Ocean Sci. Discuss., 9, C1714–C1727, 2013
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Ocean Science Discussions

Interactive comment on "A modelling study of the hydrographic structure of the Ross Sea" *by* M. Tonelli et al.

M. Tonelli et al.

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Response to referee #3

I would like to thank reviewer #3 for his helpful and very constructive comments. I have accepted all of them and introduced the comments and suggestions in the text

The point-by-point response follows:

"There isn't enough information given on how the OMP is used. None of the terms in eq. 1 are defined and, although most are obvious, is "O" supposed to be Oxygen and "PV" potential vorticity? No mention of oxygen is given (or whatever "O" is) and the one brief mention of potential vorticity (line 16, pg. 3441) does not discuss at all how the PV is calculated or what value of PV is used to define the different water types"

The reviewer is correct. The OMP equation was re-written and properly explained in the text. The SWT contributions or fractions xi for each data point are obtained by finding the best linear mixing combination in parameter space defined by temperature (θ), salinity (S) and potential vorticity (PV) which minimizes the residuals in a non-negative least squares sense (R).

x_1θ_1 + x_2θ_2 + x_3θ_3 = θ_Obs + R_θ

x_1S_1 + x_2S_2 + x_3S_3 = S_Obs + R_S

x_1PV_1 + x_2PV_2 + x_3PV_3 = PV_Obs + R_PV

x_1 + x_2 + x_3 = 1 + R_mass

where the observed values of temperature TObs , salinity SObs and PVObs with their respective residuals R define the columns on the right-hand side. The values Ti , Si and PVi (i = 1, ..., 4) represent the predetermined (known) parameter values of the 3 source water types for each parameter. The last row expresses the condition of mass conservation. In a continuously stratified system in geostrophic equilibrium potential vorticity PV can be shown to be given by

PV = Nˆ2 f / g

with N the Brunt - Väisälä frequency, f the Coriolis frequency and g the acceleration of gravity. This quantity can be evaluated from the temperature and salinity information supplied with the data, and the OMP analysis package includes the option to have potential vorticity calculated from the supplied data set.

“There is no comparison of Figure 4 to observations. Couldn’t the authors use the Orsi and Wiederwohl climatology to make a similar section from observations?”

We have analyzed a section with observations from NODC for comparison. Figure 2 shows TS diagrams for NODC and modeled data; Figure 3 shows temperature and salinity cross sections for NODC and modeled data; Figures 4 to 7 show OMP results

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for NODC and modeled data.

“The results are limited to a single cross-section. If the utility of the model for creating AABW is to be judged, than I think it would be helpful to look at quantities over the entire Ross Sea shelf. The Orsi and Wiederwohl TS plot that Fig. 3 (which, I think, is just along 165W) is compared to is for the entire Ross Sea. What about comparing actual temperature and salinity cross-sections? Volumetric comparisons of water masses (observation based volume estimates are available in Orsi and Wiederwohl)?”

The reviewer is correct in that the choice of 165W for a representative TS-diagram for the RS is not adequate to evaluate the denser water masses. This point was also raised by reviewer #1 and T/S for the western continental shelf area is examined for NODC and modeled results. Salinity and temperature cross-sections were added (new Figure 3).

“The paper does examine the water masses (CDW and Shelf Water) that go into making AABW, but never directly looks at how the model is doing in creating AABW itself.”

Investigation of the AABW formation with a model with explicit ice-shelves is underway and will be analyzed in a companion paper for the whole Southern Ocean.

Specific comments

“3432/9-11: I don’t think the details about the CORE normal year forcing need to be in the abstract. I suggest removing this sentence.”

Details were removed from the abstract

“3433/18 and Figure 2: I think Cape Adare and Cape Colbeck should be marked on a figure somewhere. I suggest adding an inset to figure 2 that shows a blowup of the Ross Sea (or just showing the Ross Sea as figure 2) with Cape Adare and Cape Colbeck labeled and the cross section shown.”

What is now Figure 2 (the model domain map) will be shown as Figure 1; a panel

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showing just the Ross Sea, labeling all the features that come up in the text (e.g., Cape Adare, Cape Colbeck and the RIS). Figure 1 was removed, since it is only cited once to describe the dense water formation under the RIS.

“3433/21-22: The current along the continental slope is not the eastward flowing ACC, but rather the westward flowing southern limb of the Ross gyre (as the authors mention previously).”

The reviewer is correct. It was miswritten and corrected to: “The southern limb of the Ross Gyre follows the continental slope carrying the CDW from east to west...”

“3433/26-3434/2: The Ross Sea Polynya likely produces much more ice than the Terra Nova Bay (TNB) polynya (Martin et al. (2007), Journal of Marine Systems) and has a major effect on HSSW formation. It should probably be mentioned along with the TNB polynya.”

The impact of the Ross Polynya is mentioned in the text: ”HSSW production results from the extensive brine rejection in the RS polynya..”; “... the Terra Nova Bay polynya, whose annual recurrence provides salt fluxes large enough to increase the water column salinity and to strengthen the formation of the HSSW, primarily related to the RS polynya”

“3435/2: I think a more up to date reference for ROMS (e.g. Haidvogel et al., 2008) should be used.”

The reviewer is correct and we have added Haidvogel et al., 2008.

“Section 2.1: Was tidal forcing used in the model?”

Considering that this was an initial approach to the impact of ice-shelves, we opted to not include tidal forcing at this time. This is explicitly stated in the text.

“3435/5-6: I think it’s a little deceptive to state that the resolution reaches "less than 5 km over the continental shelf". The resolution is less than 5 km at the model southern

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boundary at 85.5S, but the zonal resolution at the southernmost open ocean point (78S in the Ross Sea) is 11-12km. I don't know how meridional resolution is changed w/ latitude, but I suspect the meridional resolution at 78S is similar to the zonal resolution. I suggest rephrasing this to something like "reaching less than 5 km at the southern model boundary"

The reviewer is correct, this was rephrased in the text as suggested "reaching less than 5 km at the southern model boundary"

"3435/28: I don't think the Holland and Jenkins (2001) reference is appropriate here a it is more about adding an ice shelf to an isopycnic coordinate model than the heat and salt fluxes in any kind of sea-ice model."

The Holland and Jenkins (2001) was removed from the text

"3435/28-3436/7: What kind of mechanical friction is used between the ice shelf base and the top water surface?"

At the ice shelf water interface we apply a quadratic drag similar to the bottom drag.

"3437/5: I think Fairall et al. (1996) is COARE2.5. Doesn't ROMS now use COARE3.0? If so, I think the reference should be Fairall et al. (2003)."

The reviewer is correct and the reference Fairall et al, (2003) substitutes the older one.

3437/eq.1: As mentioned above, please explicitly define all the terms in this equation. Also, if this what is used, where do "O" and "PV_Obs" come from?

All the terms of eq. 1 are now explained in the text.

"3438/11-17: I think the density comparison is actually better than the authors think. Orsi and Wiederwohl used neutral density while it looks like the authors are using sigma-0. If the authors recalculate their TS plot to use neutral density, I'd bet it's a lot closer to what Orsi and Wiederwohl got"

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This point was also raised by reviewer 2. The choice made was to use NODC data to calculate the reference T/S. Figure 2 is redrafted. NODC data were also used to produce salinity and temperature transects and to perform the OMP water masses investigation.

"3440/4-6: These results may suggest that the model is reproducing AABW formation, but then why not explicitly compute the modeled AABW formation?"

AABW presents spatial an temporal variations that require a more careful investigation which is being carried on for the Southern Ocean as a whole and hopefully will be a companion paper.

"3440/16: The authors could explicitly calculate the modeled Ross Ice Shelf basal melt rate and compare it to observed estimates to prove that the basal melting is reasonable."

The ice-shelf parameterization is only thermodynamically active. There is no mass exchange and the volume is static in time. That is why we cannot compute basal melt.

"Table 1: 0.5 C seems cool for end member CDW. I guess that's what the model has (Figure 3), but can the authors speculate as to why the offshelf CDW is that much cooler than reality? Also, do the types for SW and ISW overlap? Is that why Figure 4 shows both 100% SW and 100% ISW in the ice shelf cavity and along the bottom of the open shelf close to the cavity?

In our results the CDW is colder than expected and this is pointed out in the text. ISW was actually separated using HSSW, but shown alone since this is a eastern RS section, the reviewer is correct and overlapping 100% is physically impossible.

A new separation scheme will better characterize SW: HSSW and ISW. We first run OMP to separate ISW, HSSW and LSSW over de continental shelf. On a second run we separate SW, CDW and AASW along the 175°E transect up to 65°S. This was performed for our modeled results and for NODC data for comparison.

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"Figure 1: I think this figure needs to include an extra line below the farthest offshelf ISW line showing HSSW going offshelf (as in Figure 1 of Smethie and Jacobs). The figure as drawn implies that AABW is formed just from ISW and CDW, when in fact the volume on the continental shelf of HSSW is much greater than that of ISW (Orsi and Wiederwohl) and the HSSW is a critical component of the AABW."

Figure 1 was removed since it is cited only once in the text.

Figure 4: caption is now fixed.

Technical Corrections.

All the technical corrections were introduced in the text. 3432/8: 3433/11: 3433/15: 3433/18: 3434/17: 3435/24: 3437/2: 3438/2: 3441/7: 3444/2.

Interactive comment on Ocean Sci. Discuss., 9, 3431, 2012.

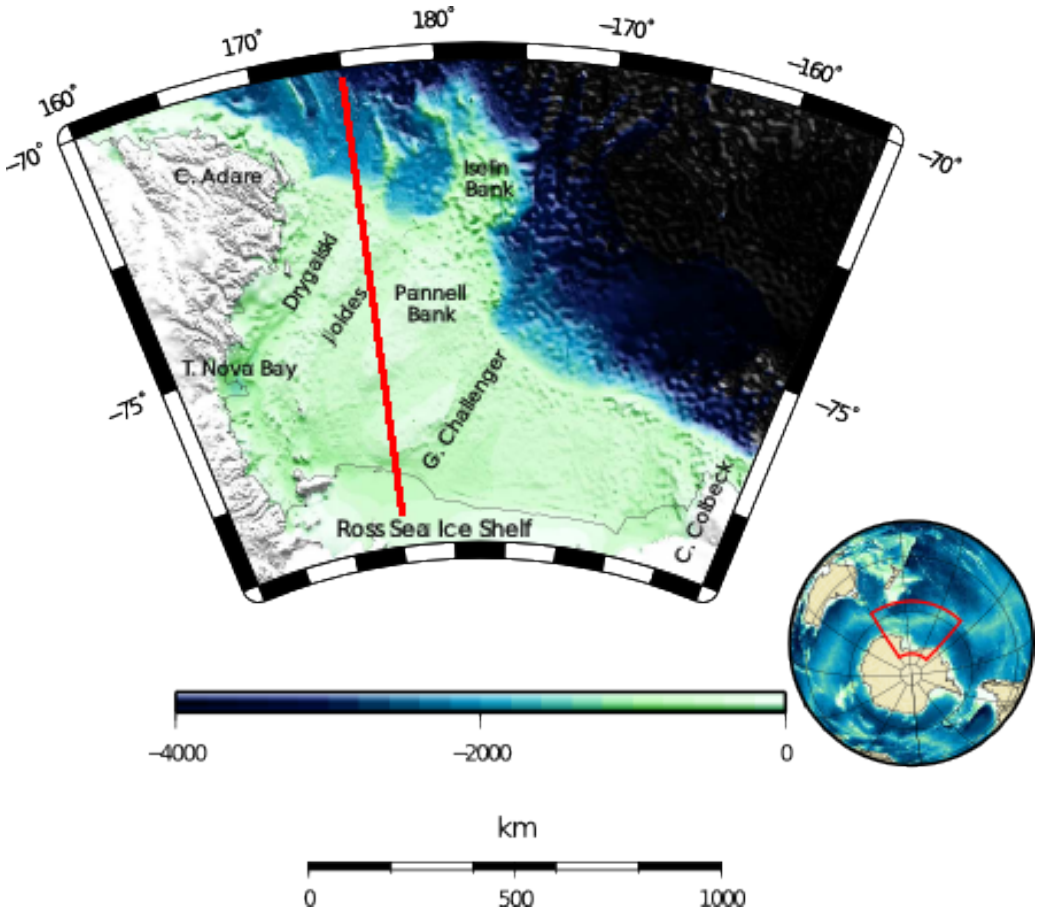

Fig. 1. Ross Sea bathymetry with the principal geomorphological features marked. The red line marks the analyzed section at 175°E.

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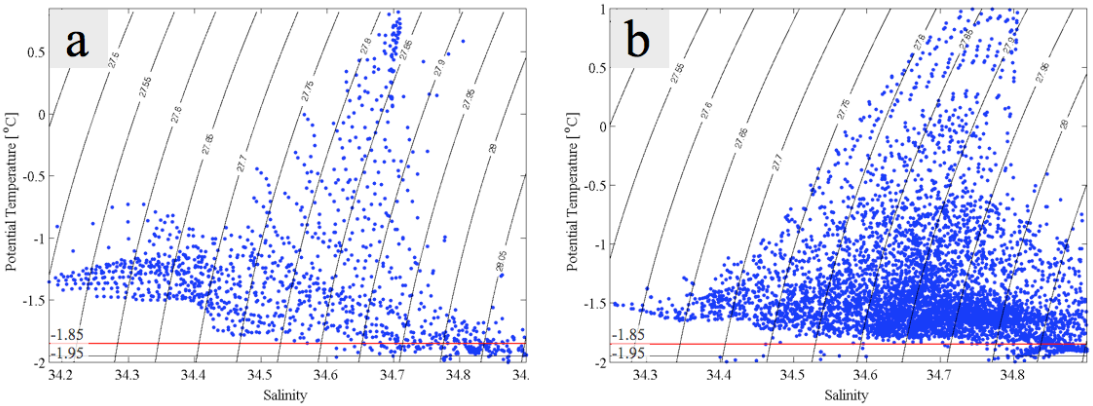

Fig. 2. TS diagrams with data from the western continental shelf of the Ross Sea. Diagram "a" represents NODC data and diagram "b" represents modeled data.

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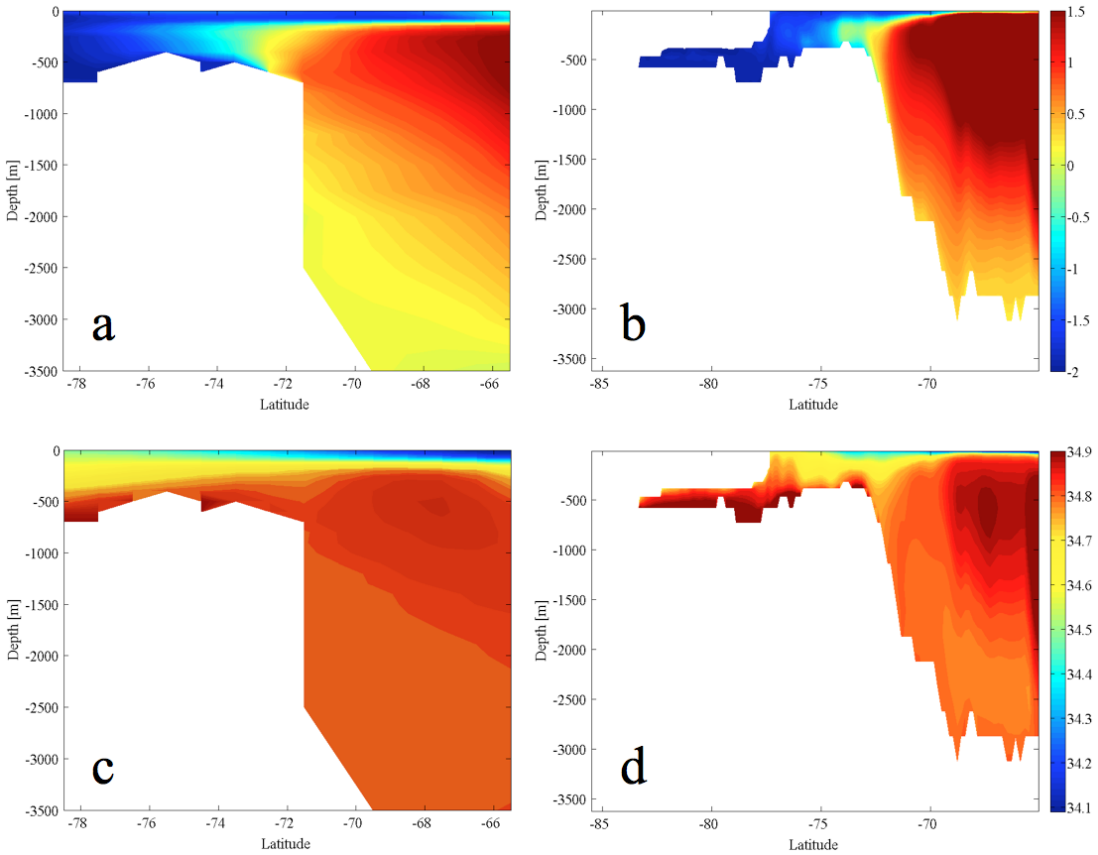

Fig. 3. Temperature and salinity cross sections at 175°E. "a" temperature from NODC; "b" temperature from modeled data; "c" salinity from NODC; "d" temperature from modeled data.

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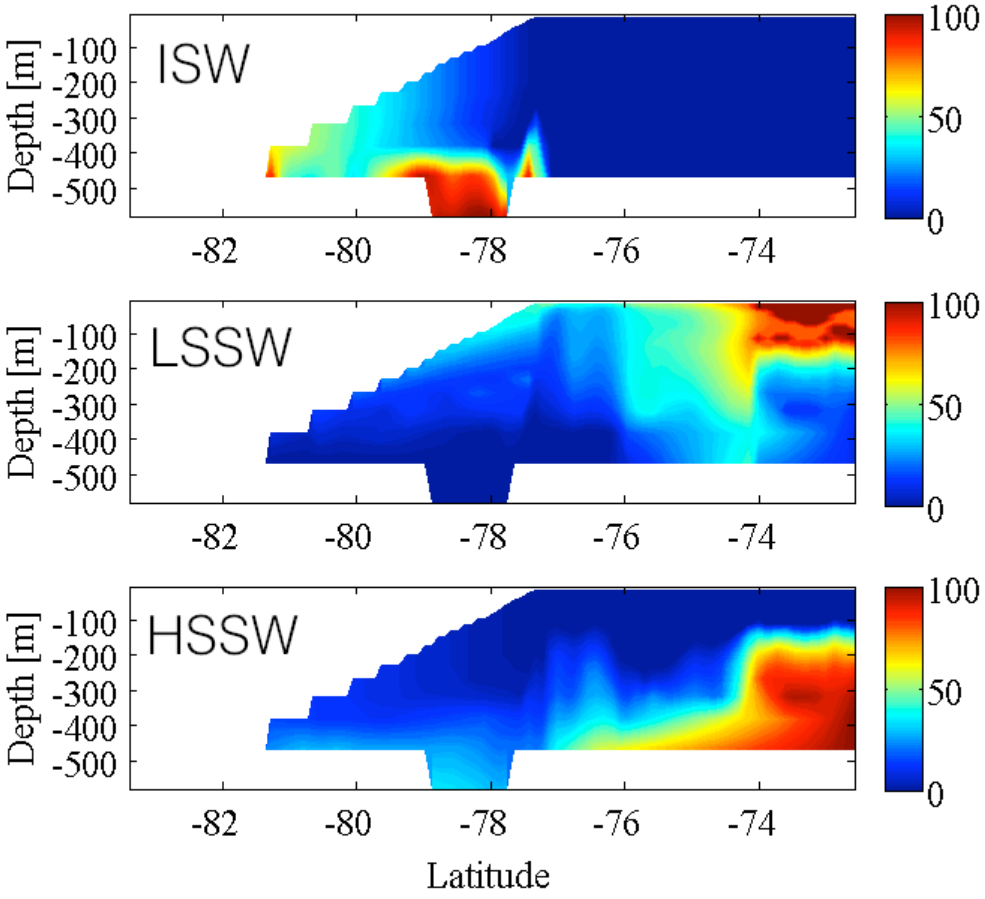

Fig. 4. Water masses spacial contribution (%) over de continental shelf at the meridional section along the 175°E from modeled data. Ice Shelf Water (ISW); Low Salinity Shelf Water (LSSW) and High Salinity Sh

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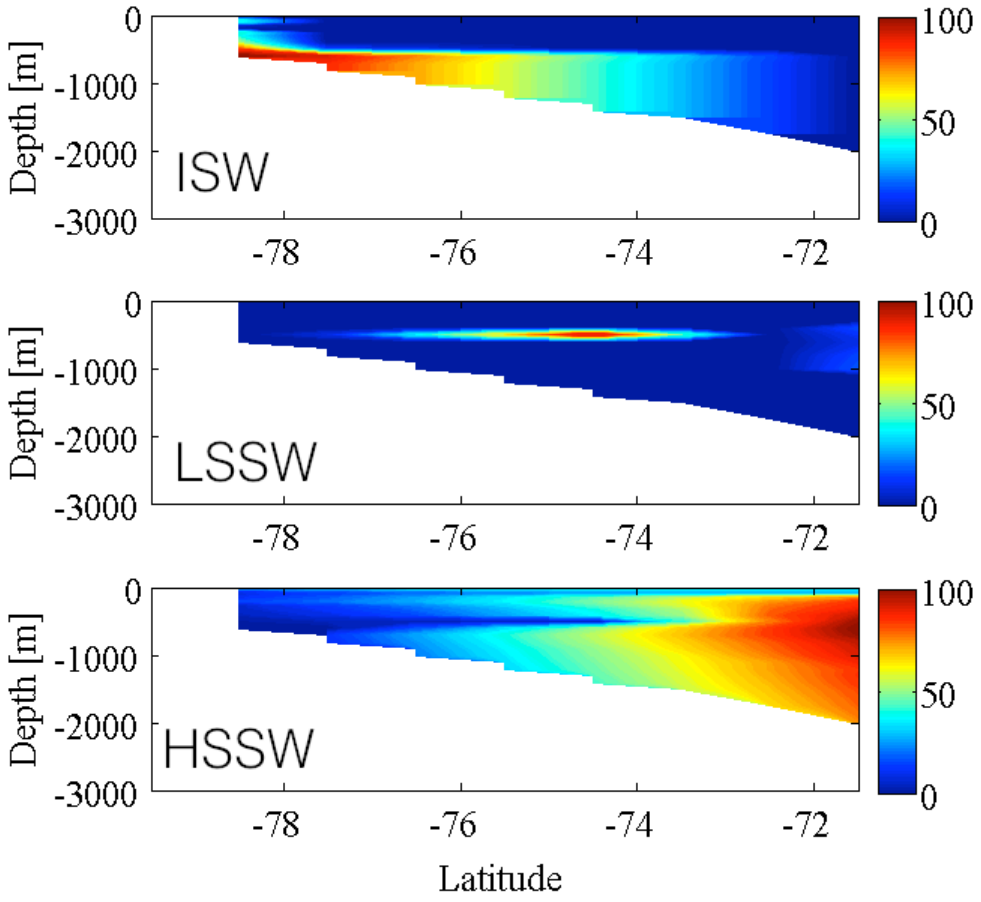

Fig. 5. Water masses spacial contribution (%) over de continental shelf at the meridional section along the 175°E from NODC data. Ice Shelf Water (ISW); Low Salinity Shelf Water (LSSW) and High Salinity Shelf

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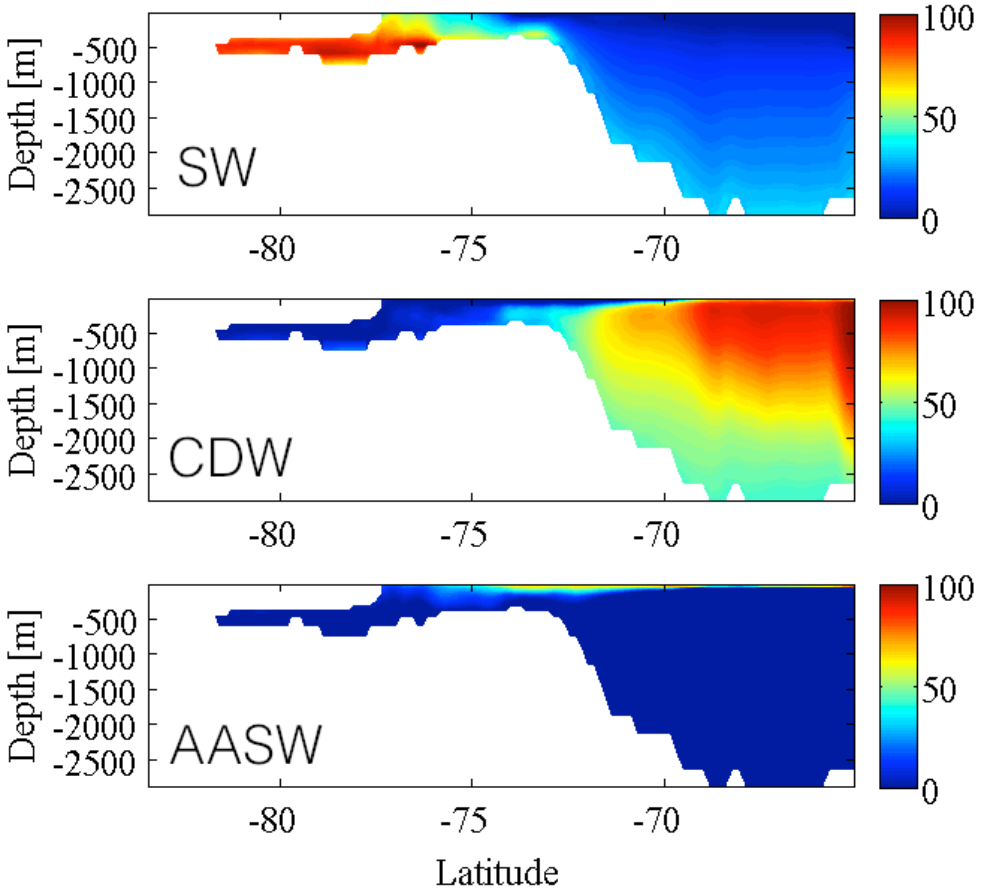

Fig. 6. Water masses spacial contribution (%) along the meridional section at 175°E from modeled data. Shelf Water (SW); Circumpolar Deep Water (CDW) and Antarctic Surface Water (AASW).

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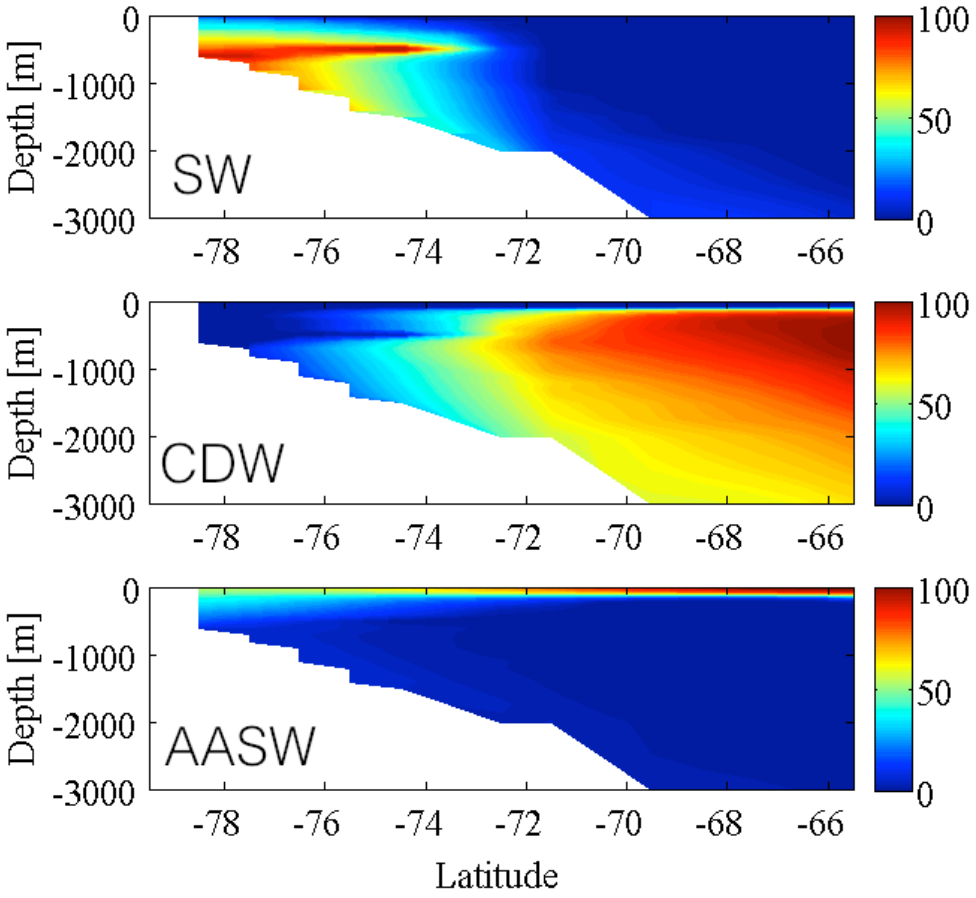

Fig. 7. Water masses spacial contribution (%) along the meridional section at 175°E from NODC data. Shelf Water (SW); Circumpolar Deep Water (CDW) and Antarctic Surface Water (AASW).

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