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Ocean Science Discussions

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Interactive Comment

Interactive comment on "Modelling the variability of the Antarctic Slope Current" *by* P. Mathiot et al.

P. Mathiot et al.

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Anonymous Referee #2 Received and published: 17 February 2011 General comments: This paper describes numerical experiments of the volume flow of the Antarctic Slope Current. The model study performed is fine, but the paper is not presented in an optimal way, and more analyses should be added. I agree with reviewer #1 in that a better focus on what was actually learned from the model runs is needed, and suggest how to change the outline below.

The figures are generally fine, and illustrate the main points. A figure on the properties of the ASC should be added.

The major revision needed here is on the structure of the paper, and doing away with the overload of not meaningful acronyms.

1 This is the worst example I remember to have seen so far. The only two acronyms that bear any meaning are the WIND and SEASO ones. The others could all be deleted. This is a fairly short paper, and it would generally benefit from writing names out in full. ASC is the only one I suggest to keep. Give the tests names like "no season", or "mean wind" or "temperature".

Mathiot et al.: We have changes the names of the runs conducted with the regional model to make then more explicit (REF, WIND, TEMP, and WIND+TEMP, SEASO). Furthermore, we have deleted many acronyms in the text that can be disturbing.

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2 Structure: The paper should be re-organized. The findings are interesting, but I was struggling to remember all the different runs, and sensitivity tests along the way. You should first present your best long run (1950-2000).

Mathiot et al.: We agree with the reviewer that it is more standard to present first the best run and then all the sensitivity experiments. However, we consider that the description of all configurations and forcing fields in a unique section allows finding easily all the information if needed.

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2 bis I also find it strange that different periods where analyzed (1990-2000) and (1985-1989), why not use the 1985-1989 for all runs? I presume you do not have the atmospheric model results for the 1990's otherise that seems like the best period to use.

Mathiot et al.: You are right, to avoid confusion, all the results are now analyzed over the period 1985-1989. We cannot choose the period 1990-2000 because we haven't got computer time to continue the regional simulations performed with the regional model over this time period.

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3 I guess your "standard run" is what you have termed ORCA05. Present these results first. All results, all around Antarctica. Call it the "standard run", or something everybody understands (not an acronym with no meaning).

Mathiot et al.: Part 3 (model resolution) is devoted to the model sentivity to resolution but also explains why we choose a resolution of 0.5° studying the model sensitivity to the forcing. In this way, we think one has to consider all model resolutions with the same weight before choosing the best model configuration for the next part.

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4 It is still not OK if you explain why someone termed it ORCA, perhaps it is the name of the model. The reader gets confused with such acronyms.

Mathiot et al.: Yes, ORCA is the name of the global configuration of the NEMO model. The same name is used in all the papers using this configuration (Barnier et al., 2006) and in other studies using ORCA025, ORCA05, ORCA2 as Renner et al. (2009), Treguier et al. (2007), Biastoch et al. (2008), Brodeau et al. (2010) . . . We have modified the section 2.2.1 and 2.4 to avoid any confusion:

“... The global configuration (named ORCA) of the NEMO model is based on a family of tripolar grids, ORCA grids. . . . The ORCA configurations (shared by the ocean and sea ice models) selected here have an effective resolution, which gets finer with increasing latitudes, of ∼222 km (2° resolution, ORCA2), ∼111 km (1° resolution, ORCA1), ∼55.5 km (0.5° resolution, ORCA05) and ∼27.8 km (0.25° resolution, ORCA025) at the equator. The grid is finer at 60°S (e.g. ∼13.8 km in ORCA025). . . .” and “... To study the sensitivity of the ASC to the model resolution and atmospheric forcing, two series of simulations are conducted. The first one corresponds to global simulations performed in ORCA configuration (Penduff et al., 2010) at four resolutions over the last 50 years (Table 1): 2° (ORCA2), 1° (ORCA1), 0.5° (ORCA05) and 0.25° (ORCA025). . . .”

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5 After you have presented your best model run, then present the differences for the other resolutions in a separate section. You can still use most of your original figures. Also discuss a little more why the better resolution run (ORCA25, but call it "the fine scale run" or something better) is not better, as one would expect.

Mathiot et al.: as discussed in Q3, we have decided to keep the structure as before in order to avoid to repeating two times the same information (first for the standard run, and then for the sensitivity experiments). We also discuss in more details why ORCA025 is not better. See text in section 3.

“. . . In ORCA025, the ASC has a different behavior than in the other simulations. The transport does not increase continuously between 140°E and 90°E as in ORCA2, ORCA1 or ORCA05. The mean transport in this area is also lower than in ORCA05. The wide gyre between 135°E and 100°E simulated in ORCA05 is smaller in ORCA025 (7 Sv). Furthermore, the ASC transport presents many large peaks due to stationary eddies in the Australian Antarctic Basin (Fig. 3). As far as the PET is concerned, there is no recirculation along the Kerguelen Plateau in ORCA025. All the flow crosses the PET. This feature is characteristic of one large gyre (Weddell Gyre merged with Australian Antarctic Gyre), while two are present in the observations (Roquet, 2009). In the Fawn Trough on the Kerguelen Plateau, ORCA05 is also better than ORCA025. A flow across this passage is observed at 43 Sv (Park et al., 2009). ORCA05 simulates a transport of 39 Sv. ORCA025 underestimates this transport (29 Sv) as shown in Table 2. Simulations carried out with a regional model based on ORCA025 in the Kerguelen Plateau area (Roquet, 2009) indicate that the representation of the details of bathymetry, which are related to the resolution, has a large impact on the oceanic circulation simulated. The number and intensity of the spurious stationary eddies present in the Antarctic-Australian basin using in simulation using a raw bathymetry (instead of a smoothed bathymetry as in the present study; Fig. 3, 4 and 5b) are lower, with lower intensity. With such a raw bathymetry, the transport of the Antarctic Australian gyre and the transport across the Fawn Trough both increase by 5 Sv. Thus, it appears that a large part of the biases observed in ORCA025 are linked with the choice of the bathymetry. . . ."

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6 Reviewer #1 seems to be confused about the length of the runs, something I understand well in this acronym jungle.

Mathiot et al.: All results are now analyzed over the same period to avoid this confusion. The names of the simulations have been changed and we tried to limit the number of acronyms.

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7 The sensitivity runs (1980-1989) with the different forcing are good science, but the presentation is awkward too. You have the above run to compare with. The full atmospheric model forcing is probably "the best" here, but nobody will demand to see a 50 year run using this as the "standard run".

Mathiot et al.: The standard run (named REF) is the same as ORCA05 but on a regional configuration for the period 1980-1989 as stated now in the revised manuscript.

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8 A few other general minor issues are the description of (model) resolution. Often this is done without a 'latitude' or 'longitude' added.

Mathiot et al.: To keep the grid isotropic, the horizontal resolution in $^\circ$ can't be the same at the equator and at 60 $^\circ$S. The model keeps a resolution of 2° in the longitude, the resolution along meridional direction is about 1° in latitude at 60°S. This is now stated in the manuscript in section 2.2.1:

"...The global configuration (named ORCA) of the NEMO model is based on a family of tripolar grids, ORCA grids. The geographical South Pole is conserved and from

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80°S to 20°N, the grid is a regular Mercator grid (isotropic, getting finer at high latitude as the cosine of latitude). Following Murray's (1996) idea, the singularity of the North Pole is treated by changing the coordinate system using two poles. The grid is computed following the semianalytical method of Madec and Imbard (1996). The ORCA configurations (shared by the ocean and sea ice models) selected here have an effective resolution, which gets finer with increasing latitudes, of ∼222 km (2° resolution, ORCA2), ∼111 km (1° resolution, ORCA1), ∼55.5 km (0.5° resolution, ORCA05) and ∼27.8 km (0.25° resolution, ORCA025) at the equator. The grid is finer at 60°S (e.g. ∼13.8 km in ORCA025). . . ."

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9 My last general comment is on hydrographic properties. You have nothing there. I suspects that they are not so good, or that you will "save them" for a different paper perhaps. I suggest you at least add one section where a good climatic mean from observations can be made. There is plenty of data on the World Ocean Database for the Greenwich meridian, so this is a good option. If some other section better illustrates the model performance use that if you will.

Mathiot et al.: We have redrawn Fig. 6 and 7 with the section 0° and we now compare the model results with CTD data AWI 232 and 233 used in Klatt et al. (2005). We added some sentences about this in section 4.1:

" . . . The comparison of hydrographic properties derived from CTD data provided by AWI 233 and 232 moorings with the model results (Fig. 9) shows two behaviors. In surface, the seasonal cycle of water temperature and the temperature gradient between AWI 232 and AWI 233 is weaker in the four simulations than in the observations. At depth, the simulated temperature of the Antarctic Circumpolar Deep Water is too warm (+ 0.6 °C) along the continental slope and at the shelf break (AWI 232 and AWI 233). Comparison between our simulations and the observed section 60°E in summer (Meijer et al., 2010) also shows a warmer water and a weaker temperature

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gradient (not shown). Mathiot et al. (2010) compare the temperature measured during the Broke East Hydrographic Survey between 150°E and 80°E (Bindoff et al., 2000) and ORCA05 simulation and they highlight also a too warm Circumpolar Deep Water (CDW) along the continental slope. Across the Weddell Sea, Renner et al. (2009) noticed the same biases along the Antarctic continental slope at 12 °W and also across all the Weddell Sea in ORCA025 simulation. Clearly these bias in hydrographic properties affect the zonal velocity of the ASC in our simulations. Further hypotheses can be put forward to explain these hydrographic biases: a too low resolution to simulate strong temperature and density gradient, too low sea ice area during summer with DFS3 forcing (due to missing processes in sea ice model or to poor quality of forcing fields), too strong mixing of the HSSW with the CDW in the model and also poor representation of the Antarctic Shelf Water properties. . . .“

TS properties along the continental slope are not well simulated; sensitivity to forcing fields is low expected on the shelf (shallow water). Thus these simulations cannot be used it currently for another paper.

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10 Below, when I write an acronym, it generally means that you should delete it. At least you should spell it out fully the first time. If it is a name it should be spelled with capitalized first letter, not all.

Specific comments: Abstract: This is fine, apart from the acronyms. Both the abstract, and conclusion, should be readable without having read the rest of the paper. This implies that all acronyms should be defined. The only one you should use is ASC. Even ERA40 should be spelled out, but I suggest to remove the acronym and just state "reanalysis" in the abstract. CORE too, and certainly MAR!

DONE

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Both ERA40 and CORE would need proper referencing as well, as you have done for CORE on page 6, line 18. I couldn't find the ERA40 reference at all.

Mathiot et al.: We write in the revised manuscript (section 2.3):

"The second one is provided by a dynamical downscaling of the ECMWF 40 Year Reanalysis (ERA40 reanalysis, Simmons and Gibson, 2000)"

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1. Introduction. page 4, line 2. modelling studies ...

DONE

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2. Experimental design. NEMO ORCA Page 5, line 18. Make sure to specify lon/lat! Here you mean longitude as 1 deg W = 55 km at 60 deg S. But the model resolution is not clear to me. Is it also using 1 deg N ?? Then the delta Y = 110 km ....

Mathiot et al.: To keep the grid isotropic, the horizontal resolution in $^\circ$ can't be the same at the equator and at 60 $^\circ$S. The model keeps a resolution of 2° in the longitude, the resolution along meridional direction is about 1° in latitude at 60°S. This is now stated in the manuscript in section 2.2.1:

"...The global configuration (named ORCA) of the NEMO model is based on a family of tripolar grids, ORCA grids. The geographical South Pole is conserved and from 80°S to 20°N, the grid is a regular Mercator grid (isotropic, getting finer at high latitude as the cosine of latitude). Following Murray's (1996) idea, the singularity of the North Pole is treated by changing the coordinate system using two poles. The grid is computed following the semianalytical method of Madec and Imbard (1996). The ORCA configurations (shared by the ocean and sea ice models) selected here have an effective resolution, which gets finer with increasing latitudes, of ∼222 km (2° resolution, ORCA2), ∼111 km (1° resolution, ORCA1), ∼55.5 km (0.5° resolution, ORCA05) and

~27.8 km (0.25° resolution, ORCA025) at the equator. The grid is finer at 60°S (e.g. ~13.8 km in ORCA025). . . ."

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page 6. first line. What is the purpose of introducing this name PERIANT ??? For a reader it is totally unnecessary, and serves to confuse. Just state that you have used a regional configuration of a global model, and give the references. MAR DFS3 T10Q10 SEASO

DONE

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Section 2.3 and 2.4 should be re-written to follow the new structure of the paper. First present the "standard run" with resolution and forcing. Then describe the forcing used for the sensitivity.

Mathiot et al.: For presentation reasons and to easily find useful information, we think, it is better to present all model configurations in one section, and all the forcing fields in another section.

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3. Sensitivity.... You should first present your best shot at how the ASC flows. This is likely your ORCA05 run.

Mathiot et al.: See Q3 in first page

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3 bis: And you should have a section called somthing like "Mean flow of the ASC". Now you present a number of cases, but do not dare to judge which is best. This is what it is about, you are the expert. Present what you think is right, based on your model experience, or discuss with your co-authors.

Mathiot et al.: We added some comments in section 3 to detail which simulation is the best run and why we used a resolution of 0.5° for the sensitivity experiments to the forcing:

“The comparison of the ORCA2, ORCA1, ORCA05 and ORCA025 results with oceanographic data suggests that resolutions of 2° and 1° are not high enough to simulate the ASC (typical resolution of climate model, Randall et al., 2007). We need a resolution of 0.5° (about 23 km at 65°S) to catch the main features of ASC. At higher resolution (ORCA025), the absence of Antarctic Australian Gyre and the presence of stationary eddies are not realistic. The results are thus worst than in ORCA05. This seems to be due to representation of bathymetry in this area and this point has to be improved to simulate well the circulation across the Kerguelen Plateau (PET and Fawn Trough) and in the Antarctic Australian basin. Because of the good results and its affordable computational cost, the resolution of 0.5° is kept in the next section to study the impact of the atmospheric forcing on the ASC. A circumpolar overview of the ASC is given for this resolution (Fig. 5) for the best simulation ORCA05. The four main gyres seen in the observations (Gouretsky, 1999; McCartney and Donohue, 2007; Nunez Vaz and Lennon, 1996; Klatt et al., 2005) are well represented (the Ross Gyre at roughly 150°W, the Antarctic Australian Gyre at 90°E, the small Prydz Bay Gyre at 75°E and the Weddell Gyre at 0°E) and transports across typical sections and in gyres (0°E, Fawn Trough, Antarctic Australian gyre, Drake) presented in Table 2 are realistic.”

Page 10, line 5-8. The Greenwich meridian is probably the best sampled section in the southern ocean. Data exist back to 1977. It is strange that you have chosed NOT to include it as one of the your sections in figure 8. Also Klatt et al (2005) have the current meter data, and you mention it here in the text. It leaves the impression that results are here "worse" than for other sections. This is clearly nothing to hide away. You have some good results, and they are worth publishing.

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Mathiot et al.: We have redrawn Fig. 6 and 7 with the section 0° and we now compare the model results with CTD data AWI 232 and 233 used in Klatt et al. (2005). We added some sentences about this in section 4.1:

“A detailed comparison of the mean seasonal cycles of zonal velocity in the different simulations (1985-1989) with the mean seasonal cycle provided by the current meters AWI 233 and 232 over the period 1996 to 2000 (black dot in Fig. 6 and 7) confirms and completes the previous discussion (Fig. 8 and 9). At the shelf break (AWI 233), REF and TEMP underestimate the maximum velocity (June) at 240 m and 740 m. However, the minimum is well represented. In simulations WIND and WIND+TEMP, it is the opposite: the summer zonal velocity is overestimated and the winter zonal velocity is well represented. At 69°S, on the continental slope, the four simulations show too large zonal velocities but with the right seasonal cycle at both 240 m and 740 m depths. At 1900 m depth, REF and TEMP match well the observations. However, WIND and WIND+TEMP show too large zonal velocities and a too large seasonal cycle. Therefore, the seasonal cycle in the four simulations is too low at the shelf break (AWI 233) and the core of the ASC is too large in all simulations and also too deep in simulations with the strongest winds (WIND and WIND+TEMP) (AWI 232). ”

Page 11, line 7. ... enters the Weddell Gyre (delete "in").

DONE

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line 8. Not clear sentence. west of 60 deg E ???? Then you are not in the Weddell Gyre at least. Use west, or east, not "after" ....

DONE

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line 15, ... of two as in the (add "as").

DONE

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line 25. Not global. Use "circumpolar".

DONE

Page 12 line 1. Don't you mean: " The ASC is not present along the ....." ??? Figure 8 and 9 shows negative values for section 1 as far as I can see...

Mathiot et al.: Yes, this is now clarified in the new version of the manuscript (section 4.1):

"Along the west side of the Antarctic Peninsula (section #1), the Antarctic Circumpolar Current reaches the shelf (presence of an eastward current in Fig. 5 and Fig. 11). Consequently, ASC is absent in all simulations carried out (at least on the annual average). This is also the case in other observations and modelling studies (Beardsley et al., 2004; Martison et al., 2008; Pinones et al., 2010).."

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line 7. studies. not study.

DONE

Page 13. line 5. by "jet" you mean current? Jet is normally used for strong atmospheric winds, so you need to specify at least. 1000 m depth, also add depth. Unless you mean am atmospheric jet at 1000 m height.

DONE

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line 11. discussed later.

DONE

Page 14. line 2. The model resolution issue again. Isn't 0.5 deg latitude your model resolution? You cannot (of course) resolve a 0.1 deg S wide front unless you have such a resolution.

Mathiot et al.: With the new climatological section 0°E, there are no problem of comparison between model at 0.5° resolution and strong and sharp frontal current. However, we are agree with you, the model at 0.5° resolution is unable to simulate sharp frontal current.

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line 8. shown, not show.

DONE

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line 29 Isn't this your section #11??? The Brunt Ice sheld is otherwise hard to find from reading your paper ....

DONE

Page 15. line 1. increases up to. You do not know where it increases. It could well be along the long continental shelf in the southern Weddell Sea too. If you did check, mention it clearly.

Mathiot et al.: A section has been added at the beginning of the Antarctic Peninsula.

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This allows us to know where the transport increases in Weddell Sea. See section 4.1:

"... After crossing the PET, the ASC is almost stable up to the base of the Antarctic Peninsula (section #13). However, in areas where the slope is very steep (#12), the cumulated transport (between the coast and 3500 m depth line) slightly decreases. Along the Antarctic Peninsula (section #13 to #14 in Fig. 11), the ASC transport strongly increases up to 27 Sv in TEMP and 34 Sv in WIND+TEMP. This increase is due to the presence of strong barrier winds along the Antarctic Peninsula and also due to a wide continental slope. After section 14, almost all the flow turns east in the ACC and in the Weddell Gyre. ..."

Line 4. It looks as section #1 has smaller than zero flow to me from figure 8 and 9. Does this not mean eastward flow??

Mathiot et al.: Yes, you are right. See new section 4.1:

"... Along the west side of the Antarctic Peninsula (section #1), the Antarctic Circumpolar Current reaches the shelf (presence of an eastward current in Fig. 5 and Fig. 11). Consequently, ASC is absent in all simulations carried out (at least on the annual average). ..."

Conclusion. Again - all abbreviations should be defined. This is often what people read first. The DRAKKAR project does not belong here, it belongs in the acknowledgement. Same for all the other ones.

Mathiot et al.: DONE

And start describing the best results, and then discuss the model resolution differences.

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You have (so far) only investigated the volume flux of the ASC. This is OK. but you should say sensitivity of the ASC volume flux. Both in line 6 (Page 18), and line 16 (Page 18).

DONE

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