The resolution-dependent role of the AMOC in simulated ocean heat uptake

The AMOC joins the lower branch of the global overturning circulation to outcrop in the Southern Ocean. Heuristically, the unique proximity of these outcrop regions allows for a range of oceanic responses to a greenhouse warming scenario. Freshwater or heat anomalies over the Southern Ocean surface can both alter the dynamics of the AMOC and lower MOC cell, and/or be advected away from the region via two pathways: northward with the near surface flow of the AMOC, or downward into the abyssal ocean via the Antarctic Bottom Water (AABW) that ventilates the lower overturning cell. The majority of CMIP models show the first of these pathways, the warming and northward advection of surface waters by the upper cell of the AMOC to be the primary mechanism for heat uptake in the Southern Ocean.

We will present model results indicating that the partitioning of heat into the AMOC and lower cell upon entering the Southern Ocean depends sensitively on model resolution. Specifically, we present the differences in the pattern of Southern Ocean warming in the Community Climate System Model 3.5 (CCSM 3.5) run at two resolutions in the ocean and sea ice components, after being forced with a 1% increase in CO_2 per year until doubling. Our fine resolution simulation was run at 0.1 degrees, at which sea ice formation is more faithfully captured, and eddies are resolved, while our coarse simulation was run at 1 degree, which is the standard resolution of most CMIP 5 models and relies on eddy parameterization.

After CO_2 doubling, the Southern Ocean takes up a similar amount of heat at both resolutions, however the distribution of warming diverges in the abyssal ocean. Below 4000 meters, our fine resolution simulation takes up two orders of magnitude more heat than its coarse resolution counterpart, while waters of the AMOC warm less in this region. This simulation sheds light on possible mechanisms for the recently observed warming of AABW (Purkey and Johnson, 2011), which is not a robust result in the majority of standard resolution model simulations of greenhouse warming scenarios. We find that the increased strength of the lower MOC relative to the AMOC at fine resolution is of primary importance in driving heat into the abyssal ocean, rather than the magnitude of overturning reduction in each cell following surface warming. We attribute the stronger lower MOC at fine resolution to the localized fluxes of brine from sea ice formation and to the difference in the behavior of resolved eddies along the continental shelf front and in the abyssal ocean.

One important aspect of this study is its implications for the efficacy of ocean heat uptake. We develop a framework to explore the impact this variable spatial pattern of simulated deep ocean heat uptake has on the rate of transient climate warming. In this way, we can assess the relative efficacy of heat uptake by different water masses in the AMOC and throughout the global ocean, each with a different mean timescale of sequestration from the surface ocean. We can then assess the importance of correctly simulating patterns of deep ocean heat uptake and the surface processes that drive these patterns.