5.8 **EXPERIENCES WITH A GRID-BASED FORECASTING APPROACH USING IFPS AT THE TULSA WFO**

Steven E. Nelson*
National Weather Service
Norman, OK

Eric Howieson and Steven Amburn
National Weather Service
Tulsa, OK

1. INTRODUCTION

The Interactive Forecast Preparation System (IFPS), planned and developed for nationwide implementation in the National Weather Service (NWS) since the 1980's, is finally here (Ruth, 2002; Mandt, 2002). With IFPS, a NWS Weather Forecast Office (WFO), River Forecast Center (RFC), or National Center can generate multiple products from a single forecast database. The IFPS is a key component of the Advanced Weather Interactive Processing System (AWIPS).

The primary advantage of the IFPS over its previous versions is the ability to interact with and format products directly from a comprehensive gridded database. One of the most powerful tools to interact with the gridded database, the Graphical Forecast Editor (GFE), was recently incorporated into what is now IFPS. The GFE is a product of over 10 years of work by the NOAA Forecast Systems Laboratory (FSL). In previous versions of IFPS, the digital database revolved around matrix editors, in which counties were the smallest editable area.

This paper outlines the early stages of a transition from a county-based forecast methodology to a grid-based forecast methodology using IFPS at the Tulsa WFO. Problems and successes encountered by using this new approach are also described.

2. BACKGROUND

The Tulsa WFO began making operational forecasts from a digital database in 1997, using IFPS's immediate predecessor, the Interactive Computer Worded Forecast (ICWF). The office received this early version in order to demonstrate the IFP concept in AWIPS (Wolf and Helms, 1998). While ICWF product generation was somewhat limited, experimental text products such as the Revised Digital Forecast (RDF) were able to be generated (see Figure 1).

To further demonstrate the IFP concept, a local application was developed at the Tulsa WFO to create a graphical meteogram from the RDF product (see Figure 2). The RDF text product and graphical meteogram were then incorporated into the office's county-based forecast on its web site (http://www.srh.noaa.gov/tulsa). This new county-based forecast was met with a flood of positive comments from users and continues to be the most accessed page on the Tulsa WFO web site, with over 1000 access per day.

* *Corresponding author address*: Steven E. Nelson, National Weather Service Forecast Office, 1200 Westheimer Dr., Room 101, Norman, OK 73069-7902; Email: *steven.nelson@noaa.gov*


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FOUS54 KTSA 292056
RDFTUL

EASTERN OKLAHOMA/NORTHWEST ARKANSAS REVISED DIGITAL FORECASTS
NATIONAL WEATHER SERVICE TULSA OK
400 PM CDT SAT SEP 29 2001

OKZ060-061-064>067-070-071-300941-
CREEK-MCINTOSH-MUSKOGEE-OKFUSKEE-OKMULGEE-ROGERS-TULSA-
INCLUDING THE CITIES OF...BRISTOW...CLAREMORE...EUFAULA...
MUSKOGEE...OKEMAH...OKMULGEE...TULSA
400 PM CDT SAT SEP 29 2001

                 \     SUN  09/30/01     \     MON  10/01/01
CDT          19 22  1  4  7 10 13 16 19 22  1  4  7 10 13 16 19

POP 12HR                 0           0           0           0
QPF 12HR                 0           0           0           0
MN/MX                   46          77          46          80
TEMP         71 60 54 50 47 60 71 76 71 60 54 50 47 62 74 79
DEWPT        52 51 50 49 46 51 50 49 50 50 50 49 46 52 52 51
RH           51 72 86 96 96 72 47 39 47 69 86 96 96 70 46 38
WIND DIR     NE  E SE --  E  E NE NE  E SE  S -- SW SW  W  W
WIND SPD      5  2  2  0  2  2  5  2  2  2  2  0  2  5  5  5
CLOUDS       CL CL CL CL CL CL CL CL CL CL CL CL CL CL CL SC SC

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Figure 1. Example of the Revised Digital Forecast (RDF) product produced from IFPS's predecessor, ICWF.

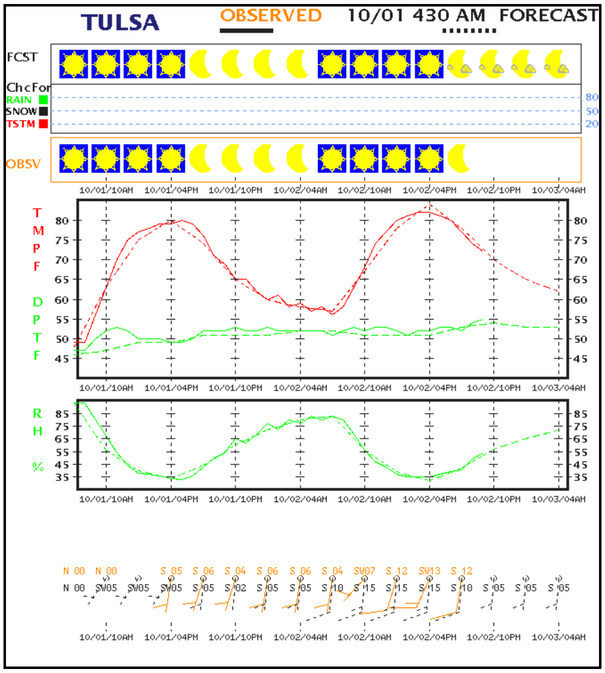

Figure 2. Example of the locally-created Graphical Meteogram derived from the RDF product.

While the new products from ICWF demonstrated the potential of the IFP concept, it was decided that the office could provide even better products with diverse resolution. The office looked toward the NWS vision for that opportunity.

The NWS Vision 2005 for IFPS calls for the NWS to "prepare and disseminate forecast products in digital form that offers high resolution" (http://205.156.54.206/sp/strplan.htm). To many, this indicates that the forecast database should be in a grid format, as opposed to the matrix-based and county-based database in ICWF.

To make this vision reality, the NWS decided to merge the GFE with ICWF to create the IFPS that exists today. With this merger, a powerful grid editing tool could work with the matrix editor in ICWF. While this combination is flexible and brings the best of both applications together, it also allows for very different techniques in forecast methodology, namely a matrix-based approach or a grid-based approach.

3. IMPLEMENTATION OF GRID-BASED FORECASTING

In March of 2001, IFPS was installed on AWIPS at WFO Tulsa and made the operational system for preparing all routine and updated forecasts. However, the problem of how to prepare forecasts with this powerful, yet diverse system immediately arose. Should the office begin using a complete grid-based approach or continue the matrix-based approach of the past?

Ideally, the most efficient way to produce multiple high-and low resolution products from a single digital database was to prepare all forecasts directly on the gridded database using the GFE. Unfortunately, the forecasters at the Tulsa WFO were much more experienced using a matrix-based approach with the old ICWF. Very little time for training on the operational use of GFE had been allotted. Further, the current set of forecast products at the Tulsa WFO originated from the forecast matrices and not the grids.

Because of these obstacles, it was decided to gradually move towards a grid-based forecasting approach. The basic steps to accomplish this would be to configure the software and grid-based product generation, then to train the forecasters on the new approach and suggested methodologies, then begin mandatory use of GFE to prepare gridded forecasts for a few fields, and finally collect feedback from forecasters. This basic approach was to be implemented on a few grids at a time. For instance, the first required grids to edit with GFE would be Temperature and Dew Point Temperature. A few months later, after additional configuration, training, and feedback, Wind and Sky Cover would be required grids to edit with GFE.

It was also decided to use the latest version of GFE on the Linux platform with the IFPS running on AWIPS. The Tulsa WFO forecasters had been exposed previously to the most recent versions of GFE on a Linux platform as part of the Rapid Prototyping Project (RPP) for IFPS (Jannuzzi, 2002). The success of the RPP in the NWS and at WFO Tulsa lended confidence that merging a Linux version of GFE with IFPS would be successful.

Between March and May of 2001, configuration of GFE on a Linux platform occurred. Testing and training of the forecasters began in May. In early June, mandatory use of GFE to edit the Temperature and Dew Point Temperature grids was begun. Forecasters had ready access to "cheat sheets" and references to assist them during the editing process in GFE.

At the time of this writing, forecasters at the Tulsa WFO were editing numerous forecast elements on a high-resolution grid in the GFE (see Table 1).

Forecast Elements	
Temperature	Heat Index
Dew Point	Relative Humidty
Wind	Wind Chill
Sky Cover	1700ft Mix Height
Mixing Height	Low-level Stability
Transport Wind	

Table 1. Forecast elements completely edited with the GFE by Tulsa WFO forecasters as of September 27, 2001.

Another factor that was driving the office toward a grid-based approach was the spin-up of a fire weather program. Prior to 2001, Oklahoma WFOs did not issue routine fire weather forecasts. At the request of state and federal fire management officials, a routine Fire Weather Forecast (FWF) was developed and implemented in March of 2001 at the Tulsa WFO (Taylor and Howieson, 2001).

With IFPS already in place at the office, it seemed sensible to produce the FWF directly from the digital database. Both efficiency and product consistency would be gained. Unfortunately, a supported FWF formatter was not available in IFPS and would not be available for the foreseeable future. It was decided to develop a FWF formatter at the office, which would use both the matrix-

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FNUS54 KTSA 022055

EASTERN OKLAHOMA/NORTHWEST ARKANSAS FIRE WEATHER FORECASTS
NATIONAL WEATHER SERVICE TULSA OK
400 PM CDT TUE OCT 2 2001

.RED FLAG...NONE.

.DISCUSSION...
WARM AND BREEZY CONDITIONS WILL CONTINUE ON WEDNESDAY AS SURFACE LOW
PRESSURE DEVELOPS OVER THE CENTRAL PLAINS. LOW LEVEL MOISTURE WILL
CONTINUE TO INCREASE AHEAD OF A COLD FRONT...THAT WILL MOVE INTO
SOUTHEAST KANSAS WEDNESDAY NIGHT.

OKZ060-061-064>068-070-071-030949-
CHEROKEE-CREEK-MCINTOSH-MUSKOGEE-OKFUSKEE-OKMULGEE-ROGERS-TULSA-
INCLUDING THE CITIES OF...BRISTOW...CLAREMORE...EUFAULA...MUSKOGEE...
OKEMAH...OKMULGEE...TAHLEQUAH...TULSA
400 PM CDT TUE OCT 2 2001

                      TONIGHT           TOMORROW          TOMORROW NIGHT

CLOUD COVER           CLEAR             MOSTLY SUNNY      MOSTLY CLEAR
MAX/MIN TEMPERATURE   54                85                61
MAX/MIN HUMIDITY (%)  86                34                90
AM 20FT WIND (MPH)                      S 8
PM 20FT WIND (MPH)    S 7               S 12              S 7
PRECIP TYPE           NONE              NONE              NONE
PRECIP CHANCE(%)      0                 0                 0
PRECIP AMOUNT (IN)    0                 0                 0
MIXING HEIGHT (FT)    100               5200              0
1700FT MIXHGT T (F)   N/A               73                N/A
TRANSPORT WIND (MPH)  S 1               W 14              W 14
VENTILATION RATE      0                 11400             0
STABILITY             F                 B                 F

.FORECAST EXTENDED...
.THURSDAY...PARTLY CLOUDY. A CHANCE OF SHOWERS AND THUNDERSTORMS IN
THE AFTERNOON. HIGHS IN THE MID 80S. CHANCE OF RAIN 30 PERCENT.
.THURSDAY NIGHT...PARTLY CLOUDY WITH A CHANCE OF SHOWERS AND
THUNDERSTORMS. LOWS IN THE MID 50S. CHANCE OF RAIN 30 PERCENT.
.FRIDAY...A CHANCE OF SHOWERS AND THUNDERSTORMS EARLY...OTHERWISE
PARTLY CLOUDY. HIGHS IN THE LOWER 60S.
.SATURDAY...MOSTLY CLEAR. LOWS NEAR 40 AND HIGHS NEAR 70.
.SUNDAY...PARTLY CLOUDY. LOWS IN THE LOWER 50S AND HIGHS IN THE
UPPER 70S.
.MONDAY...PARTLY CLOUDY WITH A CHANCE OF SHOWERS AND THUNDERSTORMS.
LOWS IN THE UPPER 50S AND HIGHS IN THE MID 80S.
.TUESDAY...MOSTLY CLOUDY WITH A CHANCE OF SHOWERS AND THUNDERSTORMS.
LOWS IN THE LOWER 60S AND HIGHS NEAR 80.
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Figure 3. Example of the Fire Weather Forecast (FWF) product produced by a locally-developed formatter in IFPS.

based data and gridded data in GFE. After development and testing, the FWF formatter was introduced at the start of the routine issuance of the FWF. The formatter produces both a text product (see Figure 3) as well as data that feeds a web-based fire weather display (http://www.nwstulsa.noaa.gov/cgi-bin/fwf.pl).

With the addition of the routine FWF, the total number of official text products produced from a digital database at the Tulsa WFO had increased to seven (see Table 2 for a complete list).

Text Products Produced with IFPS	
Area Forecast Discussion*	Area Forecast Product
Coded Cities Forecast	Fire Weather Forecast
Zone Forecast Product	NFDRS Point Forecasts
Revised Digital Forecast	

* Tabular portion only

Table 2. Text products produced entirely with IFPS by the Tulsa WFO as of September 27, 2001.

4. BENEFITS FROM A GRID BASED APPROACH

The benefits from switching to a grid-based forecasting methodology in IFPS were revealed quickly, particularly in the light of new avenues of communication. With its broad reach and ease of use, the Internet has opened the doors to the delivery of modernized and experimental products. IFPS excels at the production of products delivered via the Internet. Products can be formatted in multiple formats, text, image and grid. Web-based applications can be developed to interact with the grids directly. IFPS products produced from a grid are also not constrained by political boundaries, such as with text products based on counties. Benefits were also obtained by the forecaster using the system. The forecaster can concentrate on editing features on whichever scale he or she chooses, rather than on a county-based system only.

4.1 Graphical Forecasts

Several grid-based products are being produced from the Tulsa WFO IFPS. Figure 4 shows a typical image produced from the office's GFE. Maps, data, and other overlays can all be easily customized. A web-based application was developed at the Tulsa WFO to display a time series of these forecast images from the local forecast as well as from model forecasts directly. The application also displays a table of values valid at each county that corresponds to the image. Readers are encouraged to visit http://www.nwstulsa.noaa.gov/cgi-bin/forecast.pl to use this application in real-time.

4.2 Web-Based Interactive Application (EMDS)

Another web-based application that leverages the gridded forecast database at the Tulsa WFO is the Emergency Management Decision Support (EMDS) system. EMDS was developed by FSL and has been in

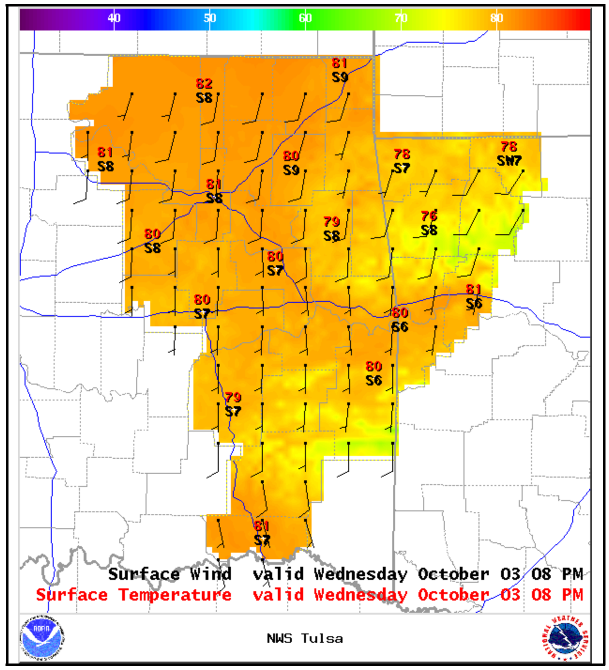

Figure 4. Temperature and wind forecast image produced by GFE in IFPS.

use at the office since December of 1999. The main purpose of EMDS is to provide a means of disseminating the large suite of products issued by the modernized WFO to weather sensitive users in the field. The EMDS is a client-side java applet/application that displays weather information in a highly graphical, multi-windowed, multi-modal display. General features of the EMDS include looping, zooming, and auto updating of contour and image type products. In addition, the EMDS displays NWS text products and will automatically update when a new product is sent from the WFO.

In July 2001, the Tulsa WFO became the first NWS office to disseminate graphical products generated in the GFE via the EMDS. After the forecaster has completed drawing the grids for all fields, the grids are sent directly from the GFE to the Local Data Acquisition and Dissemination (LDAD) system. One of the significant differences between the EMDS and displaying static images on the Internet is that the EMDS actually displays the grid data and not just a static image. This allows the EMDS user to sample the image or contour overlay, or a combination of image and contour overlay, to get more precise readouts. A majority of the current suite of products generated by the Tulsa forecasters using GFE can be displayed through the EMDS by default. These fields include Max/Min Temperature, Temperature, Dewpoint, Wind, Probability of Precipitation (PoP), Total Precipitation, Percent Cloud Cover, Mixing Height, and Transport Winds. Most of these parameters can be displayed either as images or as contours. The Wind and Transport Winds can also be displayed as vectors. Additional fields can be displayed as they become available from the GFE. The ability for the Tulsa WFO to provide this type of data to its Emergency Management and Forestry community has greatly enhanced their abilities to stay up to date on the latest and most accurate weather conditions (Taylor and Howieson 2001).

4.3 National Digital Forecast Database (NDFD)

The NWS has recently begun a project to produce a seamless mosaic of forecast grids produced by all WFOs. The National Digital Forecast Database (NDFD) is projected to be a prominent source of operational forecasts to large groups of users, including the private, public and university sectors (Mandt, 2002).

The Tulsa WFO is part of the early stages of NDFD testing. The office recently upgraded its GFE software that includes an Intersite Coordination (ISC) capability to share grids with a central facility as well as neighboring WFOs. The ISC capability is being tested at the time of this writing.

5. CHALLENGES TO A GRID-BASED APPROACH

Several obstacle to making a grid-based approach to forecasting succeed were discovered. While some hurdles were discovered quickly, most were found after significant time had past.

5.1 Training on Rapidly Evolving Software

A major obstacle in the short-term at the Tulsa WFO has been providing sufficient training. The NWS plan for IFPS training has used a "train-the-trainer" approach, where two staff from each WFO attends a 2 week resident course (Beckman, 2002). Unfortunately, since the two staff must go back to train the rest of the forecasters, the results are not always uniform and in many cases insufficient.

An additional problem that is occurring at the Tulsa WFO is that because the GFE is a rapidly evolving part of IFPS, it is very challenging to keep forecasters up-to-date on the new features and methodologies available to make a forecast. The short-term answer at the Tulsa office is to provide incremental training as major new features are introduced. This problem is likely unavoidable and might actually be considered a "good problem" due to the rapid improvements to the software.

5.2 Technical Limitations

Some of the main obstacles to successful grid-based forecasting are technical in nature. The GFE runs on a linux platform with high-performance PC architecture. While the GFE runs at acceptable levels at 10 km or even 5 km, the performance drops rapidly at higher resolutions. At WFOs where precise handling of steep terrain and marine areas is crucial, this limitation will be sizable. Fortunately, this limitation will decrease with time as PC-based technology improves and software efficiency improvement continue to occur.

Another technical limitation has to do with grid-based product dissemination, rather than with forecasting. In the NWS, web hosting to the 120 or so WFOs in the continental U.S. is provided by only 4 regional centers. Most administrators and customers of NWS web services agree that capacity and bandwidth considerations were initially underestimated. This problem has not been resolved at the time of this writing. With the introduction of hundreds of images, interactive web-based applications like EMDS, and very large grid files themselves into the product stream delivered on the Internet, the capacity and bandwidth at the regional centers will be sorely tested and will likely be insufficient to meet everyday demand, let alone peak demand. This limitation alone may be sufficient to cause IFPS to never meet its objectives of delivering high-resolution information to users.

5.3 No Precedent for Grid Forecasting

Perhaps the largest impediment to grid-based forecasting are the forecasters themselves. NWS forecasters have been producing forecasts pretty much the same way for the last 50 years prior to IFP. Observations and, more recently, computer forecasts, are analyzed, conceptual models are used to process the data into a forecast scenario, and finally the forecast scenario is turned into a worded forecast. To deal with forecast uncertainty, The worded forecast is prepared with an appropriate amount of "vagueness".

In the IFP era of forecasting, NWS forecasters explicitly edit a high-resolution (less than 5km spacing) gridded database. While the observations and computer forecasts are increasing in resolution, there is little training and experience for human forecasters on such scales. Forecasters have less understanding of any relevant conceptual models appropriate for high-resolution forecasts. Classic conceptual models such as quasi-geostrophic theory, large-scale convective system understanding, and knowledge of point-based climatology may not also not apply to editing data on a grid. To help combat this problem, the Tulsa WFO will be creating a high-resolution grid of "climatology" for a few fields initially. This climatology will be computed from 1 to 2 years worth of data from the Automated Surface Observing System (ASOS) network and Oklahoma Mesonetwork (Crawford, 2002) across Eastern Oklahoma and Northwest Arkansas.

There is also a problem of too much implied accuracy in an explicit high-resolution gridded forecast. In the past, forecasters introduced uncertainty through "vagueness" within a worded forecast. This problem is similar to that of a singleton forecast by a computer model, where only one exact solution is produced from the numerous possible solutions (caused by unpredictable model, analysis, and observational errors). To combat this problem, one could introduce uncertainty directly into the gridded forecasts, through probabilities as opposed to explicit forecasts. With ensemble models becoming operational, forecasters could receive some objective guidance on the amount of uncertainty. Such a change in forecasting may be practical in the short-term however and must be carefully considered.

5.4 Other Limitations

Some other obstacles are impeding progress with a grid-based forecasting approach. One significant problem is the limitation placed on text product development directly from the gridded data. While this is obviously a desirable feature and in many ways superior to county-based (matrix-based) text products, development has been slowed. Freeing up all possible ways to produce products from the high-resolution data directly will help encourage forecasters to do their work in the grids. It will also improve product quality.

6. SUMMARY

The early stages of the implementation of IFPS at the Tulsa WFO are described, and in particular the transition to a grid-based forecast methodology. While there are significant obstacles, it is hoped they will eventually be overcome. Indeed, if this forecasting methodology can succeed, no longer will NWS products be constrained to county-based, low-resolution text products. A wealth of information in various formats can easily be provided to users of different needs -- all from a single high-resolution database.

7. ACKNOWLEDGMENTS

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