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2D and 3D modelling of the Congo River and Region Of Freshwater Influence (ROFI) with SLIM

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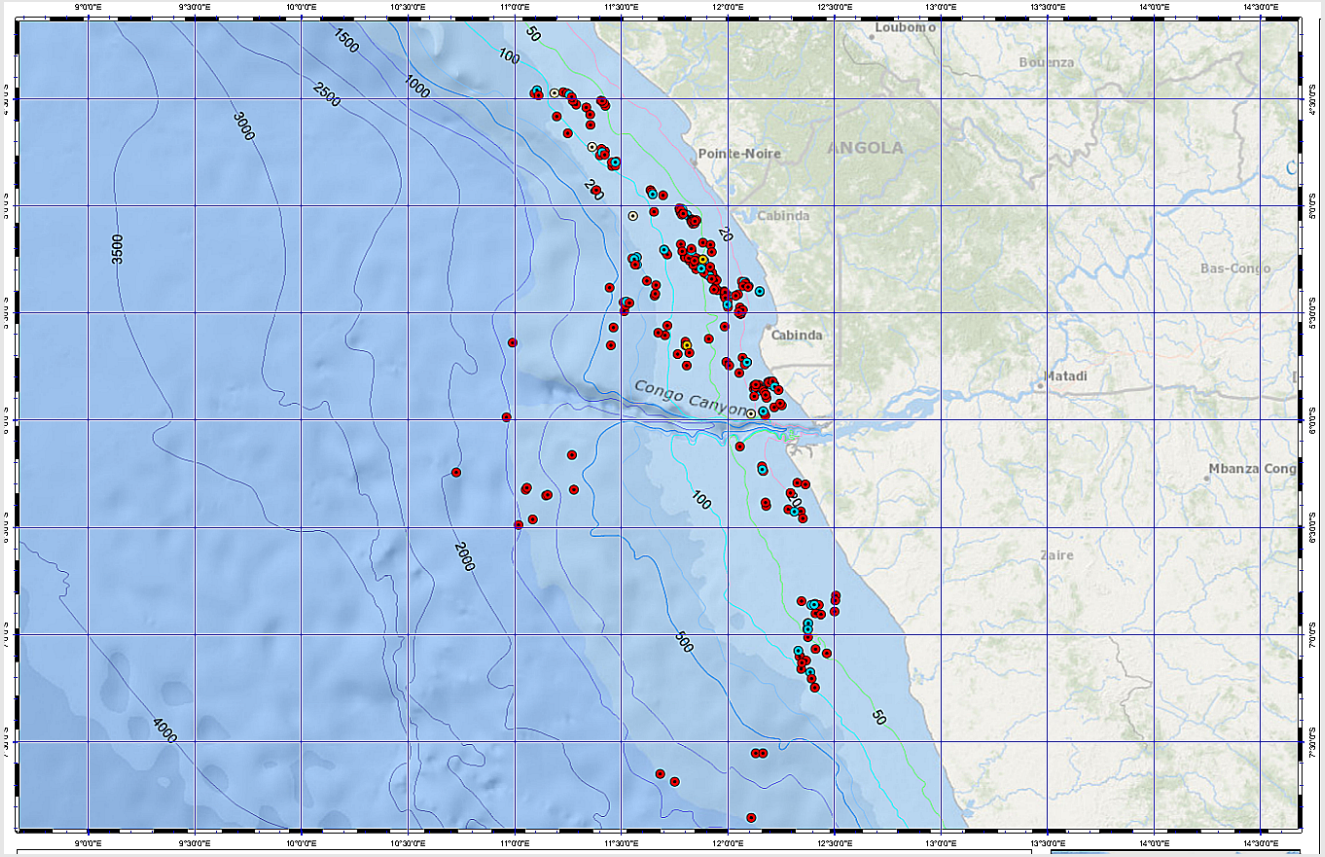
August 27th, 2014

Motivations

- Oil producers need accurate modelling for contingency planning;
- developing SLIM 3D and applying it on a relevant application.



Drilling stations in Congo River estuary

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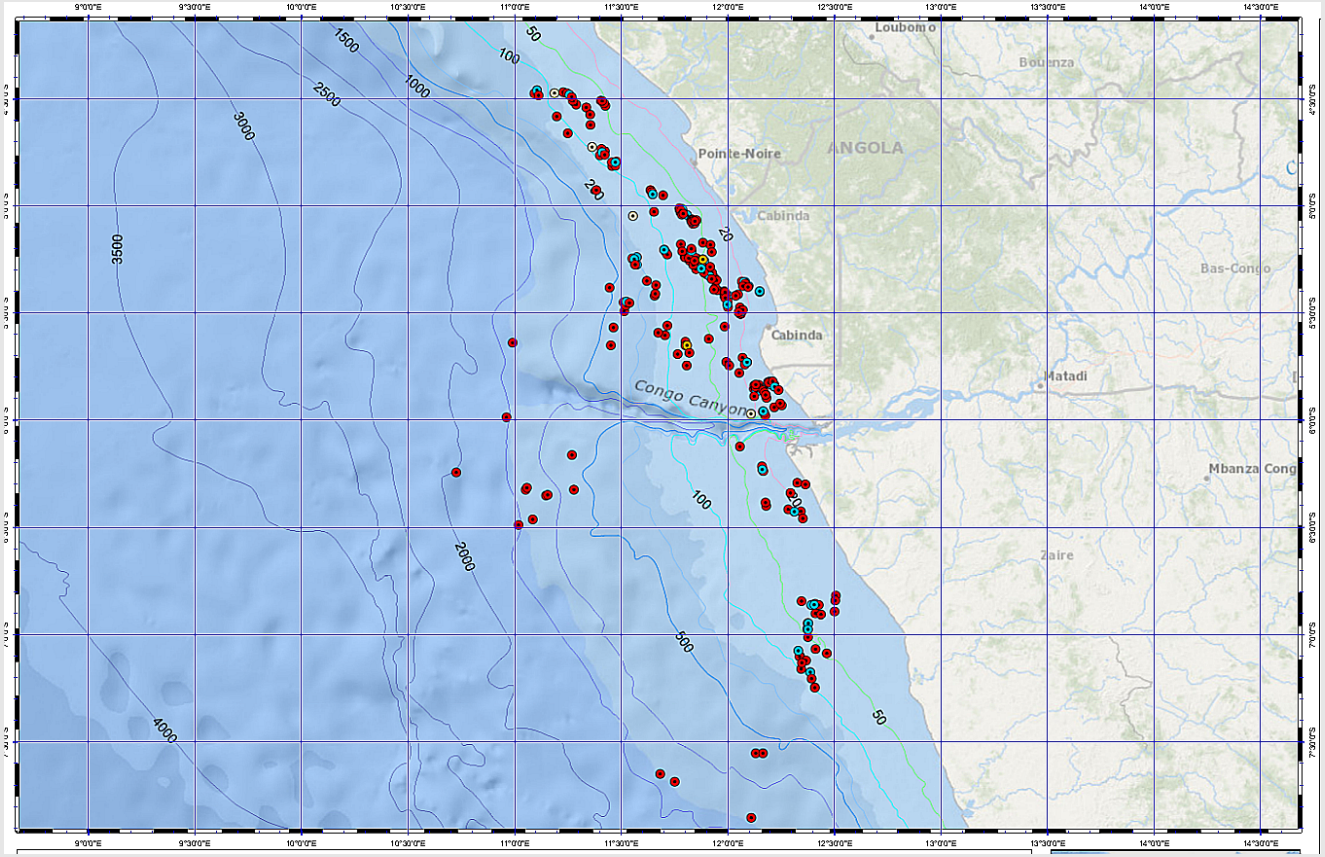


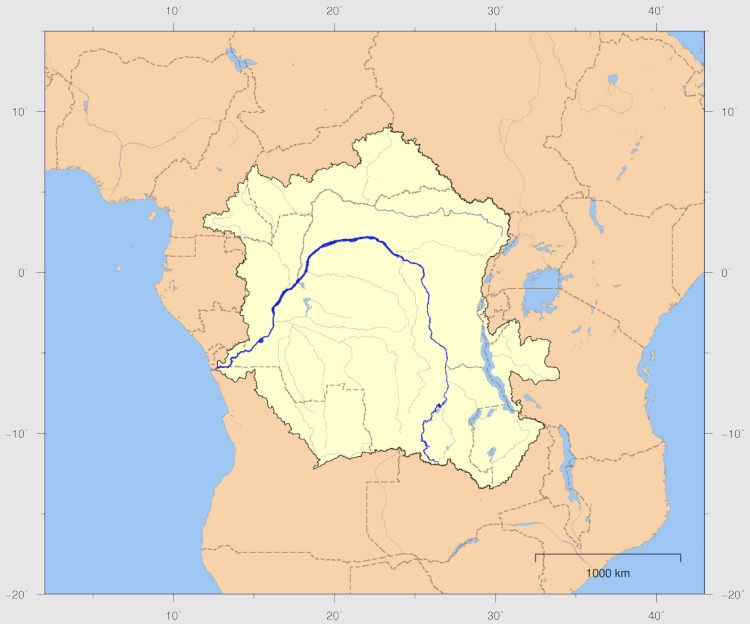
Drilling stations in Congo River estuary

Outlook

1. An overview of Congo River SLIM 2D model
2. 3D tidal modelling

Congo River and ROFI quick overview

The Congo River: second largest river discharge in the world



Congo River watershed overview

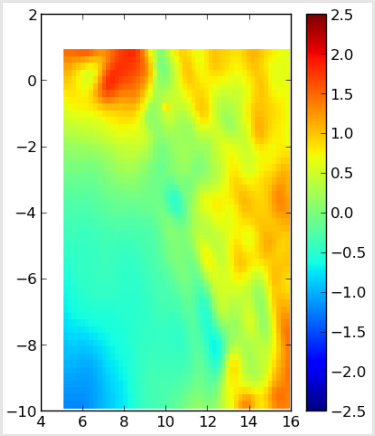
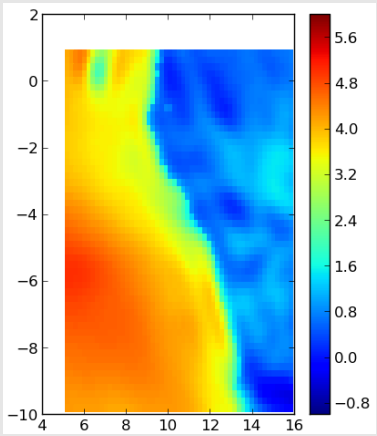
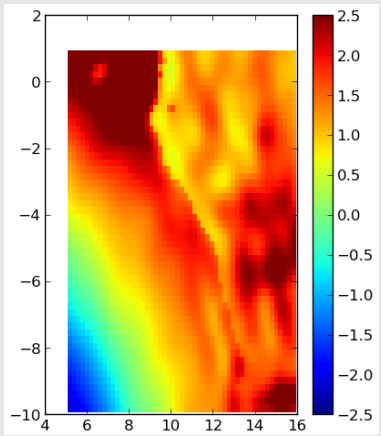
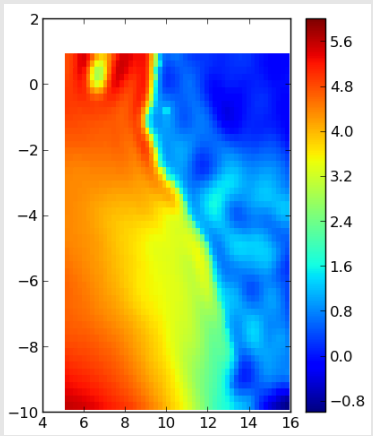
- Very remote region;
- watershed: $\sim 3.7 \cdot 10^6$ km^2,
  - $\sim$ 1× Nile River watershed,
  - $\sim$ 46× Tagus River watershed,
  - $\sim$ 40× Portugal area;
- average flow: $\sim$ 41,000 m^3 s^{-1},

  min $\sim$ 23,000 m^3 s^{-1}, max $\sim$ 80,000 m^3 s^{-1},
  - $\sim$ 15× Nile River average flow,
  - $\sim$ 82× Tagus River average flow;
- river length: $\sim$ 4,700 km,

  tidal influence: 150 km upstream;
- alternate very shallow area and very deep area.

Congo River and ROFI quick overview

Two seasons (equatorial area)

	longitudinal	latitudinal
January 2012		
July 2012		

Wind speed geographical distribution (in $m\,s^{-1}$), monthly means

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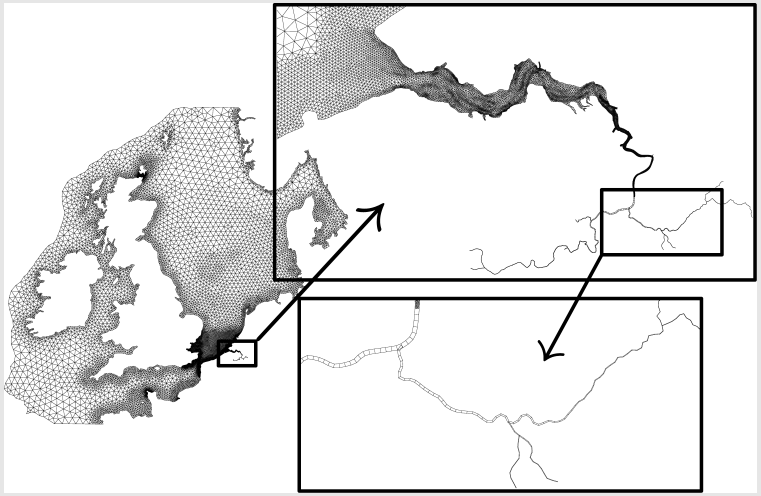
Second-generation Louvain-la-neuve Ice-ocean Model (SLIM)

- Discontinuous Galerkin finite element method;
- multi-rate time stepping;
- 2D depth-average shallow-water equations;
- applied to various complex environmental flows (Great Barrier Reef, Scheldt River, Mahakam River, Lake Tanganyika, ...).



Scheldt estuary model

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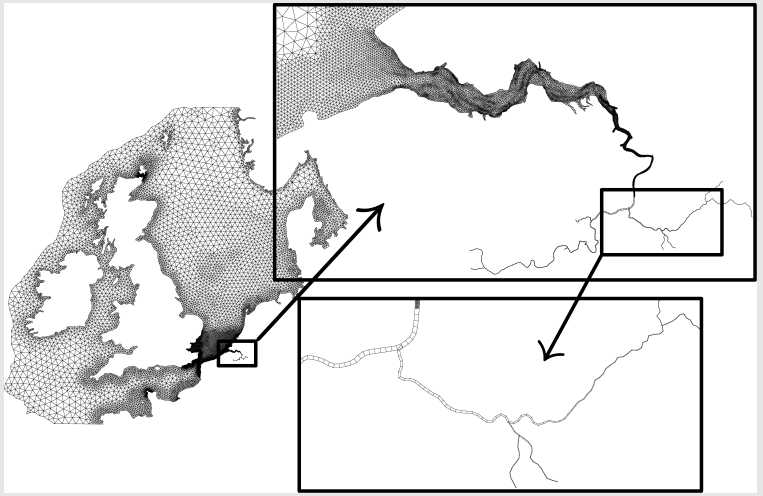
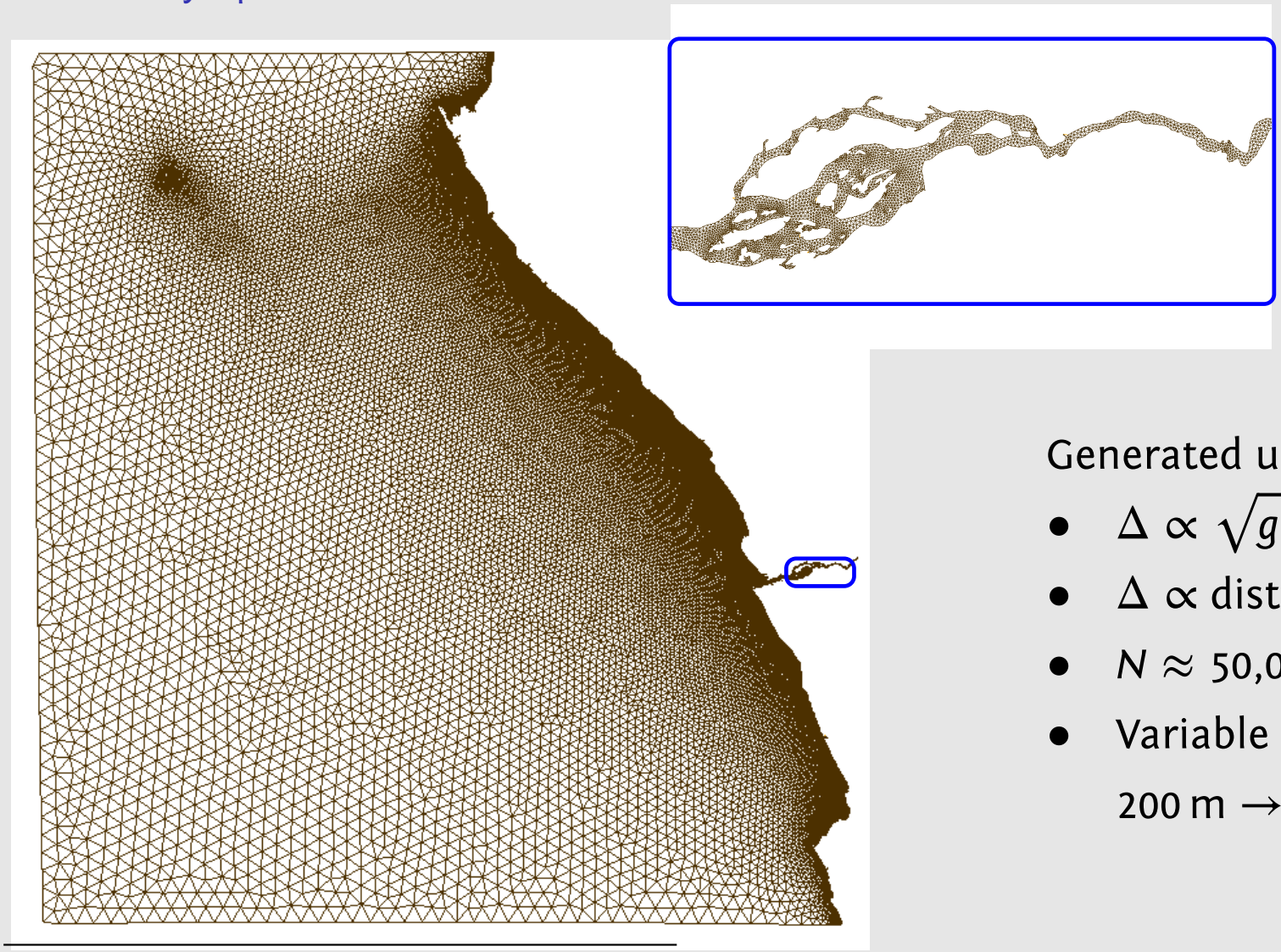


Scheldt estuary model

Congo River 2D model

See V. Vallaeys' poster



Generated using GMSH[1]

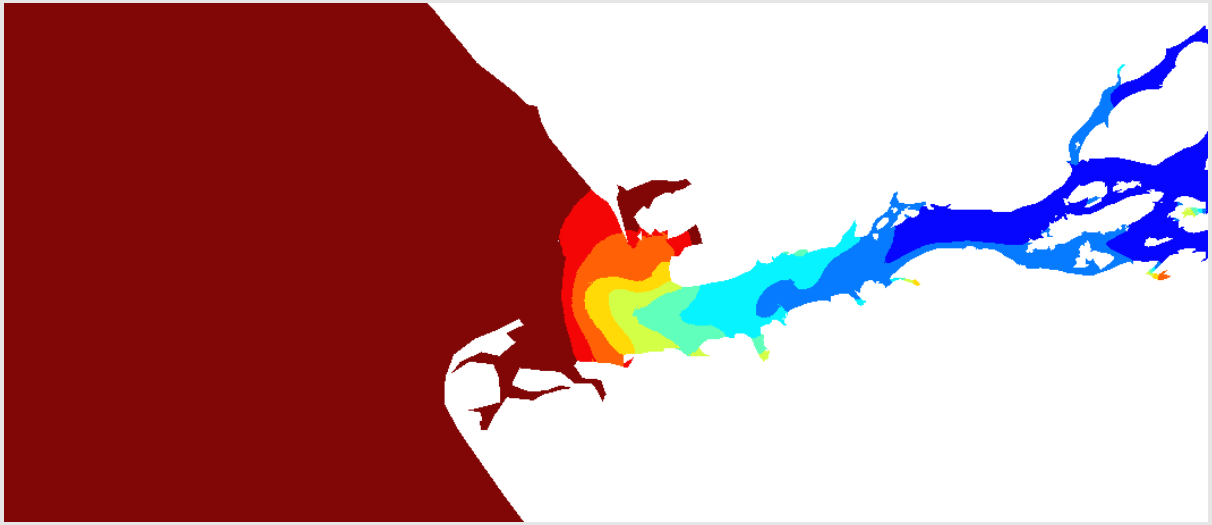
- $\Delta \propto \sqrt{gH}$
- $\Delta \propto$ distance to coast
- $N \approx 50{,}000$ elements
- Variable element size

  200 m $\rightarrow$ 20 km

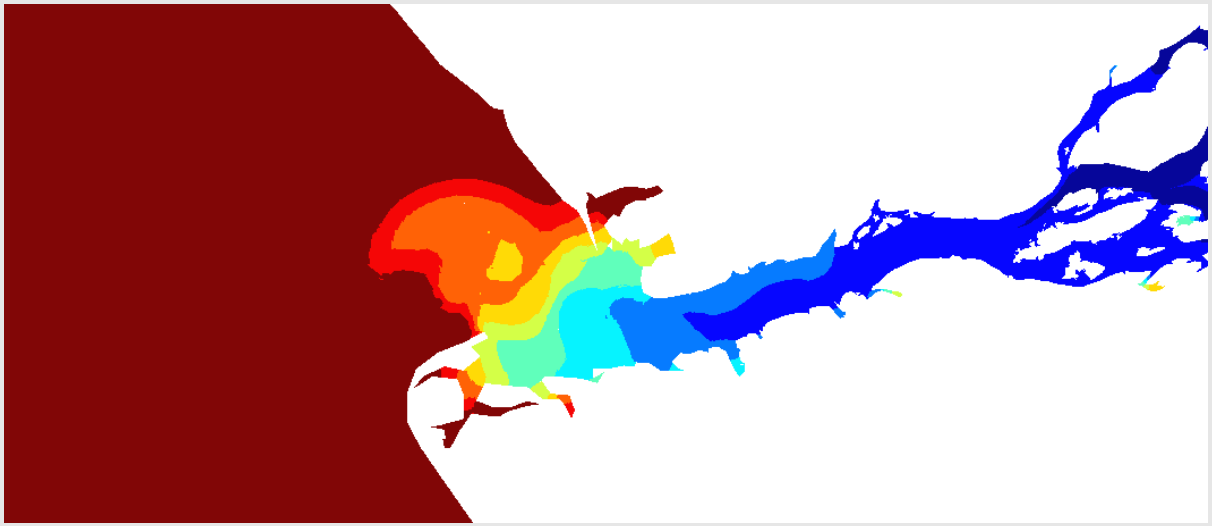
[1] www.geuz.org/gmsh

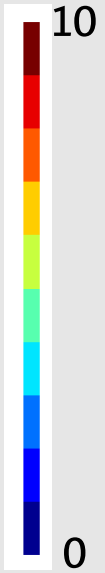
Water age in the Congo River mouth oscillates with tides

Minimal discharge



Maximal discharge

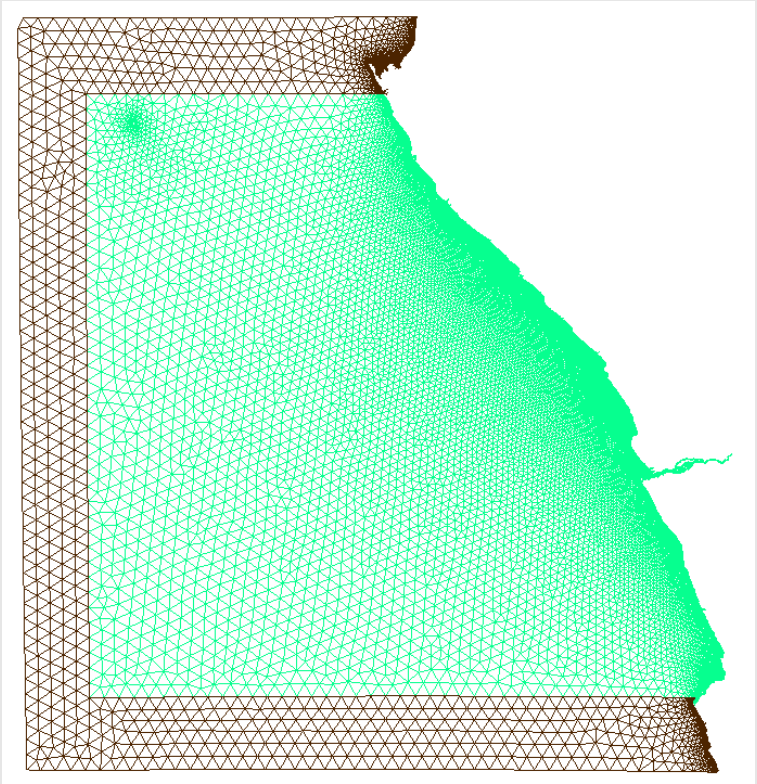




Nesting with a global circulation model

Flow relaxation method (FRS), also called Sponge layer method

- Rather than imposing current at domain open boundary, do it on an absorption layer;
- on the outside boundary, imposing global model current (u);
- on the inside boundary, imposing regional model current ($u_\star$);
- inside the absorption layer, the forcing is a combination of current from global and regional model, according a function λ, for instance $\lambda\left(u, u_\star\right) = \beta\left(u - u_\star\right)$.



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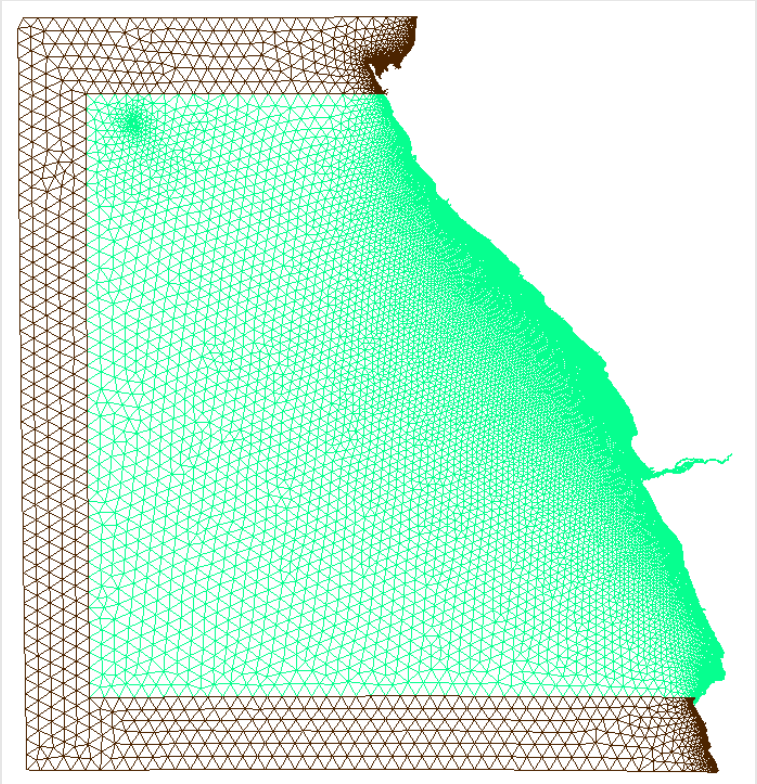

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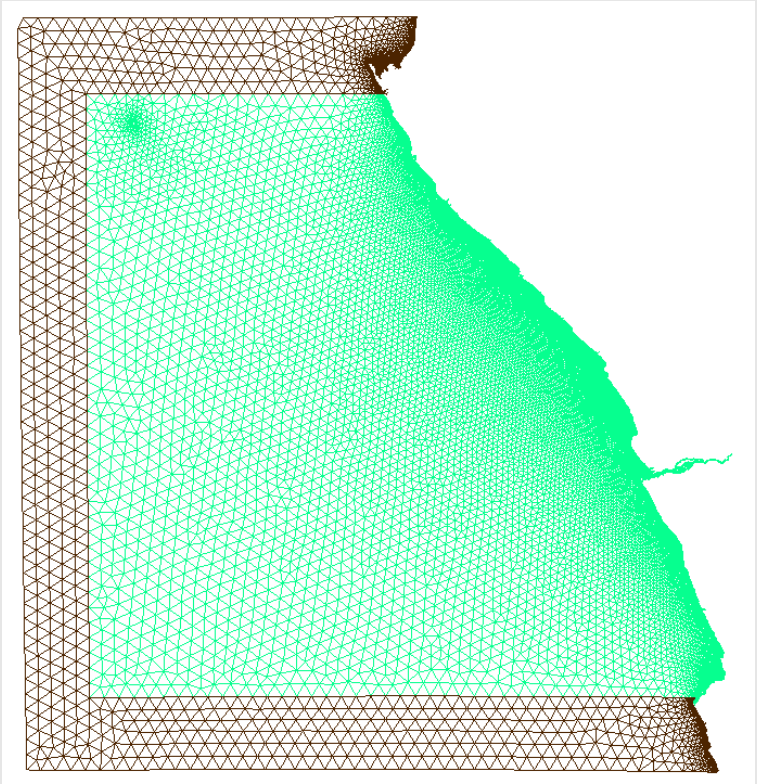

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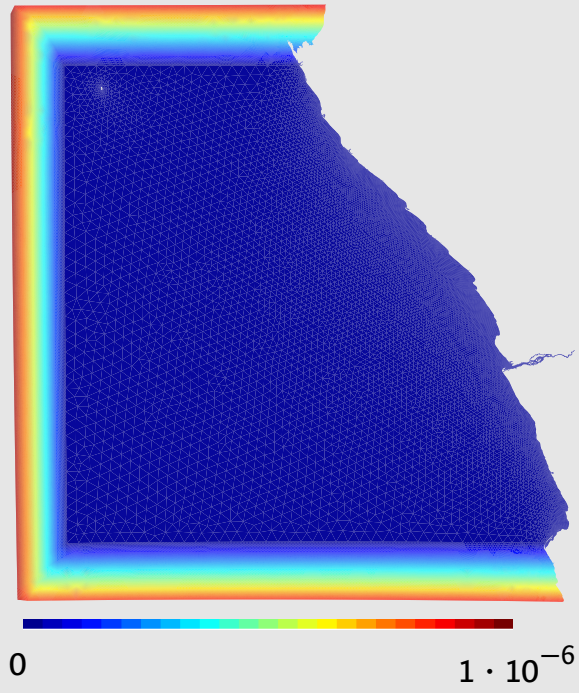
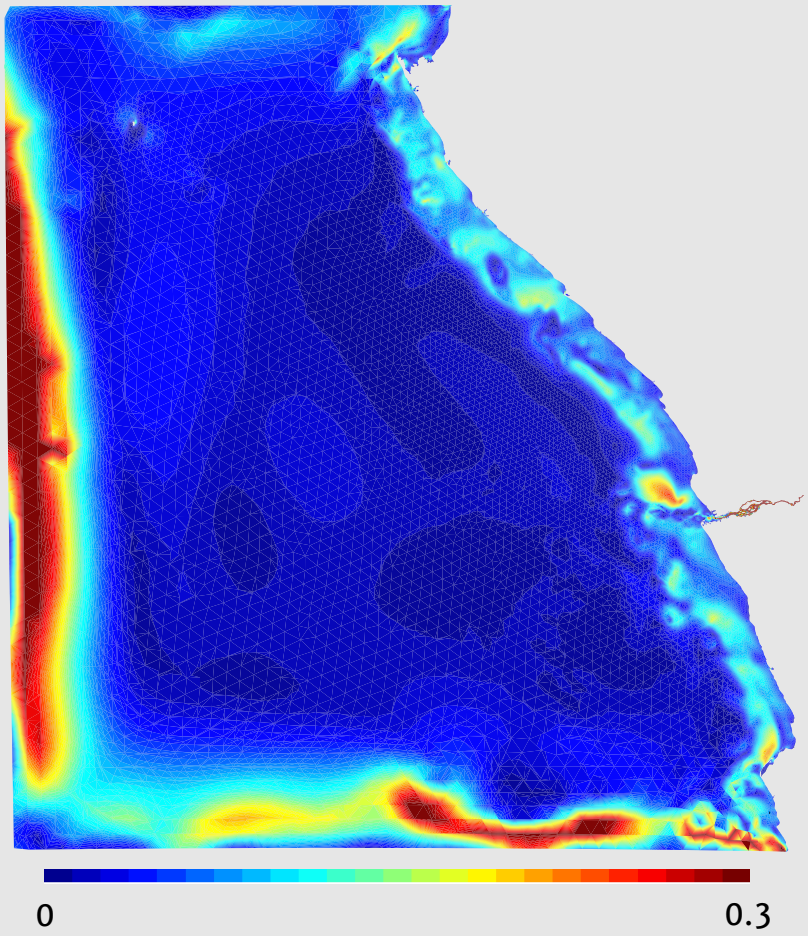
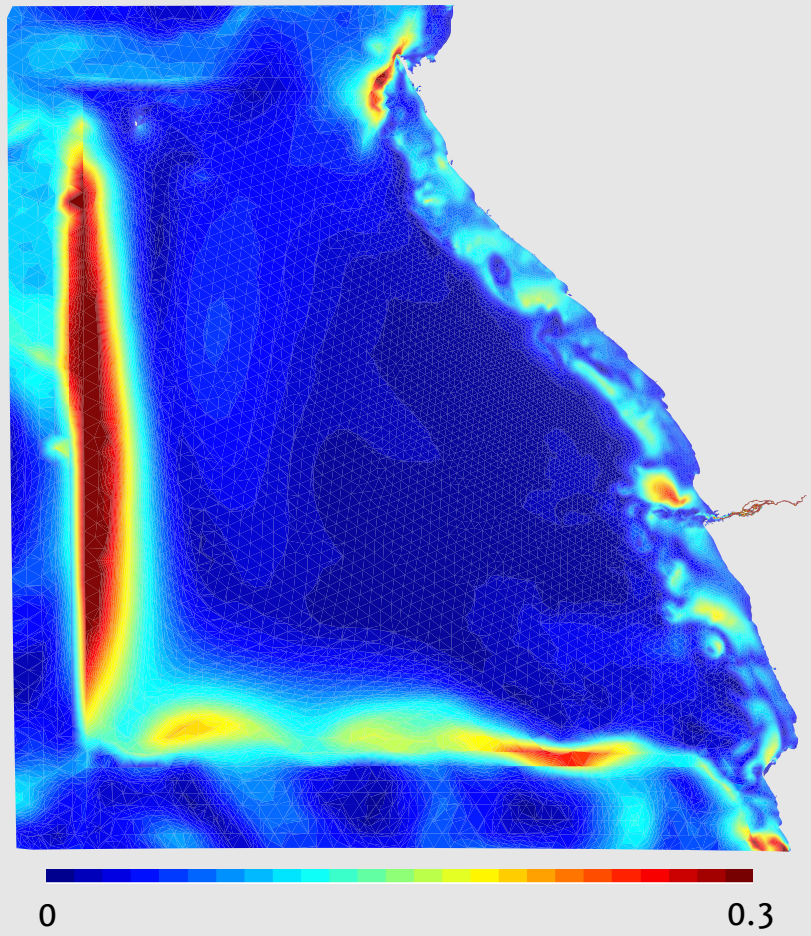


Implementation somehow troublesome



Global circulation imposed without nesting



Global circulation imposed with nesting

Speed vectors norms (in $m\,s^{-1}$)

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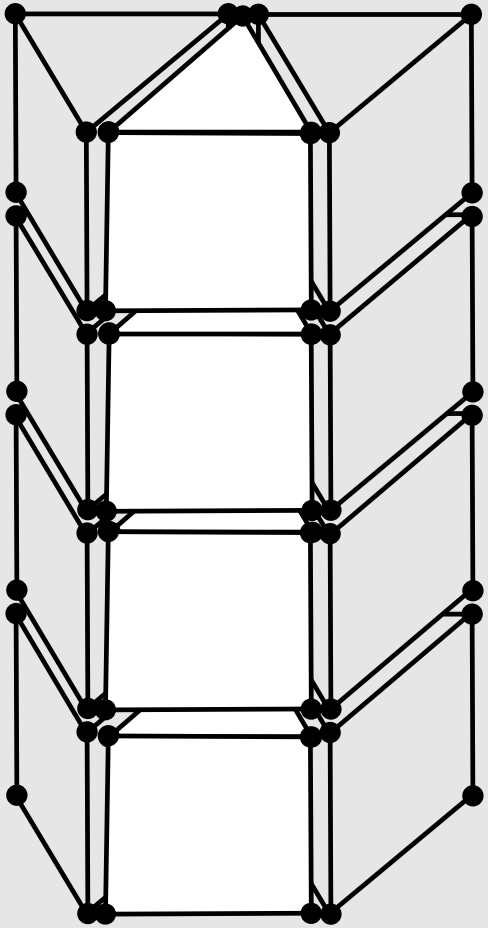
SLIM 3D: a three-dimensional baroclinic DG-FE model

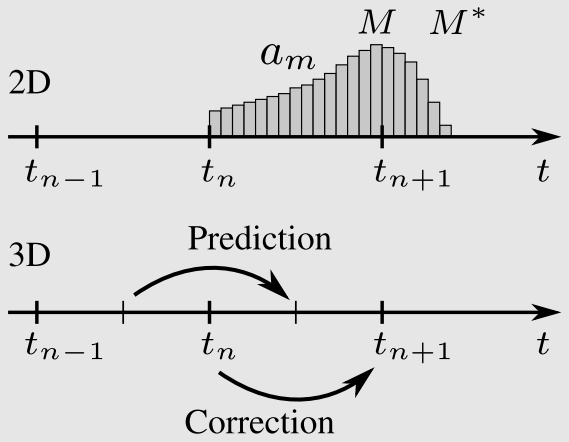


- Boussinesq's approximation;
- prismatic elements;
- moving mesh (see P. Delandmeter's presentation):
  - arbitrary lagrangian-eulerian;
  - mass conservation;
  - tracer consistency (approx.);
- slope limiter:
  - filters spurious tracer extrema;
- turbulence model:
  - either coupled to GOTM[a];
  - or PP parametrization;
- parallel implementation.

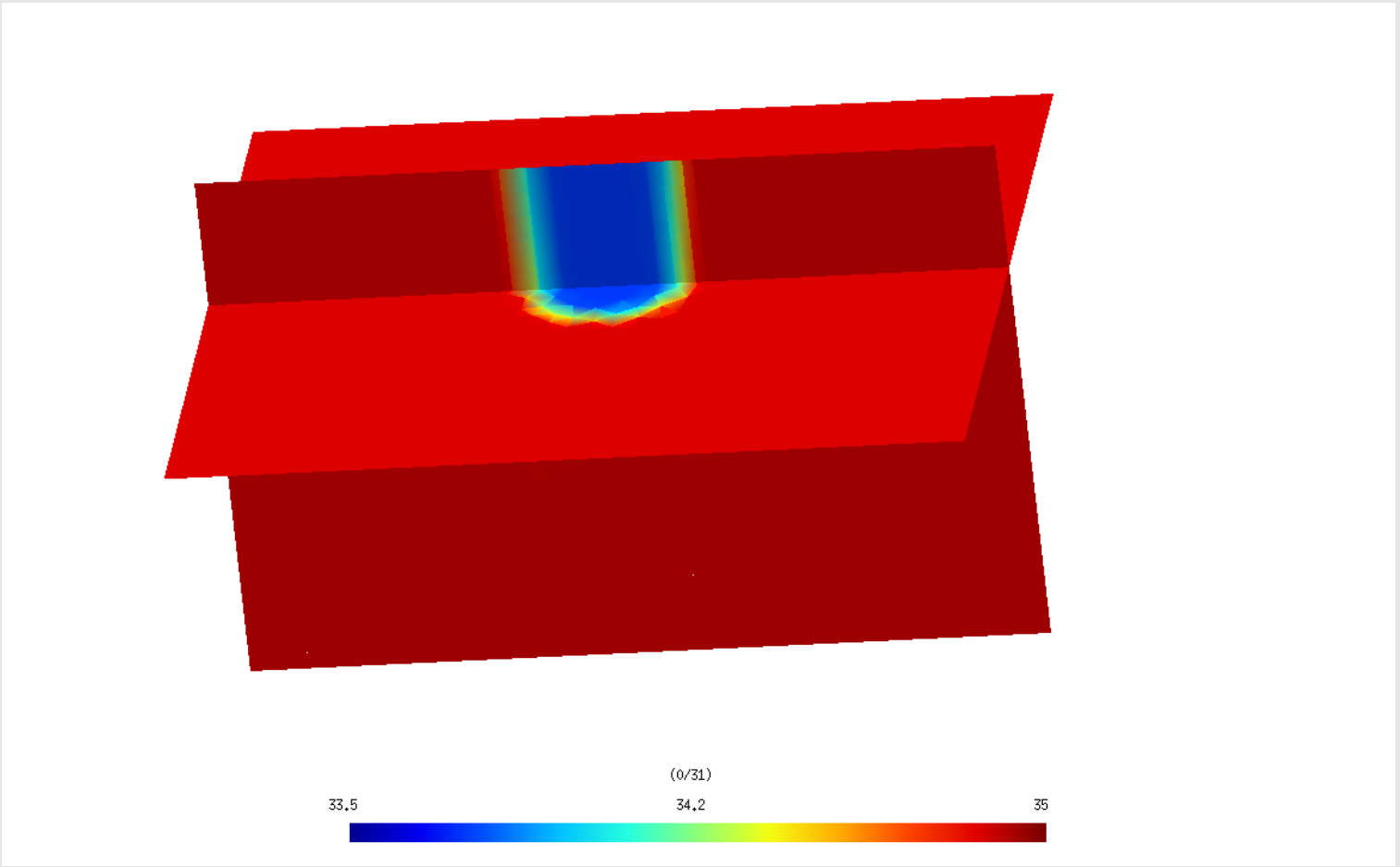
[a] www.gotm.net

Time integration

- Split-explicit approach;
- 2D – barotropic mode:
  - Adams-Bashforth 3 scheme;
  - filtered;
- 3D – baroclinic mode:
  - LF-AM3 predictor-corrector scheme;
  - corrector step computed on an updated mesh;
  - vertical diffusion treated semi-implicitly;



SLIM 3D has already been tested on standard test cases

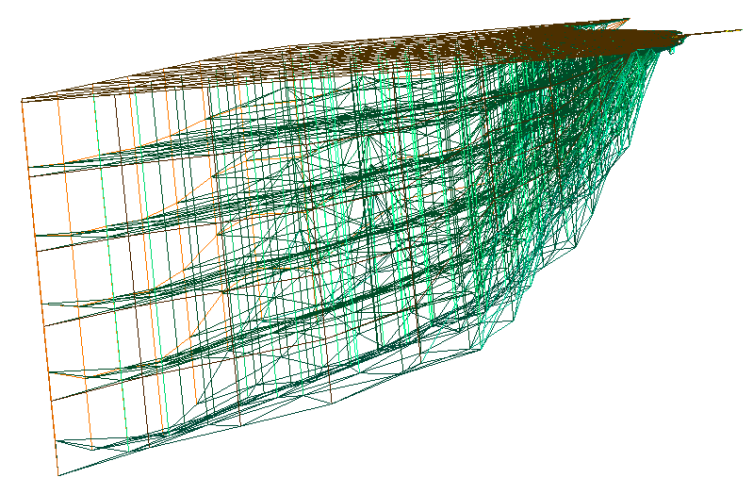


Salinity (in psu)

From Tartinville et al. (1998).

σ-layer

Overview

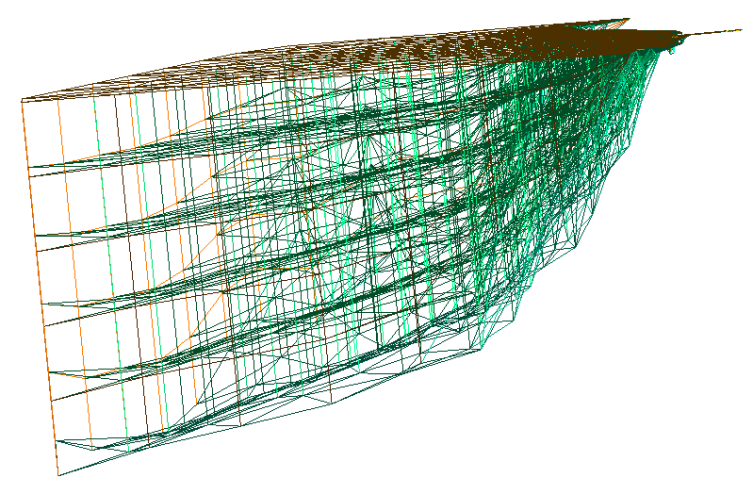


Congo River and ROFI 3D coarse σ-layer mesh (magnified scale on depth)

- Pressure gradient is used rather than depth;
- fit smoothly with bottom geometry;
- difficulty in handling step-like features.

σ-layer

Overview



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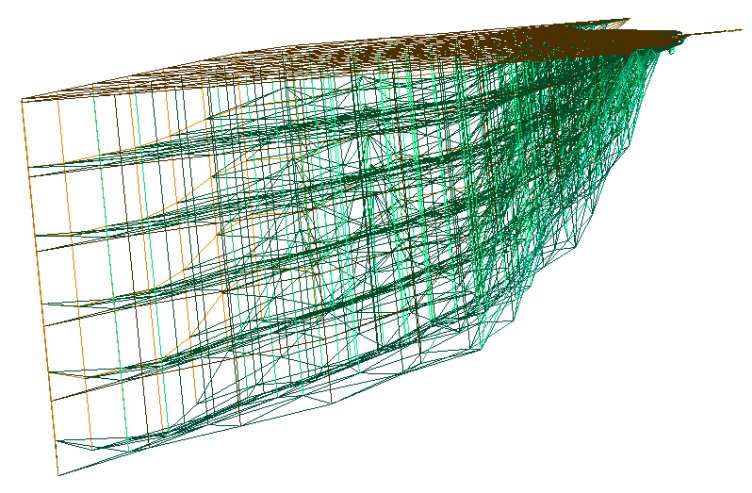

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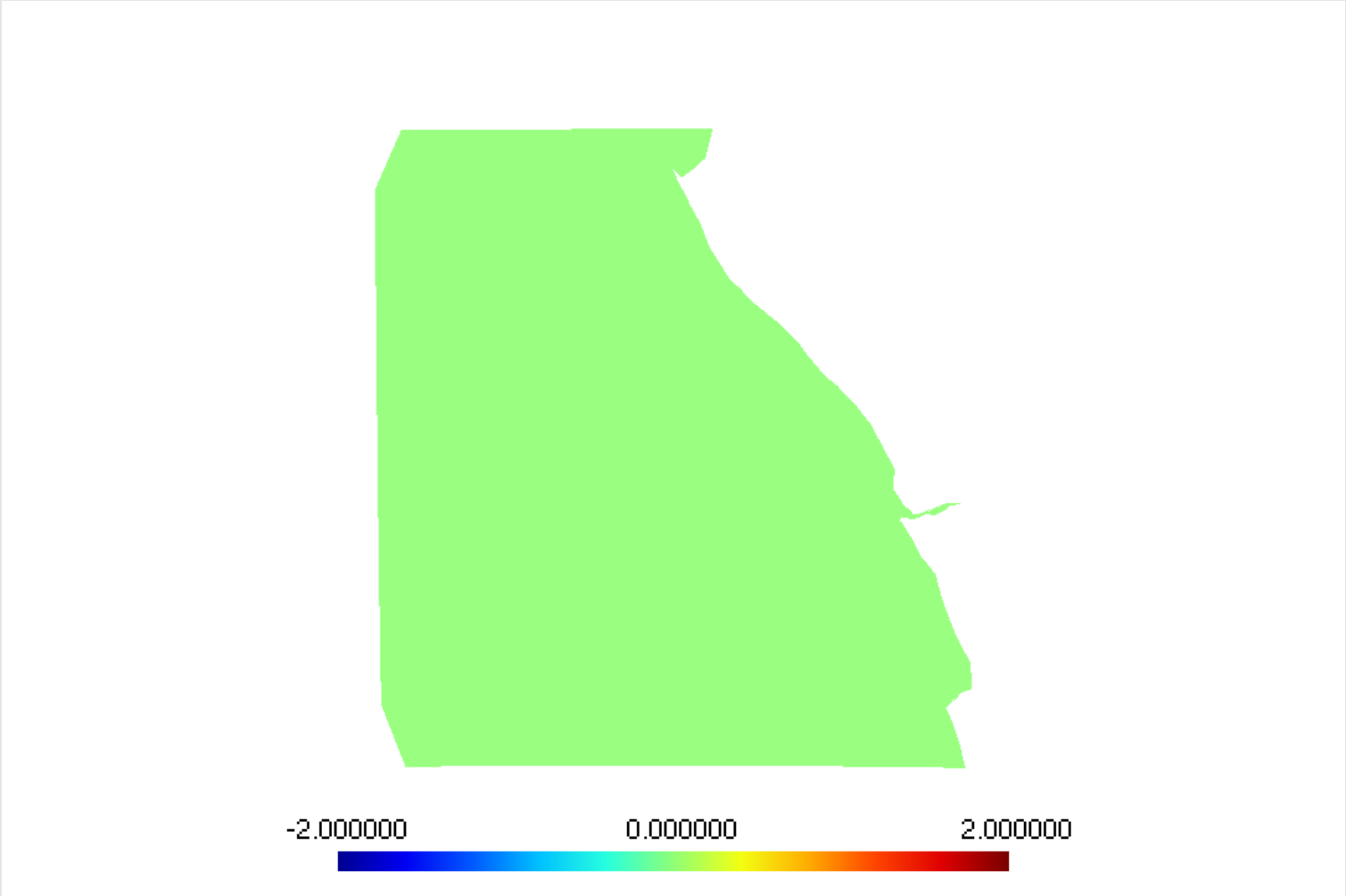
σ-coordinates

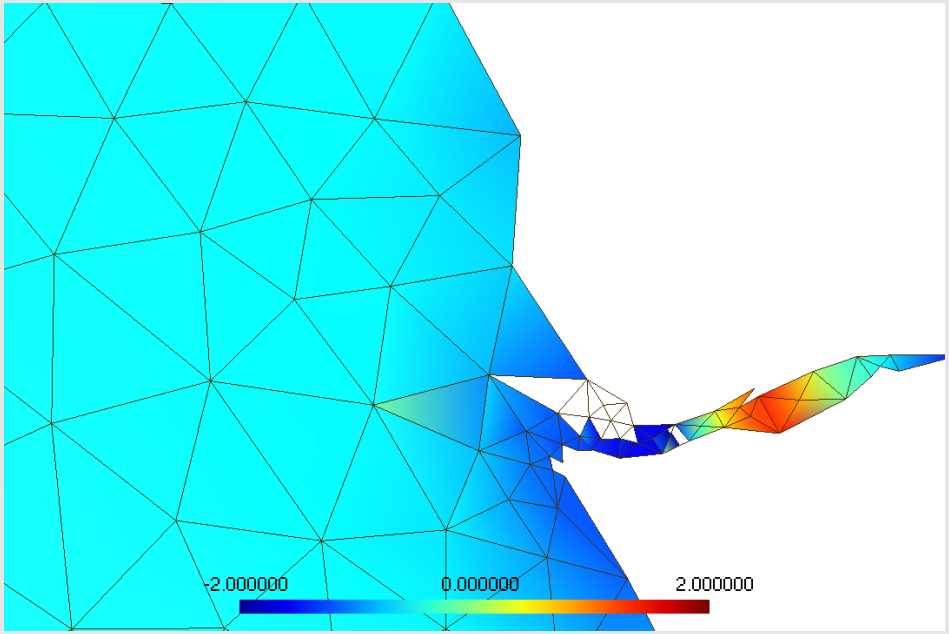
First run: tide only



Elevation (in m)

σ-coordinates

Handling step-like features



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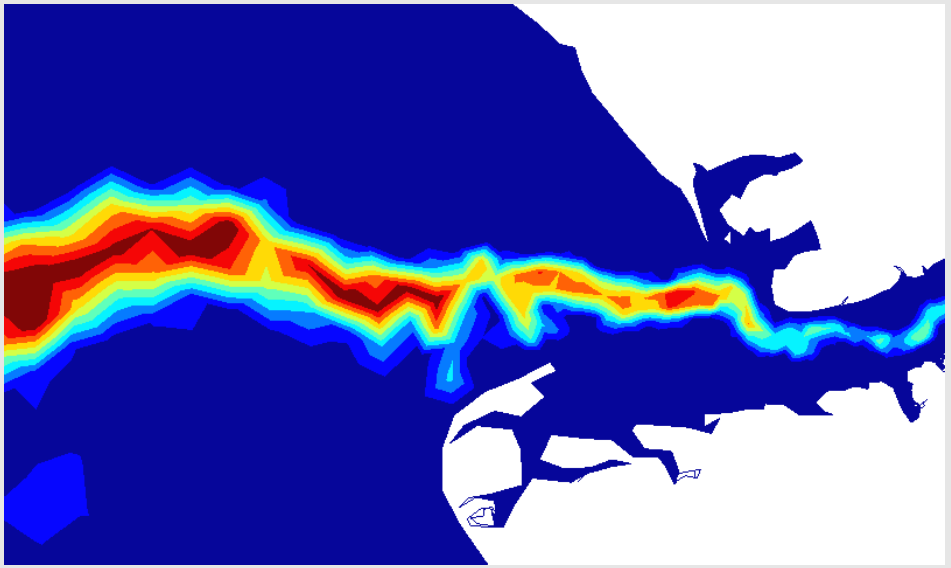
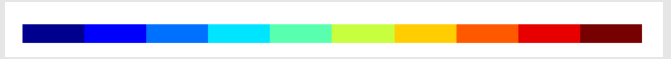


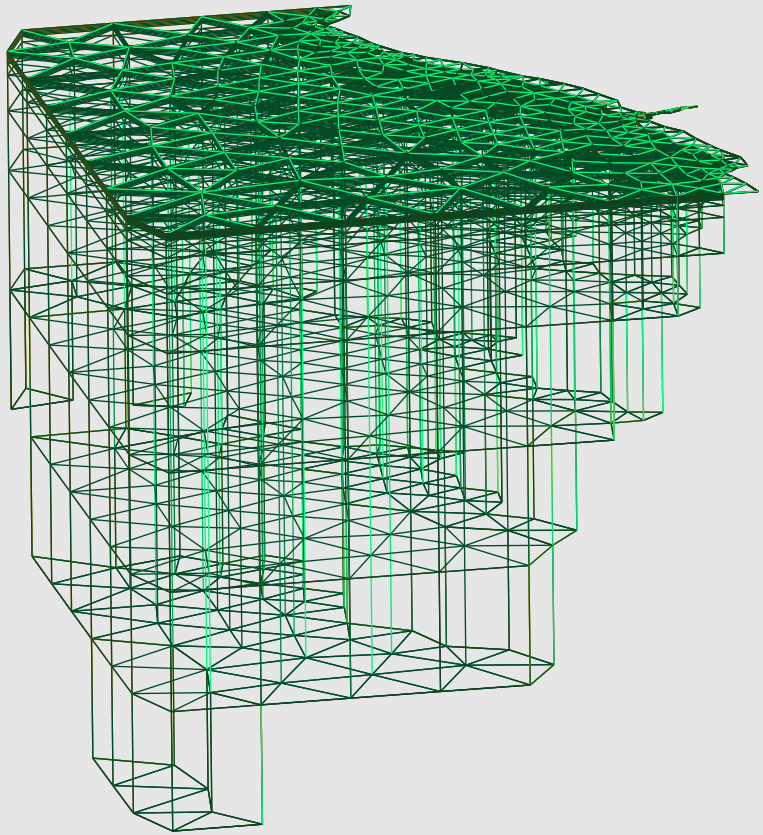


Bathymetry (in m)

Z-coordinates

Overview

- Using arbitrary depth;
- fit more roughly bottom geometry;
- handle step-like features.



Congo River and ROFI 3D coarse z-coordinate mesh (magnified scale on depth)

Z-coordinates

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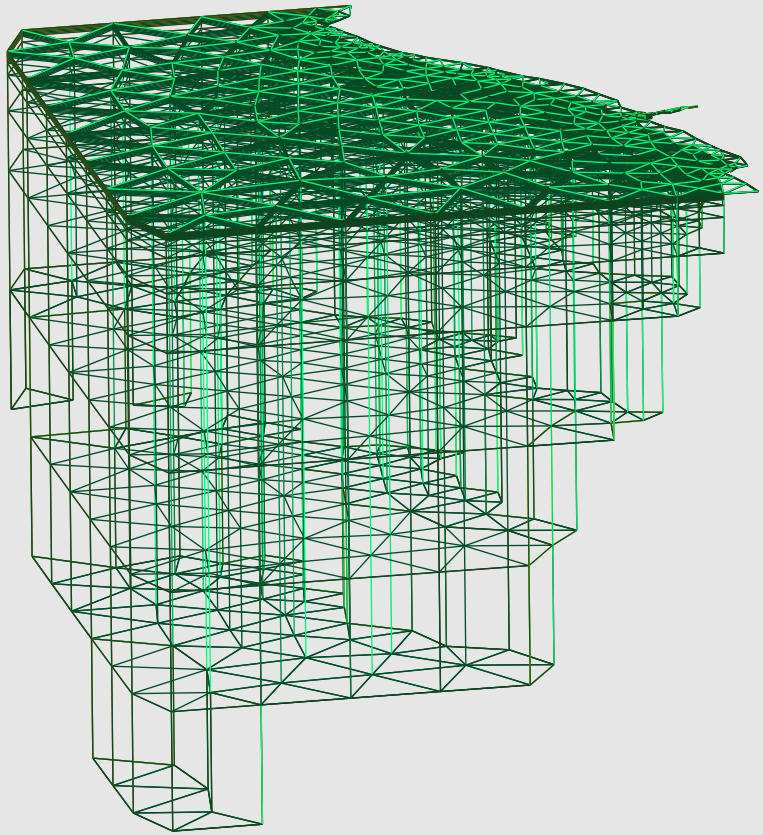

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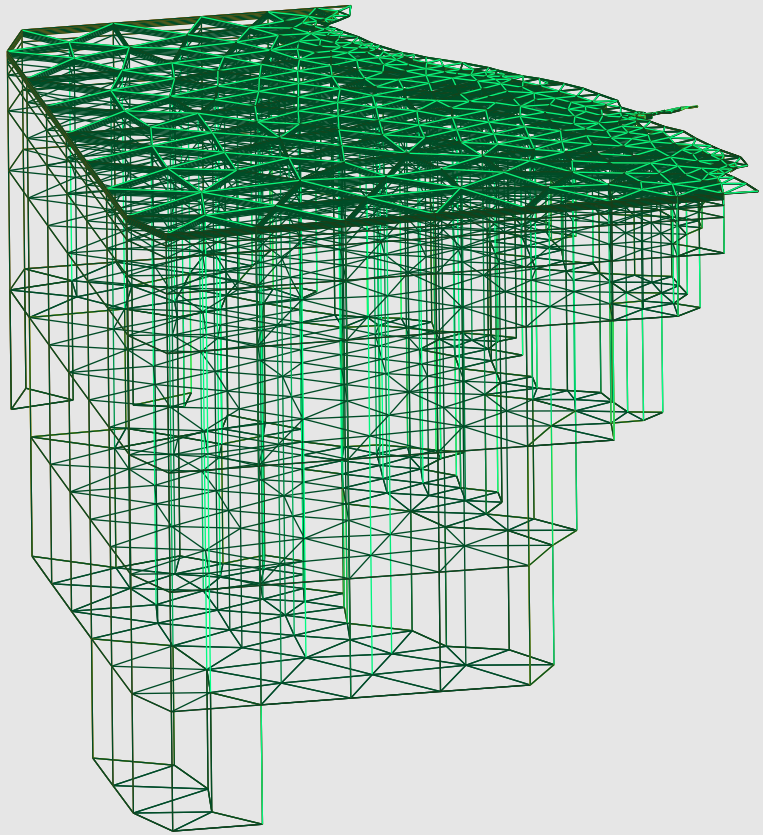

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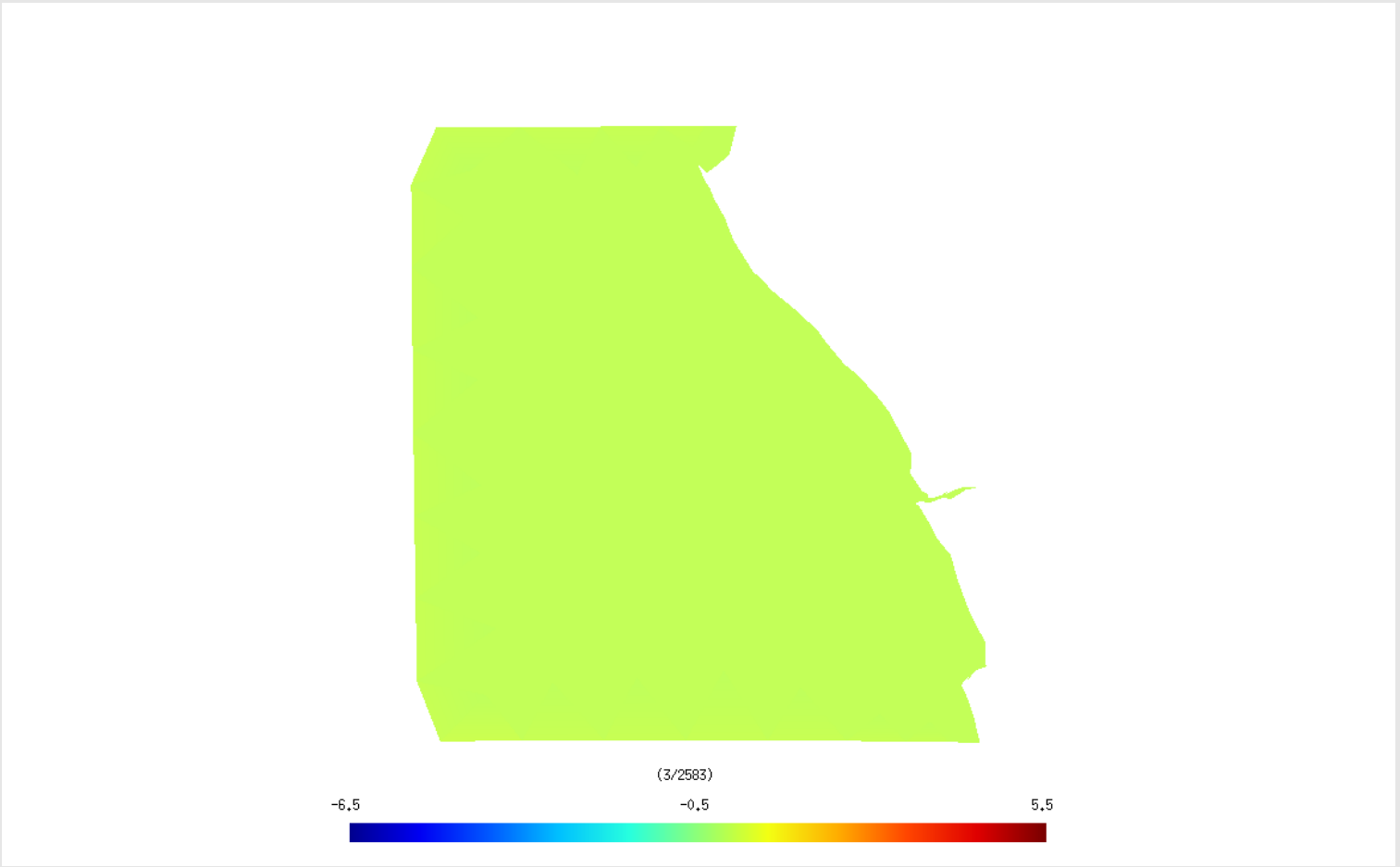

Elevation (in m)

Conclusion

- 2D model:
  - mostly complete;
  - few improvements in the mesh;
  - nesting;
- 3D model:
  - early development stage;
  - mixing σ-layers with z-layers where needed;
  - including a relatively small 3D model into a larger 2D model (current 2D model).

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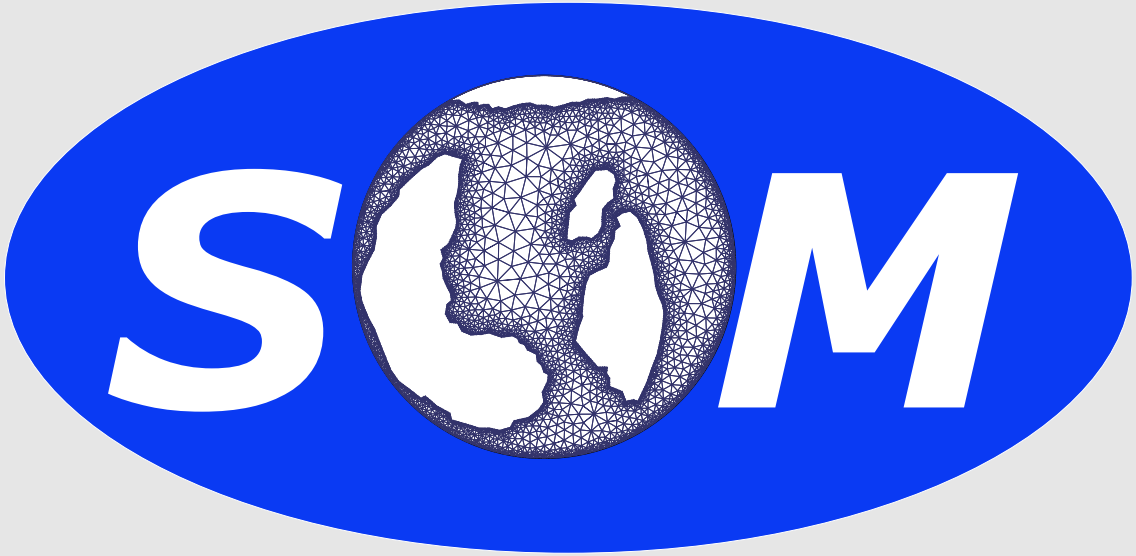

sites.uclouvain.be/slim