Geosci. Model Dev. Discuss., 7, C3686–C3690, 2015
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Geoscientific Model Development Discussions
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# *Interactive comment on* "Carbon isotopes in the ocean model of the Community Earth System Model (CESM1)" *by* A. Jahn et al.

**A. Jahn et al.**

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Received and published: 1 May 2015

We thank the reviewer for his/her time and for the very detailed and constructive comments, which helped us to improve the manuscript. In the following, we have addressed all comments, with the original review text in italics.

*The manuscript by Jahn et al. describes a new implementation of the carbon isotopes 14C and 13C into the ocean component of the Community Earth System Model (CESM1). 14C and 13C are tracers that are often used as paleoclimatological proxies, but that can also be used e.g. as proxies of anthropogenic carbon or to validate the ventilation of the deep ocean in circulation models. Two different implementations are described: One that models only 14C and neglects biological uptake following the OCMIP-2 protocol, and one that models both 14C and 13C and that takes into ac-*



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*count fractionation during biological formation of particulate carbon (both organic and calcium carbonate). After a detailed and useful description of the implementation in chapter 3, it demonstrates the use of the implemented carbon isotopes by comparing them to present-day ocean observations in chapter 4. One interesting aspect of the paper is that several formulations for the fractination during phytoplankton growth that have been discussed in the biological literature are implemented here, so that one can see whether they result in very different distributions of 13C in the ocean. The effect is relatively minor, which is reassuring for people using carbon isotopes as proxies.*

We thank the reviewer for his/her positive evaluation of the manuscript.

*Major comments*

1. *What is lacking in the manuscript is a brief overview over where the implementation differs from that in other models, e.g. those cited on page 7463. This could easily be amended.*

   As suggested, we have now included a short statement in the introduction where the other models that include carbon isotopes are mentioned, and also added a discussion of how the model differs in other places in the manuscript (e.g, in the discussion of the fractionation during the formation of calcium carbonate).

2. *The description of the model implementation of the carbon isotopes, which is the main focus of the paper, is detailed and well-written, and it will become a useful reference for other groups that want to include isotopes into their ocean biogeochemical models. I would therefore recommend to accept the paper for publication after a few minor revisions. I share the concern by the first reviewer that the model runs presented in the results section are not in equilibrium, especially the distribution of 14C in the biotic run. Probably, in the meantime the model has run for a few thousand model years longer and I would suggest to replace the figures and numbers in the results section with ones from a later stage of the model experiments.*



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We have now run the model for another 2450 years, for a total spin-up of 6010 years, and have updated the text and all figures accordingly (with very little changes in the figures and only small changes in some numbers that did not change any conclusions or comparisons with the observations). While the biotoc radiocarbon is still not fully spun-up, it is now at 26% compared to 5% for the OCMIP2 criteria, which is very strict. The 13C and DIC did not change much during the continued spin-up, so we consider these spun-up, and a shorter spin-up of 3000 years or less seems sufficient for these tracers. As the main purpose of this article is to document the implementation, we think that this is good enough for now. We look forward to eventually having a fast spin-up technique available that will allow us to use the biotic radiocarbon for science applications beyond the documentation of the model.

3. *The authors use a constant fractionation of 2‰ for 13C during formation of calcium carbonate, referring to Ziveri et al. (2003) (page 7474). Ziveri shows a range of about 5‰different species (from +3 to -2), and several other studies indicate a smaller fractionation around 1‰ see e.g. Zeebe and Wolf-Gladrow (2001), Figure 3.2.13. Al- though the effect on 13C in dissolved inorganic carbon is probably negligible, this may bias the interpretion of 13C values from marine carbonates. I would suggest that the authors describe briefly the range of fractionation factors found and add a few more citations.*

   We have expanded this paragraph to mention what other model implementations have used as well as give the range of the values reported by Ziveri et al. See below for the revised text. “While the fractionation during calcium carbonate formation is much smaller than the fractionation during photosynthesis (Turner, 1982), we include a small constant fractionation of 2‰ for calcium carbonate formation, based on work by Ziveri et. al. (2003) that found a range of 3‰ to -2‰ for different species. Other implementations of 13C in ocean models have used values of 1‰ (e.g., Sonnerup et. Al. 1999, Alessandro Bopp 2008) or have assumed



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no isotopic fractionation for calcification (e.g., Marchal et al 1998, Schmittner et. al. 2013). However, the effect of the calcium carbonate pump on $\delta^{13}$C is small as was shown by Schmittner et. al. (2013), so the choice of the value for the fractionation during calcium carbonate formation is not expected to have a big impact on the results in the current ecosystem model with one species of calcium carbonate."

4. *Chapter 5 describes very briefly that the carbon isotopes have now also been implemented in CESM version 1.2, which includes a simple description of marine sediments. How this sediment model works, however, is not described in sufficient detail, and neither is how the carbon isotopes are represented in it. Early diagnosis can affect the isotopic composition of DIC near the bottom of the ocean and of foraminifera recording it (Mackensen et al., 1993), and it would be useful to know whether these effects are represented in the model. I would therefore suggest that the authors add a little more model description here. Are the modeled distributions of carbon isotopes in the water column affected to some extent by the addition of a sediment module, e.g. by a burial loss with a 13C that differs from the average 13C of seawater?*

   As mentioned in the reply to reviewer 1, we have decided to remove the discussion of the changes to the carbon isotopes in the CESM1.2, as the CESM has continued to evolve since we submitted this paper (including how the sedimentation is parameterized), and there will be no release of the CESM1.3 in 2015 after all. This means that the carbon isotopes will therefore only be included in the CESM2 release in 2016, which will have yet further changes compared to the CESM1.0.5 shown here, making the discussion of the changes in the CESM1.2 obsolete. Once the CESM2 code is finalized we will include a description of how the carbon isotopes are included in that version in the description of that model. In the meantime, we will include the carbon isotope code as used here (in version CESM1.0.5) with the revised manuscript.



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*Minor comments*

- *Page 7478, line 18: 'differences . . . is': either use singular or plural*
  Thank you for finding this error, it has been corrected to "differences .... are"
- *Page 7492, line 28: 'active uptake or' ! 'active uptake of'*
  Thank you for finding this error, it has been corrected to "active uptake of"
- *Page 7494, caption table 1: 'using' ! 'used'*
  Thank you for finding this error., it has been corrected to "Parameters used ..."

Interactive comment on Geosci. Model Dev. Discuss., 7, 7461, 2014.