Response to comment by Anonymous Referee #2

This work aims to assess the main observed modes of variability and origins of Rossby wave packets (RWP) in the northern hemisphere winter.

It uses a spectral decomposition method of the upper-level circulation at each latitude to retrieve the most dominant modes of variability in the space of zonal wave number and phase speed. The first two modes are found to be associated with RWPs, and so these are used for further analysis to identify regressions with diagnostics of blocking, large-scale patterns and wave propagation.

The authors also investigate the possible origins of the wavetrains characterizing both modes. They find a likely link between the first mode and tropical convection and the MJO, and elucidate that the second mode is related to extratropical origins, though this link is less clear. They point out other interesting features, such as that both modes exhibit higher synoptic eddy activity and subtropical jet extension that allows the hemispheric wave propagation, which allow a more complete picture of how these modes come about. The paper is clearly written and conclusions well argued. The results contribute significantly to the field of eddy-mean flow interaction and teleconnections in the northern hemisphere. I only have minor comments after which I recommend it for publication.

Thanks a lot for your constructive comments and for the time spent reading the paper. A detailed answer to each comment is given below.

General minor points:

- what is the sensitivity to the windows chosen for the spectral decomposition, and same for the thresholds chosen to isolate PC extremes?

The choice of the time window is one of the factors determining the type of harmonics that the spectral analysis is capable of resolving. This happens because the length of this time window T_W determines the minimum frequency $\omega_{min} = 2\pi/T_W$ resolved by the spectral analysis and, therefore, the minimal phase speed $c_{min} = \omega_{min}\, acos(\phi)\, /n$ of the wavenumber/phase speed harmonics that can be resolved. In general, the larger T_W the smaller ω_{min} and c_{min} become: however, increasing too much the size of the time window would mean that several days are analyzed at once, smoothing the day-to-day spectral variability from which CRWPs are emerging. A simpler analogy to understand this problem would be the one of taking averages over blocks of days, for instance to diagnose the occurrence of heatwaves by taking extremes in 2-m temperature over a given region. One can choose to do so for overlapping bi-weekly, monthly or two-monthly time intervals: shorter time windows would emphasize extreme warm spells, while longer time windows would emphasize persistent warm spells that are not necessarily the most intense (the choice of the appropriate time window depends, of course, on the research question that is being addressed).

Coming back to the specific case addressed in this work, we show here how the seasonal mean (DJF) spectral power density changes as it is computed over time windows with different lengths: 41d, 61d (the one employed in the paper) and 81d (Fig. R2.1). The double cosine tapering is adjusted to always match the first 20% and the final 20% of the days in each time interval.

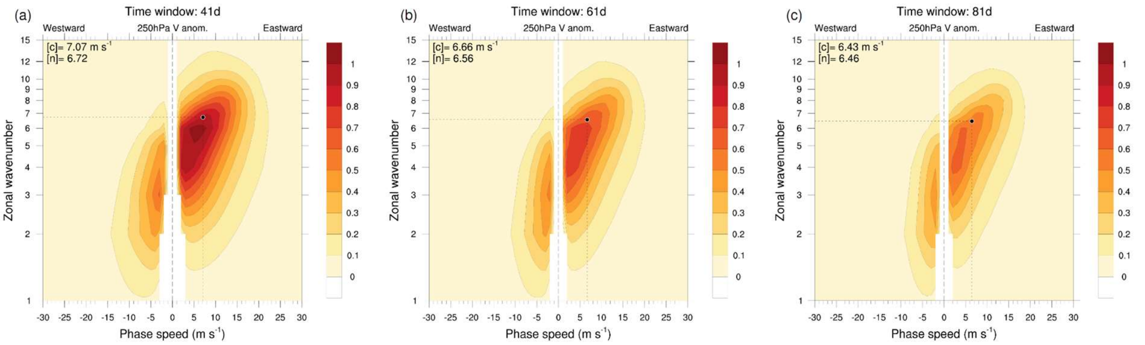

Fig. R2.1: DJF mean of wavenumber/phase speed spectra of meridional wind anomaly at 250hPa, obtained from spectral analysis performed over different consecutive time intervals: (a) 41 days, (b) 61 days and (c) 81 days. Units and notation as in Fig. 1 of the manuscript.

It can be noticed that reducing T_W from 61d to 41d increases the average spectral power density everywhere, in particular for rapid transients with high wavenumbers and phase speeds (Fig. R3.2a). This is due, first of all, to the higher variability of the flow in this shorter time interval and is consistent with Parseval's identity. It is also likely due to a reduced capability of resolving low phase speeds for harmonics with low wavenumbers: this is shown by the broader area of missing values in Fig. R3.2a. Moving to larger T_W reduces this effect: given that the area with unresolved harmonics does not vary between 61d and 81d, we chose 61d to retain some variability while being able to resolve most harmonics at low wavenumbers. The EOF analysis was also repeated after having used a time window of 81d to compute the spectra, in order to better resolve slow-moving harmonics, and the first two EOF patterns remained substantially the same.

The latitude chosen for the spectral analysis also affects the resolved harmonics: a Supplementary Text S2 in Supplementary material will be added to explain these effects in detail (see also the comment raised to the second point of the third reviewer).

About the thresholds chosen to identify CRWP events, their choice always features a certain degree of subjectivity: in our case, we chose the upper and lower 15% and a duration of 5 days to have a sufficient balance between intensity of PC events and number of events. The results of the composite analysis are not fundamentally different if the top 10% of PC values, or longer events, are chosen (cf. Fig. R2.2).

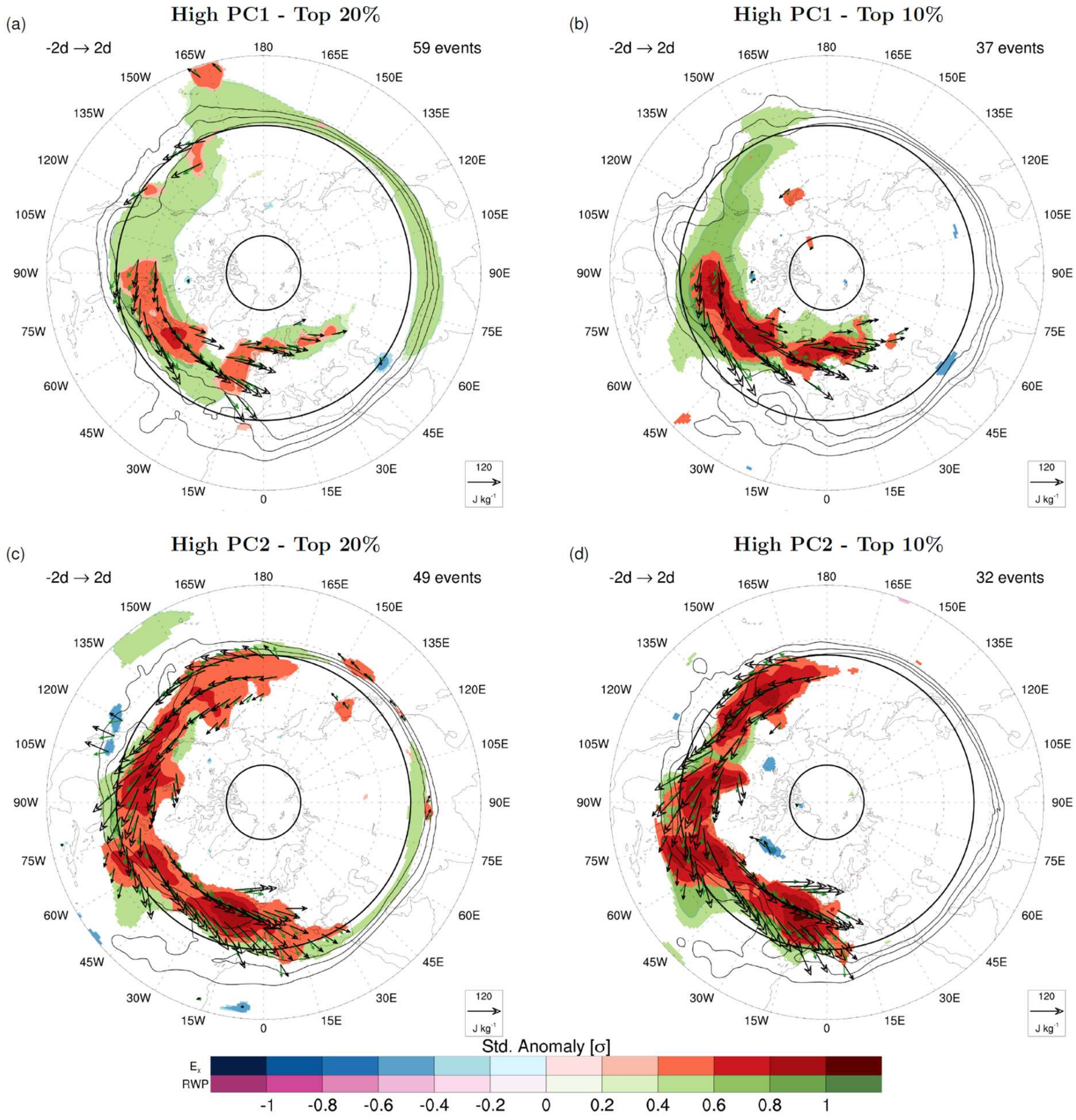

Fig. R2.2: Composites of pentad-mean, standardized anomalies of PV at 250hPa, E_x and logarithm of RWP amplitude at $t_{\square\square\square}$ of events respectively in the (a) top 20% of PC1 (b) top 10% of PC1 (c) top 20% of PC2 and (d) top 10% of PC2. The number of events is indicated in the top right of each plot. Bold black latitude circles indicate 35°N and 75°N. The composite of PV at 250 hPa is overlaid (black contours, only 1PVU, 1.5PVU and 2PVU). Only significant standardized anomalies (p<0.01) are shown, in Fig. 4 of the manuscript.

- As I understand it, the authors use the EOFs of the spectral decomposition as the basis for their composites and regressions, because they want to analyse regimes based on the different wavenumbers/phase speeds, groups of which we know have different characteristics (e.g., planetary waves vs synoptioc waves). I like that the analysis is based on reducing dimensionality for physical reasons, but I wonder whether some of the composites, e.g. Fig. 9, would yield a less noisy time series if the v*T* and baroclinicity were directly related to the RWP? It seems that especially Fig. 8(d-f) yield consistent patterns, but with the spread being so large, the authors conclude that these consistent changes in baroclinicity are not significant. At least comment outlining the disadvantages of this technique would be useful. **Thanks for this comment, we will discuss the limitations of employing EOF analysis in a new Discussion section, added between the Results and the Conclusions sections.**

- the Figure labels could be enlarged. **True, thanks for noticing it. We will increase the size of labels in Figures.**

Specific clarifications

- L20: between one year or the other - you mean inter-annually? **Yes, we reworded it to “across seasons and between different years”.**

- The next three points aim to differentiate between the two types of mechanisms more clearly: - L22: single storm track (internal mechanism)…between the two (hemispheric Mechanisms [or something like that]) - L23: AN internal mechanism - L27: [new line] On the other hand… storm tracks (hemispheric mechanism) **Thanks for these comments, we will rewrite the lines specifying the difference between local and hemispheric mechanisms.**

- L89: please state how the smoothing was performed **We employed a 30-day moving average: it will be stated explicitly in the text and rephrased it to “further smoothed using a 30-day moving average”.**

- Eq. 5: it may be worth adding a comment that vT is proportional to the vertical E-vector component and will also be investigated. **Even though this is true, we are a bit reluctant to talk about the Eliassen-Palm flux and the vertical propagation of Rossby waves here because these topics are not discussed in the rest of the manuscript. Therefore, for simplicity, we would like to leave the description as it is.**

- L104: "interpolated along lines of constant phase speed” What exactly do you mean? **Thanks for this comment. The approach is the one used in the paper by Randel and Held (1991), the main reference for wavenumber/phase speed spectra. We will add a detailed explanation of the interpolation procedure to the Supplementary Material.**

- L186: it may be worth including Orlanski (1998) as a reference here, for the interpretation of the horizontal E vectors (https://journals.ametsoc.org/view/journals/atsc/55/16/1520-0469_1998_055_2577_pdost_2.0.co_2.xml) **Thanks a lot for this suggestion, the reference will be added.**

- Fig. 4: I couldn’t see any green arrows **Thanks for pointing it out, given that they were not actually discussed in the paper we decided to remove them from Figs. 4 and 5.**