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Interactive Comment

Interactive comment on "Geothermal heating, diapycnal mixing and the abyssal circulation" *by* J. Emile-Geay and G. Madec

Anonymous Referee #1

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In this paper the authors use different methods to evaluate the relevance of geothermal heating on the abyssal thermal structure and circulation. To this end, they use simple scale analysis, more refined data analysis, and numerical models. The paper is interesting and worth publication on Ocean Science.

My main concern (discussed also in the following) is that the authors claim that geothermal heat DRIVES a circulation, while indeed it affects the abyssal thermal structure which indirectly affects the circulation.

Main points:

In section 2.2 a "geothermally driven circulation" is estimated, and the same concept is iterated through the paper. The authors consider the temperature difference between

AABW and water at 3500m (from Levitus dataset) and the uniform geothermal flux of 86 mW/m^2 to obtain a volume flux. This transport, however, is not the circulation DRIVEN by the geothermal heat. The analysis should lead to the following conclusion: If the abyssal circulation is the one calculated here, then geothermal heat alone would warm the water by ΔT, and thus significantly contribute to the abyssal thermal structure. Since it is believed that the abyssal circulation (whatever its "driver" is) is of the same order of magnitude of the transport calculated here, it is expected that geothermal heat cannot be neglected. In other words, the authors calculated the advective flux required to maintain the abyssal water in a steady state in presence of geothermal heat and in absence of any kind of mixing: This is not the geothermally driven circulation.

The authors should also comment on the fact that in their simple model of the abyss (the one shown in fig.4) there is no diffusion across the boundaries of their bottom box (heat fluxes associated with mixing are assumed negligible) but very good diffusion of heat inside the box (so that geothermal heat is distributed uniformely inside the box).

Specific comments:

1. In section 2.1 two methods are used to estimate the relevance of geothermal heat. The two methods (leading to fig. 2 and fig. 3 respectively) are very similar. Their difference is merely in the computation of the average of temperature gradients (as for fig.2) or the inverse of the average of inverse temperature gradients (as for fig. 3). The small discrepancies found (e.g. in fig. 2 at 4,000 m the downward heat flux is on average larger than 100 mW/m^2, while m fig. 3 it is inferred that with the same diffusivity coefficient one would get a heat flux smaller than 86 mW/m^2) are due only to the non commutability of the average and inverse opeartions.

2. Line 19 page 289: the last word should be "it" rather than "its"

3. The value of ΔT used in eq. 6 is somehow arbitrary, being the temperature difference between the core of the AABW and the water at 3500 m, along a streamline. Can the authors specify how they chose ΔT to be used for their calculations?

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4. Page 292, after eq. 17: While it is true that vertical diffusion affects w_z, and thus it appears in hidden form in the Sverdrup balance, it is not clear to me that geothermal heat affects w_z. Geothermal heat would directly drive a circulation only if it created a static instability in the bottom ocean.

5. Line 21 page 295: $\sigma'(x, y)$ (a prime is missing).

6. Line 14-15 page 296 does not make sense.

7. The method described in section 3 (the density binning method) is used to calculate the transport required to keep the abyssal ocean in steady state, in presence of a heat source such as geothermal heat. It is essentially the same argument used in section 2 to obtain a similar estimate. The similarity in the answer is thus not a surprise (see page 296, line 21).

8. Caption of fig.7: $CBW_Q geo_u ni$ should be $CBW_Q uni$.

9. In simulation $CBW_Q uni$, is the convective mixing scheme active in the bottom ocean? In other words, is the warming of the sea floor due to geothermal heating able to desitabilize the water column? At what depth? The authors do not show the thermal structure of the deep ocean in simulation CBW, but I assume that, being the deep ocean filled with cold water and essentially stagnant, vertical potential temperature gradients are very small. If this is the case, geothermal heat has long times to warm the bottom waters, and static instability can arise. Once this happens, the effective vertical diffusivity is increased, and w_z changes. The effects on the Sverdup circulation become clear.

10. Line 14 page 302: "...geothermal enhances...". Something is missing

11. Fig 12 (and section 4.5): the difference in the thik solid lines in fig. 12 (red and blue) is a bit surprising. In fact, given the same increase in heat flux at the bottom of the ocean (the geothermal heating), the transport of heat out of the bottom ocean should be identical. This transport can be either lateral (essentially meridional) or

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vertical. In the MIX experiments, is a significant part of the heat escaping through vertical diffusion? Is this the reason for the observed difference? Or perhaps the integral of the poleward heat flux is very similar in the two cases, and the difference seems large only because it is at a latitude where the latitude circle is short...

Interactive comment on Ocean Sci. Discuss., 5, 281, 2008.

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