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Modelling the Dissolved Inorganic Carbon System in the Baltic Sea

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Abstract

Oceans are capable of storing part of the emitted anthropogenic carbon dioxide (CO_2) due to the formation of carbonic acid and subsequent dissociation. CO_2 is also assimilated by biota and the inorganic carbon system is thus coupled to biogeochemical processes. Naturally, it is a substantial improvement of model realism if the inorganic carbon system is fully coupled to biogeochemistry in numerical models. The focus of this thesis has been to improve the accuracy of pH and the partial pressure of CO_2 (pCO_2) computations for a marine environment like the Baltic Sea, but the knowledge we have gained is generally applicable. A model system has been developed to consider several environmental threats simultaneously (eutrophication, acidification, and climate change) and the model skill has been certified by using objective skill metrics.

To improve the coupling between biogeochemical processes and the dissolved inorganic carbon system, generation and depletion of total alkalinity (A_T) due to several biogeochemical reactions was added to the model. *In situ* generation of A_T was found to be important, specifically in regions with permanent or periodic anoxia, as the major A_T changes were coupled to oxidation–reduction (redox) reactions. Without adding A_T from these processes, the correct pH could not be calculated in anoxic waters and the mean volume A_T content was found to be too low.

The improvements were put to use when several environmental threats were evaluated simultaneously in a study of possible future changes in the Baltic Sea pH and oxygen balances. A coupled model for the catchment and sea was set up and forced by meteorological and hydrological datasets and scenarios. The results showed that increased nutrient loads will not inhibit future Baltic Sea acidification, but the seasonal pH cycle will be amplified by increased biological production and mineralization. The study indicated future acidification of the whole Baltic Sea and that the main factor controlling the direction and magnitude of the change was the atmospheric CO_2 concentration. Through a previous investigation of the sensitivity of Baltic Sea surface water pH it was found that increased atmospheric CO_2 can affect pH also through changing the river chemistry, especially with regard to A_T. The latter could severely impact water in the northern Baltic region.

To improve modelled seasonal pCO_2 variations dissolved organic matter was added to a numerical model. The modelled phytoplankton were allowed to utilize the dissolved organic nutrients and the biological drawdown of CO_2 in the Eastern Gotland basin was much improved by this. When phytoplankton used the organic nutrients the CO_2 assimilation was higher during the summer months and the partial pressure of CO_2 decreased by ~200 μatm in the Eastern Gotland Basin as a result. In the Bothnian Bay, both the duration and magnitude of CO_2 assimilation was doubled when phytoplankton utilized dissolved organic nutrients.

KEYWORDS: Baltic Sea, Kattegat, pH, pCO_2, total alkalinity, biogeochemistry, dissolved inorganic carbon, eutrophication, acidification, climate change, numerical modelling

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