

Interactive comment on “On the export of dense water from the Weddell and Ross Seas” by R. Kerr et al.

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We thank reviewer #1 for suggestions and very constructive comments, which have significantly contributed to improve this m/s. Our reply following the list of the reviewer comments.

Authors Responses (AR) to Reviewers:

Referee 1:

General Comments

The authors present results from a 20-year model run focusing on seasonal and inter-annual variability of transports and properties of Antarctic bottom water from the Ross

C724

and Weddell Seas. As the authors point out, such a long-term study is not feasible using only observational data (at this point anyway) so models offer an alternative to examining interannual variability. This is a timely study, given the increasing published evidence of long-term changes in the thermohaline properties of the Ross and Weddell Seas. Generally, I found the ms to be worthy of publication, but there are some sections which I found difficult to follow, and I had a very hard time viewing some of the figures. These problems I'm sure can be easily rectified, and so I recommend publication with the minor revisions indicated below.

Specific comments 2 Model description and forcing: It is well known that export of deep and bottom water from the Ross Sea is particularly sensitive to tides (Padman, et al. 2009). How well does the model chosen for this study represent the effect of tides on the exported bottom water properties and transports?

AR: The OCCAM model does not include tides at all. We agree that it would be better to include tides, but to our knowledge there are no long runs of high resolution ocean - ice models including tides. We have added a sentence in the m/s to highlight this point. Please, see below. The lack of tides to influence the exchange between the shelf and the deep ocean is one reason why we do not discuss here the volume flux spilling off the continental shelf.

"Additionally, export of deep and bottom water from the Ross Sea is particularly sensitive to tides (Padman et al., 2009), however the model output used here does not allow investigation of this influence."

Why is sea ice thickness set to 1.5 m everywhere? This seems too thick, especially for the Weddell. And the snow cover of 0.15 m seems too small, especially for the western Weddell and Amundsen Sea regions, where snow cover routinely exceeds 1 m. Maybe this is fine for initializing the model.

AR: The initial conditions were taken from the OCCAM sea ice model report (see Aksenov 2002) and those are the conditions set for this particular run of the OCCAM

C725

Model. As we did not run the model we had no control over those parameters. We rephrased the sentence to clarify, please see below.

"The initial condition to initialize the model for sea ice in the Southern Ocean was set to 1.50 m thickness. . ."

The model bathymetry is based on a very old data set. In particular, the shape and slopes of the NW Ross Sea continental shelf-slope break in the digital bathymetry data sets were greatly revised in the years after 2002. Getting the bathymetry right is important in regions where the Rossby radii are quite small, and where the outflow of deep and bottom water is strongly influenced by the bottom topography. Would the use of a more appropriate model bathymetry influence the results presented?

AR: Although not directly stated, some sills depths were manually corrected in the model for this particular run (see for instance the OCCAM manual or Renner et al. 2008). However, although we acknowledge the importance of the bathymetry to correctly represent the bottom water outflow from the source regions, we do not believe that the bathymetry dataset is greatly influencing our results. Observing a latitudinal section of the OCCAM's bottom volume transport spilling off the shelf (not shown in the m/s) in the NW Weddell Sea and comparing with results obtained from Muench & Gordon (1995; their Fig. 8) at an approximately similar area, the main direction of OCCAM's volume transport in this area qualitatively agrees with that showed by M&G 95. This fact gives confidence that the model is representing that phenomenon correctly.

We included a sentence regarding this question in the m/s. Please see below.

"It is well known that the shape of the ocean floor and, specially, the seabed corrugations act to steer the main downslope flow of dense shelf waters towards the deep ocean, thus impacting directly the contribution of AABW. This was recently highlighted by Muench et al. (2009) for the Northwestern Ross Sea. They point out that corrugations enhance entrainment and reduce along-slope speed of the dense outflow. Thus, the authors show the importance of considering small-scale local topography when

C726

modeling dense outflows. The bathymetry used in OCCAM does not benefit from recent high resolution swath bathymetric surveys around the Antarctic and therefore may be locally incorrect and/or too smooth. However, comparing a latitudinal section of the OCCAM's bottom volume transport spilling off the shelf (not shown) in the Northwestern Weddell Sea with results obtained from Gordon and Muench (1995; see their Fig. 8) in an approximately similar area, the main direction of OCCAM's volume transport in this area agrees with that shown by Gordon and Muench."

3 Southern Ocean representation Figure 2. This figure is too small to convey the important information embodied in the graphics. Even viewing it on the computer and enlarging it, I am still unable to see important details in the T/S diagrams, and I'm unable to read the water mass labels and density values. This figure deserves more space, as it's essential for evaluating the success of the model in representing the water mass characteristics.

AR: We agree that the figure was too small as it is presented in OSD. However, this is more a technical problem that must be corrected by the journal technical staff. We have sent an A4 paper size figure to be published in OSD. Thus, we kindly ask to the Editor to consider enlarging this figure in the final m/s.

Fig 3 - also too small. I can't see the increase in surface later temperature to 0C described in the text. In addition to making these larger, perhaps blowup figures of the Weddell and Ross shelf areas would help the reader discern the details of the high salinity distributions on the shelves, which are so crucial to the deep water formation processes.

AR: As stated above, we kindly ask to the Editor to consider enlarging this figure in the final m/s as well. However, we have rephrased the sentence as below. "The temperature slightly increases, but remains below 0°C, along the continental margin of the Weddell and Ross Seas. . ."

5 Correlations I had a difficult time following the explanation given for the lag-0 correla-

C727

tion between AABW export and AABW source water T/S properties, especially in light of Figure 14, which clearly shows a non-zero lag between changes in the properties in the SW Weddell and those in the Weddell Export Section. I suspect my trouble with this may stem in part from the small size of the panels in Fig 10 and Fig 11; I could not see many of the features being discussed in the text. It might be interesting to somehow present the lagged cross correlation between the transport and the salinity anomaly in say, a representative box in the SW Weddell. There may be structure in the lagged correlations which might be related to the source-export transit time. Figure 12 is also too small, Maybe circumpolar maps are not as useful here as individual maps of the Weddell and Ross?

AR: Following the reviewer's suggestion and in order to clarify this point, we now plotted the cross-correlation results only in the Weddell and Ross Sectors instead of circumpolar maps of the correlations. Thus, whereas the m/s in OSD presented only correlations between AABW transports in the Weddell export section and properties at surface and intermediate layers, we now plot both cross-correlation maps related to Weddell and Ross export sections (see new Fig. 11 & 12).

I suppose one way to test the assertion that the lag-0 correlation is due to gyre-scale wind field changes would be to calculate the correlation directly between transport and the wind.

AR: As this suggestion was indicated by both reviewers we performed a cross-correlation analysis between zonal wind stress and AABW export in the NW Weddell Sea. Thus, a sentence was included in the m/s talking about lagged correlations between the wind stress and AABW export time series. Please see below.

"To show dynamical link between AABW export and surface variables we performed a lagged correlation between zonal wind stress (defined here as the annual mean between 60°S and 65°S - 040°W and 020°E) and AABW export time series in the Weddell Sea export section. The result (not shown) unveils the highest correlations

C728

with a five months lag (36%) and around lag-0 (25-35%). The former was the same period of influence previously reported by Jullion et al. (2010) study, which revealed that the variability in the wind stress field over the Weddell Sea leads changes in AABW properties in the Eastern Drake Passage by approximately five months. Moreover, the same study suggested that the variability in AABW properties over that same area could be controlled by AABW export from the Weddell Sea."

Technical comments P1660 line 23 _"... and almost uninterrupted properties" perhaps "measurements" or "observations would be a better choice than "properties"

AR: Done. We change the word "properties" to "measurements".

I 25: "historical observed subsurface Southern Ocean databases lack long historical records" the second "historical" is redundant"

AR: Done. The second word "historical" was deleted.

"... are seasonally biased and suffer from scarcity of data in some areas of difficult access due to environmental conditions and/or logistic operations, therefore modelling results are an alternative way to study the impact of source water variability on AABW export".

Perhaps make this two sentences. drop the "therefore.."

AR: Done. We removed the last sentence.

P1673 lines 25: "Similar negative values of volume transport anomaly is observed during this year" should be " are observed"

AR: Done. We have corrected the grammar.

Reference cited Padman, L., S. L. Howard, A. H. Orsi and R. D. Muench (2009). "Tides of the northwestern Ross Sea and their impact on dense outflows of Antarctic BottomWater." *Deep Sea Research Part II: Topical Studies in Oceanography* 56(13-14): 818-834.

C729

AR: The reference was included in the m/s.

Interactive comment on Ocean Sci. Discuss., 8, 1657, 2011.