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"Climate shift of the Atlantic Meridional Overturning Circulation (AMOC) in Reanalyses (ORAS5): possible causes, and sources of uncertainty"

Vincenzo de Toma, Chunxue Yang, and Vincenzo Artale
Tor Vergata University of Rome, Tor Vergata University of Rome, Physics, Italy (vincenzo.detoma@students.uniroma2.eu)

We present preliminary results and insights from the analysis of the ensemble of Oceanic Reanalysis System 5 (ORAS5), produced by the European Center for Medium Weather Forecast (ECMWF), which reconstruct ocean's past history from 1979 to 2018, with monthly means temporal and spatial resolution of 0.25° and 75 vertical levels.

We focused on the AMOC, which can be considered as one of the main drivers of the Earth's Climate System, and we observed that the strength at 26.5°N presents a shift in the mean of about 5 Sverdrup in the period 1995-2000 which can be considered as a climate tipping point.

We aim to investigate the causes of this reduction and propose three mechanisms responsible for the observed AMOC volume transport reduction: the Gulf Stream Separation path, changes of the Mediterranean Outflow Water (MOW) and the North Atlantic Deep Water (NADW) formation processes in the Labrador Sea respectively.

The Gulf Stream Separation path is investigated by visualizing the barotropic stream function averaged over two periods, before and after the 1995-2000. In particular it is possible to detect a shift in the direction of the barotropic currents, which is enhanced further by seasonal climatology analysis. In the first period (greater volume transport), patterns are more intense, and the Gulf Stream reach higher latitudes, allowing for a more vigorous deep water formation in the Labrador Sea than in the second period.

Moreover, we observe the AMOC volume transport reduction at 26.5°N accompanied with a reduction in the heat fluxes over the Labrador Sea. We think this reduction of heat fluxes has a cascade effect on horizontal averages for temperature, salinity, and potential density profiles, which are manifestations of less deep water production in the Labrador Sea, that can ultimately drive the AMOC weakening.

Finally, the Mediterranean Sea has experienced, in the last decades, a general warming trend, in particular of deep water temperatures since the mid-1980s. It is well known that this warming induce a large variability in the hydrological characteristics of the MOW becoming more likely one key factor driving the AMOC variability observed in ORAS5. In fact, there’s a larger ensemble spread in both the temperature and salinity climatological profiles at 40°N, i. e. in correspondence of the Gibraltar Strait and Gulf of Cadiz.

This analysis highlights the high sensitivity of the MOW to perturbations producing the different ensemble members of ORAS5.

Our hypothesis is that the nonlinear interaction between these three mechanisms could have a complex feedback on the AMOC variability.

In conclusion, our preliminary results brought out the relevance of the deep water formation process in the Labrador Sea, the MOW and the Gulf Stream path as the main sources of the AMOC variability and stability. Besides, our analysis points out the need for further studies, e. g. increasing resolution at the Straits (like Gibraltar Strait), investigating correlations with the variability of the subpolar gyre and developing conceptual studies, using Intermediate Complexity Models interpreted under the lens of Dynamical System Theory and Statistical Mechanics.