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Modeling the Circulation of the NW European Shelf Seas: Present and Deep Past

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Motivation

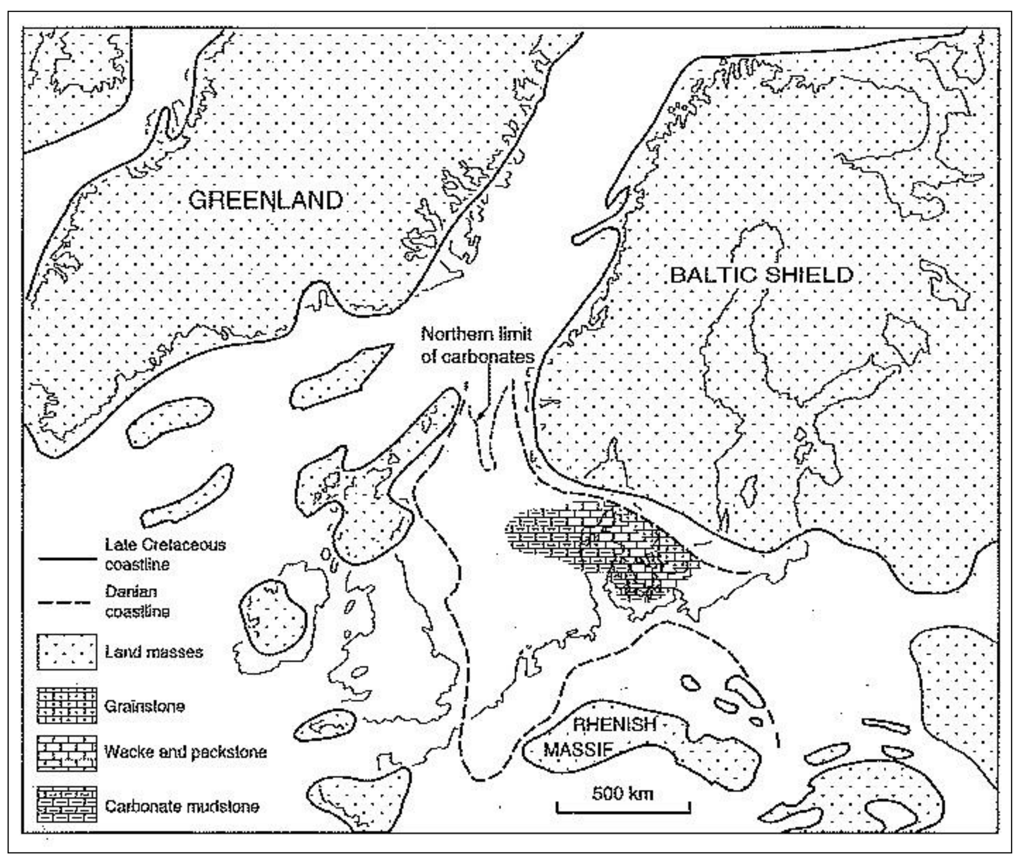

Fig.1 NW Europe during the Late Cretaceous.
From Surlyk (1997)

This poster presents the preliminary steps of a project to model circulation, productivity and sediment distribution in the Cretaceous North Sea region through the modelling capacities of the Regional Ocean Modelling System (ROMS), coupled with the biogeochemical submodule of Azhar et al., (2014).

The chalk of Northwest Europe is a biogenic sedimentary rock, consisting of the shells of coccolithophores, a carbonate shell bearing branch of haptophyte algae. Whereas in the present day, these algae mainly live in the open oceans, in the Late Cretaceous (c.100-65 Ma), they inhabited a shelf sea covering much of Northwest Europe (fig. 1), leaving a widespread, kilometer thick sedimentary succession of chalk, which today is not only an important palaeoclimatic archive, but also serves as a reservoir for hydrocarbons and drinking water.
Understanding the processes governing the deposition of this succession is important, since it gives an improved understanding of its reservoir properties and their spatial variation, but also because it gives an insight into the dynamics of a shelf sea under a greenhouse climate such as that of the Cretaceous.

Due to our limited knowledge of palaeobathymetry and –circulation, it is advantageous to do a ground truth case for the modern day North Sea, in order to test the model's capability to reproduce known circulation and productivity patterns. The first results of this work are presented in this poster.

Biogeochemical Model

The biogeochemical module to be employed (results not shown) is described in Azhar, M. A., et al. (2014). It consists of 14 state Variables, including nitrate , nitrite ammonium, phosphate, oxygen, hydrogen sulfide, two classes of phytoplankton(phytoplankton and nitrogen-fixing diazotrophs). The module is modified from a previous module (Fennel et al., 2006), in order to make it applicable to anoxic systems, e.g. under upwelling and eutrophic systems, and has been shown to reproduce the distribution of chemical species process rates within the oxygen minimum zone (OZM) off Chile well.

This makes it suitable for studying the Cretaceous oceans, as the period underwent several Ocean Anoxic Events (OAEs). Furthermore, it can further the study of effects of predicted changes in sea level and ocean ventilation under a changing future climate.
The study proposes to expand the module with a coccolithophore class of phytoplankton and a carbonate ooze sediment being coupled to the productivity of this class.

Model domain

The model grid is run on a 98x130 cell grid with 20 vertical layers. The grid resolution varies from 8.8 km in the North to 10.6 km in the South.

The bathymetry is extracted from the Sandwell and Smith (1997) database with forcing, boundary conditions and climate conditions extracted from the World Ocean Atlas 2013.

Timestepping is 30 minutes for long timesteps and 1 for short, and the boundaries are nudged every 72 days.

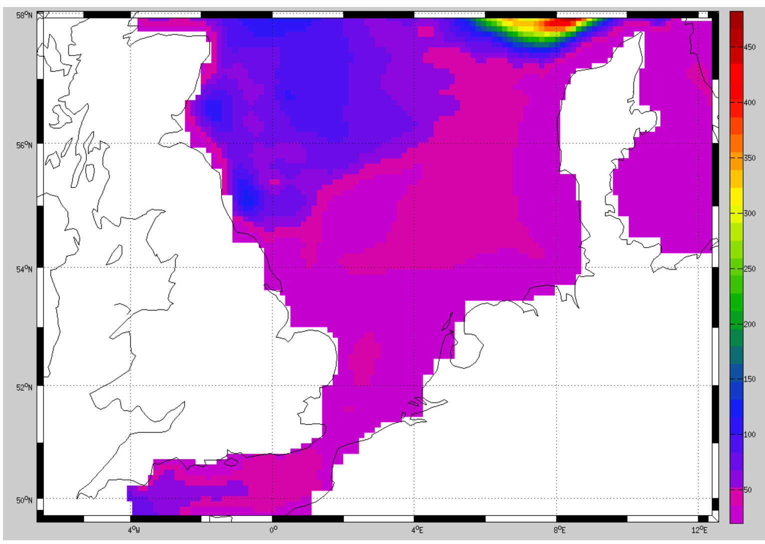

Figure 2 Model domain with bathymetry.

Discussion

As seen in the figures below, with the applied model parameters and initial conditions, the model reproduces the overall circulation pattern of the model domain fairly well. The counter-clockwise circulation in the North Sea with Arctic water entering from the North, going down the British coast and across the basin continue up the coast of Jutland and into the Inner Danish waters is reproduced. Likewise, the southern inflow of Atlantic water through the English Channel with a backflow along the English coast (not shown in figure) is reproduced. The circulation within the Inner Danish waters is not well reproduced, as the outflow of Baltic waters does not occur.

For salinity, whereas the general distribution is fairly well reproduced (with a notable exception at the mouth of the Elbe and Rhine rivers, which are presently not included in the model), the values are significantly lower, with model results ranging from 22 to 30 in the model compared to 31 to 35 in the OSPAR data.

Data

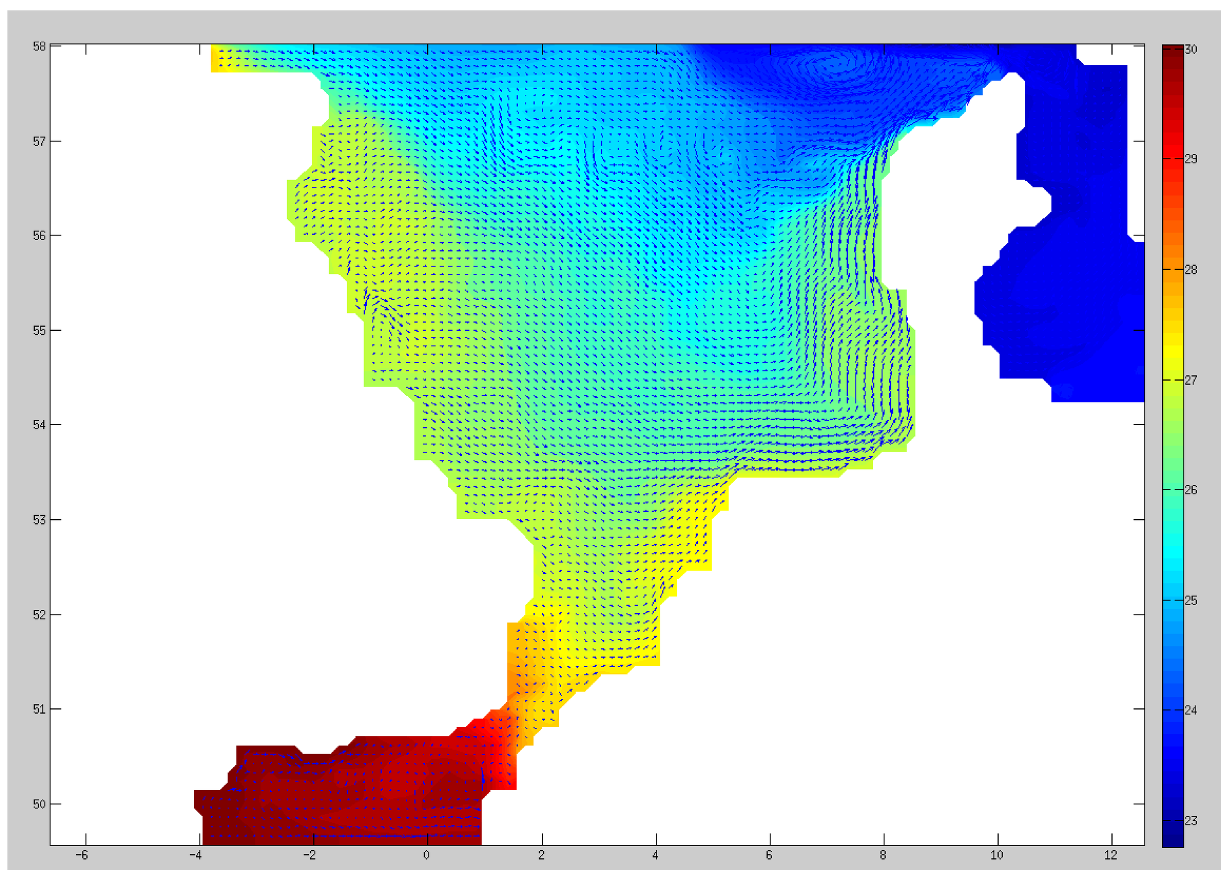

Figure 3a) 30 day average surface salinity in January of model year 15 with depth integrated current vectors superimposed

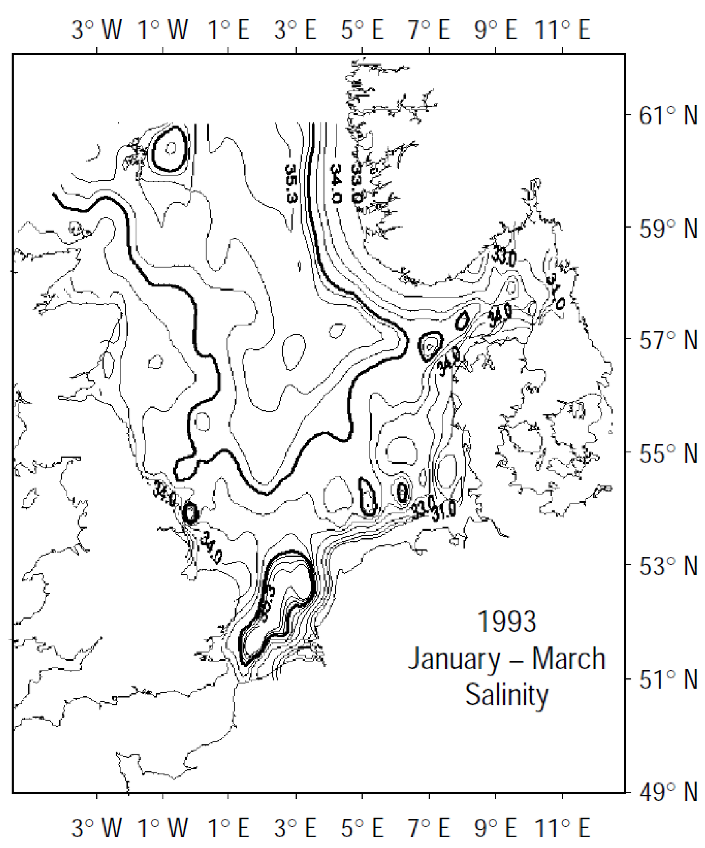

Figure 3b) Surface salinity in January of 1993 (from OSPAR, 2000)

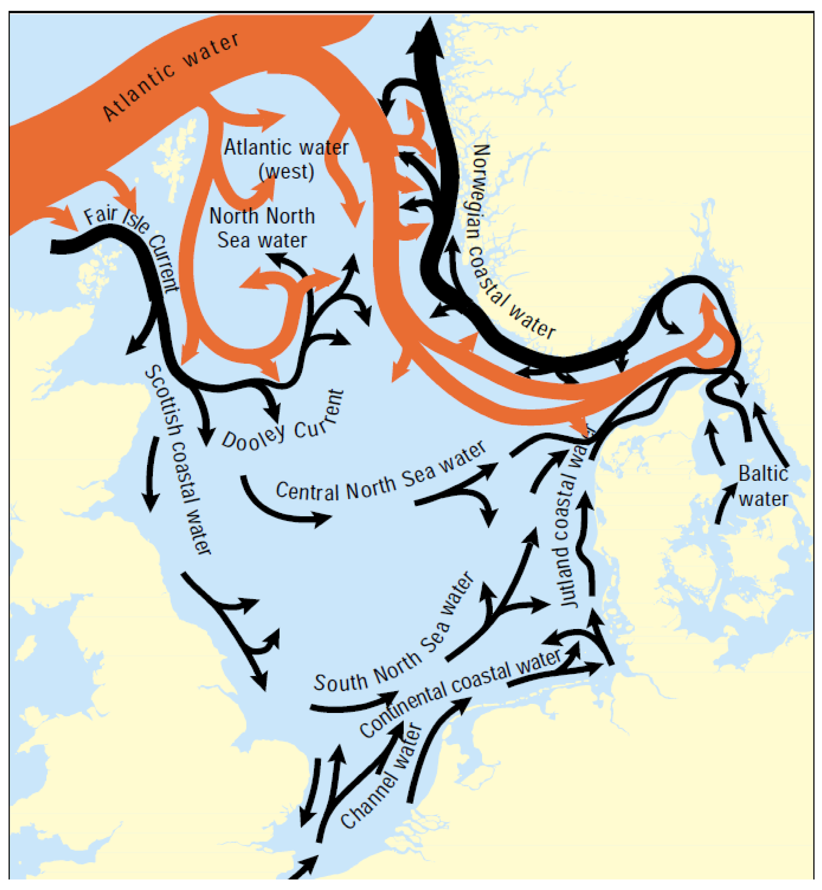

Figure 3c) General circulation pattern (from OSPAR, 2000)

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