Conditional weather resampling for ensemble streamflow forecasting

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Seasonal streamflow forecasting by Bonneville Power Administration (BPA):

- Classical ESP
- Meteo from 55 historical years to represent climate
- Run a hydrologic model starting from the current initial state

Initial state:
- Soil moisture
- Snow pack
- Reservoir levels

EXTENDED STREAMFLOW FORECASTING
USING NWSRFS

By Gerald N. Day, A. M. ASCE

ABSTRACT: Extended forecasting using the National Weather Service River Forecast System (NWSRFS) is done with the NWS Extended Streamflow Prediction (ESP) program. This paper examines the theory, capabilities, and potential applications of the ESP procedure. ESP uses conceptual hydrologic/hydraulic models to forecast future streamflow using the current snow, soil moisture, river, and reservoir conditions with historical meteorological data.

The ESP procedure assumes that meteorological events that occurred in the past are representative of events that may occur in the future. Each year of historical meteorological data is assumed to be a possible representation of the future and is used to simulate a streamflow trace. The simulated streamflow traces can be scanned for maximum flow, minimum flow, volume of flow, reservoir stage, etc., for any period in the future. ESP produces a probabilistic forecast for each streamflow variable and period of interest. The procedure was

One area of future research for ESP is the ability to incorporate knowledge of the current climatology into the procedure. Historical years of precipitation and temperature may or may not be equally representative of the current climatology.

by the National Weather Service (NWS) and the Soil Conservation Service (SCS). Both of these agencies currently rely primarily on regression procedures to forecast seasonal water supply volumes. The regression procedures use a combination of monthly precipitation, first of the month snow water equivalent measurements, and past streamflow to predict streamflow volumes. The 10 and 90% exceedance probability levels are estimated from historical knowledge of how forecast accuracy varies throughout the forecast season. In most years, the regression procedures provide excellent forecasts of seasonal streamflow volumes; however, they sometimes fail to perform well in extreme years.
El Niño effects on local weather in PNW

El Niño
Warm and dry

La Niña
Cold and wet
Climate Mode Indices

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Historical and current phases available online:
http://www.cpc.ncep.noaa.gov/
http://www.esrl.noaa.gov/psd/
http://jisao.washington.edu/ (PDO)
Use climate mode information to improve the skill of the ESP

Initial state:
- Soil moisture
- Snow pack
- Reservoir levels
- Streamflow

Add climate mode info
Conditioning of the ESP

Select the years with most similar climate indices (at forecast time)

Select ESP members with similar phases

Time of the forecast

Dismiss ESP members with dissimilar phases

Smaller ensemble leads to more sampling uncertainty, less accurate quantile estimates and less forecast skill.
Solution

Generate more ensemble members

Have a closer look at the ESP:

27 permutations for 3 years
150,000 permutations for 55 years
Solution

Instead of full historical years (ESP), use parts of historical years:

• Monthly resampling period (1 seam per 30 days)

• Assemble historical MAP and MAT into forecast time series

• Condition on climate mode indices
## Conditional sampling

### Historical time series of monthly climate index

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### Simulated time series

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<tr>
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1998-JUL
2001-AUG
2005-SEP

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Results

Ensembles of synthetic ENSO index time series

1973
La Niña year
Negative MEI

1978
Average year

1997
El Niño year
Positive MEI
Results

Ensembles of monthly precipitation

1973
La Niña year
Wet winter

1978
Average year

1997
El Niño year
Dry winter
Results

Ensembles of monthly averaged temperature

1973  
La Niña year  
Cold winter

1978  
Average year

1997  
El Niño year  
Warm winter
Results

Ensembles of monthly averaged streamflow

1973
La Niña year
High volume

1978
Average year

1997
El Niño year
Low volume
Implemented in CHPS
Hybrid method

- ‘ReduceESP’ selects historical traces from ESP
- ‘StochResampler’ generates additional traces
Brier skill score relative to ESP

Ensemble size effect is canceled out

Improvement of skill is found for two out of three test catchments

![Graph showing Brier skill score vs. Nr historical years in ensemble]

- Improved skill
- More ESP traces replaced by resampled traces
Mix of 10 full historical years and 40 resampled traces seems optimal
Conclusions

• Improved skill (~5%) found for 2 out of 3 test basins

• No improvement found for one basin, but also no reduction of skill

• Apparently this basin is less affected by ENSO
Thanks for your attention
Approach 1: Use NCEP CFS

Mapping the CFS2 100km grid from to Columbia River subbasins
Considerable local bias corrections needed (factor 2 in precip!)
Forecast skill worse than ESP

![Hungry Horse June SQME](chart.png)
Forecast lead time

Skill as a function of lead time (10 historical years and 40 resampled):

Improvement of forecast skill for lead times of 3 months and more
Improvement in the order of 5%, depending on the subbasin