Geophysical Research Abstracts, Vol. 9, 08522, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-08522

Sensitivity of the oceanic heat transport to the strength of the Atlantic overturning circulation

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The relationship between the strength of the Atlantic meridional overturning circulation (AMOC) and the Atlantic northward heat transport is investigated in a global coupled atmosphere-ocean model by modifying the AMOC strength in two ways: by varying the background vertical diffusivity (κ_v) and by imposing a steadily increasing surface freshwater flux in the North Atlantic leading to a gradual decrease of the AMOC strength. The surface wind forcing imposes a non-zero cutoff value in the heat transport dependence on κ_v which introduces a scale, making power-laws unsuitable: while these yield a much smaller slope than the classic 2/3 power law obtained previoulsy with idealized ocean models, the sensitivity of our model is larger than in most of the latter, and comparable to that obtained previously with a coupled climate model. This suggests that the oceanic heat transport sensitivity is bound to be larger than indicated by studies employing idealized ocean models. In the runs with varying κ_v, a linear relationship is found between the northward heat transport and the mass transport at all latitudes. The same result is found north of the latitude of maximum heat transport (15°N) in the run with enhanced freshwater flux; our results are supported by the close match found with a high-resolution ocean model. South of 15°N, heat transport saturates with increasing AMOC strength. A simple conceptual model is proposed to explain this behaviour and used to estimate the surface heat flux feedback from observations and coupled climate models. The vertical distribution of heat transport shows the surface intensification found in previous work, which is independent of κ_v. Thus the contribution of the upper flow to the net poleward heat transport is controlled both by the winds and the diffusion-driven component of the ocean circulation.

In the absence of a deep AMOC, heat transport is reduced drastically everywhere. At 50°N, at the core of the North Atlantic current, the reduction is of 90%. The change in northward heat transport is accomplished mainly within the upper ocean, implying that the bulk of the heat transport is carried by the upper ocean, mainly through the existence of a deep AMOC.