Review of “The genesis of Typhoon Nuri as observed during the Tropical Cyclone Structure 2008 (TCS08) field experiment Part 2: Observations of the convective environment” by M. T. Montgomery and R. K. Smith

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This paper follows up on the authors’ results for tropical cyclogenesis in the PREDICT project by performing the same analysis on the development of Typhoon Nuri, which was observed during TPARC/TCS08. In this paper they concentrate on a comparison of the thermodynamic environments for the first two Nuri case studies, referred to as Nuri1 and Nuri2. In a nutshell they found that the averaged environmental sounding moistened at middle levels between Nuri1 and Nuri2, warmed by about 1 K in the upper troposphere, but did not change much in the lower troposphere. These results are consistent with our 3D-Var analyses of Nuri1 and Nuri2 (see figure 1), though we see slightly greater changes in the virtual temperature profile, due probably to our slightly smaller averaging area. The paper is well written, and I recommend acceptance subject to minor revision with one caveat, which is presented below.

The caveat

The authors make the following comment in their conclusions section:

> “Two notable thermodynamic models that have been offered previously to explain tropical cyclogenesis in general and the formation of Nuri in particular have assumed a modest cooling of the lower troposphere in the disturbance region in association with a cyclonic circulation that has a maximum in the middle troposphere. To test this thermodynamic hypothesis, we examined the change in the system-mean virtual temperature near the pouch region of the developing disturbance during the genesis phase, but found no systematic cooling in virtual temperature of the lower troposphere (below 4 km) during the genesis. We did find a small warming of the upper troposphere, though this warming is less than

1 K. **Neither these results nor those of the PREDICT experiment support the thermodynamic hypothesis on the scale of the recirculating pouch region.**" (Emphasis added.)

I believe that the emphasized sentence overstates the case against the thermodynamic hypothesis and needs to be tempered, for reasons discussed below.

Montgomery and Smith discount the thermodynamic models (including one proposed by Raymond and Sessions 2007) because the difference in average virtual temperature in the lowest 4 km between Nuri1 and Nuri2 is negligible, whereas Raymond and Sessions assumed that a disturbed environment is both warmer at upper levels than an undisturbed environment and cooler at lower levels. However, Nuri1 was already a strong easterly wave, and comparison of the Nuri1 mean sounding with a less disturbed environment, such as that occurring in the TCS030 case (see figure 2), shows strong cooling below 4 km. Thus, as figure 3 demonstrates, the net change in the temperature profile between TCS030 and Nuri2 exhibits both upper level warming and lower level cooling.

To put this in perspective, the premise of the Raymond-Sessions calculation was to determine the change in convective response which occurs in going from an environment in radiative-convective equilibrium to one which is highly disturbed. As noted above, the warming in the upper troposphere and cooling in the lower troposphere assumed by Raymond and Sessions are comparable to that seen between TCS030 and Nuri2 in figure3. The mean tropical environment (which differs little from the undisturbed environment since the fractional areal coverage of strong disturbances is small) is likely to be close to radiative-convective equilibrium, as the tropics as a whole exports only a small fraction of incoming solar energy to higher latitudes. It is therefore more appropriate to compare the Raymond-Sessions results with the Nuri2 - TCS030 difference than with the Nuri2 - Nuri1 difference.

To show that TCS030 is appropriate as a benchmark for an undisturbed tropical environment, we compare the virtual temperature profiles of TCS030 and Hagupit2 in figure 4. Hagupit developed into a typhoon about a week after the Hagupit2 mission. However, for most of that week, the pre-Hagupit disturbance drifted to the west as a weak wave without developing, making it more like TCS030 than Nuri. With the exception of a thin layer near the surface, the Hagupit2 profile is actually warmer than TCS030 through most of the observed depth range (see figure 5). Only below about 1.5 km is Hagupit2 cooler than TCS030. Thus, the mean temperature of the Hagupit2 sounding below 4 km is quite close to that of TCS030. In contrast, Nuri1 is considerably cooler than Hagupit2 in the lowest 4 km. The evidence at hand thus favors the hypothesis that the Nuri1 environment was significantly cooler than the undisturbed environment at low levels. Another interesting example of cooling at low levels in a tropical cyclone environment is given by Mapes and Houze (1995).

Montgomery and Smith correctly point out that virtual temperature is more closely related to buoyancy than temperature. However, figures 1-5 show that the virtual temperature correction is small in comparison with differences in temperature profiles between different cases.

Minor comments

1. The sounding for Nuri4 should probably be cut off at 3 km in figure 5, since, as the authors note, the deep soundings in this case are unrepresentative of the storm core.

2. The same is probably true of Nuri3, as it is unlikely that the few soundings the C130 made before having to return to Guam are representative.

References

Mapes, B., and R. A. Houze, Jr., 1995: Diabatic divergence profiles in western Pacific mesoscale convective systems. J. Atmos. Sci., 52, 1807-1828.

Raymond, D. J. and Sessions, S. L.: Evolution of convection during tropical cyclogenesis, Geophys. Res. Lett., 34, L06811, doi:10.1029/2006GL028607, 2007.

Raymond, D. J., Sessions, S. L. and Lopez, C. L.: Thermodynamics of Tropical Cyclogenesis in the Northwest Pacific, J. Geophys. Res., 116, D18101, doi:10.1029/2011JD015624, 2011.

Figures

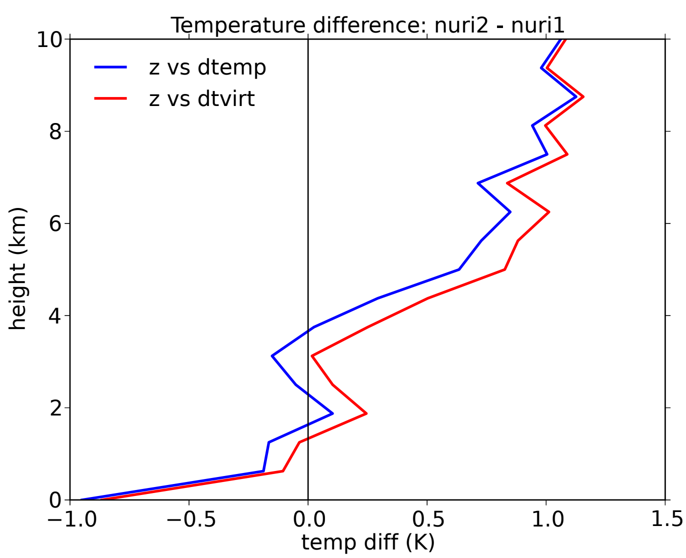

Figure 1: Mean temperature and virtual temperature difference between Nuri2 and Nuri1 environments.

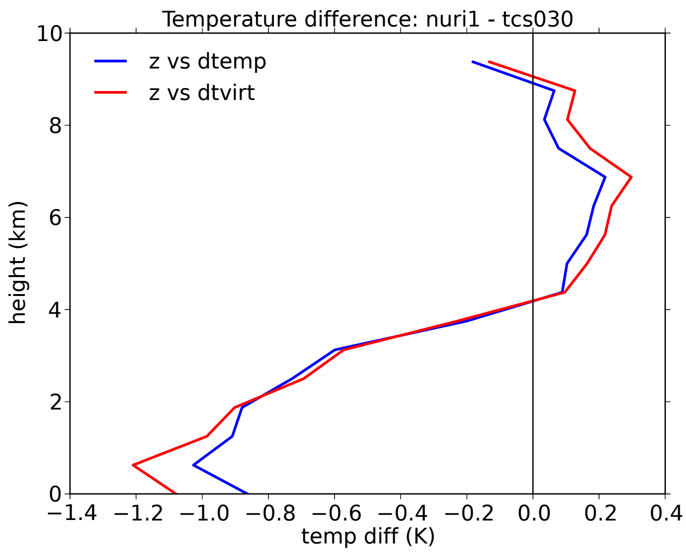

Figure 2: As in figure 1 except Nuri1 minus TCS030.

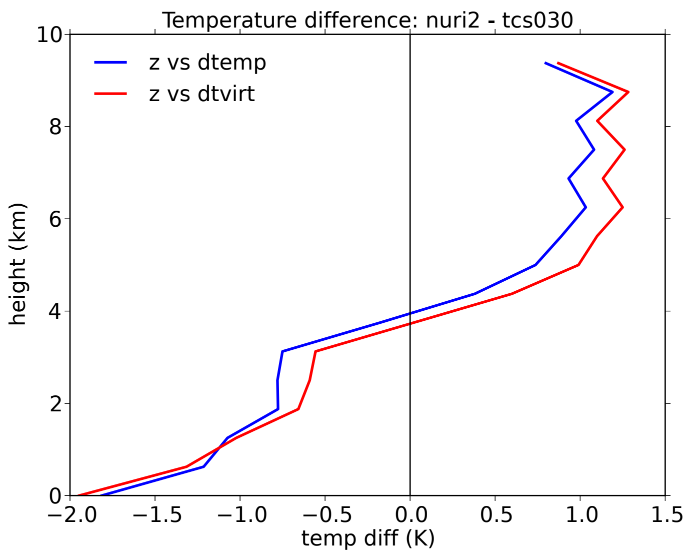

Figure 3: As in figure 1 except Nuri2 minus TCS030.

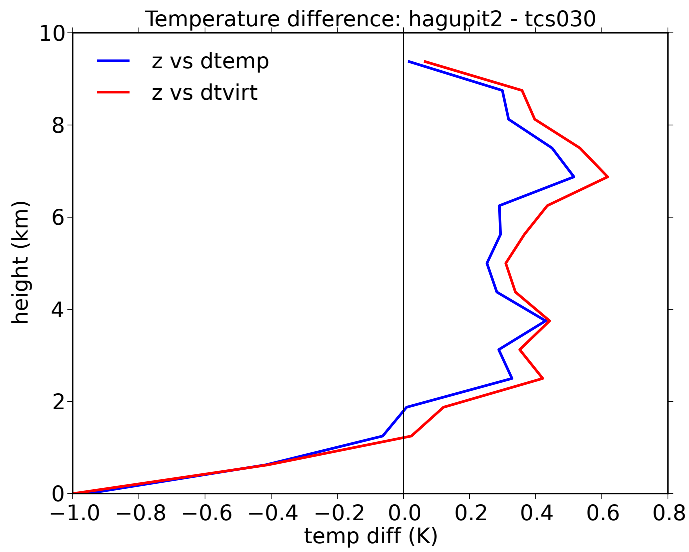

Figure 4: As in figure 1 except Hagupit2 minus TCS030.

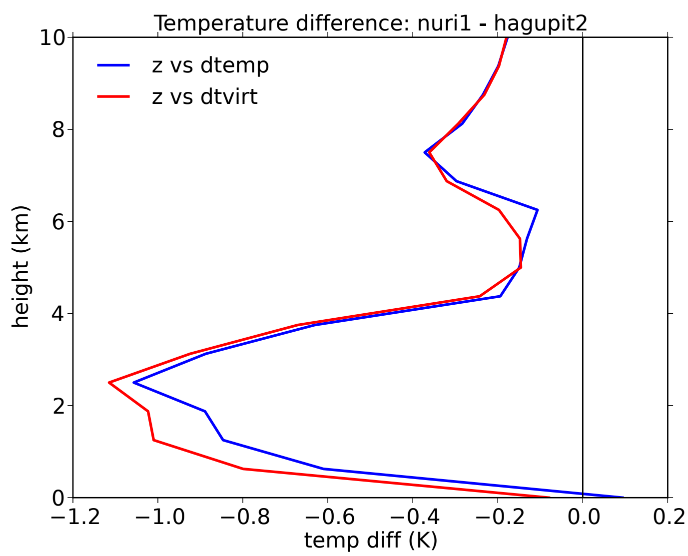

Figure 5: As in figure 1 except Nuri1 minus Hagupit2.