

***Interactive comment on* “Simple kinematic models for the environmental interaction of tropical cyclones in vertical wind shear” by M. Riemer and M. T. Montgomery**

Anonymous Referee #3

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Summary: A simple kinematic framework for the interaction of tropical cyclones with environmental air is presented under the assumptions of a layer-wise two-dimensional and steady flow. The authors argue that the kinematic structure is responsible for intensity modulation in both an idealized experiment and a point vortex model subjected to background flow. This paper is scientifically significant and will motivate future research.

General Comments: The authors provide overall well written and interesting arguments that “dividing streamlines” emanating from a stagnation point are the key structures which govern the interaction of dry or moist environmental air with the core. While the

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paper is well written, there are several terms that are used synonymously or are not clearly defined. In some cases, the terminology is not consistent with many previous studies. These will be addressed further in the general and specific comments.

Steady Flow: The authors have made the assumption of a steady flow in a storm-relative reference frame. Since this is the first paper since WMF84 to address the kinematic structures related to streamlines and stagnation points, the assumption of a steady flow is a reasonable assumption for introducing these new ideas. However, there are some places where additional care should be taken or additional details given about the implications of this assumption. The authors hint at the requirement of including time-dependence by showing the times required for trajectories to enter the downdraft region, and by noting the time scale of intensity modulation due to downdrafts. The relationship between these time scales and the time scales involved in the numerical computations of streamlines is likely important when one considers the implications of these results in the case where the flow is not assumed to be steady, yet has not been addressed in this paper. A brief discussion of this relationship could validate the assumptions of a steady flow and strengthen the results of this paper.

Stagnation Points: The transient nature of stagnation points is well known and is apparent in this paper. A point that could be made more clear is whether the sensitivity of translation points both in number and location is due to the time averaging of the velocity fields or the time averaging of the background flow.

The term separatrix or separatrices is used many times in this paper, but the meaning is not clear. The meaning of separatrix is a boundary separating two types of solutions of a differential equation, and generally means an enclosed structure. In the context of streamlines, a separatrix is formed by enclosed streamlines. On P28065 L15, P28067 L17, and many other places in the text, separatrix refers to a single spiraling streamline, which does not divide different solution behavior, as all solutions are spiraling inward. In the unstable direction, the manifold of the hyperbolic stagnation point which leads to a sink or limit cycle is not distinguished from any other streamlines. The manifolds

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are distinguished, and form separatrices only because nearby trajectories behave differently by splitting as they approach the stagnation point. Backward trajectories, as in Figure 6, would show different behavior only as they approached the stagnation point, depending on which side of the manifold they originated.

Figure 7 (a) represents a separatrix, while the manifolds in 7 (b) and (c) are not separatrices for the purpose of air entering the core. In the latter cases, the stable manifold branch which comes close to the center may be part of a separatrix, since solutions either enter the core or they don't, depending on the which side of the stable manifold they originate.

I recommend changing P28065 L15 to indicate that manifolds are not the same as separatrices. The use of the separatrix at other places in the text should be carefully checked, and can likely be removed in most cases.

Specific Comments: P28062 L2: “dividing streamline” If the flow is steady, all streamlines are dividing. The particular streamline emanating from a hyperbolic fixed point is apparently what is meant here. The convention of “unstable manifold” is well established in many previous studies including Ide Et Al. 2002, which you reference. I would suggest that the authors either define dividing streamline specifically where it is first mentioned in the text to mean this particular streamline, or simply use the unstable manifold convention.

P28062 L17: “the stagnation point” is central to the results of the paper, and should be defined explicitly.

P28063 L1 The authors state “In the vicinity of the eyewall, both assumptions break down.” While this statement is true, some of the results of this paper including the idea of a limit cycle far away from the stagnation point are highly dependent on this assumption. Is this limit cycle purely an artifact of a steady flow, or of the averaging of the velocities, or is it apparent in the unsteady flow as well?

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P28063 L17 The term Lagrangian coherent structure is more general than the time-dependent analogs of the manifolds which are computed in this study, and generally means any structure that can be tracked through the time-dependent flow. Perhaps saying that these LCSs are finite-time manifolds of the time-dependent flow would remove any confusion as to how a LCS is defined.

P 28064 L10 Is the average translation speed time averaged or spatially averaged?

P 28065 L11 and P 28070 L 18 The velocities are averaged over a 6 hour period. However, the manifolds are streamlines computed by starting at the stagnation point. Figure 6 indicates that trajectories along the streamline near the fixed point require more than 1 day to reach the downdraft region. This appears to be an assumption that the flow is steady for the integration time of trajectories, which is as long as the 24 hour time of intensity modulation, not only the 6 hours of averaging. To be able to infer information about the core region from a distinguished streamline originating at a stagnation point, the assumption of a steady flow is as long as the integration time required to produce the streamline.

P28067 L5 The stagnation point is located at 1000 km, while the storm relative flow is averaged from 200 km to 1000 km. Are the values at 200 km and 1000 km similar?

P28069 L5-12 The multiple stagnation points appear very close to each other, so the flow toward the limit cycle is more related to the streamlines than the stagnation points.

P28079 L17-21 I don't think italics are necessary.

P28099 L7. Both branches of the unstable manifold extend away, but one leaves the domain. Only one branch of the stable manifold can be seen. What does the other manifold branch do if it doesn't extend away? Is the time scale just very slow in the stable direction at that location?

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 28057, 2010.