Geophysical Research Abstracts,
Vol. 10, EGU2008-A-03127, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-03127
EGU General Assembly 2008

Thermohaline circulation hysteresis loops obtained for a grid-enabled fully-coupled climate model under different parameterizations of ocean vertical mixing

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We use the GENIE earth system modelling framework to investigate hysteresis in the thermohaline circulation (THC) under different parameterizations of vertical ocean mixing. In a default case, the vertical diffusivity is constant. Alternatively, diffusivity varies with stratification. Classic THC hysteresis experiments are carried out with the "GENIE-2" model, which features efficient, yet fully 3D and dynamical, representations of the atmosphere and the ocean: a frictional-geostrophic ocean on a 5.625° mesh with 8 levels, coupled with the Reading Intermediate General Circulation Model (IGCM) at T21 resolution with 7 vertical levels.

A small ensemble of hysteresis loops are obtained for different initial states (strong or weak overturning) and for different vertical mixing, by slowly increasing and decreasing an additional freshwater flux over the mid-latitude North Atlantic. Each hysteresis loop comprises around 15 000 years of simulation. The necessary thousands of years of 3D ocean-atmosphere model integration were achieved in around 2 months by using UK Grid computing resources, including multiple nodes of the National Grid Service, and additional clusters in Norwich, Southampton and Bristol. A specially developed database system was used to execute and manage the runs.

The results reveal the extent to which THC bi-stability is contingent on vertical mixing

in the ocean. For an initially strong THC state, hysteresis behaviour is rather insensitive to the choice of vertical mixing scheme. Both positive and negative feedbacks are associated with variation of vertical diffusivity in response to an evolving THC, and vice versa. The present study demonstrates how such feedbacks can now be systematically investigated by combining a suitable modeling framework and novel computational resources. The same technique could be applied to full complexity models, to efficiently search for potential hysteresis in the system.