Third Response, Manuscript: egusphere-2024-382

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1 General Comments

Thank you for the feedback. We have addressed all the remaining minor points brought up by the reviewer.

2 Response to Reviewer 1

2.1 Minor Comments

Comment - Paragraph starting L539: If I've understood correctly, the new methodology attributes to the NPV feature the change in relative vorticity between the time of NPV identification and that of a background flow of a region slightly upstream at an earlier time. To my mind this is much better than inverting the full relative vorticity anomaly as was done before, because it represents (at least some approximation to) the influence of diabatic heating over the preceding period. However:

> **Response:** Thank-you, your summary of our new methodology is also correctly interpreted.

Comment: I do not think it is fair to attribute this wind to 'the NPV feature' which to me suggests it is fully associated with that part of the absolute vorticity field that is below zero. As you now point out, this is very small. I do agree that this quantity is some approximation to the influence of the diabatic heating which caused the negative PV. Can you rephrase?

> **Response:** This is a fair comment, we have rephrased much of this paragraph to make it clear that we are not inverting just the anticyclonic vorticity associated with NPV, but we are in fact inverting the anticyclonic vorticity field that we suspect is attributed to diabatic heating. We reiterate this point in the results section and make it clear that the inversion not only includes the inertially unstable part, but some additional part with respect to the pre-defined base-state prior to heating occurring. In addition, we make note of the inversion results from just the inertially unstable component for the interest of the reader.

Comment: There are clearly several approximations going on here which I think need spelling out more clearly, to aid the reader. First, relative vorticity is not conserved by adiabatic flow. Second, the shape of the ridges evolve over the preceding period. Thirdly, you omit the influence of diabatic heating in any regions of positive PV (which I could imagine may counteract the acceleration associated with the negative PV region).

> **Response:** We agree with the suggestion to clearly state some of the approximations made. We have added the approximations to the methods section outlining the inversion process and reference in the paragraph of L539 to check the methods regarding assumptions made. We also make it further clear that relative vorticity inversion omits diabatic heating influence. Although, this is a useful property to have due to acknowledging that synoptic-scale NPV features are quasi-adiabatic and that we are interested in their kinematic properties because of this.
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> We have added the following section to the methods section: "To clarify some key assumptions made during two-dimensional relative vorticity inversion and coordinate shifting process: First, any diabatic effects that might have induced positive PV tendencies within the region considered for the inversion are neglected. Second, it is important to clarify that relative vorticity is not conserved by adiabatic flow. Lastly, when performing the temporal shifting in coordinate space, it is important to remember that the shape of ridges evolves over the preceding period, which may influence the wind estimates derived from the inversion."
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> We do want to respond to the reviewer's further thoughts on the omission of diabatic heating. We suspect that any potential diabatic heating will not impact the circulation obtained from the relative vorticity inversion in the three cases. To expand on this point, all of our cases are associated with anticyclonic relative vorticity within the ridge (there is occasionally very minimal, highly localized cyclonic relative vorticity within the ridge, but its spatial scale is much smaller than the NPV feature's length scale). Unless there is sufficient diabatic heating to cause positive PV tendency leading to subsequent development of a mesoscale region of cyclonic relative vorticity to the right side of the NPV feature, we

do not expect there to be a deceleration to the flow associated with the NPV feature.

To make this point clear, we highly suggest checking Figure 6 and Figure 7 in Oertel and Schemm (2021), who examine smaller, mesoscale relative vorticity dipoles produces by convective-scale heating. The figures very clearly illustrate the deceleration phenomena. In their case-study, an anticyclonic relative vorticity pole lies to the left of a cyclonic relative vorticity pole. The resulting inversion leads to a deceleration of the flow between the dipoles. In our study examining synoptic-scale NPV features, the ridges in the three cases are essentially entirely defined by anticyclonic relative vorticity. There is no cyclonic relative vorticity to decelerate the flow to the right of the NPV feature. However, large swaths of cyclonic relative vorticity lie to the left of the NPV feature (on the polar side of the 2 PVU contour). Consequently, the circulation between synoptic-scale NPV and cyclonic vorticity on the poleward side of the jet stream will lead to acceleration of the flow about the jet stream (as shown by our vector arrows in the schematic, Figure 10).

Comment - L140: Why do you claim this estimate is 'conservative'? Please clarify.

Response: Thank-you for catching this. We were intending to suggest that this is an approximate estimate. But we can see how the use of the word conservative may imply otherwise. We have removed "conservative" and rephrased to "approximate". This also includes removing the section "Although the vorticity inversion provides a conservative estimate".

3 References:

Oertel, A. and Schemm, S., 2021. Quantifying the circulation induced by convective clouds in kilometer-scale simulations. Quarterly Journal of the Royal Meteorological Society, 147(736), pp.1752-1766.