Responses to Editor:

Both reviewers are reasonably satisfied with the improvements made to the paper. Reviewer 1 has made additional suggestions for improving to the clarity of the paper. The authors should consider these suggestions carefully when submitting their final version. Given the reviewers reports, this paper can proceed to publication in ACP.

Response: I am very grateful to you and reviewers for the efforts putted in our manuscript.

The main concern from reviewer#1 have been addressed as below:

Since wind velocity is a vector, which can be eastward (with positive value) or negative (with negative value). The wind direction is represented by its sign, i.e., the eastward (westward) wind is represented by positive (negative) value. Then the strength of wind is represented by its magnitude (or absolute value), i.e., stronger eastward (westward) wind has larger positive (negative) value. Thus, in the text, we use values (with sign and magnitude) to represent wind speeds. The "increasing" means the increasing of the values. In a same way, the MEI index is also represented by its value.

In the new version, we have added "We note that the wind direction is represented by its sign, i.e., the eastward (westward) wind is represented by positive (negative) value. Then the strength of wind is represented by its magnitude (or absolute value), i.e., stronger eastward (westward) wind has larger positive (negative) value. In the following, we use values (with sign and magnitude) to represent wind speeds. For example, the "increasing of BU" means the increasing of the values of BU. In a same way, the MEI index is also represented by its value" in the first paragraph of Sec. 2.2.

Responses to Reviewer#1:

I have read the track-changes revised version and the responses to reviewers. The authors have conscientiously tried to address each of the reviewers' comments. I still have a hard time in understanding the meaning of some important sentences. I think that a significant effort is needed to clarify the meaning of many of the sentences; perhaps ACP has personnel who can help sort that out during typesetting? If so, then I recommend publication.

Response: Thanks for your efforts in our manuscript. Following your suggestions, we have made point-to-point revisions and responses. Please see below and text for details.

Comments:

1. In the abstract, it is still hard sometimes to understand the sense of physical relationships. For example, one can say that during QBO E at 30 hPa the polar vortex is weaker during the NH winter (the "Holton-Tan effect"). This is a specific statement of both phase and amplitude of a relationship between two specific locations, which is what is required for the reader to be able to comprehend what you mean. Please consider this in thinking about all of your statements. Please make sure that it is clear where the locations are that you are talking about and what the phase relationship is. If you are going to describe a pattern, then you need to describe the pattern and not just say "increasing" or something like that.

   Response: This point should be clarified.

   Since wind velocity is a vector, which can be eastward (with positive value) or negative (with negative value). The wind direction is represented by its sign, i.e., the eastward (westward) wind is represented by positive (negative) value. Then the strength of wind is represented by its magnitude (or absolute value), i.e., stronger eastward (westward) wind has larger positive (negative) value. Thus, in the text, we use values (with sign and magnitude) to represent wind speeds. The "increasing" means the increasing of the values. In a same way, the MEI index is also represented by its value.

   Following your comments#3:

   Your understanding "the whole data set increase by +10 m/s at every location in latitude-altitude when the MEI goes up by 0.1" is just what we want to express.

   For example, if the responses of BU to MEI is 5 ms^{-1}/MEI at certain location, we mean that if values of MEI have an increment of 0.1, the BU will have an increment of 0.5 ms^{-1}. This does not depend on the sign of MEI or BU, but depend on their increment or decrement.

   Another example, "as the increasing of the QBO wind, both BU and MerU change from increasing to decreasing with the increasing height". This means that "as the increasing of **the**

values representing QBO wind, **the values** of both BU and MerU change from increasing to decreasing with the increasing height".

In the new version, we have added "We note that the wind direction is represented by its sign, i.e., the eastward (westward) wind is represented by positive (negative) value. Then the strength of wind is represented by its magnitude (or absolute value), i.e., stronger eastward (westward) wind has larger positive (negative) value. In the following, we use values (with sign and magnitude) to represent wind speeds. For example, the "increasing of BU" means the increasing of the values of BU. In a same way, the MEI index is also represented by its value" in the first paragraph of Sec. 2.2.

2. I still cannot understand the meaning of (line 35) "As the increasing of the QBO wind, both BU and MerU change from increasing to decreasing with the increasing height." What does increasing of the QBO wind mean? The QBO exists over a broad range of latitude and altitude and descends with time. Does it mean when U at 30 hPa over the equator goes from easterly to westerly there are change in BU? (But what does change in BU mean?) Does it mean when the amplitude of the QBO is larger? What does it mean for something to "change from increasing to decreasing with the increasing height"? Since it is the QBO, would whatever you are talking about then increase again with increasing height? Are you talking about at the equator? If so, is there an opposite phased response at higher latitudes? Are you talking only about amplitude, or are you also talking about phase?

Response: Following the response to comment#1. The "increasing of the QBO wind" means "increasing of the values representing QBO wind".

In line 33-34, we have revised as "As the increasing of the values representing QBO wind (short for QBO wind), bot values of representing BU and MerU (short for both BU and MerU) change from increasing to decreasing with the increasing height and extend from the equator to higher latitudes".

3. l37-39: "Both BU and MerU increase with the increasing of MEI (an indicator of ENSO) and decrease with increasing F10.7 (an indicator of solar activity) responses to ENSO and F10.7 are strongest (positive and negatively, respectively) in the southern stratospheric polar jet region below 70 km." What does it mean for BU to increase with increasing MEI? Does the whole data set increase by +10 m/s at every location in latitude-altitude when the MEI goes up by 0.1? When the MEI is positive, aren't there both positive and negative wind anomalies in different regions? If so, how can BU increase with increasing MEI?

Response: Your understanding "the whole data set increase by +10 m/s at every location in latitude-altitude when the MEI goes up by 0.1" is just what we want to express. For example, if the

responses of BU to MEI is 5 ms^{-1}/MEI at certain location, we mean that if values of MEI have an increment of 0.1, the BU will have an increment of 0.5 ms^{-1}. This does not depend on the sign of MEI or BU, but depend on their increment or decrement.

In line 35-37: we have revised as "both BU and MerU increase with the increasing of the values of MEI (an indicator of ENSO) and decrease with increasing F10.7 (an indicator of solar activity) in the southern stratospheric polar jet region below 70 km"

4. l63-66: Do you have any possible mechanism or other evidence that the QBO is controlled by the lunar period? Since the QBO period varies from 22 to 34 months, how can that be related to a mathematical superposition of an earth year and a lunar month? Why would lunar gravity affect the tropical stratosphere? The normal theory of causation involves deep convection exciting gravity waves, with wave-mean flow interaction. It is a highly developed theory and has been tested in many ways. Are you sure you want to say that the QBO is due to the moon? I don't think that Baldwin et al. said that the QBO is related to the lunar period.

Response: Thanks for your suggestion. We have removed the point on "QBO is controlled by the lunar period" in the new version.

5. l120: I believe that there is a 1985 paper about the diurnal tide by Hitchman and Leovy, JAS, p. 557.

Response: Thanks for your suggestion. Hitchman & Leovy (1985) has been cited. This sentence is revised as "To overcome the tidal alias above 80 over the equator (Hitchman and Leovy, 1985, 1986…)" in lines 122 and 168.

Hitchman, M. H. and Leovy, C. B.: Diurnal Tide in the Equatorial Middle Atmosphere as Seen in LIMS Temperatures, J. Atmos. Sci., 42, 557–561, https://doi.org/10.1175/1520-0469(1985)042<0557:DTITEM>2.0.CO;2, 1985.

6. Since the QBO is a fundamental part of the atmosphere, and is included in the data set, it strikes me as odd to view "the BU" as "responding" to the QBO, rather than simply observing that there is a QBO signal in the data set. Why say that a data set responds to part of itself instead of saying simply that the data exhibits a QBO signal?

Response: Sure, the QBO is a fundamental part of the atmosphere and can be seen clearly in equatorial stratosphere (Figure R1). However, the QBO signal is not as obviously in the mesosphere and at middle and high latitudes (Figure R2) as that in the equatorial stratosphere. As reviewed by Baldwin et al. (2001), the effects of QBO can extended to the mesosphere and to middle and high

latitudes. To see to what extent the influences of the QBO in the equatorial stratosphere on the winds at other latitudes and height, the multiple linear regression (MLR) method was used to isolate the relative contributions of the variations and effects of QBO, ENSO, and solar activity on zonal winds.

Baldwin, M. P., Gray, L. J., Dunkerton, T. J., Hamilton, K., Haynes, P. H., Randel, W. J., Holton, J. R., Alexander, M. J., Hirota, I., Horinouchi, T., Jones, D. B. A., Kinnersley, J. S., Marquardt, C., Sato, K., and Takahashi, M.: The quasi-biennial oscillation, Rev. Geophys., 39, 179–229, https://doi.org/10.1029/1999RG000073, 2001.
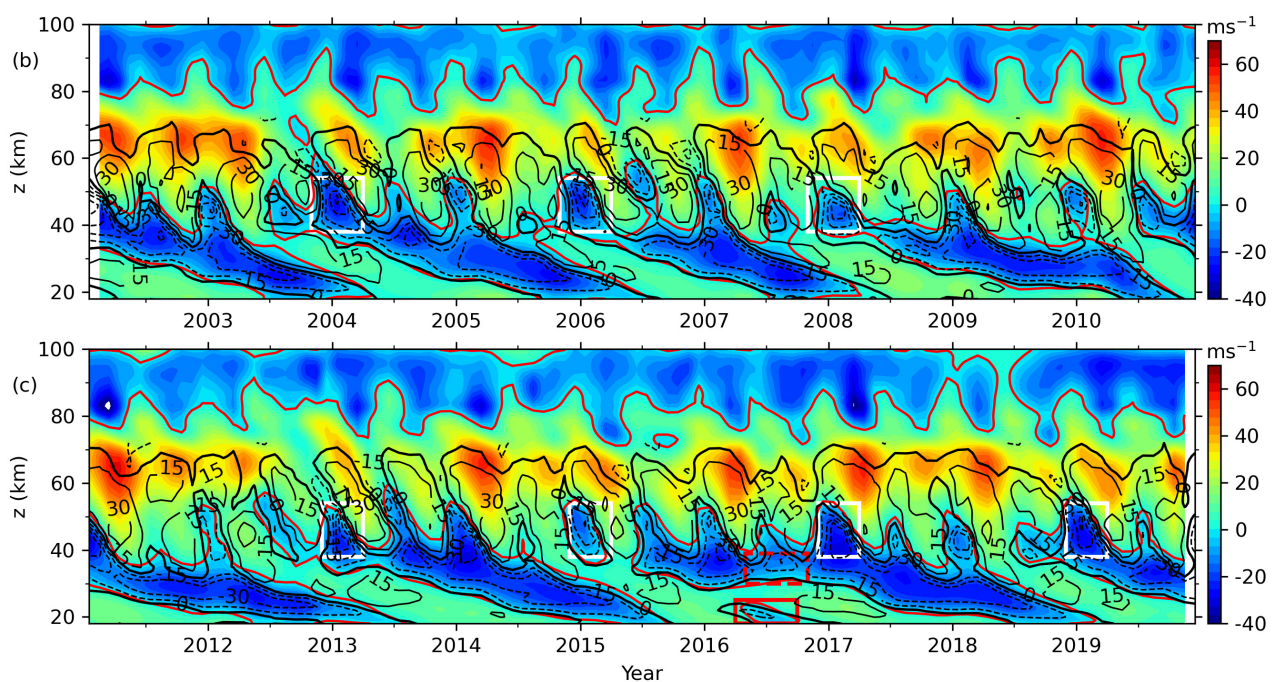
Figure R1: Balance winds (color filled contour, positive for eastward) and MerU (lines with contour interval of 20 ms^{-1}, the eastward and westward winds are represented as solid and dash lines, respectively) at the equator. This is the Figure 2 of Liu et al. (2021)
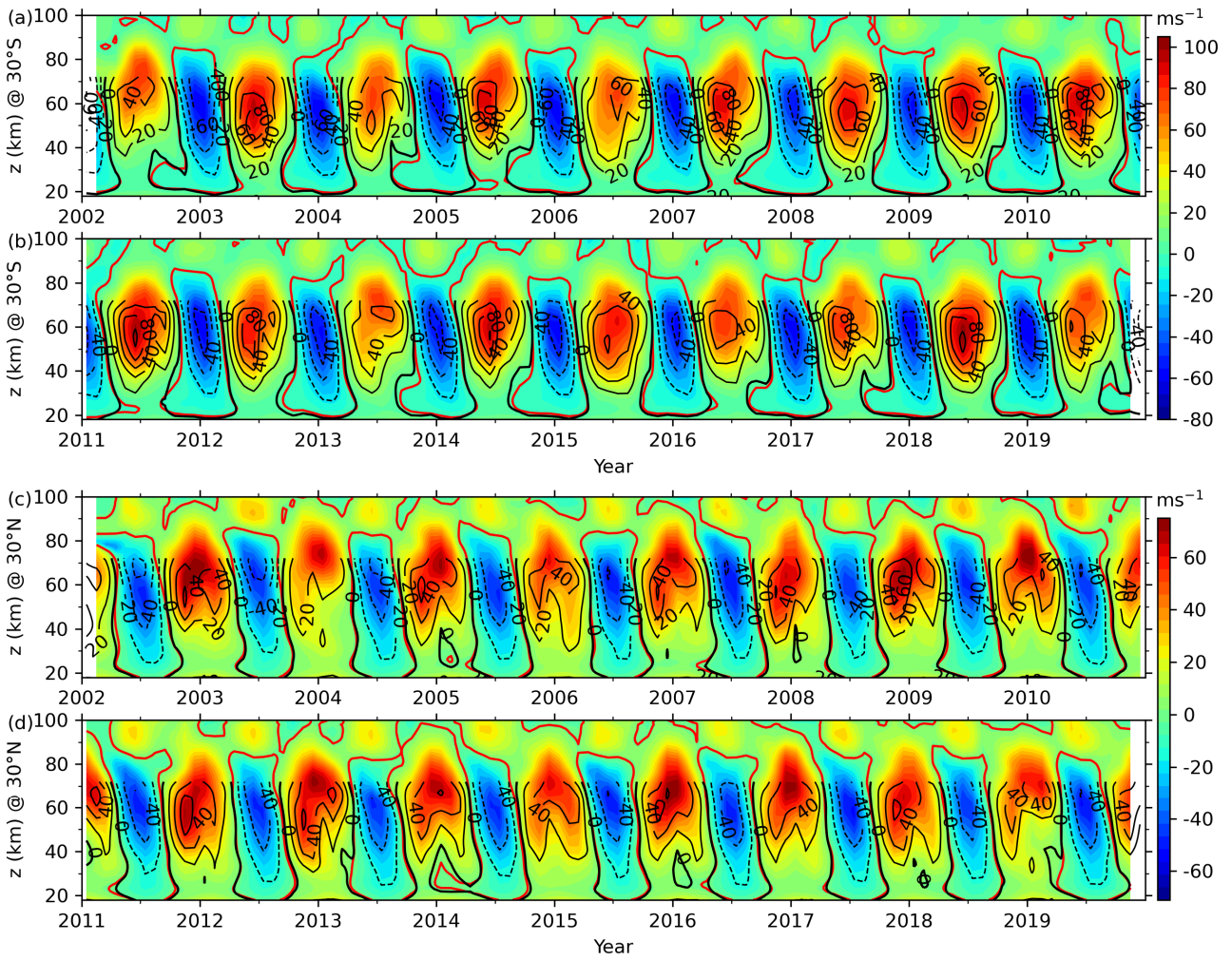
Figure R2: Time-height sections of the BU (color filled contour, positive for eastward) and MerU (lines with contour interval of 20 ms^{-1}, the eastward and westward winds are represented as solid and dash lines, respectively) at 30°S (a, b) and 30°N (c, d). This is the Figure 3 of Liu et al. (2021)