Title: "Improved ocean circulation modeling with combined effects of surface waves and M2 internal tides on vertical mixing: a case study for the Indian Ocean"

Summary

The main result of this study is to investigate the contribution of surface wave- and internal tides-induced vertical mixing in the upper ocean of the Indian Ocean. By adding three mixing schemes (vertical diffusive terms) into ocean circulation model, namely non-breaking surface-wave-generated turbulent mixing, the mixing induced by the wave transport flux residue, and the internal-tide-generated turbulent mixing schemes, the role of three vertical mixing schemes is quantified by switching off each diffusive term. Especially, the surface wave mainly improves the vertical mixing in the sea surface while the internal tide mainly contributes to the vertical mixing in the ocean interior. Improvement of upper ocean temperature structure is observed when all three schemes are combined.

Recommendation: Major revision.

The authors have presented a clear description of three mixing schemes, model experiments, and results that shows significant improvement of upper ocean thermal structure in the Indian Ocean. The study would be of importance to local oceanography, and it will also help improving the vertical mixing parameterization scheme that is used in the low-resolution models. However, a first impression of this paper is that the topic, i.e., what scientific object the authors are intended to improve, is not very clear, which could be related to the presentation of the introduction. The results also need more explanation. I would recommend major revision this time.

Here are some specific points below:

Major point:

1. The introduction part is not well-written, especially with respect to the relationship between vertical mixing process and upper ocean dynamic and thermodynamic processes in the Indian Ocean. For example, the paragraph from Lines 65 to 75 mainly introduces the importance of surface wave and internal tide in the Indian Ocean. But, how they are related to the upper thermal structure, and most importantly, the upper ocean dynamics, haven't been well-documented in this paragraph. In 2.4, the authors have clearly stated that the three vertical mixing schemes has been added to the momentum equation, which means that the ocean dynamic process is also influenced by three mixing schemes. Therefore, the relationship between vertical mixing (due to surface wave and internal tide) and upper ocean dynamic process should be documented in the introduction.

2. Although the authors have stated the reason for not presenting the circulation pattern in the Indian Ocean (Lines from 350 to 355), the performance of ocean dynamic process should be presented (at least discussed) in the Result Section. As mentioned in the Major point 1, the momentum equation in the ocean model of this study is also influenced by three mixing schemes, and it in turn affects the thermal dynamic process (upper ocean temperature structure). Hence, the role of those three schemes on the ocean dynamic process, e.g., general circulation (mean state), and eddy activity (anomaly), should be investigated. Especially for the latter, since it is directly related to the parameterization of turbulent mixing, and is an important factor to the tracer conservation (Jayne and Marotzke, 2002).

Reference:

Jayne, S. R., and Marotzke, J. 2002: The oceanic eddy heat transport. J. Phys. Oceanogr., 32(12), 3328–3345. doi: 10.1175/1520-0485(2002)032<3328:TOEHT>2.0.CO;2.

Minor points:

1. Line 60. Why choose M2 internal tides?

2. Lines 155-160: A short description of the Mellor-Yamada scheme is needed for the readers to understand the difference between the experiment 1 and other experiments in the Result Section.

3. Line 225: Please provide the reason why you choose the 10.5°S Section.

4. Line 245: The EIO only occurs once in this manuscript. Hence it is not necessary to define this abbreviation.

5. The thermocline structure at the equatorial region (normally defined as the depth of the 20 degree temperature, referred as Z20C) is one of the distinctive feature in the Indian Ocean. Because of the weak westerly at the equator, the Indian Ocean shows deeper and reversed slope of Z20C as compared to its counterpart in the Pacific Ocean. The mean state structure of Z20C is very important for the Indian Ocean air-sea interaction (e.g., Indian Ocean Dipole). Therefore, it would be worthwhile to find out how the Z20C responds to those three mixing schemes. I would suggest the authors to show the upper-ocean thermal structure at the Equator in Section 4.2.

6. The fontsize of text in some figures should be made larger (e.g., Figure 8, Figure 9).