

Interactive comment on “Stratospheric ozone and QBO interaction with the tropical troposphere on intraseasonal and interannual time-scales: a wave interaction perspective” by Breno Raphaldini et al.

Anonymous Referee #3

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This paper examines the influence of the tropical stratosphere (namely the QBO and tropical ozone) on one of the principal modes of tropical troposphere intra-seasonal variability – the Madden Julian Oscillation. This is pursued using causal inference techniques drawn from information theory and a normal mode decomposition of ERA-Interim wind and thermodynamical (geopotential heights) data. Various wave modes have been found linking these phenomena on intraseasonal and interannual timescales. The study concludes that the Himalayas are important in accounting for QBO-MJO connections on long timescales.

The current paper is generally well written, but falls well short in describing the analy-

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sis in full and putting forward plausible physical mechanisms linking the normal modes with the tropical waves and the QBO and MJO across a wide range of timescales. Furthermore, important details have been omitted in most of the figures. In this reviewer's opinion the papers methodology does not quite match up with the stated aims for the paper. I recommend at least a major revision to the current paper.

Main Points:

- The analysis and interpretation of section 3 is suspect (and possibly in other sections). Figure 1 clearly shows regular and artificial peaks at regular (frequency) intervals most likely resulting from the bandpass pre-processing of the data. The features look similar to those which would appear in data convolved with a square filter. I recommend that suitable prefiltering is done to minimise these numerical artefacts (i.e. using appropriate tapering methods).
- It seems to this reviewer that the annual cycle has been retained in the data. Presumably retention of the annual cycle and sub-harmonics will obscure attribution of causality between the various timeseries? Why has the annual cycle been retained and what impact will this have on the interpretation of the results?
- The authors should provide figures for the timeseries used in the paper, before and after processing, including those short and long timeseries used throughout the manuscript.
- The authors have not justified the use of indices thought relevant for MJO-QBO connections, namely MJO indices and the westward propagating gravity wave modes (and various others wave modes). There are a number of competing mechanisms for explaining the observed correlations between the MJO and QBO. A number of these do not explicitly involve waves, but rather upper tropospheric temperature, wind-shear or static-stability. The title of the paper suggests a focus

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on waves, but this needs to naturally come following an appraisal of the various mechanisms first.

- The various horizontal/vertical normal modes used to construct QBO and MJO patterns and timeseries need to be captured somewhere (e.g. supplementary materials) as they feature prominently in the analysis.
- There is a lot of various missing information on the figures (labels, units, tickmarks etc), which has mostly been identified in the points below. All figures need to be improved for future review.
- The spectra look very smooth; has any smoothing been applied to the power spectra? If so, how has this been achieved?
- Figures 8-11. What physical mechanism will causally link wave modes on inter-annual to decadal timescales? What hypothesis is being tested?
- Can the authors put forward a plausible physical mechanism linking the Himalayas near 30-40N and two equatorially confined phenomena – MJO and QBO? Furthermore, how should this mediate the observed statistical relationship between the QBO and MJO?
- The authors have looked at large scale circulation processes in assessing long-time scale relationships between the QBO and MJO. What though are the roles for small-scale gravity waves in linking QBO and MJO connections?

Other Points:

(title) *interannual*

(P1, L2) ...*provides evidence*...

(P1, L4) ...*global-scale*...

(P1, L5) ...Partial Directed Coherence method *was used* and enabled us...

(P1, L8) what does *the latter* refer to; the wind? If so, please make this explicit.

(P1, L18) Capitalise *Quasi-Biennial Oscillation*

(P1, L19-20) replace "...determinant for the tropical monsoons and with global impacts." With "...impacts the tropical monsoons and so has global influence."

(P2, L1) replace *propagation* with *descending*

(P2, L1-2) Need a reference for influence of QBO on climate e.g. (Holton and Tan, 1980)

(P2, L2-3) suggest removing "*and inference of the dominant frequencies*" as it does not add to the sentence.

(P2, L6) replace *stratospheric* with *solar*. Furthermore, this paragraph ought to more explicitly delineate/separate solar influence and stratospheric influence, on the troposphere

(P2, L11) missing space (...*instance, Baldwin*...)

(P2, L14) replace *depends on* with *is sensitive to*.

(P2, L16) replace *depending on* with *to*

(P2, L20) missing reference at the end of the sentence. A good reference might be (Kim et al., 2020)

(P2, L21) remove *series*

(P2, L23) replace *circuntances* (sic) with *conditions*

(P2, L30) what is meant by *unfiltered* in this context?

(P2, L31) *European Centre for Medium-Range Weather Forecasts*

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(P3, L4) I do not understand how multiplying the spectrum by its complex conjugate (i.e. to find the power-spectrum) introduces spurious power at particular frequencies. Is there a reference where this effect is further explained?

(P3, L7-10) Was the seasonal cycle removed from the data?

(P3, L14) remove *for*

(P3, L18) suggest removing *responsible for* with *contributing to*.

(P4, L2) *has* -> *have*

(P4, L18) Clarify: *both former methods*: Grainger Causality and what other method?

(P5, L17) ...based on the concept...

(P5, L20) *captures*

(P5, L24) *nonlinear*

(P4, L29) The definition and use of the frequency range $[-.5,.5)$ needs to be explained here. Why include -0.5 but exclude 0.5?

(P6, L18) The first sentence is not a sentence; please rephrase. For the second sentence I suggest changing *well-adjusted* to *well-represented*.

(P7, figure 2 3) Half of the panels do not have axis labelling or tickmarks (none indicate y-axis units).

(P7, L11) ...*which* can be seen...

(P7, L14) ...*which* is a strong indication...

(P7, L13) QBO has a mean period of 28 months, so it is difficult to link it with ozone and the MJO indices in figure 2. Furthermore, interpreting statistically significant features appearing at different frequencies within the 2 MJO indices challenges the meaningfulness of the results.

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(P7, L15) Any link with the global monsoon system cannot be substantiated within figure 2.

(P7, figure 3) figure 3 looks lossy (fuzzy/bitmap), perhaps a vectorised figure can be made.

(P7, figure 4) Please state the scale (and units) of the wind vectors and the pressure units?

(P7, figure 5) To better show the patterns associated with the QBO can the authors redo figure 5 with a log-pressure vertical scale (i.e. z).

(P8, L1) *We seek interactions between...*

(P8, figure 6 7) Units? Labels? Tick-marks?

(figure 8 caption) *influence*

References:

Holton, J. R. and Tan, H.-C. (1980) 'The Influence of the Equatorial Quasi-Biennial Oscillation on the Global Circulation at 50 mb', *Journal of the Atmospheric Sciences*, 37(10), pp. 2200–2208. doi: 10.1175/1520-0469(1980)037<2200:TIOTEQ>2.0.CO;2.

Kim, H. et al. (2020) 'The Lack of QBO–MJO Connection in CMIP6 Models', *Geophysical Research Letters*, 47(11). doi: 10.1029/2020GL087295.

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