# THE NEW DIGITAL FORECAST DATABASE OF THE NATIONAL WEATHER SERVICE

BY HARRY R. GLAHN AND DAVID P. RUTH

This new database capitalizes on the revolutionary way NWS forecasters are working together to make their high-resolution, up-to-date forecasts available to the nation.

Many technological advances and scientific breakthroughs have allowed the National Weather Service (NWS) weather forecasts and warnings to become much more specific and accurate. Better ways of communicating weather information to potential users have been devised. Partnerships with commercial enterprises have been forged as a way for much of the information to flow to the public and other users.

However, the production and dissemination of routine National Weather Service forecasts must keep pace with the need for such information in this digital age. A primary means of providing sensible weather element forecasts (e.g., cloud cover, maximum temperature) from NWS Weather Forecast Offices (WFOs) is still textual in form. The flagship product of the NWS for years has been the zone forecast: a brief, plain-English description of what the weather will be over the next few days for a multicounty area. Similar text, containing much of the same information, is produced to support marine and federal fire weather interests and emergency managers. Some of these products are voiced over the National Oceanographic and Atmospheric Administration (NOAA) Weather Radio. In the past, because such textual products have been composed on word-processing equipment, the output of the forecast staff has been essentially limited by typing speed. The new Interactive Forecast Preparation System (IFPS; Ruth 2002) circumvents this, providing not only for familiar textual and voiced products, but also providing in digital (i.e., numerical) form the data from which these products are prepared. These digital forecasts are being put into a National Digital Forecast Database (NDFD) and will be made widely available to partners and customers.

Once a database of local forecasts exists at a WFO, today's forecasters can produce textual, graphic, and voiced products automatically by software. In essence, the forecaster now enters the forecast variables in digital form instead of redundantly typing several products containing largely the same information. But the real power of a digital database is that it opens the door for providing much more forecast information and in more useful forms. The NDFD will con-

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NYZ047-051-054-058-061-MAZ001-082241-
BERKSHIRE-EASTERN COLUMBIA-EASTERN RENSSELAER-SCHOHARIE-
WESTERN ALBANY-WESTERN GREENE-
400 AM EST SAT DEC 8 2001

...WINTER STORM WATCH FOR SATURDAY NIGHT...

.TODAY...PARTLY SUNNY THROUGH EARLY THIS AFTERNOON...THEN BECOMING
MOSTLY CLOUDY.  HIGHS IN THE MID 30S.  LIGHT EAST WIND.
.TONIGHT...SNOW.  SNOW ACCUMULATION 4 TO 6 INCHES. LOWS IN THE UPPER
20S.  EAST WIND 10 TO 15 MPH.  CHANCE OF SNOW NEAR 100 PERCENT.
.SUNDAY...SNOW LIKELY...ENDING IN THE MORNING.  PARTLY SUNNY FROM
LATE MORNING ON.  TOTAL ACCUMULATION OF 7 OR MORE INCHES POSSIBLE.
HIGHS IN THE MID 30S.  NORTH WIND AROUND 15 MPH.  CHANCE OF SNOW 70
PERCENT.
.SUNDAY NIGHT...CLEAR.  LOWS IN THE MID 20S.
.MONDAY...SUNNY.  HIGHS IN THE LOWER 40S.
.MONDAY NIGHT...PARTLY CLOUDY.  LOWS IN THE UPPER 20S.
.TUESDAY...MOSTLY CLEAR.  HIGHS IN THE LOWER 40S.
.WEDNESDAY...PARTLY CLOUDY.  LOWS IN THE MID 20S AND HIGHS IN THE MID
40S.
.THURSDAY...CLOUDY WITH A CHANCE OF RAIN.  WINDY.  LOWS IN THE UPPER
30S AND HIGHS IN THE LOWER 50S.
.FRIDAY...PARTLY CLOUDY WITH A CHANCE OF SNOW SHOWERS.  LOWS IN THE
UPPER 20S AND HIGHS IN THE MID 30S.
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**FIG. 1. Textual zone forecast from Albany, NY.**

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NYZ047-051-054-058-061-MAZ001-082041-
BERKSHIRE-EASTERN COLUMBIA-EASTERN RENSSELAER-SCHOHARIE-
WESTERN ALBANY-WESTERN GREENE-
341 AM EST SAT DEC 8 2001

              SAT  12/08/01     \     SUN  12/09/01     \     MON  12/10/01
EST        03 06 09 12 15 18 21 24 03 06 09 12 15 18 21 24 03 06 09 12 15 18

POP 12HR                  20          100           70           20           10
QPF 12HR                   0       .50-.99       .10-.24           0            0
MAX QPF                    0       .50-.99       .10-.24           0
SNOW 12HR              00-00          4- 8
MX/MN                     35           28           36           24           41
TEMP            22 27 32 34 31 31 31 32 33 34 32 31 30 29 29
WIND CHILL         21 27 29 22 20 20 20 22 23 24 22 20 21 20 20
DEWPT           19 19 22 23 25 25 26 27 28 28 28 27 26 26 26 25
RH              88 71 66 64 78 78 81 85 85 82 78 82 81 85 88 85
WIND DIR        SE  E  E  E  E  E  E NE  N  N  N NW NW NW NW NW
WIND SPD         2  5  5  5 10 15 15 15 15 15 15 15 15 10 10 10  5  5 10 10
CLOUDS          SC B1 B2 B2 OV OV OV OV OV B2 B2 B1 CL CL CL SC CL CL CL CL
SNOW                        D  D  D  D  L  L


             \TUE 12/11/01\WED 12/12/01\THU 12/13/01\FRI 12/14/01
EST        21 03 09 15 21  03 09 15 21  03 09 15 21  03 09 15 21

POP 12HR      10    10    10    10    20    50    50    40
MX/MN         29    42    25    44    39    53    27    34
CLOUDS        SC    SC    SC    SC    B2    OV    B1    B1
RAIN                                          C     C
SNOW SHWRS                                                C
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**FIG. 2. Digital forecast for the same zone and time as shown in Fig. 1.**

tain much more data than the NWS was previously able to provide, at timescales as small as hourly and space scales of a few kilometers. For instance, instead of the textual zone forecast shown in Fig. 1, a digital forecast for the same area is shown in Fig. 2. While each of these forecasts has its use today, and both were produced from the local digital database at WFO Albany, New York, the product in Fig. 2 contains much more information.

The NDFD will be the first product of its kind in the United States and, to our knowledge, in the world. The official forecasts of the sensible weather elements are largely produced by WFOs; however, some official products will be provided by the National Centers for Environmental Prediction (NCEP), such as maximum expected winds from hurricanes, offshore marine products, and climate forecasts.

NDFD will start in 2003 for the 50 states and Puerto Rico, and will eventually cover ocean areas where the United States has forecast responsibility. It may also grow to encompass digital descriptions of meteorological features such as frontal boundaries and areas of high risk weather.

**INTERACTIVE FORECAST PREPARATION SYSTEM.** The creation of NDFD starts with the formulation of digital forecasts at each WFO. This, in turn, required the development and implementation of efficient methods whereby the results of the thought processes of WFO forecasters could be put into digital (or numerical) form. IFPS has been developed for this purpose. It has been under development for a number of years (Ruth et al. 1998; Peroutka et al. 1998), but the processing power of the Advanced Weather Interactive Processing System (AWIPS; Seguin 2002) was necessary to make it feasible nationwide.

What does it mean to "make digital forecasts?" All information in a digital computer is digital. Putting a few forecasts into AWIPS is no trick; they can be simply typed in. But it is no small task to enter the large number of values needed to represent forecast conditions at the needed space and timescales for even some relatively small area such as a county-sized zone from the present out to a few days. Further, a WFO is responsible for making forecasts for areas much larger than a single county.

IFPS incorporates three methods for entering digital forecasts into the database (Ruth 2000): matrix entry, graphical entry, and model interpretation.

- *Matrix entry.* The Interactive Computer Worded Forecast (ICWF); (Ruth and Peroutka 1993) employed this method, making interactive earlier technology for producing text from digital fore-

casts (Glahn 1970, 1979), and has been integrated into IFPS. While this method was successful (Rezek 2002; Dickman 2002) and still provides a method for "fine tuning" data entered by other methods to specific times and locations, it has been largely replaced by the graphical method.

- *Graphical entry* can insert forecasts into a gridded database at a spatial resolution essentially bounded only by computer power (Wier et al. 1998). The graphics depict an underlying grid of values. The forecaster works with the graphics until he or she is satisfied them. Then, the underlying grid becomes the "forecast."
- *Model interpretation* involves working directly with numerical model output (Ruth 1998) or its interpretation (e.g., Model Output Statistics; MOS) to forecast sensible weather elements. Model interpretation, through IFPS, requires a higher level of understanding and training and is not yet being used at most WFOs. As weather prediction models improve, direct interaction with the models through this interface will probably become more prevalent.

Each of these interfaces provides a viable way of entering data into the digital database. The forecasters at WFOs choose the interfaces they use. The forecasts can have a time resolution of 1 h at short ranges and 3 or 6 h at longer ranges. Spatial resolution is expected to be at least as fine as 5 km with full implementation of IFPS in 2003. These digital forecasts automatically result in the routine textual (Peroutka et al. 1998) and voiced (Calkins et al. 1998) forecasts, and also experimental graphic products (LeFebvre et al. 1996; Dickman 2002).

The WFO digital forecasts are updated as the need arises; they become official at a designated "effective" time when entered into the NDFD. It is expected that the NDFD can be updated hourly. This does not mean that all forecasts in the NDFD will be updated hourly, but usually only a small portion affecting limited areas and/or periods.

The digital database makes the updating of forecasts easier. For minor or only moderate changes, the forecaster at a WFO can change a few numbers or grids, and a whole suite of textual, voiced, and graphic products can be generated automatically. No longer does each product have to be updated individually. This illustrates the concept of "nudging" the forecast database that is in vogue now; once the decision is made that a change is needed, the current database is nudged to make the new forecast. Time saved in creating products will allow forecasters time to apply science in their analysis. However, sometimes numerical model results will make wholesale changes necessary.

**COMPOSITION OF THE NDFD.** For each weather element and each time projection, the individual grids from the WFOs are entered into the NDFD. The grids sent by the WFOs do not overlap each other except for a narrow boundary. The NDFD always contains a current set of forecasts, as provided by the WFOs. Time and spatial resolution varies by weather element and projection as appropriate for user needs, forecast skill, and forecaster work load. The national grids are mosaics of these individual grids. The NDFD will also contain watch and warning information and weather elements from NCEP centers such as marine and climate products.

It is a challenge to insure the mosaicked grids are "seamless" at the boundaries between WFO areas. Discontinuities are much more apparent when finescale grids are abutted than with the current set of NWS products. Thus, collaboration among NCEP and WFOs to ensure consistent forecasts is critical. Collaboration is carried out at three levels—among NCEP and WFOs, between adjacent WFOs, and a final quality control check at the NDFD central server and at NCEP.

- *NCEP–WFO collaboration.* The role that NCEP's Hydrometeorological Prediction Center (HPC) plays in the production of guidance for WFOs is changing dramatically with the introduction of the NDFD. Rather than distributing general guidance in graphical and textual form to WFOs as in the traditional process (see Fig. 3), HPC provides digital guidance more specific in space and time. Forecasters at HPC, as usual, judge the strengths and weaknesses of output from NCEP's numerical models as well as model output from other countries. In addition, in this new paradigm, HPC critically analyzes the NDFD to see what areas or forecast projection may need updating. HPC initiates collaboration with WFOs in the affected areas, and together they judge the evolution of meteorological events (see Fig. 4). In this process, HPC issues digital guidance targeted for the affected areas. Collaboration can also be initiated by any of the WFOs.

  This change in HPC operations is critical to the success of the NDFD and truly makes NCEP and the WFOs a team in producing official products. While the WFOs have responsibility for the production and accuracy of their gridded products, NCEP is playing a much larger role than in the past in forecast preparation, especially at longer time ranges.

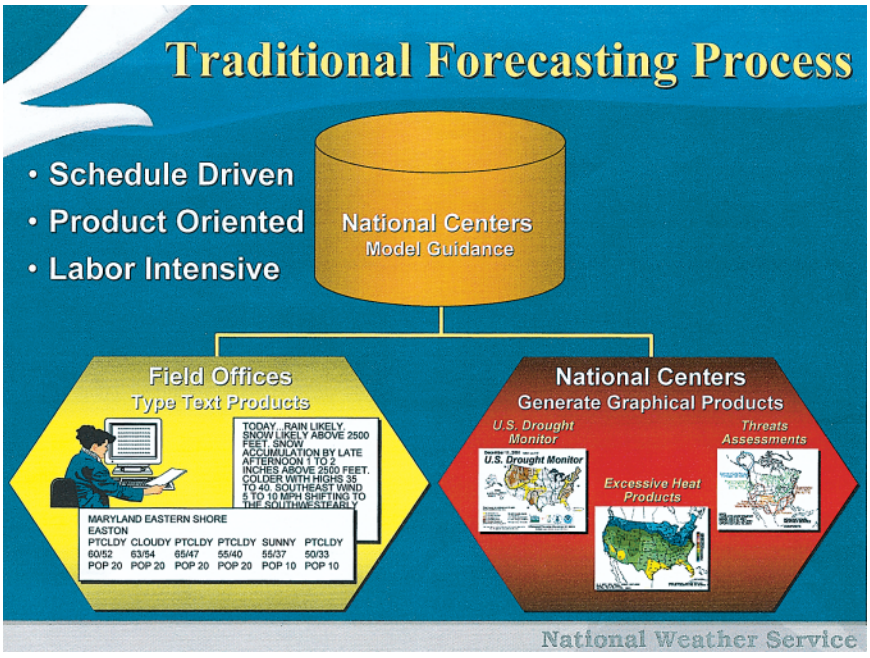


**Fig. 3. Traditional process for NCEP distributing guidance to WFOs and products being prepared.**

- *WFO–WFO collaboration.* Once the NCEP–WFO collaboration is under way or complete, the WFOs produce their grids via IFPS. Subsets of these grids are sent to the neighboring WFOs; software allows simultaneous viewing of grids from both WFOs, and provides chat capability to facilitate boundary consistency. Thus, after NCEP–WFO collaboration sets the stage, the WFOs refine and tailor to terrain, etc.
- *Central quality control.* When the forecast grids from the WFOs arrive at the NDFD central server, they are automatically checked by software for consistency at the boundaries. If a discontinuity greater than the agreed upon threshold is detected, the submitting WFOs are automatically notified of a potential problem. The WFOs have the opportunity to modify their submissions to make them more compatible with their surroundings. NCEP will also have the opportunity to view the mosaic and offer suggestions to the WFOs. As a last resort, a consensus forecast may be calculated at WFO boundaries.

This three-pronged collaboration toward producing a "consistent" mosaic should, with practice, perseverance, and dedication yield the desired results. The collaboration among NCEP and the WFOs, and the increased emphasis on consistency, should also produce more accurate forecasts.

Forecasters at NCEP will be relieved of producing those national products that can be produced automatically from the NDFD, such as temperature and probability of precipitation. At the same time, this assures that these national products are consistent with any locally produced products; consistency is achieved because the locally produced products, generated from the local digital databases, will be reflected in the NDFD, which is composed of the local databases (see Fig. 4).

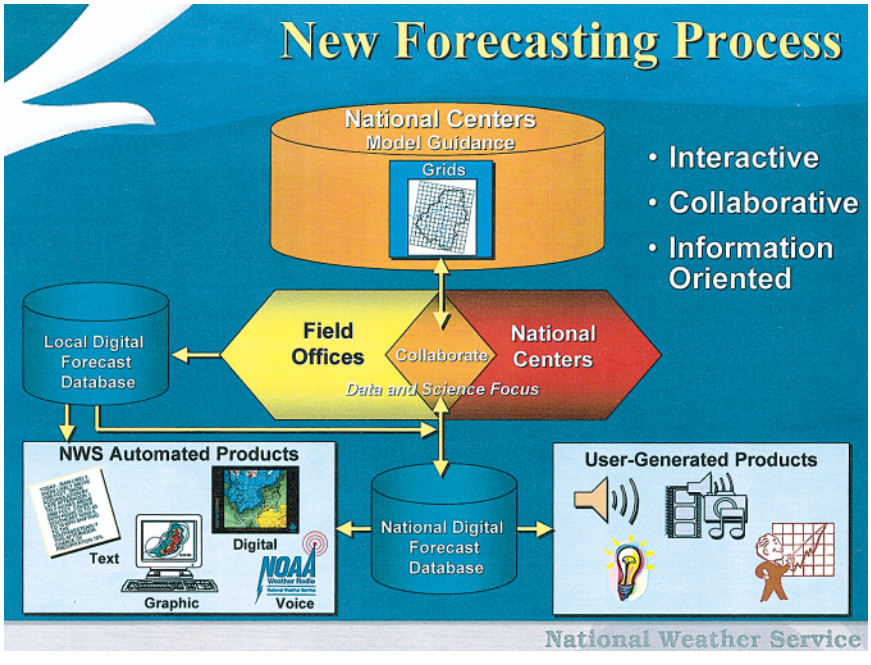


**Fig. 4. New paradigm of collaboratively preparing forecast products.**

**AVAILABILITY OF NDFD.** The NDFD should be a boon to the commercial meteorology, broadcast, and risk management industries that rely on ready and efficient access to NWS data. The NWS intends to make the entire NDFD available to customers and partners. This will be done in a multistep process, as software, techniques, and work patterns at NCEP and the WFOs are established. The dissemination of this database will be largely "pull" rather than "push" as is currently done with most official NWS forecast products. By the end of 2003, the NWS plans to make available those grids produced by WFOs. These will be in "mosaic" format, although work will still be in progress to assure consistency at WFO boundaries. A few national graphics produced from these grids will be available, such as temperature and probability of precipitation. The NWS already produces such graphic products, but not from a digital database; graphics will be prepared this way for efficiency and to ensure consistency of those products with the NDFD.

Later, mosaicked grids will be available in "packages" small enough to be dealt with by a variety of users. A single grid at 5 km or finer resolution over the United States is quite large. To get a picture of the weather over even a small time period of a day or two will require a large transfer of data. A user may not be able to deal with this quantity of data and may only be interested in, say, the southeastern seaboard. Also, the full spatial resolution available may not always be needed. Packages of data small enough to meet the user's needs will be provided, probably in late 2004, by either reducing the area covered or by decreasing the resolution or both. Note that this is just the basic NWS data being furnished in a mode that the user can accommodate, and is consistent with today's practice of providing data in modes that the user can handle. These packages are not specially tailored, value-added products for a specific clientele; such products are left for the commercial enterprises to provide, and the NDFD opens the door to an essentially unbounded array of such specialized products.

Dissemination of highly time-critical forecasts and warning such as severe thunderstorm and tornado warnings will not rely solely on the NDFD; NWS will issue these life-saving forecasts in the usual manner; however, this information will also be part of the NDFD.

**BENEFITS OF THE NDFD.** Benefits of a digital database are both external to the NWS and internal. Partners in the production and dissemination of weather forecast products should find the NDFD a gold mine of information. It will be up to date, with the exception of time-critical warnings that are disseminated within seconds by other means, and will be national in scope. It will eventually contain essentially all the basic information from which forecasts are produced by NWS. Businesses will be able to produce a plethora of products, either general information for radio and television broadcast, or tailored products for specific customers. For instance, forecasts for a drive across country with projections matched to user itinerary can be provided. Teaming this database with geographic information systems (GIS) will provide very powerful capabilities. The NDFD will give customers what they want when they need it (see Fig. 5).

Commercial products available today that provide point forecasts or large-scale graphics sometimes rely on direct model output or the algorithmetic interpretation of model output (e.g., MOS). The NDFD will

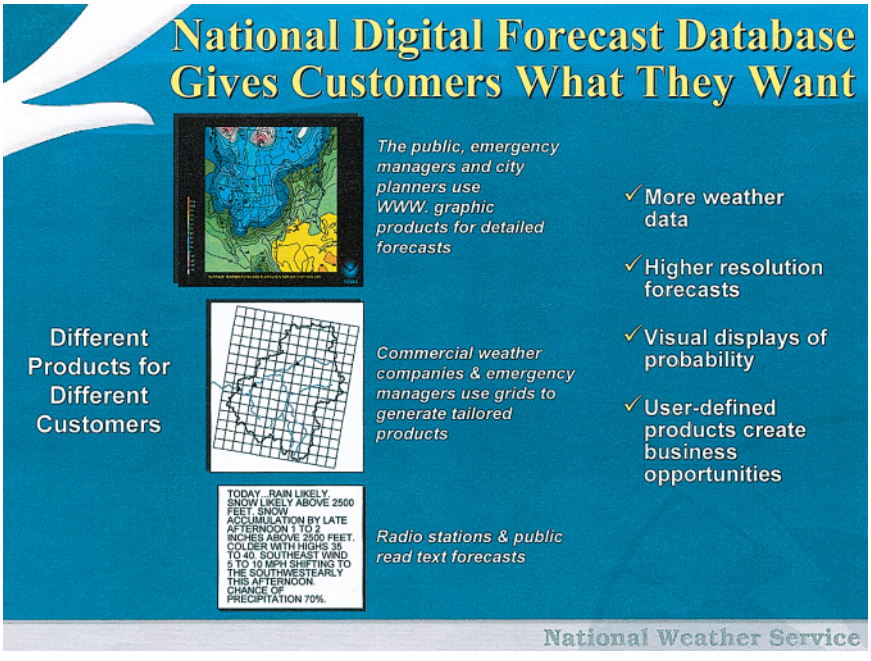


**FIG. 5. The new forecast and distribution process will be more responsive to the needs of customers and partners.**

be the source of more accurate official NWS forecasts produced by forecasters at WFOs and NCEP; previously such digital forecasts were not available.

Any individual user with a computer and access to the Internet will be able to download information from the NDFD to suit his or her needs. No longer will this customer have to wait for the timed broadcast of weather information, but can time the receipt of specific information needed to his or her schedule. The NDFD will provide a veritable data mine for every person in the United States with a computer; as such, it will be a one-stop shopping center for NWS forecasts and underlying data. Where commercial enterprises have in the past had to rely on direct model output or postprocessed products such as MOS, they will now be able to use the official NWS forecasts because they will be in digital form and be available from a single source.

It is also expected that through the much enhanced collaboration among NCEP and WFOs and between the adjacent WFOs, the resulting forecasts will be more accurate than in the past. The NDFD and its associated IFPS will usher in a new paradigm for producing and disseminating forecasts and a new plateau for the NWS in providing service in the nation.

**STATUS OF THE NDFD.** IFPS is currently being implemented nationwide with a target completion of 30 September 2003 for the conterminous states and 31 December 2003 for Alaska, Hawaii, and Guam. Many WFOs are already using IFPS to produce the full range of routine products (Dickman 2002). Three NDFD prototype areas have been established, and the WFOs in those areas are sending their grids to the NDFD central server on which the NDFD software is being developed and the NDFD prototyped. HPC is providing guidance specifically for the 17 WFOs in the prototype areas, and its full responsibilities will be dispatched when the NDFD is in full test mode in the summer of 2003. It is planned that the data from the NDFD will be provided in GRIB, edition 2 (see WMO 2001), for which decoding software is available online at www.nws.noaa.gov/mdl/iwt (see Glahn and Lawrence 2002).

Test data will be made available before full implementation. Current information on IFPS and NDFD can be found online at www.weather.gov/ndfd.

## REFERENCES


Calkins, J., M. R. Peroutka, R. K. Meiggs, and J. P. Lang, 1998: Creating NOAA Weather Radio broadcast scrips using interactive forecast preparation. Preprints, *14th Int. Conf. on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology,* Phoenix, AZ, Amer. Meteor. Soc., 355–358.

Dickman, I. R., 2002: NWS Eastern Region Interactive Forecast Preparation System (IFPS) Implementation. Preprints, *Interactive Symp. on the Advanced Weather Interactive Processing System (AWIPS),* Orlando, FL, Amer. Meteor. Soc., 28–32.

Glahn, H. R., 1970: Computer-produced worded forecasts. *Bull. Amer. Meteor. Soc.,* **51,** 1126–1131.

——, 1979: Computer worded forecasts. *Bull. Amer. Meteor. Soc.,* **60,** 4–11.

——, and B. Lawrence, 2002: GRIB2: The WMO standard for the transmission of gridded data—Current status and NWS plans. Preprints, *Interactive Symp. on the Advanced Weather Interactive Processing System (AWIPS),* Orlando, FL, Amer. Meteor. Soc., J267–J269.

LeFebvre, T. J., C. Bacco, and M. Romberg, 1996: Gridded forecast products and services under development at FSL. Preprints, *15th Int. Conf. on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology,* Norfolk, VA, Amer. Meteor. Soc., 473–476.

Peroutka, M. R., R. K. Meiggs, and M. B. Romberg, 1998: The generation of products in interactive forecast preparation. Preprints, *14th Int. Conf. on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology,* Phoenix, AZ, Amer. Meteor. Soc., 350–354.

Rezek, A., 2002: Changing the operational paradigm with Interactive Forecast Preparation System (IFPS). Preprints, *Interactive Symposium on the Advanced Weather Interactive Processing System (AWIPS),* Orlando, FL, Amer. Meteor, Soc., 23–27.

Ruth, D. P., 1998: Model interpretation using slider bars in interactive forecast preparation. Preprints, *14th Int. Conf. on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology,* Phoenix, AZ, Amer. Meteor. Soc., 464–468.

——, 2000: Models, forecasters, and interactive forecast preparation in the new millennium. Preprints, *16th Int. Conf. on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology,* Long Beach, CA, Amer. Meteor. Soc., 82–85.

——, 2002: Interactive Forecast Preparation—The future has come. Preprints, *Interactive Symposium on the Advanced Weather Interactive Processing System (AWIPS),* Orlando, FL, Amer. Meteor. Soc., 20–22.

——, and M. R. Perotka, 1993: The Interactive Computer Worded Forecast. Preprints, *9th Int. Conf. on Interactive Information and Processing Systems for Meteo-*

*rology, Oceanography, and Hydrology,* Anaheim, CA, Amer. Meteor. Soc., 321–326.

——, M. A. Mathewson, T. J. LeFebvre, and P. K. Wu, 1998: Interpretation and editing techniques for interactive forecast preparation. Preprints, *14th Int. Conf. on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology,* Phoenix, AZ, Amer. Meteor. Soc., 345–349.

Seguin, W. R., 2002: AWIPS—An end-to-end look. Preprints, *18th Int. Conf. on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology,* Orlando, FL, Amer. Meteor. Soc., J47–J51.

Wier, S., M. Mathewson, and T. J. LeFebvre, 1998: Grid editing for the interactive forecast preparation system. Preprints, *14th Int. Conf. on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology,* Phoenix, AZ, Amer. Meteor. Soc., 469–473.

WMO, 2001: *Manual on Codes,* FM 92-XII GRIB (General Regularly-Distributed Information) in Binary Form, Vol. 1.2, WMO No. 306, WMO, 76 pp.