Comments on "IFPS and the Future of the National Weather Service"

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1. Introduction

Dr. Cliff Mass (2003) is to be congratulated for his perceptive comments regarding the Interactive Forecast Preparation System (IFPS) (Ruth 2002) as it is currently being implemented by the National Weather Service (NWS). As one who has not only been involved with the evolution of IFPS, but also one who hopes to help improve on the system in some of the ways Cliff discusses, I want to comment on some points in the paper. There are several "themes" concerning IFPS and implications for the National Digital Forecast Database (NDFD), and I have categorized them, albeit imperfectly I fear, into the following:

1) Need for probability forecasts and use of ensembles (section 2)
2) Difficulties with current gridded forecast resolution (section 3)
3) Need for better tools to produce nowcasts (section 4)
4) Need for forecast skill guidance (section 5)
5) Better use of human resources (section 6)

While Cliff does not actually mention NDFD, IFPS and NDFD are so interrelated that both are discussed here.

2. Need for probability forecasts and use of ensembles

Mass (2003) states, "There is little question that the NWS must trend toward graphical forecast products if it is to remain effective and relevant." He concludes, "One of the most serious issues with IFPS is that its current design anchors the NWS to an outdated, essentially deterministic, view of forecasting that is inconsistent with the rapidly developing science and capa-

bility of modern numerical weather prediction." I would characterize the current state of IFPS not as being anchored to a nonprobabilistic approach, but rather as being at a particular state of development and capable of evolving to include additional factors, including probability forecasts. As Cliff says, this is a major paradigm shift; it has been made possible only through development and implementation of elaborate software and a willingness on the part of NWS forecasters to move toward the future. We usually have to take first steps that may, even in development, be realized as going only partway; after all, we will probably never be "all the way." That is the nature of evolutionary and innovative development and implementation.

To have tried to put into place a near-perfect system all at once—whoever's vision of perfect that might represent—would have probably been to sound the death knell to the gridded concept for a span of several years. I fully agree with the statement of the American Meteorological Society: "Much of the informational content of meteorological data, models, techniques, and forecaster thought processes is not being conveyed to the users of weather forecasts. Making and disseminating forecasts in probabilistic terms would correct a major portion of this shortcoming" (AMS 2002). Over 30 yr ago, Tribus (1970), then assistant secretary of commerce for science and technology, stated: "It was not too long ago that the major concession by the Weather Bureau to the existence of probability theory was the use of words such as 'likely,' 'probably,' or 'chance.' Fortunately this policy has been abandoned. Today we have forecasts couched in the language of probability, which represents a distinct improvement over deterministic pronouncements." This was written when probability of precipitation (PoP) had recently been introduced into Weather Bureau forecasts.[1] Unfortunately,

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[1] An excellent history of precipitation probability forecasting, especially in the Weather Bureau, is given by Hughes (1980): "the present era of probability forecasts to the public is probably best related to experimental probability forecasts started in Califor-

there has not been the progress in the use of probability in weather forecasts that Tribus evidently foresaw.

The complexities of producing and distributing probabilistic forecasts is daunting, but the time is now ripe for doing so. IFPS/NDFD is the springboard by which this can be done. The NWS Integrated Work Team that I chartered in 2000 and led by D. Ruth, which has planned and brought forth the NDFD, has considered making gridded probability forecasts at several of their meetings. Planning for more probabilistic forecasting has started, but implementation will require considerable time to achieve.

As Mass (2003) discusses, there are several scientific advances and application tools to help forecasters prepare the large number of grids that probabilistic forecasting would require. Mesoscale ensembles for the short term and global ensembles for the longer term can be postprocessed to provide probabilistic information, either by simple averaging of binary values (Zhu et al. 2002) or by more sophisticated model output statistics (MOS) techniques. Current ensembles generally do not produce the full range of possible atmospheric situations even given the best analysis of initial conditions, and thereby, without climatic-related postprocessing (e.g., calibration), the resulting probabilities will likely be too sharp to be reliable. This will improve with time, and we could even see a return to the Epstein–Fleming statistical dynamic concept (Epstein 1969; Fleming 1971) of probabilistic prediction. Although the problems with such an approach are major with full-functioned atmospheric/oceanic models—just as more runs with a larger grid length may produce better probabilistic forecasts than a lesser number of runs with a finescale grid—a simple statistical/dynamic model might furnish a better probability solution than many runs of the best non-probabilistic model.

IFPS could not be built all at one time and has known areas for improvement; we have started planning for improvements even though we are just now proving the current gridded operational concept. Some work is already in progress to postprocess ensemble data through a collaborative approach with the National Centers for Environmental Prediction (NCEP). This is only a start, and advantages must be weighed against other possibilities for use of resources.

One might ask, "Why has Tribus's view that the National Weather Service had entered the era of probability forecasting not come true?" There are, in my view, four basic reasons.

nia. . .These forecasts were first issued to the public in 1956 in San Francisco, and probability forecasts have continued there to date. They started in Los Angeles in 1957. . . . As a result . . . Weather Bureau Headquarters in 1965 . . . authorized the start of nationwide forecasting for precipitation occurrence. At first, the effort was a trial and learning program, with the forecasts not released to the public. The first public release began in the first half of 1966."

1) For many years there was little popular demand for probabilities. One still hears disparaging remarks about probability forecasts, indicating that many potential users do not understand the concept. However, Murphy (1977) and others (Murphy et al. 1980) have pointed out that much of the problem may be a misunderstanding of the definition of the event being forecast rather than not understanding the concept of probability and have reported on research supporting that view. Whatever the reason, the need for such forecasts was diffuse at best. This is rapidly changing, especially with sophisticated users and decision models (Dutton 2002). However, it is not enough for researchers and academicians to promote probability forecasting; there has to be a user clientele.

2) The hardware and software, before IFPS, did not support well a new array of products, some of which might incorporate probability information. This, too, has changed.

3) The dissemination methods were not conducive to what might be an order of magnitude increase in data. While raw bandwidth is now available, the packaging of such information for users is still a problem to be solved, one with which we would all like assistance.

4) There is a lack of interest on the part of the work force to move to new methods and products. This is understandable, given the lack of user "pull," the lack of good probabilistic guidance, and the inability to produce more or expanded products with the staff resources available and without such software as that which IFPS is now introducing.

All of these considerations have changed or are changing rapidly. There is growing appreciation and need for probabilistic information, creating "pull." While IFPS software does not, in general, explicitly deal with probabilistic information, the ability to manipulate grids and the growing acceptance of such methods positions the NWS to capitalize on the probabilistic guidance available through ensembles and their postprocessing. Higher-order graphical tools that can better deal with probability distributions than the current IFPS methods have been demonstrated (Ruth 1998). The future is bright for IFPS/NDFD incorporation of probability forecasts.

3. Difficulties with current gridded forecast resolution

The initial thrust in the forerunners to IFPS was to automatically produce from a digital database (not necessarily gridded), a current set of products that were inherently large scale (e.g., the zone forecast). As the gridded approach became feasible through more capable hardware and the development of interactive software, it became clear to forecasters that the meteorological

detail necessary for detailed products must be on a scale somewhat commensurate with physical features such as mountains and small bodies of water. The current resolution of 5 km, probably to go to 2.5 km as soon as the Advanced Weather Interactive Processing System (AWIPS) hardware and software will handle it, was essentially mandated by many Weather Forecast Office (WFO) forecasters and regional managers who wanted to make their forecasts maximally useful to the public and other users. The need for tools to make that possible generated a cottage industry for so-called smart tools and, in addition, drove developers to better interactive tools for producing the local grids at WFOs.

Exactly how to produce finescale grids from larger-scale models and guidance is a matter for much discussion. Mass (2003) evidently believes that while ''[i]t is expected that the cost of running models such as WRF [Weather Research and Forecasting] or Eta with a grid spacing of only a few kilometers will be prohibitive for a few years . . . there is a class of simple models, using mass conservation or basic dynamics, that can be run in the lower troposphere, driven by lower-resolution full-physics models'' that would provide a solution. We are exploring these possibilities. However, one can argue with his conclusions that having physically consistent fields ''is impossible after human intervention and subjective modification'' and ''there is little chance that subjectively modified surface temperature and humidity fields would be consistent with altered (or unaltered) clouds fields.'' I agree that ''[i]nconsistencies . . . will occur along the boundaries between NWS forecast office domains.'' Minimizing these inconsistencies was an important challenge in mosaicking the local grids into the NDFD. However, with the collaboration process worked out among the WFOs and NCEP, these challenges are being met by our NWS forecasters. The boundary points in the mosaics are being monitored, and the WFOs see the results in real time and can adjust as appropriate (see Glahn and Ruth 2003). Though a mosaic may show some diversity of opinion, it appears that the results are quite good. Some experimental mosaicked grids are being furnished to potential users, and there is a schedule for adding to the availability. A couple of examples are shown in Figs. 1 and 2; more can be viewed online at www.weather.gov/ndfd.

Mass does not discuss producing grids in the vertical dimension, which is not treated in the initial IFPS. Obtaining consistency in the vertical will pose bigger challenges than obtaining consistency of ''surface'' weather fields. Models may have to play a larger role, as we are moving smartly to the vital support of aviation.

Just as it was recognized that physical features were important in preparing gridded forecasts, it was recognized that political boundaries were not. A user who wants a forecast over an area larger than at a single point (or a 5-km square) will likely not care who makes the forecast or from whence it came. This, on anything except a microscale, almost dictates mosaicking the lo-

cal grids. It was through this recognition that the idea of NDFD was born. So, even though there are challenges in obtaining consistency of finescale grids at WFO boundaries, the NWS forecasters have risen to that particular challenge and are by all indications being successful. Time and dedication will only improve the product.

4. Need for better tools to produce nowcasts

Mass (2003) makes the statements, ''Perhaps the greatest failure of the weather forecasting enterprise in the United States is its inability to provide the public with detailed information regarding local weather features and their expected evolution during the next few hours'' and ''A major roadblock preventing the public from accessing short-term forecasts has been the lack of a suitable information analysis and delivery system, particularly since successful nowcasting demands the rapid communication of detailed information for many locations.'' He recommends: ''IFPS should be enhanced into a full-function nowcasting system that will allow forecasters to construct and communicate short-term (0–12 h) forecasts. Specifically, regional observations, radar imagery, and satellite imagery should be integrated with short-term extrapolation and analysis tools.'' He speaks of integration of mesoscale ensembles and global and full-resolution forecast output into IFPS. I think no one would disagree that these are goals that the NWS should set for itself and has in reality already done so.

In regard to Cliff's comments concerning integration of radar and satellite data into IFPS, there were many discussions early in the development of IFPS on how radar and satellite were to be used. Today, such finescale data can be viewed on AWIPS but are not incorporated directly into IFPS. An enhanced use of indispensable datasets within IFPS must be a priority for improvement.

5. Need for forecast skill guidance

It seems the discussion of ''forecast skill'' and ''forecast reliability'' is highly redundant with the discussion of probability forecasts. This exemplifies the difficulty in providing full information content of objective or subjective forecast assessments. If only a nonprobabilistic forecast were to be provided, then it could be accompanied by a ''confidence'' factor as Cliff suggests. However, if probabilistic forecasts are provided, the need for a confidence factor goes away, unless the more difficult concept of second-order probabilities is considered (Murphy and von Holstein 1971).[2] I believe we

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[2] In case the notion of second-order probabilistic forecasting is foreign, I quote from Murphy and von Holstein (1971): ''In the *standard* model of the subjective probability forecasting process, a forecaster expresses his judgment concerning (say) the occurrence of (measurable) precipitation in terms of a number p ($0 \leq p \leq 1$).
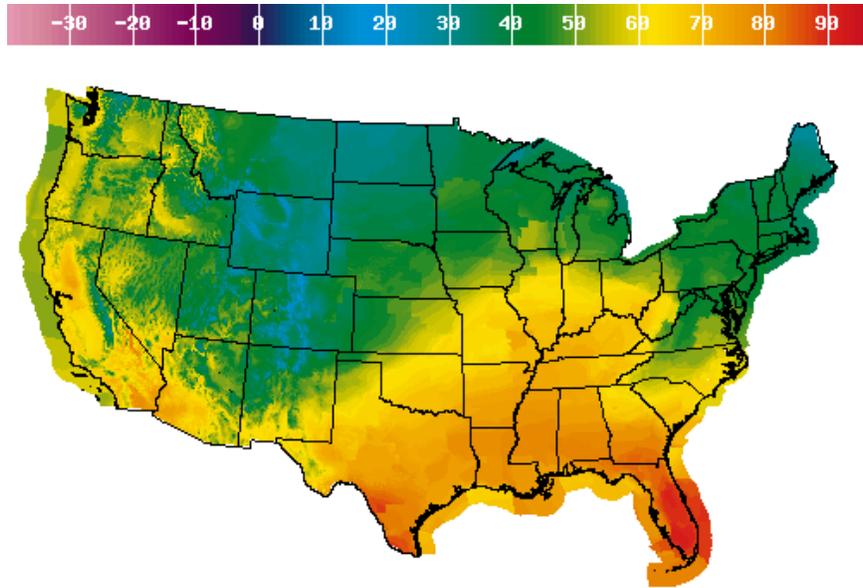
FIG. 1. Max temperature mosaic valid for the daytime period ending 20 Mar 2003, created from input from 116 WFOs.
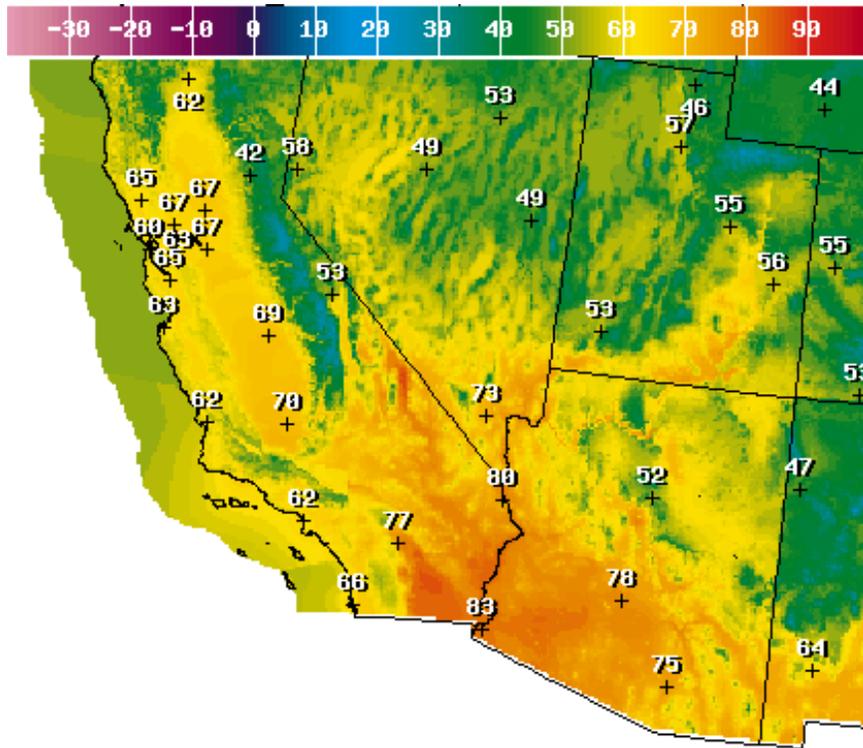

FIG. 2. Max temperature for the southwestern part of the United States for the daytime period ending 27 Mar 2003. The detail is highly dependent on elev (note the detail shown of the Grand Canyon). The plotted values are at ''sample points'' provided by the WFOs; the values are from the closest grid point in the mosaic.

have to be able to handle the ''first-order'' probability model before embarking on a ''second-order'' model.

It is apparent that not all meteorologists use the same terminology. For instance, Cliff states, ''IFPS needs to be enhanced so as to facilitate the communication of forecast reliability. This could include a forecaster providing a subjective measure of the forecast reliability (perhaps on a scale of 1–10) for each forecast hour that would be tagged to the relevant graphics, or the provision of reliability graphics produced objectively, perhaps based on forecast spread.'' By that, he is suggesting one way forecast uncertainty could be communicated. Would a ''scale value of 1'' indicate the forecast is likely to not be right? How right? Exactly right? Within some limit? Apply to the whole grid? Does the concept apply equally to grids covering large or relatively small areas? There is no question uncertainty needs to be expressed—that's what probability forecasting is all about. How to do so is far from clear, especially when one considers the users and what their ''systems'' can absorb.[3]

6. Better use of human resources

IFPS/NDFD is providing a new way for the NWS to provide a better service to the nation. After completion of the current implementation planned for the end of 2003, are we done? Certainly not. This is only the beginning. A new way to better bring the intellect of the forecasters to bear in producing their products has been devised. The product suite is changing; new ways of communicating information are being devised. A part of this tapestry is the continual improvement of numerical models and the accompanying speed of computers to not only run more sophisticated models, but to run several instances of one or more models to produce ensembles. How will the forecaster be able to assimilate all this information? The improvement the forecaster can make for some weather elements, and especially for the longer time ranges, is becoming smaller. Better ways of synthesizing the myriad information into meaningful ''information'' packages are needed so that the forecaster can get off the treadmill and perform the

service aspects of forecast offices that cannot be done by computer, such as, as detailed by Mass (2003), the ''[p]rovision of advisories, watches, and warnings,'' doing other ''[v]ery short-term forecasting,'' and ''[m]onitoring objective forecast systems and intervening when necessary.'' Is it profitable for WFO forecasters to spend time modifying guidance at, say, 5 days and beyond? The verification systems being planned for forecasts from the NDFD will provide objective measures by which such questions can be answered.

As discussed earlier, moving from typing text to producing gridded forecasts was a major paradigm shift. It may be an even bigger paradigm shift to get forecasters to create and customers to use probability forecasts as their main fare. To introduce both of these new concepts at one time would probably have been fatal to the effort. We are successfully introducing one concept now (IFPS) and will introduce the other gradually as we get the tools and understanding in place.

7. Summary

Cliff's paper is most welcome. Through dialogue such as the kind he has initiated, new ideas come forth and improvements can be made as resources allow. Probability forecasting will expand, but there are major challenges. Adjusting to the reality of how and when numerical models and/or their postprocessed products can be improved upon by forecasters needs to be done in a deliberate and organized way. Better service to the nation will result when each component of the production–delivery system is optimally contributing.

Further, this model prescribes that the forecaster modifies p when he receives additional relevant information. However, recent discussions with National Weather Service forecasters have indicated that this model may not provide an adequate description of the behavior of certain forecasters. Apparently, these forecasters express their judgments in terms of a probability distribution $F(p)$ on the probability p, and modify $F(p)$ upon the receipt of additional relevant information. Since p is itself a probability, the distribution $F(p)$ consists of 'second-order' probabilities. Thus, we can refer to the standard model as a *first-order* model and to the model which involves second-order probabilities as a *second-order* model.''

[3] ''Absorb'' could include human comprehension, an automated processing model, or a combination.

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