National Weather Service Advanced Capabilities in Flash Flood Forecasting

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Introduction. The modernization of the National Weather Service (NWS) includes three major systems. These systems are the Doppler Weather Surveillance Radar (WSR-88D), the Advanced Weather Interactive Processing System (AWIPS), and the Automated Surface Observing System (ASOS). These advanced technologies are providing significant data and processing capabilities which are directly applicable to the flash flood problem.

In particular, the Weather Forecast Office (WFO) Hydrologic Forecast System (WHFS) provides the forecasters with unparalleled access to real-time data and the capability to process and identify potential flash flood situations. All of these technologies contribute to improved capabilities of the NWS to provide early and useful flash flood products to cooperators and the public.

On July 31, 1976, more than 12 inches of rain fell in the Big Thompson Canyon in Colorado. The resulting flood left more than 140 people dead and destroyed homes and businesses. There has been a significant effort within the NWS over the last 20 years to improve our capabilities to respond to these types of events.

Background. Following the Big Thompson flash flood, in an effort to provide the WFO with the tools necessary to effectively forecast these types of events, the Forecast Systems Lab (FSL), with funding support from the NWS, began the Program for Regional Observing and Forecast Services (PROFS) which was a proof of concept project for an NWS field office advanced workstation environment. The PROFS workstations added considerable functionality in data handling, graphical display capability, and additional local model generation capability. The NWS and FSL, as a risk-reduction activity, then cooperated in the Denver AWIPS Risk Reduction and Requirements Evaluation (DAR^{3}E) in the mid-1980's. The DAR^{3}E project was designed to put a series of the PROF developed workstations in an operational Weather Service Forecast Office (WFSO). PROFS and the early DAR^{3}E implementations had limited functionality to address the hydrologic operations at the WSFO. Over the next few years, through 1992, some limited success was achieved in adding hydrologic displays and applications to the DAR^{3}E system and a later pre-AWIPS system. By mid-1993, the hydrologic application development on the pre-AWIPS system and the WSFO hydrologic development effort was moved to the Office of Hydrology (OH).

Weather Forecast Office Hydrologic Forecast System. The WHFS features an integrated data management approach, employing a relational database management system (RDBMS) for storing the large volume of data necessary for hydrologic forecast operations. The WHFS database incorporates many data elements ranging from modernized data sets such as

NEXRAD precipitation estimates and GOES satellite imagery, to more traditional hydrologic data sets provided by automated reporting stations and cooperative observers.

The supporting River Forecast Center (RFC) is the primary source of hydrologic guidance for the WFO, providing river stage forecasts on a daily and event-oriented basis. RFC guidance is also provided in the form of modernized flash flood guidance products that indicate current soil moisture conditions and associated rainfall thresholds necessary to induce flood activity.

A collection of tools is provided within WHFS to allow the WFO hydrologic program manager to manage through a series of graphical user interfaces. HydroBase, one of these tools, provides a method of managing station data, allowing for definition of various station attributes (Figure 1). Much of the data utilized by forecast applications are also defined through HydroBase. Program management tools, such as automated generation of monthly flood stage reports, are also part of HydroBase.

WHFS Capabilities. During a typical hydrologic situation, the forecaster may employ many aspects of the WHFS in combination to evaluate the current hydrologic conditions, evaluate data, and issue products notifying the public of flood situations.

The Stage and Display (HydroView) application provides the forecaster with a method of monitoring and tracking the hydrologic situation in real-time (Figure 2). This application provides a geographic depiction of the WFO County Warning Area (CWA) with the ability to overlay an array of Hydrometeorological data. Station icons may be overlaid in combination with hydrologic or geopolitical boundaries such as rivers, river basins, county outlines, or major towns and highways. River station icons are color-coded to indicate the proximity of the latest observation to action or flood stage. Precipitation stations are color-coded to represent a precipitation accumulation for a selected time duration. This display is automatically refreshed at 15 minute intervals, using the most recent observations and forecasts available. The forecaster may view a time-series display of river stage and precipitation observations for a period of up to 21 days. Forecast data is provided for a 5-day time period.

The Area-Wide Hydrologic Prediction System (AWHPS) provides the forecaster at the WFO with an analysis of a flash flood threat in the WFO forecast area (Figure 3). AWHPS uses data from NEXRAD and gridded flash flood guidance from the servicing RFC to provide a graphical depiction of (1) Critical Rainfall Probability (CRP), (2) 1-hour rainfall projection, and (3) a difference display.

The NEXRAD product that is used in the AWHPS system is the Hourly Digital Precipitation (HDP) product, which provides a gridded accumulation of precipitation for the previous hour each volume scan of the radar. The modernized flash flood guidance from the RFC indicates, for each HRAP grid, the amount of rainfall required in a particular duration to cause over-bank flood of small streams. The common durations for the rainfall in the flash flood guidance computations are 1, 3, and 6 hours.

Two CRPs are computed for each duration: the first is the CRP based on the radar estimated rainfall, and the second is the CRP based on the radar estimated rainfall plus the 1-hour projection. The CRP gives a statistical probability that the rainfall in a particular HRAP grid has exceeded the flash flood guidance for that grid square. The difference fields are a graphical depiction of the quantitative difference between the flash flood guidance and the radar estimated rainfall for each duration. A second difference graphic will depict the same information for the radar estimated plus 1-hour projected rainfall totals. Utilizing the CRP products, the forecaster will be able to outline the potential flash flood area. At that point, the forecaster can issue the appropriate public product, either a flash flood watch or a flash flood warning.

The Site-Specific Hydrologic Prediction System (SSHPS) is a local hydrologic model provided to allow the WFO forecaster to supplement RFC river forecast guidance by generating forecast river stages for fast-response headwater and river basins (Figure 4). River stage observations and precipitation estimates are provided as input to a simplified rainfall-runoff model, which produces an estimate of streamflow rise due to runoff reaching the river channel. Initial soil moisture conditions are accounted for through model state variables provided by the RFC. Dependent upon the model definition, other inputs such as snowmelt runoff and potential evapotranspiration may also be considered. Model definitions for individual basins are calibrated by the RFC, employing the NWS River Forecast System (NWSRFS) hydrologic models as a baseline.

Gridded or point precipitation estimates may be used as model input, and may be selected by the forecaster prior to the execution of the model. Each of these forms of estimates is ingested through a precipitation preprocessor that calculates basin average precipitation values for a time duration specified by the model definition. Gridded estimates are utilized on a best-available basis employing Stage III, Stage II, and Stage I NEXRAD estimates. Future precipitation estimates may be incorporated through the assimilation of gridded Quantitative Precipitation Forecasts (QPF) products generated by the WFO, the RFC, or a national center. The forecaster interacts with the SSHPS through a graphical user interface that allows for interactive review and adjustment of model results and input.

Conclusions. WFO Hydrologic forecast operations in the AWIPS-era will differ dramatically from those in the pre-modernized NWS. The advent of more powerful computing technologies provides the opportunity to implement sophisticated hydrologic modeling, analysis, and forecast tools in a manner suitable for use of dealing with the wide range of possible hydrologic conditions and situations. Significant portions of the initial WHFS capability will be fielded to WFO's beginning in the fall of 1996, with full hydrologic forecast capability available shortly thereafter. This WHFS implementation will provide the WFO forecaster with the tools necessary to meet the goals of the NWS hydrologic services program, serve as the baseline for future enhancements, and dramatically enhance the WFO's ability to identify and respond to short-lived hydrologic events such as flash floods.

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References

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