

Geosci. Model Dev. Discuss., author comment AC2  
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## Comment on gmd-2020-426

Trevor J. McDougall et al.

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Author comment on "The interpretation of temperature and salinity variables in numerical ocean model output, and the calculation of heat fluxes and heat content" by Trevor J. McDougall et al., Geosci. Model Dev. Discuss.,  
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Response to the reviews by Baylor Fox-Kemper, and Remi Tailleux

We thank Baylor Fox-Kemper for his review of our paper. When we prepare a revised manuscript we will include comments about the storage requirements of our recommendations, and the accuracy of depth-integrated quantities such as dynamic height.

The review by Remi Tailleux has provided us with a lengthy and strongly worded disagreement with our manuscript. The main disagreements that this reviewer has with our paper are based on the following three viewpoints with which we disagree,

- a concentration by the reviewer only on the terms that contribute to the globally volume-integrated heat content of the ocean, rather than also being concerned with errors in modelling temperature in specific geographic locations,
- a hope (that also pervades the Tailleux (2015) paper), that retaining potential temperature as a model's temperature variable could be made to be competitive, in terms of accuracy and practicality, compared with adopting Conservative Temperature in numerical ocean circulation models, and,
- what we believe is an error made in Tailleux (2010) and Tailleux (2015) in the choice of physical property that is assumed to be conserved under turbulent mixing.

The error made by Tailleux (2010) and Tailleux (2015), referred to above, underlie many of this reviewer's comments; in particular, his "Specific comments" numbered 4, 9, 10, 11, 17, 20 and 22. This error is the assumption that Total Energy, is a conservative variable. Because this issue underlies so many of the reviewer's comments and is central to both the Tailleux (2010) and Tailleux (2015) papers, TMcD directly addresses this issue in an Appendix to our Response to Remi Tailleux's review. This detailed Response is posted as an Author Comment to that review.

Since we disagree with almost all of the many points made in Remi Tailleux's review of our manuscript, our revised manuscript will not incorporate any substantive changes as a result of this review.

Regarding the ensuing discussion that took place publicly between the two reviewers, we make the following two remarks.

- The GISS model has, for some years now, used potential enthalpy as its ocean “temperature” variable. However this is just one point of difference between the GISS model and others, and so a study of the differences between the GISS model output and that of other models will depend on many more contrasts of the model’s construction than just this one aspect.
- Our recommendation is that ocean models should store and disseminate their model’s temperature variable. What is at stake is how this temperature variable should be interpreted, and we make the case that in all types of ocean model the model’s temperature variable should be interpreted as Conservative Temperature. Yes, we know that for decades oceanographers have interpreted their ocean model temperature as being potential temperature. But doing so has meant that some of the heat that should pass between the atmosphere and the ocean simply disappeared in a non-conservative fashion at the sea surface. This is surely not acceptable. As a community of scientists modelling climate and climate change, it seems obvious that we should not countenance such a loss of heat in our coupled climate models. Fortunately, we show that a simple fix is available; namely re-interpret the model’s temperature to be Conservative Temperature.