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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Multivariate analysis of Kelvin wave seasonal variability in ECMWF L91 analyses" *by* Marten Blaauw and Nedjeljka Žagar

Anonymous Referee #2

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**Recommendation: Major revisions

**General comments:

The authors have developed a powerful analysis technique whereby they are able to decompose any 3-dimensional atmospheric analysis product into its (linear) global normal modes, which includes the equatorial Kelvin wave as one of its components. As I understand it, this decomposition is computed for each individual time point of the analysis, and no information on the propagation from one time point to the next is used for the categorization into the different normal modes. This is quite different to what has been done in many other studies, for example, Wheeler and Kiladis (1999) who used wavenumber-frequency spectra and filtering for identification of equatorial waves. Therefore, what is called a "Kelvin wave" in this study is somewhat different to those

other studies, since the identified structures may not be propagating, but may be stationary or even display propagation in the opposite direction to what is usually ascribed to a particular mode. This difference with other studies requires careful explanation and should be highlighted, but is not necessarily a problem with the paper.

Another aspect of this work that I think needs highlighting is that the normal mode decomposition is based on the assumption that the equations of motion are linearized about a basic state of rest (i.e. zero winds, line 88). It is unclear to me how much this assumption may affect the results.

I also wonder what assumptions are made about the static stability for the calculation of the normal modes. The static stability is important for setting the relationship between the horizontal and vertical structures of the normal modes. For the same gravity wave speed, c, a Kelvin wave in the stratosphere will have a shorter vertical wavelength than a Kelvin wave in the troposphere, due to the different static stability. But both these Kelvin waves will have the same meridional (horizontal) structure, which is set by the equatorial Rossby radius, a function of g. So what temperature and static stability profiles do you assume, and how can this affect the results? What would happen if you assumed a "moist static stability" for the troposphere? Instead of the traditional dry static stability?

To be more convinced about the utility of the technique for understanding, I also wonder what the wavenumber-frequency spectra of the decomposed "Kelvin waves" would look like. You could do this at each level and see what equivalent depth dominates at each level. I imagine that in the troposphere you may see a predominance of the MJO and the c=$\sim$20m/s convectively-coupled Kelvin waves, but as you enter the stratosphere the equivalent depth should start increasing due to the filtering provided by the background winds. These results would be useful to compare to Hendon and Wheeler (2008, J. Atmos. Sci, Vol 65).

Perhaps another interesting comparison to make is how the transient behaviour in OLR

matches the transient behaviour in your Kelvin wave dataset. Do the convectively-coupled Kelvin waves identified in OLR by the technique of Wheeler and Kiladis (1999) show up in your independent Kelvin wave dataset? To me, this would be much more interesting than some of the analysis provided here.

In summary, I must admit that I was a little underwhelmed by the results presented here. I think more interesting things could have been studied. But at the same time, the work is rigorous and may be more interesting to others, so it still adds something to the published literature.

**Specific comments:

Line 5. Why do you call it a "barotropic" KW response? Shouldn't this be the baroclinic mode with a half-sinusoid vertical structure in the troposphere?

Line 64. Missing "the" before "information".

Lines 74 or 75. Change to "covers approximately 6.5 years from January 2007 until June 2013".

Line 93. "denotedm"?

Lines 104-105. It is confusing to me to denote the KW as the n=0 EIG mode, since in many other papers (e.g. Matsuno 1966 and Wheeler and Kiladis 1999) the n=0 mode is the continuation of the mixed Rossby-gravity mode through the wavenumber 0 axis. In these papers the KW is the n=-1 solution.

Lines 138-139. I found this difficult to read because of the use of parentheses to provide the opposite meaning – please read the paper https://eos.org/opinions/parentheses-are-are-not-for-references-and-clarification-saving-space

Line 141. "zonal wind" not "zonal wave".

Line 146 and many other locations. Add "the" before "Eastern hemisphere".

Figure 4. I didn't find this figure to be very informative. A wavenumber-frequency spectrum of the Kelvin wave dataset at a few different vertical levels would have been more interesting.

Line 221 and many other locations. What is "summer" at the equator? It doesn't make sense to call the seasons using "summer", "autumn", "winter", and "spring" for equatorial waves. I would prefer you just call them "DJF", "MAM", "JJA", "SON".

Line 260. You say "when the ENSO index is positive". Do you mean "during El Nino"?

Lines 262-265. It is perhaps also important to note that the MJO was quite strong in 2007-08 (e.g. as defined by the Real-time Multivariate MJO index), and that the MJO has been found to be generally stronger in easterly QBO years (Sun et al. 2017). I am also fairly certain that the MJO must project quite stronger onto your Kelvin wave mode.

Line 298. I think you mean "warm anomalies", not "heating".

Line 305. Why do you call these intramonthly KWs the "free propagating" waves? If "free" means away from the forcing of convection, then isn't every wave in the stratosphere "free"?

Line 385. Please call this section "Intramonthly propagating Kelvin waves".

Figure 13. I found this very difficult to understand. On line 415 you say "different years", but what different years"? Is this a composite of all years? On line 416 you say "specific longitude". What specific longitude? The caption says it is a "climatology", but why is it so noisy if it is a climatology?

Figure 1 caption. Remove text "(panel b in Fig. 1)"

Figure 5. There appears to be some data missing at the end of 2009.

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