Downscaling climate scenarios for the North Sea

by

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Introduction

The human activities in shelf sea areas, such as petroleum activity, shipping, fisheries and aquaculture are strongly influenced by the climate conditions in the area. Global coupled atmosphere-ice-ocean models provide scenarios for the future climate. However, the ocean climate in a shelf sea may depend on topographic details and exhange of water with the deeper ocean, which may be poorly represented in a global model. On this background the Norwegian research programme RegClim has started an activity on dynamical downscaling scenarios from global climate models to the shelf seas adjacent to Norway; the North Sea and the Barents Sea.

The North Sea is a shallow shelf sea, semienclosed by UK to the west, the European continent in south, and Scandinavia in east, see map below. In north it is limited by the deeper Norwegian Sea. The circulation is dominated by the outflowing fresh Norwegian Coastal Curren (NCC) and the inflowing high salinity Atlantic inflow from the Norwegian Sea.

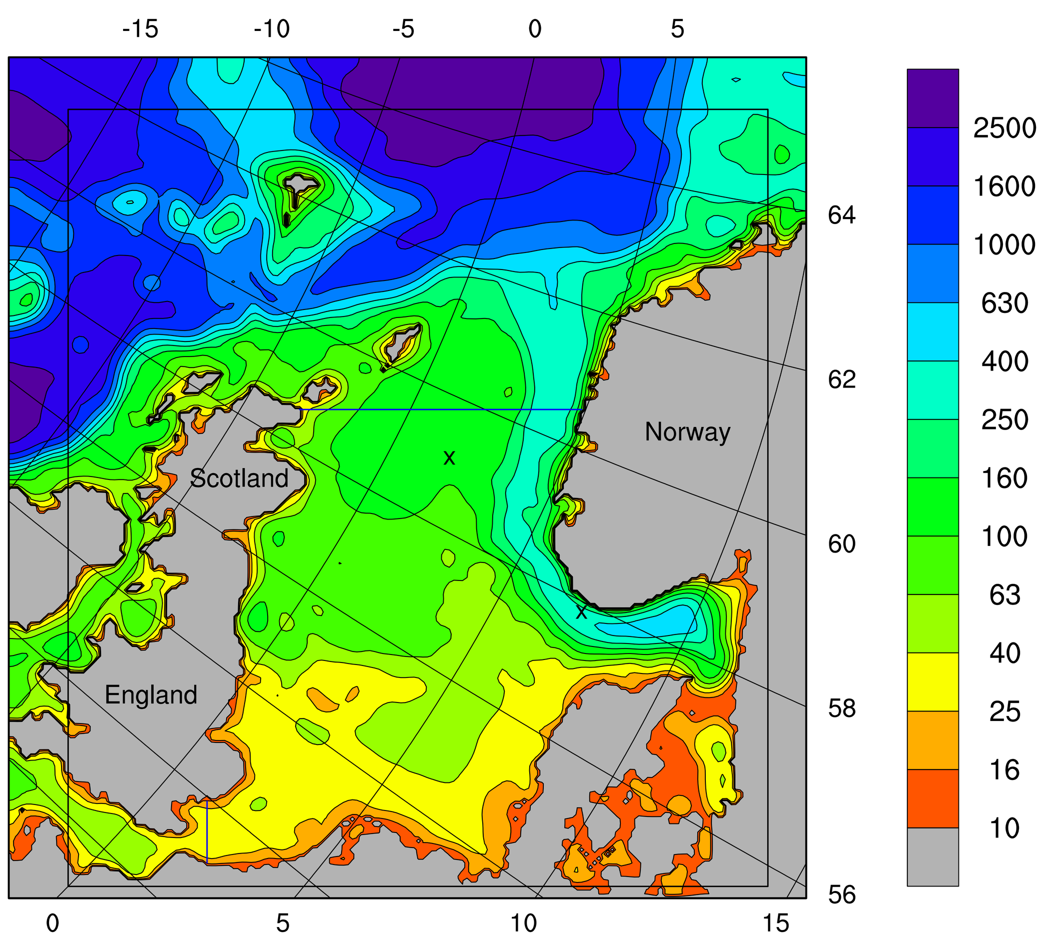


Figure 1: Topography of the North Sea model domain

For this downscaling task we use the Regional Ocean Model System (ROMS). As a prerequisite we must show that the model is able to reproduce the present climate in a validation study. Thereafter it can be used to downscale scenarios produced for the IPCC process by the Bergen Climate Model (BCM). Here results from the validation study and some preliminary results from the control run is presented.

The Regional Ocean Model System

The Regional Ocean Model System (ROMS) is a community model developed by Hernan Arango at Rutgers University and Alexander Shchepetkin at UCLA. The model and its numerical methods are explained in a series of papers (Shchepetkin and McWilliams, 1998, 2003, 2005; Ezer et al., 2002).

It uses terrain-following coordinates in the vertical. The model uses relative high order schemes including a vertical parabolic spline representation. ROMS has been designed for effective parallellisation. The model is highly flexible and configurable.

For this study the model has been modified to use the Flow Relaxation Scheme (FRS) at the open boundaries (Engedahl, 1995; Ådlandsvik and Budgell, 2003). 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 boundary zone with increasing relaxation towards a clamped condition at the boundary.

North Sea validation study

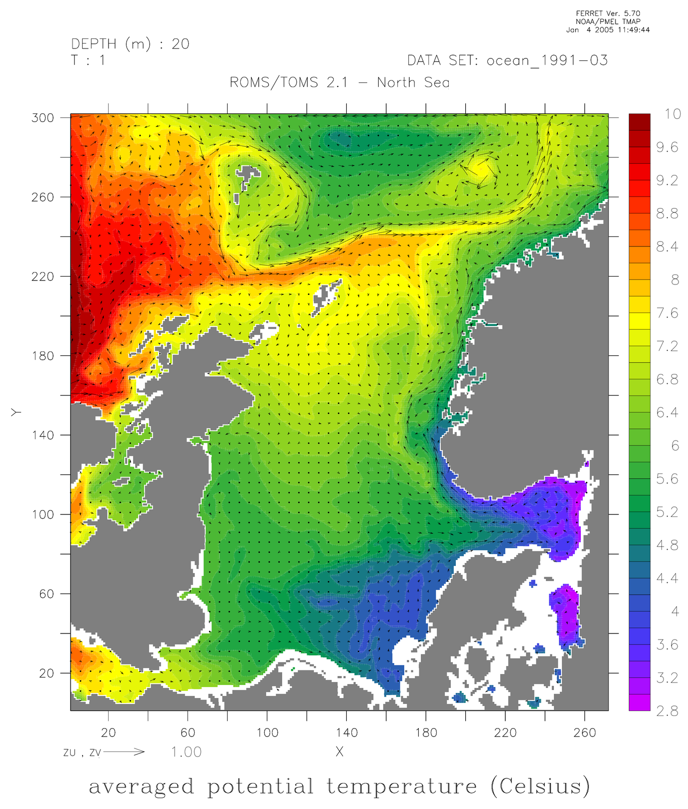
Model set up

- Stretched domain, resolution from 3.5 to 6.5 km
- 32 vertical s-levels
- Vertical mixing: GLS formulation of Mellor-Yamada
- No explicit horizontal mixing
- 2D boundary scheme: combination Chapman+Flather
- 3D boundary scheme: FRS (Flow Relaxation Scheme)

Model forcing

Atmospherical NCAR/NCEP reanalysis
Fresh water Climatologal river run-off, including the Baltic + NCEP presipitation over sea
Tide 8 constituents
Lateral boundaries DNMI-IMR climatology (Engedahl et al., 1998)

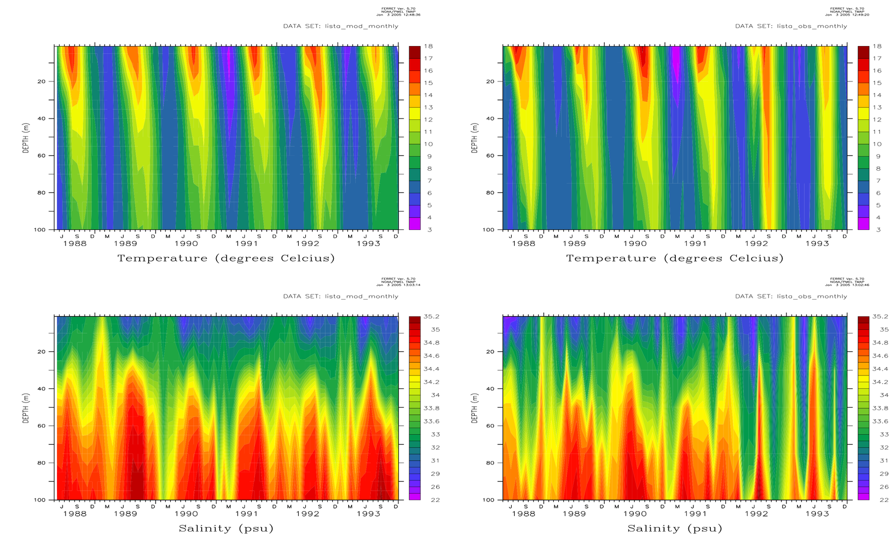
Near surface temperature and current



This figure shows the sea surface temperature and current at 20 m detph, averaged over the month of May 1991. The model recaptures the main observed features in the area. In north-west we have the warm Atlantic Water flowing into the Norwegian Sea in two branches, at each side of the Faero Islands. It continues along the shelf break as the Norwegian Atlantic Current. Atlantic water also enters the North Sea from north and is visible as far south as the Skagerrak. The strongest current on this time scale in the North Sea is the outflowing Norwegian Coastal Current.

Comparison with IMR Coastal Station Lista

IMR's coastal stations are repeated approximately twice per month since the 1960s
Data are available on the internet
`http://pegasus.nodc.no:8080/stasjoner/`



Model Observations

Time series of hydrography at Lista, at the "x" at the southern tip of Norway. The observation system changed from water bottles to CTD in 1982, with some initial problems with the salinity observations.

Summary from validation runs

- A spinup-time of 18 months is adequate for the North Sea.
- Without evaporation, the mean salinity becomes too low, but the salinity in the coastal current is reasonable.
- With evaporation, the salinity becomes too high, at least locally.
- In general, can not hope to balance salinity without any feedback.
- The temperature in the coastal current is not sensitive to the freshwater treatment.
- The model reproduces the temperature development in the coastal current on seasonal and interannual scale.
- Scope for improvement: non-climatological lateral boundary forcing.
- The model is doing a good job, the limiting factor is the quality of the forcing data.

Bergen Climate Model

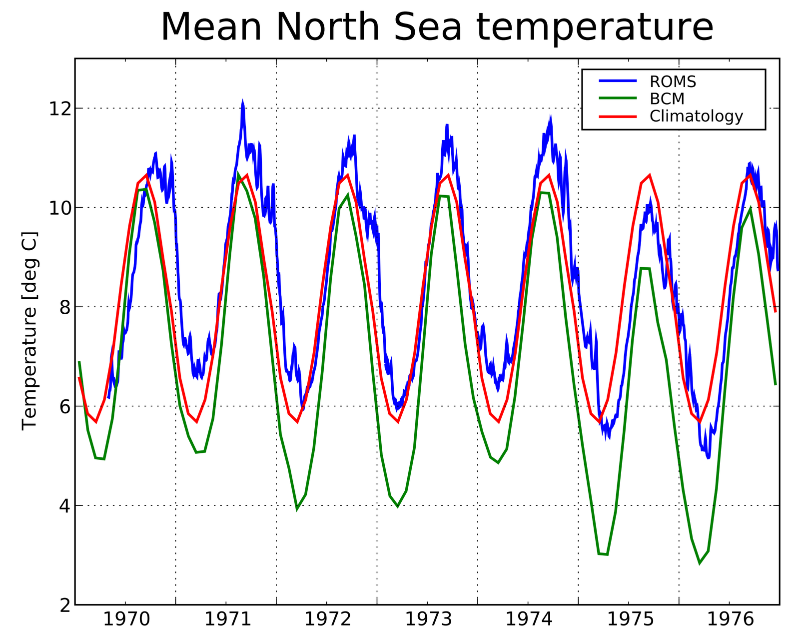
For downscaling the input is taken from the Bergen Climate Model (BCM) (Furevik et al., 2003). This is a global coupled atmosphere-ice-ocean climate model, comprised of the Arpege atmospheric model, the MICOM ocean model including a sea-ice model developed at the Bjerknes Centre for Climate Research. The resolution of the ocean submodel is approximately 80 km in the North Sea.

Set-up for control run

The set-up for the downscaling run is similar to the validation run. To save computer time, the resolution is decreased to an average of 8 km for the outer domain in Figure 1.

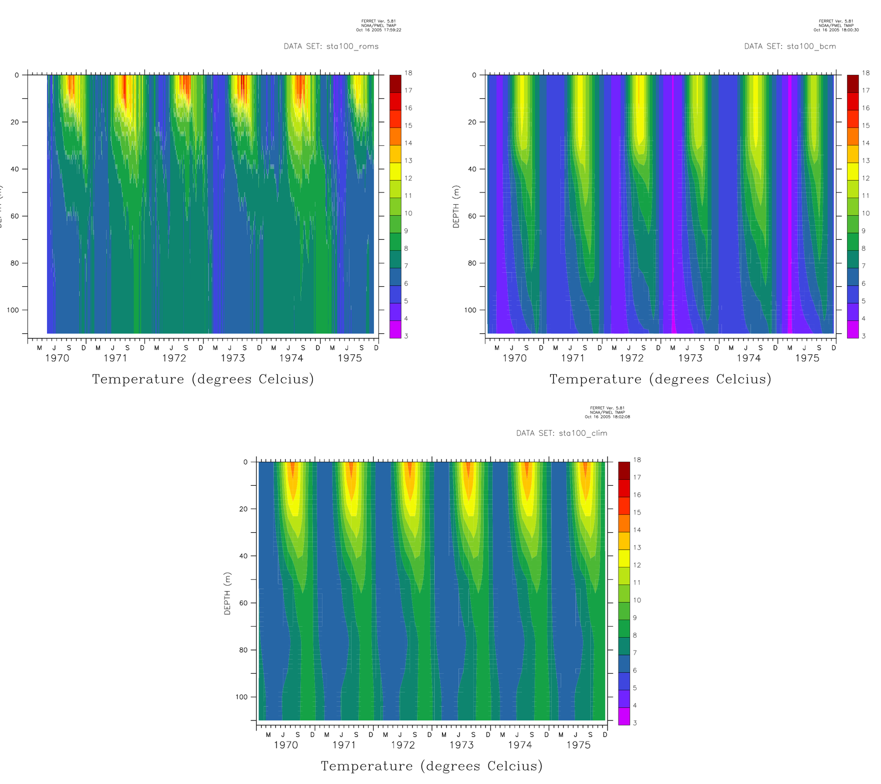
Daily atmospheric forcing and monthly ocean fields at the boundary is taken from the CMIP 20C3M run with BCM. The climatological fresh water run-off is modulated by the anomalies in the BCM presipitation.

Mean temperature in the North Sea



The figure shows the time development of the spatially averaged temperature for the North Sea, as limited by the blue lines in Figure 1. The green curve is the results from the BCM, the blue curve the downscaled results with ROMS, while the red curve is the climatology of Engedahl et al. (1998). The BCM results are close to the climatology in the summer but way too cold in the winter. The ROMS results are close to the winter climatology. In a similar salinity average (not shown), the BCM results are close to the climatology, while the ROMS result have a freshening trend.

Temperature station



This is the temperature development at the station marked "x" in the central northern North Sea. Upper-left: the downscaled results from ROMS, upper-right: the BCM output, lower panel: the climatology. Compared to the climatology, the summer mixed layer is too deep and cold in the BCM results. After downscaling the mixed layer may be slightly too shallow. downscaling. The BCM winter temperatures are too cold in all depths, while the downscaled temperature is more variable.

Preliminary conclusions from control run

- The downscaling works technically.
- The BCM reproduces the average salinity and summer temperature in the North Sea very well. The winter temperature, however, is too low, probably because of the too low Atlantic inflow to the North Sea.
- Downscaling with ROMS gives a reasonable Atlantic inflow, thereby improving the mean winter temperature.
- Downscaling improves the regional distribution pattern of temperature and salinity.
- The downscaled results show a freshening trend, probably because the boundary treatment does not let enough fresh water from the Norwegian Coastal Current pass out from the model domain.

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