Using hydrologic prediction skill elasticity to quantify the benefits of s2s climate information for hydrologic forecasting

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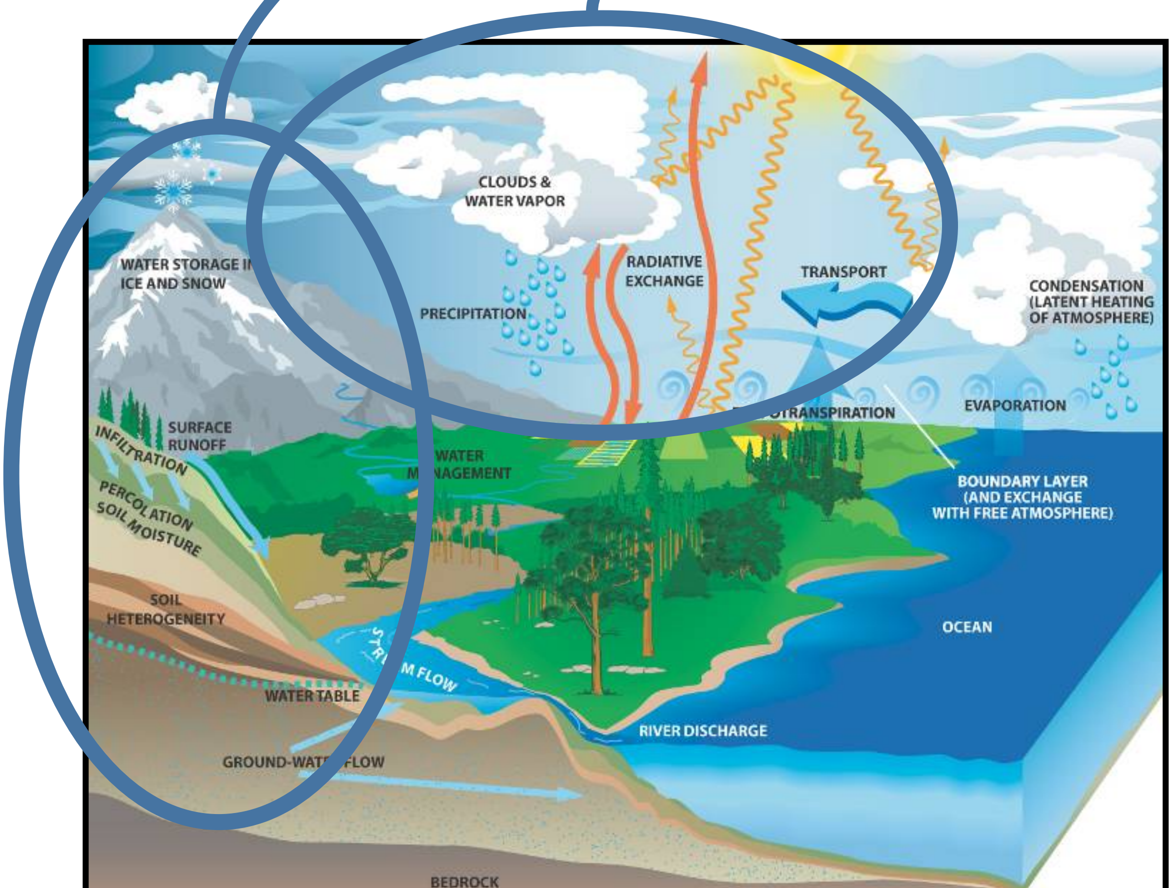
hydrologic predictability

hydrological predictability

meteorological predictability



Water Cycle (from NASA)

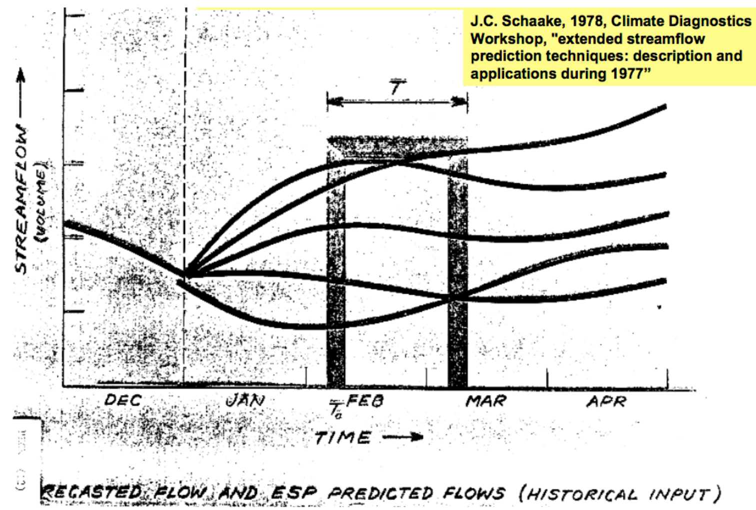
<u>Hydrological Prediction</u>: How well can we estimate catchment moisture dynamics?

<u>Atmospheric predictability</u>: How well can we forecast the weather and climate?

Ensemble Streamflow Prediction (ESP)

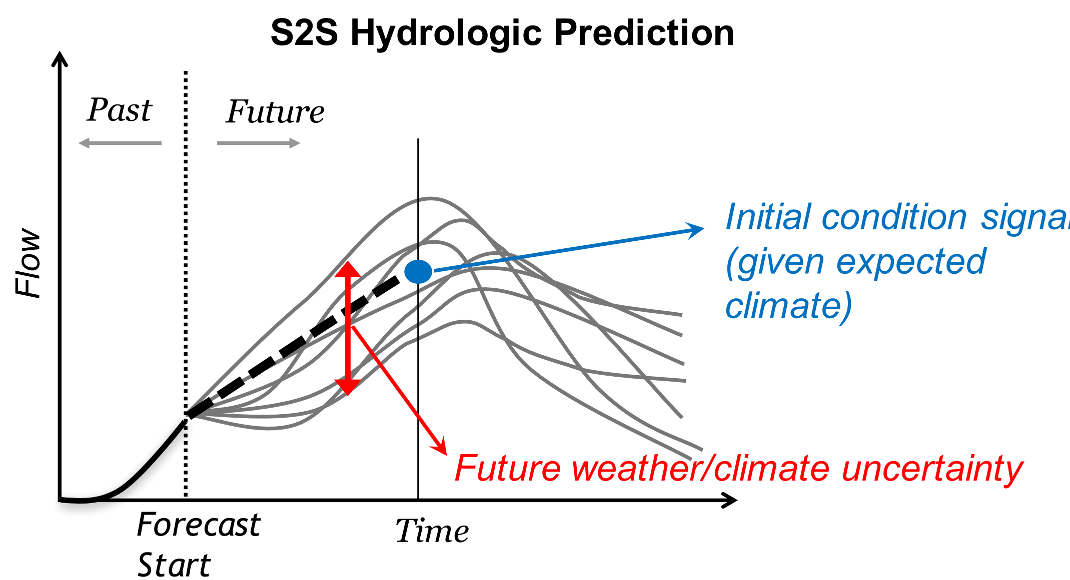
Hydrologic forecast predictability derives from two major sources

- initial land surface moisture conditions
- future weather and climate



For the last 40 years (and even earlier), operational long-range (S2S) forecasts have harnessed the first source only

- ‘Extended’ Streamflow Prediction (ESP) first used at CADWR and CNRFC in the mid 1970s
  - eg, Day, 1985; Wood et al, 2016
- NWS began ESP development in 1975

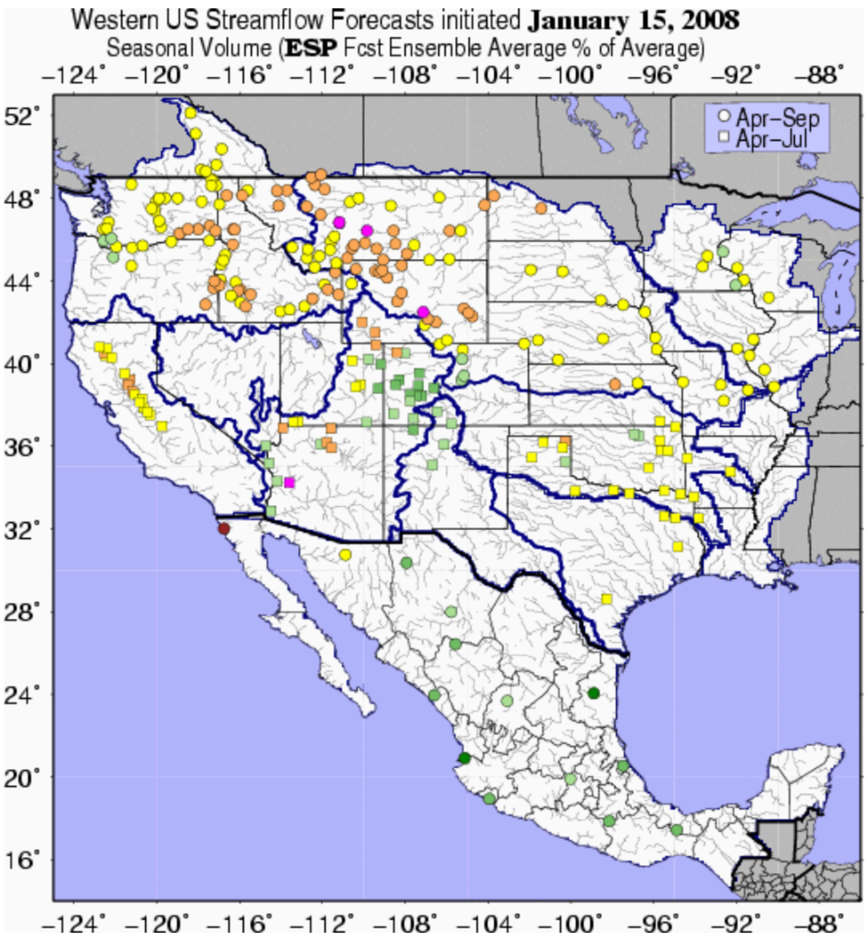


Seasonal Hydrologic Forecasting

Seasonal Volume Forecasts

The clickable map below summarizes the current ESP/CPC volume forecasts for the streamflow simulation locations that are currently active. Clicking on a point launches a window showing the monthly streamflow hydrograph distributions for each type of forecast (e.g., ESP, CPC). NEW! **Below the hydrographs, the prior evolution of selected basin-averaged hydrometeorological variables is also shown.** Tabular results for all volume forecasts are available from links at the bottom of the page.

Summer Streamflow: ESP CPC **Next 6 months Streamflow:** ESP CPC NEW!



% of normal
- > 170
- 150 – 170
- 130 – 150
- 110 – 130
- 90 – 110
- 70 – 90
- 50 – 70
- 30 – 50
- < 30

Station ID
COMRC

Station Name
Neosho River Near Commerce, OK (0718500

Ensemble Median % of Average
92

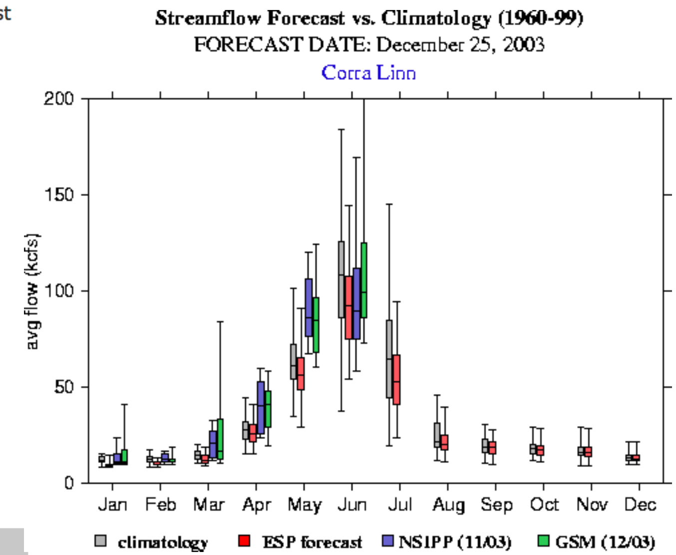
Ensemble Median % of Median
113

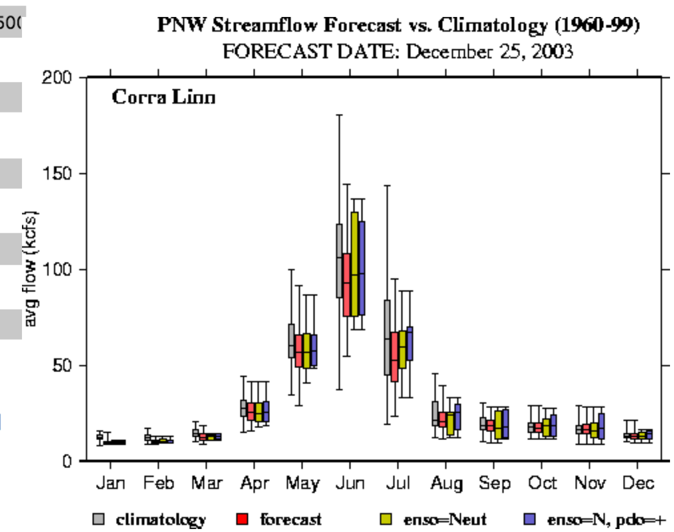
Ensemble Average % of Average
103

Forecast Period
apr-jul

Quick Links to Current Spatial Conditions

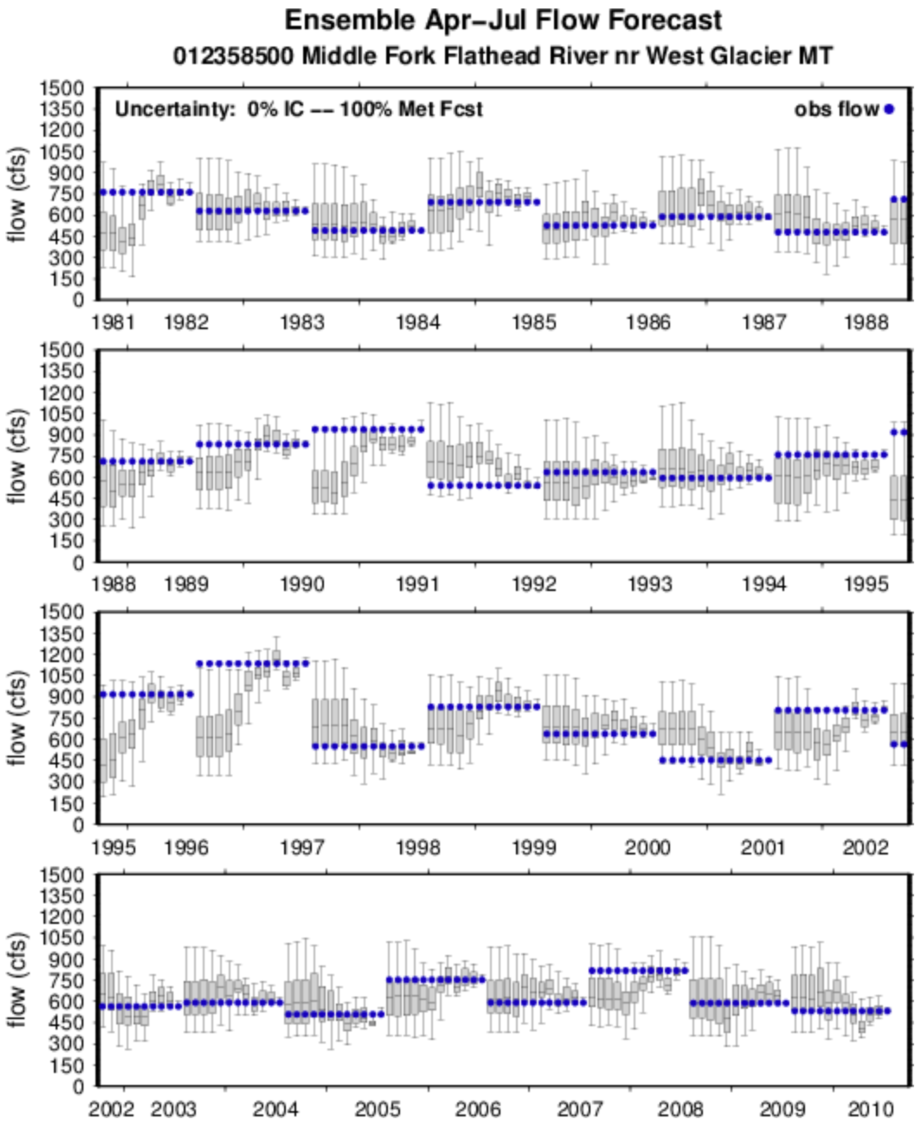
- Soil Moisture
- Snow Water Equivalent
- SNOTEL / ASP(BC)

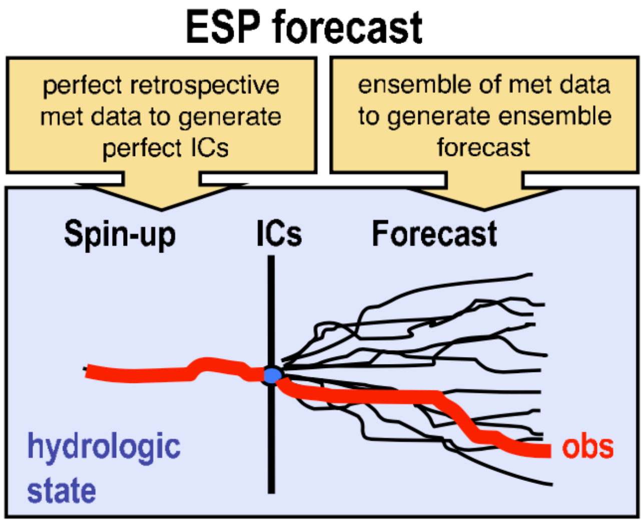


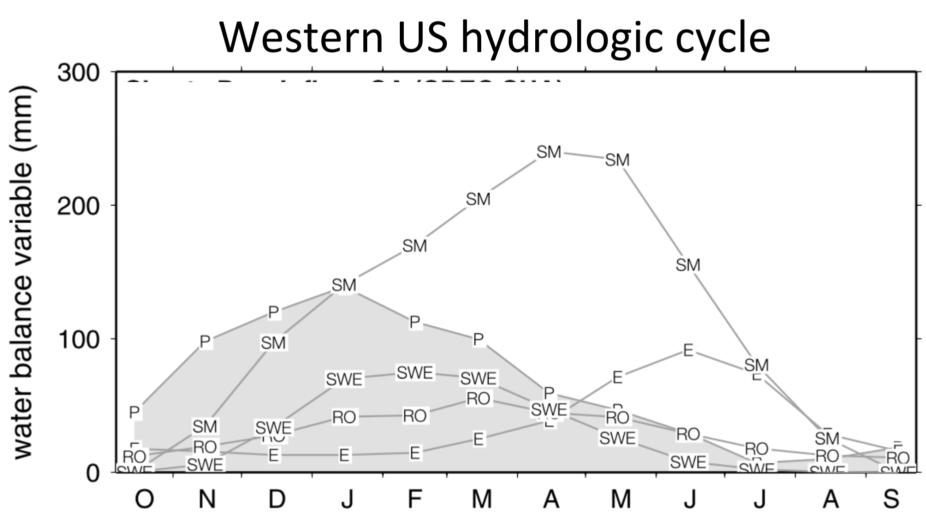


Exploring the propagation of uncertainty

- ESP Hindcasts



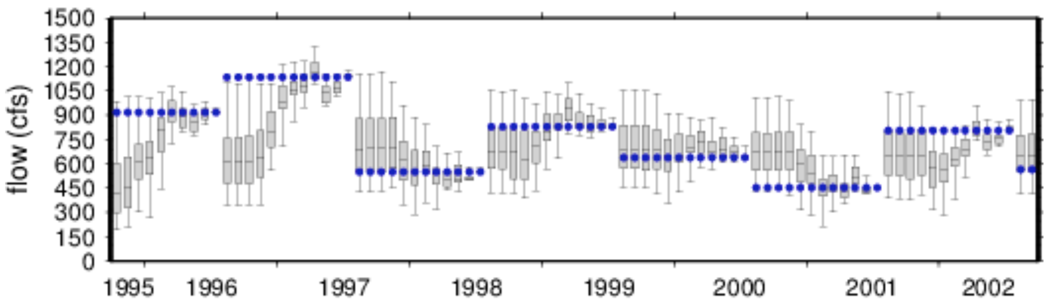


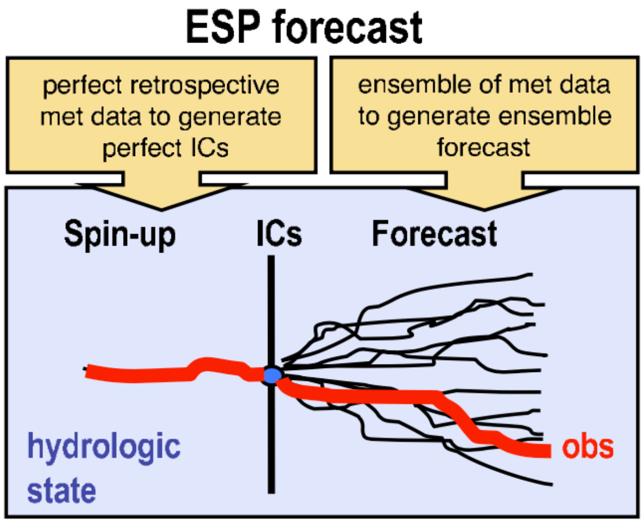


Exploring the propagation of uncertainty

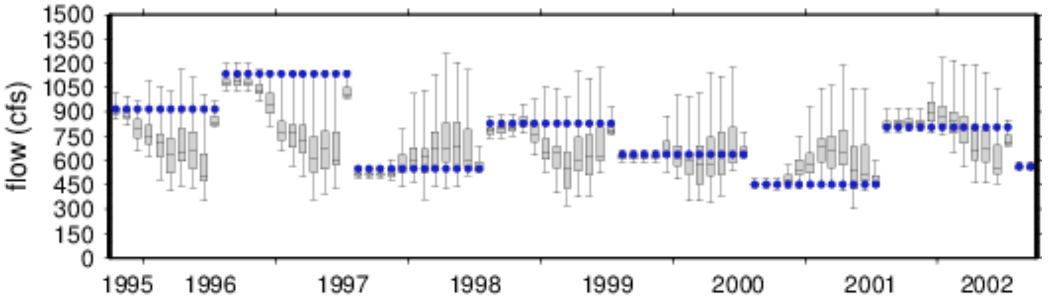
Western US spring runoff forecast

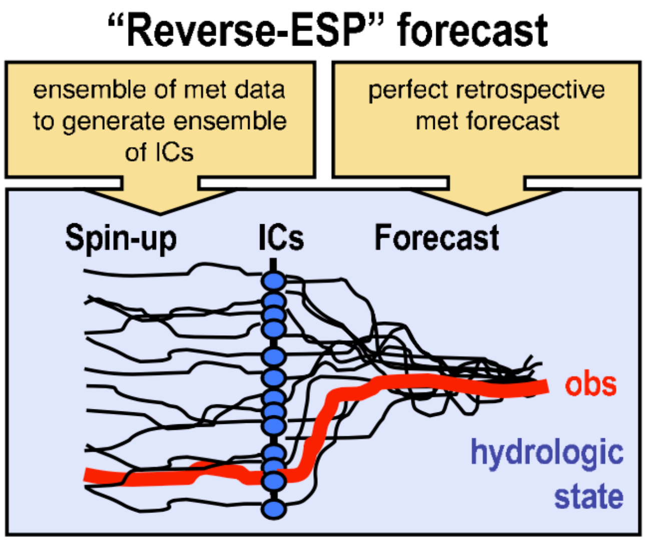
Climate (boundary condition) uncertainty





Watershed (initial condition) uncertainty



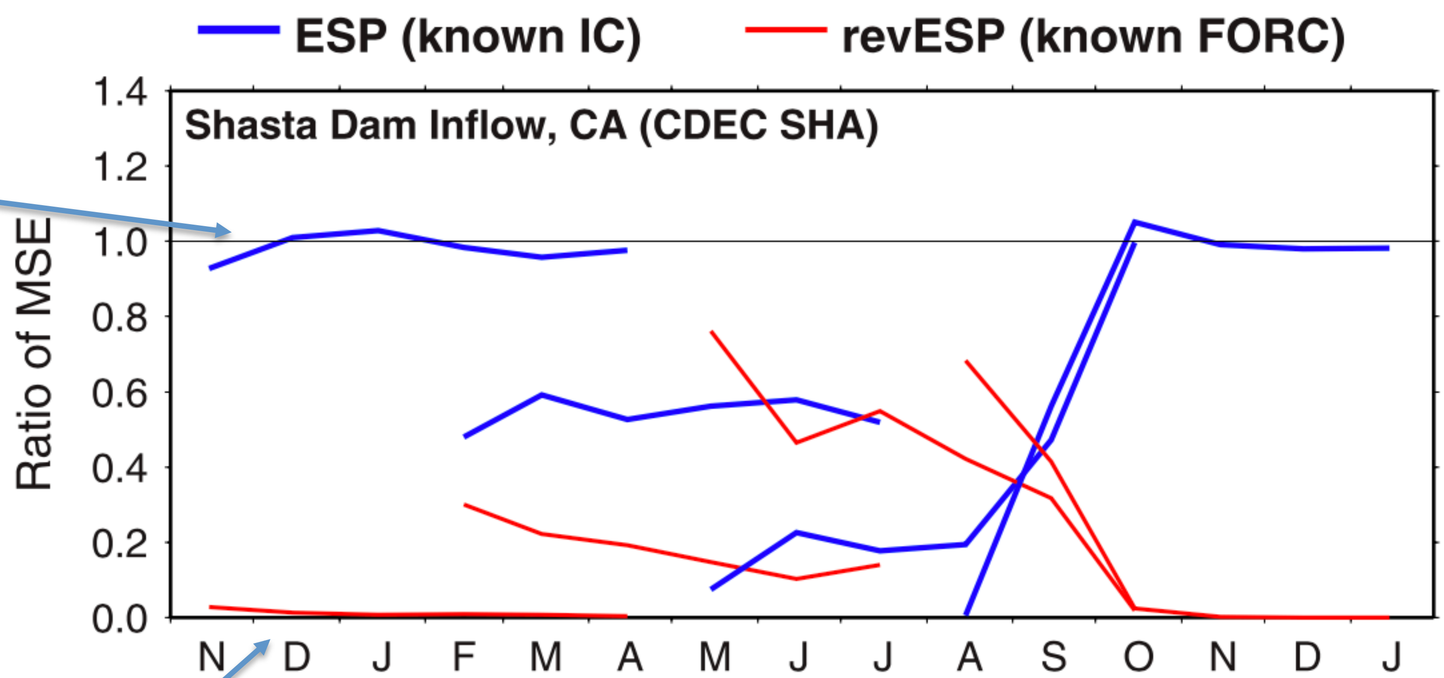


Lorenz (1975): first (IC) and second (BC) kinds of predictability; see also Collins & Allen (2002)

Quantification of uncertainty influence

Forecast errors as a fraction of climatological variance for different initializations: October 1, January 1, April 1, July 1

ICs contribute little info



Climate forecasts contribute all info

GEOPHYSICAL RESEARCH LETTERS, VOL. 35, L14401, doi:10.1029/2008GL034648, 2008

Click Here for Full Article

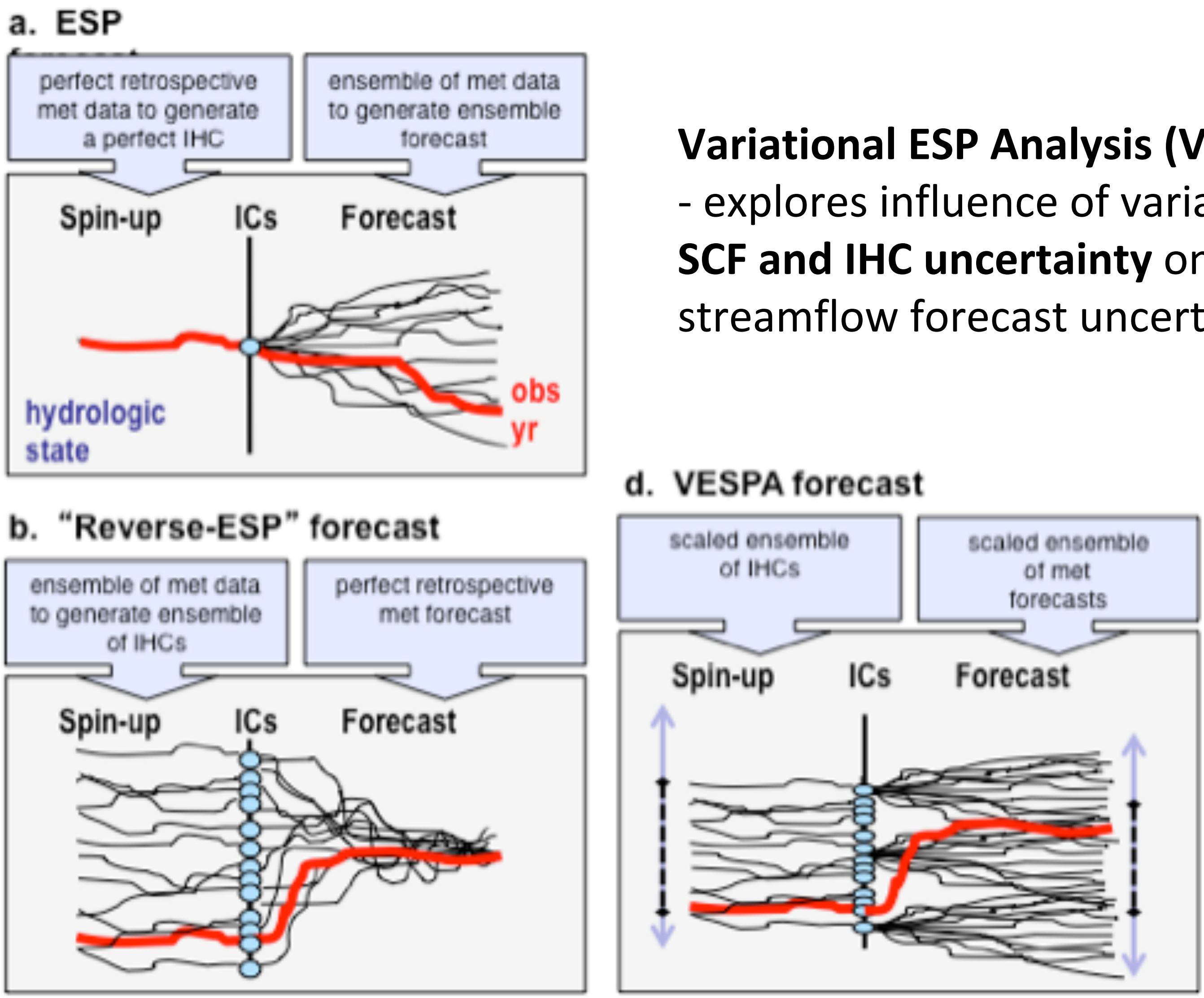
An ensemble approach for attribution of hydrologic prediction uncertainty

Andrew W. Wood[1,2] and Dennis P. Lettenmaier[1]

Received 9 May 2008; revised 19 June 2008; accepted 24 June 2008; published 30 July 2008.

Assessing the sources of flow forecast skill

vary predictor uncertainty → measure streamflow forecast uncertainty



Variational ESP Analysis (VESPA):
- explores influence of variations in **SCF and IHC uncertainty** on streamflow forecast uncertainty

Wood et al (JHM 2016)

VESPA gradients allow calculation of skill elasticities

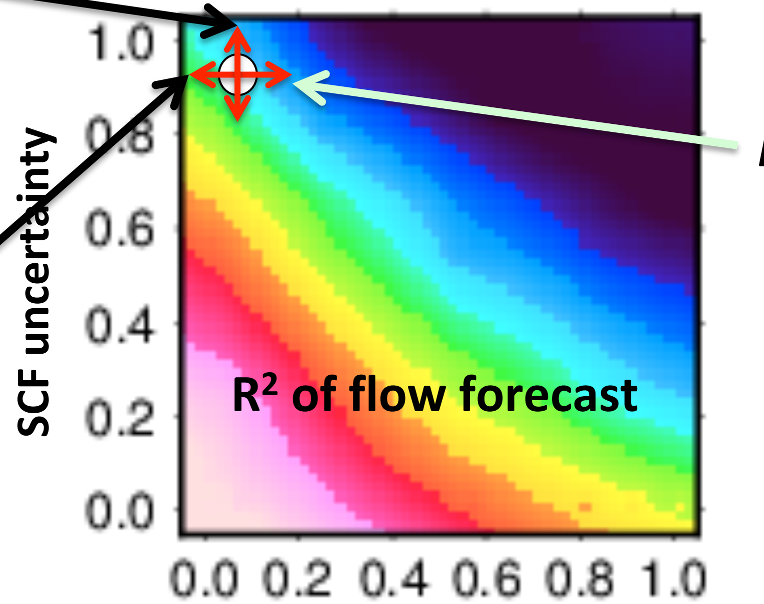
- Climate elasticity of flow forecast skill = local derivative of flow skill with respect to SCF skill

  d(flow skill) / *d*(SCF skill)

- IHC elasticity of flow forecast skill = local derivative of flow skill with respect to IHC skill

  d(flow skill) / *d*(IHC skill)

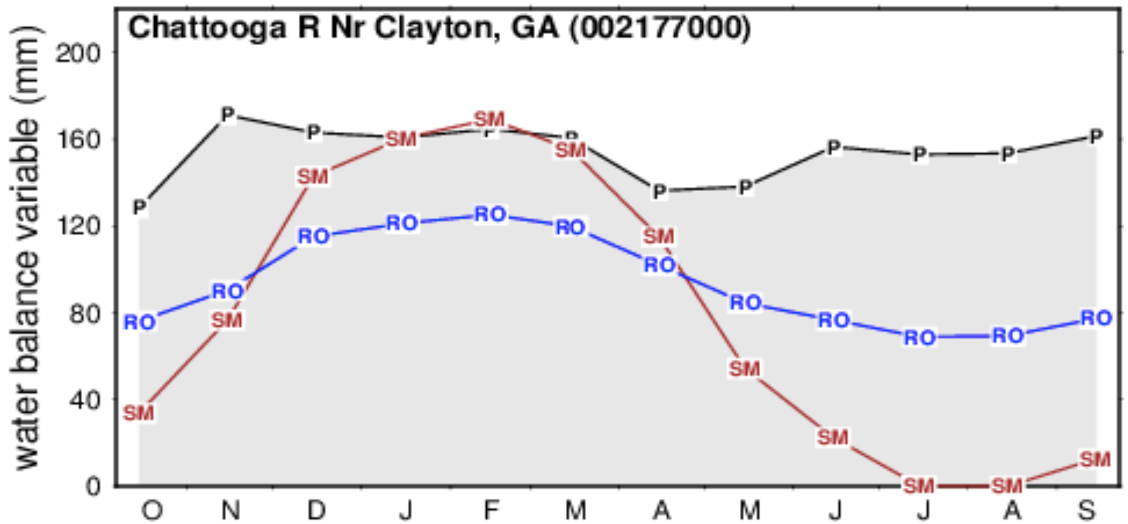
July 1 initialization
1-month runoff forecast



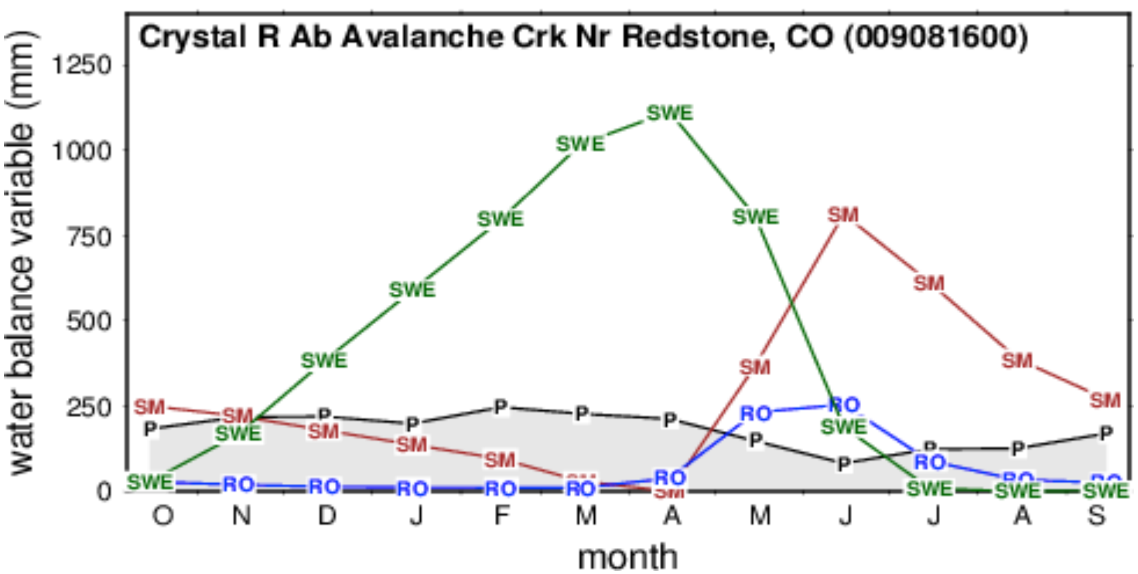
We can ask: For a specific flow forecast in a given location, what is the best way to improve the skill?

IHC: initial Hydrologic Conditions
SCF: Seasonal Climate Forecasts

Seasonal Variation in Watershed Moisture



- humid basin
- uniform rainfall
- no snow
- small cycle driven by ET

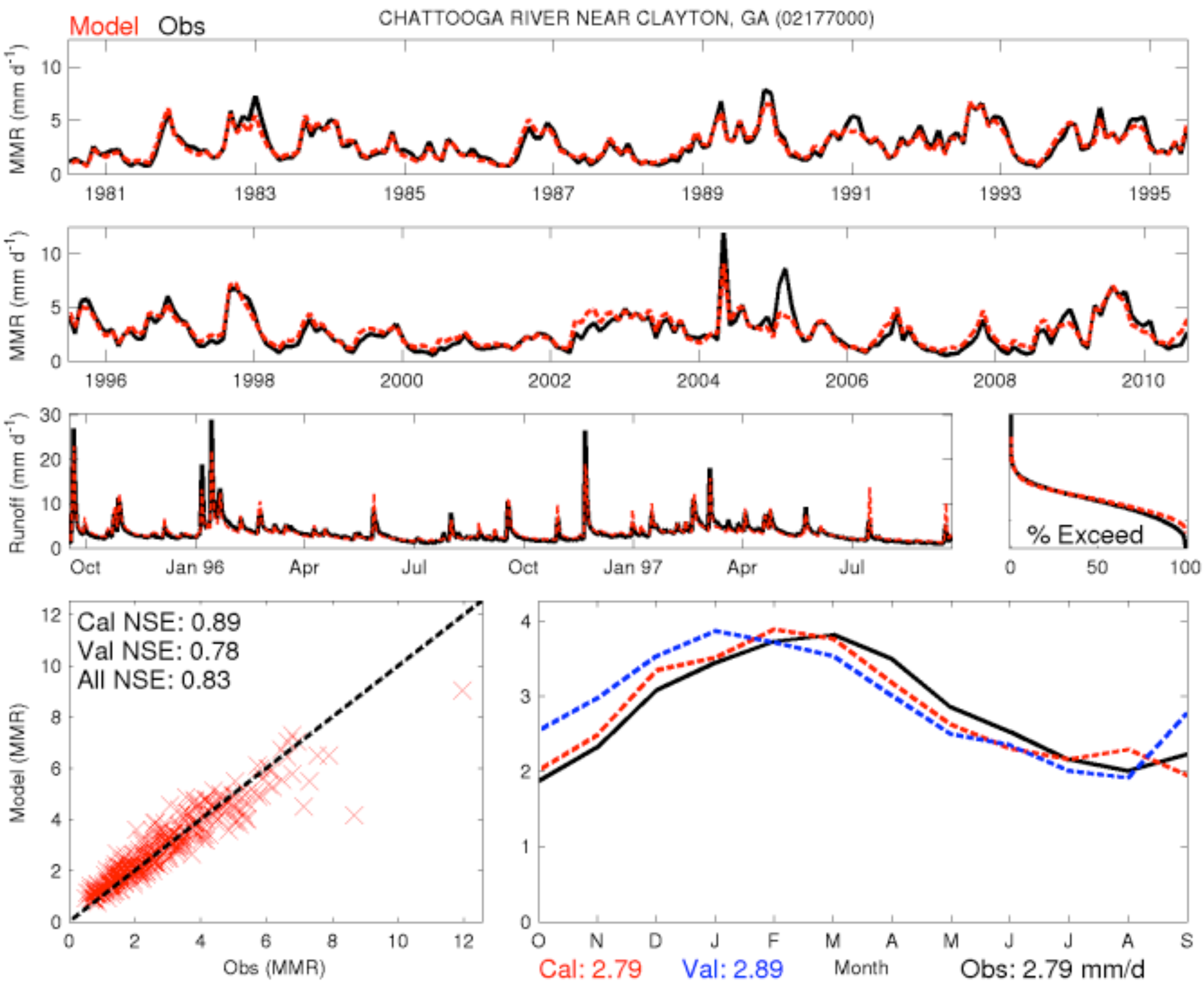


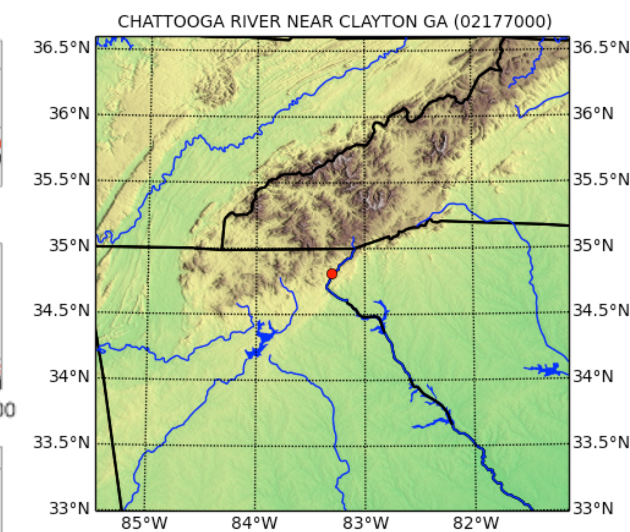
- cold basin
- drier summers
- deep snow
- large seasonal cycle
- April snowmelt dominates May-June runoff

Hydro-climatic/Seasonal Variation in Watershed Moisture

NCAR
RAL/HAP

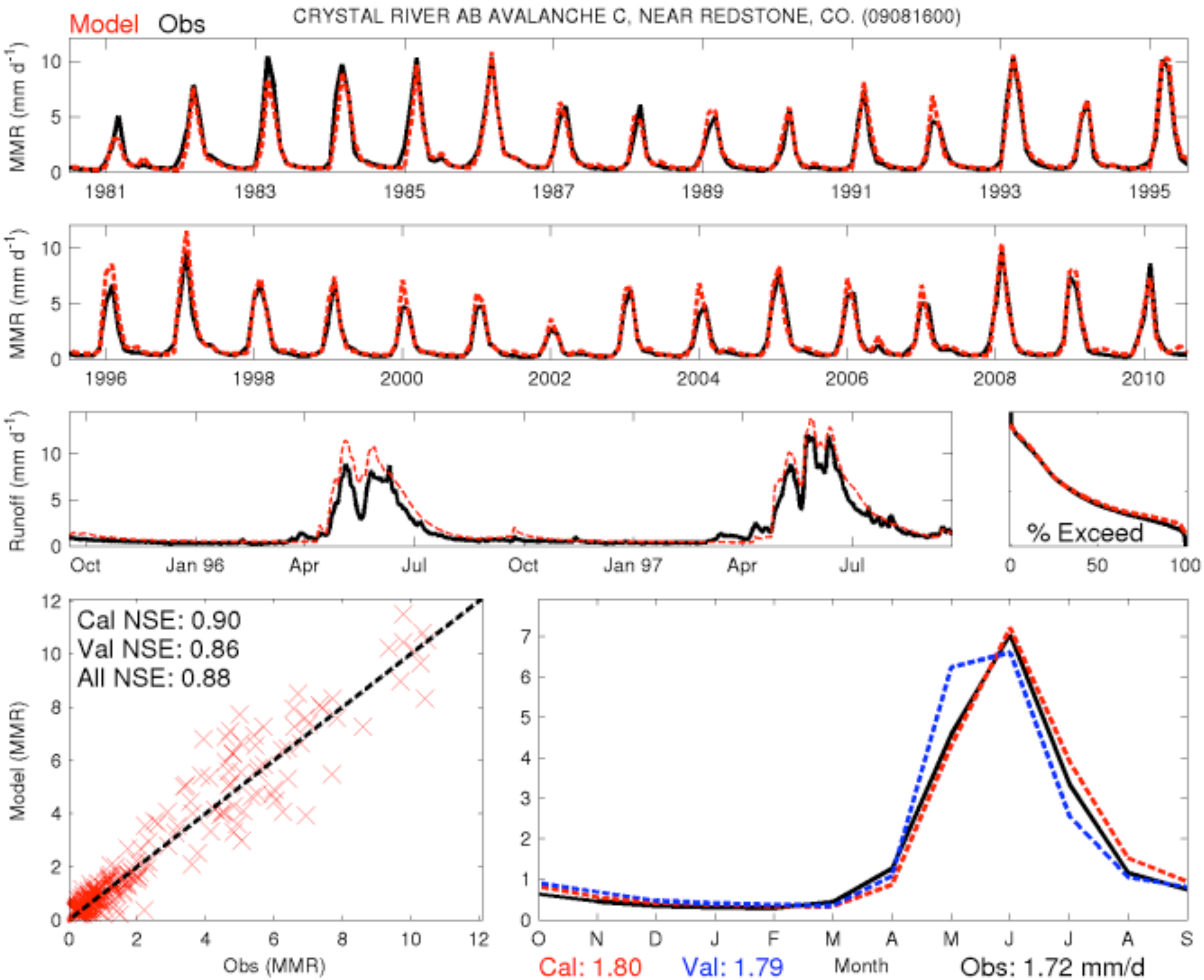
- Focused on 424 of Sac/Snow17 models for 424 of the Newman et al 762 basins
- Contrasting two today – (1) humid Eastern US basin…

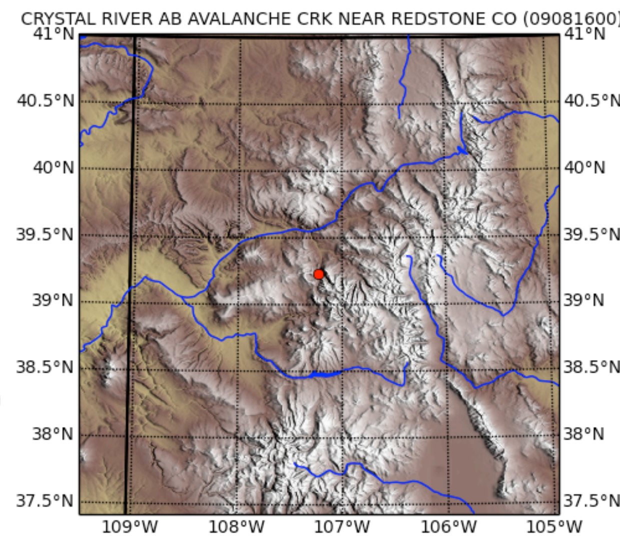




Hydro-climatic/Seasonal Variation in Watershed Moisture

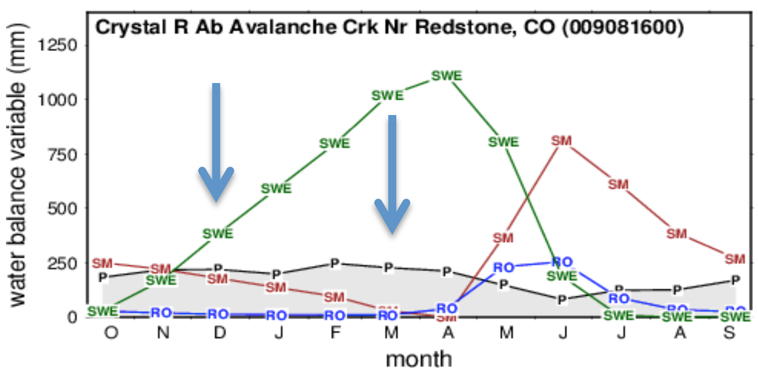
- Focused on 424 of Sac/Snow17 models for 424 of the Newman et al 762 basins
- Contrasting two today – (2) snowy Western US basin…



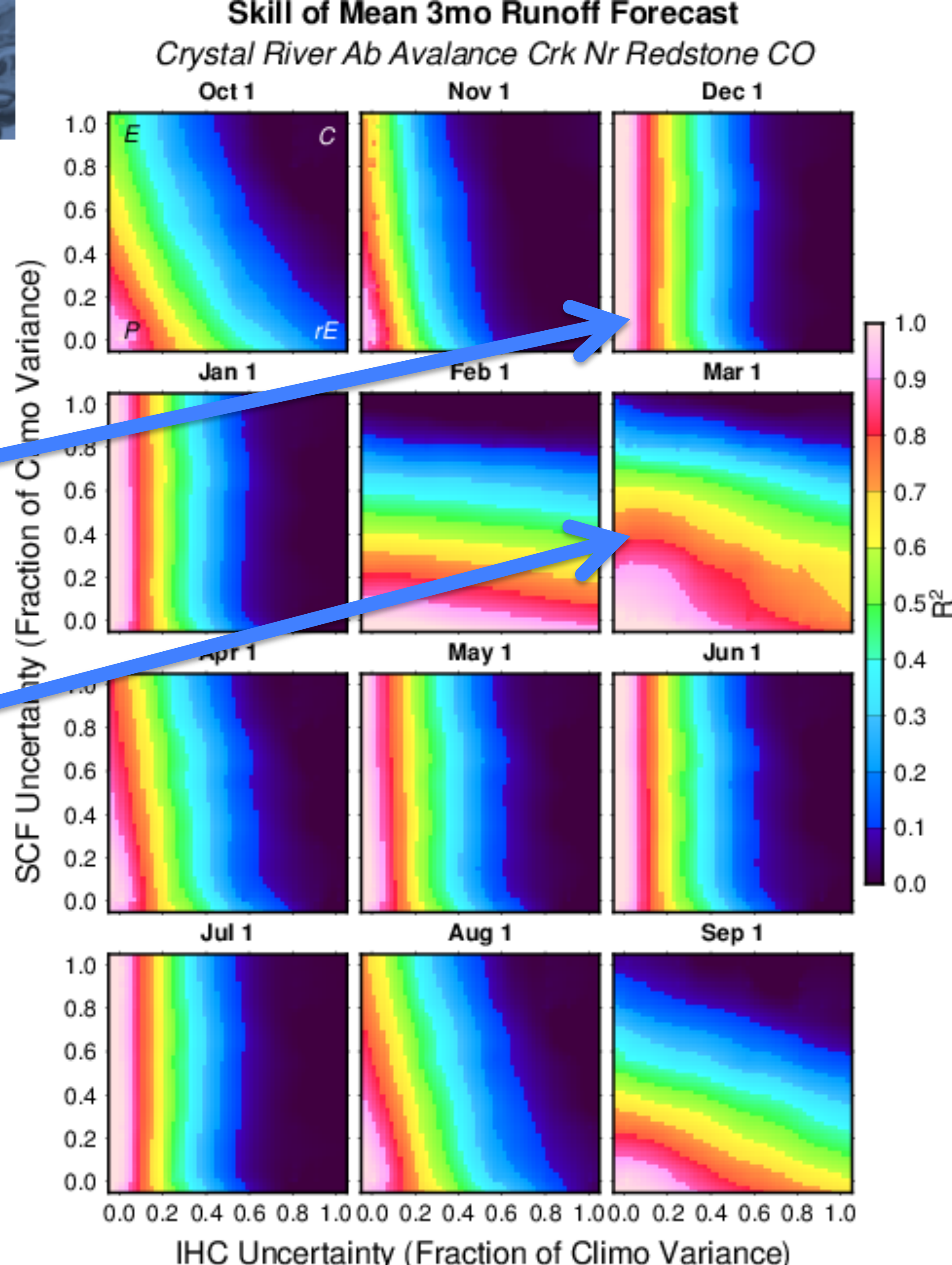


Snow-Driven Basin in the Western US

- Wide seasonal variations in influence of different skill sources
- cold forecast period (Dec-Feb) -- forecast skill depends mainly on initial condition accuracy
- warmer snowmelt forecast period forecast skill depends strongly on met. forecast skill

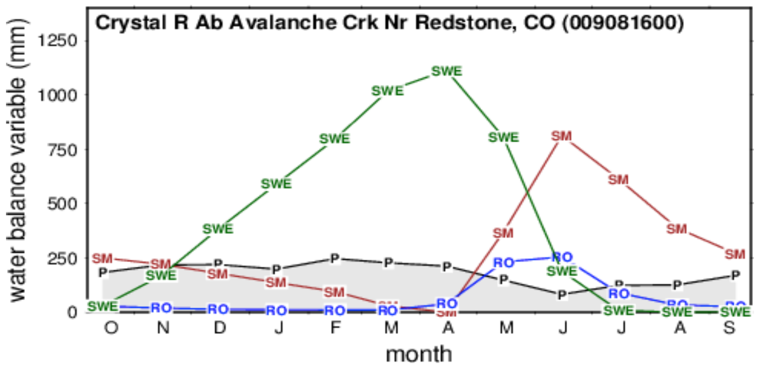


IHC: initial Hydrologic Conditions
SCF: Seasonal Climate Forecasts



Snow-Driven Basin in the Western US

- Sensitivities depend on predictand duration
- For **1 month** runoff (lead 0), IHCs dominate forecast



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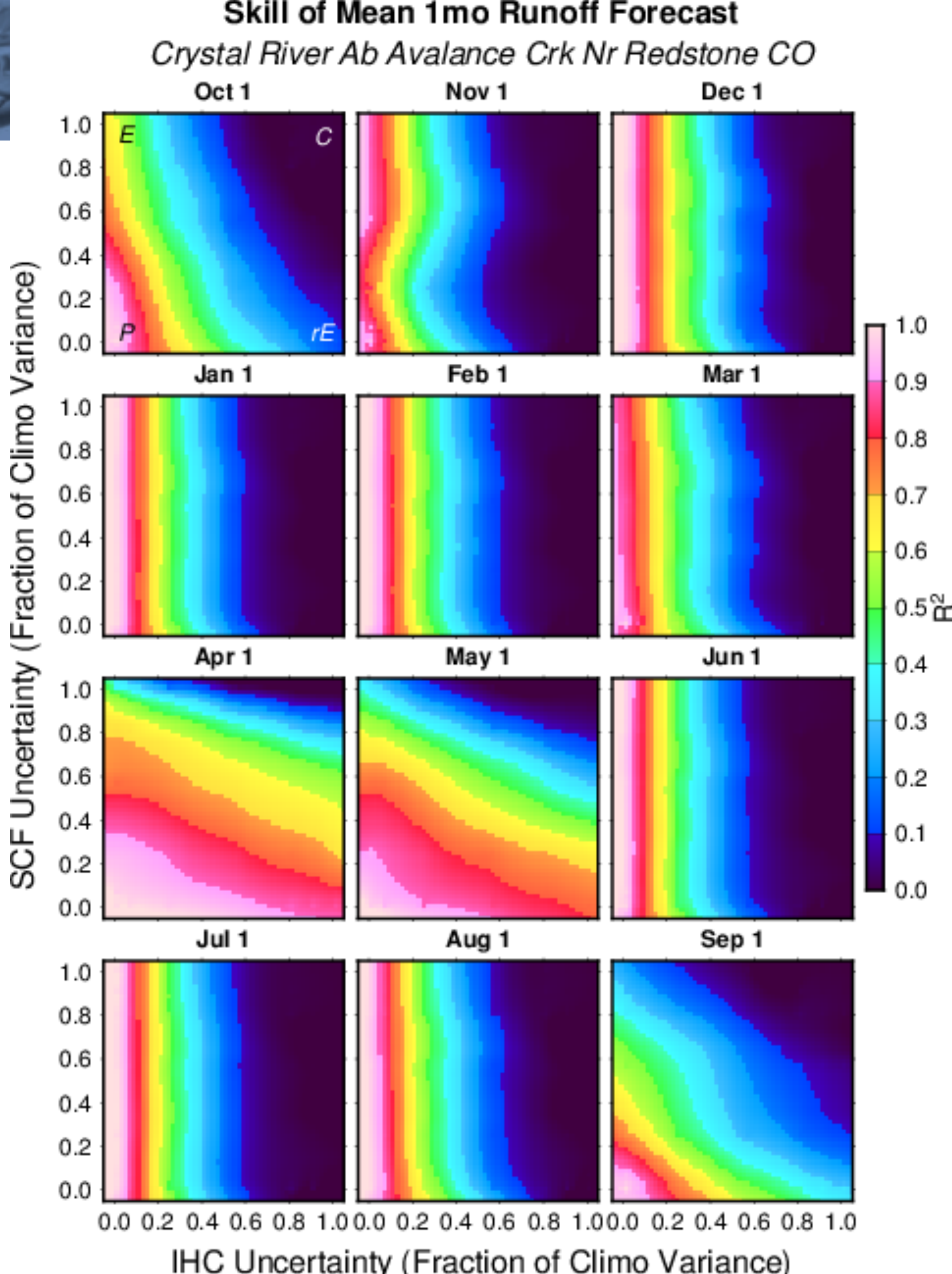
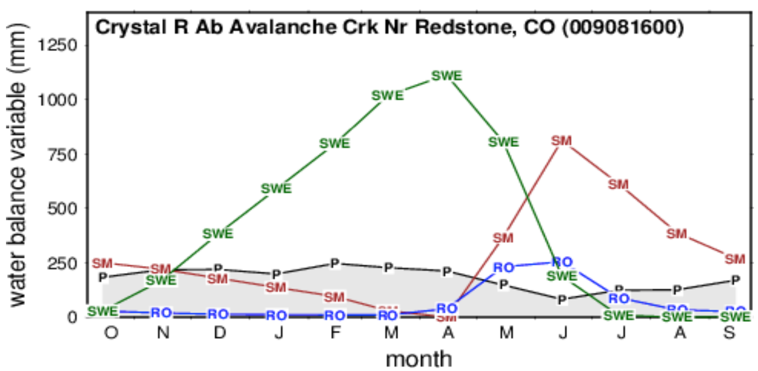


Snow-Driven Basin in the Western US

- Sensitivities depend on predictand duration

- For **6 month** runoff (lead 0), SCFs have more influence than for shorter predictands



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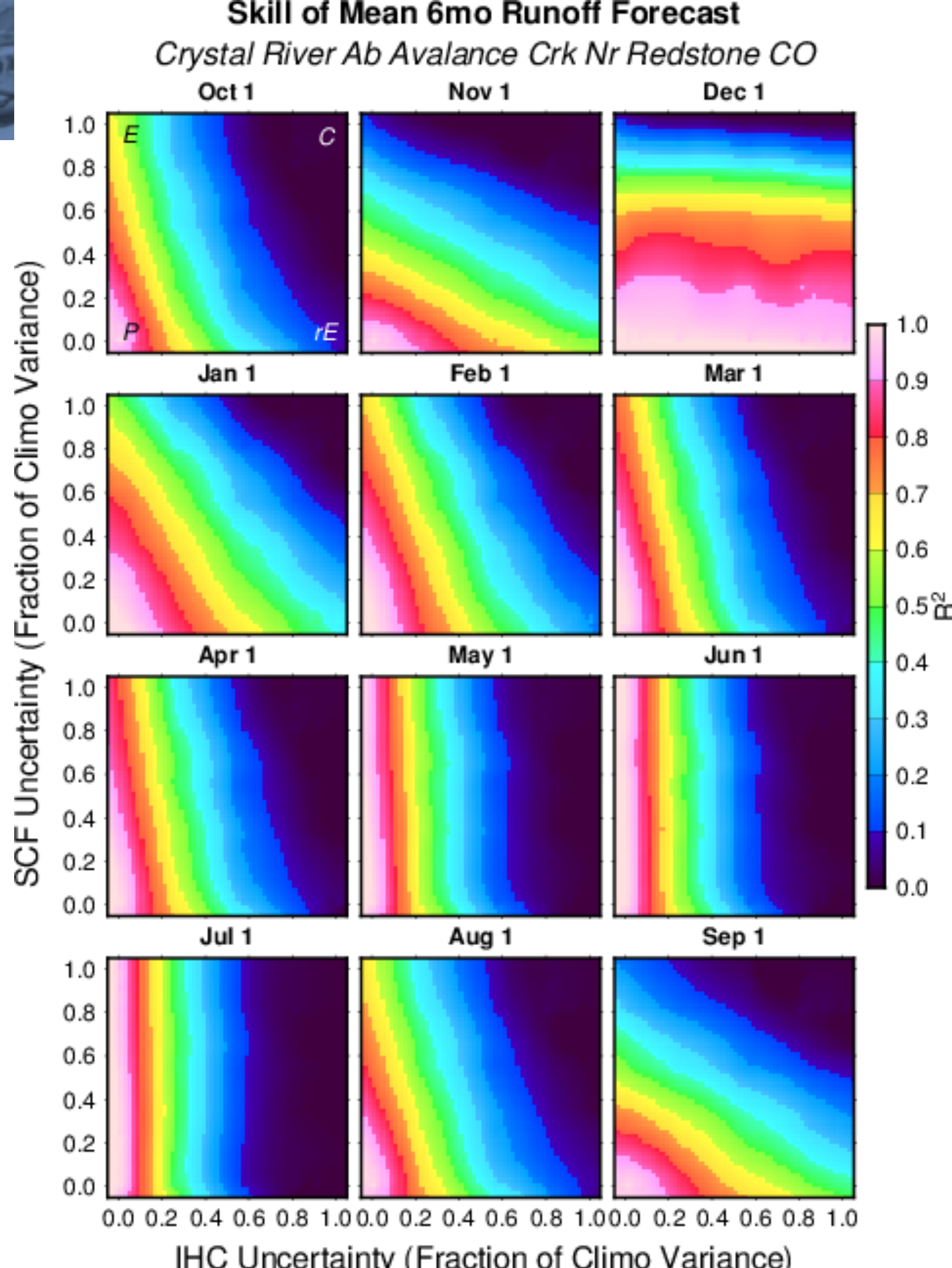
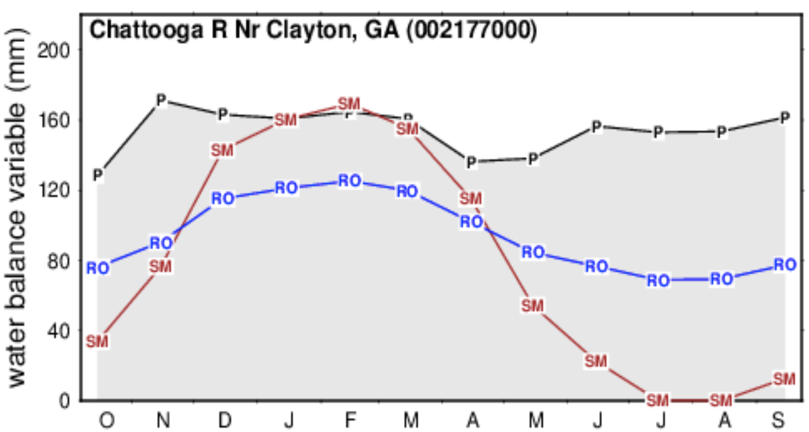
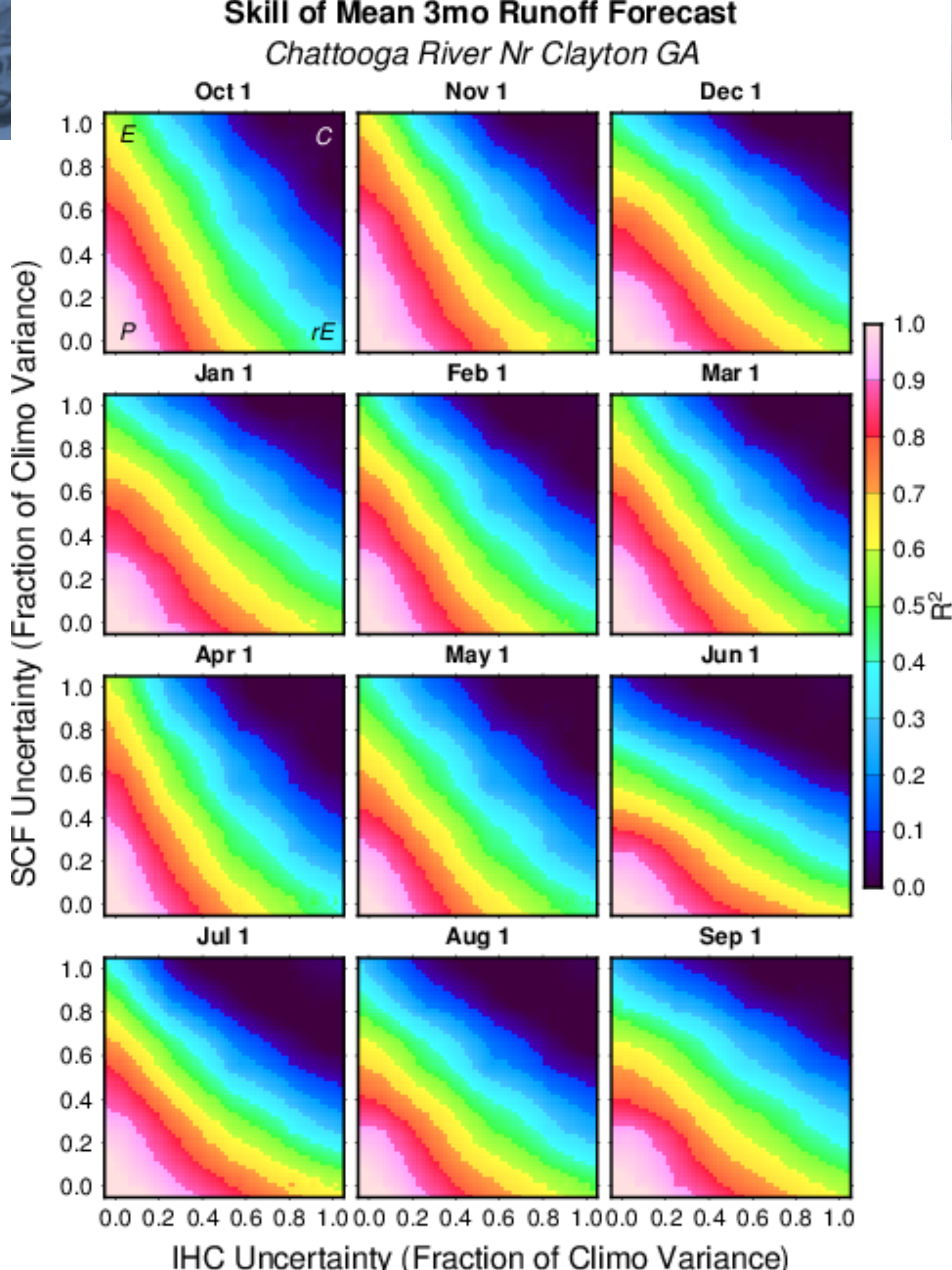


Humid Basin in the Eastern US

- Few seasonal variations in streamflow skill dependence
- Forecast skill (3 months) is always a blend of IHC and SCF influence



IHC: initial Hydrologic Conditions
SCF: Seasonal Climate Forecasts



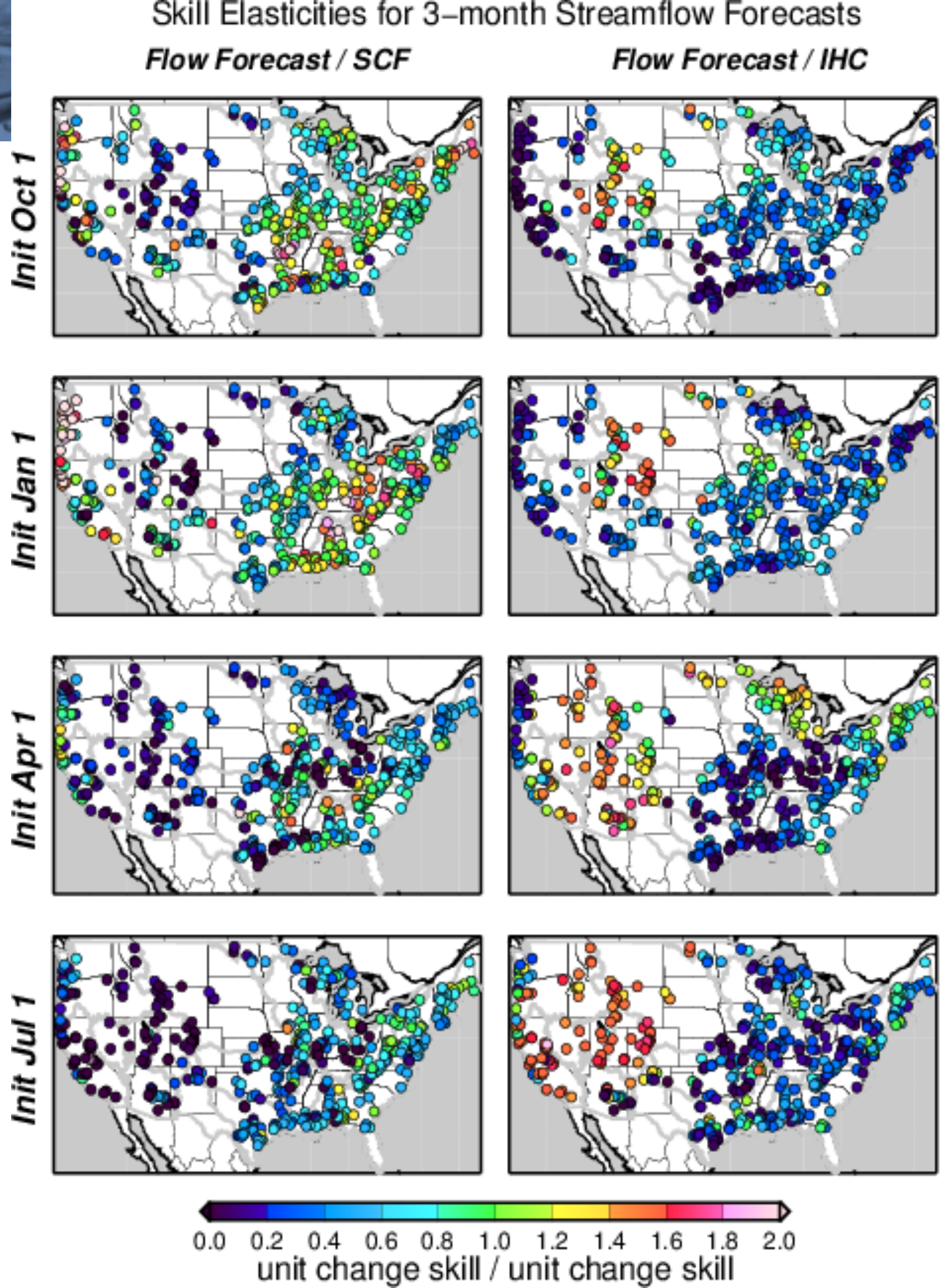
Flow Forecast
Skill Elasticities

- **The % change in flow forecast skill versus per % change in predictor source skill**

- Can help estimate the benefits of investment to improve forecasts in each area (IHC, SCF)
  - for a predictand of interest
  - for a time of interest

- Results emphasize that both SCF skill and IHC skill are important, depending on the forecast being made and the location

- This work is funded by water management agencies – Reclamation and US Army Corps of Engineers



Summary Points

- Forecast skill elasticities – a tool for skill attribution and forecast system design
  - Varying importance of improving watershed info versus S2S climate info

- ‘Windows of Opportunity’ affecting climate forecast value for hydrology and water resources
  - Conditional evaluation of a climate forecast system