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Low oxygen in coastal and marine waters

Anne-Christine Da Silva[1], N. Fagel[1], D. Gutiérrez[2], M. Yasuhara[3] and M. Grégoire[4]

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This colloquium on ocean deoxygenation was organized by the IOC-UNESCO Global Ocean Oxygen Network (GO2NE) and was a contribution to the Global Ocean Oxygen Decade (GOOD) program of the UN Ocean Decade. The meeting involved 183 people onsite and 80 online participants.

During the colloquium, a session on "Ocean Deoxygenation - how the past can inform the future?" was convened by Moriaki Yasuhara, Dimitri Gutiérrez, Anne-Christine Da Silva, and Nathalie Fagel. The session started with Babette Hoogakker's keynote, which reviewed ongoing research on paleodeoxygenation, combining foraminifera geochemistry and climate model simulations, across key warm geological time intervals such as the Miocene and mid-Pliocene. In addition, the session involved 12 talks and 10 posters covering different approaches for reconstructing and interpreting past oxygenation conditions, their drivers, and their impacts on ocean life.

This approach was complemented by proxy development and calibration studies, as well as paleoclimate modeling of changes in ocean oxygenation. For example, past ocean anoxic events leading to mass extinctions that occurred during the Silurian and the late Devonian periods were studied in relation to their orbital forcing by Michiel Arts and co-authors (University of Liège, Belgium). Tim De Backer (University of Ghent, Belgium) then presented evidence of zooplankton malformations associated with increased levels of redox-sensitive metals at the onset of the Lau extinction event in the upper Silurian. Moriaki Yasuhara's talk (University of Hong Kong, Hong Kong) presented deoxygenation and warming impacts on shallow marine communities during the Paleocene–Eocene Thermal Maximum. He showed that habitat compression via oxygen minimum zone expansion occurred in this warmer-than-present condition. Rick Hennekam (NIOZ Institute, The Netherlands) revealed early warning signals of regime shifts associated with anoxic events (sapropels) in sediment records for the past 250 kyr in the Mediterranean Sea.

New insights for the use and interpretation of paleo-oxygenation proxies were presented, involving sedimentary redox-sensitive metals Uranium and Molybdenum by Mareike Paul (University of Helsinki, Finland) and Niels van Helmond (Utrecht University, The Netherlands), as well as trace metal enrichments (Mn/Ca) in the calcareous tests of foraminifera by Inda Brinkmann (University of Lund, Sweden). Notably, first results of tests of cold-water corals as recorders of intermediate water paleoredox state, through the evaluation of Cr and Cr isotope ratios, were discussed by Lelia Matos (CCMAR, Portugal).

Paleo reconstructions of changes in oxygen minimum zones (OMZs), and associated biogeochemical cycles, involving multiple proxies, were also presented. Catherine Davis (North Carolina State University, USA) used carbon and oxygen stable isotopes, trace metal concentrations, and morphological features of deep-dwelling planktic foraminifera to characterize the deglacial expansion of the Eastern Equatorial Pacific OMZ, and changes of mid-water oxygenation from the Last Glacial to the Holocene.

For reconstruction and understanding of coastal deoxygenation and eutrophication, Dimitri Gutiérrez (Insituto del Mar del Peru, Peru) presented a multi-proxy study, including dinocysts, geochemical proxies, and benthic foraminifera, to track cultural eutrophication in an upwelling-shadow bay of the Peruvian coast. By using state-of-the-art techniques, Constance Choquel (University of Lund, Sweden) used morphological variations of benthic foraminifera to characterize changes of oxygenation in the Baltic Sea over the past 200 years. Johannes Pein (Helmholtz-Zentrum Hereon, Germany) discussed modeling results to analyze the interplay between stratification and sedimentation driving oxygen depletion in coastal environments, with promising implications for management.

Finally, a paleoclimate modeling study by Vyacheslav Khon (Heriot-Watt University, UK) showed exciting results related to the drivers of the deep-ocean deoxygenation in the Last Glacial Maximum, highlighting the impacts of the Pliocene Panama Seaway closure on ocean circulation, net primary production and ventilation that have ultimately contributed to the development of the Eastern Pacific OMZ. Taken together, these studies emphasize the importance of the paleo approach to better understand past, present, and future ecosystems, biodiversity, and climatic impacts on them.

Figure 1: Chanxhe Record, Belgium: Alternation of limestones and shales paced by orbital forcing, and at the top of the record, close to the Devonian-Carboniferous boundary (~360 Myr BP), the Hangenberg event is a widespread anoxic event associated with dark shales and mass extinction; dark shales on the left side of the image.

AFFILIATIONS
[1]Department of Geology, University of Liège, Belgium
[2]Instituto del Mar del Peru, Lima, Peru
[3]University of Hong Kong, Hong Kong
[4]MAST-FOCUS research group, Department of Astrophysics, Geophysics and Oceanography, University of Liège, Belgium

CONTACT
Anne-Christine Da Silva: ac.dasilva@uliege.be