Ocean Sci. Discuss., 5, S186–S189, 2008
www.ocean-sci-discuss.net/5/S186/2008/

Ocean Science Discussions

Interactive comment on "Role of cabbeling in water densification in the Greenland Basin" *by* Y. Kasajima and T. Johannessen

Anonymous Referee #2

Received and published: 16 October 2008

General Comments

Kasajima and Johannessen report a careful analysis of hydrographic data collected along two transects in the Greenland Basin. It is encouraging to see the deeper insights that can be gained from traditional CTD data, in this case the often overlooked process of cabbeling. Previous studies of cabbeling have emphasised this process of densification elsewhere in the World Ocean (classically in the Weddell Sea and in the North Atlantic subpolar gyre). This study is the first to my knowledge that addresses cabbeling in the Greenland Basin, where it may have a subtle but important influence on deep water formation. Analysis on neutral surfaces is appreciated.

Sections 1-3 ('Introduction', 'Hydrography', 'Water mass modification equation') are

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clear, and I have very few specific comments on these. I provide more substantive comments on Section 4, 'Cabbeling mixing in the Greenland Basin'. While Section 4.1 is clear, Sections 4.2 and 4.3 should be somewhat clarified, in terms of both methodology and interpretation. I am particularly concerned that a misunderstanding may have arisen in regard to 'integrated formation rate', although the authors may convince me otherwise. Section 5, 'Concluding remarks', could also be both clearer and more in depth, and the closing remark is rather weak. My recommendation is that the paper is acceptable for publication in Ocean Science after minor revisions and/or convincing rebuttal of my specific comments.

Specific Comments

1. p.516, lines 7-9 - The authors briefly consider the 'effective diffusivity averaged over the whole Greenland Sea' (due to cabbeling). How was this calculation undertaken? With a comprehensive temperature and salinity dataset? Or is this a 'back of envelope' calculation? Please clarify.

2. pp.517-518 and Fig. 8 - The authors introduce a 'ratio of the temperature gradient to buoyancy', but the numerator and denominator have different units, which is confusing to me (and should at least be clarified in the figure - see technical comment). I would prefer some measure of the relative influence on cabbeling velocity of variations in these two influences. Can the authors otherwise justify this ratio and substantiate what it means?

3. p.519, lines 3-6 - To get volume transport, cabbeling velocity is 'averaged over neutral surface in each frontal area'. This is confusing to me, although Table 3 seems relevant - the last column is 'vertical expansion'. Does this correspond to 'frontal area'? In that case, the area is in the zonal-vertical plane. What therefore is the meaning of the corresponding formation rates? The cabbeling velocity is orientated in the vertical sense, so an appropriate area, for transformation and formation rate, should be frontal width x frontal length (from climatology?). Can the authors clarify what they are intro-

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ducing here. Some further equations may help with any clarification of volume fluxes and formation rates.

4. p.519, lines 10-14 - The authors should further explain that the thinning or formation of different layers corresponds to a vertical divergence or convergence of cabbeling velocity with respect to increasing depth. In the 1-D context (bearing in mind specific comment 3), it would perhaps be more natural to define thinning or thickening of layers (in m per year). What is meant by 100˜240 m3/day?

5. p.519, line 19 - How can there be an integrated formation rate of 123 m3/day? Volume must be conserved. The authors should clarify (if this is what they mean) that there is a net gain, at this rate, of a dense water mass at the expense of a lighter (overlying) water mass. This seems subsequently obvious for the other three fronts, as the integrated formation rate is effectively zero (as it should be)!

6. p.521, lines 2-4 - I contend that the downward transport by cabbeling mixing at SB is not 'remarkable' (other than the local strength), as this happens at all four fronts - in each case the role of cabbeling mixing is indeed to change buoyancy, but downward transport is ubiquitous at all four fronts.

Technical Comments

1. Abstract - clarify what is meant by a NAW production of 123 m3/day (see also previous comments on methodology and interpretation

2. p.513, line 25 - quantify 'the largest part (˜54%)'

3. p.513, line 29 - clarify 'and an additional ˜30% of the total water volume'

4. p.514, line 1 - Cite Table 2 (rather than Table 4)?

5. p.514, line 19 - clarify 'therefore only water properties'

6. p.514, line 13 - clarify 'an equation of e, the vertical velocity'

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7. p.518, line 7 - Please include units of cabbeling parameter (°C-2), both in the text and in the caption/labelled axis for Fig. 9

8. p.518, line 17 - re-phrase 'contours of the cabbeling parameters are orientated vertically'

9. p.519, line 27; p.520, lines 4, 28 - These 'overall' or integrated formation rates are effectively zero (as they should be), and not worthy of mention.

10. p.521, lines 11-13 - This sentence is poorly worded, and should be re-phrased.

11. p.521, lines 18-23 - This section is text is also hard to follow. Carefully re-word this explanation.

12. p.521, line 24 - 'as a whole' is better expressed as 'on average'

13. p.522, line 11 - 'one order of magnitude lower'

14. p.522, lines 19 - 'net density gain times areal percentage'

15. p.523, lines 24-26 - The closing remark is rather weak. A more conclusive statement would be appropriate.

16. p.534, Fig. 4 caption - 'and it is not shown in'

17. p.537, Fig. 7 caption - Provide units for N2

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