UW Experimental West-wide Seasonal Hydrologic Forecasting System

Andy Wood and Dennis P. Lettenmaier

Department of Civil and Environmental Engineering

UNIVERSITY OF WASHINGTON

for

Workshop

NWS/OHD

January 27, 2005

Topics

- q forecasting system overview
- q climate forecasts
- q VIC model spin-up
  - q index station approach
  - q snotel assimilation
  - q MODIS assimilation
- q selected results for winter 2003-04
- q final comments

Forecast System Overview

http://www.hydro.washington.edu/Lettenmaier/Projects/fcst/

HOME
RESEARCH
PEOPLE
DISCLAIMER
LINKS

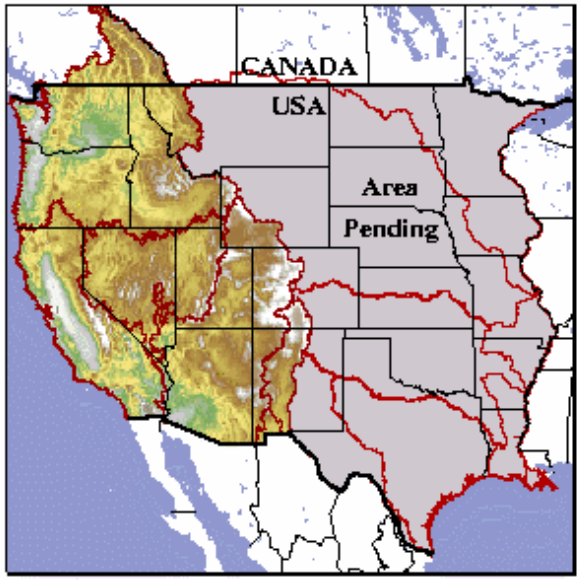
WEST-WIDE SEASONAL STREAMFLOW FORECASTING PROJECT

FORECASTS 12/25/03: Choose a basin . . .

Current Forecast Status:
- Initial conditions (SWE/SM) done
- ESP runs done
- GSM/NSIPP-1 runs done

FCST SUMMARY

Western US Forecasting Domain



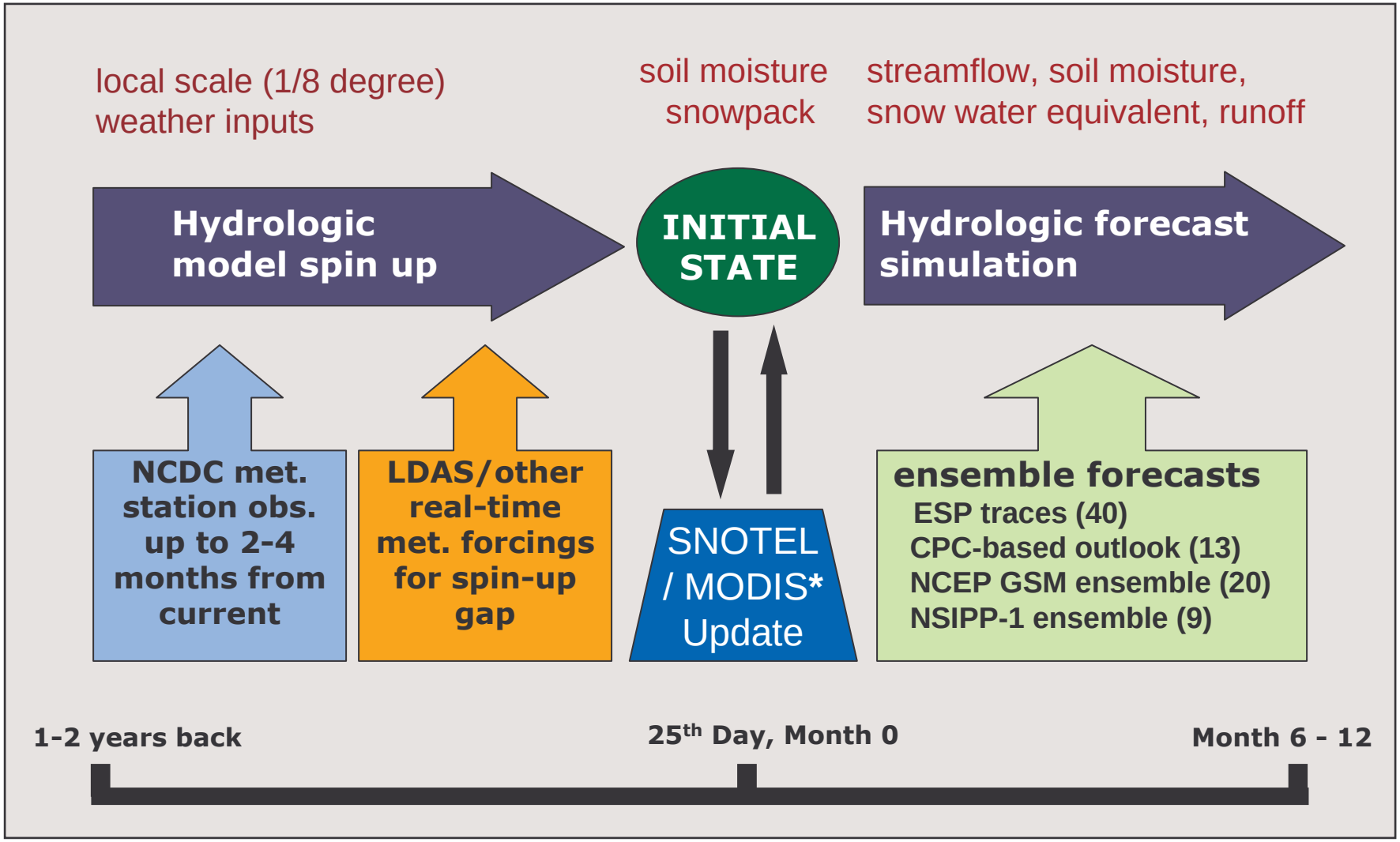
This website presents current monthly-to-seasonal hydrologic, streamflow and reservoir system forecasts for the western U.S. The experimental effort is funded by primarily by NOAA/OGP, the IRI/ARCS Regional Applications Project, and the NASA Seasonal-to-Interannual Prediction Project (NSIPP).

Currently, two forecast approaches are used, both centering on the use of macroscale hydrologic simulation with the VIC model:

- the Ensemble Streamflow Prediction (ESP, formerly Extended Streamflow Prediction) method; and the ESP method conditioned on ENSO and PDO states
- ensemble forecasts downscaled from several climate models (NCEP GSM and NASA NSIPP-1)

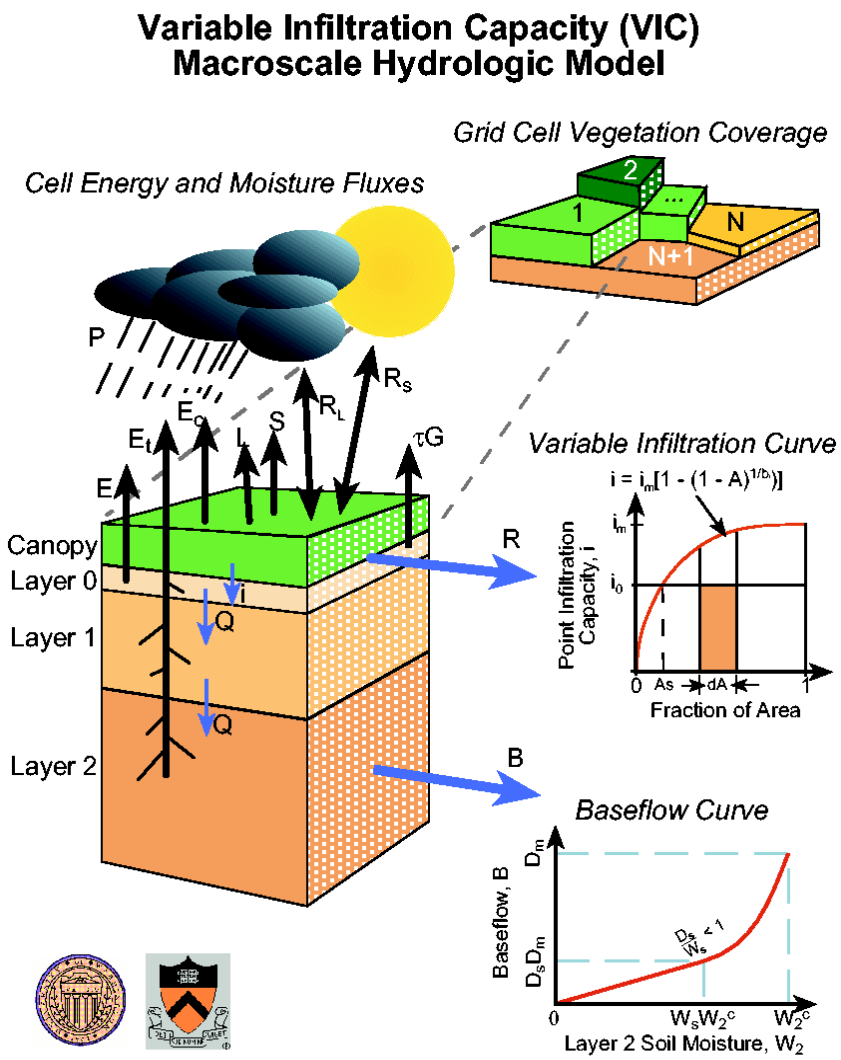
Forecast outputs include monthly streamflow ensembles, spatial distributions of snow water equivalent (SWE), soil moisture and runoff, and (*not yet active*) reservoir system storage and flow forecasts. In addition, the analyses of the initial hydrologic state at the forecast date constitute a nowcast of SWE and soil moisture conditions throughout the domain, based on observed meteorology.

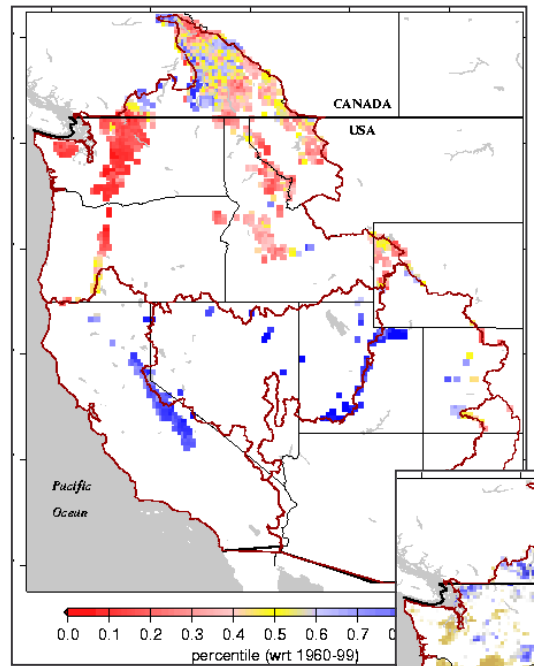
Forecast System Overview



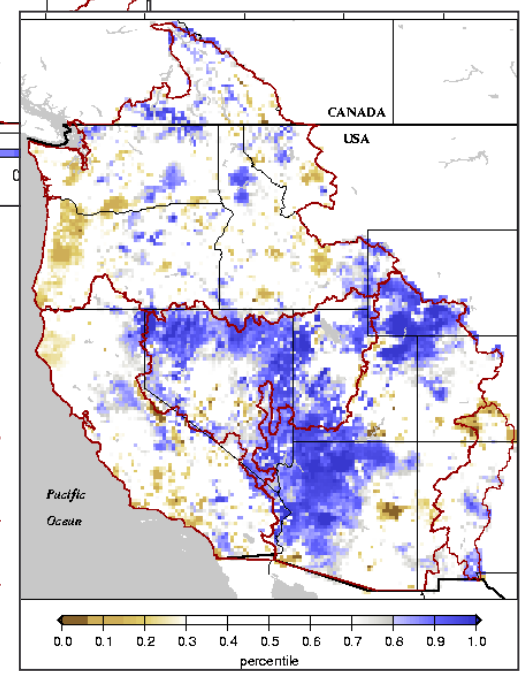
* experimental, not yet in real-time product

Forecast System Overview





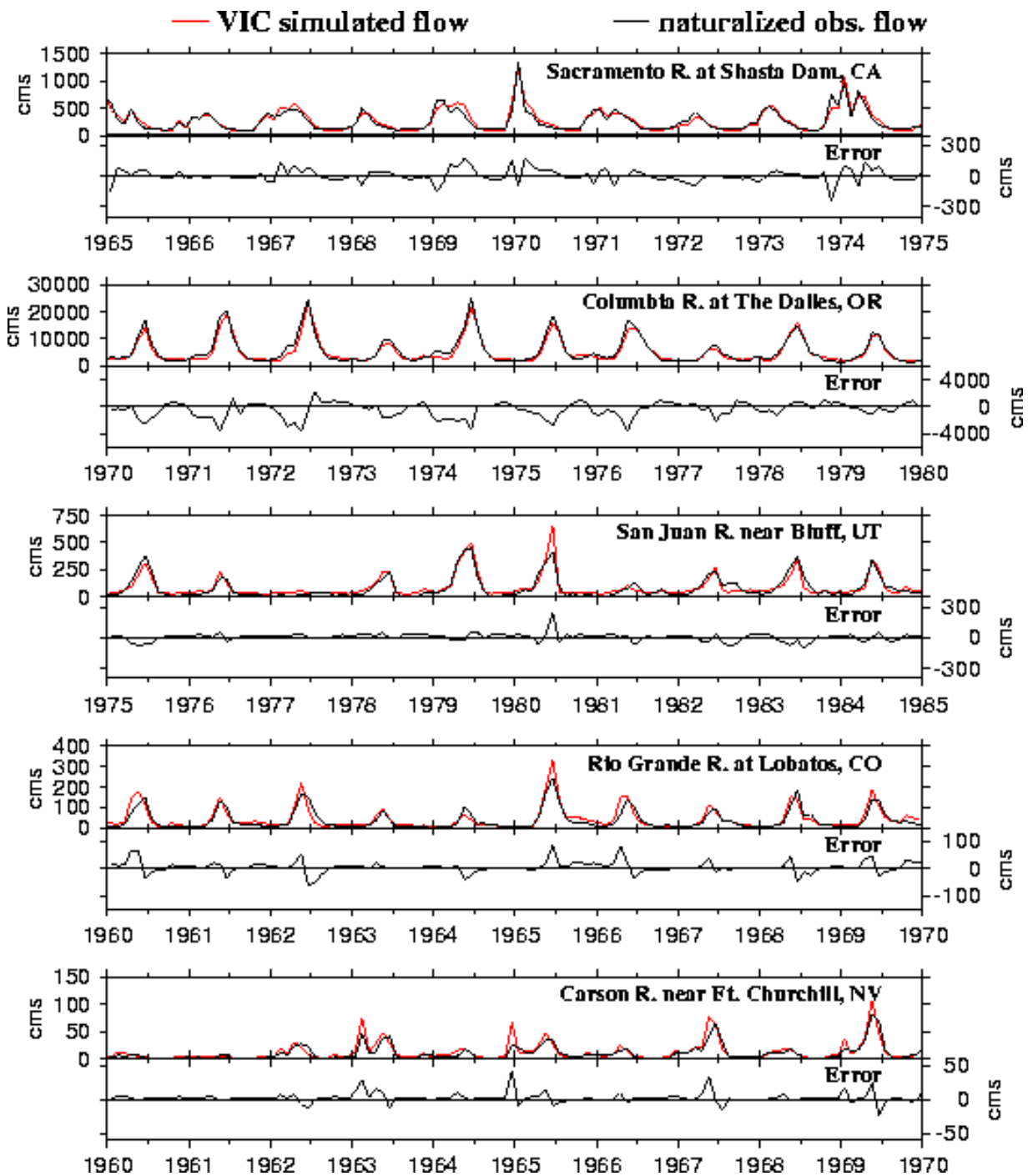
Snowpack **Initial Condition**



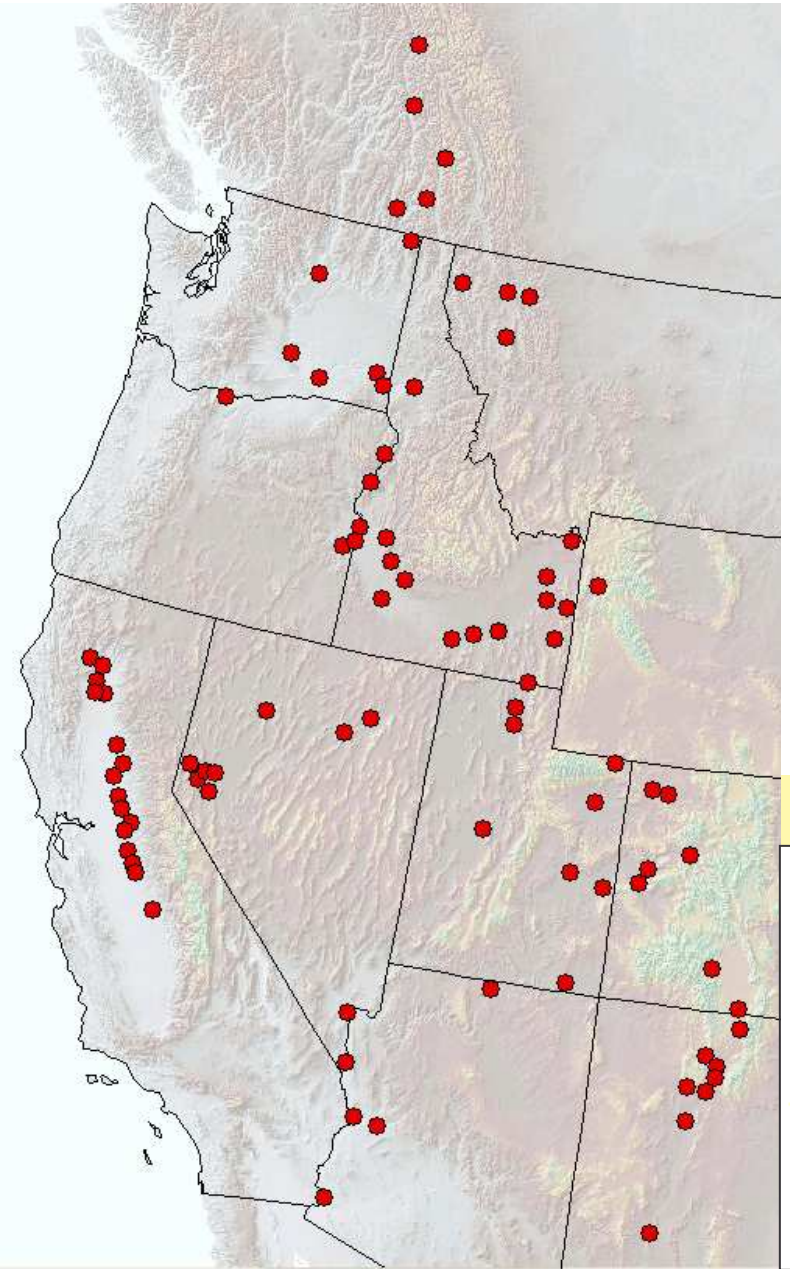
Soil Moisture **Initial Condition**

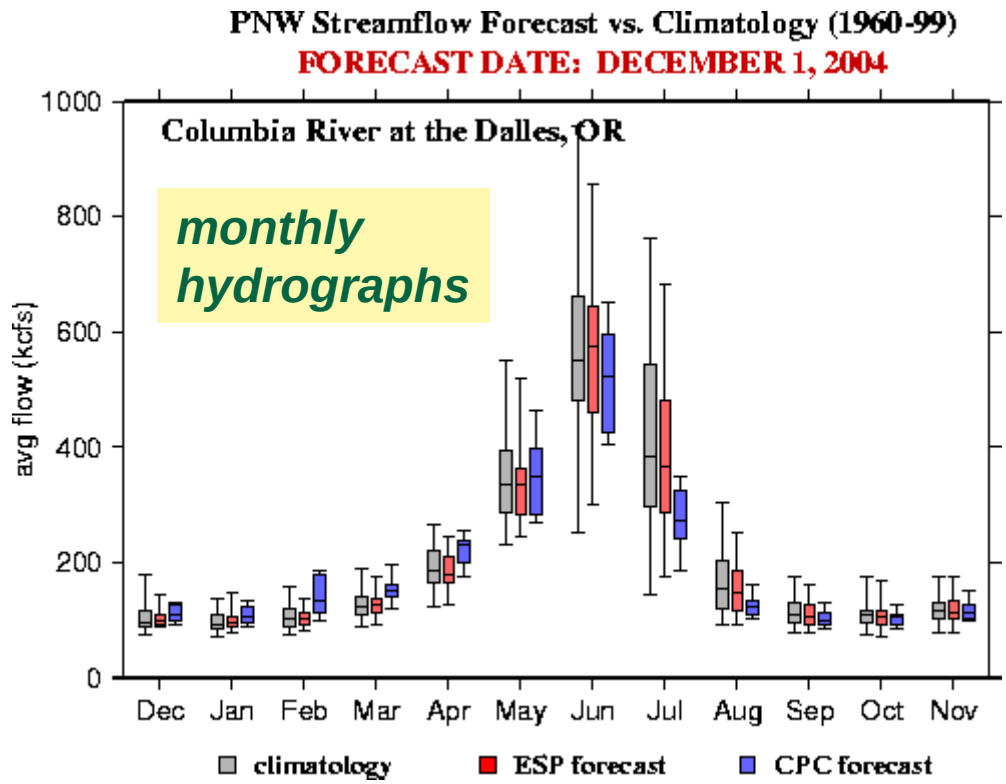
Forecast System Overview

sample validation of historic streamflow simulations



Forecast System Overview





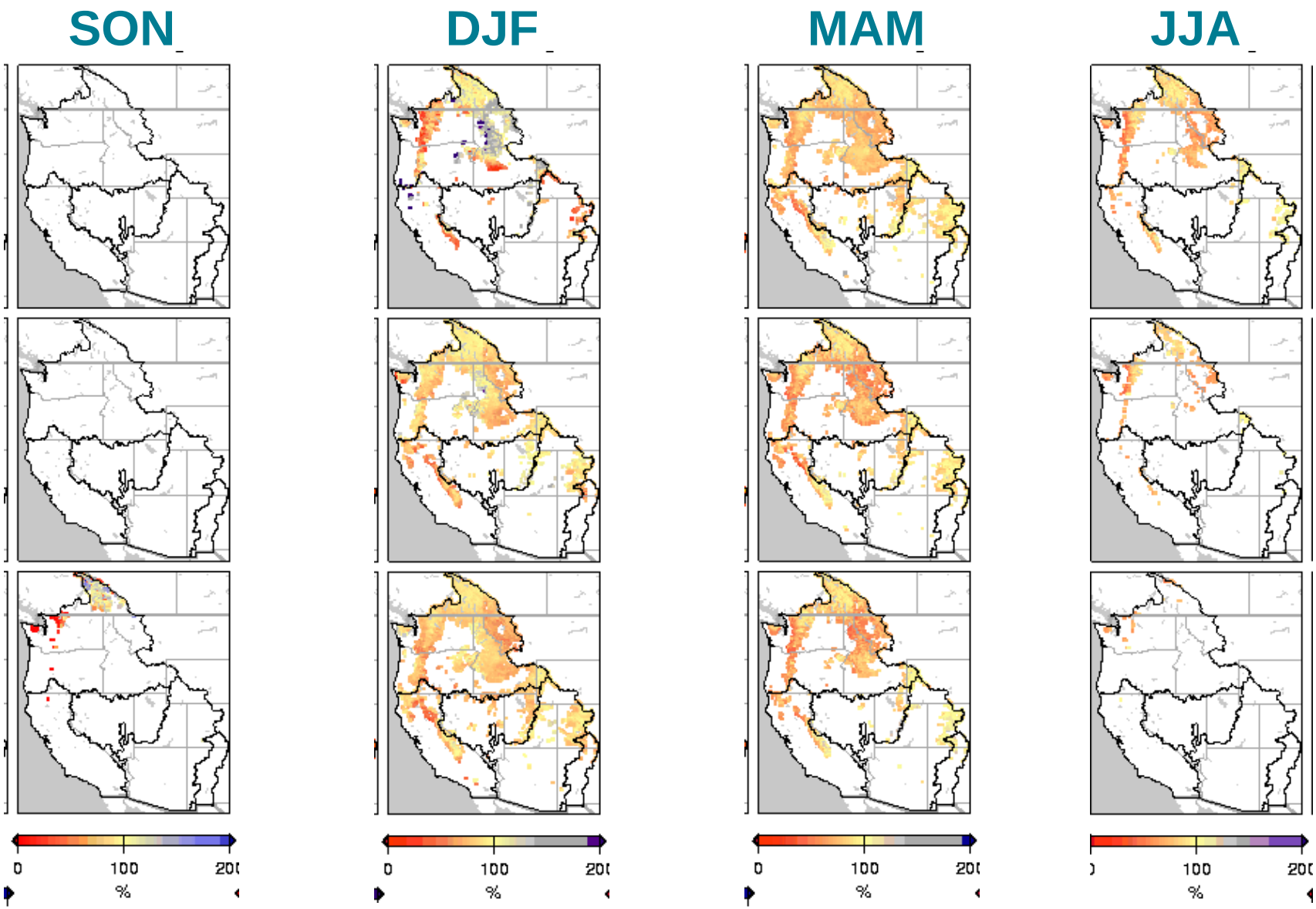
targeted statistics **e.g., runoff volumes**

Forecast flow percent of average for 2004 APR-SEP avera
at low, median and high percentiles

#	NAME	----- unconditional ----- 0.1	0.5	0.9	ENSO-Neut 0.5
1	MICAA	73	85	97	85
2	REVEL	73	85	98	85
3	ARROW	72	83	97	84

Forecast System Overview

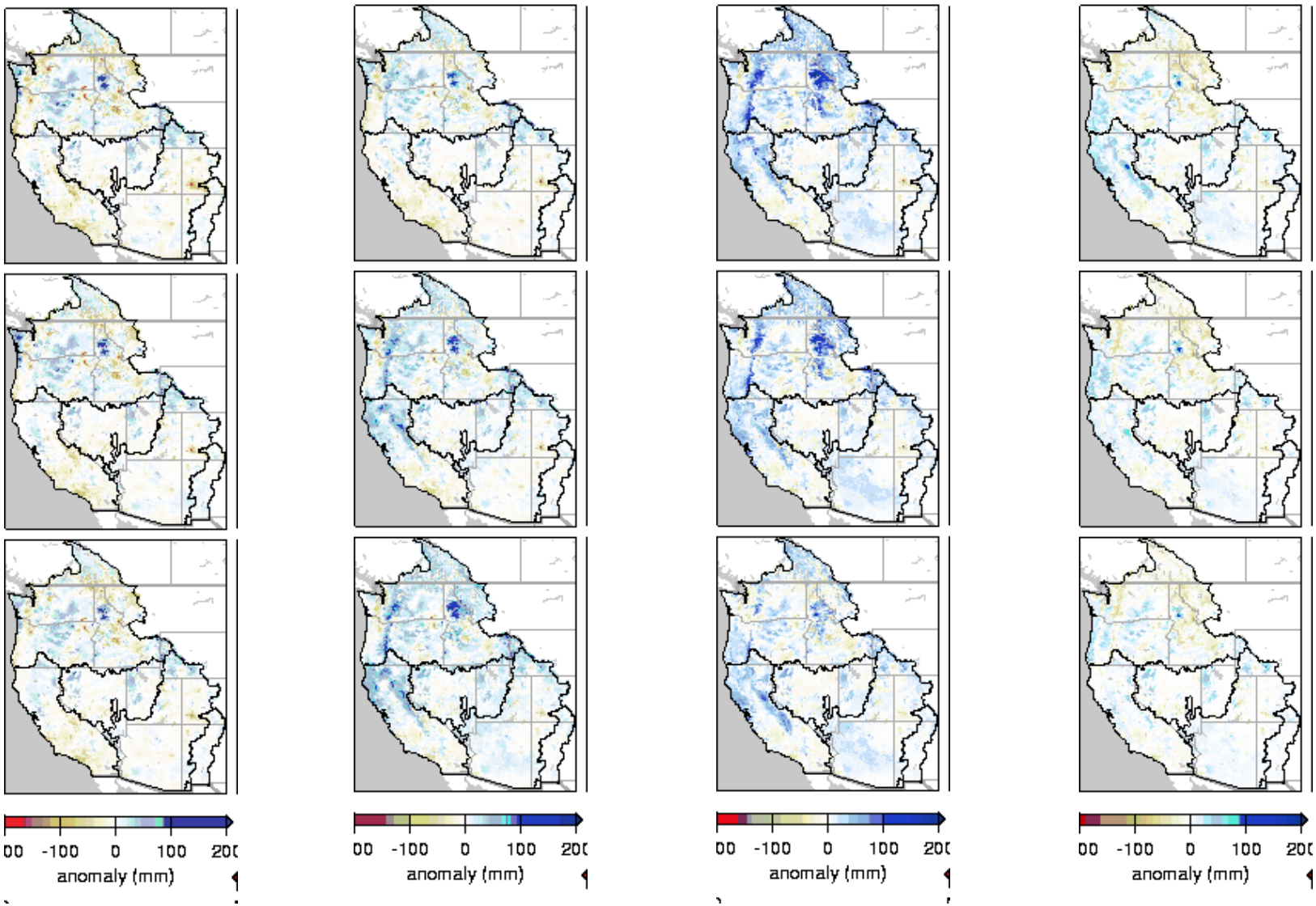
CPC-based SWE (% average) forecasts



Forecast System Overview

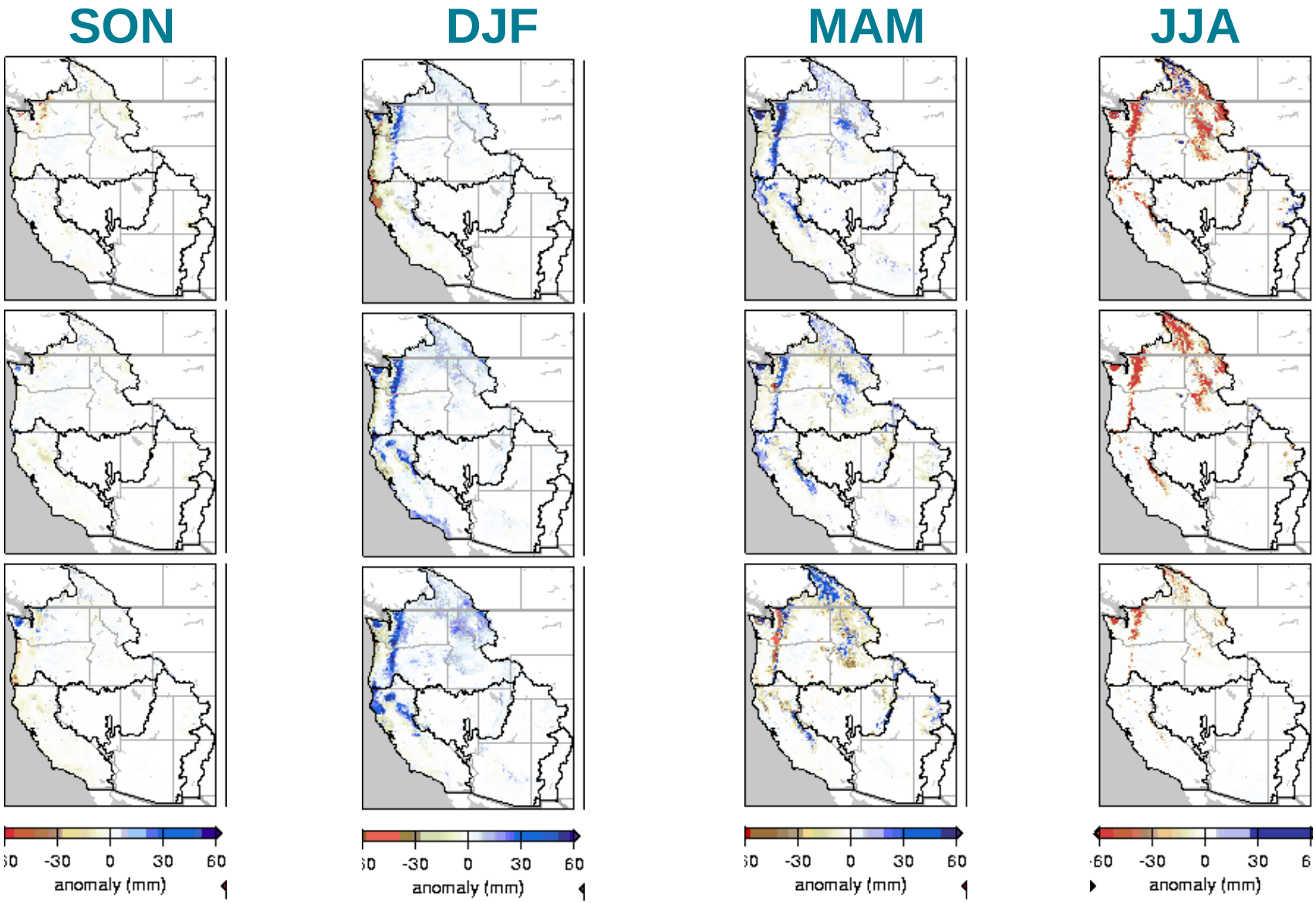
CPC-based soil moisture (anomaly) forecasts

SON **DJF** **MAM** **JJA**



Forecast System Overview

CPC-based runoff (anomaly) forecasts



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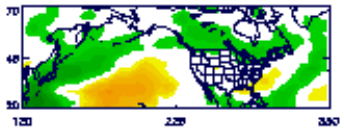
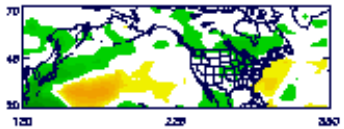
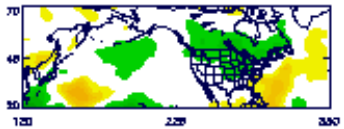
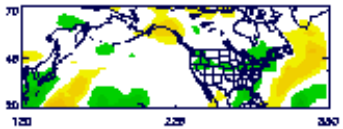
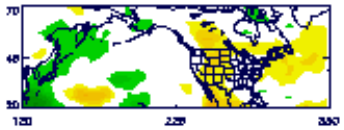
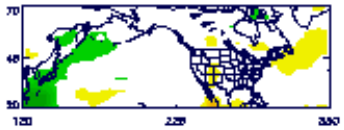
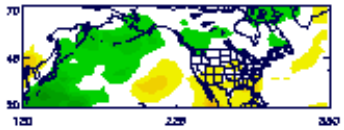
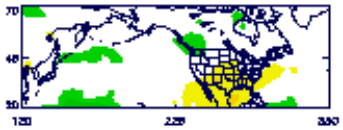
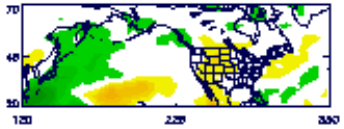
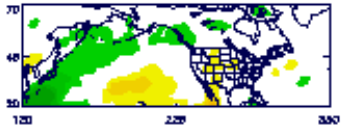
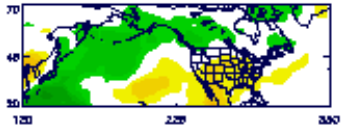
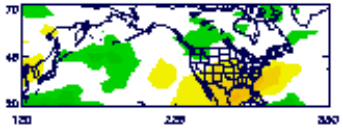
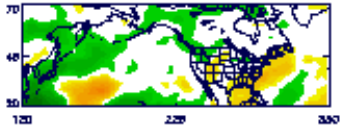
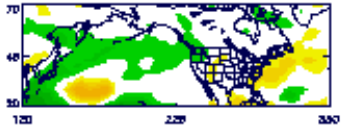
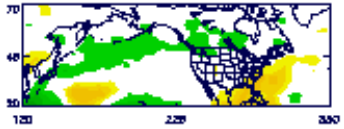
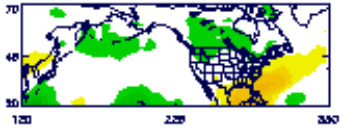
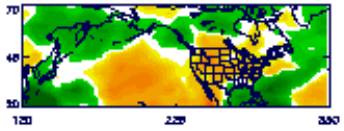
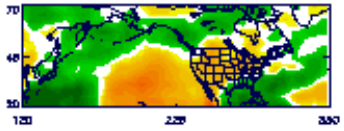
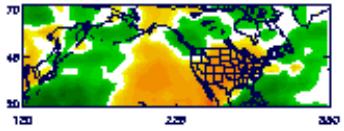
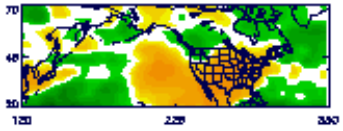
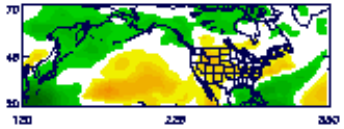
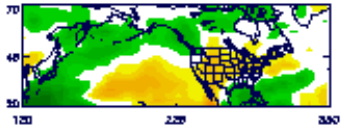
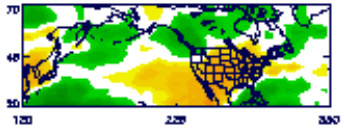
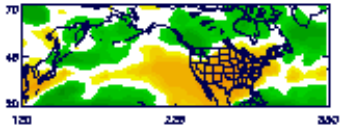
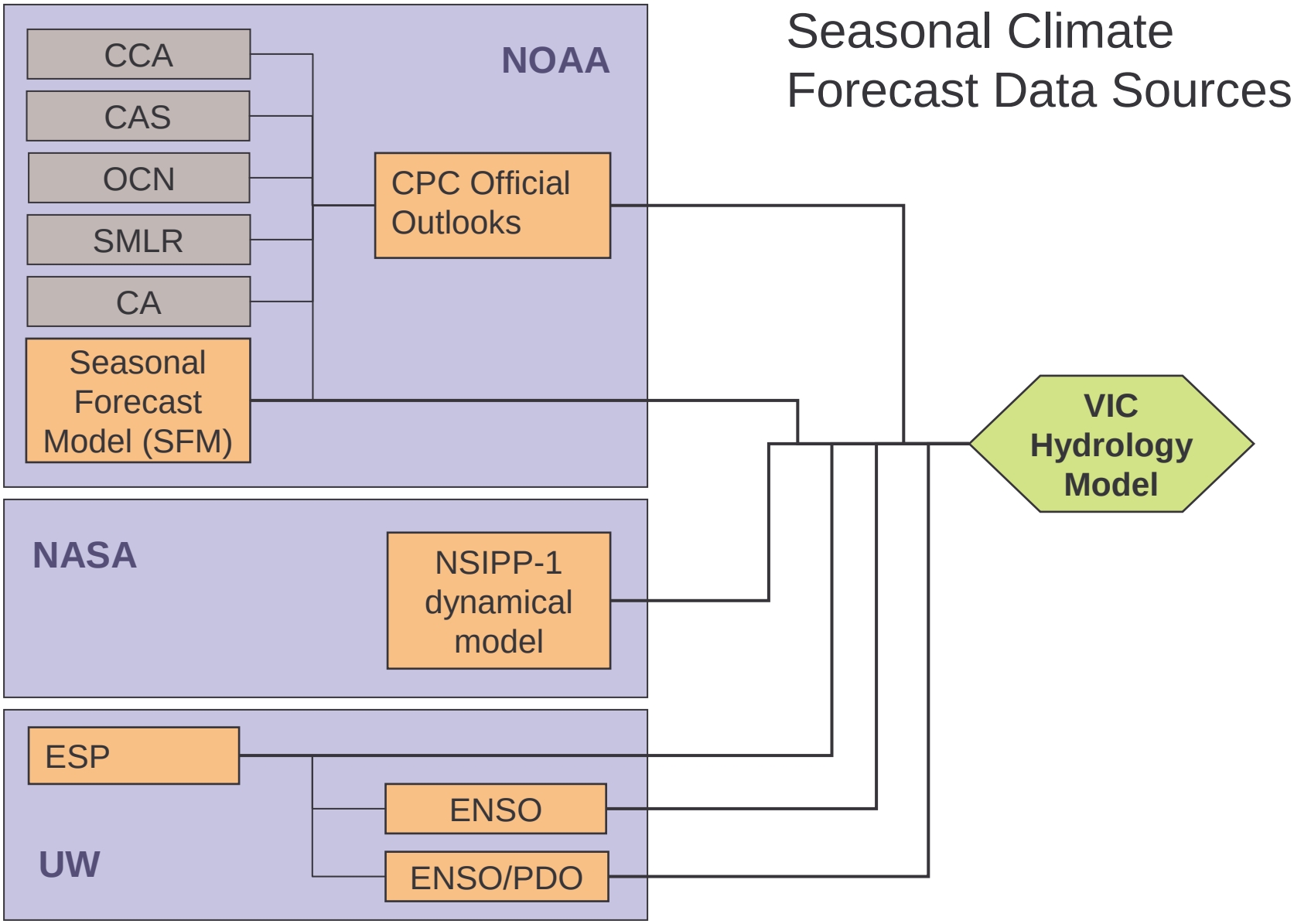
Climate Forecasts: Operational Products

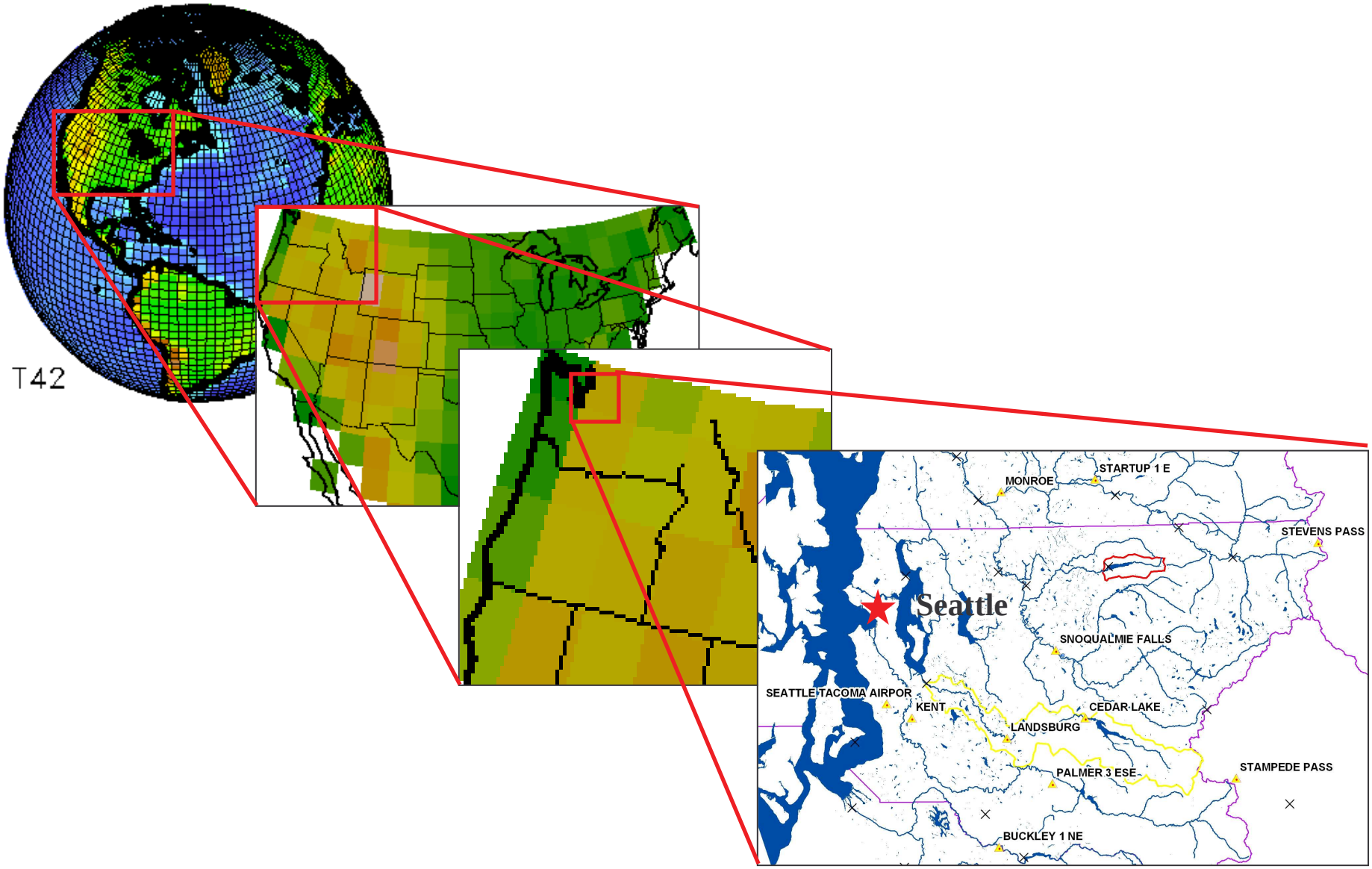
N. American Precip forecasts made: 1Jul2003

Method	ASO	SON	OND	NDJ
CCA Method				
NCEP Model				
IRI Model				
LIM Model				
NSIPP Model				
CPC Constructed Analog				

Background: W. US Forecast System



Climate Forecasts: Scale Issues

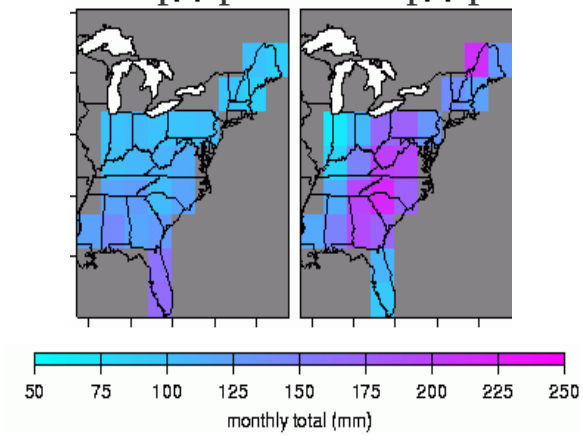


Approach: Bias Example

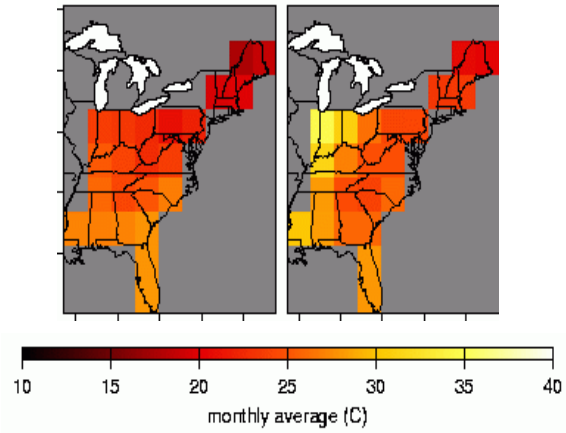
Regional Bias: spatial example

JULY

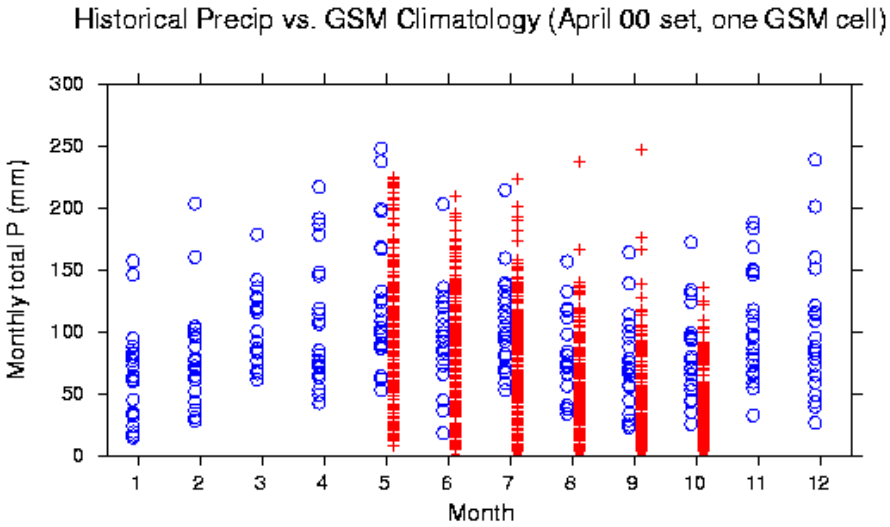
obs prcp GSM prcp

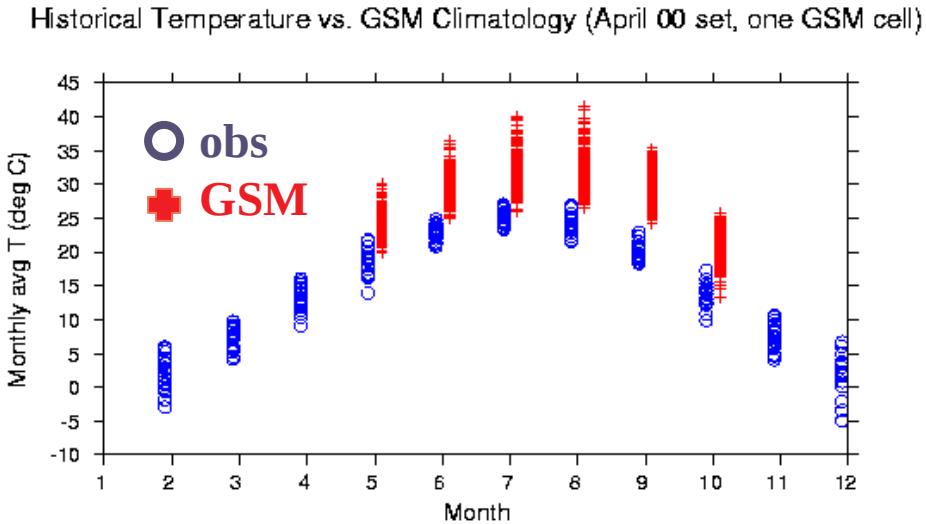


obs temp GSM temp

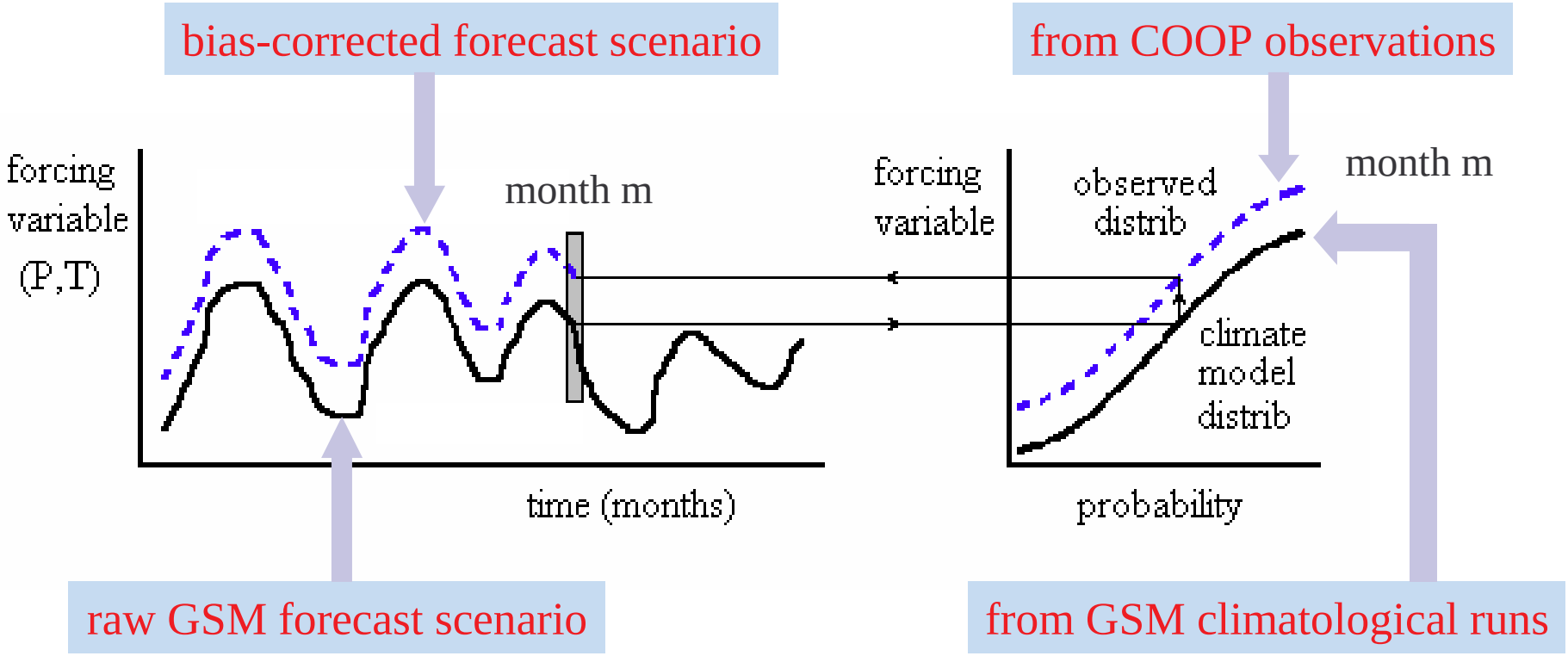


Sample GSM cell located over Ohio River basin





Approach: Bias Correction Scheme

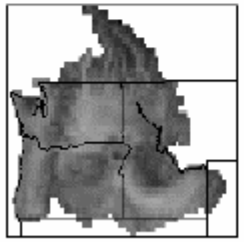


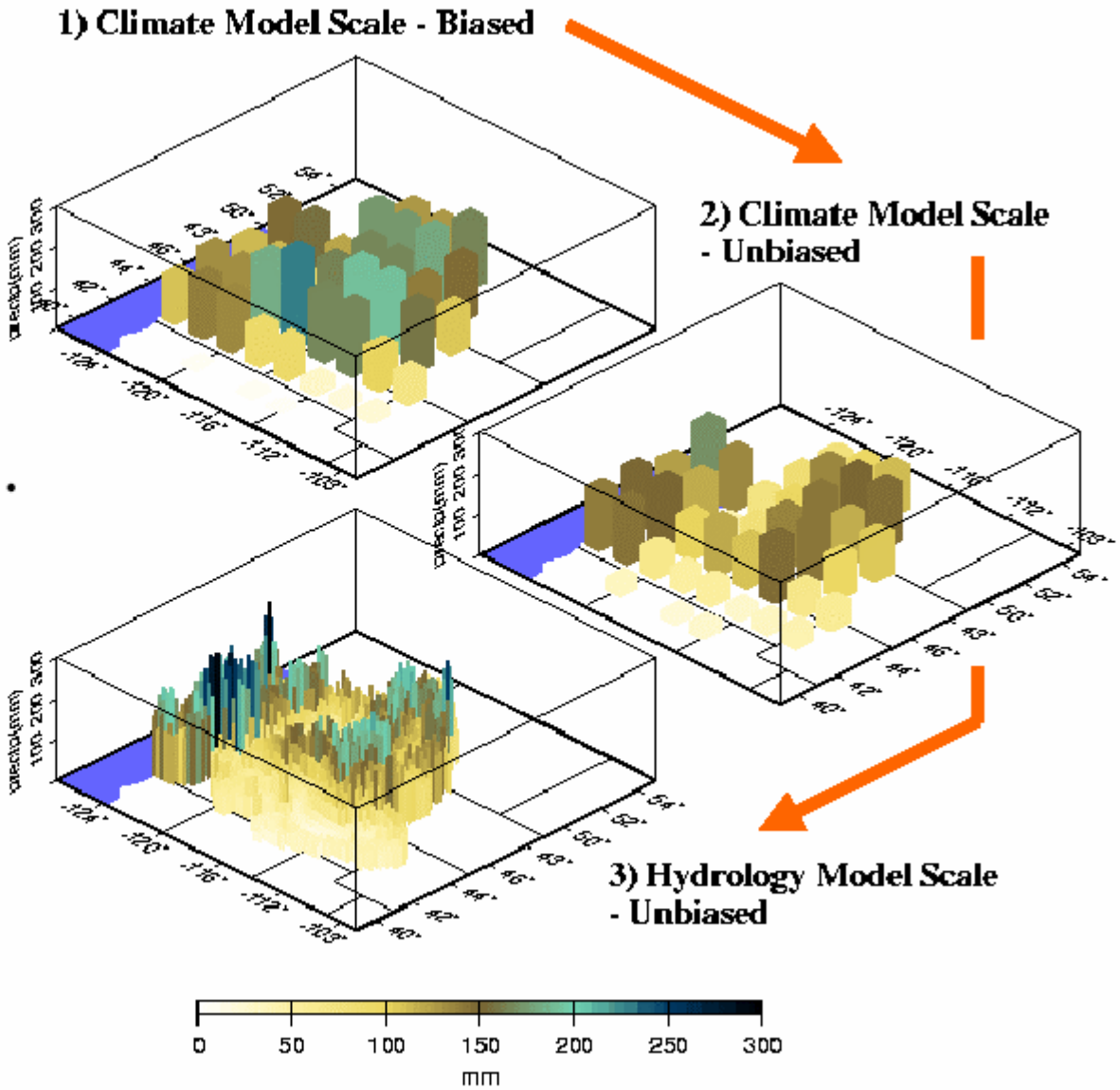
Climate Forecasts: forecast use challenges

bias-correcting…

then downscaling…

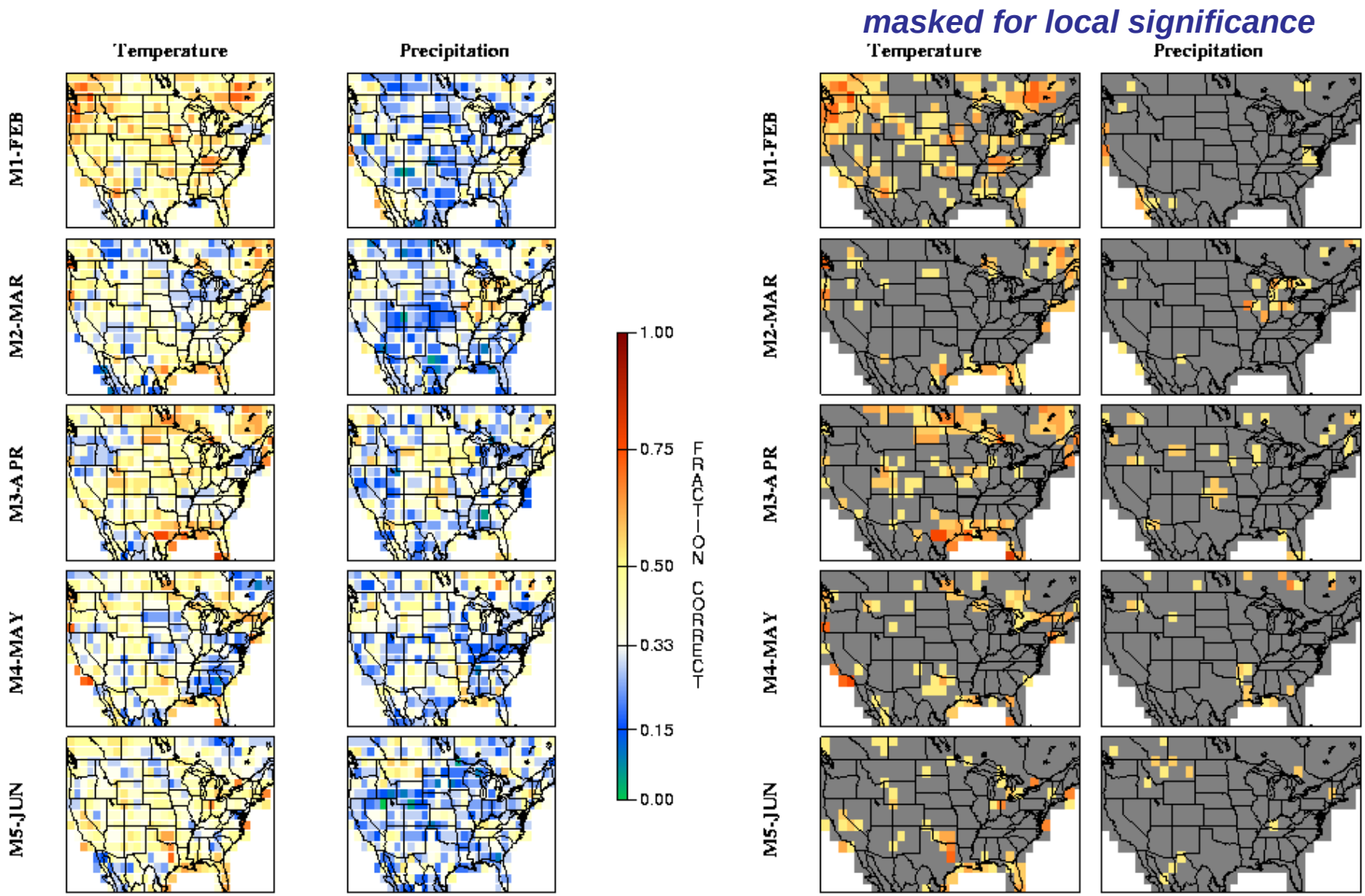
CRB domain, June precip





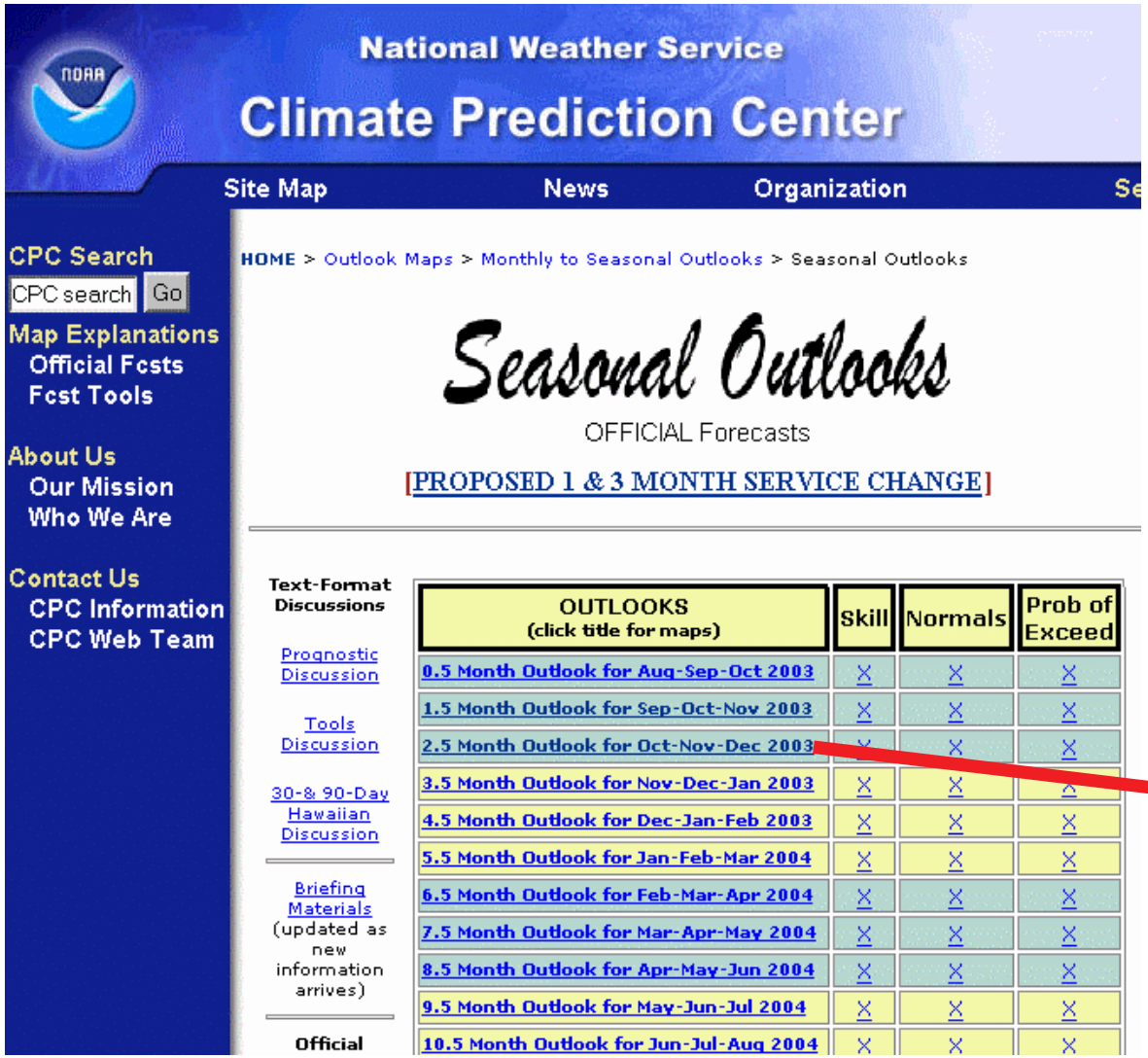
Skill Assessment: Retrospective analysis

tercile prediction skill of GSM ensemble forecast averages, JAN FCST

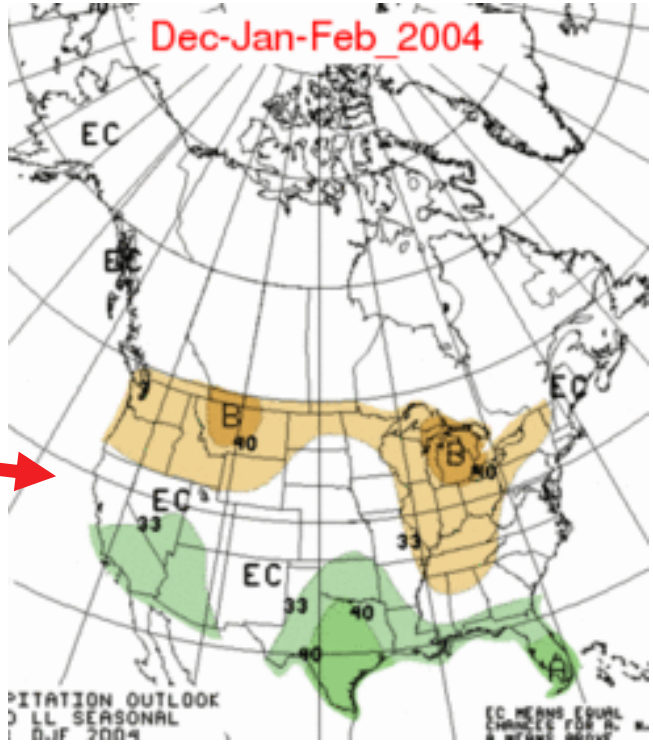


local significance at a 0.05 level (based on a binomial model of success/failure, and assuming zero spatial and zero autocorellation, so that N=21 and p(success)=.33)

Background: CPC Seasonal Outlooks

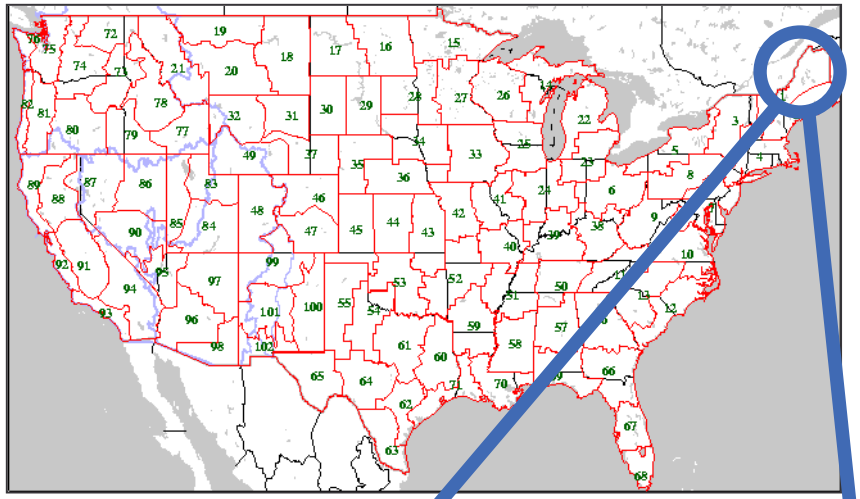


e.g., precipitation

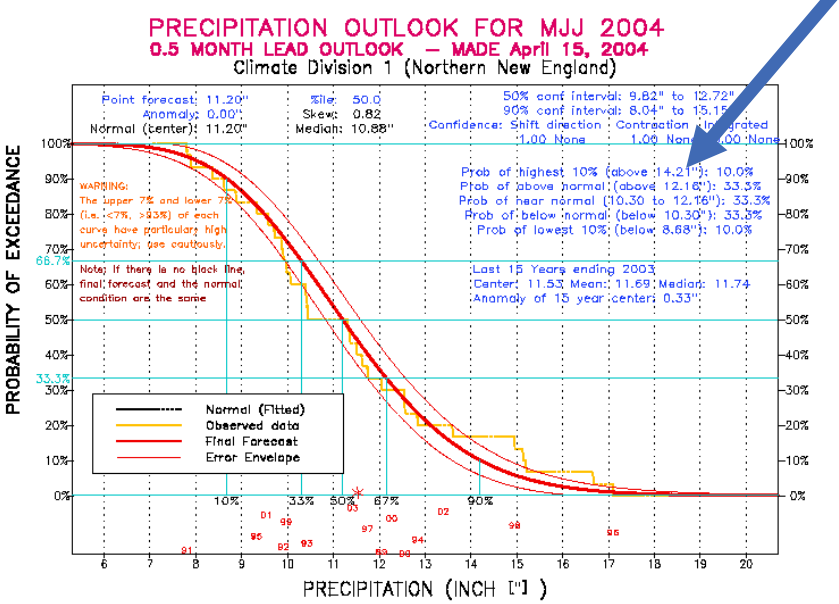


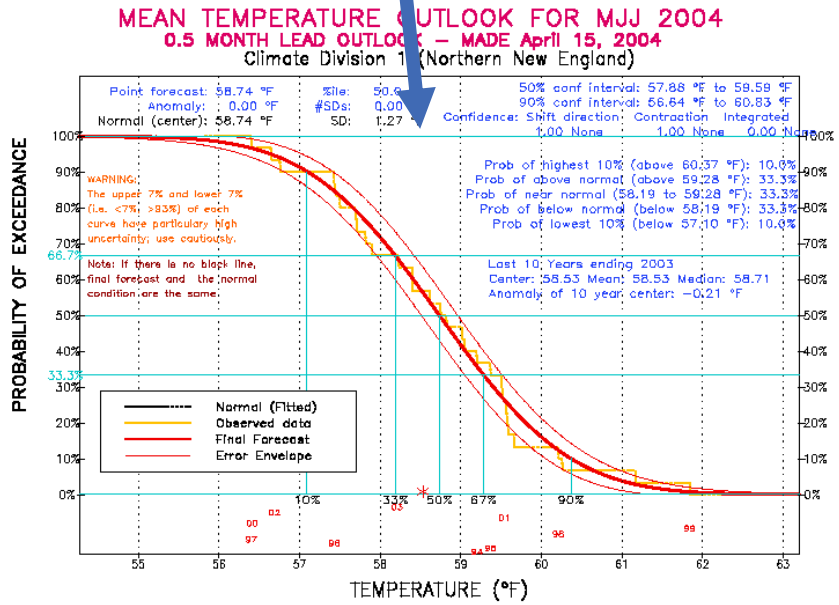
Background: CPC Seasonal Outlook Use

q spatial unit for raw forecasts is the Climate Division (102 for U.S.)



q CDFs defined by 13 percentile values (0.025 - 0.975) for P and T are given

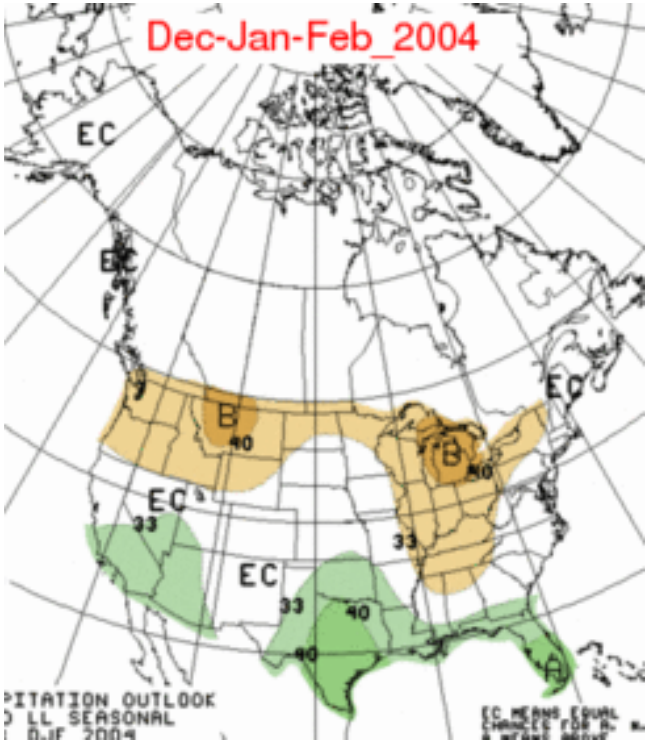


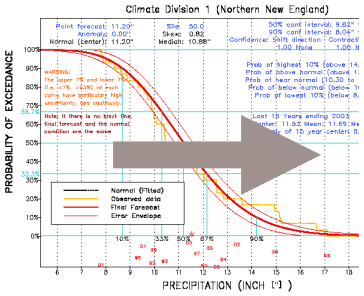


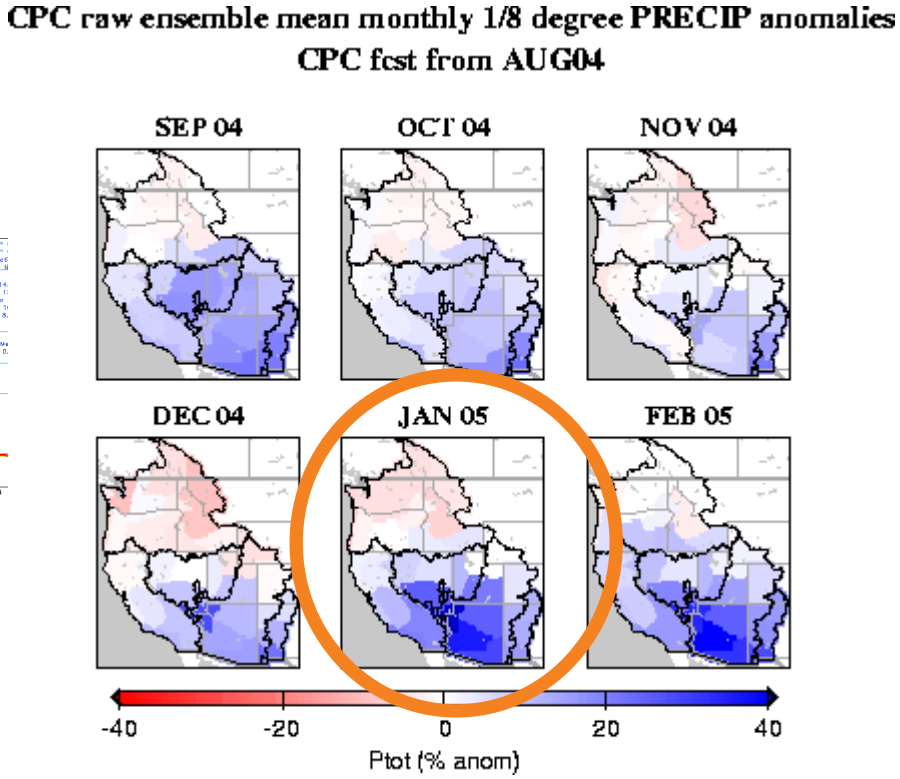
Background: CPC Seasonal Outlook Use

probabilities => anomalies

precipitation

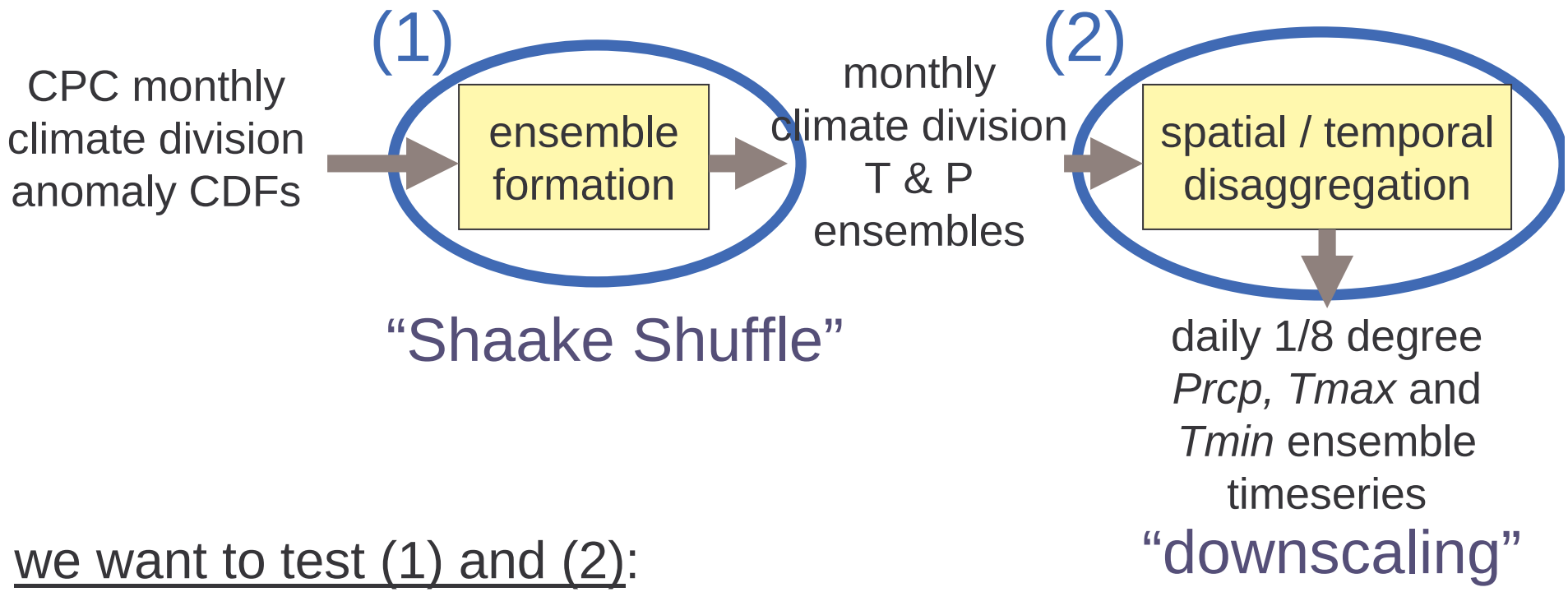






Approach: **CPC Seasonal Outlook Use**

climate division anomalies => model forcing ensembles



<u>we want to test (1) and (2)</u>:

- q testing (2) is easy, using CPC retrospective climate division dataset

- q testing (1) is more labor-intensive, less straightforward

Topics

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  - q index station approach
  - q snotel assimilation
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- q selected results for winter 2003-04
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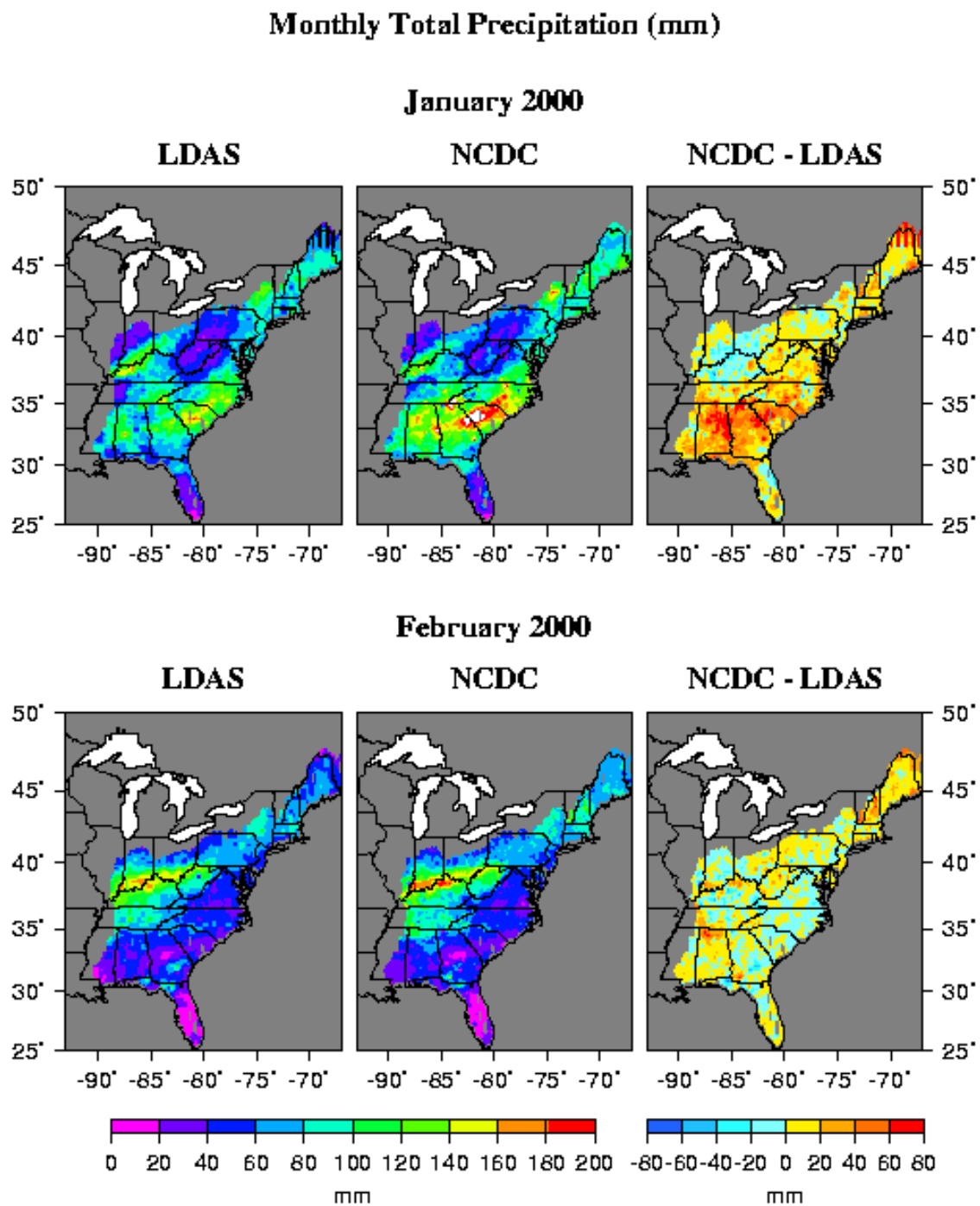
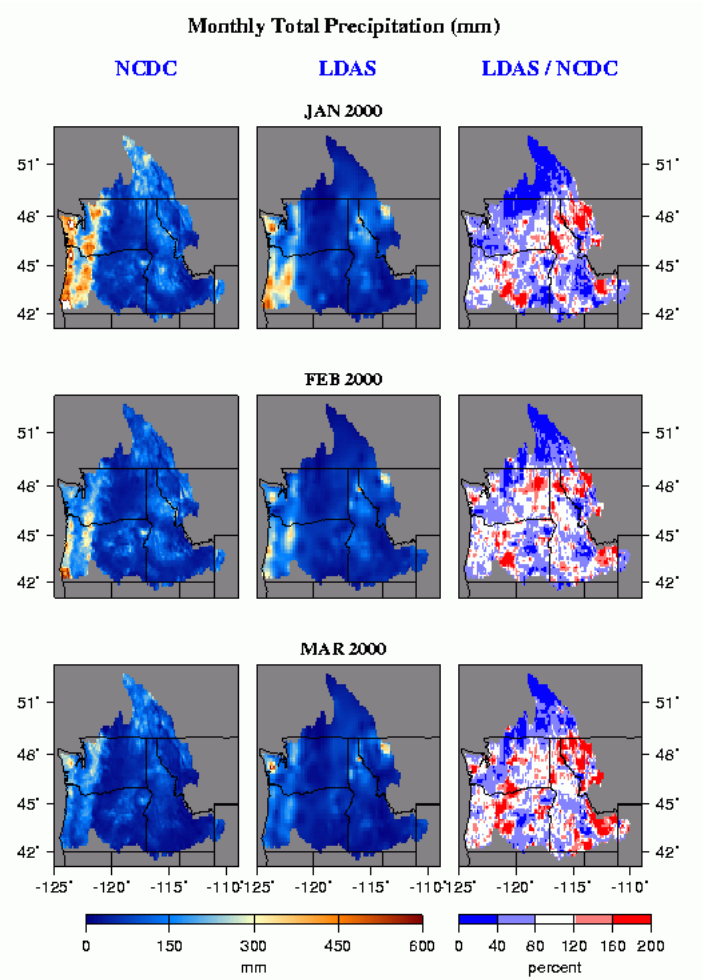
VIC model spinup methods:

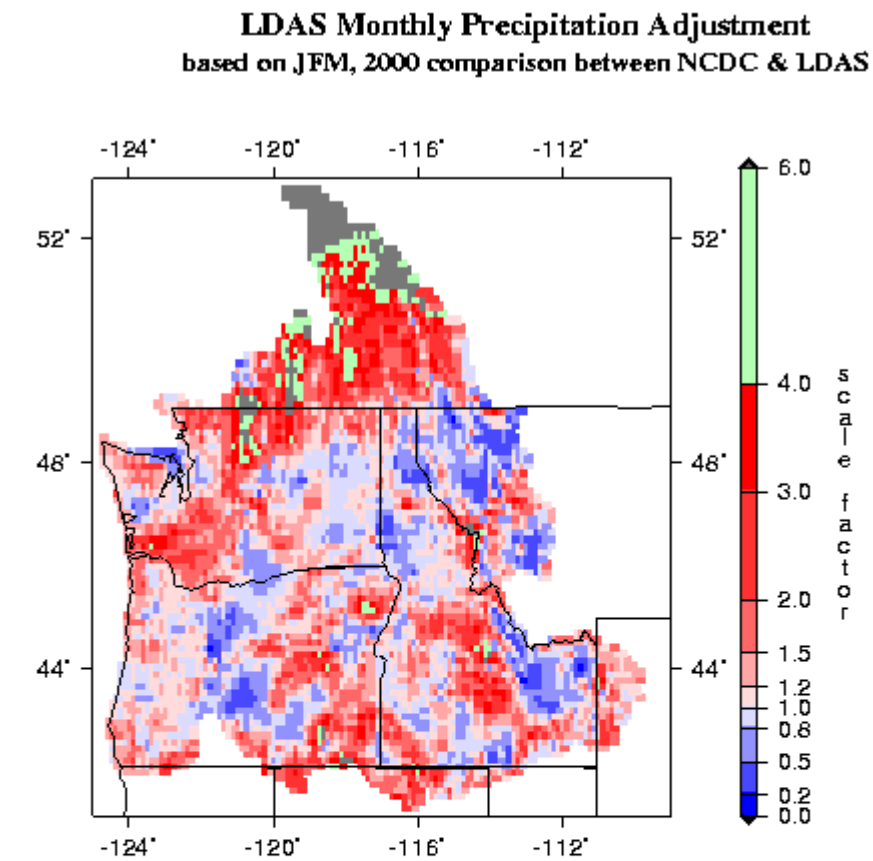
originally, LDAS use

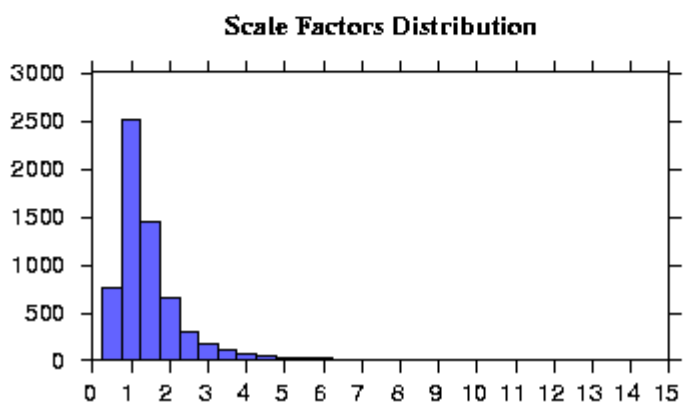


VIC model spinup methods:

LDAS had problems in west





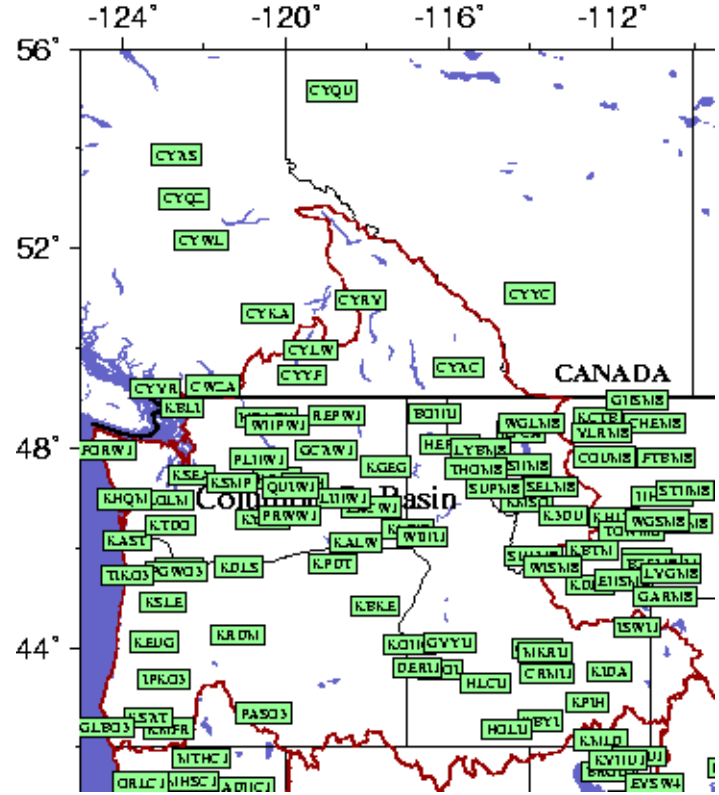


VIC model spinup methods: index stations

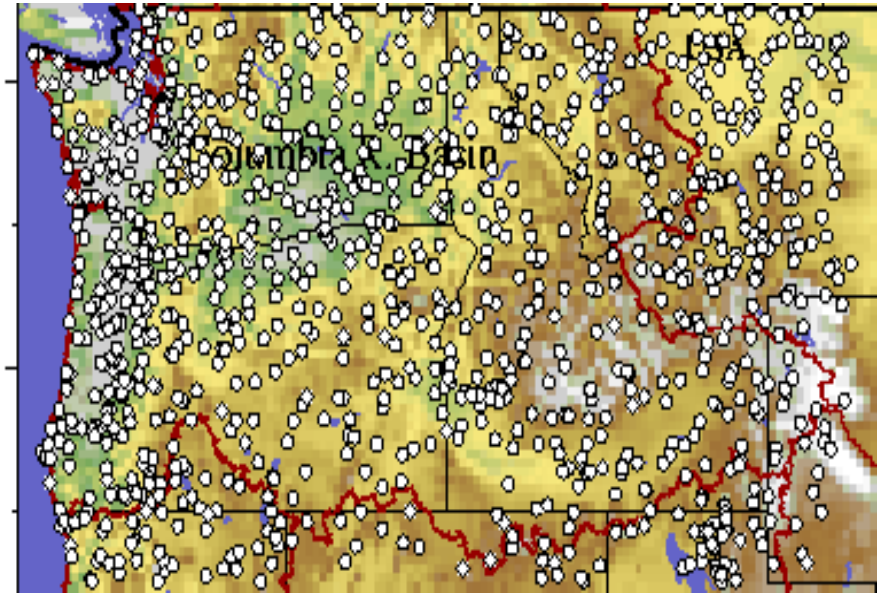
estimating spin-up period inputs

Problem: met. data availability in **3** months prior to forecast has only a tenth of long term stations used to calibrate and run model in most of spin-up period

sparse station network in real-time



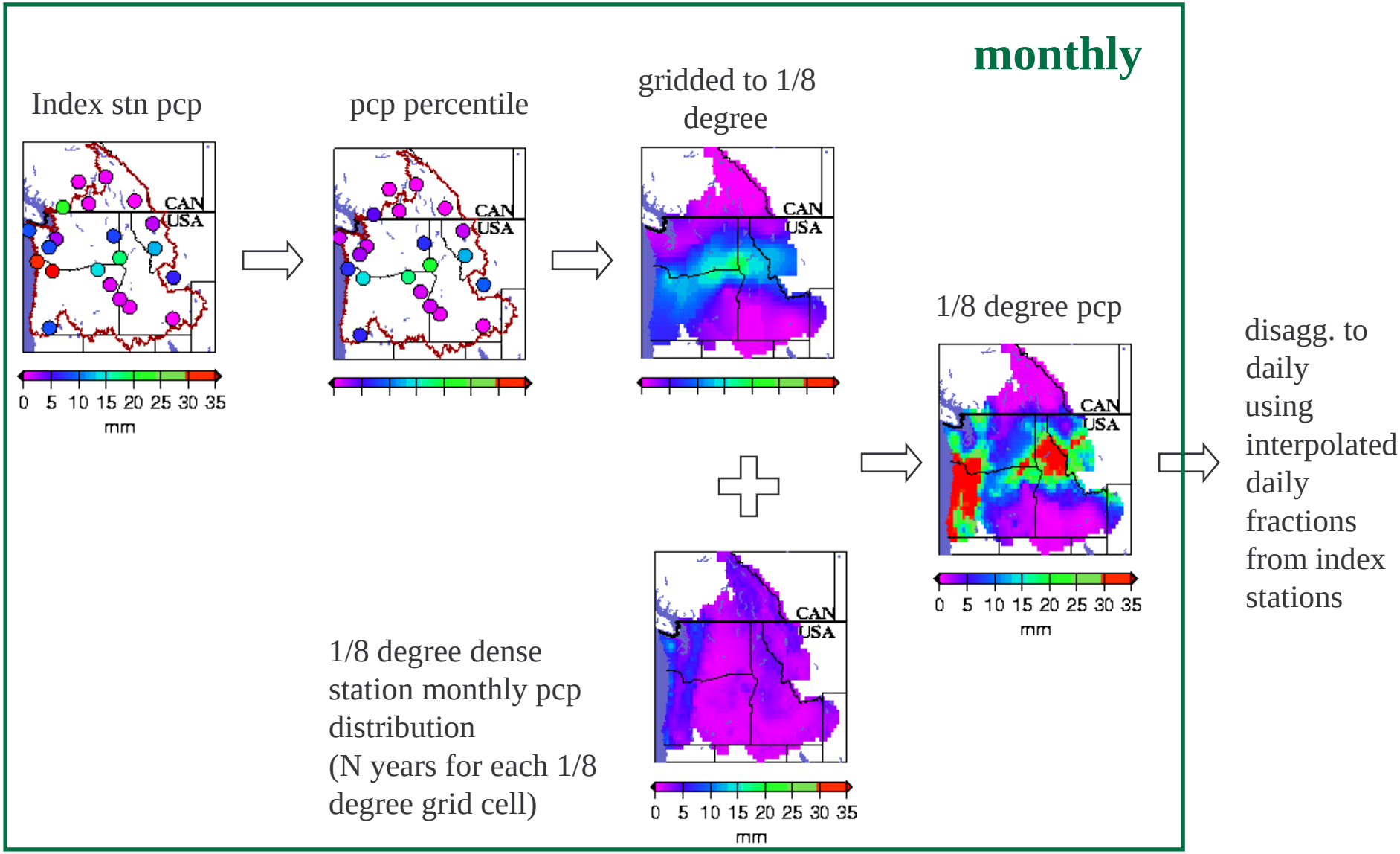
dense station network for model calibration



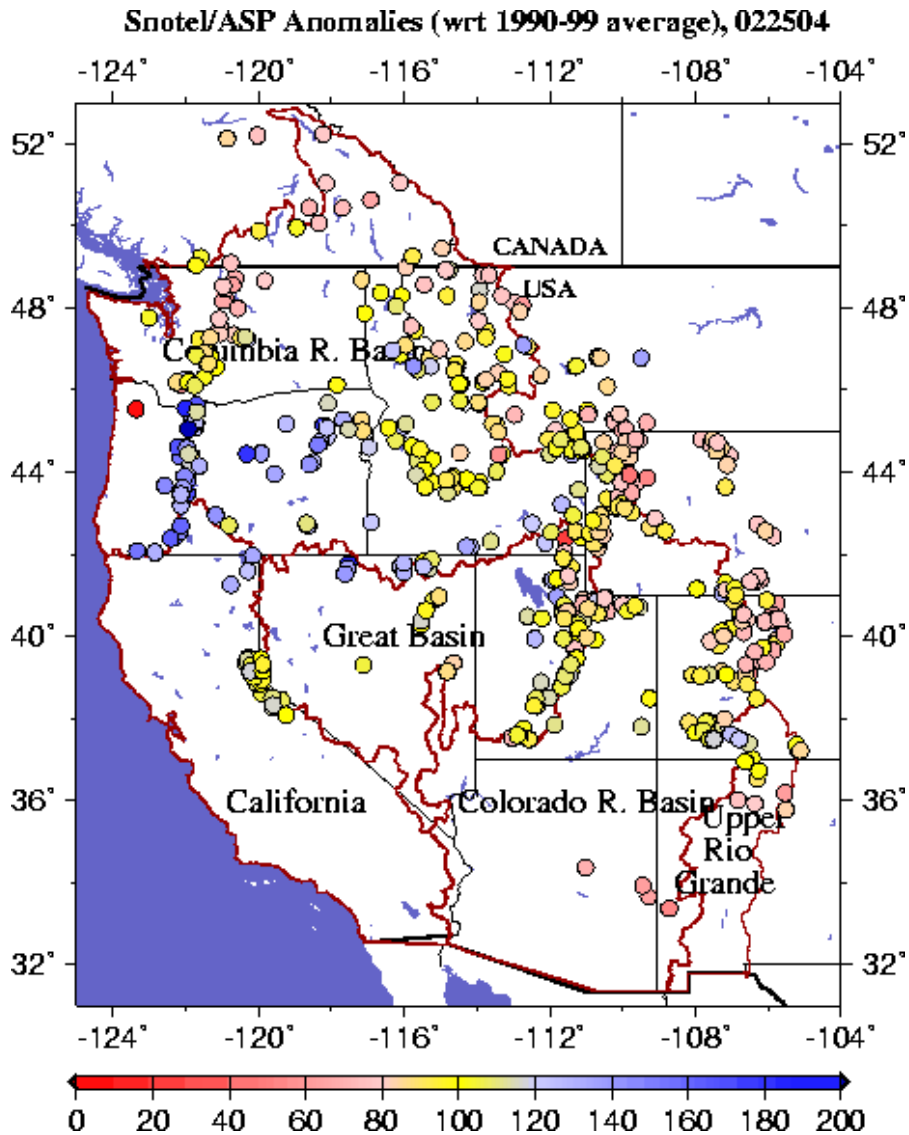
Solution: use interpolated monthly index station precip. percentiles and temperature anomalies to extract values from higher quality retrospective forcing data -- then disaggregate using daily index station signal.

VIC model spinup methods: index stations

Example for daily precipitation



VIC model spinup methods: *SNOTEL assimilation*



Problem

sparse station spin-up period incurs some systematic errors, but snow state estimation is critical

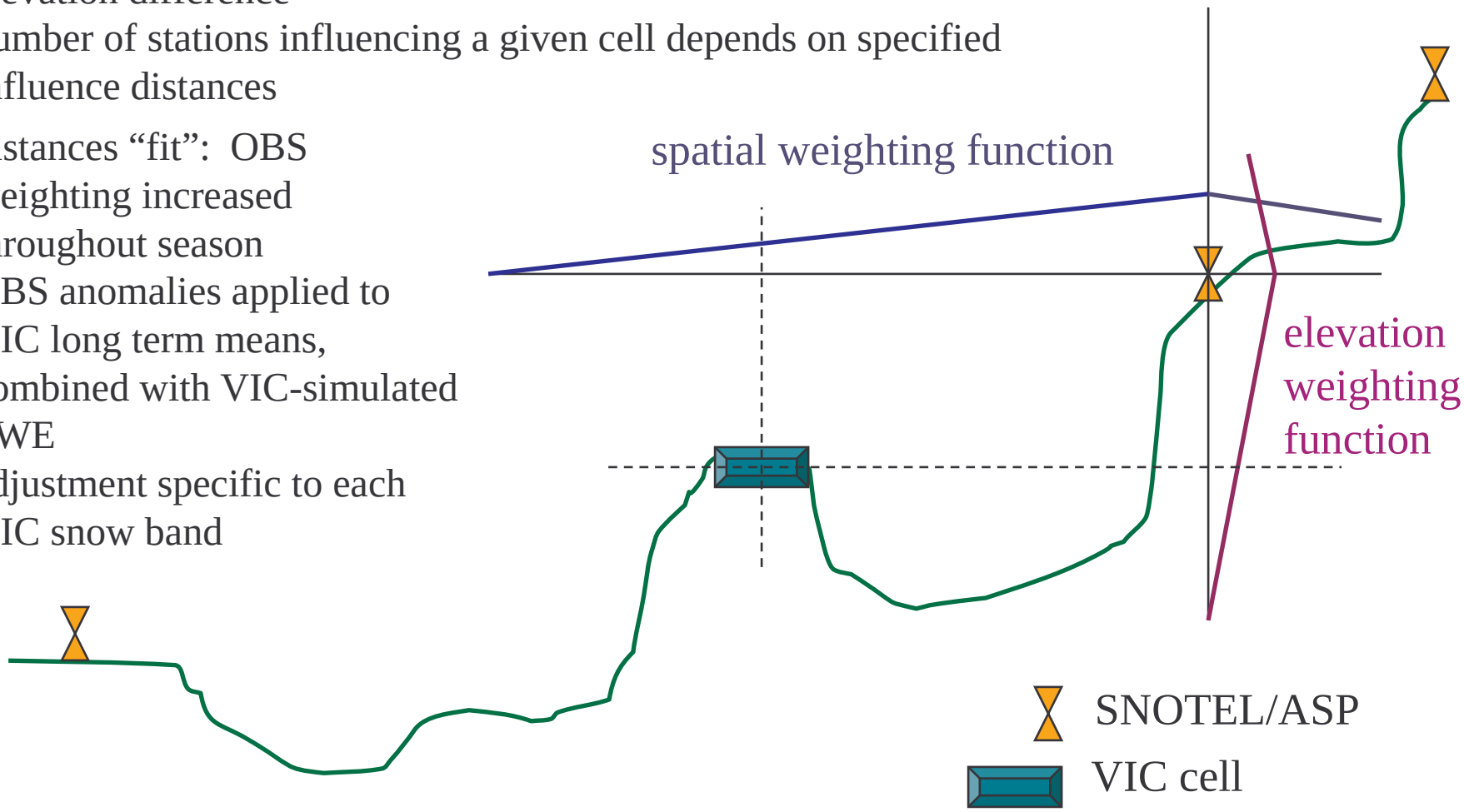
Solution

use SWE anomaly observations (from the 600+ station USDA/NRCS SNOTEL network and a dozen ASP stations in BC, Canada) to adjust snow state at the forecast start date

VIC model spinup methods: *SNOTEL assimilation*

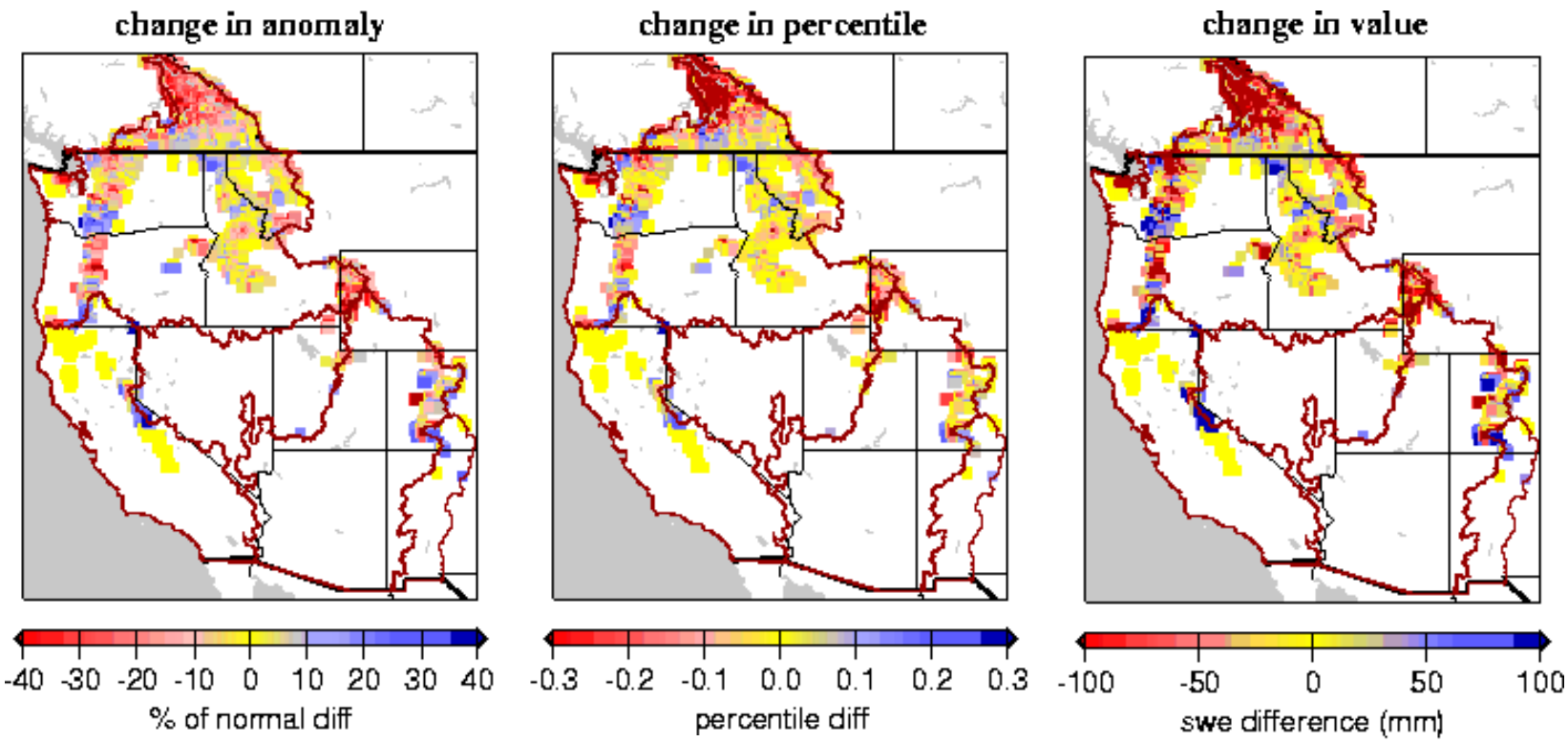
Assimilation Method

- weight station OBS' influence over VIC cell based on distance and elevation difference
- number of stations influencing a given cell depends on specified influence distances
- distances "fit": OBS weighting increased throughout season
- OBS anomalies applied to VIC long term means, combined with VIC-simulated SWE
- adjustment specific to each VIC snow band



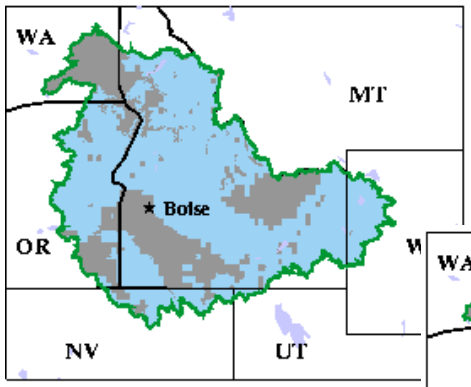
VIC model spinup methods: *SNOTEL assimilation*

April 25, 2004

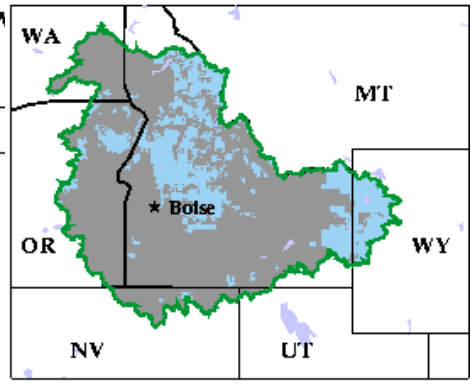


VIC model spinup methods:

snow cover (MODIS) assimilation (Snake R. trial)



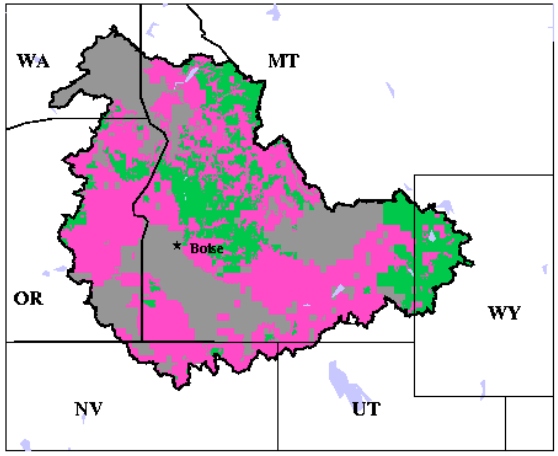
Snowcover BEFORE update

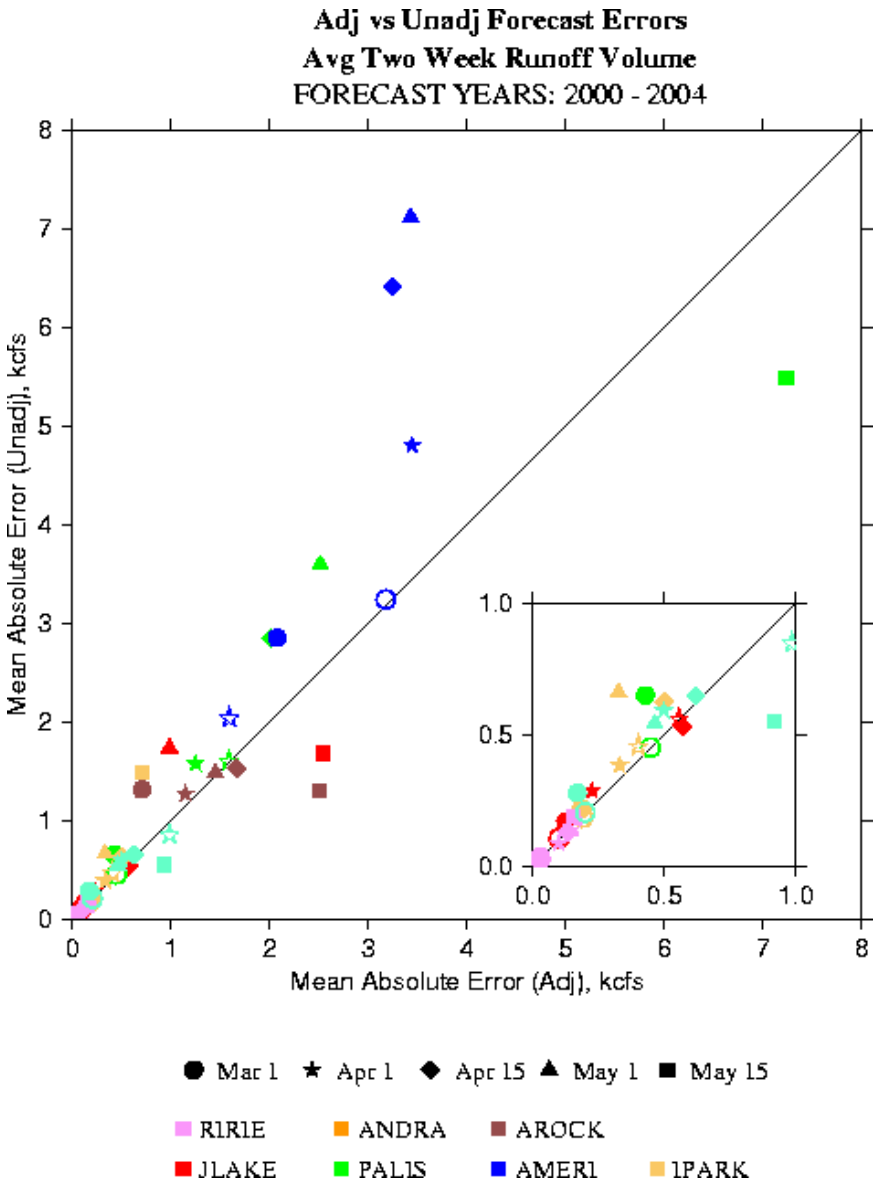


Snowcover AFTER update

MODIS update for April 1, 2004 Forecast

snow
added
removed





Topics

- q forecasting system overview
- q climate forecasts
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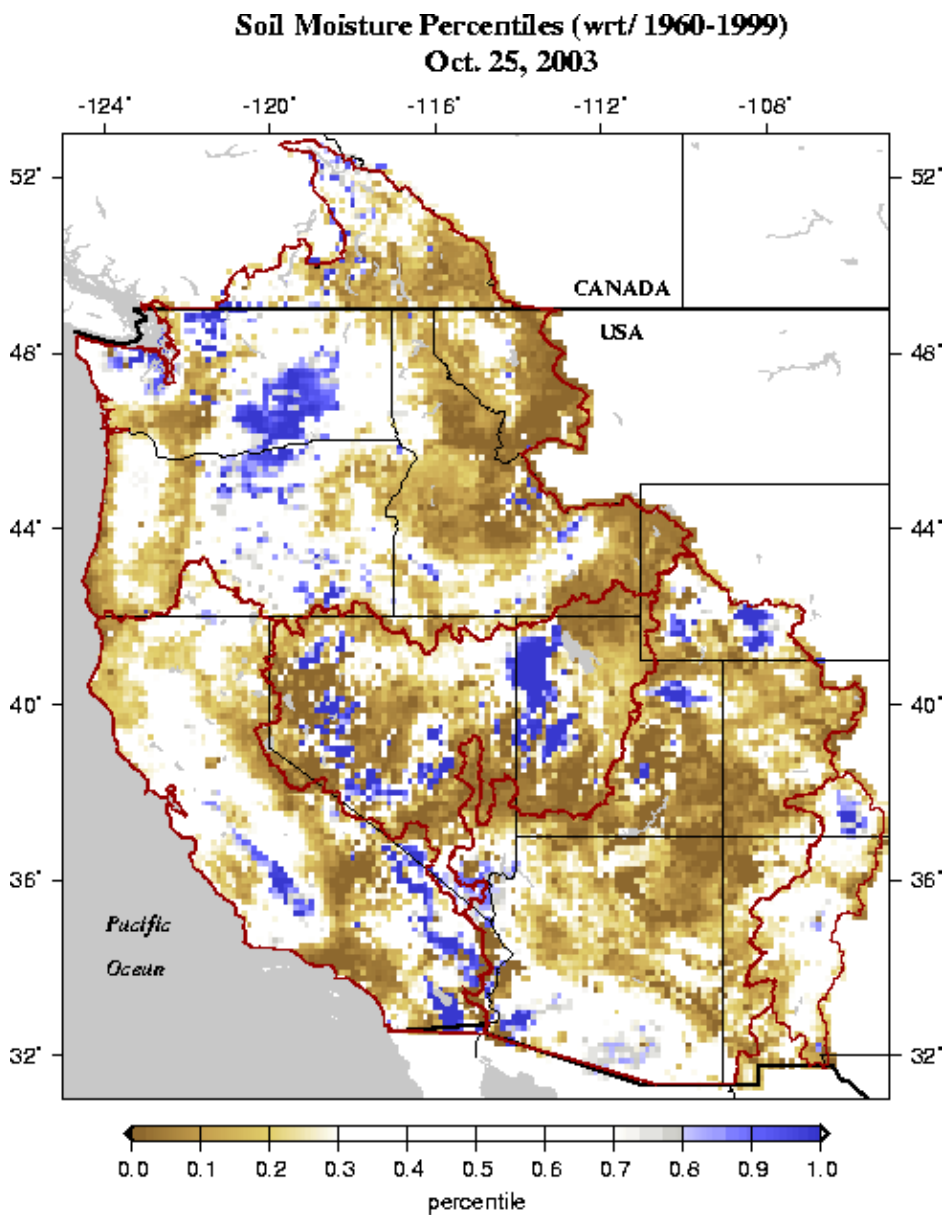
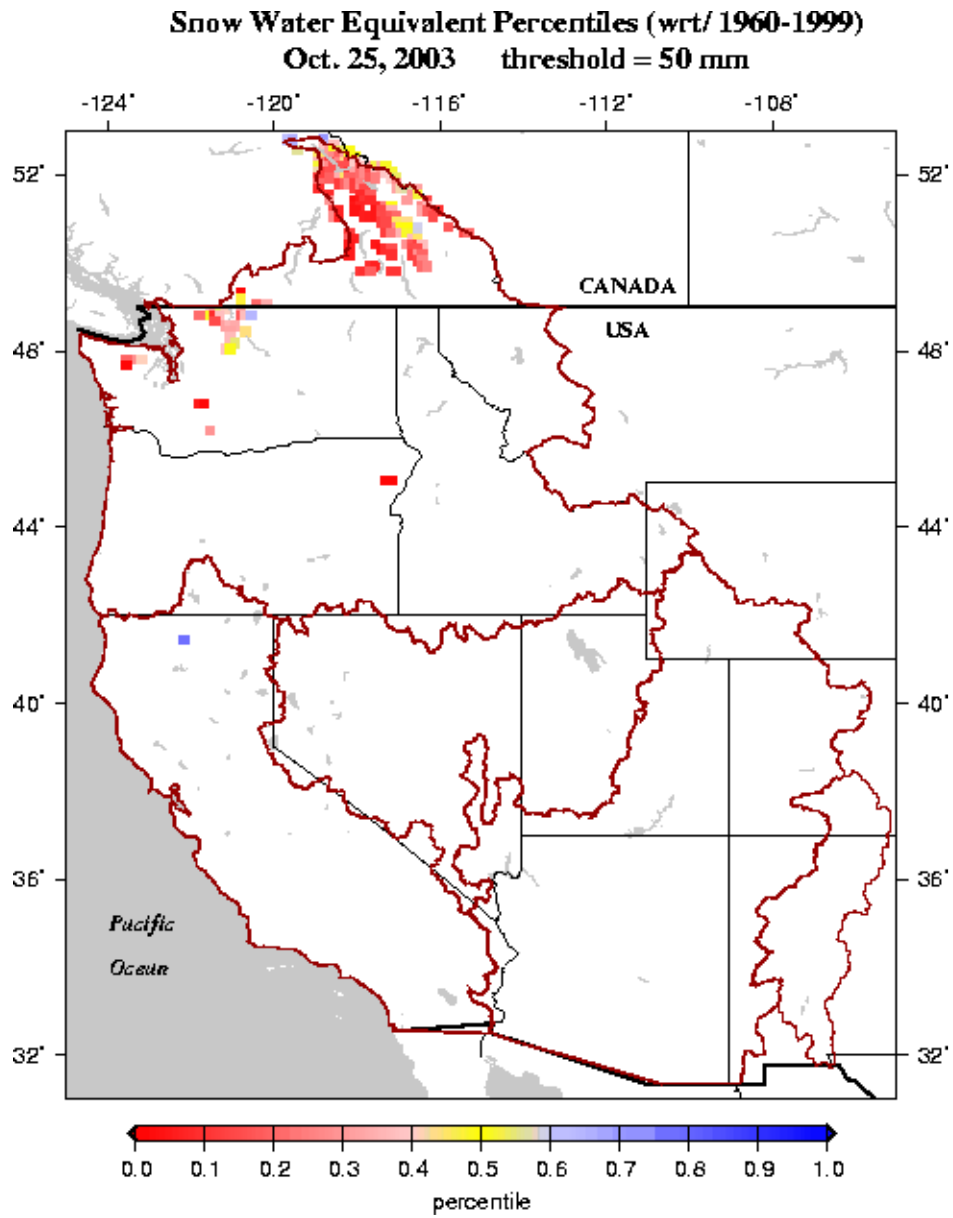
Results for Winter 2003-04: initial conditions

Soil Moisture *and* *Snow Water Equivalent (SWE)*





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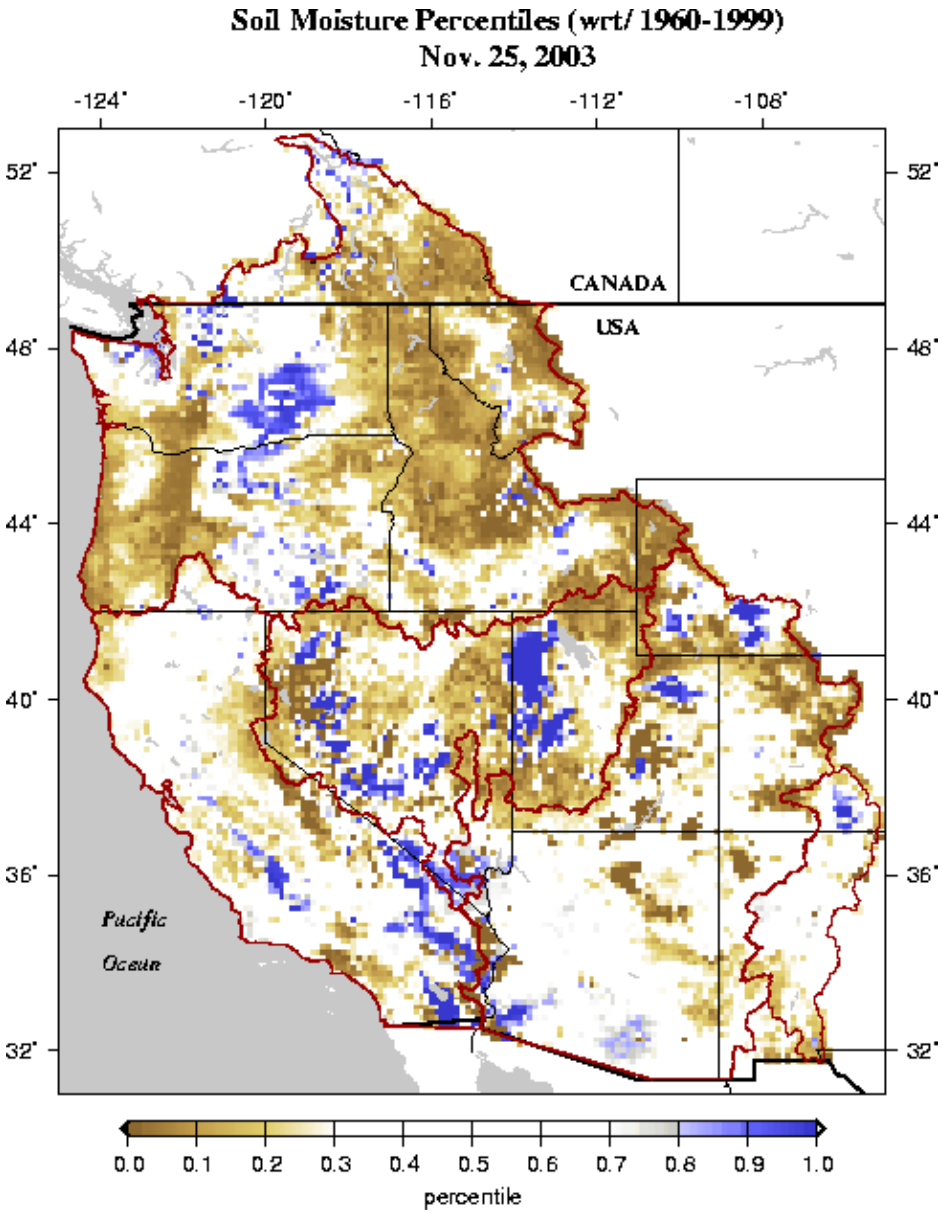

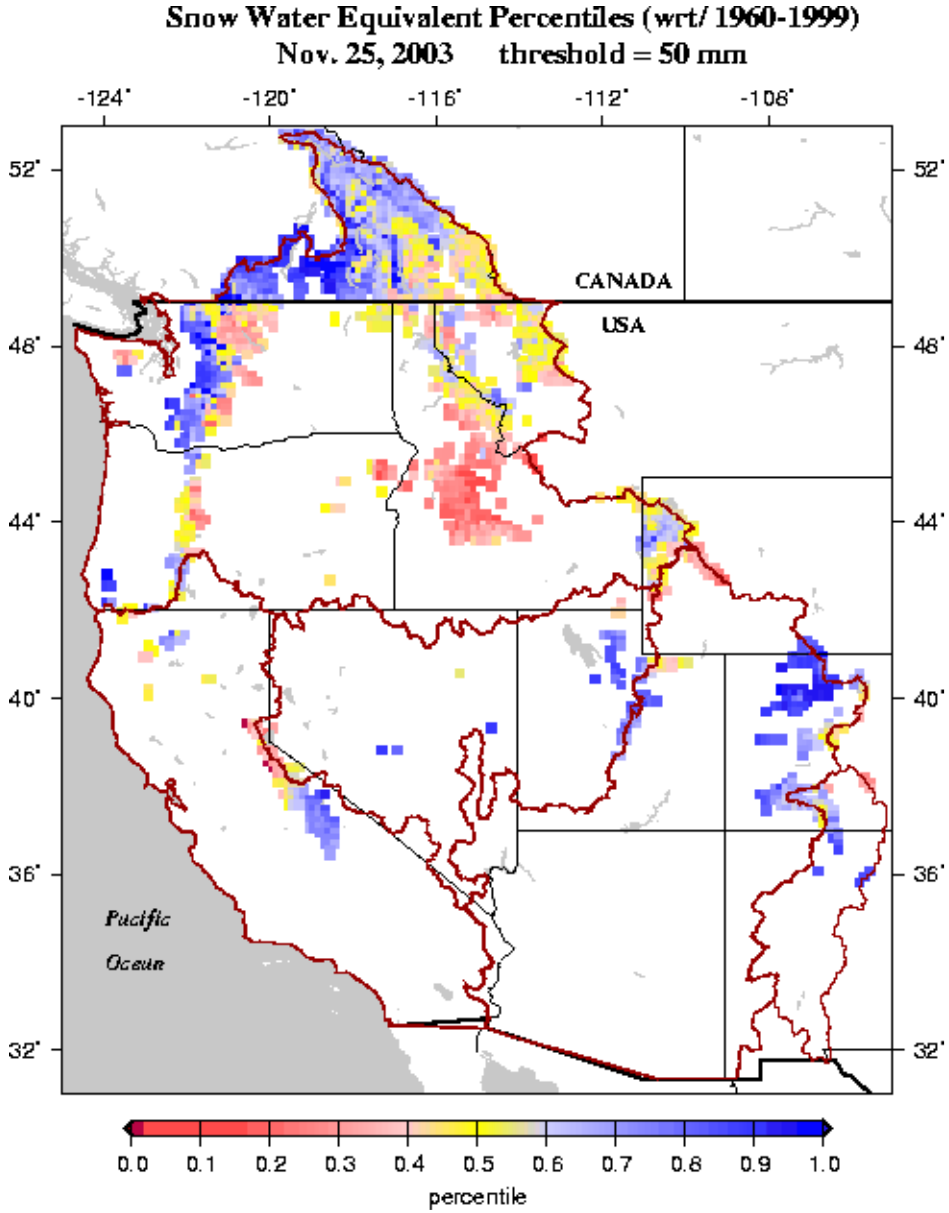

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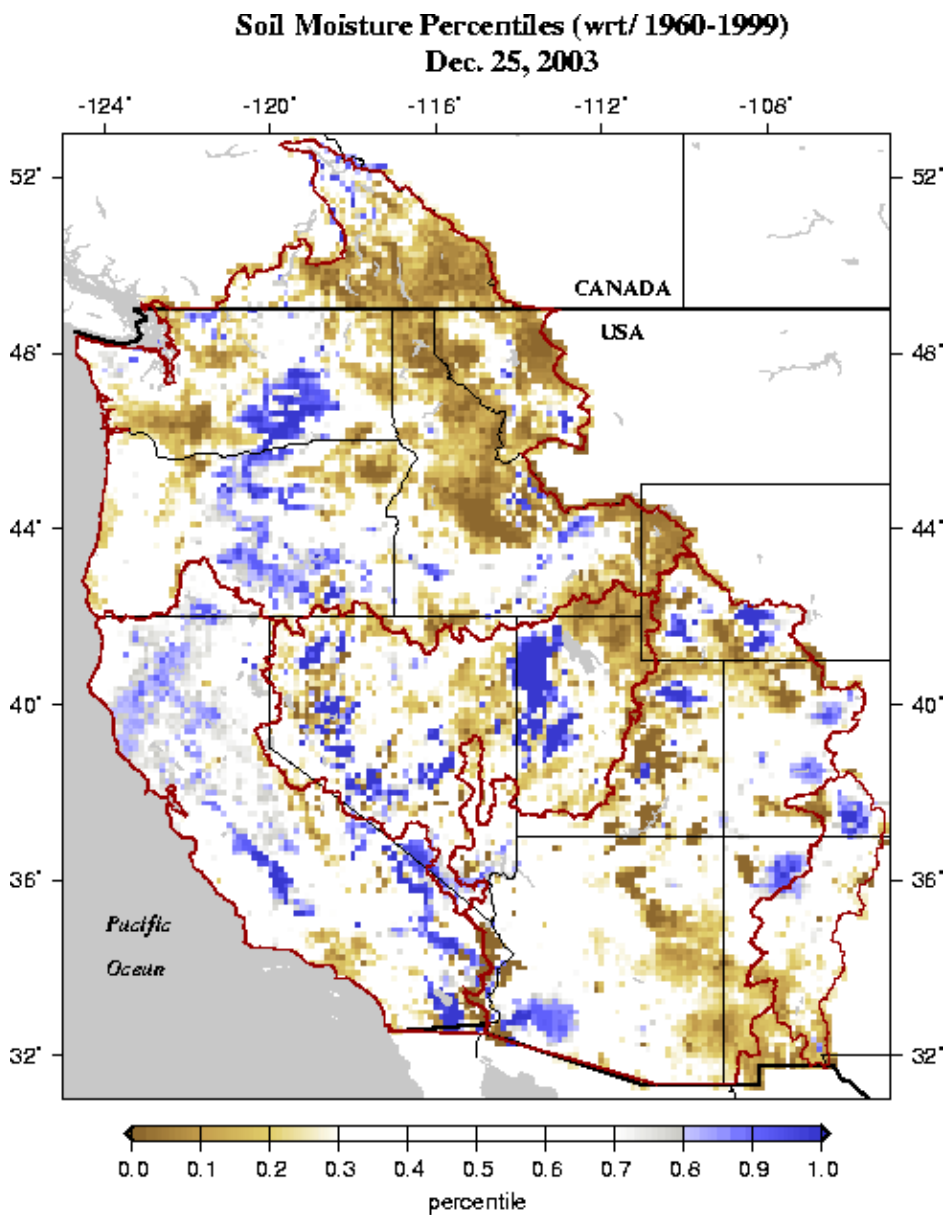

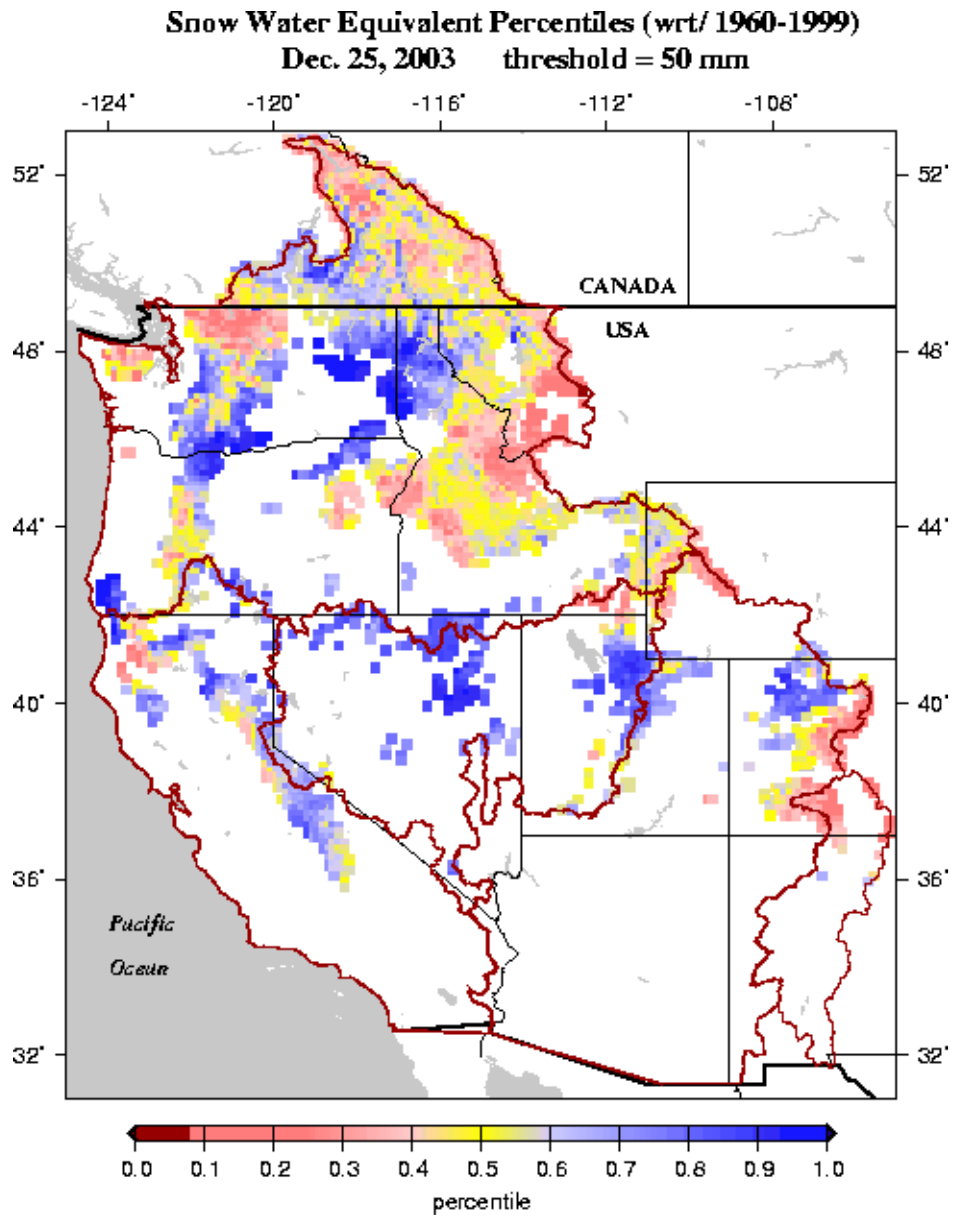

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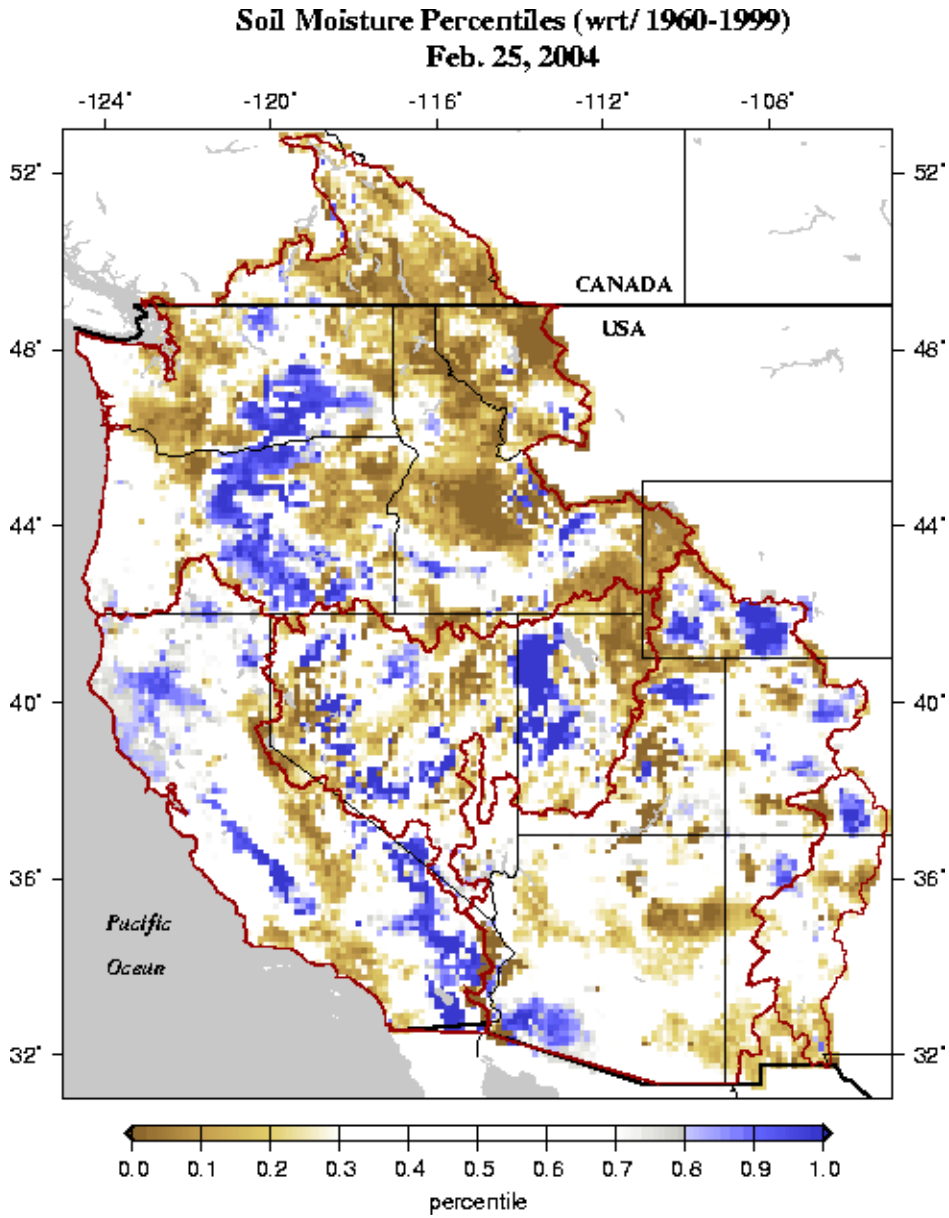
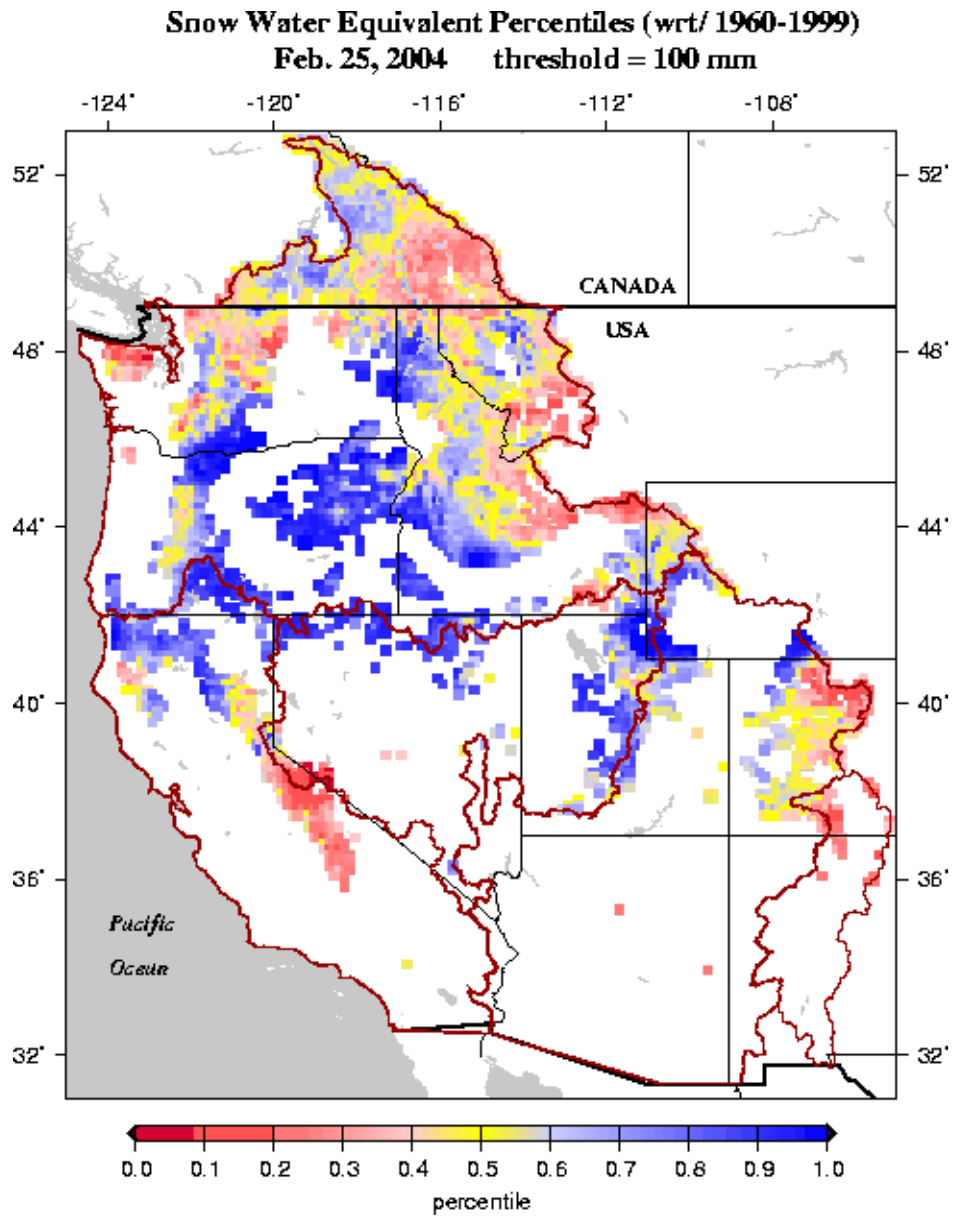


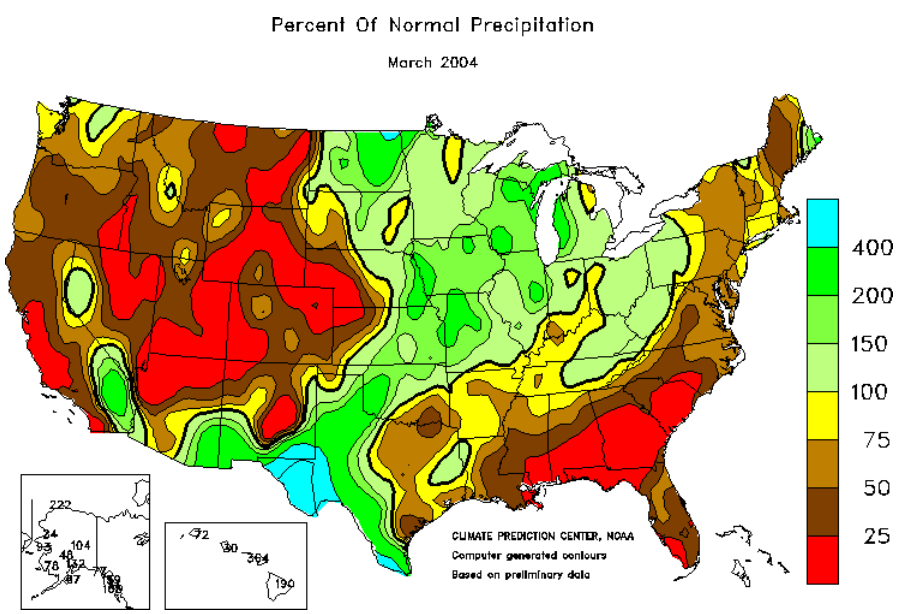


Results for Winter 2003-04: initial conditions

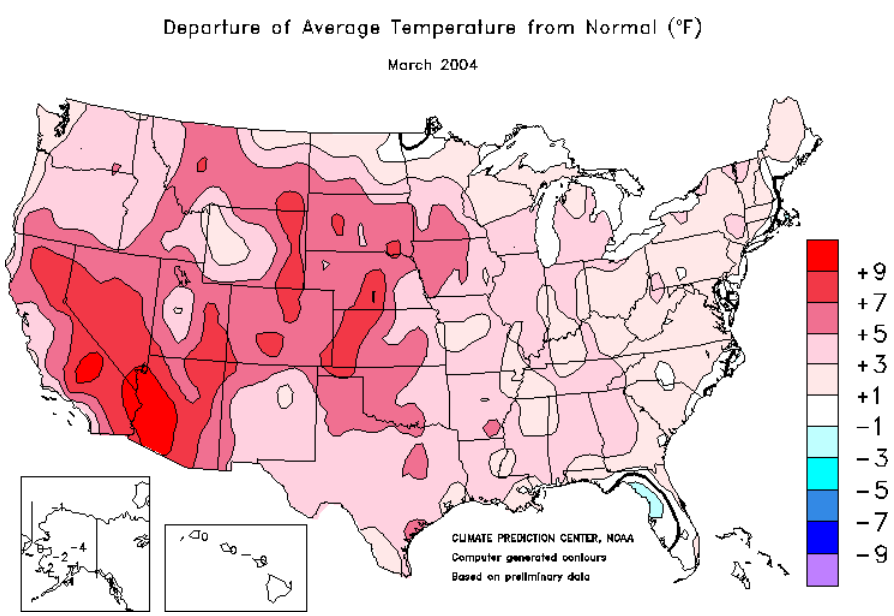
CPC estimates of seasonal precipitation and temperature

March Only

very dry

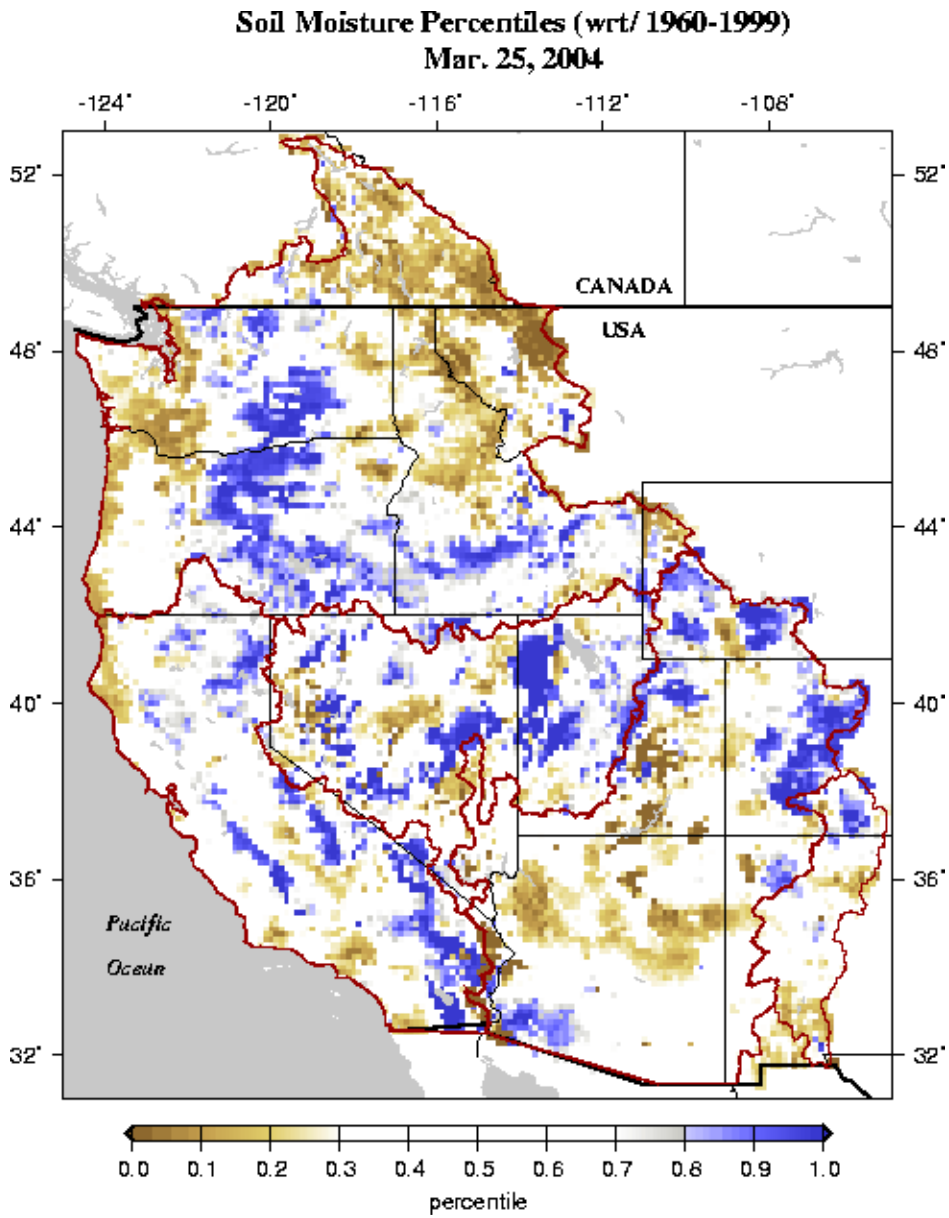


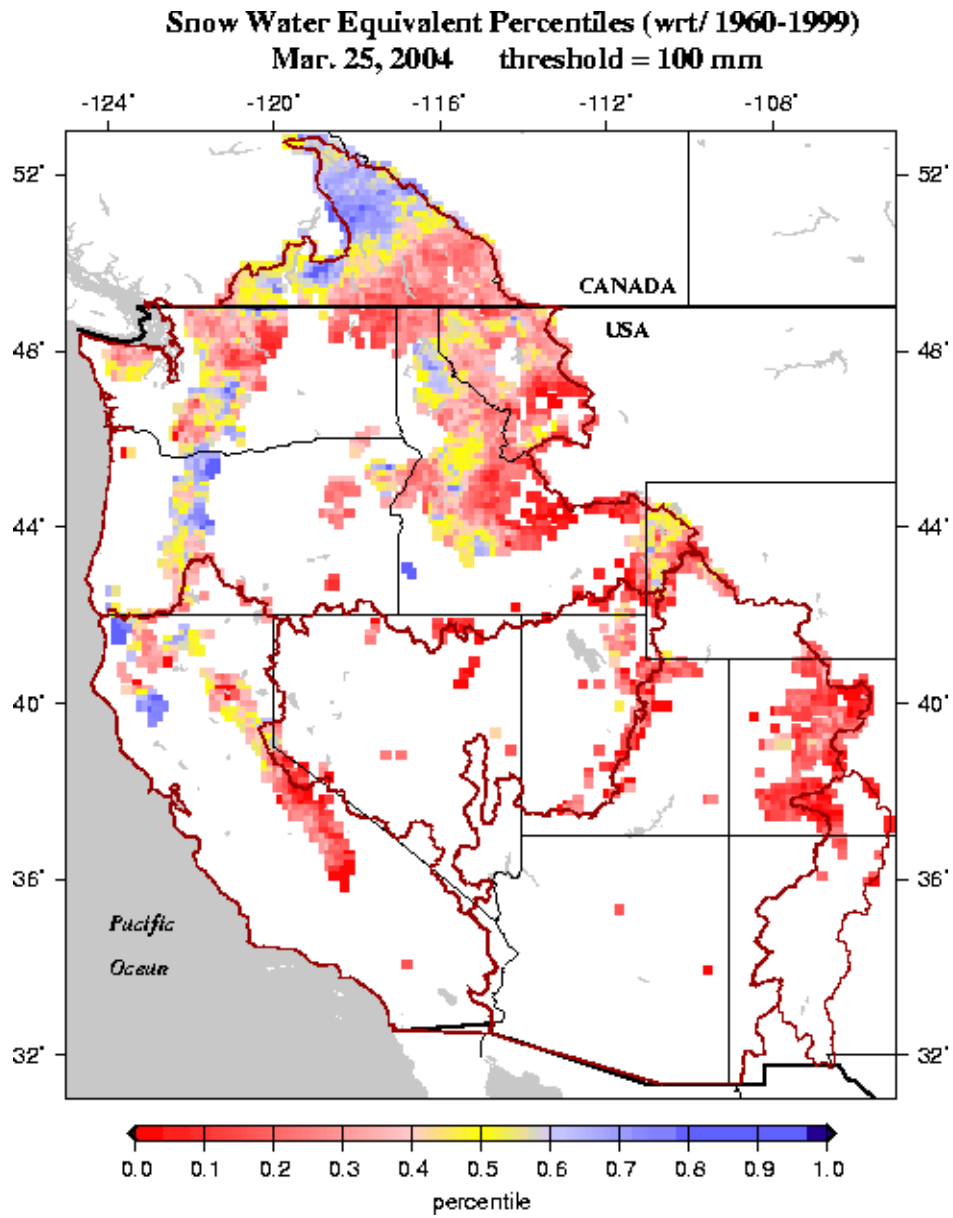
hot



Results for Winter 2003-04: initial conditions

Soil Moisture *and* *Snow Water Equivalent (SWE)*





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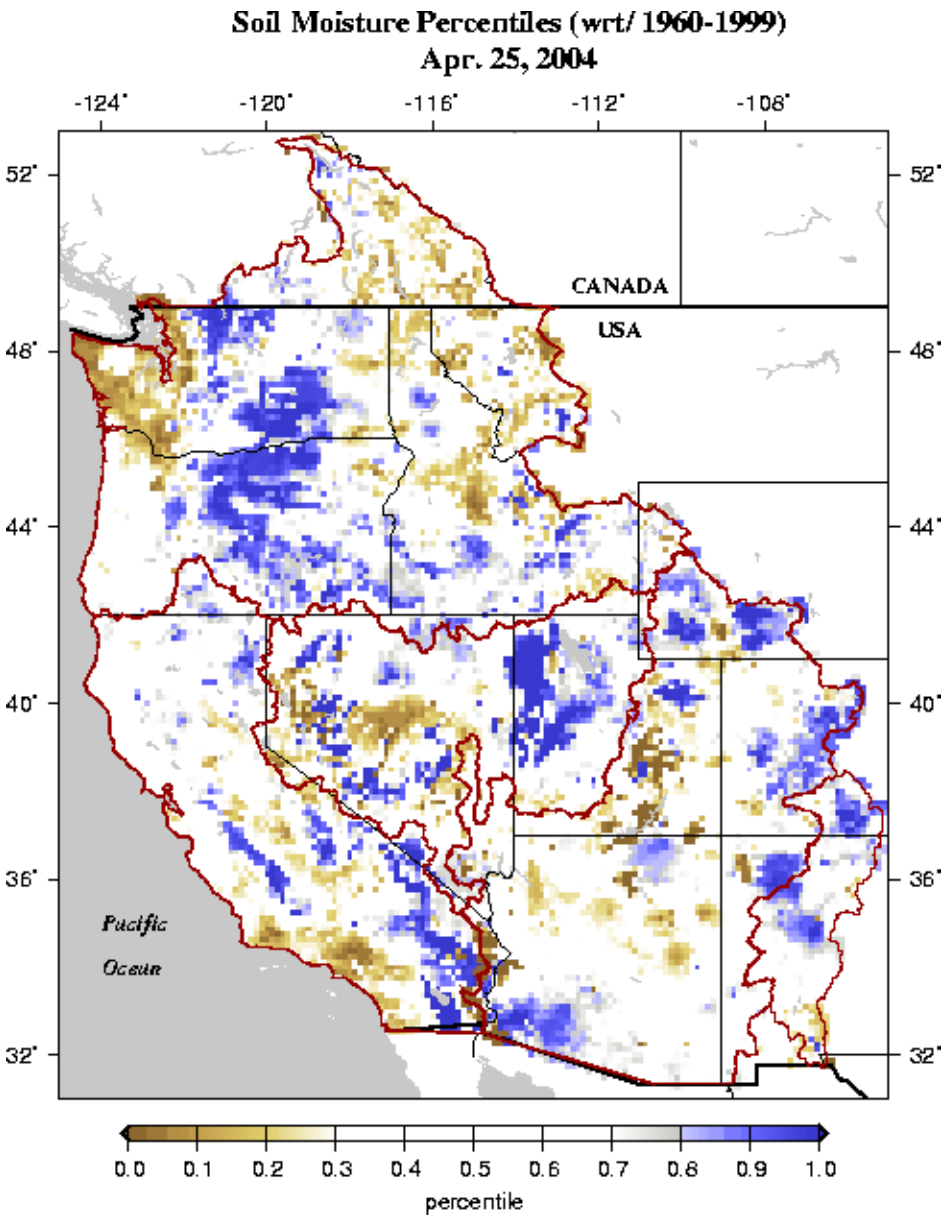

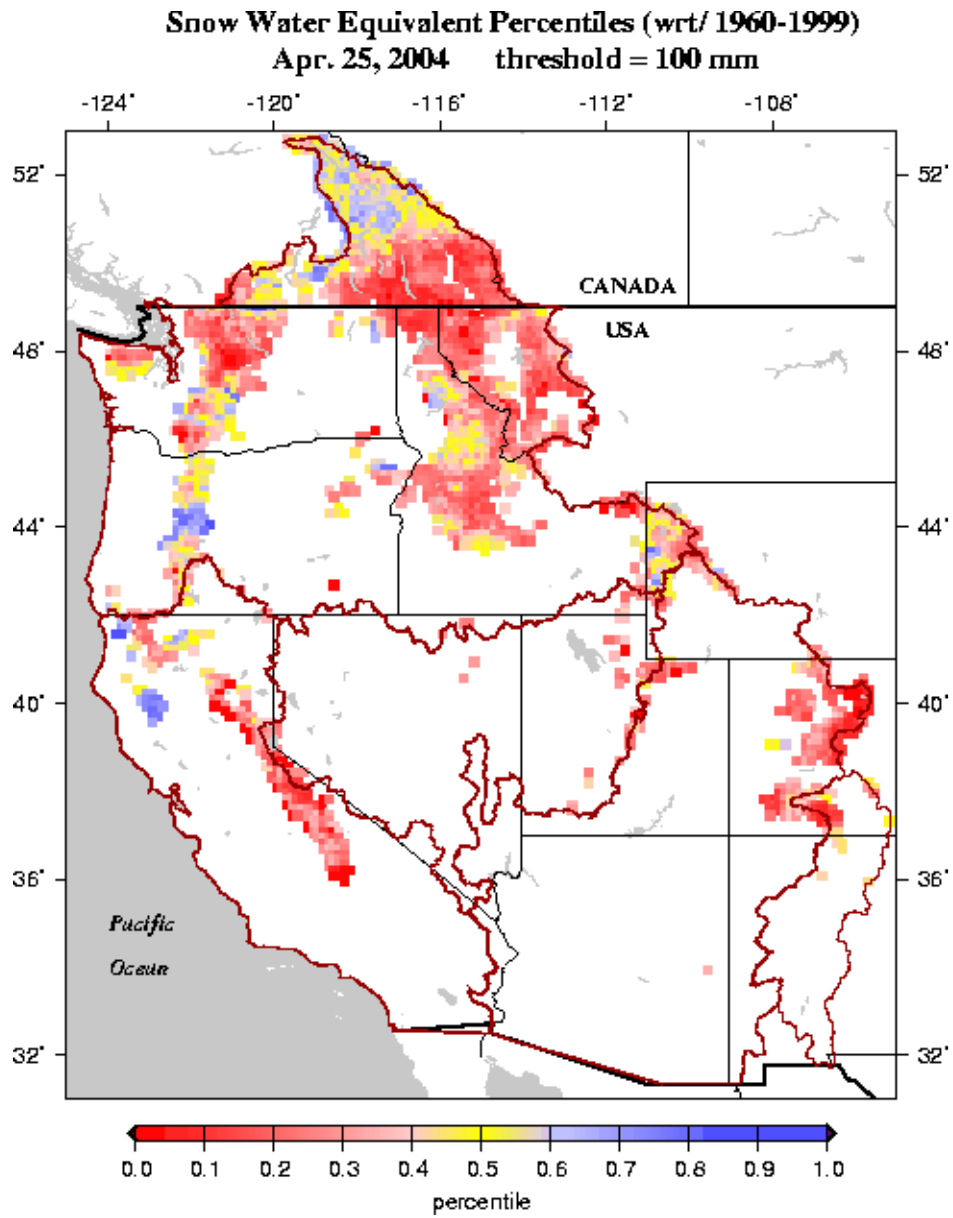

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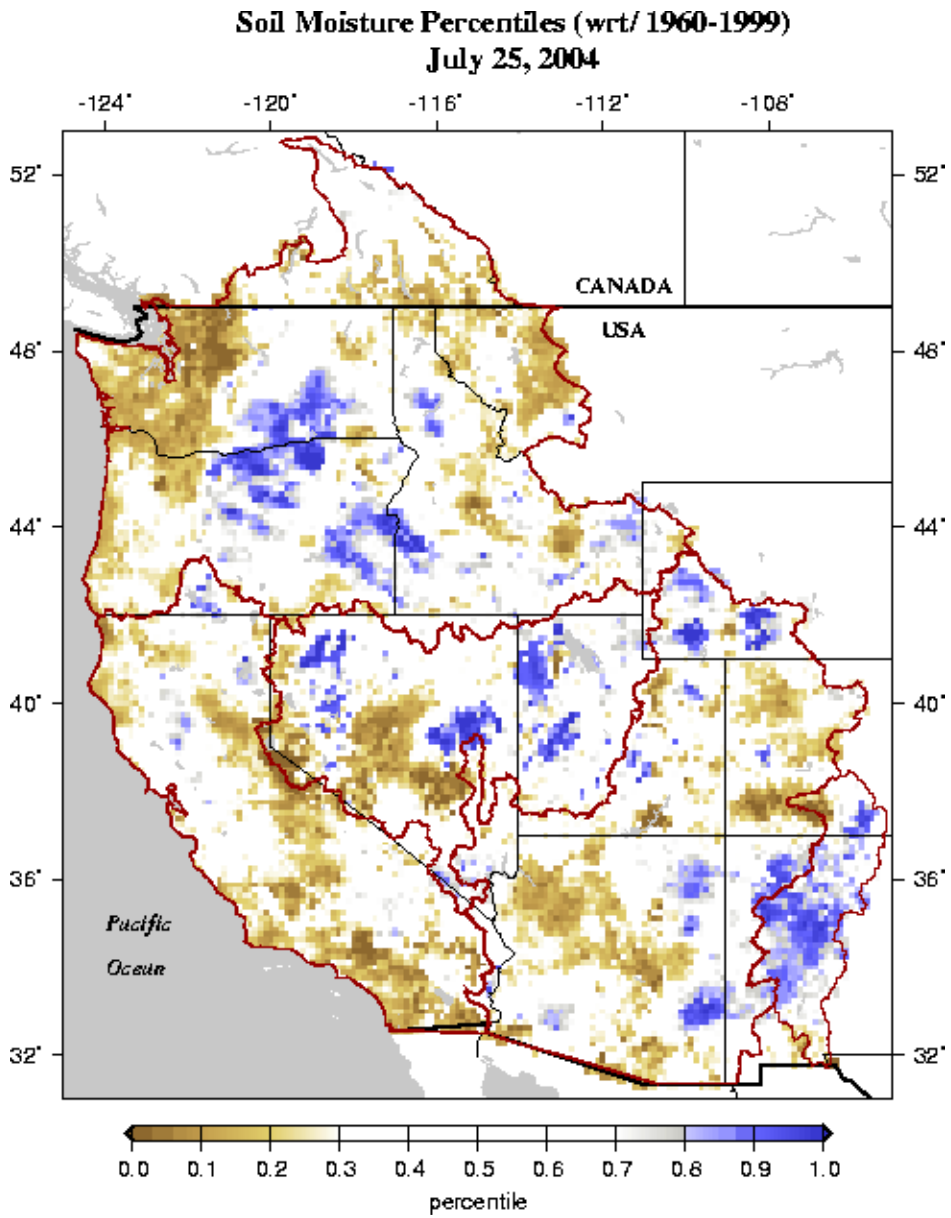

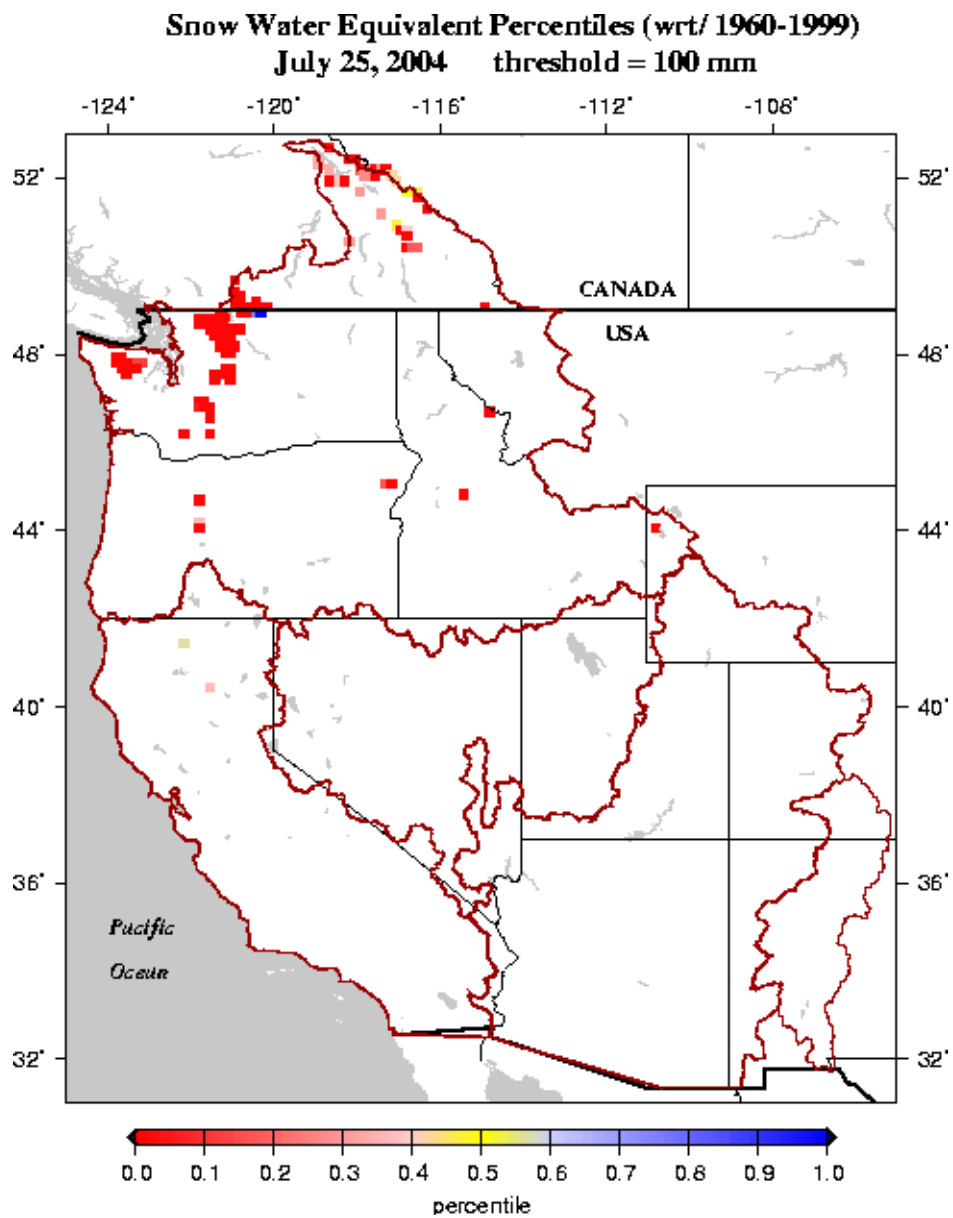

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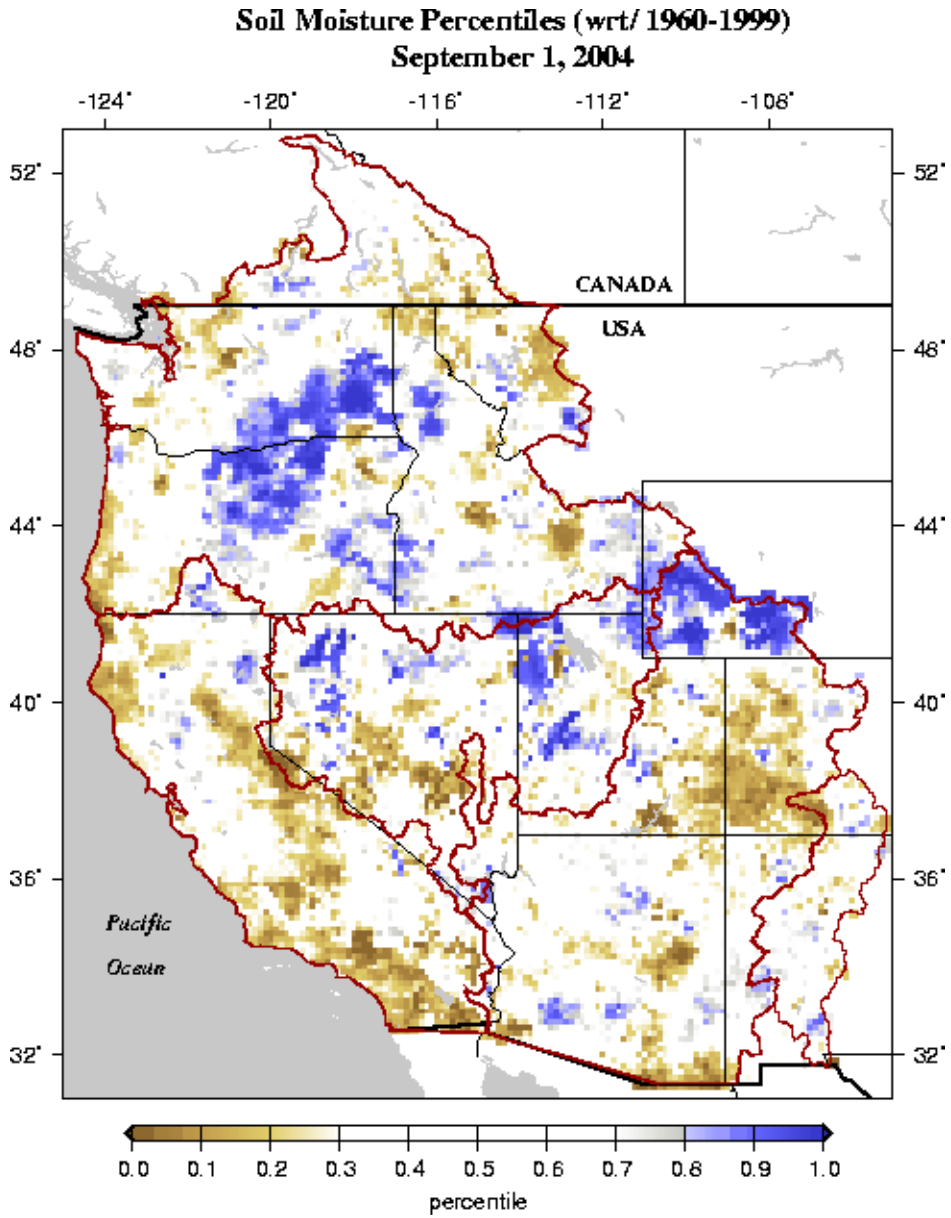
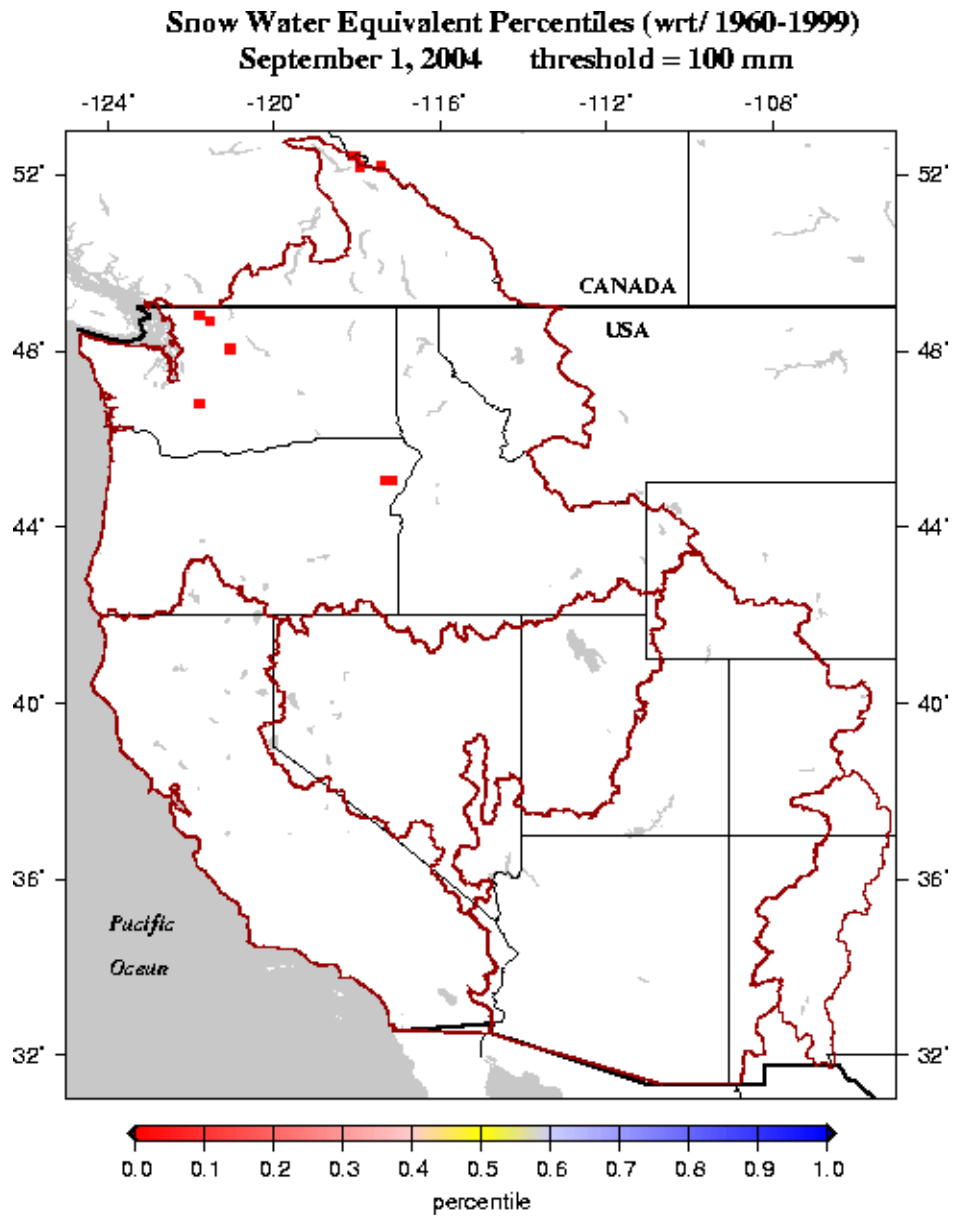
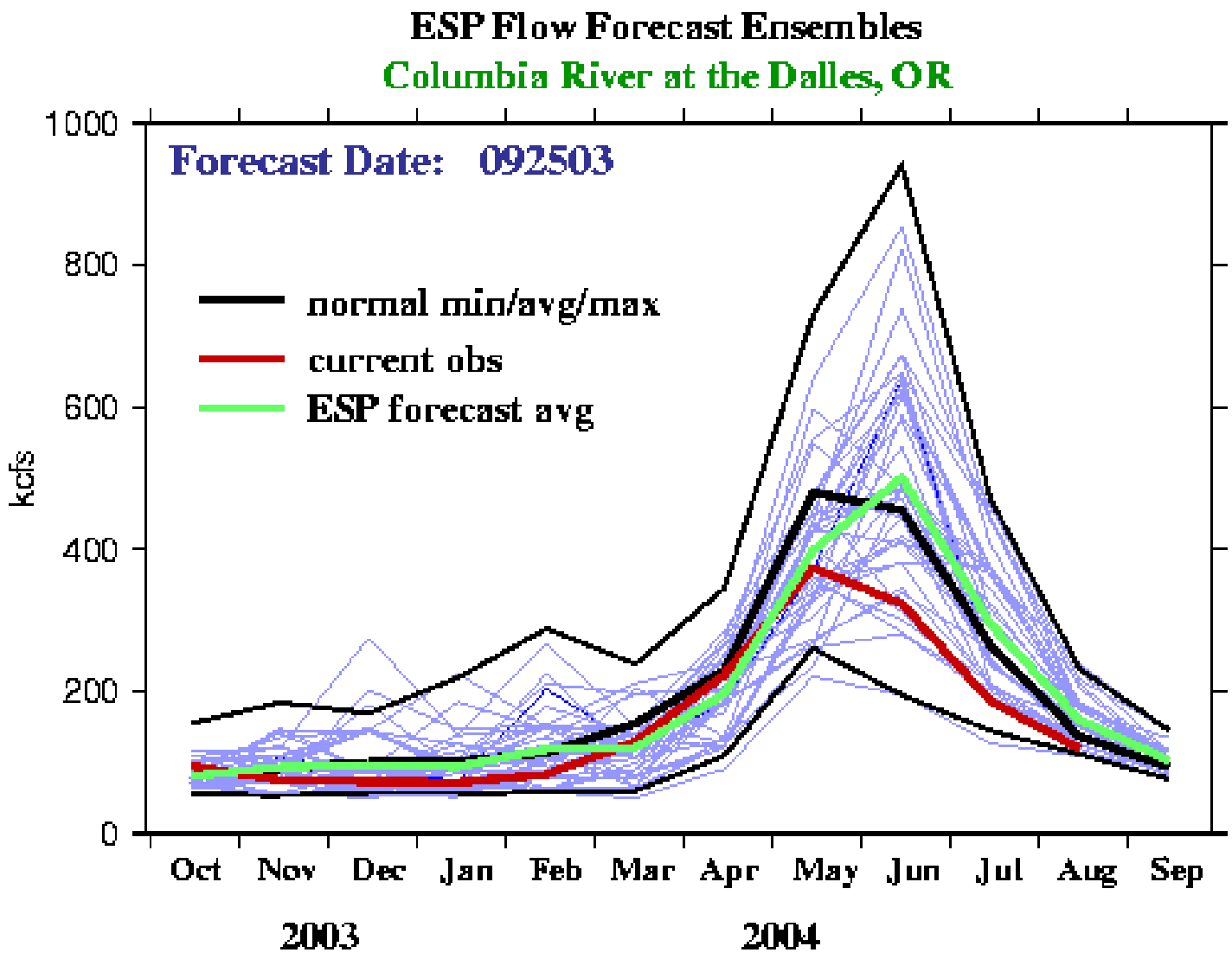




Results for Winter 2003-04: streamflow hydrographs

By Fall, slightly low flows were anticipated

By winter, moderate deficits were forecasted



Results for Winter 2003-04: volume runoff forecasts

UPPER HUMBOLDT RIVER BASIN

Streamflow Forecasts - May 1, 2003

Forecast Pt	<==== Drier		=== Future Conditions		=== Wetter ====>		
	========== Chance of Exceeding * ==========						
Forecast	90%	70%	50% (Most Prob)		30%	10%	30 Yr Avg
Period	(1000AF)	(1000AF)	(1000AF)	(% AVG.)	(1000AF)	(1000AF)	(1000AF)
MARY'S R nr Deeth, Nv							
APR-JUL	12.3	18.7	23	59	27	34	39
MAY-JUL	4.5	11.3	16.0	55	21	28	29
LAMOILLE CK nr Lamoille, Nv							
APR-JUL	13.7	17.4	20	67	23	26	30
MAY-JUL	11.6	15.4	18.0	64	21	24	28
N F HUMBOLDT R at Devils Gate							
APR-JUL	5.1	11.0	15.0	44	19.0	25	34
MAY-JUL	1.7	7.2	11.0	50	14.8	20	22

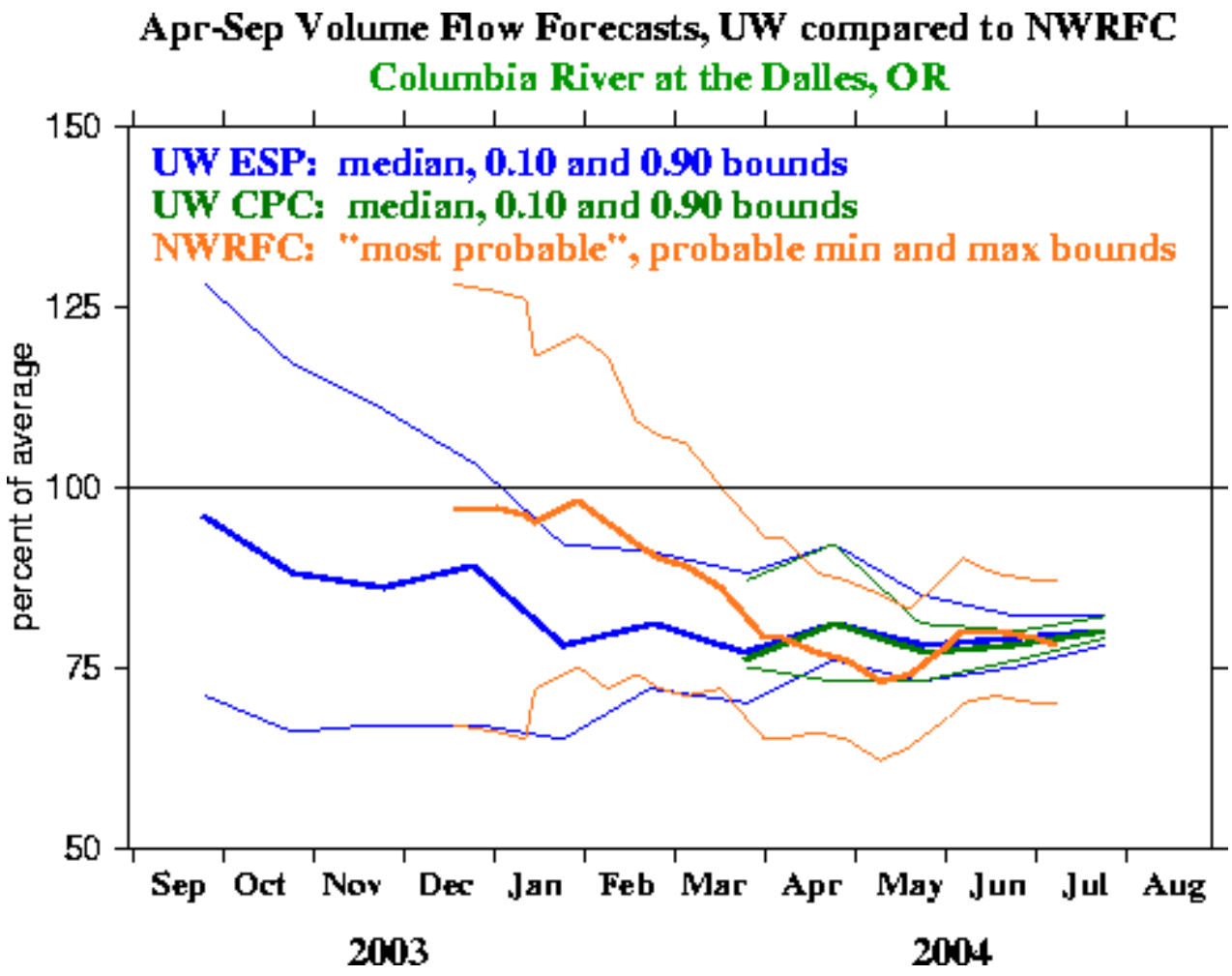
Results for Winter 2003-04: volume runoff forecasts

Comparison with RFC forecast for Columbia River at the Dalles, OR

UW forecasts made on 25th of each month

RFC forecasts made several times monthly:
1st, mid-month, late

(UW's **ESP unconditional** and **CPC forecasts** shown)



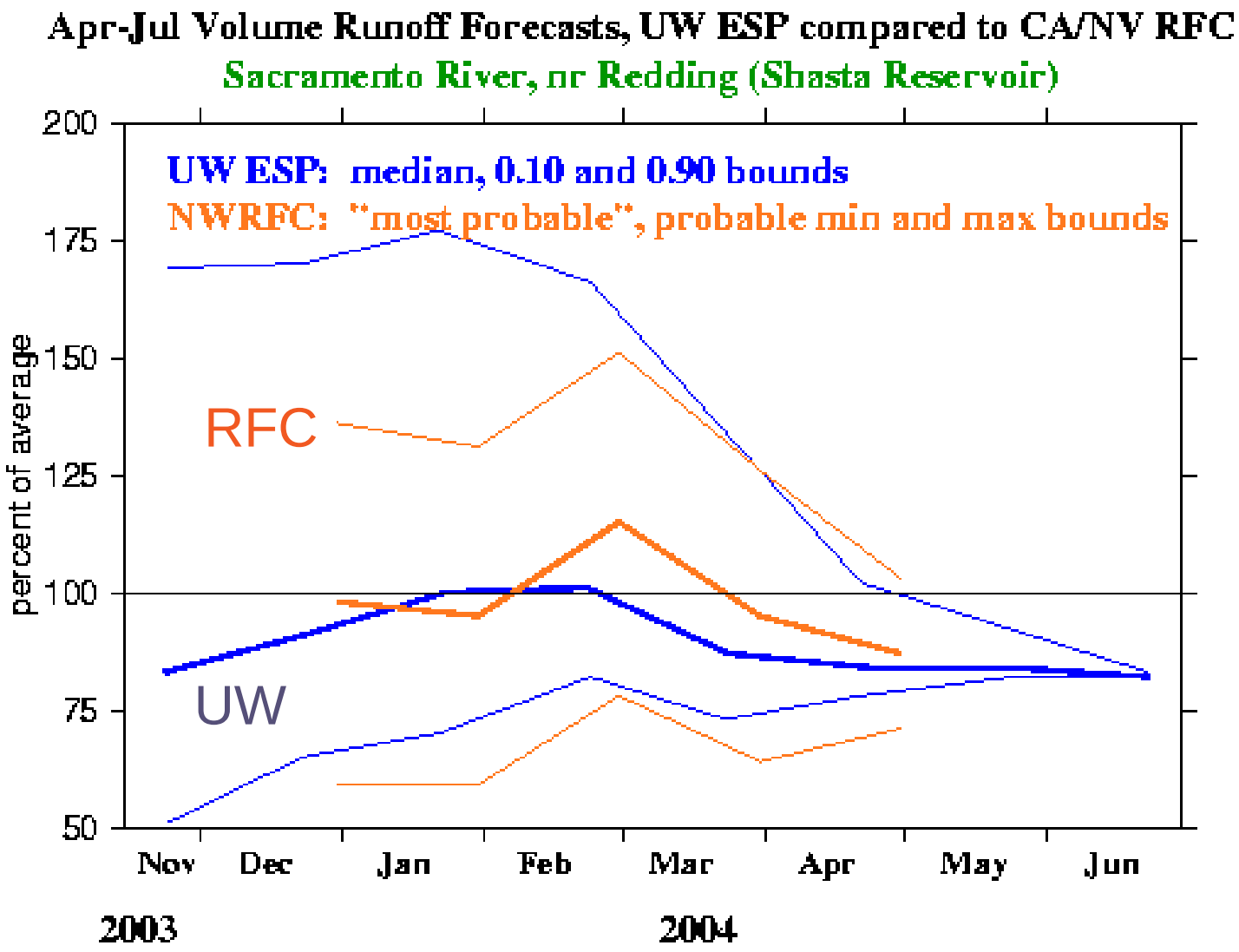
Results for Winter 2003-04: volume runoff forecasts

Comparison with RFC forecast for Sacramento River near Redding, CA

UW forecasts made on 25th of each month

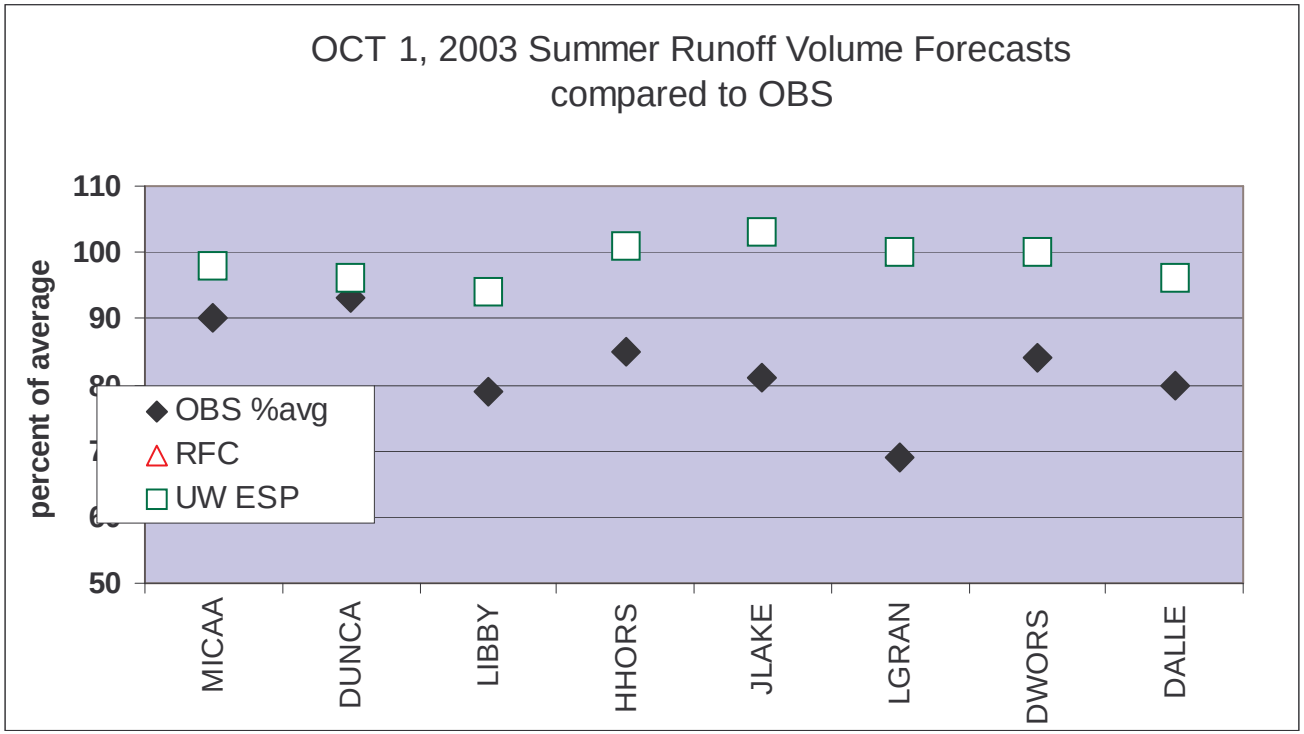
RFC forecasts made on 1st of month

(UW's **ESP unconditional** forecasts shown)



Results for Winter 2003-04: volume forecasts

for a sample of PNW locations



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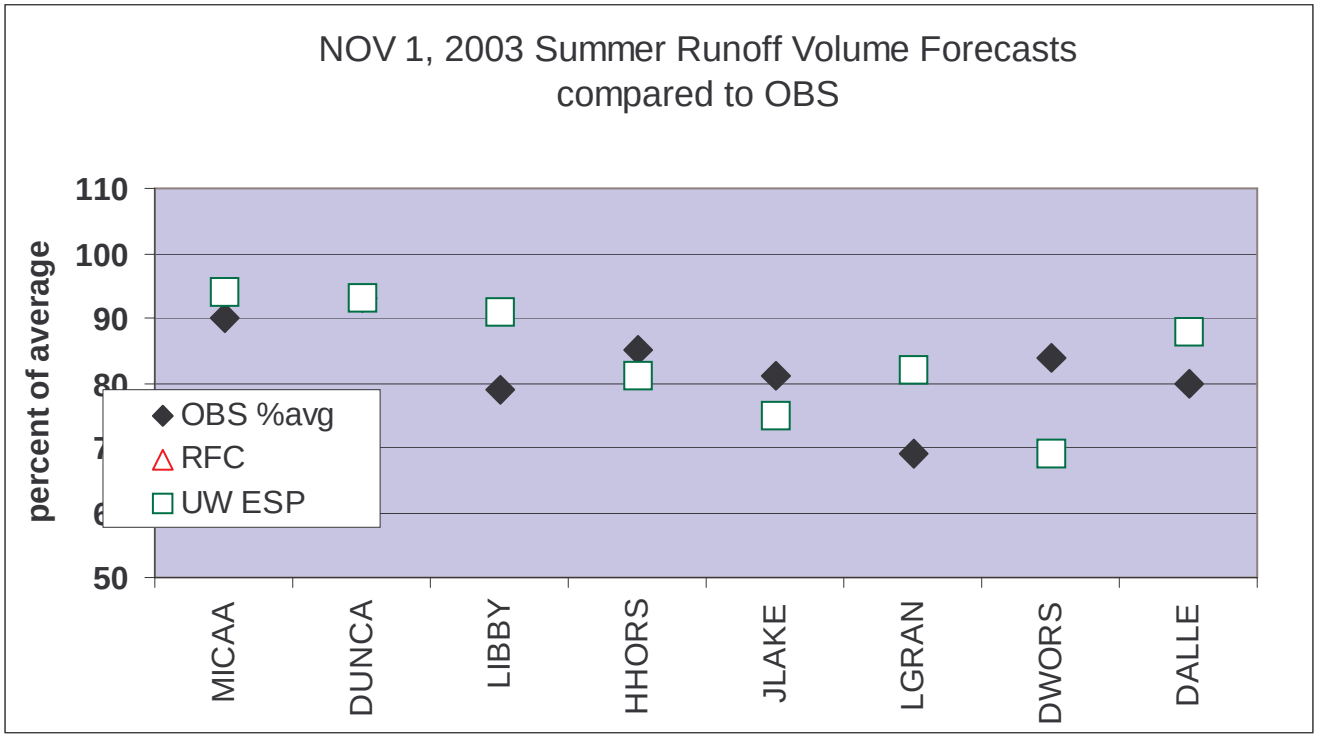

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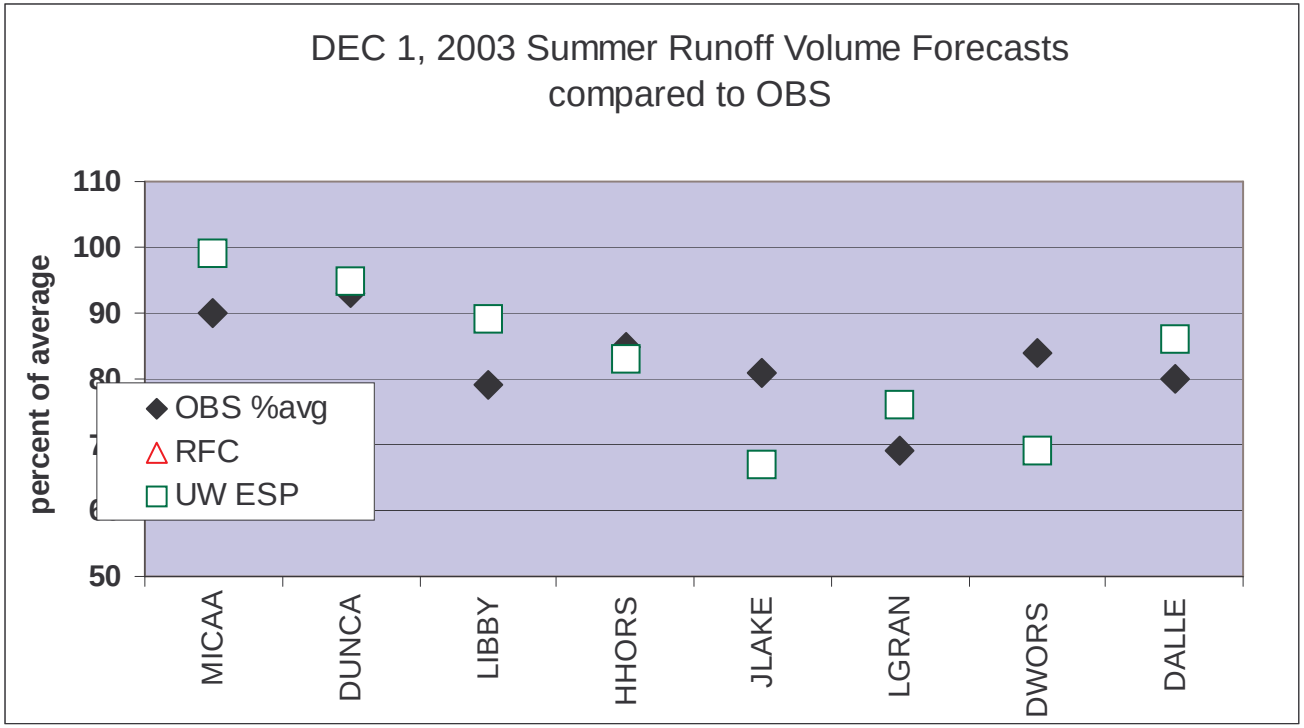

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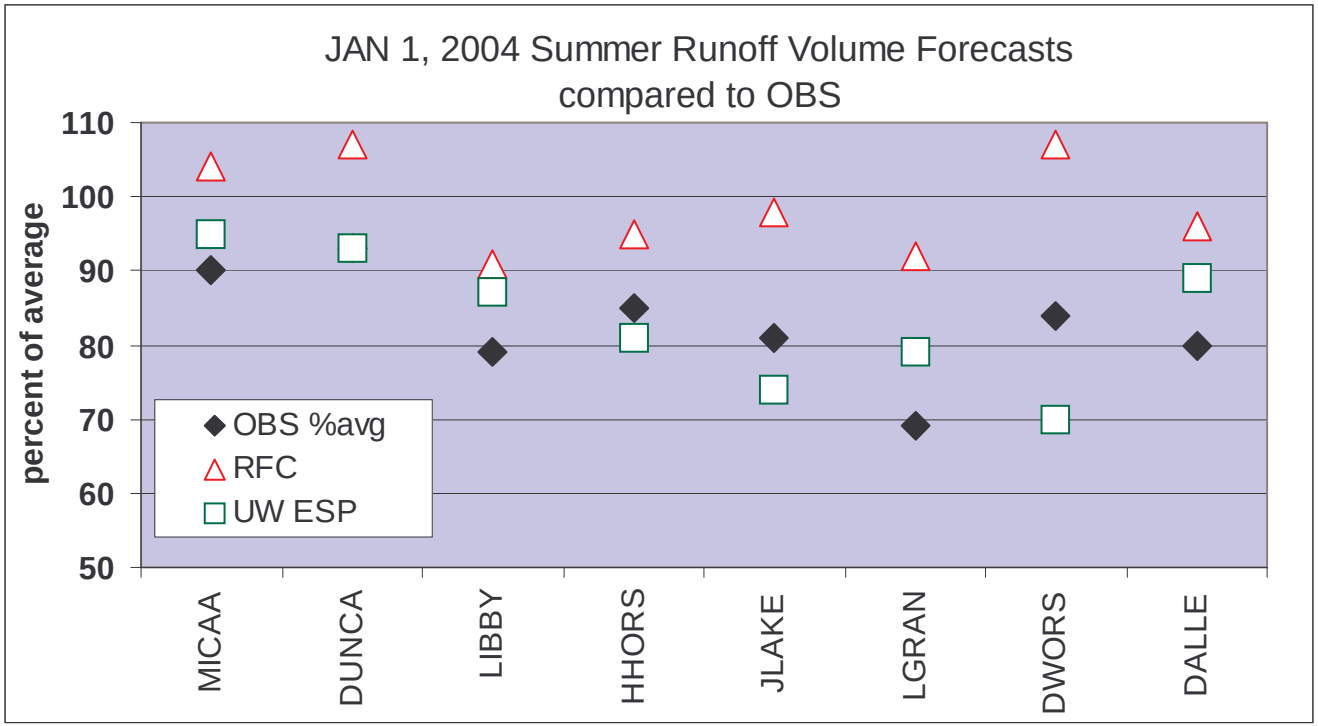

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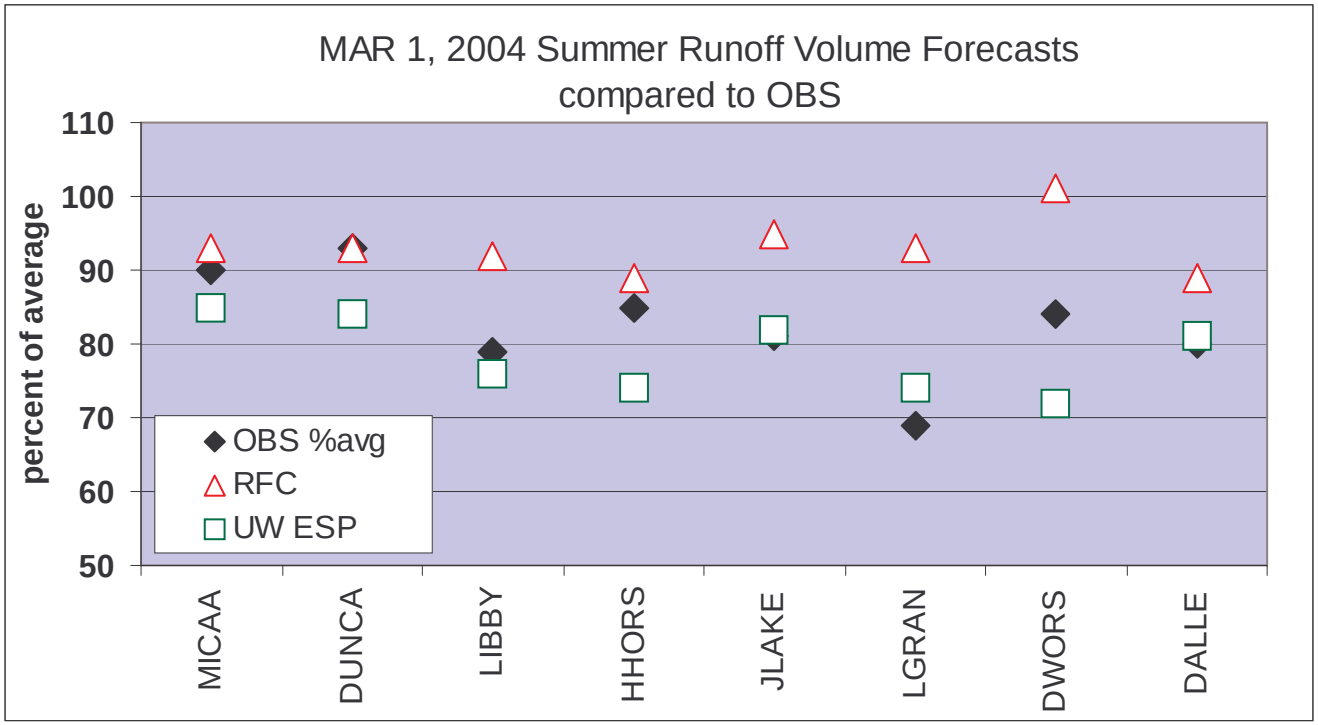

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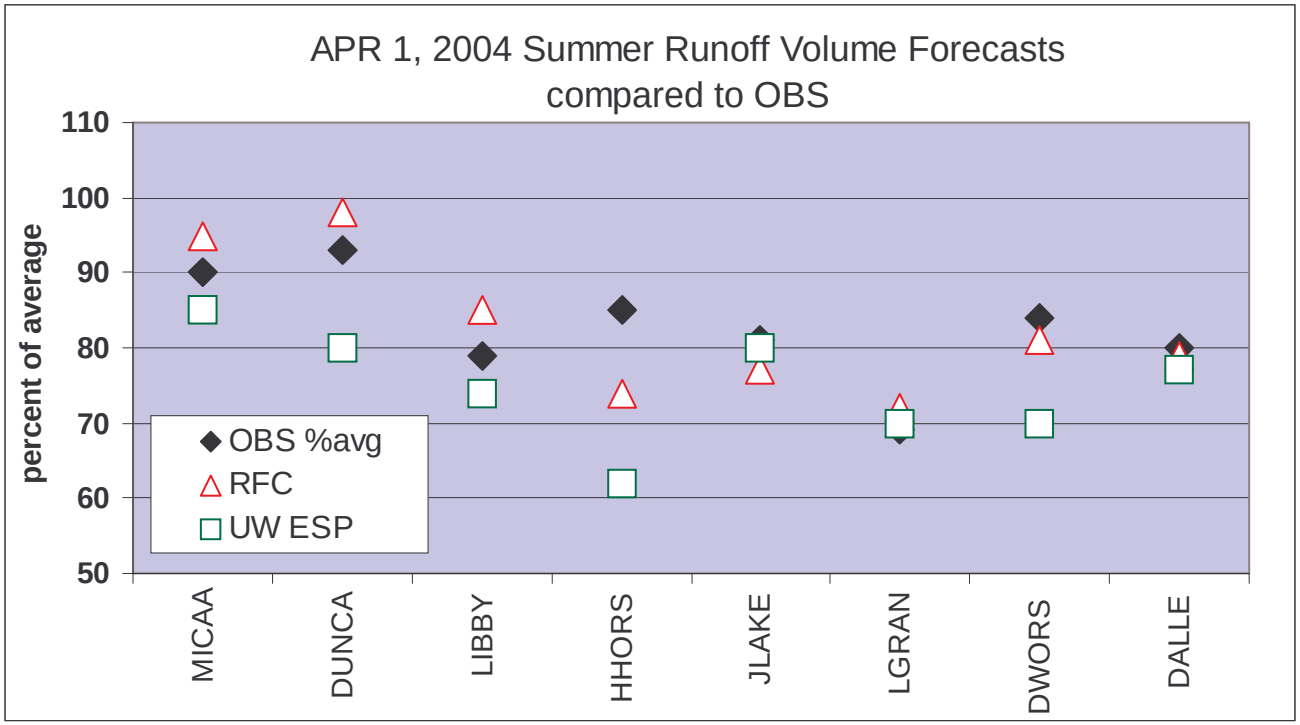

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  - snotel assimilation
  - MODIS assimilation
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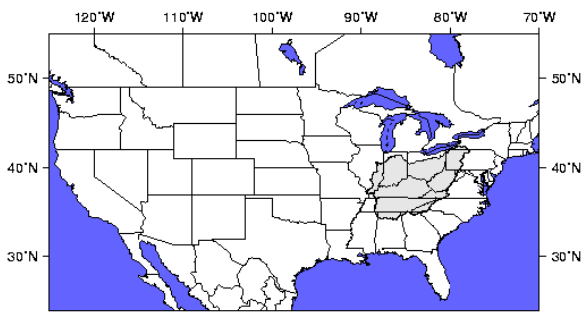
Final Comments

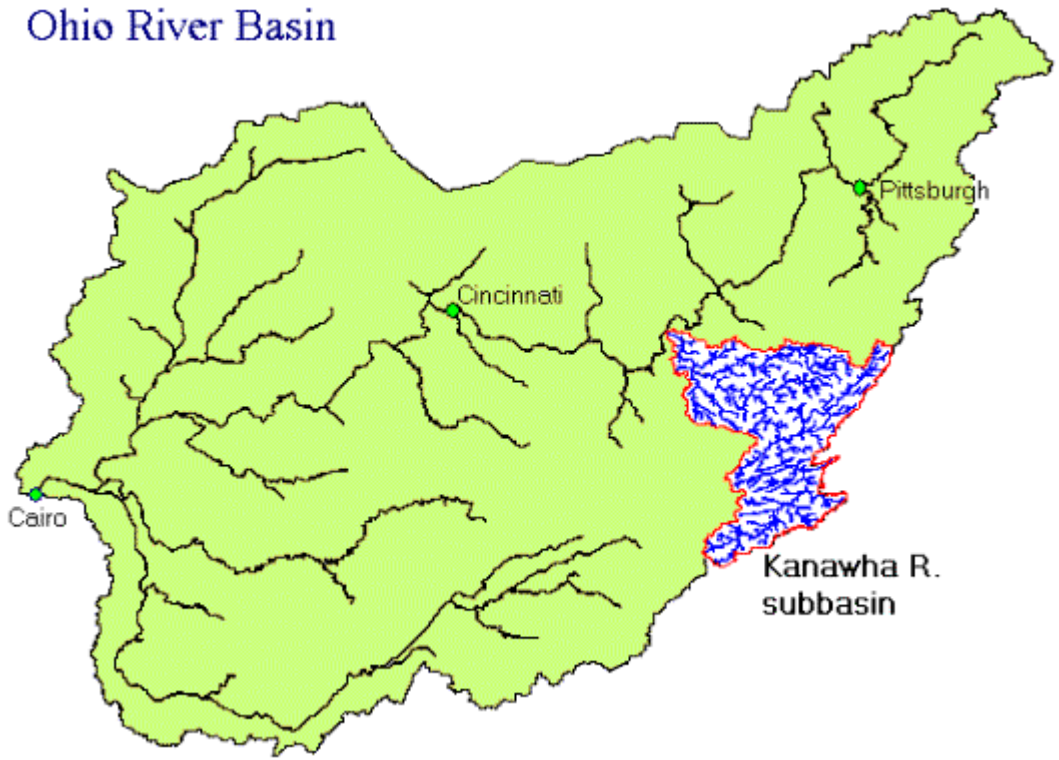
starting point…

Ohio R. Basin / Corps of Engineers study, 1998

q problems w/ climate model bias -> bias-correction approach
q problems w/ real-time data availability -> retrospective study
q problems w/ hydrology model calibration -> shrinking study domain
q Corps operators interested, but busy, needed more proof



Ohio River Basin



Final Comments

future plans…

west-wide expansion

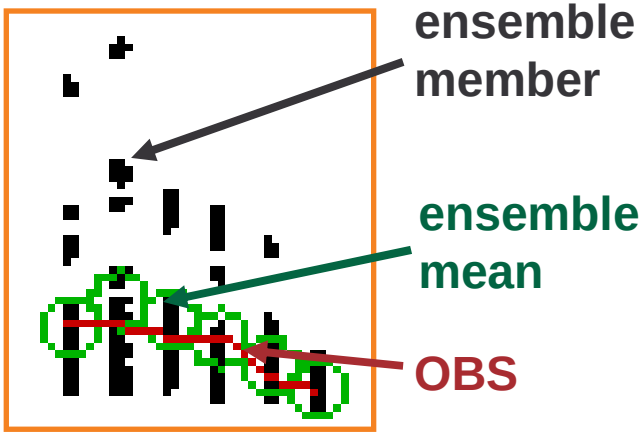
- more forecast points
- more comprehensive outputs
- reorganized web-site
- more verification

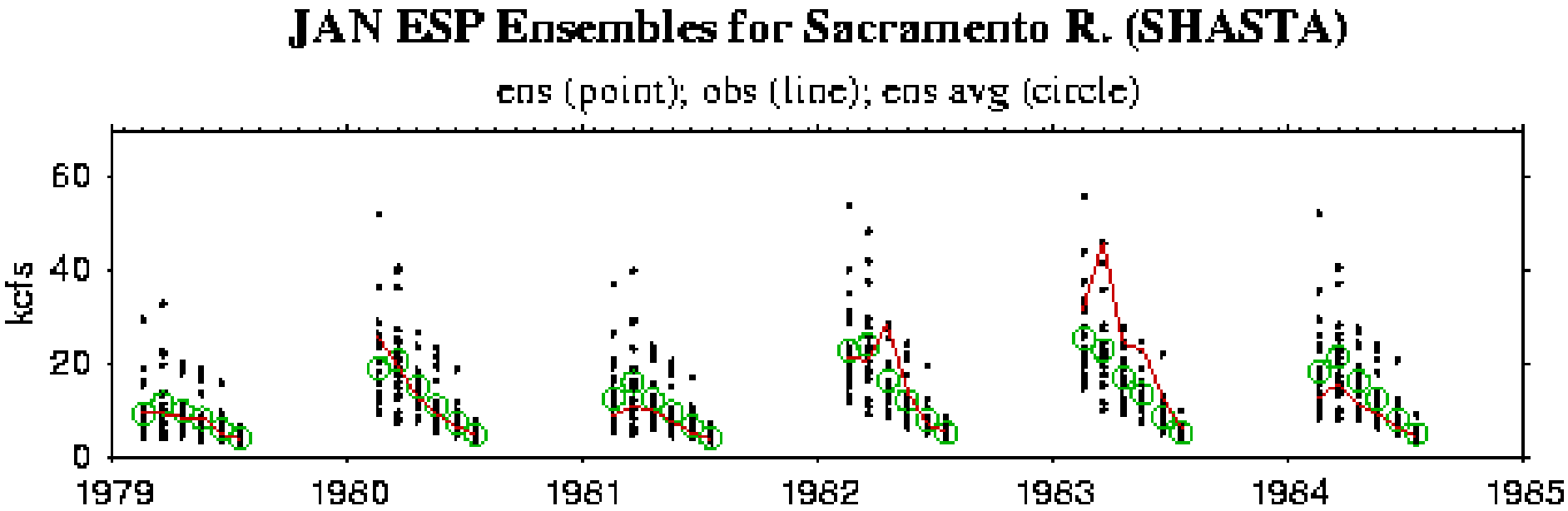
multi-model (land-surface in addition to climate)

Seasonal Hydrologic Forecast Uncertainty

Single-IC ensemble forecast:

- q early in seasonal forecast season, climate ensemble spread is large
- q errors in forecast mainly due to climate forecast errors

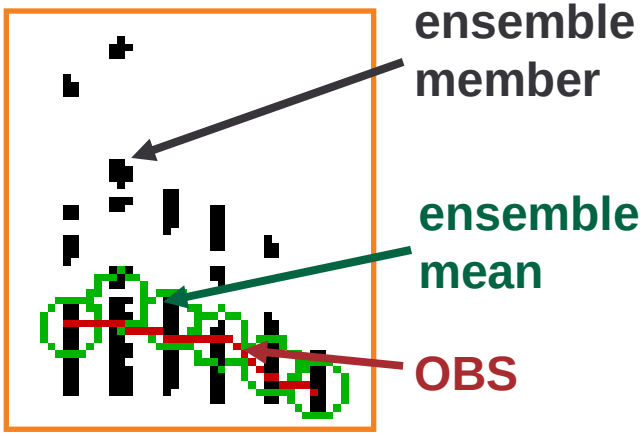


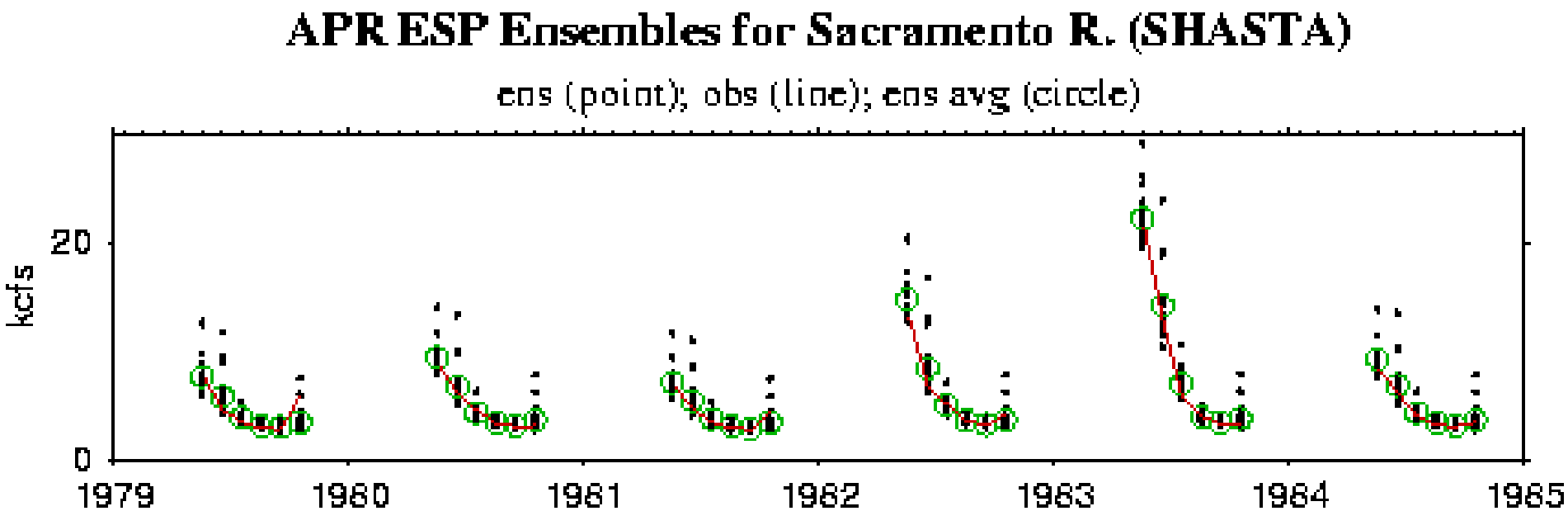


Seasonal Hydrologic Forecast Uncertainty

Single-IC ensemble forecast:

- q late in seasonal forecast season, climate ensemble is ***nearly deterministic***
- q errors in forecast mainly due to IC errors



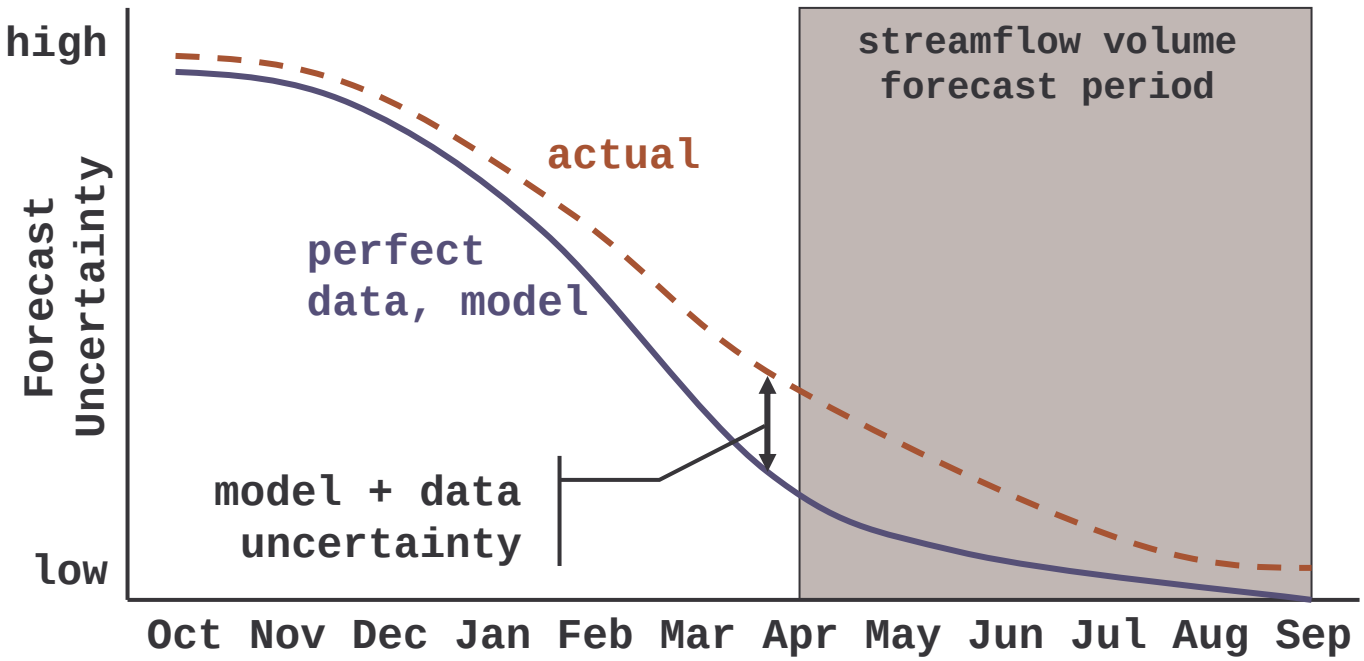


Seasonal Hydrologic Forecast Uncertainty

Importance of uncertainty in ICs vs. climate vary with lead time …

ICs low
climate f'cast high

ICs high
climate f'cast low

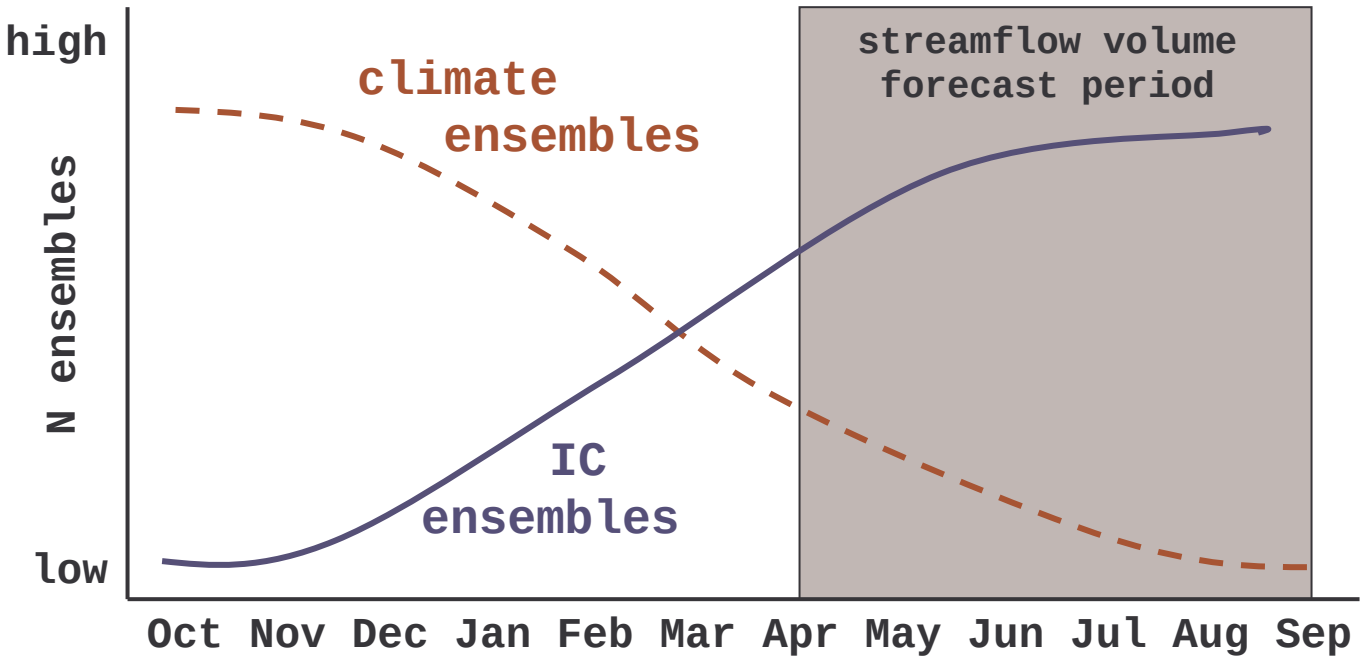


… hence importance of model & data errors also vary with lead time.

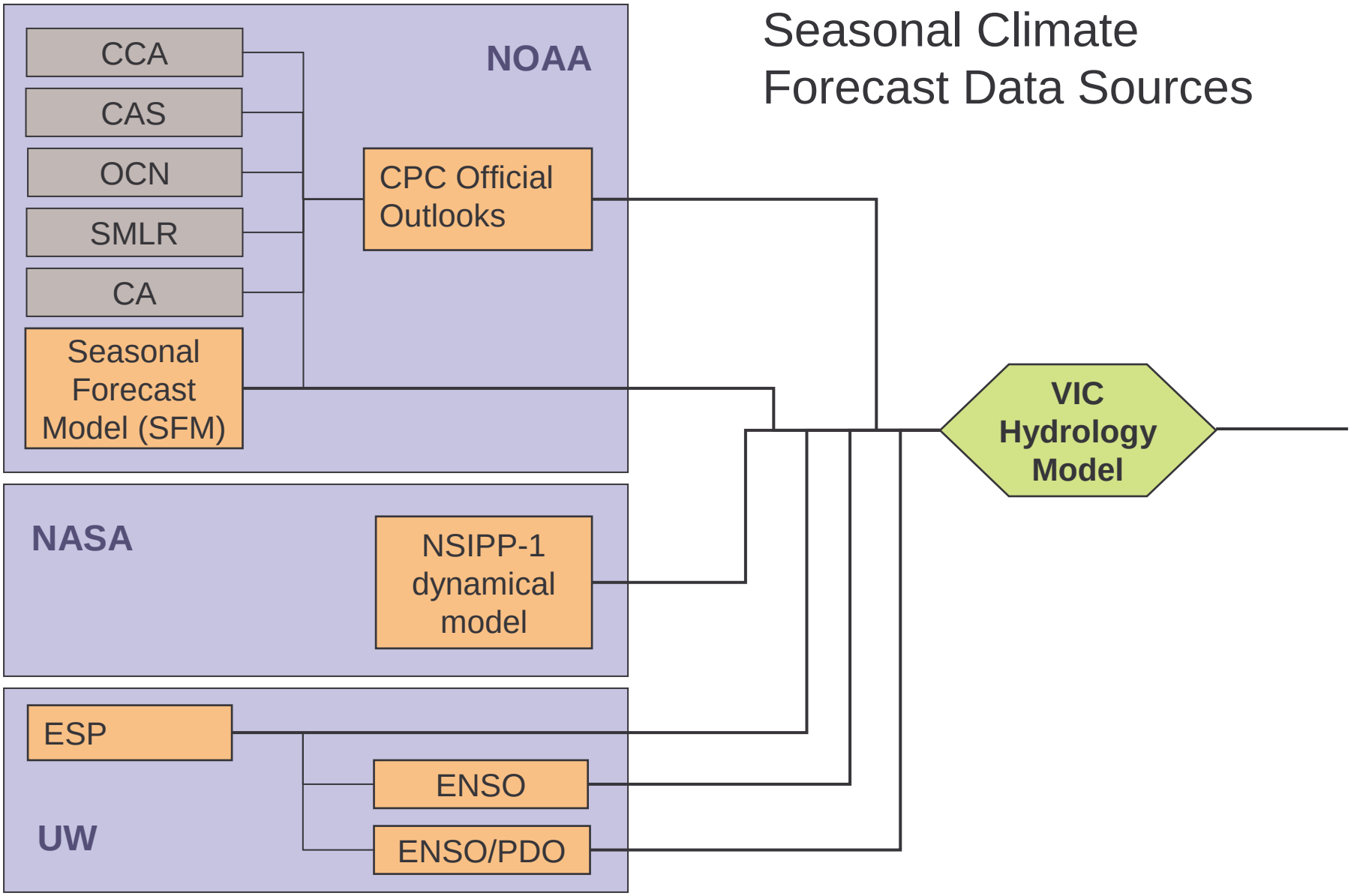
Expansion to multiple-model framework

It should be possible to balance effort given to climate vs IC part of forecasts

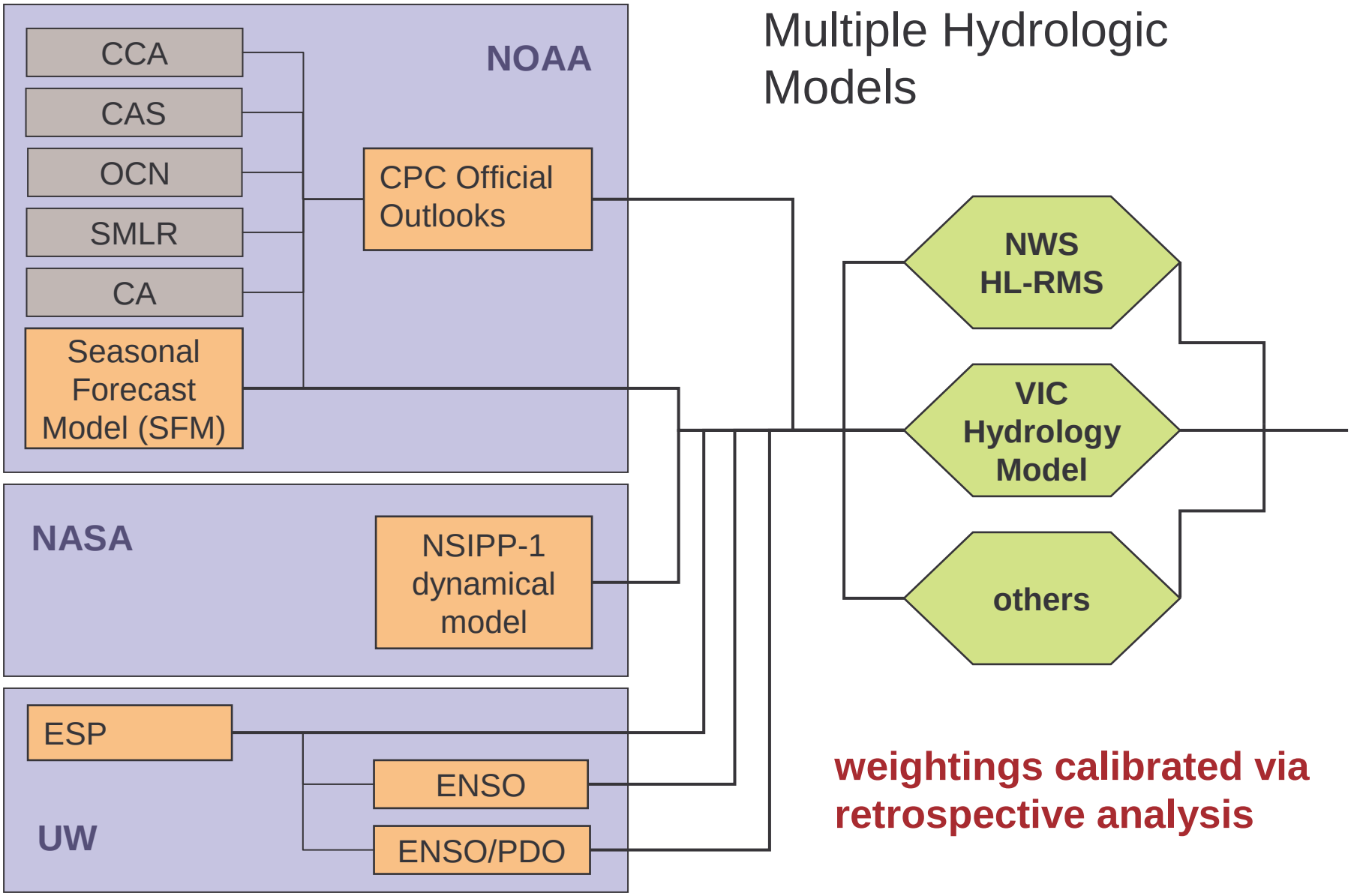
climate forecasts more important ⟷ **ICs more important**



Expansion to multiple-model framework

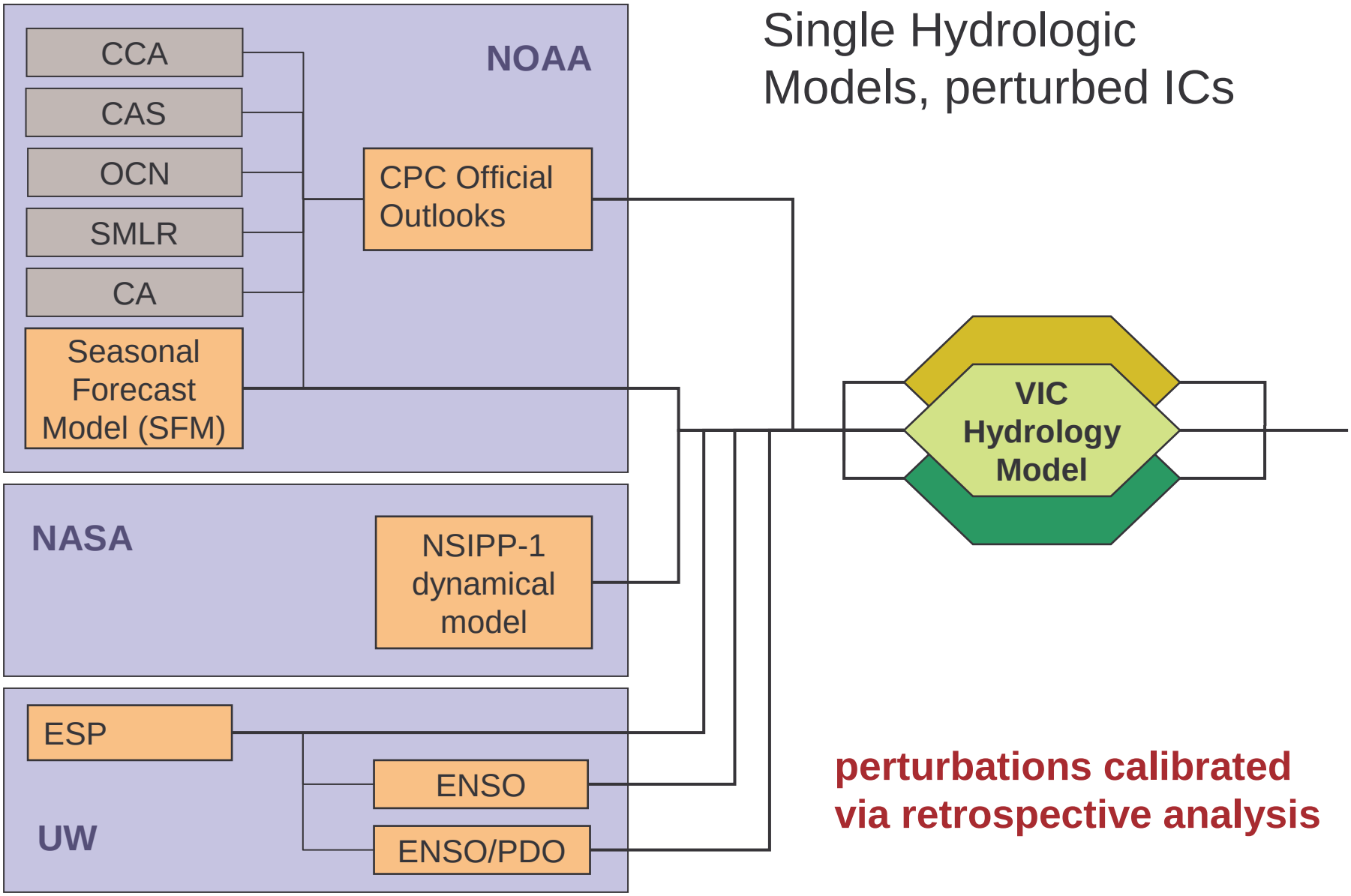


Expansion to multiple-model framework



weightings calibrated via retrospective analysis

Expansion to multiple-model framework



final comments by dennis

Approach: CPC Seasonal Outlook Use

Downscaling Evaluation

Spatial Disaggregation

- q transform CPC climate division retrospective timeseries (1960-99) into monthly anomaly timeseries (%P, delta T)
- q apply anomalies to 1/8 degree monthly P and T means (from UW COOP-based observed dataset of Maurer et al., 2001)
- q yields: 1/8 degree monthly P and T timeseries

Temporal Disaggregation

- q daily weather generator creates daily P and T sequences for 1/8 degree grid
- q scale and shift sequences by month to reproduce **monthly** 1/8 degree P and T timeseries values

Question 1:

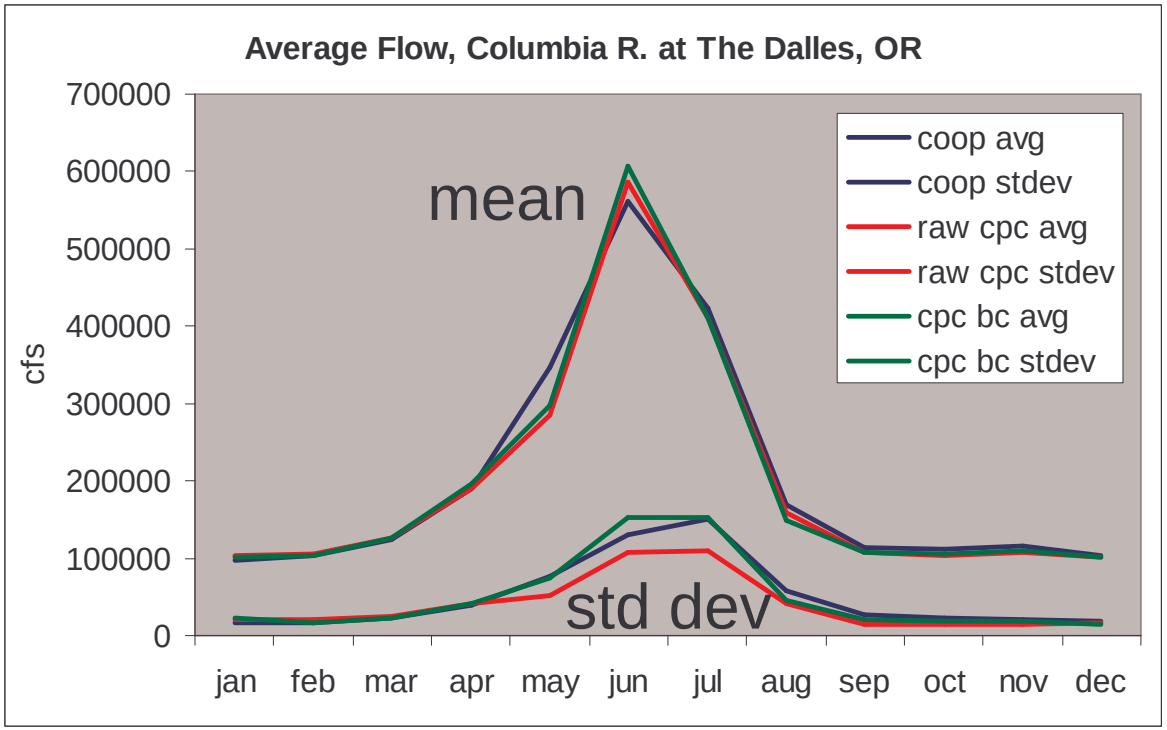
Does hydrologic simulation driven by the downscaled forcings reproduce expected* streamflow mean and variability?

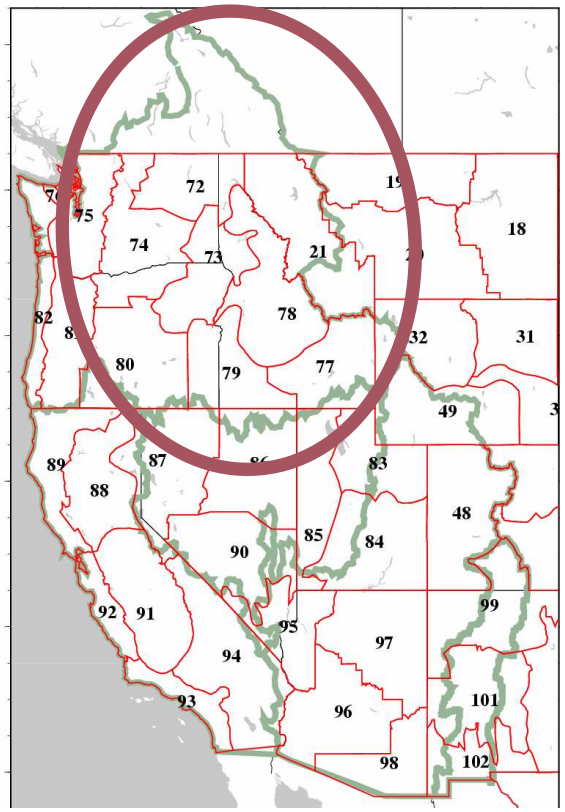
*expected = simulated from 1/8 degree observed forcings (Maurer et al.)

Results: CPC-based flow w.r.t. UW obs dataset

Answer:

YES, with help from bias-correction.....(but)

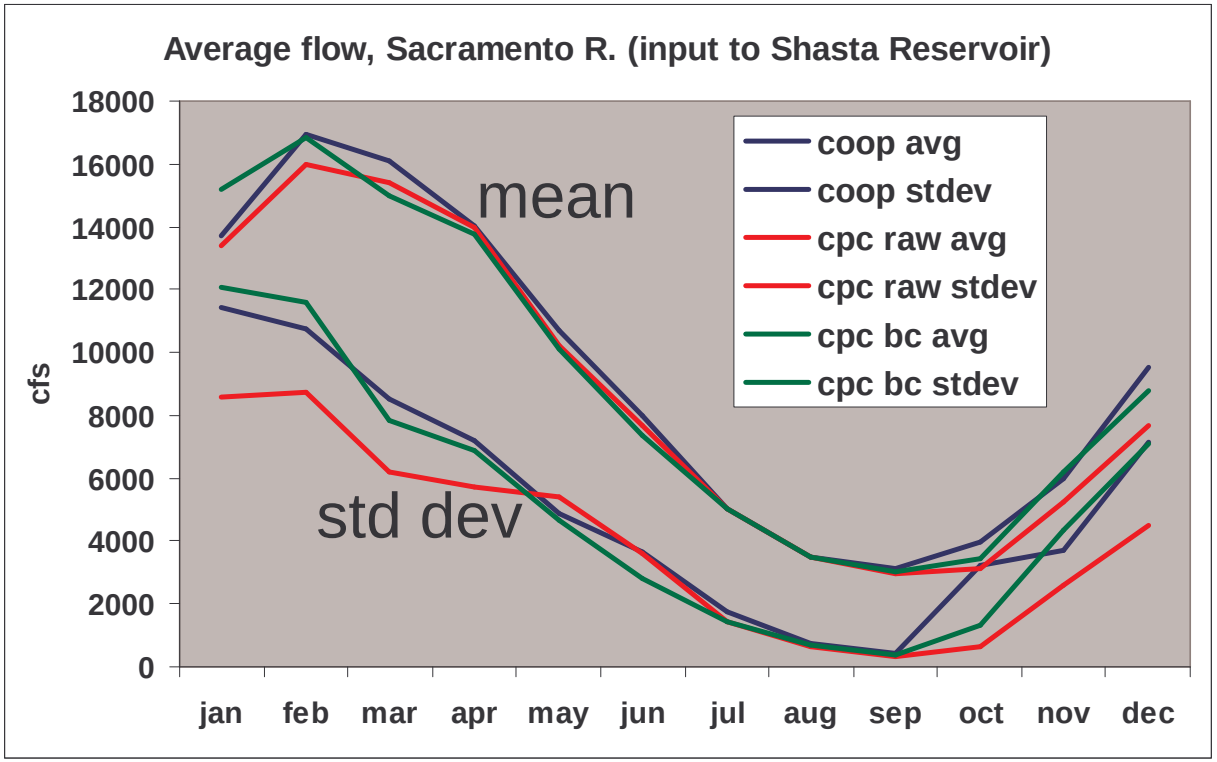


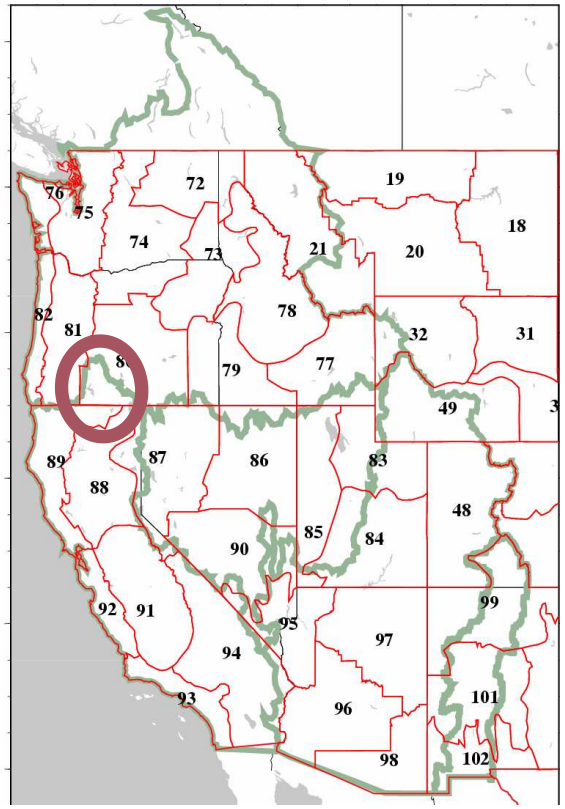


Results: CPC-based flow w.r.t. UW obs dataset

Additional examples show similar results

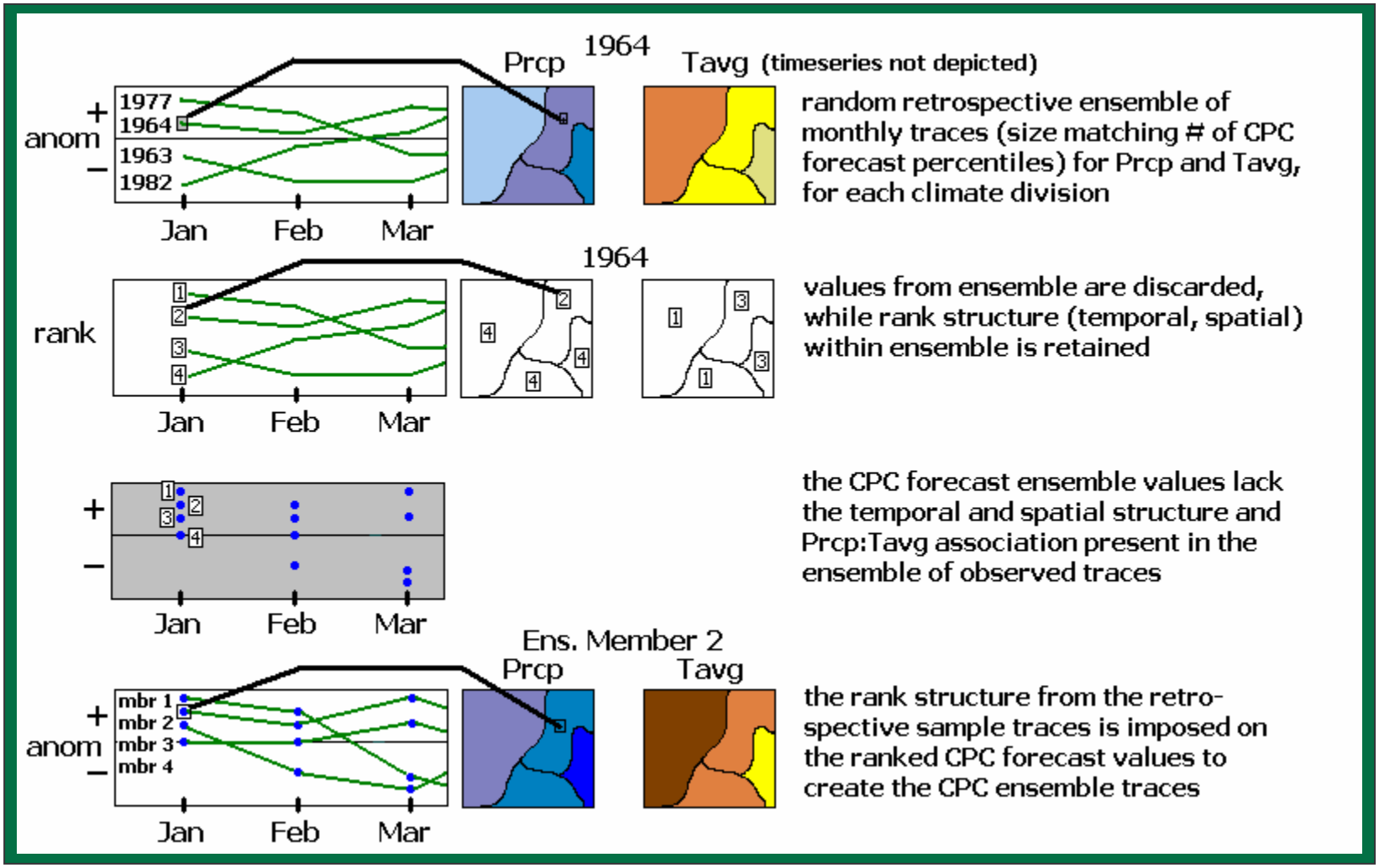
Mean pretty well reproduced; variability improved





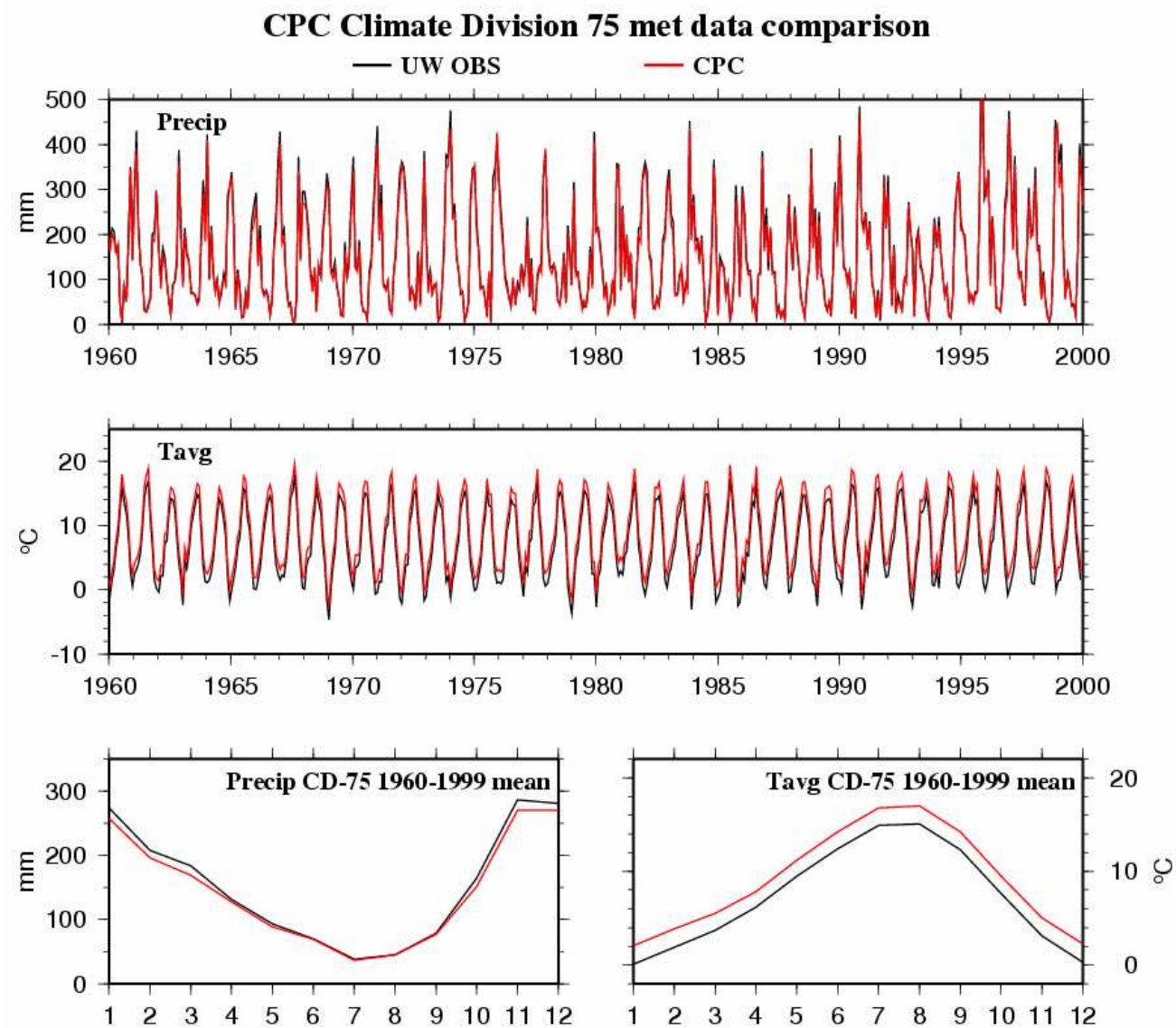
Framework: Downscaling CPC outlooks

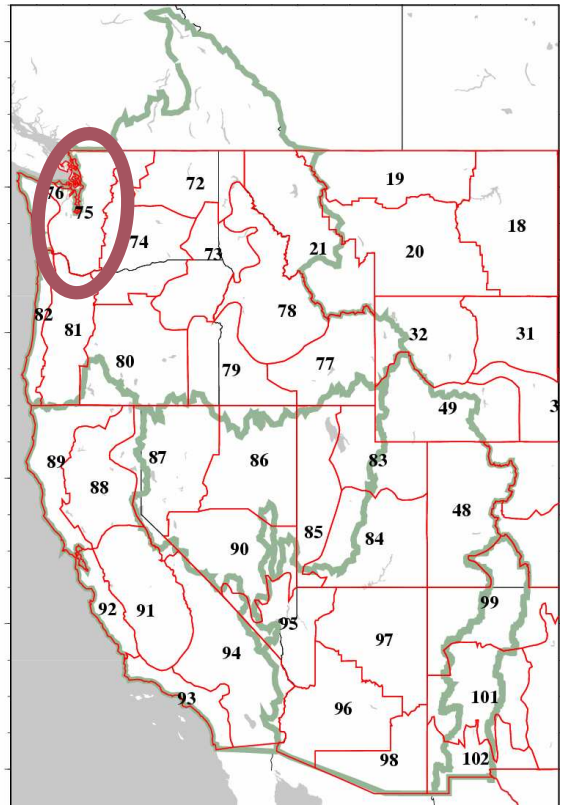
downscaling uses Shaake Shuffle (Clark et al., *J. of Hydrometeorology*, Feb. 2004) to assemble monthly forecast timeseries from CPC percentile values



Results: CPC temp/precip w.r.t. UW obs dataset

based on 1960-99





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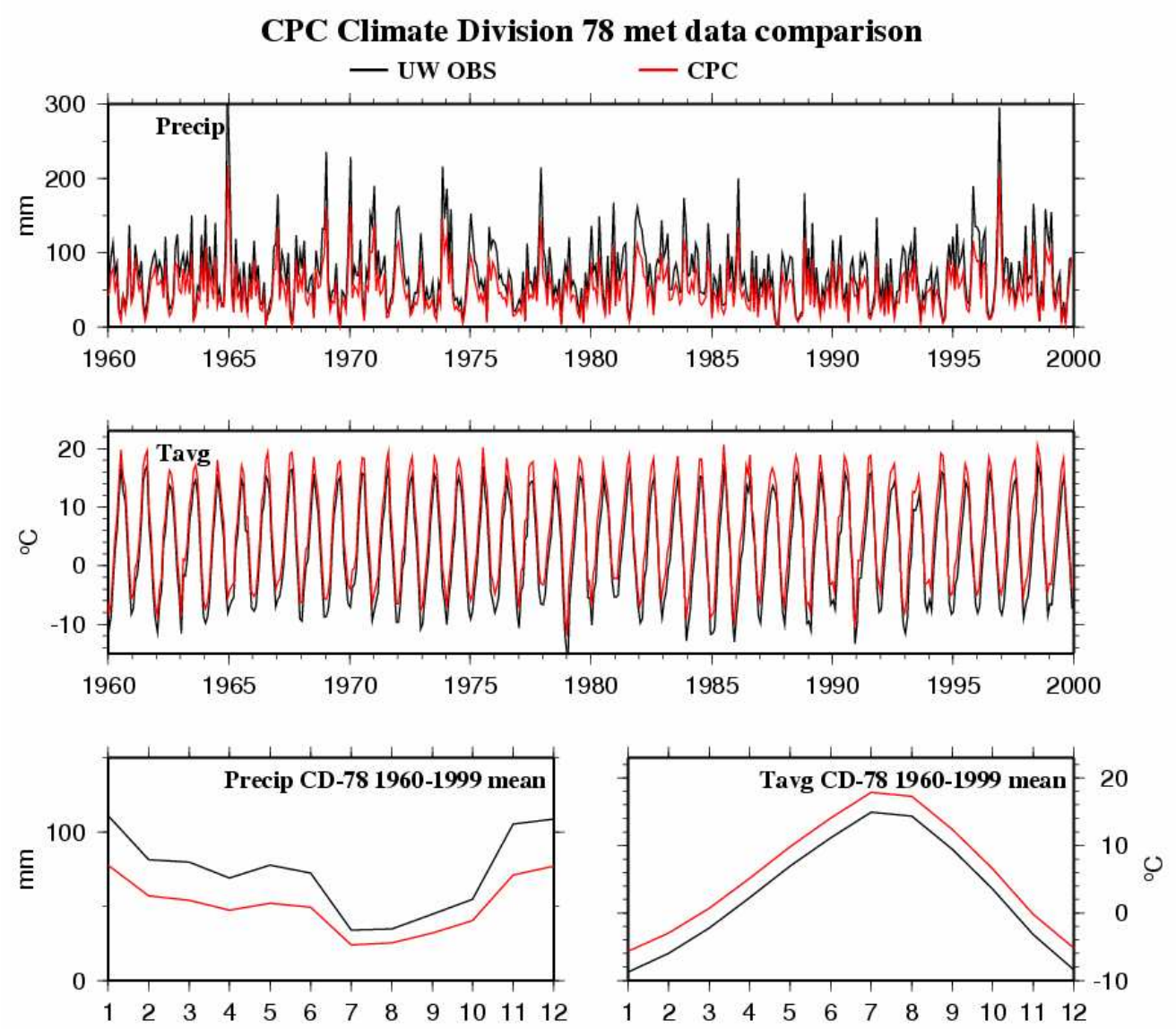

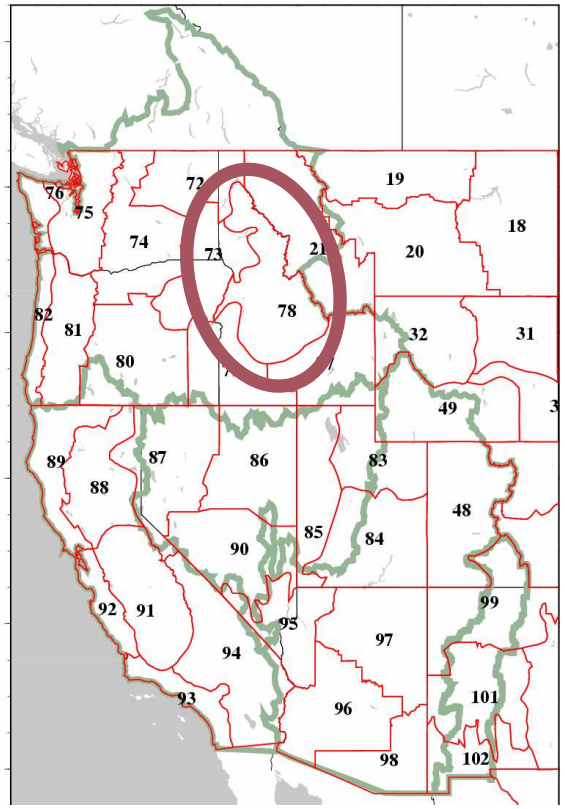

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