Earth Syst. Dynam. Discuss.,
https://doi.org/10.5194/esd-2017-45-RC4, 2017

Earth System Dynamics Discussions

Interactive comment on "Irreversible ocean thermal expansion under negative CO_2 emissions" *by* Dana Ehlert and Kirsten Zickfeld

Anonymous Referee #4

Received and published: 26 June 2017

Overview:

This manuscript explores the forward and reverse pathways of oceanic heat uptake and sea level rise and their sensitivity to sub-grid scale mixing parameterization choices in the UVic ESCM model. The experimental design is based on idealized simulations where atmospheric CO2 increases at a rate of 1%/year to quadrupling followed by a 1%/year decrease back to preindustrial values. A suite of sensitivity experiments are run based on varying a uniform constant background diffusivity, a vertically-dependent mixing scheme (Bryan & Lewis 1979), and tidal dissipation scheme (Schmittner et al. 2005). The manuscript demonstrates global sea level rise is irreversible on decadal to centennial time scales, which the authors demonstrate both in the UVic model and using a simple 2-layer diffusion model. The reversibility pathways for bottom-water

formation processes are also dependent on the nature of sub-grid scale mixing and that an increases in NADW and AABW relative to preindustrial values leads to global sea level that is below the preindustrial starting value.

Major comment:

All ocean models have some element of temperature drift. This is not discussed in the manuscript. This drift can arise for variety of reasons, including spurious mixing in depth-based coordinate models. This drift can be on the order of several tenths of a degree per century for the global volume average temperature. Drifts of this magnitude are non-negligible on the millennial timescales discussed in this manuscript. Furthermore, the magnitude of this drift is directly linked to the strength of the sub-grid scale mixing parameterizations used in ocean models. After the 6,000 year spin up of the model, suddenly varying the mixing coefficients in the model will produce noticeable changes in global ocean temperature and sea level regardless of changes in atmospheric CO2. It would be preferable to run control simulations for each of the mixing perturbations considered in this study. The difference plots in each of the figures should be relative to their respective control simulations rather than year 0 of the simulation. This approach would more cleanly separate the response to forcing from the inherent model drift.

Minor Comments:

Page 1, Line 22: Recovery on what timescale? Page 2, Line 2: How do the negative emissions in RCP2.6 compare with decreasing atmospheric CO2 at a rate of 1%/year? Page 2, Line 8: Sea ice decline should be sea ice recovery Page 3, Line 6: This is an excellent place to discuss the known constraints that the modeling community does have in regards to sub-grid scale mixing? (i.e. how big is the uncertainty?) Page 5, Line 17: On what timescale? Page 6, Line 1: Does Delta-T imply the near-surface air temperature? Page 12, Line 1: What are precise definitions used to assess AMOC and AABW rates? e.g. Is it the annual time series of the meridional overturning at the latitude of the RAPID array (26.5N)?

Figure Comments:

Figure 1, panels b & d: A line denoting zero would be helpful. Figure 2, panels c & d: What are the surface values? They could potentially be very unrealistic.

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