Assessing the Climate-Scale Variability and Seasonal Predictability of Atmospheric Rivers Affecting the West Coast of North America

Center for Western Weather and Water Extremes

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Motivations

- Aiming to study
  - Climate-scale variability of AR activity
  - Seasonal predictability

- For starters, we need
  - Automated AR Detection Methodology (ARDT) that detects precipitation-relevant ARs
  - A catalog of ARs spanning many decades

Outline

- ## Atmospheric River (AR) detection and validation
  - AR detection methodology
  - NCEP/NCAR Reanalysis-based AR catalog (SIO-R1)
  - SIO-R1 validated against an established satellite-based AR catalog (RNW*)
  - And against independent precipitation data

- ## AR climatology 1948 – 2015
  - Monthly climatology of AR landfalls
  - AR contribution to total precipitation

- ## Climate-scale variability
  - Coupled analysis of SST and AR-related Integrated Vapor Transport (IVT)
  - Coupled analysis of SST and AR-related Precipitation

- ## Predictability of Seasonal AR activity
  - IVT
  - Precipitation

* Ralph, Neiman, and Wick (RNW), *Mon. Wea. Rev.* (2004)

Data sources

Data resource   NCEP/ NCAR Reanalysis
        $2.5° \times 2.5°$ spatial resolution, 8 pressure levels
        6-hourly data

Spatial domain   20.0N – 60.0N, 160W - 100W

Time frame   1948 – 2015

Precipitation data   PRCP dataset (Livneh et al., *J. Clim.* 2013)
        $1/16°$ spatial resolution, daily PRCP amount

Spatial domain   20.0N – 52.5N, 124W – 75W

Time frame   1950 – 2013

Atmospheric river detection criteria:

C1   Area of ***IVT** in excess of 250 kg/m*s and **IWV** in excess 15 mm at least 1500 km long (offshore + inland)* crossing the West Coast of North America

C2   The grid point with IVT maximum along the extracted coastal area indicates the central landfall point

C3   *Two grid point movement (north/south) of the central landfall latitude between adjacent time steps is allowed for a single AR*

C4   Extracted area is indicated as **Atmospheric River (AR)** if such conditions *were observed for at least 18 hours*

C5   Two AR events are considered distinct if they are separated by more than one day (24 hours) or more than 5 degrees latitude.

SIO-R1 AR catalog contents:

AR events and their landfalls are recorded for each AR, over its land-falling duration:

- time of landfall (year/month/day/hour),

- latitude-longitude coordinates of the central land-falling location by grid cell,

- IVT and IWV values at these grid cells, u- and v-wind components at 850 mb.

Validation by comparison with RNW catalog and independent precipitation observations

Gershunov, Shulgina, Ralph, Lavers; in preparation

Validation of SIO-R1 against the SSM/I IWV-based RNW catalog*

1612 days with AR landfalls between 32.5 and 52.5° N for October 1997- September 2015

Overlap AR days – days presented at both AR catalogs, SIO and RNW

SIO-R1 AR days – days presented at SIO AR catalog only

RNW AR days – days presented at RNW AR catalog only

An all-year comparison for all latitudes

Seasons and latitudes:
Northern sector (42.5 – 52.5° N)

Southern sector (32.5 – 40° N)
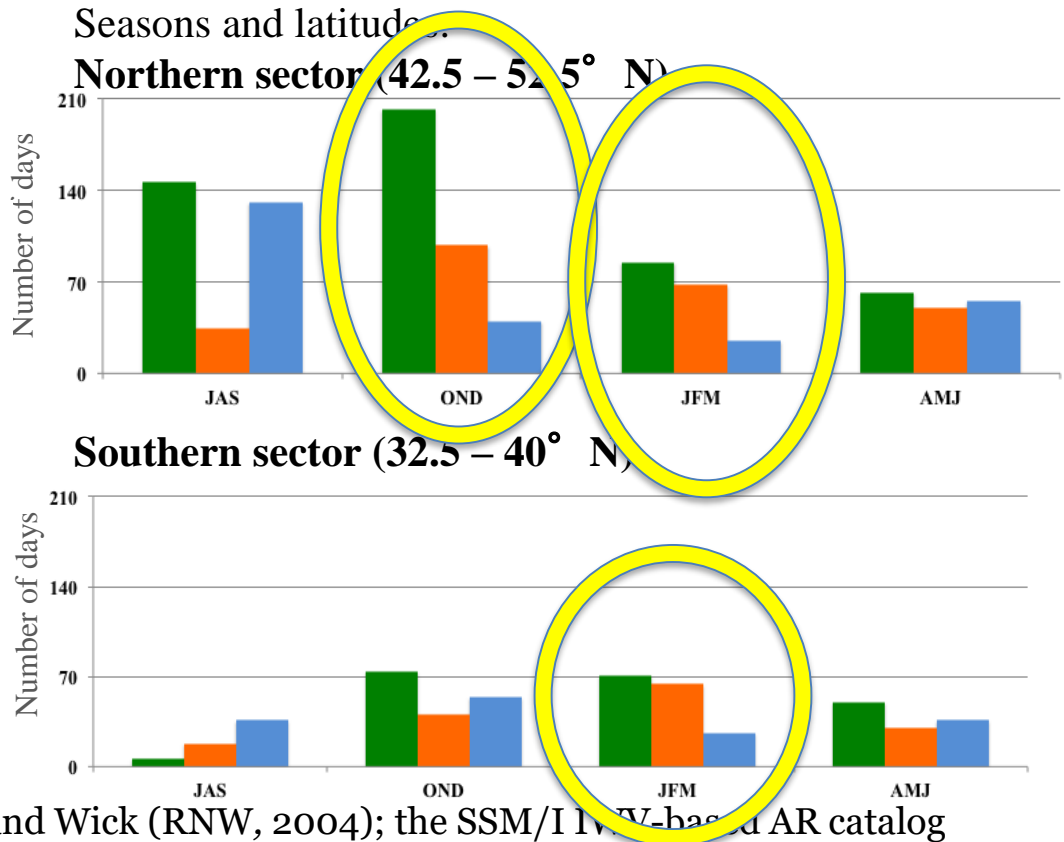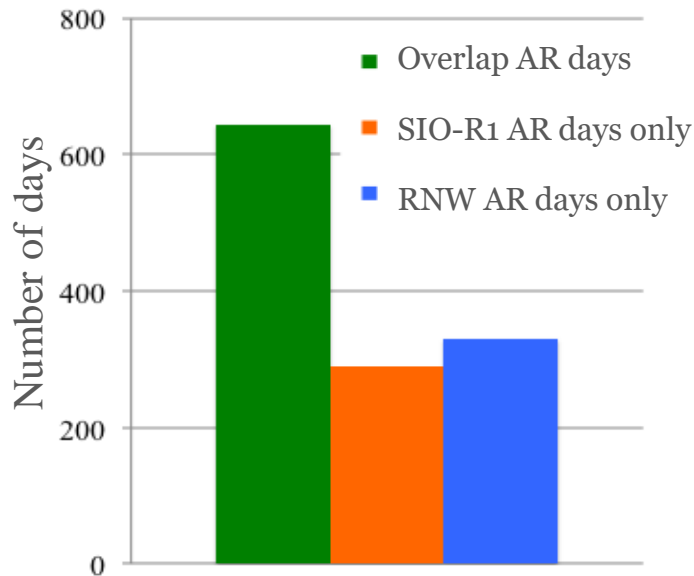
* Methodology proposed by Ralph, Neiman, and Wick (RNW, 2004); the SSM/I IWV-based AR catalog developed by Neiman et al. (2008) and recently updated through 2015

AR contribution to annual precipitation*

a) P contribution: overlap   b) P contribution: SIO-only   c) P contribution: RNW-only
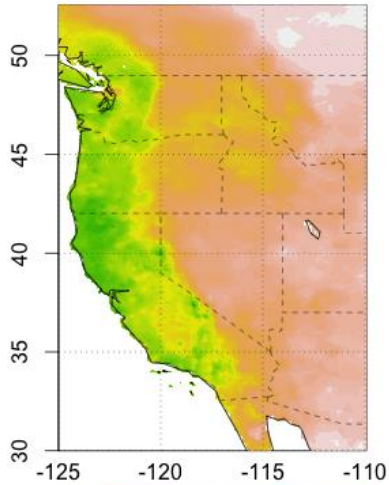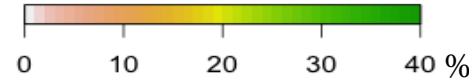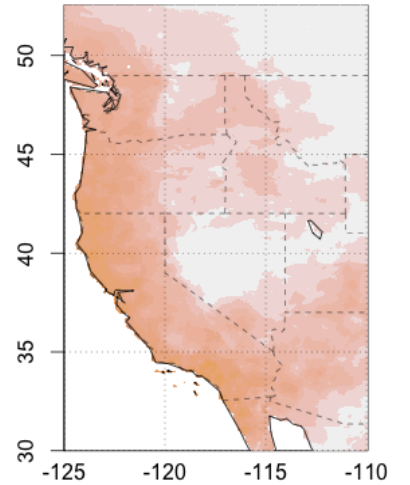
Contribution (%) of precipitation associated with AR landfalls to total annual precipitation.
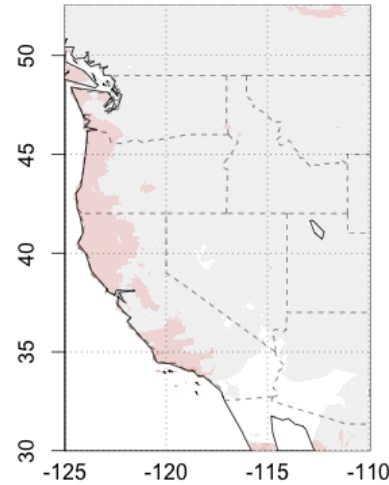
d) P intensity: overlap days   e) P intensity: SIO-only days   f) P intensity: RNW-only days
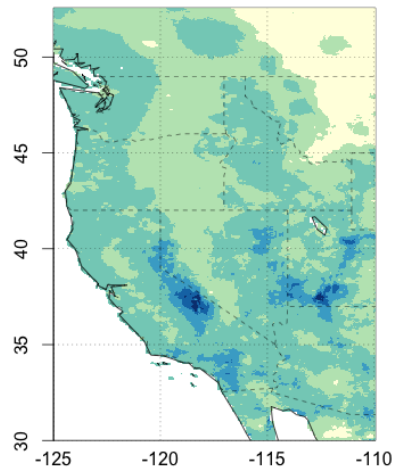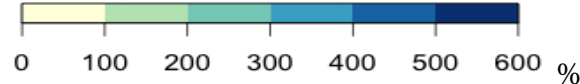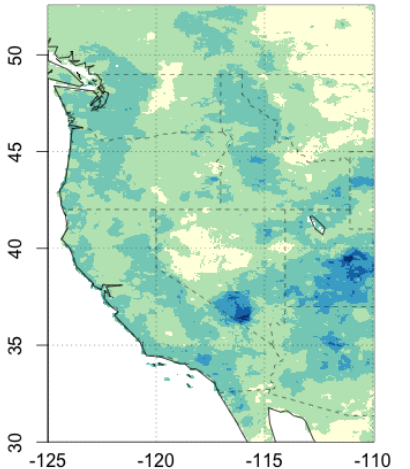
Average daily intensity (%) of precipitation associated with AR landfalls relative to local daily average precipitation intensity on wet days.

*6x6km gridded precipitation from Livneh et al., *J. Clim.* (2013)

AR climatology in SIO-R1

Gershunov, Shulgina, Ralph, Lavers; in preparation

AR activity at the North American West Coast during 1948 - 2015

a) average number of days per year with ARs

b) average duration of land-falling ARs, days

c) monthly average AR-related IVT, kg/m/s

d) AR event average IVT, kg/m/s

e) monthly average total AR IWV, mm

f) AR event average total AR IWV, mm
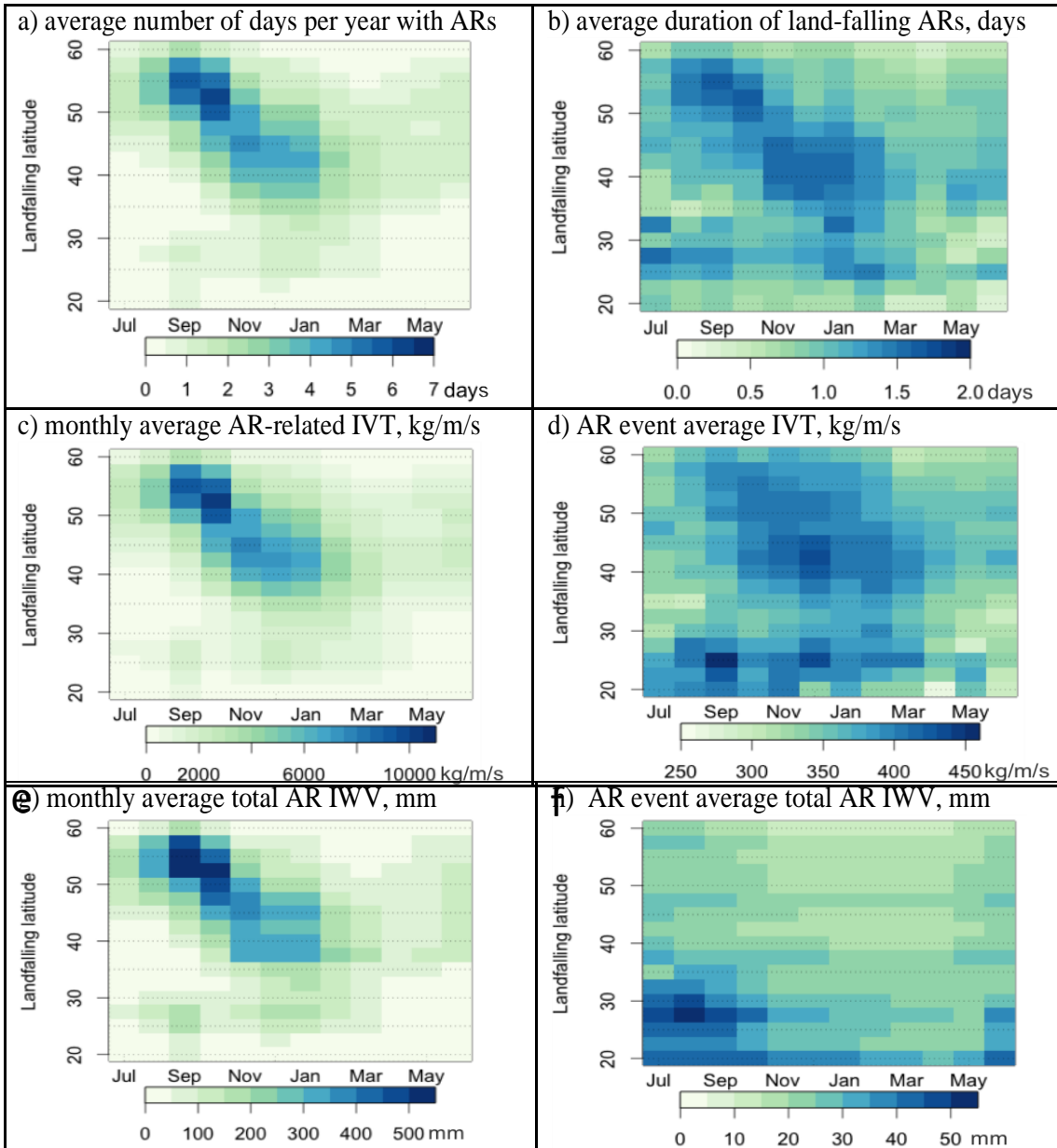
Monthly climatology: number of 6-hourly AR records rounded to days (a), corresponding average total AR IVT (c) and average IVT per AR landfall (d), monthly total AR IWV (e) and average IWV per AR record (f) presented by month and AR land-falling latitude. Bottom panel is for wind direction and speed (m/s) at 850 hPa.
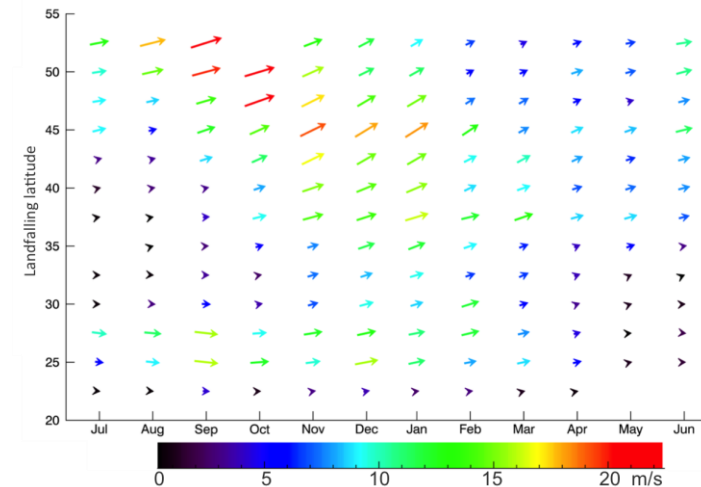
AR contribution to seasonal precipitation
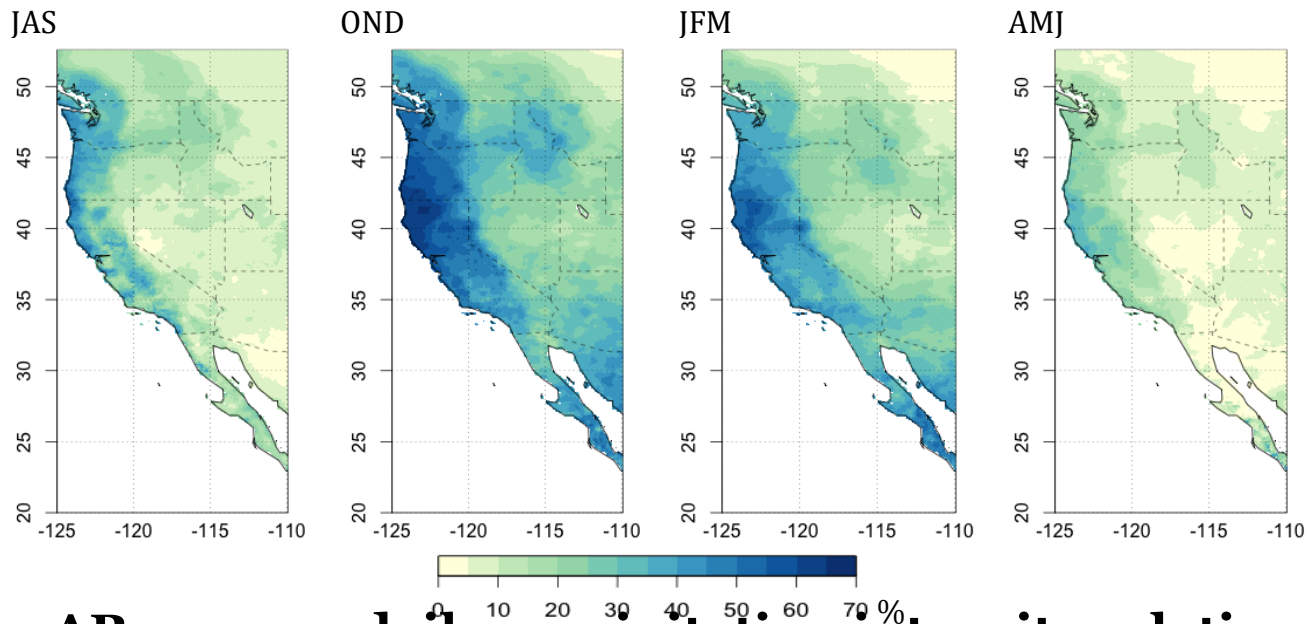
Contribution (%) of AR-related precipitation to seasonal precipitation accumulations.

AR average daily precipitation intensity relative to local climatology
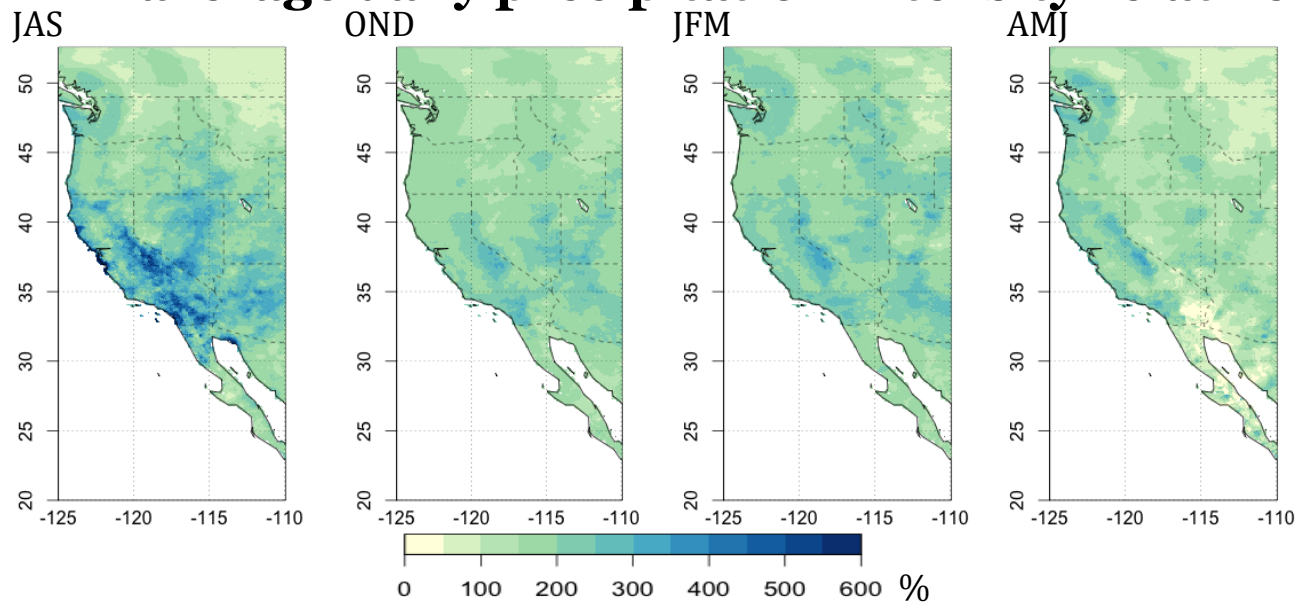
Daily intensity of precipitation associated with AR landfalls in relation to local average daily precipitation intensity by season.

Climate Variability:

Canonical Correlation Analysis (CCA)

Gershunov, Shulgina, Ralph, Lavers; in preparation

Canonical correlation analysis: AR IVT excess, OND, 1948-2015
OND AR-related IVT excess sum (IVT > 250 kg/m/s) vs. OND mean SST, 1948-2015

Canonical correlation analysis: AR IVT excess, JFM, 1948-2015

JFM AR-related IVT excess sum (IVT > 250 kg/m/s) vs. JFM mean SST, 1948-2015

JFM CC1: Cor = 0.67, AR IVT (blue), SST (red)

Canonical pattern IVT 1
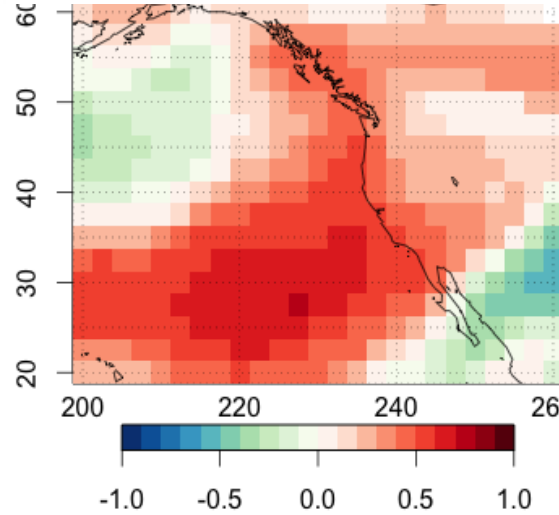
Canonical pattern SST 1
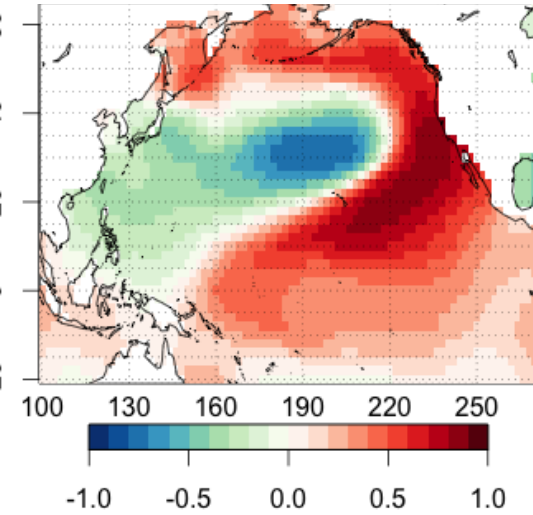
Canonical correlation analysis: AR PRCP, OND, 1950-2013
OND AR-related PRCP accumulations vs. OND mean SST, 1950-2013

OND CC1: Cor = 0.64, AR PRCP (blue), SST (red)
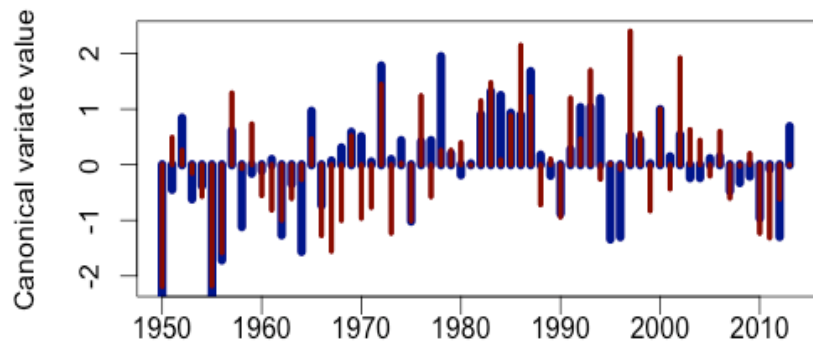
Canonical pattern PRCP 1
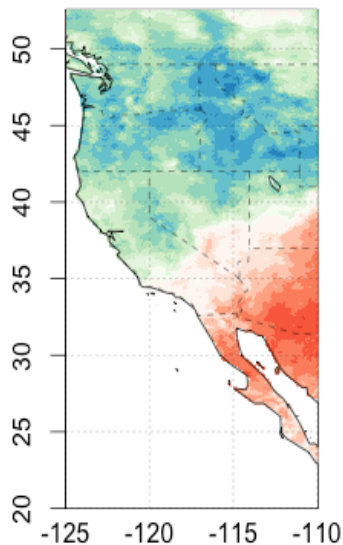
Canonical pattern SST 1
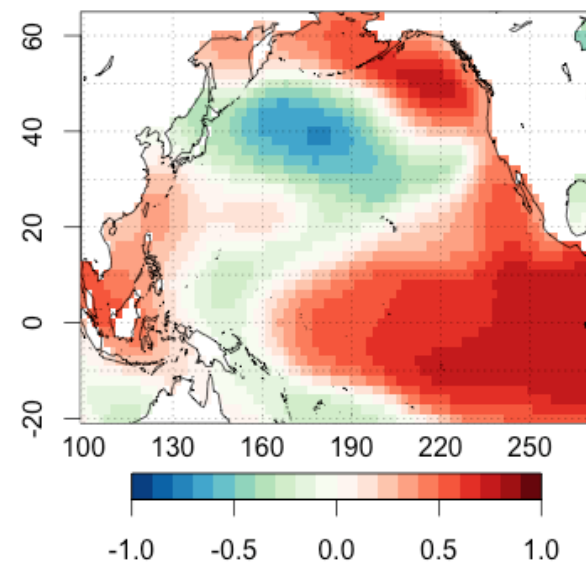
OND CC2: Cor = 0.46, AR PRCP (blue), SST (red)
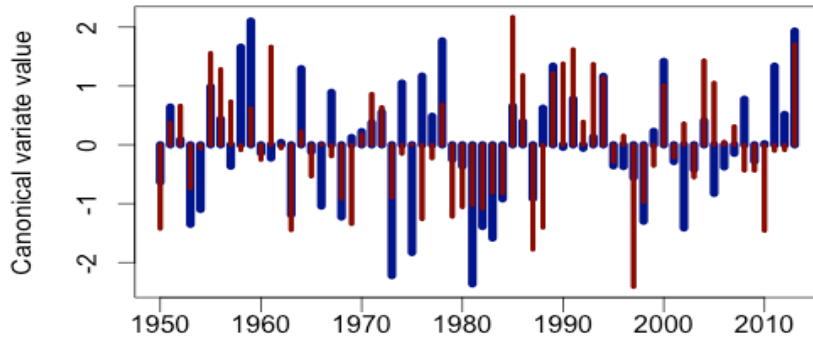
Canonical pattern PRCP 2
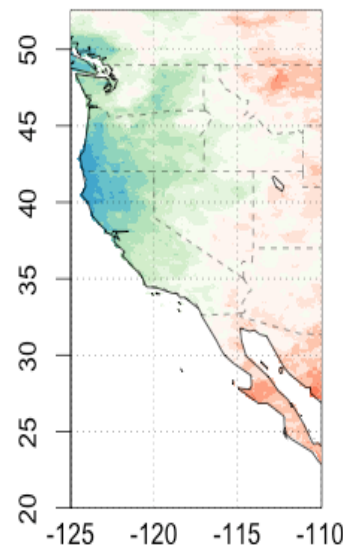
Canonical pattern SST 2
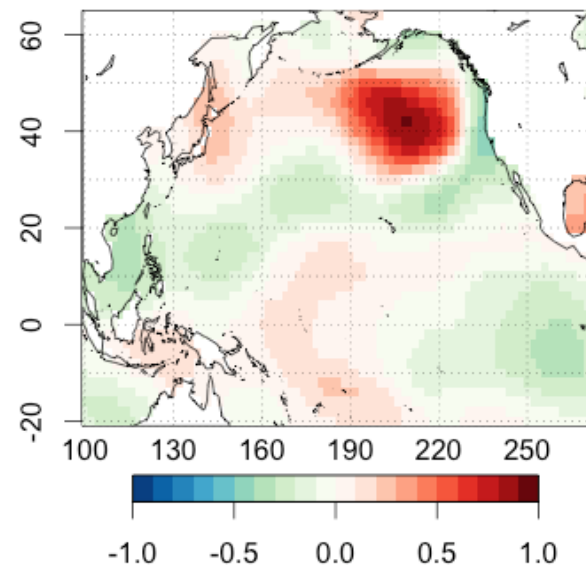
Canonical correlation analysis: AR PRCP, JFM, 1950-2013
JFM AR-related PRCP accumulations vs. JFM mean SST, 1950-2013

JFM CC1: Cor = 0.77, AR PRCP (blue), SST (red)
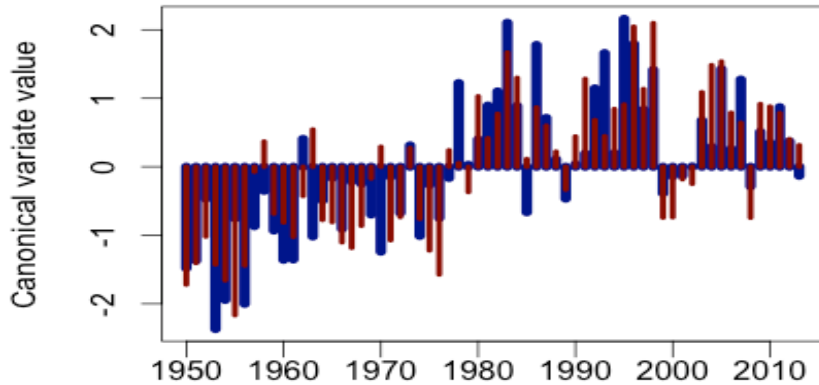
Canonical pattern PRCP 1
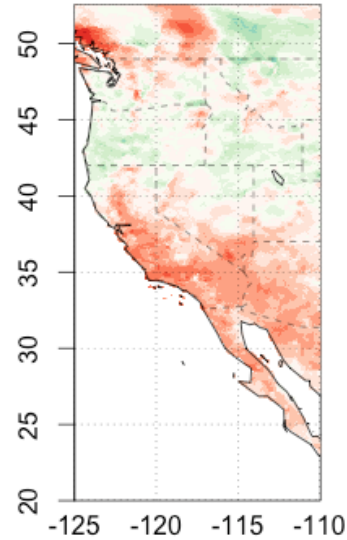
Canonical pattern SST 1
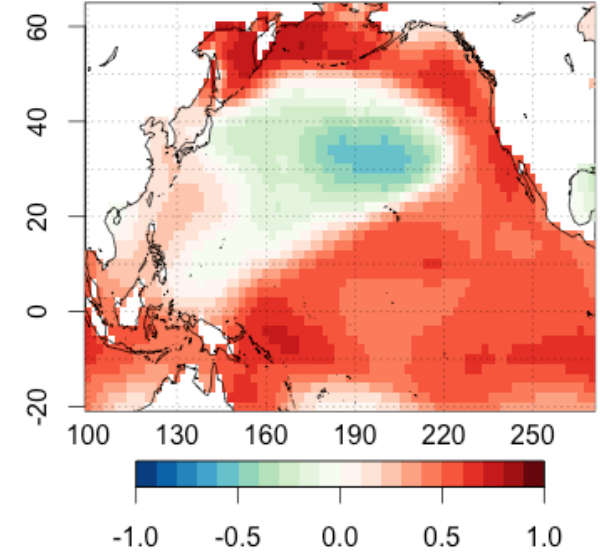
JFM CC2: Cor = 0.67, AR PRCP (blue), SST (red)
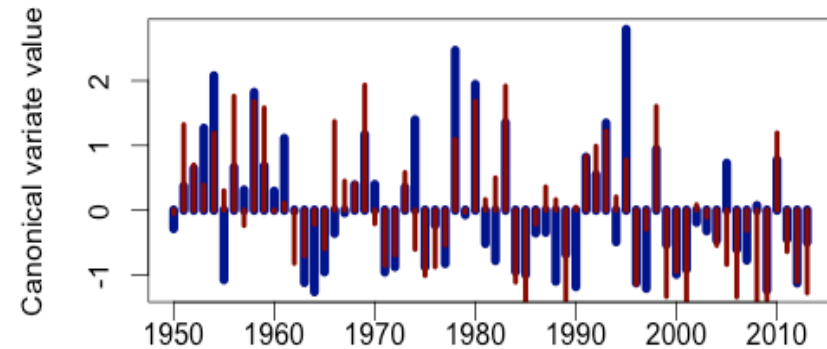
Canonical pattern PRCP 2
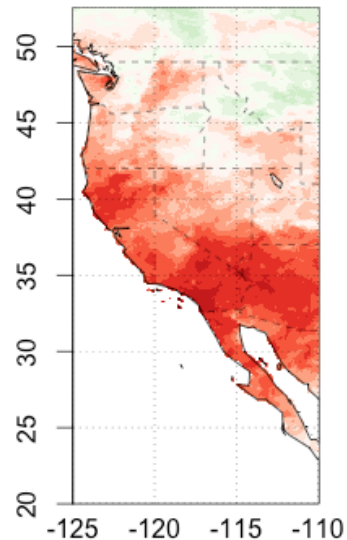
Canonical pattern SST 2
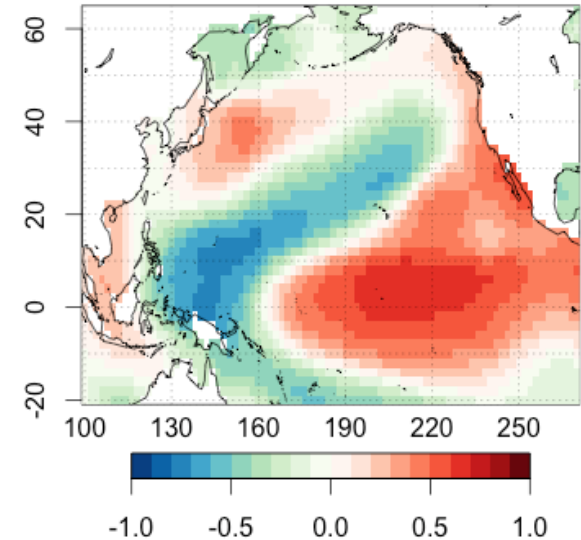
Assessing the SST-related predictability
of JFM precipitation:

Total and AR-related

CCA Predictability: JFM, 1950-2013

Predictor: JFM SST

Predictand:
JFM totPRCP anomaly %
Skill: PCs = 8, CCs = 8

Predictand:
JFM AR PRCP anomaly %
Skill: PCs = 3, CCs = 3

Predictor: December SST

Predictand:
JFM totPRCP anomaly %
Skill: PCs = 7, CCs = 7

Predictand:
JFM AR PRCP anomaly %
Skill: PCs = 8, CCs = 8
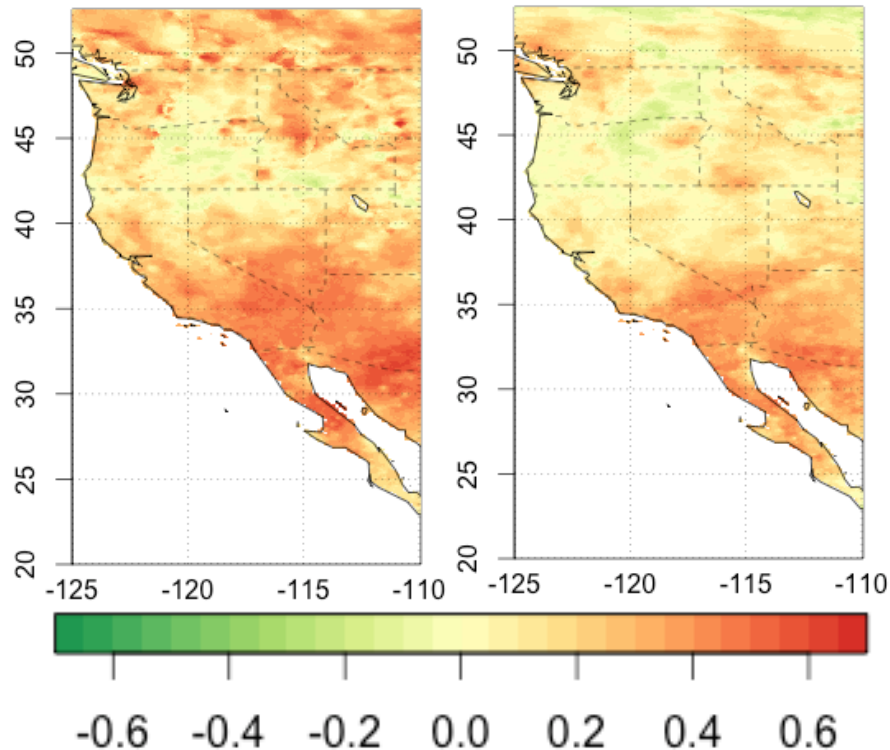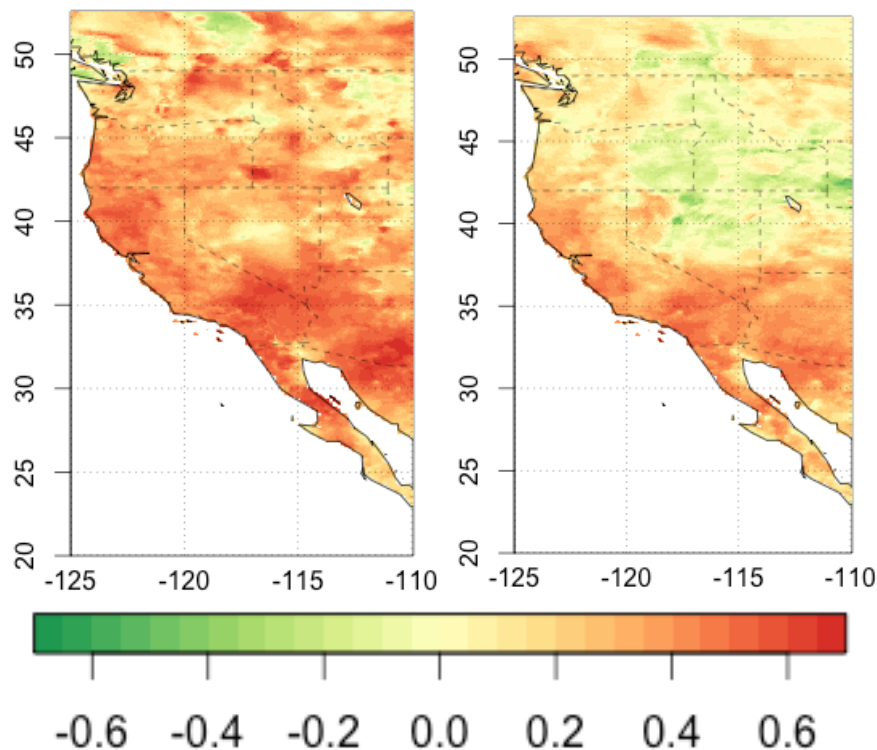
Cross-validated skill: correlations of predicted vs. observed JFM precipitation

Gershunov and Cayan, *J. Clim.* (2004)

CCA Prediction Model: PRCP anomaly, JFM, 1983/1998/2016

All PRCP anomaly (%), JFM 1983
Observed — 175%
Predicted — 200%

All PRCP anomaly (%), JFM 1998
Observed — 195%
Predicted — 150%
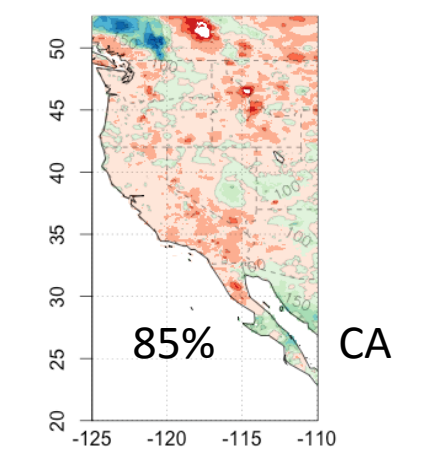
All PRCP anomaly (%), JFM 2016
Predicted — 85%   CA

AR PRCP anomaly (%), JFM 1983
Observed / Predicted
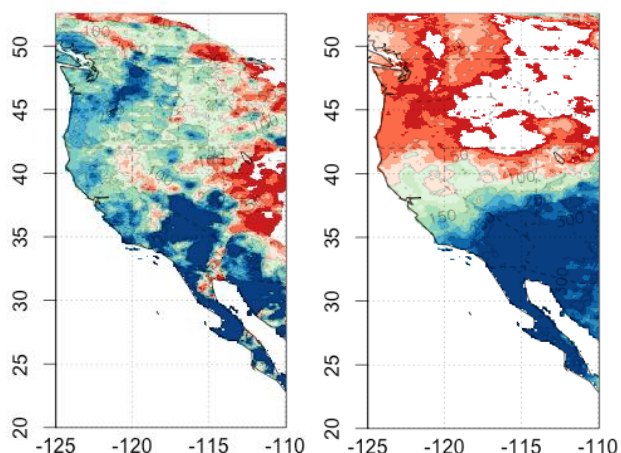
AR PRCP anomaly (%), JFM 1998
Observed / Predicted
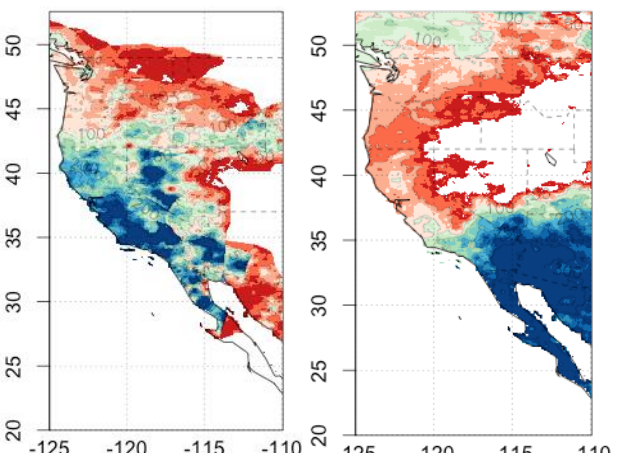
AR PRCP anomaly (%), JFM 2016
Predicted
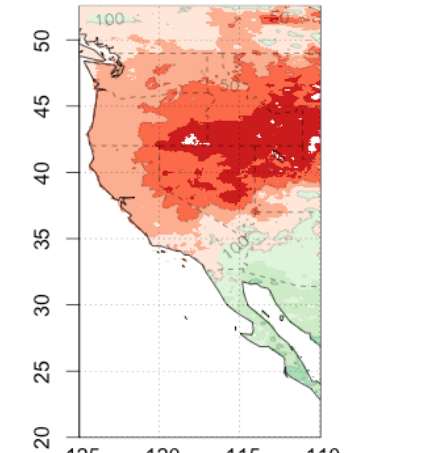
This was the observed JFM 2016 anomaly (from SCENIC/DRI)
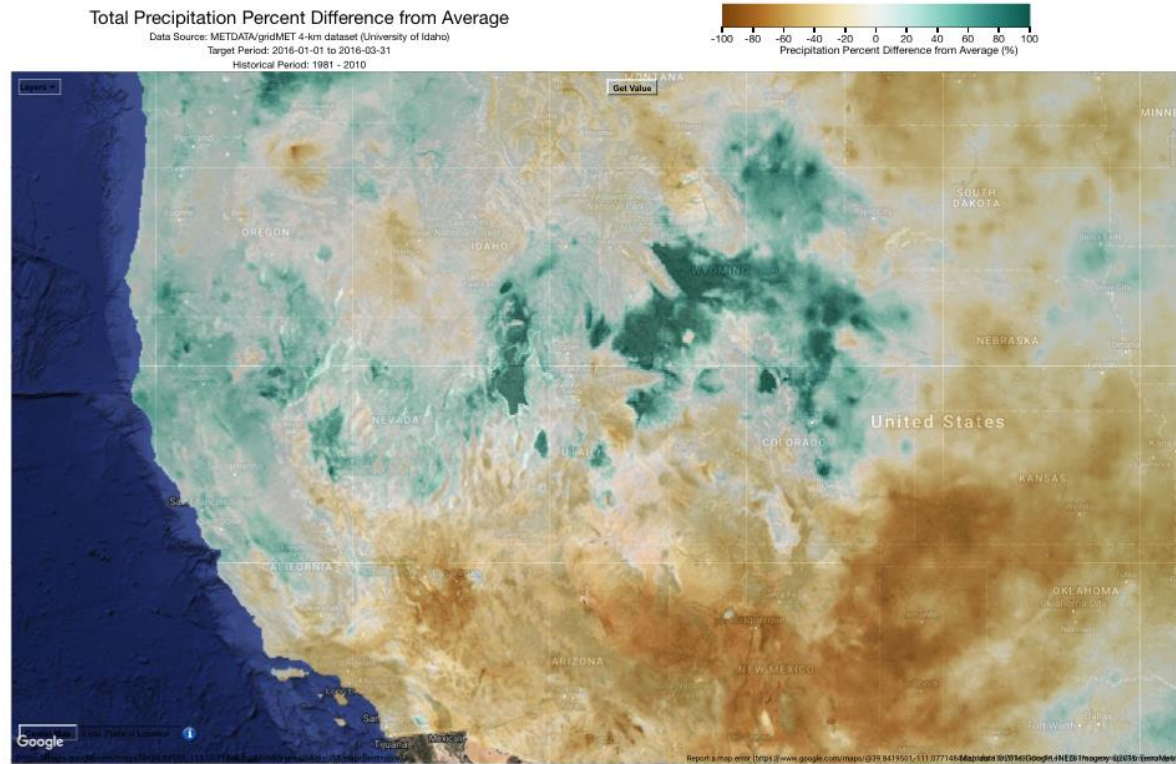
98% of normal precip in California

WHY WAS JFM 2016 PREDICTED TO BE SO DIFFERENT FROM 1983 AND 1998?

SST anomalies during the 3 big Niños: JFM

SST anomaly, JFM, **1983**   SST anomaly, JFM, **1998**   SST anomaly, JFM, **2016**
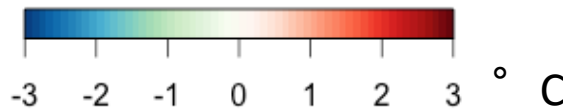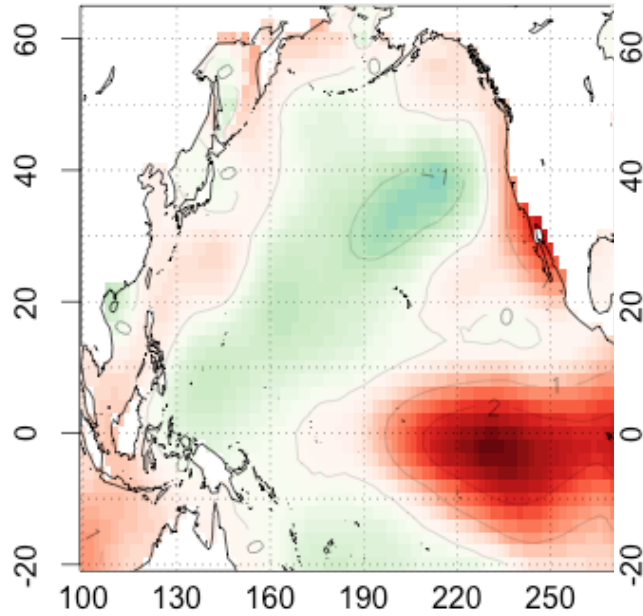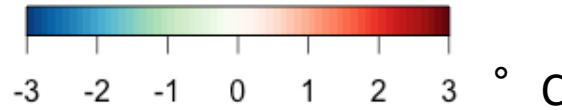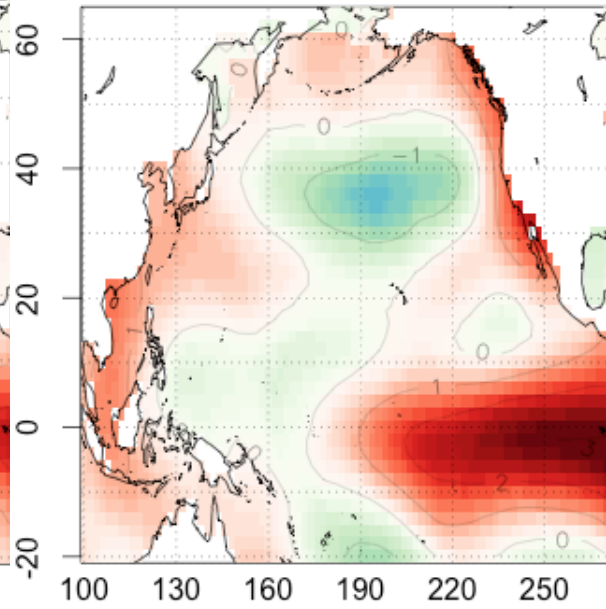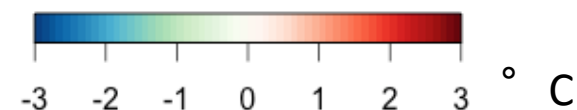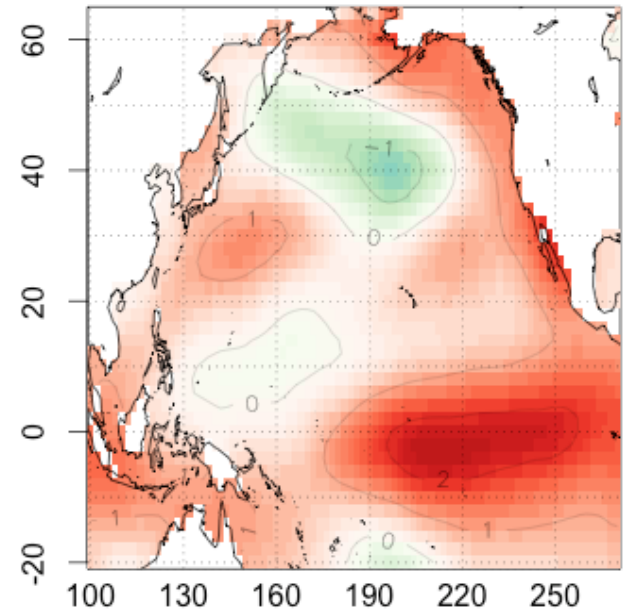
WHAT CAN WE EXPECT FROM LA NIÑA?
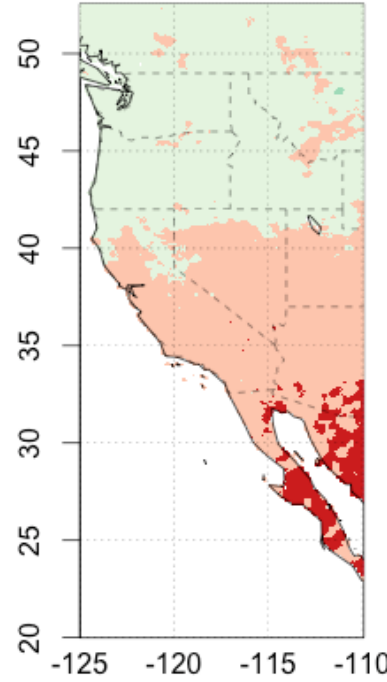
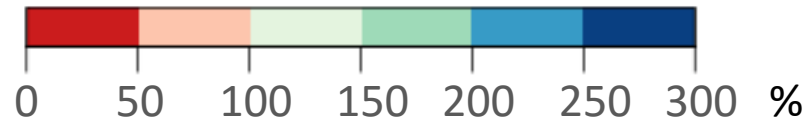# Precipitation composites for La Niña (9) years
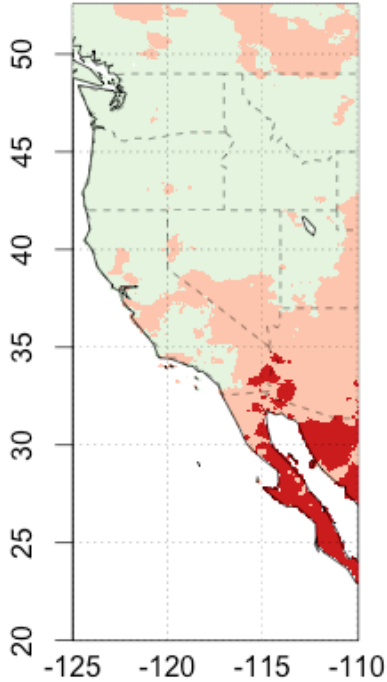
OND total PRCP · OND AR PRCP · JFM total PRCP · JFM AR PRCP
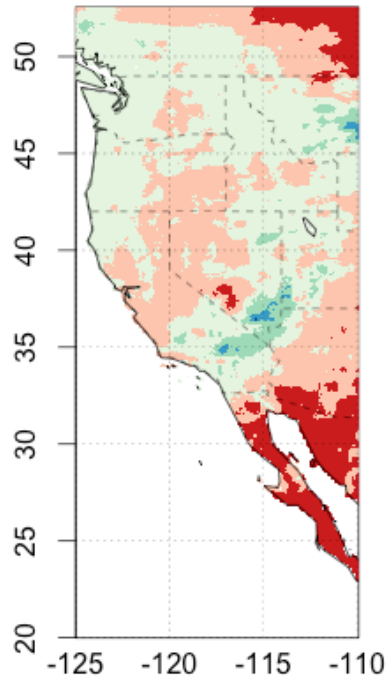
Landfalling latitude
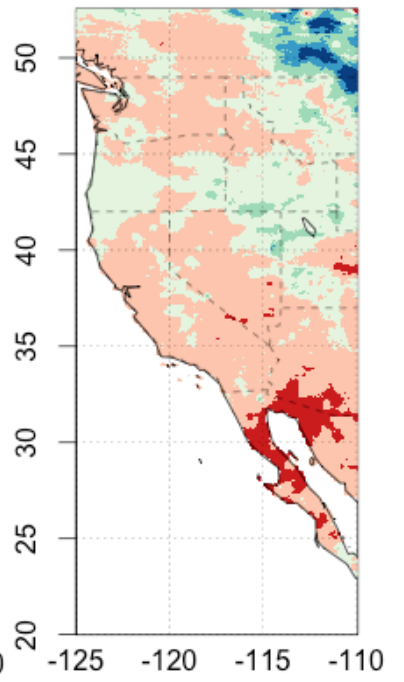
Summary

- SIO-R1: 68-yr long catalog of North American west coast land-falling ARs
  - ARDT can be applied to any region
  - Relevant for heavy precipitation
  - Long enough for climate studies

- Climatology and climate variability
  - Seasonal southward march of AR landfalls from fall to winter
  - PDO, ENSO, "blob", possibly warming signals

- Seasonal predictability (preliminary results)
  - Modest but significant skill in IVT and precipitation
  - Sources of predictability to be explored further
  - Big Niño 2016 vs. 1998 and 1983
  - La Niña

Center for Western Weather and Water Extremes

Testing CCA Prediction Model: PRCP, JFM, 1974

Total PRCP sum (mm), JFM 1974
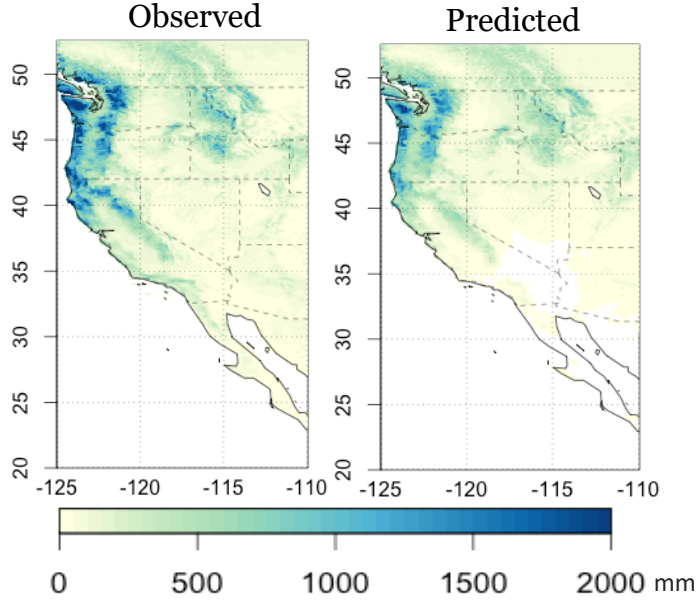
Total PRCP anomaly (%), JFM 1974
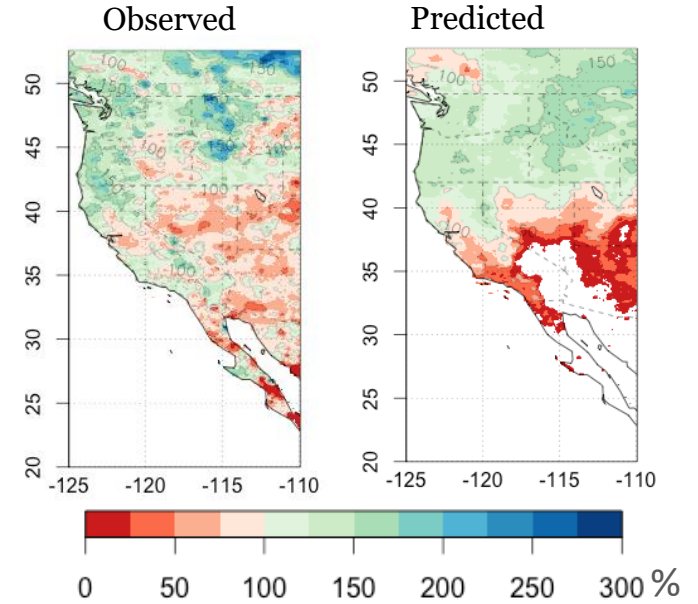
AR PRCP sum (mm), JFM 1974
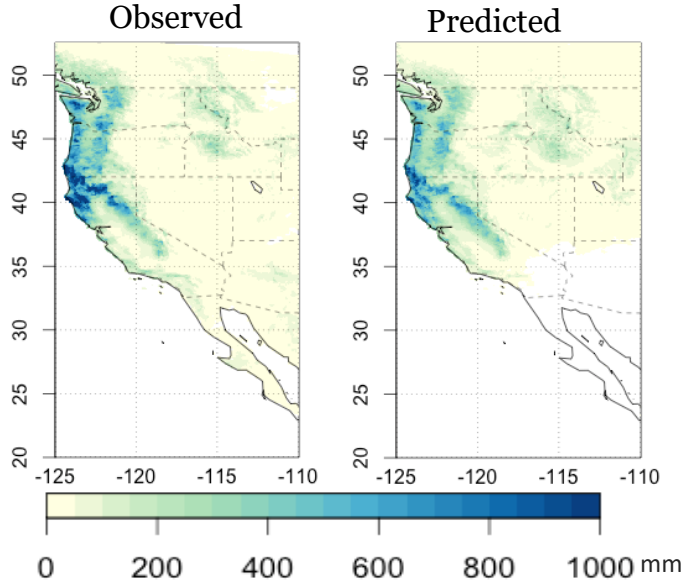
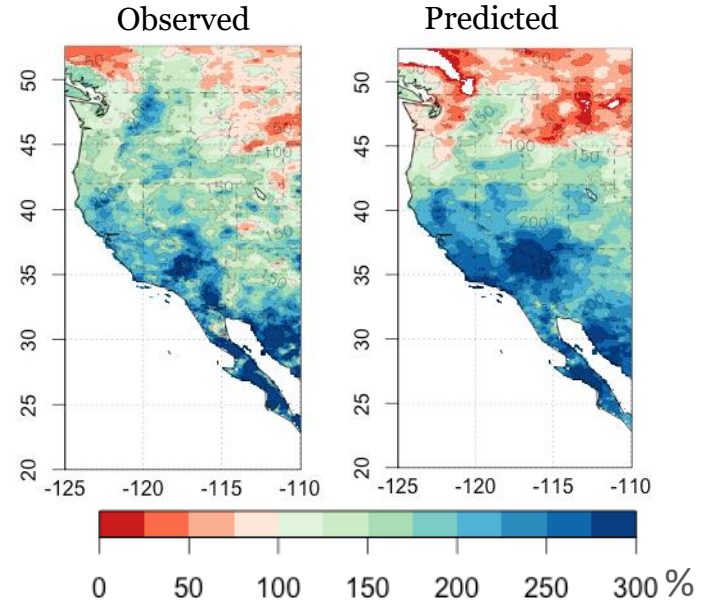**AR PRCP anomaly (%), JFM 1974**
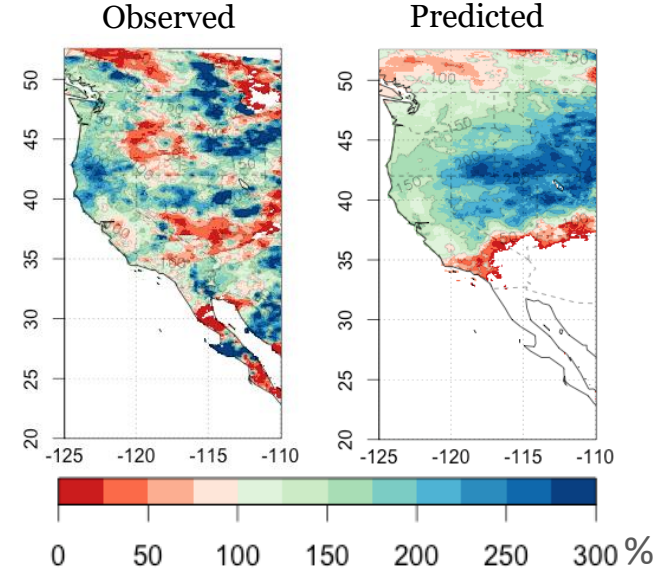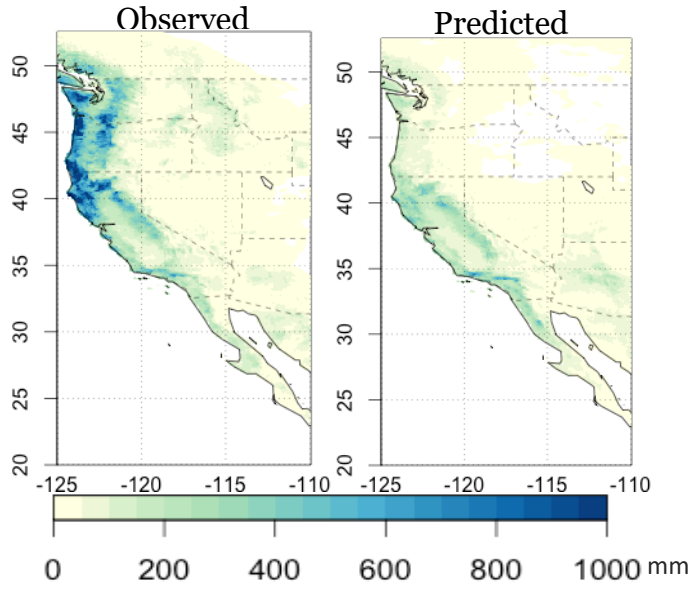
Testing CCA Prediction Model: PRCP, JFM, 1983

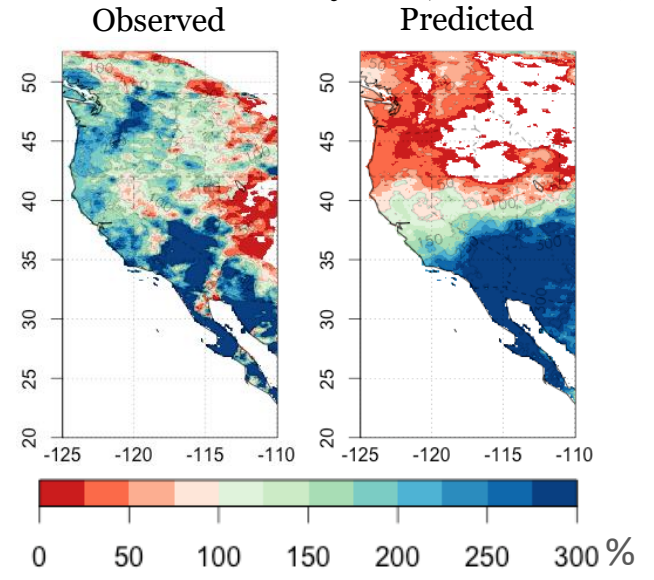**Total PRCP sum (mm), JFM 1983**
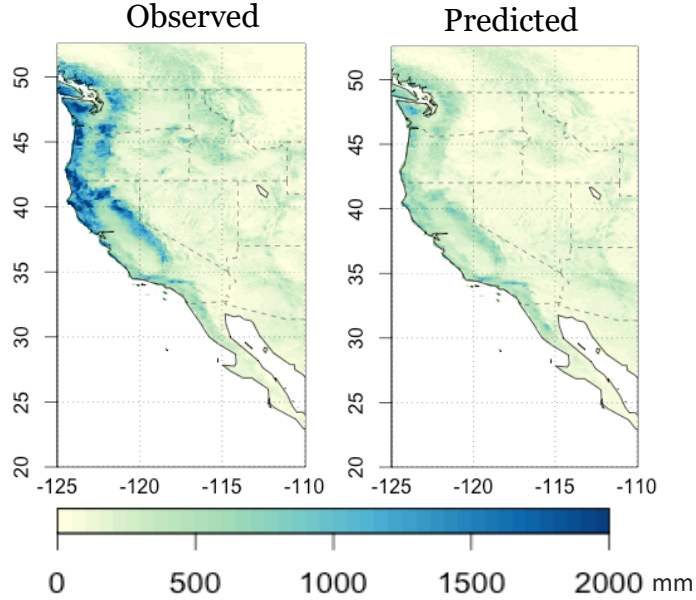
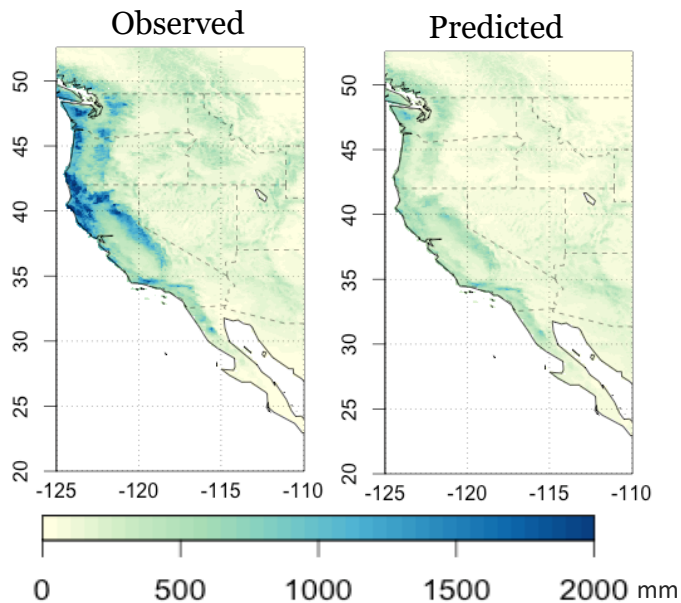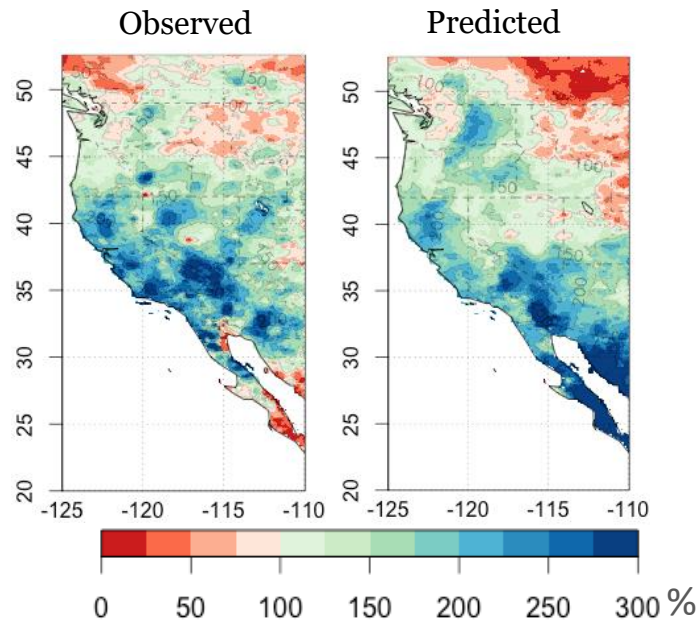**Total PRCP anomaly (%), JFM 1983**

AR PRCP sum (mm), JFM 1983

AR PRCP anomaly (%), JFM 1983
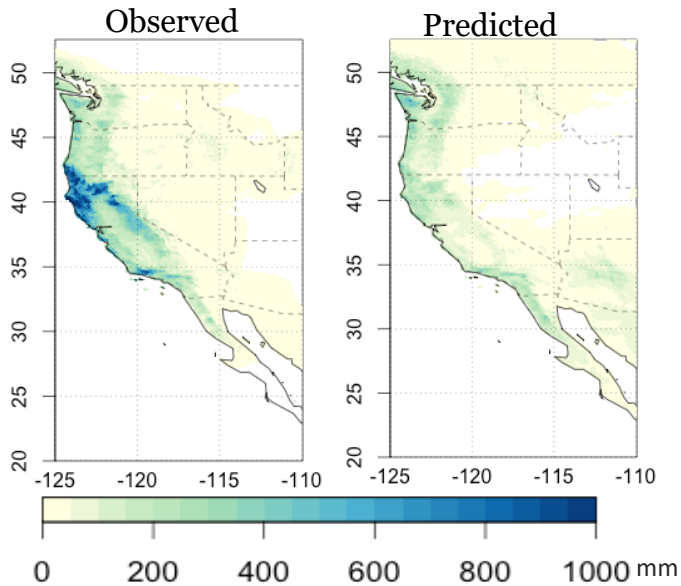
Testing CCA Prediction Model: total PRCP, JFM, 1998

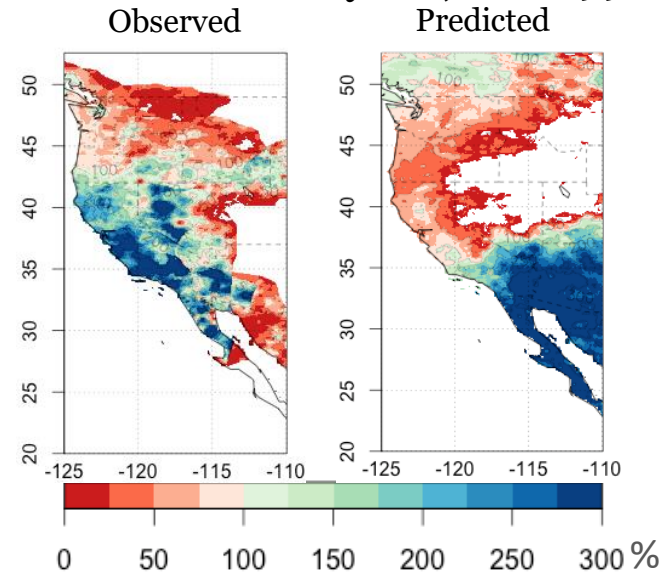

Total PRCP sum (mm), JFM 1998

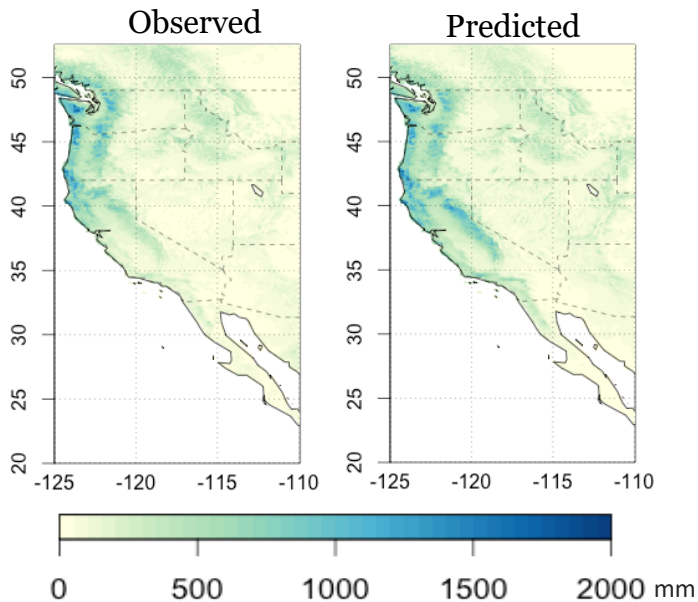Total PRCP anomaly (%), JFM 1998

AR PRCP sum (mm), JFM 1998

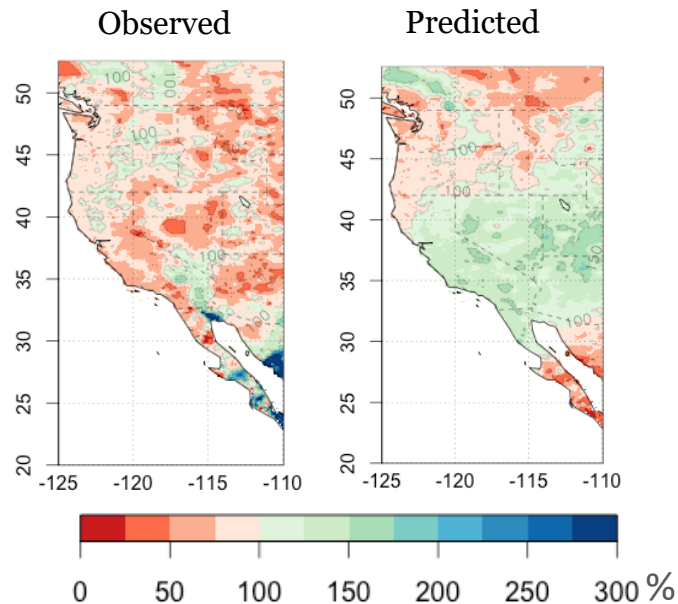AR PRCP anomaly (%), JFM 1998
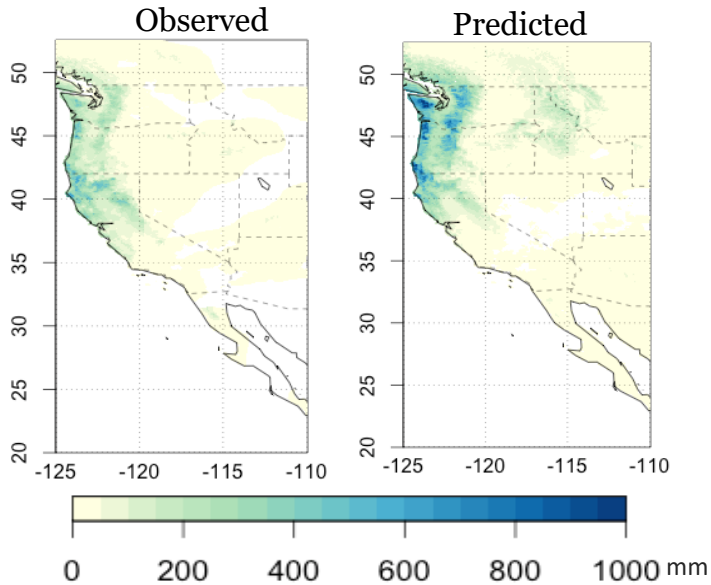
Testing CCA Prediction Model: PRCP, JFM, 2004
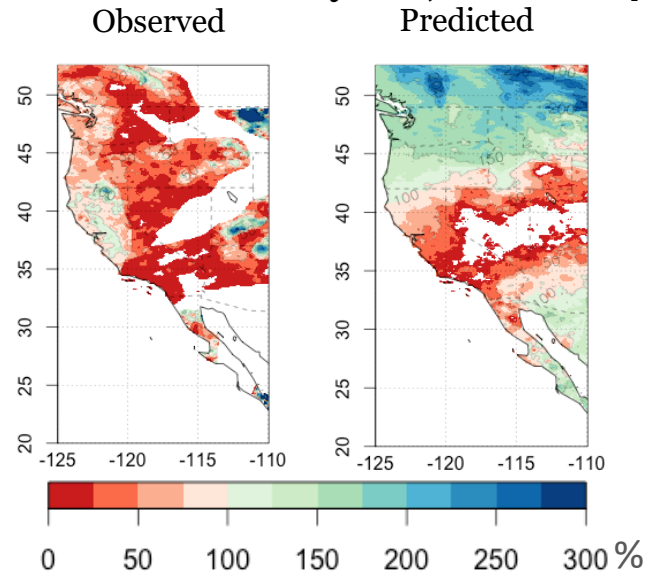

Total PRCP sum (mm), JFM 2004

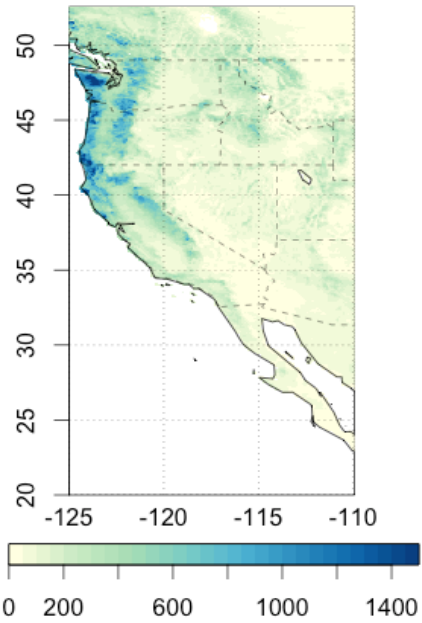**Total PRCP anomaly (%), JFM 2004**

AR PRCP sum (mm), JFM 2004

AR PRCP anomaly (%), JFM 2004

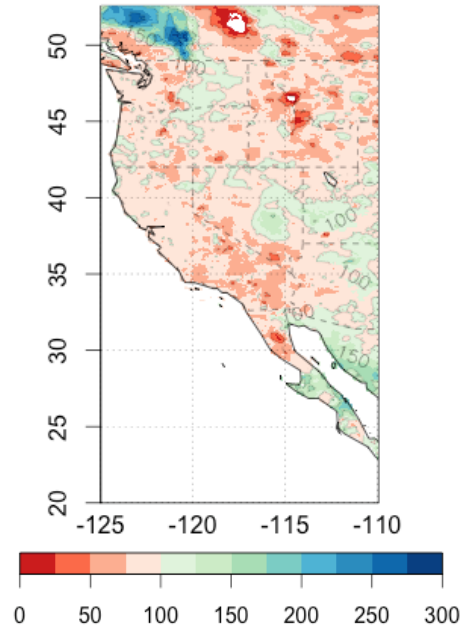# Prediction of PRCP, JFM 2016