Modelling Hadley circulation changes during the glacial-interglacial cycle

Paul J Valdes
Department of Meteorology, University of Reading UK

The role of the Hadley circulation is investigated using a set of simulations for the glacial-interglacial transition. We force a slab ocean version of the Hadley centre climate model for "snapshot" simulations at 1000 year intervals between the Last Glacial Maximum (21,000 years ago) and the recent, pre-industrial conditions. The forcing includes changes in the ice sheet and sea level (based on Peltier, 1994), CO_2 and CH_4 concentrations (based on ice cores), and orbital changes (based on Berger, 1978). Vegetation is prescribed as present day. An additional set of simulations at 3000 year intervals have been performed in which the model has been asynchronously coupled to BIOME4. However, this has relatively modest impacts on the zonal mean Hadley circulation and is therefore not considered further. The horizontal ocean heat flux convergence is derived from a pre-industrial calibration simulation, and is unchanging. Thus the set of simulations should be considered as, at best, a hypothetical scenario simulating what the glacial-interglacial climate transition would look like without ocean circulation changes.

During the Last Glacial Maximum (LGM), the JJA zonal mean Hadley circulation is relatively weak (approximately 15% smaller than the pre-industrial simulation) and remains constant during the late glacial. In the following 5000 years, it strengthens then remains approximately constant during the Holocene. By contrast, the zonal asymmetries (especially the African and Asian monsoons) change appreciably during this period and thus the zonal mean appears to be a poor indicator of tropical changes during JJA throughout the Holocene.

The DJF zonal mean Hadley circulation appears to follow a very different pattern. At the LGM, the Hadley cell is weak but then strengthens during the late glacial, reaching a peak at about 15 kyr BP. It then approximately linearly declines throughout the rest of the period eventually reaching its pre-industrial value, which is weaker than the LGM. The different behaviour between JJA and DJF can be partly associated with the lack of strong monsoonal flows during the DJF season.

The reasons for the changes in the Hadley cell will be discussed, as will be the links to the precipitation and precipitation-evaporation changes. The limitations of using a slab ocean model will also be considered by comparing the mid-Holocene results to an equivalent simulation using a fully coupled atmosphere-ocean model.