

Review of the manuscript entitled: “The dynamical lifecycle of tropical cyclones from the perspective of potential vorticity structure”, by Emmanouil Flaounas and Suzanne L. Gray, submitted to Weather and Climate Dynamics.

Recommendation: Do not accept.

This paper explores the evolution of potential vorticity in two simulated tropical cyclones that had a high impact during their lifetimes: Hurricane Katrina (2005) and Typhoon Usagi (2013).

One motivation for the study seems to be that “insights into TC dynamics from a process-based PV analysis is indeed missing from the state-of-the-art”. One might play the Devil’s advocate and advance the reason that such an analysis is missing is because a process-based PV analysis does not readily offer much in the way of direct new insights and would not be expected to. In particular, the authors never directly invoke Newton’s second law in any of their explanations.

In my humble opinion, the study seems largely an academic exercise that will be of little interest to the tropical cyclone community, itself, as there are much more straightforward ways to understand the interaction between deep convection, boundary layer friction and an evolving vortical circulation in the Tropics than resorting to PV budgets. One such framework to understand the tropical cyclone life cycle is articulated by Smith and Montgomery (2025). This framework is based directly on Newton’s equations of motion, mass continuity and the usual thermodynamic equations. In contrast, combining these equations into one for the potential vorticity, a quantity that is not materially conserved in a tropical cyclone, and then having to resort to an inversion principle, from which it is by no means straightforward to recover the flow field, seems to be an unwieldy way to seek new insights.

The conclusions are particularly weak and hardly new. One does not need to go to the efforts that the two authors have made to arrive at these conclusions. For example, the conclusion that “Cyclone dynamics can be regarded as an ensemble of interacting PV anomalies” was essentially proposed two decades ago by Montgomery et al. (2006). The statement that: “our results suggest that TC intensification begins with the formation of a vertically coherent PV tower generated by latent heat release within deep convection” was shown also by Montgomery et al. (2006).

The conclusion that: “As intensification proceeds, the cyclone progressively acquires an increasingly axisymmetric structure, with its maximum winds becoming organised around the convective eyewall” has been known for decades. The conclusion that: “At maturity, the PV anomaly evolves into a characteristic “bowl-shaped” structure composed of three dynamically distinct regions: (i) a lower inner-core bulb characterised by comparatively weak positive PV within the lowest 2–3 km of the eye, (ii) the remainder of the eye above this bulb, and (iii) the surrounding convective eyewall, where large positive diabatically generated PV dominates and extends vertically through much of the troposphere” will evoke the reaction from most readers: so what? It is a pure description of findings without any mention of their significance. Why are these facts important physically?

It is hard to imagine a forecaster getting excited by learning that “A machine learning model, based on a U-Net that we trained using idealised simulations, suggests that the PV within the inner-bulb together with the PV_{mo} within the eye contribute together by an order of 20% to the cyclone maximum intensity”, or on learning the unsurprising fact “From the perspective of PV invertibility, the cyclone reaches maximum intensity in Fig. 2 when average vertical PV structure attains maximum amplitude”. The information that follows the latter statement from line 621 onwards to line 632 is particularly lacking in insight and again, most readers will say: so what? Why are these facts important physically?

I am unable to see how one might extract insights from the PV analysis that complement or even surpass those provided by Smith and Montgomery (2025) in a much more direct framework. For this reason, I do not recommend acceptance of the manuscript.

References

Montgomery M. T., M. E. Nicholls, T. A. Cram and A. B. Saunders. 2006. A vortical hot tower route to tropical cyclogenesis. *J. Atmos. Sci.* 63, 355–386.

Smith, R. K. and M. T. Montgomery, 2025: Towards understanding the tropical cyclone life cycle. *Tropical Cyclone Research and Review*, 14, 119-131.