Modeling Interactions between the Gulf Stream and Deep Western Boundary Currents by the Tail of the Grand Banks

Ocean and Climate Change Institute
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M. Andres and M. McCartney

Synopsis

This research included a set of numerical modeling experiments designed to investigate how basin topography affects the interactions between the wind-driven upper-ocean currents and abyssal flows. While the model was highly idealized in order to elucidate the underlying dynamics, the processes identified through the experiments have real world analogs relevant to the climate system and serve as a framework for interpreting observations, not only at the Tail of the Grand Banks, but more generally at mid-ocean ridges and along basin's sloping western boundaries. The model results were incorporated in a published paper and have been used to motivate several proposals for continued research. We are grateful to the Ocean and Climate Change Institute for the support provided for this work.

Background

Oceanographers sometimes mentally separate the ocean's wind-driven circulation (including *surface* intensified currents such as the Gulf Stream) from its buoyancy-driven *abyssal* circulation, which includes the Atlantic Deep Western Boundary Current. However the circulations are, in fact, part of one system with important interactions occurring between surface- and abyssal- flows. These interactions are strongly governed by the influence of topography.

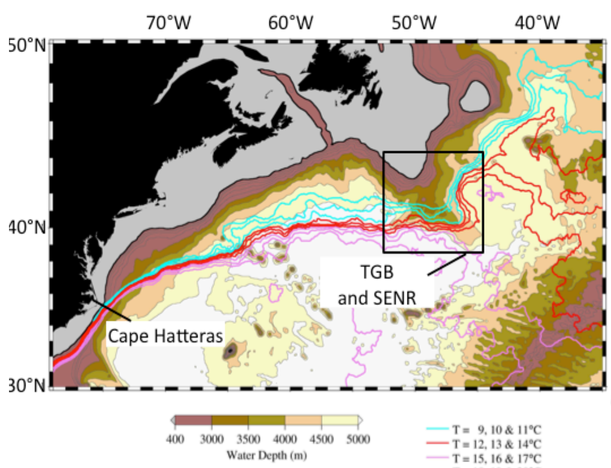

***Figure 1**. Bathymetry (shaded) showing Cape Hatteras, the Tail of the Grand Banks (TGB), and Southeast Newfoundland Ridge (SENR) where the Gulf Stream interacts with the Deep Western Boundary Current (DWBC). Gulf Stream path, defined by various isotherms as deduced from historical observations (XBTs and floats), is overlain (contours).*

One region where the poleward-flowing Gulf Stream and equatorward-flowing Deep Western Boundary Current shape one another's evolution lies southeast of Newfoundland. Here, in addition to contending with one another, currents must also navigate the Tail of the Grand Banks where a large submarine ridge (the Southeast Newfoundland Ridge) juts southeastward from the Tail of the Grand Banks into the path of the oncoming currents. The Gulf Stream, which approaches the Ridge as an eastward-flowing free jet, splits into several branches comprising northward flow that feeds the North Atlantic Current, eastward flow that feeds the Azores Current, and two recirculation gyres (**Figure 1**). In addition to this complex surface flow, the evolution of the Deep Western Boundary Current's structure is complicated because the Ridge deflects it into the path of the oncoming Gulf Stream (**Figure 2**). Prior to its interaction with the Gulf Stream and the Ridge (i.e., northeast of the Tail), the equatorward flow is not confined to the abyss, but is relatively barotropic (vertically uniform) and occupies the whole water column. On encountering the ridge and North Atlantic Current /Gulf Stream, this equatorward flow splits. Part continues towards Cape Hatteras and part retroflects and converges into the North Atlantic Current.

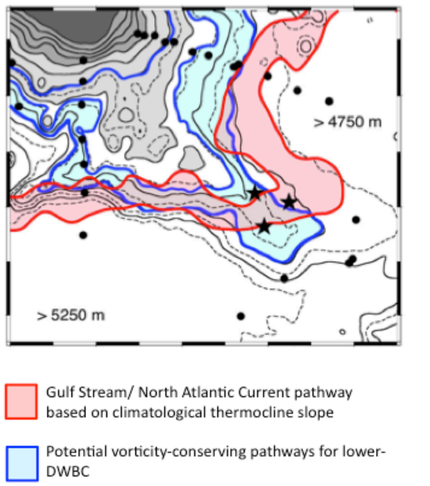

Figure 2. *Close-up of Gulf Stream and DWBC paths at the SENR.*

Key Results

We modeled the interaction of barotropic flows with topography in an idealized, linear, two-layer system forced by a steady wind. The major conclusion is that the adjustment of barotropic flow at mid-basin ridges leads to baroclinic and barotropic ridge-generated anomalies that propagate westward as long planetary Rossby waves (**Figure 3**). We have developed scaling for the adjustment time-scale and transport anomaly and have tested that scaling with the model. The results from the model have been compared with satellite altimetry observations and suggest that the process of baroclinic Rossby wave generation at ridges can explain some of the observed sea surface height variability west of mid-ocean ridges (**Figure 4**). This OCCI-funded work is included in a recently published manuscript in the *Journal of Marine Research* and was presented in a poster at the 2012 Ocean Sciences Meeting in Salt Lake City, Utah.

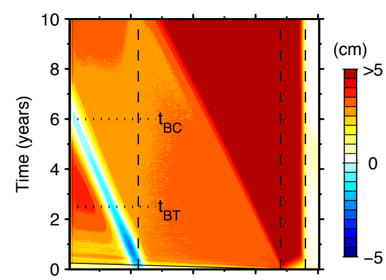

***Figure 3**. Results from the idealized model.*

The results from this work are providing the basis for some on-going research supported by a 3-year NSF grant (*collaborators: J. Yang and Y.-O. Kwon*). Specifically, we are testing whether the processes represented in the idealized model have an analog in output from an Ocean General Circulation Model (OGCM) in the North Pacific as represented by a 1/10˚ OFES model. In addition, motivated by the idealized model results, we have analyzed Argo data to look for observational evidence of this adjustment around ridges. As a result of this preliminary analysis, a proposal was submitted to the June 2012 NASA ROSES call to continue this further (*collaborator: P.E. Robbins*). Finally, the results from the idealized model been incorporated into several proposals for field-work, serving as motivation for the experiment design. An internal proposal was submitted to the 2013 Dalio call (*collaborator: A. Macdonald*) and an external proposal was submitted to the August 2012 NSF OCE call (*collaborators: M. McCartney, P. Fratantoni and K. Donohue*).

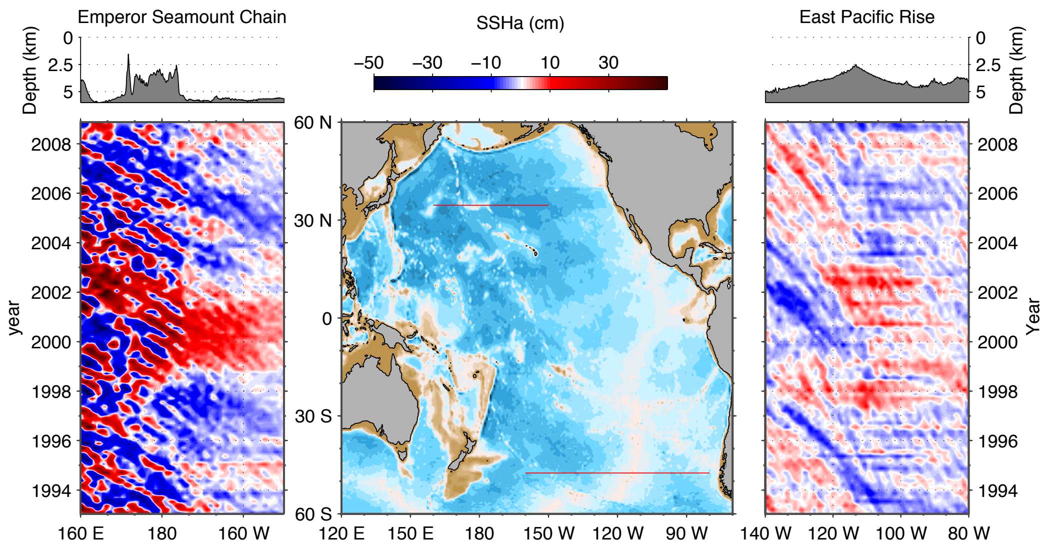

Figure 4. *Center: Pacific bathymetry. Red lines indicate sections along which Hovmöller diagrams are shown. These cross the Emperor Seamount Chain at 34-35˚N (left panel) and the East Pacific Rise at 47-48˚S (right panel); shading indicates SSHa (cm). Depth sections showing the topography are above the respective Hovmöller diagrams.*

Outcomes

Andres, M., J. Yang, and Y.-O. Kwon, 2012. Adjustment of a wind-driven two-layer system with mid-basin topography. *Journal of Marine Research*, **70**(6), 851-882.

Andres, M., Interaction of barotropic planetary Rossby waves with ocean ridges, *Ocean Sciences Meeting*, Salt Lake City, UT, February 2012. Poster.