Using ROMS in the North Sea

by

Bjørn Ådlandsvik

Bjørn Ådlandsvik
bjorn@imr.no

Institute of Marine Research
P.O.Box 1870 Nordnes
N-5817 Bergen, Norway

and

Bjerknes Centre for Climate Research
Bergen, Norway

Background

The regional ocean climate on the northern European shelf seas such as the Barents Sea and North Sea depend on several factors. In addition to large scale factors such as the Atlantic thermohaline circulation, more regional factors such as the variability of the inflow of Atlantic Water onto the shelves are important.

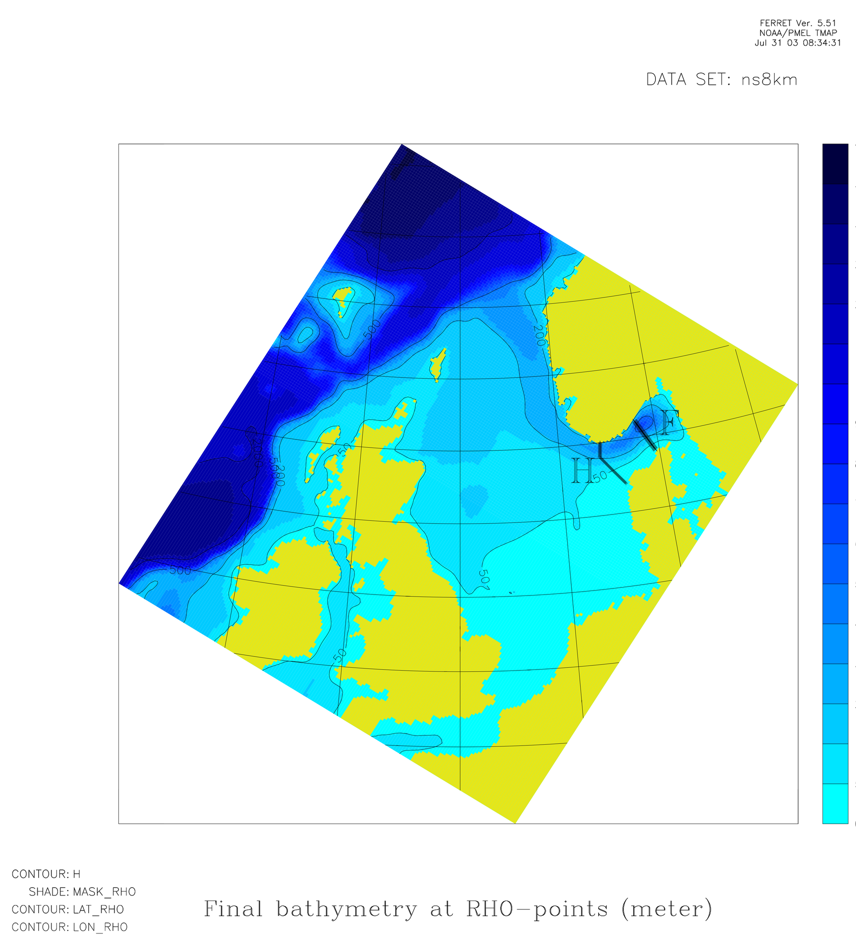
Scenarios of future shelf sea climate will be studied by dynamic downscaling, where a regional ocean model is forced both laterally and at the surface by output from global coupled atmosphere ocean models. This work is part of the Norwegian national multi-institutional project "Regional Climate Development Under Global Warming" (RegClim; `http://regclim.met.no`).

The work presented here is part of an initial phase of this study, where the ROMS model is set-up for the North Sea and validated against present climate. As the model will have to digest information from global models, emphasis is put on finding suitable boundary conditions. In particular the lateral boundary condition the Flow Relaxation Scheme (FRS) has been implemented in ROMS.

Model set-up

The model used is the Regional Ocean Model System (ROMS) version 2.0, developed by Hernan Arango and Alexander Shchepetkin.

Model domain



Model domain with land mask and bathymetry. Two of the Skagex sections are also shown. The present grid has quadratic cells on a polar stereographic map projection, with a resolution of approximately 8 km. In the vertical 32 s-levels is used.

Model settings

Vertical mixing: Mellor-Yamada (GLS formulation)

2D boundary scheme: Chapman + Flather

3D boundary scheme: FRS

Forcing

Atmospheric: NCAR/NCEP

Fresh water: Climatological river runoff (including Baltic)

Lateral: Climatology + tides

Simulation period

The model run started 1 May 1989 and continued to the end of June 1990. The averages presented here are from 26 May to 24 June 1990.

The FRS boundary treatment

The Flow Relaxation Scheme (FRS) was developed for nesting limited area meteorological models. It is also used in 3D ocean models (Engedahl, 1995), (Heggelund and Berntsen, 2000). Experience has shown this to be a robust boundary condition with a reasonable balance between allowing external information to enter the domain and the development of the interior model state. The FRS may be viewed as a clamped boundary condition augmented with a transition zone.

Algorithm

The algorithm is quite simple, after computing the model solution ϕ_{int}^{n+1} in the interior of the domain, the FRS solution ϕ^{n+1} is computed as a weighted average of the internal and the forced external solution ϕ_{ext}^{n+1} in a boundary zone.

$$\phi^{n+1} = (1-\alpha)\phi_{\text{int}}^{n+1} + \alpha\phi_{\text{ext}}^{n+1} \qquad (1)$$

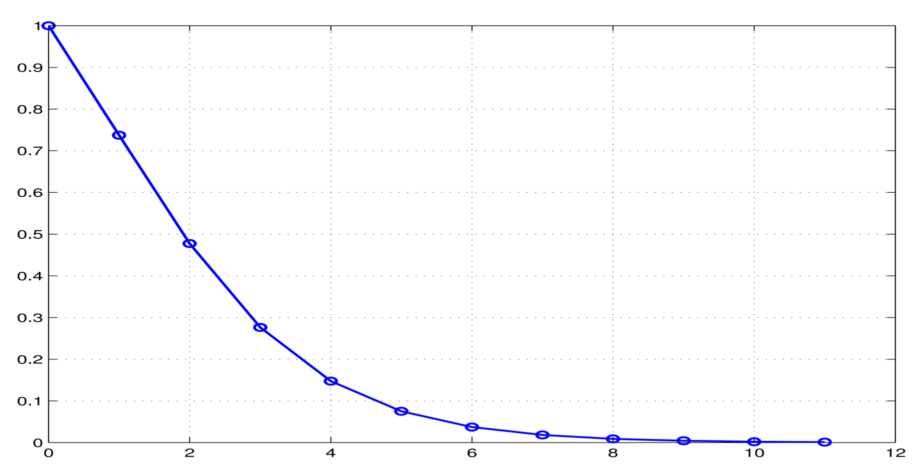
where $0 \le \alpha \le 1$. At the boundary where the internal solution is not available, a clamped condition is used, corresponding to $\alpha = 1$. This procedure is consistent with a Newtonian relaxation term, $-\kappa(\phi - \phi_{\text{ext}})$ provided $\frac{\alpha}{\Delta t} \to \kappa$ as $\Delta t \to 0$.

To minimize distortions of the interior solution from the OBC, the profile of alpha should increase slowly from zero and get steeper towards unity at the boundary. In the ROMS implementation, a suggestion from Heggelund and Berntsen (2000) is followed. Let L be the number of grid cells in the zone, choose a time scale τ and let

$$\beta_i = 1 - \tanh(4i/L). \qquad (2)$$

$$\alpha_i = \frac{\beta_i \Delta t}{\beta_i \Delta t + (1-\beta_i)\tau}. \qquad (3)$$

where $i = 0, ..., L-1$ is an index counting grid cells from the boundary ($i = 0$). The figure below shows this profile with $\Delta t = 1.5 * \tau$.



FRS vs. clamped boundary

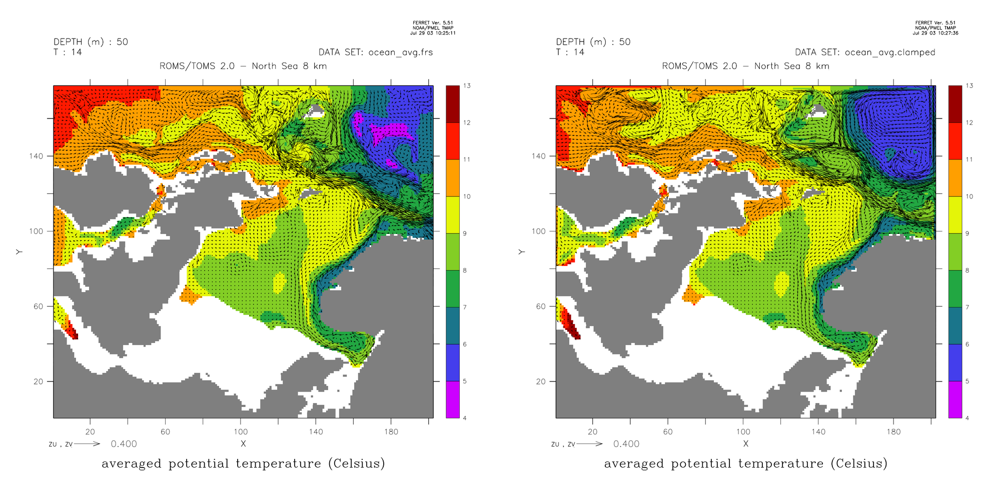


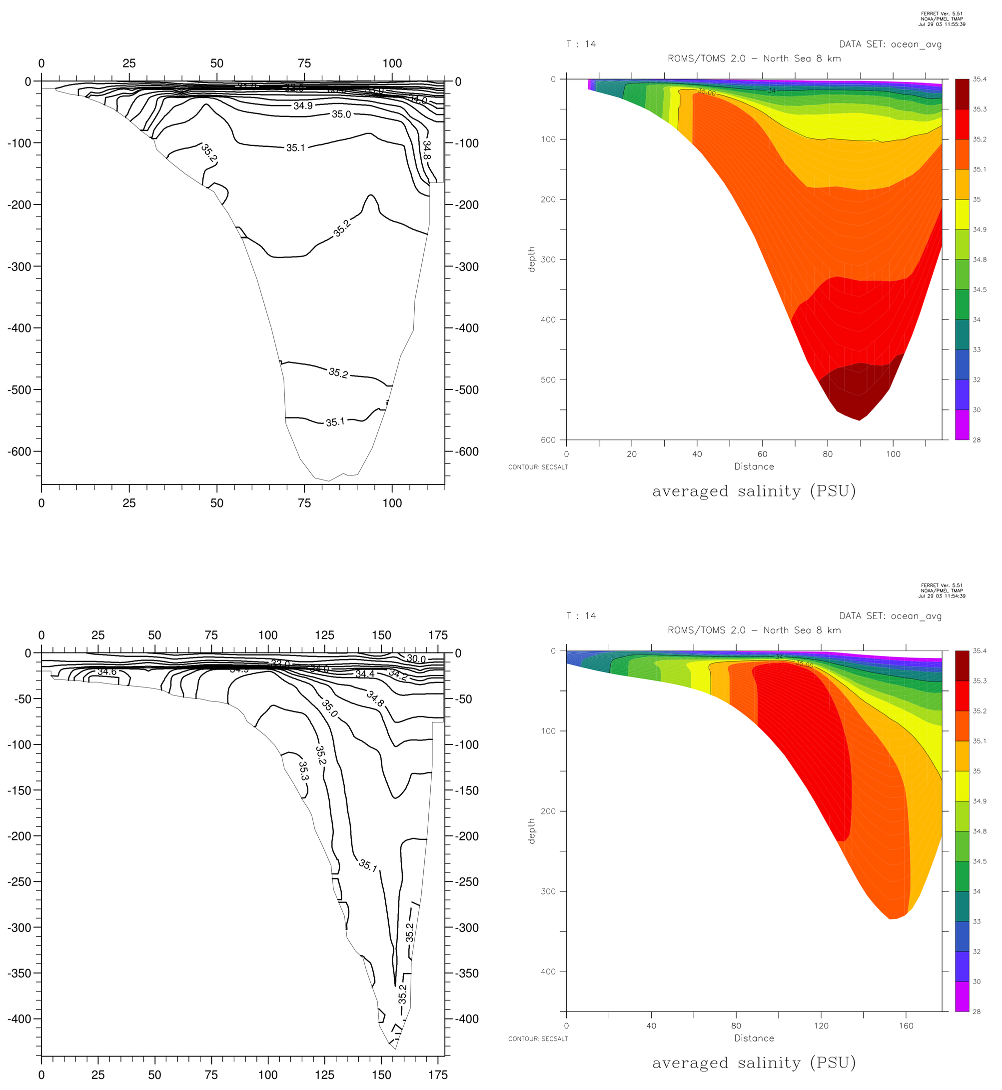
Figure 3. The surface temperature and current at 50 m depth, averaged for june 1990. The left panel is done with the FRS condition while the right panel uses a clamped boundary condition for the 3D current and tracers.

The main current is the Norwegian Atlantic Current (NAC) which passes between the Shetland and the Faeroes and follows the shelf edge towards Norway. Part of this current follows the western bank of the Norwegian Trench into the North Sea contributing to a cyclonic circulation in Skagerrak. The fresh Norwegian Coastal Current (NCC) is also reproduced.

Overall both boundary conditions are working and produces similar results in the North Sea. However, the clamped condition is not able to "swallow" enough outflow from the model domain. This produces an artificial recirculating cell in the northern corner of the model domain. The FRS condition works better in this area.

Comparison with Skagex data

During the spring of 1990 a large field experiment "SKAGEX" was conducted in Skagerrak involving 17 vessels from 7 countries. The resulting dataset is well suited for model validation, e.g. Svendsen et al. (1996), Berntsen and Svendsen (1999)



The figure above shows the averaged salinity structure for the repeated sections "F" (upper) and "H" (lower), with observations to the left and model results in colour. The observations figures are taken from Berntsen and Svendsen (1999). The positions of the sections are shown in the domain figure.

In both sections the model produces salinity values close to the observations. In section F the modelled near surface stratification is weaker than observed. The salinity increases towards the Denmark side, but the 35.2 blob on the south flank is missing. In section H, the dropping of the isolines towards Norway is reproduced. The salinity maximum is placed correctly, but the vertical structure is too steep. As a result of this, the near surface vertical stratification becomes stronger than observed. Given the coarse resolution of 8 km in the Skagerrak, the results are very promising.

Comments

- The FRS boundary condition is implemented for ROMS v. 2.0
- The FRS may work better than the clamped condition with coarse information at outflow boundaries
- This setup of ROMS reproduces the main currents in the North Sea area
- The water masses in Skagerrak are qualitatively well represented for the Skagex period.

References

J. Berntsen and E. Svendsen. Using the SKAGEX dataset for evolution of ocean model skills. *J. Mar. Systems*, 18:313–331, 1999.

H. Engedahl. Use of the flow relaxation scheme in a three-dimensional baroclinic ocean model with realistic topography. *Tellus*, 47A:365–382, 1995.

Y. Heggelund and J. Berntsen. A two-way nesting procedure for an ocean model with application to the Norwegian Sea. in Y. Heggelund; Numerical ocean modelling. On local grid refinement and nonhydrostatic physics, Dr. Scient thesis, Math. Inst., Univ. of Bergen, 2000.

E. Svendsen, J. Berntsen, M. Skogen, B. Ådlandsvik, and E. Martinsen. Model simulation of the Skagerrak circulation and hydrography during Skagex. *J. Mar. Systems*, 8:219–236, 1996.