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

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Overall goals:

- unstructured, non-linear shallow water models
- adjoint model generation
- optimization of model parameters

What is the focus of this presentation?

- influence of spatial discretization (FE, FV)
- computational efficiency

Unstructured grid models

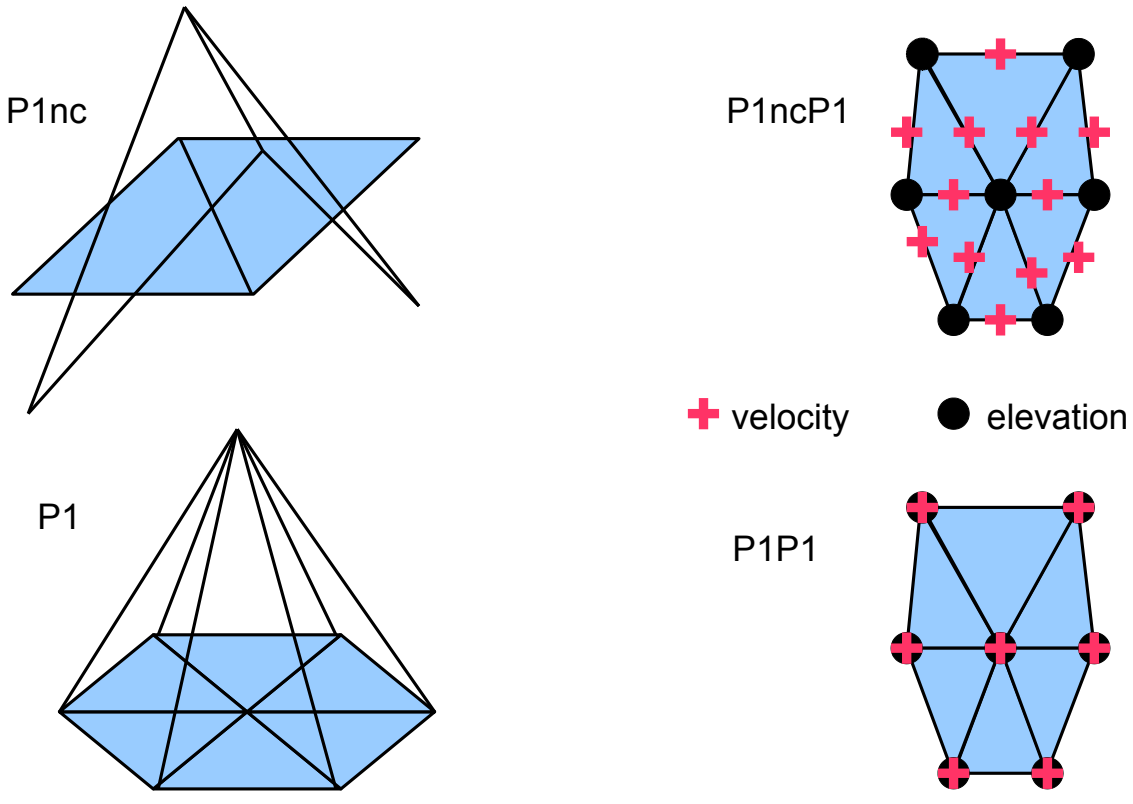
finite volume (FV): easy to implement, less accurate in space
finite element (FE): implementation more elaborate
FV:

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

FE:

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

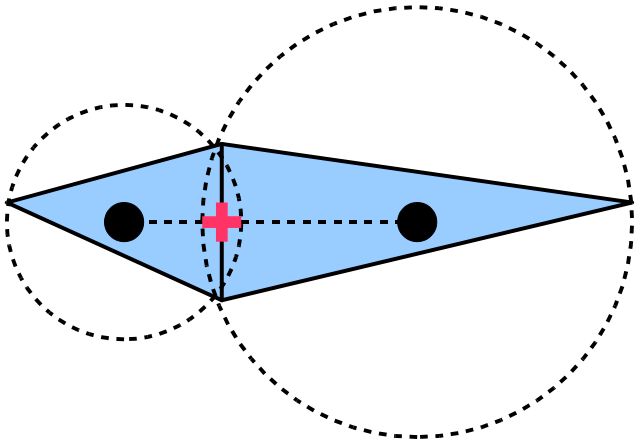
finite elements



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

finite volumes

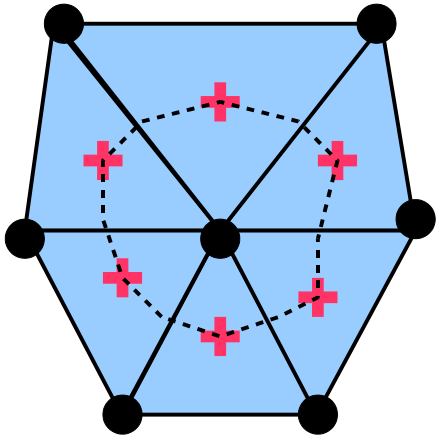
UnTRIM



elevation at circumcenters

normal velocity at mid edges

FVCOM



elevation at nodes

velocity at baricenters

What kind of time stepping provides stable and efficient algorithms?

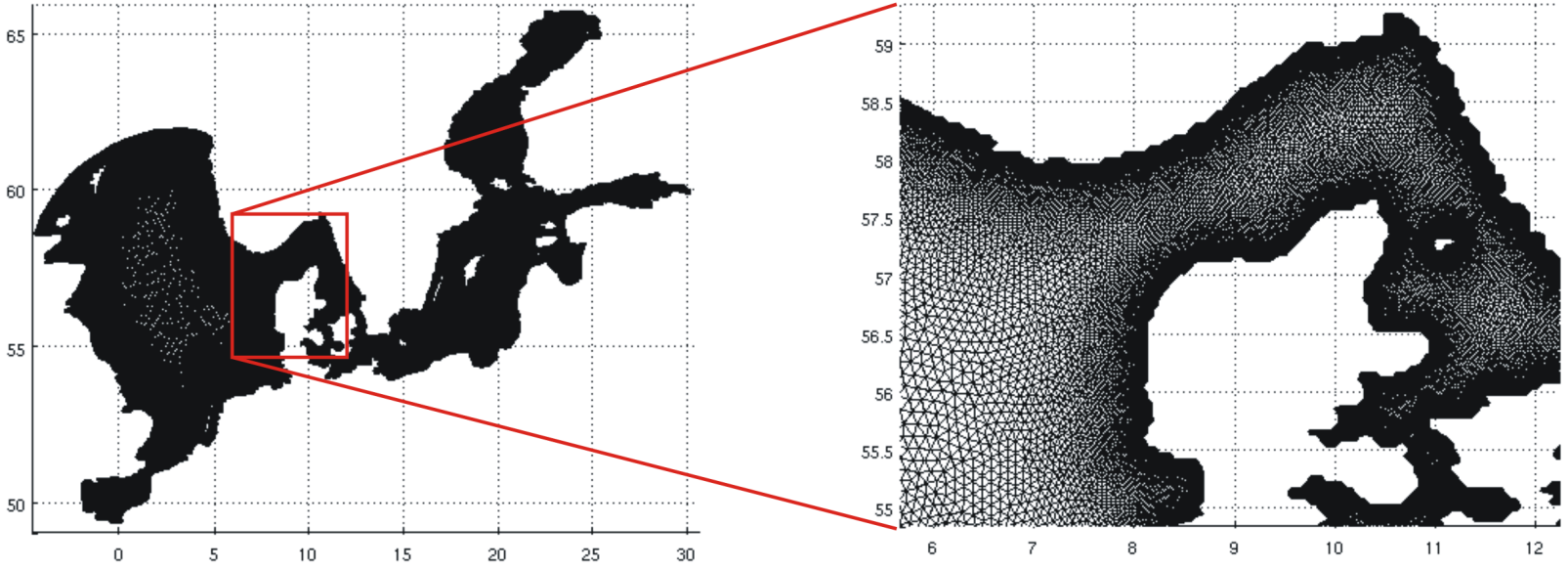
- semi-implicit: bigger time steps, but matrix inversion (needs a solver)
- explicit: small time steps for stability
- Runge-Kutta: more iterations per time step
- Adam-Bashforth: more storage

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

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

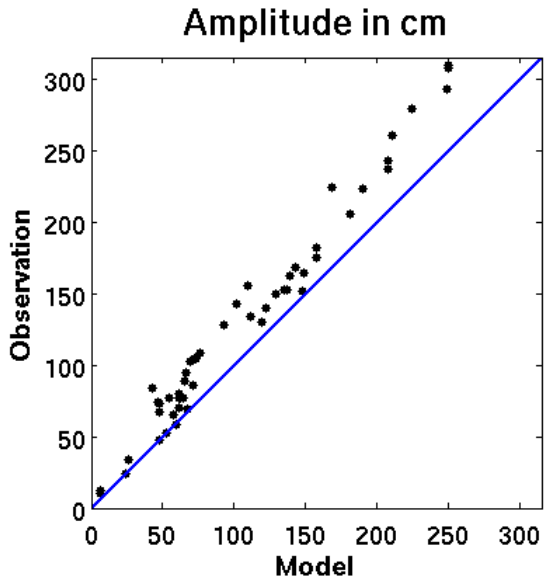


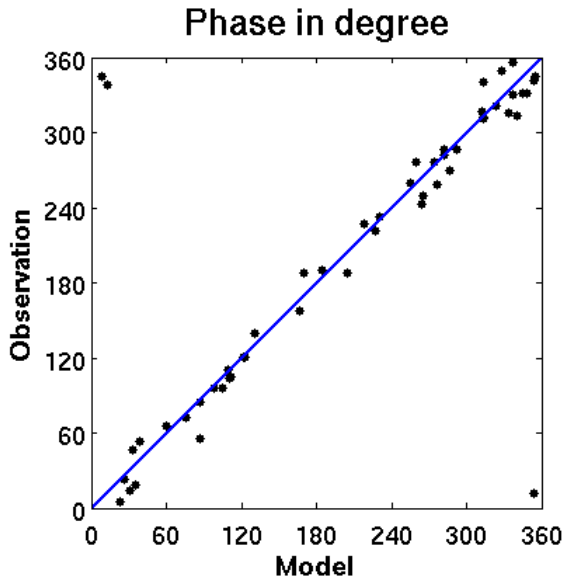
Results in the North Sea

Under the limitations

- no wetting and drying
- minimal depth of 5m
- topography not tuned
- constant bottom friction

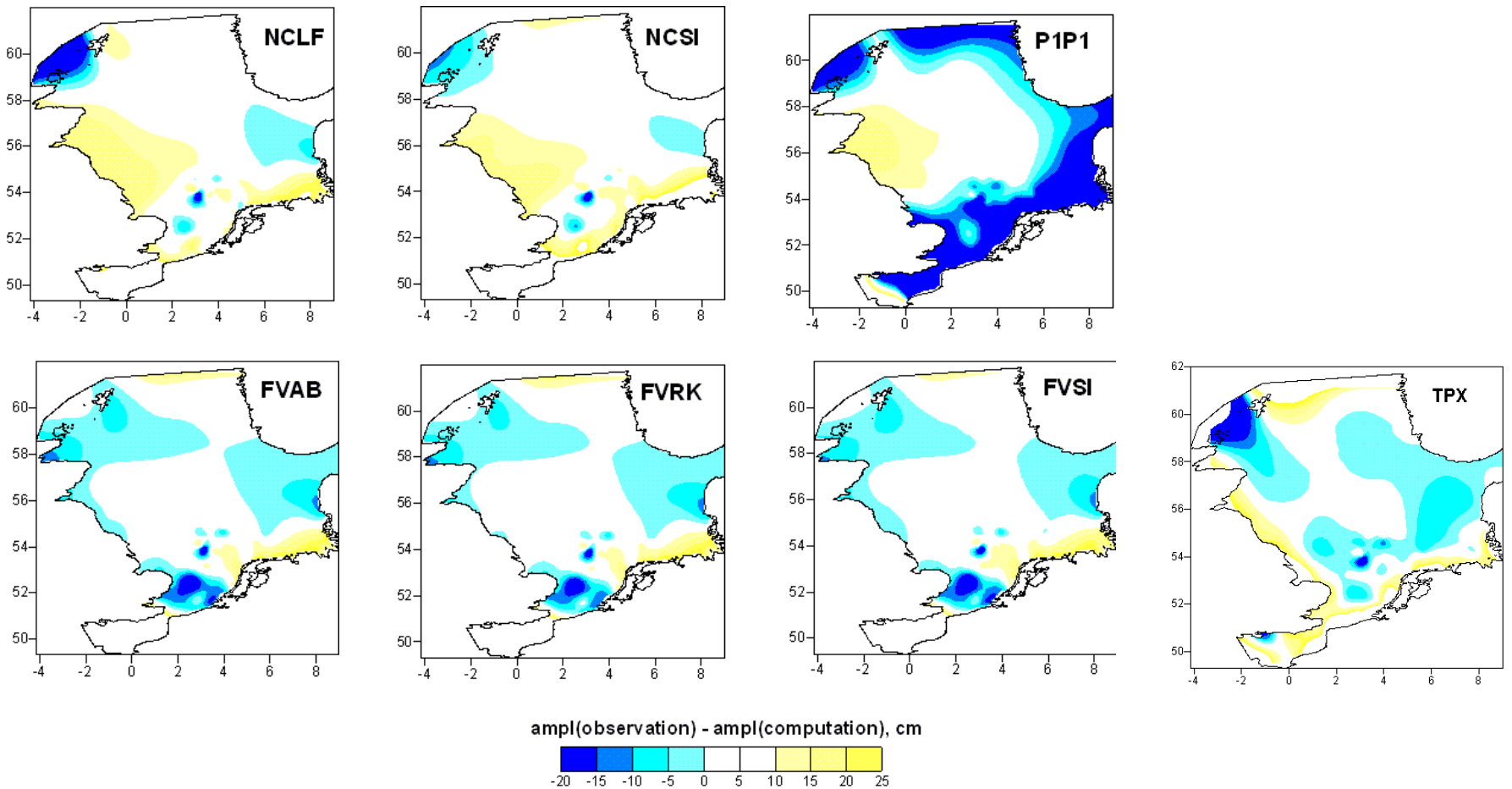
most of the codes give good results





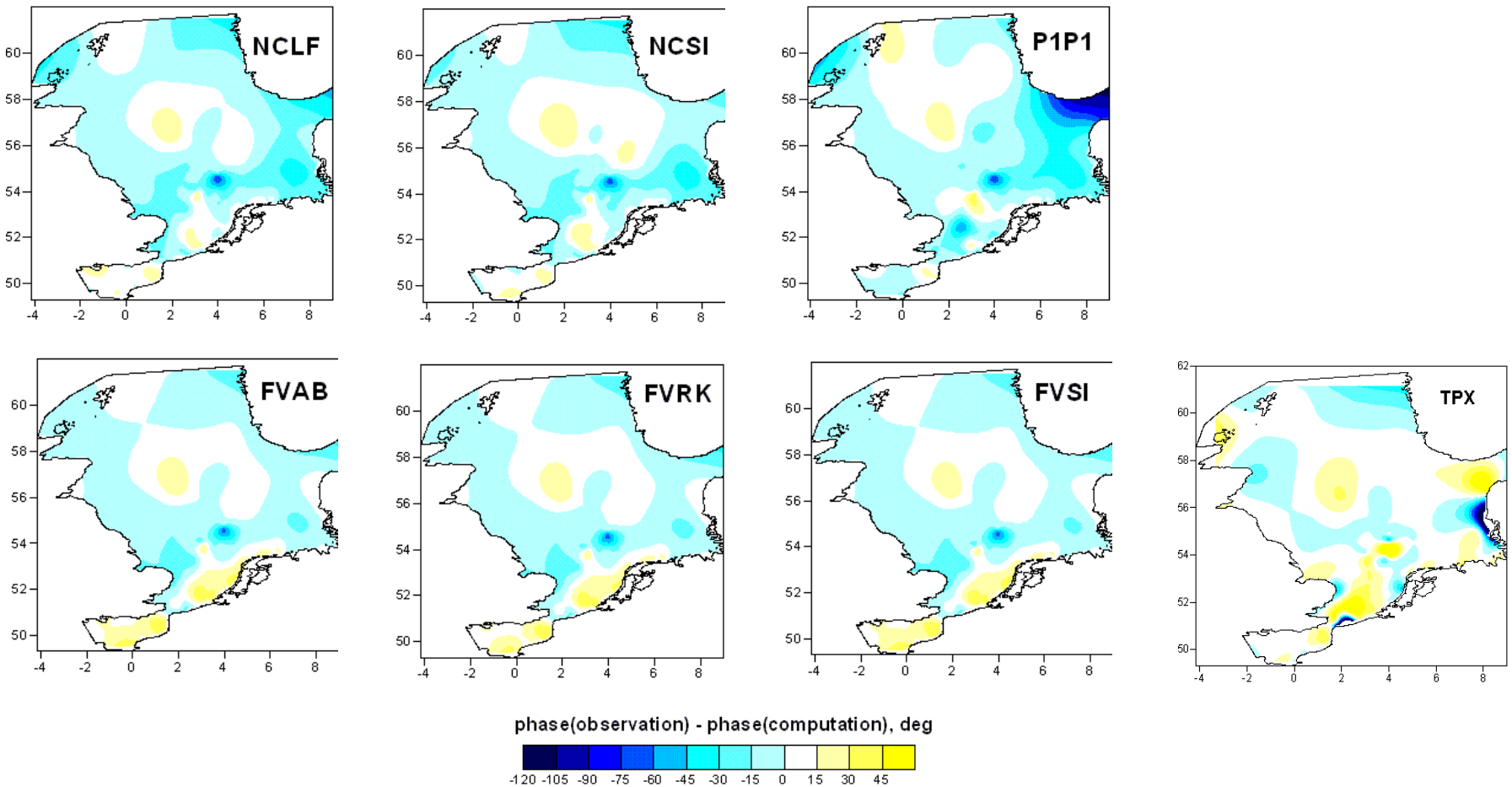
Error - spatial distribution

Amplitude

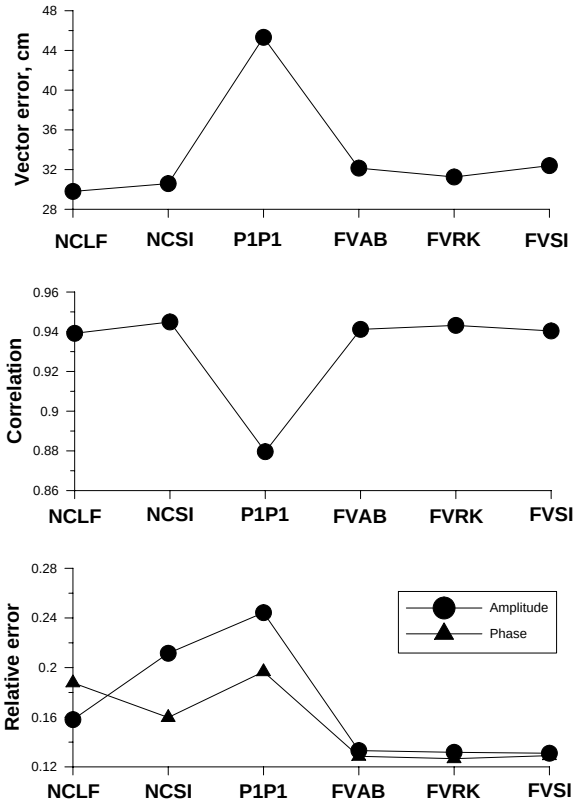


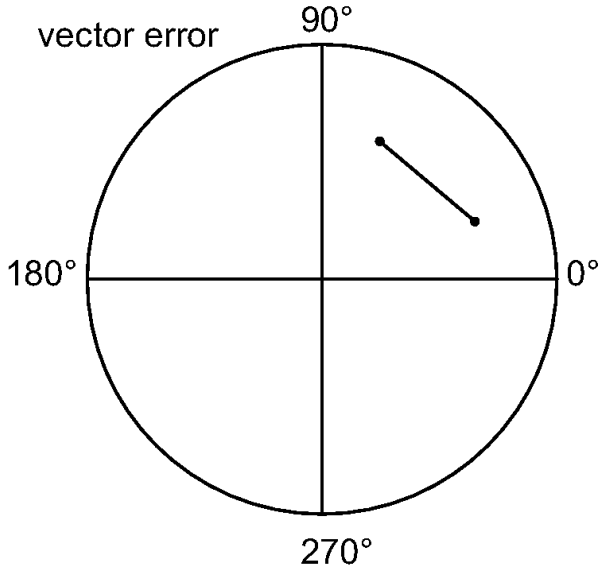
Error - spatial distribution

Phase



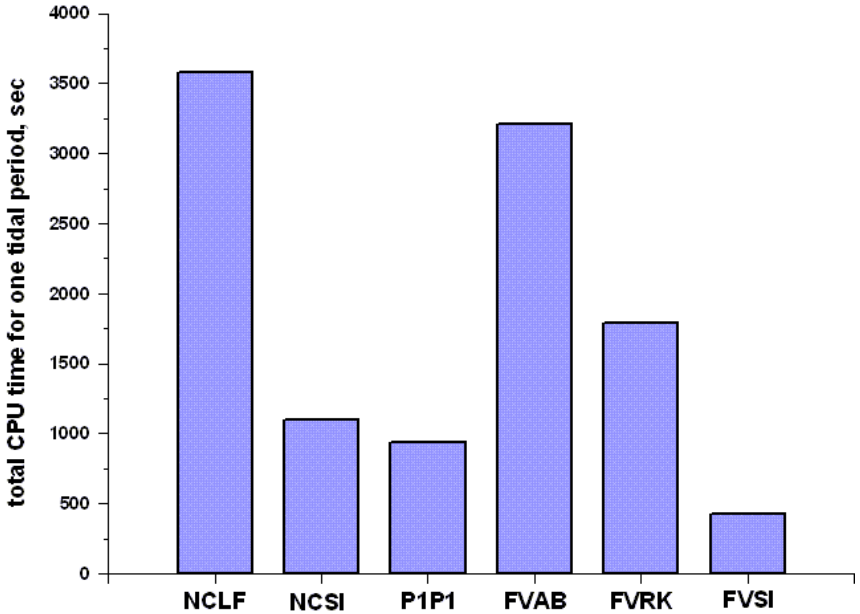
Error statistics

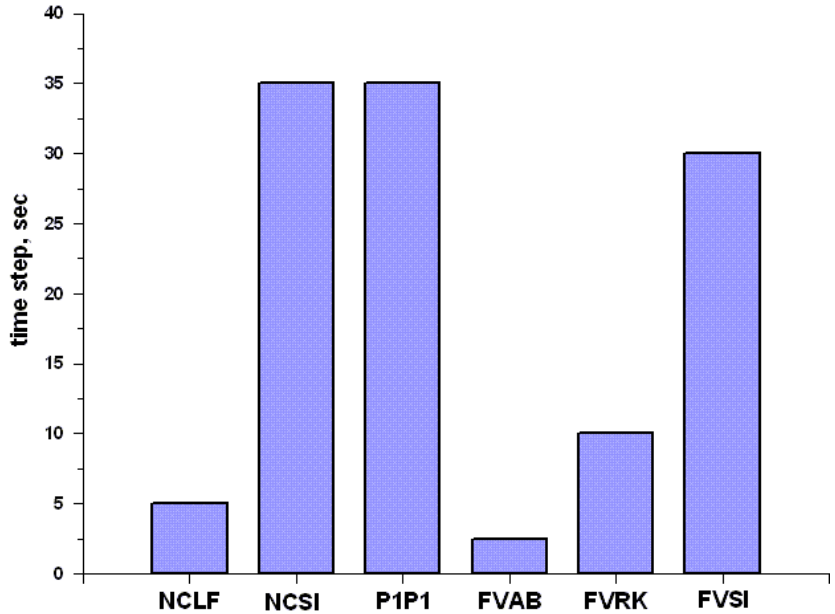




$$\text{vector error} = \frac{1}{N}\sum_{n=1}^{N}[(A_* cos\varphi_* - Acos\varphi)^2 + (A_* sin\varphi_* - Asin\varphi)^2]_n^{1/2}$$

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

Conclusions

- all models give reasonable 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 (important for the Baltic Sea)

Questions

- How does the energy balance between M2, M4 and M6 look like?
- What is the accuracy of the energy equation?
- What is the influence of numerical diffusion?
- What are good wetting & drying schemes to give correct tidal dissipation rates?