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Atmospheric Measurement Techniques Discussions

Interactive comment on "Atmospheric QBO and ENSO indices with high vertical resolution from GNSS radio occultation temperature measurements" *by* Hallgeir Wilhelmsen et al.

Anonymous Referee #3

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This paper presents the results of Empirical Orthogonal Function (EOF) analysis applied to temperature data obtained from the Global Navigational Satellite system (GNSS). Others have detected a QBO signal in GNSS temperatures, and others have done an EOF analysis of QBO winds. But the current work applies EOF analysis to GNSS temperatures, and this represents a new and original contribution.

This paper demonstrates that the GNSS data provide a straightforward means of obtaining and assessing the current and past states of both the QBO and ENSO. In another journal one might expect a deeper discussion of the dynamical significance of the signals shown, but for Atmospheric Measurement Techniques the level of this

discussion is acceptable as it stands. The emphasis of the paper is quite properly on the technique and the usefulness of its resulting indices.

I therefore recommend that this paper be accepted for publication with some minor revisions. There are some aspects that could be improved, especially with regard to its clarity and to improve its overall effectiveness. Specific points are listed below:

Scientific points:

p. 6, line 14. EOF3 and EOF3 resemble EOF1 and EOF2 just above the tropopause. Does this imply that ENSO is modulating the QBO in some way? Or is this some kind of numerical leakage, with no more physical meaning than the flipping of M2 PCs between QBO and ENSO dominance at different altitudes?

p. 6, line 26-27. The authors comment on the top half of Figure 5, where the QBO and ENSO patterns are clearly visible above and below the tropopause, respectively. But what does the bottom half of Figure 5 tell us? There are hints of a QBO-like propagation in the lower stratosphere. But other than that it is unclear how the M2 PC2s should be interpreted.

p. 6, line 25; and p. 8, lines 17-34: It might be helpful to the casual reader to explain more fully how Figure 5 differs from the right-hand upper and middle panels of Figure 10. The differences between plotting the M2 PC time series, and the M2 time series reconstituted from the PCs, might not be entirely clear at first glance.

p. 9, line 30: It is not surprising that the second method captures more of the variability. If you think of the two analyses as being akin to different kinds of statistical curve-fitting, there are a great many more coefficients in M2 to which the "fit" is being made. Smaller residual variances will naturally follow. The key question here is, is there a physical meaning to the increased fits? I suspect the answer lies in the clear relationship between signals at different altitudes. Perhaps computing time series coherence between altitudes would show formally what the eye can clearly see.

p. 9, lines 25-27: The lack of a known time lag in the M1 method is alluded to on p. 7 in the discussion on Figure 7. But perhaps a little more discussion of this could be added in the method discussion in Section 3.1.

Grammatical/stylistic points:

The formatting of the spatial points if preparing for the EOF analysis is referred to in two different ways: as "stringing along a single axis" (p. 4 line 22) and "reshaping" (p. 5, line 28). The term "reshaping" seems preferable. If "stringing" is retained, please note that the past tense of "string" is "strung", not "stringed".

p. 2, line 10: "origins" should be "originates"

p. 6, line 20: "more coarse" should be "coarser"

Figure 1. If the Nino 3.4 SST index could be plotted along the bottom of this Figure, and the QBO30 and QBO50 winds plotted at their respective altitudes, it would establish for the reader early on the relationship between these traditional indices and the measured temperature field. These would not have to be quantitative plots with overlaid labelled axes; simple unlabeled time series, similar to the tropopause altitude in gray, would suffice. Granted, the tropopause curve needs no labeling, since it varies along the labelled y-axis. But showing how the original temperatures relate to these indices would be helpful preparation for what follows in the paper.

Figures 2, 4, and 8: The use of small-multiple plots here is good. But instead of simple pasting together independent plots, each with its own title and color bar, these Figures would be improved by inserting the small plots into a labelled grid structure. For example, in Figure 2, the altitudes should be clearly labelled along the left-hand side, by each corresponding row of plots. Likewise, the EOF numbers should be indicated along the top of the figure, at the top of each column of plots. The explained variance could be retained in each plot's title, but moving the other title information to the grid margins would greatly improve readability. And eliminating all but one color bar would

make it instantly clear that the scale is not changing from plot to plot.

Figure 6. This Figure would be improved if the x- and y-axes in the top half were to be exchanged, so that the x-axis on the top figure matched that of the bottom, making them easier to compare.

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