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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Tropical cyclogenesis in a tropical wave critical layer: easterly waves" *by* T. J. Dunkerton et al.

T. J. Dunkerton et al.

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A noted in our response to the Interactive Comment by Anonymous Referee #1, the main text was shortened by about 35%, and footnotes converted to endnotes. Supporting material was moved to Appendices A-C, leaving this material, and the endnotes, as optional reading for interested readers.

The paper is lengthy and erudite, almost without mathematical equations, as in Einstein's 'Investigations on the Theory of Brownian Movement' – although we omit 'lengthy' in reference to that work. One of the suggested reviewers for our paper, who did not provide online comment, remarked that the paper was at the level of a well-known treatise on potential vorticity[1] and provides an exceptional 'density of ideas per unit length'. Some condensation was achieved in the revision, but it is otherwise difficult to condense something that is already dense. There's a legitimate concern that

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full-time professors have insufficient time to study such a paper. Our recommendation: have the students read it, and report back!

We applaud the reviewer's second suggestion, that the verbal and visual analysis be accompanied (eventually) by mathematical analysis, built on a framework of PV concepts and perhaps, the mathematics of multiple scales. We avoided this level of detail in an introductory paper because the basic message needed to be articulated first. In fact, there are many directions to pursue for quantitative analysis of issues raised in the paper. We will continue to contribute in this manner, and hope that others join the exercise. A sign of a successful paper is that (i) it makes the basic result seem obvious in retrospective, though never articulated previously, and (ii) it excites a passion for further analysis.

Since PV inversion will play a role in some of this analysis, as the reviewer anticipates, a word of caution is warranted, and elaborated upon in the last response. The notion that the kinematics of the critical layer is dominated by the large-scale flow, owing to the inverse-Laplacian nature of the PV invertibility, requires a backward mental shift from the tropical depression or hurricane, an intense concentration of PV not yet formed, to an amorphous collection of disorganized vortical elements within a better organized large-scale wave, mean-flow structure (the critical layer). It is no coincidence that the theory of nonlinear critical layers is built on multiple scaling and places greater emphasis on the Kelvin cat's eye than on the disorganized vorticity within. Proper interpretation of the sequence of events leading to formation of a tropical depression in a tropical wave critical layer rests on the connection between causality and the arrow of time: what follows chronologically (the tropical depression or hurricane) cannot be a cause of what came before (the parent wave or instability). This overarching fact lies atop all details of PV evolution in the sequence. The inverted flow structure (translating stream function) is as important as the distribution of PV 'charges' responsible for the structure. Equivalently, kinematics as is important as dynamics.

It should be noted that a predominant role of the Kelvin cat's eye is assigned to the

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time period leading up to and immediately following genesis. An intensifying storm is distinguished by its increasingly intense concentration of potential vorticity substance, and increasing autonomy as a result. It is a remarkable property of the point-vortex train in parallel shear flow that a similar cat's eye pattern is produced[2] without any outer disturbance at all. This similarity suggests an almost seamless transition from tropical wave critical layer to (one or more) tropical depressions. The revised paper introduces a conjecture that the emergence of a developing storm and demise of the parent wave may be identified with such a transition, and quantified by its vorticity concentration relative to that of the original critical layer (as measured, say, by rms values within).

[1] B.J. Hoskins, M. E. McIntyre, and A. W. Robertson: On the use and significance of isentropic potential vorticity maps. Quart. J. Royal Meteorol. Soc., 111, 877-946, 1985.

[2] Pozrikidis, C.: Introduction to Theoretical and Computational Fluid Dynamics. Oxford University Press, 1997.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 11149, 2008.