Response to comment by Anonymous Referee #2

The authors present an evaluation of the composite evolution of wave reflection events in the North Pacific, which previous studies had connected with cold spells in North America. The identification of reflection events is based on an regional index of eddy heat flux, and the dynamics of these events are characterized using geopotential height, eddy heat flux, three-dimensional wave activity flux, and the wavenumber - phase speed spectra. The main results show a westward propagating ridge and the development of a trough downstream during the evolution of reflection events, which is associated with a change of sign in the meridional eddy heat flux. In turn these eddy heat fluxes can explain the meridional transport of colder air from the pole to lower latitudes, leading to a decrease of temperature over North America.

The paper is well-written and the presentation of the results is clear. I appreciate the level of detail given in the description and interpretation of each figure. I recommend publication after consideration of the comments given below.

We would like to thank you for your helpful comments and will update our manuscript accordingly. Please, see our detailed answers below.

Comments:

- The three-dimensional wave activity flux (WAF) used in this study (Plumb 1985) is a diagnostic for the stationary component of the wave field. However, the results presented reveal the presence of migrating eddies during the evolution of reflection events, especially at the end of their life cycle. Therefore, I would suggest to use a diagnostic of the WAF suitable to the problem at hand, for example the one proposed by Takaya and Nakamura (2001). On the other hand, the authors may reconsider the need of including a WAF analysis in the paper, given the detailed analysis of the geopotential and eddy heat fluxes.

Thank you for your comment about the use of the Plumb WAF (Plumb, 1985). We agree, that the assumption of a stationary wave field does not hold when considering the entire evolution of reflection events. Our motivation was, that the wave field can be seen as approximately stationary for each individual day, which could make the use of Plumb WAF still valid. Furthermore, it has been argued that the Plumb WAF can be applied to investigate reflection events after filtering to keep planetary waves (wave-1 to 3) (Messori et al., 2022).

In line with your later comment, we also acknowledge the potential confusion arising from the way we display the vertical component of WAF in Figures 3 and 7. Thus, we suggest to display only the vertical component of the wave activity flux proposed by Takaya and Nakamura (2001). Despite a weaker signal than the Plumb (1985) WAF, the Takaya and Nakamura (2001) WAF exhibits a similar evolution during times of enhanced v'T' anomalies (cf. black lines in Fig. R1 to shading in Fig. 2 in the manuscript). Due to this similarity, we would like to include the discussion of vertical wave activity flux, as this also connects the findings of section 3.1.1 and 3.1.2 in the manuscript. We will change the arrows in figure 3 and 7 in the manuscript to black lines showing Takaya and Nakamura (2001) WAF, i.e., to match figure R1.

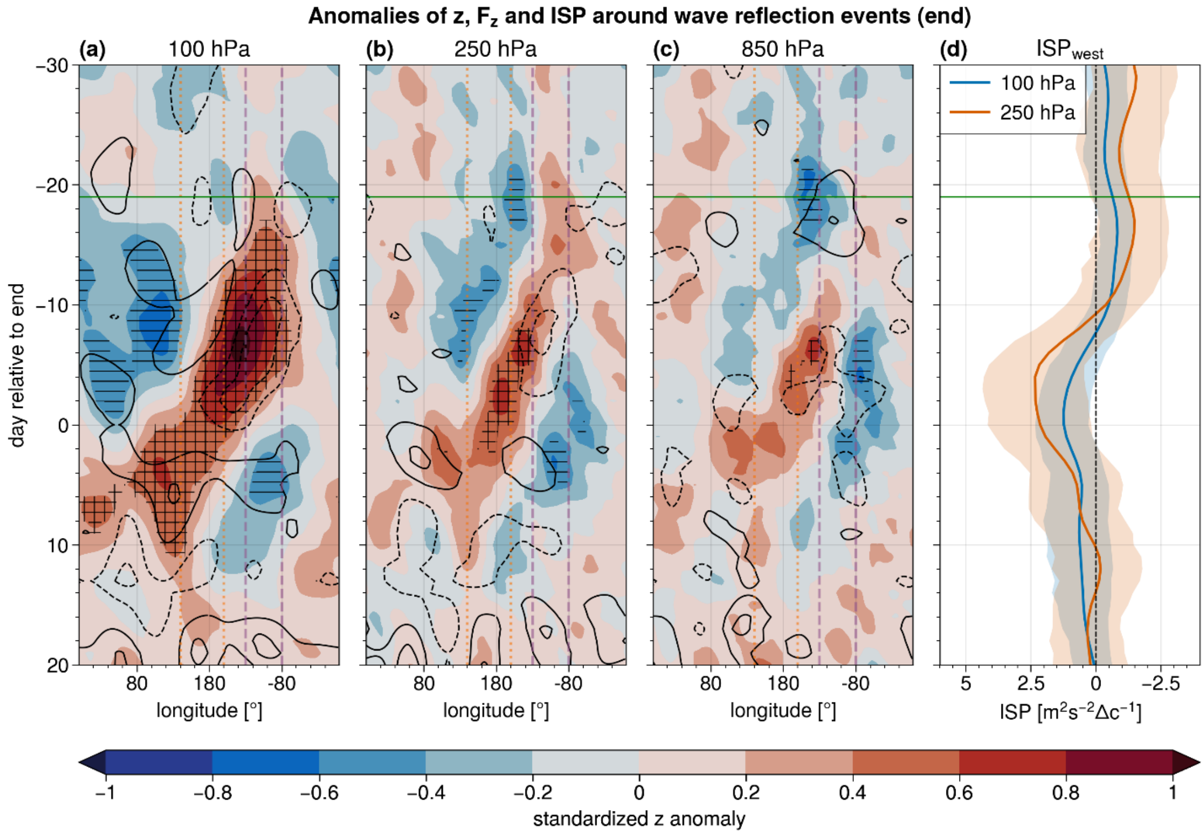

Figure R1*. Hovmöller diagram of standardized anomalies of geopotential height averaged between 45N - 75N centered around the end date of reflection events at (a) 100 hPa, (b) 250 hPa and (c) 850 hPa in shading. Horizontal hatching marks significant negative anomalies and cross-hatching significant positive anomalies. Black lines indicate standardized anomalies of the vertical component of WAF filtered to wavenumbers-1 to 4 (Takaya and Nakamura, 2001), in steps of 0.1, excluding the zero-line. (d) Time series of ISP for westward-propagating Rossby waves and the 95% confidence interval (shaded area) at 100 hPa and 250 hPa. The continuous horizontal green line shows the median onset time of reflection events. The vertical lines mark longitudes of the Siberian (orange, dotted) and Canadian domains (purple, dashed).*

- lines 41-43 and 48-50. The eddy heat flux is part of the vertical component of different 3D wave activity flux diagnostics (e.g. Plumb 1985, 1986, Takaya and Nakamura 2001), but strictly speaking it is proportional to the vertical group velocity only in a zonal mean framework, where the EP flux represents the wave activity flux in the meridional-vertical plane.

Thank you for highlighting this fact. We will adjust the description in lines 41-43 and 48-50, by adding: "… in a zonal mean framework".

- Lines 77-78. Why is the meridional wind component not deseasonalized?

Thank you for your question. Our description was unclear in this context. Neither the meridional wind nor the temperature used to compute the meridional eddy heat flux (v'T') are deseasonalized beforehand; only the v'T' itself is deseasonalized. Similarly, the meridional wind used to compute space-time spectra isn't deseasounalized beforehand either, as the spectra are deseasonalized afterwards. We will clarify this in the data description in lines 77-78: "Unless stated differently, we deseasonalized each field shown in the following analysis by subtracting the daily seasonal cycle, *computed…". Furthermore, we will add a sentence to the end of the paragraph: "The meridional eddy heat flux, WAF and space-time Rossby wave spectra are computed from the full fields and deseasonalized afterwards."*

- Eq. 1. Please specify the pressure level at which RI is defined (is it 100 hPa?).

Yes, the reflective index RI is defined at 100 hPa, following Messori et al. (2022) and Matthias and Kretschmer (2020). We will clarify this in the manuscript by adding "at 100 hPa" in the description of RI.

- Line 92. Are the weather regimes computed using year-round data? Why not only winter data? Is there any sensitivity there?

Yes, the weather regimes are computed using year-round data, as described in Lee et al. (2023). Since the seasonal cycle is normalized using empirical orthogonal function analysis combined with k-means clustering, the weather regimes are insensitive to seasonality. Lee et al. (2023) also note that the year-round regimes differ only marginally from winter-only regimes, while the classification was also more extensively tested for significance and robustness than existing seasonally-dependent classifications. Further, we note that the year-round classification of Grams et al. (2017) has been extensively used for season-specific analysis, such as in the stratosphere-troposphere analysis of Domeisen et al. (2020). We see no reason why a season-specific analysis should use season-specific regimes; the purpose of year-round regimes is that they can be used in any season. With respect to your comment, we will mention in line 92: "..., [and no regime (N)], which are insensitive to seasonality.")

- The arrows in Fig. 3 are confusing. The vertical component represents the vertical component of the WAF(?), but the vertical axis in the figure represent time. If the authors decide to keep the analysis of the WAF (after switching to Takaya and Nakamura 2001), then I would suggest to plot it on a map like Fig. 4.

Thank you for your suggestion. We agree that this way of displaying the vertical component of WAF is confusing due to the y-axis displaying time and not vertical height levels. In line with your earlier comment, we decided to switch to the WAF proposed by Takaya and Nakamura (2001), and change the arrows in figure 3 and 7 in the manuscript to black lines showing Takaya and Nakamura (2001) WAF, i.e., to match figure R1.

- Lines 297-298. How many reflective events are also regime transitions? Are the composites of Figs. 7-8 dominated by the signal of those transitions that are also reflective events? Does the composites of transitions that are NOT reflective events show a similar qualitative evolution to those that are?

If one includes regime transitions that have the central date of AKR events after the end of reflection events, 24 of 45 reflection events with this overlap can be detected. Figure 11 in Messori et al. (2022) can provide more details on the weather regimes during reflection events.

PT-AKR regime transitions during and outside of reflection events, are both similar to the composite of all PT-AKR regime transitions in the troposphere (cf. Fig. R2 b, c and R3 b, c to Fig. 7 b, c in the manuscript), while the 21 regime transitions happening during reflection events resemble also the composite of all reflection events in the lower stratosphere (Fig. R2 a to Fig. R1 a). Conversely, the 41 *regime transitions happening outside of reflection events exhibit a signal different to reflection events in the lower stratosphere (Fig. R3 a to R1 a).*

Furthermore, only the difference between PT and AKR events occurring during reflection events shows an enhancement in westward propagating wave-1 (17 of 107 PT and 23 of 91 AKR events during reflection), while those regimes occurring outside of reflection events (90 of 107 PT and 68 of 91 AKR) don't show this signal (Fig. R4 and R5). Due to the larger number of PT and AKR events happening outside of reflection events, their spectral behavior resembles the composite of all PT and AKR events more closely than those regimes happening during reflection events. With respect to your comment, we plan to add figures R2 to R5 to the appendix and mention briefly the characteristic similarities and differences between PT-AKR regime transitions happening during reflection events and outside of reflection events.

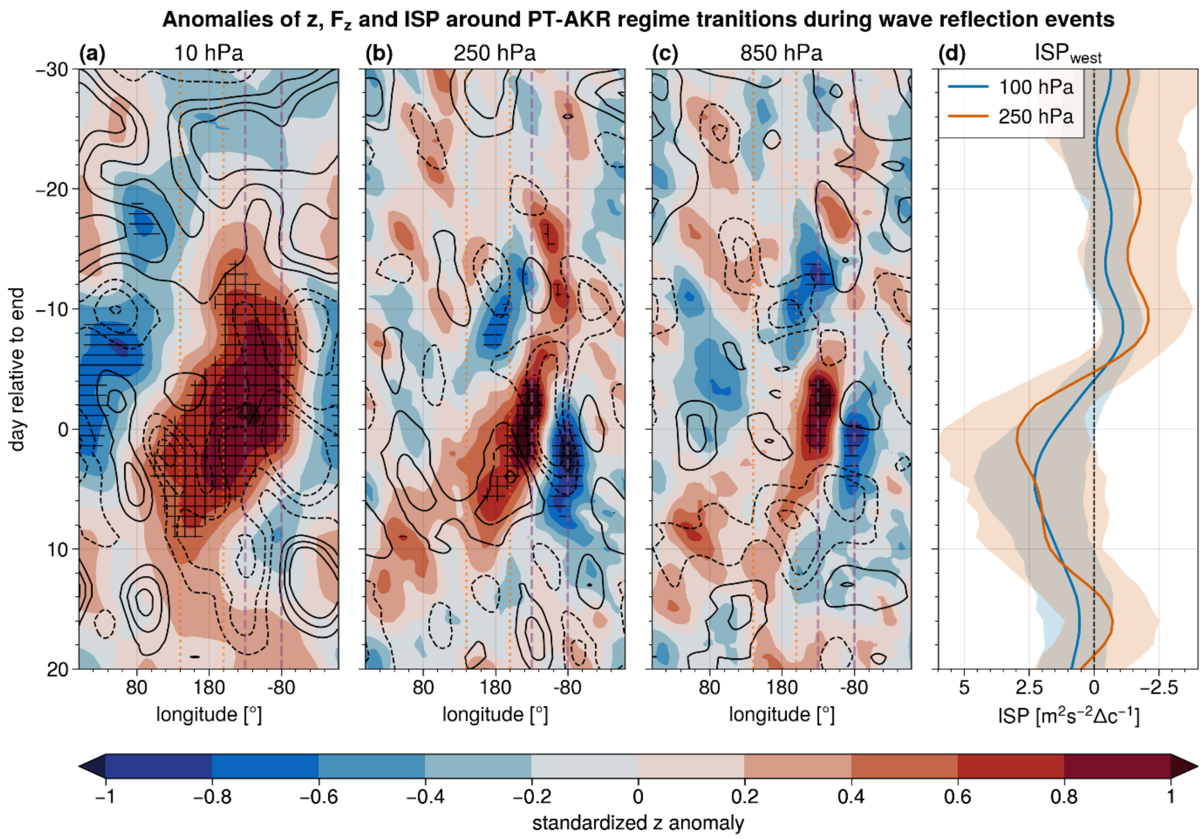

Figure R2. *Same as Fig. R1, but for PR-AKR regime transitions occurring during reflection events, with AKR central date as day 0.*

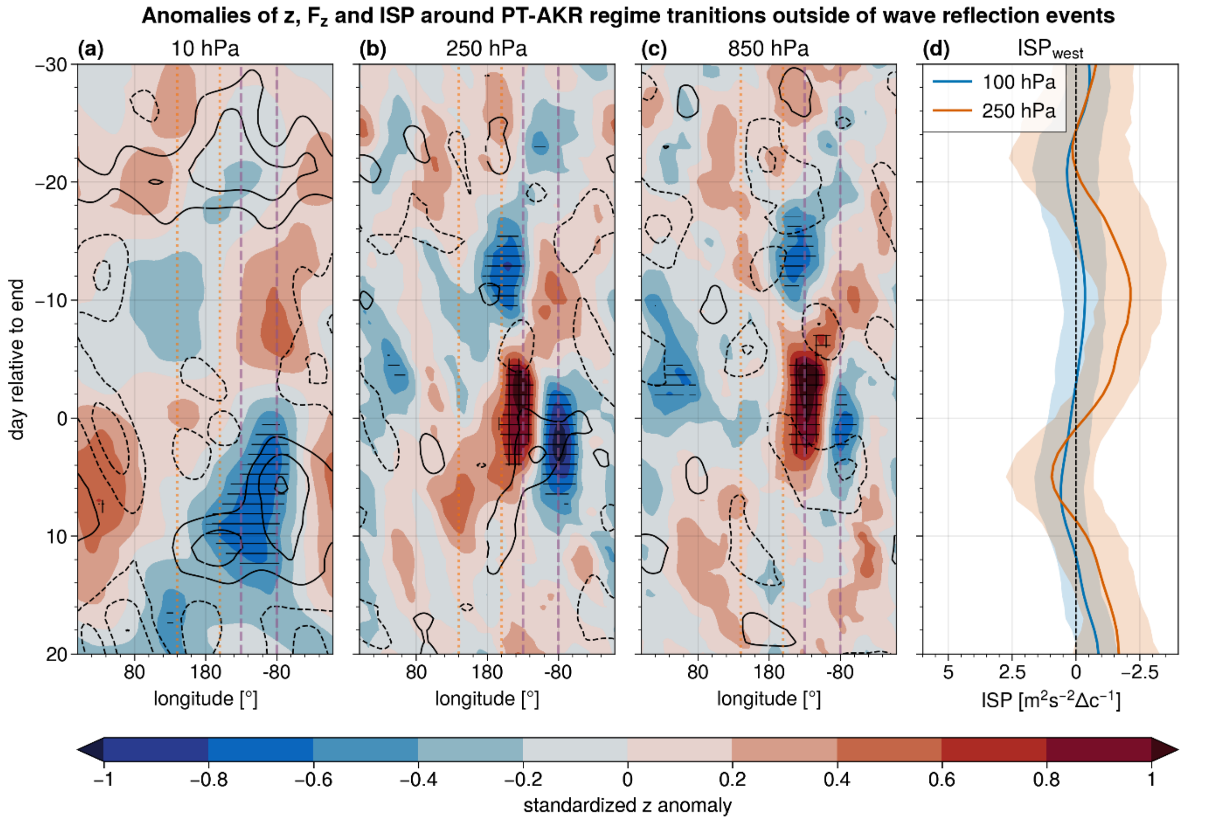

Figure R3. Same as Fig. R1, but for PR-AKR regime transitions occurring outside of reflection events, with AKR central date as day 0.

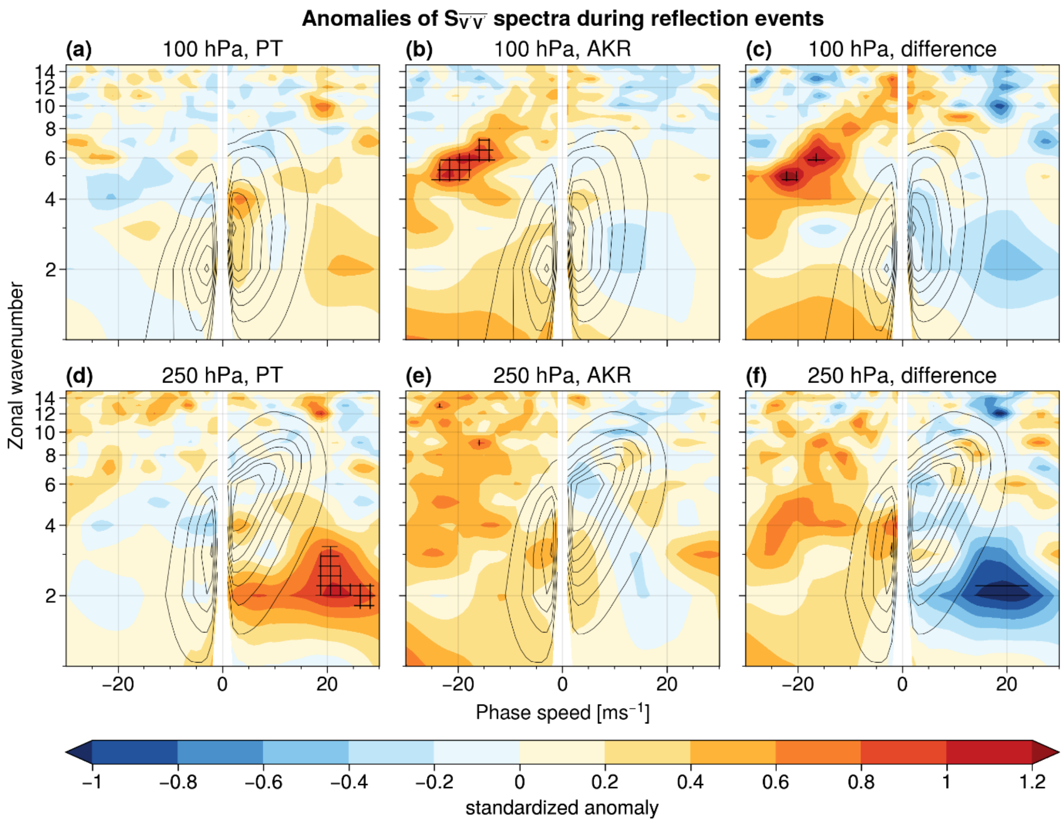

Figure R4. *Standardized anomalies of spectral power SV'V' of each harmonic at 100 hPa during reflection events with (a) PT, (b) AKR (c) difference between PT and AKR weather regimes in shading. Sub-panels (d) - (e) show the same, but for 250 hPa. Black contours show the DJFM mean for all years (100 hPa: steps of 0.05 m2 s −2 Δc−1 from 0.05 m2 s −2 Δc−1 to 0.35 m2 s −2 Δc−1; 250 hPa: steps of 0.1 m2 s −2 Δc−1 from 0.1 m2 s −2 Δc−1 to 0.7 m2 s −2 Δc−1). Horizontal hatching indicates significant negative anomalies, cross-hatching indicates significant positive anomalies.*

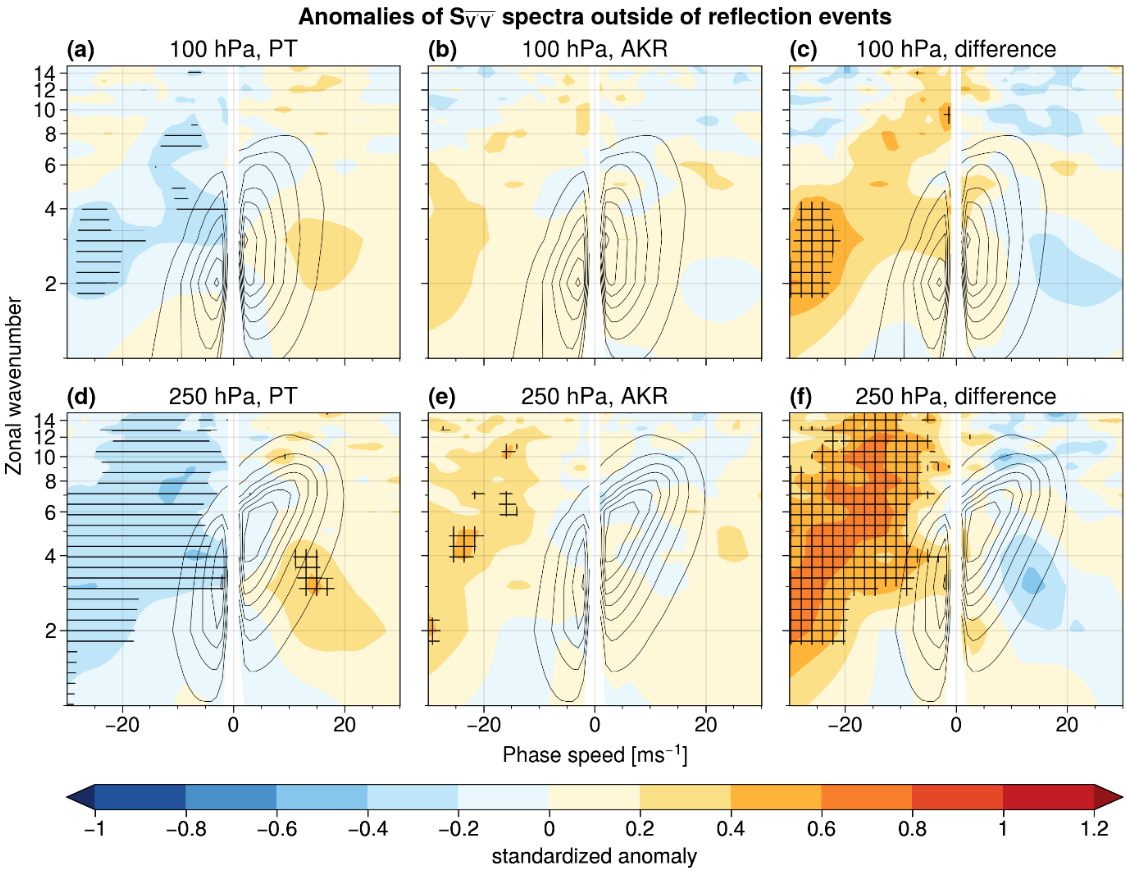

Figure R5. *Same as Fig. R6, but for PT and AKR regimes outside of reflection events.*

- I find section 3.3 unnecessary for the goals of the study. The summary at the end of the section would be a sufficient remark to make in the text without the need of showing the figures.

Thank you for your suggestion to shorten the discussion about regionalized events. In accordance with Nili Harnik's comments, we would like to highlight in the manuscript that space-time spectral analysis is applicable to investigate reflection events, despite potential limitations of regional or short-lived events. Yet, we understand that one can put less weight on that discussion in the manuscript, than we have right now. We will consider your suggestion and might only put a summary of the regionalization results to the discussion and move figures 9 and 10 and to the appendix, instead of the detailed description in section 3.3.

References:

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