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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Lagrangian mixing in an axisymmetric hurricane model" *by* B. Rutherford et al.

Anonymous Referee #1

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General comment:

This paper investigates Lagrangian mixing in a simple axisymmetric Rotunno-Emanuel-type simulation of hurricane spin-up. To this end the authors adapt and extend well established measures of Lagrangian mixing to the problem at hand. They develop some novel hybrid measures, which account for the fact that hurricane spin-up results in velocity fields which are both very nonlocal and have a strong time dependence.

Overall the authors find that regions of high mixing rougly coincide with regions of strong shear, like the boundary between the eye and the eyewall. This result is not too surprising. The authors identify two "modes" during the late steady-state phase of the simulation: a strong mode and a weak mode. They are distinguished by the average velocity fields as well as the Lagrangian mixing measures, where higher intensity co-

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incides with stronger mixing. This correlation in itself is difficult to interpret, because is does not imply a cause-and-effect relationship. The authors go on to analyse coincident and lagged time series. This yields the interesting new result that (on a short time scale) increases in mixing precede increases in hurricane intensity (as measured by the tangential wind).

Overall I find the analysis novel and interesting. Parts of the paper are rather technical in nature; some sections simply provide plots of the different mixing fields without much further comment or interpretation. These sections would profit from some further indications as to what can be learned (possibly even about real hurricanes). An exception is the new result that changes in mixing precedes changes in hurricane intensity, which merits further study.

Specific comments:

1. Mixing in a hurricane in an intrinsically 3D process. As the authors admit themselves, it is dangerous to restrict oneself to 2D dynamics in a study focussing on the mixing processes, because it is not clear to what extent 2D mixing and 3D mixing are similar. On the other hand, the only substantial result of this paper is the fact that mixing precedes changes in hurricane intensity. But we only learn something about mixing in a 2D model; can we infer from this anything about mixing in a 3D simulation or even in a real hurricane? Clearly, a similar analysis for fully 3D dynamics is beyond the scope of this paper, but I think that the authors should at least discuss this point in some more depth.

2. I am aware that there is a vast literature about measures of Lagrangian mixing, and this is apparently the main expertise of the first author. So I appreciate the introduction to such mixing measures in section 2. Nevertheless, in the discussion in the following sections I would prefer a somewhat less technical language in some places. This would facilitate the understanding for readers (like myself) which do not have a strong background in mixing measures.

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Example: I did not quite understand what is meant by "invariant manifolds" and "Lagrangian coherent structures (LCS)", first introduced in section 2.2. Later there is a reference to Shadden et al. 2005, where it is said that "ridges of FLTE fields are defined as LCSs". Could the authors be a little more verbose and actually define the terms and say what they mean? Similarly, in section 6 while discussing figures 9, 10 and 11, I am supposed to see that "trajectories in the updraft have movement that is transverse to the LCS". I could not verify this statement by looking at the plot. Some further explanation might help.

Section 3: "trajectories.... mix into the updraft through hyperbolic processes": what is meant by "hyperbolic process"? Would that (in more meteorological language) be mixing through straining in a nontrivial deformation field?

Technical details:

1. Typo on pare 18567 ("exapnsion" instead of "expansion")

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 18545, 2009.

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