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JP1.4 COMMERCIAL APPLICATION OF THE ADVANCED REGIONAL PREDICTION SYSTEM (ARPS)

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1. INTRODUCTION

The Advanced Regional Prediction System (ARPS) is a comprehensive numerical weather prediction system designed for predicting and modeling atmospheric phenomena at scales ranging from storm-scale to synoptic scale. ARPS was developed by the Center for Analysis and Prediction of Storms, a National Science Foundation Science and Technology Center at the University of Oklahoma. The centerpiece is a 3-D nonhydrostatic model using the equations of compressible fluid motion. The system also includes data analysis and radar data assimilation packages.

Since the mid-1990s CAPS has conducted operational tests of its forecast system at national supercomputing centers each spring (e.g., Droegemeier et al. 1996). From 1996-1999, American Airlines funded the development of a forecast system that could be operationally deployed ("Project Hub-CAPS," Carpenter et al. 1999).

Weather Decision Technologies, Inc., (WDT) has licensed and extended this operational system in order to provide numerical forecasts to customers in a broad range of industries, including broadcast meteorology, energy utilities, energy futures, commercial and general aviation, and emergency management. WDT maintains a close relationship with CAPS and funds a portion of its research.

We begin by describing WDT's forecast system configuration and objective analysis procedures. After describing a stand-alone system for broadcast meteorology known as MetroCast™, we conclude by discussing model results and efforts to improve forecast accuracy.

2. FORECAST SYSTEM CONFIGURATION

WDT currently produces 60 h ARPS forecasts on a 5760 × 3600 km national grid (Figure 1) four times daily. A 40 km horizontal grid with 32 vertical levels is currently used, with plans to increase the horizontal and vertical resolution in the near future. ARPS dynamics and physics are described by Xue et al. (2000, 2001), with specific features noted below.

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A vertically-stretched terrain-following grid is used, with the model top 20 km above mean sea level. The lowest vertical layer is 10 m above the ground.

Explicit (grid-resolved) precipitation processes are handled by the Lin (1983) 3-category ice scheme. The Kain-Fritsch (1990, 1993) cumulus parameterization is used at grid spacings of 18 km or more.

A 1½-order TKE-based turbulence closure is used along with the convective PBL parameterization of Sun and Chang (1986).

The surface energy balance model of Noilhan & Planton (1989) is used. There are 11 available soil categories and 13 available vegetation categories. The database has 1 km resolution across the U.S.

2.1 Input Data and Objective Analysis

For national ARPS runs, the background field for data assimilation and the time-dependent lateral boundary fields are provided by NCEP's Eta model. The AVN model may be used as a backup to the Eta. All other ARPS runs use the national ARPS run for their background and boundary fields.

Initial conditions for the model are objectively analyzed using the ARPS Data Analysis System (ADAS; Brewster 1996), which employs a Bratseth successive correction method. Cloud and precipitate fields are enhanced using satellite data, radar data (lowest four NEXRAD reflectivity levels), and METAR cloud observations (ADAS Cloud Analysis; Zhang et al. 1998). Data from various mesonets may also be inserted.

Future plans call for the use of variational techniques that use the full volume of NEXRAD data in order to retrieve the 3-D structure of updrafts and

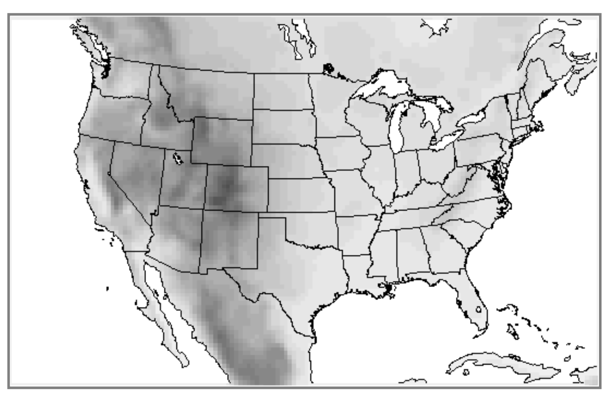

Figure 1. Domain and terrain used for the national ARPS forecasts.

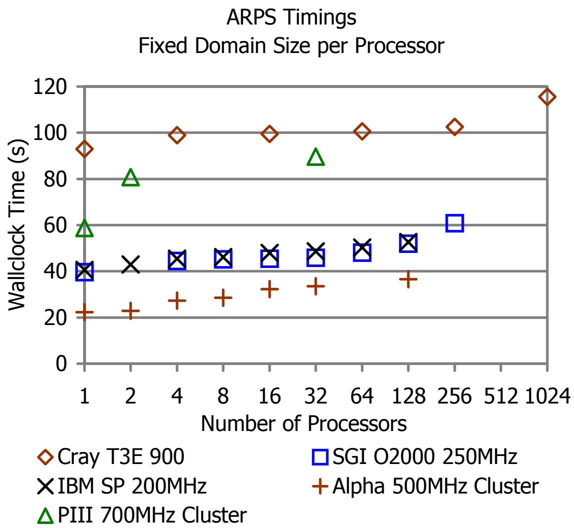

Figure 2. Execution time for an ARPS benchmark forecast where the domain size is held fixed on each processor. As the number of processors increases the overall domain grows proportionately. On an ideal machine the execution time would remain the same for any number of processors. ARPS was run in distributed memory mode using MPI. The platforms tested were: 1024-processor Cray T3E 900; 256-processor SGI Origin 2000 (250 MHz R1000); 128-processor IBM SP (200 MHz Power3 processors, 2 per node); 128-processor Compaq Alpha cluster (500 MHz Alpha 21264 processors, 4 per node); 32-processor Pentium III Cluster (SGI 1200 PIII 700 MHz processors, 2 per node).

downdrafts within thunderstorms (Xue et al. 1999). Intermittent data assimilation (Xue et al. 1998) and continuous cycling will also be implemented.

2.2 Computational Issues

ARPS is written in Fortran-90 and can be run efficiently on a variety of computing platforms and compilers without modifications to the source code. It runs efficiently in message passing mode (via MPI) on platforms ranging from a Pentium cluster to a massively-parallel Cray T3E (Figure 2). Operational forecasts have been run on systems as large as a 256-processor SGI Origin 2000. WDT currently runs national ARPS forecasts on a 32-processor Pentium III (700 MHz) Linux cluster.

3. METROCAST™

MetroCast™, developed by WDT and marketed by DTN/Kavouras Weather Services (Sappanos et al. 2001), allows broadcast meteorologists to run ARPS on their own computer. Domain size and placement, horizontal grid spacing, forecast duration, and scheduling are completely at the control of the customer. The web-based configuration tool and display can be accessed remotely (Figure 3). MetroCast typically runs on a 4-processor Pentium cluster under the Linux operating system.

When a MetroCast run is initiated, the local computer sends a request to a WDT server, which extracts initial and boundary conditions from the most recent national ARPS forecast. These fields, along with all current data (including radar and mesonet) are sent back to the local computer, where the initial field is constructed using ADAS. The forecast then runs as a 1-way nest inside the national ARPS forecast. The forecast procedure and model configuration are essentially the same as for the national runs performed at WDT's computing facility. Post-processing occurs as the run proceeds, with GRIB files produced for use with Kavouras' Triton® RT display system.

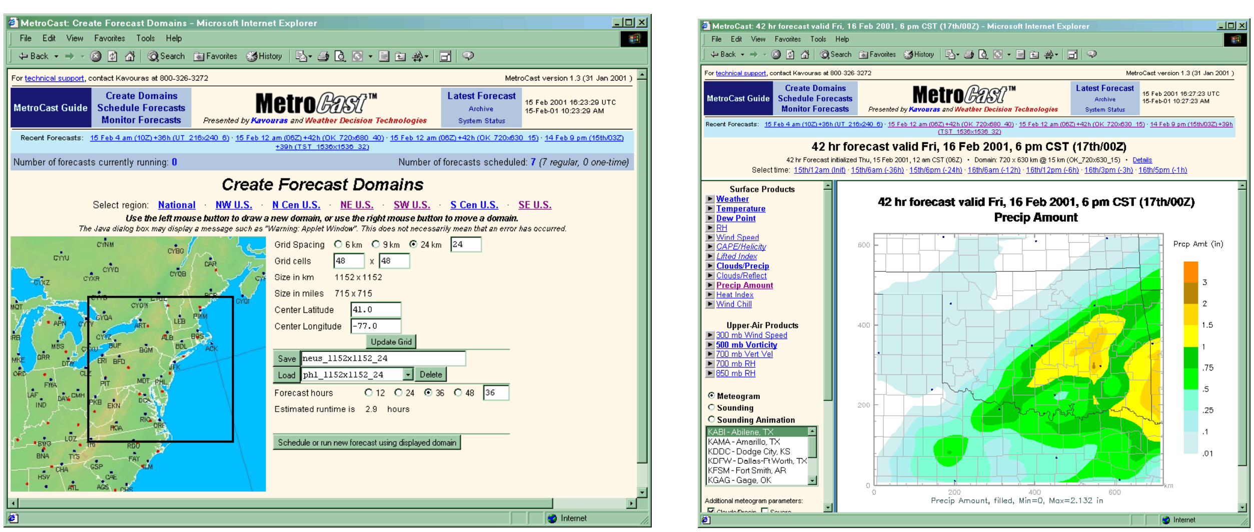

Figure 3. MetroCast™ web interface. (a) Domain creation tool. (b) Forecast output.

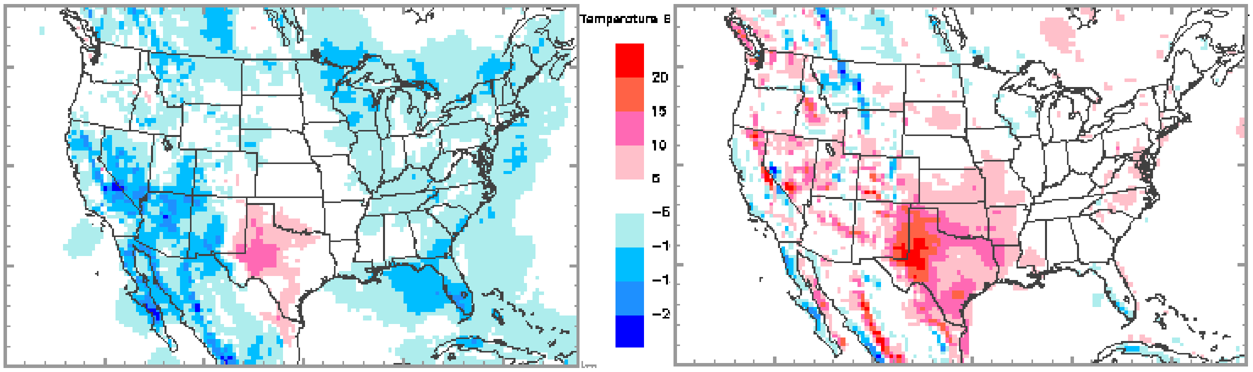

Figure 4. Preliminary results from a temperature bias correction technique that is currently under development. (a) Average temperature bias for four 36-hour ARPS forecasts in March 2001 valid at 1800 UTC. Shading interval is 5 ºF. Much of the region is 5-10 ºF too cool, except for Texas, which is too warm. (b) Bias after applying prototype correction technique. Temperature errors have been reduced to less than 5 ºF over most of the domain, although the warm bias has increased over the south-central U.S.

4. RESULTS

4.1 Forecast Products

Standard fields at the surface and aloft are available in graphical form via the web or as GRIB files. Several specialized products are available, including categorized weather (Figure 5d), lightning flash density, and aviation-related products such as turbulence and icing (Kemp et al. 1999), with others, such as agricultural products, under development.

4.2 Temperature bias correction

The temperature forecast is critically important in several industries, notably utilities and energy futures. Standard approaches for producing statistical forecast guidance, such as MOS, are difficult to apply to evolving mesoscale models, however. One simple approach toward correcting systematic biases in the model output is to subtract the seasonally-averaged bias from the gridded output (Stensrud & Skindlov 1996).

We are developing a scheme in which the model's forecast at each grid point is corrected based on the model's past performance. Preliminary results using linear regression are shown in Figure 4. More advanced schemes involving multiple regression and neural networks are also under consideration.

4.3 Sample Forecast

An intense cold front traveled across Oklahoma during the evening of 8 Feb 2001. A squall line with a narrow band of heavy precipitation was associated with the front. A region of mixed precipitation trailed the squall line. These features are captured in a 5 km ARPS forecast (Figure 5).

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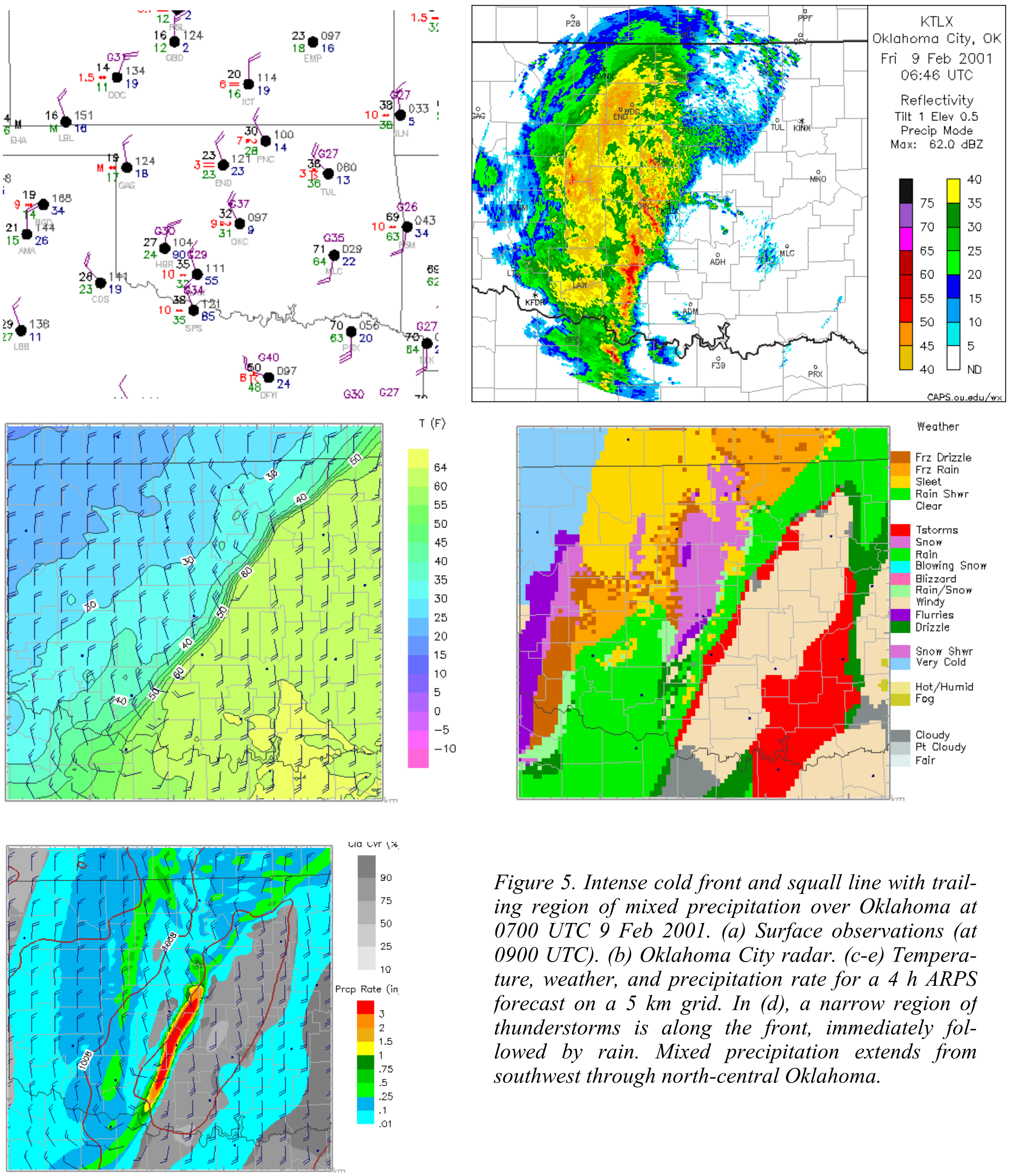

Figure 5. Intense cold front and squall line with trailing region of mixed precipitation over Oklahoma at 0700 UTC 9 Feb 2001. (a) Surface observations (at 0900 UTC). (b) Oklahoma City radar. (c-e) Temperature, weather, and precipitation rate for a 4 h ARPS forecast on a 5 km grid. In (d), a narrow region of thunderstorms is along the front, immediately followed by rain. Mixed precipitation extends from southwest through north-central Oklahoma.