Review: "Origins of Mesoscale Mixed Layer Depth Variability in the Southern Ocean"

Authors: Yu Gao, Igor Kamenkovich & Natalie Perlin

Summary

This study, using a semi-idealized high-resolution Regional Ocean-Atmosphere Model (ROAM), explores the role of mesoscale atmosphere-ocean coupling in the upper-ocean dynamics and mixed layer variability. The authors conduct two sensitivity experiments: *Smooth-Fluxes* and *Smooth-Winds*. The results from these experiments show the distinct contributions of ocean buoyancy advection, mixing and atmospheric forcing to the MLD variability in summer and winter. Overall, the effect of mesoscale heat-flux forcing is more significant than the mesoscale wind-stress forcing.

The paper contains a complete science narrative and interesting results, which are convincingly supported by a thorough study of mixed-layer buoyancy budget. The paper is well-written, but could be made a bit clearer in some specific places, as I listed below. I recommend publication after a minor revision.

Minor comments

- **Description of model domain.** Lines 91–92: "*Mesoscale anomalies are clearly visible in all fields (Fig.1).*" Because this paper is focused on the ocean mesoscale dynamics, it is worth to add a snapshot of Eddy Kinetic Energy (EKE). I suggest replacing the SSS pattern (Fig. 1b) with an EKE pattern.

- **MLD pattern in model domain.** In the model domain, which is a region in the Western Indian sector of the Southern Ocean, the deep MLD forms in the southern and eastern part of the domain (Fig. 1c). In fact, this deep MLD distribution is quite different from that in most other regions of the Southern Ocean, where the deep MLD forms on the northen flank of the ACC jets. More discussion/clarification is needed here.

- Figure 6. Line 144: I am confused about the logic here. Should the authors show the correlation between SSTA and **MLD**, instead of SSTA and MLDA, in Fig. 6? In this way,

the authors can contrast the contributions of SST with and without mesoscale anomalies to the MLD variability.

- Figure 8. Can the authors comment on why the RMS MLD anomalies in the two sensitivity experiments show a similar response in time?

- Figure 9. The signals of two sensitivity experiments in the domain average are small and not very clear. I suggest to conduct the same calculation, but only averaged for the areas where the wintertime MLDs in the control experiment are deeper than a certain threshold, i.e. $\geq$400 m. I expect that the signals would become clearer.

- Figure 3. There are some 'white spots' close to the surface in Fig. 3e,f. This issue can be solved by modifying the colorbar.