EGU24-12994, updated on 09 Dec 2024
https://doi.org/10.5194/egusphere-egu24-12994
EGU General Assembly 2024
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Oxygen dynamics in the Baltic Sea under reduced nutrient input

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The Baltic Sea is a semi-enclosed sea located in the Northern Europe. Due to the limited exchange with the Global Ocean, which leads to the long residence time (approx. 30 years), and permanent halocline, the Baltic Sea is naturally prone to hypoxic conditions, especially in the deep basins. However, the hypoxic area in the deep Baltic Sea has been rapidly increasing since the second half of the 20th century following the elevated nutrient input caused by human activity. To mitigate the eutrophication of the Baltic Sea, countries surrounding it started to reduce their nutrient loads following the Baltic Sea Action Plan. Despite the substantial nutrient input reduction, no significant decrease in the hypoxic area has yet been observed. In addition, climate change might promote deoxygenation of the Baltic Sea, further hampering nutrient load reduction efforts. The non-linear response to changes in nutrient input raises the question of when to expect the robust reduction of the hypoxic area, whether it is possible for the Baltic Sea to return to its natural state with a limited hypoxic area, and how the composition of the oxygen budget will change following the reduction of hypoxia.

To answer those questions, we conducted two sensitivity simulations utilizing a 3-dimensional coupled physical-biogeochemical model. The simulations followed the two nutrient reduction pathways – Baltic Sea Action Plan Maximum Allowable Input (BSAP) and the more radical half of the BSAP MAI (0.5 BSAP). Both simulations spanned 71 years and were compared to the reference scenario (Ref.) employing observed nutrient loads from 1948 to 2018. The lowering of the hypoxic area was observed in both scenarios. Most rapid re-oxidation was observed in the remote northern and western Gotland Basins, especially in the 0.5 BSAP scenario. The redistribution of the biggest oxygen consumption from the water column to the sediments followed it. Changes in nutrient loads explain more than 60% of the oxygen sources and sinks variability, making it the dominant driver of changes in the oxygen budget of the Baltic Sea, at least in the near future. The Baltic Sea could return to its initial state (1948) within the simulation period, but only following the radical 0.5 BSAP scenario.