Review of "Why did the storm ex-Gaston (2010) fail to redevelop during the PREDICT experiment?" by Freismuth et al.

David J. Raymond

February 14, 2016

The authors of this manuscript make parcel trajectory calculations for the failed tropical cyclone Gaston (2010), based on ECMWF analyses that included dropsonde data from the PREDICT project. There is general agreement that Gaston decayed after the second PREDICT mission on 3 September 2010 as a result of ingestion of dry air. However, the current manuscript as well as a couple of other papers cited by the authors further assert that the decay of Gaston between 2 and 3 September was also due to the incorporation of dry air.

Gjorgjievska and Raymond (2014; GR2014, cited in the manuscript) do not dispute that dry air was instrumental in the decay of Gaston after 3 September. However we also demonstrate that a more subtle process was likely occurring in the 2-3 September interval that led to the subsequent flood of dry air invading Gaston.

The first hint that dry air did not affect the convection in Gaston prior to 3 September comes from in figure 3d of GR2014. (Note that due to an unfortunate transposition error, the images for figures 3 and 4 are switched, so the image for figure 3 is shown with the figure 4 caption.) This figure demonstrates that the relative humidity averaged over a 4 by 4 degree box centered on roughly on the 5 km vortex center changed very little between 2 and 3 September. The main difference is an *increase* in the relative humidity near the 5 km vortex center in the 7-9 km range between these two dates. (See also figure 5 of GR2014).

Figure 6 of the current manuscript shows the analyzed equivalent potential temperature at 500 hPa (approximately 5 km) on 1-3 September. There is indeed a dry tendril of air sweeping around the south and east side of Gaston 1 and 2 (on 2 and 3 September respectively), but the actual 5 km circulation centers in the co-moving frame were at (39W, 15N) and (42W, 15N) on these two days, i.e., 2-4 degrees to the north and west of the dry air intrusions (see GR2014 figure 5).

Figure 6 of GR2014 shows the vertical mass flux pattern at 700 hPa in Gaston 1 on 2 September. The strongest upward motion (representing deep convection) is centered at (39.5W,14.5N), or slightly to the SW of the 500 hPa circulation center. There is evidence of downward motion roughly 1.5-2 degrees to the east of this ascent, possibly representing the effects of the intruding dry air. Nevertheless, convection responds to the thermodynamics of air in its immediate vicinity, not to air 150-200 km away, indicating that the convective core of Gaston on this date was still narrowly protected from dry air by the pouch.

Comparison of Gaston 1 and 2 with the developing cyclone Karl shows that the relative humidity profiles in the early stages of Karl were very similar to that of Gaston 2. Yet Karl developed into a major hurricane. The most obvious difference between the two cases is that Gaston 1 and 2 experienced SSTs of 28.2 C and 28.4 C respectively, whereas the first 3 Karl missions showed SSTs of 30-30.2 C (see table 1 of GR2014). Thus the SSTs in the early Karl stages exceeded those in Gaston by almost 2 C. In addition, as figure 9 of GR2014 shows, the tropical cyclone heat potential for Gaston was quite small in its initial stages and quite large for Karl.

Figure 10a of GR2014 shows that the environment of convection in Gaston 1 had strong convective inhibition near 2 km, and that considerable energy had to have been expended by the convection in breaking this inhibiting layer in the convective region. Such an inhibiting layer did not exist in the vicinity of convection in Karl 3 (11 September 2010), as figure 10c shows. The inhibiting layer in Gaston relative to Karl is almost certainly related to the lower SST experienced by Gaston.

As Figure 7 of GR2014 shows, the convective mass flux profile for Karl 3 was vastly different from that of Gaston 1, with extreme top-heavy convection in Karl 3 and extreme bottom-heavy convection in Gaston 1. This resulted in much stronger convergence below 2 km and a corresponding increase in the strength of the low-level circulation between Gaston 1 and Gaston 2 (see figure 3a – shown under the figure 4 caption as noted above). However, strong divergence above 3 km in Gaston 1 resulted in the destruction of an initially strong mid-level vortex, as figure 3a shows.

GR2014 argue that the elimination of the mid-level vortex weakened the pouch sufficiently to allow the ingestion of dry air, resulting in the subsequent decay of Gaston. Given that the relative humidity profiles for Gaston 1 and 2 and Karl 3 were nearly identical, as are the parcel buoyancy profiles above 3 km, the existence of strong convective inhibition in the environment of Gaston 1, undoubtedly related to the lower SST, is the most plausible explanation for the dramatic differences between the convection in the two cases. (As noted by the authors of this manuscript, the most extreme convective inhibition, as represented by a trade wind inversion, occurred well to the west of Gaston 1. However, relatively strong convective inhibition, as noted above, existed on all sides of the convective core in this case.)

In summary, the evidence for our view of the decay of Gaston before 3 September consists of 2 parts: (1) The relative humidity did not decrease and in fact increased at upper levels between Gaston 1 and Gaston 2 in a region centered on the 5 km circulation center. The convective core was very close to the circulation center in these two cases. (2) The low SSTs and increased static stability near the convective core of Gaston likely had a negative effect on convection in Gaston 1 even if there was technically no trade wind inversion in the convectively active area. This stands out particularly in comparison to Karl 3, in which convective inhibition was weak over the entire region, and for which the SSTs were much higher.

Part of the discrepancy between the results of GR2014 and the current manuscript may be due to the location of the pouch. For both Gaston 1 and Gaston 2, the 5 km circulation centers are on the NW edge of the pouch positions as defined in the manuscript (see figures 5a and 5b in GR2014 in comparison with figure 6 in the manuscript). Furthermore, the convective cores in these cases are much closer to the 5 km circulation centers than to the center of the pouches defined in the manuscript under review (see figure 6a in GR2014 for Gaston 1; Gaston 2 not shown). One can of course define the pouch in accordance with the circulation center at any level one desires, and Montgomery and colleagues tend to define this at 850 hPa (or perhaps 700 hPa in this paper – this is not clear). For reasons set forth in Raymond et al. (2014; Tropical cyclogenesis and mid-level vorticity. Australian Meteorological and Oceanographic Journal, 64, 11-25.) we prefer a higher level, i.e., near 5 km in many cases. Given that the convection tends to occur near the 5 km circulation center on both days, the higher level would seem to be more appropriate in this case.

The dependence on a global analysis for very delicate Lagrangian trajectory calculations also raises at least a yellow flag. Analyses incorporate sounding data in competition with model prejudices with opaque weighting factors. Our analyses depend on PREDICT dropsonde data only.

I feel that I am perhaps too close to this whole argument to give an objective recommendation on this paper, so I shall leave that to the other reviewers and the editor. However, though I do appreciate the authors' attempt to represent our position in their manuscript, I would like to see the whole story told, which explains the length of this commentary. Technically, the manuscript is well written, though some of the figures, such as figure 5, are very hard to decipher.