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Multidecadal oscillations in past Baltic Sea hypoxia: the role of sedimentary iron-phosphorus feedbacks

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The Baltic Sea currently experiences widespread deep-water hypoxia, a consequence of both anthropogenic nutrient loading and the natural susceptibility of its stratified water column to oxygen depletion. Sediment core records show that hypoxia was also prevalent in the Baltic during the Holocene Thermal Maximum (HTM) and Medieval Climate Anomaly (MCA). Sedimentary iron (Fe) and phosphorus (P) dynamics are known to play a key role in determining the intensity of Baltic Sea hypoxia through time. Rapid intensification of hypoxia at the onset of past centennial-scale hypoxic events during the HTM and MCA has been explained by release of P from sedimentary Fe oxides, leading to enhanced primary productivity and deep water oxygen consumption (Jilbert and Slomp, 2013). Similarly, rapid relief from hypoxia at the termination of these events reflects efficient trapping of P by Fe oxides as oxic conditions expand.

Here we show that within past hypoxic events in the Baltic Sea, hypoxia intensity also varied continuously on multidecadal timescales. We observe persistent oscillations in new high-resolution records of sediment redox proxies derived from Laser Ablation (LA) ICP-MS analysis. In-phase multidecadal oscillations in molybdenum/aluminium (Mo/Al), bromine/phosphorus (Br/P) and Fe/Al indicate coupling between redox conditions, the flux of carbon to the seafloor, and mobilization of Fe in shelf areas, respectively. Using a simple box model, we show that instabilities in the response of sedimentary P release to changing oxygen concentrations and carbon flux were the likely cause of the observed oscillations. When prescribing a non-linear relationship between P release, oxygen concentration and carbon flux, and forcing the model with external P loadings typical of the HTM and MCA, the simulated time-series of deep-water oxygen show pronounced oscillations similar to those observed in the sediment records. However, when external P loads typical of the modern anthropogenic interval are used in the simulations, these instabilities are overcome and deep water conditions remain permanently hypoxic. The results suggest that complete recovery from hypoxia in the modern Baltic Sea will require a substantial further decline in external nutrient loading.

Reference:

Jilbert, T. and Slomp, C.P., Rapid high-amplitude variability in Baltic Sea hypoxia during the Holocene. Geology 41 (11), 1183-1186, 2013.