Atlantic MOC Observing System Studies Using Adjoint Models

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LONG-TERM GOALS

This project, now completed, exploited the existence of state estimation tools to understand the Atlantic circulation, including the meridional overturning circulation. The particular focus was on the observing systems, what they say about the circulation, and how they might be improved, using the method of Lagrange multipliers (adjoint method) developed in the independently supported ECCO-GODAE system.

OBJECTIVES AND WORK COMPLETED

(1) Discussions of observing systems have been provided by Heimbach et al. (2010, 2011) and Wunsch (2010).

(2) Estimates of the meridional overturning circulation are described by Wunsch and Heimbach (2009, 2012).

(3) Related work, primarily within the ECCO-GODAE project, has brought close to fruition a system with a full Arctic and far more accurate sea ice sub-model. That system (ECCO version 4) will be the platform for significantly extending the study of the Atlantic circulation.

(4) The meridional correlations of the meridional overturning circulation for the 16 years of ECCO state estimate v3.73 have been studied by Wunsch (2010b) and which imply

subtropical variations are fundamentally uncorrelated with those in the subpolar gyre, at least over the time period of the estimate. The same paper produces estimates of the linear prediction times of the MOC and SST in the western subpolar gyre.

(5) Impact of ocean surface advection processes in the evolution of sea surface temperature at seasonal and interannual timescales, relative to other factors such as mixing and surface heat exchanges (Vinogradova et al. 2012);

(6) Assessment of currently unobserved deep ocean variability and its potential impact on estimates of sea level, heat content and other quantities related to changes in the MOC (Ponte 2012a, b).

IMPACT AND APPLICATIONS

The chief results are that with 20 years of observation, the AMOC is indistinguishable from a stochastic process---the result of numerous disturbances both internal (instabilities) and external (meteorological). Furthermore, over this duration, no useful coherence exists between subpolar and subtropical regions. Some linear predictive skill does exist, as a function of latitude, for the AMOC. Many processes, including a very strong annual cycle, inferred mixing coefficients, assumptions about space/time correlations, influence estimates of AMOC changes, and potential predictability. Design of a long-term measurement system needs to proceed on the basis of the existence of a multiplicity of physical regimes and time-scales.

PUBLICATIONS

Heimbach, P., C. Wunsch, R. M. Ponte, G. Forget, C. Hill and J. Utke, 2011: Timescales and regions of the sensitivity of Atlantic meridional volume and heat transport magnitudes: toward observing system design, *Deep-Sea Res.-II,* 58, 1858-1879.

Heimbach, P., G. Forget, R. Ponte, and C. Wunsch (lead authors), 2010: Observational Requirements for global-scale ocean climate analysis: Lessons from ocean state estimation. In: Hall, J., D.E. Harrison, and D. Stammer (Eds.), 2010: *Proceedings of* OceanObs'09*: Sustained Ocean Observations and Information for Society*, Venice, Italy, 21-25 September 2009, ESA Publication WPP-306, Vol. 2, doi:10.5270/OceanObs09.cwp.42.

Piecuch, C. G. and R. M. Ponte, 2012. Importance of circulation changes to Atlantic heat storage rates on seasonal and interannual timescales, *Journal of Climate*, 25, 350-362.

Ponte, R.M., 2012a. An assessment of deep steric height variability over the global ocean, *Geophysical Research Letters*, 39, L04601, doi:10.1029/
2011GL050681.

Ponte, R.M., 2012b. Heat content and temperature of the ocean. In *Encyclopedia of Sustainability Science and Technology*, eds. R.A. Meyers, J.Orcutt, Springer-Verlag, New York, in press.

Vinogradova, N.T., R.M. Ponte, C.G. Piecuch, and P. Heimbach, 2012. The role of ocean dynamics in sea surface temperature variability on climate time scales, *J. Clim.* Submitted.

Wunsch, C. and Heimbach, P., 2009: The Global Zonally Integrated Ocean Circulation, 1992-2006: Seasonal and Decadal Variability. *Journal of Physical Oceanography*, 39, 351-368.

Wunsch, C. and P. Heimbach, Two decades of the Atlantic Meridional overturning circulation: Anatomy, variations, prediction, and overcoming its limitations, *J. of Climate,* submitted, 2012.

Wunsch, C., Observational network design, 2010a: OceanObs09 plenary talk. In: Hall, J., D.E. Harrison, and D. Stammer (Eds.), 2010: *Proceedings of* OceanObs'09*: Sustained Ocean Observations and Information for Society*, Venice, Italy, 21-25 September 2009, ESA Publication WPP-306, Vol. 2.

Wunsch, C., 2012: On the linear predictability of the North Atlantic Ocean. *Deep-Sea Res.-II*, (H. T. Rossby Vol.) DOI: 10.1016/j.dsr2.2012.07.015, 2012.