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How is the North Atlantic Ocean warming?

S. J. Leadbetter (1), M. S. Lozier (2), V. Roussenov (1), R. G. Williams (1)
(1) University of Liverpool, UK, (2) Duke University, NC, USA (susanjl@liv.ac.uk)

Over the past 50 years significant changes have been observed in the temperature and heat content of the North Atlantic. The upper and intermediate waters of the tropical and subtropical ocean have warmed, whilst parts of the deep ocean and the subpolar region have cooled: the maximum warming occurred in the intermediate waters of the subtropical region.

In order to better understand these changes and to begin a search for underlying mechanisms, volume changes of isothermal layers between two 20-year periods, 1950-1970 and 1980-2000, were identified from observations of the North Atlantic. To study the mechanisms of the changes in more detail an isopycnic model was spun-up from rest and then forced with realistic forcing fields for 50 years. The same diagnostics were then carried out on the model.

The modelled and observed watermass inventories both show an expansion of the warmest and coldest layers and a depletion of waters of intermediate temperature. In the observations there is also some expansion of waters between 4 and $10^{\circ}C$.

Changes in the upper layers of the subtropics and subpolar region are dominanated by changes in the surface heat input, whilst increases in the temperature of the tropics are caused by heating due to Ekman transfer of heat. Changes in surface winds also play a significant role over the subtropics where they increase downwelling, displacing isopycnals over the upper $500m$ and hence increasing the heat content of the upper waters. Conversely enhanced advection of colder Labrador Sea water leads to cooling of around $0.1^{\circ}C$ at depths of $2000 - 4000m$.

Thus the increase in the volume of the warmest layers of the North Atlantic is due to surface wind forcing, whilst the expansion of the deepest layers has been controlled by watermass changes in the subpolar region.