The Role of Stratification-dependent Mixing for the Stability of the Atlantic Overturning in a Global Climate Model[1]

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Abstract Using the coupled climate model of intermediate complexity CLIMBER-3α, we investigate the effect of a stratification-dependent vertical diffusivity on the sensitivity of the Atlantic meridional overturning circulation to perturbations in freshwater forcing. The vertical diffusivity $\varkappa$ is calculated as $\varkappa \sim N^{-\alpha}$, where N is the local buoyancy frequency, and the parameter α is a measure of the sensitivity of the vertical diffusivity to changes in stratification.

Independent of α, the stratification of the deep ocean is weakly increased as a response to an anomalous freshwater flux in the North Atlantic in our experiments. While in the region of freshwater forcing and north of it, this

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is caused by the freshwater anomaly itself, further south it is associated with anomalously warm surface waters caused by a reduction of the northward oceanic heat transport. Subsequently, and opposed to results from previous studies, the overturning is reduced by the anomalous freshwater flux, independent of the choice of α.

However, the amount of reduction in overturning following a freshwater perturbation is found to depend critically on the choice of the mixing sensitivity α. If $\alpha \lesssim \alpha_{\text{cr}}$, the response is similar to the model's response using constant vertical diffusivity ($\alpha = 0$). For $\alpha \gtrsim \alpha_{\text{cr}}$, a sharp increase of the sensitivity is found. The value of α_{cr} is found to be between 0.5 and 1. We propose a general feedback explaining this threshold behaviour: If α is large, both positive and negative perturbations of stratification are amplified by associated changes in diffusivity. In the experiments presented here, this enhances the initial positive stratification anomaly in northern high latitudes, which is created by the anomalous freshwater flux. As a result, convection is strongly reduced, and the overturning is significantly weakened.