The use of adaptive meshes in ocean modelling: considerations from simulations of the lock-exchange flow

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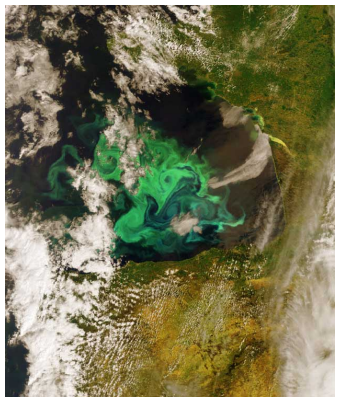
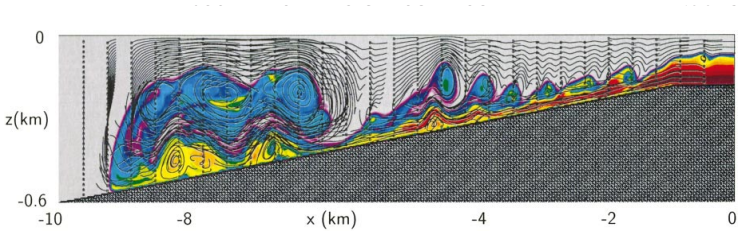
Motivation

- The challenge of modelling transient and dynamic processes in the ocean.
- Consider the potential for the use of adaptive meshes.
- Use the lock-exchange to investigate this approach.

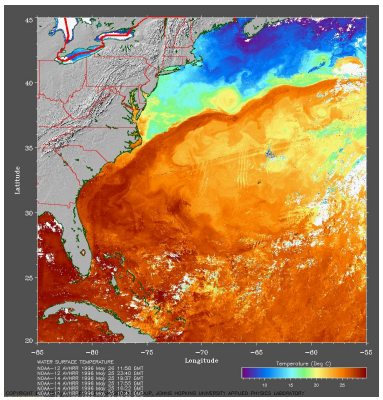


Evisat, ESA



T. M. Özgökmen and E. P. Chassignet,

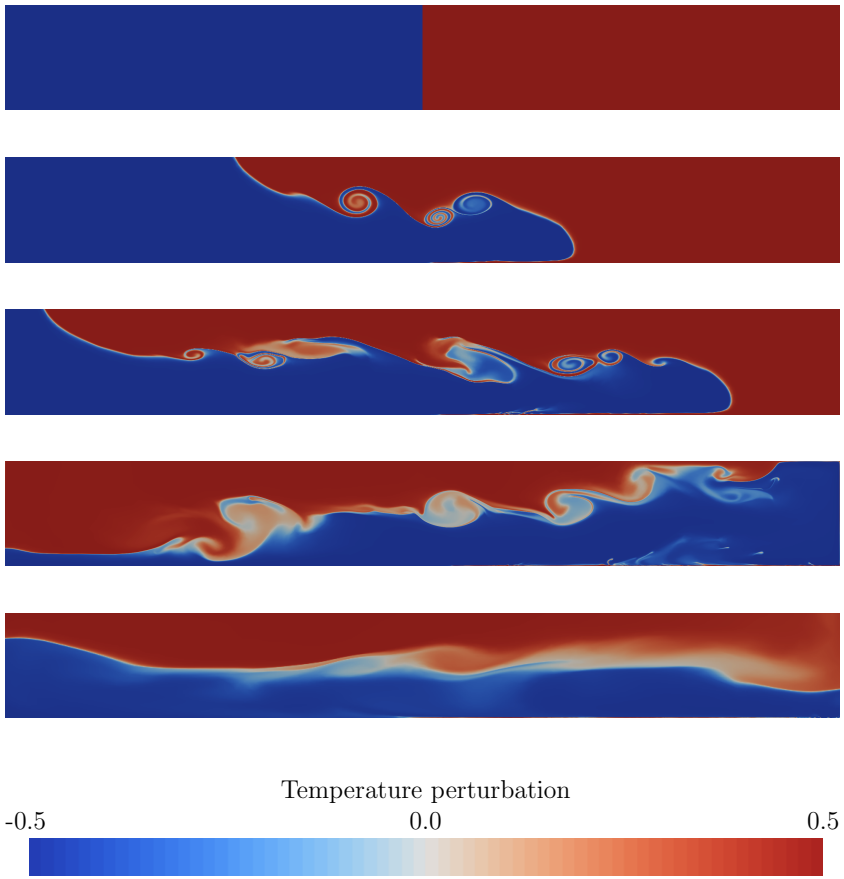
Journal of Physical Oceanography, 32, 2002



Johns Hopkins University,

Applied Physics Laboratory

The lock-exchange

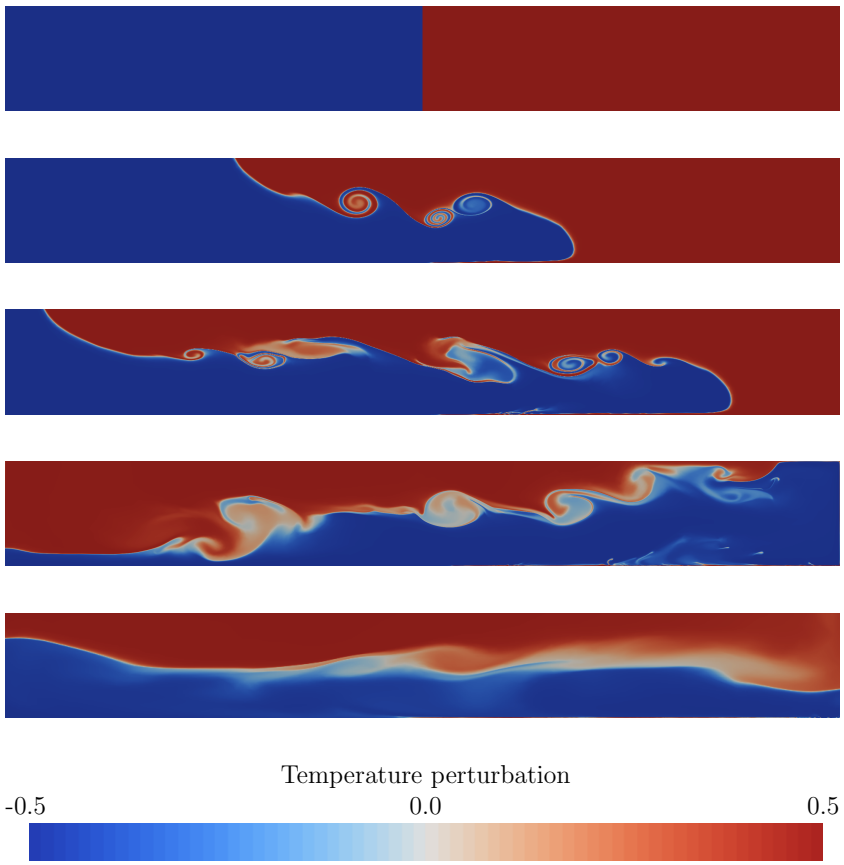


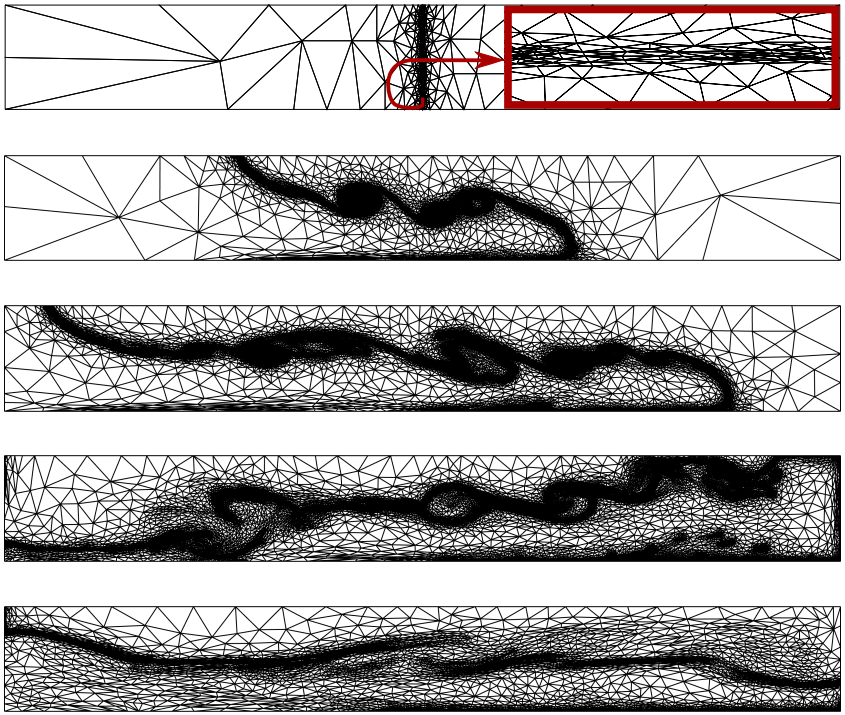
- Simple set up
- Laboratory scale
- Incorporates key physical processes
- Complex and turbulent flow
- Widely studied

The Imperial College Ocean Model (Fluidity-ICOM)

- Finite-element model
- Navier-Stokes equations under the Boussinesq approximation
- Non-hydrostatic formulation
- `http://amcg.ese.ic.ac.uk/FLUIDITY`
- Mesh generation with Gmsh: `http://www.geuz.org/gmsh/`
- **Incorporates adaptive mesh techniques**

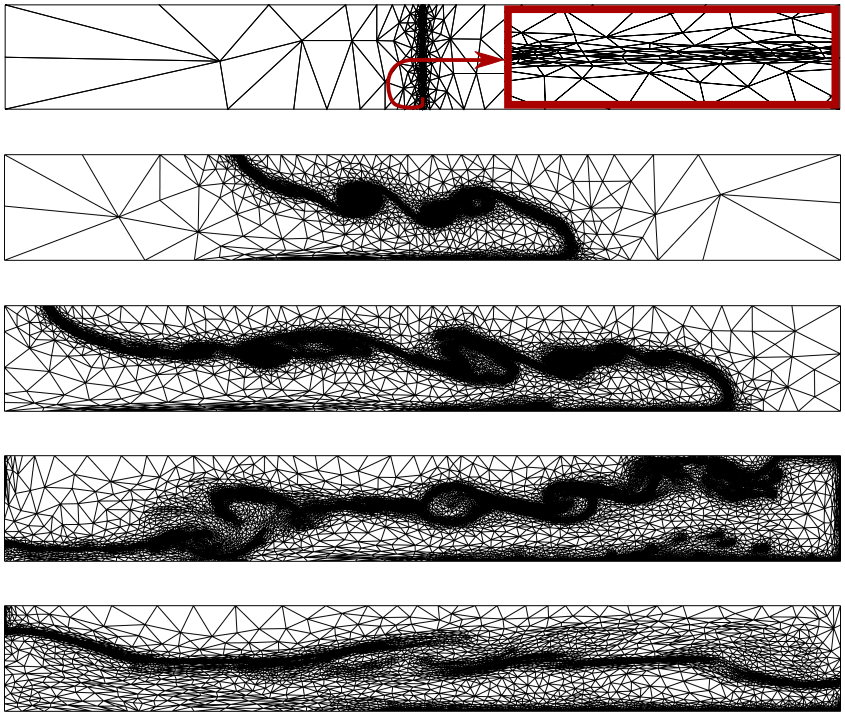
Adaptive meshes

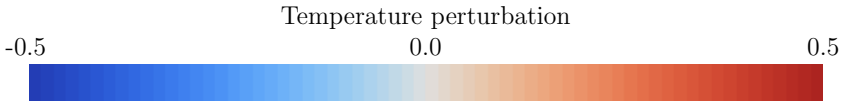




Dynamic adaptive remeshing

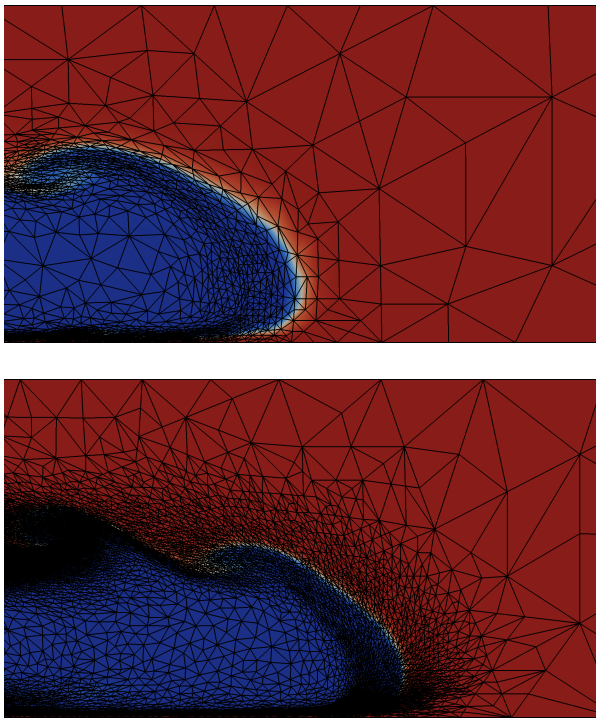
- **Metric formation**
  $M = M(H, \epsilon)$
  H: Hessian
  ϵ: user-defined weight
- Remesh - Ani2D
  `http://math.lanl.gov/~lipnikov/Research/AniGrids/AniGrids.html`
- Interpolation



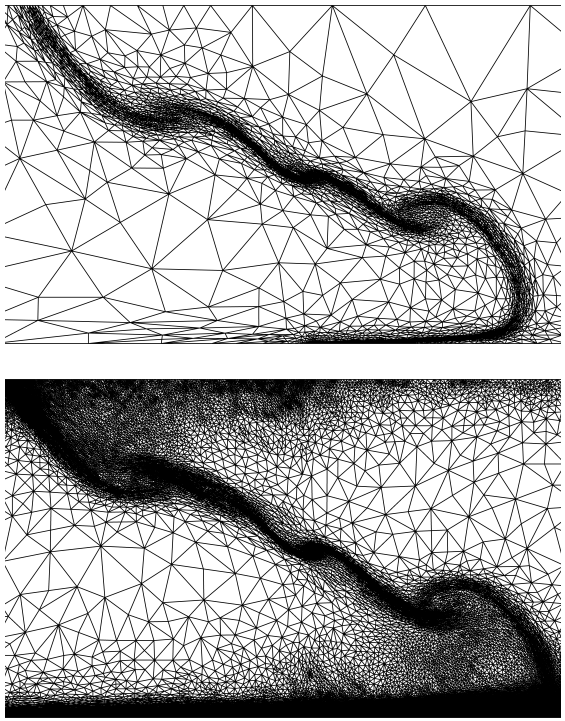


Metric formation

Metric advection

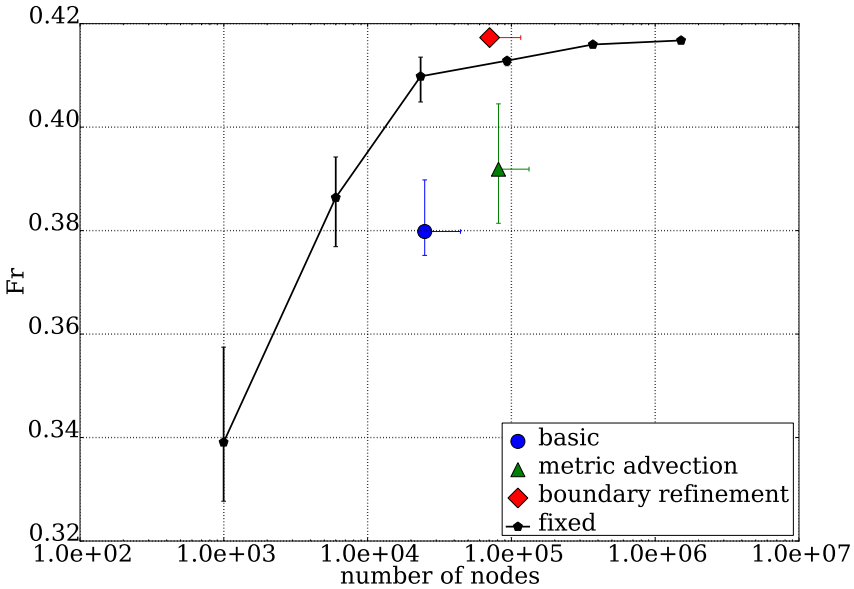


Boundary refinement, $\epsilon = \epsilon(\mathbf{x})$

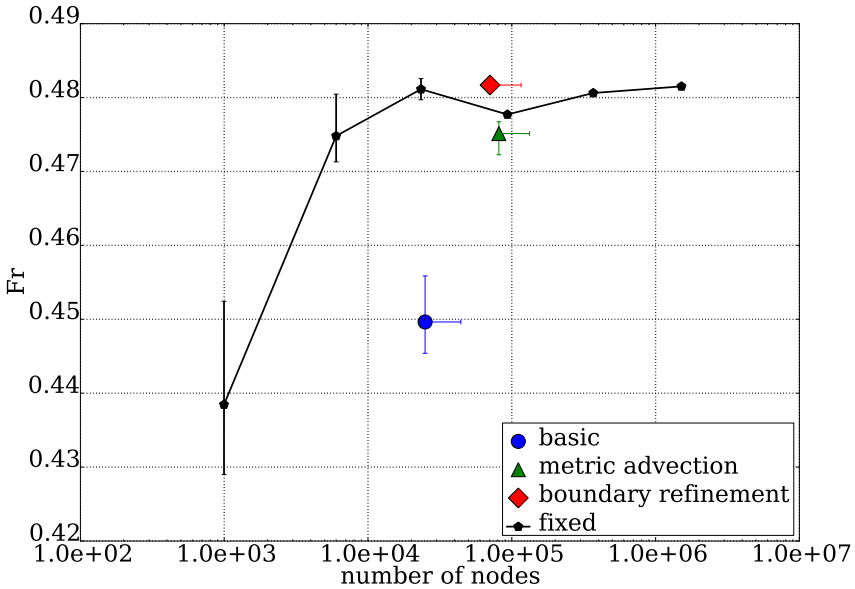


Froude number

No-slip front (bottom)



Free-slip front (top)

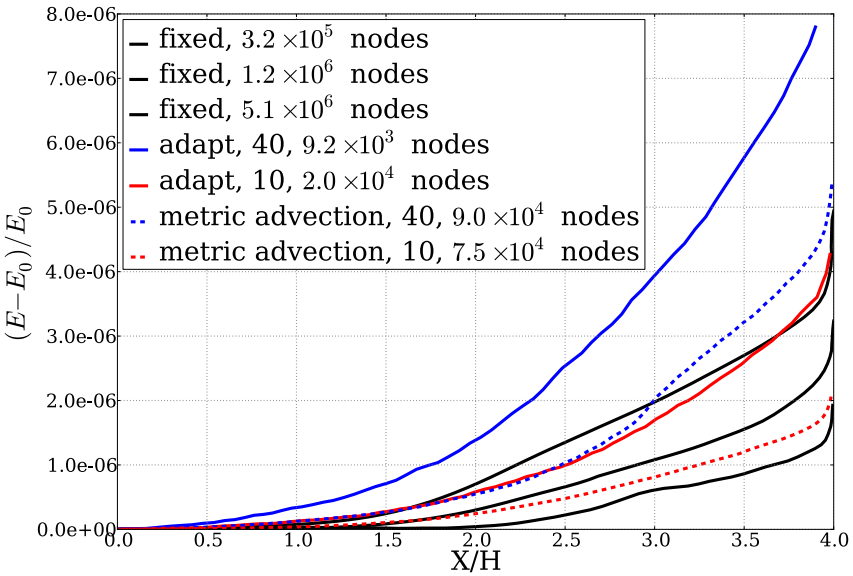


Froude number, $Fr = U/\sqrt{g'H}$ with U: front speed, g': reduced gravity and H: domain height

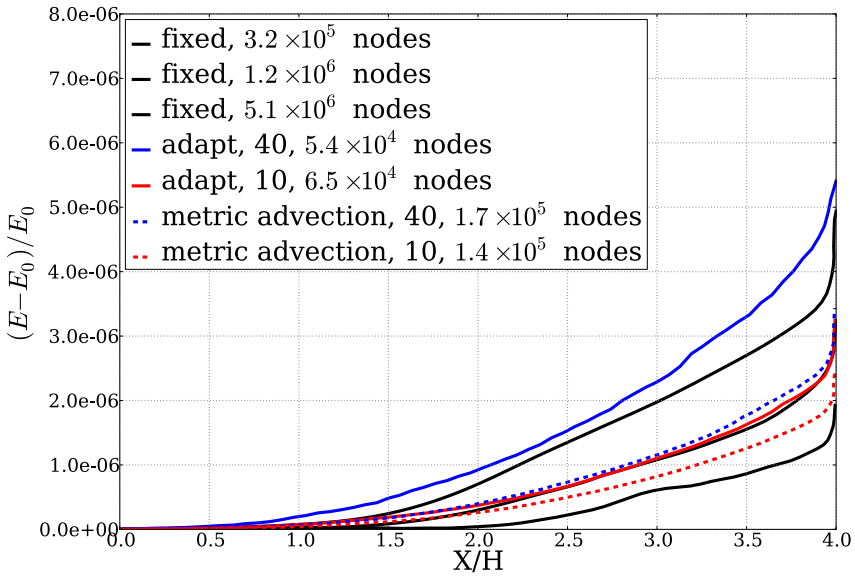
Results taken from Hiester et al. *The impact of mesh adaptivity on the gravity current front speed in a two-dimensional lock-exchange*, In Press, Ocean Modelling, doi:10.1016/j.ocemod.2011.01.003.

Mixing

No boundary refinement



With boundary refinement



Background Potential Energy, E: the potential energy of the system reference state

Changes in background potential energy $\rightarrow$ diapycnal mixing

K. B. Winters et al., Journal of Fluid Mechanics, 289, 1995; Y. Tseng and J. H. Ferziger, Physics of Fluids, 13, 2001.

Summary

- Use of a simple metric allows the adaptive mesh to capture the flow features.
- Resolution is important at
  - the boundaries,
  - the interface.
- Additional guidance of the metric achieved by
  - spatial variation of the user-defined weights,
  - the use of metric advection.
- The adaptive meshes can have comparable Froude numbers and mixing to the high resolution fixed meshes whilst using at least one order of magnitude fewer nodes.

Conclusions

- **The metric is key to the ability of the adaptive mesh to represent the flow.**
- The adaptive mesh simulations allowed the importance of flow features to be distinguished.
- The decrease in the number of nodes used by the adaptive meshes is encouraging for 3D simulations and ocean-scale domains.
- Provides a sound platform for future use and development of adaptive meshes in ocean modelling.

Thursday 7th April, OS4.4, Room 6

- 16.30: Fast and accurate multi-spectral optics in an ocean model, **Michael Lange**.

Friday 8th April, OS4.4, Poster Hall X/Y, 10.30-12.00:

- XY426: A wetting and drying algorithm for non-hydrostatic models with combined pressure/free-surface, **Simon Funke**.
- XY424: How do you fit an ocean on a graphics card? **David Ham**.
- XY439: Ocean ecosystem modelling in in an adaptive mesh model: a performance evaluation, **Jon Hill**.

Friday 8th April, NP6.5, Room 13

- 13.30: Flow past topography in relation to the Antarctic Circumpolar Current, **Alistair McVicar**.

Friday 8th April, NP6.1, Poster Hall X/Y 13.30-15.00:

- XY378: Eddy parameterisations from data-driven coarse-graining of Lagrangian trajectories, **Colin Cotter**.