Water Resource Management

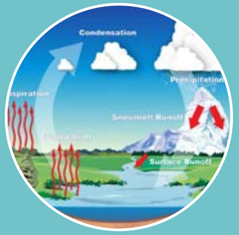
Presenter: Rob Cifelli

Subject Matter Experts: Clara Draper, Mimi Hughes, Ben Moore, Prashant Sardeshmukh, Michael Scheuerer

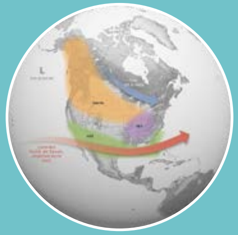
NOAA Physical Sciences Laboratory Review
November 16-20, 2020

Physical Science for Water Resources

Observe



Understand

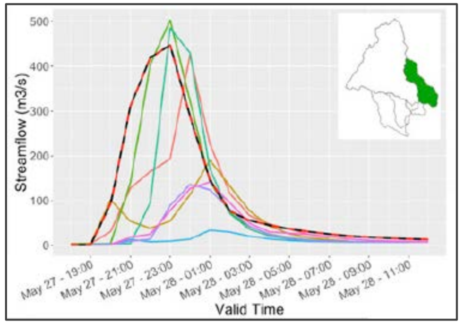


Predict/Project

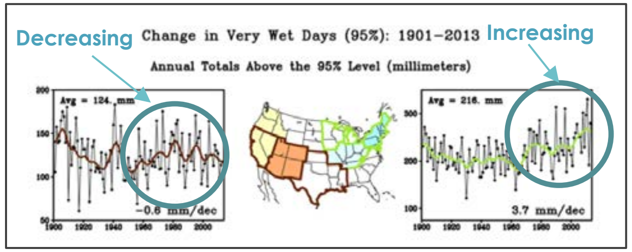
- Use observations to advance physical process understanding and guide model development for improved predictions
- Understand, predict, and assess severity of water related extreme events such as droughts and floods
- Analyze atmosphere, cryosphere, land surface, and air-sea interface processes
- Assess, attribute errors, and improve the National Water Model
- Provide scientific information necessary for cost-effective decision making

Why do we need this information?

- Co-management of drought and flood risk
- Uncertainty of water resource observations and future predictions
- The viability of the historical record for future water resource planning
    - *Is stationarity dead?*



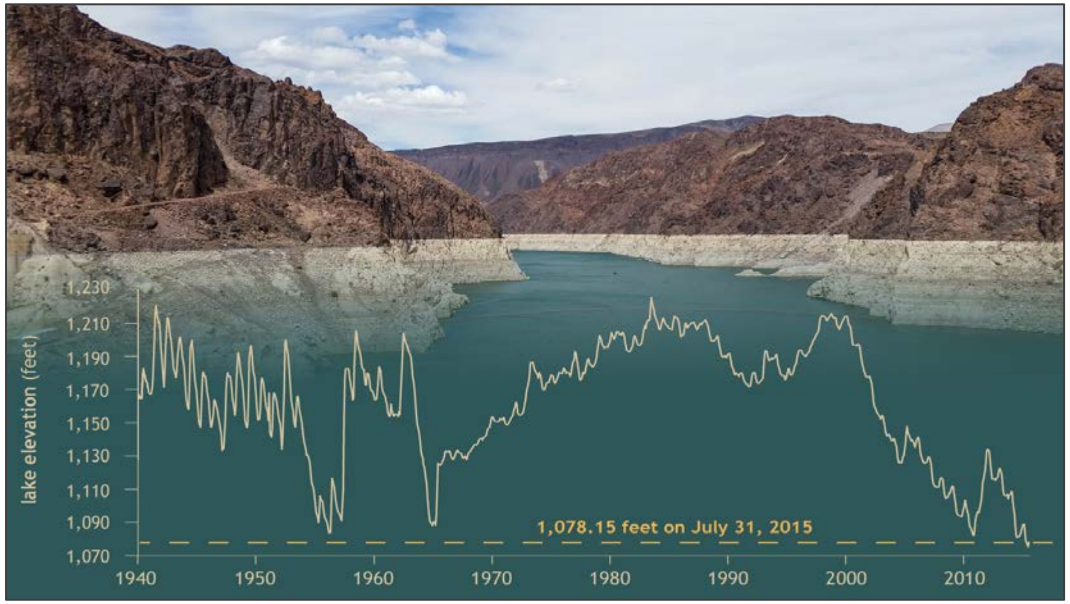
Viterbo et al 2020



Hoerling et al. 2016

Use inspired innovative research to address water resource challenges

- Extreme precipitation
  - *Too much and too little*
- Land surface conditions
- Long-term water resource resilience

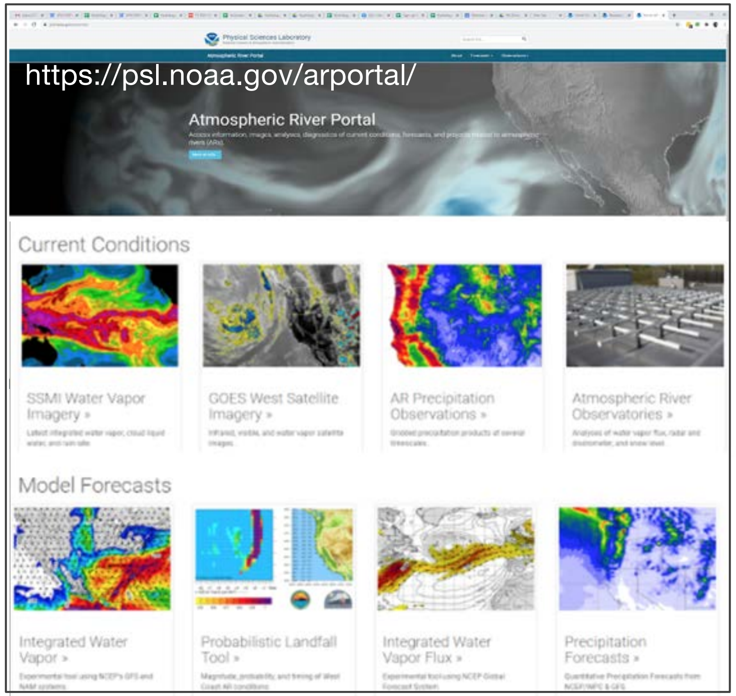


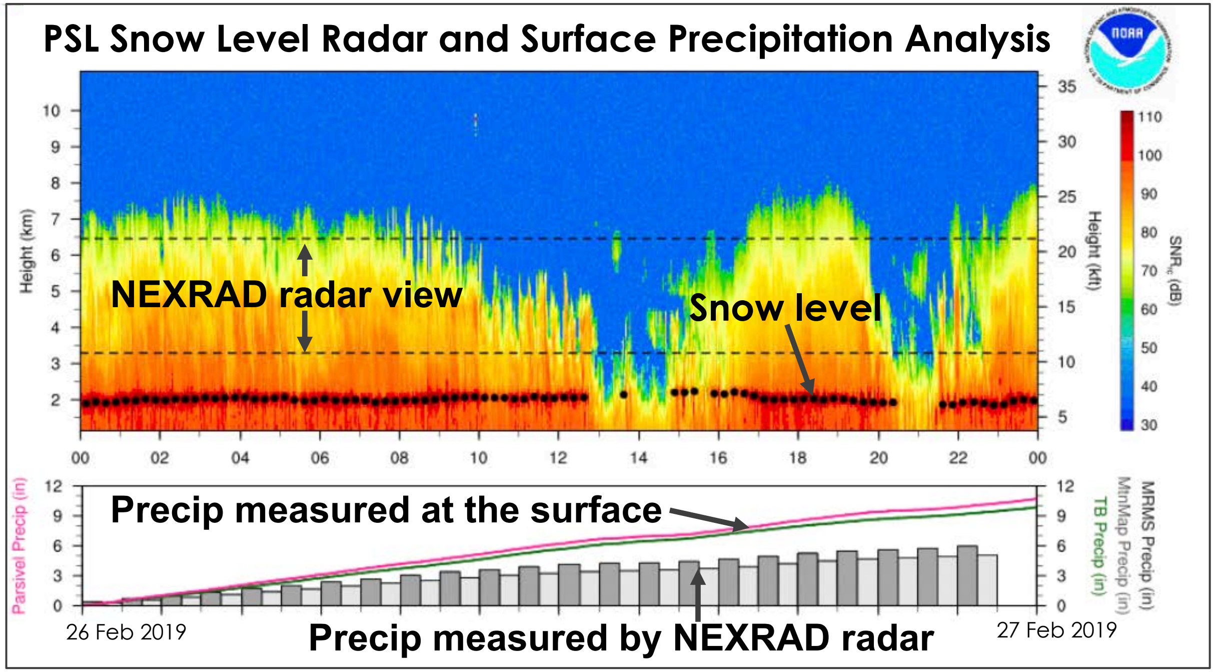
Lake Mead 2015 - Photo courtesy of climate.gov

Atmospheric River (AR) Observations

We developed a portal of AR observations for forecasters and researchers to track extreme events and verify model forecasts.

The AR portal is a suite of observation and forecast products, allowing diagnostic analyses of current conditions and forecasts related to ARs





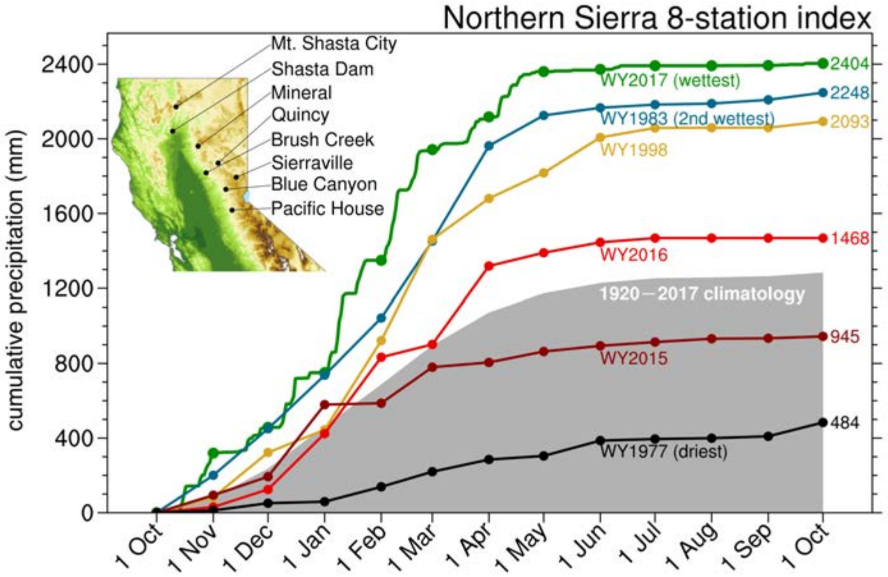
PSL product to track changes in snow level and precipitation processes during extreme events

Evaluation of Significant AR Events

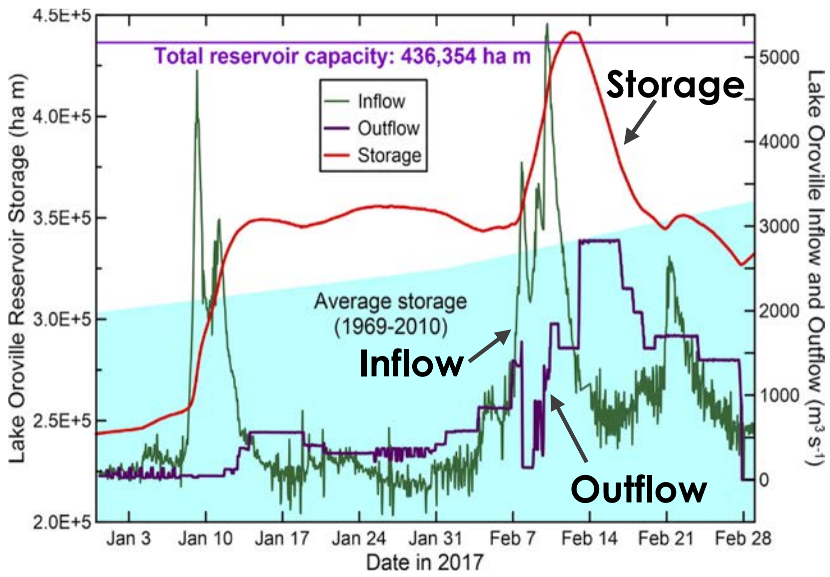
PSL uses a variety of observations to understand the meteorological conditions, forecast performance, and impacts associated with extreme events.

Water Year (WY) 2017 and the CA Oroville Dam Incident during 2-11 Feb 2017

Highly anomalous precipitation occurred in N. CA.



Precipitation resulted in excessive runoff into Lake Oroville in Feb 2017

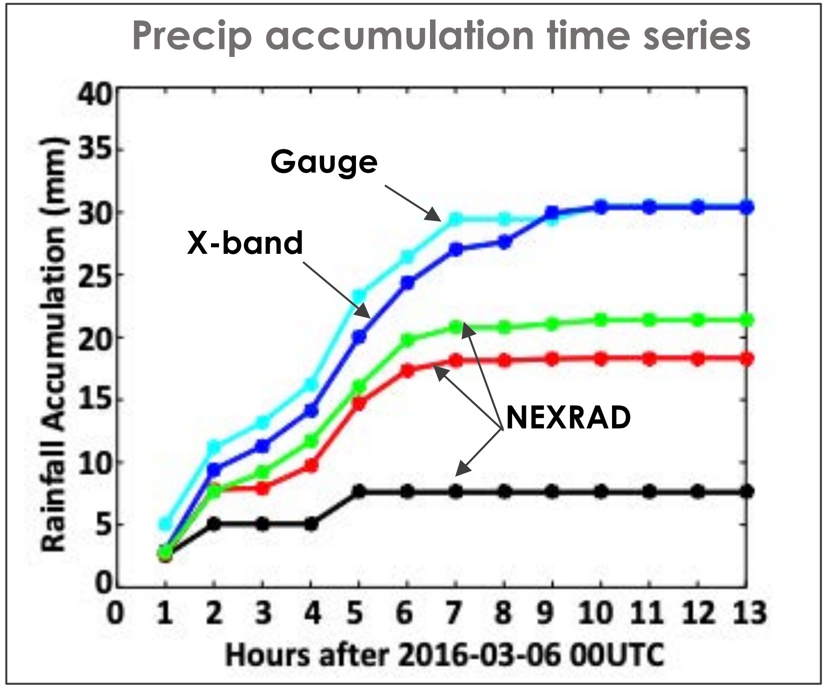


Damaged spillway at Lake Oroville in Feb. 2017

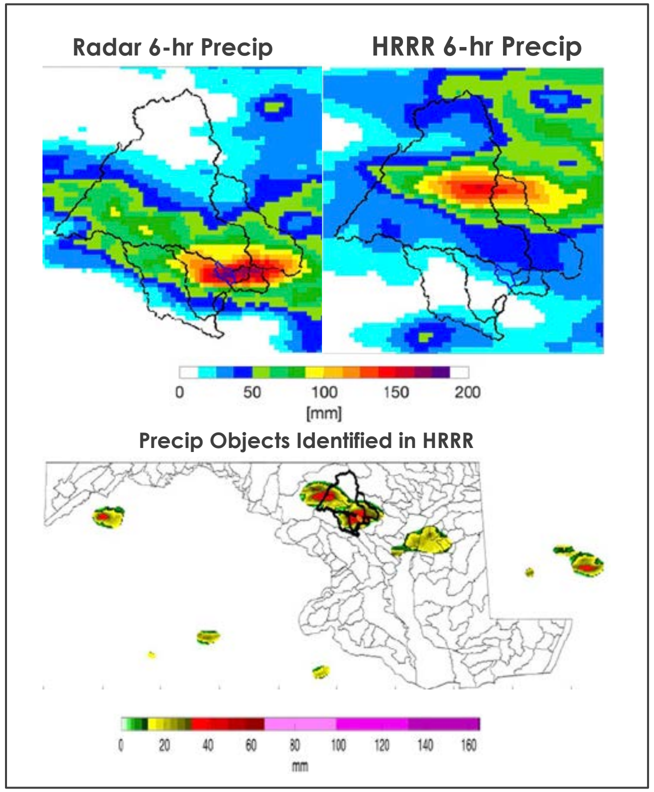
Evaluation of Forcings for Hydrologic Prediction

Advanced instrumentation is used to quantify uncertainty in traditional network observations and for validation of model forecasts. This information is used to understand sources of error in hydrologic prediction.

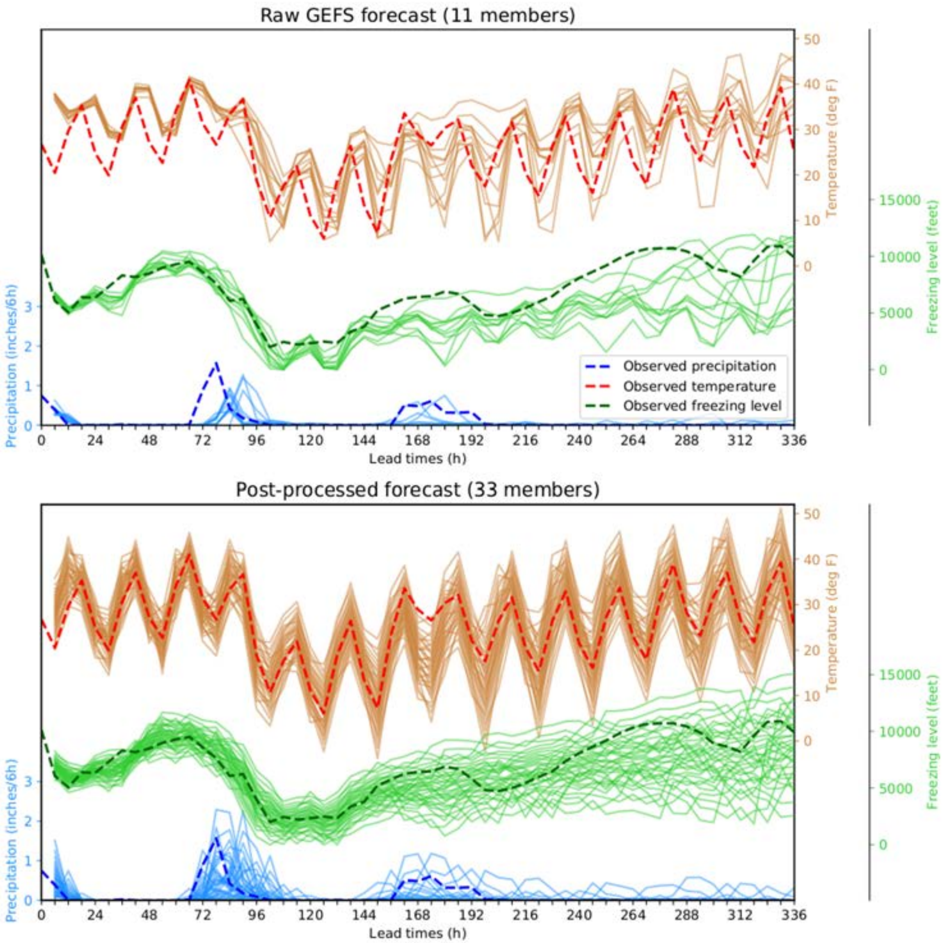
X-band vs NEXRAD radar comparisons in complex terrain of CA



Comparison of radar vs High Resolution Rapid Refresh (HRRR) model precipitation using accumulation comparison (top) and object based verification (bottom) for Ellicott City, MD 2018 Flash Flood Event

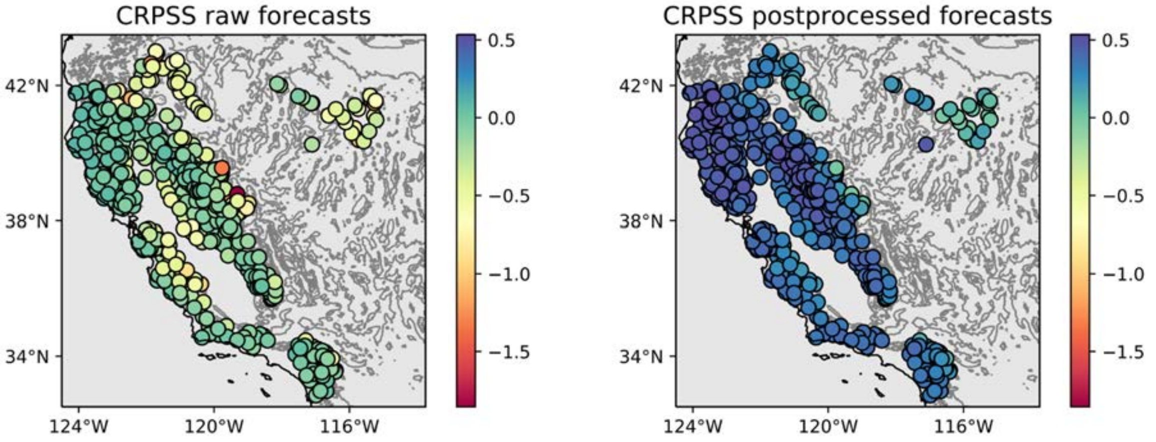


Statistical Postprocessing of Meteorological Inputs to Hydrological Forecast Systems



PSL is collaborating with River Forecast Centers to:

- Develop methods to remove forecast biases and improve the representation of uncertainty in ensemble forecasts
- Investigate to what extent the improved skill of the ensemble weather forecasts translates into more skillful streamflow forecasts



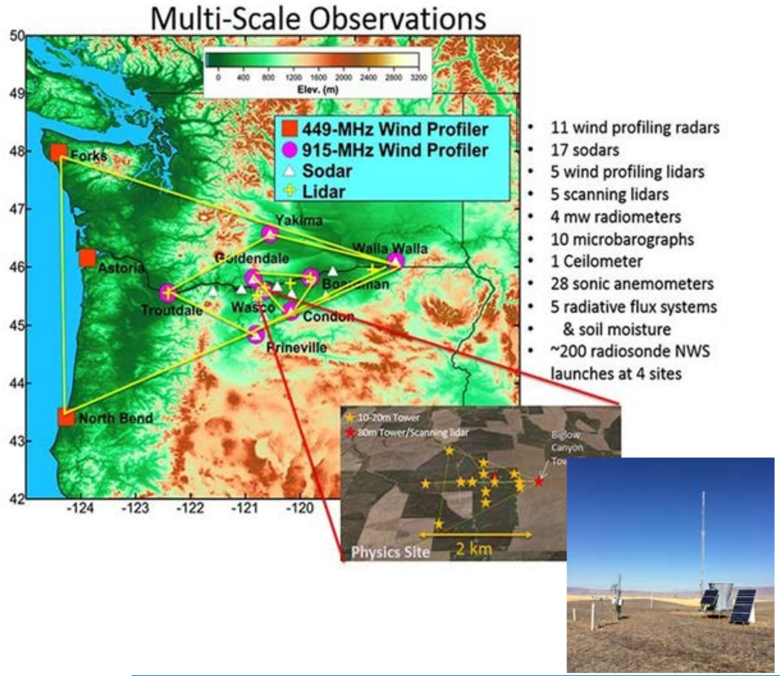
J. Bellier, M. Scheuerer, L. Smith

Development of Bulk Algorithm for Sensible and Latent Heat Fluxes

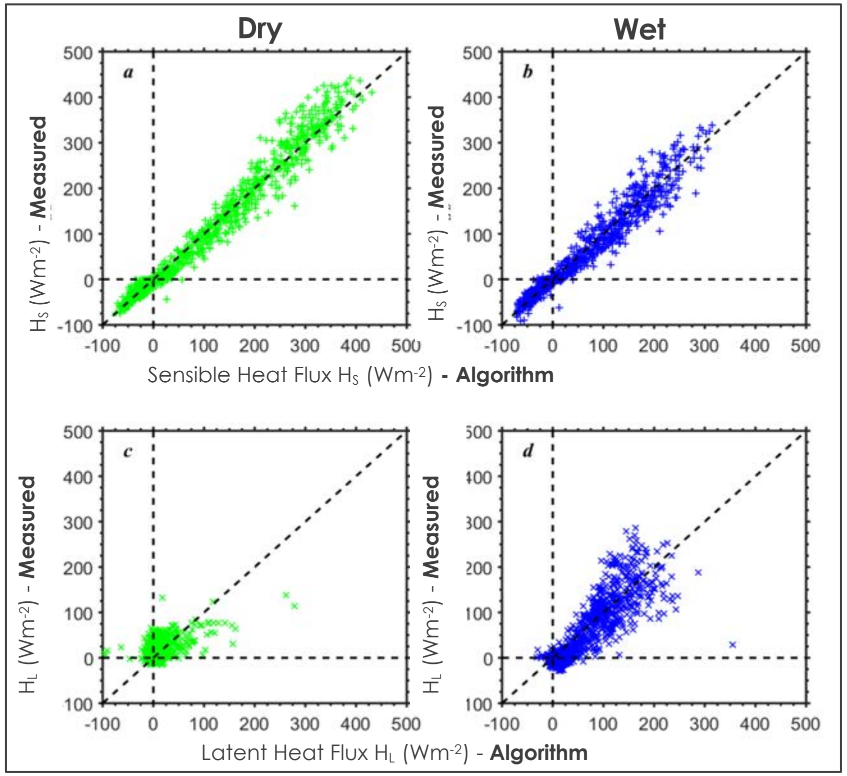
Observe | Understand | Predict/Project

A bulk flux algorithm was developed to predict turbulent fluxes over dry and wet bare soils (Grachev et al). The algorithm will be useful for improving land-atmosphere parameterizations in forecast models.

Wind Forecast Improvement Project 2 (WFIP-2)



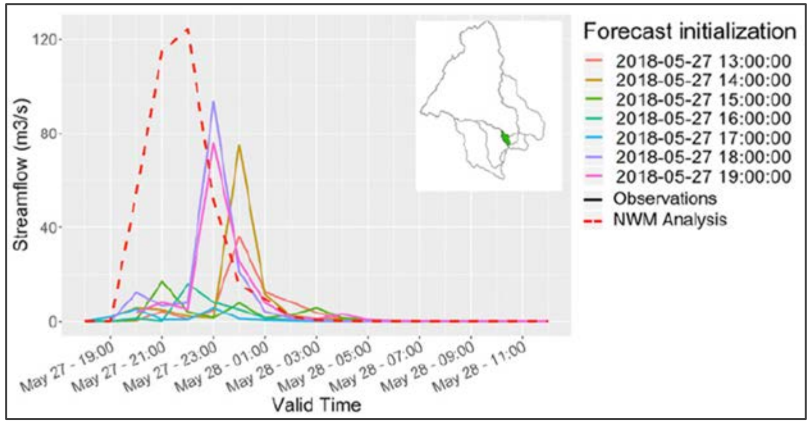
Comparison of latent/sensible heat measured vs bulk algorithm



Evaluation of the National Water Model

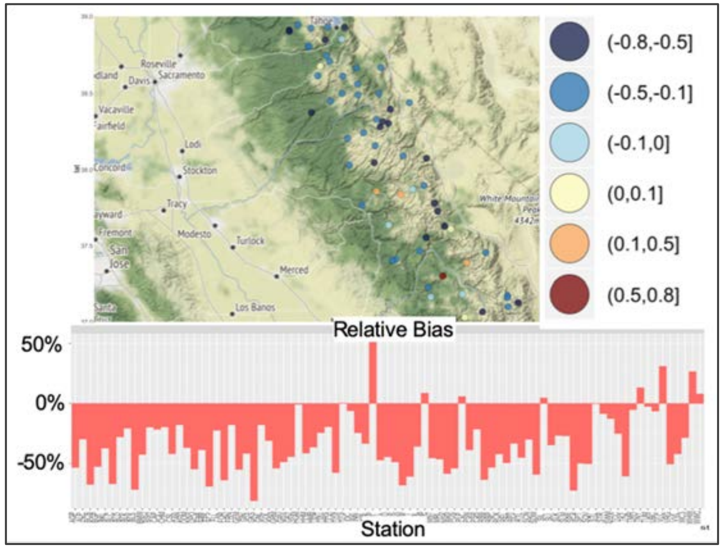
PSL uses observations to understand key physical processes responsible for model performance. This information is useful for validation and to guide future model development.

Streamflow



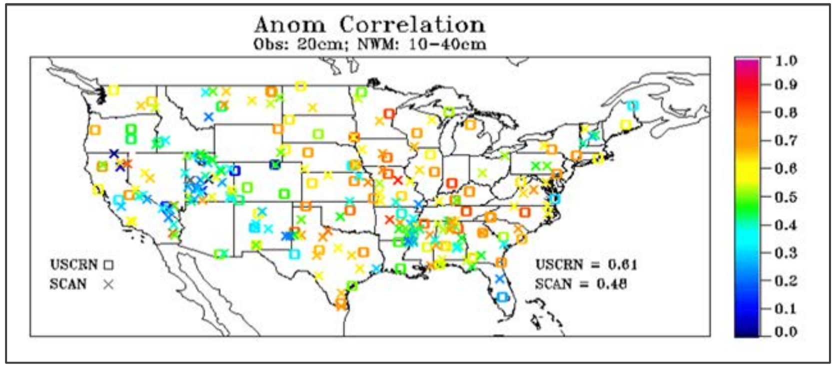
Discharge, Ellicott City, MD Flash Flood

Snow



Snow Water Equivalent, Sierra Nevada

Soil moisture

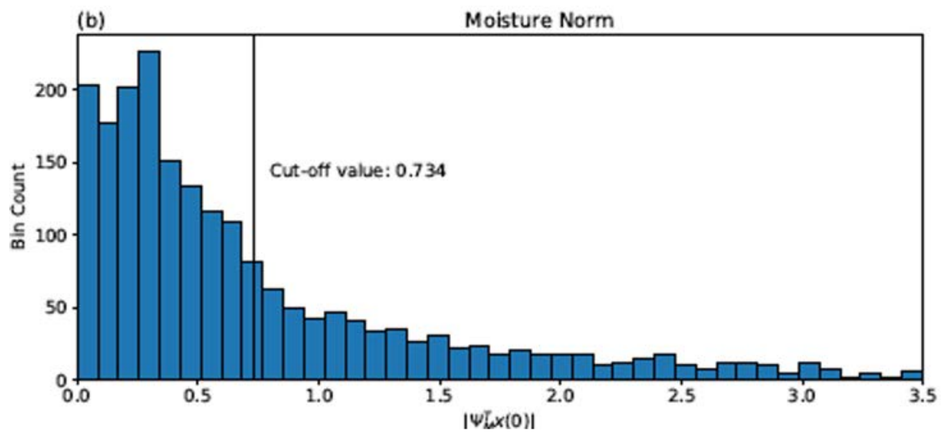


Soil Moisture Anomaly Correlation

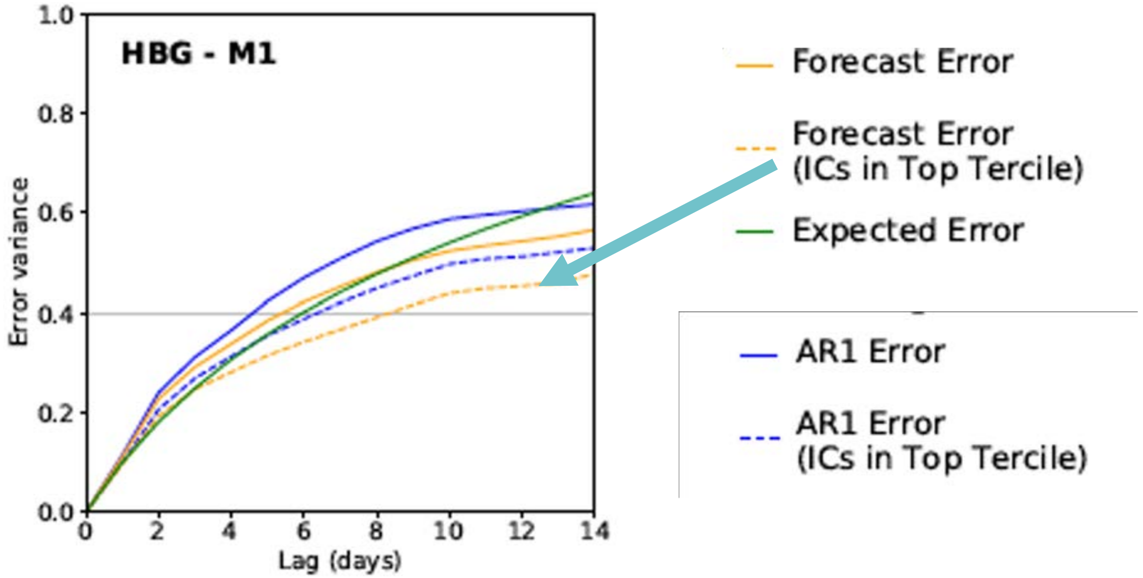
Soil Moisture Forecasts of Opportunity

PSL has developed a way to identify "forecasts of opportunity" for soil moisture extremes. We do this using Linear Inverse Modeling (LIM). Specifically, we use LIM to identify an **optimal initial pattern** of soil moisture M and temperature T anomalies that yields particularly skillful forecasts.

Histogram of correlations of the optimal pattern with observed patterns in the historical record. The vertical line demarcates the upper tercile of the correlations.



Soil moisture forecast errors at Healdsburg, CA for all initial conditions and for those from the upper tercile of the histogram. Result are shown for both LIM and AR1-process forecasts.



Penland, Fowler, Cifelli, Pulwarty

UFS Land Data Assimilation (DA) Development

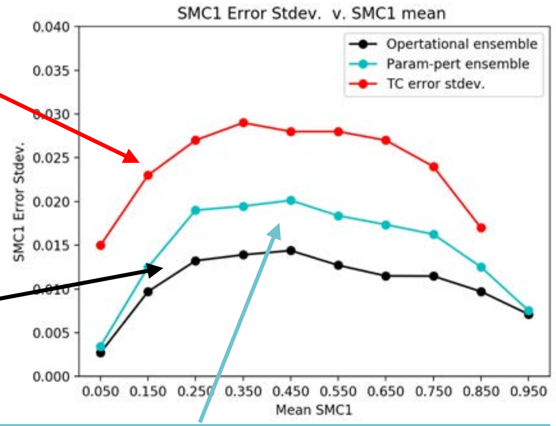
PSL is developing a state of the art Ensemble Kalman Filter land Data Assimilation system for the UFS.

- NOAA is the only major national NWP center not using DA to update the soil moisture in their global NWP model, and our snow DA is very outdated
- Introducing a modern land DA for the UFS is expected to improve UFS forecasts

Improving ensemble-based model uncertainty estimates, for use in soil moisture DA.

Best estimate of the UFS soil moisture model uncertainty (from comparison to independent data).

Current UFS ensemble spread underestimates the model soil moisture uncertainty.



Application of PSL's land model uncertainty scheme increases the ensemble spread in soil moisture. With larger model uncertainty, can proceed to develop the Ensemble Kalman Filter updates to soil moisture.

Modernising the snow data assimilation.

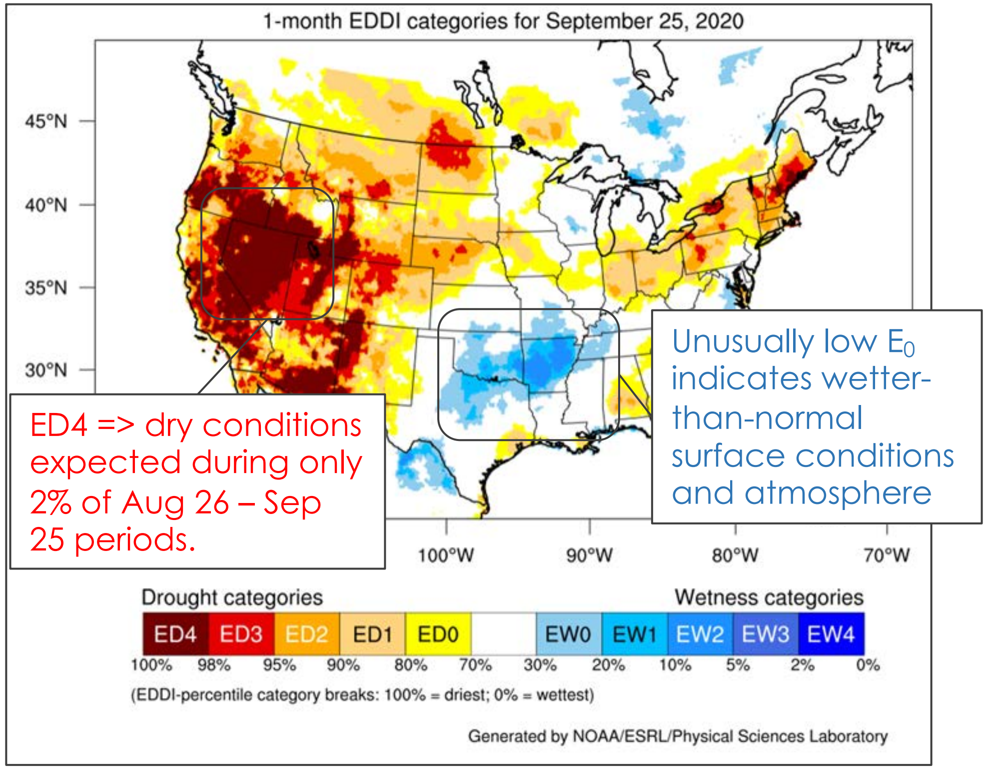
PSL developed an Optimal Interpolation snow analysis (as used by leading international NWP centers). Initial results, based on a single update, show clear improvement over current scheme. Now working on an Ensemble Kalman Filter.

	Mean Diff.	RMSE
Current UFS/GDAS analysis	57.7	243.6
PSL optimal interpolation	33.3	223.5

Table: Snow depth [mm] DA evaluation against independent station observations, for 15 Dec, 2019.

Evaporative Demand Drought Index (EDDI)

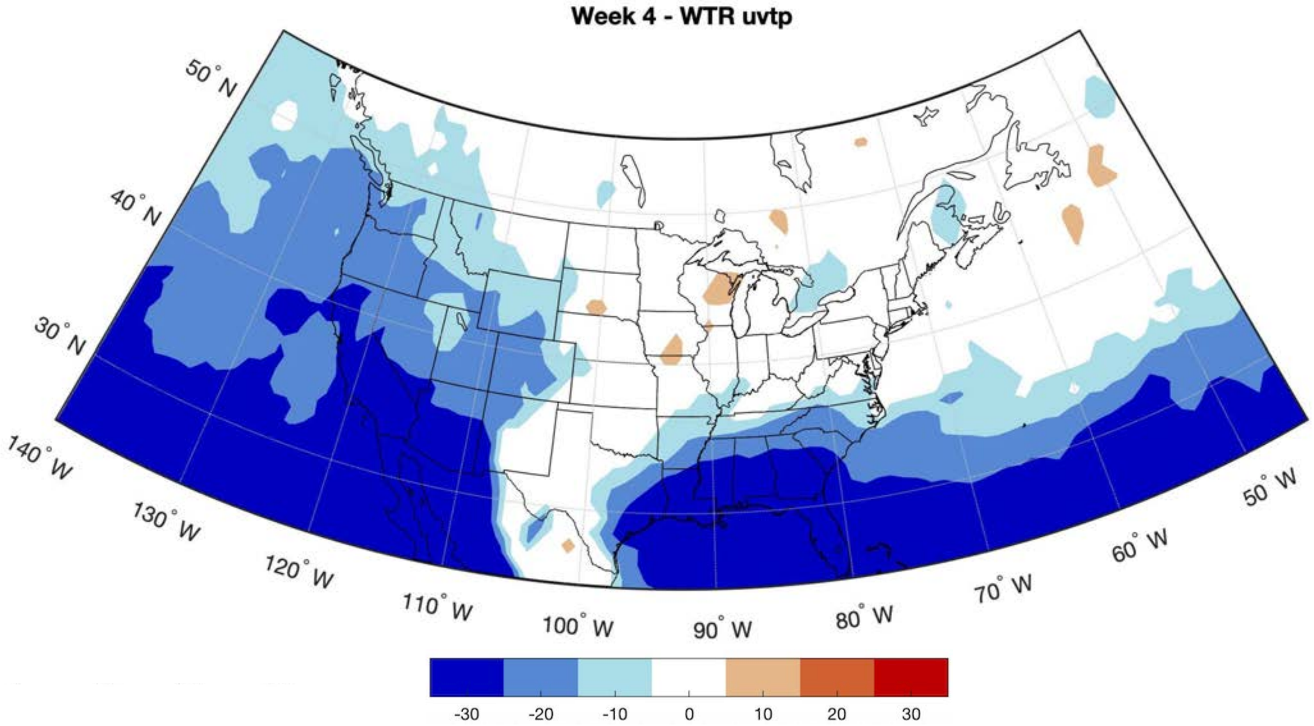
- Multi-scalar, near-real-time drought index that leads the US Drought Monitor, providing a demand perspective
- Evaporative demand (E_0):
  - "thirst of the atmosphere,"
  - responds very quickly to surface-moisture changes



Improving NOAA's S2S water predictions over the contiguous United States

We use nudging to determine whether UFS precipitation forecasts can be improved through improvements in the tropics.

Change in Week 4 precipitation forecast skill



Improved ⟷ Degraded

Tulich, Dias

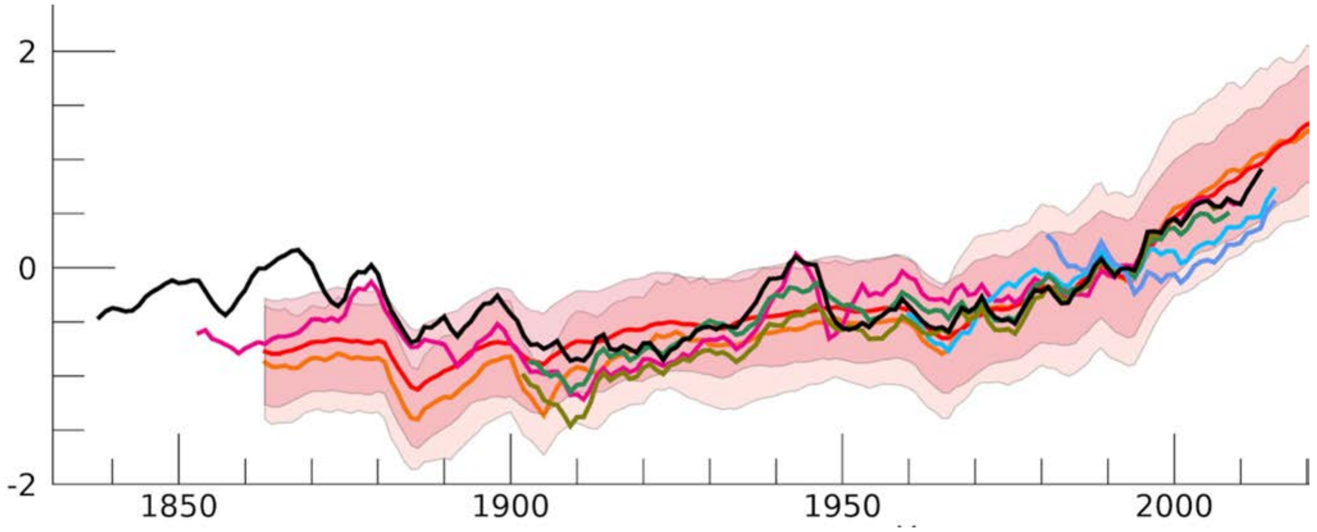
Revealing Trends in the Water Resources Historical Record

PSL is unique in having developed a 200-yr global atmospheric reanalysis dataset at 3-hourly resolution (20CRv3). This dataset will be useful for studying long-term changes in the water cycle.

<u>Global Precipitable Water</u>

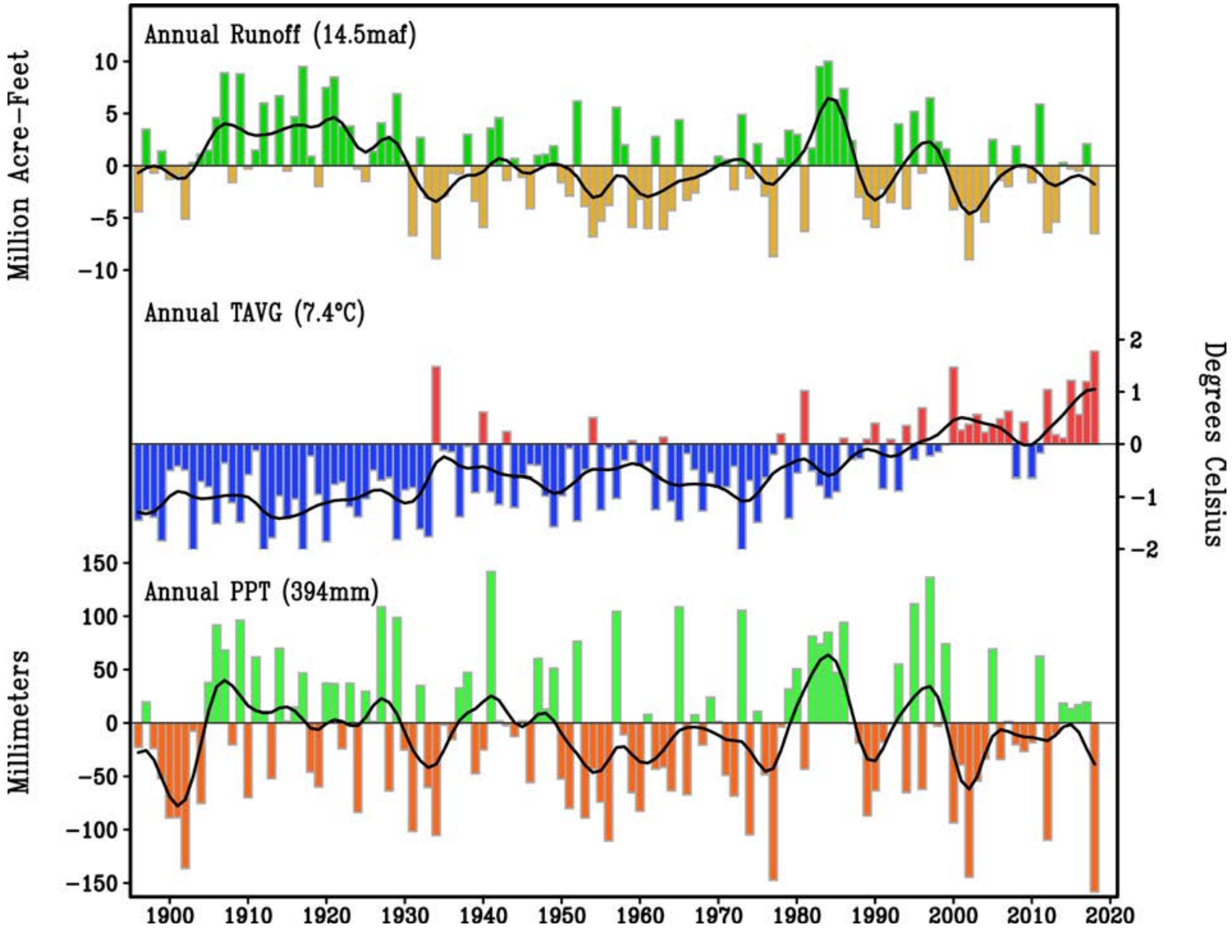
in PSD's new long-term 20CRv3 reanalysis **(black curve)**

and in other Reanalysis and model datasets **(colored curves)**



Compo, Slivinski, Whitaker, Sardeshmukh, McColl et al.

Causes for the Century-Long Decline in Colorado River Flow



PSL has developed methods to diagnose critical drivers of hydroclimatological change at the basin scale.

- Upper Colorado River flow has declined 20% since 1900
- High resolution coupled global models indicate half of the flow reduction is due to climate change
  - Most is due to reduction in pcpn
- Global land-atmosphere coupled models indicate the warming effect is about 3%/°C
  - lower sensitivity than inferred from empirical models and most uncoupled land models
- The challenge in anticipating future Colorado River flow is how pcpn, rather than sfcT, will change

M. Hoerling, J. Barsugli, J. Eischeid, X. Quan

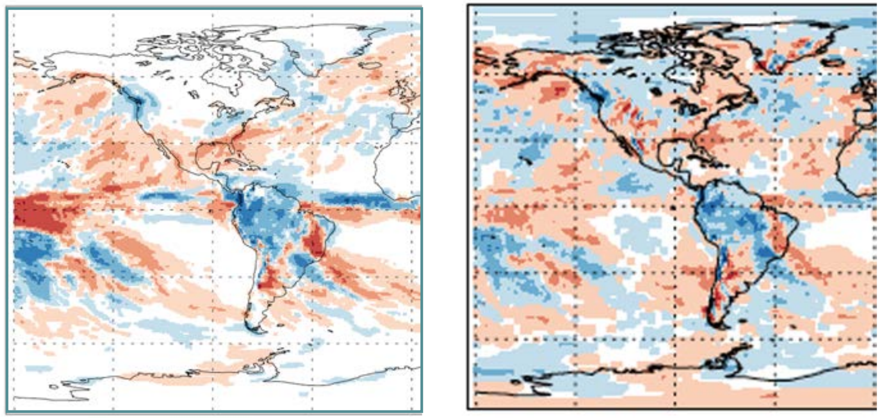
Understanding Extremes

Observe Understand Predict/Project

“Stochastically Generated Skewed” (SGS) distributions are important to estimate precipitation extremes to inform water resource management and future risk based decision making.

Precipitation *P* | **Vertical Velocity *W***

Changes in Mean



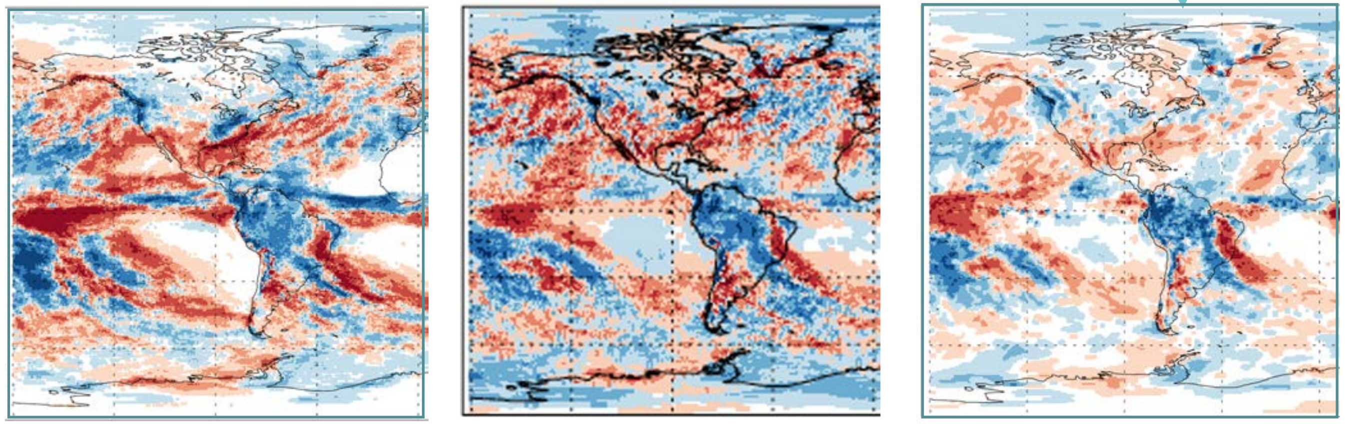
BLUE = increase
RED = decrease

“Predicted” change in extreme *W* given the change in mean *W*:

$$\Delta W_{90} \approx \left(1 + \frac{S_w}{2}\right) \Delta \overline{W}$$

using our SGS distribution theory, where S_w is the skewness of *W*

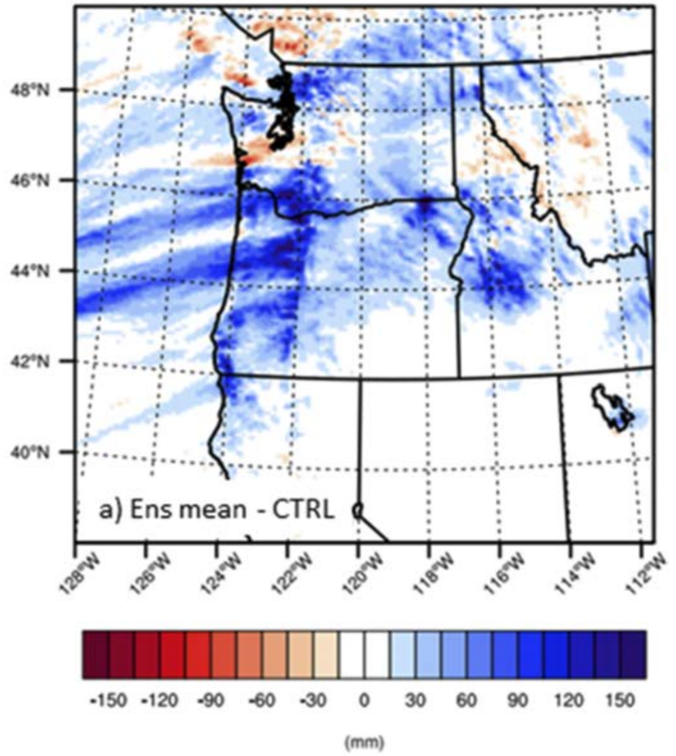
Changes in Extremes (90th percentile)

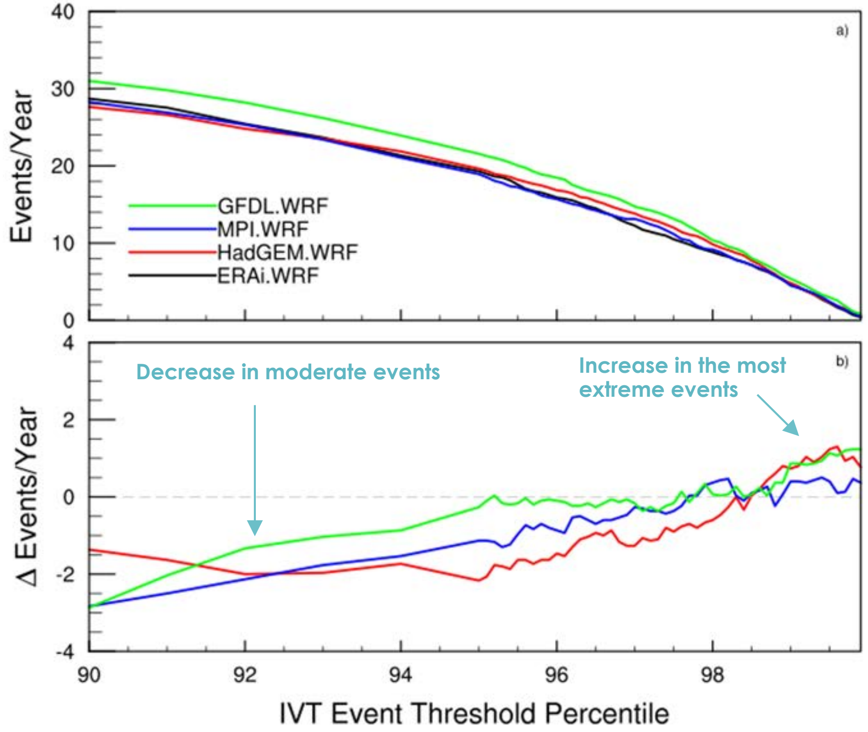


Advances in Understanding of Processes Controlling Projected Changes in Western U.S. Precipitation and Their Impacts

Larger scale processes inherent in climate modeling combined with the mesoscale processes control precipitation over complex terrain.

Projected future change in precipitation for a historical high impact event in the Pacific NW





Integrated vapor transport (IVT) events identified in the historic record

Changes in IVT **events** anticipated by the end of the 21st century

Next Five Years Activities for Water Resource Management

- Explaining the underlying causes of recent water extremes and assessing their predictability
- Advancing the use of hydrometeorology observations, including remotely sensed data for soil moisture and snow, and modeling in watersheds across the U.S. to deliver improved scientific information for managing water resources, for protecting lives and property, and for informing preparedness
- Improving forecasts and early warning of hydrologic extremes and their impacts, such as those associated with droughts and floods, and evaluating model forecast performance

Water Resource Management Summary

- PSL uses a variety of observations to characterize the fluxes of water between atmosphere, land, ice, and sea components of the earth system
- This information is used to understand and assess model performance at capturing extreme water events over time scales ranging from hours to decades
- PSL further identifies key physical processes responsible for improving predictability