Exploring the Application of Ensemble Prediction Methods Across Regional Forecasting Domains

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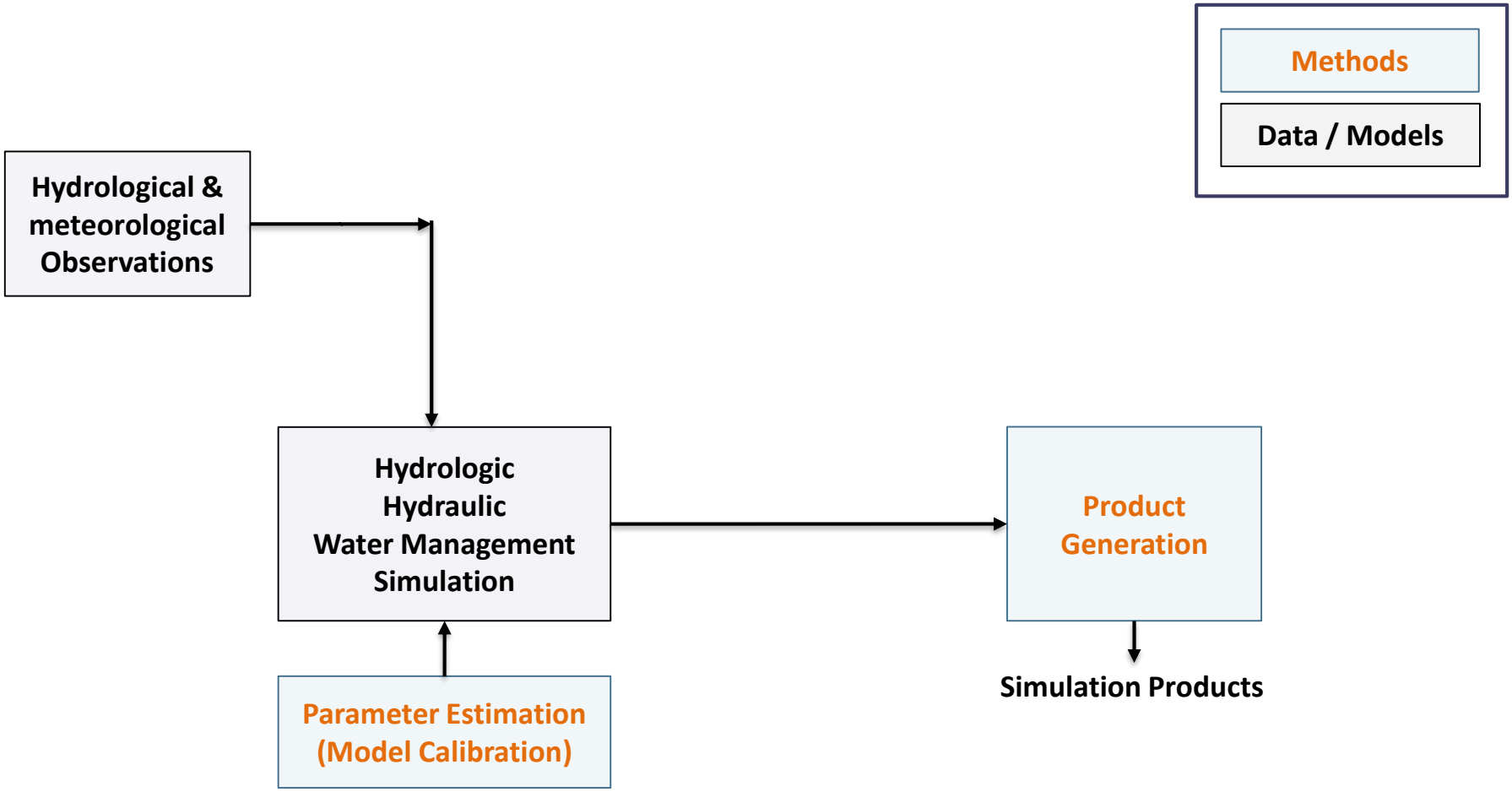
HEPEX

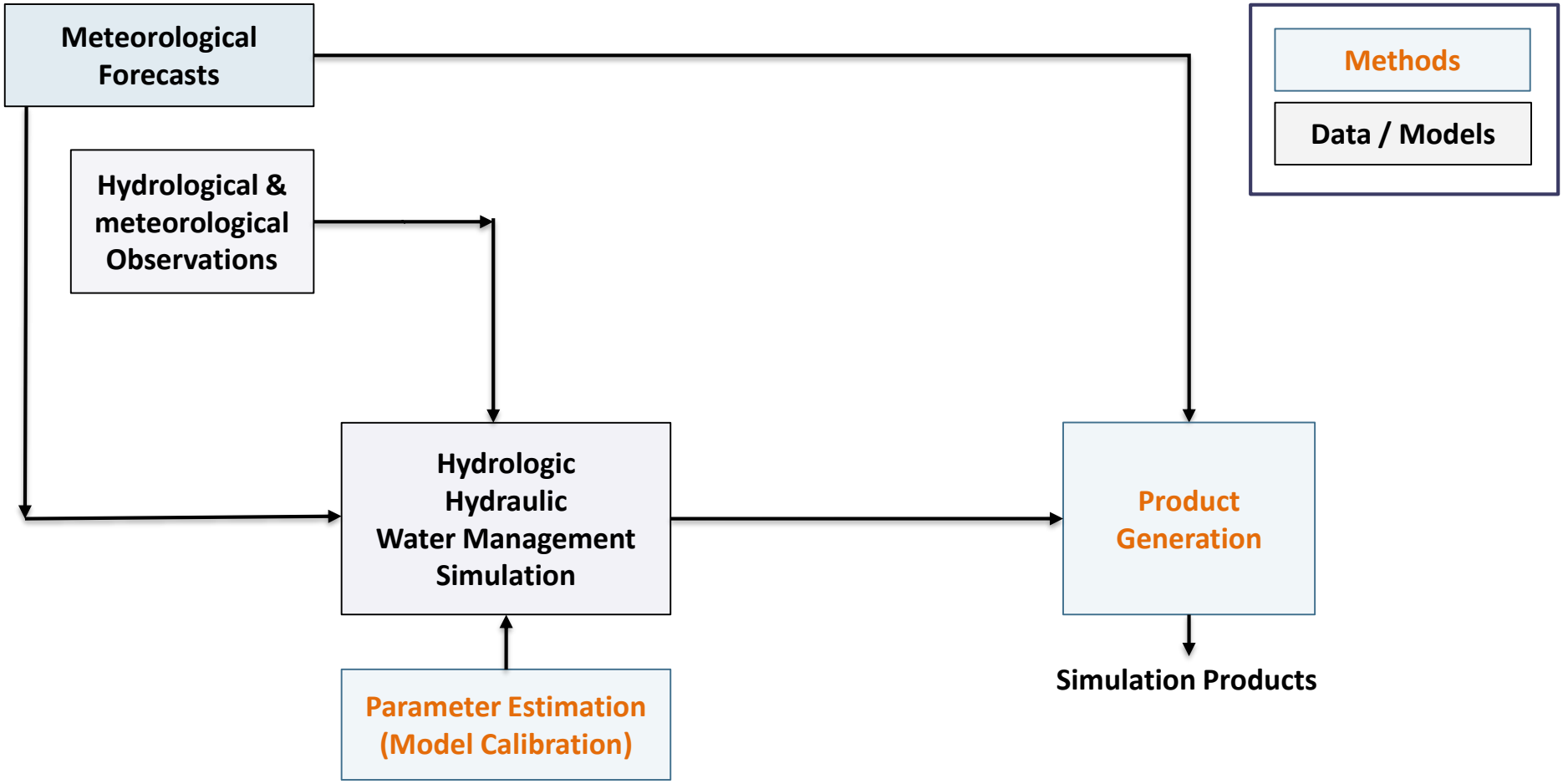
U. Melbourne, Australia – February 2018

We have broad community experience in modeling



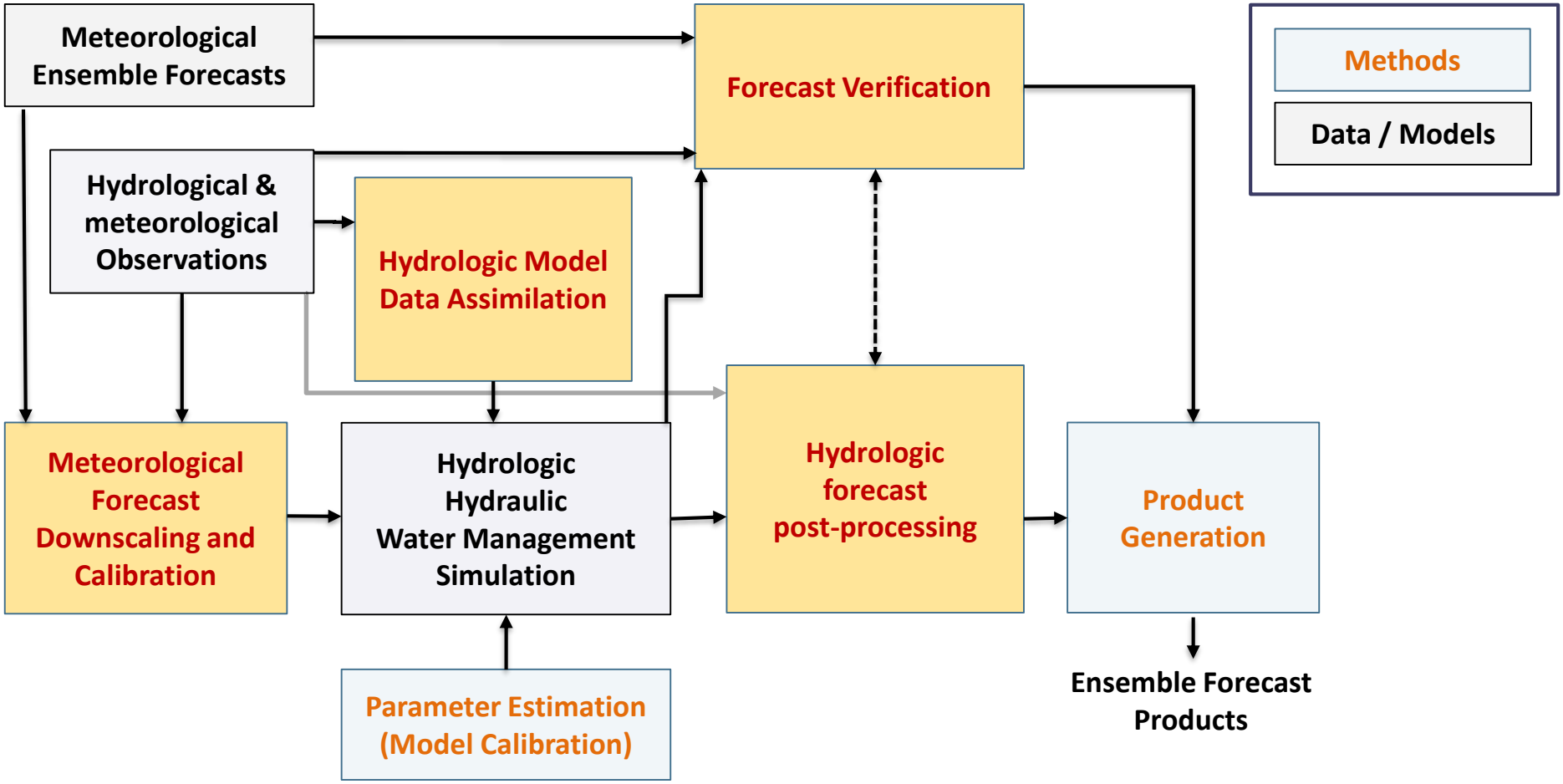
- Uncoupled systems – derive forcing meteorology from external sources to run hydrologic model

Generating forecasts seems a small leap



- Obtain similar forcings from NWP to run through same model, creating forecasts … easy!

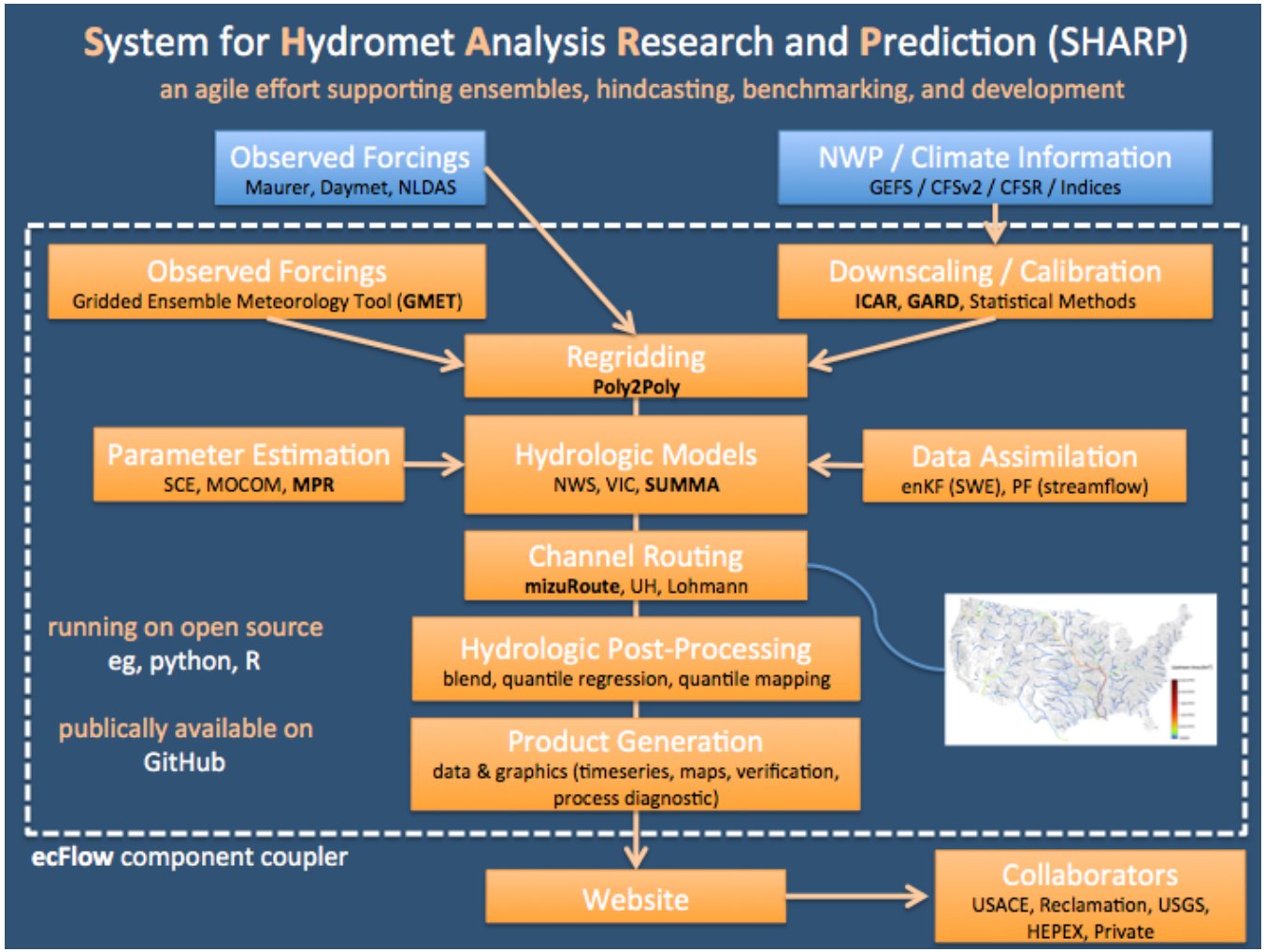
Generating *skillful* forecasts is more complex



- Interdisciplinary
  - geosciences, statistics, computing and software engr., social science
- Not taught as a coherent program in any discipline
- HEPEX focus

SHARP Testbed forecasting system

We have developed an operational system to assess methods for real-time short and seasonal range forecasts



workflow web monitor

SHARP System Status Report

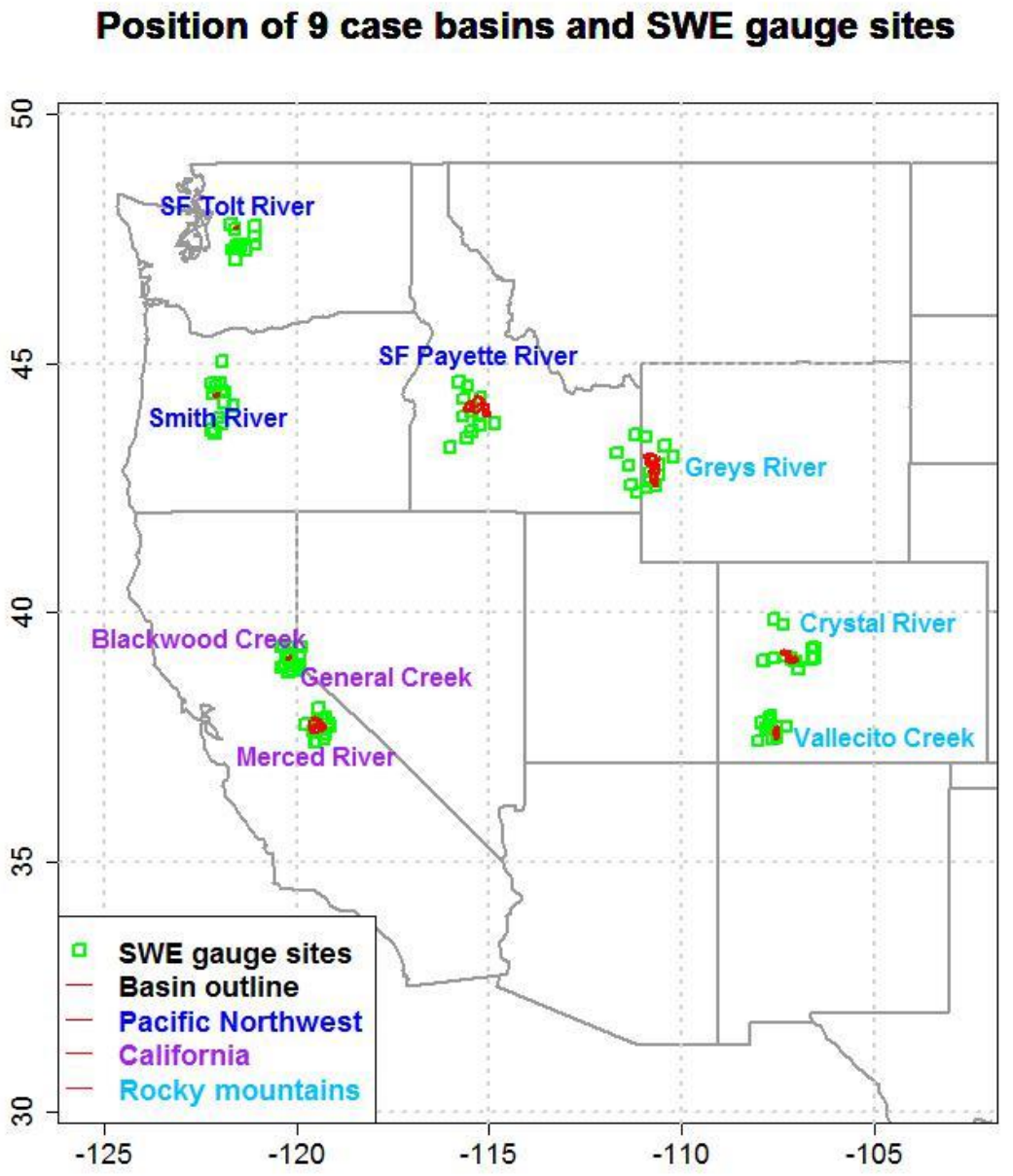
Updated: Tue Dec 13 15:13:57 UTC 2016

Job	Submitted	Completed	Failed
get_ghcnd	14:00:00	14:16:35	
get_nwcc	14:00:01	14:05:17	
get_gefs	pending	pending	
get_cfsr	14:00:01	14:02:13	
get_flow	14:00:01	14:01:03	
reformat_ghcnd	14:16:36	14:33:58	
reformat_nwcc	14:33:59	14:34:12	
QC_stn_data	14:34:12	14:38:30	
fill_stn_data_pass1	14:38:31	15:13:56	
fill_stn_data_pass2	15:13:56	pending	
fill_stn_data_pass3	pending	pending	
fill_stn_data_pass4	pending	pending	
gen_ens	pending	pending	
grid2poly	pending	pending	
make_nws_forc	pending	pending	
run_nws_spinup	pending	pending	
downscale_gefs_fcst	pending	pending	
downscale_gefs_fcst_regr	pending	pending	
reformat_gard_output	pending	pending	
reformat_gard_output_regr	pending	pending	
met_forecast_grid2poly	pending	pending	
make_nws_met_forecast	pending	pending	
run_nws_gefs_fcst	pending	pending	
plot_stn_data_map	pending	pending	
plot_mr_fcst	pending	pending	

ecFlow -- https://software.ecmwf.int/wiki/display/ECFLOW/

Hydrologic DA for seasonal prediction

- SWE measurements (snotel) can be used objectively to update hydrologic model states and improve forecasts
- Using Ensemble Kalman Filter (EnKF)
- Hindcast-based study
- Huang et al, 2016 (HESS)



Hydrol. Earth Syst. Sci., 21, 635–650, 2017
www.hydrol-earth-syst-sci.net/21/635/2017/
doi:10.5194/hess-21-635-2017

Hydrology and Earth System Sciences
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Evaluation of snow data assimilation using the ensemble Kalman filter for seasonal streamflow prediction in the western United States

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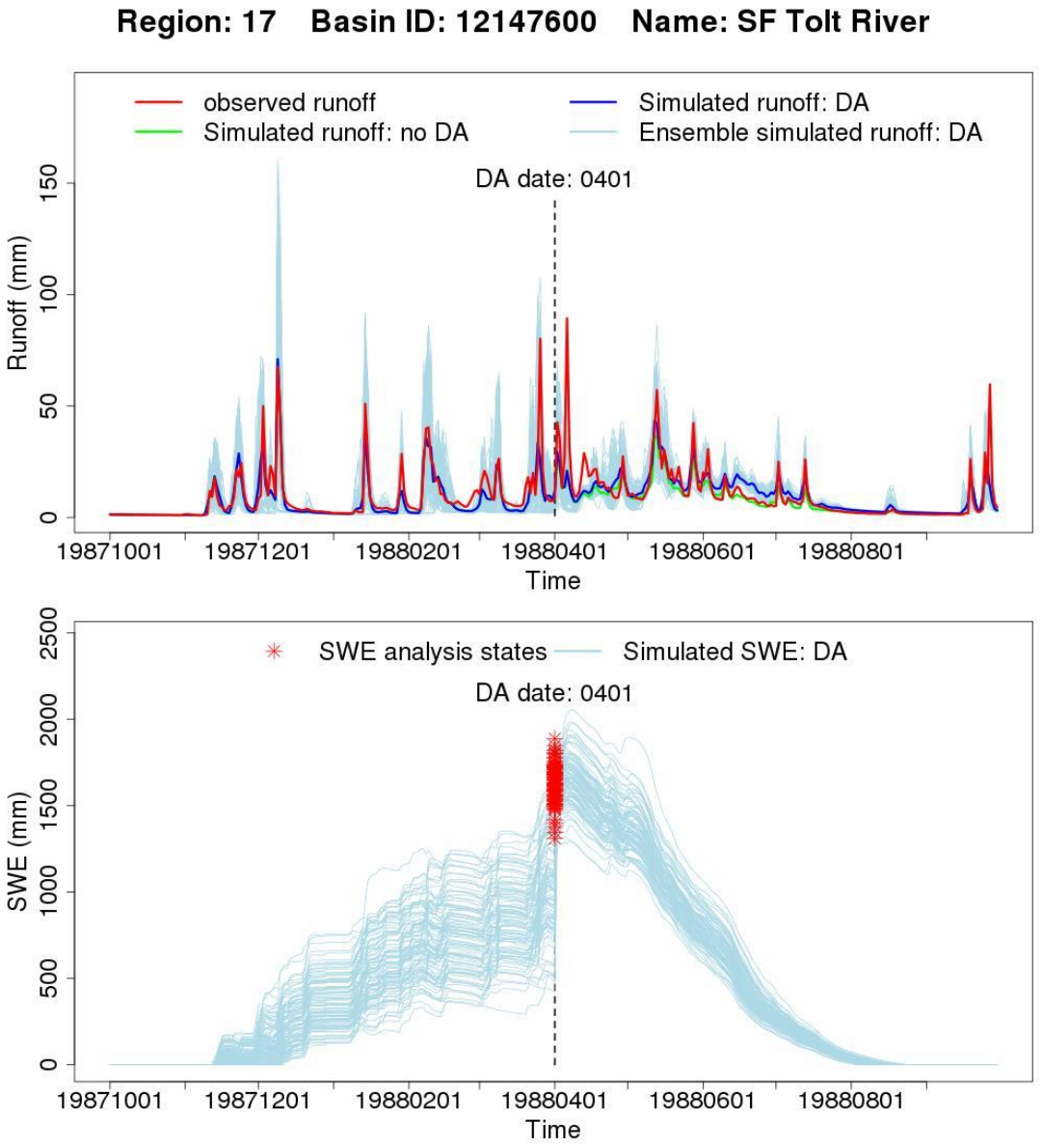
Hydrologic DA for seasonal prediction

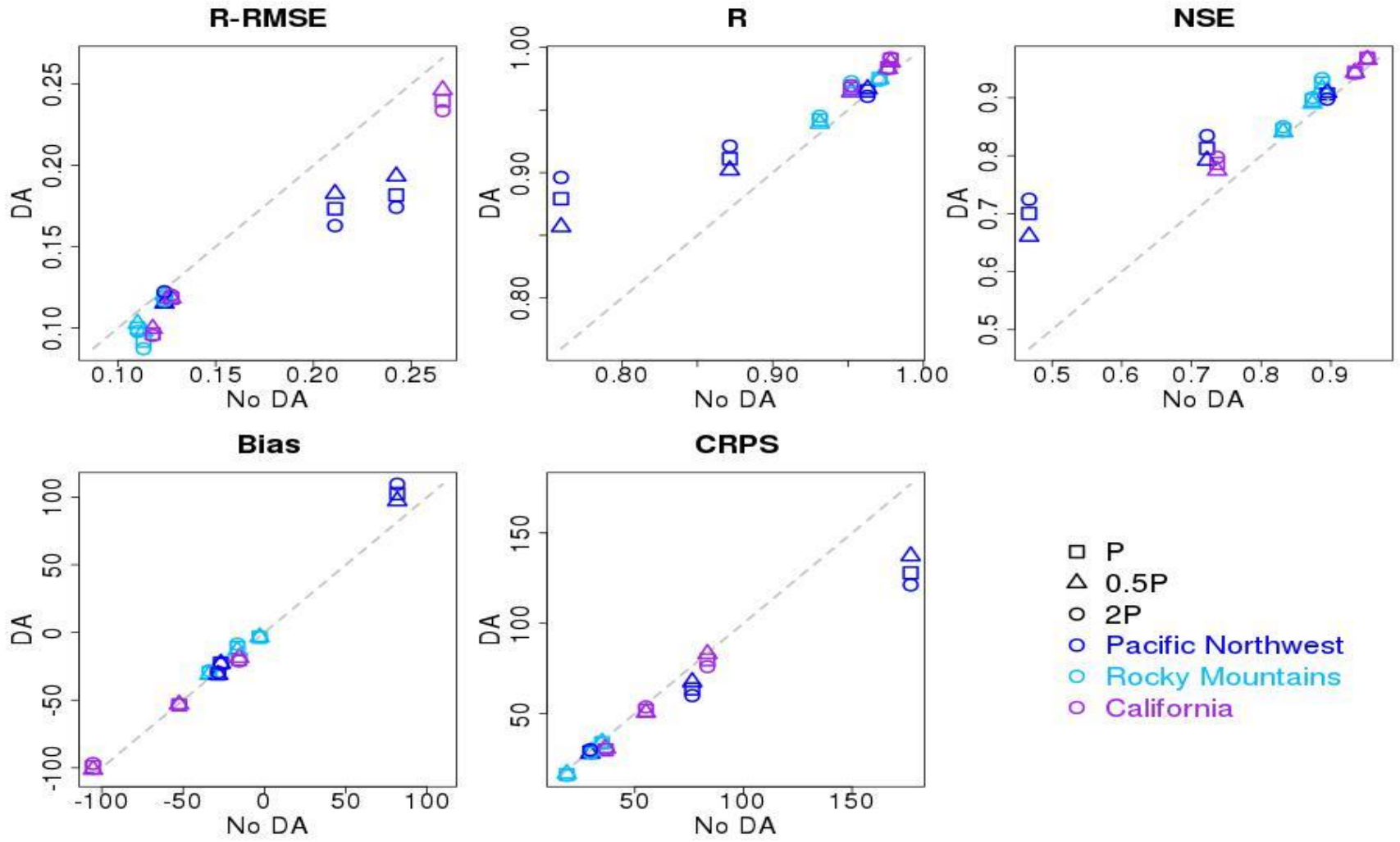
Example

- Use an ensemble method to estimate initial conditions
- Update those conditions with SWE observations
- Make ensemble predictions from mean model states
- Assess forecast skill after assimilation

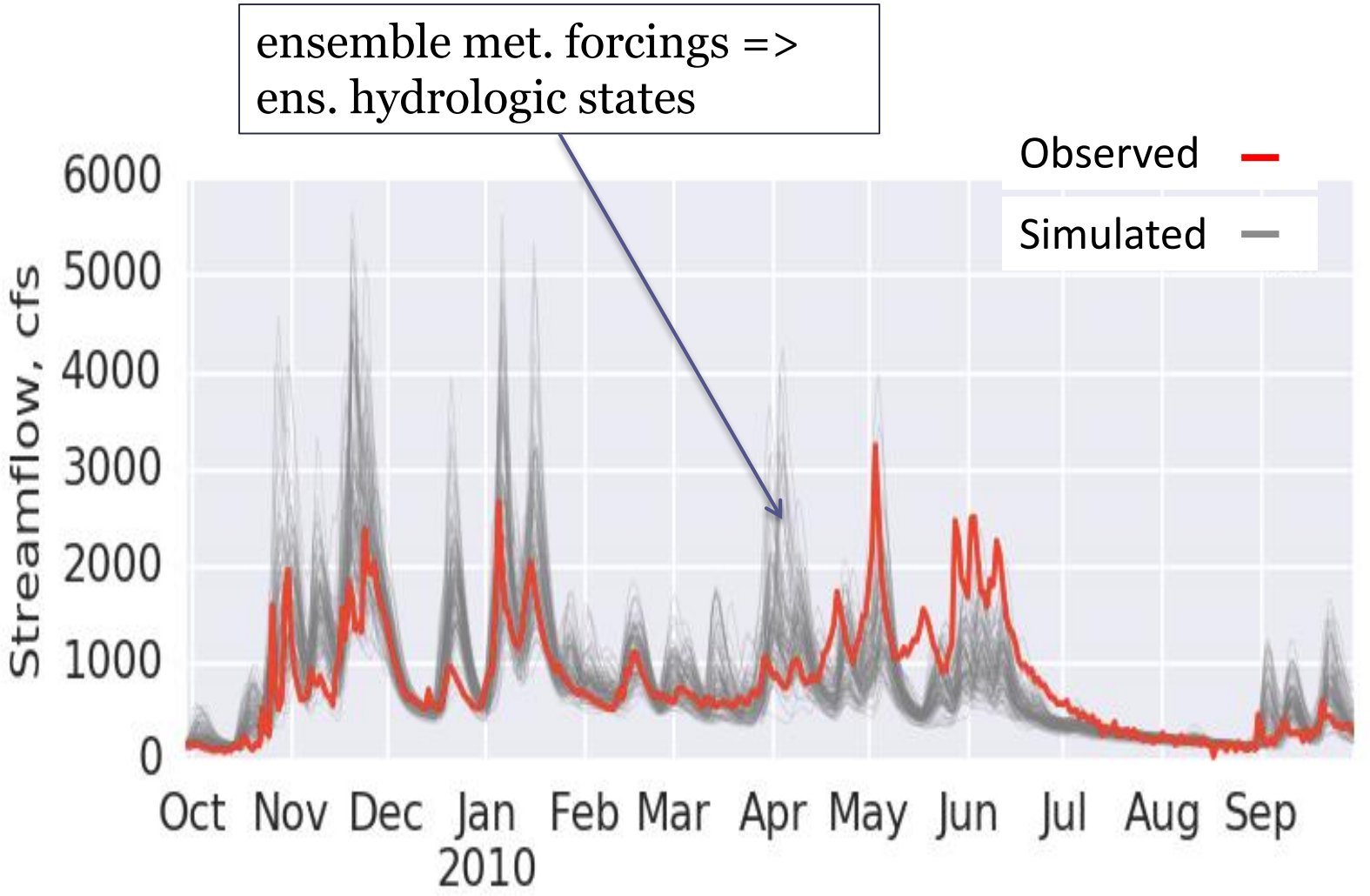


Hydrologic DA for seasonal prediction

- Evaluation metrics generally show improvements for April-July ESP mean streamflow forecast for the nine case basins.



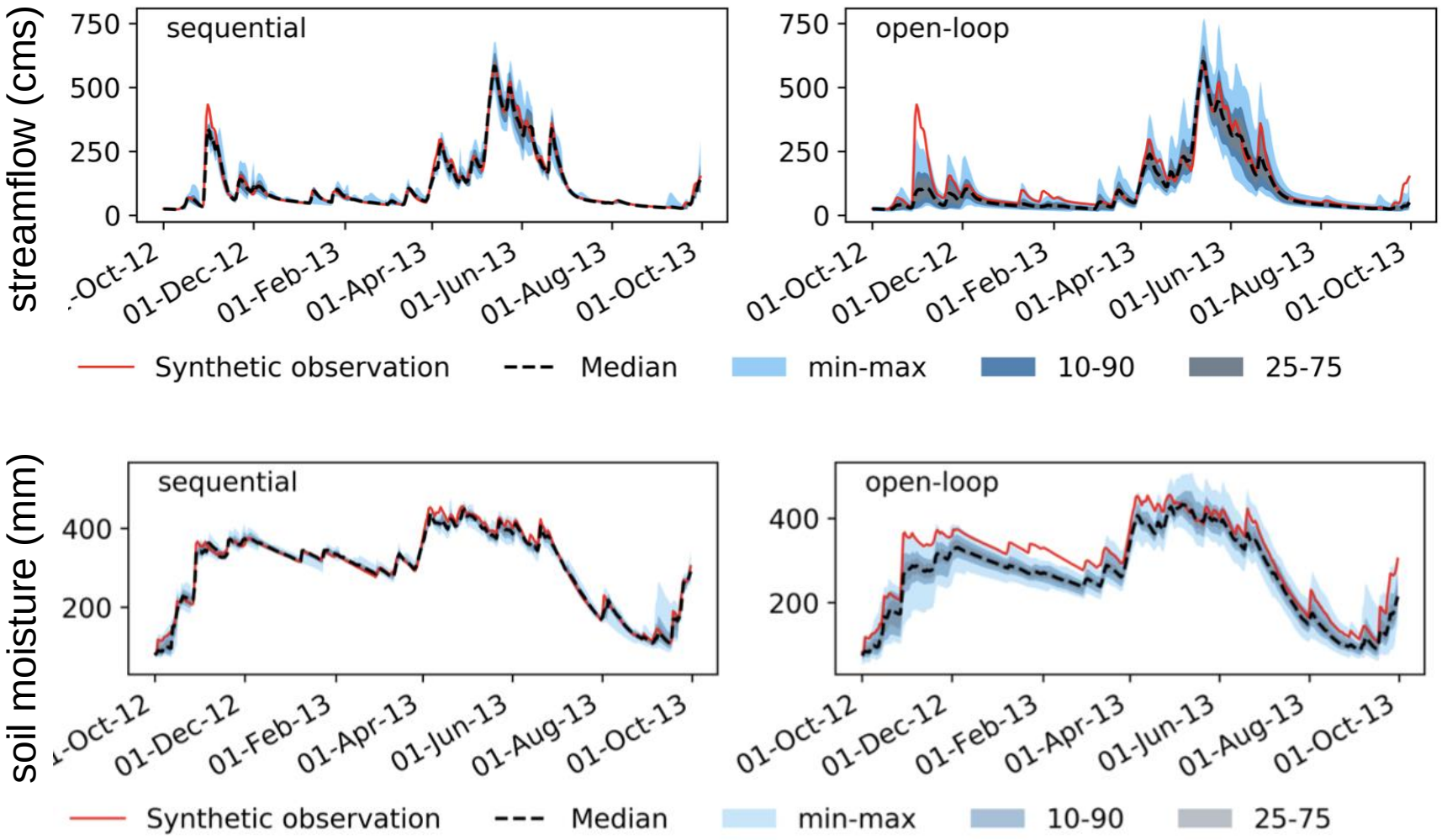
Hydrologic DA for short-range prediction



- Generate hydrologic states representing uncertainties to support data assimilation (and initialize forecasts)

Hydrologic DA for short-range prediction

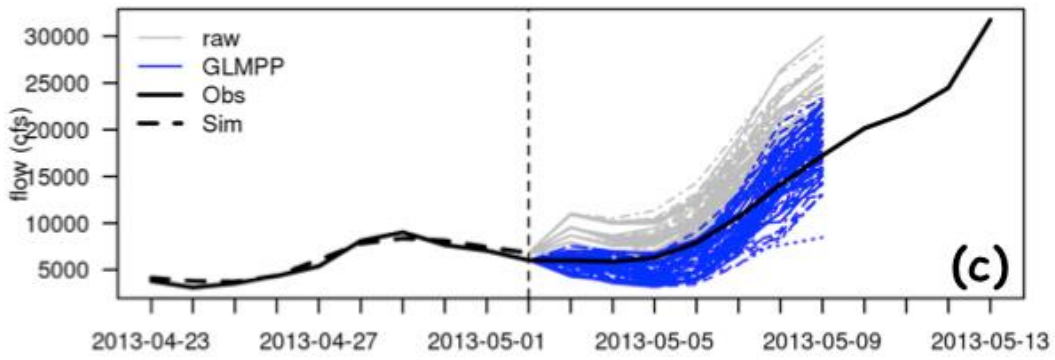
Particle Filter DA (Sequential Importance Resampling) improves both flow and SM



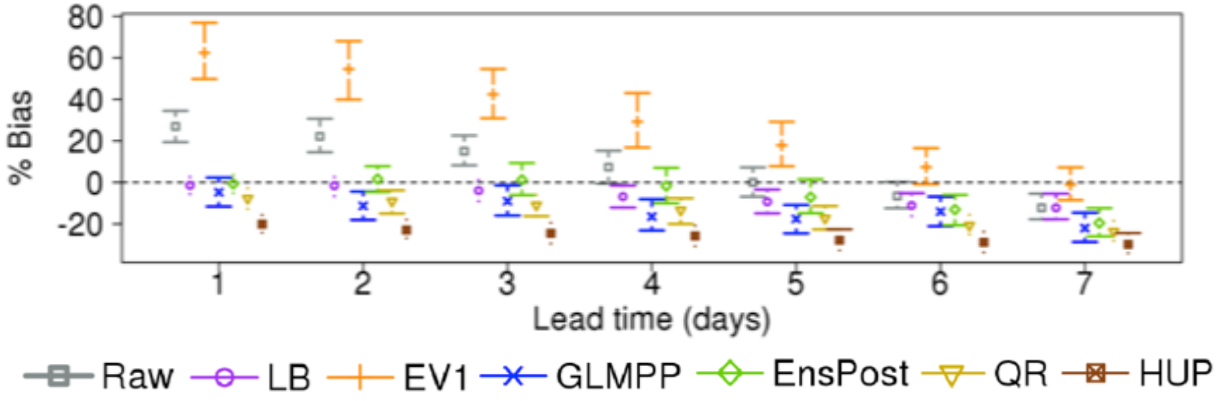
Post-processing is also critical

- reduces residual uncertainty after other parts of the process

Method	Name
LB	Linear blending
EV1	Error in variable Model Output Statistics with one variable
GLMPP	Generalized Linear Model Post-Processor
EnsPost	Ensemble Post-Processor
QR	Quantile Regression
HUP	Hydrologic Uncertainty Processor



hindcast based skill evaluation



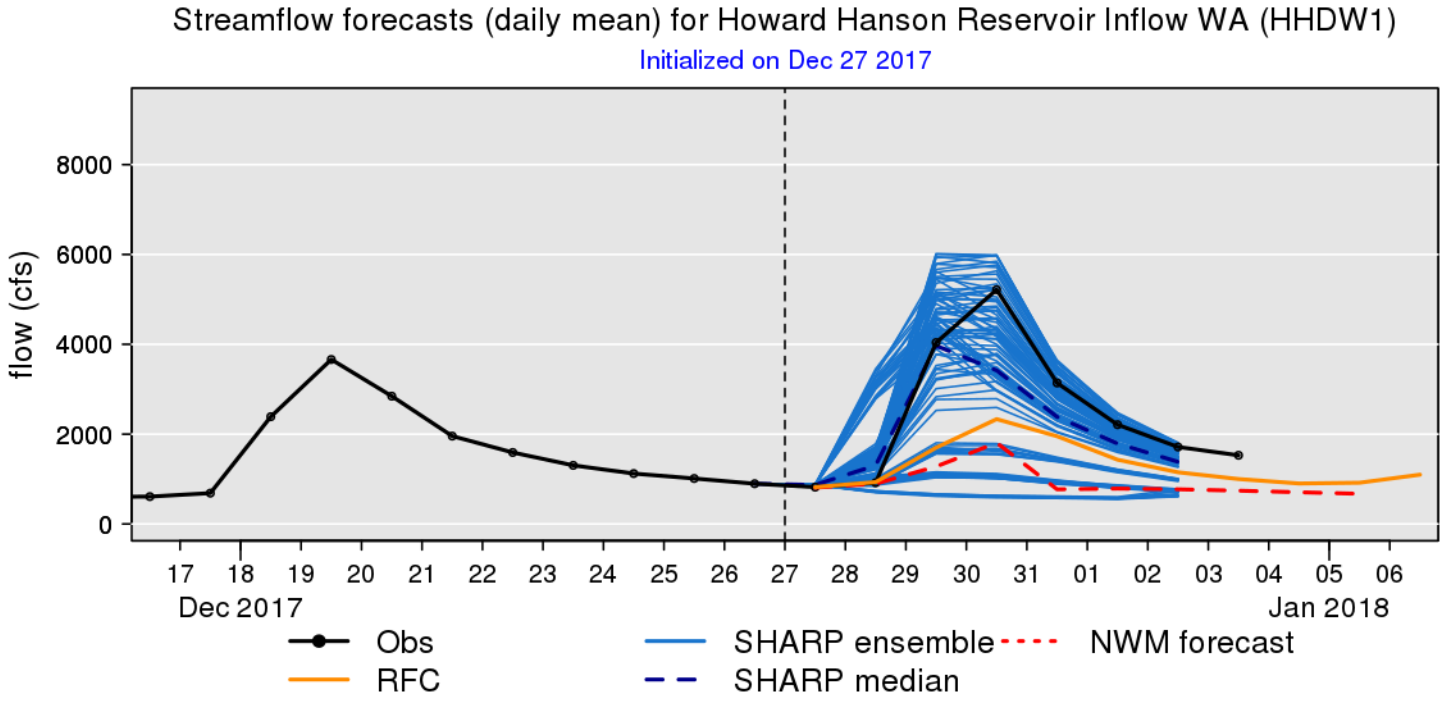
contribution by Pablo Mendoza

Require consistent hindcasts to implement

Research supported by the major US federal water agencies: USACE and Reclamation. Co-Leads – B. Nijssen

Hydrologic DA for short-range prediction

- Operational demonstration shows hydrologic DA is workable in the pilot watersheds
- Hydrologic DA can replace some of the manual adjustment (MODs) now made by human forecasters



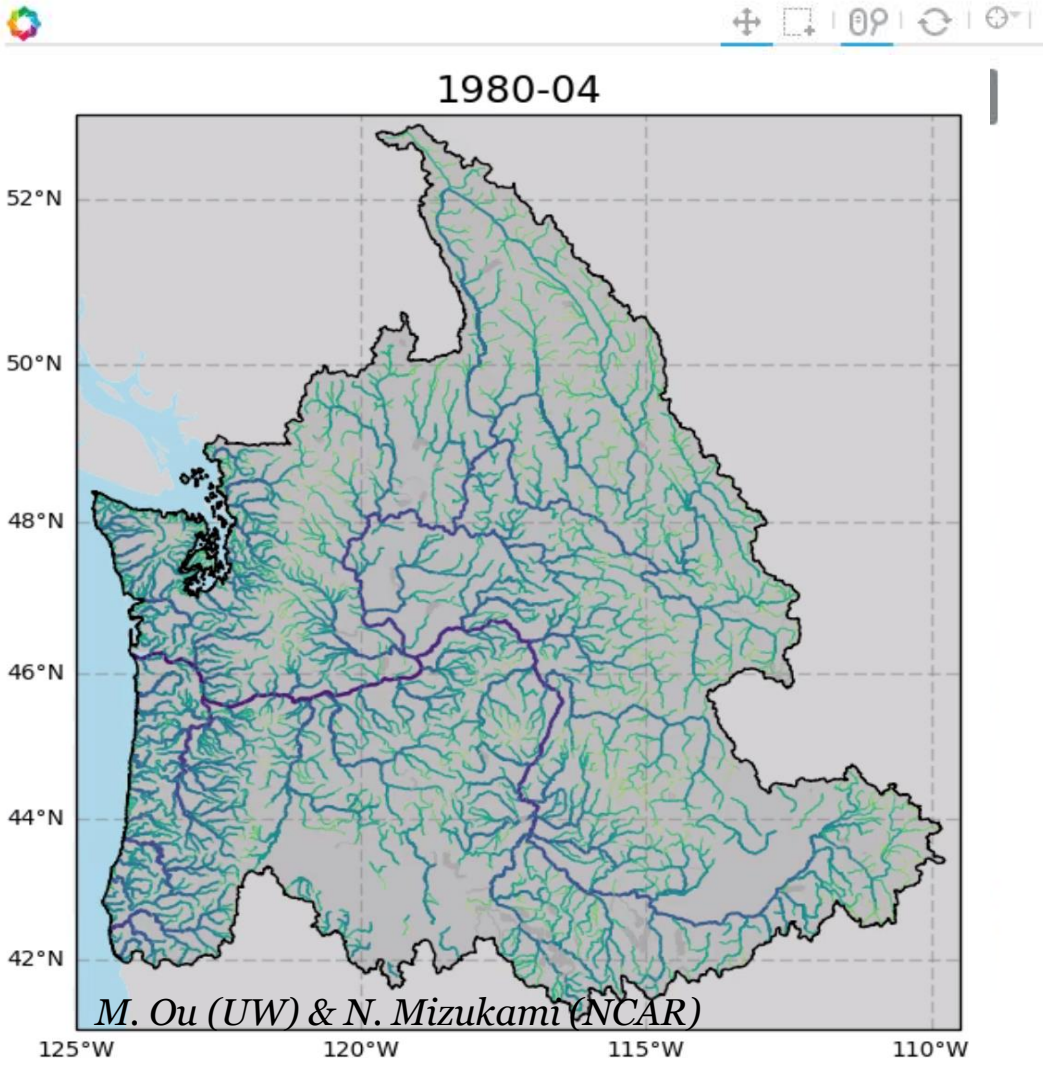
- Clark, E.A., A.W. Wood, and B. Nijssen, 2017: Assessing ensemble particle filters for the estimation of model states for streamflow forecasting, Water Resources Research (in review).
- Clark, E. A., A. W. Wood, B. Nijssen, and M. P. Clark. Implications of streamflow data assimilation via particle filter on streamflow forecasts in basins with seasonal snow. *Hydrology and Earth System Sciences*, in preparation.

Next – Prediction over large domains

- There is a need to re-connect hydrologic prediction science & uncertainty methods to large-domain prediction efforts

Scaling Challenges

- regional model calibration
- spatial coherence in downscaling and post-processing
- Spatial propagation of obs info in data assimilation
- understanding appropriate complexity of modeling
  - scale
  - physics
  - tradeoffs



Different routes to surmount these challenges

In-the-Loop

- Traditional In-the-Loop forecast paradigm

Over-the-Loop

- Medium-resolution / Ensemble / Uncoupled
- High-resolution / Deterministic / Uncoupled
- Intermediate-resolution / Ensemble / *Coupled*

Require agility: process modularity

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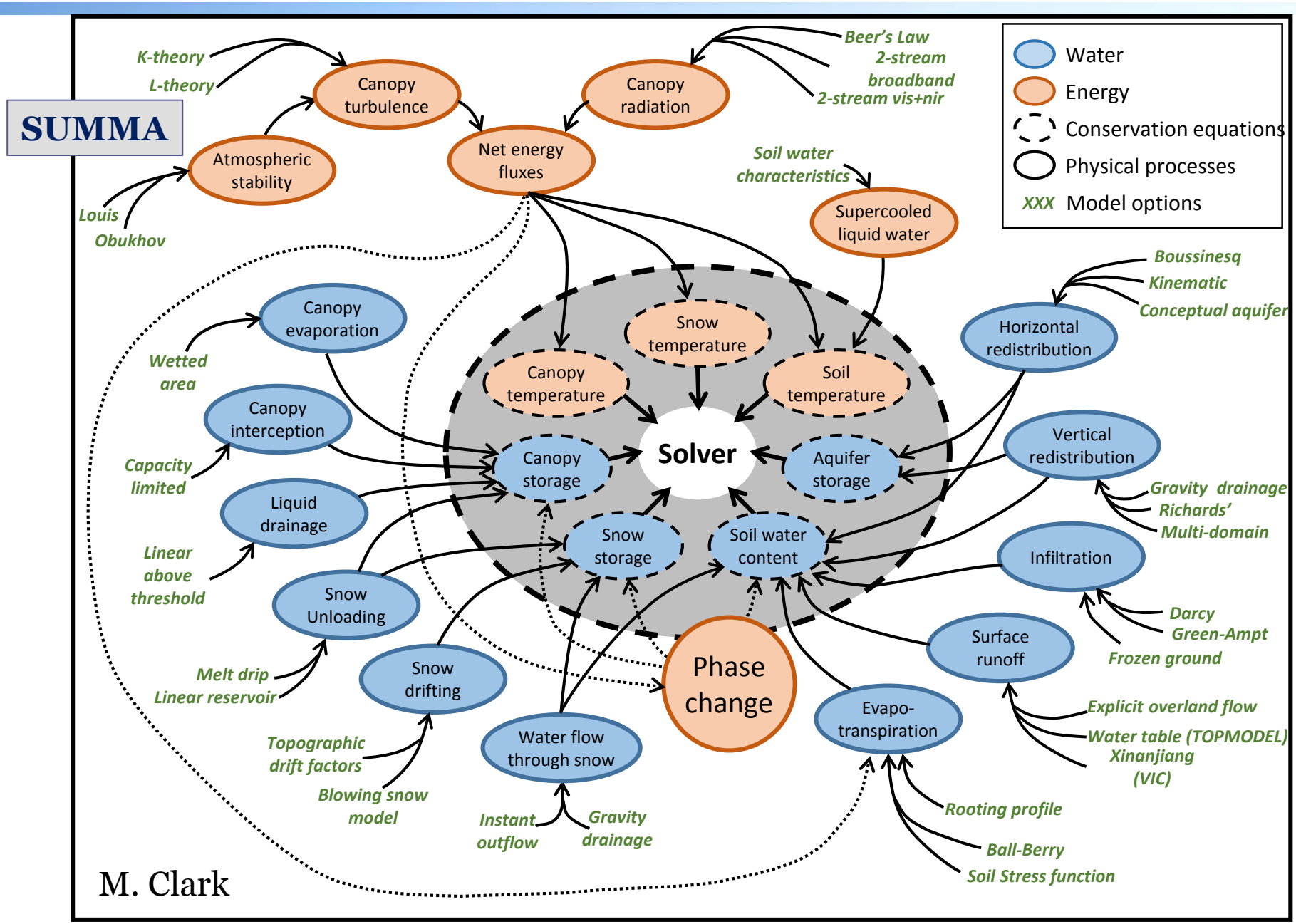
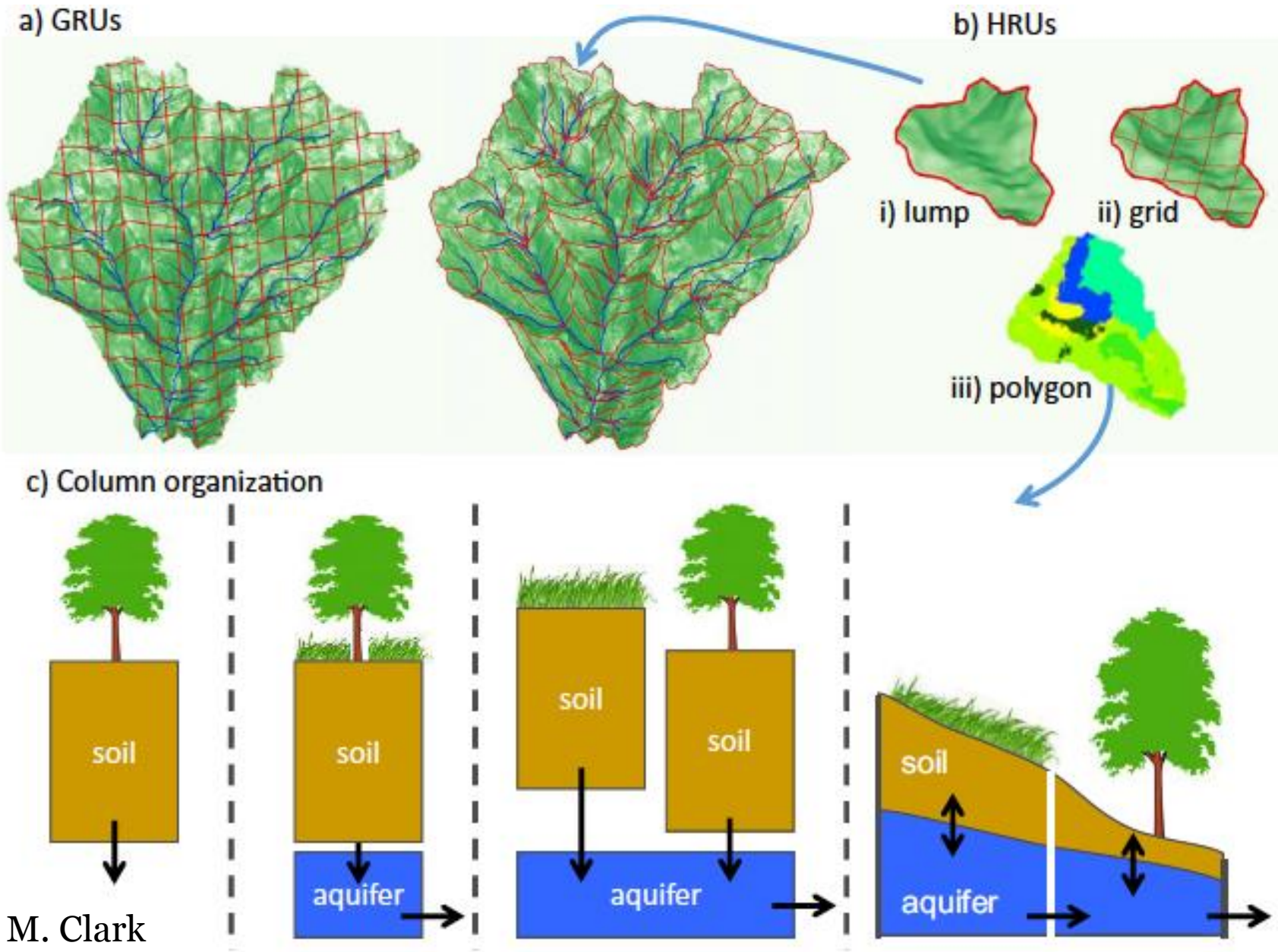


Require agility: spatial/coupling flexibility

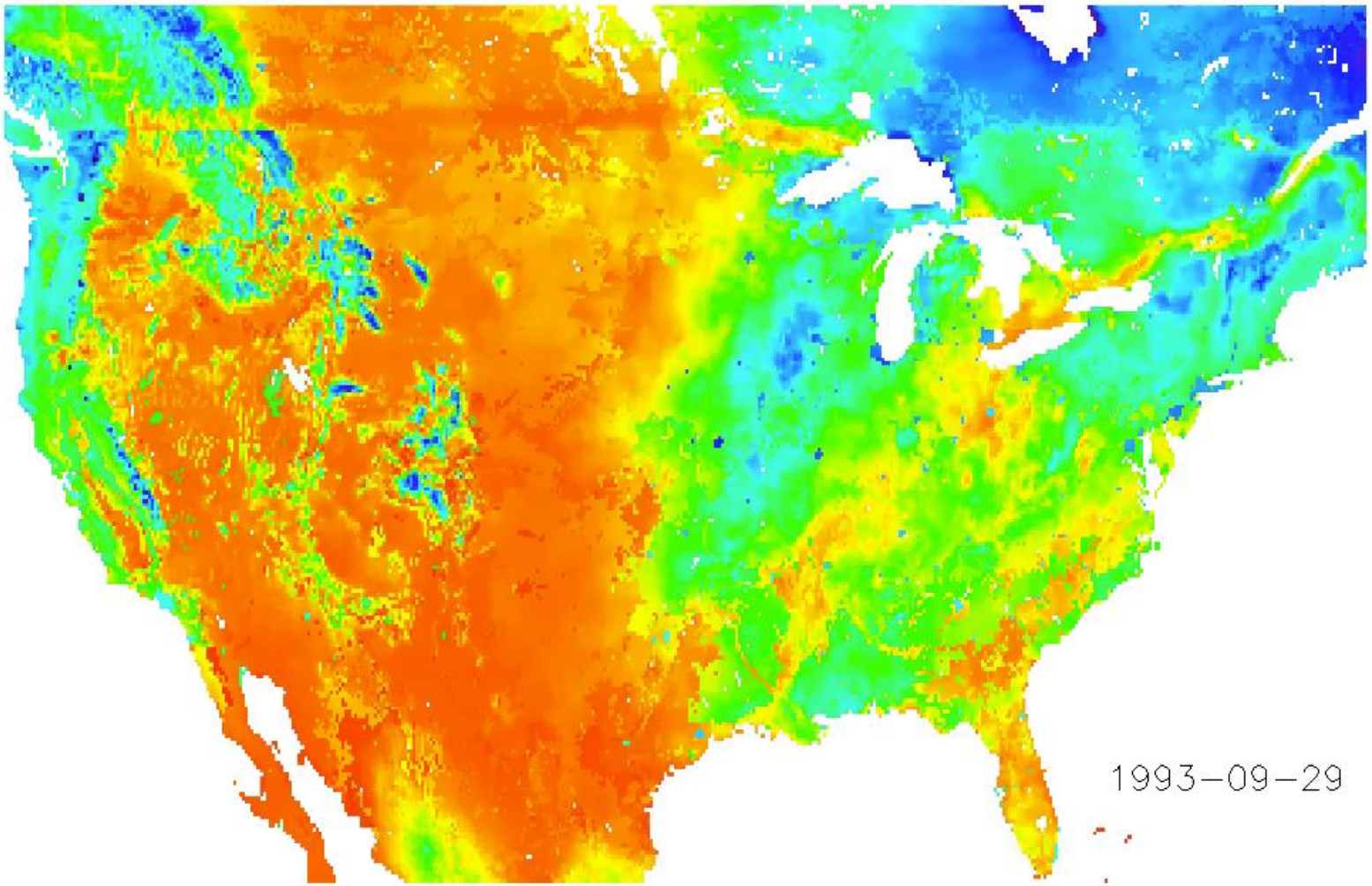


M. Clark

SUMMA at 1/8th degree over US NLDAS domain

NCAR UCAR

Soil water (mm) – 25 yr hourly simulation, 30 min on 8000 cores



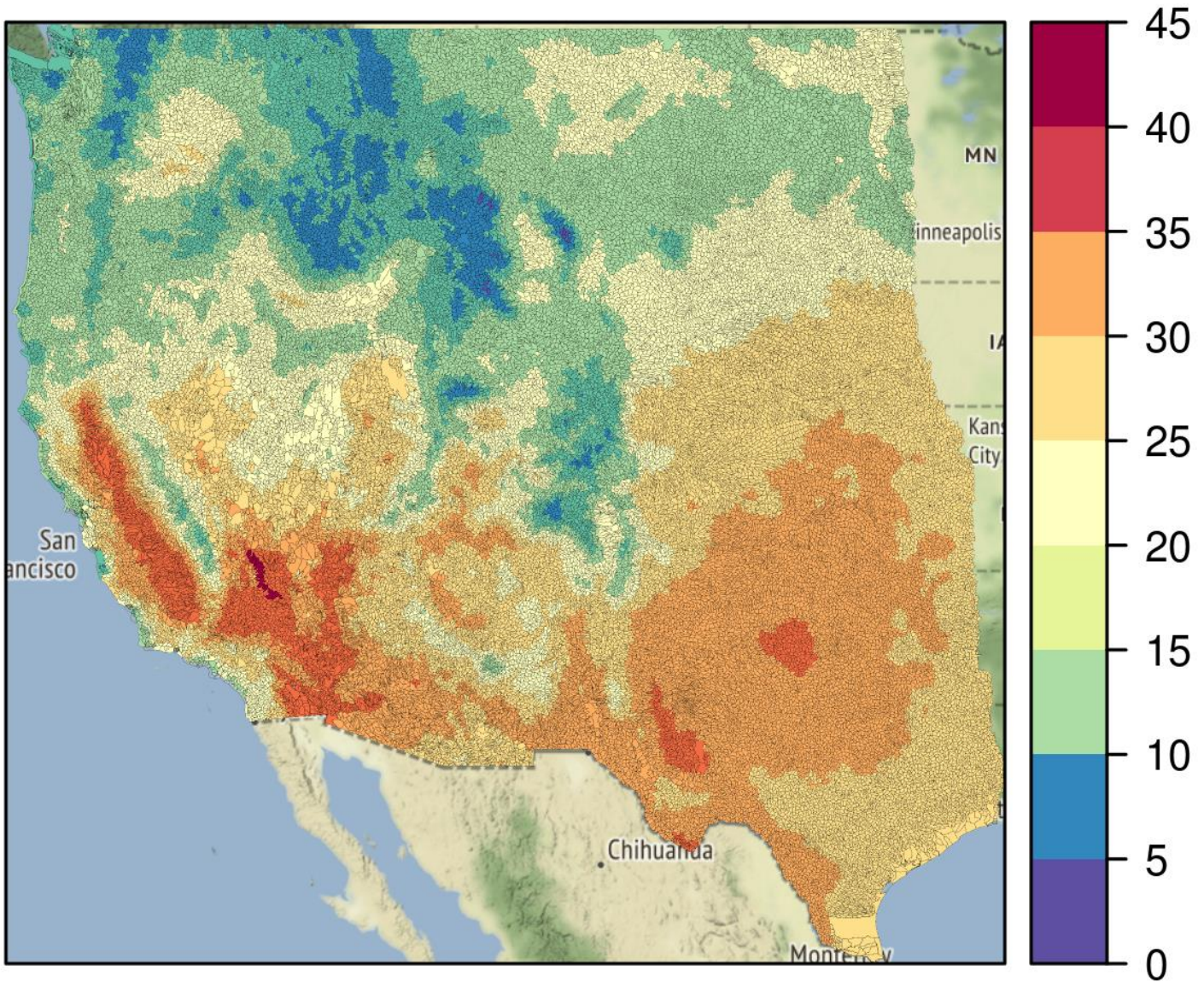
Run by Martyn Clark, NCAR

Focus on intermediate scale-modeling

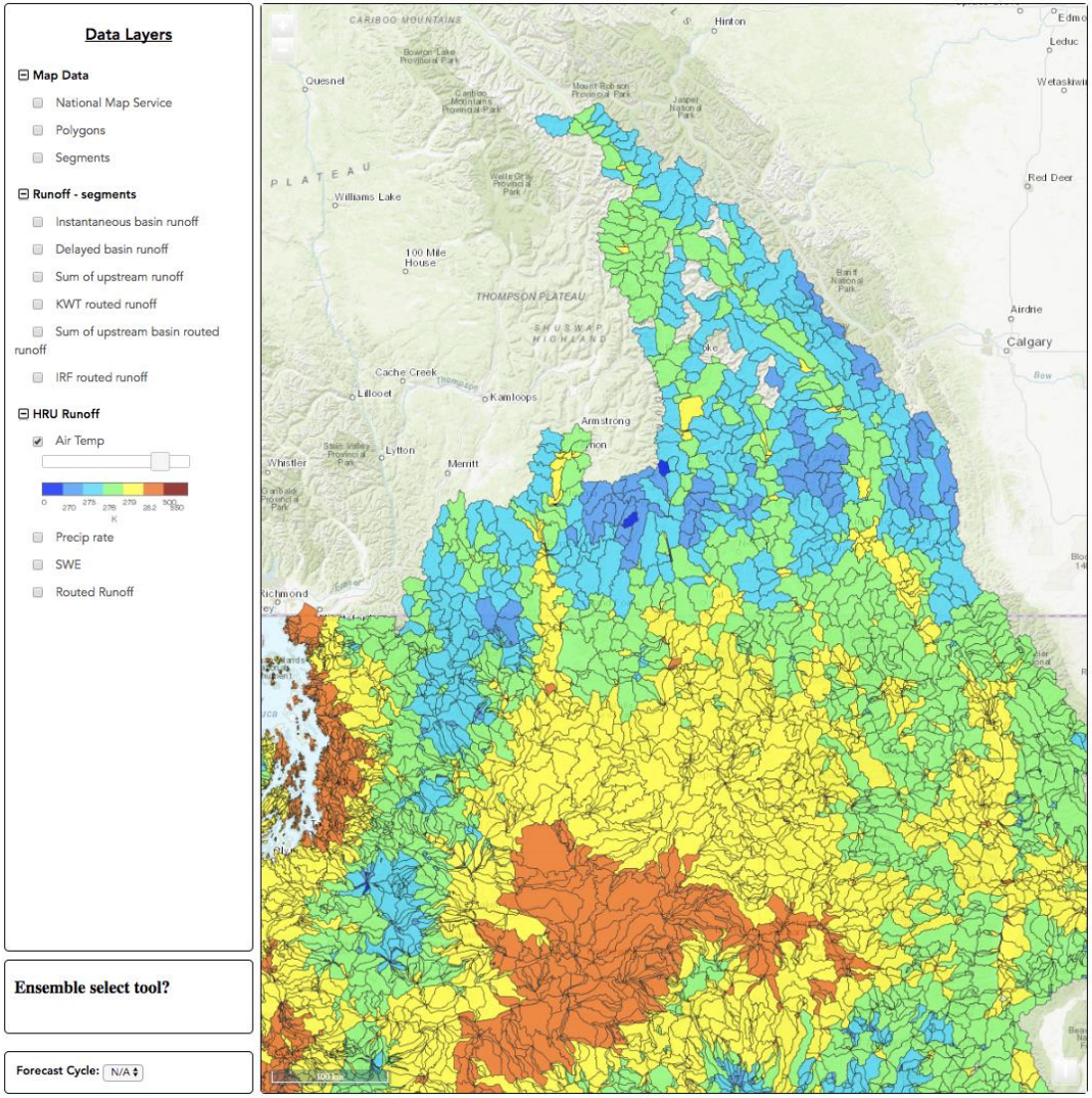
User-oriented domain

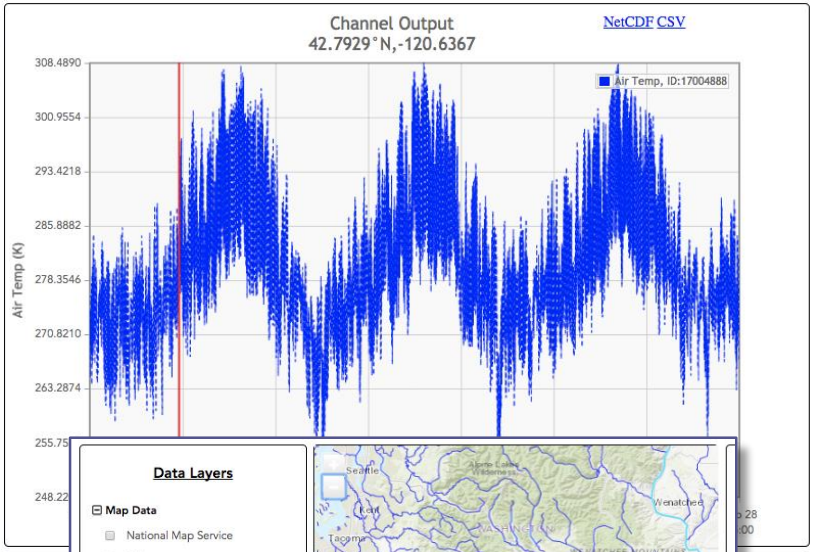
- Reclamation management area
- HUC12 scale simulations

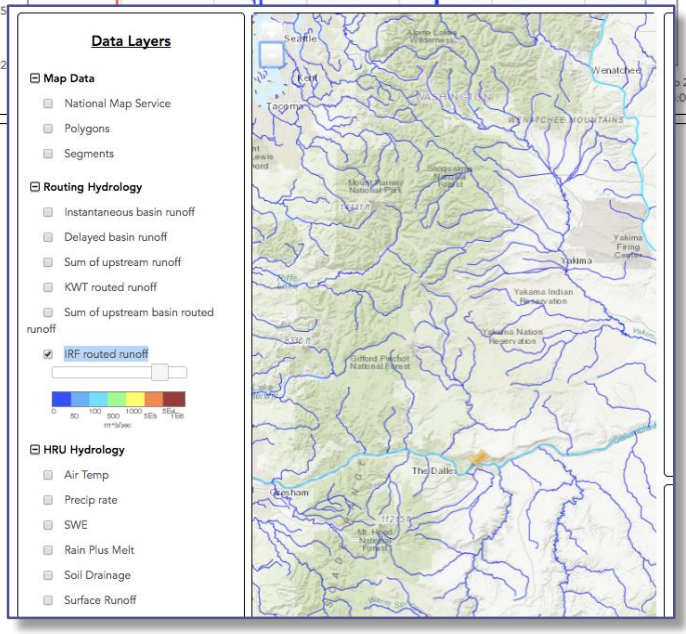
Air Temperature (deg C) – 20140715



Focus on intermediate scale-modeling







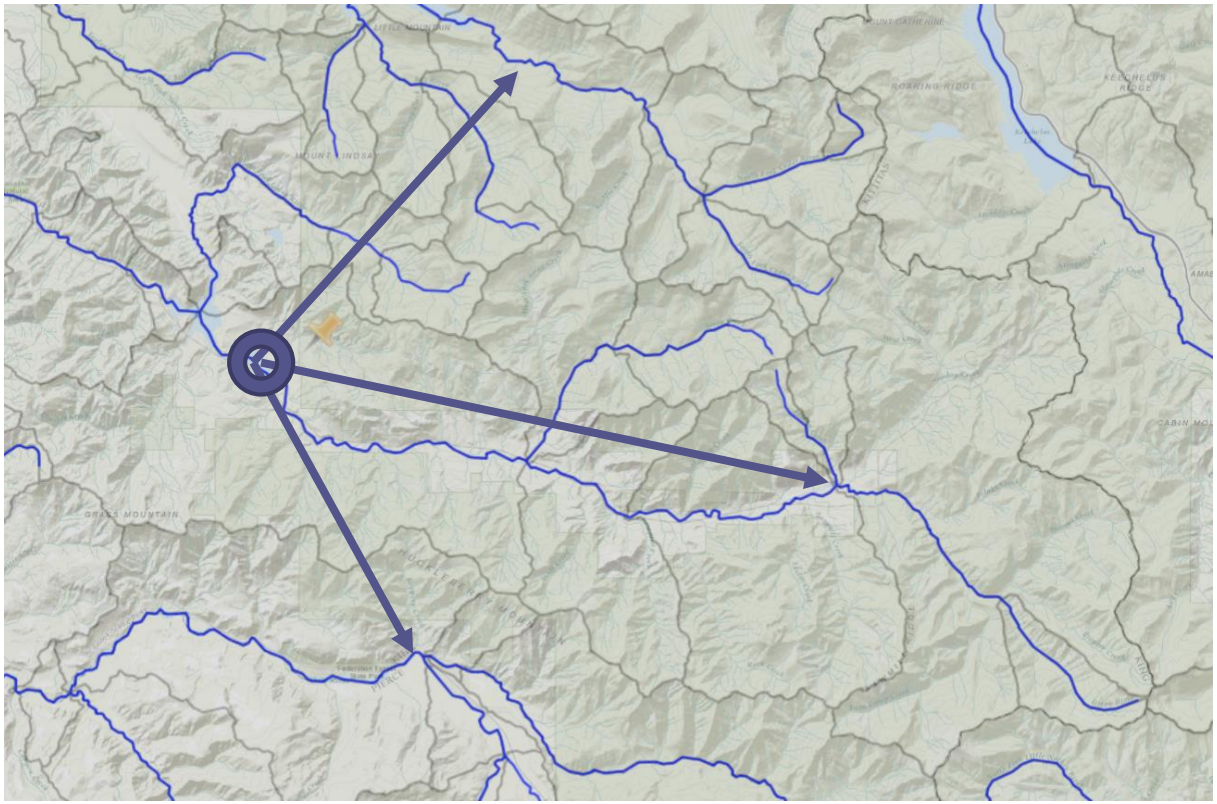
Current efforts and next steps

Challenges / Efforts

- Most past work on PF DA localization is not in hydrology, and not for streamflow (SWE DA localization is easier)
- We're beginning to investigate strategies for PF ensemble weighting across ungaged areas.

Next Steps

- Applying SUMMA in real-time, HUC12 scale (~100,000 watersheds)
- Ensemble inputs and outputs
- Model calibration and DA



Thank You

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