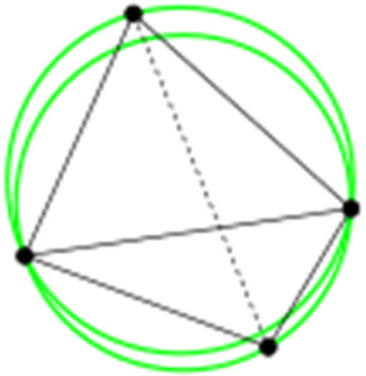
- *Choose node density to resolve*
  - *Tidal wave: minimum dimensionless wavelength should be at least 40-60*
  - *Tidal channels must be resolved with over 4-6 nodes to guarantee the reproduction of the fluxes*
  - *Sharp bathymetric gradients (e.g., shelf slope)*
  - *Solid boundaries must be adequately resolved*
  - *Sharp velocity gradients (e.g., ebb jet from a tidal inlet)*
- *Grid resolution should vary smoothly to promote:*
  - *Accuracy (minimize truncation errors)*
  - *Stability (depending on the models)*

3. Triangulation of a set of points

- Delaunay triangles: no node is inside the circumcircle of any triangle



Triangles that do not meet
the Delaunay criterion

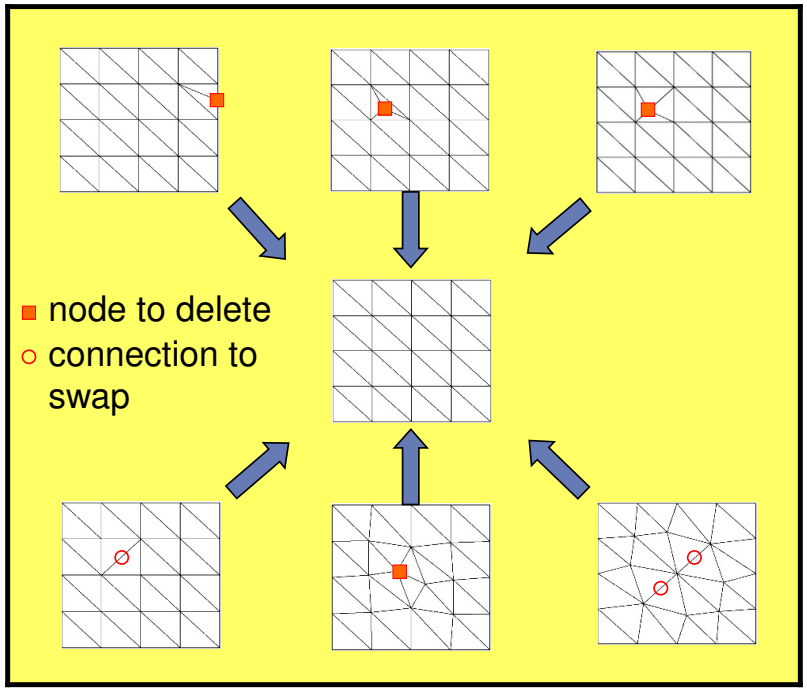


Triangles that meet
the Delaunay criterion

Figures from wikipedia

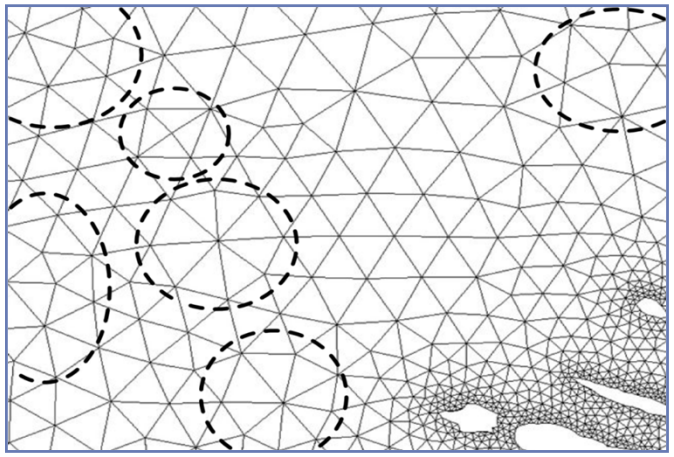
4. Optimization and verification

- *Goals:*
  - *Reduce skewness*
  - *Minimize maximum number of neighbours*
  - *Smooth transition between element sizes*
  - *Prevent angles above 90º (some models)*
- *Typical operations:*
  - *Add nodes*
  - *Delete nodes*
  - *Move nodes*
  - *Swap edges*



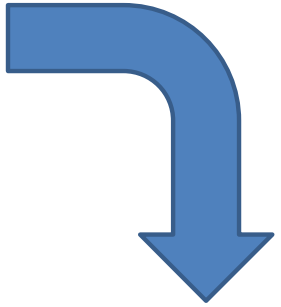
Grids that are transformed into the one in the center

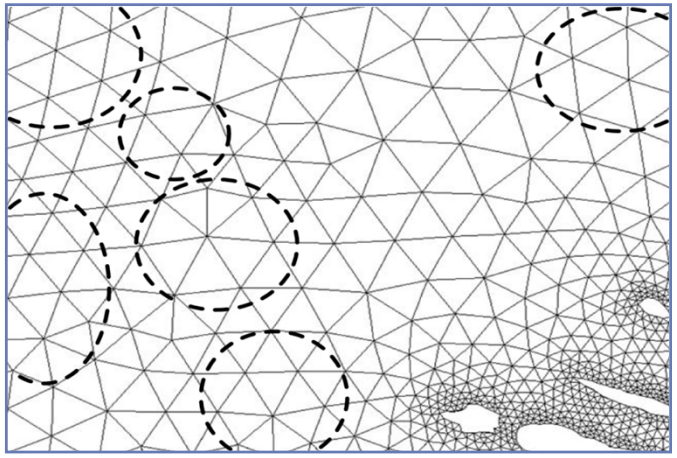
4. Optimization and verification



Before

(generated with *xmgredit*)…





… and after (optimized with *nicegrid*)

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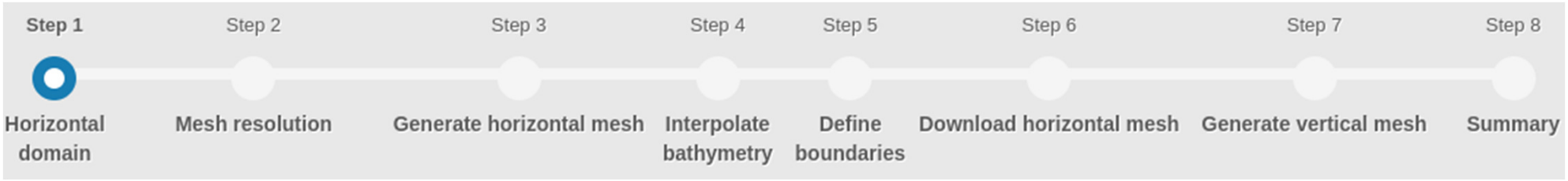
PART 2: APPLICATION

The major steps in grid generation using OPENMeshS



1. Define region of interest
   Define data sources
   Define domain
   WEBGIS

2. Define min and max resolution
   Define resolution functions
   OCSMesh

3. Generate nodes
   Triangulate nodes
   Optimize grid
   JIGSAW and NICEGRID

4. Interpolate bathymetry
   OCSMesh

5. Define boundaries
   OCSMesh or manually

6. Download mesh

7. Generate vertical mesh

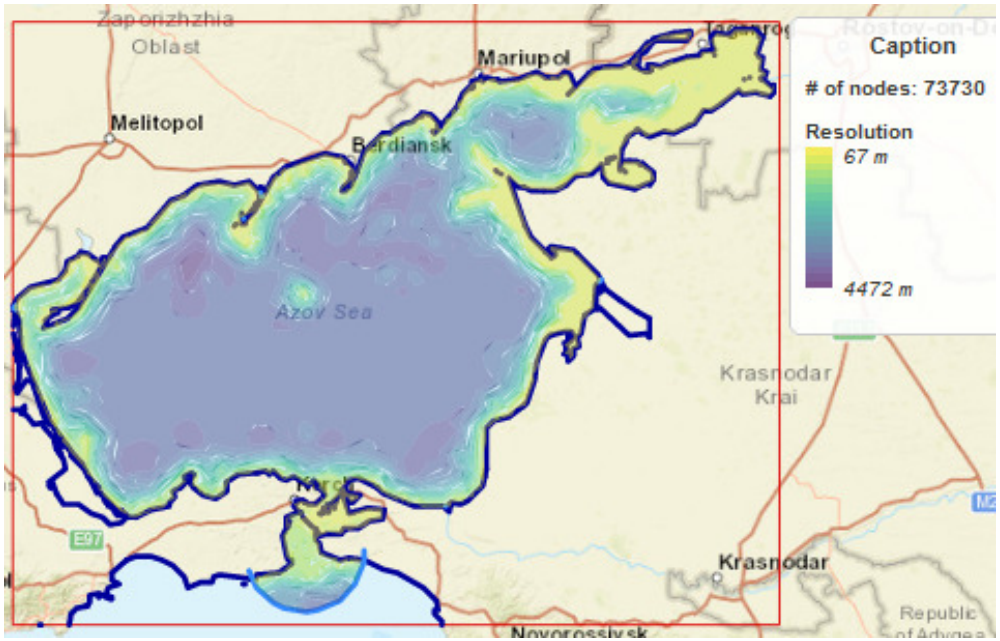
8. Verify
   Archive grid

Step 1. Horizontal domain

1. Provide a name for the mesh
2. Define region of interest by drawing a rectangle on a map
3. Select sources of bathymetry or topography, in increasing order of interpolation
4. Define the domain:
    1. Land boundaries: using available coastlines (Open Street Maps, EMODNET)
    2. Open boundaries: drawing (and editing) circles and linear segments

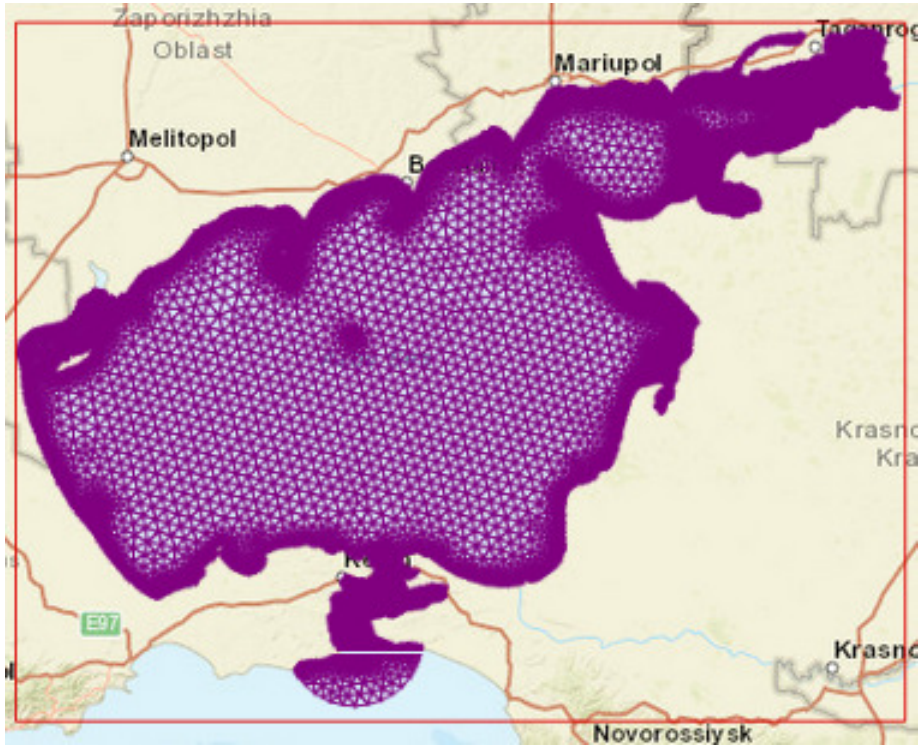
Step 2. Mesh resolution

1. Define minimum and maximum resolution (mandatory)
2. Define constant resolution between two isobaths
3. Define linear resolution growth away from an isobath
4. Define constant resolution inside a polygon



Step 3. Generate horizontal mesh

1. Generate mesh (mandatory)
2. Improve mesh with nicegrid
3. Check nicegrid report and accept changes

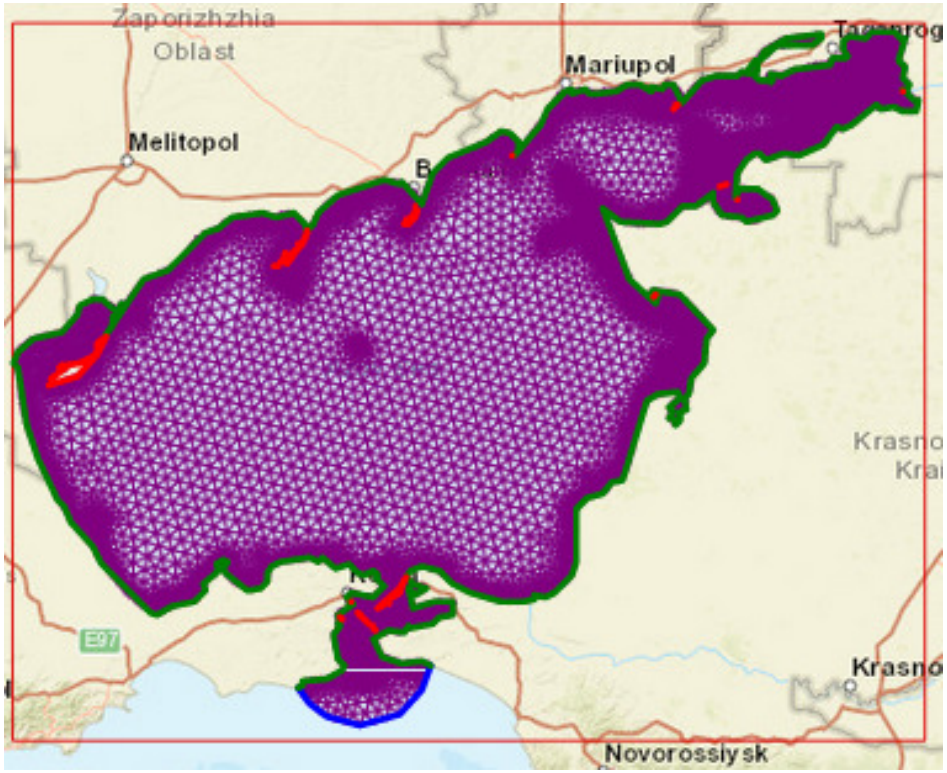


Step 4. Interpolate bathymetry

1. Interpolate bathymetry

Step 5. Define boundaries

1. Click on consecutive (counterclockwise) open boundary nodes. Closed boundaries are defined automatically
2. Possibility to impose a minimum depth at nodes from open boundary elements



Step 6. Download horizontal mesh

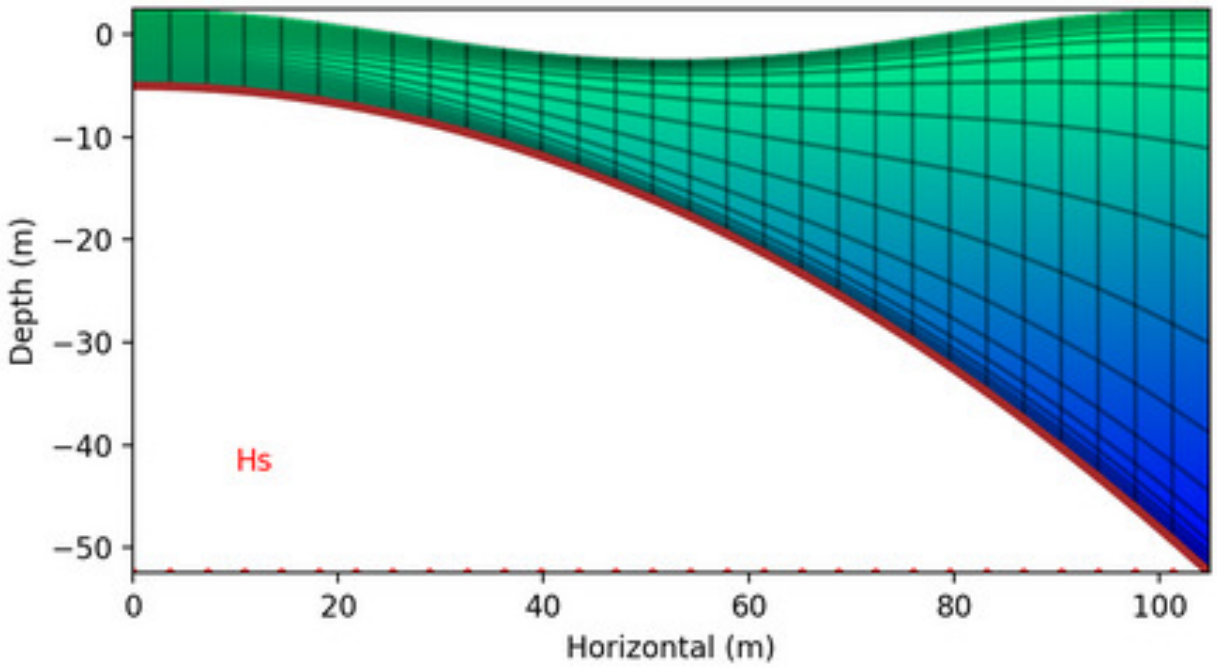
1. Select coordinate system
2. Download grid

Step 7. Generate vertical mesh

1. Define parameters
2. Visualize grid
3. Download grid

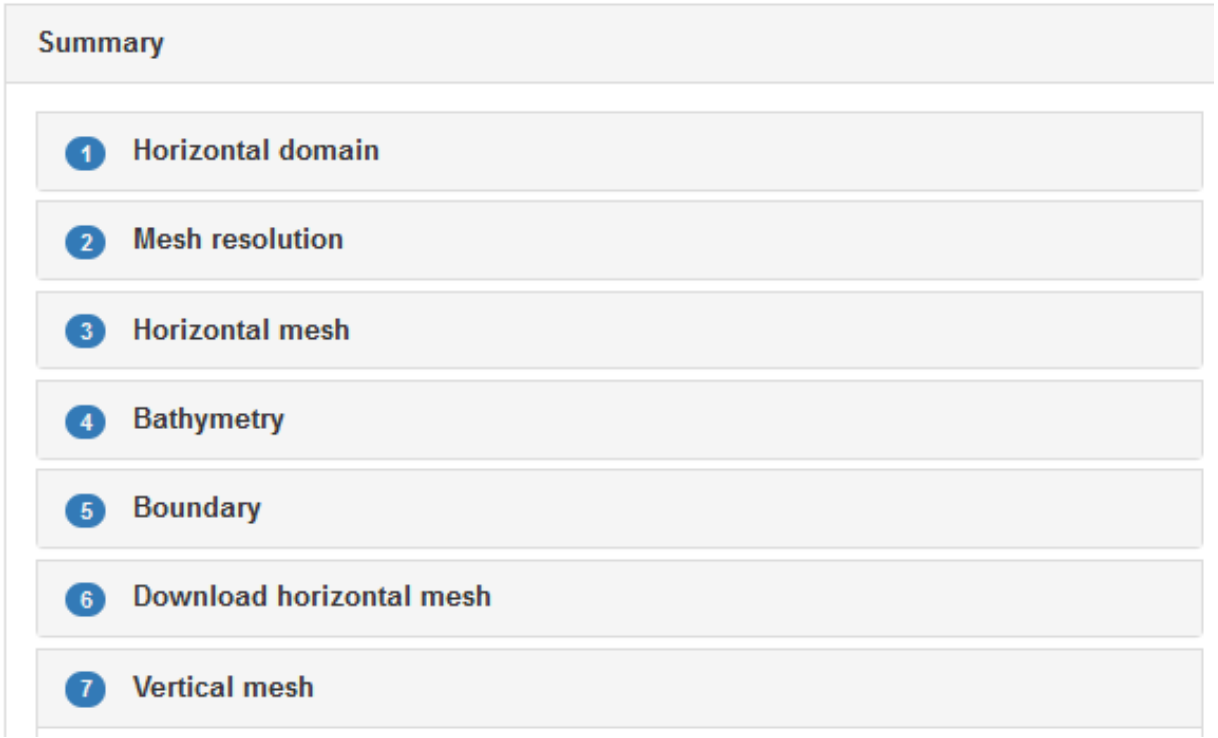
3D Mesh with the following parameters:
Vertical levels: 20
Z levels: 1
Z-S transition depth(m): 100
S-sigma transition depth(m): 5
ThetaB: 1
ThetaF: 8

Download vgrid.in



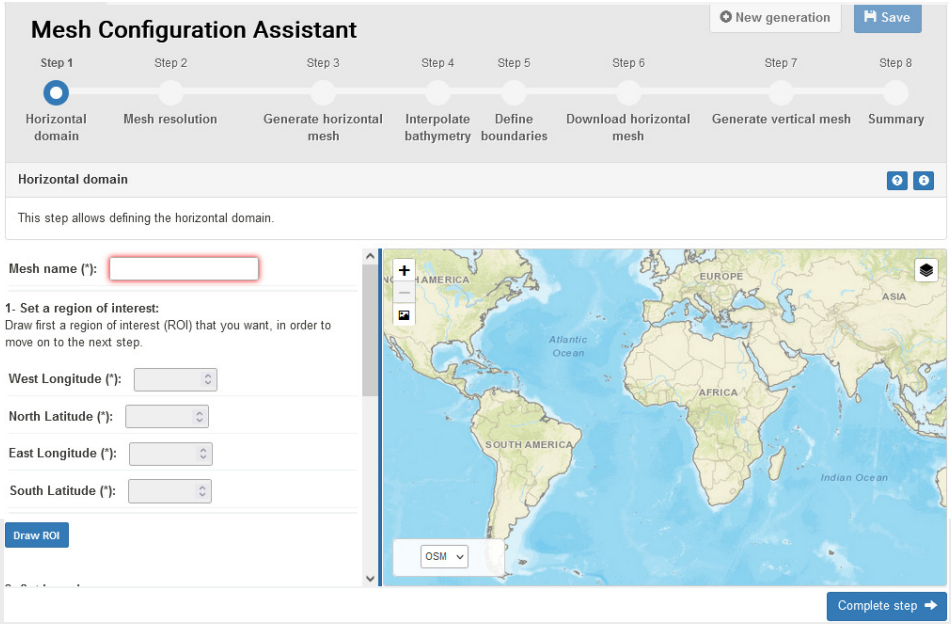
Step 8. Summary

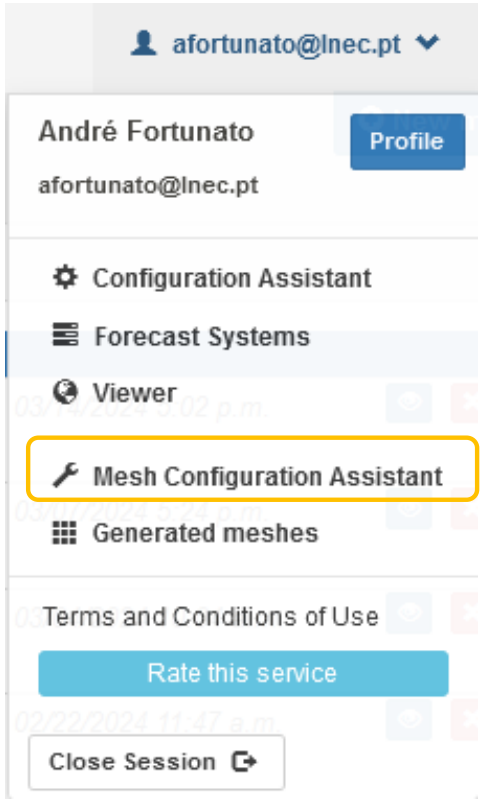
1. Verify choices made
2. Archive grid



Accessing OPENMeshS

1. Access OPENCoastS (https://opencoasts.ncg.ingrid.pt)
2. Login or register
3. Click on Mesh Configuration Assistant





Questions?