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Ensemble Streamflow Prediction in Western North America: Experience, Development, and Questions

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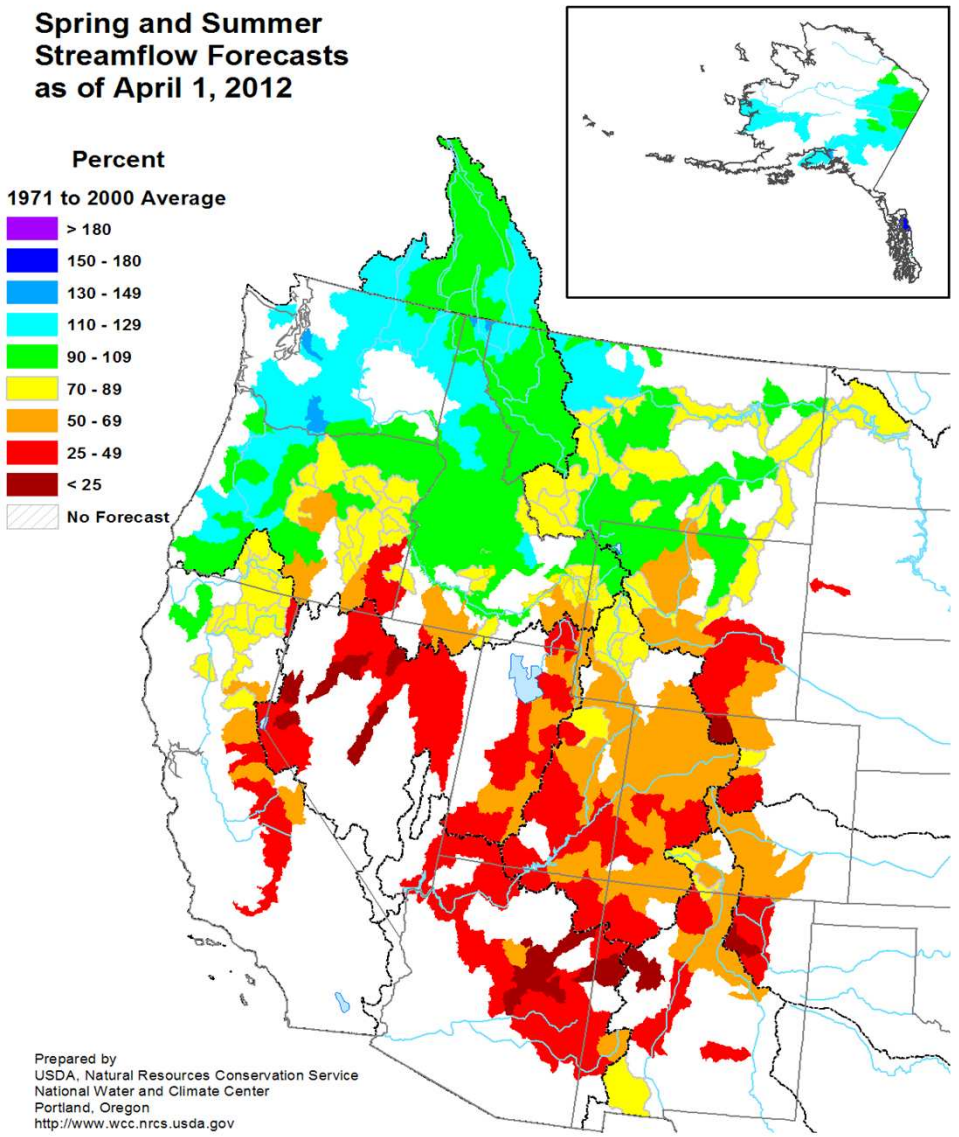
USDA-NRCS Snow Survey and Water Supply Forecasting Program

- Data collection
- Water supply forecasts
- Climate services



Collaborating Entities

- Direct coordination of forecasts with US National Weather Service
- Cooperation with other US federal water management agencies, particularly Army Corps of Engineers and Bureau of Reclamation
- Cooperation with Canadian entities: BC Hydro, BC River Forecast Centre, Alberta Environment
- Delivery of forecasts to Mexico (Rio Grande, Colorado)

Forecast Uses

Ensemble forecasts for both short- and long-term outlooks are used for these primary purposes:

- Flood control
- Hydropower
- Agricultural water supply
- Fish flows
- Navigation
- Recreation

Vancouver Workshop

- "Operational River Flow and Water Supply Forecasting" workshop was held in October 2011 in Vancouver, Canada
- Many topics on hydrological forecasting were discussed, including significant time spent on ensemble forecasting
- Summary paper forthcoming in Canadian Water Resources Journal
- Presentations available from workshop web site at: http://www.cwra.org/branches/CSHS/PostCSHSWorkshopPresentation2011.aspx

Quality of Output Depends on Quality of Input

- Good forcing data are the first prerequisite for modelling
- Data quality is paramount
- Must know spatial representativeness of data
- Spatial interpolation of forcing data is critical

Development

Research and development efforts attempt to account explicitly for all sources of uncertainty in ensemble forecasting. The techniques include the following:

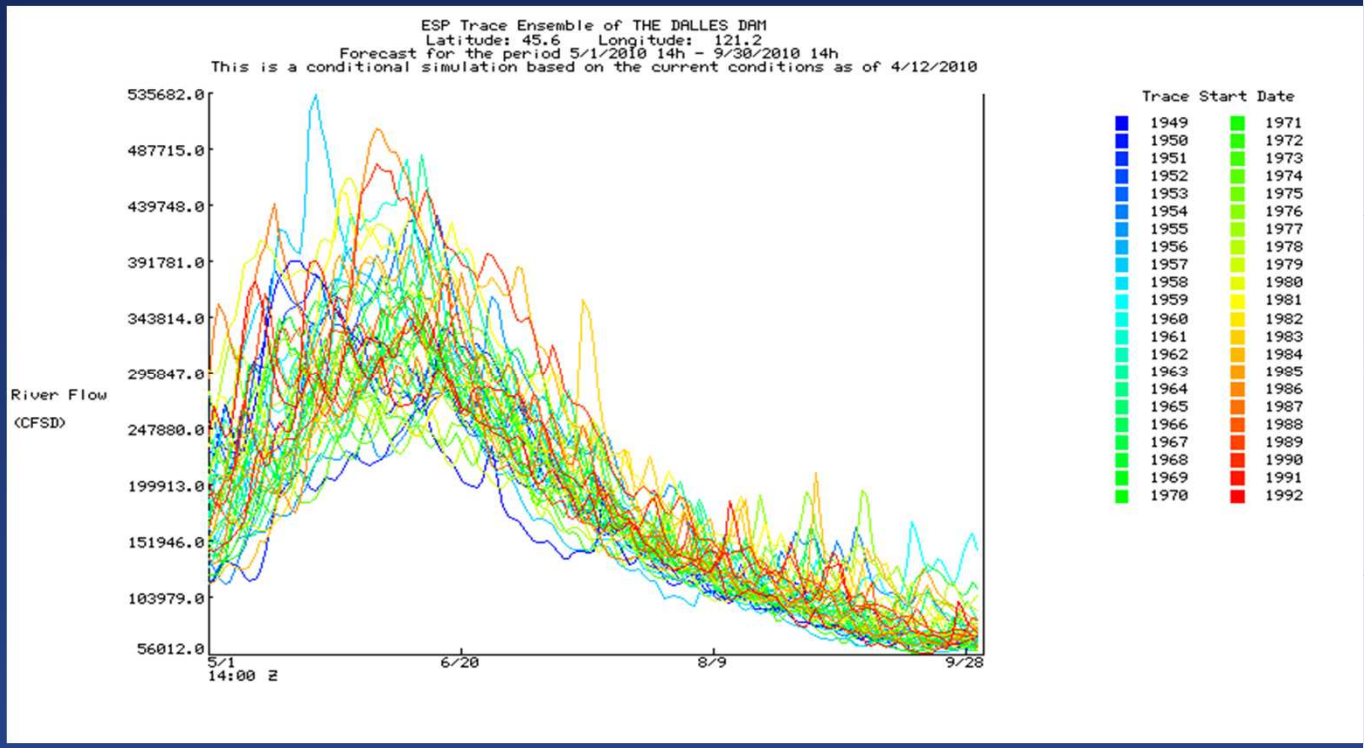
- Use of numerical weather model output ensembles or stochastically generated ensembles as future forcings rather than historical weather traces
- Random sets of initial model states and parameters
- Data assimilation / model state updating (snow, streamflow)
- Multi-modelling (i.e., an ensemble of models)

Forecast Post-Processing

- Ensemble forecasts in general have bias, and the dispersion is incorrect (usually too narrow)
- This will probably still be true even with efforts to incorporate all sources of uncertainty
- Post-processing will therefore always be needed
- Simple techniques include regression "calibration" of ensembles
- More complex procedures include joint probability distribution techniques such as copulas

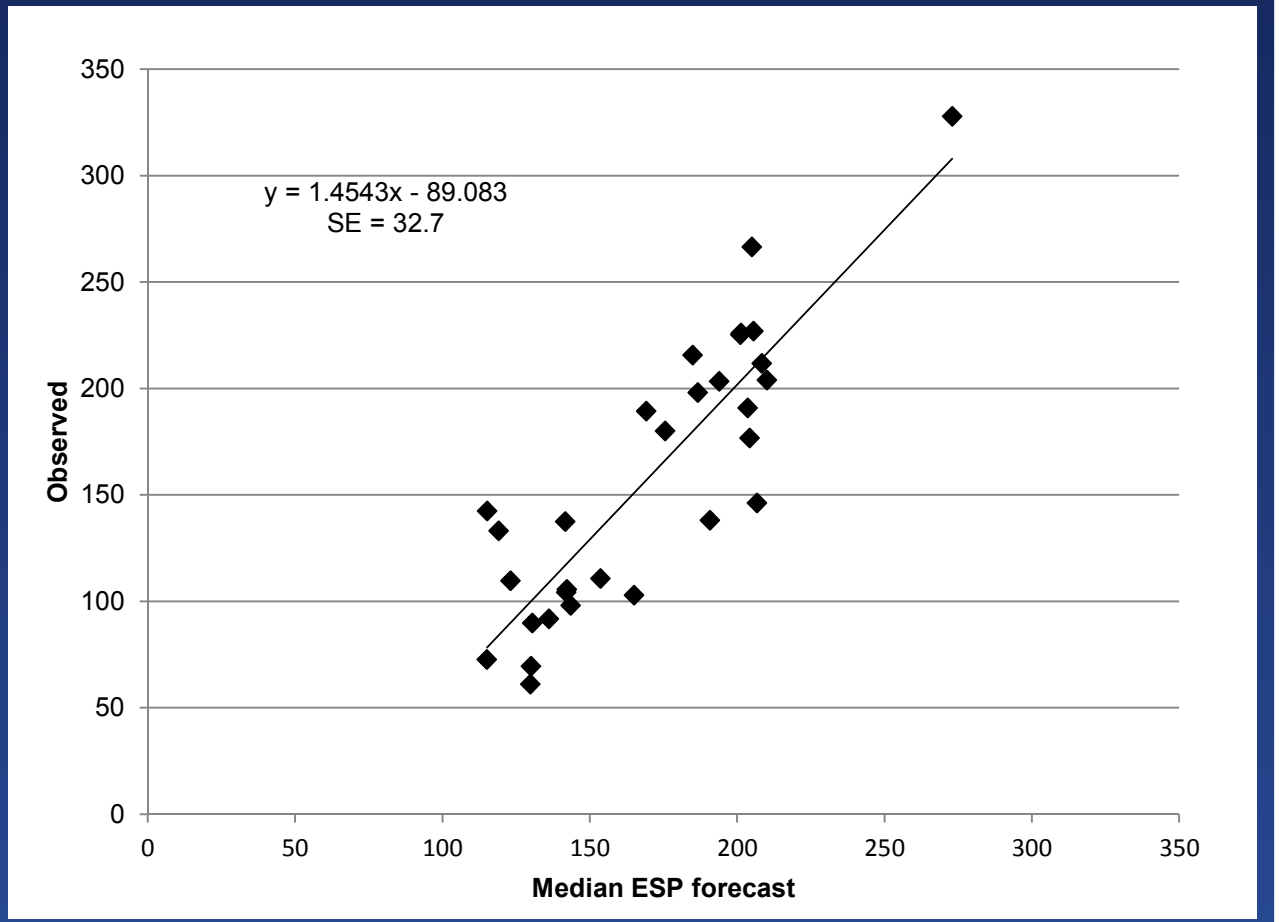
Forecast Post-Processing

Routine ensemble forecasts such as this one, issued by the US National Weather Service and generated with historical forcings, do not receive any post-processing.



Forecast Post-Processing

Simple regression-based post-processing is one possibility. This example is for seasonal streamflow volume and relates the median of the ensemble to the observed flow.



Communicating Forecast Uncertainty

- Remains a significant challenge
- Some progress has been made in simple situations, e.g., agricultural water supply
- Complex water resources systems are still difficult
- Human cognitive processes are limited in ability to comprehend probability; many people are not sufficiently trained in probability
- Allocation of risk among competing water uses is not well defined

Understanding and Using Ensemble Forecasts

- Among US federal water management agencies, the ability to understand ensemble forecasts and incorporate them into management rules is still quite limited
- Hydropower entities in Canada (especially BC Hydro and Hydro-Québec) seem to be the most sophisticated in North America with respect to generating and using ensemble forecasts

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System Complexity

Ensemble forecasting techniques are becoming increasingly sophisticated and complex. Although this makes for a more complete analysis, it also makes these systems more and more difficult to understand to all but a few experts.

Photo: Josef Garen

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System Cost

These techniques and systems also place ever higher demands on resources required for implementation and maintainance.

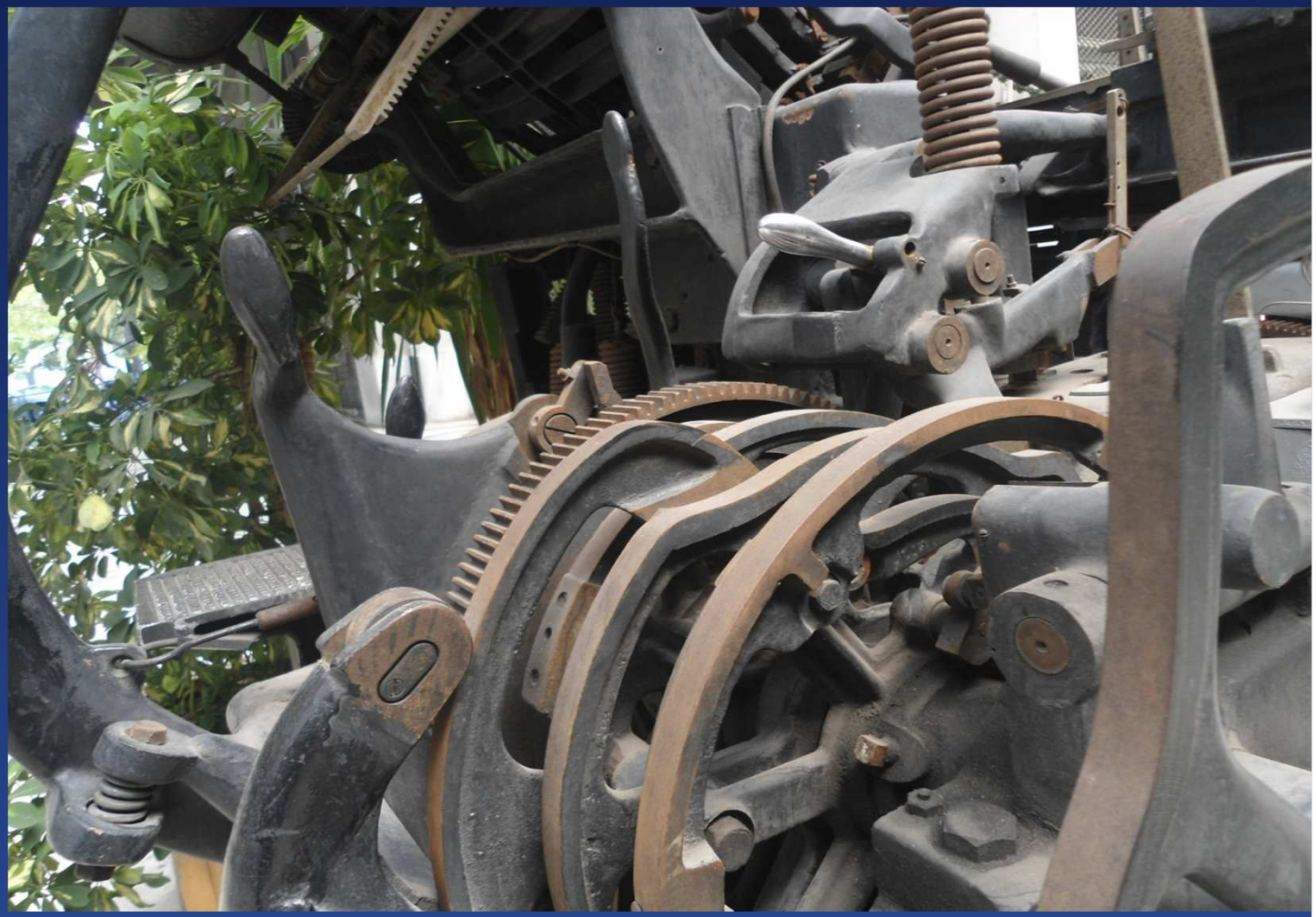
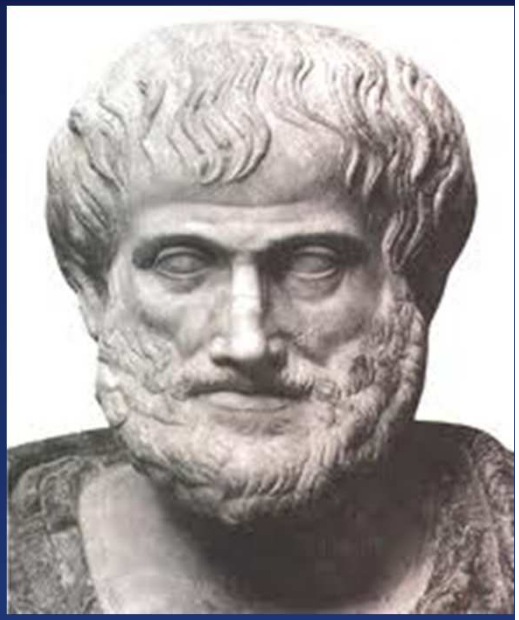


Photo: Josef Garen

Philosophical Questions

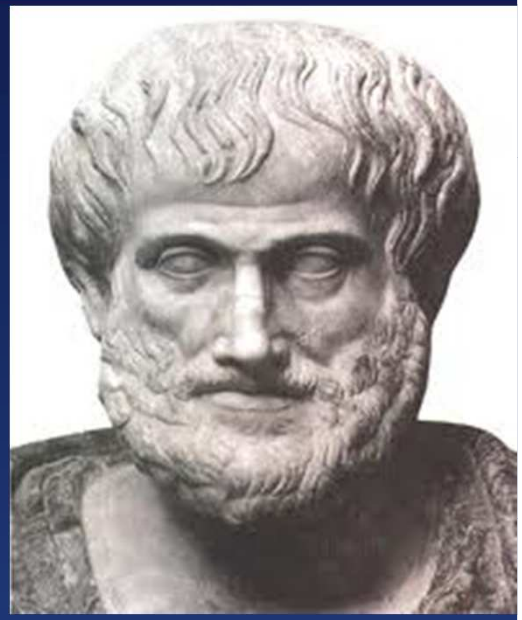


If new complex, sophisticated procedures are only intelligible to a few experts, the hydrologists who apply them operationally will likely not understand them well.

Do the procedures then become just mysterious black boxes? Will we be able to recognize it if the system is not working well or properly? Are we leaving too much of our thinking to the machine? Can we adequately manage the complexity?

Or does any of this matter?

Philosophical Questions



If new complex, sophisticated procedures are expensive in terms of human, financial, data base, and computing resources to implement, we may exceed the ability of most operational agencies to use them.

If few can actually use these techniques, what then is the goal of developing them? Or are these techniques intended only for "high-end" entities that have the necessary resources? Or is this just exploratory research?

Bridging the Gap

In other words, there is a significant gap between research and operations. To some extent, the goals of research -- development and publishing -- are only loosely linked to the needs and capabilities of operations. Few are in the position of being able to bridge the gap (which appears to me to be ever widening).

Is a paradigm change needed to bridge the gap? How can we keep the technology manageable and appropriate for real organizations, which may not have large resources available?

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Thank you for your attention!

Questions?

Comments?