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Interactive comment on "Simulating oceanic radiocarbon with the FAMOUS GCM: implications for its use as a proxy for ventilation and carbon uptake" *by* Jennifer E. Dentith et al.

Anonymous Referee #1

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Dentith et al. describe the implementation of radiocarbon (14C, or ∆14C when considering the normalized and fractionation-corrected 14C/12C ratio) into the ocean component of the FAMOUS atmosphere-ocean GCM and present two 14C simulations, one spin-up simulation with constant pre-industrial boundary conditions plus a "historical" simulation forced with transient values of atmospheric CO2 and ∆14C for 1765–2000 CE. The simulation results are compared with water column measurements available for the 1950s and the 1990s, and with 14C records from bivalves and deep-water corals spanning the period 1880–2000 CE. The model results are at least qualitatively in line with observations. FAMOUS simulates radiocarbon in two ways. The "abiotic" approach only considers uptake, transport and radioactive decay of normalized 14C/12C.

The "biotic" approach also considers isotopic fractionation due to air-sea gas exchange and the isotopic imprint of the biological pump. Comparing both approaches, Dentith et al. find that the "biotic" approach results in slightly elevated 14C/12C ratios in the deep sea (by about 20‰ in terms of ∆14C). This result corroborates early findings stating that biological effects on 14C/12C are much smaller (<10%) than the effects of transport and radioactive decay (Fiadeiro, 1982). In addition, Dentith et al. compare simulated 14C water ages with "true" water ages according to an idealized age tracer. It turns out that for large parts of the oceans, a purely kinematic interpretation of 14C/12C ages can lead to erroneous conclusions.

The paper is well written, the presentation of the results is mostly clear, and the literature is comprehensive. It may be published if the following issues are amended:

Major issue:

As described in Section 2.3.2, the model setup does not allow for meridional variability of atmospheric ∆14C. Therefore, the historical simulation misses the strong interhemispheric ∆14C gradient in the atmosphere of up to 400‰ (e.g., Fig. 1 in the manuscript) due to nuclear weapons testing. As a consequence, the model may underestimate the actual spatiotemporal 14C gradients in the ocean since the late 1950s. This shortcoming may distort the evolution of bomb 14C transients discussed in Section 3.3. It may also lead to biased post-bomb 14C distributions in subsurface and deeper waters which are discussed in Section 3.2. I would strongly recommend repeating the historical simulation forced with hemispheric averages of atmospheric ∆14C. The implementation should not be too difficult (the model has to read in three files provided by OCMIP-2).

Further issues and comments (P = page, L = line, SM = supplementary material):

P 3, L 6: The value of the half-life should be consistent with the updated value of 5700 years promoted in the SM.

P 3, L 28: "Indian" should read "Indien"

P 4, L 28: The models MOM (Toggweiler et al., 1989), LOCH (Mouchet, 2013) and LOVEVLIM (e.g., Menviel et al. 2017) could be added to the list.

P 7, L 28: (660 / Sc)**-0.5 should read (Sc / 660)**-0.5 (e.g., Orr et al. 2017, equation (12))

P 7, L 31: Missing reference (I guess it is Wanninkhof 1992)

P 8, L 8 and P 22, L 27: I could not find the paper at GMDD. What is the current status of the manuscript?

P 8, L 12: 14 and 13 should be subscripts

P 8, L 22: "δ13C is close to zero": this is the only case for DIC but not for phytoplankton

P 9, L 10: This is not correct, Stuiver and Pollach (1977) employ 5568 years.

P 9, L 16: What about turbulent diffusion, where is it included?

P 9, L 26–28 and Figure S1: The OCMIP-2 steady state criterion is somewhat different, demanding that 98% of the ocean volume has a Δ14C drift of less than 0.001‰ per year (see also Aumont et al. 1998). The total 14C inventory may have stabilized while there might be still an ongoing internal redistribution of 14C. Have you checked this?

P 13, L 5–6: "(...) the simulated Δ14C gradient between the surface ocean and approximately 1000 m depth is shallower than observed (. . .). This is visible in all regions, except the Northern Hemisphere deep water formation region (NH_DWF) and the North Pacific (NP) (. . .)." According to Figure 8 the opposite is true (indicating steeper simulated gradients everywhere except for NH_DW and NP).

P 13, L 23: "(. . .) due to the sparsity of data." You might wish to compare your results with post-bomb Δ14C (bottle) data provided by GLODAPv2 (https://odv.awi.de/data/ocean/ glodap-v22019-bottle-data/).

P 17, L 19: This is an interesting result supporting and quantifying the notion by Fi-

adeiro (1982) that 14C/12C can roughly be regarded as radio-conservative tracer in the deep sea.

P 18, L 1–6: The simulated 14C ages reflect local ageing, transport, biogeochemistry, and radioactive decay. On the other hand, the simulated ideal water ages only reflect local ageing and transport. As there is no radioactive decay of the age tracer, the age differences cannot be entirely explained with biogeochemical effects.

P 18, L 15–16: "(...) the water ages generally increase with depth because they are a simple function of advection." I disagree, there may be considerable mixing leading to nonlinear ageing of water parcels. This is seen in many tracers records.

P 31, Figure 4 (b): I would prefer to see the differences between simulated and observed values, analogously to Figure 2.

Figures 8, 10, 11, 16, S4, S5, and S6: Lines and dots are blurred.

P 38, Figure 11: The line plots should be replaced with Hovmöller diagrams.

SM, P 2: "OCMIP" should read "OCMIP-2"

References:

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