High-Resolution Simulation of Hurricane Danny (1997): Comparison with radar observations

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1. Introduction

Danny (1997) was a slow-moving, category one hurricane that made landfall on the coast of Louisiana and Alabama on 18-19 July 1997. It produced extreme precipitation over Southern Alabama, with radar rainfall estimates for total storm precipitation of 43 inches near Dauphin Island (Pasch 1997). Due to the slow movement of the storm, Danny's center remained within 100 km of WSR-88D radars at Slidell and Mobile for more than 48 hours. Radar observations of Danny showed interesting structural evolution, coinciding with its landfall. This includes the development of concentric eyewalls, outward propagation of rainbands, a complete eyewall replacement cycle, and the development of a convective mesoscale vortex in the western eyewall (Blackwell 2000). Because nearly continuous radar observations were recorded for an extended period, this case provides a unique opportunity for a detailed, mesoscale verification of a high-resolution model simulation of a hurricane at landfall. The purpose of this paper is to perform a cloud-resolving simulation of Hurricane Danny, compared with available radar observations.

2. Model and experiment design

We performed a series of numerical simulations on Hurricane Danny using the MM5 model beginning at 0000 UTC 16 July 1997, when only a weak surface low was present over the northern Gulf of Mexico. In the first experiment, the MM5 with triply nested (81/27/9 km) grids was initialized at 0000 UTC 16 July 1997, using the ECMWF TOGA analysis, without further enhancements. This version of MM5 used the following physics options: Betts-Miller cumulus parameterization, Reisner-I mixed-phase microphysics, Blackadar planetary boundary layer (PBL) scheme, and Dudhia radiation scheme. The second experiment was started at 0000 UTC 17 July, when a 3-km mesh was initialized with the 24-h forecast of the 9-km grid. The 3-km model used the same physics options as the 9-km model, with the exception that the subgrid-scale cumulus parameterization was turned off. The 3-km experiment was integrated to 1200 UTC 19 July, and was driven by the 9-km model forecasts in a one-way mode. The third experiment used 1-km MM5, and was initialized at 0900 ITC 18 July, using the 33-h forecast from the 3-km model. The 1-km MM5, using the same physics options as those of the 3-km model, was also integrated through 1200 UTC 19 July. The lateral boundary condition was provided by the output from the 3-km model at 15-min intervals.

3. Results

Figure 1 shows the time-radius section of relative vorticity, at 1-km elevation, calculated by the GBVTD method, and based on the Doppler velocity observed by the radars, compared with the relative vorticity derived from the 1-km and 3-km MM5. The time-radius section covers the time-period from 1200 UTC 18 July, through 0000 UTC 19 July 1997, and a location from the center of the storm to about 60 km radius. The maximum vorticity observed by the radar is located at approximately 10 km radius, with a maximum magnitude of about 50 x 10^{-3} s^{-1}. The radius of maximum wind is about 18-km (not shown). The 1-km MM5 accurately captured both the intensity and the size of the vortex. The 3-km MM5 also performed well, except for predicting a weaker intensity.

Figure 2 shows the corresponding figures for radar reflectivity. The observed radar reflectivity shows outward propagating radar echoes reflecting the outward propagating rainbands. This is a distinct feature of Danny (1997). Both the 3-km and the 1-km MM5 simulations were able to capture the outward propagation of hurricane rainbands, at a speed consistent with the radar observation. It should be noted that the 9-km MM5 was not able to simulate the rainband propagation, and the radius of maximum wind was about twice as large as that of the observed storm and the 1-km/3-km simulations (not shown). This suggests that to capture the detailed storm structure of Danny, cloud-resolving resolution is required.

References:

Blackwell, K. G., 2000: The evolution of hurricane Danny (1997) at landfall: Doppler-observed eyewall replacement, vortex contraction/ intensification and low-level wind maxima. *Mon. Wea. Rev.*, **128**, 4002-4016.

Pasch, R. 1997: Hurricane Danny, 16-26 July 1997. Preliminary Report from the National Hurricane Center.

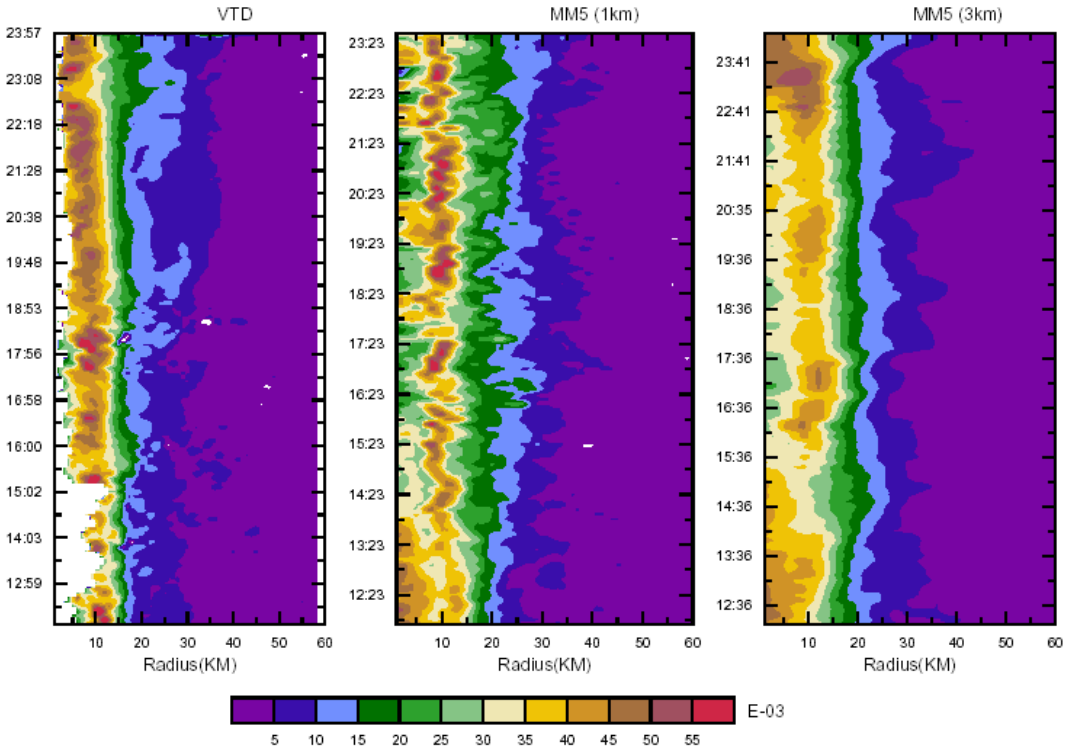

Figure 1. The time-radius section of relative vorticity at 1-km elevation obtained from KLIX radar (based on GBVTD method; left panel) and 1-km MM5 (middle panel) and 3-km MM5 (right panel). The section extends from 1200 UTC 18 July to 0000 UTC 19 July, and from center of the storm to 60-km radius.

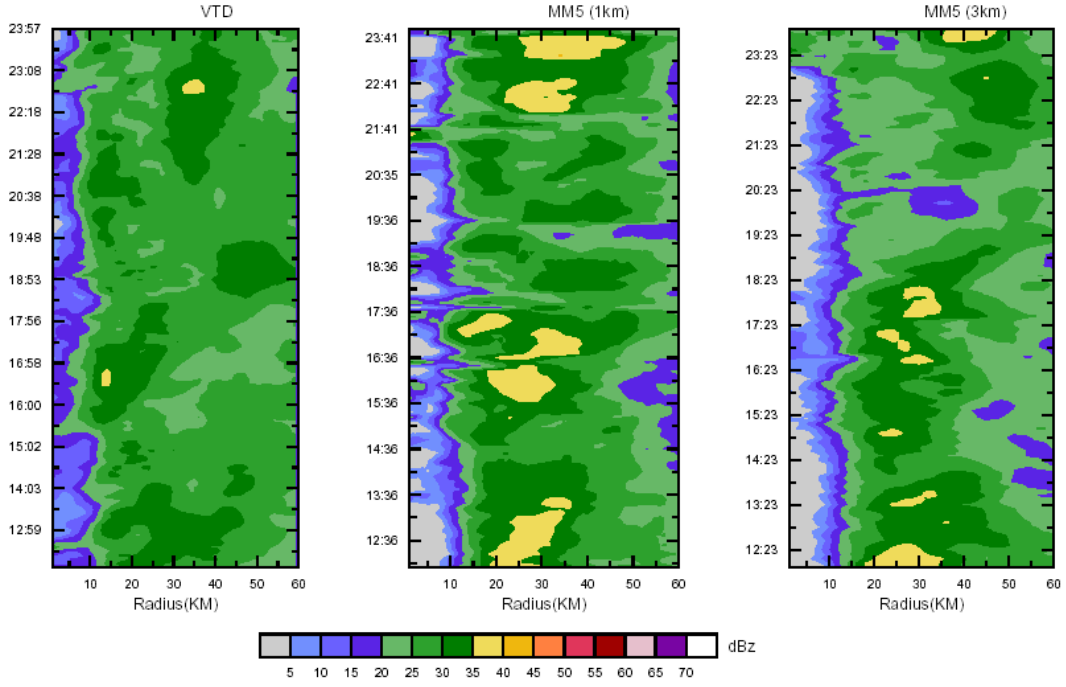

Figure 2. Same as Figure 1, except for the radar reflectivity.