Ocean Sci. Discuss., 4, S383–S390, 2007
www.ocean-sci-discuss.net/4/S383/2007/

Ocean Science Discussions

Interactive comment on "Ice-shelf – ocean interactions at Fimbul Ice Shelf, Antarctica from oxygen isotope ratio measurements" *by* M. R. Price et al.

M. R. Price et al.

Received and published: 22 December 2007

Response to Reviewers' Comments (reviewer comments in italics)

We would like to thank both reviewers for their helpful and constructive comments, and particularly for drawing our attention to pertinent references.

Reviewer 1

This manuscript estimates the contents of glacial meltwater and sea ice melt in the water masses near the Fimbul Ice Front based on temperature, salinity and oxygen isotope data from a cruise in 2005. Meltwater from the Fimbul Ice Shelf is thought to contribute to the water mass formation in the eastern Weddell Sea and also to influence

the deep convection in the Weddell Sea. The work that is presented in this manuscript is therefore important, it contains new and unique data and should be published. However, before publication the paper needs some revision. My main concern about the scientific content is about the choice of source water masses. I think the authors must justify this better. I also think the manuscript is hard to read, and I am sure the authors could express themselves more clearly. I have marked the -accepted subject to minor revisions- box, but this depends somewhat on the authors answer to my question of source water masses. If they can not justify their source water masses well enough, they should redo their estimates with other source waters. I guess this would be more like a major revision.

We have revised the paper and hope that it is now clearer and easier to read. We respond to the question of source water masses below, and also in response to Reviewer 2's points about the sea ice end member. The calculations have been redone as suggested.

I dont think the authors have justified well enough the choice of source water masses. Glacial melt and WDW are both obvious. But the third one is sea ice. What about precipitation into the water. Is this negligible or is it somehow included in the sea ice? I guess that precipitation may also be due to snow drifting off the ice shelf edge. I can not find any discussion of this, although precipitation is mentioned a few places as a process that may be important for water mass formation. The sentence starting on page 715 and ending on 716 reads: -Salinity is similarly affected by mixing–direct local precipitation and melting of winter snow -. Still precipitation is not included as a source to the oxygen isotope ratios. I would like to know why this is not important. I think the authors should do more in convincing the readers of the paper that their three-end-member mass balance is capturing the processes going on. If precipitation is not included they should show that it is negligible.

Ideally the effect of precipitation would be explicitly included, however with the three

OSD
4, S383–S390, 2007

conservative quantities we have available (salinity, O18 and mass) it is not possible to explicitly account for more than three source water masses. We have therefore clarified in the paper that where meteoric water is identified, it can be either from precipitation or glacial melt water. We must then invoke physical oceanographic arguments to distinguish between these - so we identify the higher meteoric fractions near the ice-shelf-base as glacial inputs, while the lower (but still significant) meteoric fractions in the remainder of the upper water column are likely to have significant precipitation inputs. We have also added a discussion of the expected O18 values of precipitation inputs.

Figure 1: The regions of grounded ice should be included in the figure.

Regions of grounded ice have been added to Figure 1 as suggested.

Second paragraph in section 4: WSDW, is that Weddell Sea Deep Water? What is then WDSW? Maybe it should be WSDW? However, it is probably not a spelling error either as WDSW is formed near Amery and WSDW in the southern Weddell Sea. Please spell out what WSDW and WDSW means.

This was a typo and should have been WSDW. However we acknowledge that the terminology is potentially confusing, since we are referring to water of Weddell Sea Deep Water properties, that might not originate in the Weddell Sea. We have revised this section to make this clear.

First paragraph in section 5: It is not so easy to understand what the authors want to say with this section. For instance the sentence: 'the figure shows the temperature minimum into which the ISW will mix'. What does this really mean? What I understand by the section is that the shelf break stations west of the ice tongue contains a water mass that is a mix between the shelf break stations east of the ice tongue and the ISW.

OSD

4, S383–S390, 2007

If this is what they want to say with this section, I think they should write using a clearer language, more to the point. Why start with the conclusion of Nicholls et al that the source to the ISW is found in section F, if what they want to say is simply that west of the ice tongue water masses are influenced by ISW, while east of the ice tongue they are not. –Actually, after reading the abstract I finally think I understand what the authors want to tell with this paragraph. The sentence in the abstract reads: 'Just downstream of the FIS we observe locally created ISW mixing out across the continental slope'. This sentence is quite clear and it should be included in the paragraph in section 5. The paragraph should also start by going right to the point. Only in the last sentence of the paragraph they say what they want to tell the reader, but it drowns in all the words early in the paragraph. I suggestion is to start the paragraph by saying something like: 'The data also shows clearly that locally formed ISW mixes out across the continental slope'. Then they can start with telling how we can see this. Writing it this way would make it a lot easier to read, as the reader know what the authors want to show, before going into the details of the different stations and data.

We have revised this paragraph as suggested and hope that the result is clearer. We also removed some of the information about which stations are plotted to the figure caption, so that we can focus on the message.

Reviewer 2

Specific comments: 1. Introduction: line 22, page 711, the term 'Jutul Basin' I have not found on maps from the Norwegian Polar Institute of the glacial upstream of Jutulstraumen (the ice stream). It was used by Smedsrud et al (2006) to cover the sub ice shelf cavity basin south of the sill that they also termed the 'Jutul Sill'. If 'Jutul Basin' has been used before 2006 to cover the upstream glacial basin a possibility would be to call the subice shelf basin 'Fimbul Basin'. But one should indeed try to keep the names concise. This also should apply to the ice tonuge that pretrudes north from the Fimbul, it's name is 'Troll tunga' and it last had a major break off in 1967. No proper citation on

OSD

4, S383–S390, 2007

that one tough.

We have adjusted the naming of the features as recommended.

3. Hydrographic properties. Generally fine, but one aspect not included is that one would expect the "normally" westard flow in the area to follow constant f/H contours, contours of constant watercolumn depth (Figure 12 in Nost 2004). This should make it somewhat difficult for the coastal current to flow directly below the ice toungue. But if this takes place, which it probably will do to some degree, one would also expect the current below the ice shelf front to make iot directly into the cavity on the eastern slope of the sill.

We have included a brief discussion about the way in which f/H contours would expect to guide the water flow from the east. As the reviewer notes, the water could not pass directly beneath the tongue. It presumably is diverted to the north until it finds an appropriate water column thickness. A study of the contours of water column thickness suggests that water from the eastern shelf could in principle enter the cavity, but water from greater depths (shelfbreak and beyond) would have access prohibited. We have included this in the text.

4. Oxygen isotope ratios. Here I agree with the other reviewer in that one should seek better estimates for the sea ice values, both in d18O and salinity. Eicken 1998 is a good place to start. As the area outside the Fimbul is often ice-free in summer, one would indeed expect higher sea ice salinity of the first year ice than 3 psu.

We have looked again at the literature and agree with Reviewer 2 - the sea ice end member salinity we chose was probably too low. Multi-year ice in this region of the Antarctic is not widespread, so the melting sea ice was probably formed in the previous winter season. We use a new salinity more appropriate for first year ice of 6 psu +/- 1.1 (with reference to Eicken 1998). We have considered

OSD

4, S383–S390, 2007

the effect of this uncertainty in our three end member mass balance, and found that our calculations are not unduly sensitive to it - the revised uncertainties are given in the text. The mass balance calculations have been redone, which has altered the fractions and uncertainty estimates a little, but leaves the main findings intact.

5. Discussion and Conclusion. Here a discussion of the hydrography of 2005 compared with earlier results is clearly missing. For exapmple is a CTD cast from Foldvik et al 1985 (taken in January 1979) today located below 'Trolltunga'. At this location the 0 degree isotherm was at 589 m depth, only located 20 km north of the sill. Some of the stations occupied by the AWI Greenwich meridian section also come very close to the shelf, and should be of relevance to the Discussion about the chance for having WDW in the cavity below Fimbul.

We have obtained the paper referred to here. However we are sorry to say that we did not find it greatly helpful. Although their Figure 13 does show a CTD station in the area, no precise location is given for this station, nor is it shown on the map. The location is given as 'some 2 km outside the ice shelf'. The depth of water is about 2250m. Therefore this station is in deeper water than any we discuss here. Because the isotherms and isohalines plunge so sharply at the continental slope in association with the slope current, precise station locations and water depths would be needed for any meaningful comparison to be made. We have added a note comparing the data with the AWI sections presented by Klatt et al. 2005. However we agree that this topic merits a much more careful analysis that should be the focus of a separate study.

Page 723, line 14. This is not correct in my understanding. The outflow of ISW from the Fimbul cavity should not be guided by the sill. The ISW water must form a plume like feature and be guided by the sub-ice-shelf draft (Figure 13 in Nost 2004). This would tend to guide outflow along the draft of jutlustraumen along the Greenwich meridian, or along the western edge of the cavity along 2 deg W. This should indicate that station 9

OSD
4, S383–S390, 2007

EGU

would get a signal both from the eastern area of the entire Fimbul ice shelf, as well as from the ice tonuge (Trolltunga).

We agree that a relatively buoyant plume would be directed by the basal topography (although the relatively dense flow of ISW seen on the western slope of the sill does, in fact, appear to rest against the sea floor slope). The reviewer argues that any buoyant ISW from the eastern ice shelf cavity would, to a degree, be gathered to the north by the north-south running basal ice keel, ultimately to spill westward in the area of station 9. Thus station 9 would see ISW from the tongue and from the eastern cavity beneath the ice shelf. In point of fact, Elin Darelius and Anna Wahlin recently published a paper quantifying the flux of dense water that can be directed downslope by a ridge in the continental slope. When we applied their analysis to the inverted situation of the ice shelf base we found that the capacity of the keel along such a gentle slope is very small, only a few hundred cubic metres per second. As a result, we maintain (but for altered reasons!) that the ISW seen at station 9 is most likely to originate from Trolltunga. The text has been modified accordingly.

References are OK, but these, and others, should likely be added; Eicken, H. Deriving Modes and Rates of Ice Growth in the Weddell Sea From Microstructural, Salinity and Stable-Isotope Data, 89-122. Ed: Jeffries, M. O., Antarctic Sea Ice: Physical Processes, Interactions and Variability, AGU, 1998, Antarctic Research Series

This reference has been added.

Foldvik, A. and Gammelsrod, T. and Torresen, T.,"Physical oceanography studies in the Weddell Sea during the Norwegian Antarctic Research Expedition 1978/79", Polar Research, 1985, vol 3, 195-207.

This paper has not been added because we were unable to make a meaningful comparison with the CTD station plotted therein.

OSD

4, S383–S390, 2007

Figure 2 is too small, it is hard to see both numbers, depths, and iso-lines.

We have increased the font size and line weighting for the axis labels, contour scale and station numbers. We suggest that in the printed version the figure needs to be as large as possible for clarity.

Figure 5: Very difficult to see the difference between red and magenta in my printed version. It should be better to also use different symbols.

We have altered the colours to make the difference clearer, and we have also used different symbols to try to make the lines more distinct when reproduced in black and white.

Figure 6: The color does really not add much of value here. A gray scale would have done the same job, but maybe this is not of much concern in an on-line journal these days. Just remember there are a good number of colorblind persons out there. Also I think it is a good rule that papers should be OK to read also printed on a black and white printer, or copied on a B/W copy machine. The cost of printing in color is a a lot higher, and now-days this is mostly covered by our own institutes, not the journals.

We have tried a black and white (greyscale) version but think that the colour makes it clearer. We tried photocopying the colour version in black and white and it seems ok because the colour scale chosen goes from dark to light shades.

Interactive comment on Ocean Sci. Discuss., 4, 709, 2007.