IFM-GEOMAR

Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

IFM-GEOMAR Report 2002-2004

From the Seafloor to the Atmosphere

- Marine Sciences at IFM-GEOMAR Kiel -

June 2005

Preface

For the first time, the Leibniz Institute of Marine Sciences (IFM-GEOMAR) presents a joint report of its research activities and developments in the years 2002-2004. In January 2004 the institute was founded through a merger of the former Institute for Marine Research (IfM) and the GEOMAR Research Center for Marine Geosciences. This report addresses friends and partners in science, politics and private enterprises. It gives an insight into the scientific achievements of IFM-GEOMAR and its predecessor institutes during the last three years.

3.5 Monitoring the Ocean's Breathing

The availability of oxygen in the ocean has major implications for biogeochemical processes and therefore strongly impacts on carbon and nutrient cycling in the ocean. Dissolved oxygen concentrations in the ocean reflect a complex balance between physical and biological sources and sinks. Oxygen is produced in the surface layer by biological production (photosynthesis) whereas it is removed in sub-surface waters by the respiration of sinking organic matter. Air-sea gas-exchange rapidly equilibrates near-surface waters with the atmosphere, whereas sub-surface oxygen removal is balanced by the transport of oxygen-rich surface waters into the interior ocean. The consequence is that sub-surface oxygen concentrations, and the overall partitioning of oxygen between atmosphere and ocean, are sensitive to the rate of surface-to-deep ocean circulation and mixing, biological production, as well as temperature and salinity (the latter determine oxygen solubility).

An accurate and sensitive 'wet chemistry' method to measure dissolved oxygen was developed more than a century ago. Such manual analyses of oxygen's distribution and variability have contributed greatly to our understanding of physical and biological processes in the world ocean, through the pioneering analyses by Wüst, Riley, Jenkins and others.

Most recently, precise measurement by Ralph Keeling and others of a slight downward trend in atmospheric oxygen due to the combustion of fossil fuels has opened up new approaches to study the fate of fossil fuel CO_2. Long-term measurements of atmospheric oxygen and CO_2 allow terrestrial and oceanic net sinks for man-made carbon to be distinguished thereby addressing a long-standing problem of global carbon cycle research. The new approach rests, however, on the assumption that oceanic oxygen inventories are not changing on interannual and longer timescales.

Several recent studies have, in fact, identified a decreasing trend in the concentration of dissolved O_2 over the past decades. These trends have been attributed to decreasing 'ventilation' of sub-surface waters. Basically, less oxygen is being transported downwards with the physical circulation to balance biological respiration, implying that more oxygen is ending up in the atmosphere. Such a trend, if real, has important implications for our understanding of global change. First, the oxygen trends may be a signal of an incipient reorganization of ocean

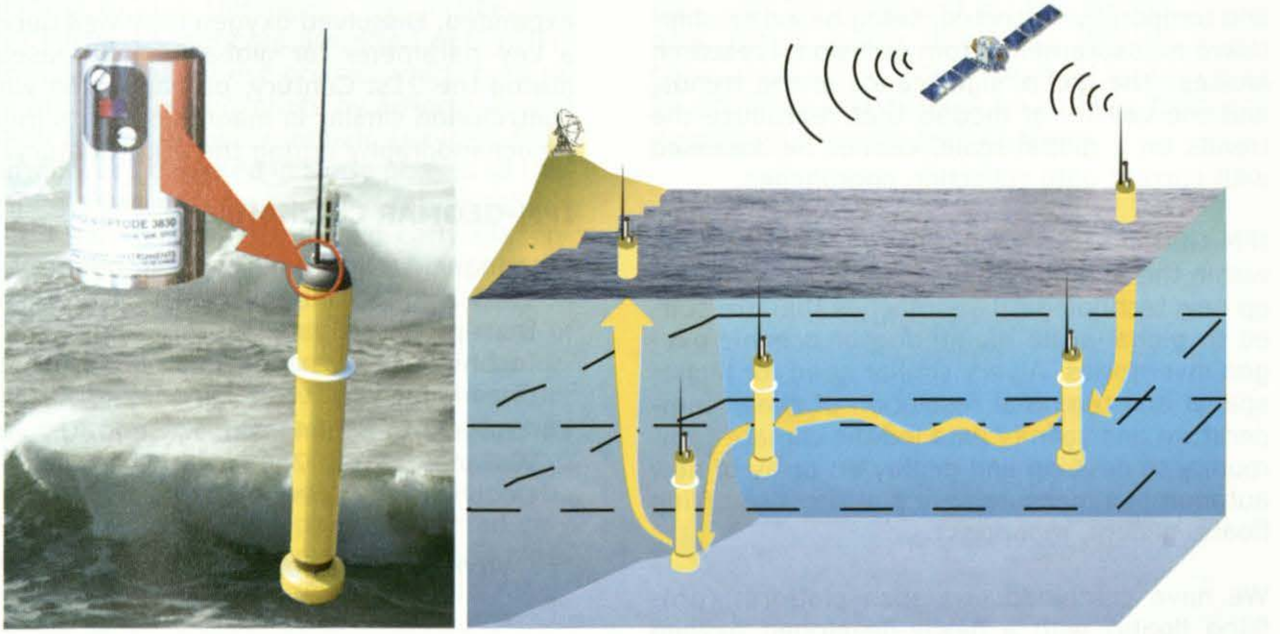

Figure 1: A global, long-term, measurement-based view of changing oceanic oxygen inventories can potentially be obtained through incorporation of accurate oxygen sensors into the next generation of profiling floats that report their data by satellite.

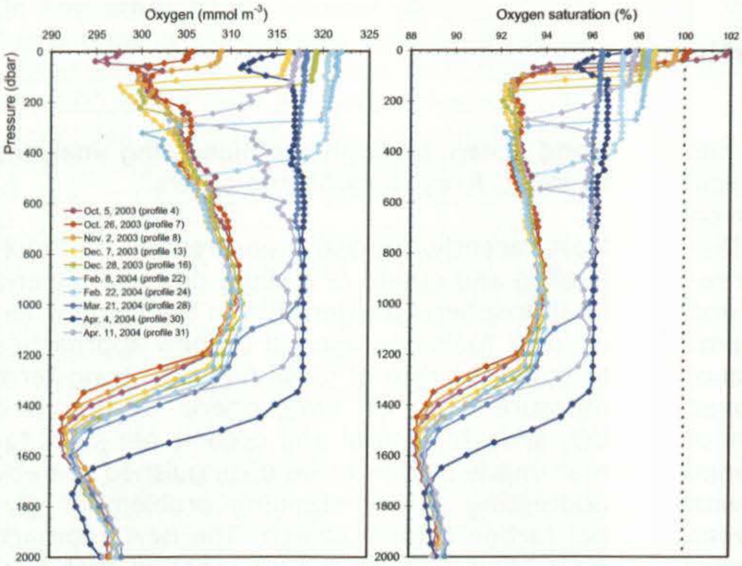

Figure 2: Selected profiles of oxygen concentration (left) and saturation (right) taken by a prototype profiling float in the central Labrador Sea. The maximum convection activity was observed in early April 2004 (profile #30). After that, the large convectively mixed water volume was sealed from contact with the atmosphere and the oxygen was exported laterally into the interior of the ocean.

circulation and mixing in response to altered climate forcing. Second, the repartitioning of oxygen between ocean and atmosphere requires a revision of the current atmospheric carbon budget and estimates of the terrestrial and oceanic carbon sinks as calculated recently by the Intergovernmental Panel on Climate Change (IPCC). Unfortunately, the database for evaluating such trends is geographically and temporally restricted, being based on shipboard measurements from occasional research cruises. The global significance of the trends, and the validity of models that reproduce the trends on a global scale, cannot be assessed with current data collection approaches.

IFM-GEOMAR scientists have been working within the SFB 460 (see section 4.1), to develop new technological approaches that are suited to global-scale monitoring of oceanic oxygen inventories. A very similar need for higher spatial and temporal resolution of ocean temperature and salinity data led the climate community to develop and deploy an array of new autonomous measurement platforms (profiling floats, gliders, moorings).

We have combined one such platform (profiling floats) with a newly-developed oxygen sensor (Fig. 1) and conducted a trial deployment of this new combination in the central Labrador Sea, which is a major region of deep convection where surface waters are mixed downwards to depths of 1-2 km during winter. The float was deployed in September, 2003 and since then measures weekly vertical profiles of temperature, salinity and dissolved oxygen in the upper 2000 m. The oxygen profiles are transmitted back to Kiel via satellite (Fig. 1) and captured a transition from late summer, well-stratified conditions (mixed layer depth <50 m) into a convectively overturning, deeply-mixed late winter situation (mixed-layer depth ~1400 m) (Fig. 2). The data are of very high quality and show no detectable sensor drift. More details about the new technology as well the data collected, and what they reveal about the 'deep breathing' of the ocean, are discussed in two recently published articles.

Based on these results, we believe that the potential to make autonomous measurements of oceanic oxygen inventories on a very large scale has been demonstrated. Currently, the international ARGO program (http://www-argo.ucsd.edu) plans to deploy 3000 profiling floats throughout the world ocean. As of early 2005, there were more than 1600 floats operating and reporting data. These floats presently measure only temperature, pressure and salinity. If these floats were equipped with O_2 sensors, our ability to measure oxygen inventories would be dramatically expanded. Dissolved oxygen may well become a key parameter for global change research during the 21st Century, perhaps even with a contribution similar in magnitude to its impact on oceanography during the 20th Century.

IFM-GEOMAR Contribtuions

Körtzinger, A., Schimanski, J., and Send, U., 2005: High-quality oxygen measurements from profiling floats: A promising new techniques. *Journal of Atmospheric and Oceanographic Technology*, **22**, 302-308.

Körtzinger, A., Schimanski, J., Send, U., and Wallace, D.W.R., 2004: The Ocean Takes a Deep Breath. *Science*, **306**, 1337.

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