Sensitivity Patterns of Atlantic Meridional Overturning and Related Climate Diagnostics over the Instrumental Period

PIs: Rui M. Ponte[1] and Patrick Heimbach[2]
[1]Atmospheric and Environmental Research (AER), Lexington, MA
[2]Massachusetts Institute of Technology (MIT), Cambridge, MA

This project extended over a period of four years (8/1/10-7/31/14) and was a joint effort between AER and MIT. A major focus of the project was on analyses of heat content variability in the Atlantic Ocean, in relation to changes in circulation, in particular in the Atlantic meridional overturning circulation (AMOC), as well as surface heat flux forcing and effects of mixing processes. The general approach was to utilize ocean state estimates produced under the ECCO (Estimating the Circulation and Climate of the Ocean) project. These estimates provide the full three-dimensional ocean state and its evolution in time and are an exact solution of a general circulation model that has been optimized, using nonlinear least squares procedures, to fit most available data within expected model and data uncertainties. As such, the solutions analyzed in our efforts are close to the data and at the same time are consistent with all the model equations and physics, allowing for computation of heat budgets with full closure and no unphysical heat sources or sinks.

Since October 2013 to the end of the project, apart from revising and publishing results in Buckley et al. (2014a), one major effort was to examine the relative roles of temperature and velocity changes in determining the advective heat transports in the North Atlantic. In this work, described in detail by Buckley et al. (2014b), anomalies in (linear) advective heat transport convergences, as well as Ekman and geostrophic contributions, are decomposed into parts due to velocity variability, temperature variability, and their co-variability. Ekman convergences are generally dominated by variability in Ekman mass transports, which reflect the instantaneous response to local wind forcing, except in the tropics where variability in the temperature field plays a significant role. In contrast, both budget analyses and simple dynamical arguments related to geostrophic advection demonstrate that geostrophic heat transport convergences due to temperature and velocity variability are highly anticorrelated, and thus their separate treatment is not insightful. In the interior of the subtropical gyre, it is argued that the sum of air-sea heat fluxes and Ekman heat transport convergences is a reasonable measure of local atmospheric forcing, and that local atmospheric forcing, so defined, explains the majority of heat storage tendency variability on all timescales resolved by ECCO (Figure 1).

Using a similarly configured version of the MITgcm, but without the ECCO adjustments, simulations in non-optimized mode were extended to 300 years using the CORE-II forcing fields and following the CORE-II protocol (six 50-year cycles were run). These simulations were part of a detailed intercomparison by Danabasoglu et al. (2014) of different model solutions under the same CORE-II protocol in terms of the mean state of the North Atlantic circulation. The hypothesis that different models subject to the same forcing would exhibit similar circulation patterns in the North Atlantic proved of limited validity.

Straneo and Heimbach (2013) provided a review of the potential impact of changes in the North Atlantic circulation on outlet glacier changes at the marine margins of the Greenland ice sheet.

Bibliography

Buckley, M. W., R. M. Ponte, G. Forget, and P. Heimbach, 2014a: Low-frequency SST and upper-ocean heat content variability in the North Atlantic. *J. Climate*, **27**, 4996–5018, doi:10.1175/JCLI-D-13-00316.1.