9.9 TRANSLATING ADVANCES IN NUMERICAL WEATHER PREDICTION INTO OFFICIAL NWS FORECASTS

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1. INTRODUCTION

Since the days of first numerical weather models, National Weather Service (NWS) forecasters have prepared and disseminated official forecasts as text. Although advances in numerical weather prediction, observing systems, and computer workstations have served to greatly improve both the quantity and quality of weather information available to NWS forecasters, the information the NWS provided to our users at the end of the century continued to be limited by how fast forecasters could type. With the nationwide implementation of the Interactive Forecast Preparation System (IFPS) at NWS Weather Forecast Offices (WFO) nearly complete, the NWS is now positioned to increase both the resolution and timeliness of its official forecasts. Instead of manually typing a myriad of text products tailored for specific user communities, forecasters rely on interactive interpretation and editing techniques to prepare detailed forecasts of weather elements in a common digital database 7 days into the future on at least a 5-km resolution grid. From this database, IFPS software automatically composes and formats the legacy text suite of products. More importantly, the high-resolution forecast itself can now be provided to our customers and partners in digital form–a strategic goal of the NWS for 2003 (NWS 1999).

The primary means by which the NWS plans to disseminate official high-resolution digital forecasts is via the National Digital Forecast Database (NDFD; Glahn and Ruth 2003). The NDFD is envisioned to provide a seamless mosaic of official NWS digital forecasts. The database is being made available to all customers and partners–public and private–so that those customers and partners can create a wide range of text, graphic, and image products of their own. Information on NDFD is available at www.weather.gov/ndfd. Figs. 1-3 show example images that can be generated from NDFD grids. Current forecast images can be viewed from the NWS homepage at www.weather.gov/forecasts/graphical.

2. THE COMING OF THE DIGITAL AGE

The previous half century witnessed an increasing reliance by operational meteorologists on computer technology to complete tasks that were formerly infeasible or accomplished by manual methods. This transition has been marked by three major advances, none immediately recognized as such, and each dependent on the success of the prior. The first advance came in the field of numerical weather prediction. Although not embraced by operational forecasters at the start, a thorough review of numerical

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model output is an indispensable step in preparing a forecast today.

A second major advance came with the statistical interpretation of numerical model output by employing techniques such as perfect prog (Klein et al. 1959) and Model Output Statistics (MOS; Glahn and Lowry 1972). Resisted by field forecasters when introduced, statistical forecasts are also now part of the routine process. In fact, MOS guidance has become an accepted benchmark by which human forecasts are judged.

The third major advance came only recently with the introduction of IFPS into NWS field offices nationwide (Ruth 2002). This advance has also been met with resistance. In its early days of development, the primary benefit of IFPS was thought to be in allowing forecasters to focus on meteorology by eliminating the tedious chore of typing forecasts. This has not been the experience at many forecast offices. The tremendous amounts of data that need to be viewed and manipulated can be so overwhelming that it has required new management strategies at local offices to accommodate peak workloads (Maximuk 2003; Rezek 2002). In those portions of the nation with complex terrain, software still can not (and likely never will) generate the same free-flowing text that a human can compose. If text products are to remain the same, this necessitates post-editing of IFPS generated products in addition to preparing forecast grids. Today, the overwhelming benefit of IFPS is instead recognized to lie in the digital data themselves. By disseminating NWS weather forecasts in a form that provides high resolution with great flexibility, we significantly increase the usefulness of NWS weather forecasts to our customers and partners (Ruth and Glahn 2003).

Each of the three advances described are now working together to make the creation of the NDFD possible. The NDFD constitutes a "mosaic" of human value added to the best numerical and statistical models of the day. With it, the NWS is able to provide much more forecast information than previously, at timescales as small as hourly and space scales of a few kilometers. More than 120 WFOs nationwide currently submit forecasts to the experimental NDFD. Forecast elements in the NDFD at the time of this writing are shown in Table 1. The database will also eventually contain digital forecasts from the National Centers for Environmental Prediction (NCEP) such as maximum expected winds from hurricanes, offshore marine products, and climate forecasts.

Table 1. NDFD elements

NDFD element name	Temporal frequency days 1-3	Temporal frequency days 4-7
Daytime Maximum Temperature	24 hours	24 hours
Nighttime Minimum Temperature	24 hours	24 hours
Probability of Precipitation (12-h)	12 hours	12 hours
Quantitative Precipitation Forecast	6 hours	n/a
Sky Cover	3 hours	6 hours
Snowfall Amount	6 hours	n/a
Surface Temperature	3 hours	6 hours
Dewpoint Temperature	3 hours	6 hours
Wind Direction	3 hours	6 hours
Wind Speed	3 hours	6 hours
Weather	3 hours	6 hours
Wave Height	12 hours	12 hours

3. A GOOD MODEL "FIRST GUESS"

The original concept for IFPS was that forecasters would start each new forecast cycle with a good "first guess" based on the most recent numerical and statistical model guidance. They would interactively make changes to model guidance by using graphical editing tools. And finally, they would push a button to produce a complete suite of forecast products. As the "first guess" from the models improved, the time spent on routine forecast preparation at NWS forecast offices would decrease, and the overall product would be improved.

The reality of IFPS operations at WFOs today is quite different. Once the 7-day digital forecast database is established, forecasters do not routinely overwrite it with new model guidance, but "nudge" it according to the latest incoming observations and model guidance. This preserves the high-resolution detail already edited into the database that most sources of model guidance do not contain. It promotes consistency from one forecast cycle to the next. And it focuses coordination discussions with adjacent offices to only those days requiring change from previous thinking.

Should a change to the database be deemed necessary, forecasters can either use tools to pull the current grids toward the latest model guidance, or they can copy in grids for selected forecast hours. These sensible weather grids are either mapped from MOS at available station locations, or are objectively interpreted from model-based soundings (LeFebvre et al. 2002). Grids can be derived from several NWS models. In order to compensate for their relatively coarse resolution on AWIPS, IFPS uses high-resolution terrain data to smartly interpolate to a finer mesh grid. Grid spacing at WFOs currently ranges from 5 km to 1.25 km. Those WFOs with the most complex terrain choose to run at the finest resolutions. If performance were not an issue, it is unclear what the ideal resolution for NDFD would be. However, it is almost certainly finer than our highest resolution models are currently able to provide as guidance.

Beginning this fall, the Meteorological Development Laboratory (MDL) plans to introduce a prototype gridded MOS product developed on the 5-km NDFD grid. Forecasts will be produced by regionalized equations that use high-resolution geophysical data as predictors. In order to measure skill at producing forecasts for any point, selected observation sites are being held back from the development sample for testing. Not only does this development have the potential to provide very good gridded guidance to forecasters in a form directly applicable to the problem at hand, but it will likely establish a much fairer baseline (than station MOS) by which to gauge forecaster skill.

4. THE HUMAN IN THE LOOP

Techniques for interacting with the digital database have improved dramatically over the past decade and will continue to evolve as both the quality and quantity of model guidance increases. A variety of interactive techniques used throughout the world are described by Ruth (2000). At present, NWS forecasters at WFOs rely on the Graphical Forecast Editor (GFE)–a grid editor developed by the Forecast Systems Laboratory (Wier et al. 1998). Grid editors enable forecasters to draw and manipulate fields of sensible weather on a map. Scripts, known as "smart tools", are written by local forecasters to quantify meteorological interdependencies among specific weather elements and terrain. These tools and procedures enable forecasters to streamline the forecast creation process and to provide scientific methods to produce mesoscale effects in the forecast database (Margraf 2004).

A clear attraction of grid editing is the large degree of control it offers forecasters to assign specific values to gridpoints with a simple point and click. Because of the relatively small areas of the country for which any one WFO has responsibility, this methodology works well. However, as the spatial and temporal resolution of model forecasts continues to increase, so too will the number of grids a forecaster will be asked to review and prepare. In addition to greater resolution, forecasters will soon be asked to prepare grids for more public, marine, and fire weather elements. Eventually, forecasters may be asked to prepare 3D grids that can support aviation forecasting, as well as new probability grids to help quantify forecast uncertainty. Under this scenario, direct editing of grids may become infeasible, even with the aide of smart tools.

In order to continue to take advantage of human expertise in the forecast process, interpretative tools that can adjust a whole continuum of model forecasts in the dimensions of time, 3D space, and probability are being prototyped at MDL. These techniques are intended to enable forecasters to make better use of high-resolution model guidance than editing techniques that currently exist.

5. THE VALUE ADDED

The deployment of IFPS nationwide has now made available an unprecedented quantity of human forecasts in digital form. And since the experimental release of NDFD in June 2003, people have wanted to know just how good is it. MDL has developed a prototype verification system to examine this question (Dagostaro et al. 2004), but no agreed upon analysis of record yet exists by which to compare gridded forecasts of sensible weather at 5-km resolution. It is possible to verify forecasts by polling the nearest NDFD gridpoint to an observation site, but this raises questions about representativeness of observations at those points, especially for areas with complex terrain.

Although direct comparisons to known standards are not yet possible, several conclusions about WFO grids in the current NDFD are evident:

- Forecast offices do a better job producing accurate 12-h fields for maximum temperature, minimum temperature and probability of precipitation than they do with hourly fields such as temperature, dewpoint, and wind. The NDFD exhibits significant and consistent diurnal biases for these elements.

- Forecast offices do a better job producing skillful forecasts in relation to model guidance for the first few days than for days 4 through 7.

- Forecast offices have difficulty producing forecasts that are consistent across WFO boundaries. This is particularly true for hourly fields like temperature, dewpoint, and wind.

- Forecast offices are still struggling to provide all required forecasts to NDFD in a timely fashion. On an average day, 5-10% of all offices in the CONUS fail to provide grids for all required elements and times.

6. CONCLUSION

Implementation of the IFPS/NDFD concept is the latest in a series of advances made possible by computer technology over the last half century. As has been the experience with prior advances, it will likely take several years to firmly establish NDFD into routine NWS operations. At the time of its initial operating capability, the NDFD will be limited to a handful of surface elements and will contain very limited information on forecast certainty. Over the next decade, we expect to increase the temporal and spatial resolution of the NDFD, introduce additional forecast elements including those that quantify forecast uncertainty, as well as provide 3D information capable of supporting aviation forecasts. The success of this new database, and especially its planned enhancements, will increasingly depend upon the availability of accurate, high-resolution, numerical and statistical, weather forecast guidance.

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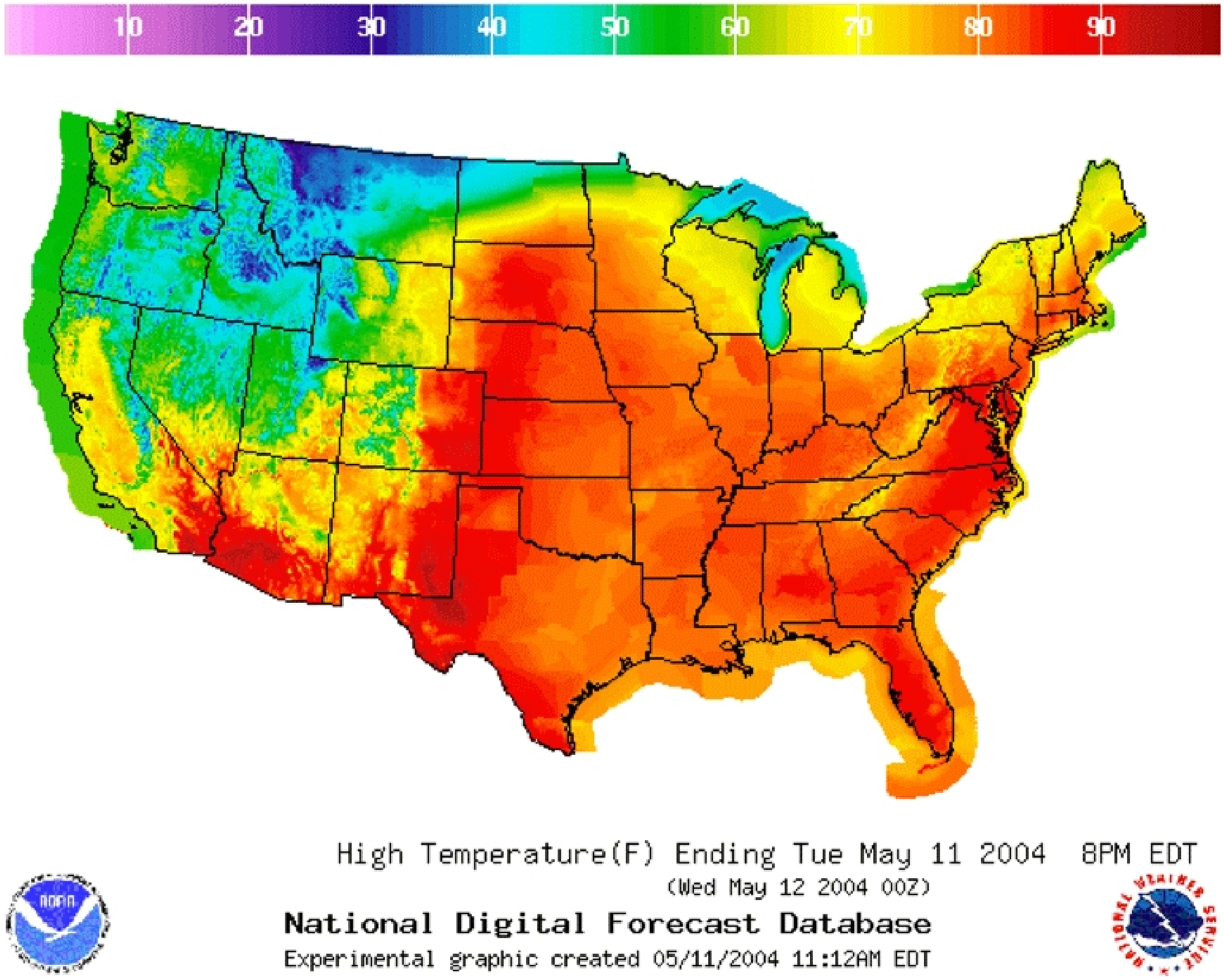

Figure 1. Sample maximum temperature image created from NDFD grid.

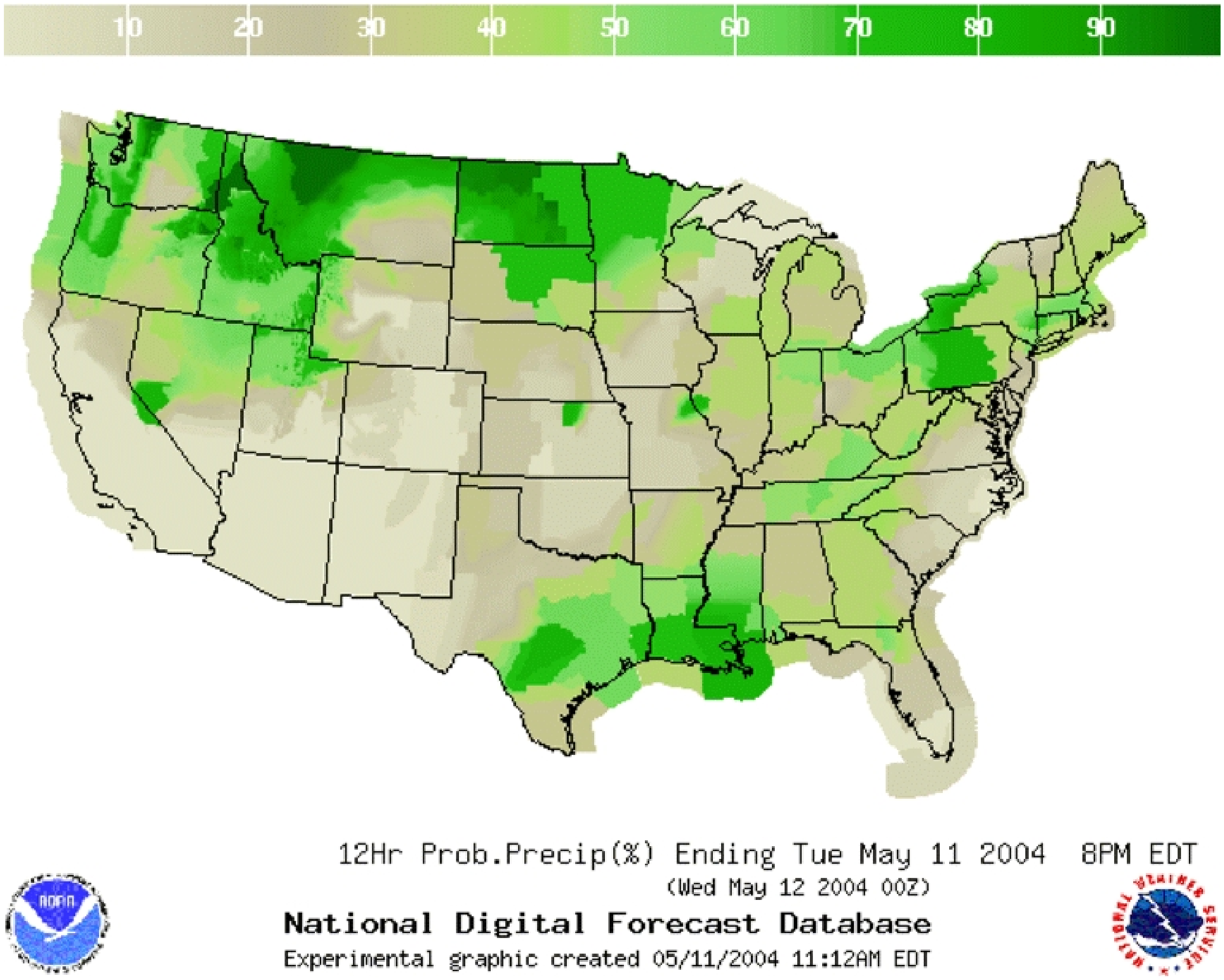

Figure 2. Sample probability of precipitation image created from NDFD grid.

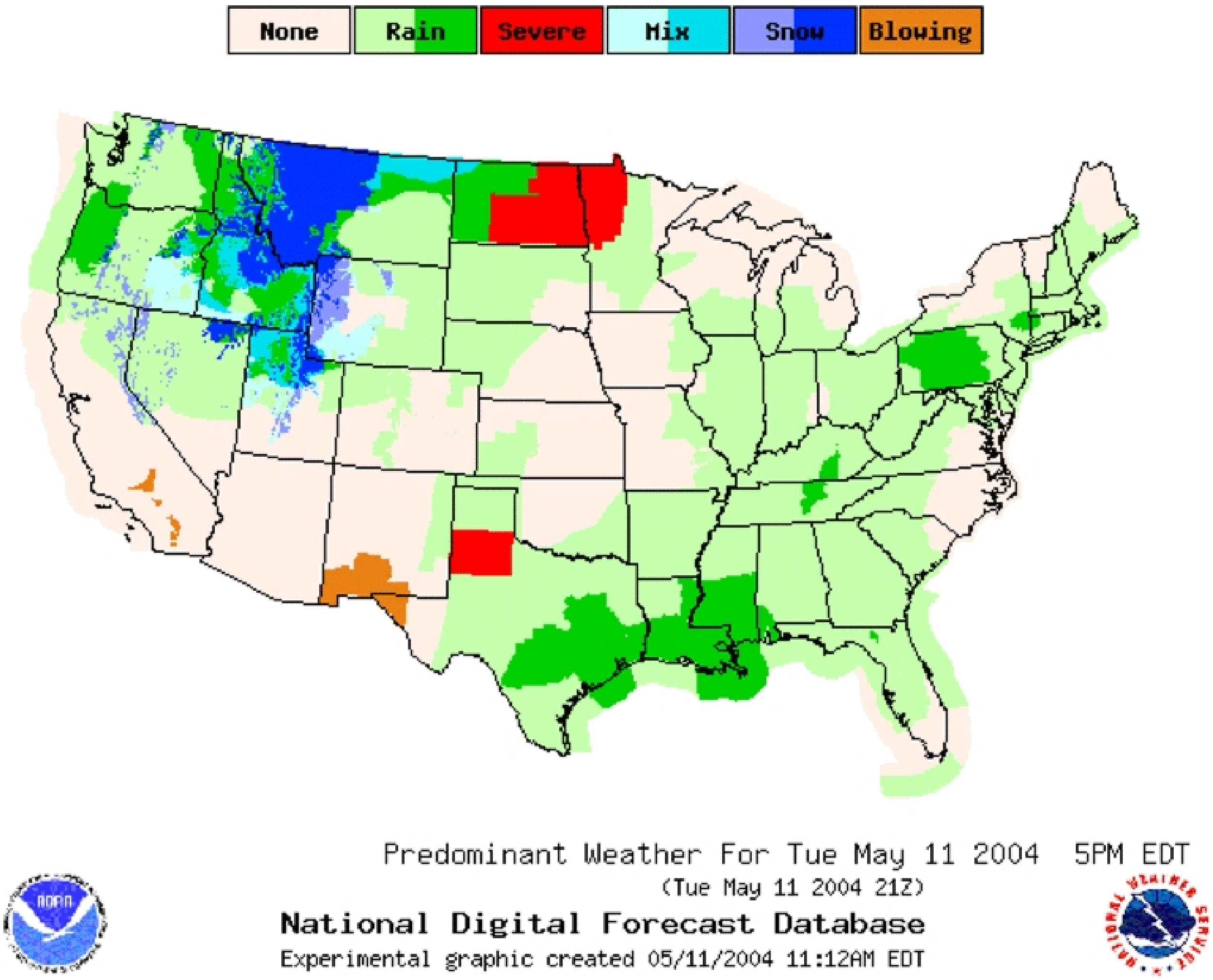

Figure 3. Sample weather image created from NDFD grid.