

Variability in the modelled and observed spring bloom in the North Atlantic

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Abstract

When projecting biogeochemical models into the future, it is important to be able to capture both the seasonal cycle and the interannual variability. *In-situ* and satellite measurements from the North Atlantic indicate that both timing and magnitude of phytoplankton blooms as well as the primary production vary considerably between years. Modelled chlorophyll and primary production produce a reasonable seasonal cycle, but the result show less interannual variability than the observations. The underlying assumptions behind these coupled physical-biological models is that the variability at the lower trophic levels is controlled by the variability in the climate system, it is therefore surprising that this variability is absent when the model is forced with an atmospheric reanalysis product that inherently contains this climatic variability. To pinpoint the reason behind the lack of variability we explore two different hypotheses for the model uniformity: (1) the observed variability occurs because of lack of representativity of the measurements (statistical sampling effects). (2) The variability stems from internal processes in the biological model. In this extended abstract, results from investigating only hypothesis (1) is presented.

Keywords: North Atlantic, interannual variability, modelling, phytoplankton

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1. Introduction

Currently models are being used to study previous variability as well as future projections of ecosystem change and variability based on climate scenarios. In order to produce the best projections possible it is important to know how the model performs in reproducing past observations. In particular, on long time-scales the model should reproduce both the mean seasonal cycle and the interannual and decadal variability. In the model system presented here, the interannual variability is far weaker than in the observations. For example the start of the spring bloom in the Norwegian Sea can shift by more than a month (Skjoldal, 2004), while in the model it varies with less than two weeks. Henson et al. (2009) show that their model has interannual variability at mid- and low latitudes, however the model is surprisingly uniform at high latitudes. They attribute the lack of interannual variability to either too simple grazing formulations or lack of mesoscale variability.

At high latitudes, many species are locked in to a seasonal cycle of diapause, moulting, and reproduction (for zooplankton) and migration and spawning for several species of fish. According to the match-mismatch hypothesis (Cushing, 1990) the timing and magnitude of the spring bloom therefore has a direct effect on the secondary production, which affect the survival of fish larvae and ultimately the year-class strength. Therefore the interannual variability in the timing and strength of the spring bloom may have a strong impact upward in the ecosystem. Thus when projecting end-to-end models into the future using climate model scenarios as the physical forcing it is essential that we also reproduce the interannual variability at lower trophic levels, as these can have strong and long-term impact on the higher trophic levels.

There are several possibilities for why the interannual variability is too weak in the model, here we investigate two possibilities:

(1) There is some internal variability (species variability etc) in the lower trophic ecosystem and not the physical forcing that causes the variability and this is not included in the current model parameterization.

(2) The variability from the observation is a statistical artefact by under sampling a highly patchy ocean (in the case of in-situ data) and only sampling the sunny ocean (in case of ocean colour).

2. Methods

The physical model used is the HYbrid Coordinate Ocean Model (HYCOM: Bleck, 2002). This model is coupled to the ecosystem model NORWECOM (Skogen and Søliland, 1998) and has been used in several studies of the North Atlantic and the Norwegian Sea (Hansen and Samuelsen, 2009; Skogen et al., 2007). The model contains three types of nutrients; nitrate, phosphate and silicate, two types of phytoplankton; diatoms and flagellates, three types of detritus (nitrogen detritus, phosphate detritus and biogenic silica), and oxygen. A few modifications have been done to the model in the last couple of years (Samuelsen and Bertino, 2011). The model now includes two species of zooplankton; micro-zooplankton and meso-zooplankton. The feeding parameterizations for the zooplankton follows that of the model ECOHAM (Pätsch and Kühn, 2008). The micro-zooplankton feed on flagellates, diatoms, and detritus, while the meso-zooplankton feed on micro-zooplankton, diatoms and detritus.

2.1 Model setup

A relatively coarse model of the North Atlantic with resolution of about 50km in the Norwegian Sea was used. The atmospheric forcing used was the ERA-Interim reanalysis (Dee et al., 2011). For river input TRIP (Oki and Sud, 1998) was used for the freshwater-input. The nutrients in the river were derived from GlobalNEWS model results (Seitzinger et al., 2010). Both the freshwater- and nutrient-input from the rivers are climatological and thus there is no interannual variability present in the river forcing. The model uses the GISS mixing scheme (Canuto et al., 2010). Relaxation to climatology is applied to the surface salinity field with a relaxation time scale of 200 days, while no relaxation is applied to the sea surface temperature. Nutrients and oxygen are relaxed back to climatological data (Conkright et al., 1998) at the southern and northern boundary. The physical model was initiated in 1991, while the ecosystem model was initialized in the beginning of 1993. The ecosystem model was initialized with climatological values for the three nutrients and oxygen and constant low values for the remaining variables. The sediment layer was initialized with constant values. The model was run up to the end of 2011. *In-situ* measurements of chlorophyll for the period 1997-2009 were used for comparison.

3. Effect of sub-sampling a patchy system

The effect of sub-sampling on the in-situ data was investigated in the following way: A sub-region was selected for that analysis, in this case the region between 65.5-67.5 °N and 1.5-5.5 °E. This region includes station M, which is the most consistent time-series in the Norwegian Sea. The maximum of the spring bloom, peak timing and day of the start of the spring bloom is then compared in 3 datasets; (1) the in-situ data, (2) the model data sub-sampled at the in-situ locations and (3) the full model data in that region. The comparison shows that when the model is sub-sampled as the in-situ data locations it shows much more variability than when all the model data are used (Figure 1). The maximum chlorophyll values vary between 1 and 6 mg chl/m³ in the observations and while the spread is similar in the model when it is sub-sampled at the observation locations, the values fall in a narrow range between 6-8 mg Chl/m³ when all the models are used. For the start day the result is similar for both the complete mode dataset and the sub-sampled dataset; the distribution of starting days is narrower than in the observations.

This shows that sparse in-situ sampling can at least to some degree exaggerate the temporal variability in the system. At a resolution of 50 km this model shows far less spatial patchiness than the one observed in ocean colour images, still the sub-sampling of the model makes a large difference in the variability. Further assumptions about smaller scale processes could lead to extensions of the above results

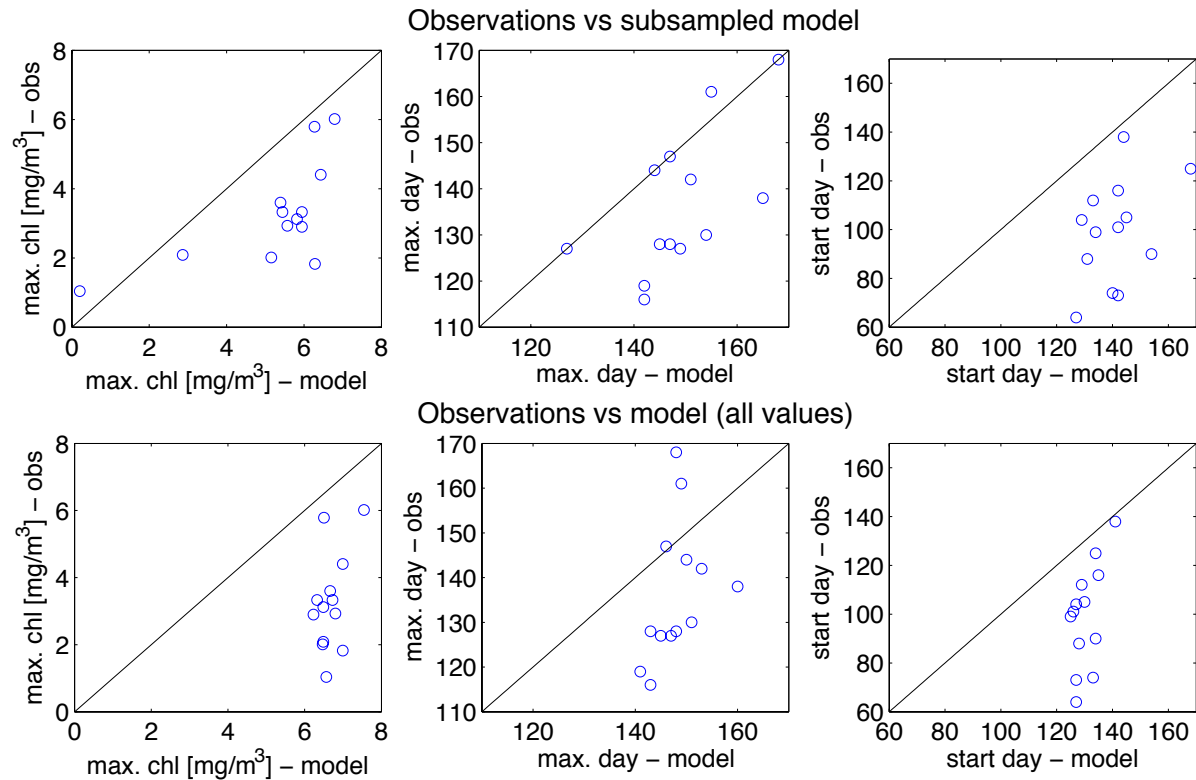


Figure 1. Comparison between, maximum chlorophyll value, peak day, and day of the start of the spring bloom between model and observation when the model is sub-sampled at the locations of the observations (upper panel) and when all the model data are used (lower panels).

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