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INFORMATION AND PRODUCTS DERIVED FROM ENSEMBLE STREAMFLOW FORECASTS

Mary Mullusky[1*], Mike DeWeese[2], Edwin Welles[1], John Schaake[1]
[1] Hydrology Laboratory, Office of Hydrologic Development, National Weather Service, NOAA, Silver Spring, MD
[2] North Central River Forecast Center, National Weather Service, NOAA, Chanhassen, MN

1. INTRODUCTION

In an effort to generate more informative streamflow forecasts, the National Weather Service (NWS) has developed an ensemble forecasting system. Numerous methods of displaying the probabilistic forecasts have been examined for both their advantages and disadvantages. The methods include those currently available to forecasters at the River Forecast Centers (RFCs) via the Ensemble Streamflow Prediction Analysis and Display Program (ESPADP) and those requested by forecasters and end users that are being used in a demonstration mode. Additionally, other methods of displaying the forecasts have been analyzed. The end product of this research is a suite of displays that will be made available to end users to assist in their decision making process.

2. EXISTING OPERATIONAL PRODUCTS

ESPADP is used in conjunction with the NWS River Forecast System (NWSRFS) Ensemble Streamflow Prediction (ESP) Model to provide interactive analysis of ESP time series. ESPADP has been operationally available to the RFCs since August, 1997. ESPADP originally provided displays of four different plot types to analyze the ESP time series; Trace Ensemble Plot, Expected Value Plot, Exceedance Histogram and the Exceedance Probability Plot. Within each plot type the forecaster controls the accumulation settings and the frequency settings for their specific application. The accumulation settings include the display window, the daily accumulation, the accumulation interval and the accumulation variable. The frequency settings include the probability distribution and the probability levels for analysis. With the four plot types and the range of accumulation and frequency settings, forecasters have the ability to make a suite of ESP products for any streamflow forecast point.

With the September 2002 release of NWSRFS R22, two new plot types were made operationally available within ESPADP. The new plot types include a Non-exceedance Histogram and a Non-exceedance Probability Plot. These new plot types allow the forecaster to analyze and display low flow or drought conditions more intuitively. Figure 1 shows the Non Exceedance Histogram of weekly minimum river stages for the Minnesota River at Jordan, Minnesota. This example shows that in the second week the minimum flow has a 25% chance of falling below 5.5 feet and a 75% chance of falling below 6.3 feet. Figure 2 shows the Non-exceedance Probability Plot for the Minnesota River at Jordan Minnesota. This example shows the probability of the minimum stage over the next 90 days falling below certain river levels for both the forecast simulation (triangles) and the calibration simulation (circles). The forecast simulation begins each ensemble forecast with the current conditions and the calibration simulation begins at the beginning of the period of record. The calibration simulation is a method used by forecasters to assess model errors and biases. In this example, it represents an approximation of the probability distribution under "average" conditions.

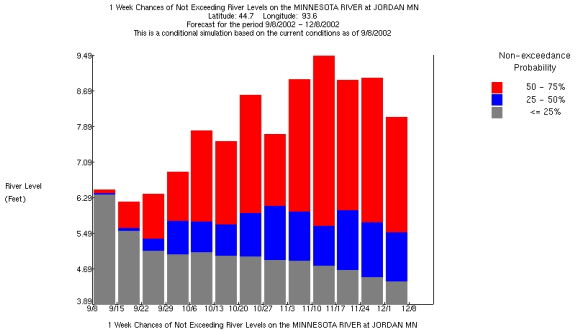

Figure 1: Non-Exceedance Histogram

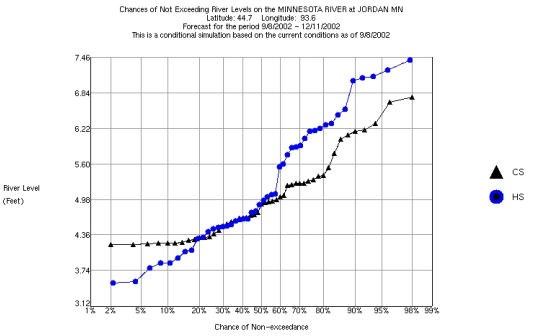

Figure 2: Non-Exceedance Probability Plot

ESPADP can also be used to analyze precipitation and temperature ensembles. In this way the forecaster

* *Corresponding author address:* Mary Mullusky, NWS/OHD/Hydrology Lab, 1325 East-West Highway, Silver Spring, MD 20910; e-mail: Mary.Mullusky@noaa.gov

can analyze the meteorological inputs that force the rainfall/runoff models within NWSRFS and view the resulting streamflows. This can be especially useful when forecasters integrate meteorological forecasts and climate outlooks into the ESP system (Perica, 1998). All plot types operationally available in ESPADP for stage and streamflow are available for precipitation and temperature.

3. DEMONSTRATION PRODUCTS

In addition to the operational products available in ESPADP other products have been created to meet the specific needs of forecasters and end users and are available as demonstration products. These demonstration products include a River Forecast Interface, Probabilistic River Stages Plot, Stage Exceedance Probabilities Plot, and Probabilistic Flood Forecasting Maps.

One early attempt to clearly display the complexity of information available in the ensembles was the River Forecast Interface developed at the University of Virginia as a part of an NWS Eastern Region Probabilistic River Stage Forecasting Risk Reduction demonstration project. This display, shown in Figure 3, provides the user three views of similar information color coded to make identification of likely flooding as simple as possible. The distributions are first displayed, followed by a bar chart of the distributions and then a mapping of the distribution into the cross section of the river at the forecast point. Creative solutions such as this one are needed to make the information in the ensembles accessible.

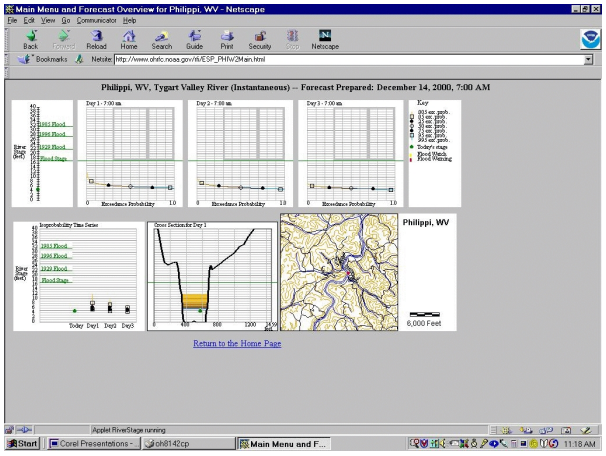

Figure 3: The River Forecast Interface

The Probabilistic River Stages Plot and the Stage Exceedance Probabilities Plot are simply two different ways of viewing the information provided by the ESP time series of stages at a certain forecast point. The Probabilistic River Stages Plot for the Juniata River at Huntingdon, PA is shown in Figure 4. The plot shows the range of river stage exceedance probabilities at each forecast time interval. Figure 5 shows the companion picture, a Historical Flood Data Plot, which gives a historical perspective to the selected probabilistic river stages. In this figure the forecasted 10-90% exceedance probability stages for the selected day are shown on a staff gage with the different action levels and record flood for that forecast location. The Stage Exceedance Probabilities Plot is shown in Figure 6 for the Sabine River at Fort Smith. This figure shows the probability of exceeding predetermined river stages. For this example the predetermined river stages are the action stage and the flood stage.

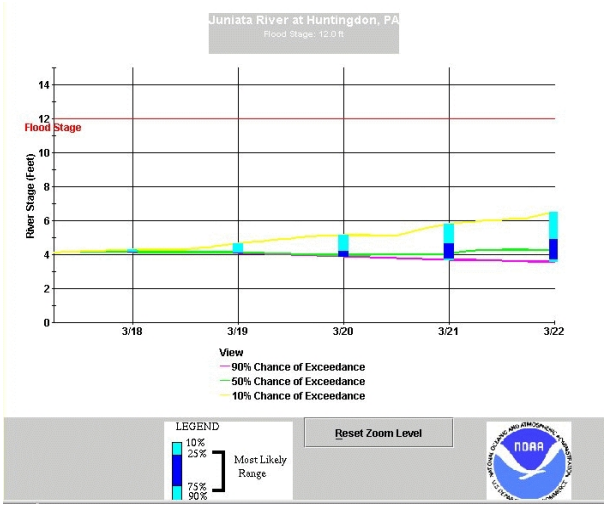

Figure 4: Probabilistic River Stages Plot

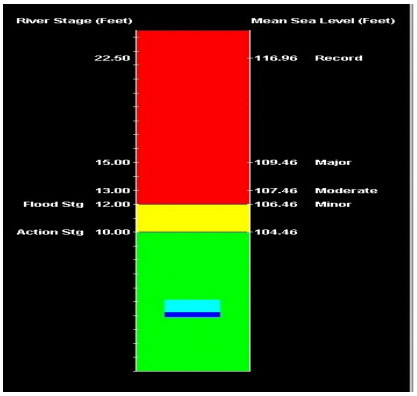

Figure 5: Historical Flood Stages

Another demonstration plot type used by the NWS are Probabilistic Flood Forecasting Maps. Probabilistic water surface profiles are computed using the one-dimensional unsteady flow hydraulic model FLDWAV with the ESP methodology. These water surface profiles are then mapped with the NWS flood forecasting mapping application FLDVIEW to produce probabilistic maps of the expected flood extent. Given an appropriate digital terrain model, a water surface profile, and the river centerline,

FLDVIEW will generate a flood forecast raster in shapefile format which can be overlaid with other information (e.g., orthophoto images, tiger maps, etc.). FLDVIEW can generate either a deterministic (instantaneous or peak condition) or probabilistic flood map (Cajina et al., 2002). A probabilistic flood forecasting map was created for the Juniata River near Lewistown, PA and is shown in Figure 7.

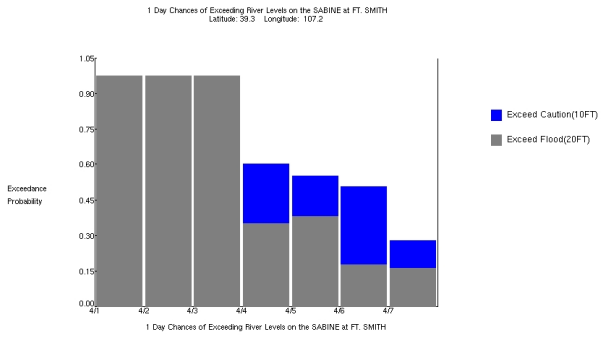

Figure 6: Stage Exccedance Probabilities Plot

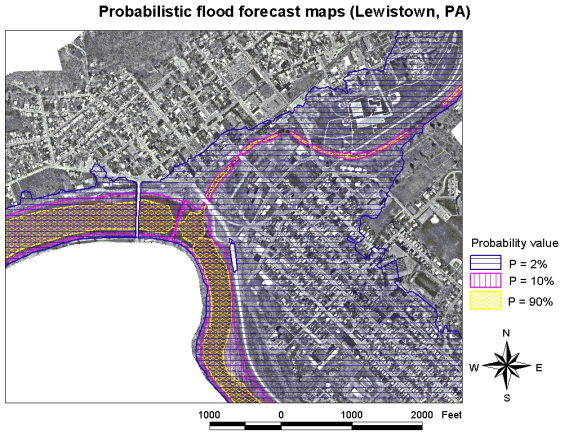

Figure 7: Probabilistic Flood Forecasting Map

4. AHPS PRODUCTS INFORMATION TEAM

The NWS has established an agency wide team to define a set of core products for the initial Advanced Hydrologic Prediction Service (AHPS) implementation. NWS managers leading AHPS have a vision of easy access to a consistent core suite of AHPS graphic products and information. The team's mission is to define a consistent core suite of graphical NWS hydrologic products and information which support the full spectrum of hydrologic services from flash floods through extended-range river forecasts. Hydrologic information includes observed and forecast data. The team is also to establish standards to ensure a) the content and format of the core suite of products and information are consistent and b) consistent and easy access to these products and information.

Because the hydrology of the nation varies substantially from region to region the admirable goal of a single suite of products delivered at all forecast points for all seasons may not be realistic. For example, water managers using reservoir inflow forecasts upstream of a reservoir to make release decisions require different types of forecast information than do emergency managers fighting a flood on an urban headwater basin. The initial core suite of AHPS products will provide the flexibility to meet user needs with appropriately selected information. Additionally, RFCs can customize products above and beyond the core suite of AHPS products to meet the needs of their unique customers.

NWS regional managers have already concurred on a single format for AHPS web pages and the implementation across all NWS regions is underway. This format follows that developed in the NWS Central region and can be viewed at http://www.crh.noaa.gov/ahps/. A single map of the entire region is displayed and users can select the region of interest to see a more detailed map listing forecast points. From the map of forecast points, products can be selected. In addition, after selecting a forecast point, the user can navigate up and down a river reach by selecting the 'upstream' or 'downstream' buttons. This feature simplifies the navigation up and down stream for the user and makes the boundaries between forecast offices transparent to the users. By following a river from up to down stream an interested user can follow the passage of a flood wave through a region.

5. TRAINING

Numerous methods of displaying probabilistic streamflow forecast information have been demonstrated. However, this by itself is not enough. The NWS must take an active role in training hydrologic forecasters on analyzing and interpreting the resulting probabilistic displays. To accomplish this, hydrologic forecasters need a basic understanding of probability and statistics, and a basic understanding of ensemble forecasting including how climatological adjustment tools affect forecast results. Additionally, there is a need for forecasters and end users to understand how to take advantage of the probabilistic forecasts to make the risk based decisions needed. The NWS has been addressing this need for training in a number of ways. Statistical and ESP workshops are available to forecasters yearly. A web based training module on ensembles is currently being developed. NWS has been active in outreach efforts including participating in professional conferences and working with the academic and research community on these issues.

6. CONCLUSIONS

Numerous methods of displaying probabilistic forecasts have been developed by the NWS in an effort to

generate more informative streamflow forecasts and assist end users in understanding and making risk-based decisions from these forecasts. The operational program ESPADP, gives forecasters the ability to create a suite of displays of probabilistic streamflow, stages, precipitation and temperature. At the request of forecasters and end users, demonstration graphics have also been developed in an effort to make the probabilistic information more understandable. In an effort to provide a consistent core suite of graphical NWS hydrologic products and information, which support the full spectrum of hydrologic services, the NWS has created the AHPS Products and Information Team. Additionally, the NWS is involved in training and outreach efforts to assist forecasters and end users on interpreting and using probabilistic forecasts.

Another complicating factor in assessing the value of certain probabilistic displays is the distinction between forecasters and end users. Ultimately, the needs of the forecaster and the needs of the end user when viewing probabilistic displays are inherently different. The NWS must recognize these differing needs and create the tools necessary to accommodate both to provide successful probabilistic information.

7. REFERENCES

Cajina, N, J. Sylvestre, E. Henderson, M. Logan, and M. Richardson, 2002: FLDVIEW: The NWS Flood Forecast Mapping Application. Preprints of the 18th International Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography and Hydrology, 82nd AMS Annual Meeting, Orlando, Florida.

Perica S., 1998: Integration of Meteorological Forecasts/Climate Outlooks into an Ensemble Streamflow Prediction System. Preprints of the 14th Conference on Probability and Statistics in the Atmospheric Sciences, 78th AMS Annual Meeting, Phoenix, Arizona, 130-133.