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Irreversible ocean thermal expansion under carbon dioxide removal

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Irreversible ocean thermal expansion under carbon dioxide removal

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Supplementary material

Ocean temperature drift

Global mean ocean temperatures drift in the last 1000 years of the spin up simulations does not exceed 0.045 °C, which is one order of magnitude smaller than global mean ocean temperature changes in the simulations forced with an increase and decrease in atmospheric CO_2 (compare Figure S1 and Figure 1c in the main manuscript).

The drift in ocean temperature over the last 1000 spin up years is less than 0.007 °C for a depth below 400 m for most model versions. Exceptions are the simulations with $k_{v,const}$*0.3* where the temperature varies up to 0.017 °C at a depth of 4930 m to 5490 m, $k_{v,const}$*0.05*, where temperature varies by up to 0.092 °C at a depth of 1830 m to 2200 m, and $k_{v,B\&L}$*high* where the temperature varies up to 0.058 °C at a depth of 2200 m to 2580 m. In the following we discuss the implications of this model drift for the results discussed in Section 3.2. For this discussion we assume that the drift over the last 1000 spin-up simulation years is the same as over the time frame of the forced simulations, although it is more likely that it is lower in the forced simulations. Taking the drift in $k_{v,const}$*0.05* into account in the forced simulation increases the warming at intermediate depth (Figure S2b, yellow lines). Thus the warming signal in the mid ocean in *kv,const0.05* would be even stronger when accounting for model drift and the general results shown in this study do not change. The case is the similar for the temperature drift in the mid and deep ocean in the $k_{v,B\&L}$*high* model version: The drift is negative and taking it into account increases the warming in the mid and deep ocean in the forced simulation of the $k_{v,B\&L}$*high* model version and therefore makes the decline in ocean temperature in the default model version even faster compared to the $k_{v,B\&L}$*high* model version. Thus the result that the simulation with a lower diffusivity (default setting model version) has similar or faster ocean temperature decline rate than the simulation with higher vertical diffusivity ($k_{v,B\&L}$*high* model version) remains true when taking drift into account. The drift in the deeper ocean in the model version $k_{v,const}$*0.3* is small compared to the changes in ocean temperature at depth in the forced simulations (compare solid and dashed orange lines in Figure S2b).

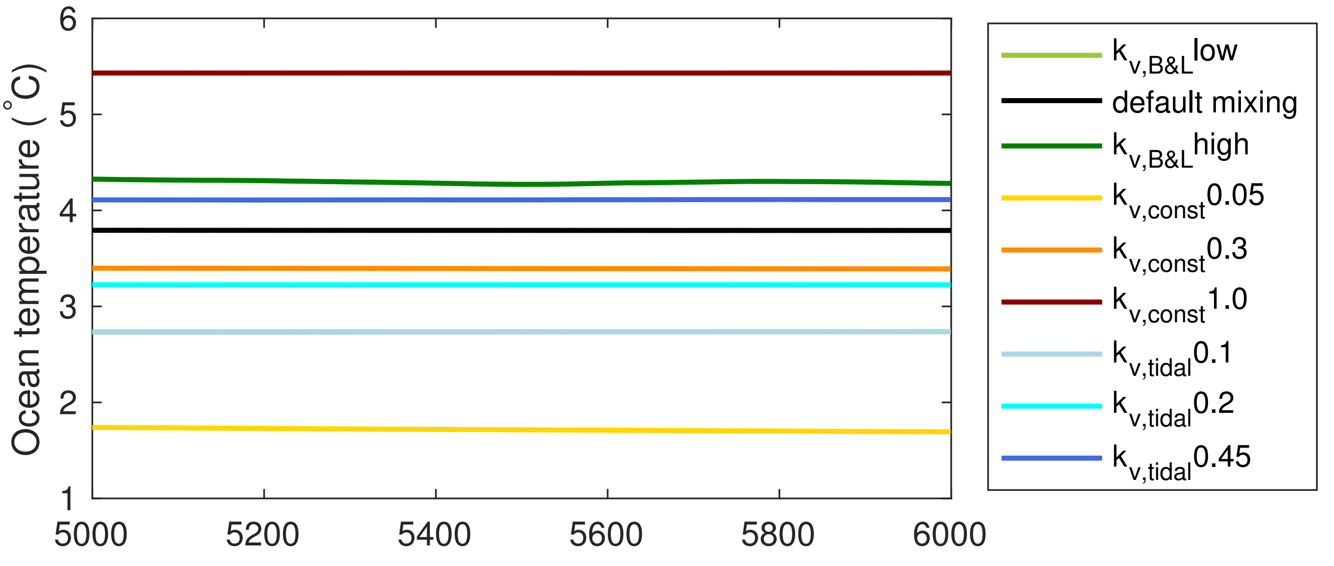

Figure S1. Global mean ocean temperature over the last 1000 years of the spin-up simulations.

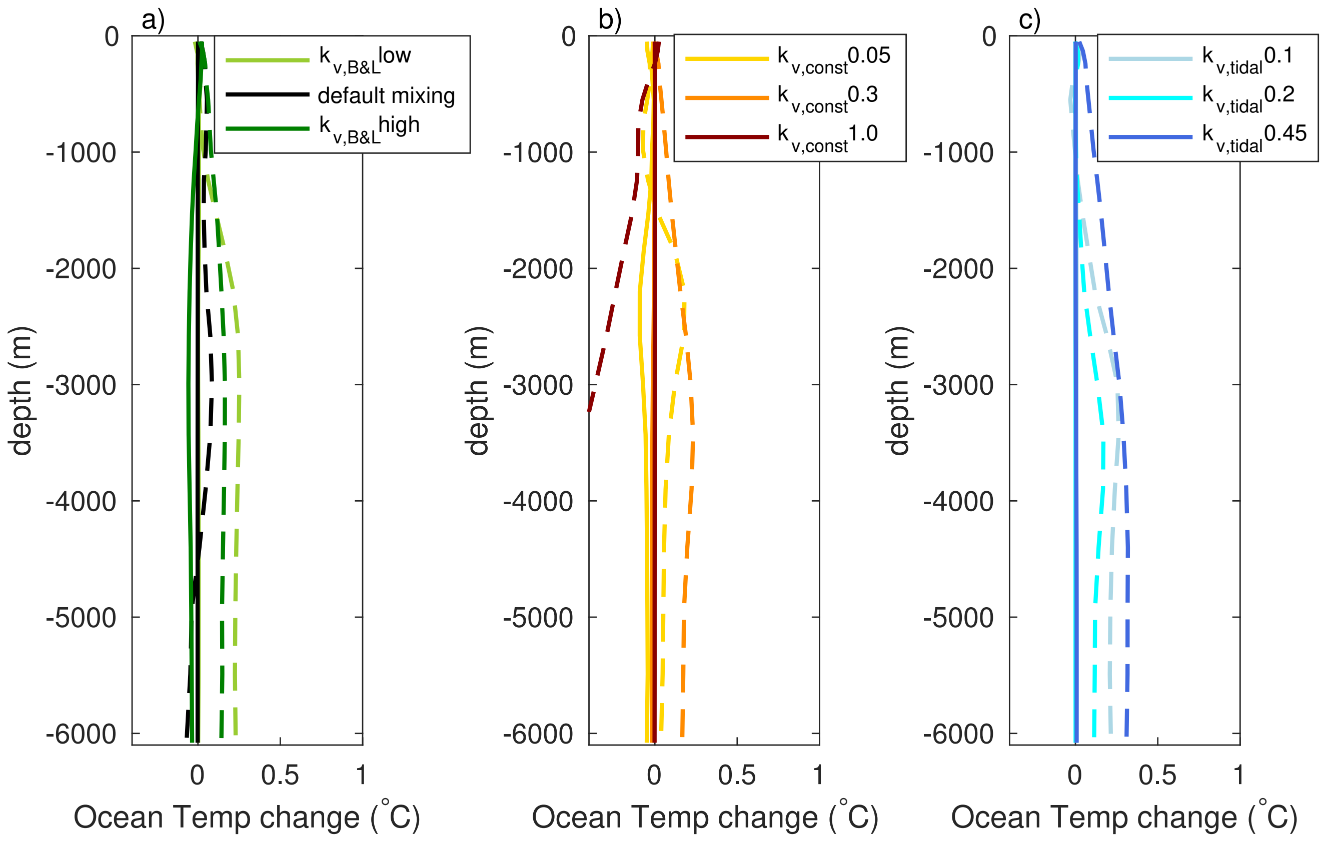

Figure S2. Depth profile of ocean temperature change. Dashed lines show the change in temperature in year 1100 relative to year 0 in the forced simulations. Continuous lines show the drift in ocean temperature for the last 1000 spin-up years for Bryan& Lewis mixing scheme (a), constant mixing scheme (b), and tidal mixing scheme (c). The temperature range is chosen to be the same as in Figure 2b-d in the main manuscript.