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Diapycnal Mixing and the Physical Carbon Pump in a Box Model of the Meridional Overturning Circulation

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The Meridional Overturning Circulation (MOC) plays a central role in controlling atmospheric greenhouse gases by regulating the transfer of carbon between the deep ocean reservoir and the surface ocean, where exchange with the atmosphere is possible.

In this context, diapycnal ocean mixing is important for two main reasons:

Firstly, it directly controls the diffusive exchange of carbon between the surface and deep ocean.

Secondly, it has been shown that the properties of the MOC depend critically on details of the formulation of diapycnal mixing, both in box models and complex AOGCMs. While in box models, a dependency of the diapycnal mixing on the background stratification can lead to reversed sensitivity of the MOC to freshwater forcing (i. e., increased MOC with increased freshwater forcing; Nilsson and Walin, 2001; Marzeion and Drange, 2006), in an AOGCM it was shown that stratification-dependent mixing may destabilize the AMOC, increasing the weakening effect of freshwater on the MOC (Marzeion et al. 2007, 2009).

Here, we couple a box model of the MOC with a box model of the atmosphere, and include a simple representation of the physical carbon pump. The ocean model is driven both by wind and thermohaline forcing. In the case of constant diapycnal mixing, the model exhibits multiple equilibria, and millennial scale oscillations in certain regions of the parameter space (Johnson et al., 2007). We then explore the behavior of the model, both for the equilibrium case and in a range of idealized, time-dependent experiments.