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Ocean Science Discussions

Interactive comment on "How does ocean ventilation change under global warming?" *by* A. Gnanadesikan et al.

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I would like to thanks both reviewers for their pertinent and constructive remarks on this paper, which clearly helped the authors to revise and clarify several points that were slightly overlooked in the original manuscript. I noticed that they acknowledge the importance of the subject and the interest of the results presented.

The answers given by the authors to these remarks, and the corrections they propose to make to the revised manuscript are convincing, and I recommend that the authors go ahead with their corrections along these lines and to send the revised version.

After a careful analysis of the paper, the reviews and the response of the authors, I have several comments on just a few points.

1 - Comments on the 1-D model.

Both reviewers rightly questioned the realism of this model and its adequacy to the scientific discussion. I found that the usefulness of this model was very unclear in the original manuscript, because (i) an error in the model equation, (ii) insufficient comment on the model principle, and (iii) a poor legend in Fig. 6. I go through those three points below, hoping that my comments, which described what I understood from this part may contribute to make this part clearer.

Point (i): Eq (1) was written as :

dA/dt = - wdA/dz + d/dz(KdA/dz) (a) when it should be :

dA/dt = 1 - wdA/dz + d/dz(KdA/dz) (b)

because ages increases as time goes by. The steady state solution, which correspond to dA/dt = 0, can be found by solving the following equation :

1 = wdA/dz - d/dz(KdA/dz) (1)

which is equation (1) given in the revised paper, and which solution is given in equation (2) of the revised paper, and is discussed in Fig. 6.

Point (ii): I think that discussing (b) (i.e. the equation with the time derivative) is useful because it gives the principle of the model, and provides physical insight on the analysis of the steady state solution (2) shown in Fig. 6. Eq (b) says that water would age at a rate of one year per year (1st term in the rsh), but that advection or diffusion of water of different age from above or below will moderate this aging. If we integrate (b) in time with initial condition A = 0 everywhere, and A = 0 at z = 0 and z = -D (0 and -D defining the limits of the model interior, not the surface and bottom of the ocean where w has to be 0), the 2nd and 3rd terms in (b) will first be very small and the age of water will increase almost linearly with time. After long time, the vertical gradient of age will increase significantly (since A remains 0 at the top and bottom) to a point where 2nd and 3rd terms in (b) can balance the linear increase of age, and a steady state can be

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reached. Note that the evolution of A is fully determined by the dynamical quantities w and K, and the dimensionless number relevant to the discussion of the solution is the Peclet number, Pe = wD/K.

Point (iii): Legend of Fig. 6 was not accurate. The value of Pe should be shown on each curve, and the legend for Fig. 6c (Fig. 6d) should explicitly mention that what is plotted is the difference between the dotted and full curves shown in Fig. 6a (Fig. 6 b).

I think these points contributed to make the section on the 1-D model rather obscure.

2 - Comments on the relevance of the 1-D model in this study:

I like the idea of a simple model, but it must contribute to explain thing in a simple way. Although this model has been used in other studies, it is very likely that it is not familiar to many, and that it needs to be presented carefully to have a clear impact in the study (which means that we expect more than a reference to a published paper). The revised discussion of the solution of (1) proposed by the authors in their response represents a significant improvement compared to the initial paper. However, I find it not fully satisfactory for several reasons:

2a) It is not quite true to say that (1) is the equation governing age in the interior. It is the equation governing the steady state, and its vertical integration yields the steady state age profile (2). I think that understanding of the "pipe" and "network" behaviours of the equation shown in Fig. 6 would gain from a discussion of the time dependent equation (which is not anymore in the paper). This equation best explains the term 1/w in the expression of the age A at steady state which is responsible for the great difference in quantity seen in Fig. 6a (changing Pe from 40 to 20 changes the maximum age from 500y to 2000y).

2b) the "pipe" behaviour corresponds to a small Pe (and not a large Pe as in the text, but this is clearly a misprint, not an error). Please correct.

2c) The "network" behaviour corresponds to large Pe (the text is correct here). The

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behaviour of the "network" model to a change in upwelling rate provides a change in age profile which is consistent with that shown in Fig. 3 (i.e. showing a reduction of age of intermediate waters in the shadow zone), and identifies the reduction of the upwelling of older waters from below as an important (even dominant) contribution to this age reduction. The discussion here is sufficiently argued. But be more convincing, one should argue about why the shadow zone can be consider as a zone of large Pe.

3) Other remarks Please pay great attention to figure labels and legends which often miss accuracy.

Interactive comment on Ocean Sci. Discuss., 3, 805, 2006.