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Mechanism behind the NAO effect on temperature and salinity of the northern North Atlantic intermediate and deep waters inferred from hydrographic observations

A. Sarafanov

P.P. Shirshov Institute of Oceanology, Polar oceanography group, Moscow, Russian Federation (sarafanov@mail.ru)

The North Atlantic Oscillation (NAO) is shown to be responsible for up to two thirds of the observed thermohaline changes at the intermediate and deep levels in the northern North Atlantic since the 1950s. Persistent NAO decline leads to warming and salinification in the intermediate–deep water column, and vice versa. Salinity of the intermediate and deep water masses in their formation regions follows the NAO with a time lag of one to several years that corresponds to the fast response of convection activity and the subpolar gyre circulation to the NAO-related changes in the surface forcing inferred from model experiments and observed in nature.

An observation-based explanation for the close link between the NAO and coherent decadal changes in the intermediate and deep water temperature and salinity in the region is proposed. The two factors dominate this link: (i) intensity of convection in the Labrador Sea controlling injection of relatively cold fresh waters into the intermediate layer and (ii) intensity and eastward extension of the subpolar gyre that regulates the relative contribution of cold fresh subpolar waters and warm saline subtropical waters to the entrainment into the Norwegian Sea overflow south of the Iceland–Scotland Ridge. These factors act in phase leading to the well-documented coherent thermohaline changes in the intermediate–deep water column. Accordingly, the two key sites of the fast transfer of the NAO-induced upper-ocean changes to deeper levels can be specified: the Labrador Sea and the northeastern periphery of the North Atlantic.

Due to weakening of the surface forcing associated with the NAO transition into neutral to low phase (1950s to mid-1960s, mid-1990s to mid-2000s), wintertime convection in the Labrador Sea weakens diminishing cold fresh water penetration into the intermediate layer. This results in warming and salinification at the intermediate depths in the subpolar gyre. Concurrently, the subpolar gyre contracts allowing northward advance of warm saline upper-ocean and intermediate subtropical waters in the northeastern Atlantic. Northward progression of subtropical waters increases temperature and salinity at the upper intermediate levels and, correspondingly, increases temperature and salinity of the northeast Atlantic waters entrained into the Iceland–Scotland overflow along its pathway to the deep Iceland basin. This results in temperature and salinity increase at the deep levels. The contrary changes caused by amplifying surface forcing (mid-1960s to mid-1990s) lead to cooling and freshening of the intermediate–deep water column in the northern North Atlantic.

The typical rates of changes in the water column are of the order of 0.1°C per decade for temperature and 0.01 per decade for salinity. The recent event of warming and salinification associated with the NAO decline between the mid-1990s and mid-2000s resulted in the temperature / salinity increase by 0.3°C / 0.036 on average for the intermediate–deep water column (sigma-0 > 27.45) according to the 1997–2006 data from the shipboard transatlantic monitoring at 60°N.