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Quantification of long-term variations in oceanic pH and uptake of CO_2: comparative assessment in three different regional ecosystems.

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Summary

We present long-term hindcast simulations using the model ECOSMO II in the North Sea, Baltic Sea and Barents Sea. In each region, the long-term changes in pH and ocean-atmosphere CO_2 relate differently with physical variables (temperature and circulation), primary production and climate oscillations (NAO and AMO). The results indicate the interannual to decadal variability of the carbonate system is modulated by different processes to a different extent in the areas studied.

Introduction

Long-term trends in ocean acidification are determined primarily by air-sea exchange and atmospheric carbon concentration. However, regional and inter-annual variability is significantly modulated by changes in the physical environment and regional ecosystem dynamics.

The North Sea, Baltic Sea and Barents Sea are shelf systems with specific characteristics which have a large influence in their biogeochemistry. Despite their connection and geographical proximity, the Baltic and North Seas are quite different (Rodhe *et al.*, 2005). In the Baltic Sea the water exchange with the North Sea is restricted and the strong halocline decouples the surface and bottom layers, with consequences for biological productivity and other biogeochemical reactions. The North Sea, on the other hand, is more open and strongly influenced by nutrient rich inflow of Atlantic waters through its northern boundary. The North Sea is only seasonally stratified and well mixed during winter. The Barents Sea biogeochemistry is strongly influenced by the Atlantic inflow between continental Norway and Svalbard (Smedsrud *et al.*, 2013) which is a major nutrient source as the freshwater input is relatively low. These particularities ultimately shape the variations in carbonate chemistry and CO_2 air-sea fluxes.

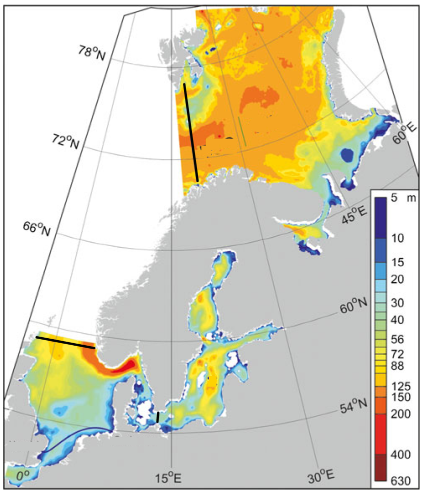


Figure 1: Map of the study areas. The thick black lines indicate the transect defined for inflow calculations. Modified from Barthel et. al (2012)

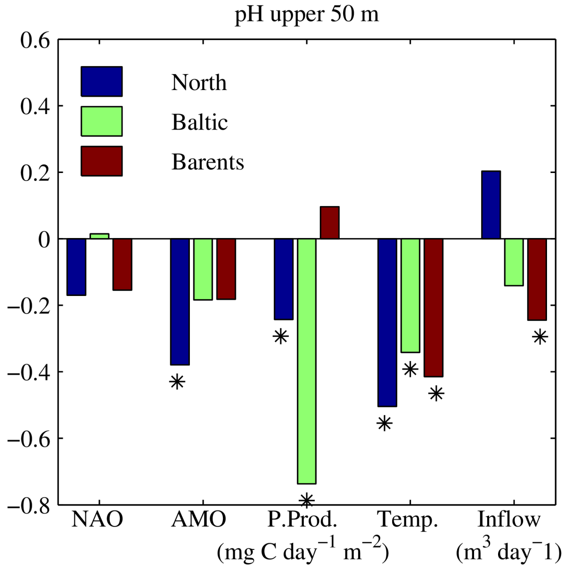
Materials and Methods

We used the bio-physical model ECOSMO II, described in detail in Daewel and Schrum (2013), coupled to a carbon chemistry model (Blackford and Gilbert, 2007). The biochemical model includes 3 functional groups of phytoplankton (diatoms, flagellates and cyanobacteria) and resolves 3 macronutrients cycles. Both dissolved inorganic carbon (DIC) and Alkalinity are derived from ECOSMO depending on primary production, advection and river loads, and provide the input for the carbon module. The model was integrated over a 60-year hindcast period, from 1948 to 2007, in each of the three shelf regions in the North Atlantic: North, Baltic and Barents Seas (Figure 1).

Annual means of key variables in the upper 50 m of the ocean (pH, air-sea CO_2 fluxes (positive values represent CO_2 uptake by the ocean)) were analysed with respect to potential key processes such as net primary production, average temperature, the Atlantic inflow into the North Sea and Barents Sea, and the North Sea inflow into the Baltic Sea (Figure 1).

Results

In Figure 2 the Pearson's correlation coefficients of different pairs of variables are shown. Statistically significant correlations are found between pH and primary production in the Baltic Sea and North Sea and between CO_2 air-sea flux and production in the North Sea and the Barents Sea. Temperature correlates negatively to pH in all regions, but positively to CO_2 fluxes in the North Sea and negatively to CO_2 fluxes in the Baltic Sea. The considered climate indices (NAO, AMO) show little significant correlation to CO_2 fluxes and pH, and the inflow from adjacent areas seems to correlate with CO_2 fluxes only in the Baltic Sea and to a lesser extent with pH in the Barents Sea.



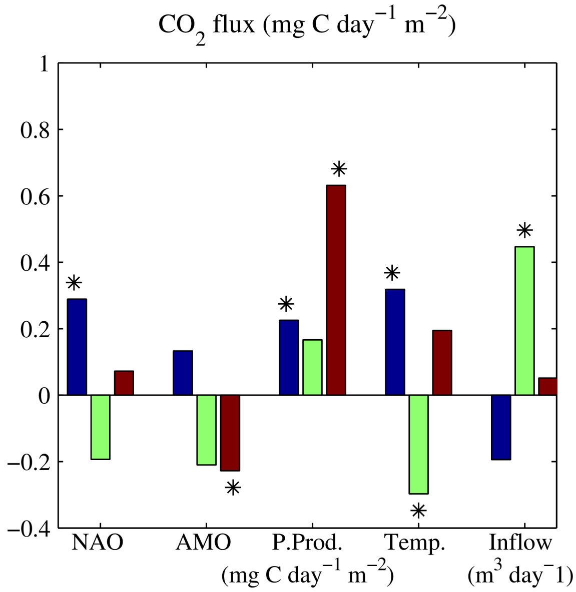


Figure 2: Pearson's correlation coefficient r for different pairs of variables. The stars indicate statistically significant correlations with a significance level alpha of 0.1.

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