An unstructured grid model of the Belgian continental shelf and the Scheldt estuary

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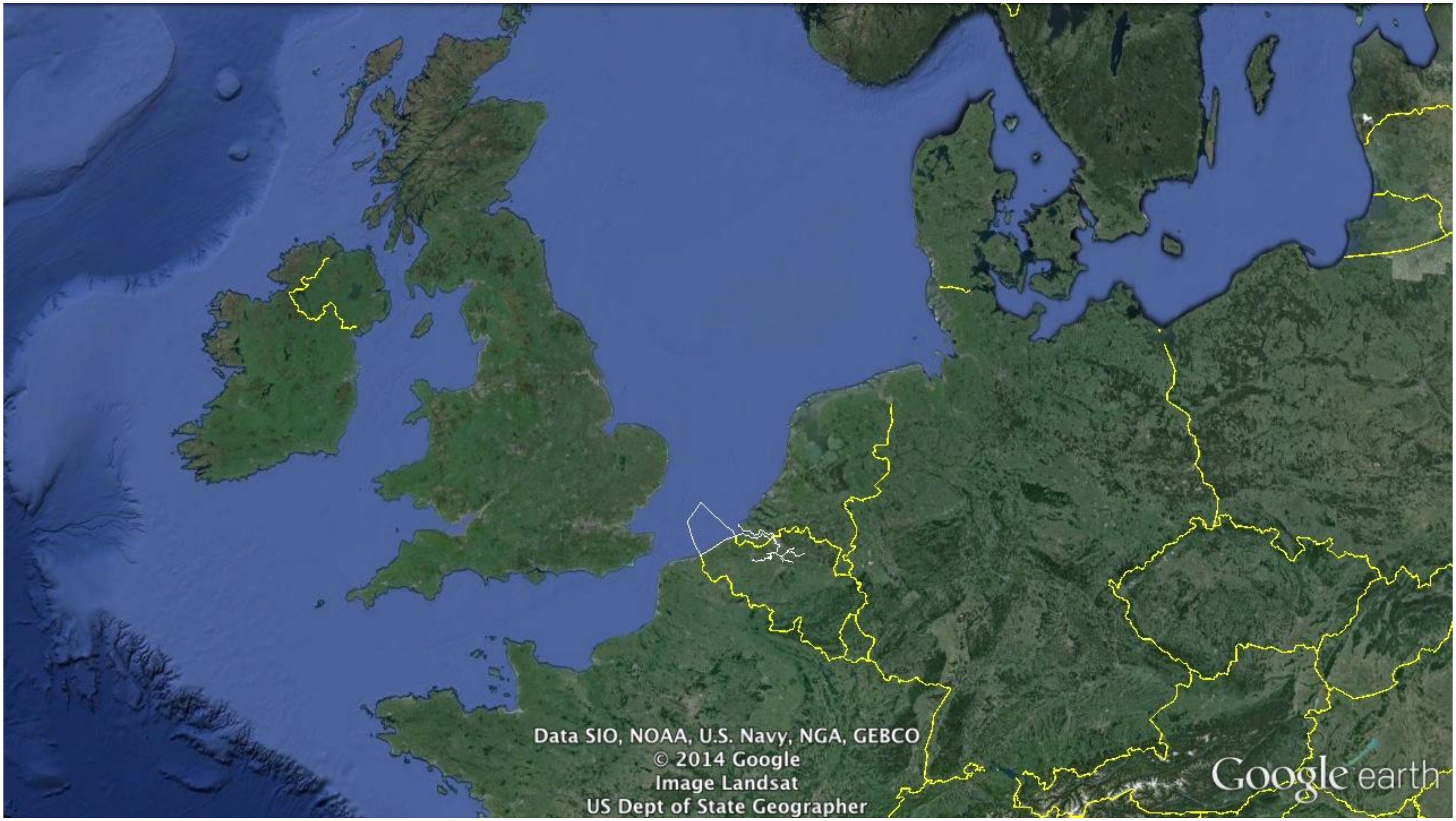
Belgian continental shelf and Scheldt estuary



Belgian continental shelf and Scheldt estuary

Super storms

- North Sea flood of 1953
  - 2551 persons killed (NED, UK, BEL, at sea)
  - a lot of material damages
- Cyclone Xaver in 2013 (*Sinterklaasstorm*)
  - 10 persons killed
  - much less damages
- What about the next one?

Unstructured grid model strategy

- TELEMAC
  - finite element solver (triangular grids)
  - 2D/3D hydrodynamics
  - wave propagation
  - sediment transport and bed evolution
- Gmsh
  - unstructured grid generator
- Gmsh-TELEMAC Matlab toolbox
  - convert Gmsh grids into TELEMAC input files
  - pre-process domain contour
  - pre-process bathymetry

Outline

1. Pre-process domain contour
2. Pre-process bathymetry
3. First TELEMAC simulations

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Domain contour from GSHHG

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Domain contour from ETOPO

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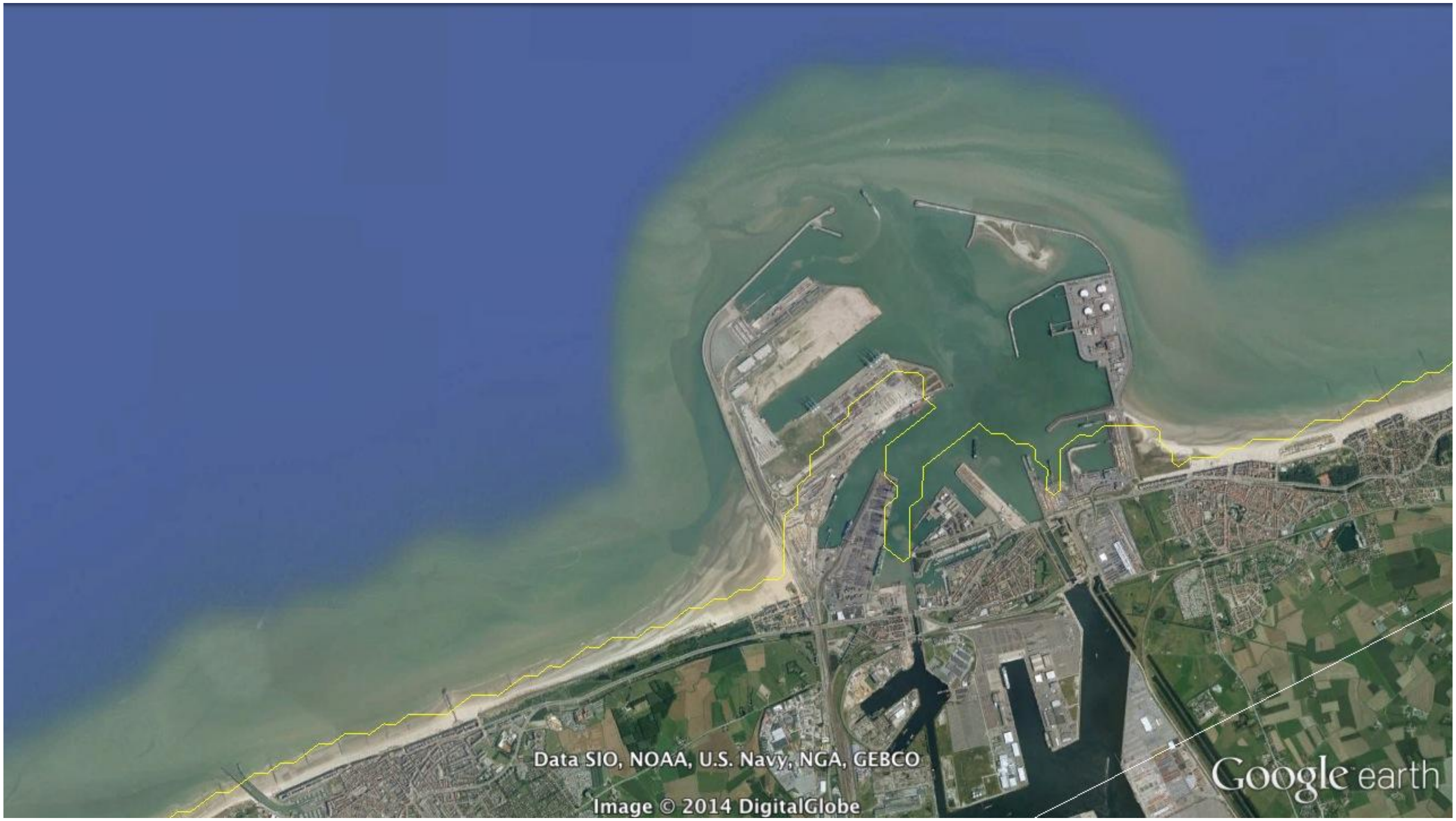
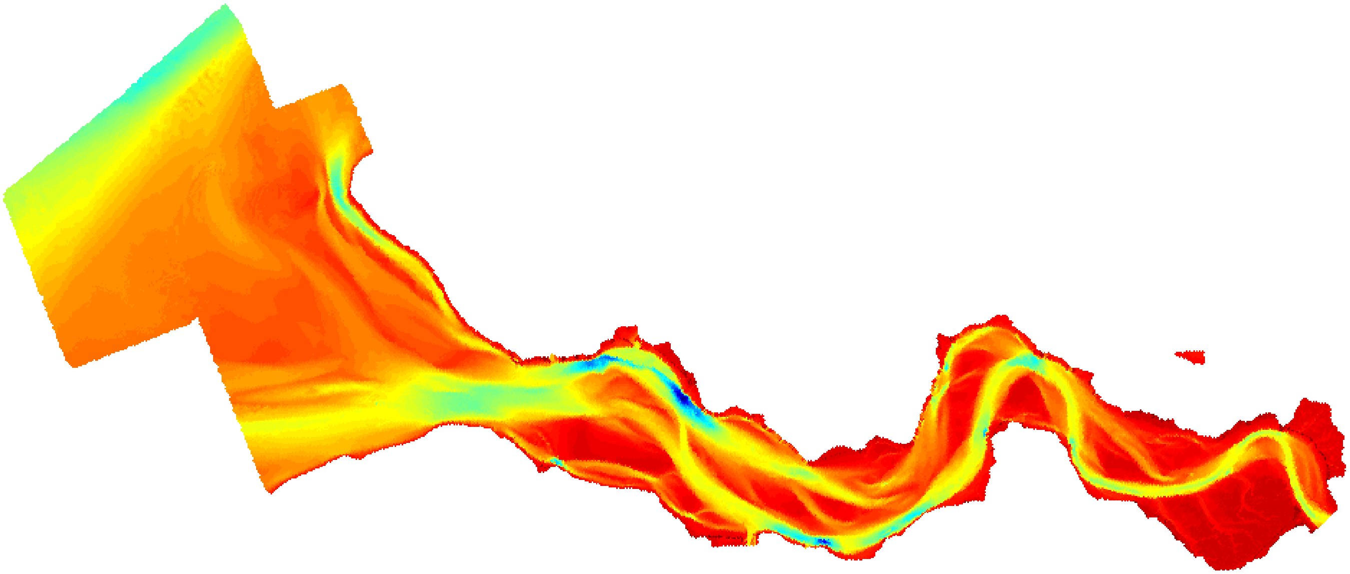
Domain contour from KML files (Google Earth)



Domain contour from KML files (Google Earth)

Domain contour from a point cloud alpha shape



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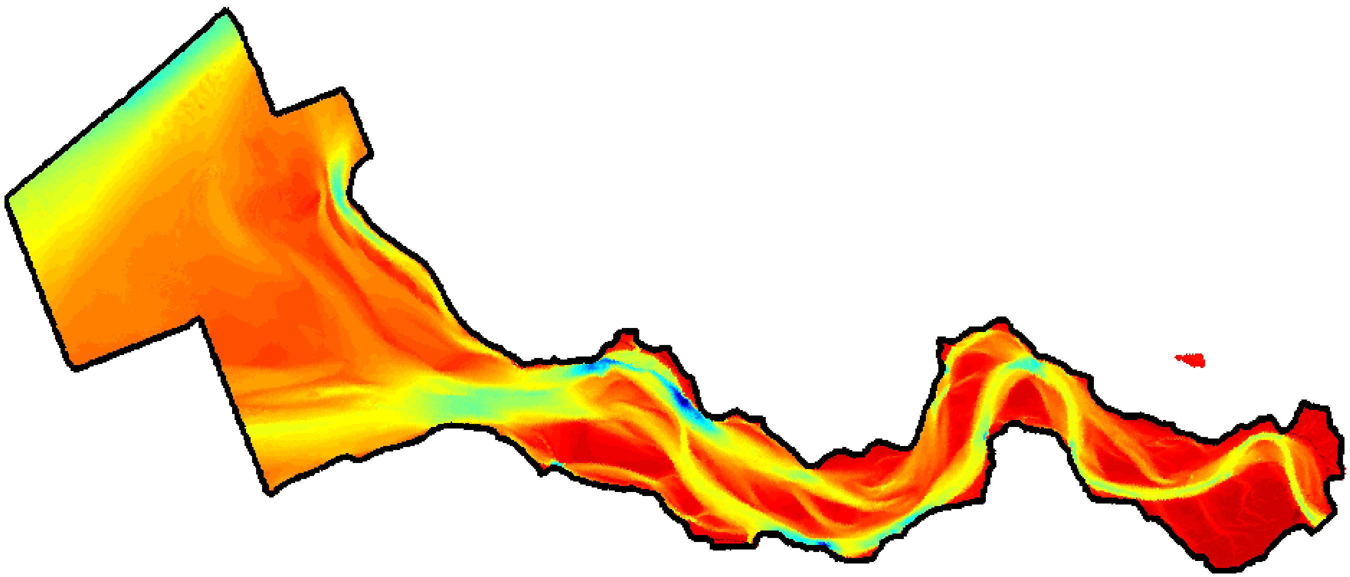

Domain contour from a point cloud alpha shape

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Manipulate raw contour data using Inkscape

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Pre-process domain contour

1. Load raw contour data from different data sources
   - GSHHG
   - ETOPO
   - Google Earth
   - bathymetry point cloud
2. Save them in a SVG file
3. Manipulate them to obtain the final contour (Inkscape)

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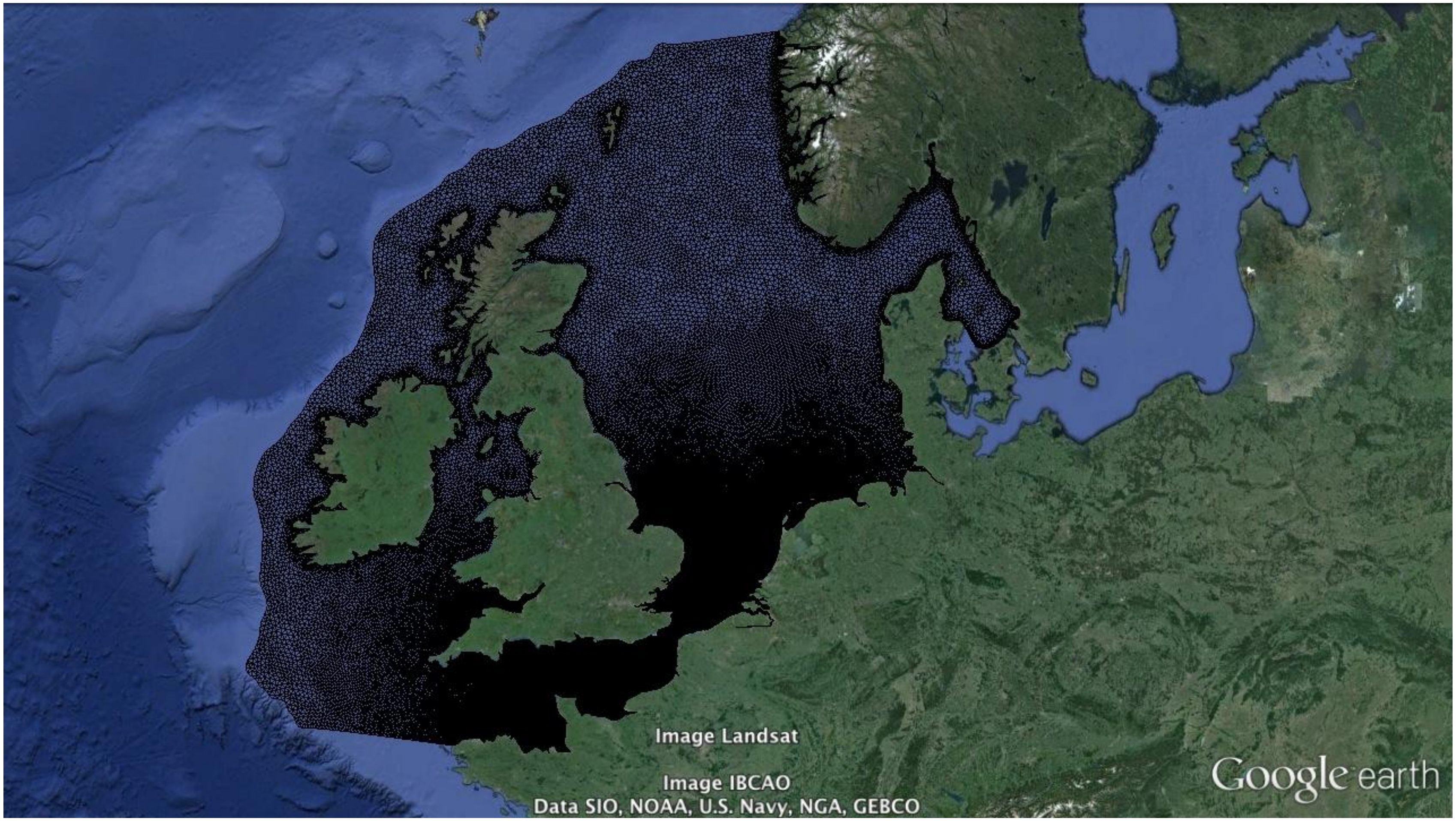
4. Save the final contour in a GEO file
5. Generate unstructured grid (Gmsh)

Generate grid using Gmsh



Generate grid using Gmsh

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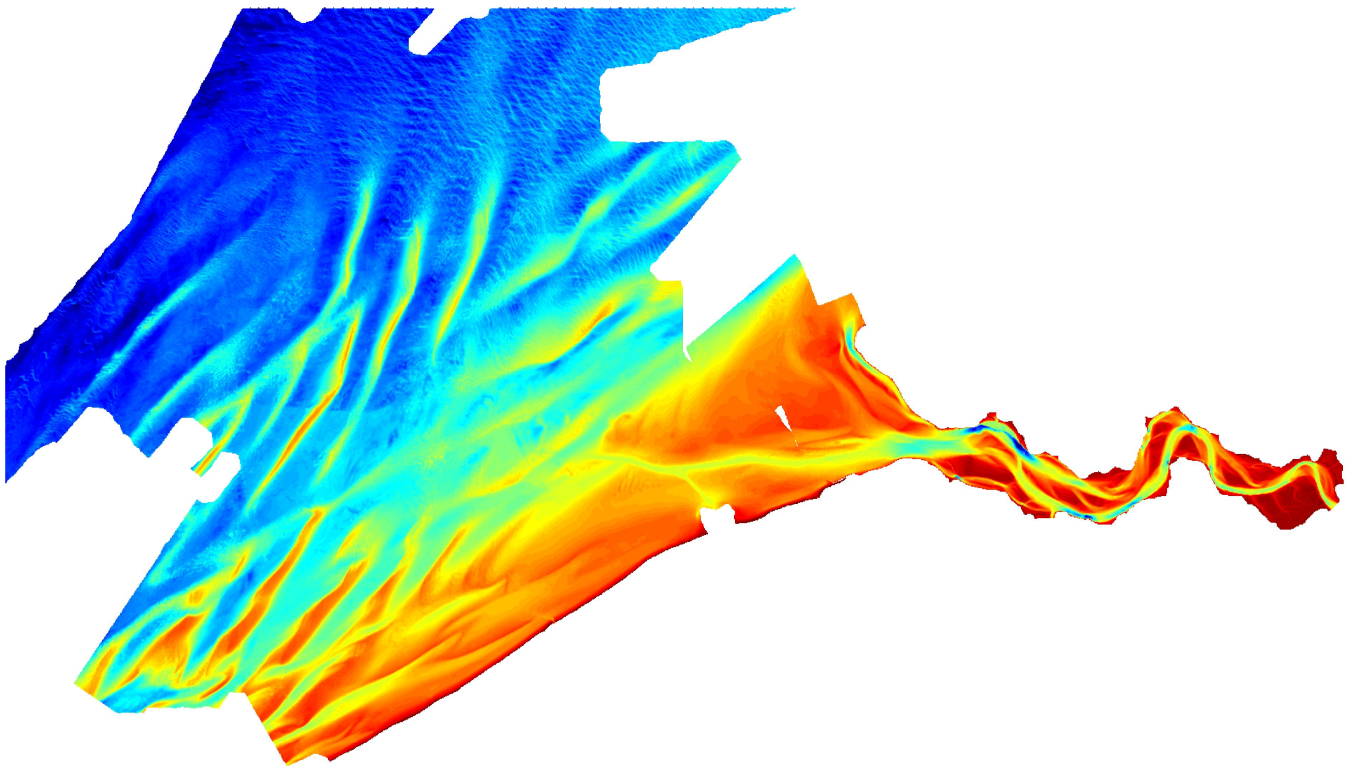
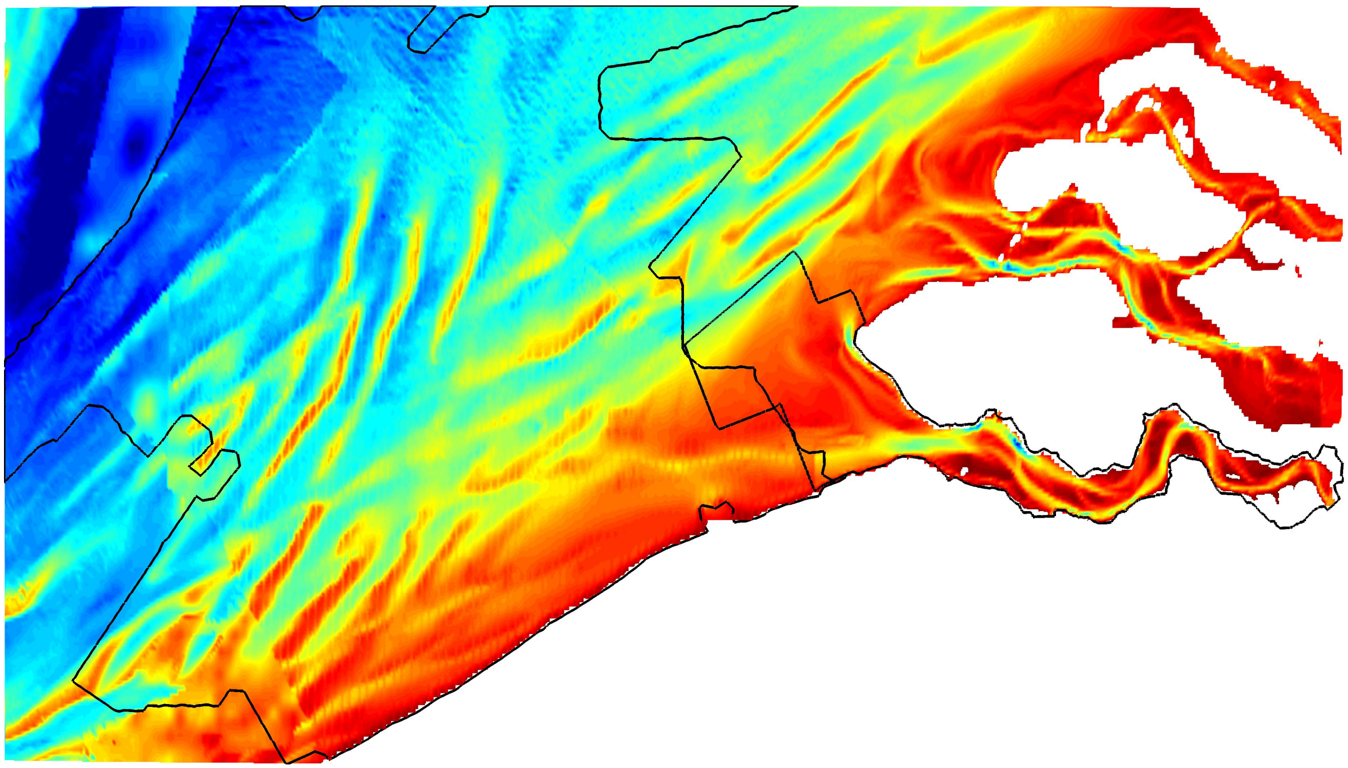
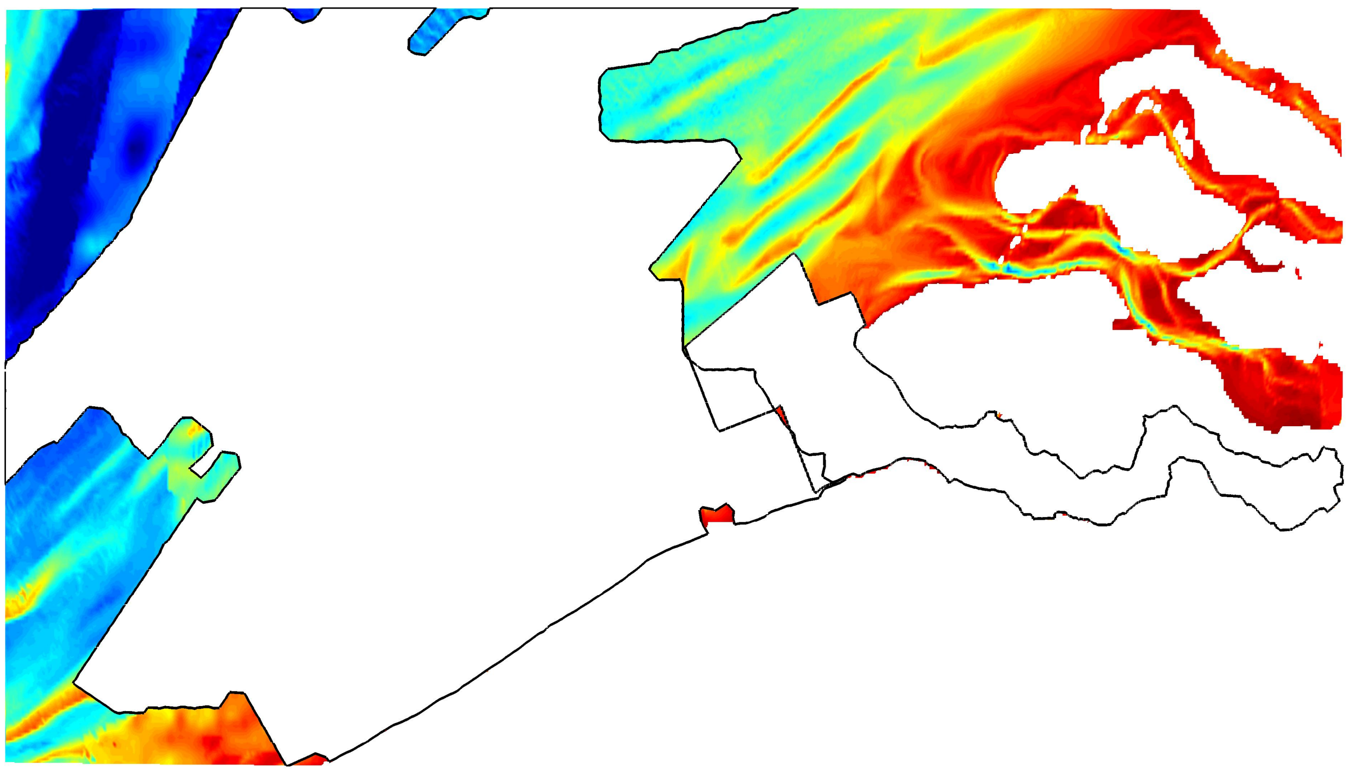
High precision bathymetry



Lower precision bathymetry



Remove lower resolution data where high resolution bathymetry is available



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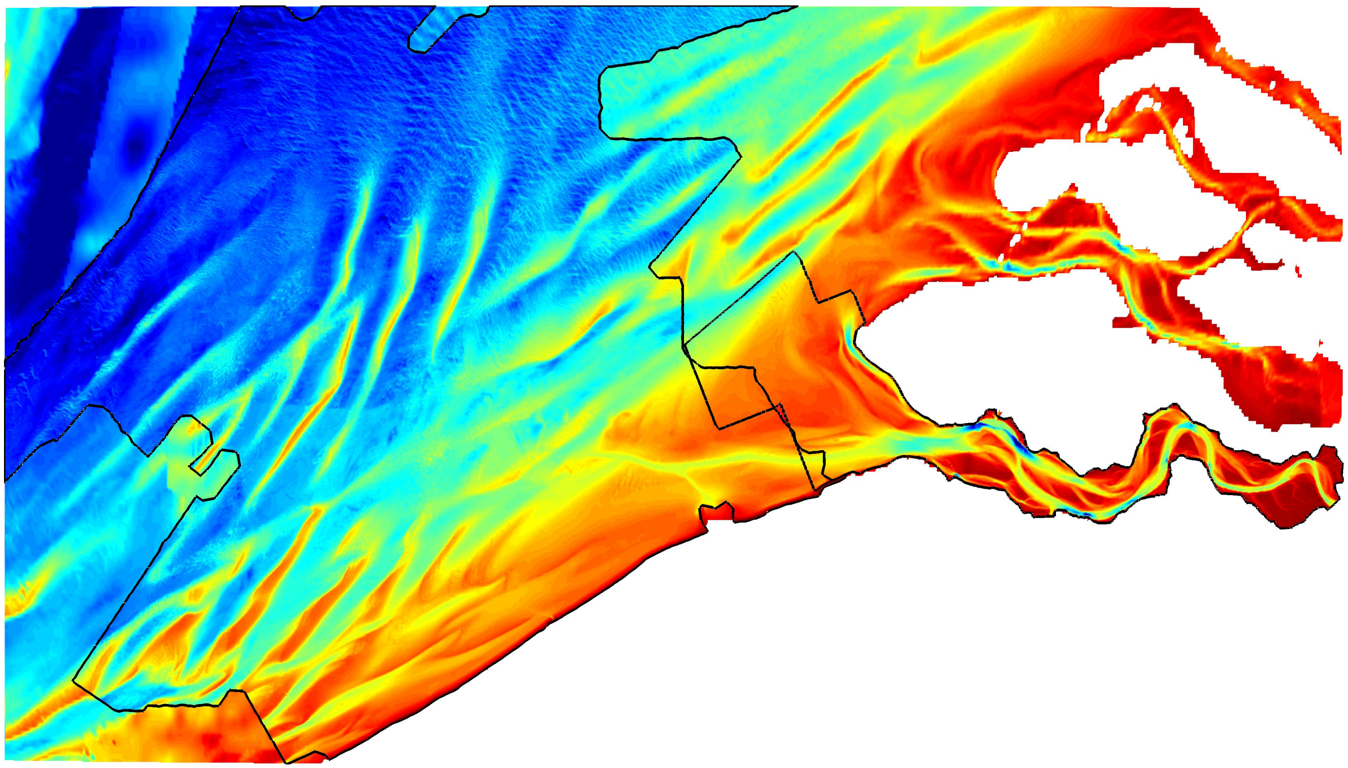

Pre-process bathymetry

1. Load bathymetry from different sources
   - EMODnet (Europe)
   - ETOPO (world)
   - (x, y, z) ASCII files
2. Define a hierarchy
3. Interpolate data on grid nodes

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4. Save grid and bathymetry in a SLF file (TELEMAC input file)

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Model setup: physical parameters

- Shallow water equations (wave form)
- Tide at the shelf break
  - from European Shelf 1/30° of OTIS Regional Tidal Solutions
  - amplitude and phase of 13 harmonic constituents
- Meteo
  - from HIRLAM (High Resolution Limited Area Model)
  - wind and air pressure (spatial resolution of 10 km; time step of 3h)
- Viscosity: 0.1 m^2/s
- Bottom friction
  - Manning's formula
  - friction coefficient: 0.025 $s/m^{1/3}$

Model setup: numerical parameters

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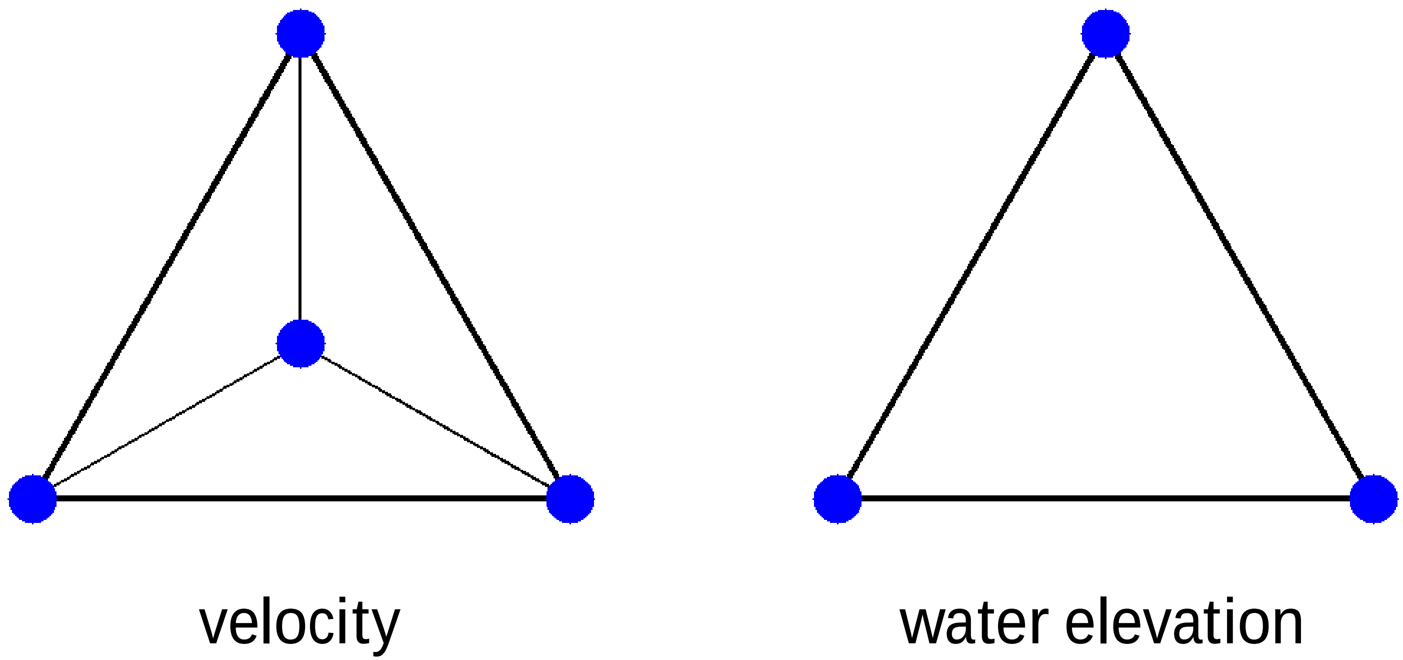
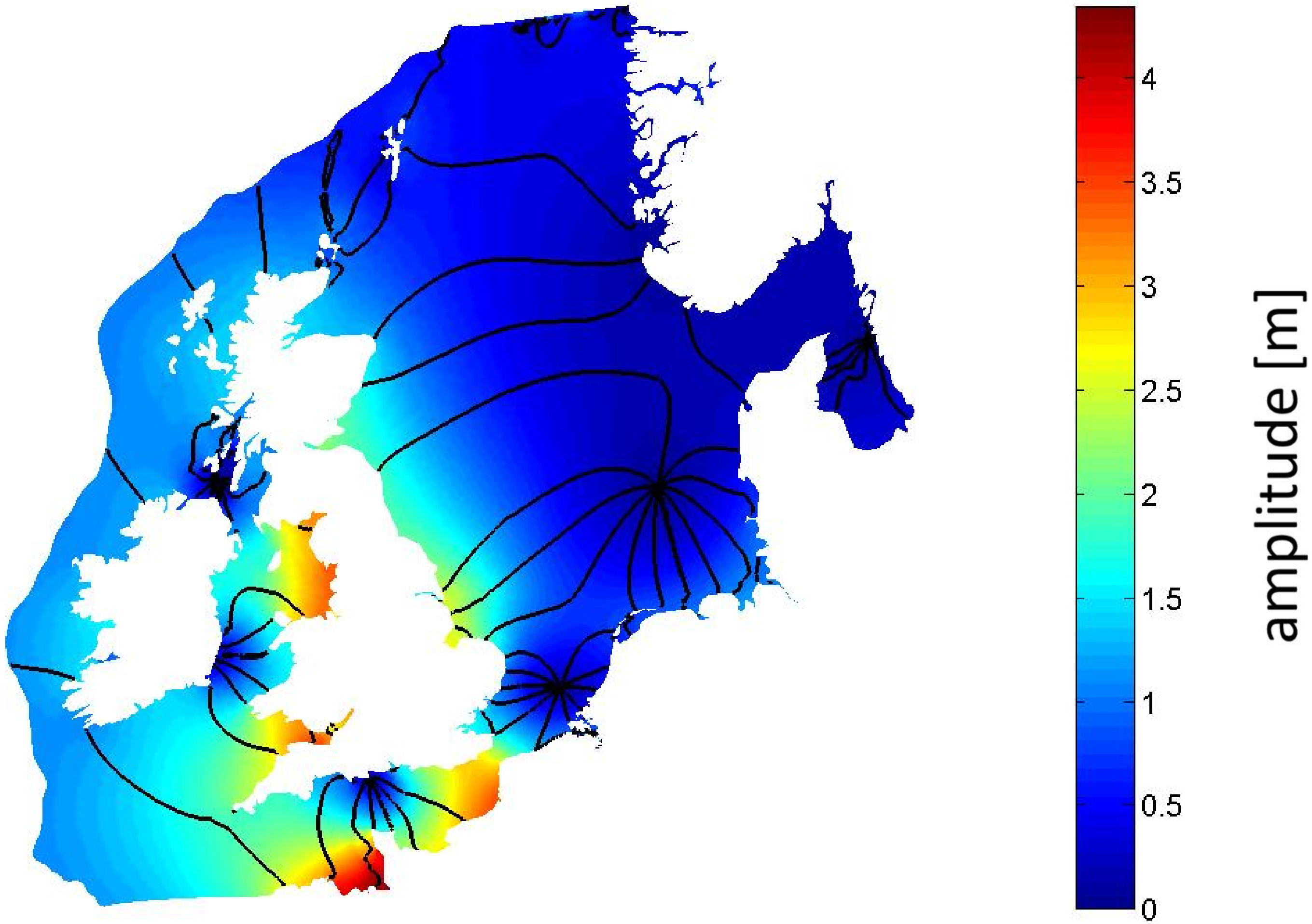
Spatial discretization: quasi-bubble – linear



Model setup: numerical parameters

- Spatial discretization: quasi-bubble – linear
- Spatial resolution:
  - from 100 m in the Scheldt river
  - to 10 km at the shelf break
- 247,514 triangles
- Time step: 50 s
- Computational time:
  - 1-month simulation (January 2009)
  - 16 processors on 2 different nodes
  - 1h10’32’’ (i.e. about 14h/year)

M_2 component of the water elevation



Conclusion

We designed a fully open source strategy to build an unstructured grid model from scratch

- Pre-process domain contour (for any structured grid generator software) and bathymetry
  - Gmsh-TELEMAC Matlab toolbox
  - Inkscape
- Generate triangular meshes
  - Gmsh
- Perform finite element simulations
  - TELEMAC
  - Gmsh-TELEMAC Matlab toolbox (to produce TELEMAC input files)

Future work

- Calibration/validation of the model
  - bottom friction
  - wind stress (drag coefficient)
- Estimate consequences of possible future extreme events
- Include more physics
  - wave propagation
  - sediment dynamics
  - 3D hydrodynamics
- Keep on development of Gmsh-TELEMAC Matlab toolbox

More information

- Gmsh-TELEMAC Matlab toolbox: www.oliviergourgue.net/download

- Inkscape: www.inkscape.org
- Gmsh: geuz.org/gmsh
- TELEMAC: www.opentelemac.org

- E-mail: olivier.gourgue@vub.ac.be