

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 #1

Received and published: 26 July 2020

Stratospheric ozone and QBO interaction with the tropical troposphere on intraseasonal and interannual time-scales: a wave interaction perspective, by Raphaldini et al

This study uses a "Partial Directed Coherence" method which is based on the concepts of Granger Causality to infer relationships between the QBO, ozone, the MJO and various wave modes identified by a normal mode decomposition. It is found that ozone and stratospheric winds influence the MJO, which confirms the results of previous studies. The potentially new insight that this study could offer is an insight into the mechanism behind the QBO-MJO connection through interactions involving inertio-gravity waves and Rossby waves. However, I have several major concerns that I think need to be

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addressed before this study should be accepted for publication.

Major comments:

(1) I think the statistics of the method need to be much more carefully described. At the moment, we aren't really given any indication of how the significance is determined other than a reference to another article. One thing I am particularly concerned about is that by doing this frequency decomposition as well as using multiple variables, it means that effectively a very large number of tests has been performed. Is this accounted for when performing the significance tests. For example, if you test 100 different frequencies and use a 95% level, you'd expect 5 different frequencies to show a significant signal. Furthermore, how is autocorrelation in the time series for the low frequencies accounted for in the significance testing. For the decadal timescales there will be very few degrees of freedom in the observational record and I would hope that this is being accounted for in the statistical testing but it's not clear. So, I strongly recommend an improved discussion of the statistical testing and the significance of results in light of these complicating factors.

(2) I question whether showing the interaction between the gravity waves and the MJO is really an explanation. At pg 2, l3, it is stated that this connection represents a partial explanation, but it's not really a mechanistic understanding. It certainly hints at something that should be investigated, but I wouldn't even call it a partial explanation. One aspect I'm concerned about with this inference is whether the stratospheric zonal winds are accounted for when assessing the connection between the gravity waves and the MJO or not. It's not entirely clear to me. Is the connection between the gravity waves and the MJO just a simple assessment of the connection between the gravity waves and the MJO or is it an assessment of whether the gravity waves provide you more information beyond what you'd already get given the connection between the stratospheric zonal wind and the MJO. If it is not the latter, then isn't it possible that this connection between the gravity waves and the MJO simply represent the connection between the QBO and the MJO where the gravity wave variability is a signal of the

QBO and not necessarily connected to the MJO in a causal sense.

(3) Conclusions are drawn about what factors influence the MJO on what frequencies. I wonder if, having performed this causality analysis, which I expect will seem like a bit of a black box to many readers, whether the results could then be related back to something a bit more physical e.g., could you present the time series and lagged correlations between the fields at the relevant frequencies to convince readers of the actual correlation between these time series.

(4) I'm not entirely sure what is shown in Fig 12, but it looks kind of strange. It is described by "We recompose the zonal wind fields of WIG waves associated with the QBO". Is this showing where the amplitude of the gravity waves fluctuate along with the QBO? So it's really showing where orographically generated gravity waves are active? If so, it makes sense that there should be such a close correspondence between orography and this metric. But is it really the case that gravity waves over Greenland and Antarctica are varying with the QBO? Furthermore, I don't think it's really the orographic gravity waves that interact with the QBO, it's more the convectively generated gravity waves, which we don't really see in this figure. I think this all needs a bit more explanation and a bit more discussion of the physical linkages to complement the Partial Directed Coherence analysis.

Minor comments by line number.

pg 1, 17: This sentence is unclear. It's unclear whether ozone is influencing the MJO at periods of 1-2 months while the stratospheric winds are influencing the MJO at periods of 1.5-2.5 years or whether both are influencing the MJO at both frequencies. I think some re-wording is needed to make it clear which it is.

pg 1, 17: It's not clear to me how it can be determined that it's the stratospheric wind that is influencing the MJO and not e.g., stratospheric temperature anomalies that accompany the QBO wind variability. For example, Martin et al (2019), J. Atmos. Sci., 76, 669-688 show that the response to QBO zonal wind anomalies is much weaker

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than the response to QBO temperature anomalies when imposing them in isolation in a cloud resolving single column model. So, I suggest taking care when making causal statements such as "stratospheric wind influencing the MJO".

pg 2, l20: A reference is missing here.

pg 3, l2: what does "innovations processes" mean?

pg 3, l4: I don't think it's enough to say that there is granger causality if that a_{ij} parameter is not zero. It has to be significantly different from zero above some threshold. Suggest making that clear. Also at equation (3).

pg 4: l29: It's not very clear what $[-1/2, 1/3)$ means here. Firstly, should it really be "[..]"? Secondly, it sounds like the frequency is between $-1/2$. and $+1/2$. but it's not clear if that's the case and if that is the case, what the meaning of these $1/2$'s are e.g., what are the units?

pg 6, l25: When examining the influence of stratospheric ozone, is there any accounting for the fact that stratospheric ozone and QBO zonal wind are not independent?

pg 9, l16: "boreal summer" → "boreal winter"

Fig 1 caption: I think it should be >20 days and <180 days, not just > 20 days.

Typo's/wording:

Title: "interannual" → "interannual" pg 1, l14: "influences" → "influence" pg 1, l19: I'm not entirely sure what is meant by "is determinant for" but it sounds to me like a statement to the effect that the MJO determines the monsoons, which is not the case. Perhaps "is connected to tropical monsoons"? pg 2, l24: "how these" → "how do these" pg 2, l34: "for all levels" → "over all levels" pg 5, l9: "substitutes" → "substitute" pg 5, l19: "specially" → "especially" pg 7, l11: "what" → "which" pg 7, l14: "what" → "which" pg 8, l28: "be" → "by" pg 10, l1: "contributions" → "contributing" pg 10, l27: "borel" → "boreal" Fig 8 caption: "influnce" → "influence" Fig 11 caption: "times-cales"

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→ "time-scales" or "timescales"

Interactive comment on Earth Syst. Dynam. Discuss., <https://doi.org/10.5194/esd-2020-45>, 2020.

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