ACPD-15-8479-2015
Responses to Reviewer 1 (Prof. R. Schumacher)
Date: 9 July 2015

Title: A numerical study of convection in rainbands of Typhoon Morakot (2009) with extreme rainfall: roles of pressure perturbations with low-level wind maxima
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1. General comments:

This study uses dynamical diagnosis of numerical model simulations to understand convective processes in the rainbands of Typhoon Morakot (2009). In particular, the authors focus on the behavior of updrafts in the strong low-level vertical wind shear in the rainbands. They conclude that rather than being forced by lift along a cold pool, the location of ascent associated with the updraft/shear configuration is responsible for the back-building of convection in the rainbands.

The topic of the manuscript and the methods used are generally sound, and the paper is clearly written. The study did raise several questions for me that I think should be more thoroughly addressed in the manuscript, but I believe these bigger-picture issues still only require minor revisions. Therefore, I recommend that the manuscript be accepted if these minor revisions are sufficiently considered by the authors. I don't need to see the manuscript again, but would be willing to review a revised version of the editor prefers it.

Reply:

We appreciate the positive views and critical comments from all three reviewers, and have revised the paper accordingly. Among the changes, we have (1) added the diagnostic results at 0645 UTC (besides 0630 UTC) to show a dominant and persistent effect from the dynamical pressure perturbation in the mature cell, (2) employed 10-min radar CAPPI data at 3 km to show the back-building and merging behavior of convective cells, and (3) estimated the contribution from convection versus stratiform clouds over Taiwan plain area in the event. In addition, the figures are polished and font sizes enlarged, the method of diagnosis is validated, the scale of the low-level jet is clarified, the cold pool is examined, and the evolutions of model convective cells are discussed in more detail, as suggested.

The changes in the manuscript are marked in red, blue, and green for Reviewer 1, Reviewer 2, and Reviewer 3, respectively. The modifications made by ourselves during the revision are in orange (mostly to correct mistakes), and those made during the production stage of ACPD since our first submission (to meet the format requirements) are in pink. The point-by-point responses to each of the comments/suggestions from this reviewer are listed below.

2. "Big-picture" comments:

1) This study uses diagnostics originally developed for understanding supercell thunderstorms to look at convection in the outer rainbands of a tropical cyclone. In fact, some past studies have shown that this convection is indeed supercellular, e.g., Eastin and Link (2009); Morin and Parker (2011); see also the references therein. I think it would be useful to establish whether the convection in Morakot was consistent with supercell dynamics, or whether these convective cells were non-supercellular but potentially still explained by these diagnostic methods.

Reply:

It is clarified that although this diagnostics was initially developed to study supercell storms, it is also shown to be valid and used for quasi-linear rainbands by Parker and Johnson (2004). In addition, it is mentioned that several past studies have suggested that some convection in TC rainbands are indeed supercellular, and the works of Eastin and Link (2009) and Morin and Parker (2011) are both cited.

2) One thing that wasn't totally clear to me in the manuscript was whether the "low-level jet" (LLJ) being discussed here was something external to the tropical cyclone, or the flow associated with the TC itself (or perhaps a bit of both). Perhaps the findings here could be compared to the conceptual model of Hence and Houze (2008) for rainbands in the "secondary horizontal wind maximum"?

Reply:

In the revision, it is clarified that the LLJ was a part of the TC circulation, but was also most likely enhanced by the southwesterly monsoon. The study of Hence and Houze (2008) is also cited as suggested.

3) Although from my reading of the manuscript, the use of the pressure perturbation diagnostics is interesting and applicable to this case, the manuscript may be more convincing if at least one more time is shown, such as 0645 or 0650 UTC when we can see how the detailed diagnostics shown for 0630 UTC related to the subsequent back-building convection. I don't think it's necessary to show 4 or 5 complete figures for the later time, maybe just one figure illustrating how things evolved after this time.

Reply:

In the revision, it is clarified that the diagnostics initially developed by Rotunno and Klemp (1982) is also shown to be valid and used for quasi-linear rainbands by Parker and Johnson (2004). The diagnostic results associated with cell A1 at 0645 UTC are also shown in a new figure (Fig. 17) and compared with those at 0630 UTC (Figs. 15 and 16), as suggested. The results show similar patterns and the effect from p_d' continue to dominate over those from buoyancy and p_b' at the rear side of A1 (mature cell), so that they are persistent through the mature stage. The time evolution of the pair A1 and A2 after 0630 UTC is also shown in Fig. 8, and it is described in more detail in relation to the results of dynamical pressure diagnostics in the revision, as suggested. Consistent with the diagnostics, cell A1 continues to strengthen for about 15 min (through 0645 UTC) but travels at a slower speed after 0630 UTC (linked to the induced vertical PGF at its rear flank), and cell A2 shows significant development afterwards and eventually becomes the dominant cell of the pair (near 0700 UTC).

4) There is some interesting 3-dimensional structure to the low-level vertical velocity field to the west of the updraft, as seen in Figs. 11 and 12, but this isn’t really addressed in the subsequent discussion. (I’m referring to the “line” of upward motion that extends to the south-southwest of the main updraft.) Is this ascent explained also by the pressure perturbation diagnostics, or is something else going on there? And is it important to the back-building convection?

Reply:

The vertical velocity (at 1058 m) surrounding A1 is largely forced by the low-level convergence (at 547 m), so the two fields have very similar patterns. This is pointed out and described more clearly during the discussion of Fig. 9. The pattern surrounding A1 extends south and west (toward the area of the initiation of A2) is largely due to the deceleration in *u*-wind and confluence in *v*-wind, respectively. Both the speed convergence in *u* and confluence in *v* across A1 are consistent with (and mainly in response to) the development of deep convection. Thus, even though the background westerly LLJ is consistent with the confluence in *v* and is stronger toward the east (cf. Fig. 7), the deep convection still exhibits significant modulation effects on the local wind field. In the revision, the above phenomena and their relationships are described more clearly and explained in more details.

References

Eastin, M.D., and M. C. Link, 2009: Miniature Supercells in an Offshore Outer Rainband of Hurricane Ivan (2004). Mon. Wea. Rev., 137, 2081–2104. doi: http://dx.doi.org/10.1175/2009MWR2753.1

Hence, D. A., and R. A. Houze Jr. (2008), Kinematic structure of convective-scale elements in the rainbands of Hurricanes Katrina and Rita (2005), J. Geophys. Res., 113, D15108, doi:10.1029/2007JD009429.
Morin, M. J., and M. D. Parker (2011), A numerical investigation of supercells in landfalling tropical cyclones, Geophys. Res. Lett., 38, L10801, doi:10.1029/2011GL047448.