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OPERATIONAL FORECASTING WITH AFPS

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1. INTRODUCTION

Anticipating the chance to improve the efficiency and quality of weather forecasting, the National Weather Service (NWS) Office of Meteorology (OM) sketched out a new operations concept as part of the overall modernization (NWS, 1994). The concept radically alters operational forecasters' duties. Rather than express the forecast in words, the forecaster would initialize and maintain a set of digital forecasts over the forecast area. From this forecast database, routine forecast products would be automatically generated, examined by the forecaster, and disseminated.

To support this concept, the NOAA Forecast Systems Laboratory (FSL), in conjunction with the National Weather Service Techniques Development Laboratory (TDL), has been tasked to build the AWIPS Forecast Preparation System (AFPS). The AFPS concept (NOAA, 1993) and development work comprise three broad categories: initializing graphical depictions of weather elements, editing those depictions, and generating forecast products. Currently, FSL is developing prototypes that address the initialization and graphical editing components. Earlier prototypes are described by Wakefield et al. (1993) and by Wakefield and Mathewson (1994).

This paper is describes the AFPS as it applies to this new concept so that the forecast community can be alerted to these revolutionary changes. The introduction of the AFPS promises not only to alter operational procedures but to fundamentally change the way the forecasters approach the forecast process. We envision that forecasters will spend roughly one-third of their forecast shift, the time currently spent composing text products, to graphically prepare forecasts using AFPS.

At the outset of the project, the AFPS Forecaster Working Group (AFWG), comprising forecasters with diverse expertise, was formed to provide guidance to the AFPS development team. While this advice has proven to be invaluable, we believe that it is important to invite comments from the entire forecasting community. Without such feedback, the deployment of AFPS becomes a very risky endeavor.

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2. OPERATIONS CONCEPT

Currently, Weather Service forecasters' duties are divided along program lines (e.g., public, aviation, marine). Each forecaster is assigned a particular program and assumes the responsibility for generating a product suite that addresses that program. Many products in the suite contain the same information. Each product is packaged differently to cater to its intended users. After reviewing various observational and guidance data sets, the forecaster formulates the forecast and spends two to three hours composing products at a keyboard. With the exception of watches and warnings, all products are generated according to a relatively fixed product schedule.

In contrast to current operations, forecasters in the AWIPS era will assume responsibility for a particular forecast time period rather than a product suite. As each forecast shift begins, forecasters will participate in a briefing to identify forecast problems and their timing. Based on this briefing, forecasters will agree upon their time-based assignments. Each forecaster then will define and maintain a set of weather forecast elements that describe the state of the atmosphere for their assigned time period. Later, product generators will create text and graphic products based on these weather elements.

These two operational concepts differ radically. Forecasters will no longer express the forecast in words, but rather as digital forecast values using graphical depictions. Since the forecaster is responsible for a time period rather than a product suite, the redundancy associated with composing the same forecast in different products is removed. The tedious chore of typing is greatly reduced, since routine products will be generated automatically. The forecaster will have more time to concentrate on meteorology and be able to place more emphasis on event-based products.

3. OPERATIONS SCENARIO

Given the operations concept outlined by OM and the current AFPS design, which is based on this concept, we present an operations scenario that describes the essence of a typical NWS Weather Forecast Office (WFO) shift using AFPS. We do not imply that this scenario will be adopted or endorsed by the NWS when AFPS is deployed nationwide, but simply present a likely scenario based on current information.

Stage 1 - The Briefing

An AFPS-supported forecast shift begins with forecasters gathering to discuss the various weather regimes expected during the forecast period. The main purpose of the briefing is to determine time-based forecaster assignments. These assignments may be based on when the weather changes from one regime to another or on expected workloads when considering the likelihood of issuing short-fuse warning products.

Stage 2 - View Data

The process of viewing data differs little from how forecasts are done without AFPS. Using an AWIPS workstation, each forecaster examines a variety of observations and forecast guidance, focusing on a particular time period of responsibility. In addition, forecasters will utilize a suite of diagnostic applications to help them analyze the state of the atmosphere. Forecasters assigned to the first few hours will concentrate on observational data and objective analyses which will help them diagnose the current state of the atmosphere. Once mesoscale forecast guidance is running operationally at the forecast office, it will be used to aid in short-term prediction. Forecasters assigned to time periods beyond 12 hours will primarily focus on synoptic scale numerical guidance.

Stage 3 - Initialize Forecast Data

After reviewing the observational and guidance data, the forecaster should clearly understand which guidance datasets provide the best estimate at the future state of the atmosphere. AFPS will generate gridded forecast elements based on synoptic guidance products such as MOS, eta, NGM, observation-based data such as previous observations, climatology, and local-scale models, once they are made available. Forecasters need only to select the desired forecast elements and insert them into the forecast database. Usually, the current forecast, inherited from the previous forecaster, will be an excellent starting point. In these cases, initialization is not required and the current forecast will need only minor adjustments.

Stage 4 - Modify the First Guess

Once the forecast database has been initialized by either guidance, observations, or the previous forecast, fine adjustments must be performed until the forecast depiction, and thus the underlying digital forecast data, accurately reflects the forecaster's mental image. AFPS provides a variety of tools to edit forecast data.

Time edit tools are available to adjust the time over which each depiction is valid. The forecaster may move the entire depiction forward or backward in time or simply adjust the start or end time of individual forecast periods. To add more temporal resolution to the forecast, depictions can be divided, leaving two forecast periods where there was just one. Some initialization methods may leave gaps in the time series of depictions. In these cases, the forecaster can invoke a function that interpolates a depiction based on the values found in earlier and later depictions. Wier (1995) describes the algorithms used in this interpolation function.

While viewing the forecast data in a spatial or temporal presentation, the forecaster may wish to make adjustments to account for local effects or to negate bias in a model. These data editing tools are discussed in detail later.

Stage 5 - Review Products

When the forecaster is satisfied that the forecast database accurately represents the future state of the atmosphere, products based on these data will be created upon forecaster request or following a time-based product generation schedule. As each new text product is generated, the forecaster will review it to ensure it that accurately describes the forecast. If minor adjustments are needed, the forecaster invokes a text editor and modifies the text. If the forecaster fundamentally disagrees with the text product, the inconsistent forecast components should be identified in the forecast database and edited again.

Stage 6 - Maintain the Forecast

With the forecast grids completed and products generating automatically, the forecaster's job moves into the monitoring and maintenance phase. Each forecaster continually scans new datasets, both observations and guidance, and assesses whether these new data suggest a significantly different forecast than the one in the database. If convinced that the current forecast needs some adjustment, the forecaster retrieves and edits the appropriate grids until they accurately depict the new forecast.

The differences between the duties of the short-term (0-12 hours) forecaster and long-term (greater than 12 hours) forecasters are greatest in the maintenance stage. Since both forecasters are interested in only those products that apply to their assigned time period, the short-term forecaster must survey much more data. While the long term forecaster receives fresh numerical guidance once or twice per shift, the short term forecaster gets frequent updates of radar imagery, detailed objective analyses, satellite imagery, and profiler data.

Summary

The operations concept outlined by OM addresses much of the redundancy and tedium found in today's NWS offices. By dividing their duties by time rather than program, forecasters can focus on a single forecast period, eliminating the redundancy of everyone studying the same period. Using AFPS, the forecaster defines weather element values that make up the forecast rather than composing words so more thought is devoted to meteorology. This new concept also allows more flexibility to balance the workload during a forecast shift in situations when short-fuse warnings are required. During these situations, the short-term forecaster may decide not to adjust the current forecast, but focus his attention on the more important task of issuing severe weather warnings.

The six-stage scenario described above outlines a full NWS WFO forecast shift. AFPS addresses Stages 3, 4, and 6 of the outline, initializing and editing the forecast data. The following two sections describe the AFPS system as it applies to these stages.

4. INITIALIZING FORECAST DATA

AFPS forecast data comprises hundreds of two-dimensional grids partitioned by forecast element and time. Each element consists of a set of data grids, called DataSlices, each of which defines the element over some forecast time period. Figure 1 illustrates the forecast worksheet, which displays DataSlices as rectangular blocks.

Each row represents a single forecast element. Each rectangular block represents the time period over which a DataSlice is valid. The time scale at the bottom shows when each DataSlice begins and ends.

The forecast worksheet provides functions so that the forecaster can edit the time component of the DataSlice and launch an editor to modify the data component. Reference worksheets, another type of worksheet, are based on data derived from objective analyses and numerical model output. Forecasters use these reference worksheets to initialize data in the forecast worksheet.

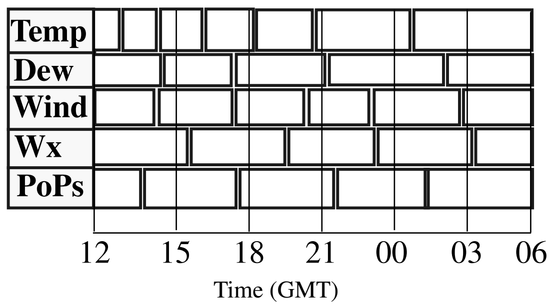


Figure 1. Forecast Worksheet displaying DataSlice as rectangular blocks.

Initializing the Forecast Worksheet

Forecast data are initialized by copying DataSlices from a reference worksheet and inserting them into the forecast worksheet.

The forecaster begins by selecting a reference worksheet which was generated automatically when the model grids arrived. During the generation process, AFPS converts the data from their original format to AFPS DataSlices. Once the reference worksheet is displayed, the forecaster may view the data to assess quality. If they decide that a particular set of DataSlices accurately represents the forecast state of a weather element, they select those DataSlices using the mouse. After selecting the ***COPY*** option, the DataSlices are saved so that they may be inserted later. Copying DataSlices is the only operation allowed on reference worksheets since they are *read-only* — they may not be modified.

Once the copy process is complete, the forecasters move their attention to the forecast worksheet. By selecting existing forecast DataSlices, and then selecting the ***PASTE*** option, the previously copied reference data replaces the forecast data. These DataSlices are now part of the forecast worksheet.

This series of operations is repeated for additional time periods and other weather elements, until all useful guidance is copied to the forecast worksheet. In most cases, these first guesses will need some adjustment to account for local effects, forecast timing, and model bias. To edit forecast data, the forecaster launches one of the forecast data editors.

5. EDITING FORECAST DATA

Each DataSlice has two major components: the gridded data, that contains weather element values, and the time component, that defines the period over which the data are valid. The time period is represented by a start time and end time, and will be limited to a minimum length, perhaps one hour.

5.1 Editing the Time Component

Time is edited directly on the forecast worksheet. Forecasters can select either edge of a DataSlice to adjust its start or end time. In addition, they may also select a whole DataSlice and slide it forward or backward in time, possibly pushing or pulling adjacent DataSlices along with it. When satisfied with the timing, a spatial or temporal editor may be launched that allows editing the of data component of the DataSlice.

5.2 Editing the Data Component

AFPS offers two types of editors that modify the forecast grids. The spatial editor displays exactly one DataSlice at a time and offers tools with which the forecaster can modify the gridded data. The temporal editor presents forecast data as a time series at a single grid point. Both editors modify only the gridded data. The AFPS development team is continuously developing and testing a variety prototypes. The spiral software model, which is employed by the AFPS project, prescribes that we revisit and enhance some of the tools shown here.

5.2.1 *The Spatial Editor*

The spatial editor can depict a DataSlice in several different ways, depending on its type (i.e., scalar, vector, or discrete). Regardless of type, all depictions are derived directly from the gridded data. All types can be depicted as images, contours, or boundaries. Images use colors to represent values. While several weather elements may be displayed at once, only one may be displayed as an image. The others must be line-oriented depictions (e.g., contours).

Scalar fields, such as temperature, can be displayed as images or contours. Three depictions are used to display vector data. The vector image depiction uses color to display the vector magnitude and monochrome wind barbs to indicate direction. The wind barb depiction plots wind barbs that are colored according to magnitude. The arrows depiction plots arrows pointed downwind while length and color depend on magnitude. Discrete data, such as weather, are displayed two ways: the discrete image depiction paints a unique colored bit pattern for each discrete value and the bounded area depiction displays discrete data as outlined areas.

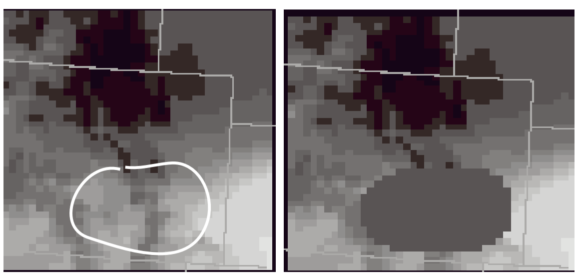
The spatial editor offers nine edit tools with which forecasters can edit data. Not every tool is available for every data type. However, many tools edit all data types. Spatial edit tools come in two types: gridpoint tools and freehand tools. Gridpoint tools operate on a set of grid points that the forecaster previously defined. All gridpoint tools modify only the points that were previously selected. Freehand tools modify the data on-the-fly as the user moves the workstation cursor over the data. No gridpoints need be selected for freehand tools. In general, grid point tools are used to make large modifications, where freehand tools are best at small adjustments.

Each tool is described below with illustrations that depict the data before the edit operation (left image) and then after the data were modified (right image).

Gridpoint Tools

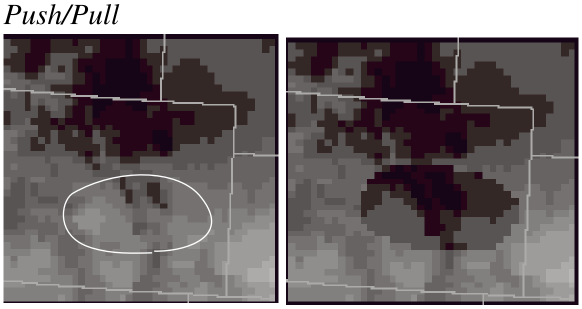
All six gridpoint tools operate on a set of forecaster-selected grid points. In the examples below, the white circular shape surrounds this set of grid points. For each operation, only the grid points inside the circular shape are modified. In all of the images, each shade of gray equates to a scalar value such as 50 F.

Set Value



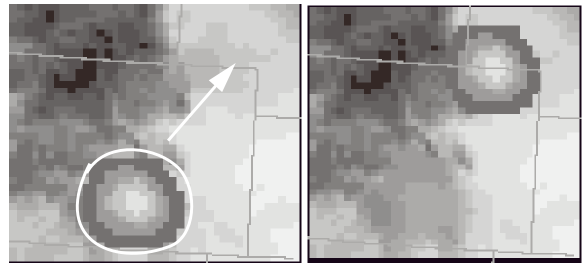
When the ***Set Value*** tool is applied to a set of grid points, all of the grid points are set to the same value. In this example, the oval shape near the bottom of the left image encloses the set of grid points. The image at the right shows that all of the points inside the oval were set to the same value.

Push/Pull



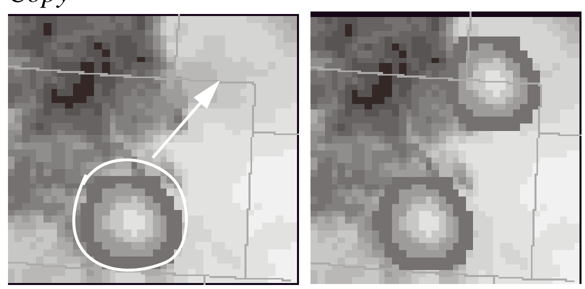
The ***Push/Pull*** tool increments or decrements each selected grid point. With each click of mouse button 1, a small amount is added to each grid point. Mouse button 2 decrements each grid point by the same amount. The amount can be adjusted at any time. The image on the right shows that points inside the area were decremented. Note that the small scale features that existed before the push/pull operation are still present afterward.

Move



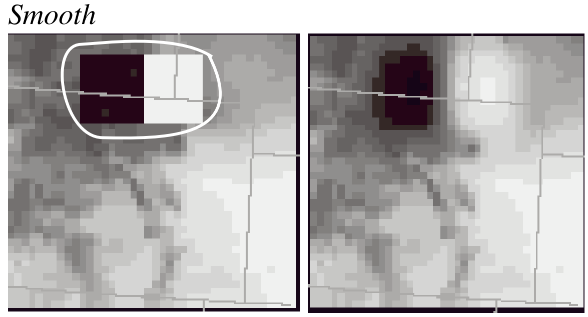
The ***Move*** operation allows the forecaster to move a feature across the forecast area. In this example, the bull's-eye feature in the lower part of the left image was selected and moved toward the upper right, as indicated by the white arrow. The image on the right shows that this feature has indeed moved to the upper right part of the forecast area. In addition, the originally selected area has been filled in with representative values from the surrounding area by an interpolation routine.

Copy



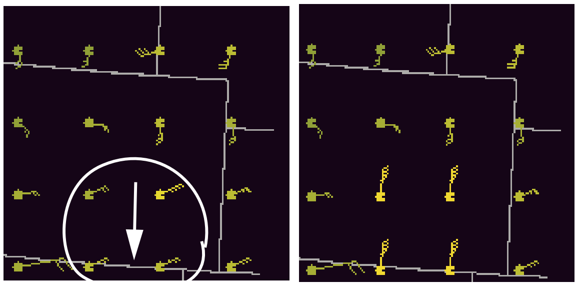
The ***Copy*** tool works exactly like the ***Move*** tool except that the selected area is not filled in but left unmodified. Note that there are two bull's-eye features in the right image, the original in the lower half of the image and the copied version found in the upper right.

Smooth



The ***Smooth*** tool smooths the selected data, reducing sharp gradients. In this example, an artificially strong gradient was placed in the upper part of the left image. The white oval indicates the area over which the ***Smooth*** tool was applied. The image on the right shows that the gradients between the black and white areas have been significantly reduced.

Vector

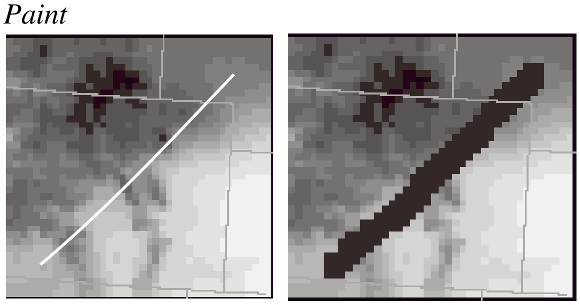


The ***Vector*** tool allows the forecaster to quickly and easily adjust vector data, such as wind. In the left image, the white circle indicates the area that was selected to be modified. To modify the vectors inside this area, the mouse button was pressed and, while holding the button down, the mouse was dragged in the direction indicated by the white arrow. Each time a mouse motion is detected, the distance and direction from the down-click point is calculated and a vector is derived. This vector is applied to each grid point inside the circle. As the mouse moves, the wind barb display updates, so value at each grid point is known at all times. The right image shows that the four wind barbs inside the circle were set to the north at 45 knots.

Freehand Tools

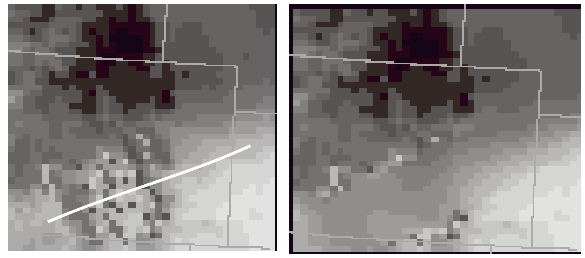
Freehand tools do not require that any grid points be preselected. The location of the cursor determines which grid points are affected. Each freehand tool modifies the data as the mouse is moved across the spatial display.

Paint



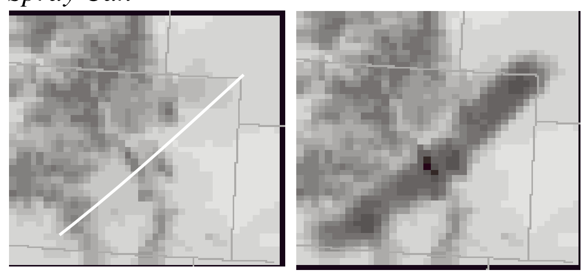
The ***Paint*** tool sets each grid point it touches to a specific value. Setting this value (dipping the brush) can be accomplished three ways. Selecting any displayed value with mouse button 2 or selecting a color from the legend (not shown) sets the paint value. This value can be set via the keyboard as well. Pressing and holding down mouse button 1 paints all grid points that the cursor passes over. In the example above, the path of the cursor is indicated by the white line and the image on the right shows the effect.

Bulldozer



The ***Bulldozer*** is a freehand ***Smooth*** tool. It levels off peaks in the data and fills in the valleys. The white line in the image on the left shows the path of the cursor while using the ***Bulldozer***. Note that the noisy data present in the left image has been smoothed.

Spray Can



The ***Spray Can*** tool is analogous to the ***Push/Pull*** gridpoint tool. As the cursor passes over each point, a small amount is added or subtracted, depending on which mouse button is pressed. The white line in the left image show the path of the cursor. The right image shows that the points along this path were decremented by a small amount.

5.2.2 *The Temporal Editor*

Figure 2 illustrates how the temporal editor displays AFPS forecast data in the time-series format. The display plots a single grid point versus time. The temporal editor can vertically stack many elements at once, so the same time scale can be shared. Weather elements that share the same units can be displayed on the same time series plot. The time periods are clearly delineated with vertical lines that indicate the start and end time of each DataSlice.

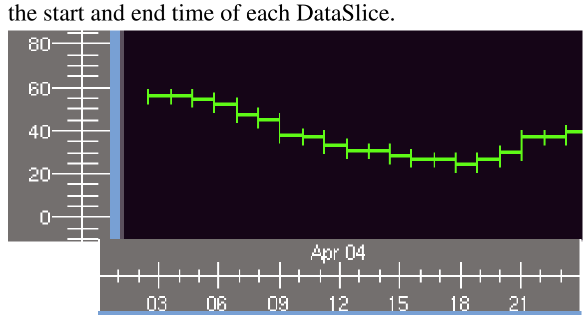


Figure 2. The Temporal Editor

Time series data can be edited by selecting an edit tool, such as the ***Adjust*** tool, and then indicating a DataSlice and a new data value with the mouse. To modify scalar data, only one mouse click is required. The x-coordinate indicates the DataSlice and the y-coordinate determines the weather element's new value. In its default mode, the temporal editor modifies a single grid point as part of a single DataSlice. Two other modes, however, allow the forecaster to apply edit operations to a set of grid points, rather than just one. This set of grid points, called the area of influence, is defined by the forecaster. In absolute mode, all points inside the area of influence are set to the value indicated by the editor. In relative mode, the difference between the premodified value and the postmodified value is calculated and applied to the entire area. For example, forecasters can select an area of influence (e.g., a forecast zone) and then launches a temporal editor whose location is inside the same area. Analyzing the temporal display for temperature, they find the desired DataSlice and increase the value by 5 degrees. Five degrees is then added to each point inside the area of influence. Editing temporal data in relative mode lets one adjust large areas of data while preserving the small-scale gradients present in the existing data.

For scalar data, the temporal editor offers only the ***adjust*** tool. Vector data can be edited two ways: the ***adjust*** tool modifies only the magnitude component and the ***vector*** tool (described in Section 5.2.1) sets both the magnitude and direction components. Since discrete data are nonnumerical and represented by text strings, the vertical scale is meaningless in a discrete data display. The ***Modify Tag*** tool lets forecasters select a DataSlice to modify and define a new value. The new discrete value can be defined three ways: pick an existing value, pick a value from a menu, or type the value using the keyboard.

5.3 Summary

All AFPS forecast data have four dimensions: x, y, value, and time. The spatial editor holds time fixed and displays the weather element value as a function of space (x, y). The temporal editor holds x and y fixed and displays element values versus time. For elements that change slowly with time, the spatial editor works well. For those elements with higher temporal resolution, the temporal editor provides tools that can modify a large amount of data very efficiently.

6. CONCLUDING REMARKS

The NWS modernization promises massive changes in forecast operations. Reassigning forecast duties from program-based to temporal-based is among the most far-reaching of these changes. No longer will forecasters study guidance and think of the forecast in terms of words. Forecasting with AFPS encourages the forecaster to think in terms of the weather elements that comprise the forecast. Text product formatters will relieve forecasters of hours of typing, allowing them the time to focus on meteorology. No longer will resources be wasted in reformatting the same forecast into different products.

AFPS is roughly half way through the development phase. Many of the edit tools are complete, but much work remains to fully implement forecast initialization. Beginning next year, AFPS will be tested in an operational setting to work out bugs and get a feel for the workload requirements associated with graphically forecasting the weather.

In addition to advice from NWS management and the AFWG, the AFPS development team is perpetually seeking feedback on the requirements and design. All comments are welcome and should be directed to the corresponding author or via E-mail to lefebvre@fsl.noaa.gov.

7. REFERENCES

NOAA, 1993: NOAA Special Report *The AWIPS Forecast Preparation System*, USGPO 89042, July 1993, 100 pp. NOAA/ERL/FSL, Boulder, CO, and NOAA/NWS/OSD/TDL, Silver Spring, MD.

NWS, Office of Meteorology, 1994: Integrated operations and services plan (draft), June 1994, 52 pp. NOAA/NWS/OM, Silver Spring, MD.

Wakefield, J. S., M. A. Mathewson, T. J. LeFebvre, D. H. Leserman, R. G. Mayer, S. K. Wier, M. S. Young, and X. Xu, 1993: Graphical forecast editing tools for AWIPS. Preprints, *Ninth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Anaheim, Amer. Meteor. Soc., 254-258.

Wakefield, J. S., M. A. Mathewson, 1994: An integrated approach to graphical forecast editing. Preprints, *Tenth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Nashville, Amer. Meteor. Soc., 23-26.

Wier, S.K., 1995:, Interpolating between grids of meteorological data. Preprints, *Eleventh International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Dallas, Amer. Meteor. Soc., (in this preprint volume).