atmosphere

Supplementary Materials of

Investigating the Spatio-Temporal Distribution of Gravity Wave Potential Energy over the Equatorial Region using the ERA5 Reanalysis Data

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S1. A Comparison Between E_P Obtained from ERA5 and TIMED/SABER

The TIMED/SABER (abbreviated as SABER hereafter) V2.0 Level 2A temperature profiles during 2002–2019 were employed to evaluate equatorial E_P using the methods and procedures mentioned in Section 2 of the main text. The result is shown in Figure S1 following the ERA5 result.

Figure S1a repeats the bottom panel of Figure 2 in the main text, which is the zonal mean E_P over the equatorial region (±10° latitude). Figure S1b shows the same thing but is evaluated using SABER data. Although SABER data are not available below 17 km altitude and before 2002, the plot uses the same design as Figure S1a for displaying the same altitudinal range and period. The two results show good agreement in the stratosphere. However, the mesospheric E_P obtained from SABER is much larger than from ERA5. A significant enhancement of the SABER E_P is found above ~ 60 km altitude.

The significant enhancement of SABER mesospheric E_P disturbs our interpretation of the result. We further use the normalized potential energy (E_P*), which is modified from the definition of [49] and defined as $E_P{}^* = E_P/\langle E_P \rangle$, where $\langle E_P \rangle$ is the temporal mean of E_P at each altitude.

Figure S2 shows the zonal mean E_P* obtained from ERA5 and SABER. Both plots show good agreement in the stratosphere, though ERA5 provides more details in small temporal and altitudinal scales. In the mesosphere, the ERA5 E_P* shows its semiannual variation as well as a high dependence on the zonal wind phase; the ERA5 E_P* is low while the westerly is very strong around 65 km altitude (Figure S2a). On the other hand, the SABER mesospheric E_P* shows only the semiannual signal; its high-E_P* bands from the stratosphere penetrate through the strong westerly in the middle mesosphere without significant changes in the E_P* value (Figure S2b). The results imply that the mesospheric E_P obtained from SABER seems not so confident as that from ERA5 because the former shows low sensitivity to the zonal wind.

We found that SABER temperature profiles usually contain a perturbation with a vertical scale of ~5 km. Figure S3 gives an example. Figure S3a demonstrates a typical temperature profile (T) over the equatorial region observed by SABER, and the background temperature ($\overline{T}$), which is the redundancy term after the filtering process, is displayed in Figure S3b. Figure S3c shows the temperature fluctuation, which is the difference between observed temperature and background temperature ($T' = T - \overline{T}$). An evident perturbation, i.e., alternate variation in temperature fluctuation, is found in Figure S3c, and the Brunt–Väisälä frequency square term (N^2) in Figure S3d.

After checking numerous profiles, we suppose this kind of perturbation is not gravity wave activity due to three reasons: (1) the trough and crest of the perturbation repeat every ~5 km in altitude, whereas the wavelength of gravity waves generally increases with increasing altitude; (2) the magnitude of the perturbation enhances dramatically above 60–70 km altitude; (3) this kind of perturbation exists in the upper stratosphere and mesosphere even though the gravity wave activity in the lower stratosphere is low (e.g., the case in Figure S3). The abnormal perturbation in temperature finally results in a very large E_P value as shown in Figure S3e.

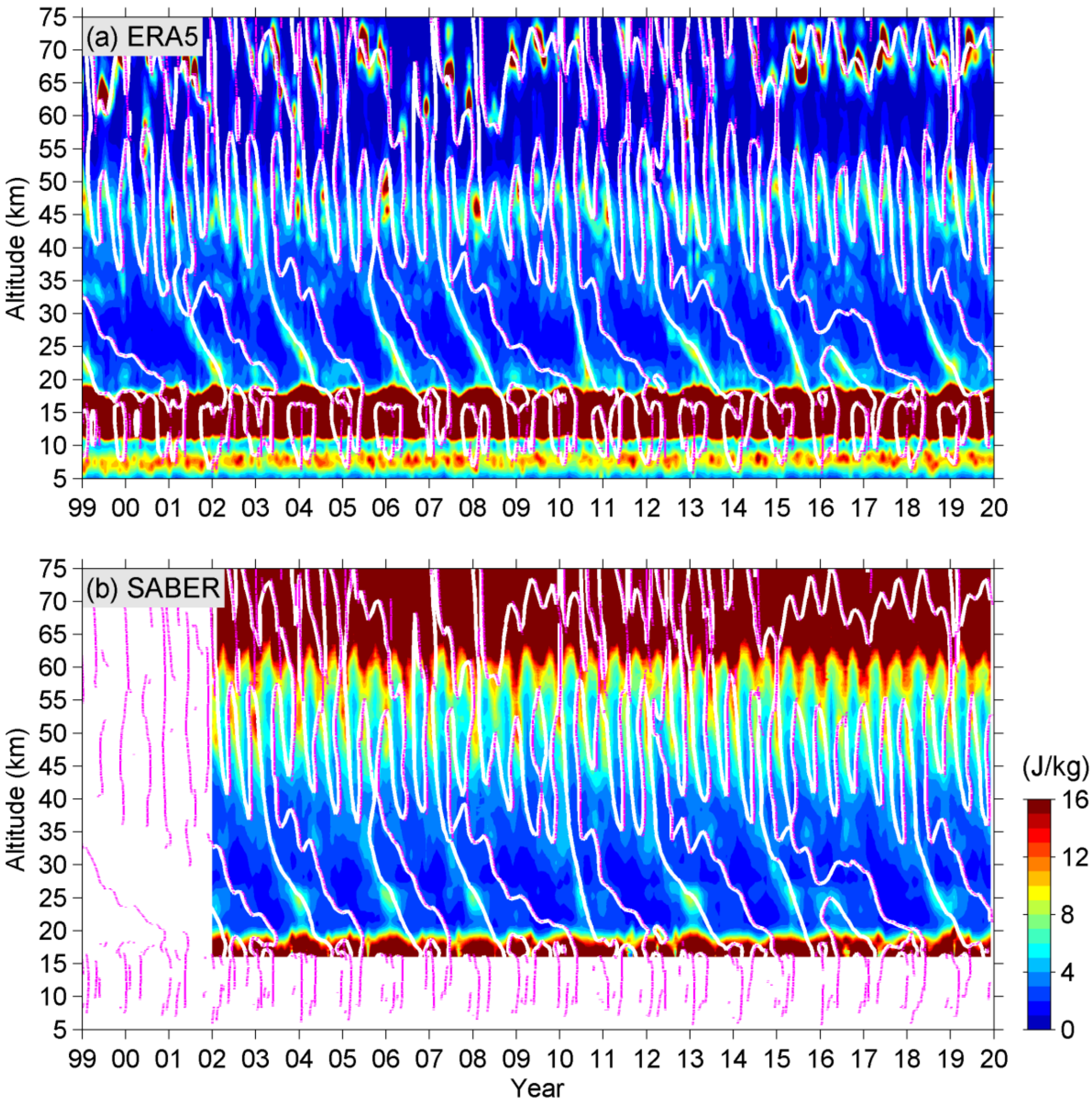

Figure S1. The zonal mean E_P in (**a**) 1999–2019 obtained from ERA5 and (**b**) 2002–2019 obtained from the Thermosphere Ionosphere Mesosphere Energetics and Dynamics/ Sounding of the Atmosphere using Broadband Emission Radiometry instrument (TIMED/SABER). The zero-wind shears of the zonal mean zonal wind are also overlaid on the plots. White contours indicate westerly shears, where the zonal wind reverses from easterly to westerly, and the white contours with magenta shadowing indicate easterly shears.

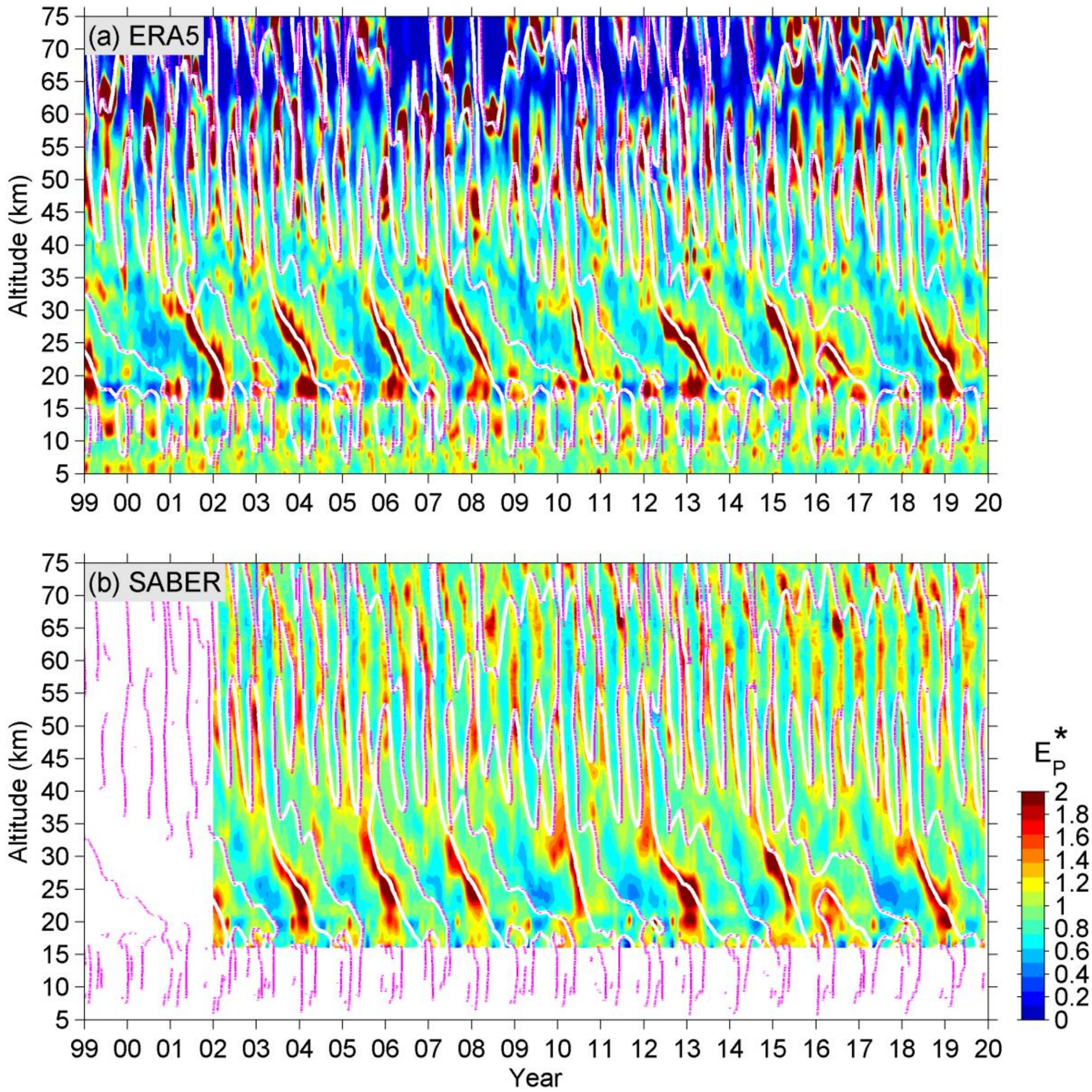

Figure S2. Same as Figure S1, but showing normalized E_P.

S2. Remarks on the ERA5 and SABER Temperature Data and Their Application on Evaluating E_P

Differences in the mesospheric temperature ranging from several K to a few tens K between SABER and other observations have been reported in some previous studies (e.g., the comparisons with satellite [81], LIDARs [82,83], ground-based airglow observations [84], rocket falling sphere/in-situ measurements [85]; also comprehensive assessments of SABER temperature profiles [86,87]).

Mesospheric temperature observations are relatively rare compared to stratospheric and tropospheric temperature observations, especially in-situ measurements. Radiosonde observations are available below ~35 km altitude. However, there is no routine in-situ temperature measurement in the upper stratosphere and mesosphere. It is not able to decide which mesospheric temperature dataset is more realistic due to the insufficiency of in-situ measurements.

ERA5 was chosen to investigate the equatorial gravity wave activity in the present study, not only because it can provide 41-year high-resolution gridded data but also considering its performance. ERA5 has assimilated numerous mesospheric data, include the observations by SSMIS radiometric sensor onboard DMSP satellites and some Global Navigation Satellite System radio occultation (GNSS-RO) missions [56,58]. SSMIS can provide brightness temperature profiles up to 0.02 hPa (~75 km altitude). GNSS-RO missions, such as CHAMP, SAC-C, COSMIC satellite series, GRACE-A/B, METOP-A/B, TerraSAR-X, and TanDEM-X, can provide atmospheric temperature profiles up to 60 km altitude in the lower mesosphere. All of these data are assimilated into ERA5 with appropriate adjustments [58]. It seems ERA5 is a reliable dataset to study the spatio-temporal variation of gravity wave activity, as we have done in the present study. However, we still think SABER is suitable to study the climatology of gravity waves. Figures S1 and S2 reveal that the SABER E_P fits well with the ERA5 E_P in the stratosphere. Although SABER may overestimate the mesospheric E_P (Figure S1; also refer to Figure 3 in [49]), the influence can be reduced using normalization. The global climatology and interannual variability of E_P from the stratosphere to the mesosphere-lower-thermosphere (MLT) region has been studied by [49] using SABER.

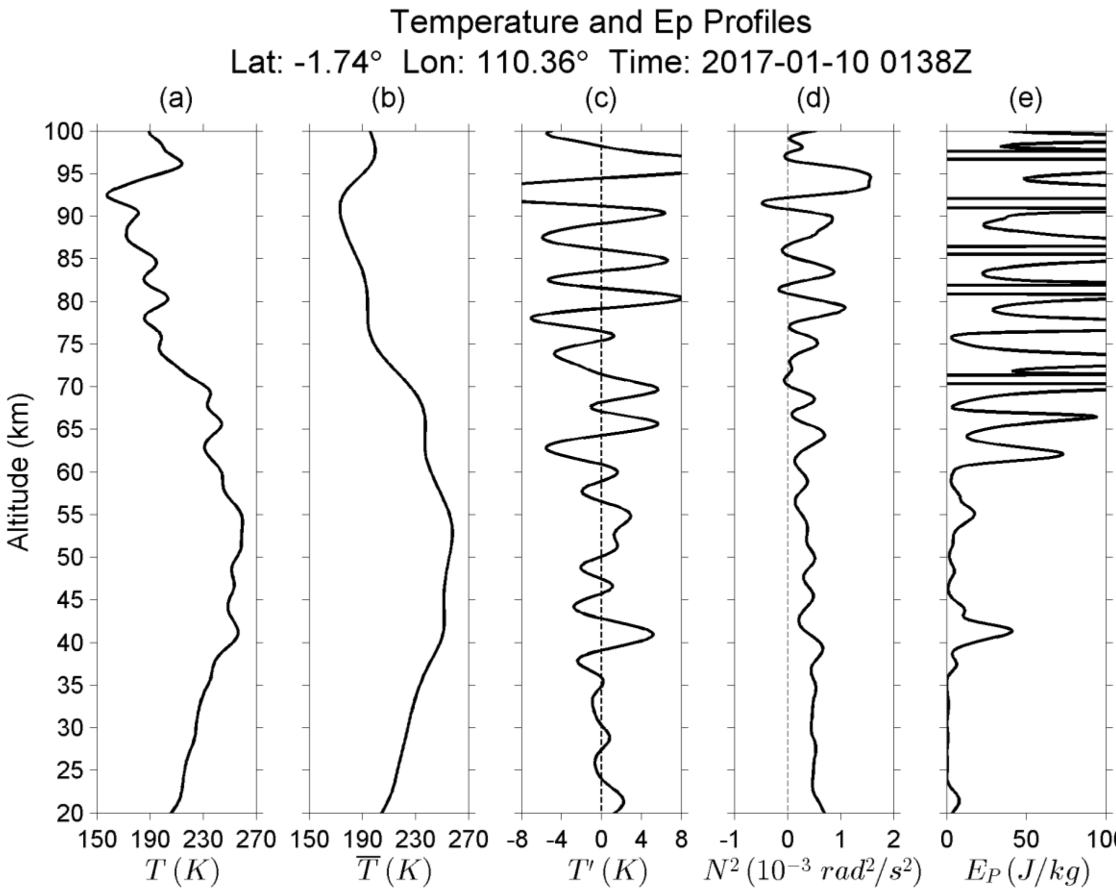

Figure S3. The typical profiles of (**a**) temperature, (**b**) background temperature, (**c**) temperature fluctuation, (**d**) square term of Brunt-Väisälä frequency, and (e) potential energy, as observed by SABER.