1A.1 NATIONAL WEATHER SERVICE RIVER FORECAST SYSTEM (NWSRFS) OPERATIONAL PROCEDURES FOR USING SHORT AND LONG RANGE PRECIPITATION FORECASTS AS INPUT TO ENSEMBLE STREAMFLOW PREDICTION (ESP)

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1. INTRODUCTION

The portion of the National Weather Service (NWS) River Forecast System that produces probabilistic forecasts of streamflow and streamflow-related variables for periods up to 12 months was originally called the Extended Streamflow Prediction (ESP) system (suggested name change is Ensemble Streamflow Prediction - ESP). The ESP was not principally configured to handle weather forecasts as input, with the exception of a deterministic short-term precipitation forecasts. Instead, it used multiple years of historical time series of precipitation and temperature as possible future meteorological realizations to create an ensemble of streamflow traces. These traces were then analyzed statistically to make a probabilistic forecast of any streamflow-related variable. In order to improve hydrologic predictions through weather and climate forecasts, the NWS/ Office of Hydrology/ Hydrologic Research Laboratory (HRL) has begun development of strategies/ methodologies that would facilitate incorporation of probabilistic weather and climate forecasts into the ESP.

Probabilistic quantitative precipitation and temperature forecast (PQPF) that would match input requirements of the current ESP system would be a gridpoint joint probabilistic representation of precipitation and temperature at spatial and temporal scales that are relevant to ESP hydrologic models, up to several months in future. An alternative form of a good PQPF product would be a QPF that has uncertainty inherent in the information (e.g., description of the likelihood that precipitation amounts will exceed several selected thresholds) at hydrologic relevant spatial and temporal scales for all required lead times. In addition some basic storm/weather type information may be necessary to enable hydrologists to reconstruct spatial and temporal correlation structure of different rainfall fields / weather systems.

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None of the current National Center for Environmental Predictions (NCEP) QPF products meets all of the desired ESP input requirements, and it is not expected that such products would be available in the near future, especially for lead times longer than 2-3 days. Current weather/ climate outlooks products may provide valuable guidance information for creating probabilistic QPFs for the ESP system, but they require additional processing before being used with ESP.

To introduce meteorological forecasts/climate outlooks into hydrologic forecasts, we (a) identified available precipitation forecast /climate outlooks guidance products, (b) selected a few products based on their performance and characteristics relevant to the ESP system, and (c) developed basic strategies for producing grided probabilistic quantitative precipitation forecasts at hydrologic relevant scales from selected products.

Relative to the type of meteorological forecasts used, three forecast intervals are identified:

(a) short-term period (days 1-2) where human-value-added PQPF is used,
(b) medium-range forecast period (days 2(3)-14) where weather information will come from the NCEP ensemble forecast,
(c) long-term forecast period (more than 2 weeks) that is covered with Climate Prediction Center (CPC) monthly/ seasonal outlooks.

2. CURRENT STATUS

2.1 Meteorological Forecasts / Climate Outlooks Included into the ESP

Currently, the following precipitation forecasts are part of the ESP:

(a) Value-added day 1 probabilistic precipitation forecast, generated once per day in Weather Forecast Offices (WFOs) and mosaiced by forecasters in NWS field offices. These gridded PQPS's contain information about the probability of precipitation and two conditional exceedence fractiles for 24-hr accumulation

at an approximately 5,000 km^2 scale. In addition, 6-hr expected value QPFs are specified to provide information needed for disaggregation of the 24-hr total precipitation in four 6-hr subperiods. These grided fields are utilized as input to the HRL Ensemble Precipitation Processor (EPP; see Seo et al, 1999 for more details) to produce an ensemble of ESP-relevant precipitation time series. An alternative product, used when value-added PQPF is not available, is deterministic QPF for day-1 with a temporal resolution of 6 hrs.

(b) One to 5-day forecasts made daily at the Hydrometeorological Prediction Center (HPC) of the NCEP. Precipitation forecast is given as an amount of precipitation (in inches) expected to accumulate in a 5-day period; a temperature forecast is expressed as a maximum and minimum anomaly from a 5-day climatological mean value in degrees Fahrenheit.

(c) Six to 10-day categorical forecasts, that are issued every Monday, Wednesday and Friday by the CPC. A temperature forecast is expressed in one of the following five categories: much-below-normal, below-normal, near-normal, above-normal, and much-above-normal. An expected 5-day-precipitation-total is given in one of the following four categories: no precipitation, below-normal, near-normal, and above-normal.

(d) Monthly/seasonal outlooks for the next month, and thirteen 3-month outlooks starting with a 2-week lead time, successively lagged by one month and covering a period up to 13 months in the future. Monthly and seasonal outlooks are released approximately in the middle of each month at the CPC. Products include maps of probability anomalies that indicate the likelihood of surface temperature and total precipitation falling within the lower, middle, and upper third of their climatological distributions (below-normal, near-normal, or above-normal category).

1 to 5-day forecasts and 6 to 10-day forecasts of temperature and precipitation are only transient additions to the ESP, because of their nonprobabilistic format. They will be replaced with other probabilistic-type weather forecasts as described in Section 3.

2.2 Operational Procedures for Using Precipitation Forecasts

ESP utilizes forecaster-prepared PQPF information for day 1, and uses the Ensemble Precipitation Processor, a statistical model recently developed by the Hydrologic Research Laboratory, to generate an ensemble of precipitation time series at hydrologic relevant scale (see Seo et al., 1999 , for more detail).

In order to incorporate nonprobabilistic 1 to 5-day and 6 to 10-day forecasts into the ESP using the methodology developed for probabilistic monthly/seasonal forecasts, these forecasts are transformed into probabilistic statements. This is accomplished by assigning, in advance, a distribution-anomaly number for each forecast number/category.

CPC monthly/seasonal outlooks are utilized in the ESP in one of three ways: (a) through modification of full set of historical meteorological data prior to input into ESP based on all or selected forecasts/outlooks. The criterion for adjustment is that marginal exceedence probabilities of the adjusted time series are consistent with the issued forecasts (see Perica, 1998), (b) by applying an automated year weighting technique on hydrologic time series relative to one selected climate forecast (so-called the CPC year-weigh technique, or post-adjustment technique), and (c) using a manual year weighting technique, which allows the user to select subsets of historical data representative of the given climate prediction.

3. FUTURE PLANS FOR INCORPORATING NCEP ENSEMBLE-BASED WEATHER PRODUCTS IN THE ESP

3.1 Products to Be Used

As a result of recent developments in ensemble/ probabilistic weather forecasting, HRL and the Environmental Modeling Center (EMC) of the NCEP started a joint effort to develop and test new approaches for coupling NCEP's global ensemble forecasts with hydrologic models for making hydrologic predictions over a range of time periods from 1 to 14 days.

At the EMC, an ensemble of 17 weather forecasts with the NCEP global model is run operationally on a daily basis with a 16-day prediction window. The NCEP then provides users with forecasts of approximately 20 different variables at 2.5 x 2.5 latitude-longitude grid

boxes. Given that precipitation inputs for the NWS hydrologic models are typically mean areal precipitation amounts accumulated over areas ranging between 100 -10000 km^2 during 1-12 hours, and that NCEP global model precipitation forecasts are 24-hour amounts accumulated over 2.5 x 2.5 degree grid boxes, precipitation forecasts must be interpreted at smaller time and space scales that match input requirements of the NWS hydrologic models.

3.2 Strategies for Deriving Probabilistic Precipitation Forecasts at Hydrologic Relevant Scales from NCEP Global Model Ensemble Forecasts

Two different strategies are formulated in the HRL in order to use global precipitation estimates in the ESP. The first relies on GCM precipitation forecasts, while the second uses statistical methods to translate large-scale atmospheric fields, such as sea level pressure or geopotential heights, to local precipitation. The main argument for the second approach is that GCMs represent free atmospheric variables better than surface variables (e.g., precipitation). In the first approach, using GCM precipitation forecasts, ESP will utilize either GCM-based statistically post-processed precipitation distributions, or directly a whole ensemble. A disadvantage of using distributions instead of ensemble is the need for reconstruction of space-time rainfall structure at global model scales. An important advantage is that statistically post-processed distributions may significantly reduce ensemble biases. In order to use ensemble members directly, it will be unavoidable to adjust them prior to their use in hydrologic models to remove biases in the marginal distributions.

Once global model scale ensemble members are created, they have to be downscaled to hydrologic-relevant spatial and temporal scales. Three downscaling schemes are considered. The first scheme uses already developed EPP techniques. The second downscaling scheme is based on the hypothesis of scale invariance of standardized rainfall gradients. The third scheme builds a hydrologically relevant meteorological ensemble from a historical record.

4. SUMMARY

The enhanced ESP system is envisioned to be a system that will receive, and take advantage of, probabilistic quantitative precipitation forecasts (PQPFs) and climate outlooks to create probabilistic river stage forecasts. Relative to the type of meteorological forecasts used, and methodologies developed to create ESP-relevant input, three forecast intervals are identified:

(a) short-term period (day 1) where human-value-added PQPF is used,
(b) medium-range forecast period (days 2-14) where weather information will come from the NCEP ensemble,
(c) long-term forecast period (more than 2 weeks) that will be covered with CPC monthly/seasonal outlooks

In the current stage of development, ESP can take advantage of short-term PQPF and monthly and seasonal climate outlooks produced at the CPC. Non-probabilistic 1 to 5-day forecasts and 6 to 10-day forecasts are only transient additions to the ESP that currently provide weather information for a medium-range forecast period. However, these forecasts will be replaced by NCEP global ensemble forecasts once methodologies for incorporating ensemble forecasts into ESP are fully developed and tested.

5. REFERENCES

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