Author's responses to review by Anonymous Referee #3 for "The genesis of Hurricane Nate and its interaction with a nearby environment of very dry air"

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We have considered all of the comments made by both reviewers, and have used those comments to produce a revised manuscript. In the revised manuscript, the largest difference from the previous is a new Figure 2 that shows the location of the attracting line separating the two regions within the Nate pouch on Sept. 5. This line is then tracked through the remainder of the time interval, and it is shown again at a later time in Figure 3. This figure helps to address the concern of one of the reviewers that the regions comprising the Nate pouch were not clearly marked, and the confusion that the region that we call R_1 was in fact the same as the region that we call L_1. New labels added to Figure 3 (a) make it very clear that these are separate regions.

In the revised manuscript, added text is given in blue, while deleted text is shown in red. The reviewer's comments are listed below while our responses follow in blue.

Reviewer 1:

Minor comments:

* end Section 2: KAM torus needs introduction/ references

We have added references for the KAM torus and its finite-time Lagrangian version.

* end Section 2: The definition of vortex core (Eq. 4) is unclear. Is there a threshold to be exceeded for the Lagrangian vorticity to qualify as vortex core? In addition, it should be noted that this is only one of several possible definitions of a vortex core.

We have changed the text to indicate that we have chosen to use a finite-time Lagrangian definition of a vortex core, and have stated that the vortex core must have positive cyclonic Lagrangian averaged vorticity. This definition does not require any certain thresholds to be met, only that the vorticity be positive.

* Section 4, 2nd line: Unclear how southerly flow can advect feature of Lee when that system is to the northeast. Please clarify.

We have corrected this statement to indicate that northerly flow was responsible for the vorticity advection.

* Section 4, 2nd paragraph: The authors have agreed in their response to the first review that discussion of the Eulerian frame is not important here. I thus suggest deleting this paragraph, as it is hardly helpful to the reader without an associated figure anyways.

We agree with the suggestion and have eliminated this paragraph.

* caption Fig. 2, first line: M ? K

We have made the correction.

* last sentence in Section 4g: I disagree with the authors statement. To me, a distinct gradient in relative humidity associated with the shear sheath is not evident in Fig. 7c. I suggest deleting the sentence.

We have deleted this statement, as this suggestion was also made by the other reviewer.

* conclusions, third paragraph; When Nate was a tropical storm in close proximity to dry air, the entrainment of dry air was limited to what was transported by lobes when an enclosed Lagrangian boundary was present: The relative role of lobe transport and the direct pathway at 850 hPa is discussed more completely in the paragraph after the enumeration. The simple statement here ignores the role of the direct pathway. I suggest deleting the statement here, as it is incomplete and there is redundancy with the later discussion anyways.

We agree with this suggestion and have eliminated this paragraph.

* conclusions, enumeration 1) and 2) suggest an interesting link between the hyperbolic manifolds and the underlying dynamics. Can a similar link be provided for the existence of lobes?

The dynamical connection to lobes occurs when folding of vorticity filaments near a saddle causes the alternating exchange of material into and out of the cat's eye. This point is now highlighted in point 3 of the enumeration.

* conclusions, first paragraph after the enumeration: I suggest deleting the reference to the Eulerian streamlines, consistent with elimination of references to an Eulerian frame throughout the revised manuscript.

We agree and have eliminated the comparison between Lagrangian manifolds and Eulerian streamlines.

Reviewer 2:

Review of the revised manuscript by Rutherford et al. The authors have done a great effort to substantially improve their manuscript. Their results are now better explained with a much more precise wording. I still request some important corrections before publication.

We appreciate the reviewer's comments, and have revised the manuscript to address these remaining concerns. Specifically, we have taken care to make the definitions of R_1 and L_1 much more clear by adding a new Figure.

Major comments: 1. I appreciate the effort of the authors to display the separation of air masses R1 and R2 in Fig.2a and the manifold related to Lee. However I still find the presentation of the results rather confusing. In particular, I have a lot of difficulties in understanding the precise (not qualitative) definitions of the pouch, of the different regions R1, R2, relation with the lobe L1 or the air coming from Nate). (a) It would be useful to have a figure at an earlier time (for instance 12 UTC Sept. 5 since it is mentioned in the text line 19, page 10) to see the appearance of L1. (b) How are defined R1 and R2 at 12UTC 7Sept? Is it just L1 and the pouch, respectively? Do you track the manifold related with Lee? The separation curve should be displayed on Fig. 2d or 2e. This is quite important in your discussion page 10.

The regions R1 and L1 are separate regions, as R1 is in the interior of the pouch at 0 UTC 6 Sept. and L1 is still outside. An additional label of L1 in Figure 3 (a) and a comment where L1 is first introduced have been added to clarify this issue.

(a) An additional figure showing the attracting line at an earlier time has also been added.

(b) With R1 clearly distinguished from L1, it is clear that the discussion on page 10 is about the 2 separate regions within the pouch. The location of the curve separating these regions has been added to Figure 2 (d).

2. Line 15, page 10, it is claimed that the pouch region originating from Lee contains high PV air while line 23 page 11, it is claimed that L1 contains low PV air. But (a) I am completely unable to deduce these two statements from Fig. 3b. Instead of having a continuous gray shading, can you map only a limited number of gray nuances? Also can you show only positive PV values? (b) Also isn't it contradictory that L1 and R1 have air masses with different properties if both represent the lobe region? I guess this is the main problem of the manuscript as it is not precise enough to distinguish R1 and the pouch region, so that in many places the reader is confused between the two regions.

As indicated in the response to the previous comment, L1 and R1 represent separate regions, and so there is no contradiction on page 10. The PV shading has been changed to make the pv features easier to distinguish.

3. Concerning the non-divergent lobe transport, line 31, page 15, you cannot claim that 'divergence has little impact on manifold structure' since, precisely, the non-divergent alone cannot explain the size of the lobe! Actually, it is quite interesting to see that the lobes almost completely disappear (contrary to what you state) and are parallel to contours of the water vapor mixing ratio. This should be discussed as it means that the velocity divergence is responsible of the convergence of the material lines towards the center of the cyclone and of the inward transport of dry air. On the contrary, non-divergent motions seem related to a transport barrier so that no air from outside can enter inside the vortex.

The non-divergent flow certainly influences the size of the lobes, and is responsible for the convergence of the material lines. Though the size of the lobes is greatly reduced, the number of lobes does not change. We have elaborated this discussion on page 15 and emphasized the role of convergence in the inward advection.

4. Last statement page 16 is incorrect: I am unable to see a quick drop in relative humidity outside the shear sheath. Values are still quite high (r> 85%) at radius r= 2.5.

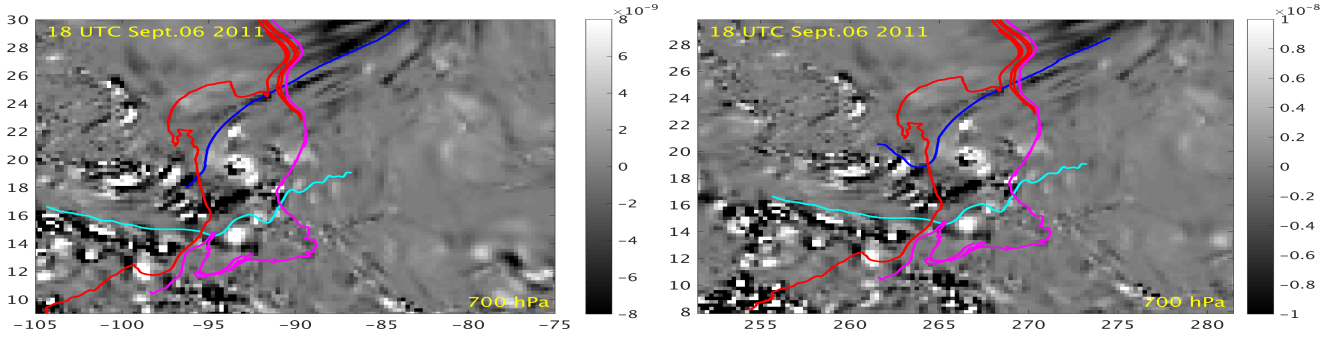
This statement has been eliminated.

5. Your Okubo-Weiss definition does not take into account the divergent part of the flow. It has to be taken into account in addition to the shearing effects since it brings material inwards, even if there is a 'shear sheath'. This is quite important to discuss, as even hyperbolicity is ill-defined in this context.

The magnitude of vorticity is typically an order of magnitude greater than divergence, and has very little effect on the OW values. The following figure shows the OW parameter without divergence, as in Figure 3(c) in the paper, and with divergence. The differences are very minor, so we have made no changes to the figures, but have added a comment about the role of divergence where OW is introduced.

Minor comments: 1. Top of page 10. In ECMWF, L1 has a negative circulation. On the contrary, when looking at Fig. 4a, L1 in WRF simulation is positive. Please comment.

The circulation of L1 in the WRF simulation is actually still negative, and should be clearer with the new color scale.



(a) (b)

Figure 1. The stable (red, magenta) and unstable (blue, cyan) manifolds are overlaid on the OW field (s^{-2}) without divergence in (a) and with divergence in (b) at 18 UTC Sept. 6 at 700 hPa.

2. The color palette is also awful for (relative?) vorticity in Fig.4. Can you use something that would be more practical? Same thing for Fig.3. All panels are kind of 'blurred'. Also in Fig.4, the color of the manifolds is reversed compared to Fig.2.

We have changed the color palette in Figures 3 and 4 to make vorticity features easier to distinguish. We have also switched the red and magenta manifold colors in Figures 4 and 5 to make them consistent with the other figures.

3. Page 16, line 17. It is incorrect to say that 'the strain regions are advected inwards'. There is no advection in here!

We now state that the strain regions are converge inwards, but not into the core.

4. You still do not explain in the text how results of figure 7 are obtained (radial average around the center defined by ...).

We now state that the center location used for the radial averages in Figure 7 are taken from the best-track storm location.

5. Figure 7. You should say that the radius is in degree.

We have added in the caption that the radius is in degrees.