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Preliminary results of an unstructured-mesh model of the Congo River, estuary and ROFI

JONSMOD2014

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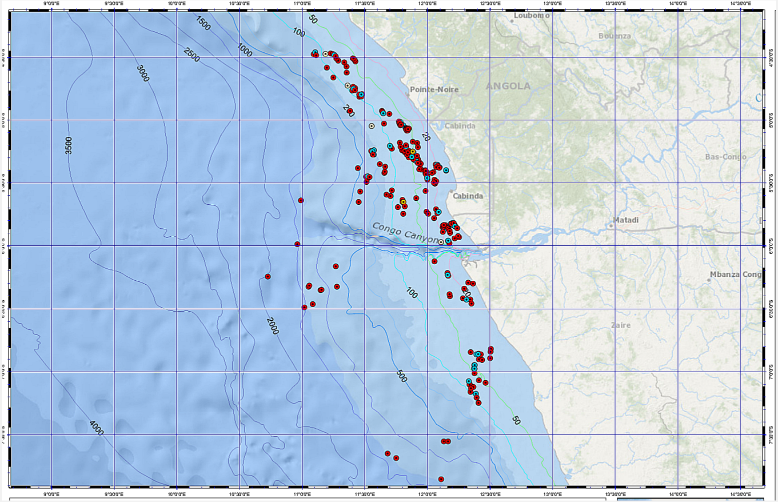
Motivation

Oil producers need good models of the Congo River ROFI

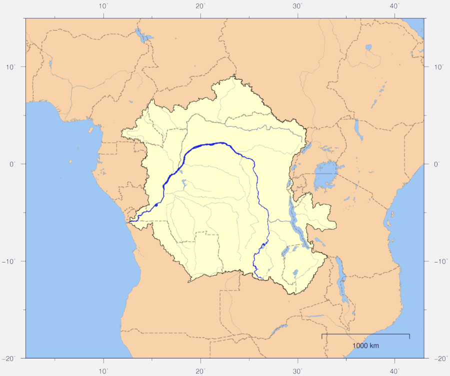


The Congo River is the second largest river in terms of discharge and watershed size

- Very remote region
- Watershed: $\sim 3.7 \times 10^6$ km^2
  - $\sim$ Nile
  - $\sim 170\times$ Scheldt
  - $\sim 121\times$ Belgium
- Average flow: $\sim 41{,}000\,\mathrm{m^3\,s^{-1}}$

  min $\sim 23{,}000\,\mathrm{m^3\,s^{-1}}$, max $\sim 80{,}000\,\mathrm{m^3\,s^{-1}}$
  - $\sim 15\times$ Nile
  - $> 300\times$ Scheldt
- Length: $\sim 4{,}700$ km

  Tidal influence: 150 km upstream

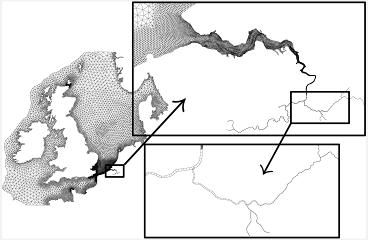


Watershed of the Congo River

The multi-scale model SLIM is well suited to this area

Second-generation **L**ouvain-la-Neuve **I**ce-ocean **M**odel

- Discontinuous Galerkin Finite Element Method
- Multi-rate time stepping
- 2D depth-averaged shallow-water equations
  - Applied to a number of complex environmental flows (Great Barrier Reef, Scheldt River, Mahakam River, Lake Tanganyika, ...)
- 3D baroclinic model under development

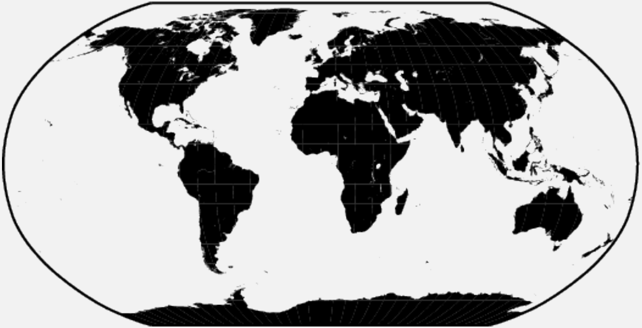


Scheldt estuary model

www.climate.be/SLIM

The coastline is derived from various sources

- GSHHG database outside the river
- Nautical charts within the river (with use of GeoDesk)



ylebars.github.io/GeoDesk/

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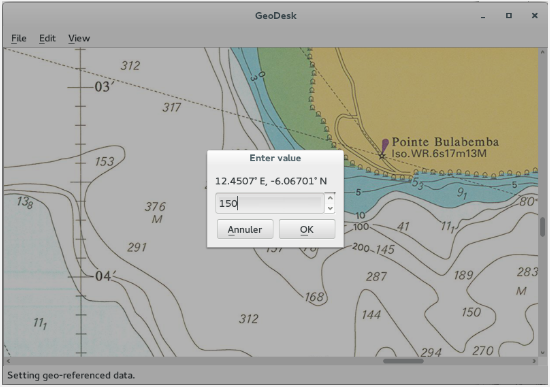

GeoDesk in use

ylebars.github.io/GeoDesk/

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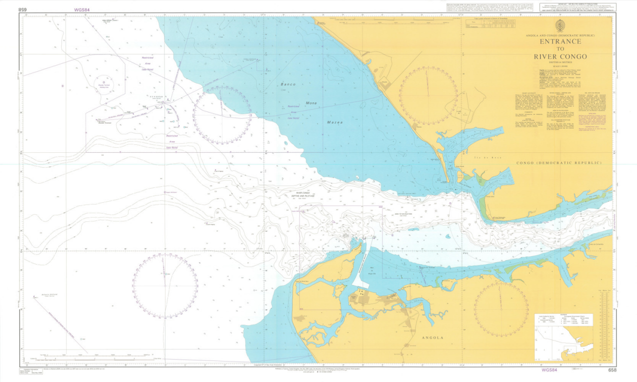

Commercial nautical chart

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Digital coastline

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The bathymetry is also derived from various sources

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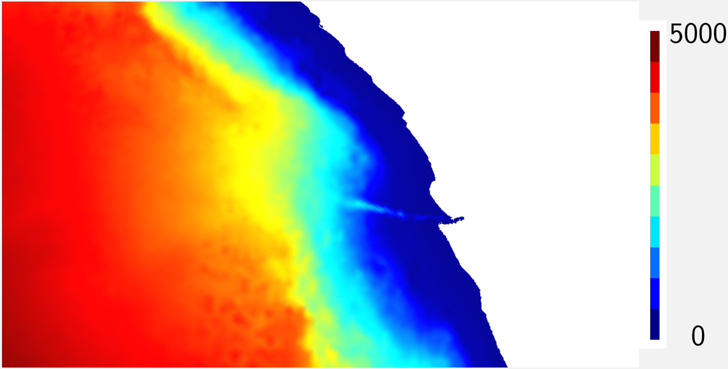

Bathymetry (in m)

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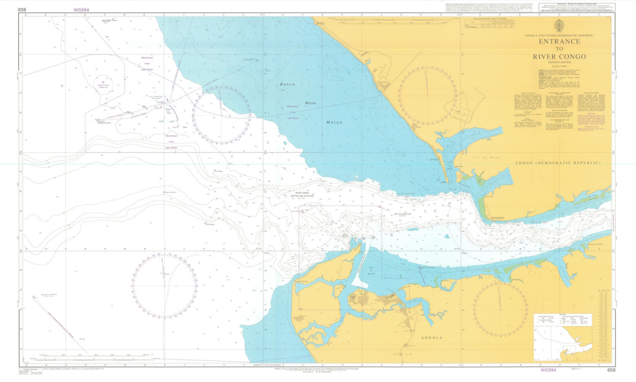

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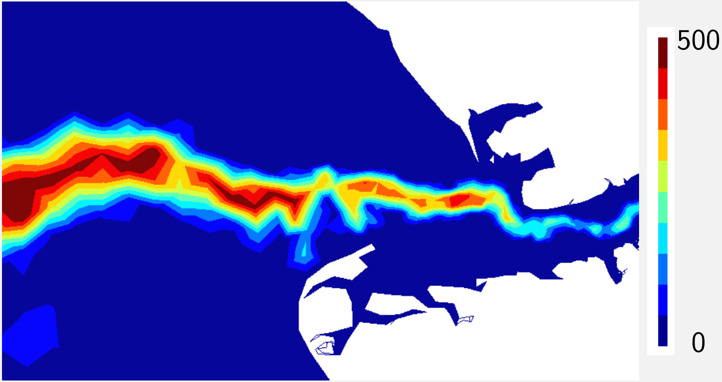

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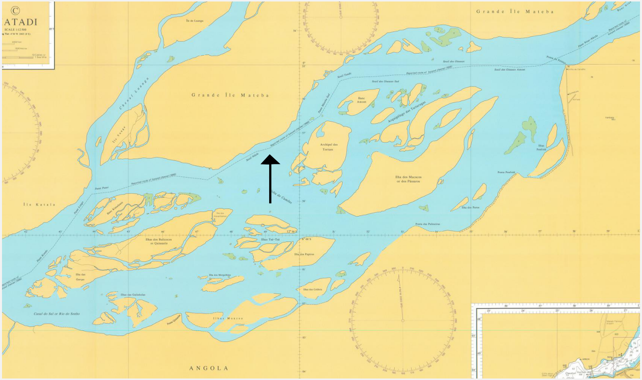

Unobserved area

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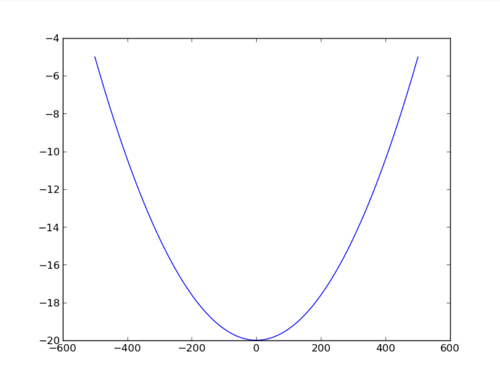

Channel profile (in m)

ylebars.github.io/GeoDesk/

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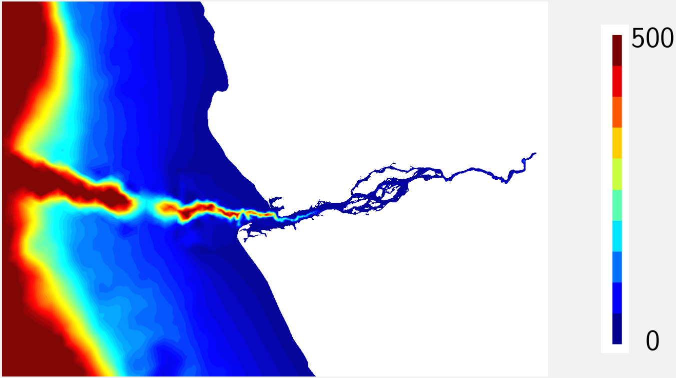
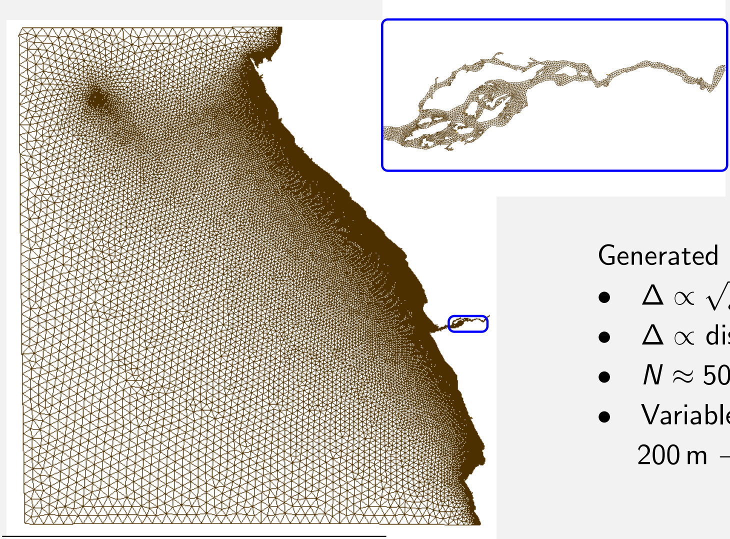


Bathymetry (in m)

ylebars.github.io/GeoDesk/

Distance to coastline and bathymetry are then used to produce a multi-scale mesh



Generated using GMSH

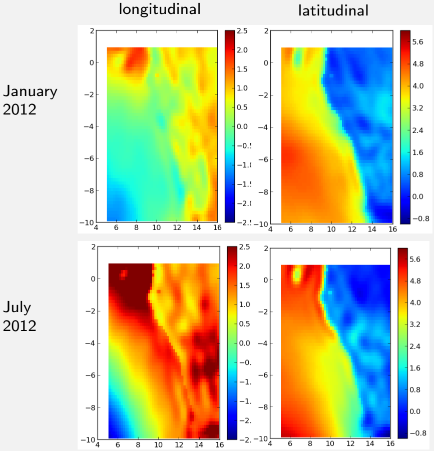
- $\Delta \propto \sqrt{gH}$
- $\Delta \propto$ distance to coast
- $N \approx 50{,}000$ elements
- Variable element size

  $200\,\text{m} \rightarrow 20\,\text{km}$

www.geuz.org/gmsh

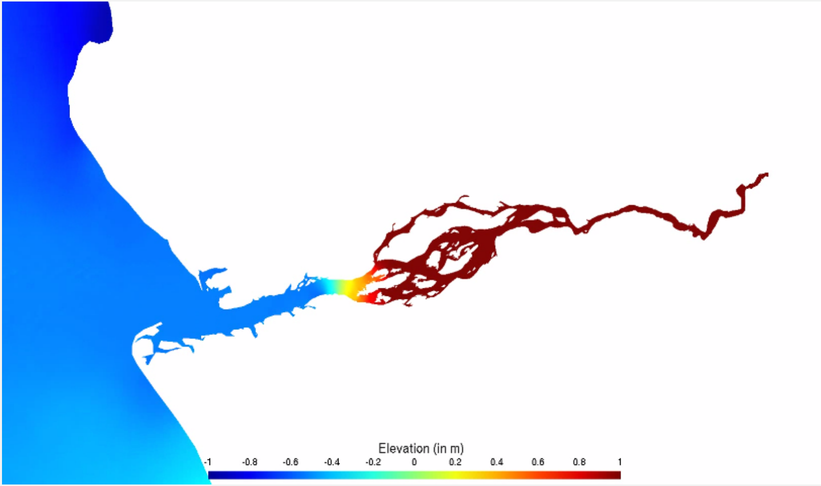
Upstream and downstream boundary conditions

- Upstream to the limit of the tidal influence
  - Imposed discharge at Matadi
- Downstream in open ocean
  - OBC provided by a global ocean tidal model (FES2012) and ocean global circulation (HYCOM) imposed with FRS
  - Wind forcing imposed as a surface stress (ECMWF)



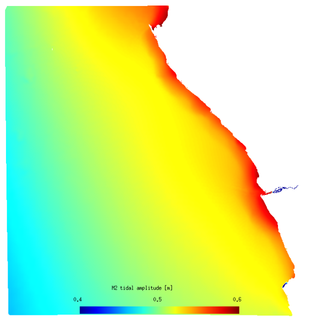
Wind speed geographical distribution (in $\mathrm{m\,s^{-1}}$), monthly means

With all these ingedients, the model is finally up and running

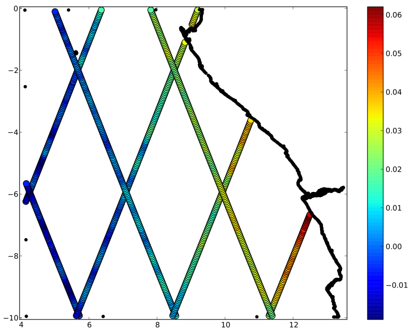


Validation with satellite altimetry data

M_2 amplitude



Computed tidal amplitude [m]

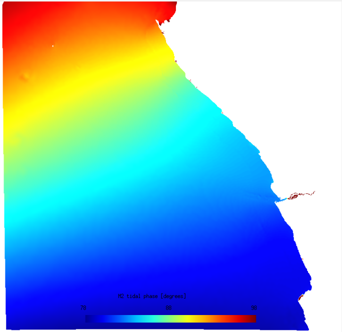


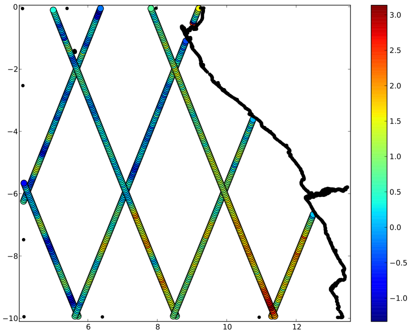
Absolute error w.r.t altimetry [m]

General error	absolute	relative
mean	1.26 cm	2.53 %
RMS	2.09 cm	4.09 %

Validation with satellite altimetry data

M_2 phase





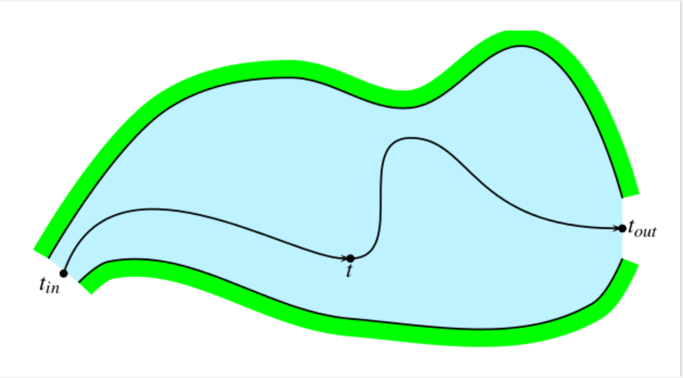
Computed tidal phase [°]

Absolute error w.r.t altimetry [°]

General error	absolute
mean	0.68°
RMS	1.00°

The water age is a useful tool to analyze various flow regimes

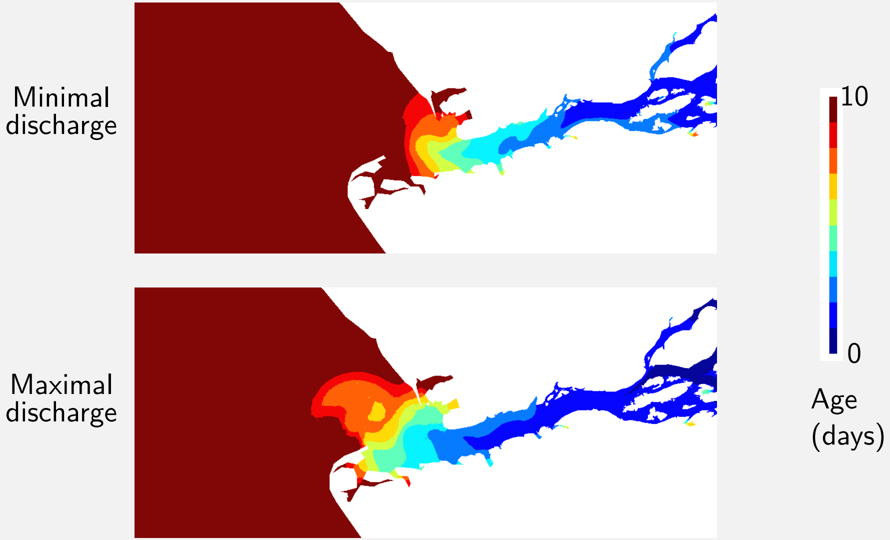
Water age is the time spent since the particle entered the domain $t - t_{in}$



(Figure courtesy E.J.M. Delhez)

Shen and Haas (2004)

Water age in the Congo River mouth oscillates with tides



Conclusions and outlooks

- Conclusions
  - We have developed a methodology to model a complex multi-scale area
  - We have developed several tools to deal with sparse datasets
  - The model has been validated with altimetric data
  - Preliminary water age simulations have been performed
- Outlooks
  - In depth studying of 2D hydrodynamics (impact on oil drilling)
  - Apply 3D model to simulate freshwater plume (under heavy development)

Thank you

www.climate.be/SLIM