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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Intraseasonal to interannual variability of Kelvin wave momentum fluxes as derived from high-resolution radiosonde data" *by* Jeremiah P. Sjoberg et al.

Anonymous Referee #1

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This paper describes a method to estimate time series of Kelvin wave momentum flux from radiosonde data, and by applying the method, seasonal and QBO-related variations of the flux are obtained using 11-year sonde data. In addition, the sensitivity of the estimates to the vertical and temporal resolutions is assessed. The flow of the text is logically natural, and the figures attached are high quality. The method used seems proper and advantageous to obtain continuous time series of flux for target period bands, although it also has a limitation for easterly background winds (see the specific comments below). I recommend this paper for publication after revisions regarding the following comments.

[specific comments]

1. In section 2.2, the authors describe in detail the estimation method which is extended from the method used in previous studies. I suggest clarifying the difference, extension, or improvement from the previous method. For example, in P5 L28–31, the authors state that the results from their method are similar to those from previous studies in terms of overall range of vertical wavelengths, confirming the fidelity of the method. However, it is not clearly stated what the improvement/advantage of the present method is. Clarifying this in section 2.2 and/or in conclusion section could help readers and strengthen the paper.

2. P4 L20–23: To demonstrate resolution effects more completely, the sensitivity of estimates not only to output resolutions (Δt_{win} and Δz_{win}) but also to raw data resolutions (i.e., vertical/temporal stepping of raw data before interpolation procedure) could be investigated. For example, from a 50-m resolution profile, one could make a 300-m resolution profile by picking one data point every six points. Interpolation using the original 50-m data and that using the sub-sampled 300-m data can result in different estimates of parameters even for the same Δz_{win} value.

3. P6 L6: "strong easterlies often result in negative k." : This can be in part due to the restriction of ground-based frequency to be positive. In principle, the spectral transform in time just gives the absolute value of the frequency, so that we still have freedom to determine its sign, while the intrinsic frequency (and k) is fixed to be positive. What will happen in the results if negative ground-based frequencies are allowed in the strong easterly regions ?

4. Figs. 4 and 5: Too many regions are filled by missing for the easterly wind where the Kelvin wave flux is actually maximal (e.g., Ern and Preusse, 2009). Also, the regions

of large momentum flux in the westerly shear layer, which are important for the QBO to descend, are very close to the missing regions below. Therefore, the large Kelvin wave flux in such strong easterly regions could be of interest. It would be very nice if the authors explore ways to estimate the momentum flux in such easterly regions, as much as they can.

5. I feel that the grammar used is not perfect. The judgment for English editing will be left to the authors and other reviewers.

[minor comments]

P1 L4-5: "Estimates ... larger." : Readers could read this as the authors themselves also estimated the momentum flux from satellite and reanalysis data. I suggest deleting this sentence.

P2 L5: "identical" → "opposite" ? Please check this and make it consistent with the descriptions in this paragraph.

P2 L8–17: Some phrases are repetitive within this paragraph. Please reorganize this paragraph.

P2 L19: "vertical momentum" → "zonal momentum"

P3 L9: I suggest including ", variability, " between "climatologies" and "vertical ...", considering the title of this paper.

P3 L16: What do the "two climatologies" mean ?

P3 L29: What is an approximated vertical step corresponding to the 2 seconds, considering lifting speed of the balloon ?

P4 L13: "linearly interpolated in height and spline interpolated in time": The linear interpolation also is one of the spline interpolations. Please include the order of the spline interpolation in time used here (e.g., cubic spline).

P4 L17: "linear and spline" → "orders of" / "changes to" → "changes in"

P4 L18: "point. An exception to this is if the time" → "point, unless the time"

P4 footnote: "too short" → "too long" ? Based on my experience, the scale height in the tropical lower stratosphere is about 6 km or even shorter.

P5 L6: "but that variations in the stratification ... L_z." : Where (and how) is this assumption used in your method ?

P5 L25: "temperature leads zonal wind": What is the criterion for this lead/lag relation ? e.g., phase difference of 45–135°, or 0–180° ? It is better to include this information in the text, considering that the determination of lead/lag relation between two variables is ambiguous as the phase difference becomes close to 0 or 180°.

P5 L27: Please include the minus sign in front of the "2π", as the authors defined m to be negative (P5 L5).

Fig. 1 caption: Please include "40-day mean" in (c) in front of "vertical quadrature spectrum". In addition, I suggest changing "filtering window" to "period" (L5; L6; L8) in order to clarify its meaning.

P8 L6: "as expected ... (a)" : Zonal wavelengths cannot be expected from visual inspection of (a) in which the time–height cross section is shown.

Fig. 2: The right axes are not linear while the left axes are linear. I have thought that the percent difference is defined as $(M - M_0)/M_0$ where M_0 is the momentum flux estimated with the reference (250-m and 24-hour) resolutions. If it is right, the percent difference and M have linear relationship.

Fig. 2 caption: "time mean momentum fluxes from ..." : Based on the text, it is more

precise to describe this as “momentum flux, estimated using time-mean parameters, from ...”

P9 L7–10: As already pointed out by the technical review of the manuscript, there is no curve in the figure that the authors describe in these sentences. The dashed curve, which is referred to by these sentences, is totally different one, as mentioned in the figure caption and on P9 L5.

P9 L18: “enhanced” : What does this mean ?

P10 L5: “full zonal mean” : I do not agree to use the term “zonal mean momentum flux” for the flux estimated using one-site data, as here. The temporal mean could approximate the zonal mean for zonal wind or temperature in the stratosphere, as mentioned by the authors, but it could not approximate the zonal mean of anomaly flux in general. Please consider revising this, as well as in P17 L13–14.

Fig. 6: Could you explain why the parameters in (b)–(d) are weighted by period ? (i.e., reason why the parameters with longer periods are more highlighted)

P14 L1: “the westerly QBO phase persists longer in the lower stratosphere” : This could be partly due to the missing when the wind is easterly. Or, is the zonal mean zonal wind here composited regardless of the missing for momentum flux estimates?

P15 L12: For given zonal mean N and U, the sign of k (i.e., missing or not) depends only on the magnitude of m by Eq. (4), as the authors fix ω to be positive. Thus, the numerous missing for the 5–8 day period bands may imply that for these short periods the vertical wavelengths are shorter than those for 8–20 day waves. Is this true overall ? It seems to be not the case for the example in Fig. 1.

Fig. 7: While the climatological momentum flux is much larger below 20 km than above as shown in Fig. 6a, the flux below 20 km shown in Fig. 7 seems not that large compared to above, even when averaged over the QBO phases. Does this imply that a large portion of the flux below 20 km shown in Fig. 6a comes from the 5–8 day waves

that are excluded in Fig. 7 ?

P15 L13: “The same structure” : same as what ?

P15 L18–P16 L1: “signals of downward descending fluxes” → “descending signals of the flux”

Fig. 8: Based on the positions of number of days indicated in this figure and based on the shape of the contours in Fig. 7, I assume that the QBO phase bins are centered at 0, 0.25, 0.5, 0.75, and so on. However, the histogram in Fig. 8 is centered at 0.125, 0.375, and so on. Please correct the figure.

P16 L13: “for linear . . . resolution” → “with increased vertical step”

P16 L17: Please insert “for westerly background wind” after “results in larger momentum fluxes”, because there is the inverse relationship for easterly cases (Eq. (4)).

P17 L24: “planetary-scale, zonal mean momentum fluxes” → “planetary-scale wave momentum fluxes”

P18 L5: “MJO is” → something like “active-MJO mean is”

P19 L7: “As shown by Fig. 9” → “As mentioned” (It was “not shown”).

[typos / technical corrections]

P1 L1: “estimates . . . remains” : plural/singular

P1 L8: “the” → “a”

P1 L9: “ARM” : The full name of the ARM is not introduced. Also, it is not clear in this sentence whether the ARM site data is by the DOE or DYNAMO.

P1 L9: Delete “available”.

P1 L11: Delete “(QBO)”.

P1 L24: “Qausi-Biennial” : change this to small letters, as in the abstract.

P2 L1: “is an . . . connection” → “are . . . connections”

P2 L11 and L12: “waves with phase speed in the direction of mean flow” : change “speed” to “velocity” (because speed cannot describe the direction), or change the phrase to “waves propagating to the direction of ...”

P3 L5: “show” → “showed”

P3 L22 and P4 L5: Delete “Madden Julian Oscillation”, while remaining “MJO” (as already introduced in P1 L19).

P4 L7: “empirical”

P4 L14: “has”

P4 L28: The meaning of the symbol “T” is not introduced.

P4 L29: “density” → “density (ρ)” / “from which” → “of which”

P5 L29: “nearly the same as” → “close to” (One may not agree that 4.5 km and 4.0 km are nearly the same.)

P8 L19: “coexistence . . . occur” : singular/plural

P8 L21: “are increasingly” → “increase”

Fig. 2 caption, L3: “250 m” → “24 hour”

P11 L5: “Nauru”

P13 L10: “1” → “(1)”

Eq. (5): Please insert “$1/\pi$” in front of “$\tan^{-1}$”.

P16 L7: “nature . . . are” : singular/plural

Fig. 9 caption: “16” → “15” (based on the text, P18 L4; P19 L9).

P18 L14: “showed”

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