Sensitivity of the Subtropical AMOC to Buoyancy Fluxes over the Subpolar North Atlantic

We explore the delayed impact that buoyancy fluxes over the subpolar North Atlantic exert on the AMOC at 26N (the RAPID line). We perform adjoint experiments with the MITgcm global ocean model, linearized about the ECCO state estimate. In contrast to previous studies, the AMOC sensitivities to surface freshwater and heat fluxes differ markedly between each other in their temporal evolutions and offer surprising new insights. As expected, a freshwater injection over the Subpolar Gyre (SPG) always induces a delayed AMOC weakening. However, the sensitivity to surface heat fluxes exhibits a stronger seasonality with a counterintuitive sign reversal. The seasonal sign reversal in the AMOC sensitivity to surface heat fluxes suggests that both anomalous winter cooling and anomalous summer warming of the SPG can induce a delayed AMOC strengthening.

We perform a combination of forward and adjoint experiments to identify the physical mechanism behind this surprising result. We find that a cooling or a warming of the SPG triggers a large response by surface freshwater fluxes. The relationship between heat and freshwater flux anomalies is strongly modulated by the mixed layer depth. This explains the pronounced seasonality in the AMOC sensitivities to surface heat fluxes.

Additionally, we translate our results into density-spice space: the AMOC at 26N shows a larger sensitivity to density than to spice anomalies, with the sensitivity to spice anomalies being notable only in the high latitude upper ocean where water mass transformation occurs. Our results show that density anomalies originating in the SPG can impact the subtropical AMOC via two types of signal propagation: a slow advective pathway along the Deep Western Boundary Current and a fast propagation mechanism via topographically guided waves at depth. Finally, we explore how the north-south connectivity mechanisms work in the opposite direction: we analyze the impact of the subtropical North Atlantic on the meridional overturning in the Subpolar Gyre with a particular focus on transport across the OSNAP array.