Report #1

Submitted on 03 Jul 2023
Anonymous referee #2

Anonymous during peer-review: **Yes** No

Anonymous in acknowledgements of published article: **Yes** No

Checklist for reviewers

1) Scientific significance Does the manuscript represent a substantial contribution to scientific progress within the scope of this journal (substantial new concepts, ideas, methods, or data)?	Excellent **Good** Fair Poor
2) Scientific quality Are the scientific approach and applied methods valid? Are the results discussed in an appropriate and balanced way (consideration of related work, including appropriate references)?	Excellent **Good** Fair Poor
3) Presentation quality Are the scientific results and conclusions presented in a clear, concise, and well structured way (number and quality of figures/tables, appropriate use of English language)?	Excellent **Good** Fair Poor

For final publication, the manuscript should be

accepted as is

accepted subject to technical corrections

accepted subject to minor revisions

reconsidered after major revisions

rejected

Were a revised manuscript to be sent for another round of reviews:

I would be willing to review the revised manuscript.

I would not be willing to review the revised manuscript.

Suggestions for revision or reasons for rejection
(visible to the public if the article is accepted and published)

The authors have made significant improvements to the manuscript, and their efforts are commendable. However, there is still some uncertainty regarding the authors' focus on perturbations applied only to the Indian Ocean region. I speculate here that similar results would be obtained if perturbations were applied to other regions, such as the Amazon. Nonetheless, the authors acknowledge this limitation and suggest it as a subject for future research.

Note to the Reviewer: All line numbers refer to the pdf that includes all changes (both additions and deletions) denoted in red font.

Some minor comments:

L13: This zonal wave 1, the error variance of Q never reaches 90% of saturation. --- Something seems to be amiss in this sentence. This is fixed – see new L13.

L47: add the before mid-latitudes. This is fixed – see new L47

Fig. 3: How do we know that the spectrum doesn't grow after 60 days, i.e., that the red line is truly the saturations spectrum? The external error has been added to this Figure. See changes in new L248

L262: add space before the new sentence begins This has been done.

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Review of "Intrinsic Predictability Limits airising from Indian Ocean MJO Heating: Effects on tropical and extratropical teleconnections" by David M. Straus, Daniela I. V. Domeisen, Sarah-Jane Lock, Franco Molteni, and Priyanka Yadav

Note to the Reviewer: The questions/concerns led to an enhanced paper, for which we are grateful. All line numbers refer to the pdf that includes all changes (both additions and deletions) denoted in red font. More specific reponses are given below.

Synopsis:
The study by Straus et al. aims at identifying predictability limits arising from tropical diabatic heating over the Indian Ocean during MJO phases 2/3. For this purpose, a set of ECMWF-IFS

hindcasts is performed with the stochastic parametrization scheme (SPPT) being only applied in a limited range of longitudes over the tropics. The authors find that planetary wave components of the tropical heating and divergence is predictable out to 40 days. However, the Rossby wave source which allows the influence of the tropical heating to propagate to the extratropics is only predictable for 20-30 days. Except for numerous minor technical inaccuracies the paper is well written. In my view, the most important deficit is that the discussion lacks the role that systems other than the MJO could play. For example, the MJO modulates the storm track activity (Moore et al. 2010; Lee and Lim 2012) over the western North Pacific which effects the magnitude of the RWS and presumably its intrinsic predictability. After these minor comments have been addressed, I recommend the paper for publication in WCD.
- Since the paper only discusses error growth in phases 2-3, the storm track activity and hence Rossby wave source) dependence on the phase of the MJO does not affect our particular results. But it does mean that the RWS behavior we find is not universal, but only applied to MJO phases 2-3. Please see new L 392-394.

Minor:
l. 28: Do you mean the stratosphere with "upper atmosphere"? Yes – this has been fixed – see new L28

l. 56: "high resolution" is a relative term. Please try to be more specific. See added phrases on new L53 and new L56.

l. 69: It would be helpful to the reader if the motivation for such initial condition perturbation experiments was provided. Wouldn't such experiments also help to understand the effect of observational uncertainties in those regions? We added "Such experiments could be used, 70 for example to understand the potential impact of changes in the observing system on error growth." on new L69-70.

l. 101: You may want to add that the configuration is close to what was used at that time at ECMWF. (Not sure what is meant here?)

l. 112: Wang et al. (2023) report a pronounced seasonality of MJO teleconnections, e.g., with a stronger positive geopotential height anomaly over the central North Pacific in January to March compared to October to December. Thus, what is the motivation for choosing one initialization date in November and the other in January? Added on new L117-122: "The large ensemble size used dictated that we keep the number of MJO-phase 3 initial dates to a relatively small number (here 13). In order to make contact with previous reforecasts (the subject of a future publication), and to span varying parts of the seasonal cycle, 01 January and 01 November were chosen. However, we acknowledge that additional experiments would enable us to discriminate between the teleconnections in early and late winter, since they are known to be different, see e.g. Abid et al. (2021). All reforecasts initialized on 01 January (01 November) will be referred to as Jan (Nov) reforecasts."

"

Table 2: Would it be possible for completeness to provide all Nino 3.4 indices in the table? Yes this has been done.

l. 174-178: Have you considered to provide the definitions of internal error variance, ensemble error variance, and external error variance as equations? This may make it easier to the reader to understand the three parameters. We have extensively revised the definitions of the different error variances, including detailed equations. See new L185-204.

l. 192: After having read the full manuscript I somehow wonder about the influence of ENSO. From my point of view, this discussion distracts from the main results of the study and I wonder if this aspect should be part of the paper also due to the limited sample size? We agree: Figure 1 now shows only the mean heating and its standard deviation averaged over all experiments, with no distinction between 01 November and 01 January forecasts. The discussion of the role of ENSO has been removed (new L214-219).

l. 201: It is interesting to note that the RWS maximizes roughly 10 days after forecast initialization and that the magnitude of the RWS is larger for the more northern latitudinal band. Is it possible that the high magnitude in RWS between 20 to 35°N is related to synoptic activity which typically increases after MJO phases 2 and 3 over the western North Pacific? . For example, Lee and Lim (2012) show negative Rossby wave source over the western North Pacific after MJO Phase 3 (their Fig. 3) which may be related to the outflow of rapidly ascending air streams in midlatitudes that typically reach their peak activity in the same region after MJO phases 2/3 (Quinting et al. 2023; their Fig. 1).
There are a number of revisions and new analyses that have been carried out in regard to the Rossby Wave Source, answering this concern and ones further in the list. We have:
- Replotted Figure 2 so that it shows the same longitude range as Figure 1
- In preparation for the discussion of the stretching and advection components of the RWS, we have expanded the equation and added a bit more description new L160-162.
- The evolution of the two components (stretching term and advection term) are now plotted in new Figure A2 (in the same format as Figure 2). A discussion has been added in new L 229-231.
- The contribution of the stretching and advection terms (and their interaction) as a function of zonal wavenumber and forecast time is plotted in new Figure A3, and discussed on new L 268-273.
- A discussion of the contribution of mid-latitude baroclinic systems to the RWS is added in new L344-348.

l. 202: The comparison of Figs. 1 and 2 is difficult due to the different longitude ranges.

Accordingly, I would like to kindly ask the authors to show the same longitude range in Fig. 1 as in Fig. 2.
- Fig. 2 has been replotted to use the same longitudes as Fig. 1

l. 239: This is related to my earlier comment: Does this indicate that the RWS is related to divergent flow of midlatitude disturbances rather than to divergent flow directly associated with the convection of the MJO itself? Further, the RWS includes divergence as well as the gradient of vorticity? Did you investigate separately for divergence and vorticity when the forecast error variance reaches a fraction of 0.5, 0.7, and 0.9?
- Please see the discussion of the Rossby Wave Source above. Since the RWS error variance includes (negative) terms resulting from the interaction between stretching and advection components, it would be difficult to interpret the predictability times for individual components.

l. 275: Though it is probably difficult to quantify, could the authors include some discussion on the seasonality of the MJO teleconnections. E.g., Wang et al. (2023) report a stronger positive geopotential height anomaly over the central North Pacific in January than in November which likely favours wave flux into the stratosphere.
- See new lines L378-381 and 383-384, where we mention the seasonality of the teleconnections.

l. 297: Though I agree with this conclusion, it would be good to emphasize that by day 10 the perturbations in the midlatitudes cover already all longitudes.
- See new line L330

l. 310: This statement is related to my previous remark: Have you investigated for the gradient of vorticity when the forecast error variance reaches a fraction of 0.5, 0.7, and 0.9? Such information or at least some discussion would be highly interesting.
-Please see response above regarding the Rossby Wave Source.

l. 313: This sentence can be removed as it is the same as in line 310.
- agreed. The sentence has been remove

l. 323: I assume that "J" is referring to Judt (2020)? Please clarify.
- Yes – added the full reference.

l. 352: Do you mean with "more globally" simply "globally"? If yes, one could use the operational extended-range predictions of ECMWf as comparison.
- We added a few words to clarify this – see new L393-395

Technical:

We tried to cover all these – see a few details below

l. 72: Please remove "the" before "this".

l. 75: SPPT instead of SPTT

x

l. 112 and elsewhere: Please use the date format as provided in the WCD guidelines: https://www.weather-climate-dynamics.net/submission.html

- When referring to the initial conditions, we now use 01 January and 01 February instead of abbreviations. But we use a shorthand in referring to the reforecasts, as explained in new L122

l. 124: To be consistent throughout the manuscript, please use the "°" symbol when providing coordinate information.

l. 161: "a" instead of "at"

l. 166 and elsewhere: Please make sure to provide units following the guidelines of WCD.

l. 286 and elsewhere: when indicating ranges between two numbers please use en-dash.

l. 338: Insert blank between "Figure" and "7".

Fig. 4: Is it on purpose that the averaging was performed between 15°-32°N?

Yes- as a kind of compromise between the two latitude ranges shown in Fig. 2

References:

Lee, Y.-Y., and Lim, G.-H. (2012), Dependency of the North Pacific winter storm tracks on the zonal distribution of MJO convection, J. Geophys. Res., 117, D14101, doi:10.1029/2011JD016417.

Deng, Y. and T. Jiang, 2011: Intraseasonal Modulation of the North Pacific Storm Track by Tropical Convection in Boreal Winter. J. Clim., 24, 1122-1137. https://doi.org/10.1175/2010JCLI3676.1

Moore, R. W., O. Martius, and T. Spengler, 2010: The Modulation of the Subtropical and Extratropical Atmosphere in the Pacific Basin in Response to the Madden–Julian Oscillation. Mon. Wea. Rev., 138, 2761–2779, https://doi.org/10.1175/2010MWR3194.1.
(Rossby wave-breaking)

Quinting, J., Grams, C. M., Chang, E. K.-M., Pfahl, S., and Wernli, H.: Warm conveyor belt activity over the Pacific: Modulation by the Madden-Julian Oscillation and impact on tropical-extratropical teleconnections, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-783, 2023.

(WCB)

Wang, J., M. J. DeFlorio, B. Guan, and C. M. Castellano, 2023: Seasonality of MJO Impacts on Precipitation Extremes over the Western United States. J. Hydrometeor., 24, 151–166, https://doi.org/10.1175/JHM-D-22-0089.1.