THE INFLUENCE OF THE NAO ON THE CONTINENTAL SHELF PUMP ON THE NORTHWEST-EUROPEAN SHELF

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ABSTRACT
Using a coupled 3D hydrodynamic-biogeochemical model system for the Northwest-European shelf we simulated the years 1993-96, which exhibit an extremely strong transition from a NAOI-high to a NAOI-low regime. The induced temperature-shift had two consequences for the carbon budget of the North Sea: Firstly it increased the CO_2 solubility and secondly it destabilized the water column in spring 1996. The latter effect was the precondition for mixing events which brought new nitrogen for primary production into the upper layer. Consequently the air-sea flux was 540 Gmol C a^{-1} in 1996, the NAOI-low year, and it was 203 Gmol C a^{-1} in 1995, the year with the highest NAOI.

INTRODUCTION
The North Sea as an example for a broad shelf with open boundaries to the open ocean acts as a sink for atmospheric CO_2 [*Thomas et al*., 2004], even though its ecosystem is a net producer of inorganic carbon. This apparent contradiction disappears when we view the North Sea system as divided into two subregions with different features: The permanently mixed shallow southern North Sea highly influenced by inputs via large rivers and atmosphere and the seasonally stratified deeper northern North Sea with a significant North Atlantic exchange. Net autotrophic regions, where the production of organic material exceeds the consumption, are the southern North Sea and the upper layer of the northern part. In the deep northern North Sea, however, a pronounced heterotrophic situation exists. The inorganic carbon produced in this deep layer is exported effectively into the adjacent North Atlantic.

PHYSICALLY AND BIOLOGICALLY INDUCED FLUXES
In order to understand this mechanism and its correlation with climatic variations we applied the coupled hydrodynamic-biogeochemical 3D model system ECOHAM3 for the Northwest-European shelf (48° - 63°N, 15°W - 12°E) for the years 1993-96, which exhibit an extremely strong transition from a NAOI-high to a NAOI-low regime from winter 94/95 to winter 95/96. For validation the observations made during the EU-funded project CANOBA (2001/2002) were used.

In order to differentiate between physically and biologically induced carbon fluxes we performed an alternative simulation without any biological processes and found as well strong reactions on these climate extremes in the years 1995 and 1996: whereas in the NAOI-high year 1995 the physical air-sea flux (PASF) is negative, i.e. the North Sea acts as a source of CO_2, in the NAOI-low year 1996 the sign of the physically induced CO_2 flux reverses. This is a consequence of a reduced outgassing in the southern North Sea and an increased absorption of CO_2 in the northern North Sea in 1996. The main reason for this change is the lower sea surface temperature (in the southern North Sea by about 2°C) in the first half of the year 1996 compared with the corresponding time interval of 1995. We calculated the biologically induced air-sea flux BASF, a measure for the strength of the biological pump, by subtracting the physically caused flux PASF from the air-sea flux ASF of the 'full' model run (assuming linear superposition of the two fluxes: ASF=PASF+BASF). The BASF was positive in both regions of the North Sea for both years. It correlates well with the NPP (net primary production) in the corresponding region and year: A NPP increase generally goes along with an increase of BASF and vice versa. For the NAOI-low year 1996 the southern North Sea exhibited the lowest NPP together with the lowest BASF, while the northern North Sea showed the highest NPP and the highest BASF. The triggering mechanism for the decreased NPP in the southern North Sea was the reduced nutrient supply by rivers in 1996 in comparison to 1995. The enhanced NPP of the northern North Sea in 1996 was caused by the meteorologically induced destabilization of the water column allowing more efficient vertical nutrient entrainment. The BASF for the whole North Sea came out to 487 and 412 Gmol C a^{-1} for 1995 and 1996, respectively.

The annual NCP (net community production, defined as NPP minus heterotrophic respiration) was positive for the southern North Sea. It is positively correlated with the BASF, i.e. if we look at the BASF for this region the apparent contradiction, simultaneous influx of CO_2 and net heterotrophy, does not exist. For the northern part we found a negative NCP (net heterotrophy) and also a positive BASF (CO_2 influx). In the latter case the deeper layers, where the remineralisation mainly takes place, are for a large part of the year not in contact with the atmosphere, therefore one cannot expect a tight connection between inorganic carbon production and BASF.

CONCLUSION

Thus, the complex relationship between trophic state and ASF on ocean margins can only be deciphered when taking into account the meteorological, hydrodynamical and biological processes. A simple overall correlation is not at hand. A certain reduction of complexity, however, seems possible, when we look at the biologically induced air-sea flux of CO_2. The question is, whether this flux is accessible to observations, too.

REFERENCES

Thomas, H., Y. Bozec, K. Elkalay and H.J.W de Baar (2004), Enhanced open ocean storage of CO_2 from shelf sea pumping. Science, Vol 304: 1005-1008.