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Do deep convection control the long-term variability of the Atlantic Meridional Overturning Circulation?

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Atlantic Meridional Overturning Circulation (AMOC) contribute to long-term climate variability of Northern Hemisphere. The North Atlantic Ocean carries 25% of global heat transferred tropics to polar latitudes of the Northern Hemisphere (Srokosz, 2012). In the subpolar seas of the North Atlantic water goes down in few localized areas to deep convection, where all Atlantic deep water masses are formed. This process pumps a huge amount of CO_2 to the deep ocean, which have strong consequence for global climate (Buckley and Marshall, 2016; Kuhlbrodt, 2007). The water comes back to the surface mainly in upwelling regions of the Southern Ocean (Toggweiler and Samuels 1998, Delworth and Zeng, 2008), as well as in the tropics due to vertical mixing.

In this study we try to link the long-term variability of the AMOC to it's main driving mechanisms: the deep ocean convection in the Greenland, the Labrador and the Irminger seas, and to wind driven upwelling in the Southern Ocean.

As a reference for the AMOC intensity on the decadal and longer time scales, we use AMOC indexes from several studies (Caesar, 2018; Chen and Tung, 2018), which extend the time series back to the 1950s. The intensity of deep convection (IC) over the same time period is computed using convection index (Bashmacnikov et al., 2019). Wind-driving upwelling in the Southern Ocean is computed through evaluation of the divergence of Ekman fluxes (ED), using the wind velocity from atmospheric reanalysis (ERA 40 1957-1979 and ERA-Interim 1980-2016).

To estimate contribution of each of the forcing factors to the temporal variability of the AMOC, were used cross-correlation and regression analyses with varying time lags. The biggest cross-correlation coefficient was found with the IC in the Greenland Sea, the negative lags indicate that it is the AMOC, which affects the variability of convection intensity. The second largest cross-correlation coefficient was found with the IC in the Labrador Sea (0.7) with the lag of 13 years. The maximum cross-correlation with the IC in the Irminger Sea was 0.6 on a narrow interval of the time lags. The ED in Southern ocean demonstrate a significant correlation with the AMOC, with the correlation coefficient of 0.5 at the time lag of 15 years.

The contributions of each of the control mechanisms to temporal variability of the AMOC were investigated by the regression analysis for the time lags at which the maximum cross-correlations of each of the parameters are obtained. As a result the maximum regression coefficient was obtained for the IC in the Irminger Sea (0.65), the second one for the ED (0.35) using the time lags of 9 and 25 years, respectively. The regression coefficient for the IC in the Labrador Sea did not exceed 0.2 for all tested time lags. The physical mechanism, connecting the variability of the AMOC intensity to these two control mechanisms is a subject of our further research.

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