3.9 OPERATIONAL EVALUATION OF THE LAPS−MM5 "HOT START" LOCAL FORECAST MODEL

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1. INTRODUCTION

Within the past few years, as computers have grown exponentially in capability per unit cost, mesoscale numerical weather prediction (NWP) models have been increasingly used as a "real−time" weather forecasting tool by researchers and some operational agencies. It is now possible for individual weather forecast offices (WFOs) to acquire a relatively inexpensive cluster of personal computers on which to run these sophisticated, high−resolution models to support their operations.

The Local Analysis and Prediction Branch of the NOAA Forecast Systems Laboratory (FSL) has been focused on the problem of local−scale data assimilation and NWP for several years. To address this goal, the Local Analysis and Prediction System (LAPS, Albers et al. 1996) was developed to provide a means to combine all available sources of meteorological data, including radar, satellite, and locally acquired data (e.g., local mesonets, etc.) into a single, coherent three−dimensional representation of the atmosphere and sensible weather at high spatial and temporal resolution. Alone, the analysis component of LAPS can be used as a short−term "nowcasting" tool. When coupled with a forecast model, LAPS can also provide quantitative forecasts.

During the summer of 2000, FSL began testing a new version of LAPS that allows an NWP model to be diabatically initialized with all microphysical species (cloud water, ice, rain, snow, and graupel) present in the model initial conditions and in dynamic balance with the model mass and momentum fields (Schultz and Albers 2001, McGinley and Smart 2001). In the early fall, FSL began using this new technique to initialize real−time simulations using the NCAR/PSU Mesoscale Model 5 (MM5). The output is made available on the Internet (http://laps.fsl.noaa.gov) and on FSL's Advanced Weather Information and Processing System (AWIPS) workstations for evaluation purposes and is frequently used during local weather discussions. Due to its unique diabatic initialization technique, it has been dubbed the "hot start" MM5 forecast, hereafter referred to as "MM5HOT".

Although preliminary quantitative evaluation of these forecasts shows improved skill in forecasting clouds and precipitation in the early portion (0−6 h) of the forecasts compared to other initialization methods (Shaw et al. 2001), an assessment of the operational utility of the MM5HOT was desired.

Since the completion the new David Skaggs Research Center in Boulder in 1999, FSL and the Denver National Weather Service (NWS) WFO have been collocated. This has provided for improved cooperation between FSL researchers and NWS operational forecasters. This relationship allows new tools and techniques under development by researchers within FSL to be used and evaluated by operational forecasters. This feedback can then be used to further improve the technology before potential full technical transition occurs to the rest of the NWS offices. Additionally, the forecasters benefit from having these additional tools available to them to assist in daily operations. This paper discusses the results of a collaborative effort that has been underway since December 2000 to provide operational feedback on the MM5HOT forecasts.

2. OPERATIONAL CONSIDERATIONS

For any tool to be useful in an operational environment, there are several critical issues that must be addressed. First, the forecasters must perceive that the tool has the potential to provide added value during their forecast preparation. This is dictated by the vast amounts of various tools and data sources available in the modern WFO due to improved communications and computing technology. There is generally insufficient time to consider all data sources, so those that are perceived and/or demonstrated to add the most value will be the most used. In the case of the Boulder WFO, the utility of a local model was demonstrated during a cooperative experiment in which two mesoscale models (RAMS and MM5) were run by FSL for evaluation during the winter of 1996−1997 (Szoke et al. 1998). Following that experiment, a modified version of the RAMS model was run in real time on a workstation within the Boulder WFO for approximately two years, ending in the summer of 2000. Finally, the forecasters had a positive perception of the MM5HOT as a result of seminars and personal communication with FSL staff.

Second, the tool must be easy to use in the

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operational environment without extra steps that may not fit within the hectic pace of active weather days. While it is generally easy to access web products, it is not as convenient as having the grids available on the system where the operational data and products are viewed and created. During the study described in Szoke et al. (1998), the web products were frequently not used due to this very reason. Thus, FSL worked with the Boulder WFO to set up a mechanism to transfer the grids in a format that can be displayed on their operational AWIPS workstations. Not only does this make access easier, but it allows the forecasters to quickly assess the forecast quality by overlaying satellite and radar imagery and observations on the forecast fields. This was the single most important step taken that led to the forecasters routinely using the model output.

Third, the tool or data source must be available in a timely manner so that the forecaster can consider it prior to putting together the final forecast products. The MM5HOT runs on FSL's High Performance Computing System (HPCS), a massively parallel Linux cluster of Compaq Alpha PCs. Using 24 processors, the model is launched four times per day at 45 min after the model initialization time, when the LAPS analysis is complete. The complete 24−h forecast is available to the NWS forecasters on their AWIPS workstations within 2 h of the model cycle time. This configuration is run four times per day with cycle times of 0000, 0600, 1200, and 1800 UTC and provides hourly output for all 24 h of the forecast at full spatial resolution. Although the use of the HPCS may not be representative of a typical forecast office, a much smaller cluster of Linux−based PCs (e.g., 6−8 processors) has become a very powerful and relatively affordable solution that could provide similar timeliness for a smaller domain configured for their county warning area (CWA).

3. LOCAL FORECAST CHALLENGES

Figure 1 shows the Boulder CWA of responsibility. The CWA covers an area with highly varying topography, ranging from approximately 1050 m in the northeastern portion (Platte River valley) to over 4200 m along the Continental Civide. The Rocky Mountains in the western portion of the area play a major role in the area's weather. Mountain wave activity can produce localized wind storms, including Chinook wind events. Additionally, two subtle areas of elevated terrain are oriented east−to−west along the northern boundary (Cheyenne Ridge) and the southern boundary (Palmer Divide). These two features modify local wind flow to produce circulations often responsible for convergence zones that produce or enhance localized areas of precipitation. This highly variable topography makes the Boulder CWA an ideal location to employ a mesoscale model to better capture and forecast small−scale weather events.

4. MODEL CONFIGURATION

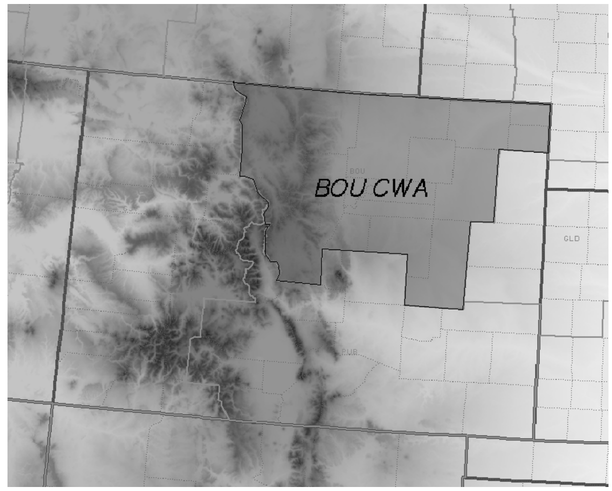

Figure 1. County Warning Area for the Boulder WFO (shaded area) overlaid on topography.

The LAPS analysis and the latest version of MM5 (version 3, release 4) were configured for the domain shown in Fig. 2, and consists of 125 by 105 horizontal grid points using a 10−km grid spacing. The LAPS analysis used 21 vertical levels on constant pressure surfaces at 50−mb intervals from 1100 mb to 100 mb. The forecast model uses 41 vertical sigma levels (pressure−based terrain−following coordinate) with the finest resolution near the boundary layer. Table 1 summarizes the physics options used for the real−time forecast runs. These settings refer to the standard options available in this release of MM5.

Table 1. MM5 run−time configuration.

Convective Scheme	Kain−Fritsch
Microphysics	Schultz
PBL Scheme	Blackadar
Land Surface	5−Layer Soil Model
Radiation	RRTM
Time Step	30 seconds

As a result of LAPS versatility to use virtually any source of operational meteorological data, the real−time forecasts can benefit from frequent assimilation of traditional data sources as well as those only available within the local office. The following data sources are routinely used in the analyses that initialize the real−time forecasts: GOES imager and sounder radiances, WSR−88D reflectivity and VAD winds, vertical wind profilers, aircraft observations (ACARS and PIREPs), radiosonde reports, and surface observations (includes standard METAR reports and several mesonets located throughout the region).

5. RESULTS

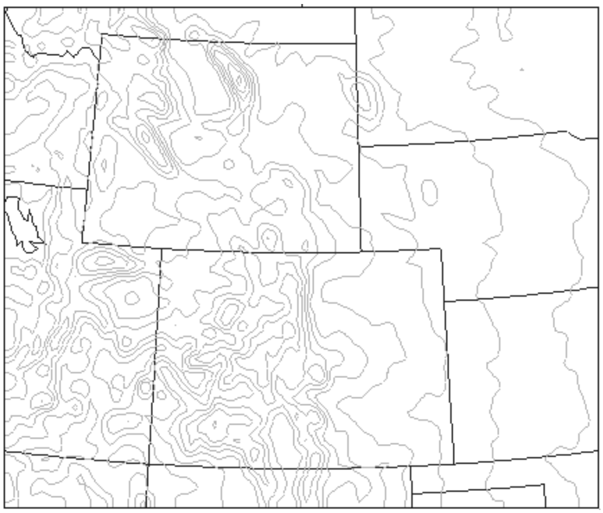

Figure 2. The LAPS−MM5 hot start domain, consisting of 125 x 105 gridpoints with 10 km spacing. Contours are of the model topography.

Although the MM5HOT forecasts have only been undergoing operational evaluation since January 2001, preliminary feedback has been very favorable. Most, if not all, of the forecasters evaluate the forecast output when preparing the short−term forecasts, and it is frequently mentioned in the area forecast discussions when the weather situation dictates the need for mesoscale guidance. Additionally, confidence in the forecast grids is high enough to warrant the use of the grids in the Graphical Forecast Editor (GFE), a component of the Interactive Forecast Preparation System (IFPS, Mathewson et al. 2000) developed at FSL and being evaluated by the Boulder WFO. Through April 2001, the forecasters have used the GFE to create hourly temperature, wind, and dewpoint fields at the surface for display on their public web page. They have the option to initialize these grids with any available model, and they sometimes use the MM5HOT forecasts in this manner for the first 24−h period.

Several benefits of using MM5HOT within the Boulder WFO have been identified:

- The MM5HOT does much better than the national models at forecasting local winds, particularly when they are modified due to subtle orographic effects. Examples of the model's ability to correctly diagnose and forecast the presence of the "Longmont Anticyclone" and the "Denver Cyclone" are discussed in Szoke and Shaw (2001). Forecaster feedback indicates that the model forecast of winds for the various airports along the Colorado Front Range urban corridor can often be used with little modification when preparing terminal forecasts.

- Mountain wave activity is handled much better by the local model than the national−scale models because of the increased vertical resolution and the pressure−based, terrain−following coordinate. In these situations, the model has been a great asset in determining the eastward extent of the mountain wave−induced winds. Often, these situations result in very strong westerly winds along the immediate Front Range areas with a rapid transition to weak easterly flow a few km east of the foothills. Additionally, the higher−resolution topography allows the model to better identify lower−elevation areas where a deeper boundary layer may preclude full downward mixing of the westerly momentum, despite these locations' apparent favorable position relative to the mountain wave.

- The model does a good job of predicting localized precipitation patterns related to subtle orographic features (e.g., the Cheyenne Ridge and Palmer Divide) not represented well in the national−scale models.

- The surface temperature forecasts from the model do a much better job of representing significant differences due to subtle elevation differences not captured in the national−scale models. For example, in the presence of a Chinook wind situation, areas located in the Platte River valley will often not experience mixing of the drier, westerly winds all the way down to the surface, and will thus remain 10−20 K cooler with calm or very light winds. The model frequently correctly forecasts these situations.

- In addition to the meteorological advantages, the WFO benefits from the flexibility inherent in running the model locally. Since the grids do not have to be transmitted on the Satellite Broadcast Network (SBN) like the national grids, the office is able to get every grid point of the output with a 1−h time increment. In contrast, NCEP is currently running the Eta with a 22−km grid spacing, but is only able to transmit the upper−level data on a coarser 40−km grid due to bandwidth limitations. Additionally, having the raw model output available locally allows additional variables to be displayed, such as the various prognosed microphysical fields and derived parameters such as visibility, cloud ceiling, etc. Traditionally, these fields must be inferred by the forecaster. Having them explicitly available from the model provides a new dimension to the use of model output in the forecast process. Furthermore, since LAPS is able to produce a complete, three−dimensional analysis every hour (or more frequently) due to its use of radar, satellite, wind profilers, and aircraft observations, the model can be initialized at any given hour of the day and run to any arbitrary forecast length. This allows the model to run at optimum times to meet the local office's production schedule. With the current national data production and distribution architecture, it would be impossible to tailor model production schedules to meet the exact needs of every WFO. Finally, the model configuration can be adjusted more quickly and on an "as needed" basis to provide the optimal results for the CWA's special forecast problems.

- From a scientific perspective, the forecasters are very interested in the model's ability to depict high−resolution weather phenomena that national−scale models cannot (either due to native resolution or communications bandwidth issues). This stimulation leads to improved understanding of the physical processes that are associated with various events, which presumably can lead to improved forecasts.

No assessment would be complete without finding negative aspects, and there have been a few identified during this effort:

- The model surface temperature forecasts tend to have a cold bias on sunny days during the peak heating period and tend to be too warm at night. The daytime bias can be as much as 5−10 K.

- There is an accentuated cold bias in the surface temperatures when a grid point is initialized with snow cover present and the actual snow melts during the time covered by the simulation. This is due to the land surface option currently exercised in the real−time runs, which does not allow the snow cover to change during the simulation. This may be mitigated through the use of a more advanced surface model option, and there are plans to do so.

- Although the model tends to do a good job forecasting local precipitation patterns, the actual amount of accumulated precipitation tends to be too high. The cause of this is being investigated.

- Convective cells generated by the model tend to have greater spatial coverage than observed, which is to be expected when using a grid−spacing as coarse as 10 km. This may be mitigated by running the model at sufficient horizontal resolutions to explicitly resolve convection (e.g., 1−3 km grid spacing).

- Although the use of the FSL HPCS allows the model simulations to be completed quickly, the use of a research−oriented computing system can lead to reliability problems not normally experienced with the national models. During peak usage, the model must wait in a job queue until processors are available. Additionally, the HPCS is on the cutting−edge of affordable supercomputing technology, and there have been growing pains in the use of this system which has been on line less than a year as of April 2001. On a positive note, the fact that the forecasters complain when the model is not available as expected is a testimony to the usefulness of the product.

Overall, based on verbal feedback from the NWS staff, the forecasts produced by the MM5HOT have been beneficial in their daily operations thus far.

6. CONCLUSIONS

The use of a locally run mesoscale analysis and forecast system such as the one discussed in this paper can add significant value to the operational forecast process, particularly in areas where topographic effects play a large role in localized weather phenomena. These benefits are largely due to the following:

- A locally run model offers more flexibility (physics options, cycle times, domain, etc.) than what can be provided by a centralized facility.

- Running a model locally eliminates the communications network as a limiting factor in determining the temporal and spatial resolution at which grids can be displayed.

- A locally run analysis system can take advantage of data sources that may not be available to a centralized facility and can run more frequent analyses for the local area.

Additionally, the MM5HOT system described in this paper has demonstrated potential to improve explicit NWP forecasts of clouds and precipitation in the 0−6 h period due to its unique diabatic initialization (Shaw et al. 2001, Birkenheuer et al. 2001).

Planned work includes the installation of a similar system at three NWS WFOs during the summer of 2001, as well as at the two USAF space launch facilities. This will provide further opportunities for feedback from the operational community. Additionally, the LAPS diabatic initialization technique continues to be improved, and future tests will include the use of other forecast models, such as the new Weather Research and Forecast (WRF) model. As the ability to compute and store data continues to increase exponentially, it is not an unrealistic vision to imagine every operational local forecast office running a mesoscale data assimilation and forecast system in the near future. This could serve as a complementary tool to the national−scale NWP forecasts produced at the centralized facilities and the various nowcasting tools and techniques being developed.

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