15.2

FUTURE FORECAST WORKSTATIONS/SYSTEMS

Carl S. Bullock

Forecast Systems Laboratory, Boulder, Colorado

1. INTRODUCTION

The amount of data available to operational forecasters has increased rapidly in the last decade and continues to increase. Remote sensing systems such as geostationary and polar orbiting satellites, radar, and automatic surface observing systems will provide orders of magnitude more data during the coming decade than today's systems. New and more sophisticated analysis and assimilation techniques are brought to bear to make sense of these data for initialization of numerical weather prediction models. These techniques themselves produce output which operational forecasters will peruse. But the greatest potential increase of meteorological data comes from numerical weather prediction (NWP) models themselves. The models are run at higher resolution and produce approximately an order of magnitude more data for each doubling of resolution. In addition, to deal more objectively with the chaotic nature of the atmosphere, ensemble forecasting methods have developed over the last decade. Depending on the number of members used in an ensemble, this can result in 10-100 times more model output.

Clearly, forecast systems of the future must be designed to deal effectively with a much greater volume of data. The first issue that must be considered is how to obtain and manage such a large volume of data. With the current AWIPS system it has become clear that the demands for new data quickly outstrip the existing communications medium. The AWIPS experience leads to the conclusion that lacking unlimited bandwidth, a two-tiered approach is needed with respect where data resides. There will continue to be a need for locally resident data to serve the weather watch and warning function and for frequently used sets of data. But not all data needs to reside locally. Recent developments in the atmospheric and oceanographic community open the possibility of easily accessing less frequently used data sets over the network. How this might work is described in another paper in this conference (Davis, 2005).

With ever-increasing amounts of data, it becomes unreasonable for the forecaster to peruse all of it individually. More powerful visualization tools will be needed that synthesize data from several sources into an information rich presentation. This is particularly true for ensemble model data which effectively adds another dimension to the four that are represented in the NWP grids. This adds a degree of freedom which should be carefully explored in order to optimize forecaster interaction. It is very important that tools be provided to forecasters that allow them to optimize the human contribution. Forecasters are capable of interpreting and evaluating information if given the proper tools and training (Roebber, 2004). In part this is achieved by relating the information to a conceptual model of the atmosphere. Tools that assist in this process are needed, including 3D displays. Computer graphic display technology continues to evolve rapidly driven largely by the computer game industry. This has brought 3D displays into more common usage, although most games do not include explicit control of display parameters. While the technology continues to evolve, 3D displays of meteorological fields remain underutilized in operations.

The future role of the forecaster remains a topic of much discussion (Roebber, 2004). Most agree that forecasters provide a valuable service in the short term (0-12 hours), particularly for warnings (Mass, 2003). Beyond that there is much debate about how far out in time the forecaster can add value to the information provided by NWP. For purposes of this paper, I assume that as forecasters become more skilled in working with ensemble output they will be able to add value to the forecast process out through five days. This will come in part with a shift away from a forecasting a single deterministic number to a probability-based approach. Ensemble models are well suited to creating probabilities, and with proper training forecasters will be able to participate constructively. In fact the current state of single model forecasts beyond 5 days shows significant swings from run to run over a given area. Forecasters are needed in this case to moderate run-to-run changes. This is an area that will greatly benefit from ensembles and probability-based forecasts.

This paper will discuss the feasibility of issuing warnings based on ensemble forecasts as opposed to observations. We briefly touch on what kind of system infrastructure would be needed by forecasters to accomplish this approach. We also look at what might be needed to move from the current deterministic approach used in forecasts to one that includes probabilities as an expression of uncertainty.

Corresponding author address: Carl S. Bullock, Forecast Systems Laboratory R/FS6, Boulder, CO 80305-3328; email: Carl.S.Bullock@noaa.gov

2. WARN ON FORECAST

Recent experiments with high-resolution mesoscale models suggest that within the next decade it will be possible to issue earlier warnings for severe weather phenomena. Realistic structures of convective systems have been forecast up to 36 hours in advance during BAMEX (Weisman, 2004). Mesoscale models run as part of the Coastal Storms Initiative at the Jacksonville, FL Weather Forecast Office show marked improvement in forecasting precipitation (Mahoney et al, 2004). These are just two examples of many that could be cited. The timing and location are not always correct however. To overcome this deficiency an ensemble approach could be employed. Ensembles can help characterize the likely distribution of possible solutions. Such an approach has already been used in a number of experiments and has demonstrated improved skill over a single deterministic model. (Legg, 2004).

One concept for future forecast operations is based on running a mesoscale model that covers the local area of responsibility for 24 hours. This becomes practical in light of the strides that are being made to standardize the different modules of the WRF model. A modeling expert is no longer required on site to run local mesoscale models. Standard modules are now available to handle the various aspects incident to running a model (assimilation, initialization, post-processing, etc). We further postulate that the computing power will continue to increase at local offices allowing them to run a model at somewhere between 1-4 km resolution.

While it will be very possible for an office to run a mesoscale model, it would be problematic for an office to run an ensemble. This would require either running at much lower resolution or having much more computing power. We suggest that the best way to approach this is to run an ensemble member at many offices. Typically severe weather does not strike all of the country simultaneously. Thus it is conceivable that other offices not under any threat of severe weather could run an ensemble member for a threatened office. Taking this a step further, it is possible that NOAA as an entity could make computing resources available to threatened offices by harnessing grid computing technology. For example, severe weather frequently peaks in the central plains of the United States during late evening and early morning. If computers were harnessed that are otherwise underutilized, they could be used to run a mesoscale model ensemble to diagnose areas most likely to experience severe weather. There are many technical issues that would have to be resolved, but such a scenario is within the current limits of technology.

The combination of distributed data and grid computing means that a local office can harness computer resources across a network and is no longer limited to local resources. Grid computing would harness computer resources wherever they are available. The distributed data approach allows an office to access data elsewhere on the network instead of being limited to locally available data. Thus information from high resolution ensembles could be made available at an office expecting severe weather without requiring that the computing resources be local.

3. PROBABILITY-BASED FORECASTS

In commenting on the current forecast methodology, Mass (Mass, 2003) points out that deterministic forecasts at 7 days have low skill. While there is useful information that can be provided to the public at day seven, a single value is almost a disservice since it implies greater skill than warranted. Some method of communicating uncertainty is needed so that users do not assume that forecasts of dew points a week ahead have the same certainty as tomorrow's maximum temperature. Most suggest that some form of probability must be added to forecasts, perhaps even a probability distribution function with the most likely value highlighted. Whatever the most appropriate form turns out to be, it seems clear that forecasters will need to include this in forecasts in the future.

Ensembles are well suited to generate probabilities of weather parameters. Because they can represent a range of possible solutions, ensemble output can easily be adapted to generate probabilities. As an example of such an approach, the United Kingdom Meteorology Office experimented with ECMWF ensembles to generate probabilities for certain weather events such as high winds and heavy precipitation (Legg, 2004). This approach demonstrated skill at 4 days and beyond in predicting gales and heavy rain. These techniques will require additional work to be properly calibrated, but the results thus far are very promising. Thus it seems reasonable to assume that skillful guidance for probability-based forecasts will be available. Forecasters will need a new set of tools (and training) to display and manipulate probability distributions and relate these to the output of numerical weather prediction models.

4. SUMMARY

Forecasters can look forward to more and better data in the future as new observing systems come on line and as better methods of handling data become operational. More powerful tools and better training will be required to optimize the meteorologist's role in the forecast process. Ensembles of high resolution, mesoscale models will provide a basis for issuing alerts of severe weather sooner. The incorporation of probabilities into all forecast parameters will be enabled by ensembles and new forecaster tools.

5. REFERENCES

Davis, D.L., T. B. Kent, G. J. Edwards, J. E. Ramer, U. H. Grote, C. S. Bullock, E. J. Mandel, J. P. Tuell, and T. Hopkins, 2005: Investigations using NOMADS in an AWIPS environment*. Preprints 21st Conf. Interactive Information Processing System (IIPS)*, San Diego, CA, Amer. Meteor. Soc.

Legg, T.P., and K. R. Mylne, 2004: Early warnings of severe weather from ensemble forecast information. *Wea. Forecasting,* 19, 891–906.

Mahoney, J. L., M. Kay, B. Shaw, J. McGinley, J. Smart, and J. Savadel, 2004: Coastal Storms Initiative: Summary of 1 June-31 August 2003 Evaluation*. NOAA Technical Memorandum OAR FSL-31.*

Mass, C. F., 2003: IFPS and the future of the National Weather Service. *Wea. Forecasting*., 18, 75–79.

Roebber, P. J., D. M. Schultz, B. A. Colle and D. J. Stensrud, 2004: Toward improved prediction: High-resolution and ensemble modeling systems in operations. *Wea. Forecasting,* 19, 936–949.

Weisman, M. L., C. Davis, and J. Done, 2004: The promise and challenge of explicit convective forecasting with the WRF model*. Preprints 22nd Conf on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc.

Use of color to highlight important features/areas. Conceptual model abstractions. Difference fields or spreads.

We are looking for signals in the data.

Data pull vs push
Local ensembles
Grid computing
New visualization
Generation of initial grids - probability based
Grid editing

Diagnosis
Analysis
Initialization critique
Model adjustment
Grid generation tools
Abstractions
Conceptual models- identify key components and harness data mining tools to find them in current/forecast data
Testing hypothesis - what are key features, how will this evolve, what signals
Data mining to discover key features or user directed