

Interactive comment on “Simulation of hurricane response to suppression of warm rain by sub-micron aerosols” *by* D. Rosenfeld et al.

D. Rosenfeld et al.

Received and published: 21 June 2007

The authors thank the Referee V. Phillips for the constructive and helpful comments. Following are our responses to the comments, which are replicated here in *italic text*.

Comment: *Page 5652, Line 8: A bulk microphysics scheme cannot be “explicit”. An explicit microphysics scheme refers to a size-resolving (spectral) scheme, not a bulk scheme.*

Response: Accepted. We would like to mention that the word "explicit" is often used instead of "cloud-resolved". In this sense the bulk microphysics scheme used can be considered as "explicit". We changed “explicit” to “cloud-resolved”.

Comment: 5652, Line 16: Can evidence be cited in favour of 27 degC being a realistic prescription of the sea surface temperature over the Gulf of Mexico ?

Response: This is obviously an error in the text. The SST field was taken over the computational area from the reanalysis and was spatially inhomogeneous. The SST=27°C was at the point of the initial location of the TC. The SST over the Gulf of Mexico was obviously higher. Otherwise we would not get the intense hurricane.

Comment: *Page 5652, Line 27: What observed concentrations of sea-salt CCN are possible? Spracklen et al. (2005, ACPD) have done a modeling study of sea-salt CCN concentrations and find concentrations are generally very low. More evidence would be good on this point. The reason I have doubts about the role that sea-salt giant CCN can have is that Feingold et al. (1999, JAS) have shown that giant CCN > 1 micron only initiate rain in clouds that are close to the threshold anyway for precipitation. Clouds engulfed in smoke or intensively seeded would seem to be far from such a threshold. Physically, just after such giant CCN activate (e.g. at cloud-base), surely their size will converge to that of the other droplets formed on smaller CCN (e.g. Rogers and Yau 1991) ? Maybe not if their initial size is very large.*

Response: In general we agree with the reviewer concerning his doubts about the effect of giant CCN on precipitation from very continental clouds. Such CCN play a small role in the presence of a large amount of small CCN, because growth of droplets of high concentration decreases supersaturation in clouds, and correspondingly, decreases the growth rate of drops formed on the giant CCN. The giant CCN can play an important role in clouds with large number of small drops if their dry size is extremely large (exceeding 20 microns in diameter ultra-giant CCN), when these

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particles are able to trigger collisions immediately after their penetration into a cloud. The following text was added to the manuscript: "Woodcock (1953) measured, just below cloud base of clouds of a tropical cyclone near Florida, 10 micrometer diameter wet sea spray particles at a concentration of 1cm^{-3} under hurricane force winds (32ms^{-1}). The concentration of 22 micrometer sea spray particles was 0.3cm^{-3} , and 47 micrometer particles at 0.1cm^{-3} . Such concentration of ultra-giant CCN should overwhelm the rain suppression seeding effect even in clouds with very small drops."

Comment: *Page 5655, Line 12: It could be mentioned that the extra cloud-droplets are there at the TC periphery in the NWRP run because of the lack of accretion of cloud-liquid by precipitation.*

Response: Accepted. The comment was added to the text.

Comment: *I wonder why the simulations must be referred to with mnemonics. Discussion about "NWR" and "NWRP" all seems unnecessarily cryptic. Could they simply just be described as "zero-warm rain" or "zero-peripheral warm rain" simulations? It is confusing to refer to the control run as "WR", which seems to connote yet another perturbation run. Why not call the control run "the control run"?*

Response: We use the names of simulations in a lot of places. So, it was decided to use the mnemonics. We accepted the suggested change of name from WR to Control.

Comment: *Page 5655, Lines 19-22: It is unclear which simulations are being compared.*

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Response: The text is clarified.

Comment: *Page 5656, Lines 1-5: The sensitivity of the latent heating may be viewed as arising from the fact that ordinarily, the warm rain process provides a major sink for cloud-liquid because of accretion. So, when warm rain is absent, there is much more cloud-liquid to freeze aloft. Maybe a mass budget for cloud-liquid would make this point clearly.*

Response: Indeed some warming is seen in Figure 4g just above the freezing level, but it does not extend to the cloud tops except for the first 9 hours. The contribution of aerosols to extra heating (by extra condensation and extra freezing) and to the redistribution of latent heat release in the vertical is discussed in detail by Khain et al. (2005), Phillips et al. (2007) using a spectral bin microphysics model containing a detailed heat and moisture budgets. It was too difficult to perform such budget analysis in the WRF model. However, the effects of aerosols as they were simulated in the TC model were qualitatively similar to those discussed in the 2D studies.

Comment: *Page 5656. line 15. It is not true that the potential temperature must remain unchanged during evaporation.*

Response: Accepted. The term "potential temperature" was changed to the intended "equivalent potential temperature". Note that the temperature is given in Figure 4g and the relative humidity is illustrated in Figure 4f. The captions of Figures 4f and 4g need to be exchanged.

Comment: *Page 5656, Line 16: Because the air is cooler (i.e. its potential temperature is reduced), its buoyancy is also reduced (proportional to the fractional excess of*

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the potential temperature over the environmental value). This is why the evaporative cooling at low levels in the NWR and NWRP cases reduces the deep convective ascent, causing the eye to be more compact.

Response: The reviewer explanation is exactly what we had in mind. We have sharpened the text accordingly.

Comment: *Page 5657, Line 27: The statement that low-level evaporative cooling “might explain” the reduction in TC intensity in simulations by Cotton et al. 2007 seems unnecessarily vague. The whole point of using models is that one can be sure of the internal functioning of the model, even if there is uncertainty about how realistic the model is. So, it ought to be possible to analyse the paper by Cotton et al. (2007) more carefully and say with certainty whether or not evaporative cooling is important. At least, some more details here could be provided in support of this argument.*

Response: We agree that the detailed analysis of the results obtained by Cotton et al. (2007) is required to make a certain conclusion about the reason of the TC weakening in their model. Unfortunately no temperature or relative humidity profiles are provided in their simulations, so that we cannot analyze their simulations in the desired way.

Comment: *Another schematic diagram of the hurricane track would be good (e.g. a plan view from above). It could illustrate the organisational and early stages of the cyclone’s lifecycle, and the spatial extent of the seeding window over which the storm is sensitive to seeding.*

Response: Figures 6 - 8 were added. The new figures can be viewed at

http://www.earth.huji.ac.il/data/pics/Figs_6-8.pdf

The figure captions are:

Figure 6: The radius of the eye for the three simulation experiments. Note the smaller radius of the eye for greater extent of suppression of warm rain, going from the full warm rain control run (WR) to the no warm rain in the periphery (NWRP) and to the fully suppressed warm rain everywhere (NWR).

Figure 7: The radius of the area with hurricane force winds. Note the smaller radius of area with hurricane force winds for greater extent of suppression of warm rain, going from the full warm rain control run (WR) to the no warm rain in the periphery (NWRP) and to the fully suppressed warm rain everywhere (NWR).

Figure 8: Time tracks of the observed and simulated hurricane for the Control run with full warm rain, NWR (no warm rain allowed) and NWRP (no warm rain allowed at the periphery). Note that the suppression of warm rain diverts the track eastward.

Comment: *Clarification is required about how the present simulations demonstrate the existence of a “seeding window”. How is this inferred from your results?*

Response: The following text was added: The size of the seeding window in the simulation includes the convective clouds that occurred at radial distances with winds smaller than 22m s^{-1} . According to the combined information in Figs. 4a and 5 this area included the ring of outer 150 km of the clouds at $t=18$ hours, more than 100 km into the hurricane at $t=36$ hours, and at least 50 km from the outer edge of the hurricane low clouds at $t=48$ hours, which was the time of peak intensity.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 5647, 2007.

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