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Interactive Comment

Interactive comment on "Exploring the isopycnal mixing and helium-heat paradoxes in a suite of Earth System Models" *by* A. Gnanadesikan et al.

Anonymous Referee #2

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This paper presents two purported paradoxes: (1) The He paradox: there appears to be helium (isotope) missing from the deep ocean, relative to the amount expected from known geothermal heating. Since both He production and heating are thought to be produced by radioactive decay in Earth's interior, it is possible to derive an expected He yield for a given amount of heat—but direct more observational estimates of the He flux are smaller. (2) The isopycnal mixing paradox: theory suggest that isopycnal mixing is small (O(10ˆ2) mˆ2/s) in the ocean interior, but direct observations suggest values closer to O(10ˆ3) mˆ2/s. Calling this a paradox is a bit of a stretch, but okay. The authors test whether increased isopycnal mixing can resolve the He paradox, hypothesizing that a faster air-sea equilibration timescale for He over 14C will make the He tracer more sensitive to increases in ventilation rates. They run experiments with isopycnal mixing coefficients spanning a range of values and conclude that the ventilation increases do not fundamentally change the relationship between He and 14C.

While there is no fundamental new insight gained into either paradox, this paper presents a nice analysis testing an interesting hypothesis, and is exemplary of an important type of study using geochemical tracers to help constrain model physics.

Detailed comments

pg 2534, ln 11-14: This sentence, "Because helium isotopes equilibrate rapidly with the atmosphere, but radiocarbon equilibrates slowly, it might be thought that resolving the isopycnal mixing paradox in favor of the higher observational estimates of ARedi might also solve the helium paradox", is problematic. First, the second clause does not logically follow from the first—unless, perhaps, one invokes several unstated assumptions. It would be helpful to state the logical chain more explicitly.

p2537, ln 16: the isotopic equilibration is further slowed beyond just CO2 because it depends on gross, not net, gas exchange.

p2537, ln 25-26: "The [highest] radiocarbon is found in the North Atlantic...", i.e. the most freshly ventilated waters.

p2546, ln 10: change "data" to "observations" or similar—use of data to mean observations is a colloquialism and confusing (apply this change throughout). I am not sure I understand the statement, "The plot is cut off above 1000 m as all the models overlie the data for these depths." Is the cut-off at 100 m?

Fig. 4: How close to equilibrium are these tracer profiles? OCMIP specifies a criterion for radiocarbon equilibration; do the experiments (both the control and branches) meet this? Add a statement quantifying drift.

p2547, ln 3-5: What about diapycnal mixing?

p2547, ln 19-20: Is 14C tracer being directly mixed down by isopycnal mixing, or does the increased isopycnal mixing reduce stratification, thereby removing the surface di-

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apycnal mixing bottle-neck?

Fig. 5: there is an inconsistency between the caption (little delta) and figure labels (cap delta).

p2551, near ln 25: do all passive tracers have the same (eddy) diffusivity?

Interactive comment on Ocean Sci. Discuss., 11, 2533, 2014.

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