Dynamics of oxygen in coastal seas - the Baltic Sea example

Abstract

In this thesis, oxygen dynamics in the coastal seas is investigated utilizing the Baltic Sea as a prominent example of a marine system severely affected by human impact, which led to the biggest hypoxic area worldwide. Since the oxygen sources and especially sinks are difficult to measure, a regional coupled circulation model (RCM) was applied to reconstruct oxygen sources and sinks in the central Baltic Sea on the climatological time scale and to run a few sensitivity studies with reduced nutrient forcing. In addition, the multidecadal variability in the Baltic Sea's salinity field is discussed. Conceptually, three different topics are discussed.

The first topic is oxygen dynamics in the central Baltic Sea during the 71-year period (1948-2018) and its ventilation by oxygen transported from the North Sea with the 29 biggest inflows during that time. The overall trend of deoxygenation during that time was observed. It is accompanied by a shift in oxygen consumption from the sediments to the water column. The effectiveness of the ventilation by inflows has reduced dramatically, especially in the remote sub-basins, due to elevated oxygen consumption. However, the processes triggered by inflowing oxygen did not change noticeably. It is mostly mineralization of detritus. Mineralization of detritus in the sediments and nitrification in the water column were found to be the biggest oxygen sinks.

The second topic deals with the question of how the Baltic Sea would react to a reduced nutrient forcing and whether it can be returned to the anthropogenically unperturbed state. Two sensitivity experiments with a reduced nutrient forcing (1st experiment with the Baltic Sea Action Plan Maximum Allowable Input - BSAP MAI, and 2nd with halved BSAP MAI). Both simulations encompassed a 70-year period. An overall improvement was observed in the case of both scenarios, especially in the remote sub-basin. The oxygen consumption shifted back to the sediments, and upward advection of hydrogen sulfide ceased in the remote sub-basins. It was found that the system could be returned to its unperturbed state (in this case, the year 1948), but it happened within the next 71 years only under the more rigorous halved BSAP MAI forcing.

The third topic is dedicated to the multidecadal salinity variations in the Baltic Sea. Conducting five sensitivity experiments, it was found that the multidecadal variability of the salinity field is mainly controlled by both the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Variability (AMV). In addition, the positive feedback connecting mean salinity and Major Baltic Inflows (MBIs) was observed. When the mean salinity is lower, the MBIs also transport less salt into the Baltic Sea (since the water transported out of the Baltic Sea is less saline), and vice versa.

In summary, the Baltic Sea has been rapidly deoxygenating since the 1970s. It is still possible to reverse those changes, but it will take a long time.