

Interactive comment on “The vorticity budget of developing Typhoon Nuri (2008)” by D. J. Raymond and C. López Carrillo

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Received and published: 23 August 2010

An analysis of the formation of Typhoon Nuri is presented using scanning Doppler radar and dropsonde data. The Typhoon formed despite a non-trivial sheared environment. The authors demonstrated that the storm developed in a protected environment consistent with the marsupial pouch theorem. However, in the sheared flow the closed circulations in the lower and middle troposphere were displaced horizontally, but retained some overlap. This overlap was important for the Typhoon development because it defined a deep protected region, within which the Typhoon core developed. The high spatial resolution data collected at three stages of the Typhoon development provided an excellent opportunity to investigate the intensifying circulation. A vorticity budget revealed the dominant system-scale cyclonic vorticity tendencies to be horizontal conver-

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gence in the low- to mid-troposphere, and tilting above. The authors used the vorticity budget to demonstrate that the Ekman balance assumption (balance between Coriolis, pressure gradient and friction forces) was inappropriate for the Typhoon boundary layer during a period of intensification. Comparisons were made with a non-developing system.

General comments: The study is thorough and puts the available data to good use. While there is nothing surprising in the results, the study is very important for supporting or confirming theories arising from contemporary modelling studies (e.g., marsupial pouch, the role of deep convection).

The conclusion regarding the appropriateness of the Ekman balance assumption during a period of strong development is also not surprising. If the BL circulation is intensifying, and the only term contributing to a cyclonic vorticity tendency is convergence, then the convergence must exceed the friction term. Perhaps there could be some commentary on the possibility of near balance at other times, for example Figs. 15 and 18 show the two terms are of similar order of magnitude. The difference probably falls within the factor of two uncertainty range regarding the friction magnitude. Such balance would be more likely in a mature storm of steady intensity.

Specific comments: Only the last three digits of the page numbers will be listed below.

1. P 590: Eq. 1 appears to be constructed in geometric coordinates (x,y,z) , in which case the baroclinic term should probably be included for completeness, as well as a sentence or two to justify its neglect in the budget. Also it is probably worth mentioning which equation from HM87 was used to derive Eq. 1.

2. P 591, L17: When describing the Ekman balance it might be worth including the centrifugal force, given the tropical cyclone application.

3. P 592, L1: Strictly speaking the “divergence of absolute vorticity” described here is the “horizontal divergence of the horizontal flux of the vertical component of absolute

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vorticity”.

4. P 593, L1-7: You could quote Tory and Montgomery (2006, IWTC-VI report) and/or Tory and Frank (2010, p76, Global perspectives on tropical cyclones Volume 2) in which this process is described and illustrated schematically.

5. P 599, L1-2: It might be worth quoting the logarithmic wind profile to justify the conclusion that using CBLAST results valid at 10 m height produces a slight overestimate for the surface stress at a level more than 60 times higher.

6. P 600, L 4: Has FNL been defined yet?

7. P 601, L 10: Just a comment on style. The sentence reads as if the authors were surprised that TCS030 did not develop after passing over warmer water. (Given the vorticity distribution I'm sure they would have been surprised if it did develop.)

8. P 602, L 2: “.east and southeast sides of the disturbance.” I found this location hard to understand at first. It might be less ambiguous if the enhanced vorticity location was described with respect to the 5 km circulation centre rather than the surface centre.

9. P 603, L 25: It's not immediately obvious what “this” at the end of the line is referring to.

10. P 604, L 6: Begin the sentence with “Figure 10...” to avoid ambiguity.

11. P 604, L 7: Explain how the 7 m/s shear was determined. The shear in Nuri 1, 2 and 3, appears to be about 3, 7 and 9 m/s respectively.

12. P 604, L 17-19: Haynes and McIntyre recommend not splitting the advective flux into these terms, due to cancellation between the terms. So it might be worth explaining that while mathematically more correct, it is physically impractical, because the advection contribution can be very noisy, particularly when you have numerous vorticity anomalies in the circulation.

13. P 605, L 8-9: The lack of PBL stretching could also be due to a lack of vorticity

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to be stretched. However, in this case the PBL stretching tendency is negative in the vicinity of the convection, which suggests that the mass flux is downward, giving rise to vortex “squashing” rather than “stretching”.

14. P 605, L 15: The discussion on closed vorticity flux lines is useful and a nice way to illustrate the vorticity containment by the system. But I do not think the figures contain enough of the circulation to conclude with certainty that the vorticity flux lines are closed for the Nuri examples and open for the non-developer. A few more sentences would be required to justify the conclusion that the curved field of TCS030 PBL vectors is open and that of Nuri 2 is closed.

15. P 605, L 24: Mention the different scales between Figs. 11-14.

16. P 605, L 25-27: The “However” in this sentence implies some connection with the previous sentence, which I think I am missing.

17. P 606, L 9-10: It might be worth splitting this sentence into two, because only the latter half relates to the next sentence, which is connected by the conjunctive adverb “thus”.

18. P 606, L 20: Add “comparatively” after “. . .of tilting is”. The tilting term is actually larger at low levels in Nuri 2 than 1.

19. P 608, L16: Replace “explains” with something like “gives a possible explanation for”.

20. P 608, L 27-28: The conclusion here and in the abstract is that the overlapped pouch is important because it gives a full column deep protected region from the PBL to 5 km. It might be worth noting that this is also where convection is likely to be favoured, due to the isentropic upslope flow tendency towards the down-tilt direction of a tilted vortex.

21. P 610, L 5: While the conclusion that TCS030 did not spin up because it did not have a closed circulation is probably true, one could also argue that there just wasn't

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enough vorticity in the vicinity.

22. P 617: What does the colour scale refer to? Replace “ar” in the caption with “as”.

23. P 619: Are the units correct?

24. P 622: What are the vorticity units in Fig. 7?

25. P 626: Remove “in” from the fourth line of the caption.

26. P 630: It might be worth commenting on the negative mass flux at low levels. Also how is the mass flux normalized?

27. P 633: Change caption to read “. . .over the 2 degree square box illustrated in Fig. 6 centered. . .”.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 16589, 2010.