Ocean Science

Discussions

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Interactive comment on "Deep Circulation in the South China Sea Simulated in a Regional Model" *by* Xiaolong Zhao et al.

Anonymous Referee #1

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This study uses observation and high resolution simulation to study the deep circulation in the South China Sea. The topic is very important and interesting. This study indeed provides some useful aspects to describe the deep circulation from modeling perspective, especially related to the magnitude of the circulation and potential mechanisms. I think this study would very much interest the research community of South China Sea and I would recommend this study after its revision. I do have some major/medium comments that the authors need to consider very carefully in clarifying some confusing points, only after which this study may be considered to be accepted in Ocean Science.

1. line 106: "Given the lack of observations and inadequate quality control, detailed structures of circulation in the deep SCS have not been mapped out and described adequately"

You have spent many paragraphs and great details introducing previous works on observations and modeling of SCS circulation. But now you suddenly say this circulation "have not been mapped out and described adequately". This statement is too general and may not be fair to previous studies. Please be *specific* about the problems you want to address, and how they are new from previous studies. This is very important.

2. line 107: "Combining the mooring array in Zhou et al. (2017) with results from eddy-resolving model simulations, the present study investigates deep circulation under enhanced mixing in the SCS."

Again, this is too general. Have not any previous studies also used observation and models to "study investigates deep circulation under enhanced mixing in the SCS"? You need to be specific about the new points of your study to distinguish from previous studies.

3. line 129: "Despite the fact that surface forcing is significant in this region as regulating the upper layer circulation, evidence of surface forcing to the deep layer dynamics has not yet been found. Since the current work is designed to be a process study, surface forcing was not applied in the experiments."

"Evidence of surface forcing to deep layer dynamics has not yet been found" does not justify that surface forcing is not important. I think there is a big question mark here, and you cannot just skip the surface forcing simply like this without a detailed discussion, with an excuse of being a process study. For example, have you compared your experiment of "no surface forcing" with an experiment with surface forcing to get this conclusion? For example, of course wind and air-sea buoyancy flux may directly regulate deep ocean circulation down to 3-4 km depths such as at Weddell Sea, see this paper: An idealized model of Weddell Gyre export variability. Journal of Physical Oceanography, 44, 1671-1688. 2014. Moreover, you initialize model from observation. But without surface forcing such as wind and air-sea buoyancy flux, how can you continue to maintain a relatively realistic stratification for your ocean simulation?

For example, air-sea buoyancy flux can cause convection (either shallow or deep) that can significantly modify the ocean stratification even at depth and change the ocean circulation, see this paper: On the abruptness of Bølling–Allerød warming. Journal of Climate, 29, 4965–4975. 2016, and this paper: Ocean Convective Available Potential Energy. Part II: Energetics of Thermobaric Convection and Thermobaric Cabbeling. Journal of Physical Oceanography, 46, 1097–1115. 2016.

My point is this: You may not do further experiment; but I think the authors should discuss the limitations of this configuration of no surface forcing carefully, including at least acknowledge the potential other mechanisms (see papers above) that may have an effect on deep layer dynamics.

4. line 136: "Based on similar configurations with all of the numerical experiments started from rest and integrated for 10 years, Zhao et al. (2014) studied the deep water circulation in the Luzon Strait, which was in good agreement with the observations."

Please be specific on what aspects Zhao et al. (2014) was in good agreement with the observations. If the previous study is already so good, why do you perform the current study? Be specific of what is the new points/motivation of this study comparing with previous study.

5. line 149: "In order to obtain a steady state of the deep circulation in the SCS, we integrated all of the numerical experiments for 20 years"

I know it is expensive to run models. But do you really think 20 years are enough to reach steady state for a new mixing configuration? I thought from textbook it takes 100-1000 years to do so. What is the evidence of a steady state of your simulation? I know it is lots of work, and you may not re-run your model. But please be very careful here and state the limitation sincerely if it exists.

6. line 154: "eddy-resolving model simulations"

You call your 1/12° and 32 level model eddy-resolving. Please be careful that this can

be misleading. You should emphasize it is only mesoscale-eddy-resolving but does not well resolve submesoscale eddies (or even smaller-scale turbulence), which can also have great impact on large-scale ocean circulation (see papers below). It may be helpful to discuss/cite these papers: Ocean submesoscales as a key component of the global heat budget. Nature Communications, 9, 775. and Yu et al. 2019. An Annual Cycle of Submesoscale Vertical Flow and Restratification in the Upper Ocean. Journal of Physical Oceanography, doi 10.1175/JPO-D-18-0253

7. Figure 2: this is nice, but why the two panels do not have the same topography?

8. Figure 2: why the simulation has a larger magnitude of velocity than the observation?

9. Figure 2: you put vertical layer number in your simulation result, but why in each layer there is vertical variation of velocity? i.e. how can you have a variation within a grid box?

10. Figure 5: is this figure showing the difference between 28 and 29th layer? not sure what the capture means of "the 28th to 29th layer ". . .please explain.

11. Figure 7: you seem not mention how do you calculate your EKE.

12. Figure 7: you have not explained the EKE patterns carefully in your section 3.3. Why you have large EKE patterns (green, yellow, red) in certain locations? is it due to topography or boundary current? You may want to discuss briefly the role of topography or so on determining EKE, such as shown in this paper: On the Minimum Potential Energy State and the eddy-size-constrained APE Density. Journal of Physical Oceanography, 46, 2663–2674. 2016.

13. Figure 8: why your color scheme is inhomogeneous here? why the yellow range is so large?

14. line 219 "3.4 Model Sensitivity to Distribution of Mixing". You say in line 89 "Yang et al. (2016) recently obtained the three-dimensional distribution of turbulent mixing in the SCS for the first time." Have you tried to use this three-dimensional distribution of

turbulent mixing for your simulation? so you may get more realistic simulation?

15. line 200: "3.3 Temporal Variability of the Deep Circulation". You have not discussed the seasonal variability here. How large is the seasonality? Note the eddy KE and the KE of internal waves can have strong seasonality over the globe including SCS (see paper below). You may may discuss/cite this: Partitioning Ocean Motions Into Balanced Motions and Internal Gravity Waves: A Modeling Study in Anticipation of Future Space Missions, Journal of Geophysical Research, 123, 8084–8105. 2018.

16. last section: you summarize your result here. But you need also to compare your result with previous studies and clearly state what are some new results distinguished from previous studies.

17. last section: You discuss lots about effects of vertical mixing for the circulation, which is still useful although relatively well known. Personally speaking, I think other potential good direction for future studies may include to research on how topography (such as beta effect due to topography), bottom drag, and eddies influence the deep ocean circulation, stratification, and tracer transport. For example, you may take advantage of your high-resolution model to discuss how eddies at different scales (e.g. small scales resolved by high-reso model) may influence ocean circulation, such as by inverse cascade of kinetic energy: good to mention the following study: Klein et al. 2019. Ocean Scale Interactions from Space. Earth and Space Science, AGU, doi 10.1029/2018EA000492 (e.g. see its figure 13)

Minor comments.

line 24: "The Taiwan Strait to the East China Sea in the north", should decapitalize "The"

line 128: what is "1' resolution"?