P2.3 EVALUATION OF LOCAL-SCALE FORECASTS FOR SEVERE WEATHER OF 20 JULY 2000

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1. INTRODUCTION

Scientists at NOAA's Forecast Systems Laboratory are attempting to address the issue of local-scale modeling using a new version of our Local Analysis and Prediction System (LAPS, Albers et al. 1996) to directly initialize the cloud and precipitation fields of a local forecast model (hot start). LAPS has been integrated into the Advanced Weather Information Processing System (AWIPS) as part of the National Weather Service (NWS) modernization. Research to expand LAPS capabilities is one avenue toward providing advanced technologies and new innovations to the operational forecaster. One of the greatest deficiencies of numerical weather prediction models is their lack of skill in predicting clouds and precipitation in the early portions (0-6 h) of their forecast period.

A project has been underway for the past year to develop a national, high-resolution, real-time analysis of water in all phases (McGinley et al. 2000) using LAPS. As part of this project, two significant improvements were implemented which ultimately made it possible to perform a diabatic initialization of a mesoscale model with analyzed hydrometeor species. This paper describes work in progress, and the next step toward advancing hot-start model initialization. A demonstration of the local modeling capabilities with this system will be shown for a severe weather event in eastern Colorado on 20 July 2000.

1.1 *LAPS Background*

During the 1980s FSL conducted forecast exercises to test its workstation prototypes. Forecasters were burdened with the impossible task of reviewing all the incoming data made possible through new technologies, while producing timely forecasts. It became obvious that local data needed to be objectively analyzed in conjunction with nationally disseminated data. Conceived as a resolution to this challenge, LAPS was designed to analyze all local data in real time on an affordable computer workstation, using its own output fields to initialize local-scale forecast models. A more detailed review of LAPS is available in McGinley et al. (1991).

Under development since 1990, LAPS combines nationally disseminated data with local data for real-time objective analyses of all data available to the local weather forecast office. LAPS analyses are of suitable quality to initialize a local-scale forecast model. With a wide variety of private and government users around the world, it has demonstrated a robust capability to combine nearly all available sources of meteorological information into a single, coherent three-dimensional view of the atmosphere for real-time "nowcasting" and short-range prediction. Throughout its history, the LAPS analyses have been coupled with a variety of mesoscale forecast models, including RAMS, MM5, Eta, and ARPS. Its versatility to ingest a multitude of data types combined with its portability and computational efficiency have made it ideal for such applications. Mesoscale forecast models can address specific problems of a small forecast domain with greater detail than can be achieved with nationally disseminated model guidance (Snook et al. 1998). Typically this has been identifying mountain waves, quantitative precipitation forecasts (QPFs), and locating the sea breeze interaction and other boundaries (Szoke et al. 2000). Forecasts have been used to identify regions of instability in the preconvective environment. Since 10-km grid resolution is generally too coarse to predict convection and storm interactions, the models generally have not been found to be that useful for forecasting actual storms, though some rather dramatically successful forecasts have been documented, Szoke and Marroquin 2000.

The LAPS system is routinely tested with new data sources and innovative improvements, using more than "conventional" data, which have potential for national dissemination.

2. LAPS ENHANCEMENTS FOR WATER IN ALL PHASES

2.1 *Cloud Scheme*

As part of our recent upgrades, two major changes have occurred. First, the LAPS cloud analysis (Albers et al. 1996) was modified to improve the diagnosis of hydrometeor concentrations in all phases. The cloud analysis begins by combining a variety of data sources

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including a model first guess of cloud liquid and ice (or relative humidity), observed satellite brightness temperatures, surface and aircraft cloud observations, radar reflectivity (low-level or volume), and visible satellite imagery. Other LAPS state variables are used for supporting information, such as the temperature, humidity, and height analyses. At this point, a three-dimensional distribution of cloud fraction is calculated. This cloud field is then processed into concentrations of the various water species using temperature, humidity, stability, and radar reflectivity. The analyzed water species include cloud liquid and ice, as well as precipitating rain, snow, and ice. The precipitating species are calculated with an improved one-dimensional model that considers these hydrometeors (mainly indicated by radar) as they fall through the known temperature and humidity profiles. A surface precipitation type field is computed using surface precipitation observations as additional information. Along with this step various other parameters are derived, including heights of the bases and tops and the three-dimensional cloud type. From the type and depth of each cloud layer, an appropriate vertical motion profile is determined for each vertical column containing clouds (Schultz and Albers 2001).

2.2 *Balance Scheme*

The second major improvement has been to the LAPS dynamical balance package (Shaw et al. 2001). The balance package is run using the initial analysis of the atmospheric state variables after the cloud analysis has completed. The purpose of the balance package is to ensure that the final mass and momentum fields are consistent with the cloud and precipitation fields. This is the crucial component of the analysis, since attempts by others to directly initialize clouds have met with limited success (Cram et al. 1994, Raymond 1995). The usual result is a rapid dissipation of the clouds within the first few time steps of model integration due to lack of such a balance. The scheme employs several dynamical constraints as well as a diabatic term within a three-dimensional, variational formulation to adjust the wind, temperature, and height fields based on the background vertical velocity field and the diagnosed cloud motions from the cloud analysis. During the minimization of the variational cost function in this step, the time tendencies of the u and v wind components are also minimized, which results in a very stable initial condition such that the numerical forecast model is not "shocked" at the initial time and the cloud field is maintained.

2.3 *Model testing*

For several months beginning in the fall of 2000, we have been using the improved LAPS analyses to diabatically initialize the NCAR/PSU MM5 forecast model for a domain centered over Colorado and Wyoming with a grid-spacing of 10 km. These simulations are run four times per day in realtime on FSL's massively parallel High Performance Computing System (HPCS). Products from these runs are posted on our web site (http://laps.fsl.noaa.gov). The gridded fields are also provided to the Denver-Boulder National Weather Service (NWS) Forecast Office (WFO) for display on AWIPS, and have proven to be a valuable source of information during the preparation of operational public forecasts for their area of responsibility (Shaw and Thaler 2001).

3. CASE STUDY

The case study employed version 3 of the NCAR/PSU MM5 model. A grid spacing of 10 km was used for a 125 by 105 grid point horizontal domain covering all of Colorado and Wyoming, eastern Utah, western Kansas and Nebraska, and the northern fringes of Arizona and New Mexico. The vertical grid consists of 41 levels, with the highest resolution contained within the boundary layer. The Schultz (1995) explicit microphysics and the Kain-Fritsch convective parameterization were employed. The Rapid Radiative Transfer Model (RRTM) scheme was used as the longwave radiation package, and the Blackadar scheme was used for the PBL parameterizations.

We have used this initialization technique as part of a case study of a severe weather event that occurred in eastern Colorado on 20 July 2000. Figures 1-6 show a comparison between observed low-level reflectivity and simulated reflectivity from two different MM5 forecasts valid at the initial time (1800 UTC) and 4 h into the simulation (2200 UTC). One of the simulations ("MM5HOT") was initialized using the technique described above and the other ("MM5ETA") was initialized using the 00 h forecast from the 1800 UTC cycle of the NCEP Eta model. The 1800 UTC cycle of the Eta provided lateral boundary conditions for both simulations. Since the MM5HOT simulation had the hydrometeor fields provided by LAPS, the diagnosed reflectivity pattern matches the observed reflectivity almost identically. Furthermore, by 2200 UTC (Fig. 2), the major area of convection initially in southern Nebraska at 1800 UTC was generally maintained and moved southward into eastern Colorado and western Kansas, where numerous reports of hail and tornadoes occurred during the next few hours. Fig. 2 shows additional convection not produced by the model (Fig. 5), however, the model did simulate convection in the regions that did receive severe weather. Additionally, new convection developed in the MM5HOT simulation in eastern Wyoming, consistent with the observed reflectivity. In contrast, the MM5ETA simulation had very limited reflectivity fields by this point. The MM5ETA method of initialization, which does not include any hydrometeor

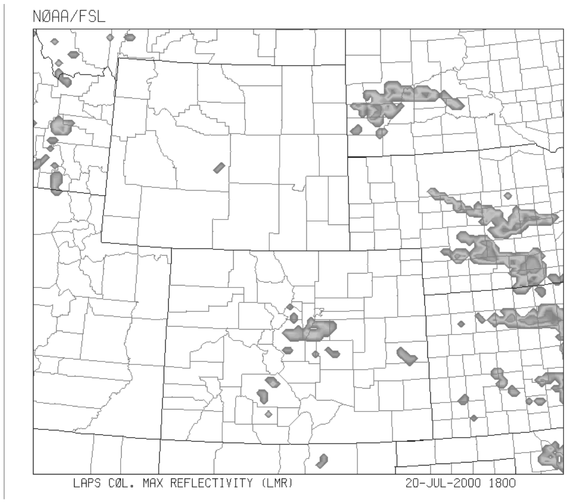

Fig. 1. LAPS analyzed reflectivity (verification) 1800 UTC (initial time)

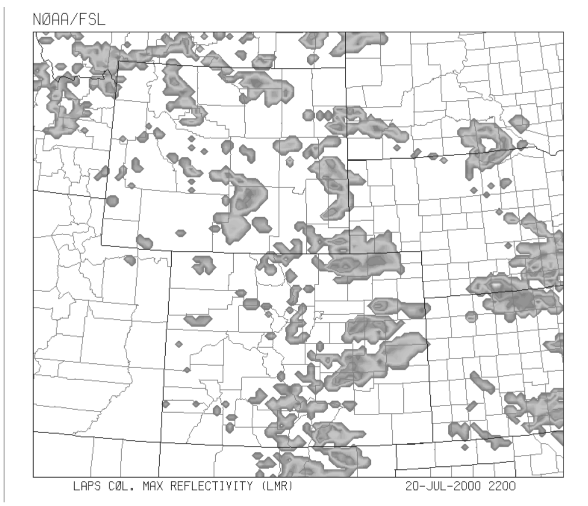

Fig. 2. LAPS reflectivity at 2200 UTC, 4 h into the forecast.

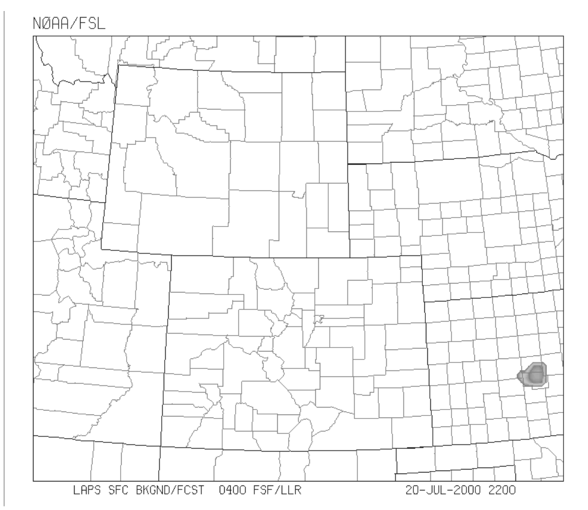

Fig. 3. MM5eta 4 h into the forecast just beginning to indicate convection in central KS.

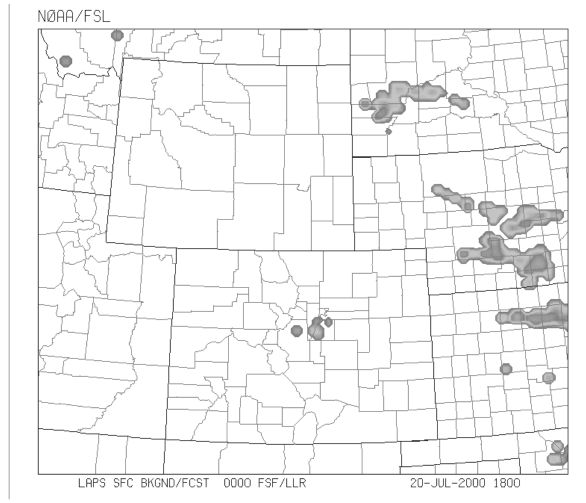

Fig. 4. MM5HOT at initial time showing initialized presence of convection; compare to Fig. 1.

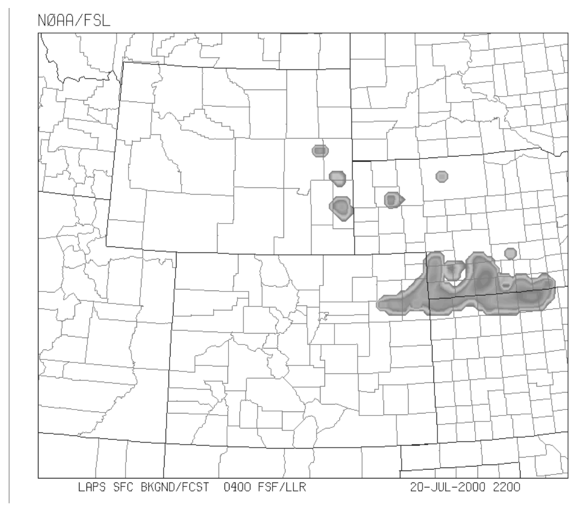

Fig. 5 MM5HOT at 4 h into the forecast.

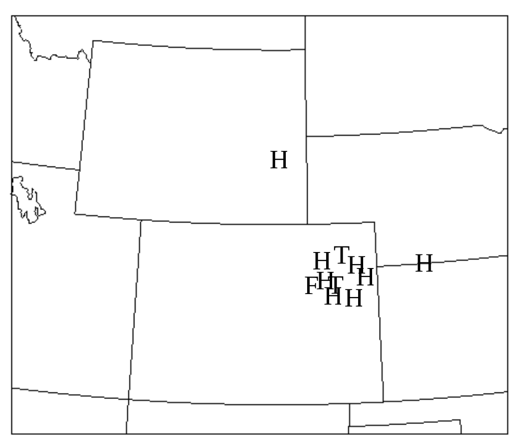

Fig. 6. Location of severe reports in the Colorado eastern plains and Kansas 2100-2300 UTC. (H=hail, T=tornado, F=flood)

fields (no “hot-start”) or the addition of any new observation data (no LAPS), is the typical configuration used by many real-time users of mesoscale models.

4. SUMMARY AND RECOMMENDATIONS

This work has promising implications for short-range NWP forecasts. We acknowledge this is only one case and do not claim the spinup problem has been solved by this hot start method. However, it is a promising start to the types of methods that may be very useful in advancing the use of mesoscale modeling for short-range QPF and severe weather forecasting. Testing with our real-time runs continues, and we anticipate interesting results during the 2001 convective weather season. Thus far, the experimental runs are having a positive impact on the operations at the Denver-Boulder WFO. Also, such a system will be ported to three NWS WFOs located in the southern region later this year, as well as at the two USAF spacelift facilities at Patrick AFB, Florida, and Vandenberg AFB, California. Future work includes continued enhancements to the balance package and cloud analysis, improved verification methods, coupling to other forecast models, and the use of higher resolution grids.

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