14.5 INTERPOLATING BETWEEN GRIDS OF METEOROLOGICAL DATA FOR AFPS

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1. INTRODUCTION

The AWIPS Forecast Preparation System (AFPS), being developed at the Forecast Systems Laboratory (FSL) in Boulder, Colorado, and the National Weather Service (NWS) Techniques Development Laboratory (TDL) in Silver Spring, Maryland, will support preparation of most routine forecasts at NWS Weather Forecast Offices (WFOs) when it is deployed in the late 1990s.

The AFPS allows forecasters to create and maintain a digital database of forecast information. The database is initialized with values from forecast models. Forecasters have the opportunity to view and modify the data using graphical displays and interactive tools. Text forecasts are generated automatically when desired using computer text product generators. Forecasters are free to concentrate on preparing a complete and detailed description of expected atmospheric conditions, since they do not compose and type text messages. Complete descriptions of the guiding concepts and current implementation of the AFPS are available (LeFebvre 1995; NOAA 1993a, 1993b, 1993c; Wakefield and Mathewson 1994).

The data for each weather element for a given time are stored as a grid or "DataSlice" (LeFebvre, 1995) covering the forecast area. The grid dimension will be about 75 by 75. AFPS displays use contours, colored image fields, wind barb plots, and other techniques to present the data graphically, rather than as grids of numbers, but numeric grids underlie all displays and operations.

The temporal resolution of guidance for forecasting, typically 3 hours or more, is less than the temporal resolution used by the AFPS forecast text generators, typically 1 hour. An interpolation function is provided to automatically create grids intermediate in time between two forecast grids which were prepared from guidance or by a forecaster. Interpolation is used when conditions are expected to change gradually between completed grids.

Interpolation assists preparation of forecasts, because it reduces the demand on the forecaster to draw or edit all required weather elements at all required times, when changes are needed in guidance. If the forecaster judges that some weather element cannot be estimated correctly by interpolation between completed grids, then at least some of the intermediate grids must be prepared by hand.

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2. INTERPOLATION TECHNIQUES

Interpolation of weather elements naturally divides into two techniques, each associated with a physical process which changes weather element values.

2.1 Interpolation of stationary changes

Stationary changes are gradual changes in a continuous weather element. Examples are diurnal changes in temperature, dewpoint, wind, and pressure.

Interpolating grids by stationary changes is done by linear interpolation at each grid point from known values at the same grid point immediately preceding and following the time, or by polynomial interpolation at each grid point from several known values preceding and following the time of the missing data value.

Stationary interpolation treats each grid point separately and does not consider what changes occur at other points in the grid. The values at a grid point are treated as samples of a continuous variable at different times. Interpolated values are derived from known values and times. The process is automatic and requires no forecaster control or input.

2.2 Interpolation of advected changes

Weather elements at a location can also change due to advected features. Some advected features create rapid changes in element values, sometimes reversing diurnal tendencies. The method described for handling stationary changes will not always produce usable results. A separate technique is used to interpolate grids with strong advected features that cross the forecast area.

The advecting feature is delineated by the forecaster on the finished forecast grids preceding and following the to-be-interpolated interval. An effective center of the advected feature, preceding and following the interpolated interval, is determined by the interpolation program. A motion vector is determined from the centers, which is used to shift the advected feature across intermediate interpolated grids. A temporary grid of differences is maintained and shifted, and interpolated in value at each point at each step. In this way the advected feature can move, and change in size and shape. This technique works in conjunction with the automatic stationary interpolation, even when the tendencies they represent are opposite.

This technique relies on the proper identification of the advection feature in the known grids preceding and following the interpolated interval. We now rely on the forecaster delineating the advected feature. In the future it may be possible to use automatic pattern recognition or other techniques to automate this process. However it is not clear whether such an approach will work reliably enough to be part of operational forecast generation.

As a practical matter, it has been found that changes in grid point values due to many advected meteorological changes are gradual enough and slow enough to be handled by the stationary interpolation technique.

3. DATA ELEMENT TYPES

The primary weather elements to be presented and edited by the AFPS are surface temperature, dewpoint, wind, visibility; probability and amount of precipitation, clouds, and weather type. Other elements required for forecast preparation will be automatically derived from these, or through the use of special tools or editors.

3.1 Scalar Data

Scalar data are interpolated using the stationary and advection techniques. Temperature, dewpoint, and wind can be successfully interpolated as continuous scalars.

3.1.1 *Continuous Scalar Data*

Scalar data have one value at each grid point. Continuous scalar data are represented by continuous real numbers. Temperature and dewpoint are continuous scalar fields. Interpolating for stationary and advected changes works very well on continuous scalar data such as temperature grids.

Interpolation was tested with data analyzed from observations. Analyzed grids were used both for generating interpolated grids, taking the place of forecast grids, and for direct comparison to the resulting interpolated grids.

We used surface grids from the Local Analysis and Prediction System (LAPS) project at the Forecast System Laboratory (McGinley *et al*., 1991). LAPS grids are similar in grid point spacing to the grids planned for AFPS and AWIPS. The LAPS grids cover the Denver WFO area, including over 10,000 feet (3000 m) of topographic relief. LAPS combines and analyzes SAO (surface aviation observation), mesonet, satellite, and other observations to generate the surface grids. Grids are available for all AFPS elements except probability of precipitation (a forecast) and weather. Interpolation of LAPS MSL pressure grids was also tested.

Figure 1 illustrates interpolation of temperature, and compares the interpolated temperature (Figure 1c) with analyzed data (Figure 1b) at the same time. A test of interpolation success is the difference between the value at a grid point in the interpolated grid and the value at the same grid point in the analyzed grid. The analyzed grid shown in Figure 1b and the interpolated grid shown in Figure 1c have an average difference of 2.02˚F (1.12˚C).

3.1.2 *Discrete Data*

Discrete data have one value at each grid point, selected from a small sequence of pre-determined values. Visibility is taken from the sequence (0.0, 0.25, 0.5, 0.75, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, >6.0), indicating visibility in miles. Probability of precipitation is taken from a sequence of percentages (0, 5, 10, 20,... 100).

These discrete data may be treated as a continuous scalar element, because the actual phenomenon can be correctly represented by a continuous variable. The interpolated results are grids of continuous real numbers. The interpolated values are then converted to a value from the associated sequence. How the appropriate value is chosen is undecided. For visibility, one might choose the nearest value, or choose the next lower value to ensure safety, especially in the lower visibility levels.

Unfortunately, visibility is not a continuous field, especially near areas of greatly reduced visibility. Reduced visibility may appear rapidly where no reduction in visibility had formerly existed, and it is not always brought in by advection. For example, over a short period of time, fog or other obstructions to visibility may appear and then disappear. It is not possible to predict correctly visibility by interpolation between the beginning and end visibility fields in such a case.

Figure 2 shows the actual visibility in Colorado over the course of three hours in August 1994. It is clear that no interpolation scheme could correctly estimate the visibility of the second hour given the data of the first and third hours. The data is from LAPS.

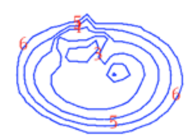

Figure 2a. LAPS analyzed visibility (miles) at 1200 UTC August 29 1994.

Figure 2b. LAPS analyzed visibility (miles) at 1300 UTC August 29 1994.

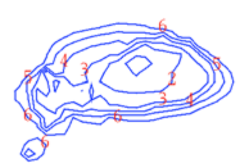

Figure 2c. LAPS analyzed visibility (miles) at 1400 UTC August 29 1994.

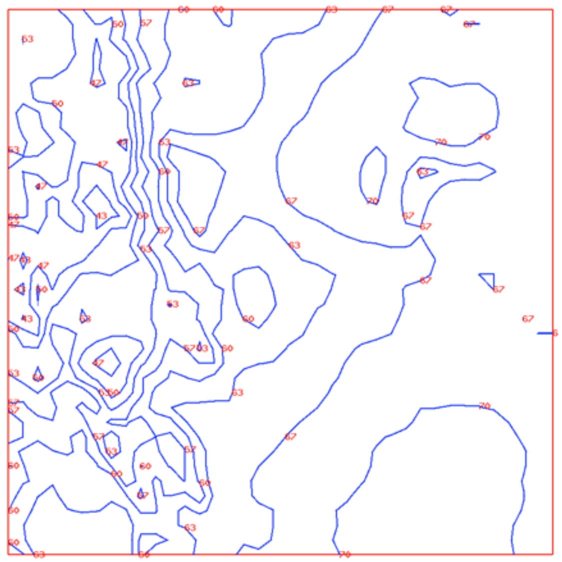

Figure 1a. LAPS analyzed surface temperature over Colorado at 0700 UTC August 17 1994.

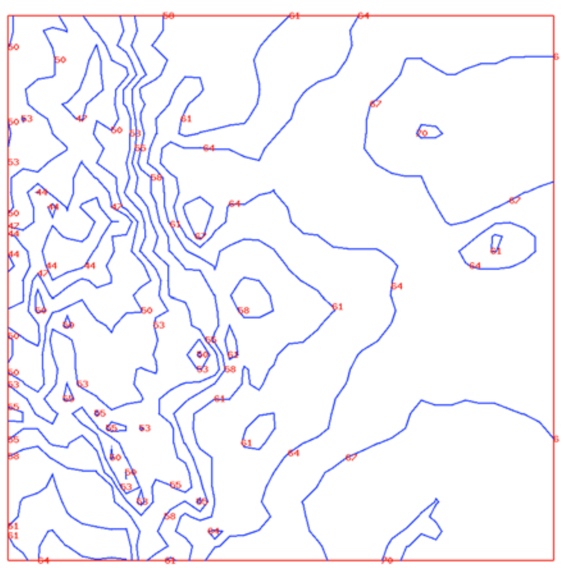

Figure 1b. LAPS analyzed surface temperature over Colorado at 0800 UTC August 17 1994.

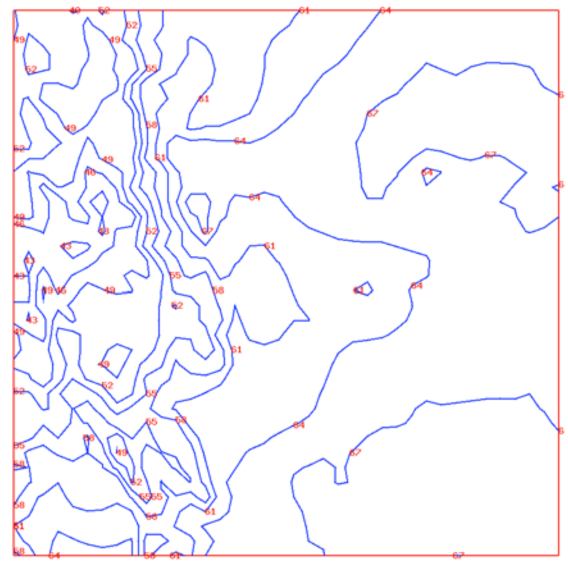

Figure 1c. AFPS interpolated surface temperature over Colorado at 0800 UTC August 17 1994.

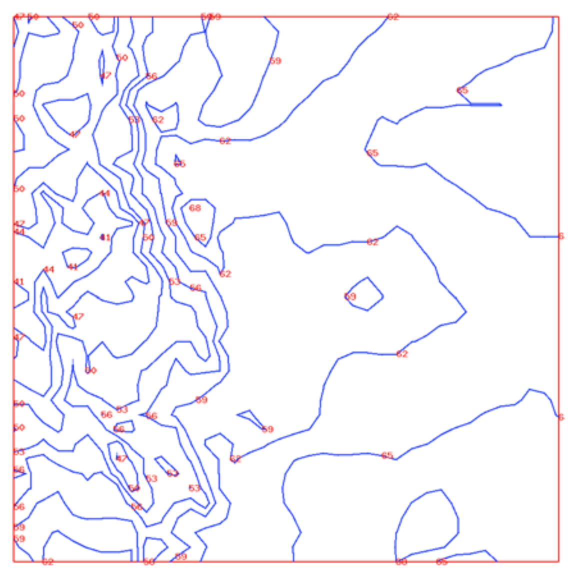

Figure 1d. LAPS analyzed surface temperature over Colorado at 0900 UTC August 17 1994.

Interpolation of visibility is not reliable and should not be used in situations where reduced visibility is a critical part of the forecast. In these cases, all visibility grids must be approved by the forecaster and edited to create the correct forecast of visibility.

As for visibility, it is not always possible to make a reasonable estimate of probability of precipitation using interpolation by stationary changes or by advected continuous fields.

3.2 Vector Data

Wind is presented to the forecaster, and edited, using graphical displays with vectors, including the conventional wind barb symbol. Wind data is stored as separate grids of speed and direction.

For interpolation, wind must be separated into two scalar components, which are then independently interpolated as continuous scalars. Interpolation using the speed and direction components makes good estimates of intermediate wind grids. The same technique can be used to interpolate successfully any continuous vector data.

Interpolation of wind by (u, v) components makes poor estimates of intermediate direction and speed. Figure 3 shows examples of unsatisfactory wind vectors generated by interpolation of (u, v) wind components.

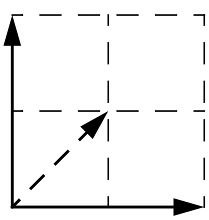

Figure 3a. Two known wind vectors with the same length, and directions differing by 90˚. A vector created by interpolating the (u,v) components of the known vectors has direction halfway between but a length of 0.717 of the length of the known winds.

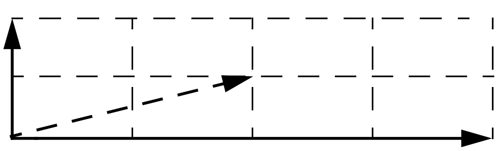

Figure 3b. Interpolation of two wind vectors differing by a factor of four in speed and by 90˚ in direction, using (u, v) components. The direction of the wind interpolated between the known winds using (u,v) components is 76˚ from one known direction and 14˚ from the other, rather than halfway between.

3.3 Categorical Data

Weather is described by a combination of three categories for precipitation coverage, type, and intensity. Weather is displayed and edited as areas with distinct boundaries and labeled with text. For the purposes of interpolation, weather at a grid point is represented as one or more combinations that may be internally represented by integers. The values are neither continuous nor sequential.

Interpolation of weather categories uses the advection technique; each category is advected separately and independently. The interpolation is automatic; no forecaster input is required to identify advected features since the categories are clearly distinct. Interpolation of one weather category works properly. An area of one weather type may change in position, size, and shape, and intermediate grids are found correctly.

However, when two or more weather categories are present, or if a category vanishes or appears, interpolation raises questions which have no well-defined solution. How are overlapping weather areas handled? How do we interpolate when one weather category changes into another? If one forecast grid shows an area of rain and the next an area of snow, does interpolation always return rain plus snow for intermediate times? The difficulty is less in computer computations than in deciding what is the desired outcome in such cases. Agreed conventions for handling such cases will be determined by consultation with forecasters.

4. MEASURES OF INTERPOLATION SUCCESS

Comparisons of many cases of interpolated grids with observed grids for the same time indicate the techniques described are satisfactory for generating intermediate grids for some weather elements. The average differences between interpolated and observed gridpoint values are 1.52˚F (0.84˚C) for temperature, 1.02 knots (0.46 m s^{-1}) for wind speed, 20.3˚ for wind direction, and 0.31 mb (0.31 hPa) for MSL pressure. These values are for a single interpolation midway in a 2-hour period. For every type of element the average of differences between real and interpolated data grids at the same time is about 5% of the data range between the largest and smallest values in the grid.

5. CONCLUDING REMARKS

Simple methods of interpolation for temperature, dewpoint, and wind speed and direction work very well and meet AFPS needs at this level of development.

Visibility, probability of precipitation, and weather type, cannot be interpolated reliably, especially in the cases where these elements are of greatest importance. These elements are not by nature continuous, and are modified by changes in state of water vapor in the atmosphere. Small changes in other weather elements can cause large and abrupt changes in visibility, precipitation, and weather type. In such cases it is impossible to interpolate correctly intermediate grids of visibility, precipitation, or weather from grids of the same type immediately preceding and following the intermediate time.

In some cases interpolation will be of little use in generating forecast grids for these weather elements. It will be incumbent on forecasters to carefully review the results of interpolation.

Interpolation will be refined and modified as needed in development and in operational simulations. Attempts to automate interpolation of advected features are planned. Ongoing discussions with operational forecasters will guide future work.

All comments are welcome and should be directed to the author, or via E-mail to wier@fsl.noaa.gov.

6. REFERENCES

LeFebvre, T. J., 1995: Operational Forecasting with AFPS. Preprints *Tenth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Dallas, Amer. Meteor. Soc., (in this preprint volume)

McGinley, J. A., S. C. Albers, and P. A. Stamus, 1991: Validation of a Composite Convective Index as Defined by a Real-Time Local Analysis System. *Weather and Forecasting*, **6**, 337-356.

NOAA, 1993a: 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.

____, 1993b: Data Requirements and Definitions, AWIPS Forecast Preparation System, June 1993, 146 pp. (unpublished) Available from Forecast Systems Laboratory, Boulder, Colorado.

____, 1993c: Graphical Forecast Editor Requirements and Concepts, AWIPS Forecast Preparation System, February 1993, 96 pp. (unpublished) Available from Forecast Systems Laboratory, Boulder, Colorado.

Wakefield, J. S., and 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.