LAPS DIABATICALLY-INITIALIZED MM5 FOR THE IHOP_2002 CAMPAIGN

Brent L. Shaw*, Dan Birkenheuer, Steve Albers*, John McGinley, Ed Szoke* and Paul Schultz
NOAA Research/Forecast Systems Laboratory, Boulder, Colorado

**Affiliation: Colorado State University/Cooperative Institute for Research in the Atmosphere (CIRA), Fort Collins, Colorado*

1. Introduction

The NOAA Forecast Systems Laboratory's (FSL) Local Analysis and Prediction System (LAPS, Albers et al. 1996) has been enhanced over the last few years to provide a capability to initialize mesoscale numerical weather prediction models with clouds and precipitation present in the initial conditions (Shaw et al. 2001a). This diabatic initialization procedure has been referred to as the "hot start" technique.

The basic technique involves the use of the three-dimensional LAPS cloud analysis which includes all microphysical species to diagnose estimated vertical velocity profiles based on cloud type, depth, horizontal scale, and stability criteria (Schultz and Albers 2001). These estimates are then used as constraints in a three-dimensional variational (3DVAR) step along with a first-guess field, the LAPS univariate temperature, moisture, height, and wind analyses to develop model initial conditions that are in dynamic balance with the observed cloud field while maintaining consistency with the observations. This "balance" step of LAPS is more fully described in McGinley and Smart (2001). What makes LAPS unique in this application is its ability to use virtually all operationally-available sources of meteorological information, including wideband WSR-88D data and GOES imagery, in a computationally efficient manner.

This technique has been used to improve explicit short-range forecasts of clouds and precipitation using mesoscale NWP models at FSL since the summer of 2000 (Shaw et al. 2001a, Shaw et al. 2001b). During the summer of 2002, this technique was used to initialize a nested MM5 domain using 12-km grid spacing for the outer grid and 4-km grid spacing for the inner grid (Figure 1). The grids were made available to forecasters supporting the IHOP field operations via FSL's FX-Net client software. Additionally, the quantitative precipitation forecasts (QPF) were verified against point observations and the NCEP Stage IV precipitation analyses via FSL's Real-Time Verification System (RTVS, Mahoney et al. 2002).

Corresponding Author: Brent L. Shaw, NOAA/FSL, 325 Broadway, R/FS1, Boulder, CO 80305
E-mail: Brent.Shaw@noaa.gov

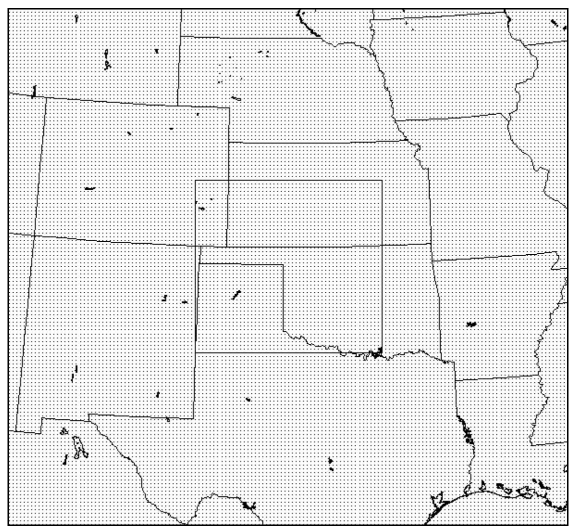


Figure 1. MM5 domain used for the IHOP field experiment. Grid-spacing on the outer domain is 12 km. The inner nest (box in center of figure) utilized 4 km grid spacing.

2. IHOP MM5 Configuration

MM5 was run at FSL on a 20-node Linux cluster every three hours. Each forecast was run out to 12 hours and provided hourly output. Incremental post-processing was performed as the model ran so products from the run were available to forecasters before the model run was complete.

The outer grid was initialized with LAPS and the inner nest obtained its initial conditions via interpolation from the outer grid.

One way nesting was utilized, so the inner grid's solution was not fed back to the outer grid. The Kain-Fritsch convective parameterization was employed on the outer grid, while the inner domain remained fully explicit for convective processes. For both domains, the Schultz (1995) microphysics scheme was selected because of its computational efficiency and compatibility with the LAPS cloud analysis. The MRF boundary layer scheme was used in conjunction with the 5-layer soil model. Longwave radiation was handled via the RRTM scheme. The timestep was 30 seconds.

3. Lessons Learned

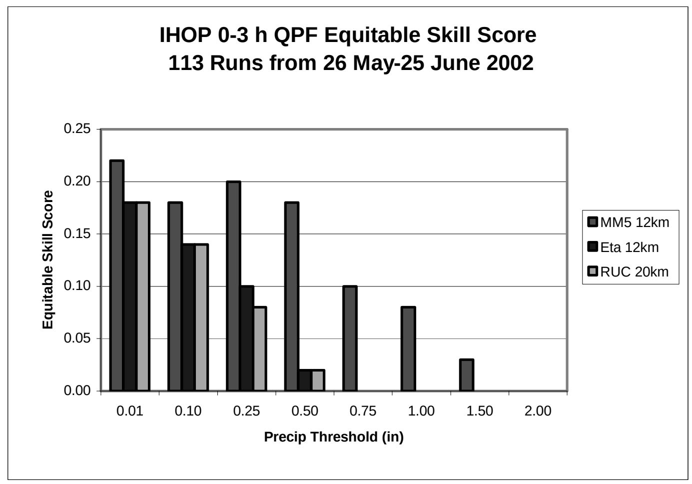
The IHOP campaign provided the first intensive evaluation of the LAPS hot-started MM5 for convective weather situations. Prior to this experiment, most of the evaluations had been done for winter cases. As such, new challenges were identified for the LAPS initialization procedure.

Early in the experiment, it was readily apparent that the model was significantly over-forecasting precipitation in the early hours of the forecast process. This was found to be a result of two issues. First, to prevent evaporation of the model clouds inserted by LAPS during the first few steps of model integration, the LAPS analysis saturated all grid boxes containing cloud water, regardless of the amount of cloud water present. This was adding significant amounts of total precipitable water to the column. Second, no limit was being applied to the amount of cloud water and ice being diagnosed by the LAPS analysis. In practice, however, one needs to be cognizant of how the microphysical scheme being employed within the forecast model operates. In this case, there were many times when the amount of cloud water and ice far exceeded (by one to three orders of magnitude) the threshold used by the Schultz microphysics for starting the liquid to rain and ice to snow conversion processes.

The model forecasts also faced problems with cases of elevated convection, which was frequently present in the domain during the morning hours. This was addressed in the LAPS initialization by changing the depth of the vertical motion profile to only consider the actual depth of the cloud. Prior to IHOP, the base of the upward vertical motion was assumed to be below the cloud by 1/3rd of the cloud depth.

4. Verification

Despite the shortcomings identified during IHOP, the results of the hot-started MM5 forecasts were still very positive. Figure 2 shows the equitable skill score and frequency bias for the 3-h QPF for the 12-km MM5, the operational 12-km Eta from NCEP, and the experimental 20-km RUC run at FSL. The MM5 demonstrated a distinct advantage for all precipitation thresholds, particularly for the higher thresholds. In the case of the thresholds above 0.75 in, the MM5 was the only model that demonstrated any skill.



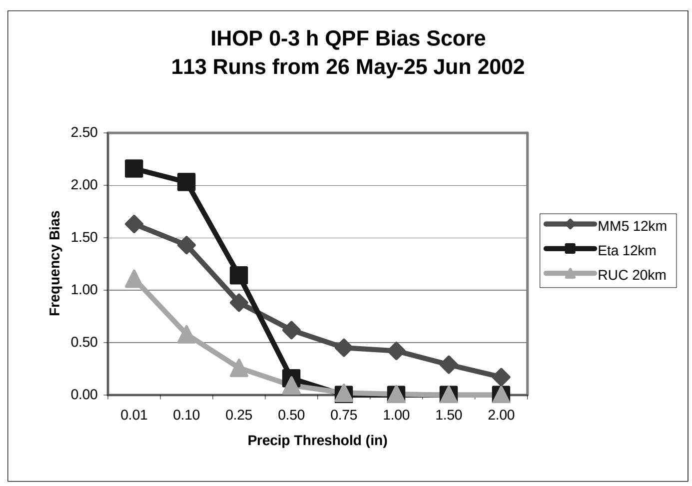


Figure 2. Equitable skill score (top) and freqency bias for 113 runs during the IHOP field experiment. Note that a perfect ESS is 1.0, and a perfect frequency bias is 1.0.

The MM5 forecasts also demonstrated significantly better skill for the 6-h QPF. For the 12-h QPF, the skill advantage was negligible, and the operational Eta matched or exceeded the MM5 skill for most categories. This is likely due to the effect of the lateral boundary conditions (which were provided by the Eta model) becoming the dominant source of the model forcing for this limited area domain.

Although it is not shown here, it is also interesting to note that the bias score of the MM5 forecasts gradually increase with forecast length. This growth in the precipitation bias has been observed in MM5 forecasts for other projects at FSL.

The demonstrated advantage in forecast skill of the LAPS-initialized MM5 is consistent with previous studies for winter cases. Although the absolute scores are lower than those observed for the winter cases, the relative improvement compared to the national models is significant.

5. Future Work and Conclusions

Work is underway to rerun all of the 6-hourly IHOP forecasts covering the entire experimental period using the latest version of LAPS, which incorporates improvements designed to address the problems identified during the experiment. These runs will be verified via the RTVS system for comparison to the original runs to determine if the changes have the desired effect. Additionally, several of the interesting case days from IHOP will be intensely evaluated, and re-runs for those special cases may be done for qualitative assessment. Finally, the LAPS hot-start technique is going to be used to run the new Weather Research and Forecast (WRF) model (Michalakes et al. 2001) for the entire IHOP period as well.

While the IHOP field experiment presented new challenges for the LAPS hot-start procedure, the preliminary results do indicate that LAPS can provide a computationally-efficient method to utilize a plethora of readily-available meteorological data, including radar and satellite, to improve explicit short-range forecasts of clouds and precipitation.

6. References

Albers, S., J. McGinley, D. Birkenheuer, and J. Smart, 1996: The Local Analysis and Prediction System (LAPS): Analysis of clouds, precipitation, and temperature. *Wea. Forecasting,* **11**, 273-287.

Mahoney, J. L., J. K. Henderson, B. G. Brown, J. E. Hart, A. Loughe, C. Fischer, and B. Sigren, 2002: The Real-Time Verification System (RTVS) and its application to aviation weather forecasts. *10th Conference on Aviation, Range, and Aerospace Meteorology*, 13-16 May, Portland, OR.

McGinley, J. A., and J. R. Smart, 2001: On providing a cloud-balanced initial condition for diabatic initialization. *14th Conference on Numerical Weather Prediction.* Fort Lauderdale, FL, Amer. Meteor. Soc., 40-44.

Michalakes, J., S. Chen, J. Dudhia, L. Hart, J. Klemp, J. Middlecoff, and W. Skamarock, 2001: "Development of a next generation regional weather research and forecast model. *Developments in Teracomputing: Proceedings of the Ninth ECMWF Workshop on the Use of High Performance Computing in Meteorology.* World Scientific, Singapore, pp. 269-276.

Schultz, P. J., 1995: An explicit cloud physics parameterization for operational numerical weather prediction. *Monthly Weather Review,* **123,** 3331-3343.

_____ and S. Albers, 2001: The use of three-dimensional analyses of cloud attributes for diabatic initialization of mesoscale models. *14th Conference on Numerical Weather Prediction.* Fort Lauderdale, FL, Amer. Meteor. Soc., J122-124.

Shaw, B. L., J. A. McGinley, and P. Schultz, 2001a: Explicit initialization of clouds and precipitation in mesoscale forecast models. *14th Conference on Numerical Weather Prediction.* Fort Lauderdale, FL, Amer. Meteor. Soc., J87-J91.

____, E. R. Thaler, and E. J. Szoke, 2001b: Operational evaluation of the LAPS-MM5 "hot start" local forecast model. *18th Conference on Weather Analysis and Forecasting,* Fort Lauderdale, FL, Amer. Meteor. Soc., 160-164.