P7A.1 FORECASTING THUNDERSTORM CHARACTERISTICS THAT HAVE A HIGH IMPACT ON AIR TRAFFIC FLOW

J. Pinto[1]*, C. Phillips[1], M. Steiner[1], R. Rasmussen[1], N. Oien[1], M. Dixon[1], W. Wang[2] and M. Weisman[2]

[1]NCAR/ Research Applications Laboratory Boulder, Colorado, USA

[2]NCAR/ Mesoscale and Microscale Meteorology, Boulder, CO, USA

1. INTRODUCTION

The degree to which thunderstorms affect air traffic is related to their intensity, coverage, spacing, orientation, organization, and echo top heights. Aviation generally try to avoid flying through storms with radar echos exceeding 35 dBZ. Accurate forecasts of the most likely areas where these storms will form and the characteristics of these storm regions (coverage, spacing, etc) at lead times of 6-12 hours can greatly improve the efficiency of the National Airspace System (NAS).

The short-term (0-8 hr) prediction of thunderstorms and their characteristics (organization, severity, orientation (for squall lines), storm spacing) is vital air traffic flow management. Nowcasting systems based on radar observations have skill at predicting storm characteristics in the 0-2 hour time frame; however, this skill rapidly declines owing to the difficulties of nowcasting storm initiation and evolution. High-resolution convection-permitting NWP runs, which no longer parameterize the convection, are able to resolve storm structures and organization; however, the skill of NWP (when comparing pixel-by-pixel at fine scales) remains rather low owing to intensity and phase (space and time) errors. Note that assimilation of radar data improves the model forecasts at the short leadtimes, however, at this time data assimilation cannot beat extrapolation forecasts at leadtime of less than 2 hours. While the skill of NWP in predicting the actual location of storms is poor, the high resolution runs have apparent skill in predicting the timing, evolution and organization of storms. The goal of this study is to determine whether high resolution NWP has skill at predicting the statistical characteristics of storms relevant to air traffic flow management at leadtimes > 3 hours (e.g., relevant for strategic planning). Data from the Weather Research and Forecasting – Advanced Weather Research (WRF-ARW) model run in realtime twice per day (00 and 12 UTC) at 4 km resolution on the NCAR supercomputer are used to evaluate the capability of convection-permitting simulations to produce realistic storm structures and their evolution. In this study we focus on the model's ability to simulate the range of characteristics of the storms occurring in the SouthEastern US in July of 2006. The TITAN (Thunderstorm Identification Tracking and Nowcasting) software has been extended to determine storm characteristics (e.g., storm coverages, size distribution, orientation, spacing, interconnectedness, etc) in the model and the observations (using the WSR-88D national mosaic provided by WSI).

Davis et al. (2006) has statistically analyzed the performance of 4 km WRF model simulations run over the central US in the summer of 2003. They found that, in general, the 4km WRF had a positive bias in fractional area covered by large storm complexes (i.e., storms > 400 km2) and related it to MCS overprediction. In this study we focus on the spacing between storms as small as 75 km2 occurring in the southeastern US.

2. METHODOLOGY

In this study we assess the ability of convection-resolving simulations performed with the WRF model to predict the coverage of storms and

* *Corresponding author address:* James Pinto, NCAR, Research Applications Laboratory, Boulder, CO 80301; e-mail: pinto@ucar.edu.

storm spacing in the SE US through comparison with the WSR-88D radar mosaic produced by Weather Systems, Inc (WSI). We focus on this region because of the range of storm conditions that occur here on a regular basis as seen in the climatology of WSR-88D used by Knieval et al. (2004) to evaluate the WRF model.

2.1 MODEL DESCRIPTION

Version 2.1.2 of the WRF ARW model was run in real-time this summer (June and July 2006) through a collaborative effort between RAL and MMM. One of the goals of this effort was to provide convection-resolving forecasts from the WRF model to Storm Prediction Center (SPC) forecasters to aid in their product development. The model was run twice per day (initialized at 00 and 12 UTC and run out to 36 hr and 18 hr, respectively) at a convection-resolving resolution of 4 km (with 34 vertical levels). The domain and forecast length of the 12 UTC simulations were reduced because of the goal of operational availability. See Figure 1 for the domain used in the 00 and 12 UTC runs. The simulations were performed on a dedicated cluster of nodes on the NCAR supercomputer with forecasts completed by 0900 MST and 1300 MST, respectively.

Initial conditions and boundary conditions were specified using the 40-km NAM (grid 212). Data assimilation was not performed. The model was run using MYJ PBL, WSM-6 category microphysics, the NOAH LSM and RRTM/Dudhia radiation. At resolutions less than 4 km, models have been shown to faithfully resolve convective structures without the aid of a convective parameterization (e.g., Weisman et al. 1997). The modeled reflectivities, which are used in the analyses, are derived using relationships between the modeled cloud and precipitation water contents and radar reflectivity.

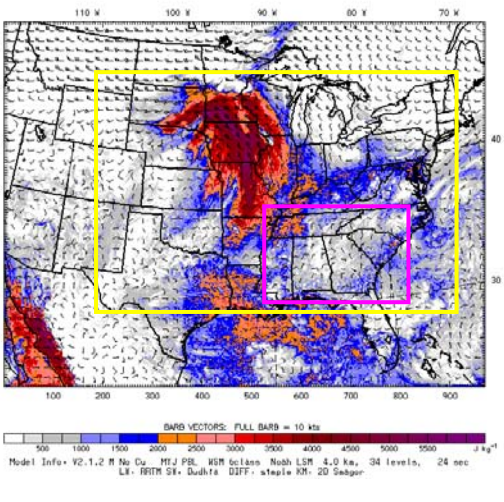

Figure 1. CAPE field valid at 2000 UTC from WRF run initialized at 00 UTC on 19 July 2006 also illustrating the domain used in the 00 UTC runs. The 12 UTC run domain is indicated by the yellow box. The magenta box depicts the area over which analyses were done.

2.2 OBSERVATIONS

The national 2-km grid of WSR-88D radar data (Klazura and Imy 1993) and produced by WSI is used to determine coverage and spacing of

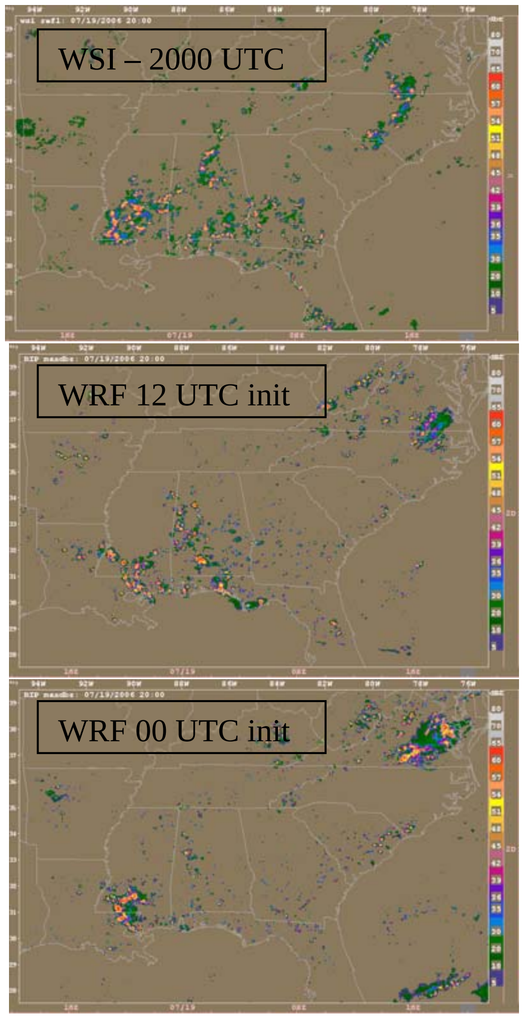

Figure 2 WSI reflectivity (top), and 08 hr forecast from the WRF12 (mid) and 20 hr forecast from WRF00 (bottom) forecasts of dBZ. Forecasts are valid at 20 UTC on 19 July 2006.

observed storms. The WSI data have been degraded to 4-km resolution using a spatial average so that the observed reflectivity field has the same resolution as that used in the model. The data have also been sub-sampled hourly to be coincident with the model output times.

2.3 ANALYSES TECHNIQUES

The goals of these analyses are to assess the model skill in forecasting storm coverage, spacing, size distribution, and organization.

To ascertain the storm spacing and size distribution, the modeled and observed reflectivity are placed on a common grid for analysis using TITAN (Dixon and Wiener 1993). TITAN is used to detect thunderstorms which are defined as having a contiguous area of 75 km^2 or greater with radar reflectivities greater than 35 dBZ. The analyses discussed below are performed over the magenta rectangular region shown in Figure 1.

An elliptical filter was used to determine the coverage of storms exceeding 35 dBZ in the model and observational datasets. The 180 by 60 km filter was rotated 360 deg in 10 deg increments to find the maximum coverage of storms exceeding 35 dBZ at each grid point.

3. CASE STUDY

Analyses of the model's ability to simulate characteristics of a region of convection that describe its permeability are ongoing. A representative case study is presented below which shows analyses of widely scattered air mass storms on a day characterized southeasterly flow around a strengthening Bermuda High out over the Atlantic and limited surface-based instability (i.e., low CAPE values over much of the southeast – Figure 1).

Air mass storms on 19 July 2006

Thunderstorms began to develop around 17 UTC and eventually organized into an MCS over Louisiana around 01 UTC the next day. The 12 UTC WRF model run performed more accurately than the run initialized 12 hours earlier in terms of the number of storm cells, their spacing (Figure 2), and their coverage (Figure 5). Both model runs were characterized by propagation errors as is evident in the offsets in the predicted storm locations over NC.

The TITAN software was used to identify storms with a region greater than 35 dBZ exceeding 75 km^2 in both the observations and the model forecasts (Figure 3). Casual inspection of these

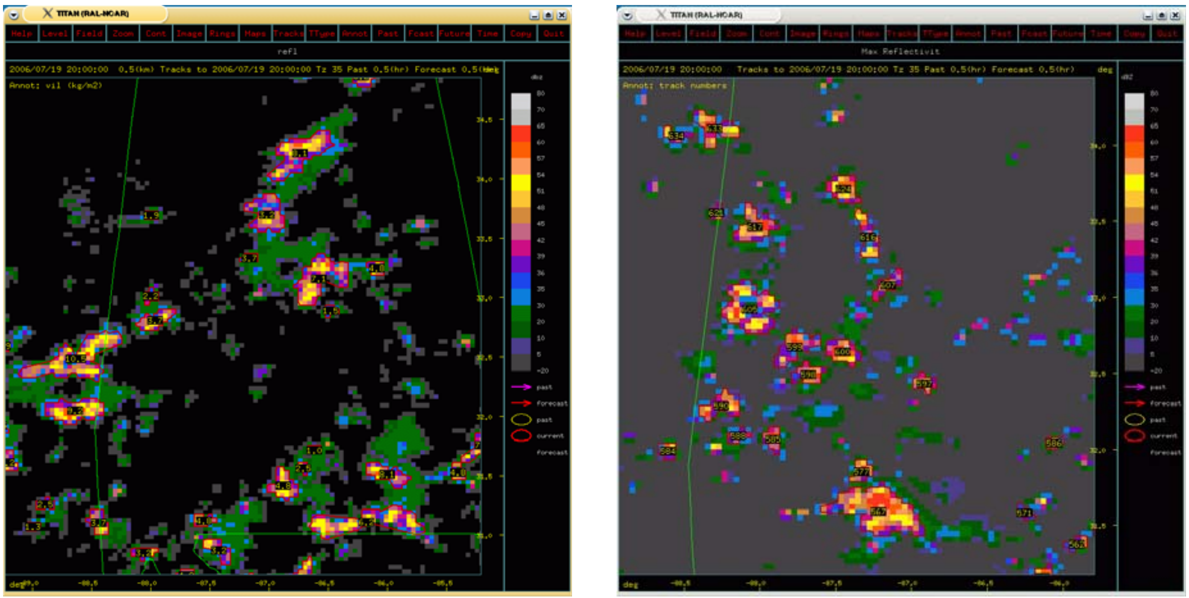

Figure 3 Example depicting storm detections in the observations (left) and in the 12 UTC WRF model run (right) valid at 2000 UTC. The storm detections are shown by the red contours with the ID number attached.

two images reveals that the model shows skill in predicting scattered convection in this region; however, the accuracy of the modeled degree of scatter and the storm cell size distribution is not obvious.

The detection data were used to calculate statistics describing the storm spacing and size characteristics for the two model runs and the observations. It is found that the evolution of storm spacing is more reliably reproduced by the shorter-range 12 UTC run than the 00 UTC run, especially in terms of the number of storm cells as well as their spacing (Figure 4). However, both model runs under-predicted the density of storms at the 50-km spacing scale (i.e., number of storms with at least two adjacent cells within 50 km). The plots in Figure 4 also indicate that the timing of storm initiation in both model runs is generally very good (i.e., within 1 hour of observed initiation of storm areas). However, the initiation rate (i.e., the slope of the curves in Figure 4) is clearly underpredicted (i.e., is less steep than observed) and dissipation is too rapid in the 12 UTC run.

The accuracy of the coverage forecast is also better in the 12 UTC WRF simulation (Figure 5). There are basically two observed areas of storms: one area located along the Gulf Coast and the other centered on North Carolina (NC). Both simulations also forecast two main comparable areas of storms with the NC area of storms being consistently forecasted to be too far south. The 00 UTC run also underpredicts the area with coverages > 5% along the Gulf Coast and overpredicts the coverages for the NC area of storms. The 12 UTC run shows marked improvement over the 00 UTC run with the area along the Gulf Coast with coverages > 5% more closely matching the observations and the coverage values being reduced for the area of storms observed near NC.

4. SUMMARY / FUTURE WORK

The statistical performance of the model in producing reliable forecasts of convection and storm coverages will be given in the presentation. In additional, statistical analyses, relating storm coverage to environmental conditions, that form relationships that may be amenable for producing short-term forecasts of storm characteristics will be discussed.

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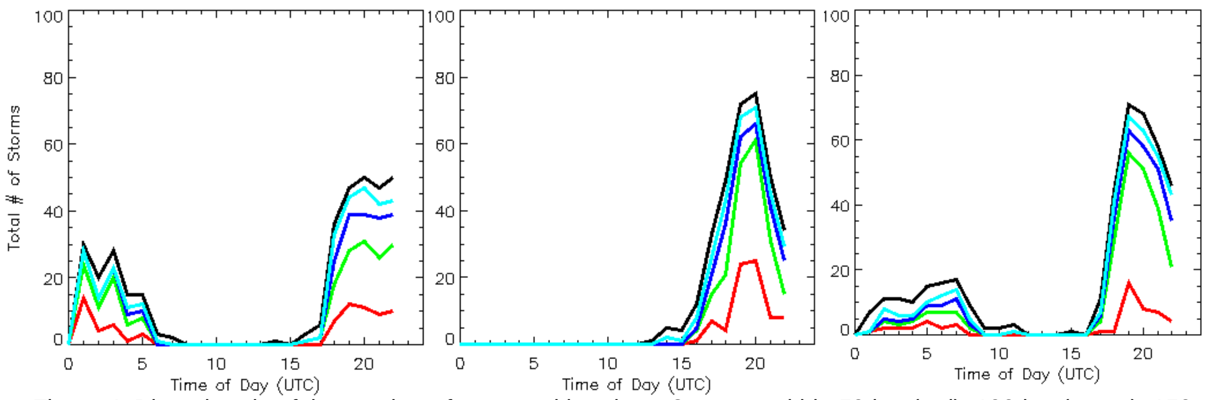

Figure 4. Diurnal cycle of the number of storms with at least 2 storms within 50 km (red), 100 km (green), 150 km (blue), 200 km (cyan), and 400 km (black). This parameter gives an indication of the density of storms in the analysis region shown in Figure 1 as obtained with the 00 UTC WRF run (left), 12 UTC WRF run (mid) and observed (right).

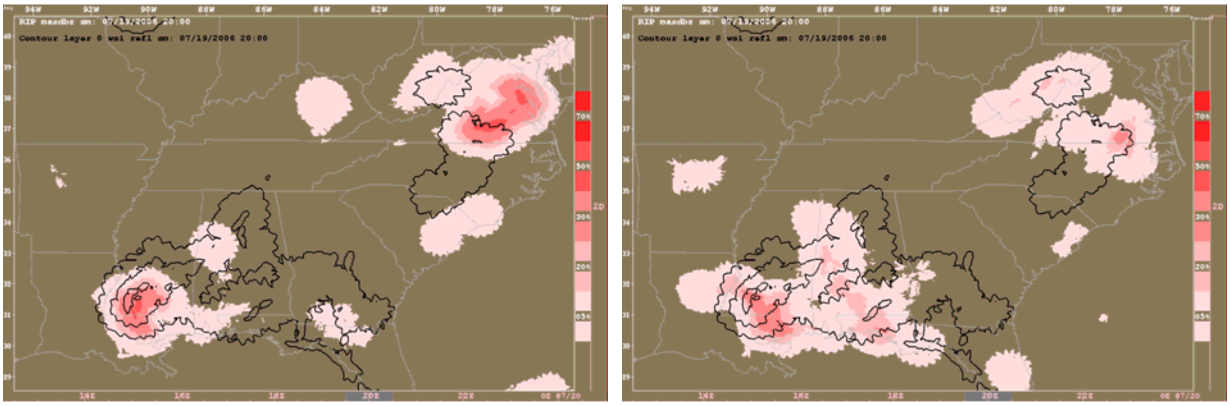

Figure 5. Coverage of reflectivity exceeding 35 dBZ in the 00 and 12 UTC WRF forecasts valid at 2000 UTC on 18 July 2006 (shades of pink). Observed coverage of reflectivity exceeding 35 dBZ are contoured.

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