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Control of the Atlantic Meridional Circulation stability by freshwater transport: a framework to interpret results from climate models.

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The stability properties of the Atlantic Meridional Overturning Circulation (AMOC) have been the subject of several numerical studies in the last decades. These studies, focusing in particular on the impact of freshwater anomalies applied at the northern end of the Atlantic Ocean, have produced widely different results for what concerns the possibility of a permanent collapse of the AMOC. Furthermore, the comparison of results using different freshwater anomalies has lead to some confusion between the transient response of the system, highly dependent on the model used and on the magnitude of the freshwater anomaly, and the possibly underlying steady states of the system.

With the aim of clarifying these aspects, a series of numerical and analytical studies has been conducted, focusing on the control of the AMOC stability by the freshwater budget of the Atlantic Ocean. The role played by the different components of the freshwater budget are investigated in a coarse resolution global climate model close to the steady state, by adding local anomaly patterns in the South Atlantic to the freshwater fluxes at the surface. These anomalies alter in particular the basin-scale salt-advection feedback, completely changing the response of the AMOC to perturbations. It is found that an appropriate dipole anomaly pattern at the southern border of the Atlantic Ocean can collapse the AMOC entirely even without any further “hosing” in the North Atlantic.

Furthermore, a simple model is developed, extending the Gnanadesikan pycnocline model, that allows the study of different steady-state regimes of the AMOC driven by the joint effect of winds over the Southern Ocean and the north–south density difference.

Overall, the sensitivity of the AMOC to changes in basin integrated net evaporation is highly dependent on the zonal salinity contrast at the southern border of the Atlantic. This suggests a new view on the stability of the AMOC, controlled by processes in the South Atlantic. Since climate models are strongly affected by biases in the salinity field and freshwater budget in the South Atlantic region, we suggest that the different outcomes of different studies of the AMOC stability may be caused by these biases, as well as to the use of anomalies of different duration that probe the response of the system on different time scales.