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Ocean Science Discussions

Interactive comment on "On the numerical resolution of the bottom layer in simulations of oceanic gravity currents" *by* N. Laanaia et al.

Anonymous Referee #1

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General comments

This manuscript describes a series of numerical simulations of a downslope dense current in a rotating system. The simulations are distinguished principally by their resolution and vertical coordinate. Some simulations are 2.5 dimensional (no gradients in the along-slope direction) while a smaller number are fully 3 dimensional. The principal conclusion of these simulations is that a lower resolution sigma coordinate model can reproduce the results of a higher resolution model provided sufficient resolution is retained in the frictional bottom boundary layer. This conclusion is of course only applicable to terrain following coordinates, where resolution can be selectively placed near the topography, whereas z-coordinate models have to have uniformly high vertical resolution throughout the whole depth in order to achieve the same resolution at the

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Interactive Discussion

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topography. While it has been known for a while that sigma coordinate simulations of dense gravity currents can be achieved with lower resolution than z-coordinate simulations (e.g. Winton et al, 1998), this is the first example quantifying the resolution necessary in terms of the frictional bottom boundary layer dynamics. However, it does not help us much with solving the problem of dense gravity current representation in ocean climate models, for which sigma coordinates are ill-suited. It does serve as a useful benchmark for future dense gravity current modeling, including perhaps future hybrid terrain-pressure coordinate models.

Specific comments

1. Reference to earlier work on the influence of vertical/horizontal resolution and vertical coordinate on gravity current modeling.

I was surprised that the authors did not refer to earlier studies which for example compare sigma and z-coordinate simulations (e.g. Ezer and Mellor, 2004; Ezer, 2005) or examine resolution criteria for gravity currents in different coordinates (e.g. Winton et al, 1998). The resolution criteria examined in this study are focused on the frictional boundary layer - it would be nice to know if this criteria is always more stringent than the earlier criteria, or if in some cases the earlier criteria would supersede the boundary layer criteria. The effort to reconcile the benefits of sigma coordinates with the use of z-coordinate models for large scale simulations lead to the hybrid formulations such as Killworth and Edwards, 1998. Nonetheless those formulations have not been widely implemented, due to the inherent difficulties of matching sigma coordinates and z-coordinates. What information can your resolution criteria provide to guide future hybrid schemes?

2. The effect of convective adjustment.

While I agree with the authors that increasing the diffusivity to a large value in a convectively unstable region while leaving the viscosity unchanged is not perhaps physically justified, it would still be useful to demonstrate that the peculiar effects seen in the con-

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vective adjustment simulation are in fact due to the viscosity changes, rather than due to the tracer mixing. I have seen other gravity current simulations where convective adjustment seemed to have no effect - this could either be because the viscosity is not being modified during convective adjustment or perhaps because the frictional layer was not properly resolved, so little inversion in stratification occurred.

3. 3D simulations

The 3D simulations are useful, in order to evaluate how the boundary layer constraints carry over to 3 dimensions. However, I didn't find the description of the 3D results to be very informative. A better quantitative comparison with the 2.5D calculation is needed. For that purpose, it would be useful to have a 3D calculation at identical resolution to one of the "successful" 2.5D simulations, yet the resolution of G03 and G11 is slightly different - why? I suggest carrying out a 2.5D and 3D calculation at identical nx and nz, and showing the results on the same plot. There is some qualitative comparison between the 2.5D and 3D calculations in the text, but I find it a bit confusing. For example, you say there is a laminar phase which lasts for 5-7 days, followed by a phase dominated by eddies. Firstly, the plots shown in figure 7 and 8 only go up to 7 days, so no evidence is therefore given of impact of the second phase on the transports. Secondly, you say that during the first phase, the downslope transport is increased by 30% compared to the 2.5D case, yet a glance at the transports at 5 days shows about 1800 for G11 and 1000 for G03, so the increase is more like 80%, not 30%. The 3 fold increase in downslope transport in G11 at later times compared to the 2.5D case described in the text is not seen in the plot (because it does not extend long enough). I would also like to see the cross-current structure for the 3D case to compare with figure 2: Is the friction layer still found on the downslope side in 3D, both in the initial laminar regime and in the later eddying regime? It is very important to show that the conclusions for the necessary resolution of the frictional layer carry over to 3-dimensions, since most practical dense gravity current simulations are indeed 3D.

Technical corrections

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p4, l12: “neither of the conditions are met” - what conditions? Please clarify.

p11 l18-22 and p11 l26-p12 l1 contain identical text. Please delete one.

p14 l2: “descents" should be “descends”.

p14, l17-18: “with only 3 levels in the zone Z3 a correct Ekman veering is observed”. Do you mean zone Z1 or zone Z3? I thought Z1 is at the bottom. Why would resolution in Z3, far from the bottom, control the simulation of Ekman veering?

References:

Ezer and Mellor, 2004: Ocean Modelling v6

Ezer 2005: Ocean Modelling v9

Winton et al, 1998, JPO v28.

Interactive comment on Ocean Sci. Discuss., 7, 417, 2010.

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