

# Sub-Seasonal to Seasonal (S2S) Climate Products for Water Management

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# Motivation

The potential value of S2S climate predictions has not fully been realized by water sector stakeholders.

- Products are not aligned with space-time analysis needs
- Products are not in a format that users can easily process
- Products are biased relative to watershed climatologies
- Products are perceived to have poor reliability

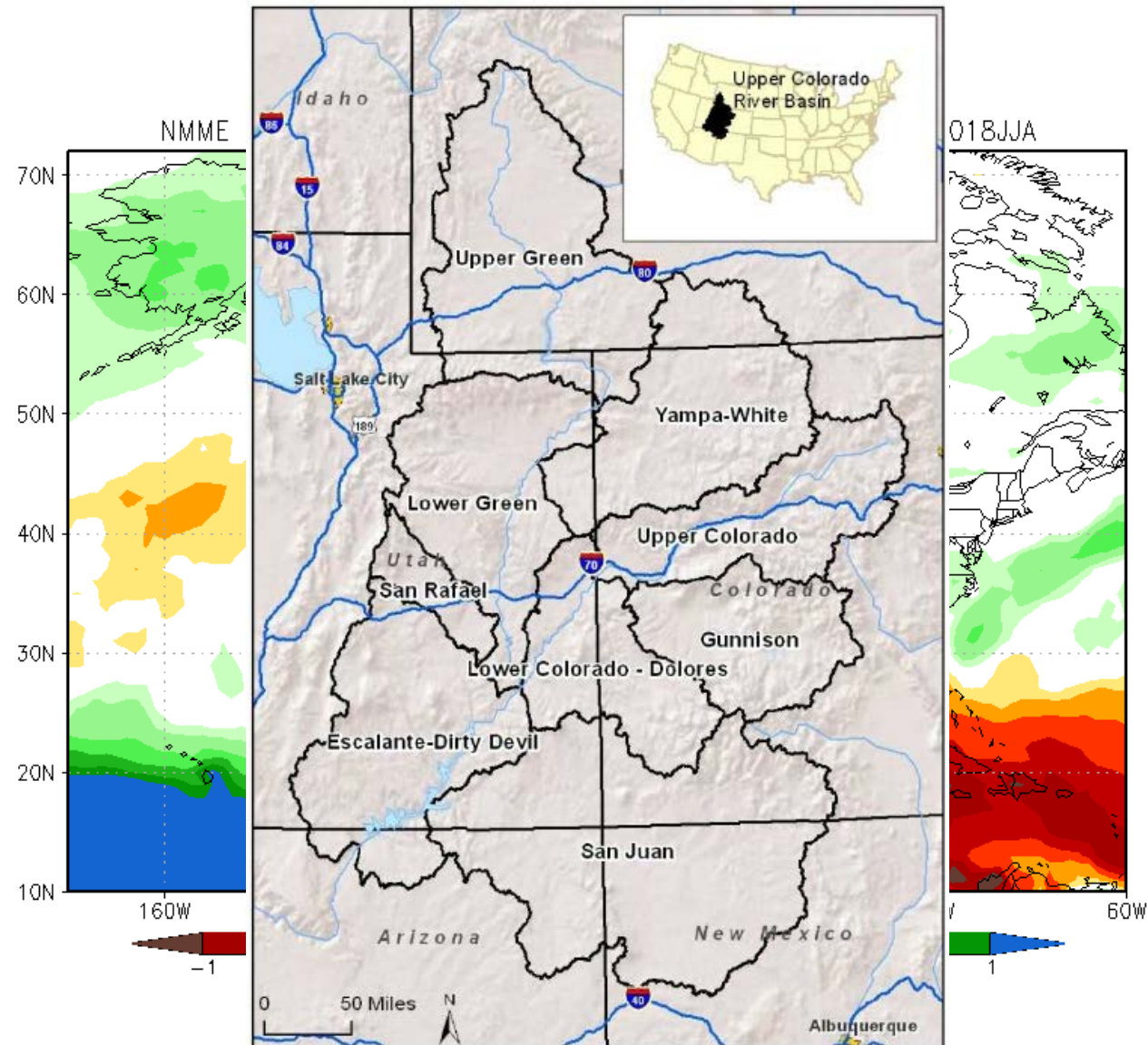




# Examples of S2S forecasts

Typical S2S operational product

It is possible to drill down spatially & temporally, but ...





# How could they be used?

The goal of this project is to make climate forecasts more useful to water managers by

- (1) applying climate forecasts to watershed scale and creating a real-time product
- (2) improving forecasts on a watershed scale
- (3) transition prototype products to CPC or NWC

Streamflow Forecasts - snowpack

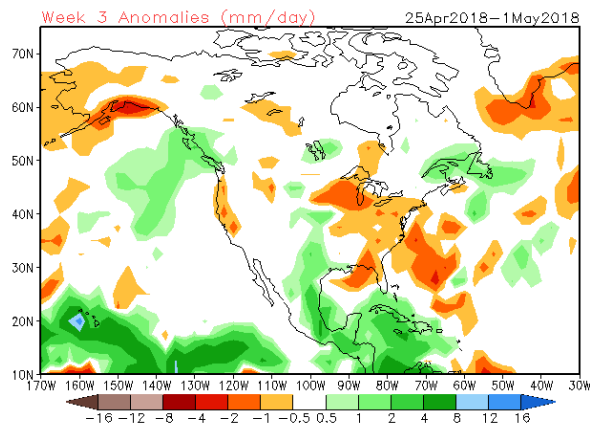
Hydro

Instream flows

# Data – Climate Forecasts

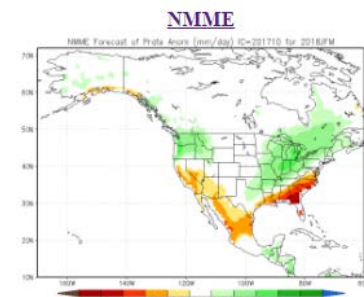
## NCEP Climate Forecast System v2 (CFSv2)

- Fully coupled atmosphere-ocean-land model
- Forecasts:
  - Four initializations daily at 6-hr time steps
  - 4 forecasts each model initialization for 16 traces daily
  - Forecast length: 45 days to 9 months
- Hindcasts: 1999-2010
  - 4 traces daily



## North American Multi-Model Ensemble (NMME)

- 7 Global Climate Models
  - CFSv2 - NOAA NCEP
  - NASA - GEOS5
  - NCAR\_CCSM4 - CCSM4.0
  - GFDL - CM2.1
  - GFDL\_FLOR - CM2.5 [FLORa06 and FLORb01]
  - CMC3 - Environment Canada CanCM3
  - CMC4 - Environment Canada CanCM4
- Forecasts: 2011-present
  - Monthly timestep leads of 7 months
  - Available monthly on the 8<sup>th</sup>
- Hindcasts: 1982-2010



## Raw Hindcasts & Forecasts

- NMME (monthly)
- CFSv2 (sub-daily)
- NLDAS (obs)

## Spatial & Temporal Processing

- Re-project (1/2 degree grid)
- Temporally average
  - CFSv2: bi-weekly (1-2, 2-3, 3-4 wk)
  - NMME: monthly to seasonal
- Spatially average to 202 USGS HUC4 watersheds (conservative remapping)

## Verification

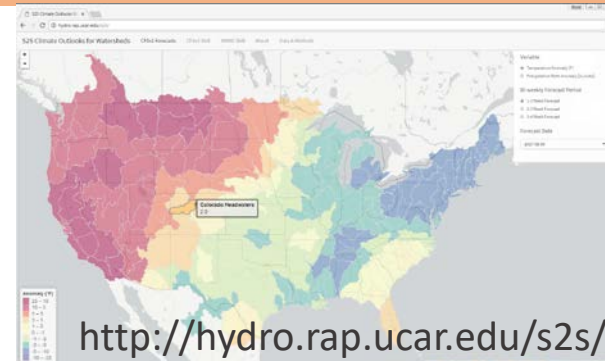
- Anomalies calculated based on climatology
- Obs Data – NLDAS
- Anomaly correlation, bias, and percent bias calculated for each model, lead, and season

## Post-Processing

- Bias-correction, calibration of raw data
- Extremes predictions

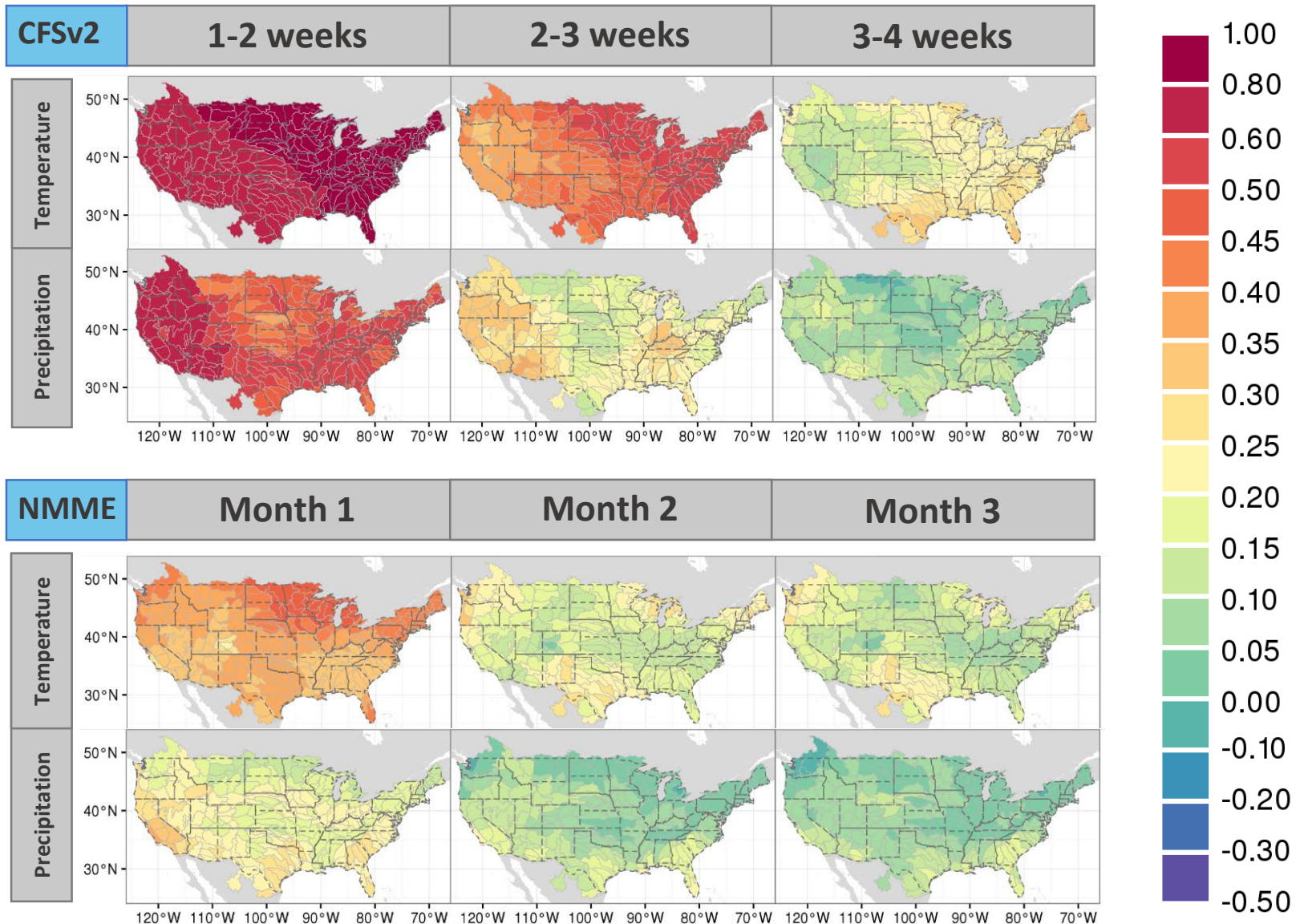
## S2S Products

- Real-time Forecasts
  - CFSv2 – bi-weekly forecast products updated daily
  - NMME – monthly forecast products updated monthly
- Benchmark Skill of Hindcasts

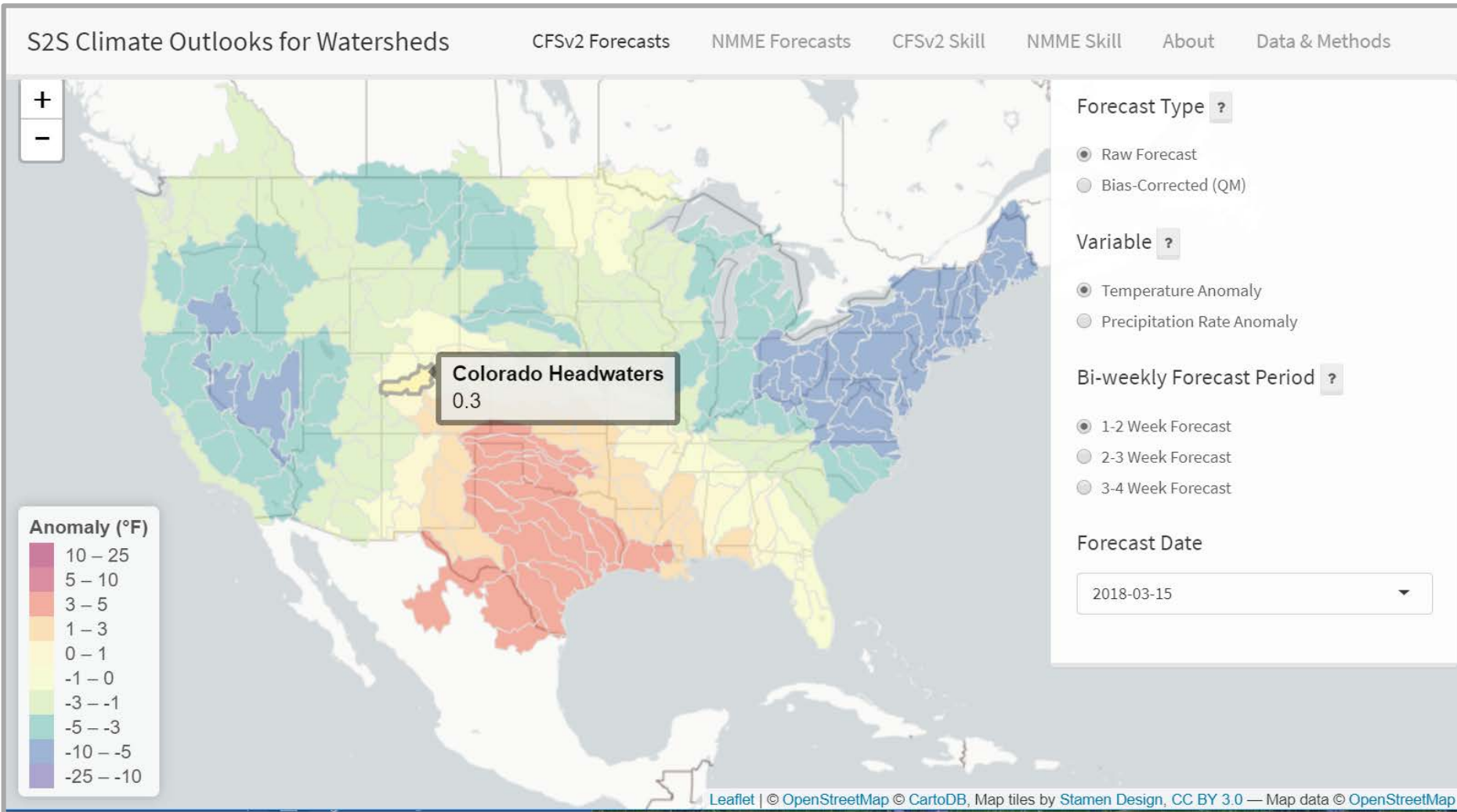




# Raw Anomaly Correlation



# S2S Product Demo



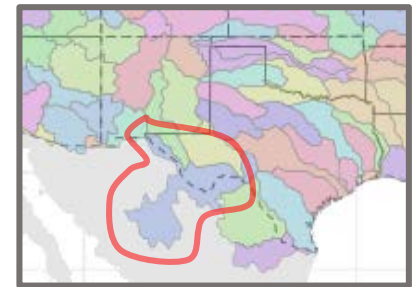
Website

<http://hydro.rap.ucar.edu/s2s/>

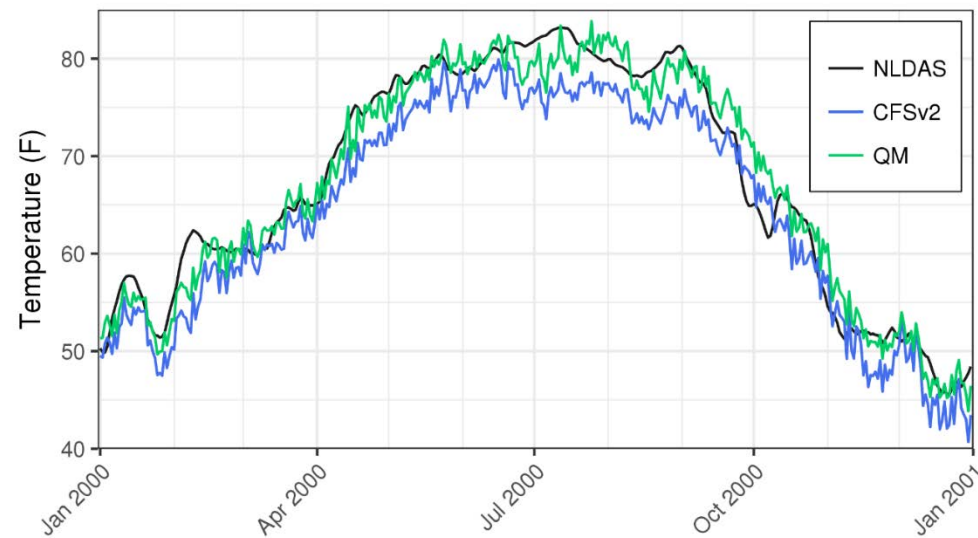
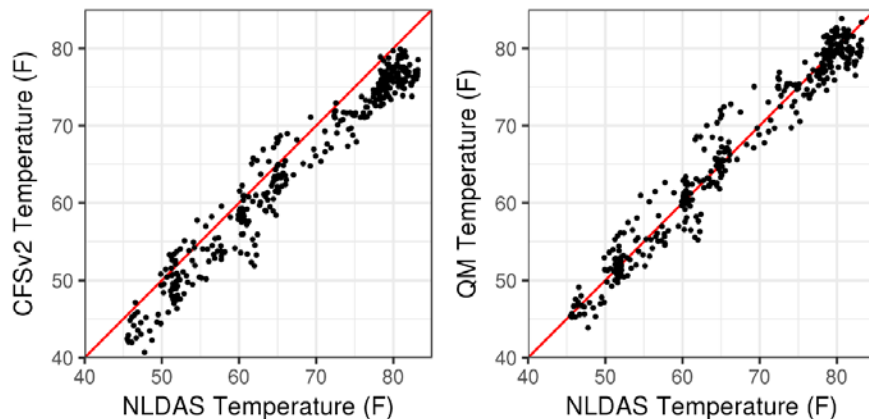


# Bias-correction – Quantile Mapping

- Bias-corrected using the Quantile Mapping (QM) method
- Estimating a pair of cumulative distribution functions for the CFSv2 reforecasts and NLDAS or each variable, lead, watershed, and time period (climatologies based on 15-day window)
- Results:
  - Removes systematic bias
  - Did not improve skill



**Rio Grande-Amistad Watershed**



# Skill Improvement through Post-processing

- Example: PLSR (Partial Least Squares Regression) is an approach similar to principal component analysis that finds the linear combination of a large number of predictors that maximizes the explained variance of the predictand

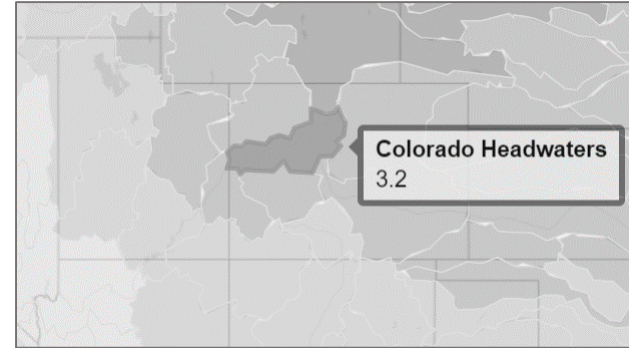
## CFSv2-based Predictors: 1999-2010

1. 500 mb Geopotential height
2. Specific Humid 2m
3. Surface Pressure
4. Sea Level Pressure
5. Precipitable Water
6. Zonal Winds (850 mb)
7. Meridional Winds (850 mb)
8. Sea Surface Temperature
9. Outgoing Longwave Radiation
10. Surface Temperature 2m
11. Surface Prate

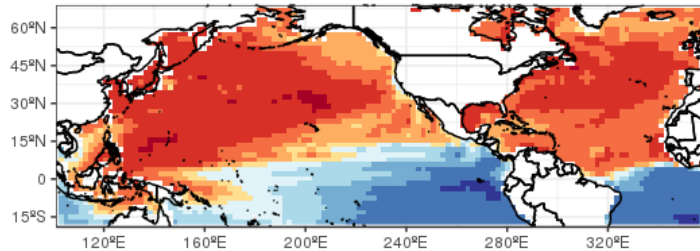


# PLSR Loadings – Colorado Headwaters

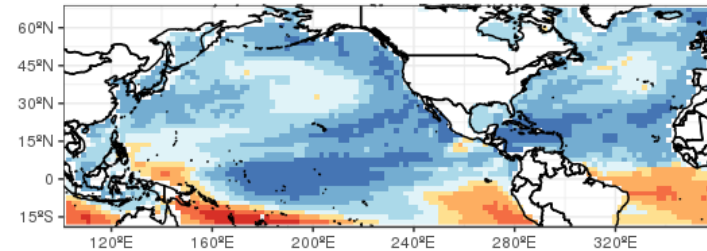
## Jan 3-4 Week Precipitation Forecast



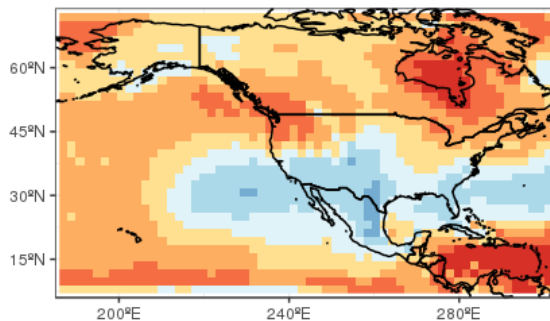
Sea Surface Temperature - Comp. 1



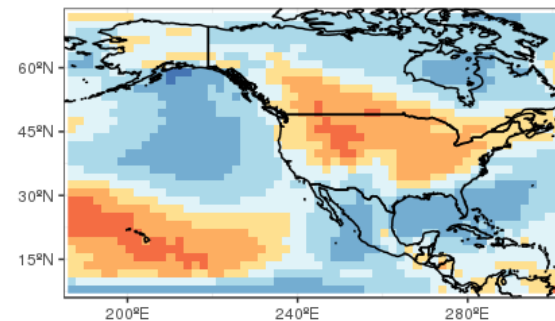
Sea Surface Temperature - Comp. 2



Surface Prate - Comp. 1

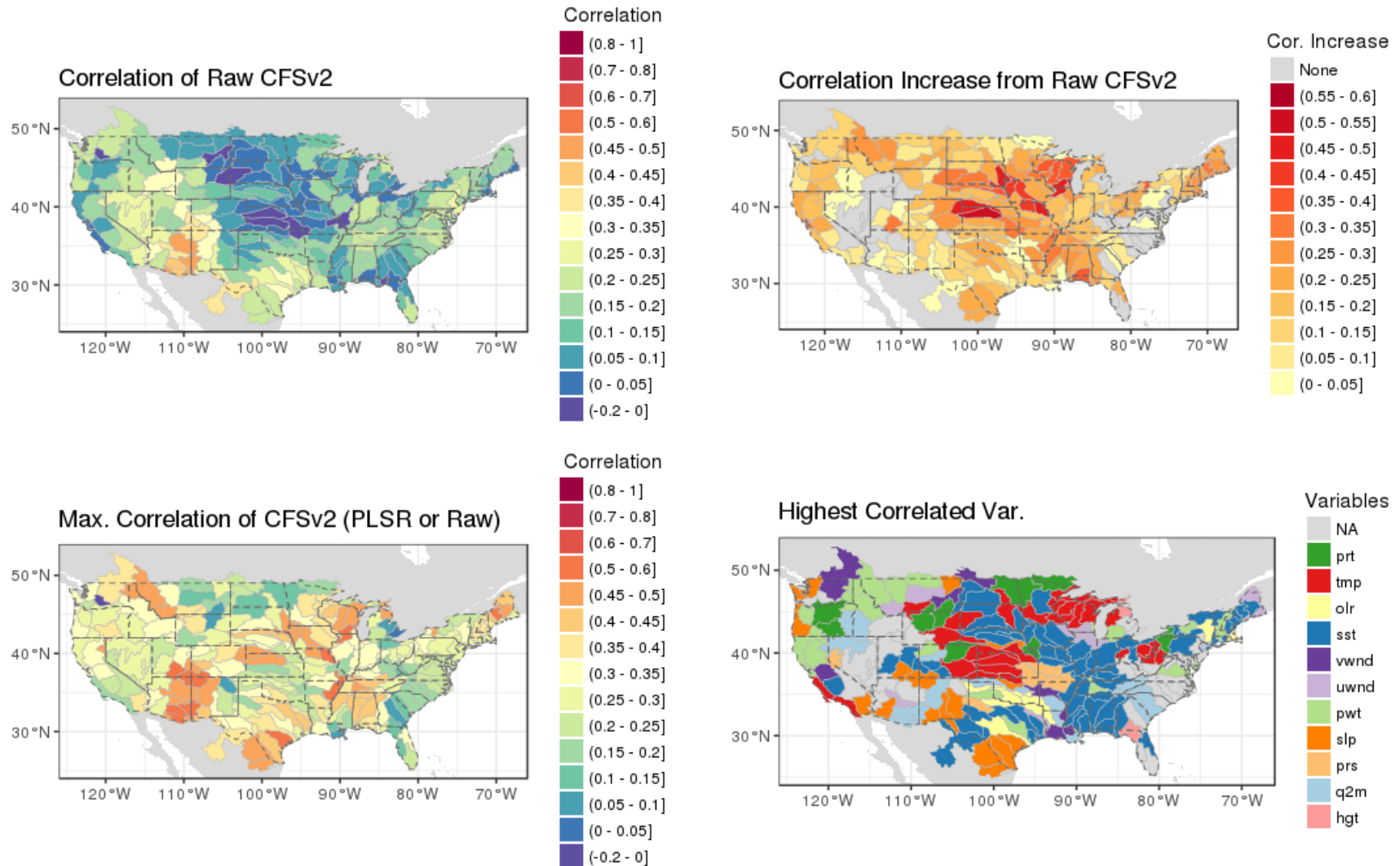


Surface Prate - Comp. 2



# PLSR – July 2-3 week Precipitation Forecast

## Leave One-Year Out Cross Validated Results – Best Predictor

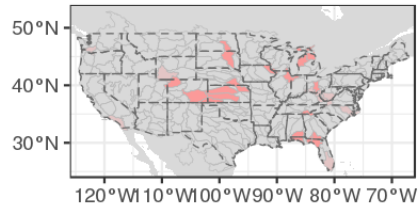




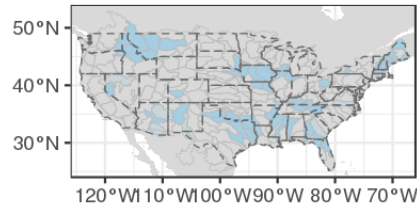
# PLSR – July 2-3 week Precipitation Forecast

## Leave One-Year Out Cross Validated Results – Top 3 Predictors

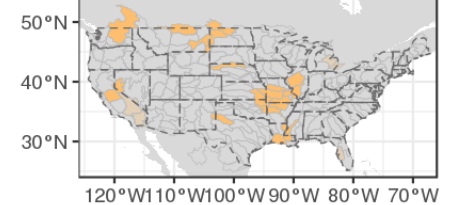
500 mb Geopotential height



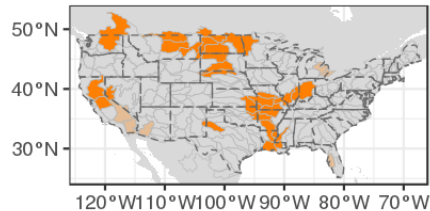
Specific Humid 2m



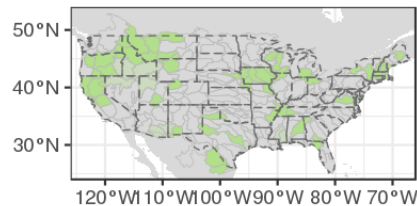
Surface Pressure



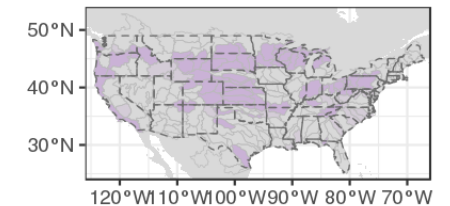
Sea Level Pressure



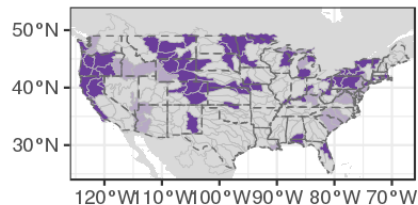
Precipitable Water



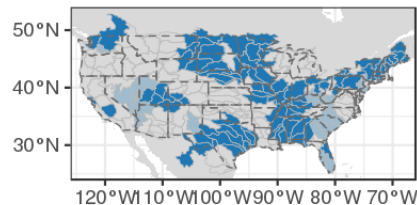
Zonal Winds (850 mb)



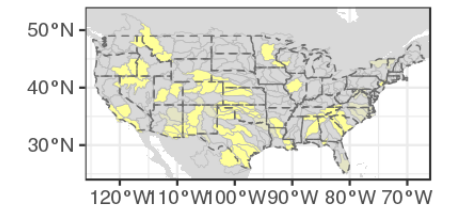
Meridional Winds (850 mb)



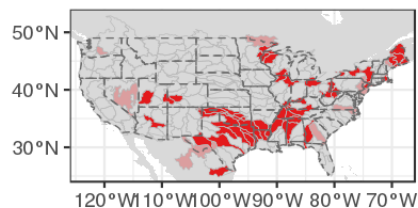
Sea Surface Temperature



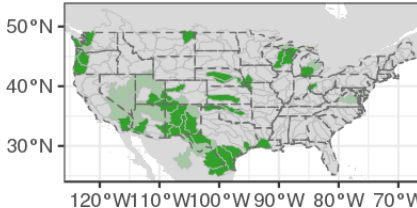
Outgoing Longwave Radiation



Surface Temperature 2m

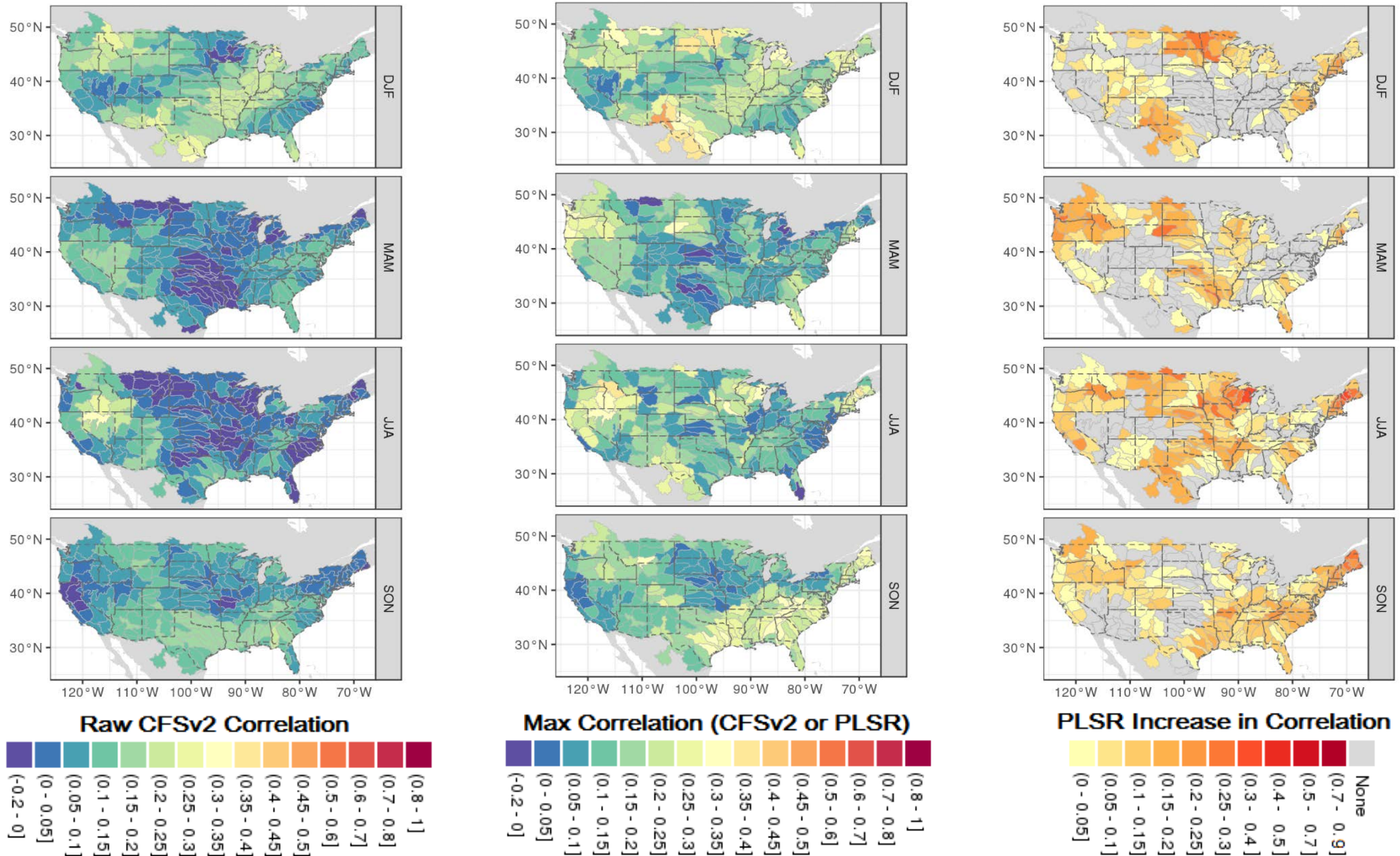


Surface Prate



# PLSR – Wk 3-4 Precipitation Forecast

Leave One-Year Out Cross Validated Results - Predictors: SST, precipitation





# Future Directions

- Train post-processing approaches to enhance skill of raw real-time S2S forecasts, where possible
- Advocate for ***weeks 2-3*** (or day 10-20) lead time as high potential products
- Interact with operational water management offices in Reclamation and US Army Corps to gauge interest in products and solicit feedback







# Questions?

<http://hydro.rap.ucar.edu/s2s/>