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# Five decades of oxygen trends in the North Atlantic

Ilaria Stendardo and Nicolas Gruber

ETH Zürich, Institute of Biogeochemistry and Pollutant Dynamics, Department of Environmental Sciences, Zürich, Switzerland (ilaria.stendardo@env.ethz.ch)

Ocean warming is expected to cause a substantial deoxygenation of the ocean's thermocline. Prior work in the North Atlantic indicated indeed a substantial loss of dissolved oxygen in its thermocline, but very few investigations have covered changes over more than 20 years. Since oxygen measurements have a long history, we potentially can extend the analysis back in time for several decades. To this end, we built a quality controlled dataset for the North Atlantic to estimate long-term trends from 1960 to 2009 based on CARINA and GLODAP (*Stendardo et al., 2010*), augmented with selected cruises from the World Ocean Database (WOD05). Oxygen trends were estimated along isopycnal surfaces for 8 regions using linear regression with bootstrapping. Our results show a decrease of oxygen in Intermediate and Mode waters in almost all regions over the last 5 decades, with an average rate of -1.5±1.4 $\mu mol\ kg^{-1}\ decade^{-1}$. The most substantial decrease occurred in the Western European Basin from 30°N to 53°N and in the northern part of the Newfoundland basin. In contrast, oxygen increased in the Labrador Sea Water throughout the North Atlantic. Integrated over each water mass, the change of oxygen over the last 49 years amounts to a loss of -37.9±13.2 *Tmol* for the Mode waters (30.9$< \sigma_1 <$31.7, depths$<$700m), a loss of -9.0±6.1 *Tmol* for the Intermediate waters (31.8$< \sigma_1 <$32.3, depths$<$700m), and a gain of 51.8±24.4 *Tmol* of oxygen for the Labrador Sea Water (32.4$< \sigma_1 <$32.45, depths$<$2000m). In total, between 1960 and 2009, the upper 700 m of the North Atlantic between 30°N and 65°N has lost -39.7 ±18.4 *Tmol* of oxygen.Comparing our results with the trends in the ocean heat content from *Levitus et al. (2009)*, we find an $O_2$/heat ratio of 3.6±1.3 nmol $J^{-1}$ for the Mode Water and a ratio of 4.8±3.3 nmol $J^{-1}$ for the Intermediate Water. These values are in good agreement with the expected oxygen loss due to ocean warming based on modeling studies (5.9 nmol $J^{-1}$).

Analysis of repeated transects between 1981 and 2005 reveal that the strongest deoxygenation of the water masses is found just below the winter outcrop, located on progressively denser isopycnal horizons as one goes from south to north. The distribution and structure of these changes suggest that they are driven by changes in circulation and ventilation rather than biology.