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Geoscientific Model Development Discussions
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Interactive comment on "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.

Anonymous Referee #3

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The paper is important, numerical experiments are well designed and carefully performed and written. However the manuscript, to my mind has some major shortages:

1. Absence of figures with observations. It is very hard to follow the text, when the authors refer to figures in the other papers. I found only one plot (Fig 16) to be very informative. Is it possible to plot similar figures from observations? I believe that most of the observed data are present in databases such as EN4.

2. Secondly the introduction of the manuscript is not satisfactory written, the style and

organisation of paragraphs require clarifications and improvements. Please answer the following questions: What is overflow: How and where do overflows originate? How long do they propagate? Relative thickness, velocity, range of mass fluxes? Why it is so important in global simulations: e.g Impact on the Global Conveyer belt (MOC) What are the main balance of forces in the overflows! Why is the fine resolution needed, what processes should be resolved in the ideal case? What is the problem in overflow simulation by z-coordinate models, show the numbers! , say predicted temperature 3C higher, etc. It would be great to have an illustration of spurious mixing due to advection+EVD. If other coordinates are better, why are z-coordinates used? What observations and criteria have been used to identify "improvement"?

3. Please characterise the region: main parameters which are important for resolution of overflow: Rossby radius, Ekman depth and maximum/mean topography slopes, slope ratio for each resolution on the sill, as the authors have found this factor is most important. Ekman depth could be estimated from the bottom shear stresses: Hekm = Cdˆ0.5*U_bot/f (Thorpe, 1988) Soulsby (1983).

4. Winton 1998 experiment: "To show the effect of this concept, we simulate the descent of a continuous source of cold water down a shelf break in an idealized configuration of NEMO (with no rotation, comparable to that of Winton et al. (1998))." It is not the Winton, 1998 experiment. Winton compared with an EKMAN – type solution, so the dynamics was rotationally important, his solution was 2D on the f-plane. The solution, shown in fig 9 is not relevant to the baseline study. You consider (fig 9) the propagation of dense boundary layer in a barotopic fluid with a very weak density difference in the plume and ambient waters (0.5C over 3000m depth). So, the balance is between gravity force and friction. Also, you cannot claim that the second case (9b) is worse or better! Is this an effect of EVD or as twice as strong shear, seen in the panel 9b? It is not clear, that solution 9a are physically more consistent compared with 9b. If you want comparisons with analytical solutions, I recommend reproducing Shapiro & Hill 1997 analytical solutions for cascading. This is not completely overflows (entrainment

is weak), but it is a good test, as approved also by laboratory experiments, (Wobus et al, 2009 and Bruciaferri et al, 2018). My recommendation is to remove this paragraph from the paper, as it is not relevant to the study.

5. I am not convinced that using EVD is a single source of increased simulated mixing when increasing the number of vertical levels. The authors state: What other processes that model start to resolve at finer vertical resolution could affect generation of strong shear and mixing, as inertial or internal waves, topographically trapped Rossby waves? Please, look at high frequency variability at the water column, say, using a Hovmöller diagram. Fig 13a,c, shows the presence of small-scale (and probably high frequency) features. To my mind it shows presence of internal waves of high amplitude.

6. Another possible cause of an enhanced mixing in the fine vertical resolution is a parameterisation of diffusivity set in a weakly stratified conditions. Indeed, in TKE vertical mixing scheme (and gls scheme in an strongly stratified conditions), the turbulent length scale is set as l= 0.1* TKEˆ(1/2)/N and vertical diffusivity AVT∼TKE/N, where TKE is a turbulent kinetic energy, defined by the tke equation but larger by some background value, N is a buoyancy frequency, which differs due to resolution. Subcritical Richardson numbers (Ri<Ricr∼1/4), responsible for generation of small –scale turbulent mixing are also vertical resolution dependant. Let us consider a plume of dense water of constant density ro_plume propagating downslope in unstratified fluid (of density ro_0) with velocity U.. Velocity shear is S=U/dz, the Richardson number at the edge of the plume is

Ri=Nˆ2/Sˆ2=g(Ro_plume –Ro_0)*dz/(Uˆ2*ro_0)

will be smaller at the finer vertical resolution which results in more mixing entrainment on the top of the dense plume. This could be examined by comparison of statistics of occurrence the negative (EVD effects) and small positive Richardson numbers at the edge of plume simulations with different resolutions. The other possibility is to check this assumption, to evaluate the number of occurrence of AVT exactly fit to EVD pa-

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rameterisations (10mˆ2/s, convection) and in the smaller range (∼0.001-1mˆ2/s, Kelvin-Helmholtz instability). In the 1/12 resolution, (Fig 8) I see combination of open-ocean convection (EVD) and shear instability turbulence. How do you explain a much larger area of open convection in the figure 8b, identified by 5-year mean very strong mixing from the surface to the bottom? May be at some point the water of other origin penetrates from the surface to the bottom and mixes with propagating plume?

7. Check consistency of bottom topography, specifically in the "worst case " L300.The authors state: "Bottom topography and coastlines are exactly those of the global 1/12 ORCA12 configuration and are not changed in sensitivity experiments, except when grid refinement is used. In this latter case the refined topography is a bi-linear interpolation of that at 1/12 , so the topographic slopes remain unchanged". It is not seen from the figure 8, where bottom topography is different in simulations L46 and L300. Does adjective TVD scheme work similar in the different vertical resolutions?

Minor comments: Abstract: What observations and criteria have been used to identify "improvement"? Contrary to expectations, in the given numerical set-up, the increase of the vertical resolution "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. Such a grid enhances the dilution of the plume in the ambient fluid and produces its thickening. Although the greater number of levels allows for a better resolution of the ageostrophic Ekman flow in the bottom layer, the final result also depends on how the local grid slope matches the topography" It is known result from Winton et al. (1998), that the model should resolve slopes and Ekman layer, so if slopes are not resolved, vertical resolution cannot help.

1. From introduction it is not clear, what is overflow, how it is formed and what processes dominates in the dynamics. Even for pure numerical –oriented paper it is important to understand, what should be in the equations and why this resolution is chosen. "An oceanic overflow is a dense water mass" – is this a water mass (object) or process? "Overflows of important magnitude are" – what do you mean under important magnitude? "is balanced by the intrusion of waters from regions different from

where the overflow waters are formed" – please, rephrase it. "For example, the flux of cold waters formed in the Arctic Ocean and the Nordic Seas that enters the North Atlantic with the Denmark Strait and Faroe Bank Channel overflows is balanced by warm and salty Atlantic waters that flows over the Iceland-Scotland Ridge towards the Arctic Ocean via upper ocean currents" It sounds as Atlantic Warm currents are caused by compensation to overflow. "However, the dynamical processes that control overflows have rather small scales" – please, emphasise what small scales processes. What is the main balance in the overflows? Why spurious mixing is considered to be strong? It is not clear from the introduction. Refer to the paper, or just point out what is wrong due to spurious mixing (volume flux, salinity , temperature?) 5. You mention the importance of non-hydrostatic physics and then mention Magaldi & Haine , 2015 paper (correct reference) showing different contrary results (see also Wobus et al, 2011). "They also characterized the dependence on various model parameters regarding the mixing of the overflow waters with ambient waters." – I don't understand what do you mean here: mixing depends on parameters? Or something else, which parameters? "found a greater sensitivity of the mixing to horizontal resolution and, but to a lesser extent, to vertical resolution and vertical viscosity" is it resolved horizontal or vertical mixing? Or spurious? How mixing have been examined? "but not the small-scale diapycnal mixing which still needs to be fully parameterized by the turbulent closure scheme." – please, rephrase it. It is true of course, as to resolve diapycnal mixing you need scales up to the dissipative one, which is of 1mm. " a resisting bias in this type of model simulations are likely to contribute." – what is resisting bias? Page 11: "The detailed list of theses experiments" Page 19: (15) "In the case of DSO60.L150 (Fig. 13a,13c) the EVD driven mixing remains confined to a very thin bottom layer below the 27.85 isopycnal and very little mixing occurs in the core of the overflow plume" - If you look at the magnitude of near bottom mixing, it is too small to be EVD, probably is it shear-driven Ekman layer; " Intermittent static instabilities occur between the 27.85 and the 27.8 isopycnals, the associated mixing being small since the temperature and salinity gradients are quite small there" - Figure shows very strong mixing>1mˆ2/s of high frequency and small scale. As T,S differences are small, Ri numbers to be small there, resulting in a strong intermittent mixing. What frequency and scales are? Is it small positive Ri (Kelvin-Helmholtz instability), or negatve Ri (convection, EVD)?

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