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New perspectives on the physics of the global overturning circulation.

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Despite being of primary climatic importance and thus having received a great deal of scientific attention, the global overturning circulation of the ocean remains poorly understood. For years it was referred to as the thermohaline circulation and conceived as a conveyer belt driven by convection of cold salty water in the North Atlantic that would then surfaces uniformly across the Atlantic and Pacific through mixing with warmer overlying waters. The strength of the so-called conveyer depended on north-south thermal and salinity gradients. A decade ago this picture was challenged by Toggweiler and Samuels (Deep-Sea Res., 1995) who proposed that North Atlantic Deep Water (NADW) formation is proportional to the strength of the winds that drive the Antarctic Circumpolar Current (ACC) in the Southern Hemisphere. Their result was based on an ocean-only GCM in which the wind stresses south of 30 deg. S were systematically weakened and strengthened about their observed values. The idea that Southern Ocean (SO) winds may have a strong influence on NADW formation is now widely accepted but fundamental questions remains. Over what timescale is the SO winds important and how do they compete with the heat and freshwater forcing? Is the wind-driven increase in NADW formation due to increased northward Ekman flow at Drake Passage latitude? If so, what determines the distribution of these waters between the Atlantic and the Pacific? How does Antarctic bottom water formation respond to the SO winds and why?

To begin to address these issues we have designed two sets of experiments to run using the GFDL MOM4 ocean general circulation model coupled to a sea-ice model and an energy moisture balance model for the atmosphere. We preferred an idealized

two-basin geometry above more realistic topography because the study is concerned with basic principles rather than exact predictions. Our initial set of experiments was designed to answer first the basic question of why the Atlantic is preferred above the Pacific as a basin for deep convection. The results show that both the length of the Atlantic and its narrowness are instrumental to its success as a sinking basin while the lengths of the adjacent continents are of minor importance.

The second set of experiments was specifically geared toward understanding the role of the SO winds on convection in all the major polar basins. As we strengthen the winds south of 40 deg. S, we find that the polar haloclines break down one by one so that the overturning in the three polar areas are switched on sequentially (North Atlantic first, Southern Ocean second and North Pacific third). This suggests that there is a threshold for deep-water formation in each area of the ocean that is governed by basin geometry, the local freshwater forcing, and the Southern Ocean winds. The threshold is easily exceeded in the North Atlantic today, barely exceeded around Antarctica, and is not exceeded at all in the North Pacific. Implications for the climate system will be examined.