16B.2

IMPACTS OF NUCLEATING AEROSOLS ON THE EVOLUTION OF AN IDEALIZED TROPICAL CYCLONE

Henian Zhang[1*], Greg M. McFarquhar[1], Stephen M. Saleeby[2], and William R. Cotton[2]

[1]University of Illinois, Urbana, Illinois
[2]Colorado State University, Fort Collins, Colorado

1. INTRODUCTION

A large number of tropical cyclones (TCs) have been observed to interact with the Saharan Air Layer (SAL), which is an elevated atmospheric layer over the eastern North Atlantic Ocean characterized by hot, dry, and dusty air drifted from the Saharan desert. Hurricane Cindy (1999), Floyd (1999), Debby (2000), Joyce (2000), Felix (2001) and Erin (2001) are such examples (Dunion and Velden, 2004). Dunion and Velden (2004) showed that the SAL tends to suppress Atlantic tropical cyclone activity by introducing dry, stable air into the storm and inhibiting convection. However, the role of dust in the SAL acting as nucleating aerosols on the tropical cyclone development has yet to be investigated.

It is estimated that about 60 to 200 million tons of Saharan dust is released into the atmosphere every year (Prospero and Carlson, 1972). Desert dust can act as cloud condensation nuclei (CCN), giant CCN (GCCN) and ice nuclei (IN). Rosenfeld et al. (2001) showed that precipitation from shallow convective clouds is strongly suppressed due to the presence of large number of small dust particles. On the other hand, desert dust coated with sulfur and other soluble materials may serve as effective GCCN, which normally accelerate precipitation processes (Levin et al. 1996). Thus, the role of CCN and GCCN on the development of highly organized, strong convective systems like tropical cyclones remains unclear.

This study aims to examine the impact of aerosols acting as CCN, GCCN and IN on the initiation and evolution of a tropical cyclone by conducting a series of numerical simulations. To highlight the effect of aerosols, simulations are initialized with an idealized pre-TC mesoscale convective vortex (MCV), which grows in a zero wind environment over an ocean with a constant sea surface temperature.

*Corresponding author address: Henian Zhang, Univ. of Illinois, Dept. of Atmospheric Sciences, Urbana, IL, 61801; email: henian@atmos.uiuc.edu.

2. MODEL CONFIGURATION

Numerical simulations are conducted using the Regional Atmospheric Modeling System (RAMS) version 4.3 and are initialized with the pressure, temperature and wind fields of an axisymmetric MCV described in Montgomery et al. (2006). An improved two-moment microphysics scheme developed by Saleeby and Cotton (2004) is used to explicitly simulate the activation of CCN and GCCN. The percentages of CCN and GCCN activated during a time step depend upon the temperature, vertical velocity of an air parcel, and the properties of CCN and GCCN such as their masses, number concentrations and median radii.

Three nested domains are used with horizontal resolutions of 24 km, 6 km and 2 km. The horizontal dimensions of the domains are 80×80, 102×102 and 152×152, respectively. There are 31 levels extending from the surface to 25 km. The vortex is allowed to grow for 3 days in a zero wind marine environment with a constant sea surface temperature (SST) of 302.15 K.

Two sets of CCN, GCCN and IN profiles are constructed to represent the clean and polluted environment. The CCN concentration in a clean environment is assumed to be 100 cm^{-3}. To represent the dust in the SAL, a CCN number concentration of 1000 cm^{-3} (Levin et al. 2005) is set to the layer between 1 km and 5 km above sea level. The polluted GCCN and IN profiles used in the simulations are based on measurements made when high concentrations of aerosols including Saharan dust were observed during the Cirrus Regional Study of Tropical Anvils and Cirrus Layers – Florida Area Cirrus Experiment (CRYSTAL-FACE) (Van den Heever et al., 2005).

3. RESULTS

The initial vortices evolve differently when growing in environments with different aerosol concentrations. Figure 1 shows the temporal evolution of the minimum sea level pressure for the three simulations in the clean environment, the polluted environment, and the environment with a clean CCN profile and polluted GCCN and IN profiles. The vortex growing in the clean environment intensified slowly and became the weakest storm at the end of the simulation. The vortex developing in an environment with a clean CCN profile and polluted GCCN and IN profiles intensified quicker than the other two simulations. The simulation with polluted CCN/GCCN/IN profiles produced the most intense storm with a minimum pressure of 968 hPa after three days. Simulations also show that the storms in different environments have different precipitation characteristics. The temporal evolution of the mean surface rain rate produced by the three vortices is shown in Figure 2. The vortex in a polluted environment generated more rain than the other two for the first 34 hours. But if averaged over the 3 days, it yielded the minimum mean surface rain rate of 4.2 mm hr^{-1} among the three. The vortex in a clean environment produced less surface precipitation in the beginning but generated the maximum overall mean surface rain rate of 4.8 mm hr^{-1}, although it is the least intense storm among the three.

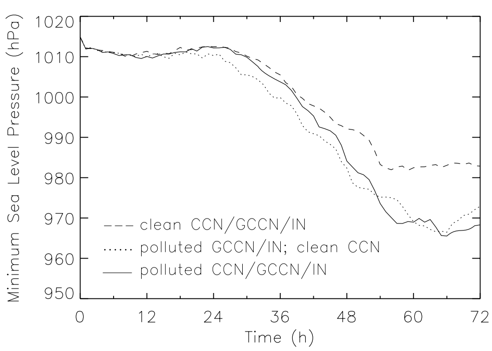

Figure 1: Temporal evolution of the minimum sea level pressure for the MCVs developed in the clean environment (dashed line), the environment with clean CCN profile and polluted GCCN and IN profile (dotted line) and the polluted SAL environment (solid line).

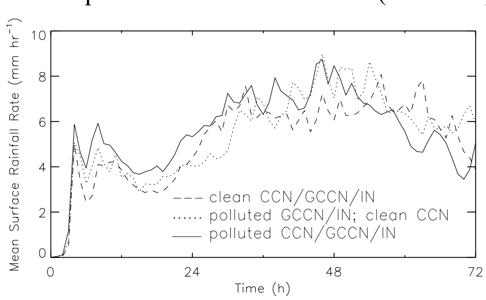

Figure 2: Temporal evolution of the mean surface rainfall rate for the three MCVs. Line types correspond to the simulations denoted in Fig. 1.

4. ACKNOWLEDGEMENTS

This work is supported by the NASA Earth System Science (ESS) Fellowship, grant number NNG04GQ99H and the Tropical Cloud Systems and Processes (TCSP) mission, grant number NNG05GR61G. The findings do not necessarily represent the reviews of the funding agency.

5. REFERENCES

Carlson, T. N., and S. G. Benjamin, 1980: Radiative heating rate of Saharan dust. *J. Atmos. Sci*., **37**, 193 – 213.

Dunion, J. P. and C. S. Velden, 2004: The impact of the Saharan Air Layer on Atlantic tropical cyclone activity. *Bull. Amer. Meteor. Soc*., **85**, 353–365.

Jordan, C. L., 1958: Mean soundings for the West Indies area. *J. Meteor.,* **15,** 91–97.

Levin, Z, E. Ganor and V. Gladstein, 1996: The Effects of Desert Particles Coated with Sulfate on Rain Formation in the Eastern Mediterranean. *J. Appl. Meteor*., **35**, 1511–1523.

Levin, Z., A. Teller, E. Ganor and Y. Yin, 2005: On the interactions of mineral dust, sea salt particles and clouds – Measurements and modeling study from the MEIDEX campaign. Submitted.

Montgomery, M. T., M. E. Nicholls, T. A. Cram and A. B. Saunders, 2005: A “vertical” hot tower route to tropical cyclogenesis. *J. Atmos. Sci*., **63**, 355-386.

Rosenfeld, D., Y. Rudich and R. Lahav, 2001: Desert dust suppressing precipitation: A possible desertification feedback loop. *Proc. Natl. Acad. Sci. USA*, **98**, 5975-5980.

Saleeby, S. M., and W. R. Cotton, 2004: Large-Droplet Mode and Prognostic Number Concentration of Cloud Droplets in the Colorado State University Regional Atmospheric Modeling System (RAMS). Part I: Module Descriptions and Supercell Test Simulations. *J. Appl. Meteor.,* **43**, 182–195.

Van den Heever, S. C., G. G. Carrió, W. R. Cotton, P. J. DeMott and A. J. Prenni, 2004: Impacts of nucleating aerosol on Florida storms. Part I: Mesoscale simulations. *J. Atmos. Sci.*, submitted.