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The Bipolar Seesaw and Its Discontents

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The thermal bipolar ocean seesaw hypothesis is the prevailing explanation for the out-of-phase changes in northern and southern high-latitude climate during the Dansgaard-Oeschger (D-O) events of the last glacial period and deglaciation (Stocker and Johnsen, 2003). However the seesaw hypothesis has been challenged on several grounds: it neglects the much larger transport of heat in the atmosphere compared to ocean, and it does not specify the modes and time scales of signal propagation in the coupled ocean-atmosphere system. The purpose of this presentation is to critically review the seesaw hypothesis and address these critiques.

We use transient simulations with a coupled ocean-atmosphere-sea-ice global climate model (GCM) to trace the ocean and atmospheric heat-transport changes and pathways of inter-hemispheric signal propagation during a simulated collapse and a simulated strengthening of the Atlantic Meridional Overturning Circulation (AMOC). While the simulated AMOC perturbations result in climate variations in close agreement with palaeo-climate observations, changes to the heat budget and their propagation throughout the globe differ from the ideas of Stocker and Johnsen (2003). The key differences are as follows. (1) Changes in ocean heat transport in the Atlantic in response to AMOC perturbations are partially compensated by changes in northward heat transport in the global atmosphere and in the Pacific Ocean. (2) There is little ocean transmission of temperature anomalies between the South Atlantic and high latitude Southern Ocean, because the lack of zonal boundaries and the steeply outcropping isopycnals of the Antarctic Circumpolar Current (ACC) act as a barrier to signal propagation. (3) On the multi-centennial timescale of the simulations the heat content of the Southern Ocean to the south of the ACC is insensitive to AMOC changes, and South Atlantic temperature anomalies, rather than crossing the ACC spread at intermediate depths into the Indian and Pacific oceans. (4) The global intermediate-depth ocean to the north of the ACC thus better fits the description of being a 'heat reservoir' for changes in the AMOC than the Southern Ocean. (5) In the simulations, signal propagation to latitudes south of the ACC (including Antarctica) is dominated by teleconnections between the Hadley Circulation, the mid-latitude westerlies and Southern Ocean sea ice extent.

We conclude with an inter-hemispheric coupling hypothesis that recognises the coupled nature of (inter-basin) ocean and atmosphere heat transport, the difficulty of propagating ocean anomalies across the ACC and the role of wind-stress, sea ice and associated surface heat flux changes on temperature variations at high latitudes.

References

Stocker, T. F., and S. J. Johnsen (2003), A minimum thermodynamic model for the bipolar seesaw, Paleoceanography, 18, PA000920, doi:10.1029/2003PA000920.