The carbon dioxide system in the Baltic Sea surface waters

Karin Wesslander

Akademisk avhandling för vinnande av Filosofie Doktorsexamen i Oceanografi som enligt beslut av lärarförslagsnämnden vid Institutionen för Geovetenskaper, Göteborgs Universitet, kommer att offentligen försvaras fredagen den 9:e september 2011, kl 10:15 i sal Stora Hörsalen, Geovetarcentrum, Guldhedsgatan 5A, Göteborg.

Examinator: Professor Anders Stigebrandt

Fakultetsopponent: Professor Arne Körtzinger
Leibniz Institute for Marine Sciences (IFM-GEOMAR), Chemical Oceanography,
Duesternbrooker Weg 20, 24105 Kiel, Germany

Karin Wesslander
Department of Earth Sciences, University of Gothenburg
Box 460, SE-405 30 Göteborg, Sweden

ISBN 978-91-628-8319-5
ISSN 1400-3813

Earth Sciences Centre
Doctoral thesis A137

Abstract

The concentration of carbon dioxide (CO_2) in the atmosphere is steadily increasing because of human activities such as fossil fuel burning. To understand how this is affecting the planet, several pieces of knowledge of the CO_2 system have to be investigated. One piece is how the coastal seas, which are used by people and influenced by industrialization, are functioning. In this thesis, the CO_2 system in the Baltic Sea surface water has been investigated using observations from the last century to the present. The Baltic Sea is characterized of a restricted water exchange with the open ocean and a large inflow of river water.

The CO_2 system, including parameters such as pH and partial pressure of CO_2 (pCO_2), has large seasonal and inter-annual variability in the Baltic Sea. These parameters are affected by several processes, such as air–sea gas exchange, physical mixing, and biological processes. Inorganic carbon is assimilated in the primary production and pCO_2 declines to ~150 µatm in summer. In winter, pCO_2 levels increase because of prevailing mineralization and mixing processes. The wind-mixed surface layer deepens to the halocline (~60 m) and brings CO_2-enriched water to the surface. Winter pCO_2 may be as high as 600 µatm in the surface water. The CO_2 system is also exposed to short-term variations caused by the daily biological cycle and physical events such as upwelling. A cruise was made in the central Baltic Sea to make synoptic measurements of oceanographic, chemical, and meteorological parameters with high temporal resolution. Large short-term variations were found in pCO_2 and oxygen (O_2), which were highly correlated. The diurnal variation of pCO_2 was up to 40 µatm.

The CO_2 system in the Baltic Sea changed as the industrialization increased around 1950, which was demonstrated using a coupled physical-biogeochemical model of the CO_2 system. Industrialization involved an increased nutrient load with eutrophication as a result. With more nutrients, primary production increased and amplified the seasonal cycle. Model results indicate that the Baltic Sea was clearly a source of atmospheric CO_2 before 1950, and with eutrophication CO_2 emissions decreased. The increased nutrient load may have counteracted the pH drop that otherwise would have been caused by the overall increase in atmospheric CO_2. Observations from the period 1993-2009, indicate that the central Baltic Sea was a net source of atmospheric CO_2 while Kattegat was a net sink.

Total alkalinity (A_T) is higher in the south-eastern Baltic Sea than in the northern parts, these differences are attributed to river runoff and geology in the drainage area. River runoff entering the south-eastern Baltic Sea drains regions rich in limestone, which have been exposed to long-term weathering. Weathering of limestone contributes to an increased A_T. The analyze of historical data indicated that during the last century, A_T increased in the river water entering the Gulf of Finland while decreasing in rivers entering the Gulf of Bothnia.

Key words: Baltic Sea, carbon dioxide, pCO_2, total alkalinity, pH, air-sea gas exchange, inter-annual, seasonal.

ISBN 978-91-628-8319-5
ISSN 1400-3813
Internet-id: http://hdl.handle.net/2077/25442