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Monitoring hypoxia: approaches to addressing a complex phenomenon in the Black Sea

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In this contribution we present an overview of results and share experiences from monitoring and assessing various hypoxia phenomena in the Black Sea. The focus is on approaches and technologies for monitoring of, e.g., mesoscale seasonal patterns in water column oxygenation, multi-decadal trends in oxycline boundary shifts, fast oxygen fluctuations at the pelagic redoxcline and the sediment-water interface, and seasonal changes in bottom-water oxygen. The various temporal scales (from hours to decades) and spatial patterns (from local to basin-scale) in water column oxygenation were addressed using state-of-the-art technologies, e.g., a free-falling pump CTD, a profiling instrumentation platform, ARGO floats equipped with oxygen optodes, static moorings equipped with oxygen optodes, and long-term monitoring programs based on standard CTD casts.

Examples from four study sites in the Black Sea and one in the Baltic Sea are presented. Oxygen sensor equipped ARGO type profiling floats proved to be powerful tools to resolve seasonal changes in water column oxygenation and emphasize the importance of mesoscale processes for oxygen distribution in the Black Sea basin.

Existing multi-decadal time-series monitoring data based on standard CTD measurements revealed the imprint of climate change and eutrophication on long-term oxygen distributions in the central Black Sea and hence, highlight the importance of maintaining long-term commitments to oxygen monitoring programs. Monitoring data from the last 90 years reflect the rising of the upper boundary of the suboxic zone in the 1970s and 1980s due to eutrophication, and again in the 1990s and 2000s due to NAO forcing, while eutrophication relaxed. Such long time series data allow separating out the effects that climatic forcing and eutrophication exert on oxygen depletion i.e. in the Black Sea.

A free-falling pump-CTD provided high-resolution profiles of oxygen and reduced compounds in the Bosporus outflow to the Black Sea, and proved highly suitable to resolve oxygen intrusions into highly stratified systems and hence, to identify and localize processes in complex redoxclines. We also present an example of novel technology applied in the Baltic Sea, which would be highly suitable for the Black Sea. The time series recordings of the profiling instrumentation platform GODESS in the Gotland Basin allowed a thorough characterization of oscillating redoxclines as temporally dynamic, three-dimensional systems.

Stand-alone static moorings equipped with optical oxygen sensors, current meters, and turbidity sensors allowed to resolve fast oxygen fluctuations at the sediment-water interface due to, e.g., internal waves and Ekman pumping on the Crimean shelf and identified the formation of seasonal (summer) hypoxia as an highly dynamic process on the north-western Black Sea shelf.

This comprehensive study within the EU-FP7 project HYPOX (“In situ monitoring of oxygen depletion in hypoxic ecosystems of coastal and open seas, and land-locked water bodies”, www.hypox.net) was able to address many aspects of hypoxia, e.g., in the Black Sea, and revealed the vital need for dedicated oxygen monitoring programs to adequately address the risk of hypoxia formation and ecosystem response. The challenge in any kind of monitoring is to choose the appropriate approach and technology that is suited to resolve the temporal and spatial scales on which the phenomenon occurs.