# ADVANCED HYDROMETEOROLOGICAL TECHNOLOGIES FOR ENSEMBLE STREAMFLOW FORECASTING

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The United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS), has the responsibility to provide river and flood forecasts and warnings for the protection of life and property within the United States. These forecast services also provide for economic and environmental well-being through improved water resources management. The continuation and advancement of these services will occur through implementation of the NWS Advanced Hydrologic Prediction System (AHPS).

NWS River Forecast Centers (RFC) typically issue stage forecasts for only 1, 2, and 3 days into the future at most forecast points, and crest forecasts out to about 1 week at a few selected forecast points. These forecasts make limited use of growing skill in short- to long-range weather and climate forecasts. AHPS will take advantage of these accomplishments by incorporating much of this information into its technology and procedures. Once implemented, the AHPS will produce hydrologic forecasts out to several months providing river forecasts which not only account for precipitation already on the ground but which also will probabilistically account for estimates of future precipitation. Forecasts resulting from this coupled prediction system will greatly improve the capability of the NWS to take timely and effective actions that will significantly mitigate the impact of major flood and drought situations. The system will also provide products to water resource managers for the evaluation of water availability and allocation for water supply, navigation, hydropower, ecosystems, and agriculture.

AHPS builds upon: (1) partnerships with other water cooperators (Federal, state, multistate, quasi-governmental, and private sector organizations); (2) the NWS infrastructure including the 13 RFCs and the NWS River Forecast System, a very large software system used by RFC hydrologists to produce forecasts of time series of discharges or stages at selected locations (approximately 4,000 along the Nation's rivers); and (3) the NWS Modernization which is providing RFCs with Advanced Weather Interactive Processing System equipment, a powerful suite of networked computer workstations with graphic capabilities. The modernization is also providing national coverage with approximately 140 Weather Surveillance Radar - 88 Doppler (WSR-88D) radars which produce multisensor, high resolution (space and time) precipitation estimates utilizing gauge precipitation observations from networks such as the new Automated Surface Observing System. The precipitation processing algorithms, using WSR-88D data, are being enhanced to account for bright-band effects and to improve the rain gauge bias adjustment, while future enhancements will address orographic effects and snow accumulation.

AHPS functionality and associated implementation activities include: (1) the Ensemble Streamflow Prediction (ESP) procedure in order to provide probabilistic hydrologic forecasts for periods up to several months; (2) the incorporation of meteorologic forecasts at all time scales within the ESP procedure; (3) advanced hydrometeorologic/hydrologic modeling procedures that better account for the natural and man-made complexities of the Nation's river basins; (4) dynamic streamflow modeling in river reaches with significant

dynamic effects caused by backwater, levee overtopping, or other transient phenomena; (5) model enhancements which account for the effect of reservoir operations in both short- and long-term forecasts; and, (6) advanced products (e.g., probability of occurrence information and inundated area mapping) for emergency and water resources management activities to other Federal, state, and local organizations.

The existing ESP procedure uses historical precipitation and temperature time series, along with current watershed conditions, as input to hydrologic models to produce probabilistic forecasts of streamflow or other hydrologic variables. Except for a limited integration of short-term deterministic quantitative precipitation forecasts (QPF), the current ESP process does not take advantage of the skills that exist in a variety of available meteorologic forecasts and climatologic outlooks. Although a number of potentially informative meteorologic and climatic products for different lead times and forecast periods exist, they do not match the spatial and temporal scales at which hydrologic models are run. Therefore, statistical techniques will be used to disaggregate the meteorologic forecasts to space and time scales fine enough for use in hydrologic models. In addition, the ESP system will be enhanced to ingest both probabilistic quantitative precipitation forecasts (PQPF) and climatic outlooks. By incorporating PQPFs into ESP, the uncertainty associated with the QPF will be integrated into hydrologic forecasts. This will lead to the use of objective methods, based on meteorologic forecasts and climatic outlooks, for the preparation of probabilistic inputs to hydrologic models. Also, studies in collaboration with NOAA's Climate Prediction Center (CPC) will be conducted which explore improving the skill in long-range precipitation forecasts by including soil moisture into the current CPC models.

When AHPS is implemented, it will provide probabilistic hydrologic forecasts for any forecast period out to several months. At that time, forecasters will be able to perform the ensemble analyses and display results with the software tool, ESP Analysis and Display Program (ESPADP). ESPADP will enhance forecast evaluation in several ways: (1) the ease with which the analyses can be accomplished will lead to greater use of the ESP forecasting technique; (2) by providing a variety of interactive graphical displays, the forecaster will be able to understand more easily and completely the probabilities generated by an ESP forecast; and (3) by providing more attractive and easily read graphical outputs, NWS cooperators will find it easier to utilize forecast products. ESPADP analyses which will be provided include forecast probability hydrographs, historical probability hydrographs, automatic forecast adjustment to account for model error, hydro-meteorological analyses to link past and present years, and forecast verification.

## Summary

NOAA has the national responsibility to provide river and flood forecasts and warnings for the protection of life and property and for the economic and environmental well-being of the Nation. The advanced hydrometeorologic/hydrologic forecast products provided by AHPS will greatly improve NOAA's capability to provide more timely and accurate forecasts. For the multiple uses of AHPS advanced products and services, NOAA will provide users tools which mitigate a wide range of their objectives. Thus, floodplain management decisions are more effectively arrived at then previously possible. With these advanced products, the operational AHPS will contribute to the leadership role of the Department of Commerce in fostering economic gains for environmentally sound decision making for all streamflow regimes.

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