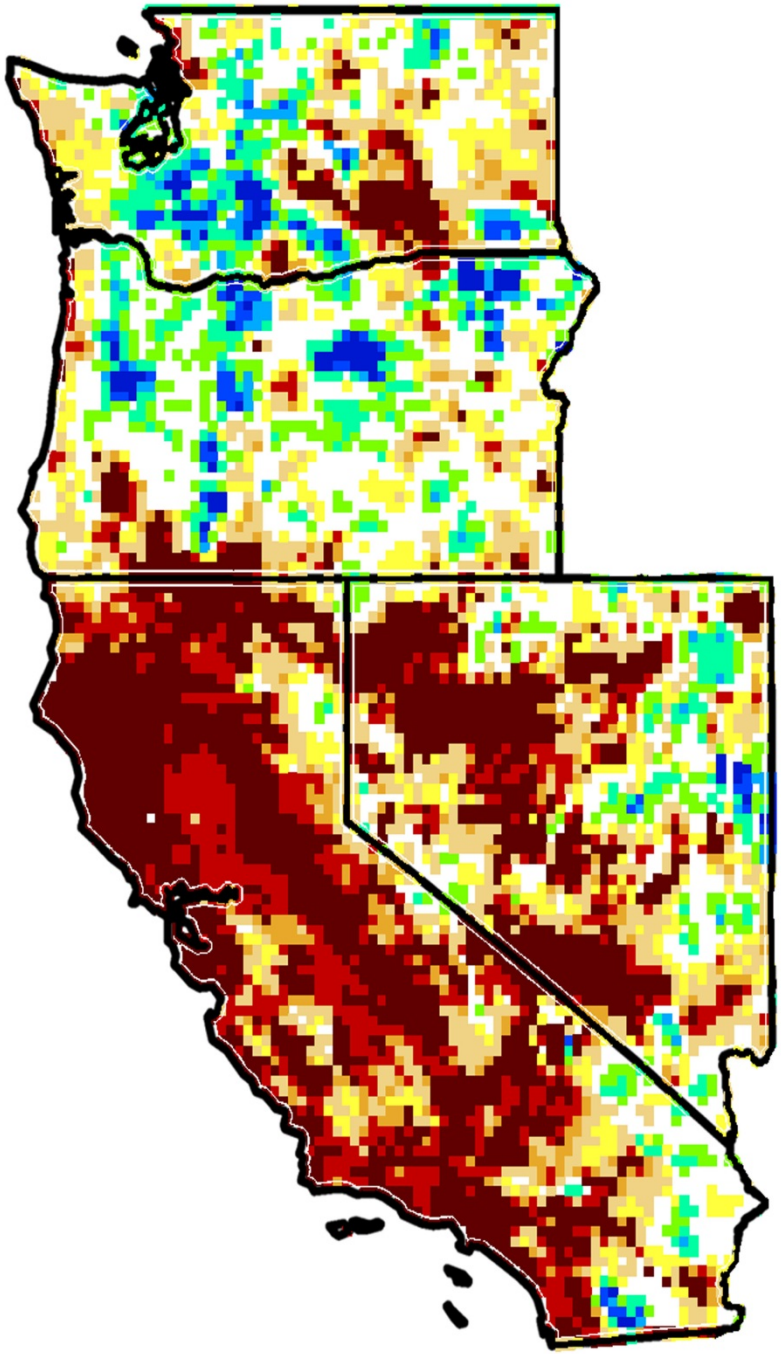


Improving seasonal drought prediction in California by combining statistical and dynamical models

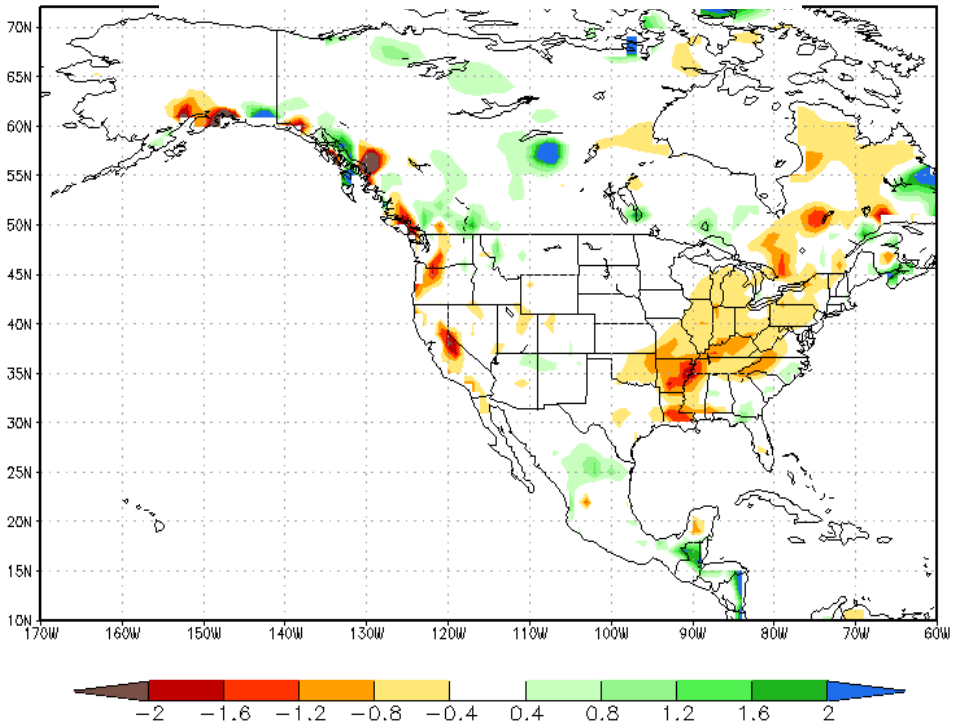
Amir AghaKouchak,

University of California, Irvine

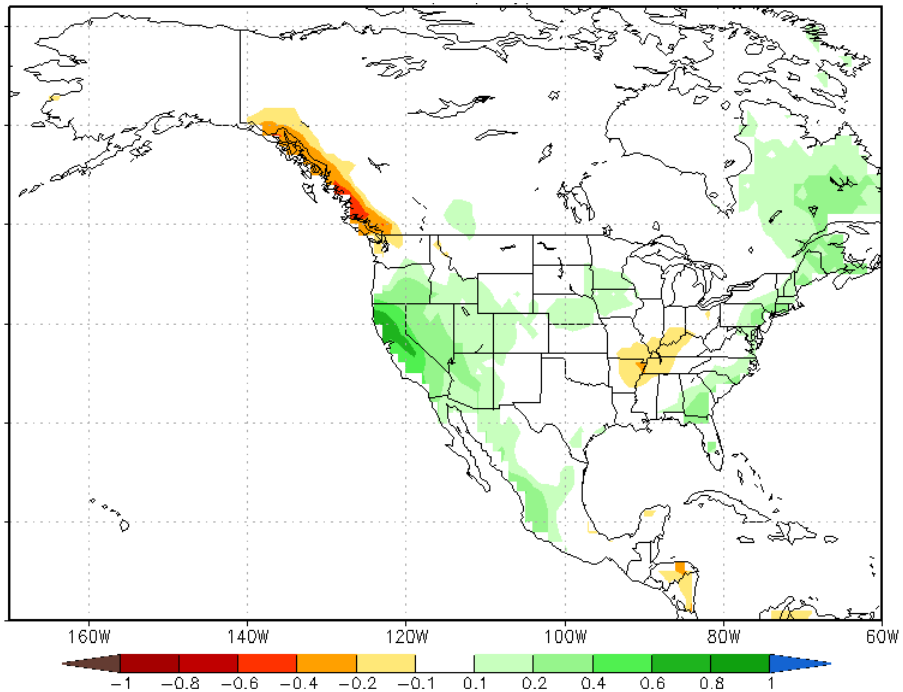
S. Madadgar, S. Shukla, A. Wood, L. Cheng, K. Hsu, M. Svoboda

Motivation

Observed Precipitation Anomaly
DJF 2014



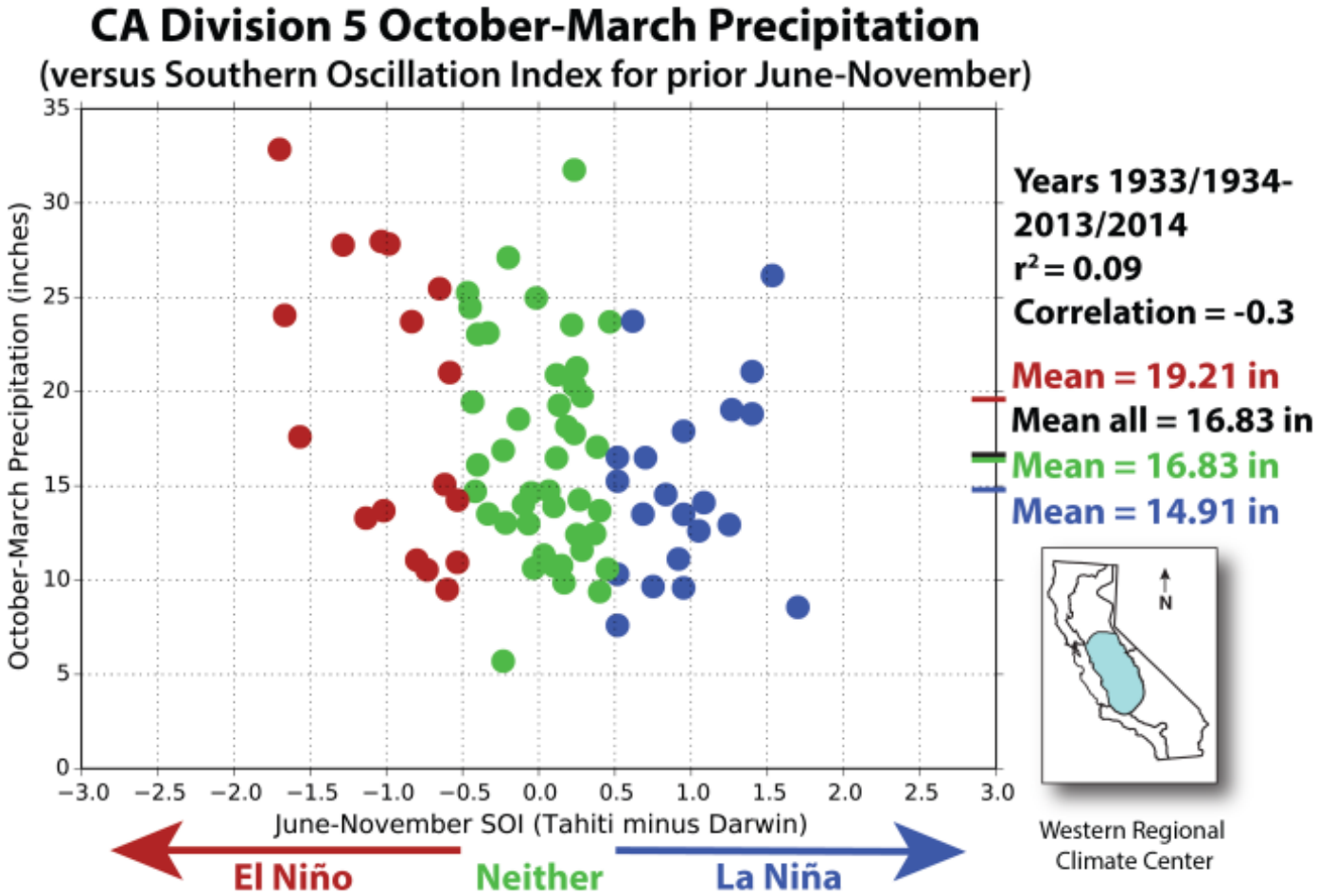
Predicted Precipitation Anomaly (mm/d)
DJF 2014 (Initialized: November)



North American Multi-Model Ensemble (NMME; Kirtman et al., 2014)

Low Predictability of Precipitation Forecasts in Dynamic Model Simulations

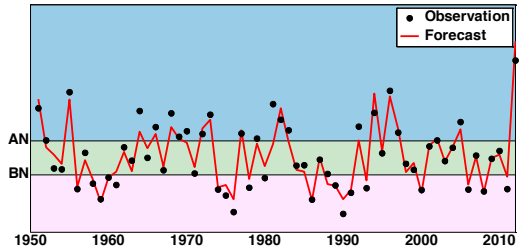
Motivation



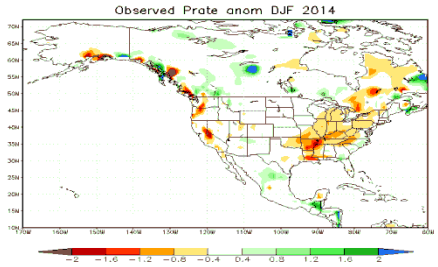
Analog-year based models also offer low predictability

Analog-Year Model Combined with Dynamical Model Simulations

Analog-Year Model



Dynamic Model Simulations



Multi-Model Assessment Using the **Expert Advice** **(EA)** Algorithm

Seasonal Precipitation Forecasts

Drought Prediction Framework

Analog-Year Model

Dynamic Model Simulations

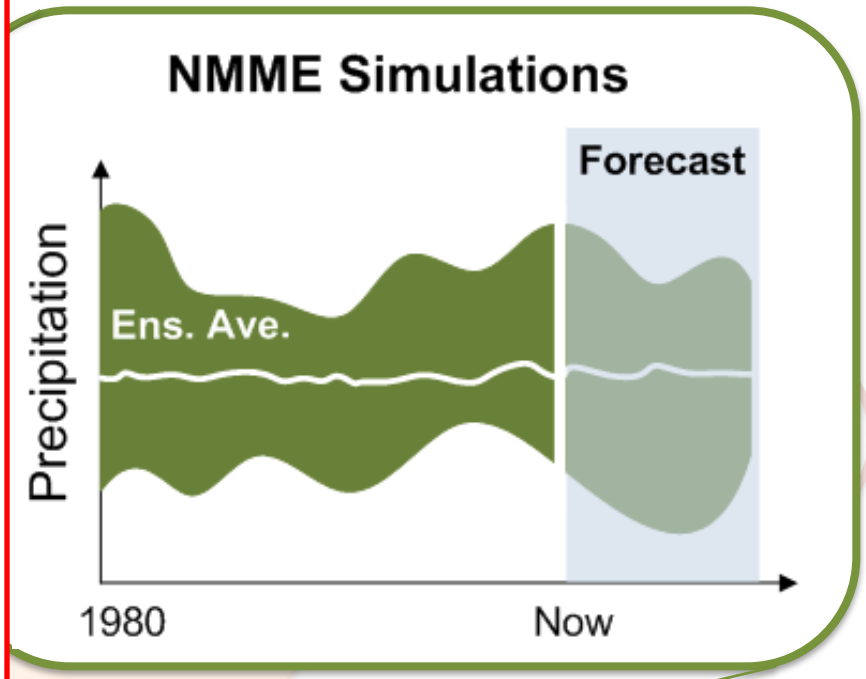
Multi-Model Assessment Using the **Expert Advice (EA)** Algorithm

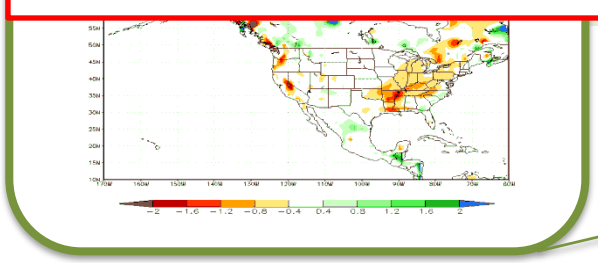
Seasonal Precipitation Forecasts

Dynamic Model Simulations

8 models (99 ensemble members):

- CMC1-CanCM3
- CMC2-CanCM4
- COLA-RSMAS-CCSM4
- GFDL-CM2p1-aer04
- GFDL-CM2p5-FLOR-A06
- GFDL-CM2p5-FLOR-B01
- 0NASA-GMAO-062012
- NCEP-CFSv2





Drought Prediction Framework

Analog-Year Model

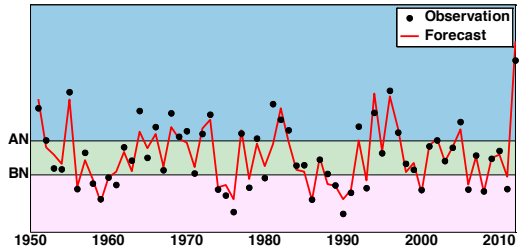
Dynamic Model Simulations

Multi-Model Assessment Using the **Expert Advice (EA)** Algorithm

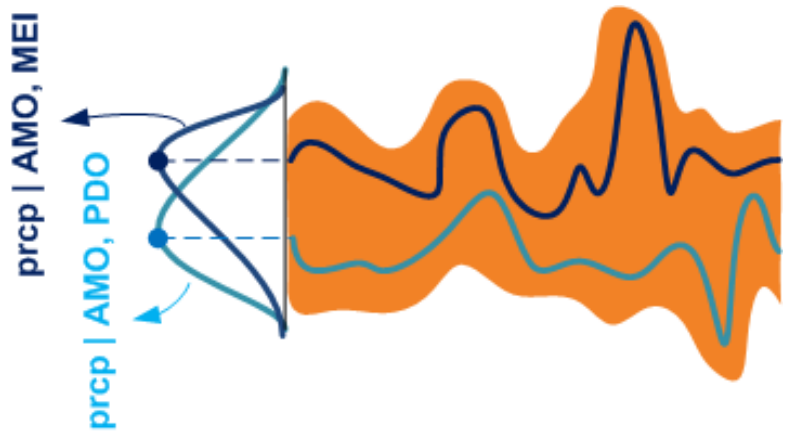
Seasonal Precipitation Forecasts

Analog-Year Model

Analog-Year Model



Prediction based on teleconnections



Dynamic Model Simulations

A Bayesian statistical model based on multivariate probability distribution functions

$$f\left(prcp \mid PDO, MEI, AMO\right)$$

EA Algorithm to Weigh Ens. Members

Mathematics Inside the EA Algorithm

For k=1 to K ensemble members:

$\lambda(\omega,\gamma) = \sum_{o\epsilon\Theta}(\gamma\{o\} - \delta_\omega\{o\})^2 \;\; \delta_\omega \in \{1,0\}$

$w_0^1, w_0^2, \ldots, w_0^K = 1$

$$\phi_n(\omega) = -\ln\left(\sum_{k=1}^{K} w_{n-1}^k \times e^{-\lambda(\omega,\gamma_n^k)}\right)$$

Solve $\sum_{\omega\in\Theta}(s - \phi_n(\omega))^+ = 2, s \in \mathbb{R}$

Set $\gamma_n(\omega) = \frac{(s-\phi_n(\omega))^+}{2} \omega \in \Theta$

$\gamma_n \in \Pr(\Theta)$

$$w_n^k = w_{n-1}^k \times e^{-\lambda(\omega_n,\gamma_n^k)}$$

$E_0^1, E_0^2, \ldots, E_0^K = 0$

Ensemble Member k: $\gamma_n^k \in \Psi$

Climate Response: $\gamma_n \in \Psi$

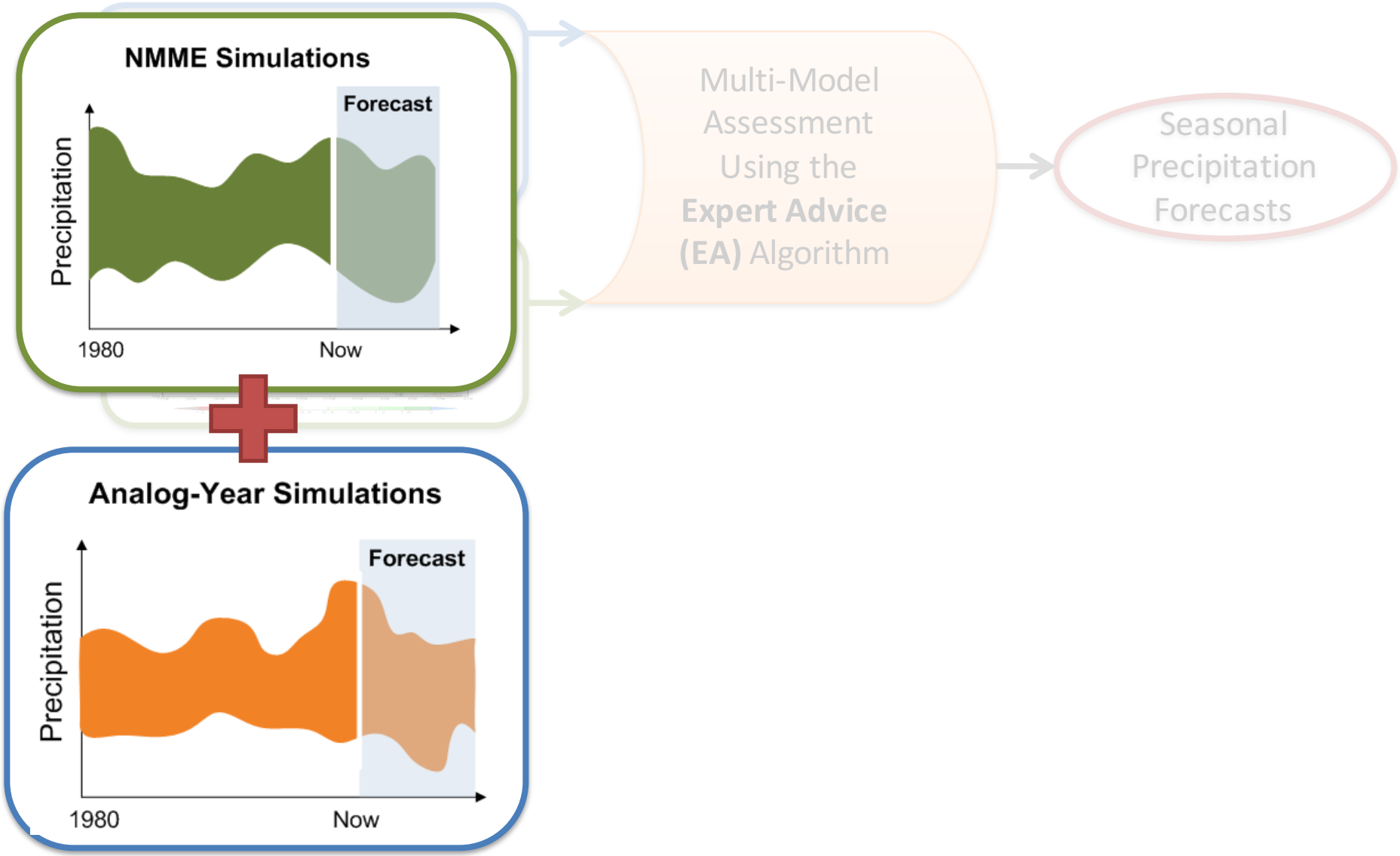
Observation: $\omega_n \in \Theta$

$E_n = E_{n-1} + \lambda(\omega_n, \gamma_n)$

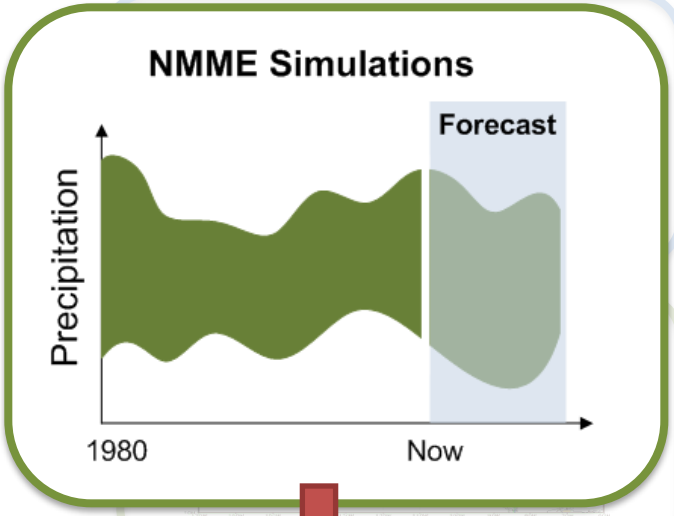
$E_n^k = E_{n-1}^k + \lambda(\omega_n, \gamma_n^k)$

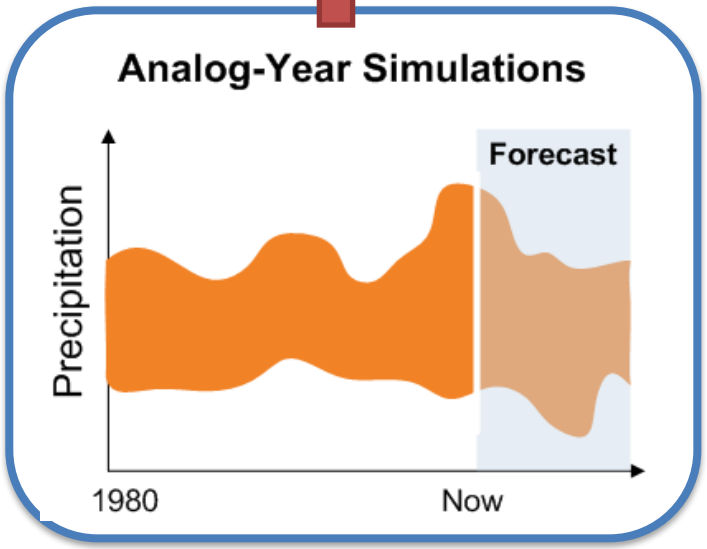
$E_n \leq \min_{k=1\ldots\ldots K} E_n^k + \ln K$

EA Algorithm to Weigh Ens. Members



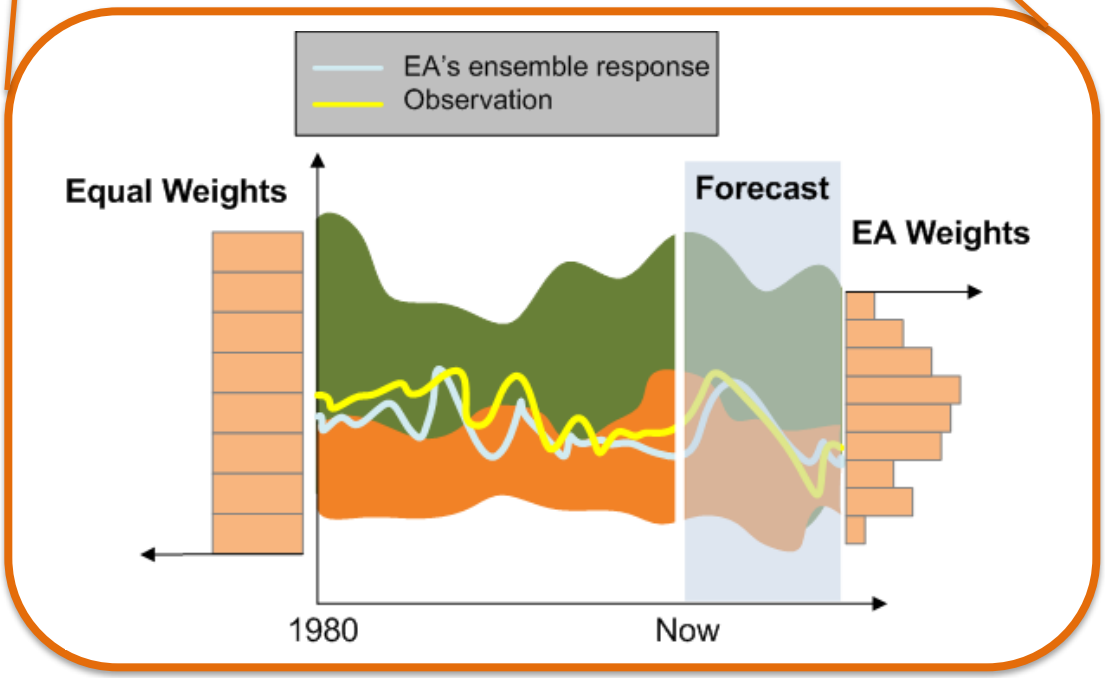
EA Algorithm to Weigh Ens. Members





Multi-Model Assessment Using the **Expert Advice (EA)** Algorithm

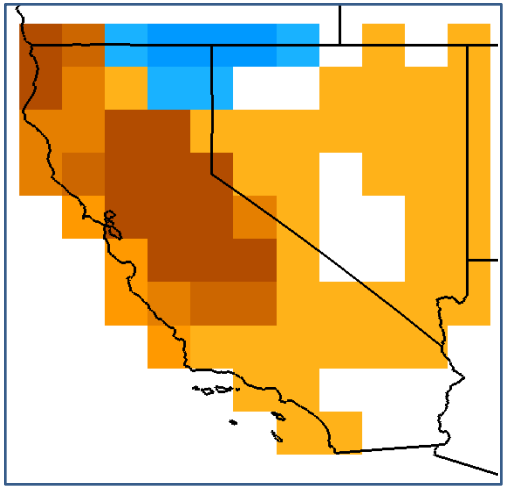
Seasonal Precipitation Forecasts



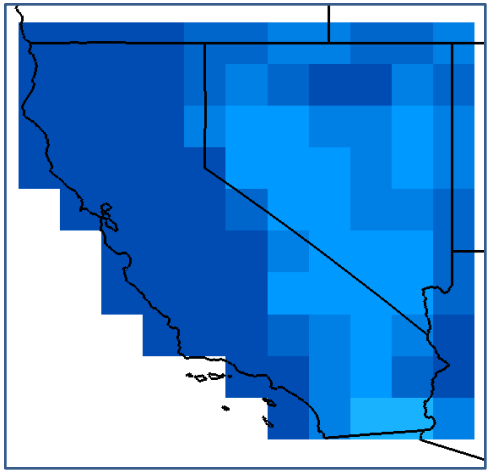
Drought Prediction

NDJ, 2014

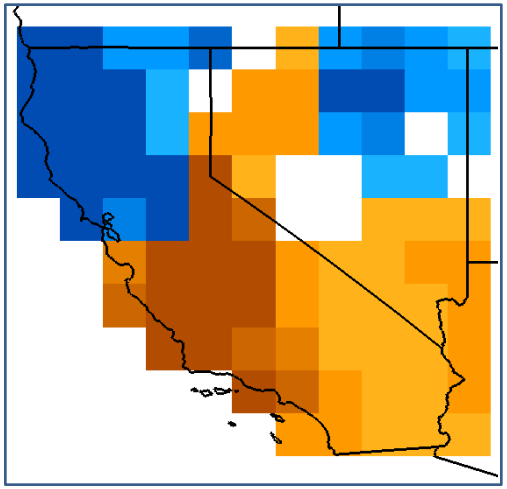
Observation

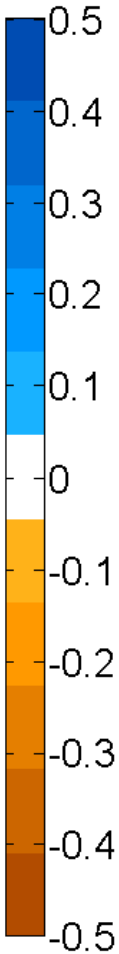


NMME (Ensemble mean)



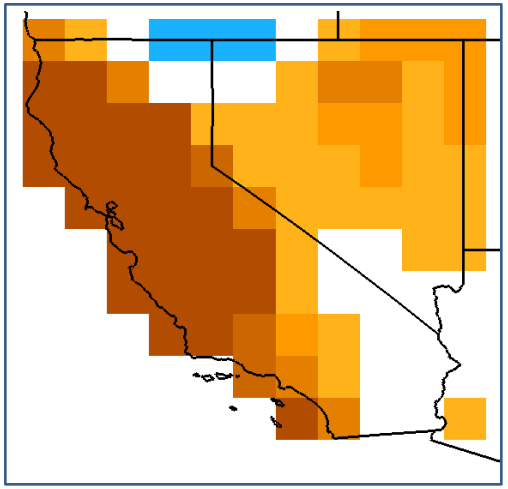
NMME + Analog-Year + EA



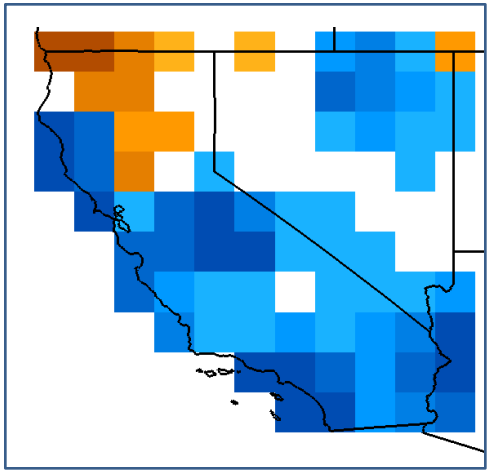


NDJFM, 2014

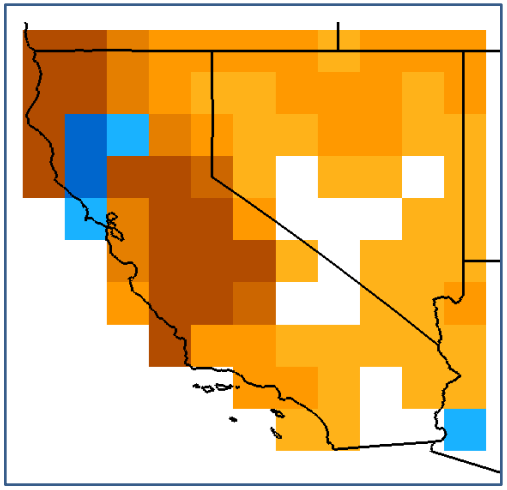
Observation

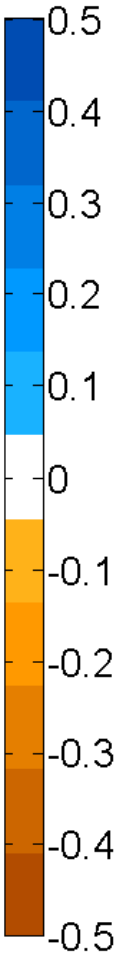


NMME (Ensemble mean)



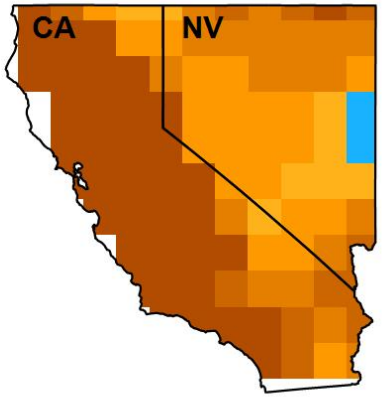
NMME + Analog-Year + EA



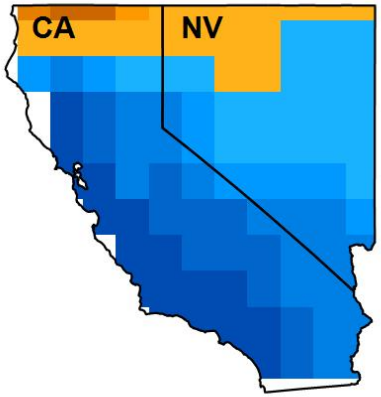


Drought Prediction

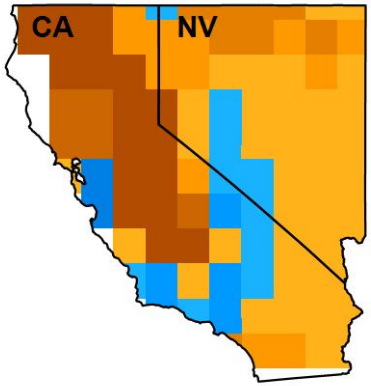
JFM (2006-07), Obs



JFM (2006-07), NMME

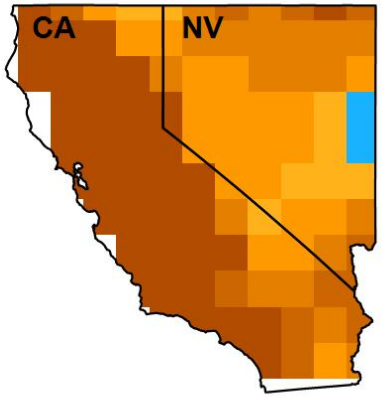


JFM (2006-07), Hybrid

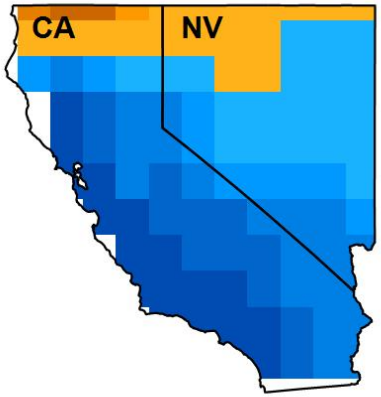


Drought Prediction

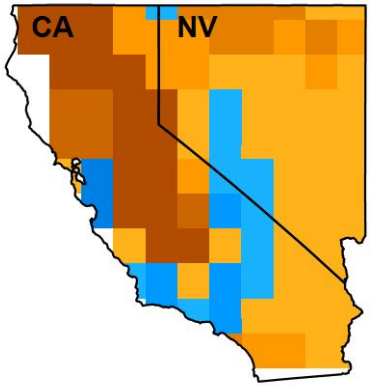
JFM (2006-07), Obs



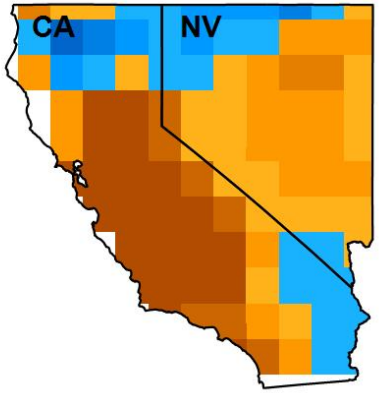
JFM (2006-07), NMME



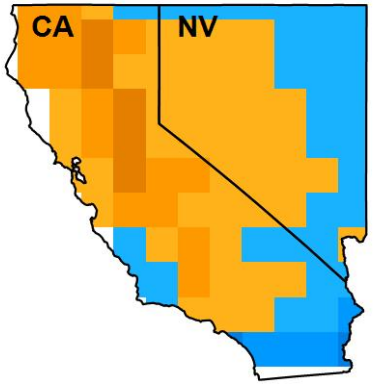
JFM (2006-07), Hybrid



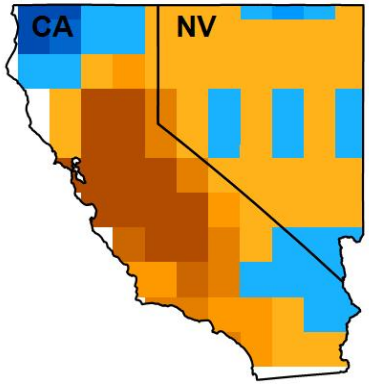
DJF (2014-15), Obs

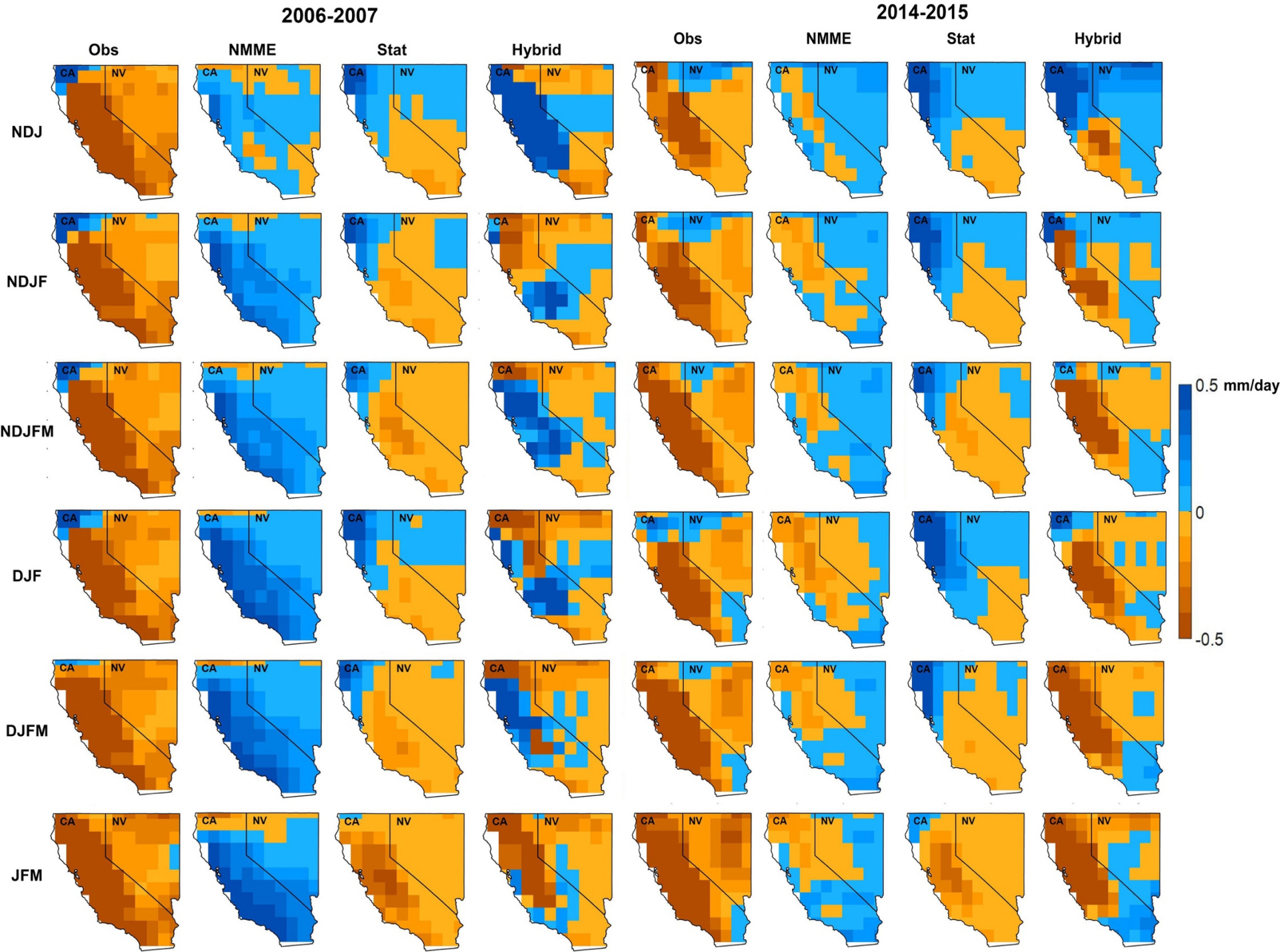


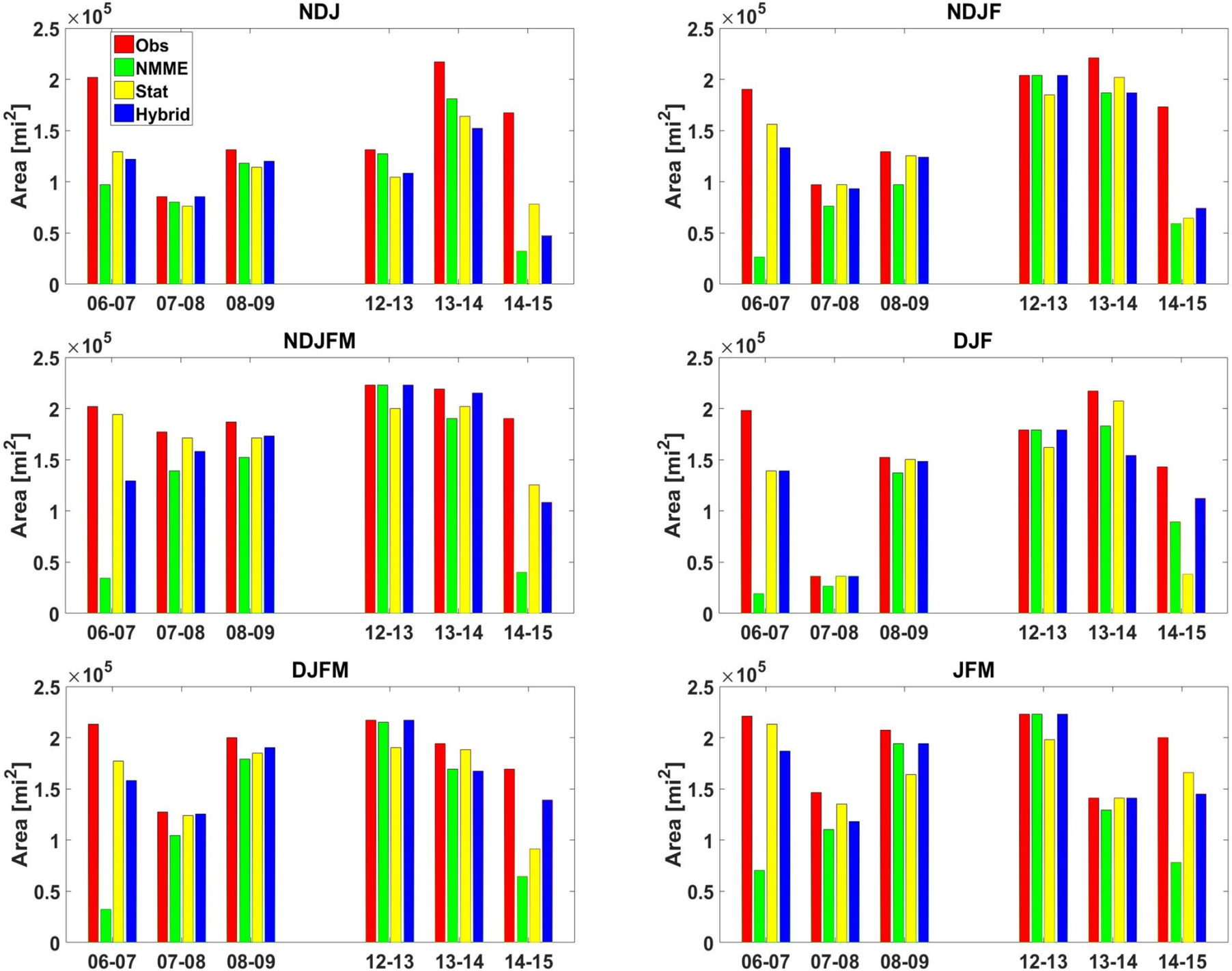
DJF (2014-15), NMME



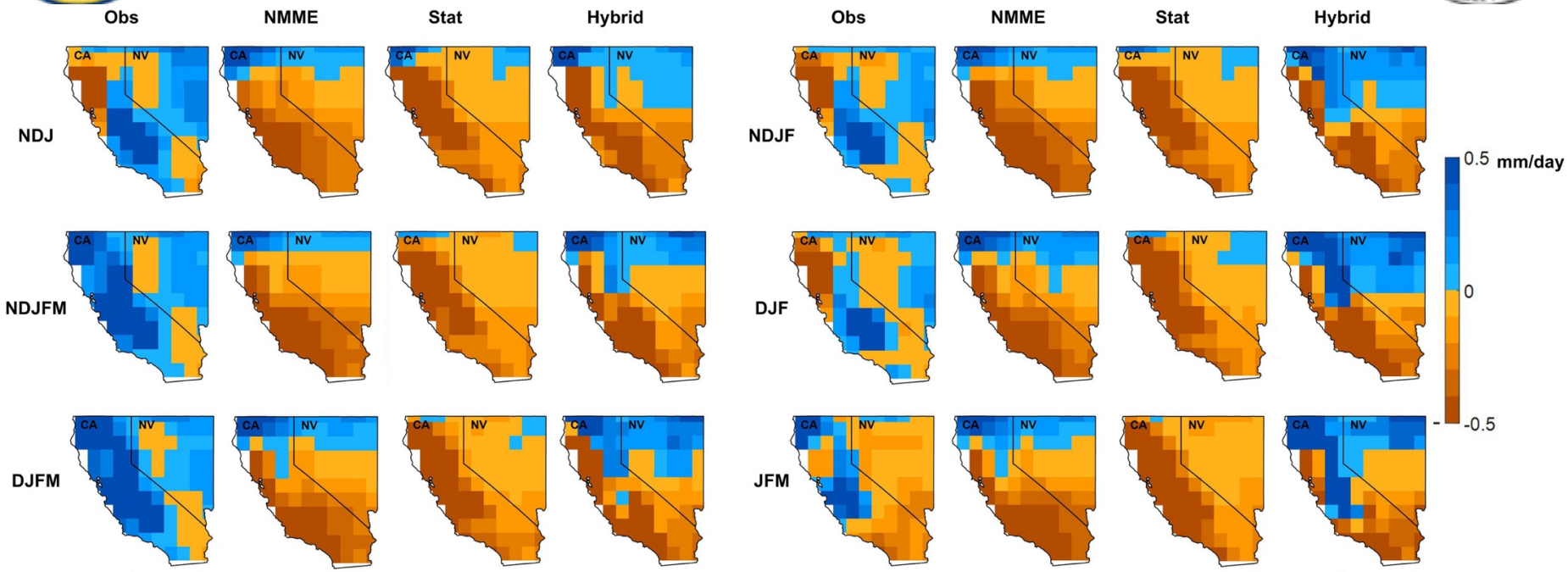
DJF (2014-15), Hybrid

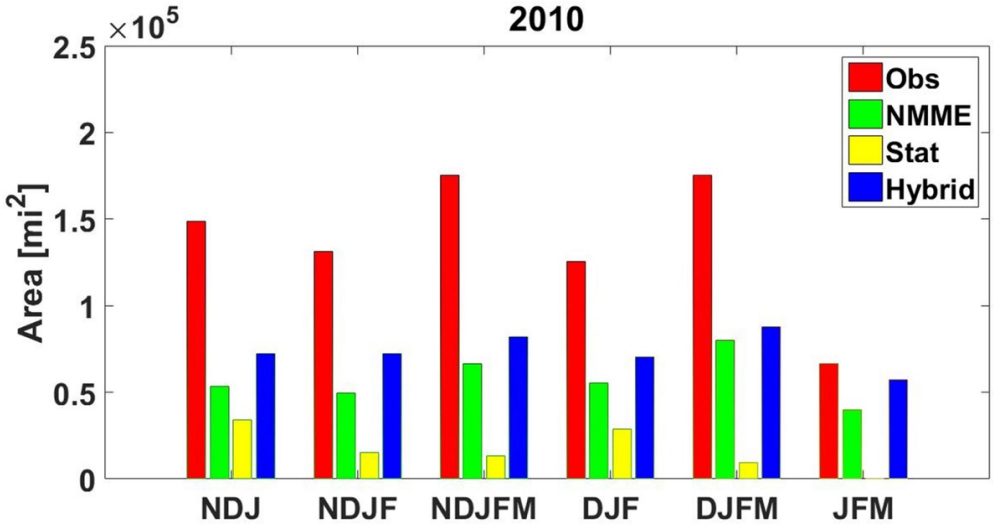



2006-2007
2014-2015
Obs
NMME
Stat
Hybrid
Obs
NMME
Stat
Hybrid
NDJ
NDJF
NDJFM
DJF
DJFM
JFM
CA
NV
0.5 mm/day
0
-0.5


NDJ
NDJF
NDJFM
DJF
DJFM
JFM
Obs
NMME
Stat
Hybrid
Area [mi^2]
$\times 10^5$
0
0.5
1
1.5
2
2.5
06-07
07-08
08-09
12-13
13-14
14-15

Drought Prediction





Summary

- ✓ Both dynamical and statistical precipitation forecast models have limited skill at seasonal to inter-seasonal scales in some regions, e.g. Southwest US.
- ✓ The proposed hybrid climate forecasting model combines the potentials of dynamical and statistical models and finds the best prediction based on the historical performance of each model.
- ✓ Overall, the hybrid framework performs better in predicting negative precipitation anomalies (10-60% improvement over NMME) than positive precipitation anomalies (5-25% improvement over NMME).

Madadgar S., AghaKouchak A., Shukla S., Wood A.W., Cheng L., Hsu K., Svoboda M., 2016, A Hybrid Statistical-Dynamical Drought Prediction Framework: Application to the Southwestern United States, *Water Resources Research*, 52 (7), 5095-5110

Questions?

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