Forced Transients in Water Mass Transformation and the Meridional Overturning

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The objective of this program is to develop a theoretical understanding of how the thermohaline circulation responds to transients in atmospheric forcing. Quantities of interest include the ocean circulation, extent of deep convection, meridional heat transport, meridional overturning circulation, and the temperature and salinity of product waters.

Recent results

There have been two major activities in the past year:

A simple dynamical systems model of a convective basin subject to time dependent precipitation has been developed and compared with an eddy resolving numerical model. This is in collaboration with Yuki Yasuda, a graduate student at the University of Tokyo and a Fellow of the WHOI Geophysical Fluid Dynamics Summer School in 2013. The response of a convective basin to transients in precipitation depends primarily on the nondimensional frequency of the forcing, its amplitude, and how close the solution lies to a critical value of precipitation that marks transition between thermal and haline modes. The theory compares reasonably well with the numerical model calculations in terms of the amplitude and phase of the temperature, salinity, and heat flux anomalies (Yasuda and Spall 2014).

A similar approach of combining a dynamical systems model with an eddy resolving general circulation model has been taken for time-dependent atmospheric temperature over a marginal sea subject to deep convection. Linearized analytic solutions are possible, while the fully nonlinear coupled equations can be directly integrated numerically. The amplitude and phase of the convective water mass temperature and salinity, the meridional heat transport, surface heat flux, and the meridional overturning circulation predicted by the theory compare well with a series of numerical model calculations. The key response is a transition from one-dimensional behavior for high frequency forcing to three-dimensional, quasi-steady behavior for low frequency forcing. The transition frequency depends on nondimensional numbers that characterize the stability of the boundary current, strength of atmospheric forcing, and the eddy flushing time scale of the basin.

Bibliography

Yasuda, Y., and M. A. Spall, 2014: Influences of time-dependent precipitation on water mass transformation, heat fluxes, and deep convection in marginal seas. *J. Phys. Oceanogr.*, submitted.