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An examination of the mesoscale structure associated with the extratropical transition of Hurricane Agnes (1972)

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1. Introduction

Considerable attention has been given to the transition of tropical cyclones to extratropical cyclones in the recent literature. Transition often occurs when the tropical system passes over cooler water (or land) and interacts with a mid-latitude trough. Such transitions are often not well forecast by operational models. Over land, the low-level circulation associated with the transitioning storm can interact with terrain or a surface baroclinic zone, resulting in localized regions of intense precipitation. These regions can often extend several hundred kilometers away from the storm center, providing another challenge to forecasters.

The transition of Tropical Storm Agnes (1972) has been well documented in the literature. DiMego and Bosart (1982a,b) examined the transition of Agnes into an extratropical cyclone. They showed that Agnes regained tropical-storm intensity over land as cyclonic vorticity advection associated with an approaching upper-level trough overspread the low-level Agnes circulation. This result shows the importance of the nolinear convergence term in the vorticity equation in generating enhanced cyclonic vorticity near the surface. Bosart and Dean (1991) focused on the synoptic and mesoscale features associated with the heavy precipitation that developed in advance on Agnes. They showed that the heavy precipitation was concentrated along a frontal boundary, which formed in situ east of the Appalachian Mountains. A detailed analysis of the surface observations showed that as Agnes moved offshore east of New Jersey, a new circulation developed over northeastern Pennsylvania along the inland frontal boundary by 0000 UTC 23 June.

The intent of this study is the examine both the synoptic and mesoscale features, as well as the distribution of precipitation associated with the extratropical transition of Agnes, using a mesoscale numerical model.

2. Methodology

The Pennsylvania State University/National Center for Atmospheric Research Mesoscale Model (MM5) Version 3 is used examine the transition of Tropical Storm Agnes. The model is run using three nested domains with 81, 27, and 9 km grid spacing, respectively. The model is initialized at 0000 UTC 21 June when Agnes is centered near Augusta, GA (AGS). The model is initialized using the NCEP/NCAR gridded reanalysis. The Kain-Fritsh (KF) cumulus parameterization and the MRF planetary boundary layer (PBL) scheme are used in the control simulation. The KF scheme is applied to all three domains though, strictly, cumulus parameterizations are not designed for domains with grid spacings less than 20 km. Simulations testing the sensitivity of the results to the choice of cumulus and PBL parameterizations will also be performed. Further, the sensitivity of the results to the initial starting time and the initial conditions will also be examined.

3. Results

Figure 1 shows the track of Tropical Storm Agnes for the 81 km domain (thick black line) and the 9 km domain (thick dashed line) of the control simulation. Also shown is the best track position (thin solid line). Both track and speed errors are seen in both the 81 and 9 km domains. The control simulation keeps Agnes much further inland and progresses it much faster compared to the observations.

Figure 2 shows the intensity of Agnes for the 81 km and 9 km domains, as well as the best track intensity. The intensity of Agnes on the 81 km domain agrees well with the best track values. The storm on the 9 km domain, on the other hand, overdeepens the storm by nearly 20 hPa. This excessive deepening is due to the use of cumulus parameterization on the 9 km domain. Similar intensity errors were identified by Davis and Bosart (2001) in their examination of Hurricane Diana (1991).

Figure 3 shows the 3 h accumulated precipitation on the 9 km domain. The 24 h period shown in Fig. 3 corresponds to the period of heaviest precipitation in the control simulation. Due to the speed of the storm in the simulation, the period of heaviest precipitation occurs 12 h prior to that shown in Bosart and Dean (1991). During the evolution, the precipitation shield extends well north of the Agnes center. The heaviest rain tends to stay along and west of the Agnes track, along the slopes of the Appalachian mountains. Rain rates exceeding 32 mm in each 3 h period extend along and just west of the Agnes track during this 24 h period.

Additional diagnostics on this case and on additional model simulations will be presented at the conference.

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4. References

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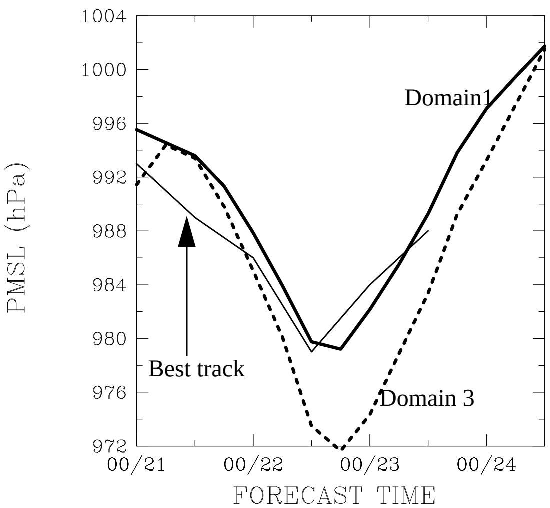

Figure 2: Time series of the mean sea-level pressure for Agnes from the best track (thin line) and from the 81 km (thick solid) and 9 km (thick dashed) domains.

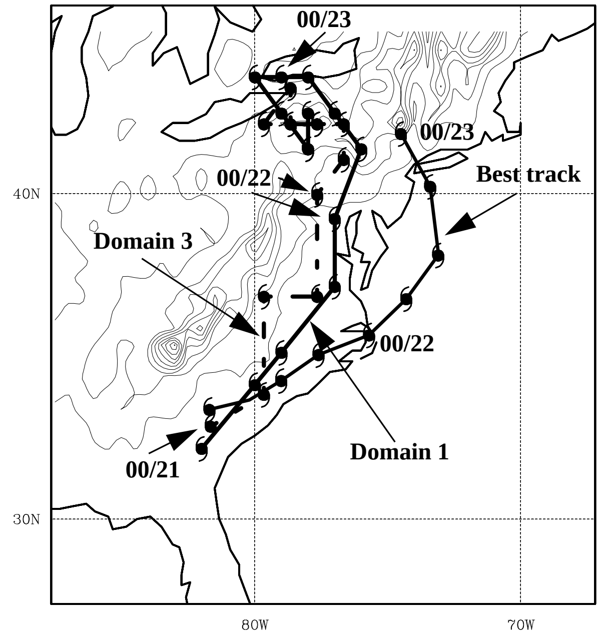

Figure 1: Six hourly positions of Tropical Storm Agnes. The thin solid line represents the best track position. The thick solid and dashed curves show the position of Agnes in the 81 km and 9 km domains of the control simulation, respectively.

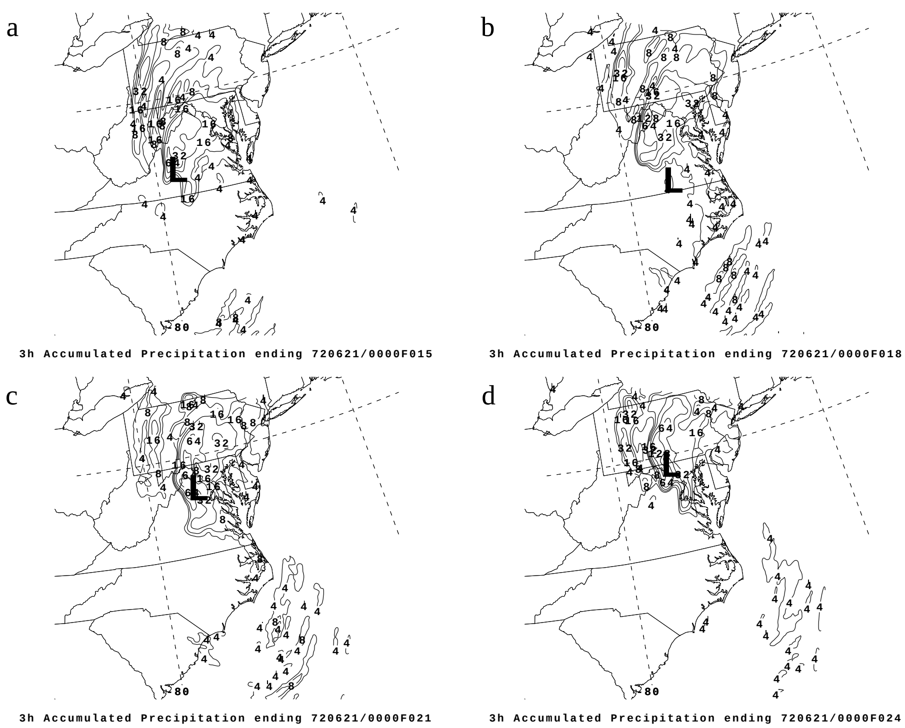

Figure 3: Three hourly total accumulated precipitation on the 9 km domain for the forecast ending a) 1500 UTC 21 June b) 1800 UTC c) 2100 UTC, and d) 0000 UTC 22 June. Contours of 2,4,8,16,32, and 64 mm are plotted.