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Interactive comment on "Isoneutral control of effective diapycnal mixing in numerical ocean models with neutral rotated diffusion tensors" *by* Antoine Hochet et al.

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We thank the referee for engaging with us on various points raised in our response to his initial comments. Like all authors, we appreciate comments that contribute to improving readability and clarity of our work, but are understandably less appreciative of comments that we feel distract from the issues discussed.

About TEOS-10 variables

The referee wrote in his initial review *However, when using WOCE data, one should provide the data in Conservative Temperature and Absolute Salinity variables (that should be an editorial decision from a couple of years ago)*. In our view, such a statement is unduly autocratic and encroaching on academic freedom, which is why we said in our response that we were hoping that the referee could not possibly be serious. To justify his comment, the referee mentions an editorial note from the Journal of Physical Oceanography (Spall et al., 2013). The said note, however, is merely an official announcement that AMS journals are making an exception to their former editorial rule of not capitalising names of variables with regard to Absolute Salinity and Conservative Temperature, starting with the paper by Graham and McDougall (2013). Contrary to what the referee's comment suggests, such a decision by no means makes it mandatory for oceanographers to use such variables. Historically, it is the first time that a colleague appears to interpret the term 'recommendation' as 'obligation'. In our opinion, the best practice is always to stay as close as possible to what is measured, which is certainly not the case of Conservative Temperature and Absolute Salinity.

Salinity variables

Our study — like all oceanographic studies for the past 40 years or so — is based on the use of reference composition salinity S, which forms the basis for both the old EOS-80 and TEOS-10 thermodynamic standards, as well as for the large majority of realistic numerical ocean model studies. We recently realised that practical salinity is the same as reference composition salinity, expressed in different units. Since it is not usual to use different notations T_K, T_C or T_F to refer to in-situ temperature T expressed in different temperature units (Kelvins, Celsius or Fahrenheit), we believe that it is similarly not justified to use the notation S_p for practical salinity, because it erroneously suggests that it is a different salinity variable than reference composition salinity variable, when this is clearly not the case. These points will be clarified in our revised manuscript. We thank the referee for bringing up the issue, and helping to clarify what has been an immense source of confusion so far.

Density variables (About General comment number 1 (around C2))

We do not understand what the referee is after. The materially conserved variables whose effective diapycnal diffusivity is estimated in our paper are ‘naturally’ existing variables that have not been artificially designed to satisfy materiality over neutrality. We just investigate the properties of such variables, and do not advocate using one particular density variable over another. Our results have no implications for determining whether one type of density variable might be better than another one, so we do not understand why the referee is asking us to discuss such implications.

General comment at the bottom of C4 about K_H and K_V

We find it impossible to relate the referee’s comment to what we do or write in our paper. What we do in our paper is to discuss the concept of effective diapycnal diffusivity K_{eff}. K_{eff} is a quantity that can be defined for any material density variable $\gamma(S,\theta)$ for any kind of diffusion tensor K. What we do is to illustrate the concept for both the cases where $K = K_H(I - kk^T) + K_V kk^T$ mixes separately in the horizontal and vertical directions, as was done in early numerical ocean models, as well as for the modern neutral rotated diffusion tensor $K = K_i(I - dd^T) + K_d dd^T$ used in current ocean models, using the form given in Griffies (2004)’s textbook. Here, k is the unit vertical vector, and d the normalised neutral vector. We do not understand where in our manuscript does the referee think that we advocate going back to using non-rotated diffusion tensors, which is a complete misrepresentation of our study. The concept of effective diffusivity discussed in our paper can be traced back to the studies by Nakamura (1996, 178 citations) and Winters and d'Asaro (1996, 105 citations), which are widely regarded as the two studies formalising the concept rigorously. As far as we are aware, the study by Klocker et al. (2009) (8 citations, of which 5 are self-citations) is not known as a study concerned with the problem of estimating effective diffusivities, so that we do not understand why we would need to justify using a well-established approach preferentially to an irrelevant one.

Comment about K^*

We do not understand what the referee is trying to say, nor do we understand the paper by McDougall et al. (2014). The referee needs to spell out exactly what he means, and what McDougall et al. (2014) are supposed to have showed or done in plain english. Just referring to a page number is not helpful. It would also be helpful if the referee could provide the physical basis for why he thinks that mixing of potential temperature and salinity is isotropic at small scales, when Smith and Ferrari appear to show otherwise.

Comment on the Munk value

The physical reason(s) for how to explain Munk's canonical value $K_v = 10^{-4} m^2/s$ are irrelevant to our discussion. What matters to our discussion is that 10^{-4} is a value that is universally accepted as being about 1 order of magnitude 'too large' compared to values most commonly observed in the main thermocline, and is therefore a useful benchmark in that regard. The only justification for using this value is that it is one that everyone in the field can recognise owing to its historical importance in the context of ocean mixing.

References

- Klocker, A., T. J. McDougall and D. R. Jackett, 2009: A new method for forming approximately neutral surfaces. Ocean Sciences, 5, 155-172. (8 citations, 5 self-citations).
- Nakamura, N. 1996: Two-dimensional mixing, edge formation, and permeability diagnosed in an area coordinate. J. Atmos. Sci., 53, 1524-1537. (178 citations)
- Winters, K.B. and E. d'Asaro, 1996: Diascalar flux and the rate of fluid mixing. J. Fluid Mech., 317, 179-193. (105 citations)

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