Prototype statistical seasonal prediction to support California DWR decision

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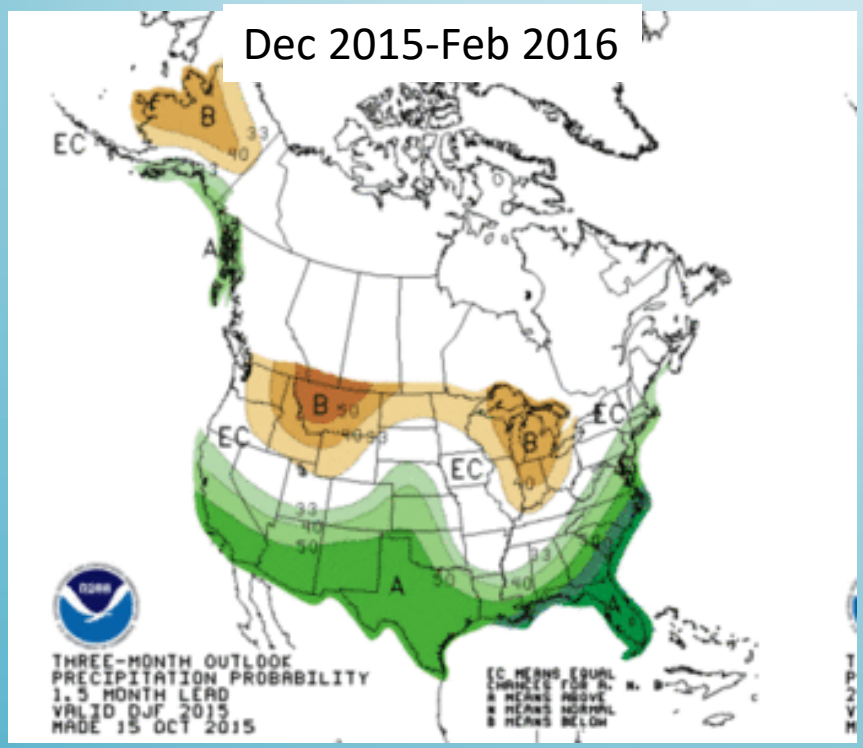
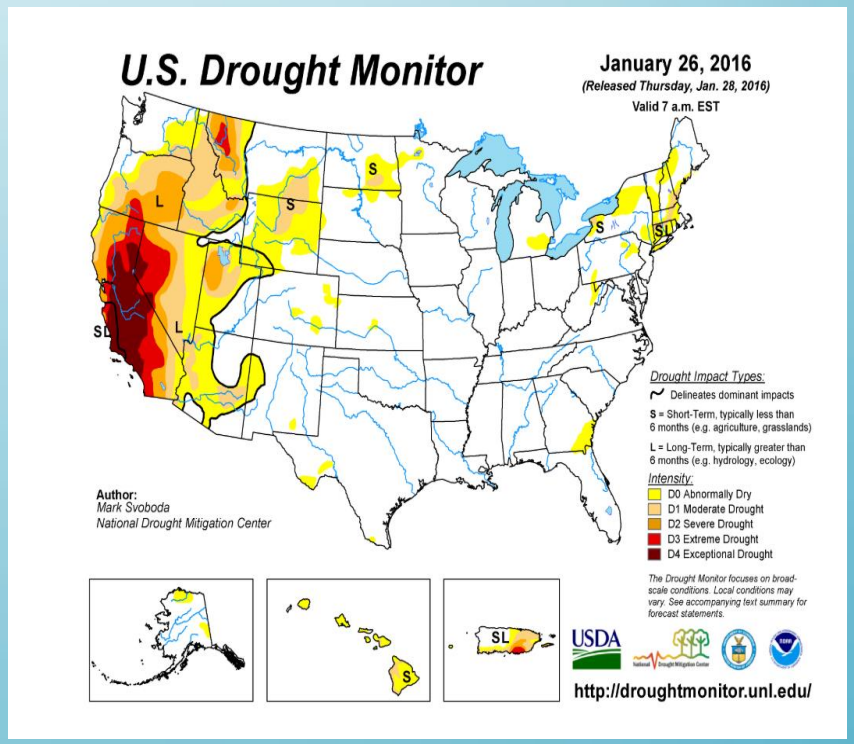
DWR S2S Workshop, San Diego
May 22st – 25nd, 2019

Why do we need statistical seasonal prediction?

Seasonal Forecast initialized in Oct. 2015

Observation, Jan 2016





Is California winter rainfall anomaly predictable on seasonal scale?

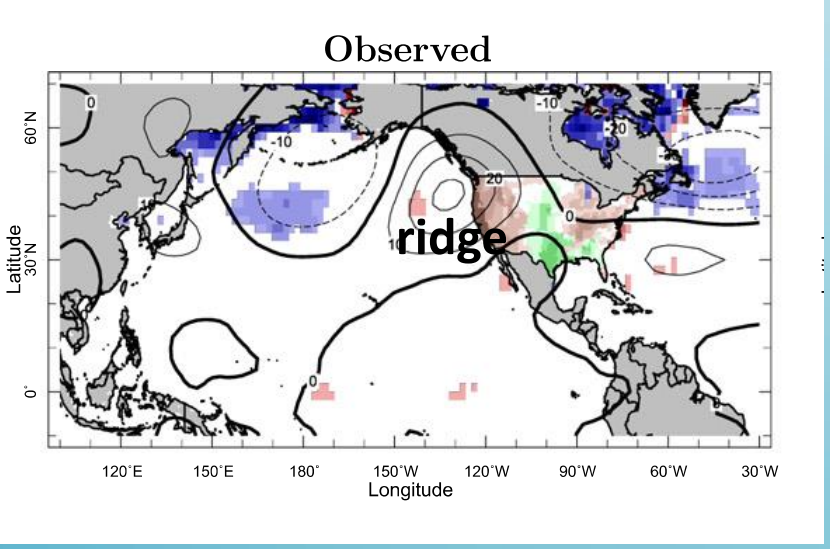
What control California Winter Rainfall?

- *Middle and upper tropospheric ridge/trough in NE Pacific*
  - *ENSO, PDO (e.g., Cayan et al. 1999; Dettinger et al. 1998; Mason & Goddard 2001; Gershunov and Cayan 2003; Wang and Schubert 2014; Seager et al. 2015)*
- *Atmospheric river, contribute 30-50% of total rainfall over US west coast (e.g., Ralph et al 2004; Dettinger 2013)*
- *Warmer surface temperature (e.g., AghaKouchak et al. 2014)*
- *Sea Ice melting (e.g., Lee et al. 2015; Sewall and Sloan 2004*

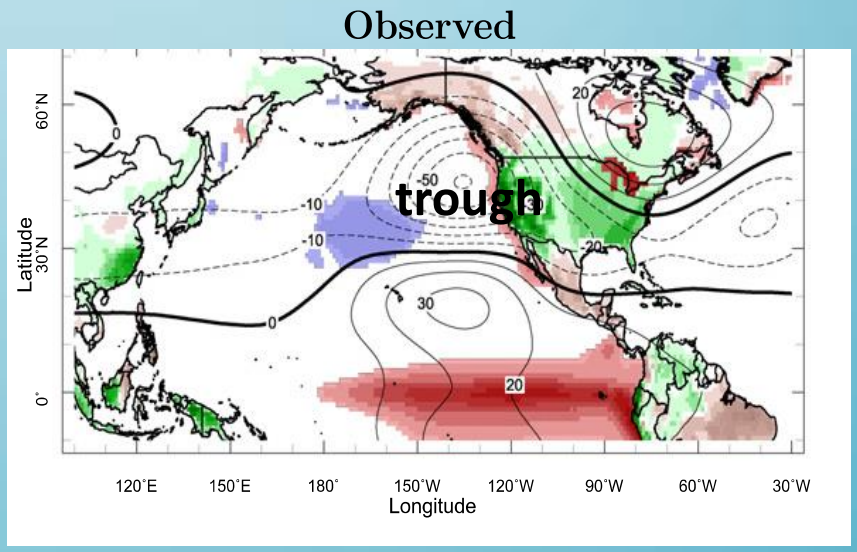
Anomalous patterns of the Large scale upper-level (200 Pa) circulation associated with the drier and wetter winters over California

- ***Drier winters: Ridge over the NE Pacific***
- ***Wetter winters: trough over the NE Pacific***

Composite for 15% driest winter



Composite for wet winters

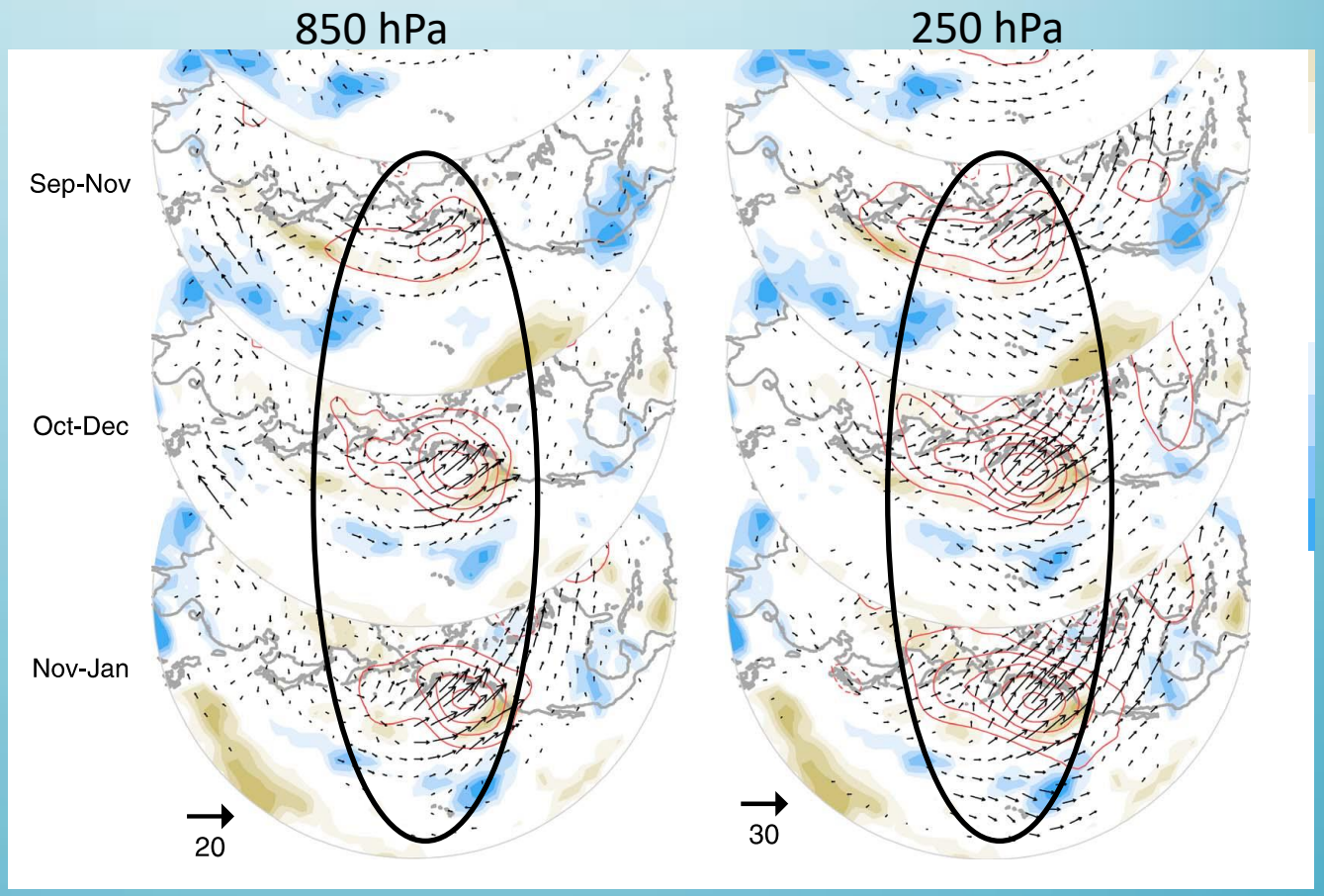


Seager et al. 2015

Observed persistence for the anomalous ridge or trough over the NE Pacific

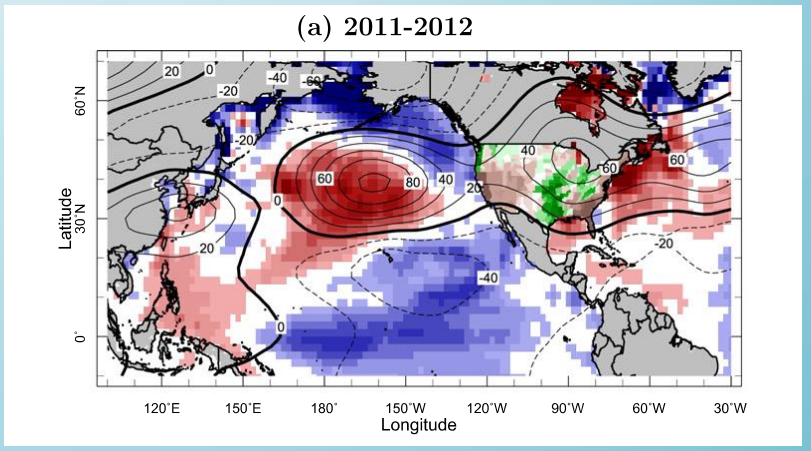
- ***Wang et al. 2014: The anomalous ridge over the NE Pacific began in fall (Sept-Nov) in 2013 (a pre-cursors of El Nino, instead of a result of El Niño).***

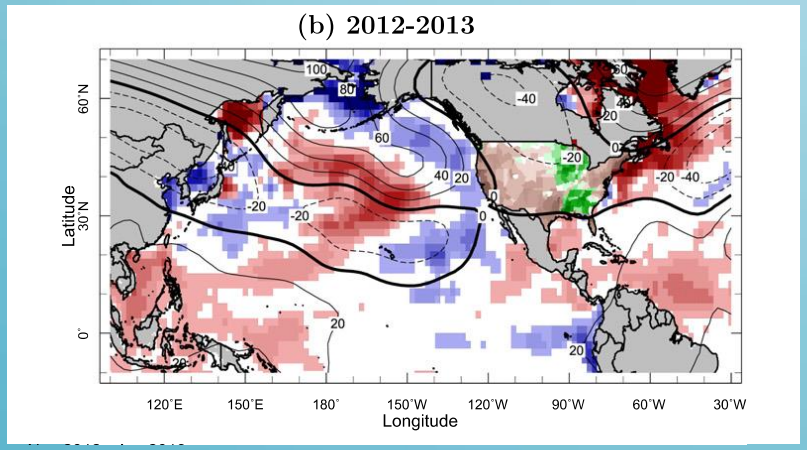
2013-2014 anomalies of geopotential height (contours), OLR (shades) and wave fluxes (vectors)

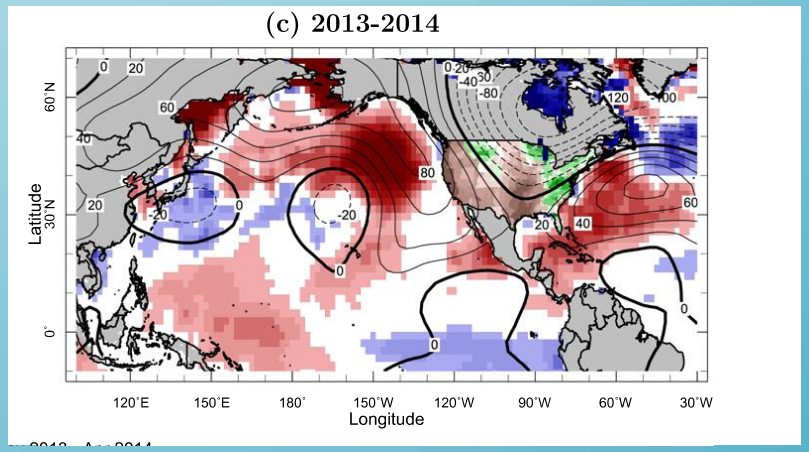


Teng & Branstator 2017: extreme ridges originate from mid-latitude atmospheric internal variability. Tropical diabatic heating anomalies are not essential, but can double the probability of the extreme ridges.

Extreme ridges can vary in structure, instead of following classical PNA pattern, as we expect from the ENSO influence





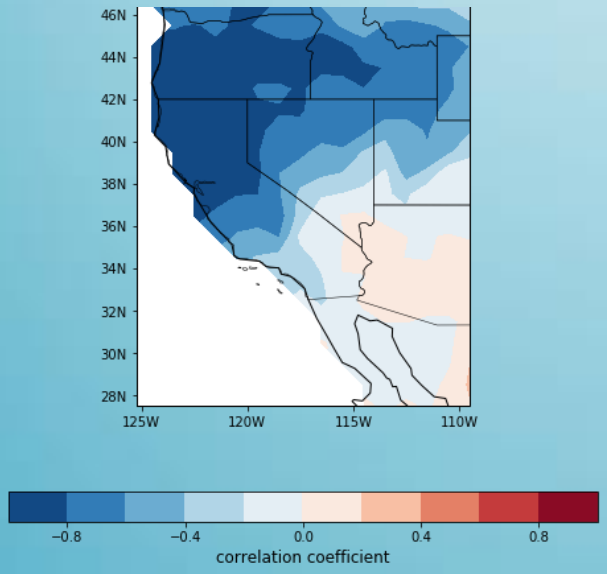


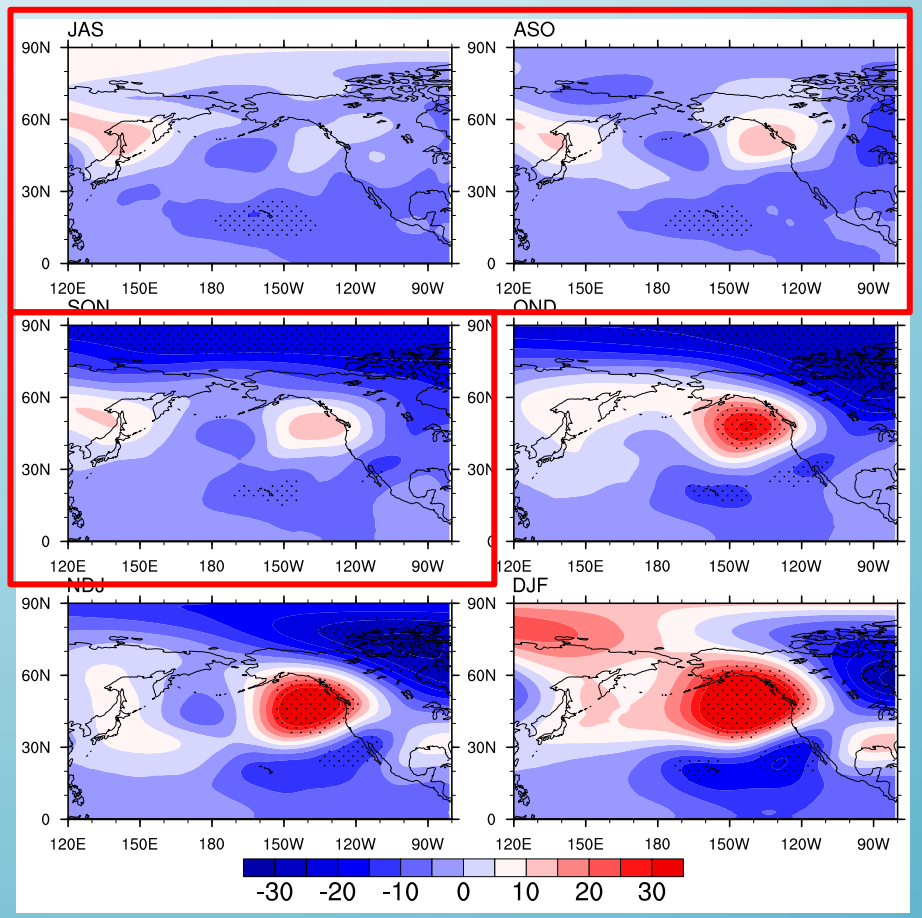
Seager et al. 2015

Searching for potential source of predictability for California rainfall anomalies

- **Large-scale anomalous atmospheric circulation pattern associated with the EOF1 of the winter rainfall begins in late summer to fall, and persistent through winter season.**
- **A potential source of seasonal predictability**

EOF1: 62% of the total variance

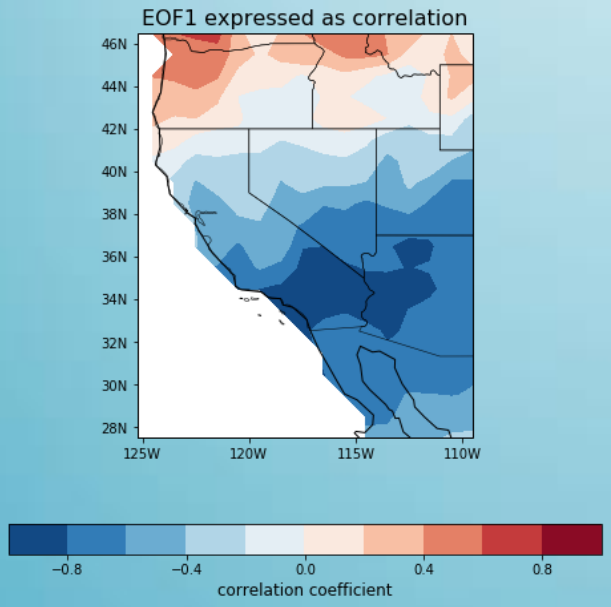


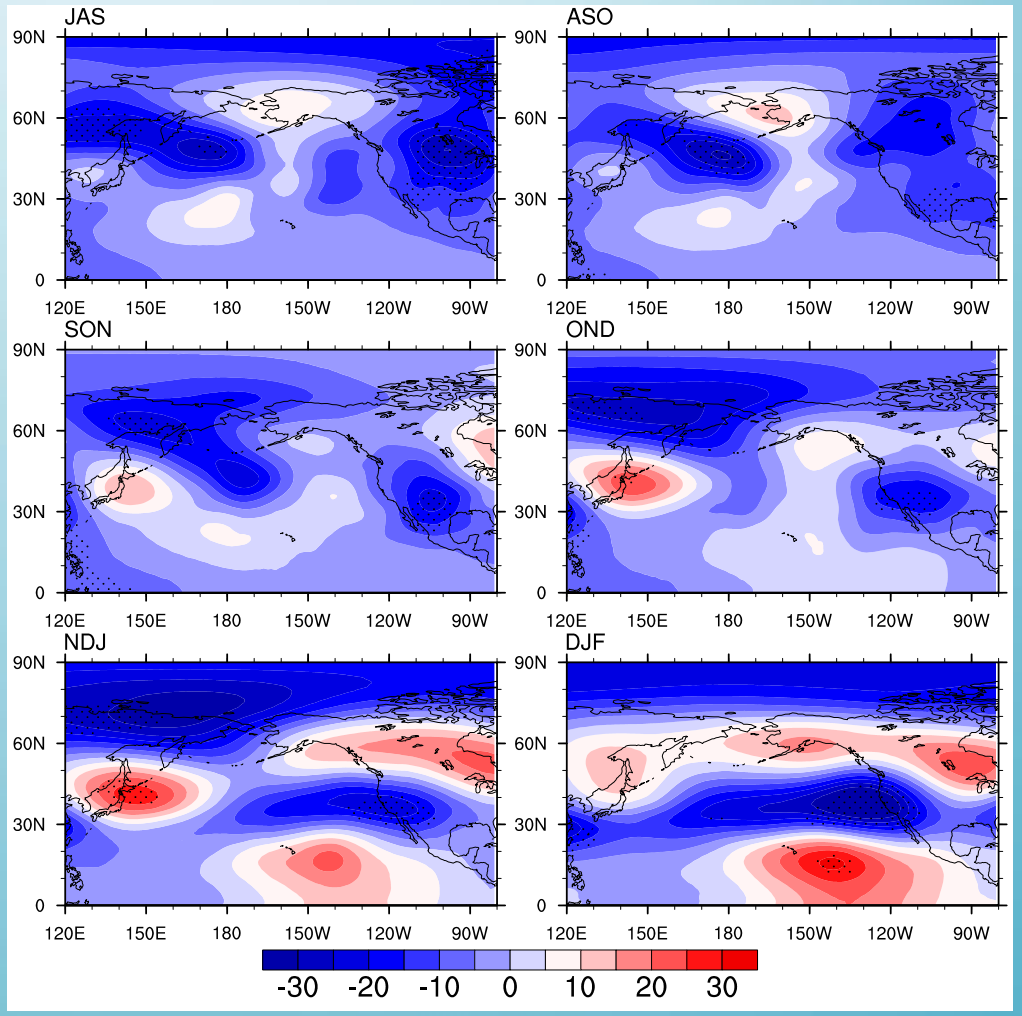


200 hPa geopotential height anomalies

- Large-scale anomalous atmospheric circulation pattern associated with the EOF2 of the winter rainfall does not show seasonal scale persistence.
- Does not provide seasonal predictability

EOF2: 19% of the total variance



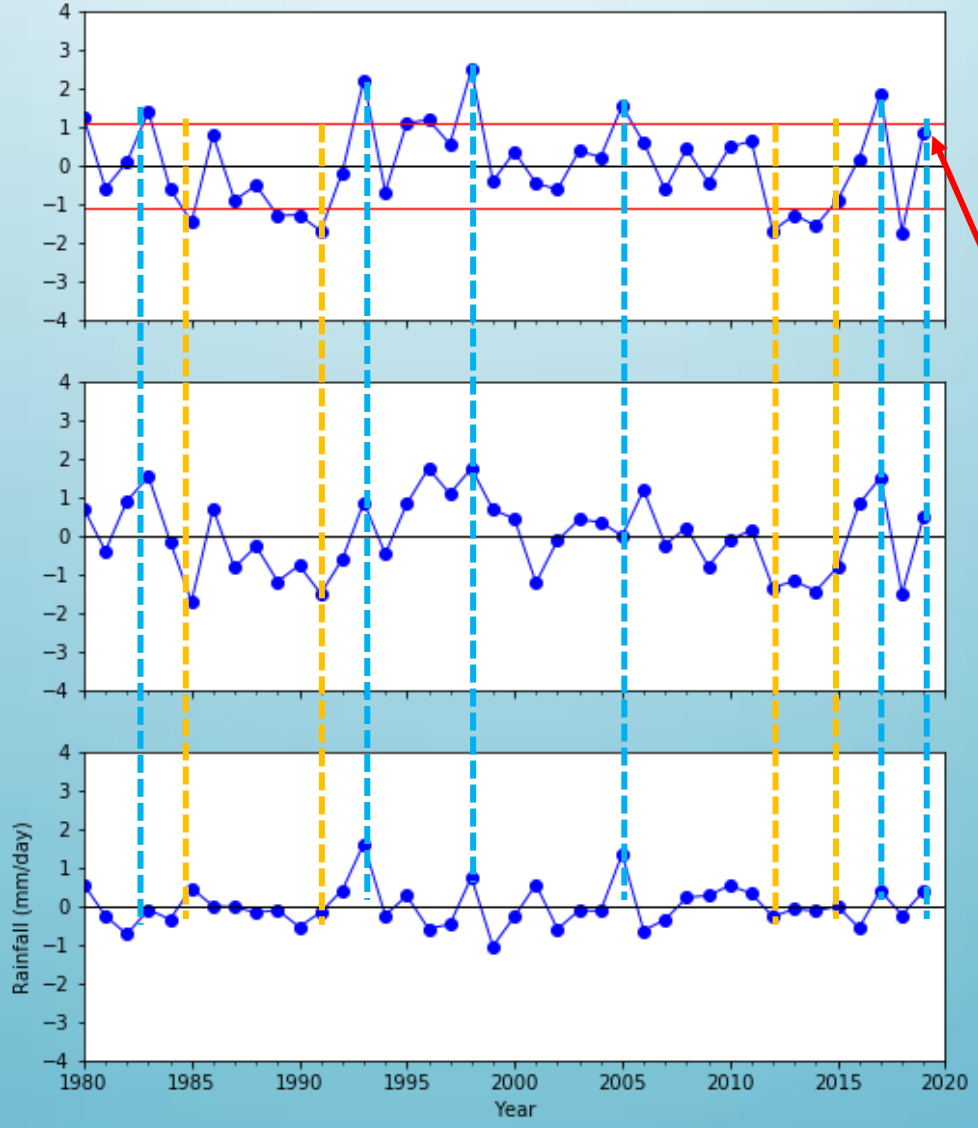


How do these two modes of rainfall variability contribute to dry and wet winters?

CA winter rainfall anomalies

EOF1 reconstructed winter rainfall anomalies

EOF2 reconstructed winter rainfall anomalies.



+/- 1 sigma

CA area-average

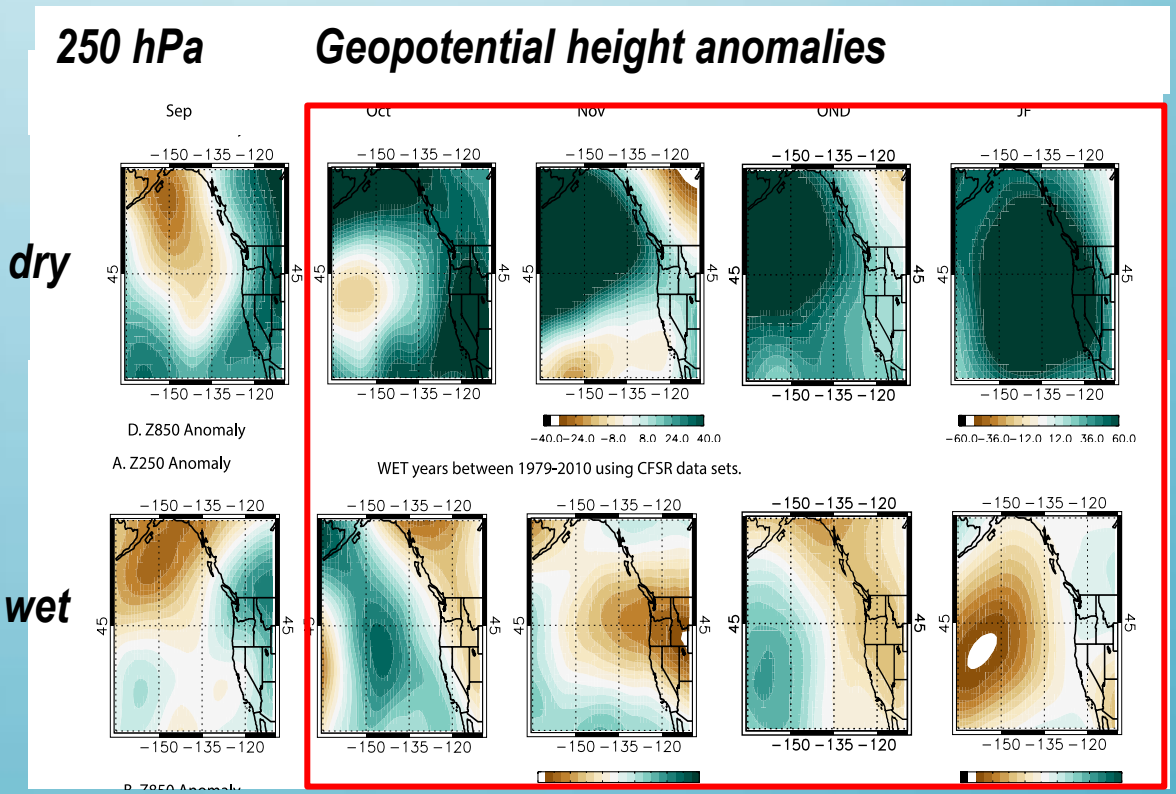
Dec 2018- Feb 2019

Observed pre-conditions in fall preceding the dry and wet winters, respectively, over the California/Nevada region

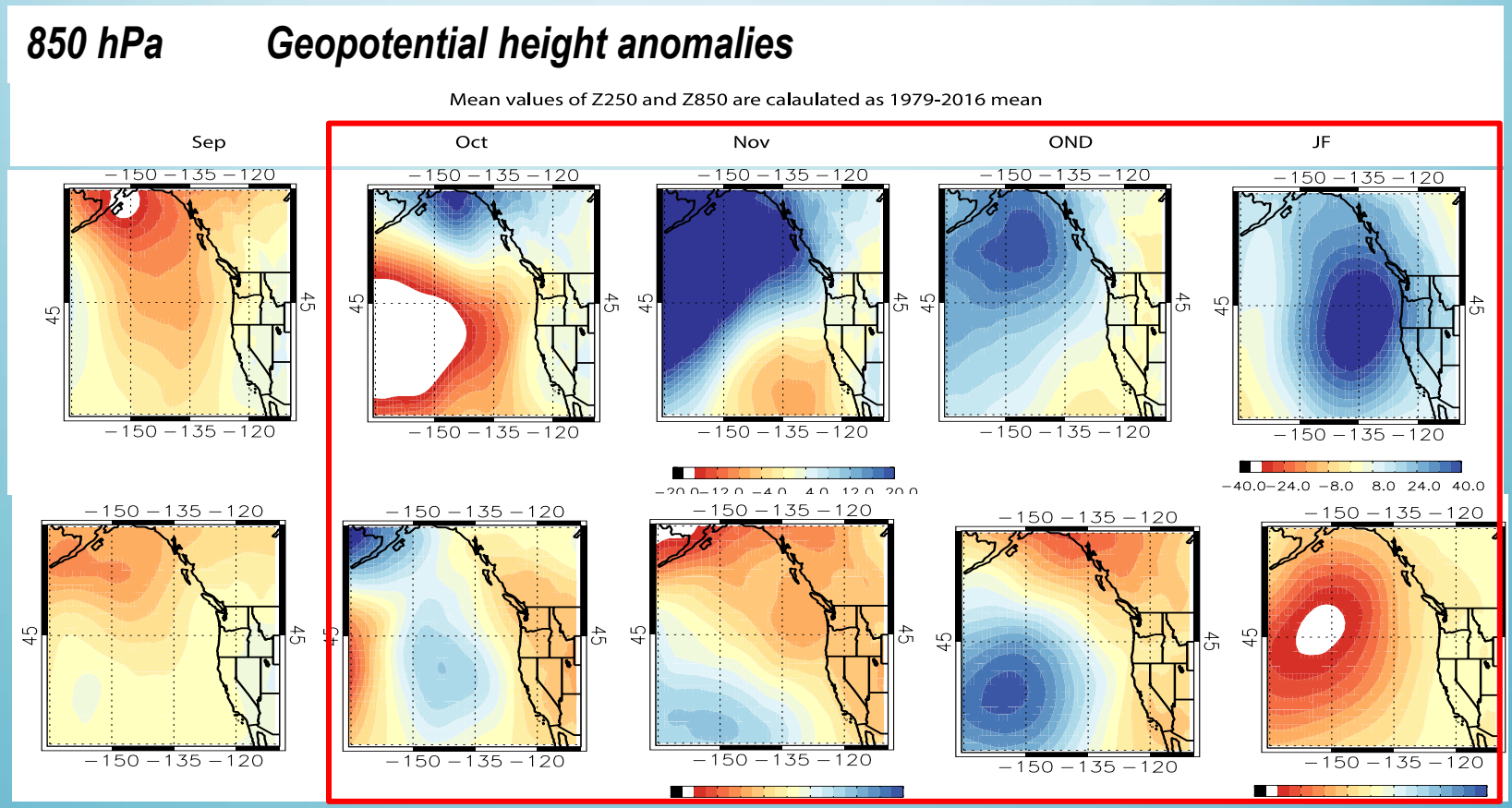
- *The anomalous upper tropospheric circulation patterns between the anomalous dry and wet winters (December-February) become clearly distinguishable in October and afterward.*

Dry winters: persistent ridge and anomalous high pressure center off the North American west coast starting in November.

Wet winters: alternation between anomalously high and low pressure centers related to propagating planetary waves from Sept to February.



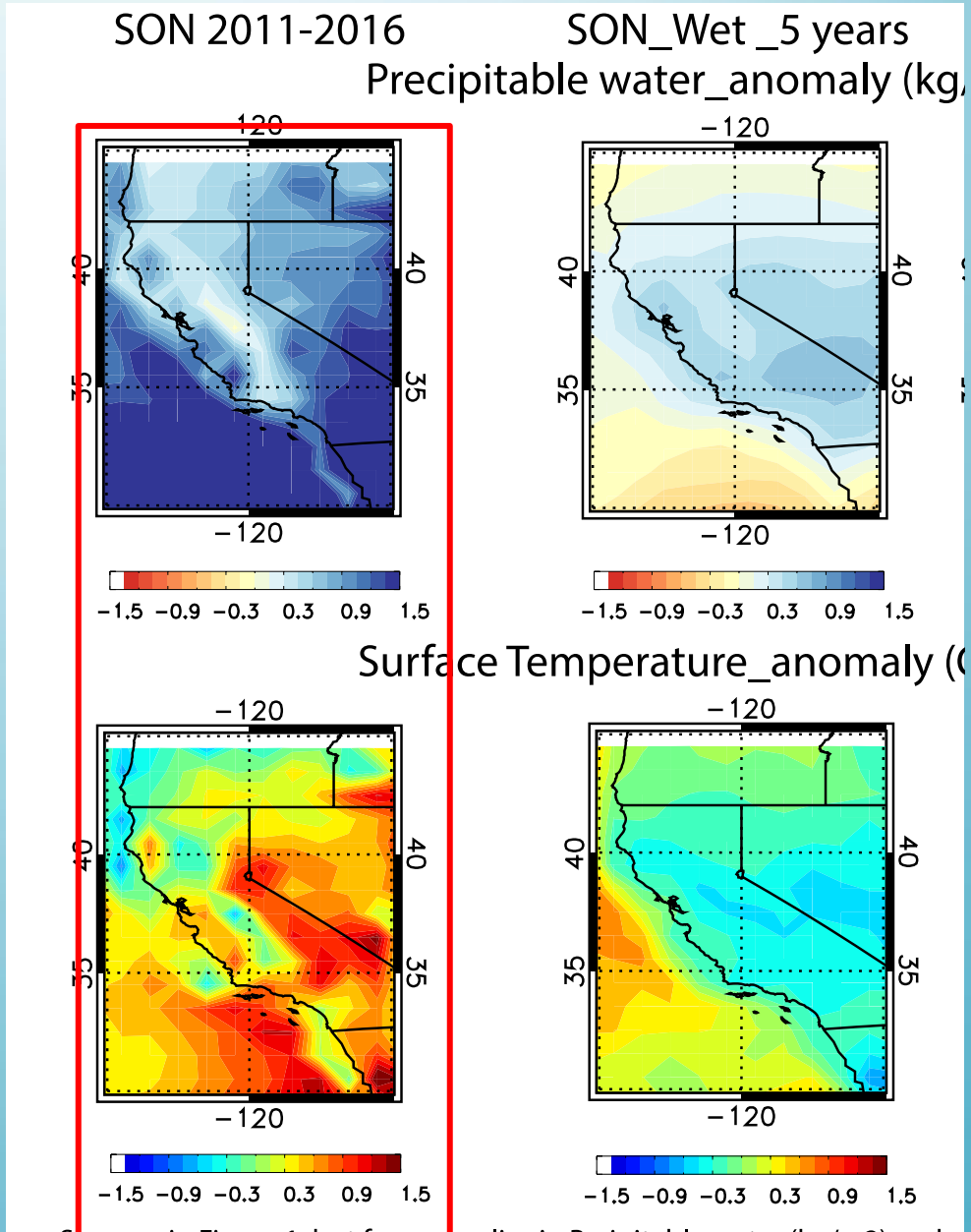
- ***The lower tropospheric anomalous circulation patterns between the anomalous dry and wet winters (December-February) also become clearly distinguishable in October and afterward.***



Observed pre-conditions in fall for drier and wetter winter

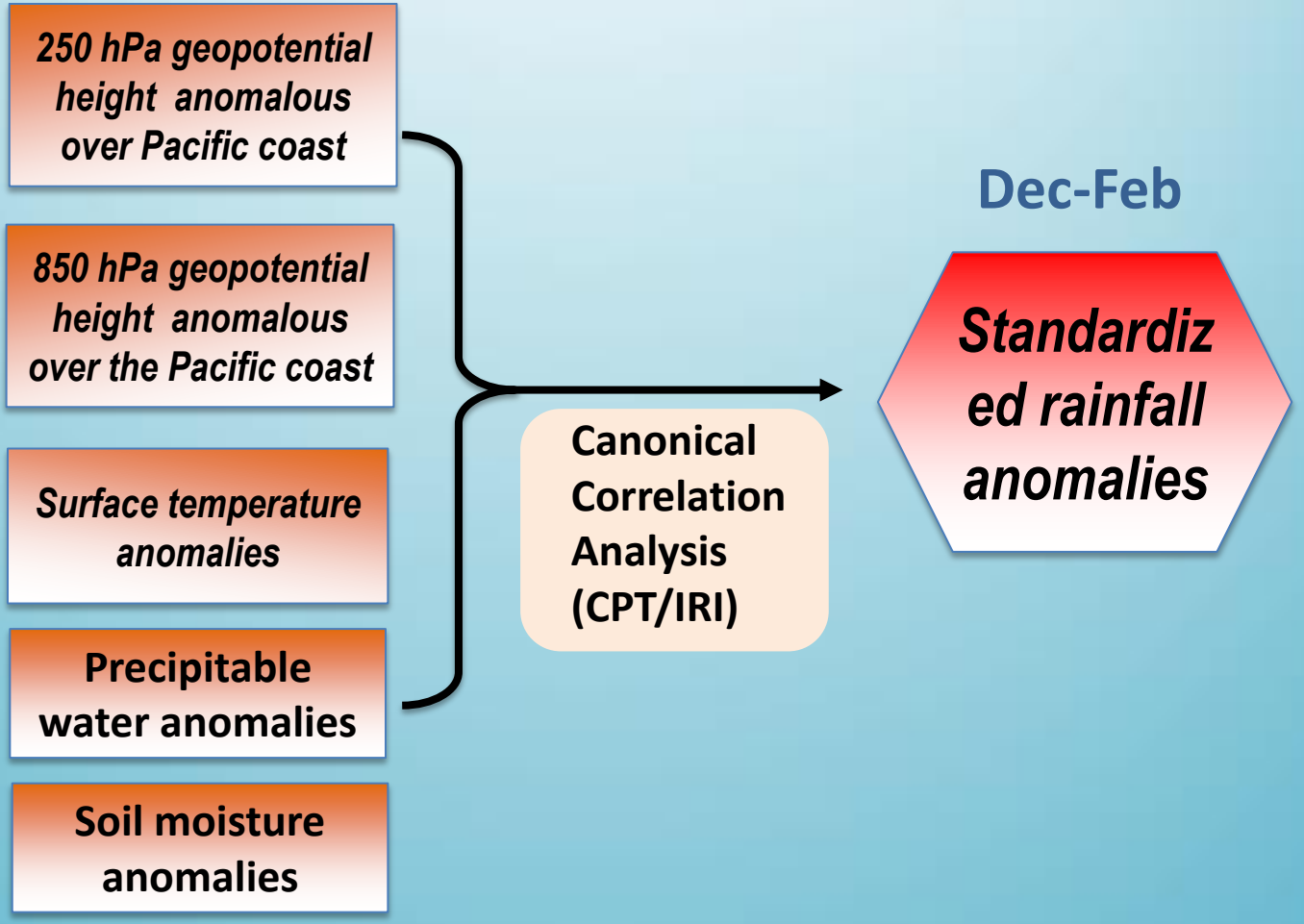
Dry winters: preceded by higher sea surface temperature and moisture in the atmosphere off the coast of S. California, and warmer surface temperature over CA/NV except over the central valley in Fall (Sept-Nov).

Wet winters: preceded by cooler surface temperature and high humidity over CA/NV, lower humidity over ocean off coast of S. California in fall.



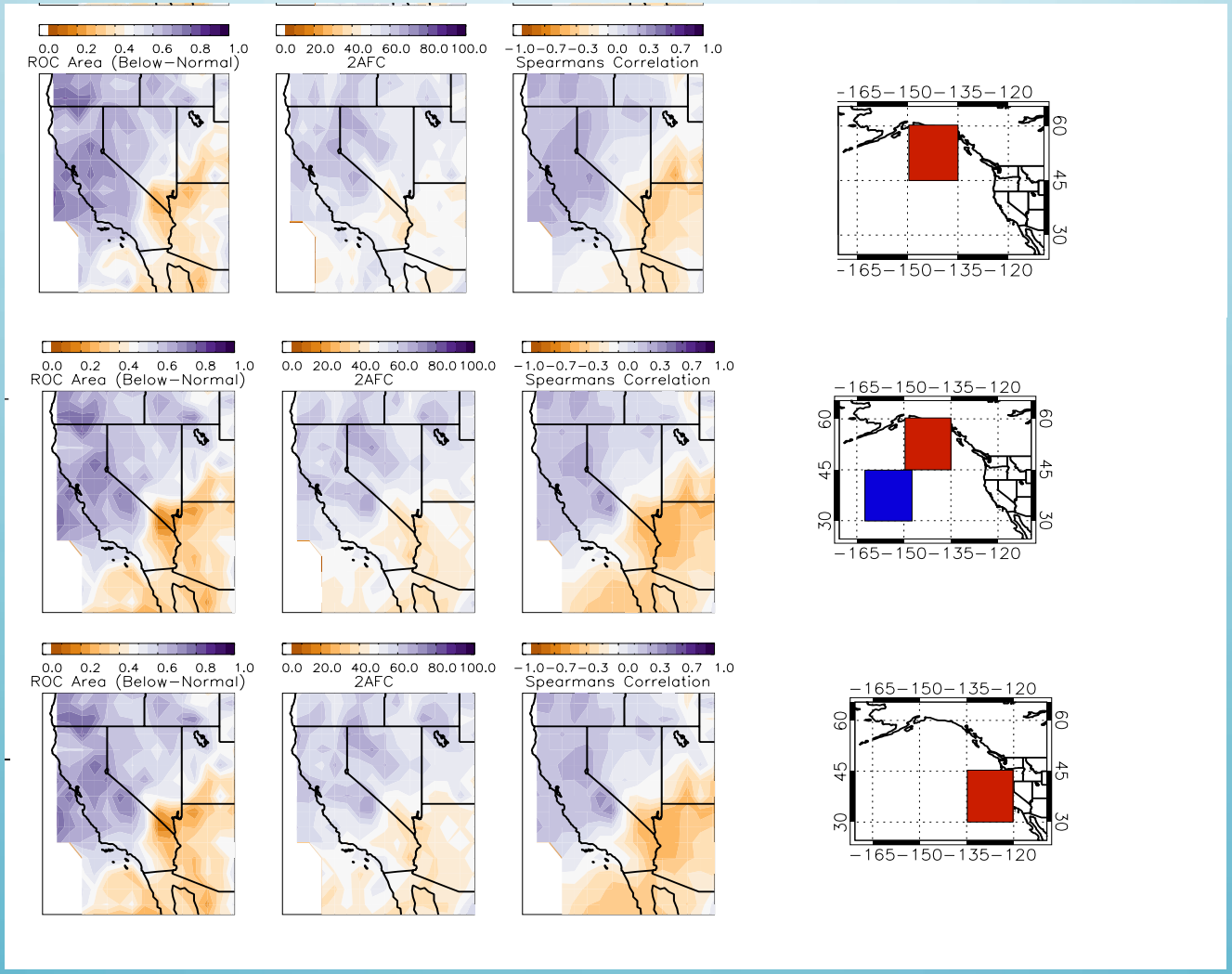
The statistical prediction model

Oct, Nov. NOAA CFSv2 realtime forecasts

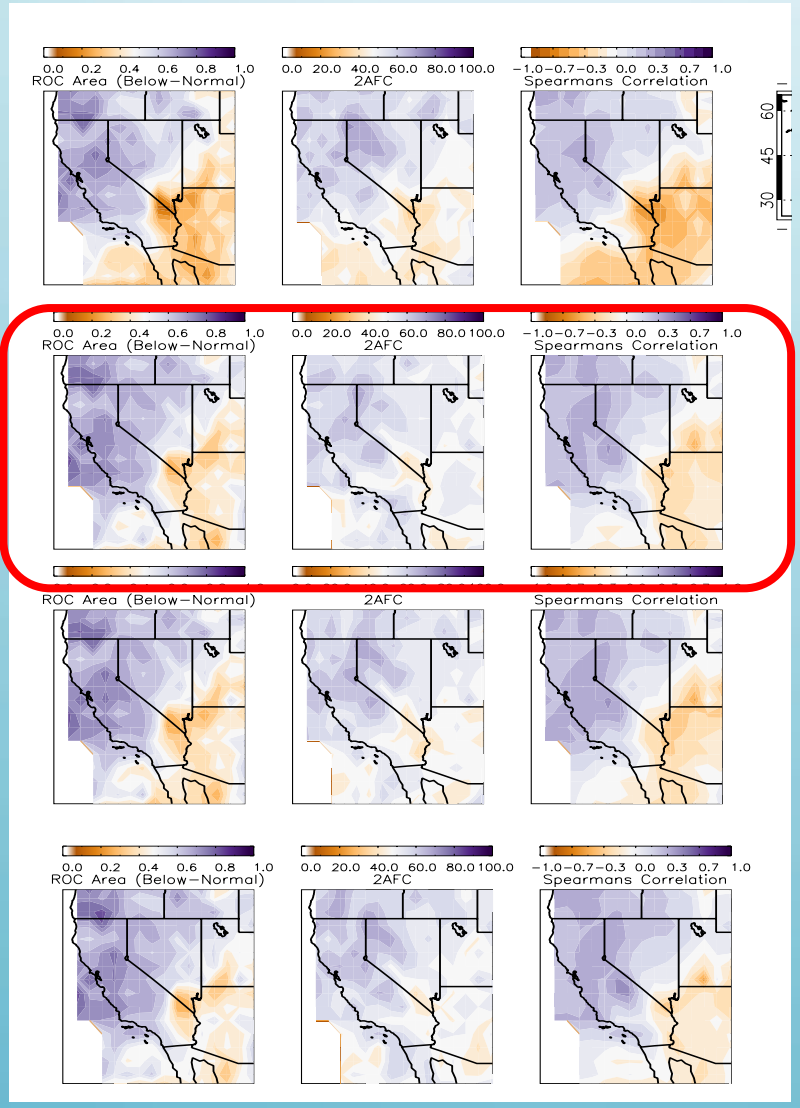


Trained by CFSR and CPC rainfall data for the period of 1980-2010
CFSv2 realtime forecast after 2010, including initializing the forecasts.

- ***The NE Pacific domain for large-scale circulation predictor provides the best overall prediction skill***



Prediction skills for various lead times:

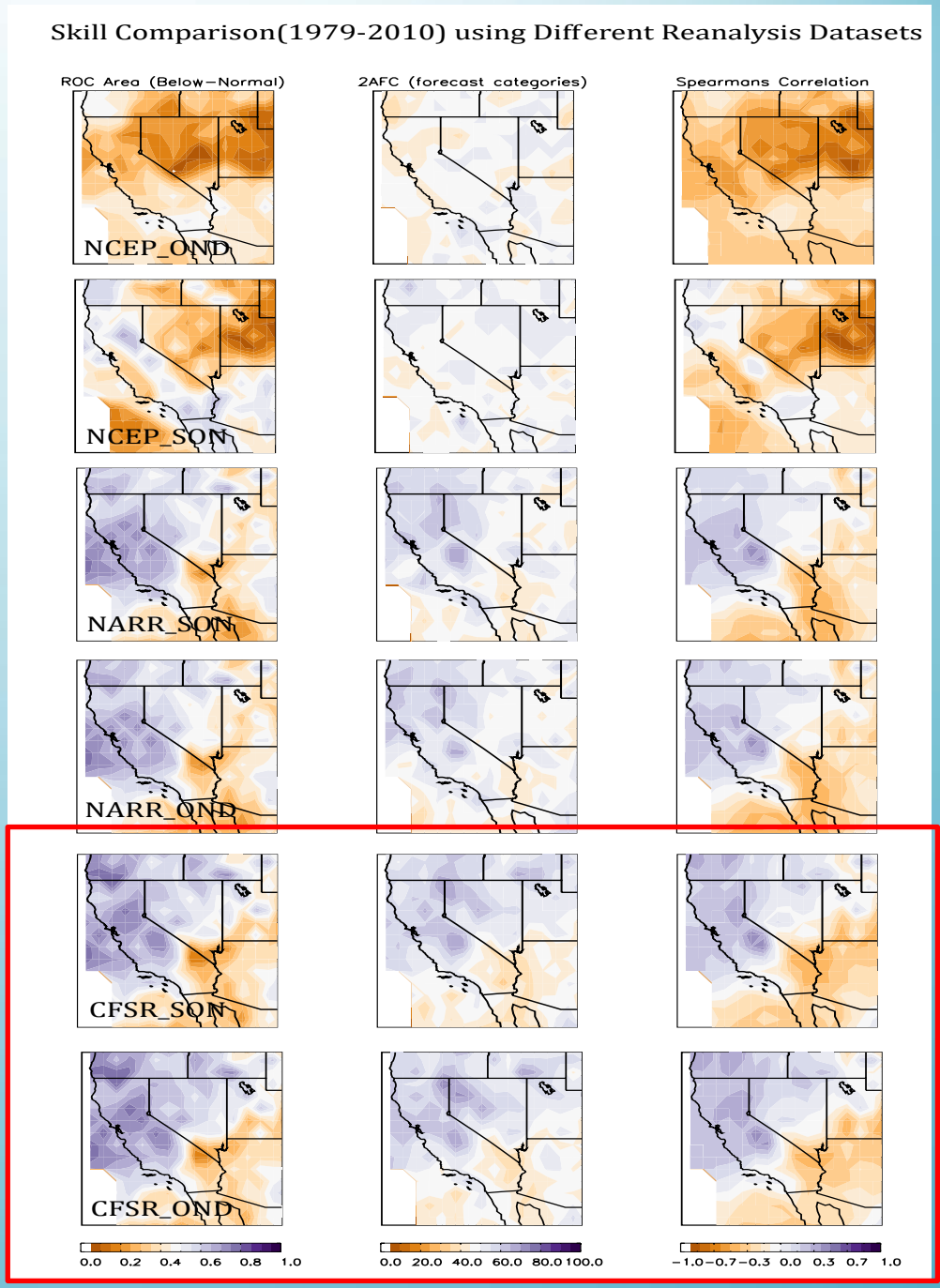


Can potentially provide prediction of Dec-Feb rainfall in the first week of Nov, 6-7 weeks before Christmas time to support mid-year adjustment decision

Relative to 1979-2010 climatology
3 point cross-validation

Sensitivity of the prediction skills to inputs data

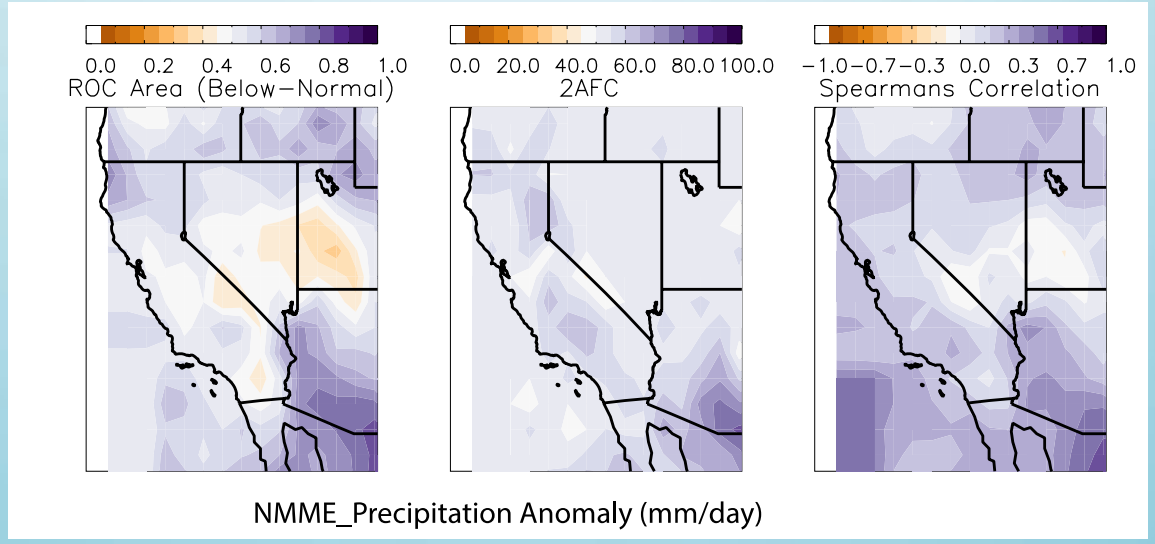
- *CFSR as input provides the highest prediction skills*
- *CFSv2 realtime forecast is used for seasonal prediction*



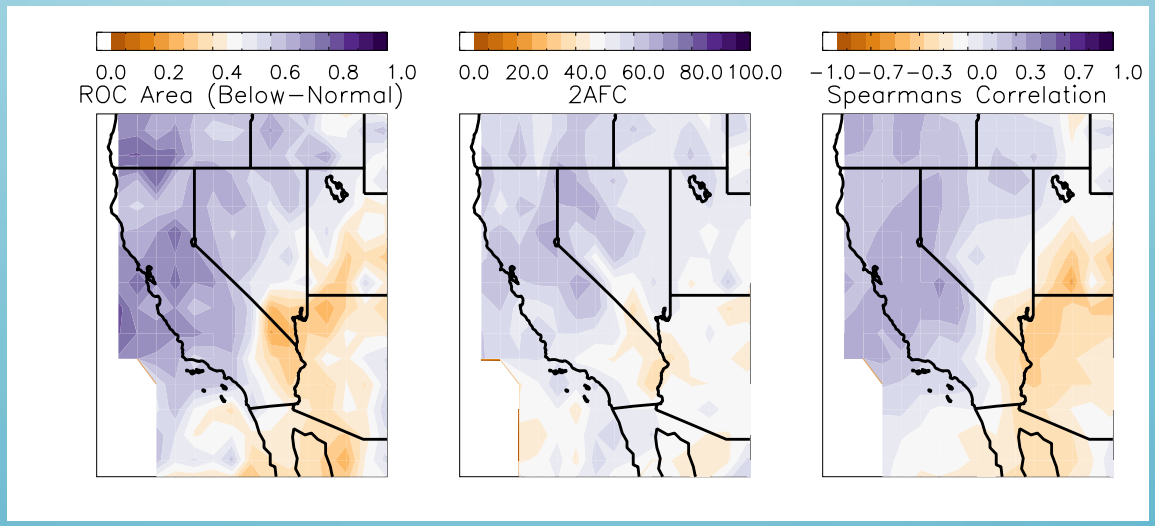
Compare to NOAA NMME prediction skills (initialized in Oct, for Dec-Feb standardized rainfall anomalies)

ROC | 2AFC | Spearmans correlation

NMME



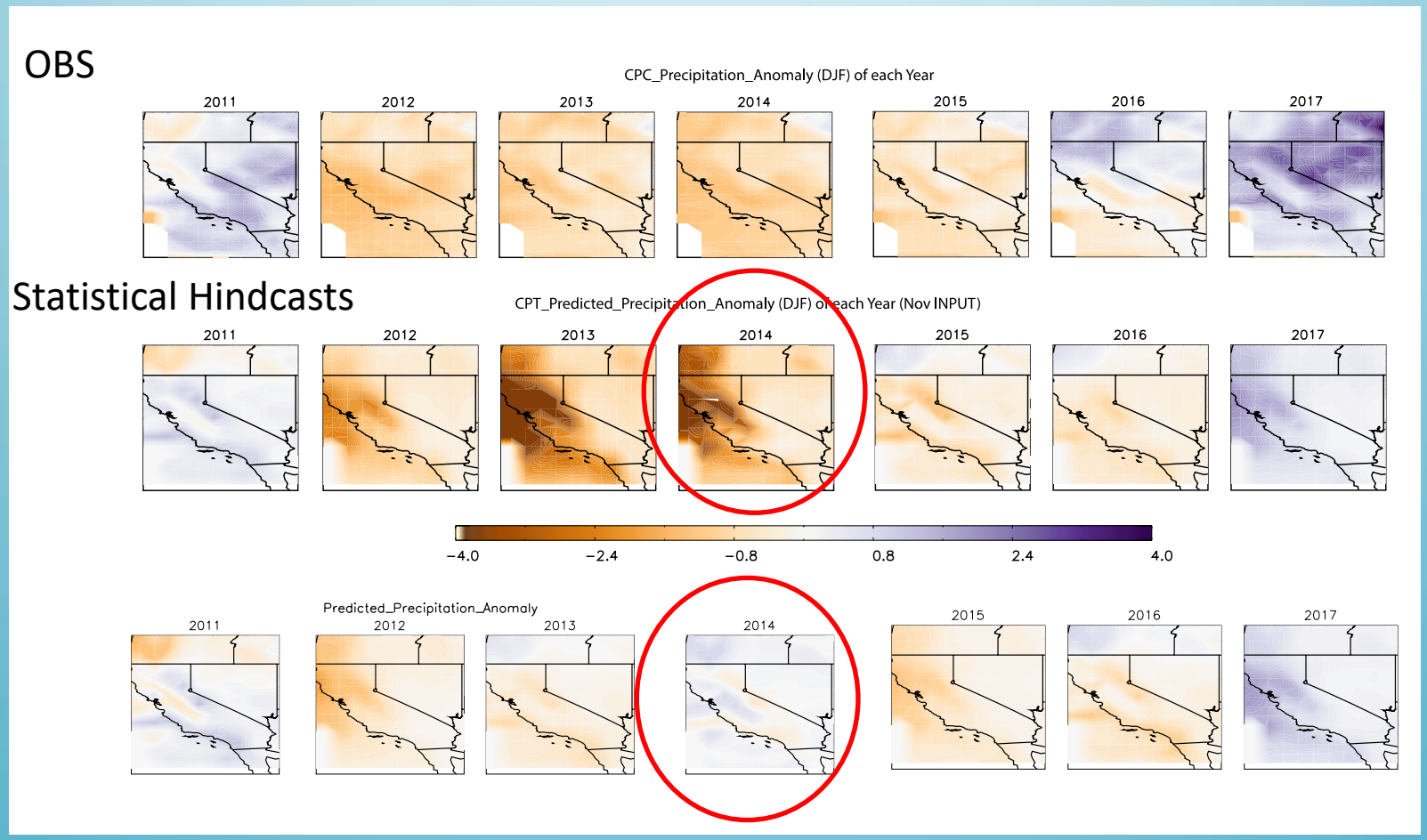
Statistical



1979-2016

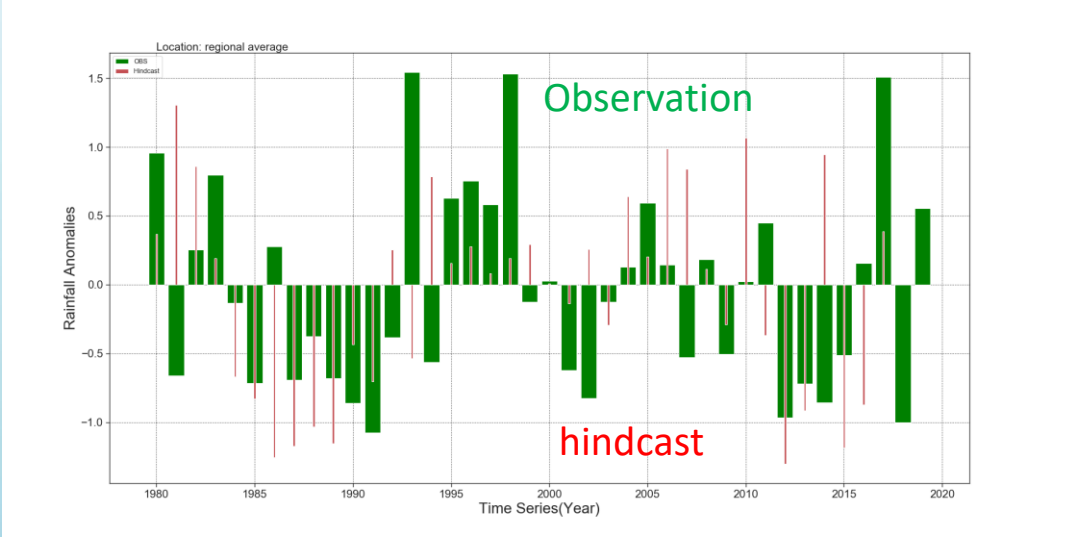
Hindcasts for 2012-2017 winter rainfall anomalies initialized using Oct. and Nov inputs

- Using Nov input can improve prediction from that using Oct input
- Thus, provides updated prediction based on Nov input in early December can improve the accuracy of the winter rainfall prediction

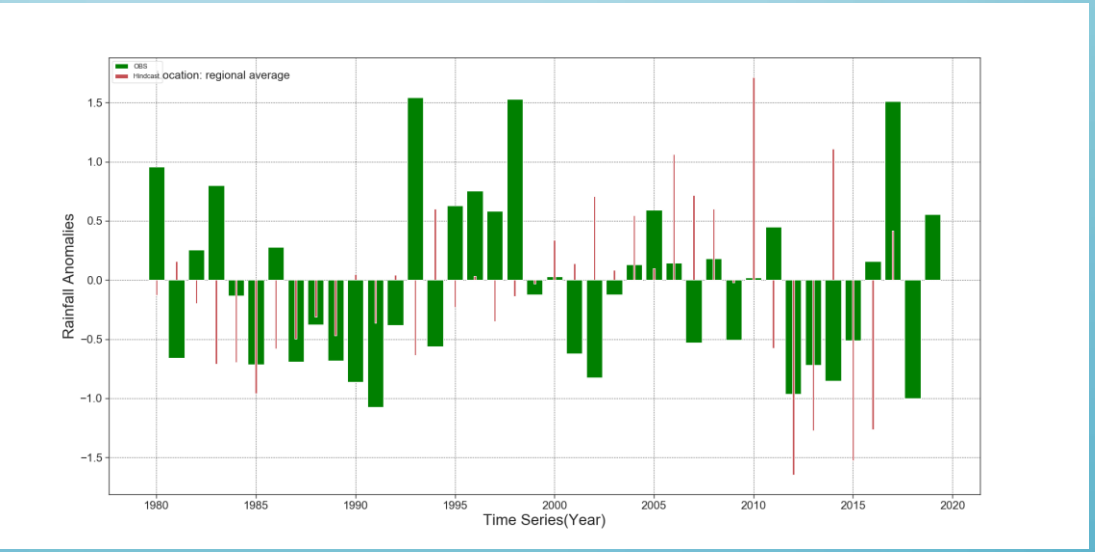


Hindcasts of December-February rainfall anomalies initialized in October

The years of the hindcasts are excluded in training the model



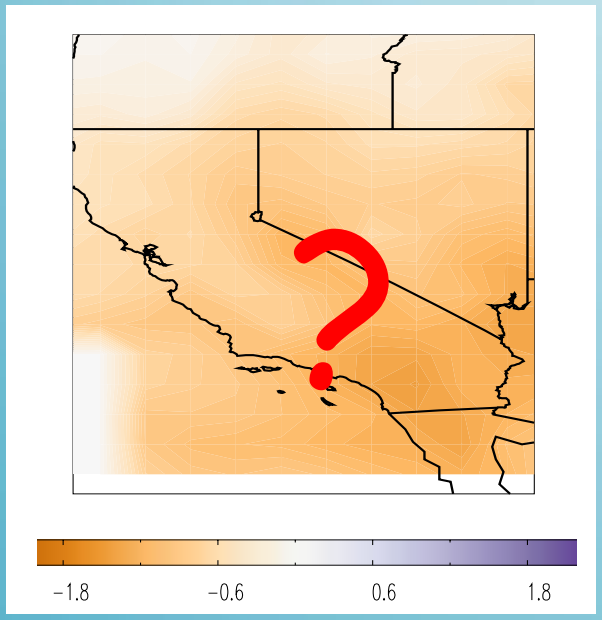
The year of and one year after the hindcasts are excluded in training the model



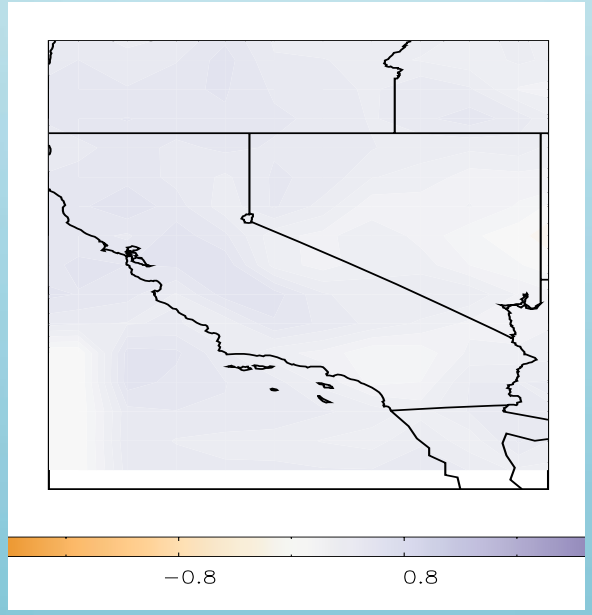
1979-2016

Forecast for standardized rainfall anomalies of the last winter (Dec 2018-Feb.2019)

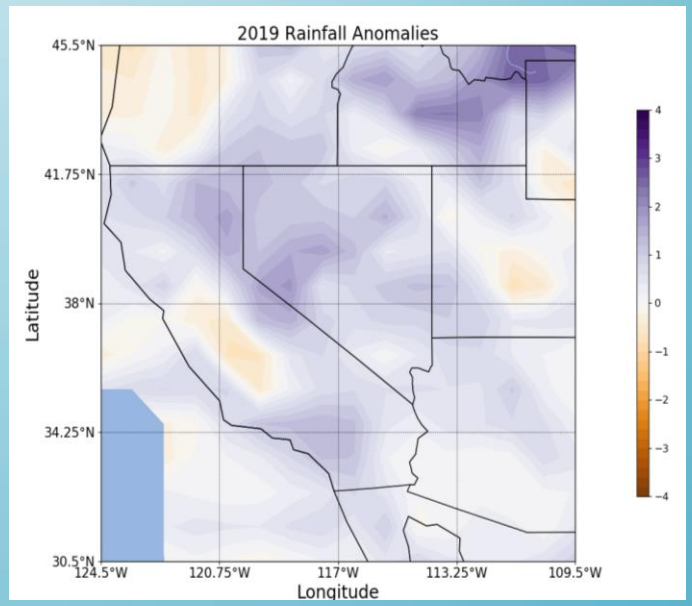
Forecast: based on conditions in Oct. 2018



Forecast: based on the conditions in Nov. 2018

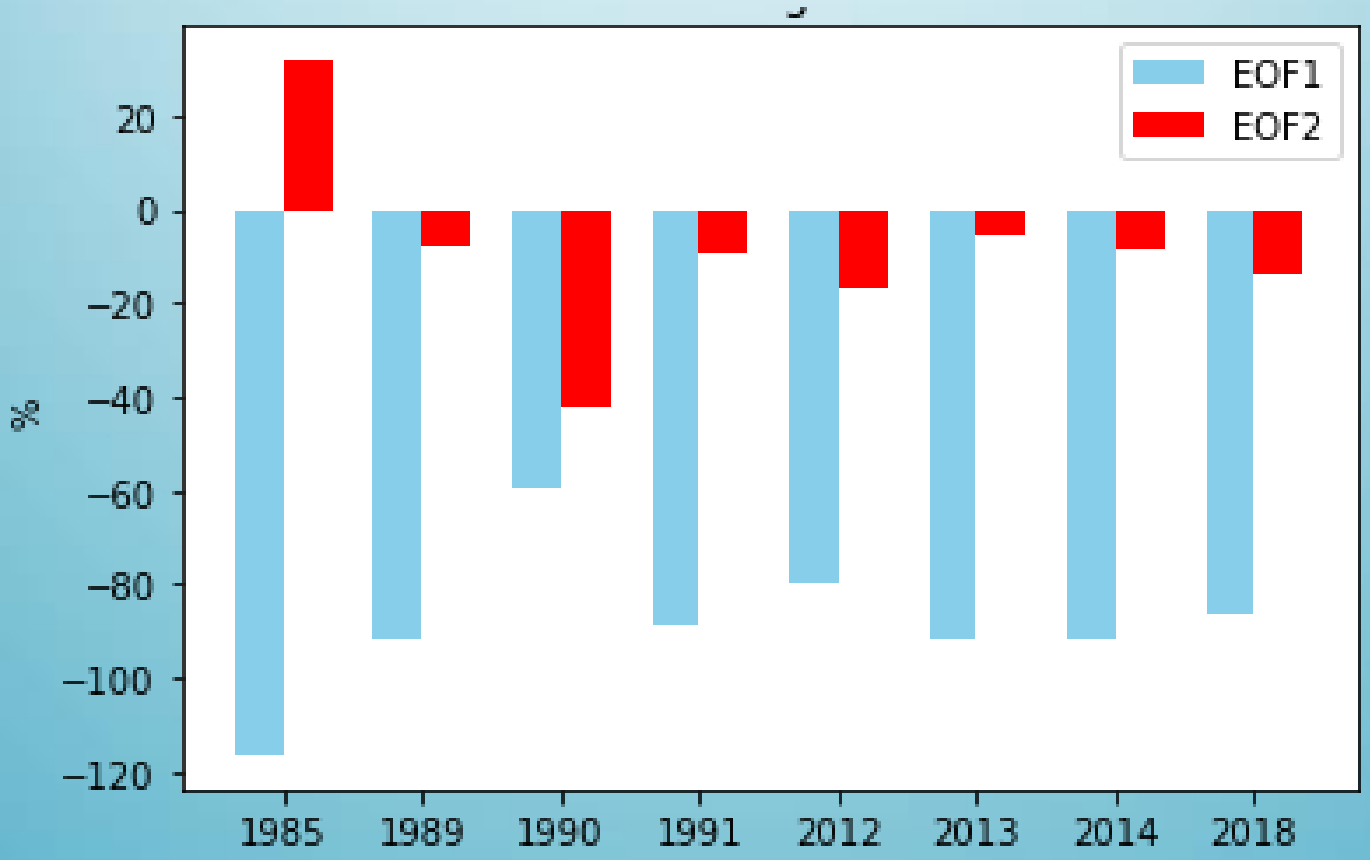


Observation: CPC

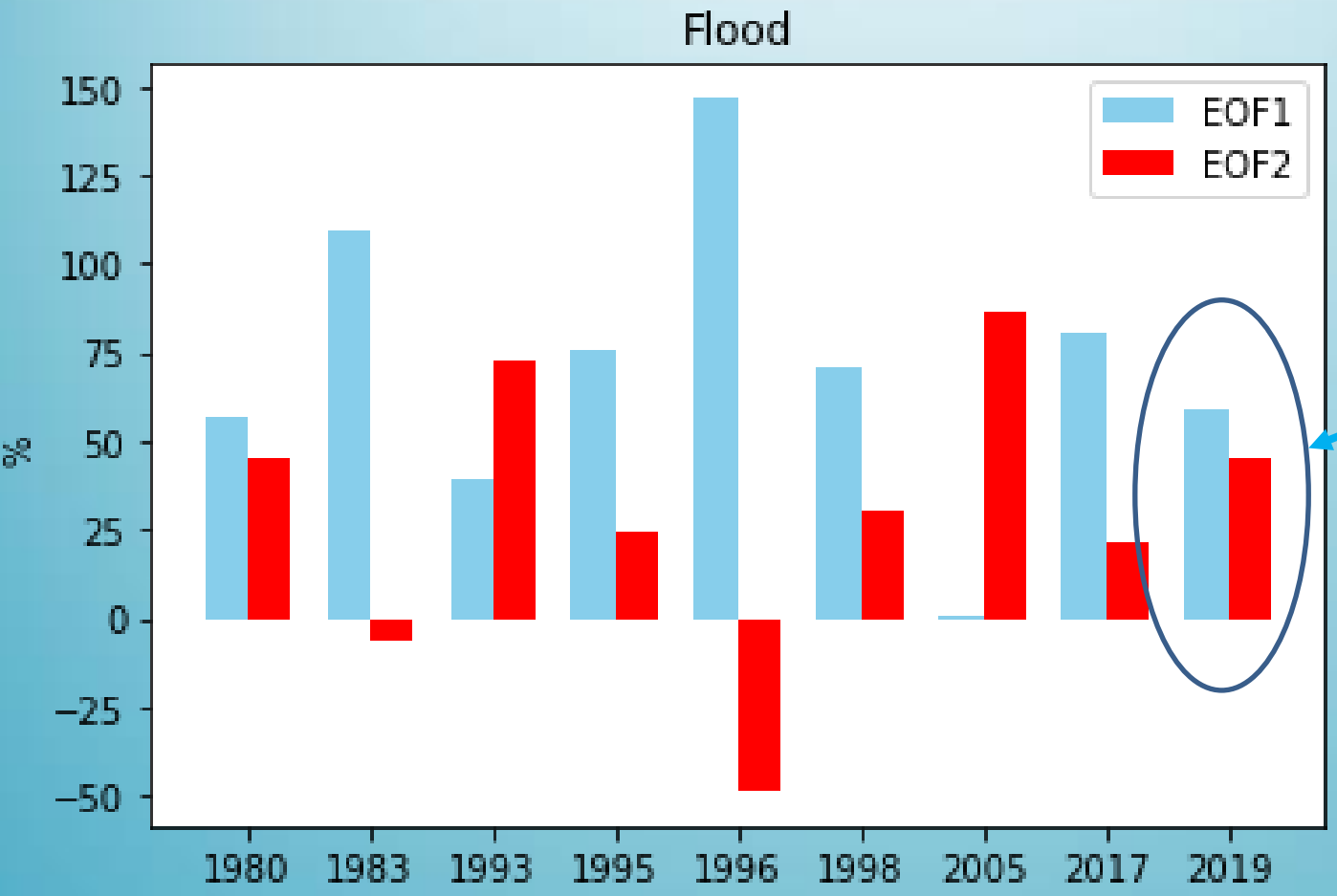


Training period: 1979-2011, rainfall anomalies are standardized for this period

Drier winters: are usually dominated by EOF1, potentially predictable on seasonal scale



Wet winters: contributed by both EOF1 and EOF2, less predictable on seasonal scale



Important contribution from EOF2 during the last winter

Summary & Future Work

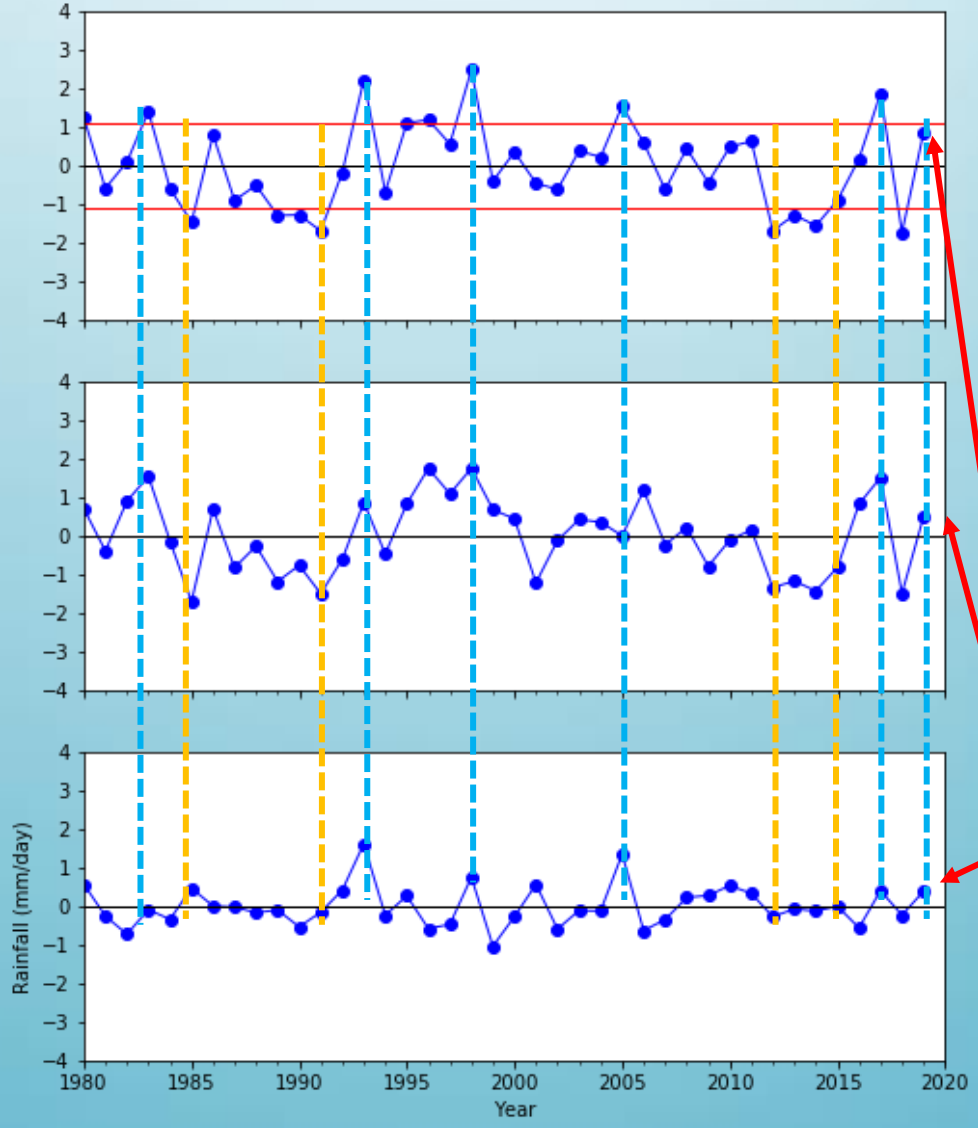
- ***Preliminary statistical seasonal prediction system, trained and initialized by CFSv2 realtime forecasts, shows a higher skill in predicting winter rainfall anomalies over CA than that of the dynamic seasonal prediction.***
- ***Drier winters are dominated by persistent large-scale circulation anomalies developed in fall, thus potentially more predictable. Wetter winters are strongly influenced by less persistent large-scale circulation anomalies, thus less predictable.***
- ***Improve the statistical prediction model:***
  - ***identifying large-scale circulation pre-conditions for EOF1 and EOF2 patterns***
  - ***Explore probabilistic prediction using self organzing mapping***

How do these two modes of rainfall variability contribute to dry and wet winters?

CA winter rainfall anomalies

EOF1 reconstructed winter rainfall anomalies

EOF2 reconstructed winter rainfall anomalies.



+/- 1 sigma

CA area-average

Dec 2018- Feb 2019