Variability of the Meridional Overturning Circulation observed since 1993 across the A25-OVIDE section in the North Atlantic subpolar gyre and its impact on the CO2 physical pump

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The meridional overturning circulation (MOC) transports heat from the subtropics to high latitudes and hence plays an important role in the Earth's climate. A region crucial for the MOC is the northern North Atlantic and the adjacent Nordic Seas, where waters transported northwards in the MOC upper limb progressively cool, gain density and eventually sink into the southward flowing lower limb. The variability of the subpolar gyre circulation, the MOC and heat transport was quantified from a joint analysis of hydrographic and velocity data from eight repeats of the Greenland to Portugal OVIDE section (1997–2014), satellite altimetry and ARGO float measurements. The obtained circulation patterns revealed remarkable transport changes in the whole water column and evidenced large variations (up to 50% of the lowest value) in the magnitude of the MOC computed in density coordinates (MOC_σ). The extent and timescales of the MOC_σ variability in 1993–2011 were then evaluated using a monthly MOC_σ index built upon altimetry and ARGO data at the OVIDE section location. The MOC_σ index, validated by the good agreement with the estimates from repeat hydrographic surveys, shows a large variability on monthly to decadal time scales, with an inter-annual variability from less than 15 Sv to about 25 Sv (1 Sv = 1,000,000 m^3s^{-1}). The heat transport estimated from the repeated hydrographic OVIDE sections is linearly related to the MOC_σ intensity. The uptake of atmospheric carbon dioxide in the subpolar North Atlantic Ocean is also strongly impacted by the variability of the MOC_σ. Anthropogenic carbon—derived from human activities—is separated from natural carbon by assuming that the latter corresponds to a pre-industrial atmosphere, whereas the remaining is anthropogenic. We found that the uptake of anthropogenic carbon dioxide occurred almost exclusively in the subtropical gyre. In contrast, natural carbon dioxide uptake dominated in the subpolar gyre. We attributed the weakening of total carbon dioxide uptake observed between 1997 and 2006 in the subpolar North Atlantic to a reduction in the natural component. We also showed that the transitory slowdown of the MOC_σ was largely responsible for this phenomenon, through a reduction of oceanic heat loss to the atmosphere, and for the concomitant decline in anthropogenic carbon dioxide storage in subpolar waters.

Keywords

Meridional overturning circulation; Thermohaline circulation; Heat flux; ARGO; OVIDE; Satellite altimetry; Hydrography; North Atlantic Subpolar Gyre; anthropogenic carbon dioxide;

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