Response to reviewers

Reviewer #3 (Comments to Author (shown to authors):

1. *I agree with the first reviewer that this paper should compare with Vitharana et al. (2021), where the negative correlation between DW1 and ENSO is clearly established, Vitharana also used SABER data.*

Response: The comparison between our results with those of Vitharana et al. (2021) has been rewritten in lines 82-93 and 248-253 in the revised manuscript.

2. The significance of this paper lies in the physical mechanisms. I am surprised to see all three sources (tropospheric heating, wind filtering and gravity waves) are pulling in the same direction, making DW1 amplitude smaller in the El Niño phase. For tropospheric heating, the Hough mode analysis is well done. The tropospheric heating however presents positive and negative correlations with DW1 amplitude at different heights and latitudes. The authors averaged the heating between 0-16 km and 35 N and 35 S and found there is an overall decreasing heating rate during El Niño. How do you justify the choice of the altitude and latitude range? Apparently, if you calculate the correlation with a different range, you can get a totally different conclusion.

Response: Thanks for your comment. According to the tidal theory, Not only HR near the equator that affects DW1 hough (1, 1) but the heating in global troposphere. For example, the major heating for H_2O in equinox is associated with the symmetric (1, -2) mode, and the (1, 1) and (1, -4) symmetric modes are excited with about equal strength with amplitudes ~20-25% of the (1, -2) heating rates (Volland and Hans, 1988; Forbes 1982). Therefore, it is more reasonable to calculate the mass weighted heating rate covering all the area of tropical troposphere (35°S-35°N, 0-16 km) to investigate the effect of tropospheric heating on tides. The correlation coefficient between 15 km DW1-T and the mass weighted HR of the whole tropical troposphere (35°S-35°N, 0-16 km) is 0.45 (significance at the 95% level according to the Student's T test). The correlation between DW1-T and the HR over the whole tropical troposphere is higher than those between DW1-T and the HR over the regions suggested by previous studies (Table 2). Although the correlations with MLT DW1 tide are weaker or even insignificant, the HR averaged over different region as selected by previous studies also suggests negative response during the El Niño winters.

The comparison between HR calculated in different areas has been discussed in lines 328-343 in the revised manuscript.

Table 2 in the revised manuscript: The correlation coefficient between the DW1 T amplitude at 15 km and the mass-weighted HR in different areas during the winters of 1979-2014. The bold numbers indicate that the correlation coefficients are significant at the 95% level. The MLR coefficient on the normalized Niño3.4 index (10^{-3} mw m^{-3} $index^{-1}$) is also exhibited.

Altitude and latitude ranges	0-16 km, 35°N-35°S)	0-12 km, 35°N-35°S)	5-10 km, 35°N-35°S)	5-10 km,20° N-20°S)
Correlation coefficient	**0.45**	**0.36**	0.32	0.32
MLR coefficient on Niño3.4	-3	-10	-26	-9

3. Similar scenario happened to R, the range is chosen between 15 and 35 degrees in each hemisphere, how is this range chosen? does the conclusion change if a different range is chosen? R is positive and negative several times below the MLT, how does that affect DW1 propogation?

Response: Thanks for your suggestion. To investigate the effect of the wave guide on the upward propagation of tide near the equator, the R near the tropics (15-30°) are considered. However, Since f tends to 0 near the equator, the $R = (\bar{\zeta} + f)/f$ tends to infinity. The R over the similar range are also adopted to McLandress et al. (2002b) and Wu et al. (2017).

We modified Figure 6 to show the significance of the regressed R on Niño index. The green thick solid line represents the mean value of the ratio of the absolute and planetary vorticity (R) at the subtropics (15-30°N and 15-30°S), and the thick lines indicate the area where the regressed coefficients are significant at 95% level. The R response to ENSO is positive at 60-100 km in the northern subtropics and 65-100 km in the southern subtropics, which would suppress the upward propagation of the DW1 tide in the mesosphere and contribute to the negative response of the DW1 tidal wind.

Liu (2015) chose 10-40°N (S) to calculate the ratio of the absolute and planetary vorticity R. Figure R2 shows the R value between 10-40°N (S). It can be seen that only the mean R values at 60-80km are continuously significant, which is consistent with figure 6 (15-30°).

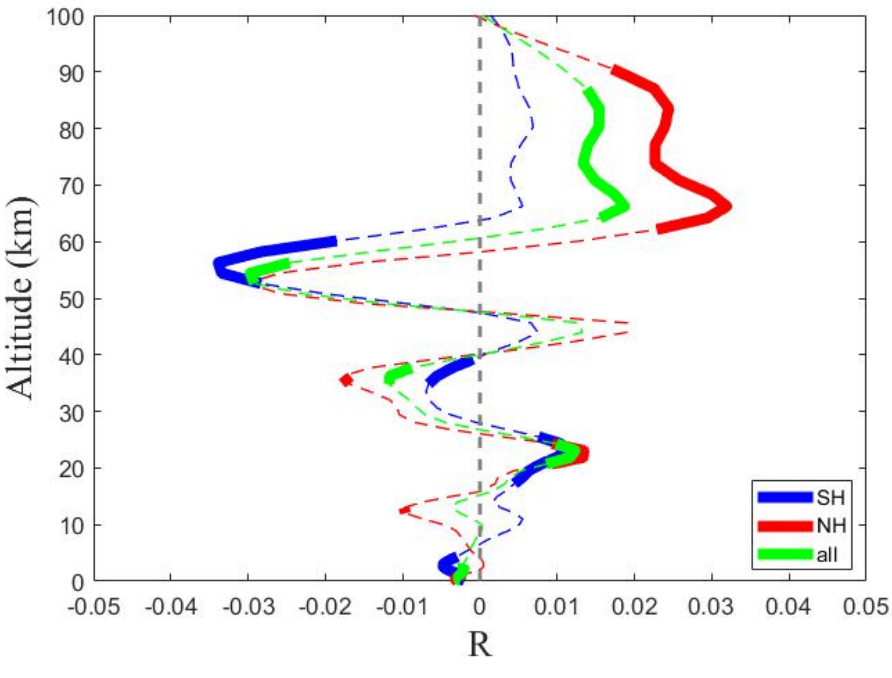

Figure R1 (Figure 6 in the revised manuscript). The anomaly of the ratio of the absolute and planetary vorticity, δR. The thin, dashed red, blue and green lines denote the averages of the

Northern Hemisphere (from 15°N to 30°N), Southern Hemisphere (from 15°S to 30°S) and the whole (15-30°N and 15-30°S) , respectively. The thick, solid lines denote confidence levels below 95% for the F test.

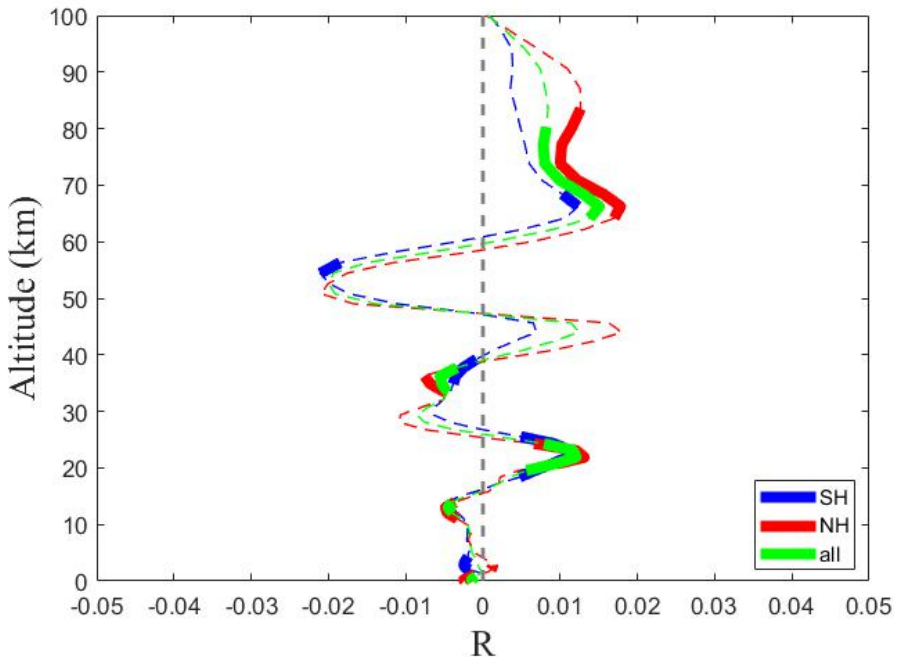

Figure R2. The linear regression coefficient of normalized Niño3.4 in δR (the anomaly of the ratio of the absolute and planetary vorticity). The thin, dashed red, blue and green lines denote the averages of the Northern Hemisphere (from 10°N to 40°N), Southern Hemisphere (from 10°S to 40°S) and the whole (10-40°N and 10-40°S), respectively. The thick, solid lines denote confidence levels below 95% for the F test.

4. I also agree with reviewer 1 that the third mechanism about gravity wave drag needs further investigation. I don't understand why the correlation between gravity wave drag and DW1 is negligible or even negative while the correlation between gravity wave forcing and DW1 is positive in the MLT region at all latitudes.

Response: Thanks for your suggestion. When gravity wave drag variability and tide tendency are close to orthogonal, the correlation between the two can be ignored, but after calculating the phase weight, the orthogonal changes of the two have been excluded, and only the gravity wave drag variability and the tide tendency in the same phase are calculated. So gravity wave forcing and tide may be significantly correlated, albeit at a time when gravity wave drag is less correlated with tide.

Similarly, if the GW drag in the same direction as the tidal tendency increases, which lead the tidal amplitude increases, then gravity wave forcing is positively correlated with the tide. But if the GW drag that is orthogonal to the tidal tendency decreases by a large margin in the same time, it is found that GW drag is negatively correlated with tide, although GW drag which is orthogonal to the tidal tendency does not actually change tide strength directly.

We have included more detailed analysis of GW drag in the main text, please see lines 379-407 in the revised manuscript.

Reference

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