Unstructured grid modelling

Intercomparison between several finite element and finite volume approaches to model the North Sea tides

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Overall goals in ECOOP (Workpackage 7.2.1):

- To provide shallow water models working on unstructured grids and capable of being effectively coupled with larger-scale external models
- To provide adjoint models for optimising model parameters (friction, topography) and open boundary conditions
- Long-term goal: full 3D unstructured grid model for coastal applications

Work performed thus far in 7.2.1:

- Setup of several unstructured grid models (both FE and FV) for the North and Baltic Seas
- Exploring the influence of spatial discretization (FE, FV) on accuracy and computational efficiency

Unstructured grid models

finite volume (FV): easy to implement, less accurate in space
finite element (FE): implementation more elaborate, more expensive
FV:

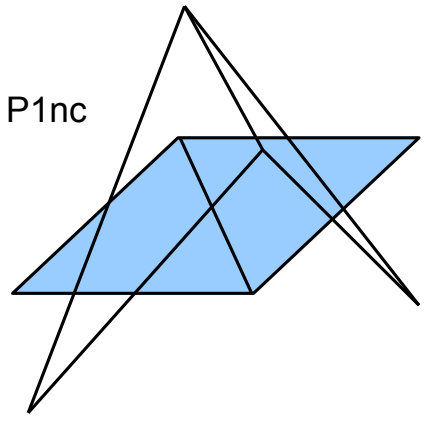
- Chen et al (FVCOM)
- Casulli&Walters (UnTRIM)

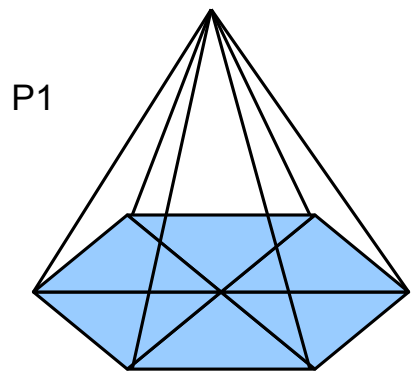
FE:

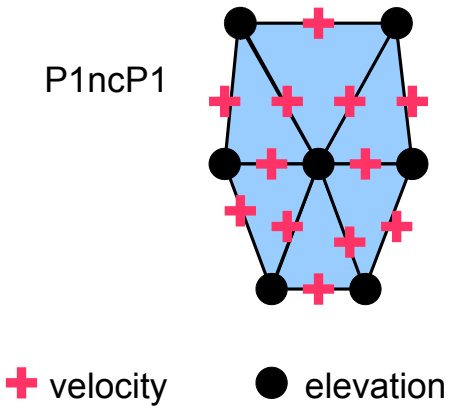
- wave continuity equation models (ADCIRC, QUODDY, MOG2D, T-UGO)
- other models (TELEMAC-2D, P1P1, NC)

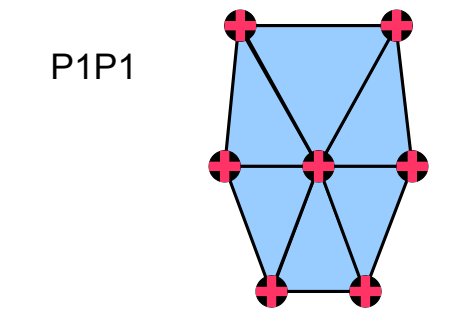
Question: Which approach provides better accuracy and is most efficient?

finite elements





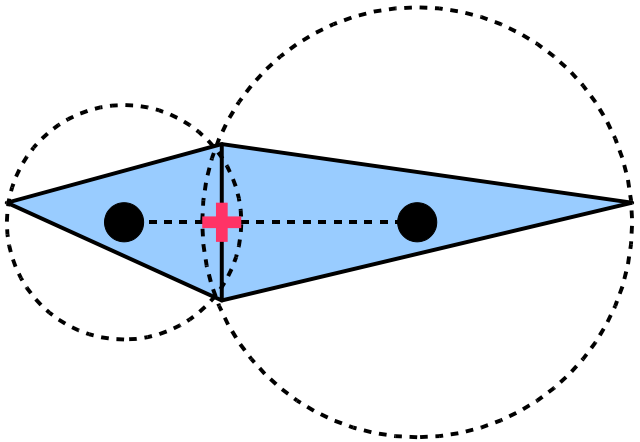




- $P_1^{nc}P_1$ (NC): approx. 3x more edges than nodes
- P_1P_1 : pressure modes, stabilization

finite volumes

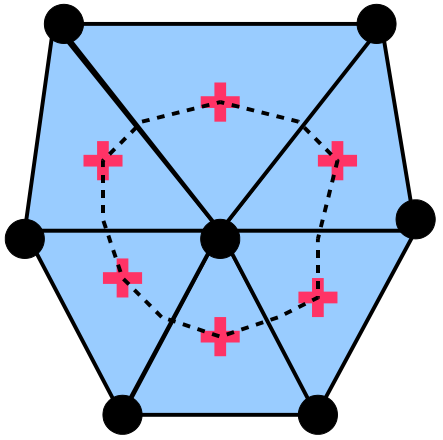
UnTRIM



elevation at circumcenters

normal velocity at mid edges

FVCOM



elevation at nodes

velocity at baricenters

Time stepping

- semi-implicit: bigger time steps, but matrix inversion (solver)
- explicit: small time steps for stability
- Runge-Kutta: more iterations per time step
- Adam-Bashforth: more storage

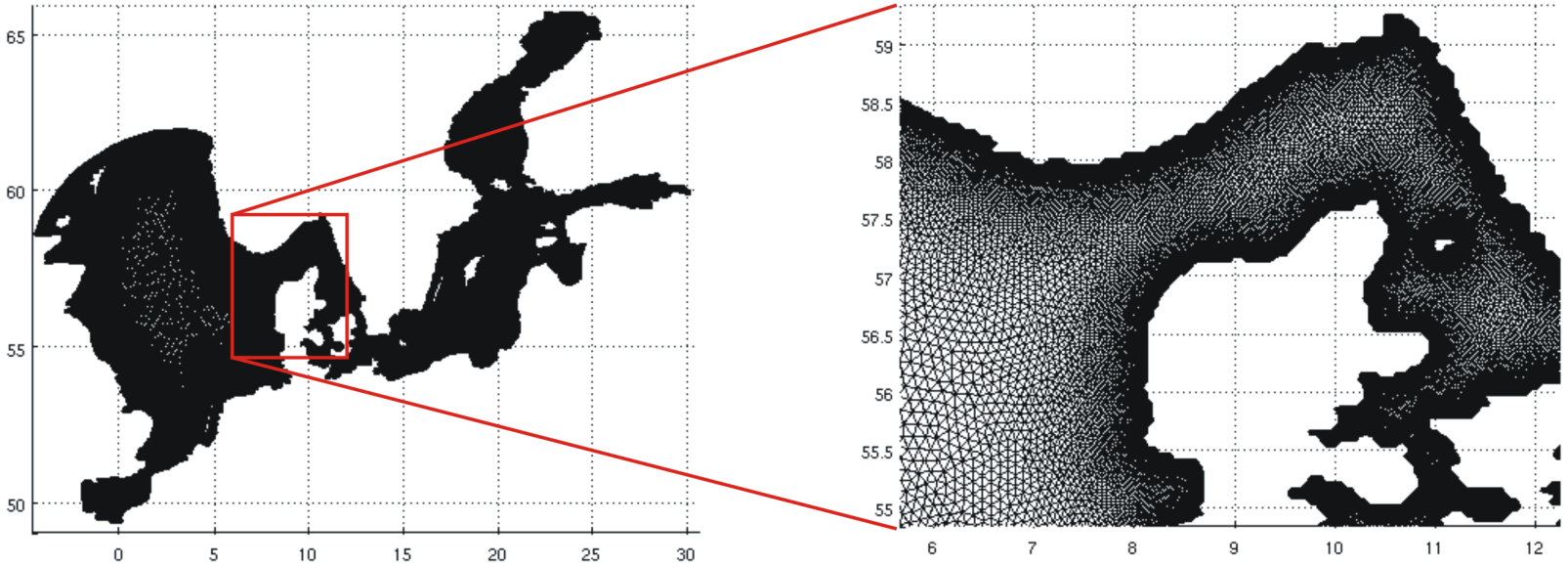
	Leap frog	Runge-Kutta	Adam-Bashforth	semi-implicit
P1P1				x
NC	x		(x)	x
FV		x	x	x

$\rightarrow$ P1P1, NCLF, NCSI, FVAB, FVRK, FVSI

Model intercomparison in the North Sea

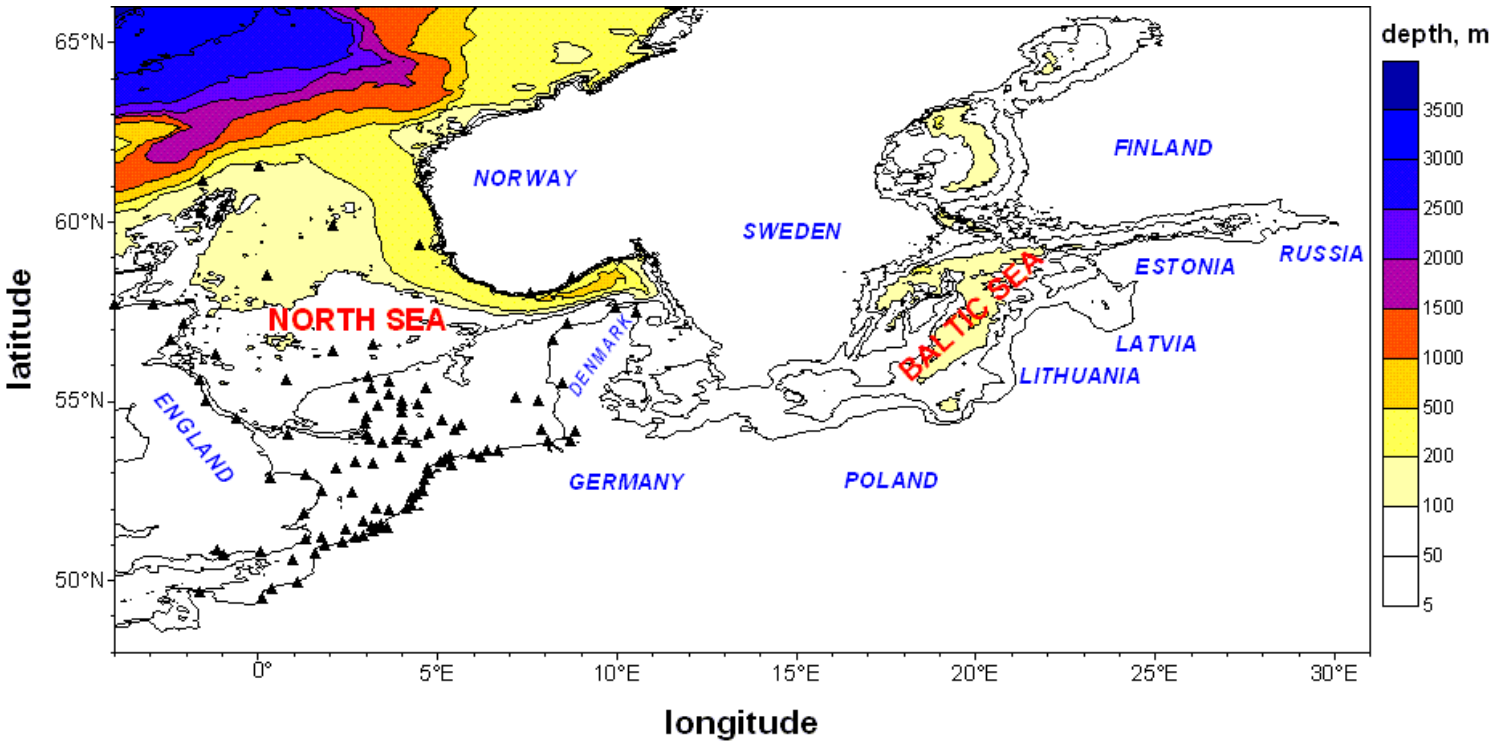
M2 tidal wave

- open boundary conditions: TPXO6.2 (OTPS Egbert et al)
- closed boundary condition: free-slip
- bathymetry: GEBCO 1min

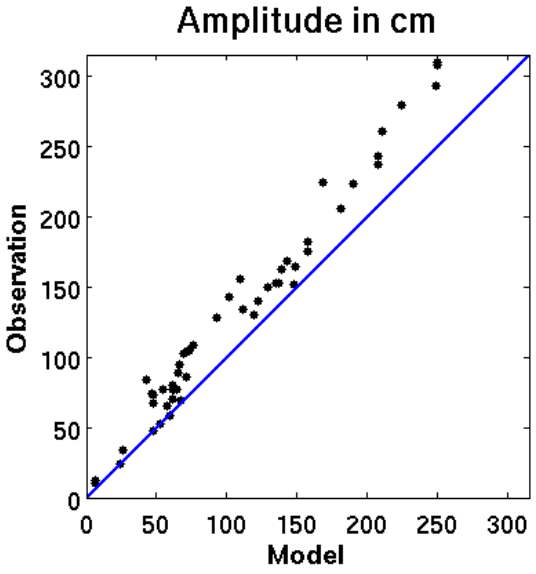


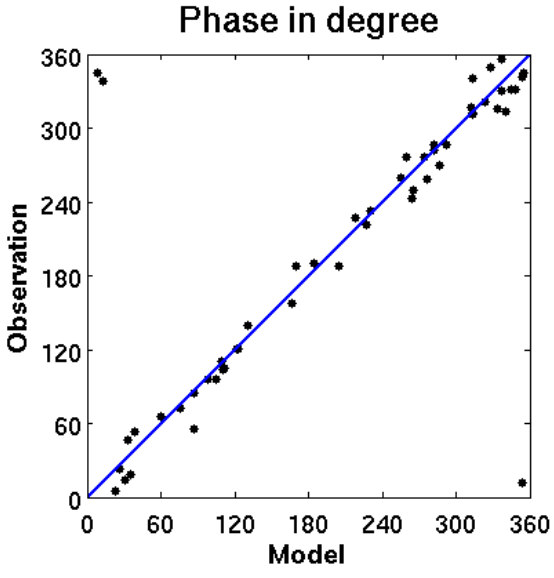
Limitations of North Sea intercomparison

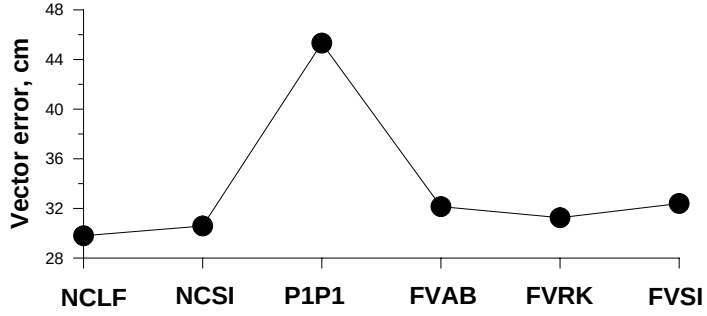
- no wetting and drying (minimal depth of 5m)
- constant bottom friction
- bathymetry not tuned

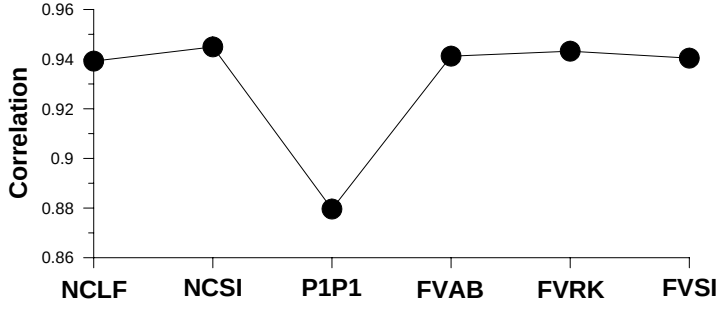


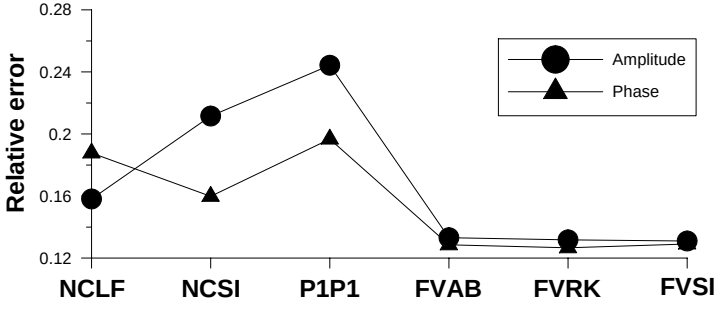
Error statistics





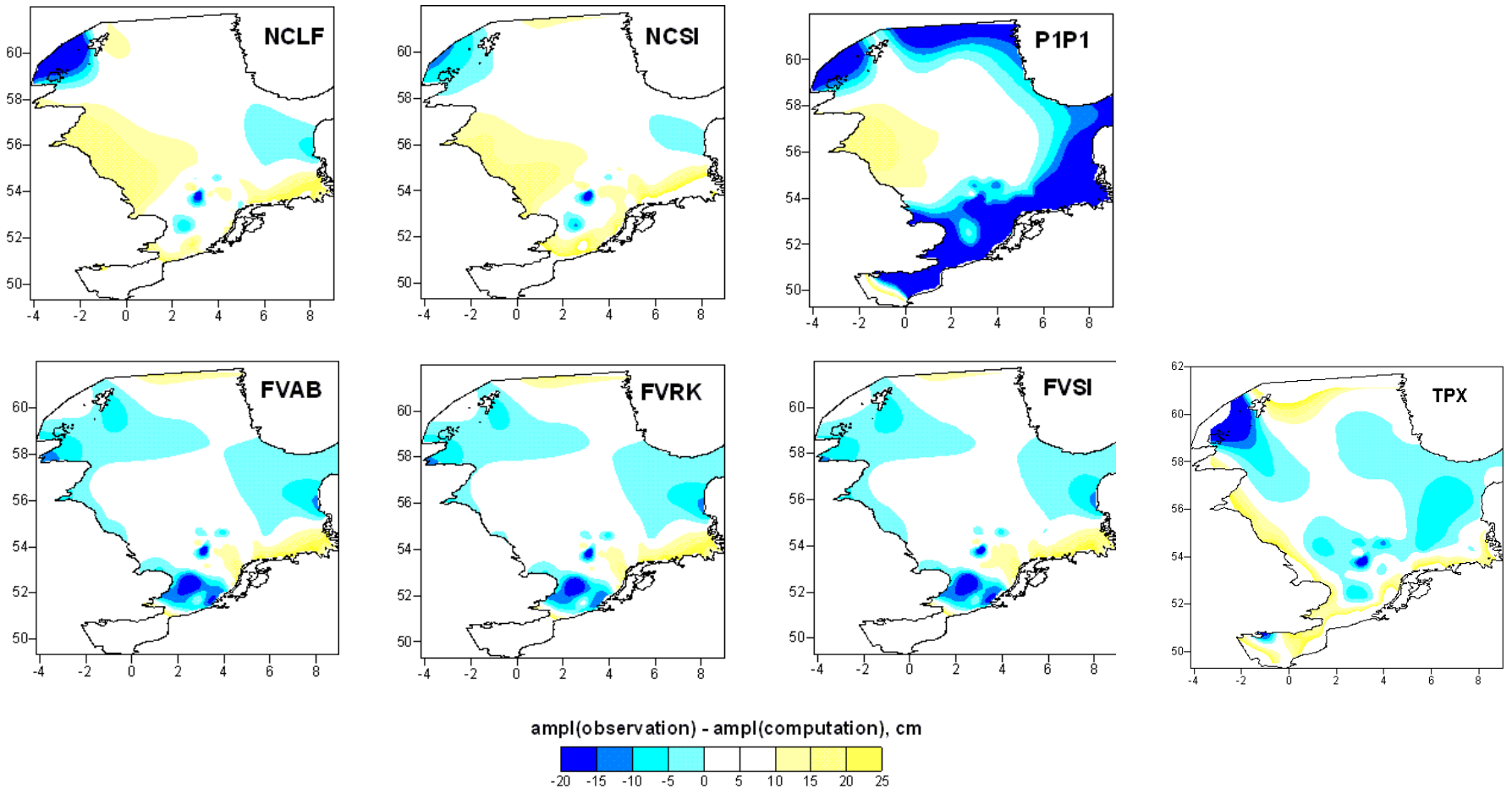




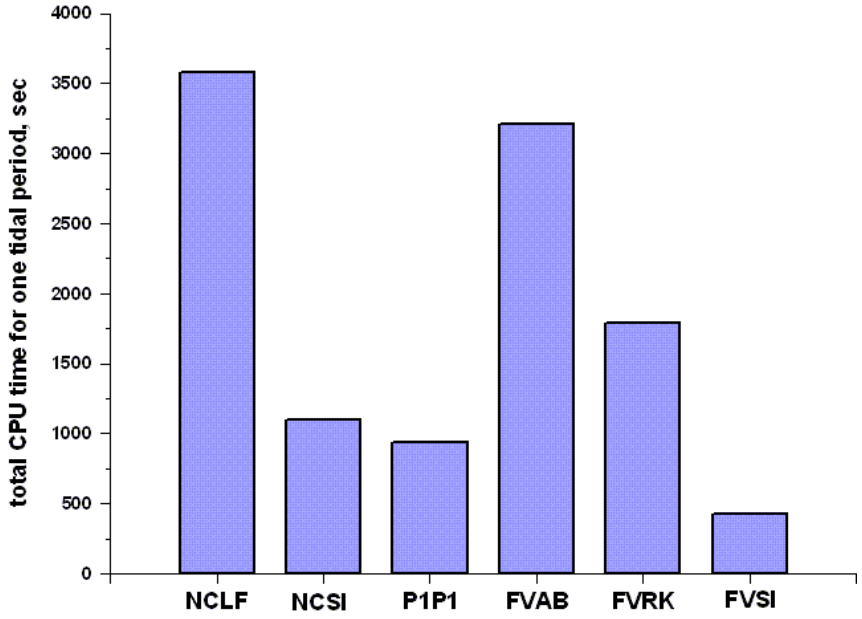


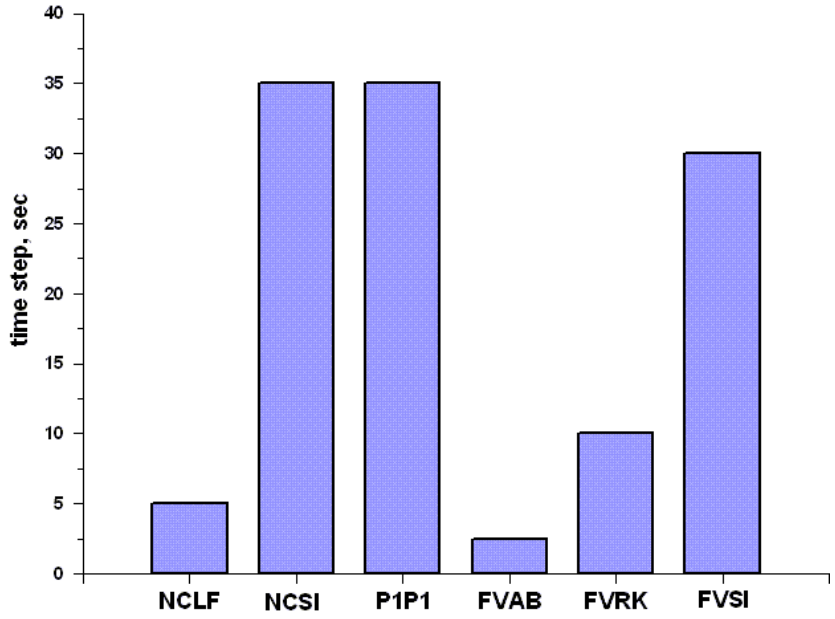
Error - spatial distribution

Amplitude



Computational cost





- IBM p655 cluster (5 nodes with 8 CPUs each)
- use of 1 CPU of a compute node (Power4+ system (1.7GHz) with 16 GByte Ram)
- size of the mesh
  - Number of nodes = 121699
  - Number of edges = 355589
  - Number of volumes = 233872

Ongoing work

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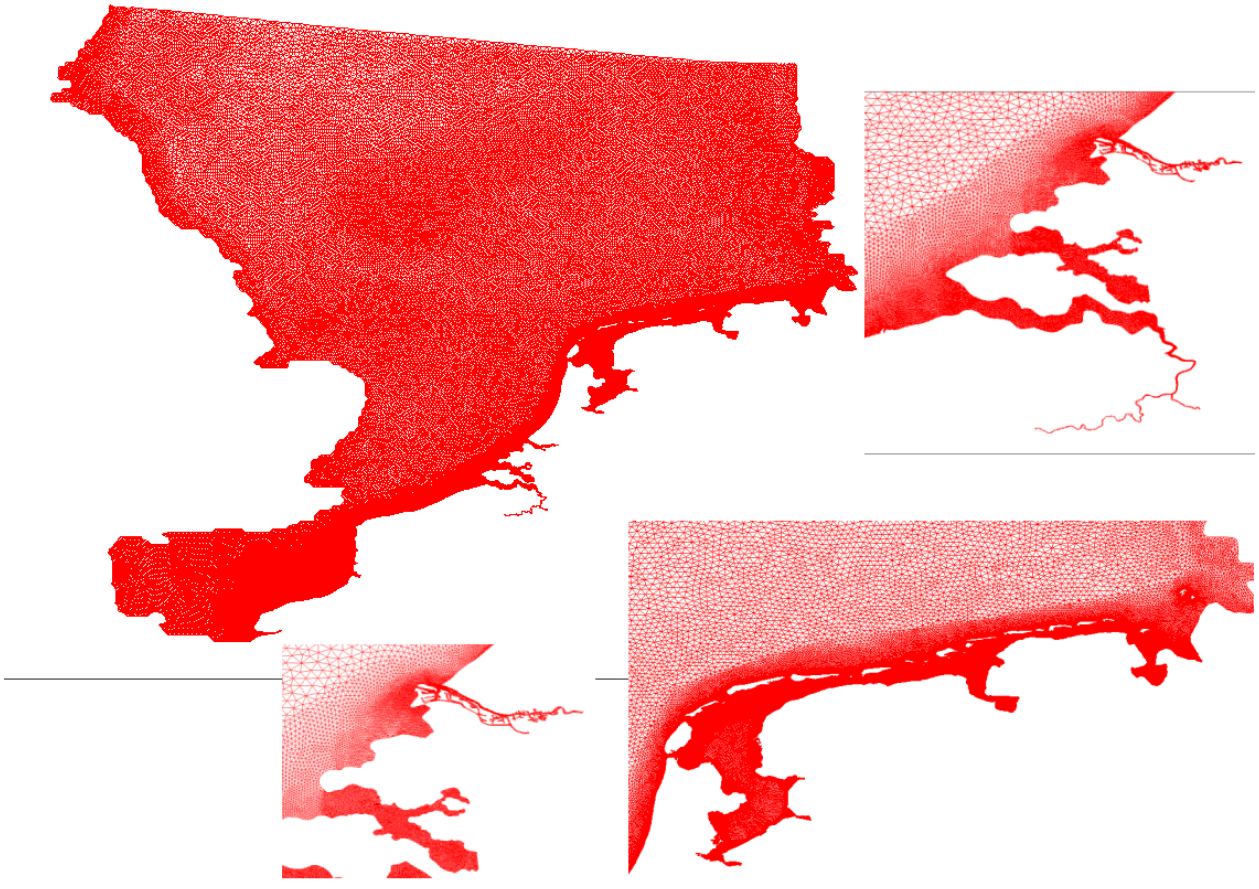
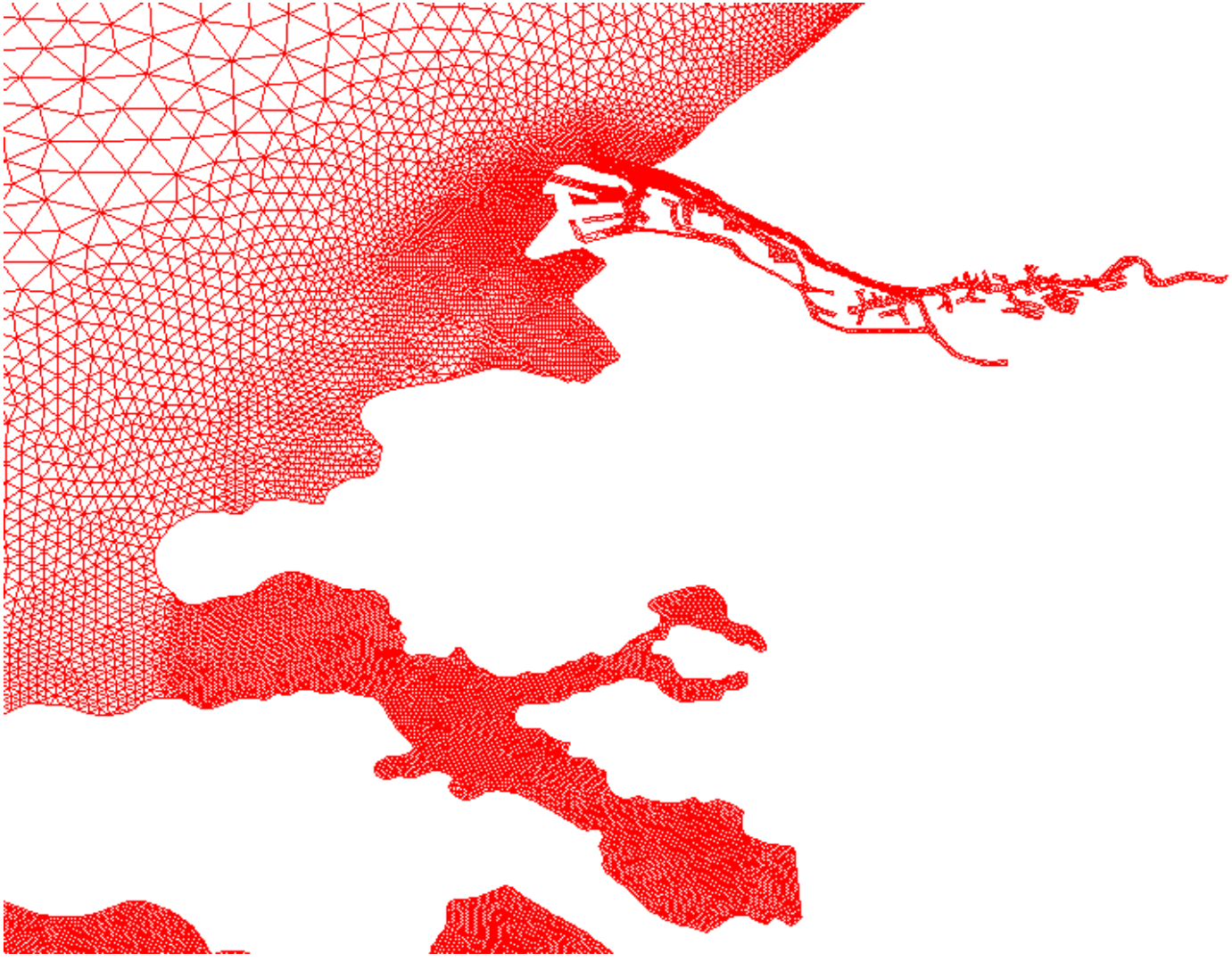


Ongoing work



Conclusions

- all models compare reasonably well with observational data and produce close results
- semi-implicit codes are faster with same accuracy

Outlook

- adjoint model via automatic differentiation
- sensitivity of bottom topography and bottom friction
- optimization of parameters, initial and boundary condition
- wetting & drying (done for NC, under testing)
- astronomical tides (small changes in Baltic Sea)