APPLICATION OF NUMERICAL MODELS IN THE FORECAST PROCESS - FROM NATIONAL CENTERS TO THE LOCAL WFO

David W. Reynolds*
National Weather Service
WFO San Francisco Bay Area
Monterey, CA

1. INTRODUCTION

Over the past fifty years we have seen an amazing transition in both numerical modeling and in the forecast process. You can read much about the evolution of numerical modeling and their application in the articles contained in this symposium. What I would like to focus on is where we are today and where we might be headed in the use of numerical models by operational forecasters within the NWS. Specifically I would like to address the issue of what is and will be the value of the forecaster given current and expected improvements in numerical modeling and the expected transition to probabilistic forecasting for the time period beyond 12 hours. Thus I will not discuss the nowcasting period.

2. PRESENT STATUS

Currently on any given day on any given forecast shift a forecaster within a WFO (Weather Forecast Office) might be able to view upwards of a dozen numerical model outputs from model runs that may be updated as frequently as every 6 hours. These models are rather evenly split between global models run at various modeling centers throughout the world and regional models run locally within the U.S. or Canada. Several of the global models are run in ensemble* mode providing additional information on forecast uncertainty. At one time, given restrictions in band-width and workstation limitations, NCEP Service Centers such as the HPC (Hydrometeorological Prediction Center) were able to access many more models at higher resolution then could a field forecaster in a WFO. This is still somewhat true today as there are continued band-width limitations but also restrictions in dissemination agreements with such entities as the European Center for Medium Range Forecasting (ECMWF), specifically the ECMWF 50 member ensemble output which HPC has access to. However, application of high speed desktop computers have allowed local high resolution models to be run either in regional centers (Mass, 2002) or in local WFOs providing additional guidance to the forecaster that would not be available at the national center. These are usually limited to valid times of 84 hours or less.

As one might expect, the forecaster, if not prudent in what he/she chooses to view, can quickly reach information overload. One can think of this multi-model analysis as a poor man's ensemble approach where by the forecaster uses the spread in the various solutions to determine confidence in his/her forecast be it in the short or medium range time period. In order for the forecaster to actually prepare a deterministic forecast, many forecasters come to rely on those models they feel they have the best understanding of. This usually means having an

* Corresponding author address: David W. Reynolds, 21 Grace Hopper Ave Stop 5 Monterey , CA , 93943.

understanding of model biases, synoptic patterns in which the particular model tends to perform best, or choosing the model that seems to have performed the best over their last few forecast shifts, all rather subjective in nature.

During an evaluation of the QPF process within the NWS (Charba et al, 2003), it was observed that the HPC forecaster producing the QPF grid over the CONUS was able to add value mostly by knowing which model to choose and correcting for model bias, i.e. dry or wet bias or position errors with respect to synoptic forcing, i.,e. heaviest precipitation too far into the cold air etc. Figure 1, (taken from Reynolds, 2003), shows the trend in manual QPF forecasts over the past 40 years. One can almost imagine a change in the slope of the 5-year running mean beginning about two years after a new model is implemented. This makes sense if this is in fact a cause-effect relationship in that it may take that length of time for a forecaster to learn the biases of the model. One can also see that after several years the trend line begins to flatten as the skill levels plateau until a new model arrives to begin another round of improvements.

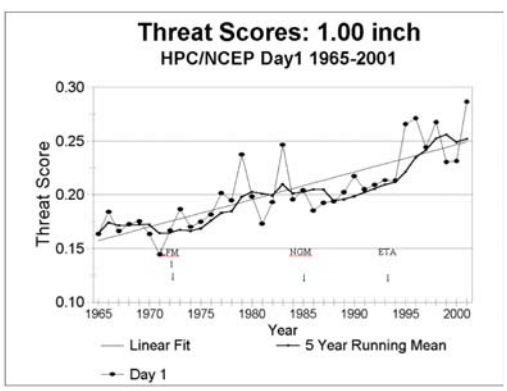


Figure 1 Day 1 24-hr threat score from HPC by year. Also plotted are the best fit and 5-year running mean trend lines.

Figure 2 shows the actual value added provided by the manual forecasts over the model. Here you see two manual forecasts, the HPC forecaster and the River Forecast Center HAS (hydrometeorological analysis and support) forecaster who manually adjusts the HPC forecast. For the entire US the data shows value added by each forecaster. Thus in a situation where model weaknesses in a single parameter are well understood, the forecaster can add significant value. The value has been estimated to be about 15 years of model development. It has not been demonstrated that such value-added capability exists for other sensible weather parameters.

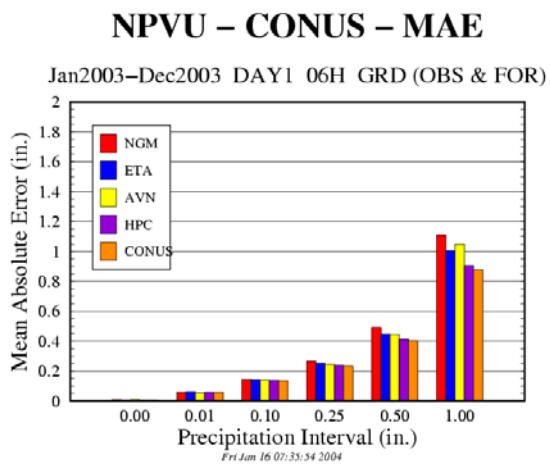


Figure 2 Day 1 24-hr QPF skill shown for the year 2003. Graph compares the 3 operational NCEP models with two manual forecasts, one from HPC and the second by the RFC HAS forecaster.

When the forecast transitions into the medium range period of days 3-7, the value of the human forecaster is seen to diminish. Figure 3 shows the most recent one-year verification from HPC showing anomaly correlations for a forecaster produced North American surface pressure field for the medium range days 3-7 encompassing the most

recent year of data. It is apparent that the forecaster in this instance is not adding value over the "Best Model" of the day. In this case it is usually the ECMWF model or the GFS ensemble that is providing the best solution. Note however that HPC is adding value over the deterministic GFS run. This indicates that more often then not this is the starting point for the forecast since they are required to modify the GFS MOS (model output statistics) associated with these runs.

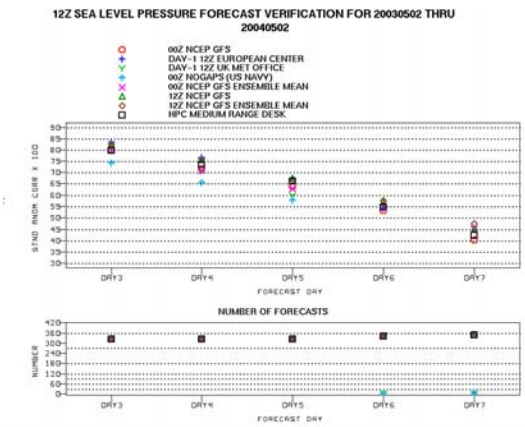


Figure 3 Standard anomaly correlations for day 3-7 12Z surface pressure forecasts over North America. Various model guidance available to the HPC forecaster as well as the HPC forecasts are plotted

There is evidence that in fact the human may add value in creating surface pressure fields in the medium range. Grahame (2000)and Hewson (2004), showed that forecasters using a process called On Screen Field Modification (OSFM) were able to improve on the best guidance through day 5. This technique provides meteorologically consistent sensible weather parameters because they are derived from the modified dynamic model. It is this ability that may hold out a valuable role for the forecaster in the future. This will be discussed further in the next section.

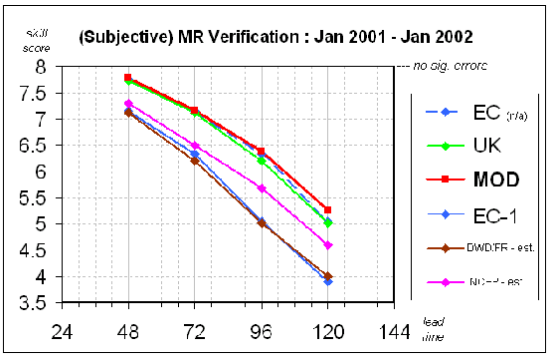
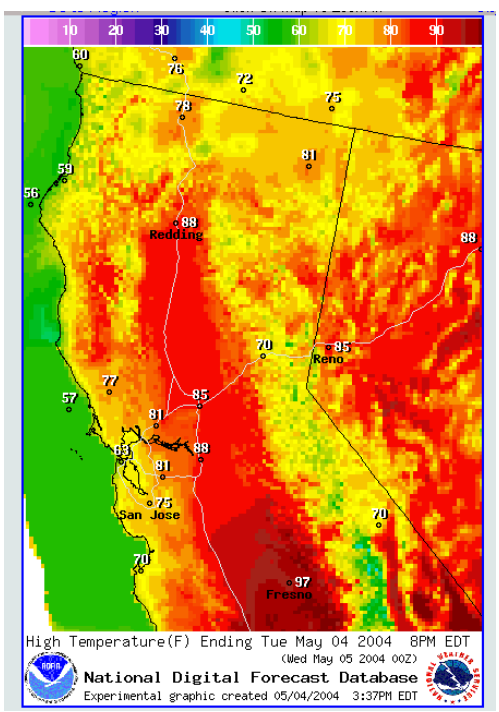


Figure 4 Subjective skill scores for various lead times. The red line represents the 'preferred solution' issued by Met Office forecasters. This provides better guidance than any other single deterministic solution

The recent initiation of a Digital Services Program within the NWS has introduced a major paradigm shift in the forecast process. This new program is well documented by Glahn and Ruth (2003). Current capabilities of the software interface severally restrict direct input of model output. This because the sensible weather grids are being generated at either 5 or 2.5 km resolution, and with coarser model resolution along with model biases in temperature, moisture etc., make it impractical to directly import model data. What is normally done to follow trends in model forecasts is to use MOS guidance to adjust the previous forecasts. This has been called nudging. Since MOS points are rather limited, the impact on the entire grid is limited without utilizing some questionable techniques like cubic spline fitting of MOS point data into the grid. Given the rather small number of MOS points this really does not provide a robust solution.

The shear volume of sensible weather grids the forecaster is being asked to

produce at a temporal and spatial scale that is unresolvable with the current operational models begs the question of whether this is really how we should be utilizing NWS forecaster resources. This idea is not new. Mass (2003), provided sound arguments for not having forecasters spending time trying to "draw" the forecast using what amounts to electronic crayons and using what are commonly referred to as "Smart Tools" to adjust the grids. These tools are simply expedient ways to populate grids using simple approaches such as interpolation, diurnal trends, climatology, or lapse rate to cool or warm temperatures at higher/lower elevations. As Scott (2004) points out, these grids have either no internal consistency among the sensible weather parameters or with any of the models they were derived from.



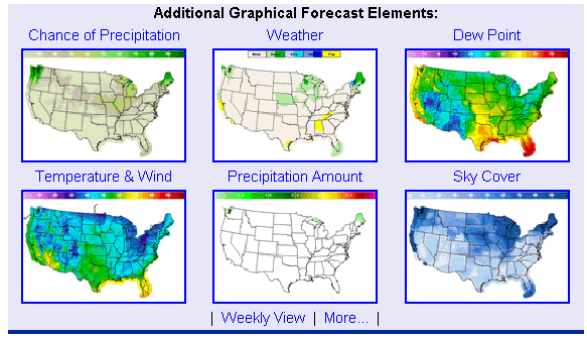


Figure 5 a) 5 km Max temperature forecast displayed on the National Digital Forecast Database (NDFD) for northern and central California. b) Various other sensible weather parameters being generated by each office of the NWS at either hourly, three hourly, or 6 hourly temporal resolution.

3. **FUTURE TRENDS**

3.1 WFO

We are approaching a time in the next five years when it will be feasible to run mesosocale ensembles at resolutions approaching 5 km. The planning of the Weather Research and Forecasting Model (WRF, http://box.mmm.ucar.edu/uswrp/reports/sscjan2004/WRFSSC_files/v3_document.htm) has incorporated the ability to run the model with different dynamic cores. Multi-model ensemble output should provide the guidance necessary to resolve many of the limitations brought about with the current digital services methodology in the short range. It is interesting to note that the multi-model ensemble approach was endorsed by both the USWRP (US Weather Research Program) Warm Season and Cool Season QPF Workshops. (http://box.mmm.ucar.edu/uswrp/reports/QPFwrkshp_Aug13.pdf) conducted over the past three years. An important first step will be to calibrate the ensemble output such that unbiased means and probability density functions

for each sensible weather parameter can be generated. The unbiased means of the distribution can be used to populate the digital services grids now being pain-stakingly populated by forecasters in each of the WFOs. These grids should be of sufficient quality to meet the needs of most customers. In addition the probabilities will provide an objective measure of the likelihood of the expected value occurring. The option would still be available to allow the forecaster to intervene in the grid editing if the model output appears to be trending well away from what might be considered a reasonable solution (QC the data). (It is interesting that the Weather Channel has already made a corporate decision to abandon its forecast staff and utilize statistical post-processed model output to populate their public forecast). Beyond this the forecaster may be asked to spend more time interfacing with the customers, providing education and outreach on hazardous weather, and collocating with the decision maker during times of severe weather such as an IMET (Incident Meteorologist) does on a wildland fire. In this case the forecaster acts as interpreter, consultant, and critical information giver on very specific mesoscale phenomena (imparting the local knowledge) that current numerical models are not capable of providing. This same concept can apply to all hazardous/high impact weather be it winter weather, river flooding, coastal flooding etc where the meteorologist works side by side with the emergency manager providing critical weather information as needed. The concept of focusing the WFO forecaster on these critical high impact weather events was recently conveyed in the an NWS Operations Philosophy for Weather Forecast Offices dated September, 2003.

The WRF model ensemble output would only cover the first 3 days of the forecast period. For the medium range period global ensemble data would be used. NCEP is working on a super ensemble approach using the GFS and Canadian models. To attain model grid resolution capable of populating the 2.5 km digital grids, downscaling techniques would be needed. In addition the same calibration methods would be needed to remove model bias.

3.2 National Center

So what might be the best role of a forecaster in a National Center like HPC with respect to value adding to numerical model output? Assuming that bias corrected ensemble forecasts provides the basis for most sensible weather parameters through 7 to 10 days, one possible role is to follow the lead of what is being done at the UKMET office. Under appropriate conditions, a well-trained meteorologist intervenes in the model data assimilation cycle, i.e. in the QC process. This can be done by supporting observations in a region that might be removed in the assimilation cycle. A software system (OSFM) has been developed to allow this intervention and then utilize the modified analysis in the forecast cycle. It has been demonstrated that the process can lead to substantial improvement in situations in which the model forecasts have been particularly poor. Figure 6 (from http://www.metoffice.com/research/nwp/publications/nwp_gazette/sept00/Storms.html) is an example of improvement in a numerical model forecast cycle by manual intervention in the surface

pressure field. This intervention lead to both surface and vertical changes in the model which led to a 10 mb improvement in surface pressure at 48 hr valid time. One can envision that the modified data assimilation becomes the basis for the ensemble run. This then leads to improvements in all of the statistical post-processed parameters. With THORPEX on the horizon it may be useful to develop methods within NCEP to allow skilled meteorologist to intervene in the control run of the global ensemble or regional ensemble where a few key observations can be further supported such that they impact the assimilation cycle and the forecast cycle. With sufficient computer capability the models could be rerun in an iterative process to the satisfaction of the forecaster. This can then be the control run for the ensemble prediction system.

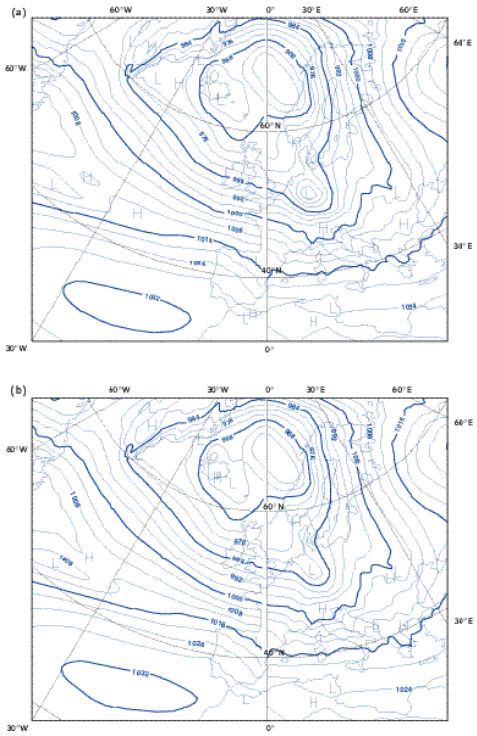


Figure 6 T+24 forecasts from our global model, valid at 12 UTC, 26 December. (a) Operational forecast (including forecaster intervention). (b) Without intervention.

4.0 **SUMMARY**

It is very apparent that we have to be much smarter in how we utilize our forecasters over the next 5 to 10 years. An emphasis needs to be placed on statistical post-processing of ensemble model output to derive unbiased sensible weather elements to provide the digital services now consuming valuable WFO and NCEP center human resources. Forecast uncertainty is a fact and needs to be quantified for the consumer of weather information. The best role of the forecaster is not in unscientific manipulation of sensible weather grids but in acting as a resource for the consumer and decision maker and in focusing efforts on high impact weather events. The UKMET office has developed a process that demonstrates a valuable role for the meteorologist in a national center in terms of positive impacts on numerical model output. This same sort of process needs to begin within NCEP. IF we are to attain this vision within the next 5 years, a demonstration of this capability needs to begin now. Given a realistic time frame for instituting change, we may already be several years behind.

5.0 **REFERENCES**

Charba, J.P, Reynolds, D.W., McDonald, B.E, Carter, 2003: Comparative verification of recent quantitative precipitation forecasts in the National Weather Service: A simple approach for scoring forecast accuracy. On. Wea. And Fcst., 18, 161-183.

Glahn, H.R., and D. Ruth, 2003: The new digital forecast database at the National Weather Service. Bull. Amer.

Meteor. Soc., 84, 195-201.

Hewson, T. , 2004: The value of field modifications in forecasting. UKMET Office Tech, Rep. No. 437. Met Office, Exeter, UK.

Grahame, N.S., 2000: Portraying uncertainty in medium range guidance. WGCEF Newsletter No 5., pp 46-50.

Mass, C. et al, 2003: Does increasing horizontal resolution produce better forecasts? The results of two years of real-time numerical weather prediction in the Pacific northwest. Bull. Amer. Meteor. Soc., 83, 407-430.

Mass, C.: 2003: IFPS and the future of the National Weather Service. Wea. And Fcst., 18, 687-692.

Reynolds, D.W., 2003: Value-added quantitative precipitation forecasts: How valuable is the forecaster? Bull. Amer. Meteor. Soc., 84, 876-878.

Scott, C.A. and V.J. Proton, 2004: Development of a link from the 4-D cube to the derived sensible weather elements. Preprints, AMS 20th Conference on Weather Analysis and Forecasting/16th Conf. on Numerical Weather Prediction. Seattle, WA. Paper 4.7.