The Gulf Stream: Conveyor or Switch?
"Assessing Meridional Transports in the North Atlantic Ocean"

Kathryn A. Kelly[1], LuAnne Thompson[2], Suzanne Dickinson[1]
[1]Applied Physics Lab, University of Washington, Seattle, WA
[2]School of Oceanography, University of Washington, Seattle WA

Abstract

The Atlantic Meridional Overturning Circulation (AMOC) transports heat from the subtropical gyre to the subpolar gyre. Changes in the poleward heat transport are commonly associated with changes in the strength of the circulation, especially changes in the Gulf Stream, following the "ocean heat conveyor" conceptual model. Assuming a degree of coherence in circulation anomalies between the gyres, the AMOC is currently monitored in the subtropical gyre near 26N. For changes in the large-scale ocean circulation to explain observed decadal anomalies of ocean heat and freshwater, there must be a robust mechanism to move water properties across the boundaries between subtropical and subpolar gyres. However, the conveyor paradigm has been challenged by recent observations showing little connectivity between the subtropical and subpolar gyres. Fifteen years of observations from satellite altimeters reveal that anomalies in transport into the subpolar gyre (through the North Atlantic Current) result from the Gulf Stream switching flow from one gyre to the other, rather than from transport anomalies in the Gulf Stream itself, as the conveyor model suggests.

A. Subtropical and Subpolar Gyre Surface Transports

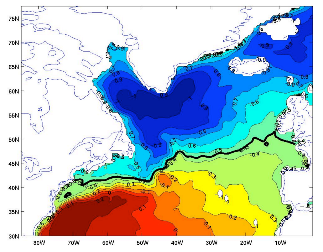

Figure 1. Mean sea surface height (Maximenko and Niiler, 2008). Bold line highlights the boundary between the subpolar and subtropical gyres, which was used to set the northeast corner of the box in Figure 2.

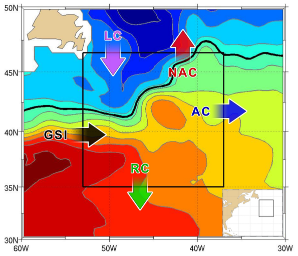

Figure 2. Box used to analyze the time series of currents at the subtropical/subpolar gyre juncture. Five surface transports were constructed from the SSH difference across the current systems: Labrador Current (LC), North Atlantic Current (NAC), Azores Current (AC), recirculation (RC), and Gulf Stream inflow (GSI).

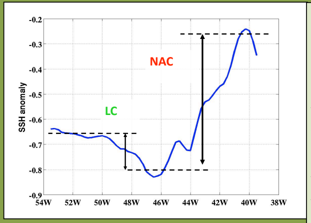

Figure 3. Example of SSH along the northern boundary of the box, showing how the LC and NAC surface transports (SSH differences) were defined relative to the minimum in SSH. All other transports were estimated as the difference in SSH at the corners of the box. The SSH difference is proportional to the geostrophic transport integrated along the edge of the box.

$$\int f\, v_g\, dx = g\, \Delta(SSH)$$

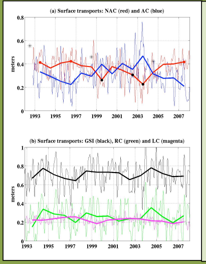

Figure 4. Surface transports for (top panel) NAC (red) and AC (blue) and (bottom panel) for GSI (black), LC (magenta), and RC (green). Positive transports are defined by the direction of the arrows in Figure 2. Note that the sum of RC and AC is smaller than GSI, so that *in the mean* part of the GSI flows into the NAC.

- GS inflow correlated with RC (*connected*)
- NAC is *anticorrelated* with AC
- NAC *NOT correlated* with GSI

B. Conveyor or Switch?

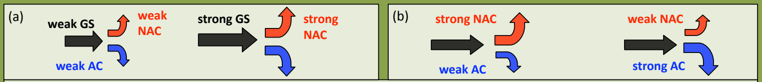

Figure 5. (a) Conveyor model: an increase in Gulf Stream inflow (GSI) results in increased flow to the NAC (subpolar gyre). (b) Switch model: NAC (subpolar gyre) and AC (subtropical gyre) transports are anti-correlated, that is, the NAC increases at the expense of the AC, but not in response to GSI increases. The anti-correlations between the NAC and the AC in Figure 4. (top panel) indicate that the switch model more accurately describes the relationship between the transports. Anomalies in the GSI are reflected in the recirculation (RC), but are not transmitted into the NAC (subpolar gyre).

C. Forcing and Consequences of the "Switch"

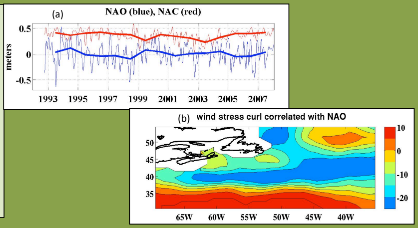

Figure 6. (a) Surface transport in the NAC (red) has a low, but significant, correlation with the North Atlantic Oscillation, (blue) lagging it by 9 months. The NAO-related wind stress curl (b) has a tripole structure that may contribute to the anti-correlation of the two gyres.

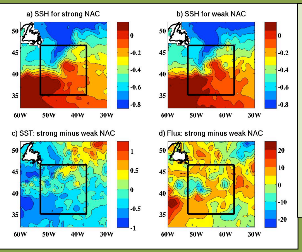

Figure 7. Composite maps for the years of strong (1993, 1996, and 2007) and weak (1999, 2002, 2003) NAC transport. (a) SSH for strong years, (b) SSH for weak years, (c) SST for strong years minus weak years, and (d) turbulent heat flux for strong years minus weak years. SST differences suggest increased heat transport into the subpolar gyre in strong NAC years.

Summary

- Transport anomalies at the subtropical/subpolar gyre boundary respond more like a switch than a conveyor
- The switching may be controlled by winds related to the North Atlantic Oscillation.
- Higher sea surface temperatures near the gyre boundary correspond to a stronger NAC.