Responses to RC2:

General Remarks

This paper describes and validates a new dataset of the monthly mean zonal wind in the height range of 18-100 km at latitudes of 50°S-50°N from 2002 to 2019, which is based on data measured by the SABER instrument. This constitutes a valuable contribution to ESSD. However, the paper is not suitable for publication in ESSD in its present form.

I think the paper could be better in three main points

1. The paper should convince the reader why the BU data set should be used. To play devil's advocate, one might be tempted to conclude "let us just use MERRA" I know there are arguments (like the altitude range of the various data sets) but these arguments could be made much clearer.
2. There is an extensive comparison in the paper between BU and other data sets, which is very good and helpful. However, such comparisons are much more helpful if conducted in a more quantitative way, rather than saying "good agreement" or "almost the same zero wind line". I suggest analysing (and perhaps showing) actual difference plots and percentage differences.
3. The theoretical basis for developing the BU data set is described in sect. 2.2. This description should be clear and straightforward to follow, which is not the case in its present form (see below).

I suggest to return the manuscript to the authors for major revisions.

Response: Thanks a lot for your efforts in evaluating our manuscript. Your comments and suggestions are valuable for us to improve the quality of our manuscript. The point-to-point responses are below.

Point 1. We have added some advantages of BU dataset as comparing to reanalysis data and observations in the abstract, introduction, and conclusions.

In the end of the abstract, we have added "The advantages of the global BU dataset are the large vertical extent (from the stratosphere to the lower thermosphere) and long-term duration (2002-2019). The BU data is useful to study the temporal variations with periods ranging from seasons to decades at 50°S-50°N. It can be used as the background wind for atmospheric wave propagation."

In the last third paragraph of the introduction, we have added "In the current state, the direct global measurement of zonal wind in the upper stratosphere and mesosphere is difficult, and the model-inherent damping in the upper model levels of MERRA2 and ERA5 is still a challenge to get realistic wind in the mesosphere and lower thermosphere (MLT) region (Ern et al., 2021). A candidate is combining the observations of temperature and pressure with balance wind theory to get zonal wind in the MLT region."

At the end of the introduction, we have added a paragraph to describe the possible applications of the BU dataset. "The advantages of the global BU dataset are their large vertical extent and long-term temporal coverage. The vertical extent is from the stratosphere to the lower thermosphere. The temporal coverage is from 2002 to 2019. Thus, the BU dataset can be used to study the global variations of zonal wind in time scales ranging from seasons to decades and from the stratosphere to the lower thermosphere. These variations include SAO, AO, QBO and ENSO (El Niño–Southern Oscillation, periods of 2-8 years, Baldwin and O'Sullivan, 1995). Although QBO and ENSO are originated from the lower atmosphere or sea surface, their influences are global and can extend to the stratosphere or even higher heights and latitudes (Baldwin and O'Sullivan, 1995; Baldwin et al., 2001). Moreover, the interactions among SAO, AO, QBO and ENSO are also important in modulating atmospheric waves, and composition from the stratosphere to the lower thermosphere (e.g., Xu et al., 2009; Liu et al., 2017; Diallo et al., 2018; Ern et al., 2011, 2014, 2021; Kawatani et al., 2020)."

At the end of the conclusion, we have revised as "The BU derived here covers a time span of 18 years and can be used to study the seasonal and interannual variations (e.g., SAO, AO, QBO, ENSO etc.) as well as their global interactions from the stratosphere to the lower thermosphere. It can also serve as the background for wave (such as, gravity waves, tides and planetary waves) propagations and global interactions from the stratosphere to the lower thermosphere."

Point 2. Following your suggestion, the comparisons are performed by analyzing difference plots and the percentage difference. The wind difference (Δu_{im}) at each height (i) and month (m) is calculated by subtracting the wind of other dataset (u_{im}^{ot}) from the BU (u_{im}^{bu}). At each height the percentage difference (P_i) is defined as the ratio of the standard derivations (σ_i) of Δu_{im} to the peak BU. We have added a new figure (Fig. 5 of this version), which summarizes the wind differences, standard deviations (σ) and percentage differences (P) between BU and MerU shown in Figs. 2-4. Moreover, we have revised Figs. 5, 6, 8 of the last version (Fig. 6, 7, 9 of this version) by adding the wind differences. Such that the comparisons are in a more quantitative way. The following analysis is based on the figure numbers of this version and has been added in the text.

The comparisons between BU and MerU

The right column of Fig. 5a shows that the BU is more westward (eastward) than MerU below ~30 km during the period of QBO westward (eastward) phase. At z~30-55 km, BU is more westward than MerU with peak differences of ~20 ms^{-1}. Above ~55 km, the BU is more eastward than MerU with peak differences of ~60 ms^{-1}. A possible reason for the less eastward MerU is the strong damping of MERRA2 (Ern et al., 2021). The standard deviations of the wind differences (left column of Fig. 5a) are less than 7 ms^{-1} below ~40 km and is about 10 ms^{-1} above 42 km. The large percentage differences (middle column of Fig. 5a) with magnitudes of ~30-40% occur at around 20 km and 43 km. In the other height ranges, the percentage differences are ~20%.

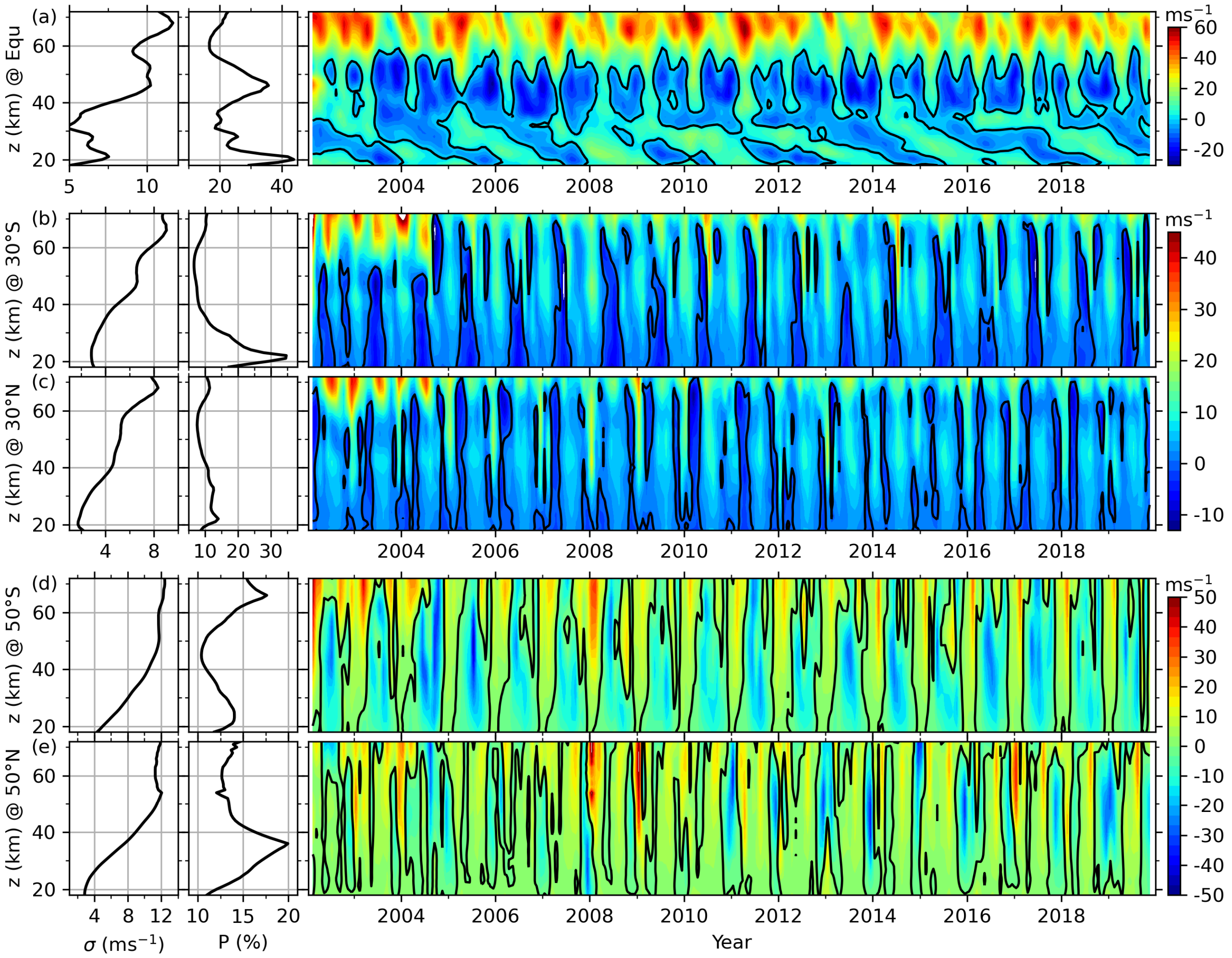

Figure 5. The wind differences between BU and MerU (right column) and their standard deviations (σ, left column) and percentage differences (P, middle column) at the equator (a), 30°N/S (b, c), and 50°N/S (d, e). The black contour lines are the zero wind difference.

At 30°N/S, the wind differences exhibit asymmetric AO generally except for the short-term variations with periods of several months. The asymmetry means that the eastward phase of AO in the wind differences lasts a longer time than the westward phase. Comparisons between Figs. 5b and 3 show that the AO in wind difference is generally in phase with that in the zonal wind. This indicates that the BU is more eastward (westward) than MerU when the wind phase is eastward (westward). Compared to the wind differences before August 2004, the wind differences are smaller above ~60 km. This might be a consequence of the improved quality of MERRA2 after assimilating the MLS data (Molod et al., 2015; Gelaro, et al., 2017). The standard deviations of the wind differences (left column of Figs 5b and 5c) vary from ~3 ms^{-1} to ~8 ms^{-1} with increasing heights. The percentage difference is ~10% in the entire height range, except for ~35% at 21 km and 30°S.

At 50°N/S, the wind differences exhibit asymmetric AO. Here the asymmetries mean that: (1) the time interval of the eastward and westward phases are different in each hemisphere, and they are also different between 50°N and 50°S. At 50°S, the westward (eastward) phase lasts a longer time than the eastward (westward) phase below (above) ~60 km. In contrast, the eastward phase lasts a longer time than the eastward phase at 50°N. The standard deviations of the wind differences (left column of Figs. 5d and 5e) vary from ~3 ms^{-1} to ~12 ms^{-1} with the increasing height. The percentage difference is in the range of 10-17% except for ~20% at 38 km and 50°N.

The comparisons between BU and UarU

The following descriptions on the wind differences have been added in the text.

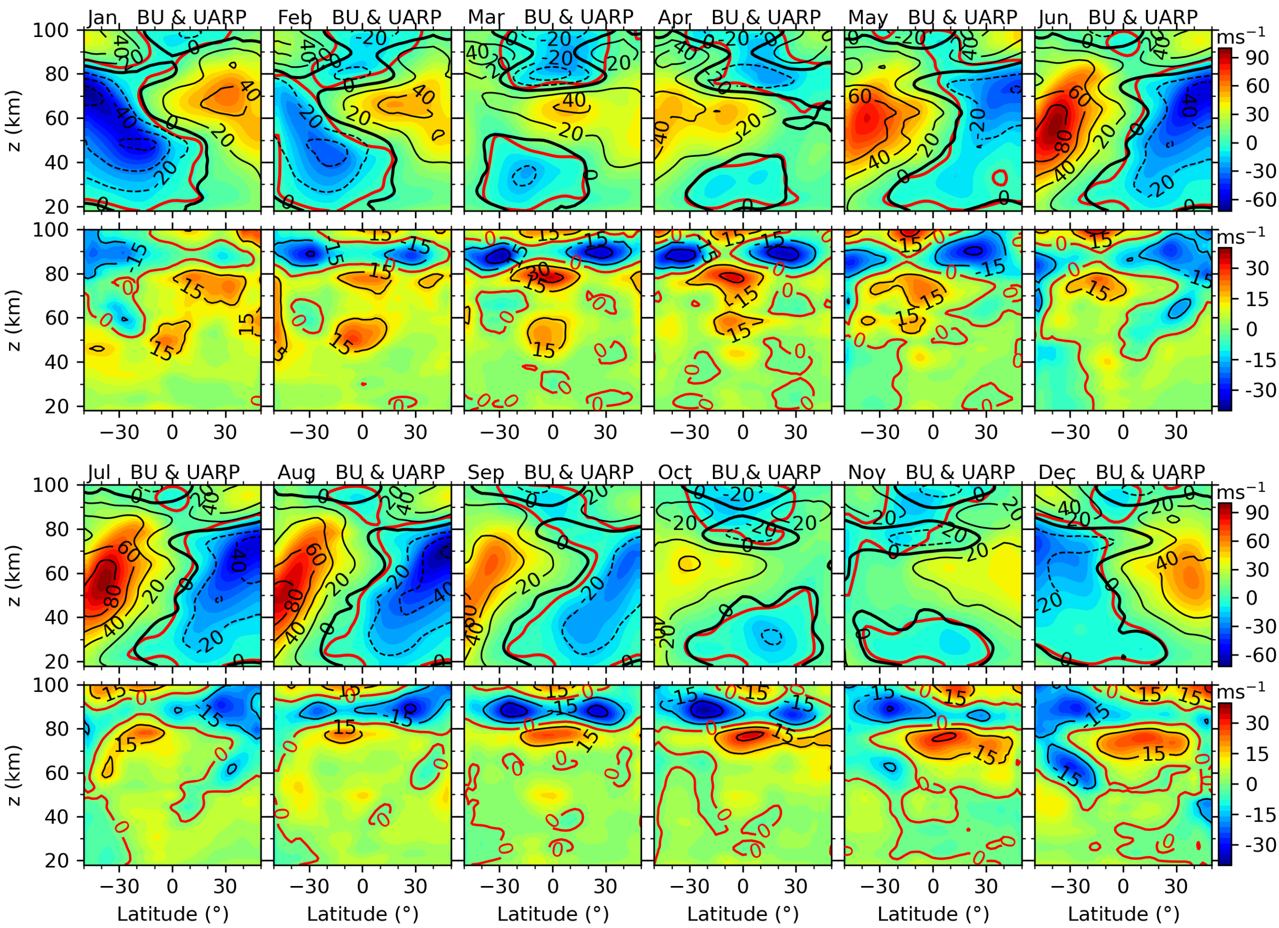

Figure 6. Latitude-height sections of BU and UraU (the first and third rows) and their differences (the second and fourth rows) in each month (denoted one the left-upper corner of each panel) of a composite year. The BU is represented by color filled contour (positive for eastward, zero wind is highlighted by thick red contour lines). The UraU is represented by contour lines with interval of 10 ms^{-1} (the eastward and westward winds are represented as solid and dash lines, respectively. Zero

wind is highlighted by thick black contour lines). The wind difference is represented by color filled contour and highlighted by contour lines. Same color scale is used in each row.

Although BU and UraU exhibit the general consistency in climatologic sense, there are still some differences between them. The wind differences between BU and UraU (the second and fourth rows of Fig. 6) reach eastward maxima of 30 ms^{-1} at around the equator and at ~70-80 km during March-April and October-December. There are also westward differences with peaks larger than 15 ms^{-1} at ~50 km and the equator during January-April. The westward peaks of -30 ms^{-1} occur at around 30°N/S and at ~85-95 km during February-May and August-October. There are also westward differences, which extend downward from ~ 100 km to ~50 km in the SH during November-January and in the NH during June-July. A short summary for the wind differences is that the eastward (westward) differences occur at around the equator (30°N/S).

The comparisons between BU and HwmU

The following descriptions on the wind differences have been added in the text.

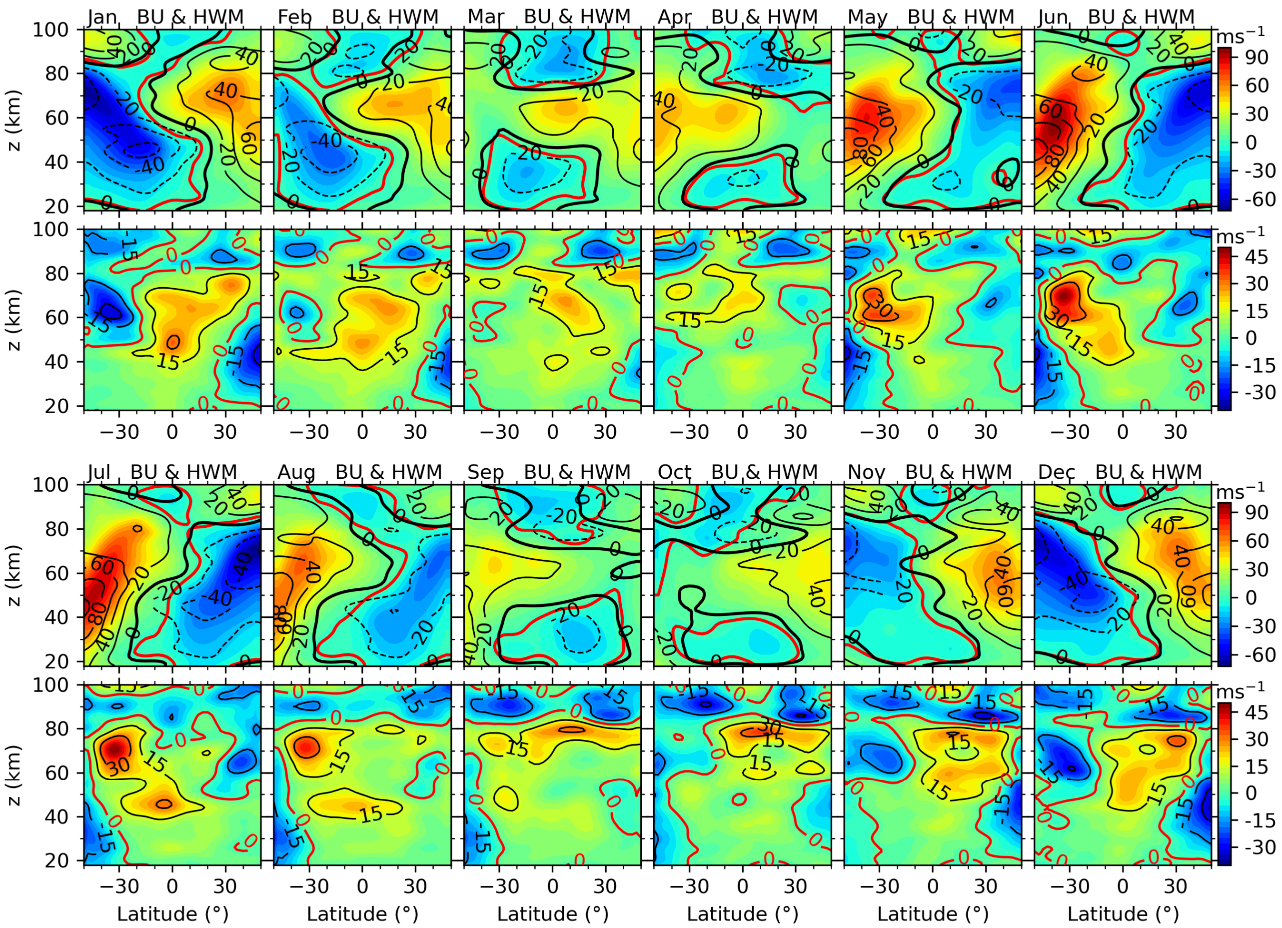

Figure 7. Same caption as Figure 6 but for the BU and HWM14. The thick black and red contour lines are the zero wind of HwmU and BU, respectively.

The differences between BU and HwmU should be mentioned (the second and fourth rows of Fig. 7). Among the composite year, the eastward differences with peak of ~45 ms^{-1} occur at ~60-80 km during May-August in the SH. This is different from the wind differences between BU and UraU, in which the eastward differences reach their peaks at around the equator. The westward differences with peaks of ~-30 ms^{-1} occur at ~30-50 km and latitudes of 30-50°N (30-50°S) during winter in the NH (SH). Moreover, the westward differences with peaks of ~-30 ms^{-1} occur at height of ~55-75 km and latitudes of 30-50°S (30-50°N) during winter in the SH (NH). Above ~80 km, the wind differences are westward in general throughout the composite year. This is in a situation like the wind difference between BU and UraU.

The comparisons between BU and MetU

The following descriptions on the wind differences have been added in the text.

At 50°N and MH station, the eastward differences of BU-MH with peaks larger than 15 ms-1 occur above 85 km and during April-June. In contrast, the eastward differences of larger than 15 ms-1 last a longer time interval for UraU-MetU and HwmU-MetU. Moreover, the westward differences are also larger in UraU-MH and HwmU-MH than those in BU-MH.

At 40°N, and BJ and CSU station, the westward differences of BU-BJ with peaks less than -15 ms^{-1} occur below ~88 km and during May-July. In contrast, the differences of UraU-BJ and HwmU-BJ are eastward with peak values of lager than 15 ms^{-1}, which are larger than those of BU-BJ. The westward differences of BU-BJ and eastward differences of UraU-BJ and HwmU-BJ are responsible for the westward differences of BU-UraU and BU-HwmU at latitudes higher than 30°N (see Figs. 6 and 7). Comparisons among the differences of BU-BJ, UraU-BJ and HwmU-BJ, the magnitudes of the differences of BU-BJ are the smallest one, although they vary with month and height.

At 18.75°N and SY station, the height range and time lasting of westward differences of BU-SY are lager and longer than those of UraU-SY and HwmU-SY. The peak value of the westward differences of BU-SY is more negative than -15 ms^{-1}. This contrasts with the eastward difference of 15 ms^{-1} of UraU-SY and HwmU-SY.

At 1.25°S and BK station, the differences of BU-BK are smaller than those of UraU-BK and HwmU-BK. This might be the inclusion of the zonal wind measured at KT station (0.2°S) when we construct BU at the equator. In contrast, the differences of UraU-BK and HwmU-BK reach their peak values of larger than 15 ms^{-1} in summer and winter.

At 22.5°S and CP station, the differences of BU-CP are eastward with peak of more negative than -15 ms^{-1} in summer and westward in winter with peak of larger than 15 ms^{-1}. In contrast, the differences of UraU-CP are eastward with peak of larger than 15 ms^{-1} below ~92 km and westward above ~92 km. Among the four datasets, the differences of HwmU-CP is the smallest one in general.

A possible reason is that the winds measured medium frequency radar at similar latitudes (Bribe Island at 28°S) have been included in the HWM14 model (Drob et al., 2008).

At 30.0°S and SM station, the differences of BU-SM are mainly westward with peak of more negative than -15 ms^{-1} during April. In contrast, the differences of UraU-SM are eastward with peaks of larger than 15 ms^{-1} at ~82-92 km throughout the composite year. Although HWM14 model included the winds measured by the medium frequency radar at Adelaide (34.5°S) and Bribe Island at (28°S), there are still eastward differences with peaks of larger than 15 ms^{-1} during June and September.

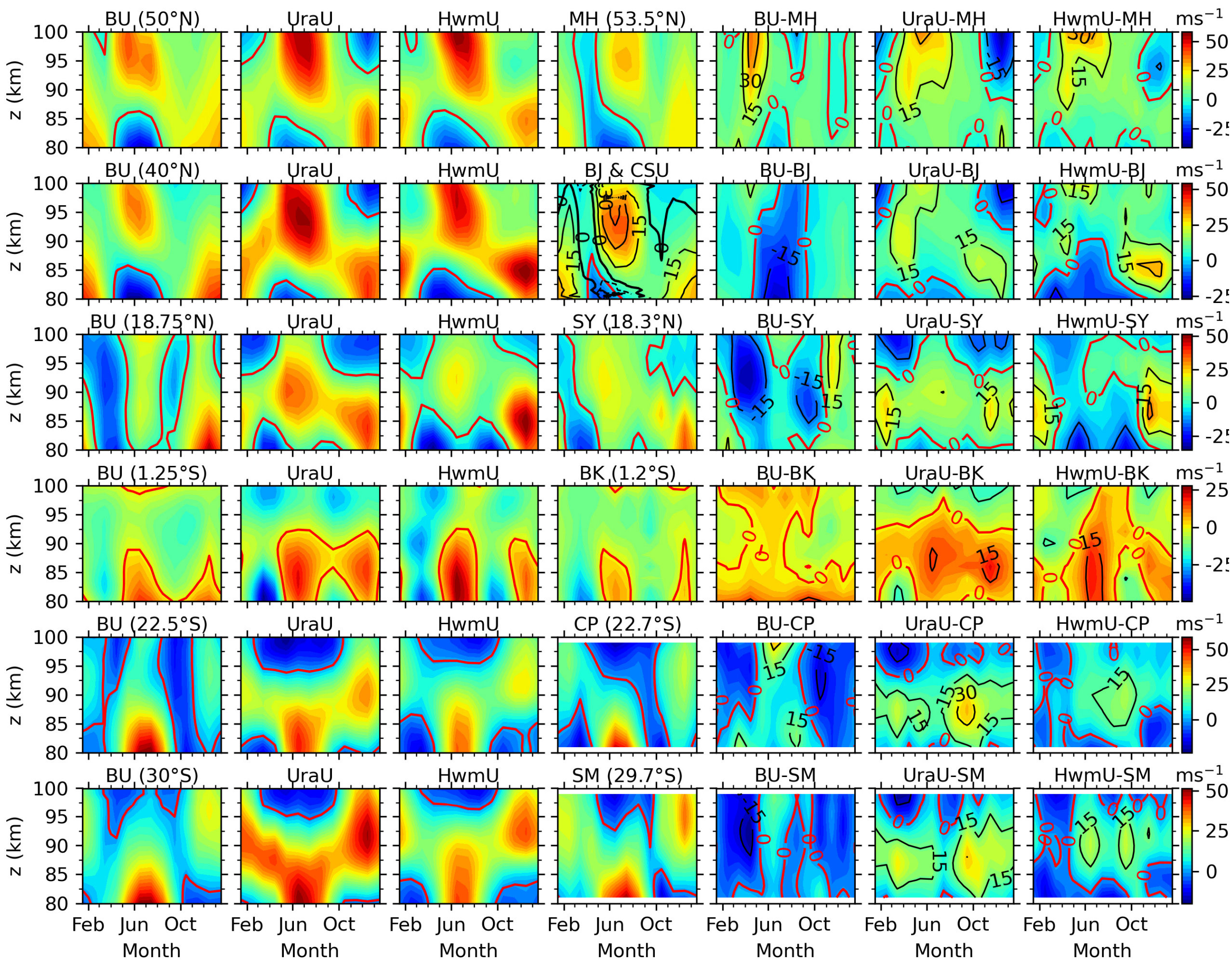

Figure 9. Monthly mean zonal winds of BU, UraU, HwmU, and MetU (from the first to fourth column) and their differences (from the fifth to seventh column) at stations of (from up to below) MH (53.5°N), BJ (40.3°N), SY (18.3°N), BK (1.2°S), CP (22.7°S) and SM (29.7°S) in a composite year. The red contour lines show the zero wind in each panel. The black contour lines (interval of 10 ms^{-1}) show the zonal wind measured by the CSU lidar (LidU). The wind difference is represented by color filled contour and highlighted by contour lines.

Point 3. The theoretical basis has been revised as the following (detailed description can be found in response to **Section 2.2**):

Eq. (3) has been successfully applied to the latitude bands of 70°S-8°S and 8°N-70°N to get zonal mean wind (Fleming et al., 1990; Smith et al., 2017). We restrict Eq. (3) at 10°N-50°N and 10°S-50°S due to the un-continuous sampling of the SABER measurements poleward of 53°N/S. At around the equator, the solution of Eq. (3) is an indeterminate form of 0/0 as $\varphi \to 0$ and can be solved through the L'Hôpital's rule if we get continuous values of $\bar{p}$ and $\bar{\rho}$. In fact, only the discrete values $\bar{p}$ and $\bar{\rho}$ with latitude interval of 2.5° can be obtained from observations. To apply Eq. (3) at the equator, one need to differentiate Eq. (3) with φ. As $\varphi \to 0$, we have $\tan\varphi \to \varphi$, $\sin\varphi \to \varphi$. Thus, Eq. (3) can be simplified as (Fleming et al., 1990; Swinbank & Ortland, 2003),

$$\bar{u} = -\frac{1}{2\Omega a\bar{\rho}}\frac{\partial^2\bar{p}}{\partial\varphi^2}. \qquad (4)$$

Comments in detail

Section 2.2: The method of deriving the BU data set is discussed here; this is an important part of the paper. It needs to be clear and should be understandable (in principle) without going back to the cited literature. First Eq. (3) should be valid at the equator (as it can be simplified to Eq. (4) at the equator). Is this correct? But in line 131 you say 10°-50°N/S for the BU data set – this seems to be a contradiction. Further, in l. 136, you say that Eq. (3) is valid from 8°S to 8°N as well as 70°-90°N and 70°-90°S. This is how I read your text. This is inconsistent with the given range of the BU data. I might not be correct here, but this discussion is not as clear as it should be.

Response: Thanks for your careful reading. The description should be clarified.

Indeed, Eq. (3) is valid at the equator in theory.

$$\frac{\bar{u}^2}{a}\tan\varphi + f\bar{u} = -\frac{1}{a\bar{\rho}}\frac{\partial\bar{p}}{\partial\varphi}. \qquad (3)$$

From Eq. (3), we get

$$\bar{u} = \frac{-f \pm \sqrt{f^2 - 4\frac{\tan\varphi}{a}\frac{1}{a\bar{\rho}}\frac{\partial\bar{p}}{\partial\varphi}}}{2\frac{\tan\varphi}{a}}. \qquad (\text{R1})$$

At the equator, $\varphi = 0$. Both the numerator and denominator of the right-hand side (RHS) of Eq. (R1) approaches to 0 as $\varphi \to 0$. In theory, the RHS of Eq. (R1) is an indeterminate form of 0/0 as $\varphi \to 0$. In theory, Eq. (R1) can be solved through the L'Hôpital's rule if we get continuous values of $\bar{p}$ and $\bar{\rho}$ as $\varphi \to 0$. In fact, the continuous values of $\bar{p}$ and $\bar{\rho}$ as $\varphi \to 0$ cannot be obtained since we have only the discrete values $\bar{p}$ and $\bar{\rho}$ with latitude interval of 2.5°. Thus, although Eq. (3) is valid at the equator, the problem is that we cannot get its solution.

At the equator, one need to differentiate Eq. (3) with φ. As $\varphi \to 0$, we have $\tan\varphi \to \varphi$, $\sin\varphi \to \varphi$, and $f = 2\Omega\sin\varphi \to 2\Omega\varphi$, Thus, Eq. (3) can be simplified to

$$\frac{\bar{u}^2}{a} + 2\Omega\bar{u} = -\frac{1}{a\bar{\rho}}\frac{\partial^2\bar{p}}{\partial\varphi^2} \quad \text{(R2)}$$

Since the magnitude of $\bar{u}^2$ (maximum with order of 10^4) is far less than the radius of the earth a (order of 10^7), $\bar{u}^2/a \sim 0$. Finally, we get

$$\bar{u} = -\frac{1}{2\Omega a\bar{\rho}}\frac{\partial^2\bar{p}}{\partial\varphi^2} \quad (4)$$

In the text, this point has been revised as following:

Eq. (3) has been successfully applied to the latitude bands of 70°S-8°S and 8°N-70°N to get zonal mean wind (Fleming et al., 1990; Smith et al., 2017). We restrict Eq. (3) at 10°N-50°N and 10°S-50°S due to the un-continuous sampling of the SABER measurements poleward of 53°N/S. At around the equator, the solution of Eq. (3) is an indeterminate form of 0/0 as $\varphi \to 0$ and can be solved through the L'Hôpital's rule if we get continuous values of $\bar{p}$ and $\bar{\rho}$. In fact, only the discrete values $\bar{p}$ and $\bar{\rho}$ with latitude interval of 2.5° can be obtained from observations. To apply Eq. (3) at the equator, one need to differentiate Eq. (3) with φ. As $\varphi \to 0$, we have $\tan\varphi \to \varphi$, $\sin\varphi \to \varphi$. Thus, Eq. (3) can be simplified as (Fleming et al., 1990; Swinbank & Ortland, 2003),

$$\bar{u} = -\frac{1}{2\Omega a\bar{\rho}}\frac{\partial^2\bar{p}}{\partial\varphi^2}. \quad (4)$$

Comparison with reanalyses

I would be helpful to know if any of the data used for BU are assimilated in MERRA2. Also be clearer about for which latitude range you compare MERRA2 and BU. Why do you not compare with ERA5? (And add the reference to Hersbach et al. (2020) for ERA5).

Response: These points should be clarified.

(1) The data used to calculate BU are the temperature and profiles measured by the SABER instrument and the zonal wind observed by a meteor radar at Koto Tabang (0.2°S). None of these data are assimilated in MERRA2. We have clarified this point in the beginning of Section 3.1 as "First of all, we should note that the BU data are derived from the temperature and pressure profiles measured by the SABER instrument and the zonal wind observed by a meteor at Koto Tabang (0.2°S). None of these data are assimilated in assimilated in MERRA2. Thus, BU and MerU are independent.".

(2) In section 2.1, we have refined the latitude range for comparing MERRA2 and BU as "Such that the monthly zonal mean (MerU) wind can be obtained to validate the BU at 50°N-50°S"

(3) Thanks for your references. We have added Hersbach et al. (2020) for ERA5. Moreover, Ern et al. (2021) have performed a comprehensive comparison between ERA5 and MERRA2, as well as some other reanalysis data. Part of results of Ern et al. (2021) have been included in our introduction as "A recent study by Ern et al. (2021) showed that both MERRA2 and ERA5 capture the semi-

annual oscillations (SAO) in the stratopause region and lower mesosphere at around the equator. In the middle atmosphere, MERRA2 produces a reasonable SAO due to the assimilated Aura Microwave Limb Sounder (MLS) data (Schwartz et al., 2008; Molod et al., 2015). Above 65 km, the mesopause SAO produced by ERA5 is stronger than that by MERRA2. This is because the stronger damping of MERRA2 reduces the amplitude of the mesopause SAO."

ERA5 has spatial resolution of 0.25° in both longitude and latitude and 137 levels (up to ~ 80 km). The main difficulty for us is to get the ERA5 data. Using the CDS API provided on the web of https://confluence.ecmwf.int/display/CKB/ERA5%3A+data+documentation, we have tried to download the ERA5 data. In fact, it takes about several hours to download the data in a model day. These data include the wind (txyz), as well data used to calculate geometric height (e.g., surface pressure (txy), geopotential (txy), temperature (txyz), and relative humidity (txyz)). Here t is hourly time, x=longitude (1440 grids from 180°W to 179.75°E), y=latitude (420 grids from 52.5°S to 52.5°N), z is model level from 1 to 137. Then using these data, the python code "compute_geopotential_on_ml.py" as well as the instructions provided at https://confluence.ecmwf.int/display/CKB/ERA5%3A+compute+pressure+and+geopotential+on+model+levels%2C+geopotential+height+and+geometric+height, we can get the wind at geometric height. In the future, if we get ERA5 data spanning one year, the comparison will be performed.

References

The citations are okay, but there could be a bit more recent references to scientific issues to which the data set could be applied. For example, Diallo et al. (2018) find that the QBO disruption in 2015-2016 reversed the lower stratosphere moistening triggered by the alignment of the warm ENSO event with westerly QBO in early boreal winter. Would the BU data set also be useful for ENSO?

Response: Thanks for your suggestion. The BU dataset is useful for ENSO. We have added this in the end of the introduction as "The advantages of the global BU dataset are the large vertical extent and long-term temporal coverage. The vertical extent is from the stratosphere to the lower thermosphere. The temporal coverage is from 2002 to 2019. Thus, the BU dataset can be used to study the variations of zonal wind in time scales ranging from season to decades from the stratosphere to the lower thermosphere. These variations include SAO, AO, QBO and ENSO (El Niño–Southern Oscillation, periods of 2-8 years, Baldwin and O'Sullivan, 1995). Although QBO and ENSO are originated from the lower atmosphere or sea surface, their influences are global and can extend to the stratosphere or even higher heights and latitudes (Baldwin and O'Sullivan, 1995; Baldwin et al., 2001). Moreover, the interactions among SAO, AO, QBO and ENSO are also important in modulating global atmospheric waves and composition from the stratosphere to the lower thermosphere and globally (e.g., Xu et al., 2009; Liu et al., 2017; Diallo et al., 2018; Ern et al., 2011, 2014, 2021; Kawatani et al., 2020)."

Moreover, Ern et al. (2021) find that reanalyses reproduce some basic features of the SAO gravity wave driving and that higher-top models (ERA-5 and MERRA-2) show stronger gravity wave driving of the SAO eastward phase in the stratopause region and in the lower mesosphere. But reanalyses are limited by model-inherent damping in the upper model levels. Would such findings be relevant for the data set discussed here? You do not need to consider the specific papers/findings mentioned here, but they might be a starting point.

Response: Sure, the findings in Ern et al. (2021) is interesting. The following has been as in the text to strengthen the importance of developing wind data in the mesosphere and lower thermosphere region. "In the current state, the direct global measurement of zonal wind in the upper stratosphere and mesosphere is difficult, and the model-inherent damping in the upper model levels of MERRA2 and ERA5 is still a challenge to get realistic wind in the mesosphere and lower thermosphere (MLT) region (Ern et al., 2021). A candidate is combining the observations of temperature and pressure with balance wind theory to get zonal wind in the MLT region."

Diallo, M., Riese, M., Birner, T., Konopka, P., Müller, R., Hegglin, M. I., Santee, M. L., Baldwin, M., Legras, B. and Ploeger, F.: Response of stratospheric water vapor and ozone to the unusual timing of El Niño and the QBO disruption in 2015-2016, Atmos. Chem. Phys., 18(17), 13055–13073, doi:10.5194/acp-18-13055-2018, 2018.

Ern, M., Diallo, M., Preusse, P., Mlynczak, M., Schwartz, M., Wu, Q. and Riese, M.: The semiannual oscillation (SAO) in the tropical middle atmosphere and its gravity wave driving in reanalyses and satellite observations, Atmos. Chem. Phys. Discuss., (March), 1–56, doi:10.5194/acp-2021-190, 2021.

Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., Schepers, D., Simmons, A., Soci, C., Abdalla, S., Abellan, X., Balsamo, G., Bechtold, P., Biavati, G., Bidlot, J., Bonavita, M., De Chiara, G., Dahlgren, P., Dee, D., Diamantakis, M., Dragani, R., Flemming, J., Forbes, R., Fuentes, M., Geer, A., Haimberger, L., Healy, S., Hogan, R. J., Hólm, E., Janisková, M., Keeley, S., Laloyaux, P., Lopez, P., Lupu, C., Radnoti, G., de Rosnay, P., Rozum, I., Vamborg, F., Villaume, S. and Thépaut, J. N.: The ERA5 global reanalysis, Q. J. R. Meteorol. Soc., 146(730), 1999–2049, doi:10.1002/qj.3803, 2020.

Presentation

Overall the paper is well written, but I suggest a revision to correct several small grammatical errors. In particular, get the difference between "well" (adverb) and "good" (adjective) correct.

Response: We have revised this as "agree well" or "good agreement" in this version.

Minor Points

1. p 1, l. 20: `tide alias' will not be clear to everyone, rephrase.

Response: We have added a note in the introduction to explain the "tide alias" as "This is because the diurnal tide is prominent and exhibits short-term (one to serval days) variations. The full diurnal cycle is composed by the data from many days (e.g., 60 days for SABER observations). Thus, the obtained are the mean of diurnal tides over these days. However, the short-term variations of diurnal tides are still in the background and alias the derived winds based on the gradient wind balance theory."

2. p. 1 l 23: make sure to clarify that (e.g.) the MERRA comparison is not only 53.3°N to 29.7°S. Also the data set is only 50°S-50°N, so how can you compare at 53.3°N?

Response: We have revised "53.3°N" as "around 50°N". Moreover, we have added a note in Section 3.3 as "Here we note that the BU at 50°N, which represents the latitude range of 47.5°N-52.5°N, is near the location of MH (53.5°N) station. The slight difference of latitude might contribute some discrepancies between the BU and MetU at MH (53.5°N) station."

3. p.1 l 25: I would not call the QBO in 2016 "anormal", I am not even sure if this is proper English. See for example Diallo et al. (2018).

Response: According to your suggestion, we revised it as "disrupted QBO" in the text.

4. p.2, l. 57: Be specific about ECMWF: do you mean ERA5 or ERA Interim or both? I guess you mean ERA5. Add the reference to Hersbach et al. (2020) for ERA5.

Response: Sure, we mean ERA5 and added Hersbach et al. (2020) for ERA5. According to the findings by Ern et al. (2021), we have added the following comparisons between ERA5 and MERRA in the text. "A recent study by Ern et al. (2021) showed that both MERRA2 and ERA5 capture the semi-annual oscillations (SAO) in the stratopause and the lower mesosphere at around the equator. In the middle atmosphere, MERRA2 produces a reasonable SAO due to the assimilated Aura Microwave Limb Sounder (MLS) data (Schwartz et al., 2008; Molod et al., 2015). Above 65 km, the mesopause SAO produced by ERA5 is stronger than that by MERRA2. This is because the stronger damping of MERRA2 reduces the amplitude of the mesopause SAO."

5. p 3, l. 80: justify the choice of these latitudes.

Response: we have revised it as "around 50°N to 29.7°S". Moreover, we have added a note in Section 3.3 as "Here we note that the BU at 50°N, which represents the latitude range of 47.5°N-52.5°N, is near the location of MH (53.5°N) station. The slight difference of latitude might contribute some discrepancies between the BU and MetU at MH (53.5°N) station."

6. p. 4, l 113: should be `Remsberg'.

Response: We have revised "Remsburg" as "Remsberg".

7. p. 4, l 117: The original profiles are from SABER -- correct? Be specific here.

Response: We have revised this sentence as "All the original profiles measured by the SABER instrument are interpolated linearly to 18-108 km with vertical interval of 1 km."

8. p. 5, l 147: I suggest to refrain from such abbreviations in titles.

Response: According to your suggestion, we have expanded the abbreviations to their full name. These subtitles are listed below:

2.3 Modification of Equatorial Balance Wind by the Wind Measured by Meteor Radar at Koto Tabang

3.1 Comparisons with the Wind from MERRA2

3.2 Comparisons with the Winds from UARP and HWM14 in a Composite Year

3.3 Comparisons with the Time Series of Winds Measured by Meter Radars

3.4 Comparisons with the Winds Measured by Meteor Radars and Lidar in a Composite Year

9. p. 11, l. 333: "tide alias" is not clear without further explanation.

Response: We have added a note in the introduction to explain the "tide alias" as "This is because the diurnal tide is prominent and exhibits shorter term (one to serval days) variations. The full diurnal cycle is composed by the data from many days (e.g., 60 days for SABER observations) to obtain diurnal tides, which is the mean of diurnal tides over these days. However, the shorter term variations of diurnal tides are still in the background and alias the derived winds."