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Interactive comment on "Formulation of an ocean model for global climate simulations" *by* S. M. Griffies et al.

S. M. Griffies et al.

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We thank the reviewer for the many useful comments. They have been incorporated into the revised draft, and we detail here how we have done so.

- p177 top: We were not previously aware of the [Tang and Roberts(2005)] paper. Their results are encouraging. We did not implement the advective portion of the [Beckmann and Döscher(1997)] scheme because the [Döscher and Beckmann(2000)] paper said that advection was not too important in their simulations, and the added complexity of the advective portion required more resources than available to code the scheme, given the time constraints of the model development. Nonetheless, the [Tang and Roberts(2005)] paper certainly does encourage us to revisit this issue, and we have revised the discussion in ths manuscript and included the [Tang and Roberts(2005)] reference.

- p179 bottom: The Sweby advection scheme shares much in common with the Quicker advection scheme of Leonard1979, HollandChowBryan1998, and MOM3manual. The diffusive nature of Quicker was documented in [Griffies et al.(2000)Griffies, Pacanowski, and Hallberg]. We have not published diffusive results for Sweby.

  The other reviewers had similar comments regarding the advection scheme. We feel it outside the focus of the present paper to fully document this scheme, and so must rely on the referenced literature. Nonetheless, motivated by the reviewers' comments, and wishing to raise this issue explicitly, we have added the following paragraph to the end of the section discussing tracer advection.

  The question of unphysically large levels of spurious dianeutral mixing arises when considering a tracer advection scheme. [Griffies et al.(2000)Griffies, Pacanowski, and Hallberg] document many of the issues involved. In particular, they note that so long as the admitted scales of simulated flow are well represented, levels of spurious dianeutral mixing associated with numerical advection should remain negligible. OM3 is a mesocale eddy *non-permitting* model in which there are three regimes of small scale flow: (1) boundary currents, (2) tropical waves, (3) inertia-gravity waves (these are especially relevant due to the use of a diurnal cycle in the climate model). The boundary current and tropical wave scales are reasonably well represented with our chosen friction and grid. The inertia-gravity waves cause density interfaces to undulate in the vertical, and the maintenance of tracer gradients in the presence of these waves can be difficult, especially in regions where the vertical grid coarsens. [Griffies et al.(2000)Griffies, Pacanowski, and Hallberg] present a one-dimensional test problem illustrating this issue (see their Figure 1). There, it is shown that centred second order tracer advection admits dispersive extrema that are then acted on by vertical convective adjustment. The net result is a level of spurious mixing that can be *larger* than that associated with third order upwind

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biased schemes. This result again argues in favour of the Sweby scheme.

- p174, line 15: Yes, this sentence is unclear. Our revised sentence now reads as follows.

  Ice thickness greater than 4m is assumed to exert no more than 4m of pressure on the sea surface.

- p190, line 16: Removed extra appearance of “time.”

- p191, line 18-19: The coupled climate model has a diurnal cycle of insolation, with atmosphere-ocean coupling every two hours. The following is the revised sentence appearing in the revised manuscript.

  Note that inertial energy is quite realistic in the coupled model since the model includes a diurnal cycle of solar insolation, and the atmosphere and sea ice fields passed to the ocean (wind stress, fresh water, turbulent and radiative fluxes) are updated every two hours.

- p194, line 3 of footnote: Extra “is” has been removed.

- p195, line 6-10: Yes, most modellers do typically choose the *same* neutral diffusivity as the skew-diffusivity. We have revised the text to highlight this point.

- p198, line 19. This sentence is indeed confusing. The revised sentence now reads

  Here, if the tracer concentration at a point moves outside a pre-defined and fixed global range, the tracer fluxes, instead of being those arising from neutral physics, are reduced to those from horizontal diffusion.

- Figure 7 caption: exponential has been corrected.

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References

[Beckmann and Döscher(1997)] Beckmann, A. and Döscher, R.: A method for improved representation of dense water spreading over topography in geopotential-coordinate models, Journal of Physical Oceanography, 27, 581–591, 1997.

[Döscher and Beckmann(2000)] Döscher, R. and Beckmann, A.: Effects of a bottom boundary layer parameterization in a coarse-resolution model of the North Atlantic Ocean, Journal of Atmospheric and Oceanic Technology, 17, 698–707, 2000.

[Griffies et al.(2000)Griffies, Pacanowski, and Hallberg] Griffies, S. M., Pacanowski, R. C., and Hallberg, R. W.: Spurious diapycnal mixing associated with advection in a z-coordinate ocean model, Monthly Weather Review, 128, 538–564, 2000.

[Holland et al.(1998)Holland, Chow, and Bryan] Holland, W. R., Chow, J. C., and Bryan, F. O.: Application of a third-order upwind scheme in the NCAR ocean model, Journal of Climate, 11, 1487–1493, 1998.

[Leonard(1979)] Leonard, B. P.: A stable and accurate convective modelling procedure based on quadratic upstream interpolation, Computer Methods in Applied Mechanics and Engineering, 19, 59–98, 1979.

[Pacanowski and Griffies(1999)] Pacanowski, R. C. and Griffies, S. M.: The MOM3 Manual, NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, USA, 680 pp, 1999.

[Tang and Roberts(2005)] Tang, Y. and Roberts, M.: The impact of a bottom boundary layer scheme on the North Atlantic Ocean in a global coupled climate model, Journal of Physical Oceanography, 35, 202–217, 2005.

Interactive comment on Ocean Science Discussions, 2, 165, 2005.