

Interactive comment on “On the freshening of the northwestern Weddell Sea continental shelf” by H. H. Hellmer et al.

Anonymous Referee #1

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General comments (overall quality of discussion paper):

The authors describe in their manuscript (m/s) the possible causes of water masses freshening in the northwestern Weddell Sea, through investigation of new winter and summer hydrographic data. Actually, in my point of view, this issue is extremely important to better understanding regional and global changes of the ocean properties in a recent climate scenario of anthropogenic warming period. Additionally, the real reasons related to freshening trends around the Antarctic continent are still under debate. Some authors report that those changes could be caused by melting of glaciers and ice shelves, and others highlight that could be an artifact of temporal and spatial irregular observations (e.g. Jacobs et al. 2002; Assmann & Timmermann 2005). However, the freshening trends reported for shelf and deep water masses in the literature (e.g.

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Discussion Paper



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Comment

Jacobs et al. 2002; Assmann & Timmermann 2005; Aoki et al. 2005; Rintoul 2007) discuss only data from the Pacific and Indian Sector of the Southern Ocean (e.g. Ross and Davis Seas). This m/s presents that a freshening trend also occur in shelf waters of the northwestern Weddell Sea, which could be revealing an Antarctic circumpolar pattern of water masses changes. Moreover, the authors present and support that change in the salinity of this ocean region is caused also by summer sea ice edge retreat and modifications in the precipitation rates. Thus, presenting new and interesting results that should be discussed by the scientific community and published in OS after some minor changes and clarifications of some points of the original m/s (see specific comments). In general, the m/s is well written and extremely concise; however English is not my mother language and I might not be the right one to correct possible English grammar errors.

References cited:

Aoki, S., Rintoul, S. R., Ushio, S., Watanab, S. and Bindoff, N. L. (2005). Freshening of the Adelie Land Bottom Water near 140°E. *Geophysical Research Letters*, 32, L23601, doi: 101029/2005GL024246.

Assmann, K. M., and Timmermann, R. (2005). Variability of dense water formation in the Ross Sea, *Ocean Dynamics*, 55, doi:10.1007/s10236-004-0106-7.

Jacobs, S. S., Guilivi, C. F., and Mele, P. (2002). Freshening of the Ross Sea during the late 20th century, *Science*, 297, 386-389.

Rintoul, S. (2007). Rapid freshening of Antarctic Bottom Water formed in the Indian and Pacific oceans, *Geophysical Research Letters*, 34, L106606, doi:10.1029/2006GL028550.

Specific Comments (individual scientific questions/issues) and Technical corrections:

P2-L20: Indicate in Figure 1 where is located the Wilkins Ice Shelf.

P3-L1 to 9: I think that older literature that first introduced and discussed about fresh-

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ening in the Ross Sea must be cited, e.g. Jacobs et al. 2002, as well as the model study of Assmann & Timmermann 2005.

P3-L16: Indicate in Figure 1 where were located the Larsen A and B ice shelves. In fact, all locations used in the text must be cited in the figures.

P3-L19: I am not sure if you should abbreviate the first name when you cite a reference of personal communication.

P3-last paragraph: I think that you should remove the paragraph to section 2 (Data and methods). It seems more an explanation of the winter cruise.

P4-L3: Why the acronym US-DOVETAIL was not included in Table I?

P4-L4: Please cite what means CFC here and not at P6-L13.

P5-L5 to 9: Please insert those regions on Fig. 2.

P5-L10: Insert a paragraph.

P5-L19: Cite what means IUP.

P5-L26. I think it is better to state: "...is better than 1.5% for both CFC-11 and CFC-12, which means 0.04 pmol kg⁻¹ and 0.03 pmol kg⁻¹, respectively.

What are you trying to highlight with the sentence in parenthesis "(which ever is the greater)"? It needs clarification.

P6-L22: Insert here that theta/S means potential temperature/salinity.

P7-L11: "As source waters" of what?? Or are you trying to say "water types"?

P7-L11 to 14: The sentence must be rephrased. Potential temperature, salinity, etc... are not water types (or source water types) used in OMP analysis, but they are parameters used as water masses tracers to quantify each water type used.

Although OMP analysis was not the main method used in the m/s, I think you should

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Interactive
Comment

briefly state about the weights used and the parameters that are more influencing the results, even you have cited the paper of Huhn et al. (2008) as a reference. In addition, the citation of recent papers using OMP analysis specifically in regions of the Southern Ocean, which talk about deficiencies and questions related to the method, should also be included in the text (e.g. Tomczak and Liefrink, 2005; de Brauwere et al. 2007; Kerr et al. 2009).

P8-L20: Please clarify if the m/s results agree qualitatively or quantitatively with the results of Garcia and Mata (2005) in the Bransfield Strait. Also, in what sense the results reported for the northwestern Weddell Sea shelf waters could be compared with that of the Bransfield Strait? Please clarify this point in the text.

P9-L8-11: I cannot following the systematically increase of CFC in Figure 7. In fact, the bold symbols in this figure make complicate to see anything upper 500 m of depth. Clarify if the CFC unit is ppt or % (upper axis – that seems wrong in this case).

P10-L8 to P12-L6: Congratulation to the authors for the excellent discussion about possible reasons of freshening in Figure 8. However, I have some concerns that I would like to discuss. The authors does not discussed about the visible difference of the freshening trend seen between 1989-1997 and 1997-2006, with the former much more higher in magnitude. This is most evident by region I than region II, which have stations sampled more close to each other. I think that the authors must be including a paragraph in this context.

P11-L20: The shelf waters residence time of 1 yr derived in the m/s is much lower than the values previously reported in the literature (e.g. see M. Hoppema papers). This should be indicated and referenced by the authors in the text.

P12-L8: Also considering the latter two topics above, why the authors do not show the SSM/I mean composites for the period 1989-1996, which is exactly the period of greater salinity change (1989-1997) in the stations of region I (Fig. 8)? What occur in the ice shelves and sea ice specifically during this decade? Should be significant for

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this difference?! The m/s needs discussion about that.

P12-L22: Please use a pattern for the units, e.g. m/a or m a-1 (L27).

Table I: It should be cited the main study of all cruise/project if available, e.g. Dovetail (e.g. Muench & Hellmer 2002) or also which means each acronyms.

Table II: Did you apply parameters weights in your analysis? Which parameter influences more your results? The conservation mass residuals were inspected? It is lower than what? As GMW is an important result for the discussion, a brief description of the approach used to determine the water types must be included, or the values were tacked out from the literature? This should be included in your text (P7). See also comments above.

Figure 1: Additional work is required to improve this figure. The axis of (a) & (b) must have the same fontsize. Please cite in the caption the upper figure not referenced, even we know that (a) & (b) are zooming in of this inset figure. The same for figure 1(b), please insert a rectangle in figure 1(a) into the area zoomed. It is necessary to insert some bathymetric lines in both (a) & (b) or a colorbar, mainly because of the bathymetry colors used in (a) & (b) are different and is preferable to be the same. The station numbers in (a) are under each other, please correct it to clarify to the reader. Why stations encircled by ellipse II (b) do not appear in (a)?

Figure 2: Some stations are not visible to distinguish from each other. For example, the stations inside the black square (that should be distinct by square, dot and triangles), and the stations encircled by red and magenta circles. I do not think that the map inset figure is necessary here, because it is previously indicated in Fig. 1. I suggest inserting maps zooming in the delimited areas cited above to clarify the stations position or the authors should improve the representation of the symbols set used.

Figure 3: The grid lines should be removed. Please clarify (and verify along the text) if you are considering < 500 m or ≤ 500 m (see P6-L21).

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Figure 4: How did you define bottom layer to determine the mean salinity (thick lines)? Is it based on depth, density? Please quote in the caption. It is better if the line connecting the points are drawn thinner or dotted to avoid confusion.

Figure 5: Why the surface sample at station #579 might be an outlier? It follows the same pattern present by #578, but with higher concentration of GMW. Please clarify this point because the stations are very close to each other. Why do not show the concentration of HSSW, WW and WDW? Do WDW appear to be necessary to include in the OMP run? If yes, why? The stations seems distant from the continental margins and the influence of WDW could be negligible. However, if the residuals are lower in the density interval of this water type, it is necessary to be included.

Figure 6: See Figure 3 comments.

Figure 7: See comments above P9-L8-11:

Figure 9: It is clear if the authors add a difference map between the decades, which I think that could clarify the sea ice concentration isolines around 64°S. A zooming area around the tip of the peninsula could also be included for this proposes. It is necessary to insert the latitudes in the map. See comment above about the SSM/I map for the period 1989-1996, it should be included, if add information to the discussion, or explained, if omitted.

Figure 10: What the capital letters word “ADJACENT” means here, is it an acronym? Insert the correct cruise name in the legend, e.g. ANT XIII must be ANT XIII/4.

References cited: Muench, R. and Hellmer, H.H. (2002). The international DOVETAIL program, Deep-Sea Research II 49 (21), 4711–4714.

Tomczak, M., and S. Lieftrink (2005), Interannual variations of water mass volumes in the Southern Ocean, J. Atmos. Ocean Sci., 10, 31– 42.

de Brauwere, A., S. H. M. Jacquet, F. De Ridder, F. Dehairs, R. Pintelon, J. Schoukens, and W. Baeyens (2007), Water mass distributions in the Southern Ocean derived

from a parametric analysis of mixing water masses, J. Geophys. Res., 112, C02021, doi:10.1029/2006JC003742.

Kerr, R., Mata, M.M., and Garcia, C.A.E. (2009). On the temporal variability of the Weddell Sea Deep Water Masses. Antarctic Science, 21 (4), 383-400. doi:10.1017/S0954102009001990.

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