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AMOC changed derived from simultaneous (absolute) freshening and (relative) cooling in the subpolar North Atlantic

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It has been suggested previously that the long-term warming hole in the subpolar North Atlantic, that is the relative cooling in this region compared to the rest of the globe, is an indicator of a slowdown of the Atlantic Meridional Overturning Circulation (Caesar et al., 2018; Drijfhout et al., 2012; Rahmstorf et al., 2015), yet other drivers like aerosols or a change in the local atmospheric forcing (e.g., the wind stress curl) have been proposed (Li et al., 2021; Piecuch et al., 2017). The still not fully answered question of the driver(s) of the warming hole also raises the question of whether or not ocean temperatures in the subpolar North Atlantic can be used as an indicator for AMOC strength. While several studies suggest that AMOC strength and temperatures in the subpolar North Atlantic are dynamically linked through the AMOC's northward heart transport (Dima et al., 2022; Latif et al., 2022; Zhang, 2008), a recent model-based study suggests that the correlation between temperature-based AMOC index (Caesar et al., 2018) and AMOC strength depends largely on the subtraction of the global warming signal (Little et al., 2020).

Based on the knowledge that the AMOC transports both heat into and freshwater out of the North Atlantic, we apply a lead-lag correlation analysis to both the North Atlantic's heat and freshwater content to identify the region and the time lag that give the strongest correlation with the strength of the AMOC (to make use of the available observational data we consider the AMOC strength at 26˚N). We find that an AMOC weakening (strengthening) leads to cooling (warming) and simultaneous freshening (salinification) in the eastern subpolar North Atlantic with the upper ocean (200-1000m) contents showing a higher correlation with AMOC strength than the surface (0-200m) contents. The temporal evolution of heat and freshwater content in the eastern subpolar gyre region are furthermore strongly anticorrelated, with a correlation value of -0.82 (for the annual values) as expected for an AMOC (or otherwise advective) driven signal. On longer time scales this anticorrelation decreases unless the heat content is corrected for a large scale warming signal. This could suggest that it is indeed necessary to look at the relative not the absolute temperature evolution in the subpolar North Atlantic to extract the AMOC signal.

Both the absolute freshening in the eastern subpolar North Atlantic as well as the relative (compared to the rest of the North Atlantic) cooling in this region suggest a linear AMOC trend of about -2 Sv from 1957-2013.

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