Geophysical Model Development Discussion gmd-2019-272-RC2

Representation of the Denmark Strait Overflow in a z-coordinate eddying configuration of the NEMO (v3.6) ocean model: Resolution and parameter impacts" by Pedro Colombo et al.

Response to the Reviewer 2

We greatly appreciate comments which helped to largely improve the clarity of our manuscript. In the following, we provide our responses in a point-by-point manner. In our responses below, we use the following legend:

- *Italic characters* for the Reviewers' comments.
- Blue color for our answers to the comments.
- *Blue color in italic* for the revised text, the specific changes being sometimes outlined in *magenta*.

The story, if summarized, is that one should be 'resolving' the topographic slope in the sense that the aspect ratio dz/dx of mesh cells is higher than the slope, and that vertical mesh resolution has to be sufficient to represent the plume (in this manuscript 150 layers provide several points (5-6) across the overflow plume in vertical direction).

Reviewer's comment 1.
My main problem with the manuscript in its current form is that this story is presented as something unexpected and not known. This starts from the abstract and is repeated several times in the text. However, at least as concern the dz/dx ratio, the limitation on this ratio is well known (and authors themselves mention several papers). The second aspect is also general enough to be surprising, of course, the overflow plume has to be resolved vertically, there is no hope on representing the overflow otherwise. The statements like "Contrary to expectations ..." are strange in this context, it is, in contrast, in agreement with expectations. The value of the manuscript is not in the fact that it finds something new and unexpected ("It is found that when the local slope of the grid is weaker than the slope of the topography the result is a more diluted vein" - Is not this known?), but in exploring and documenting precise limitations for the particular ocean circulation model, which will be appreciated by the NEMO community and very likely by other ocean modeling groups. I would recommend that the authors look critically at their statements and adjust the manuscript accordingly (the Abstract, introduction, conclusions in the first turn). I do not think the present form is acceptable.
We agree that based on the paradigm of convective entrainment expressed by Winton et al. (1998) in their figure 7, we could have expected the sensitivity that we observed. However, we were somewhat surprised by these results because we are working in a range of resolutions that correspond to those for which previous studies (e.g. Winton, 1998) suggest that the representation of the frictional sinking would be achieve with reasonable accuracy (Winton et al. (1998) state in the conclusion of their paper that: "*These conditions imply that resolution on the order of 30–50 m in the vertical and 3–5 km in the horizontal will be needed to represent frictional sinking with reasonable accuracy. This resolution is prohibitive for climate simulations*". With resolution of 5 km to 1 km (i.e. 1/12° to 1/60°) and a large number of vertical levels (150 to 300 levels of resolution of 30 m to 10 m in the depth range 600-1000 m, see Figure A1), we thought possible a behavior that would be dominated by the resolved frictional dynamics.

But finally, our study shows that the convective entrainment paradigm, driven by the EVD parameterization, remains dominant in setting the bottom temperature of the plume. Consequently, we agree to revise our statements regarding our "surprising" or "unexpected" results.

The changes made in the revised paper are listed below:

In the abstract (Page 1, lines 4-5): The text in magenta has been removed.
"*~~Contrary to expectations,~~ In the given numerical set-up, the increase of the vertical resolution did not bring improvement at eddy-permitting resolution (1/12°).*"

In the Results (Page 14, lines 4-6): The text in magenta has been removed.

"Finally, the representation of the DSO is even more degraded in the 300 level case, this resolution exhibiting the greatest dilution of the DSO waters among all resolutions. ~~which was not expected since it should allow for the best resolution of the bottom Ekman layer~~"

In the Conclusion (Page 24, lines 4-5): The text in magenta has been removed/replaced from the original text.

"~~The first unexpected~~ A first result is that the representation of the overflow showed very little sensitivity to any parameter except the horizontal and vertical resolutions. A second result is that, ~~Contrary to expectations,~~ in the given numerical set-up, the increase of the vertical resolution did not bring any improvement when an eddy-permitting horizontal grid resolution of 1/12° (i.e. ~5km) is used."

Reviewer's comment 2.
Even in higher resolution runs the bottom topography was kept from 1/12 degree case, and question arises as what will happen if the topography were adjusted according to the resolution. I would appreciate some discussion of the aspect of resolving the topography.
When horizontal resolution is increased, the bottom topography is bi-linearly interpolated from the 1/12° grid onto the finer grid (1/36° or 1/60°). Therefore, topographic changes still occur at the scale of the finer grid, but the topographic slope remaining constant over a 1/12° blocks (because of the bi-linear interpolation). This is illustrated in Figure 13a,b for example where the original 1/12° (46 levels) and the interpolated on 150 levels topographies can be compared.

For example, what would happen if 1/12 degree simulations were run on a smoother topography? This might add some useful insight.
It is very difficult to answer the question without running new model simulations, especially when the bottom topography is realistic and partial steps are used. The study of Penduff et al. (2001) addressed this issue of topographic smoothing and concluded that in an absence of a correct parameterization of current-topography interactions, a certain amount of topographic smoothing have a beneficial impact on geopotential coordinate model solution. Based on these results, we suspect that using an un-smoothed topography in the higher resolution experiments would tend to degrade the results. However, the study of Penduff at al. (2001), focused on the large scale circulation of the South Atlantic (i.e. the Confluence of the Malvinas and Brazil currents, the Zapiola Anticyclone in the Argentinian Basin) did not look at overflows, and we are not confident enough on the generalization of their results to make any comments on that issue in the paper.

We rather not discuss this complex issue in the revised paper.

Penduff, Barnier, Kerbiriou and Verron, 2001: How topographic smoothing contributes to differences between the eddy flows simulated by sigma- and geopotential-coordinate models. J. Phys. Oceanogr., 32, 122-137.

Reviewer's comment 3.
The manuscript is well written, however it tends to overdefine and at too many places phrases could be more concise. Some editing would be good at this level, but it is up to authors.
We somewhat agree with this comment, and this is likely the reason why the paper is so long. When submitting our paper to GMD, we attempted to make it interesting to and understood by oceanographers, but also by scientists from different scientific fields, as they could bring different and original views to our problems and methods. For this reason, we may have over-defined the context, and few other modelling or methodological aspects of the study, in order to make the paper accessible to scientists of different fields.

We have been through the paper again and attempted to be more concise in our comment, but still keeping our objective of being understood by non-oceanographers.

Some small issues (not all)

Page 2 line 7 check citation style: Corrected
23 'at that resolution' – which one? Can be removed. Removed

Page 3 line 4 'yield to'???? The entire sentence can be written as:

The first complication arises from the the neglect of vertical acceleration in the hydrostatic approximation leading to misrepresentation ... (see 3 above). Corrected

line 30 remove , after (2009) Corrected

page 4 lines 8 and 12 'Despite' and then again 'despite' Corrected
29 'is presented in' – contains "is presented in" is widely used. No change.

page 5 line 24 citation style Corrected

page 6 line 4 citation style Corrected
Caption to Fig.2 an –> and; Surface (a,b) and bottom (c, d) current speed (year 75) in
the global ORCA12 (a,c) and regional DSO12.L46 simulations. Only every fourth point
is shown.… Corrected in the new legend, since the Figure has been slightly modified to answer comments of Reviewer 1.

page 11 lines 4,5 Following the convention for DSO12.L46, the simulations … Corrected

page 14 line 9 Is NEMO different from all others?
Although we know the general principle of other models (e.g. MIT, HYCOM, FESOM, ROMS), we do not know precisely enough the details of the implementation of their numerics and parameterizations to make pertinent comments of that issue. In the current NEMO framework, the option widely used is to treat the static instabilities with EVD. No change in the text.
line 24 your formula does not express the ratio. Corrected
line 28 250 km wide. Corrected
line 29 when? At time t=0 of the simulation. This is the general definition of initial conditions: the state of the fluid at the beginning of the simulation. To make sure that this is clear, the initial condition is described in one single sentence (page 16, lines3-5).
"Initial conditions are as follows: a blob of cold water is placed on the bottom of the shelf with a temperature of 10°C, the temperature of the ambient fluid in the rest of the domain being 15°C and the salinity being constant (35 g/kg) in the whole domain."

Page 18
line 1 over-resolving the slope vertically worsens the overflow representation Corrected
line 2 there exists or there is Corrected
line 7 Which rationale is meant?
We refer to the rationale of the paper, i.e. what is needed to improve or understanding of the sensitivity of the representation of the DSO in NEMO to the model parameters and resolution ….
But it is absolutely not necessary to recall the main paradigm of the study here. The text now is (Page 18, line 23):
"~~Continuing with our rationale,~~ We now evaluate the representation …"

page 20 line 13 acceleration? or speed-up (units are of velocity) Corrected, speed-up
line 14 5 - 6 points Corrected