Referee #1

The paper deals with an interesting and important problem, namely the mechanism(s) responsible for oceanic mixing in a topographically-complex region. The data have been processed satisfactorily and they show some interesting features, though the interpretation of these features is not straightforward. My principal difficulty with the paper lies in the analysis of the data and the validity of the conclusions drawn from such an analysis. The heart of the analysis is the correlation of observed features of the diapycnal diffusivity patterns with the main causes of mixing identified by the authors. Many of the correlations claimed by the authors seem to be based either on visual inspection of the data plots or analysis based upon ratios of the energy fluxes associated with each of the driving agencies (e.g Fig 4) . I did not find these analyses convincing and I would have appreciated some more quantitative and rigorous data correlation procedures carried out to justify the conclusions. Figs 6, 7 and 8 are very difficult to interpret. Overall, I found the data analysis to be rather superficial and, in consequence, the conclusions unjustified by the evidence of the data analysis.

Response:

Thank you for your time and constructive comments. The convincing verifications of both the methods and results are crucial for a scientific paper. According to your helpful suggestions, we have thoroughly made the validation of the analysis methods used in present manuscript. The detailed descriptions and discussions were added to section 3.3.1 (Fig. 4 and Fig. 5), section 3.3.2 (Fig. 6 and Fig. 7) and section 3.4 (Fig. 8). Based on the verified methods and the comparison to other studies, the conclusions that have been drawn are found to be reliable and convincing.

1. As for the parameterization method itself, it is widely used in the studies of ocean mixing. The most beneficial point is that there are amount of observations of temperature and salinity by ARGO among the global ocean, with good spatial and temporal coverage. The parameterization method was used to estimate global or regional distributions of diapycnal mixing, which can supplement the scarcity of direct turbulence observations. The parameterization analysis seems not straightforward but effective in mixing investigation through several statistical analysis and correlation analysis with other impact factors (e.g. Wu et al., 2011; Whalen et al., 2012; Kunze et al., 2017; Chanona et al., 2018).

2. As for the statistical and correlation analysis methods *a. To address the relative contributions to the mixing from possible factors, we showed Fig. 4 and Fig. 5. Each 1 ° latitude band was separated into two regions with weak or strong internal tides (or other factors). Here we define the strong or weak internal tides as the internal tide conversion rate larger or smaller than the median internal tide conversion rate of the Philippine Sea (for the details see section 3.3.1). The diapycnal diffusivities in these two kinds of regions were then averaged. The similar method has been used to analyze the effect of topography and different frequency-bands internal waves on ocean interior shear and mixing (eg. Whalen et al., 2012; Zhang et al., 2018). For a more direct representation, the ratios of diapycnal diffusivities above the strong internal tides to weak internal tides were shown. The ratio larger than 1 means that the diapycnal diffusivities are significantly higher in the regions of strong internal tides. The similar analysis were used for the analysis of wind and EKE effects.*

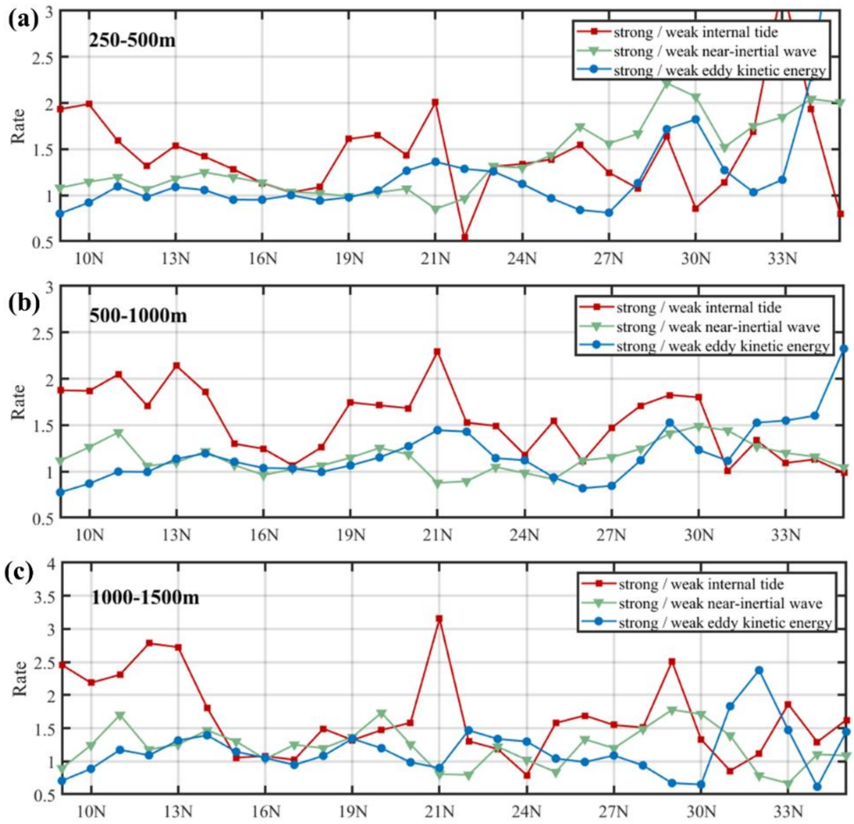
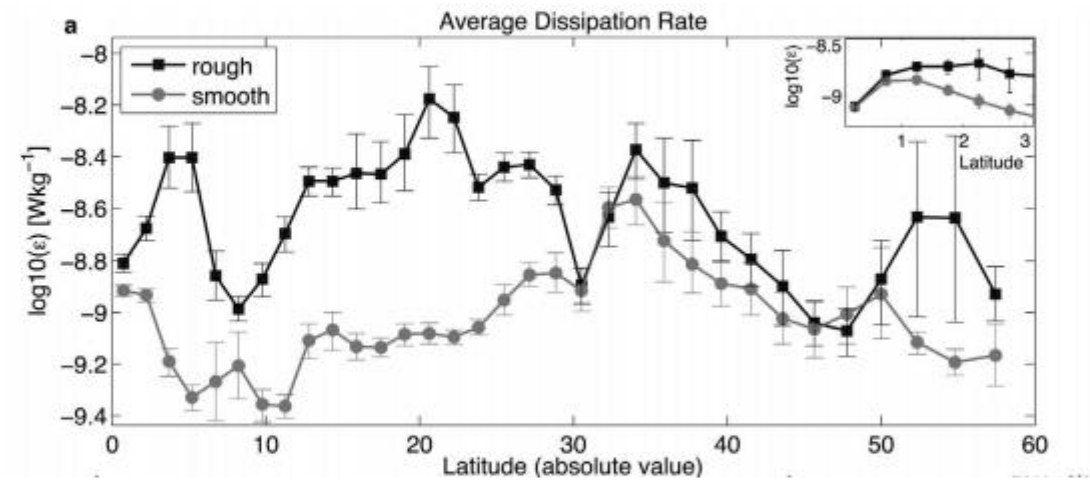


Figure 4 Ratios of diapycnal diffusivities between areas over strong (greater than median) and weak internal tide (red lines), strong (greater than median) and weak near-inertial wave (green lines) and strong (greater than median) and weak eddy kinetic energy (blue lines) for each 1° latitude bands in the depth range of (a) 250-500 m, (b) 500-1000 m and (c) 1000-1500 m, Which averages for each bands containing more than 10 estimates.



(Whalen et al., GRL, 2012, Figure 3a) E.g. Global mean dissipation rate for 3_x0005_ half-overlapping latitudinal bands in the depth range 250–1,000 m over rough (variance greater than global mean) and smooth topography with 90% bootstrapped confidence intervals.

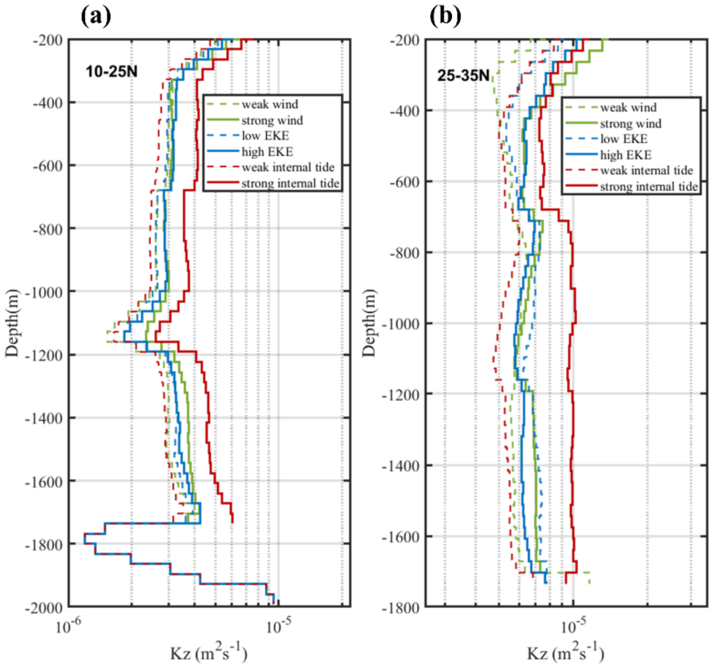
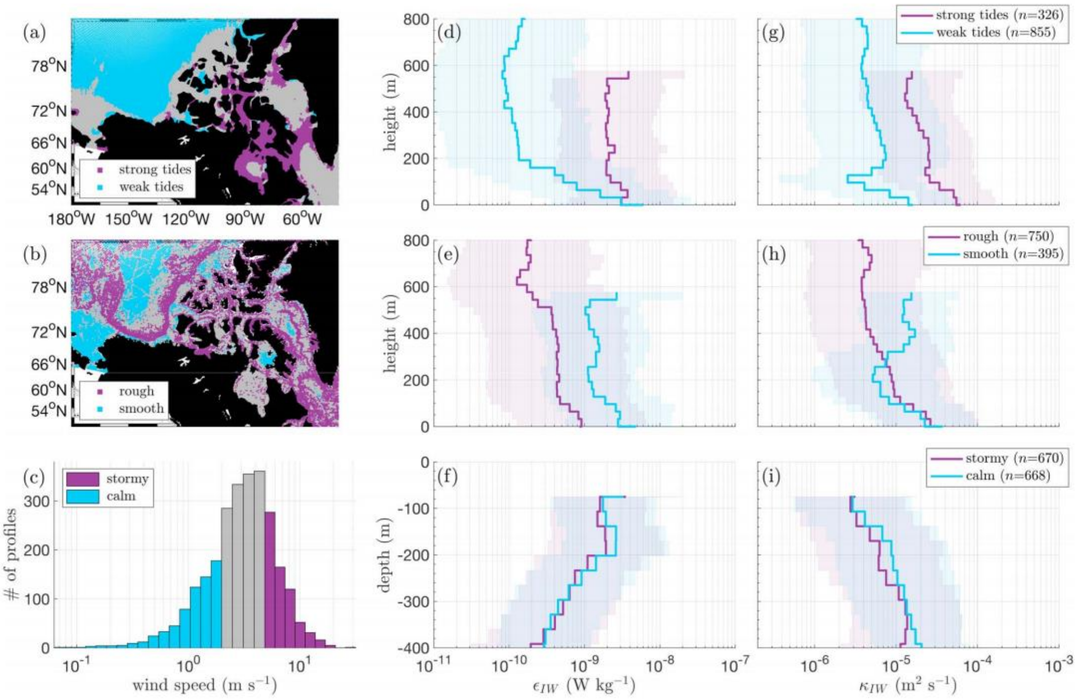


Figure 5 Vertical structures of geometric averaged diapycnal diffusivities K_z with weak and strong wind (green), low and high EKE (blue) and weak and strong internal tide (red) in the (a) low-latitude and (b) middle latitudes.



(Chanona et al., JGR, 2018, Figure 11) E.g. (a) Spatial distribution of strong (purple) and weak (blue) barotropic tidal speeds (b) spatial distribution of rough (purple) and smooth (blue) topography as determined by topographic roughness, and (c) log-scale histogram of stormy (purple) and calm (blue) 10 m wind speeds, associated with each conductivity-temperature-depth profile. High/low bin cutoffs for each parameter are defined by the upper/lower quartile limits of their corresponding distributions; gray regions indicate interquartile values not included in our analysis. Average vertical profiles of ε_{IW} (middle column) and K_{IW} (right column) are binned accordingly for (d, g) strong/weak tidal speeds, (e, h) rough/smooth topography, and (f, i) stormy/calm wind speeds. The number of profiles comprising each vertical average is given by n and shading indicates the associated geometric standard deviations.

b. In order to further verify our results of Fig. 4 and. 5, the Fig. 6 and Fig. 7 were plotted using another direct correlation analysis method. The same conclusion can be drawn from the two kinds of analysis methods. The linear regression is a popular method for statistics analysis of the correlation between two factors (eg. Wu et al., 2011; Jing et al., 2014; Jeon et al., 2018; Zhao et al., 2019). The regression coefficient can represent the response of mixing to wind (eg. Qiu et al., 2012) or other factors. Another reviewer also gave some advises for comparing and interpreting these figures. Noted that Fig. 6 and Fig. 7 have been revised according to the suggestions from both reviewers.

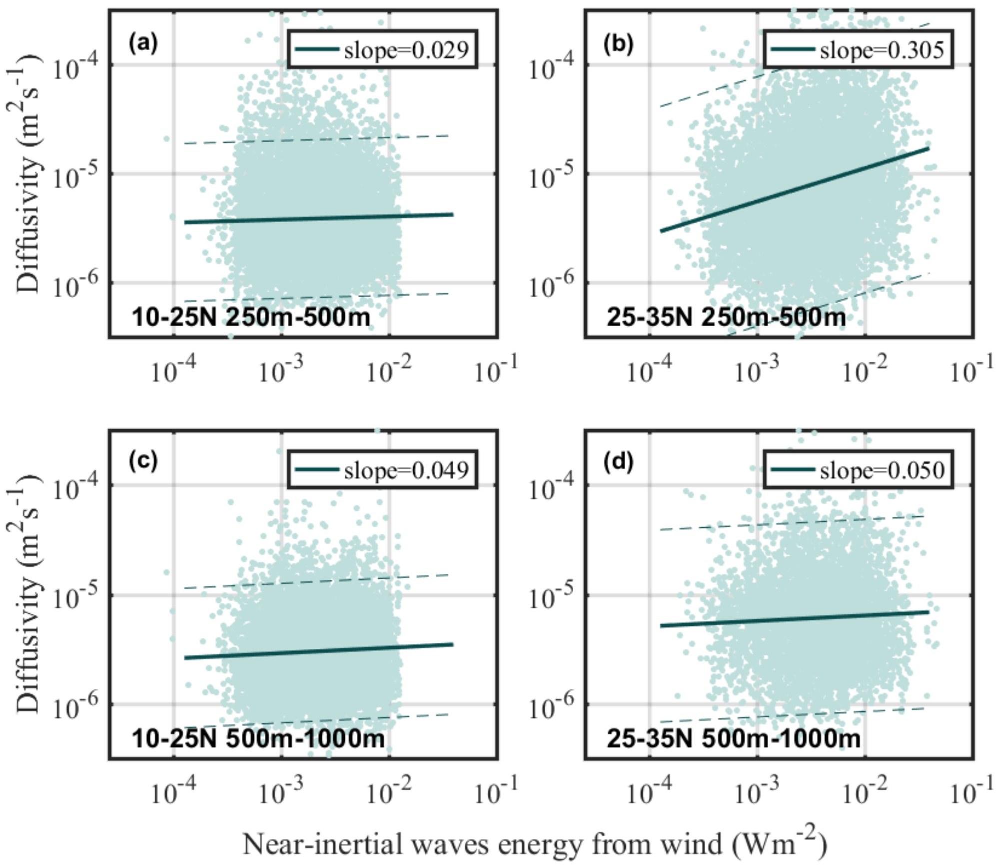


Figure 6 Scatter of log-scale Kz versus log-scale near-inertial energy flux from wind in 250-500 m between (a) 10°N -25°N and (b) 25°N-35°N, and in 500-1000 m between (c) 10°N-25°N and (d) 25°N-35°N The best-fit slopes are denoted by the solid line, the 95% confidence interval is indicated by dash lines.

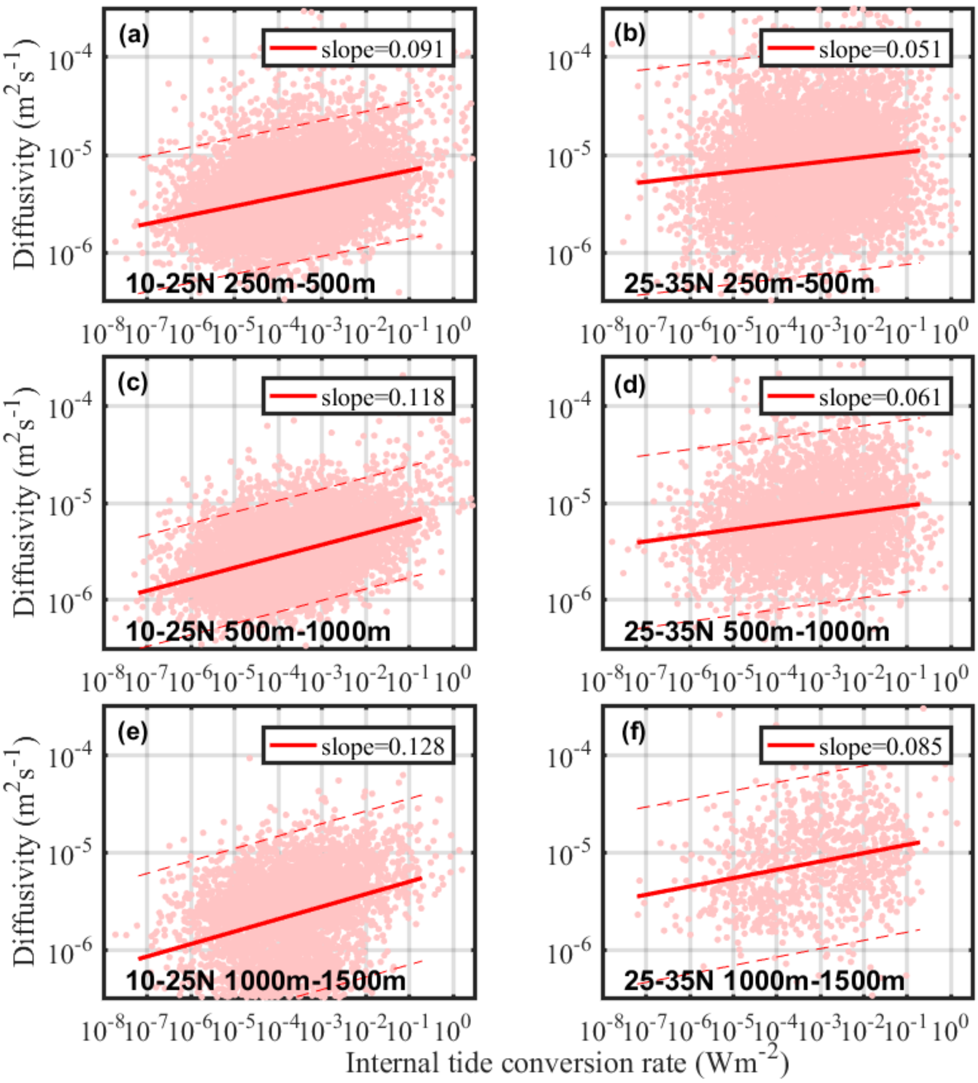


Figure 7 Scatter of log-scale K_z versus log-scale internal tide conversion rate in 250-500 m (row 1), 500-1000 m (row 2), 1000-15000 m (row 3) and the best-fit slopes are denoted by the red line. Columns 1 and are 10°N-25°N and 25°N -35°N latitude bands, the 95% confidence interval is indicated by dash lines.

3. As for the conclusions

The main conclusions in this paper include: 1. internal tides played a significant role in mixing the whole water column in the Philippine Sea. 2. the energetic mesoscale environment increases the internal tidal mixing.

We believe our conclusions are reliable and convincing, with several reasons:

a. The methods used are reasonable. The statistical methods have all passed the significance test.

b. We used different methods for the analysis and come to the same conclusion (eg. Figs. 4,5 and Figs. 6,7; Fig. 8 and Fig. 9). The results from different methods can support each other.

c. Some conclusions can be supported by previous studies. For example, according to Fig. 4 and Fig. 5, we can get the following three messages: 1. Wind and EKE play important roles on mixing the upper ocean in the mid-latitudes; 2. Strong internal tides are easier to enhance mixing in the deeper ocean. 3. Internal tides played a significant role in turbulent mixing not only in the low latitudes, but also in the mid latitudes with r strong winds. The points 1 and 2 are consistent with some previous works (e.g. Waterhouse et al., 2014; Mackinnon et al., 2017; Whalen et al., 2018). The point 3 can be explained by some theoretical and numerical studies. For example, the eddy flows can increase vertical shear and subsequently internal tide energy dissipation rate (eg. Chavanne et al., 2010, Dunphy, 2014).

Therefore, we carefully considered your comments, checked and verified our methods and results again. We believe our methods used are valid and our main conclusions are reliable and reasonable.

There are a few typographic and/or grammatical errors but, in general, the standard of English is satisfactory. The main error is to use "rates" instead of "ratios" in the

correlation analyses (line 250 and elsewhere). The use of "slopes" instead of "ratios" (e.g line 319 and elsewhere) is misleading also (if I have understood the text correctly). In equation (3) I assume that "acrcosh" should be "arccosh"?

Response:

Thank you for your comments, the “rates” (line 250 and elsewhere) was misused in this paper, and it has been corrected. The Figs. 7 and 8 used the linear regression approach, so we think the “slopes” is more suitable here. And the error in equation (3) has been corrected.

References:

Chanona, M., Waterman, S. and Gratton, Y.: Variability of internal wave-driven mixing and stratifification in Canadian Arctic shelf and shelf-slope waters, Journal of Geophysical Research: Oceans, 123, 9178–9195, 2018.

Chavanne, C., Flament, P., Luther, D., & Gurgel, K. W.: The surface expression of semidiurnal internal tides near a strong source at Hawaii. Part Ⅱ: interactions with mesoscale currents*, Journal of

Physical Oceanography, 40(6), 1180-1200, 2010.

Dunphy, M., and K. G. Lamb: Focusing and vertical mode scattering of the first mode internal tide by mesoscale eddy interaction, J. Geophys. Res. Oceans, 119, 523–536, 2014.

Jing, Z., Wu, L., Li, L., Liu, C , Liang, X., & Chen, Z., et al.: Turbulent diapycnal mixing in the subtropical northwestern pacific: spatial-seasonal variations and role of eddies, Journal of Geophysical Research Oceans, 116, 2011.

Jeon, C., Park, J.H., & Park, Y.G.: Temporal and spatial variability of near‐inertial waves in the East/Japan Sea from a high‐resolution wind‐forced ocean model, Journal of Geophysical Research: Oceans, 124, 6015–6029, 2018. https://doi.org/10.1029/2018JC014802

Kunze, E.: Internal-wave-driven mixing: global geography and budgets, Journal of Physical Oceanography, JPO-D-16-0141.1, 2017.

MacKinnon, J. A. et al.: Climate process team on internal-wave driven ocean mixing, Bull. Am. Meteorol. Soc. 98, 2429–2454, 2017.

Qiu, B., Chen, S., and Carter, G. S.: Time‐varying parametric subharmonic instability from repeat CTD surveys in the northwestern Pacific Ocean, J. Geophys. Res., 117, C09012, 2012.

Waterhouse, A.F., J.A. MacKinnon, J.D. Nash, M.H. Alford, E. Kunze, H.L. Simmons, K.L. Polzin, L.C. St. Laurent, O.M. Sun, R. Pinkel, L.D. Talley, C.B. Whalen, T.N. Huussen, G.S. Carter, I. Fer, S. Waterman, A.C. Naveira Garabato, T.B. Sanford, and C.M. Lee: Global Patterns of Diapycnal Mixing from Measurements of the Turbulent Dissipation Rate. J. Phys. Oceanogr., 44, 1854–1872, 2014

Wu, L., Jing, Z., Riser, S., & Visbeck, M.: Seasonal and spatial variations of southern ocean diapycnal mixing from argo profiling floats, Nature Geoscience, 2011.

Whalen, C. B., Talley, L. D., & Mackinnon, J. A.: Spatial and temporal variability of global ocean mixing inferred from ARGO profiles. Geophysical Research Letters, 39(18), 2012.

Whalen, C.B., MacKinnon, J.A. & Talley, L.D.: Large-scale impacts of the mesoscale environment on mixing from wind-driven internal waves. Nature Geosci 11, 842–847, 2018.

Zhang, Z., Qiu, B., Tian, J. et al.: Latitude-dependent finescale turbulent shear generations in the Pacific tropical-extratropical upper ocean, Nat Commun 9, 4086, 2018.

Zhao, Z.: Mapping internal tides from satellite altimetry without blind directions, Journal of Geophysical Research: Oceans, 124, 2019.

Referee #2

The present manuscript describes spatial pattern and seasonal variability of the diapycnal diffusivities in the Philippine Sea. It was shown that seasonal variability was strong in winter and weak in summer at mid-latitudes, with the seasonal fluctuations more obvious in the upper ocean. The diapycnal diffusivitie that is spatially inhomogeneous were estimated from ARGO float data with the fine scale parameterization. The present manuscript is good scientific quality and well written.

First of all, thank you for your support to our work, we have carefully considered your advises and revised the manuscript.

The obtained results are interesting however revision is needed:

1. More convincing comparison and analysis is needed for diapycnal diffusivities scatters fig 6-7.

Response:

We have added some detailed descriptions and marked 95% confidence interval in these figures (see section 3.3.2). Figs. 6 and 7 are used to support the conclusions from Fig. 4 and Fig. 5. The regression coefficient can represent the response of mixing to wind (eg. Qiu et al., 2012) or other factors(eg. Wu et al., 2011; Jeon et al., 2018). And the same conclusion can be drawn from the two kinds of analysis methods.

2. As far as in Fig.3 (diapycnal diffusivities) and Fig.5 (Vertical structures of geometric averaged diapycnal diffusivities) Philippine Sea was divided for two zones (a) 10°N -25°N and (b) 25°N-35°N, but on figures 6-7 Philippine Sea was divided into three zones 10°N -15°N, 15°N-25°N and 25°N-35°N it is difficult to compare the results for zone (10-25) and make a conclusions about that results on Figs. 6-7 is consistent with the results of Fig.3 and Fig.4.

Response:

Good suggestion. According to your comment, we reprocessed the data and redrew the figures. We divided the region into two parts, low latitude and mid-latitude, which are consistent with the division in Fig. 4 and Fig. 5. We found that the new division does not affect the conclusion but can actually interpret the results better. The new Fig. 6 and Fig.7 have been added in main text and corresponding contexts were revised.

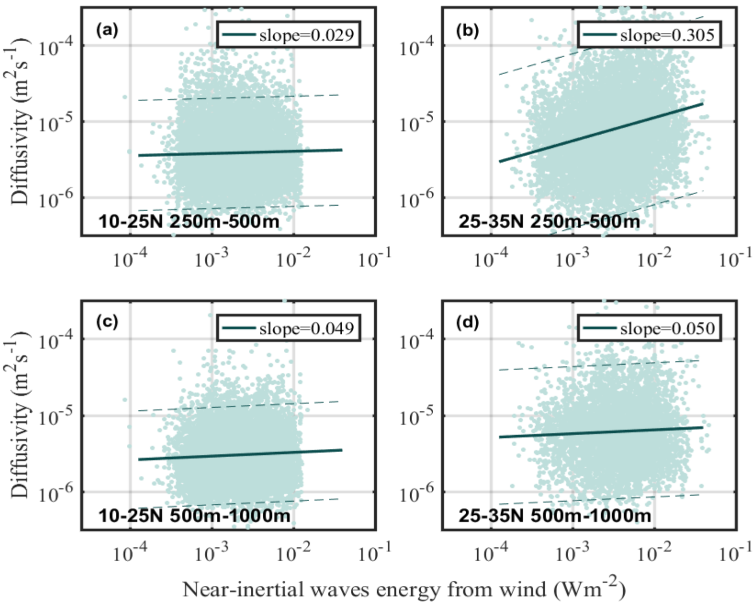


Figure 1 Scatter of log-scale Kz versus log-scale near-inertial energy flux from wind in 250-500 m between (a) 10°N -25°N and (b) 25°N-35°N, and in 500-1000 m between (c) 10°N-25°N and (d) 25°N-35°N The best-fit slopes are denoted by the solid line, the 95% confidence interval is indicated by dash lines.

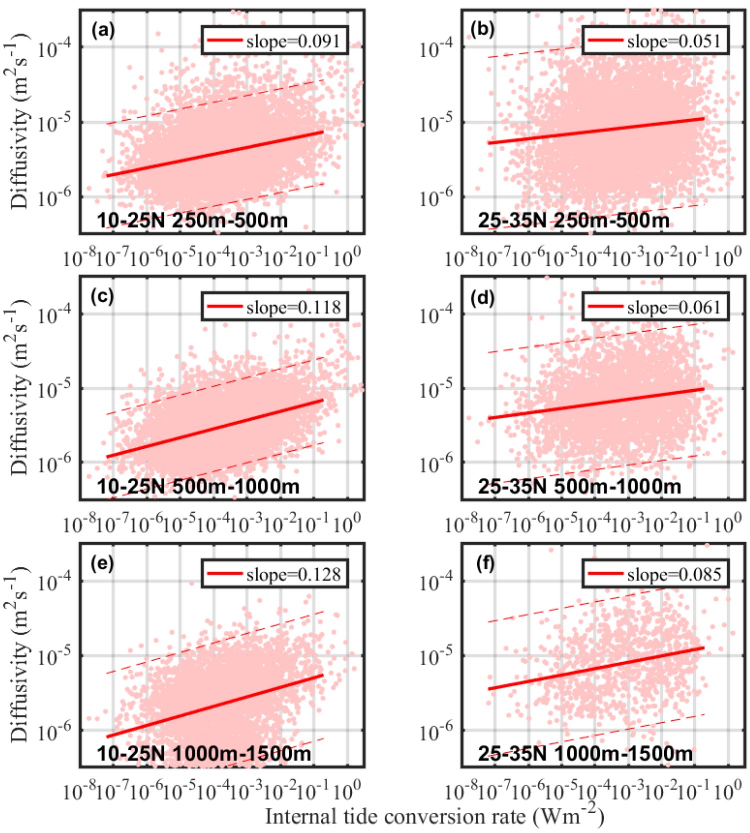


Figure 2 Scatter of log-scale K_z versus log-scale internal tide conversion rate in 250-500 m (row 1), 500-1000

m (row 2), 1000-15000 m (row 3) and the best-fit slopes are denoted by the red line. Columns 1 and are 10°N-25°N and 25°N -35°N latitude bands, the 95% confidence interval is indicated by dash lines.

3. In line 182 H is described as is the mixed-layer depth and was set to a constant 25m, however in Eq (8) H – near-inertial energy flux.

Response:

Thank you for your attention, it has been revised.

4. Typo in Figure 3 Seasonal cycles in diapycnal diffusivities (colorful line) and near-inertial energy flux from wind (green) extents to 250-500 m, 500-1000 m and 1000-1500 m in (a) 10°N -25°N and (b) 10°N-25°N (should be 25°N -35°N).

Response:

It has been corrected.

References:

Wu, L., Jing, Z., Riser, S., & Visbeck, M.: Seasonal and spatial variations of southern ocean diapycnal mixing from argo profiling floats, Nature Geoscience, 2011.

Jeon, C., Park, J.H., & Park, Y.G.: Temporal and spatial variability of near - inertial waves in the East/Japan Sea from a high - resolution wind - forced ocean model, Journal of Geophysical Research: Oceans, 124, 6015–6029, 2018. https://doi.org/10.1029/2018JC014802

Qiu, B., Chen, S., and Carter, G. S.: Time - varying parametric subharmonic instability from repeat CTD surveys in the northwestern Pacific Ocean, J. Geophys. Res., 117, C09012, 2012.