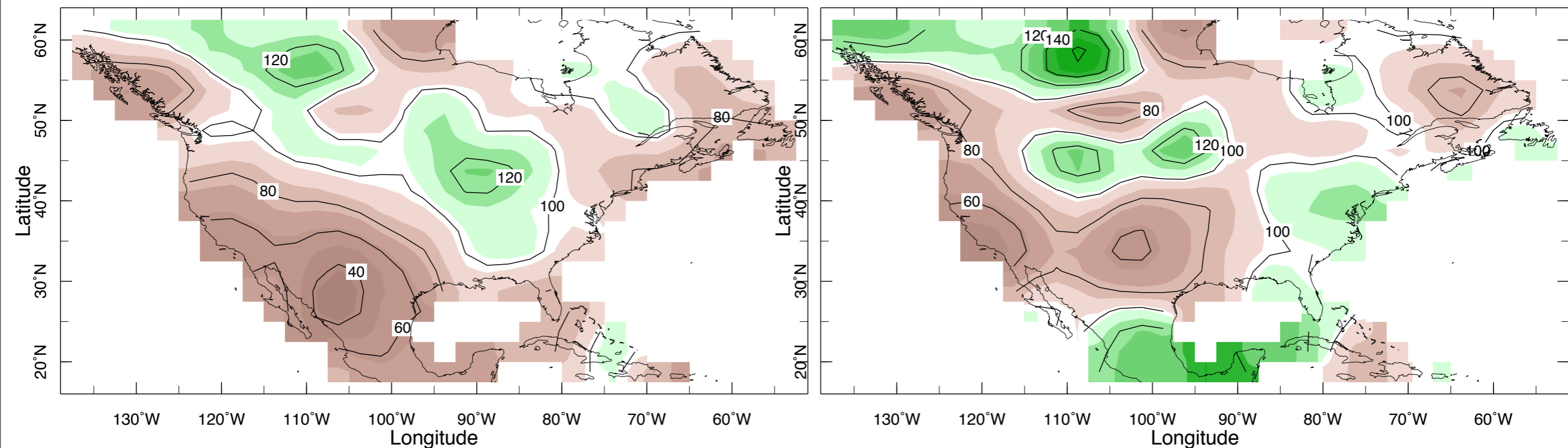


Causes of the 2013-14 California Drought:

An unfortunate series of weather,
ocean-forced variability and/or climate change?

October 2012 to April 2013
% of normal precipitation

October 2013 to April 2014
% of normal precipitation



Richard Seager

Lamont Doherty Earth Observatory, Columbia University

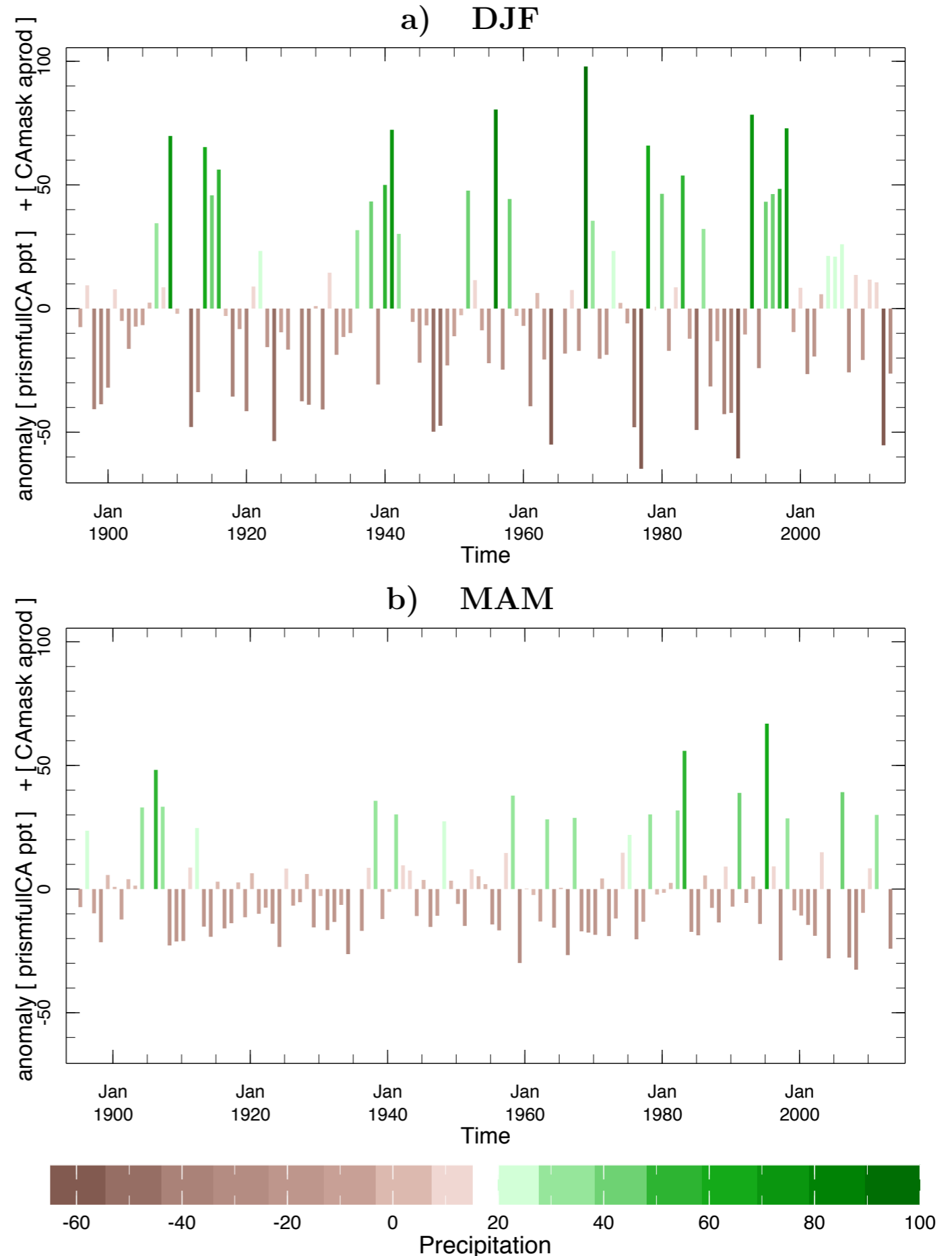
Brad Lyon

International Research Institute for Climate and Society, Columbia University

Thanks to: Martin Hoerling (NOAA ESRL), Ben Cook (NASA GISS), NOAA Drought Task Force

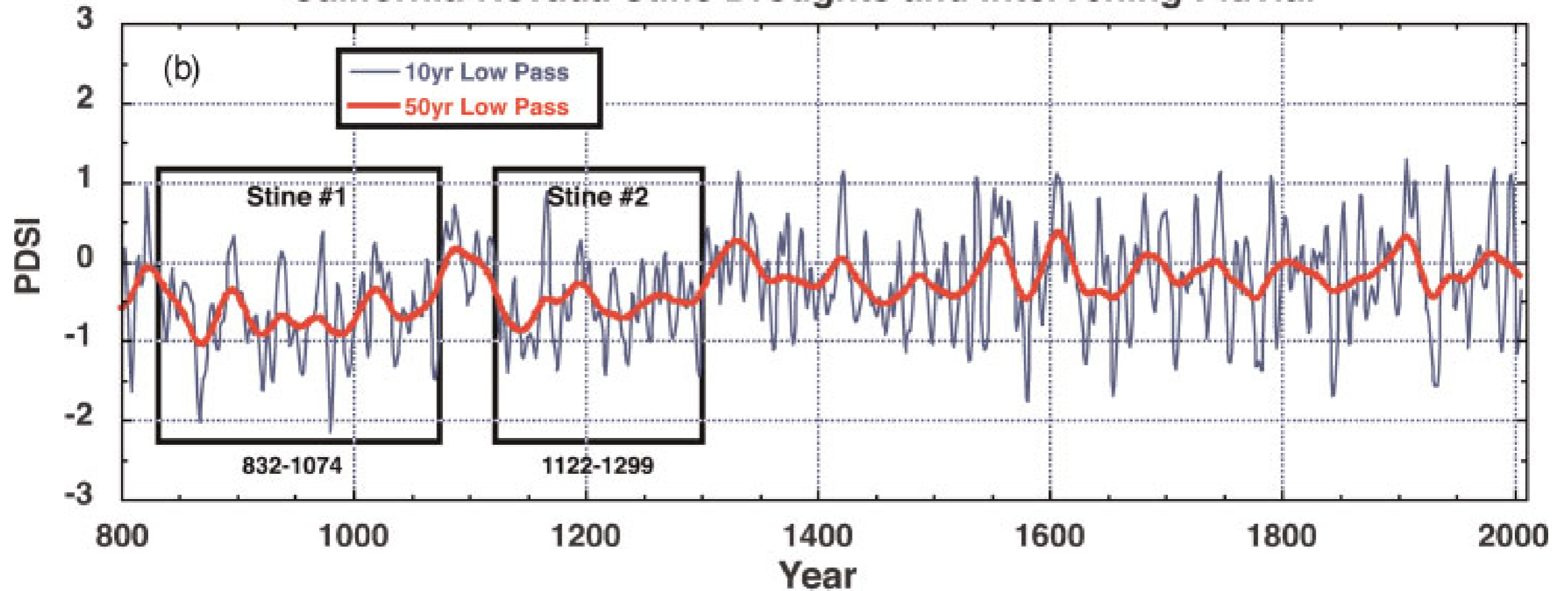
California has a rich history of droughts. Current drought appears as one of many such events both in terms of amplitude and duration.

Prism CA Precipitation Anomaly



And tree ring data tells us that even worse droughts have struck California in past centuries

California-Nevada Stine Droughts and Intervening Pluvial



Cook et al. (2010,
J. Quat. Sci.)

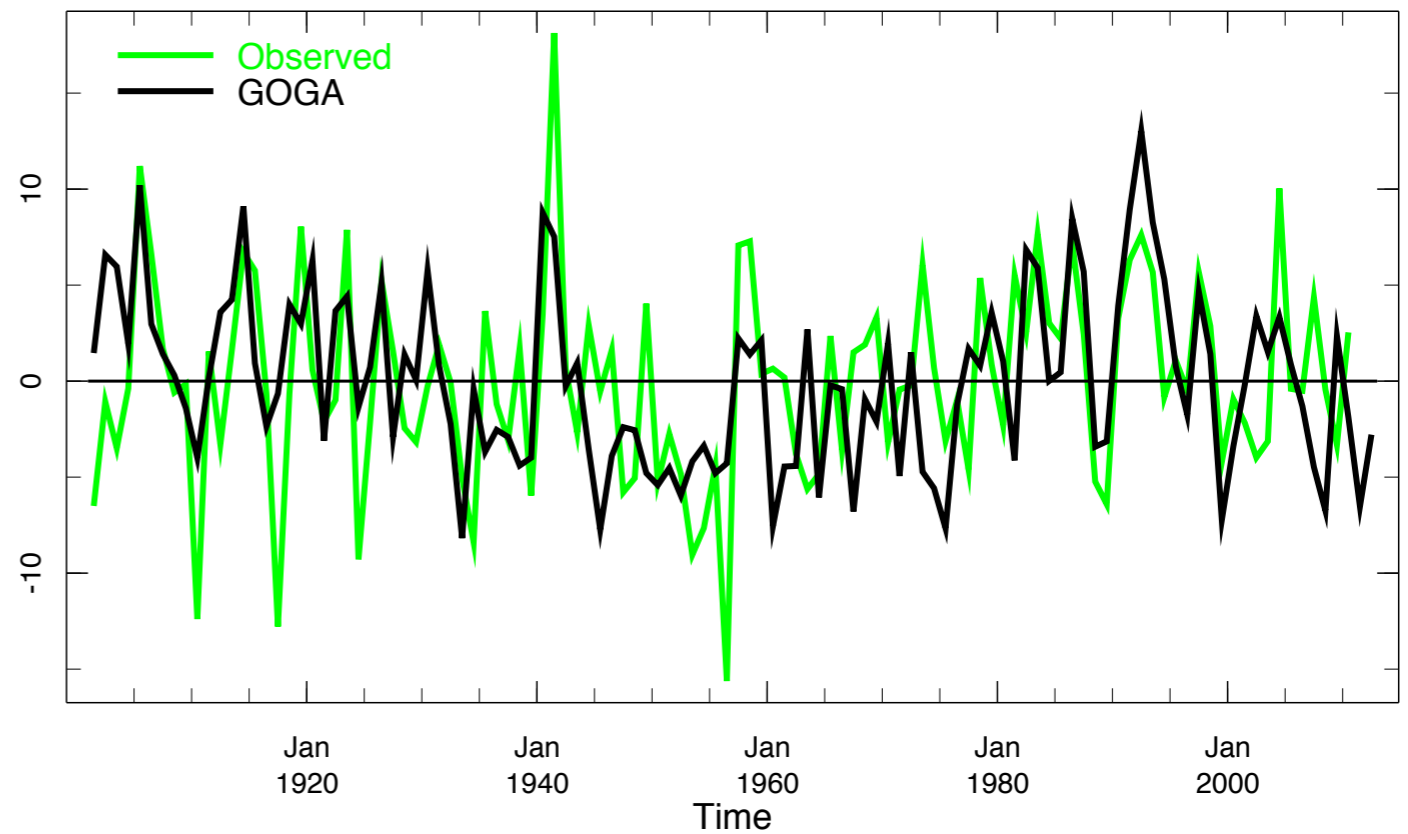


Ocean-forced atmosphere models far less skilled at reproducing precipitation variations in CA than the larger Southwest.

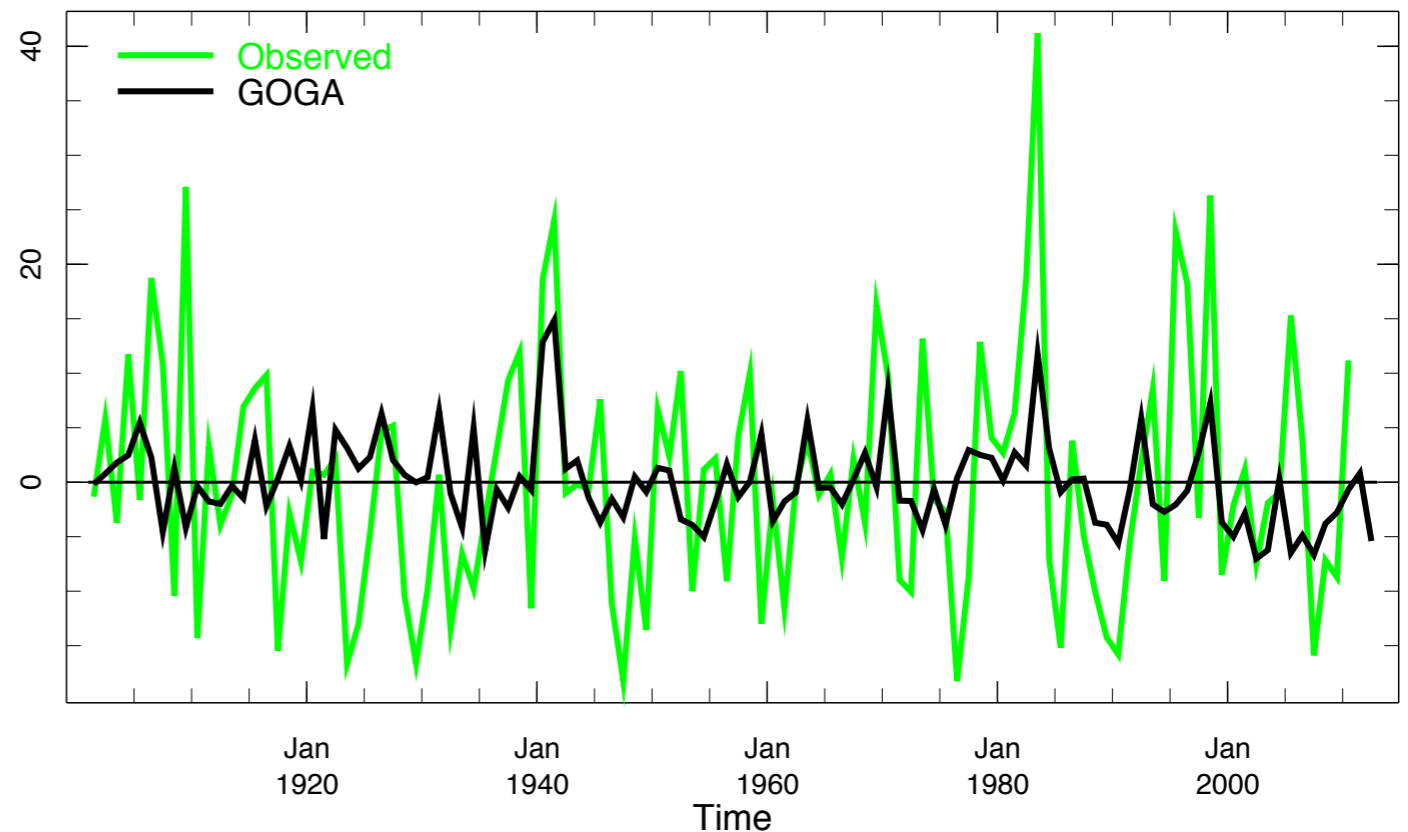
Suggests a larger role for internal atmosphere variability (unpredictable beyond the weather timescale) in controlling CA precipitation.

Annual Precip Anom, Observed (green) and GOGA (black)

a) SW, corr 0.47

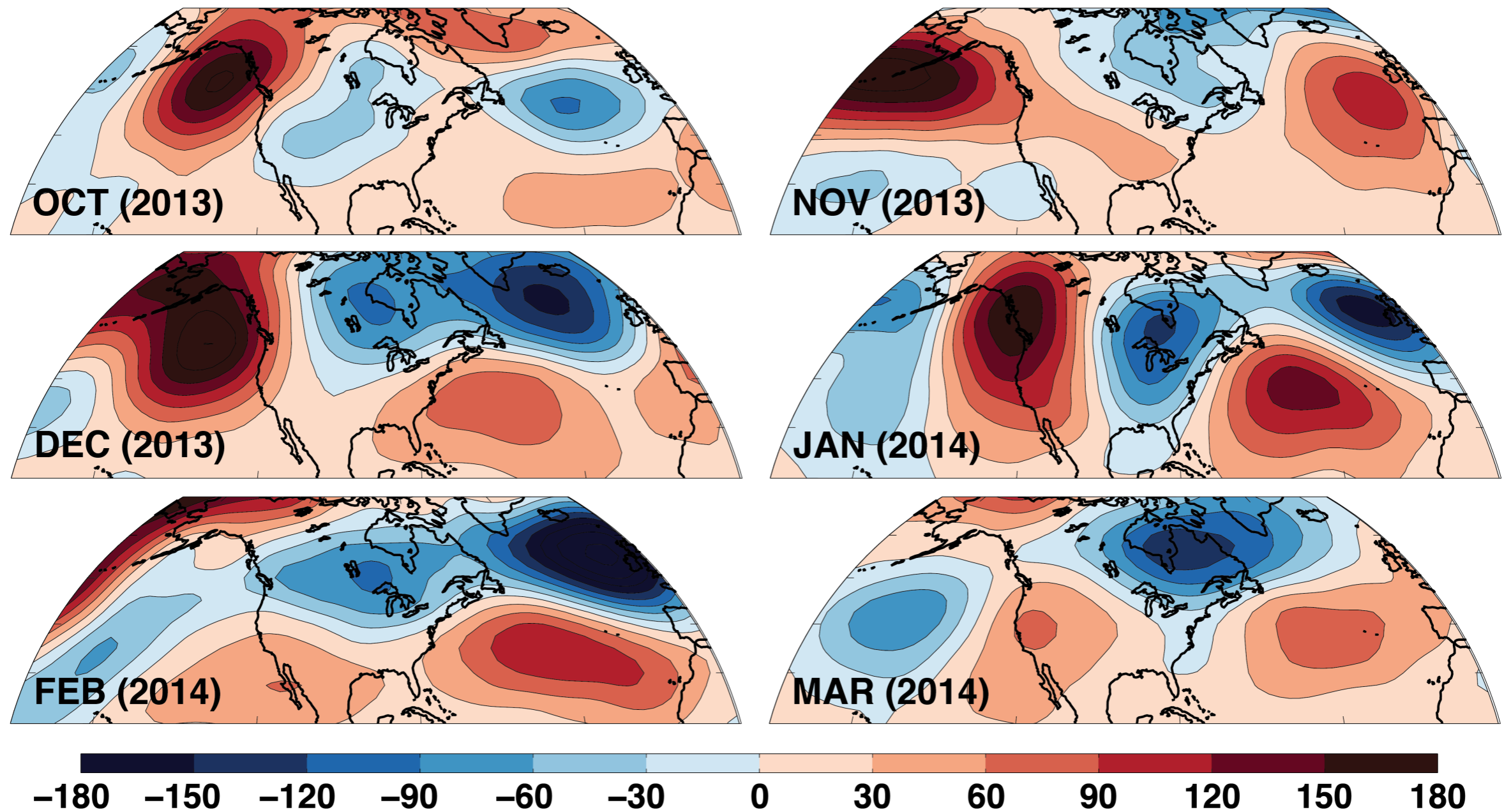


b) CA, corr 0.32



2013/14 winter drought caused by a persistent (but varying) ridge over west coast of North America

500mb height anomalies



B. Cook et al. (2014, to be submitted)

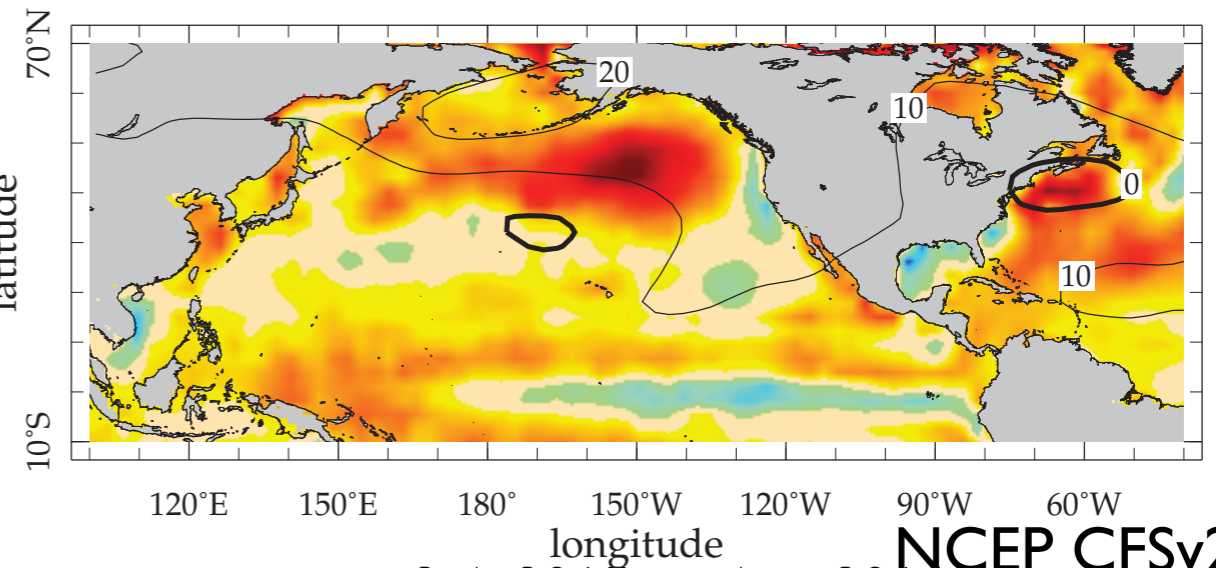
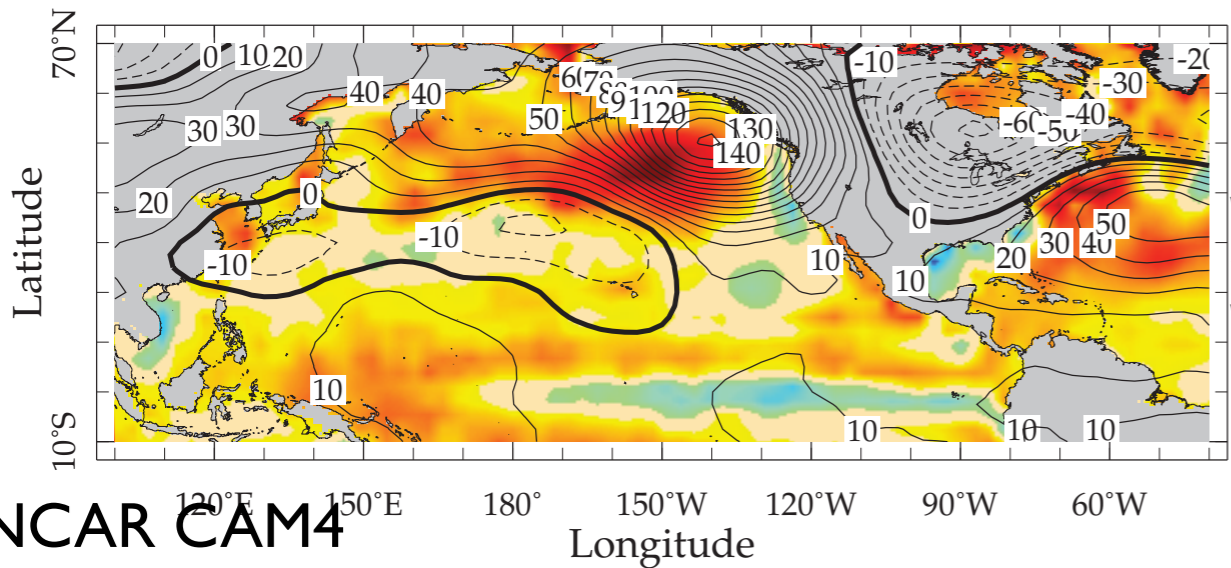
Ocean-forced simulations of winter 2013/14

only ECHAM4.5 model gets it 'right'

observed

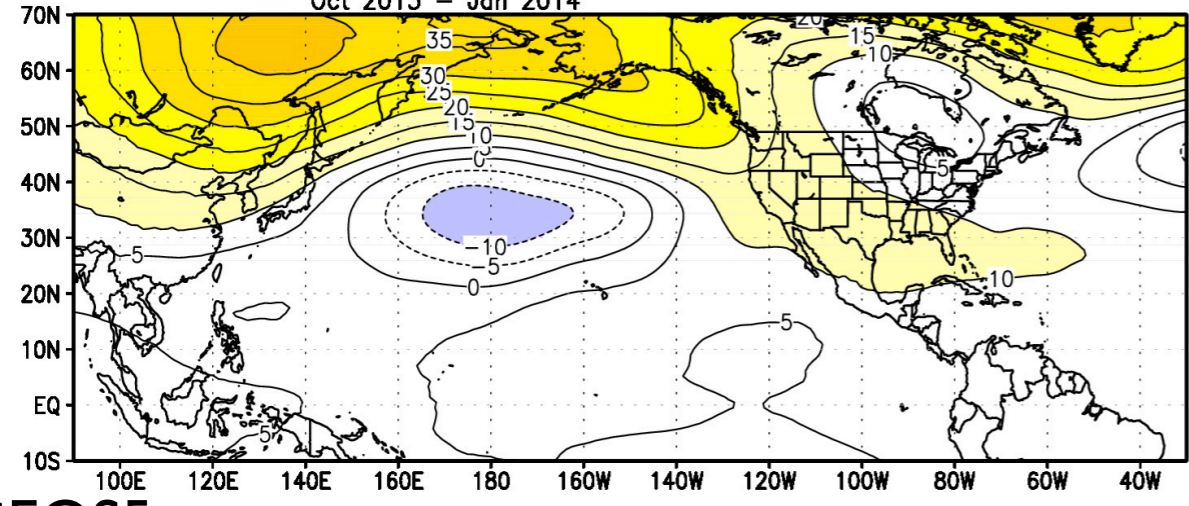
Oct 2013 - Jan 2014

NCAR CCM3

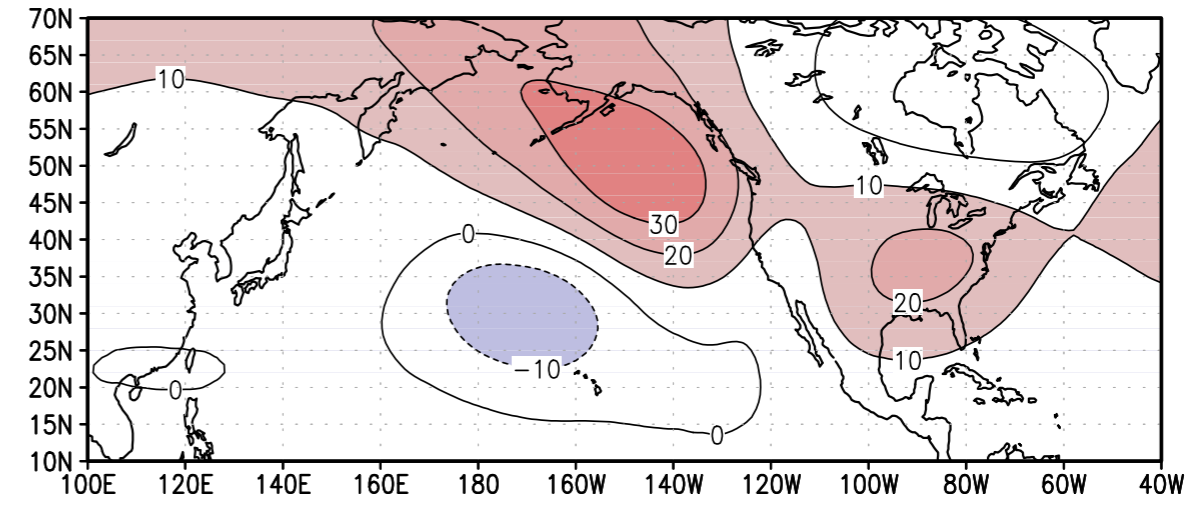


NCAR CAM4

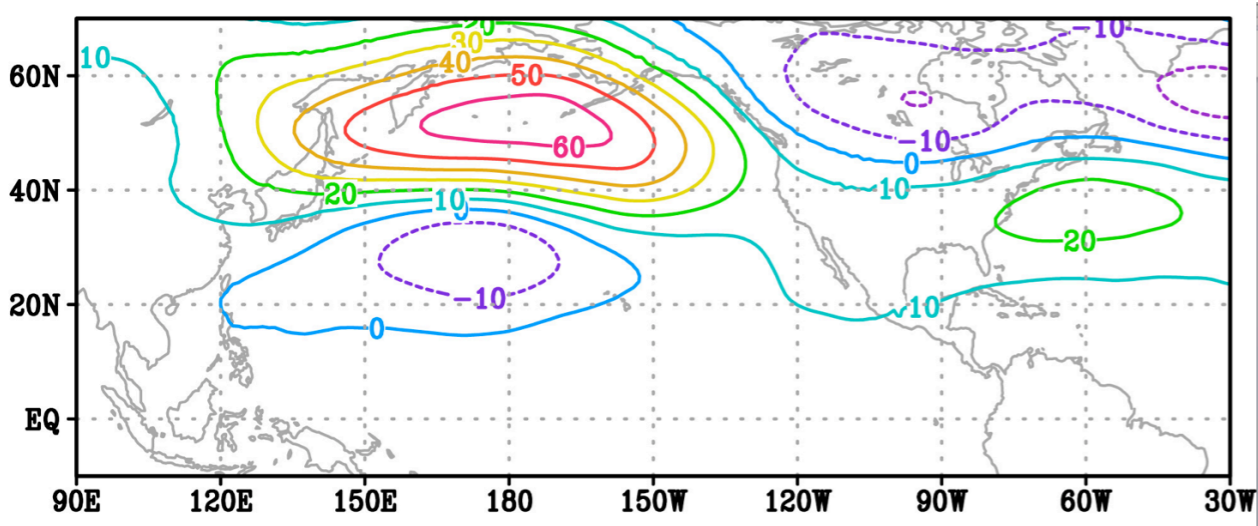
Oct 2013 - Jan 2014



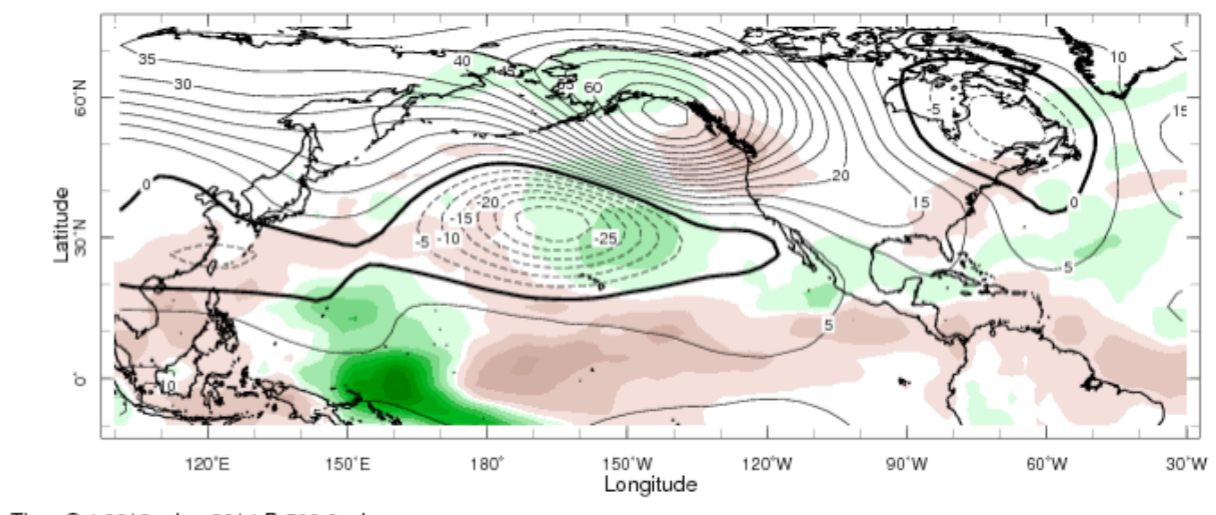
NCEP CFSv2
Oct 2013 - Jan 2014



GEOS5 GEOS5 500mb Height: Oct 2013-Jan 2014

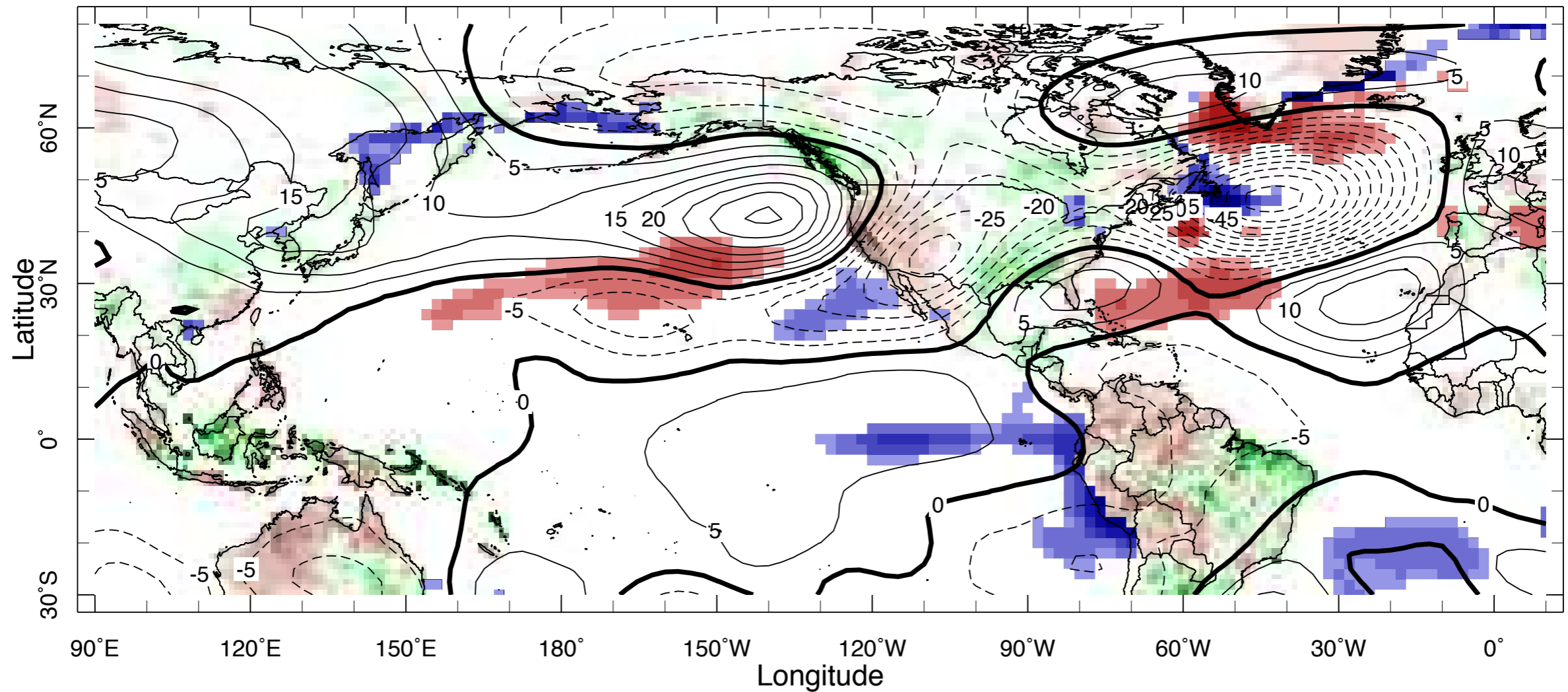


ECHAM4.5



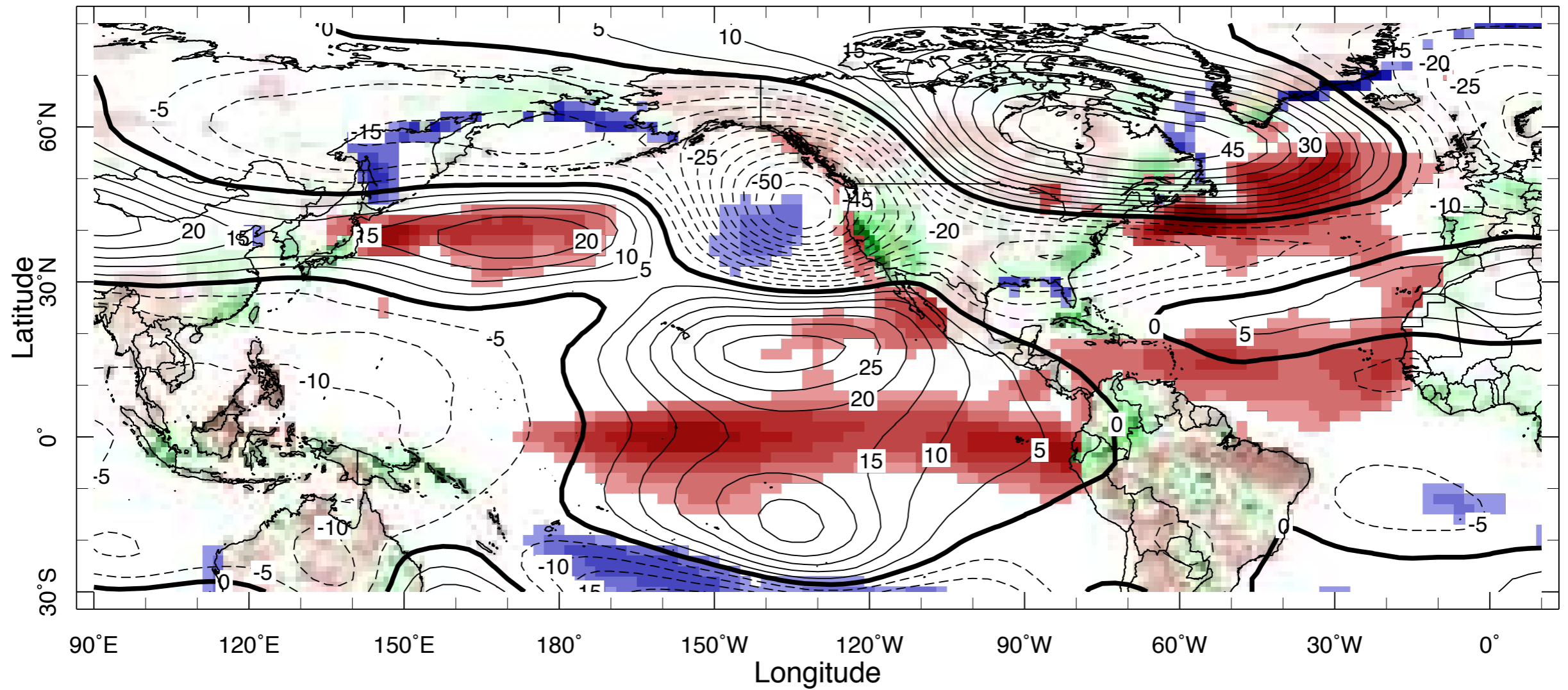
Time Oct 2013 - Jan 2014 P 500.0 mb

The inability of ocean-forced models to reproduce CA precipitation variability is not surprising

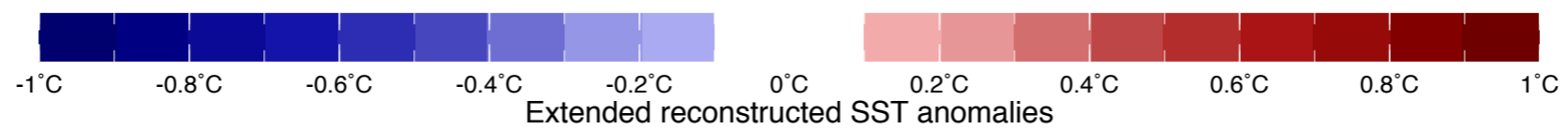


A composite of CA dry winters shows the off-coast ridge but no impressive sea surface temperature anomalies

In contrast, wet California winters tend to be caused by El Nino events



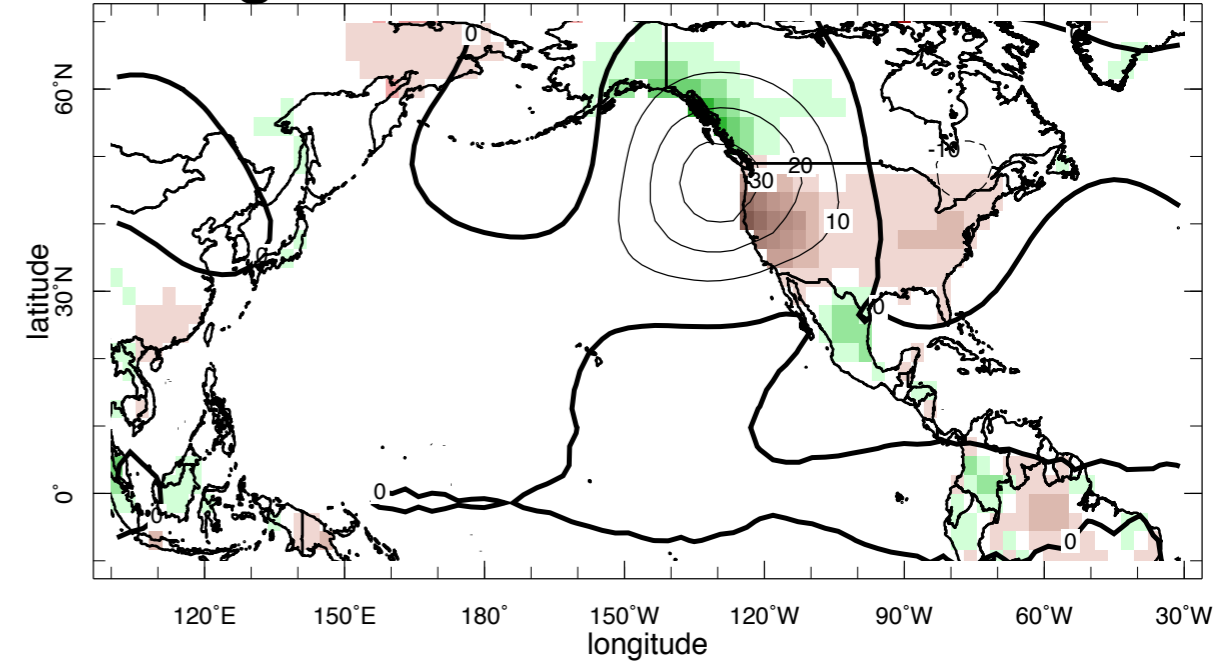
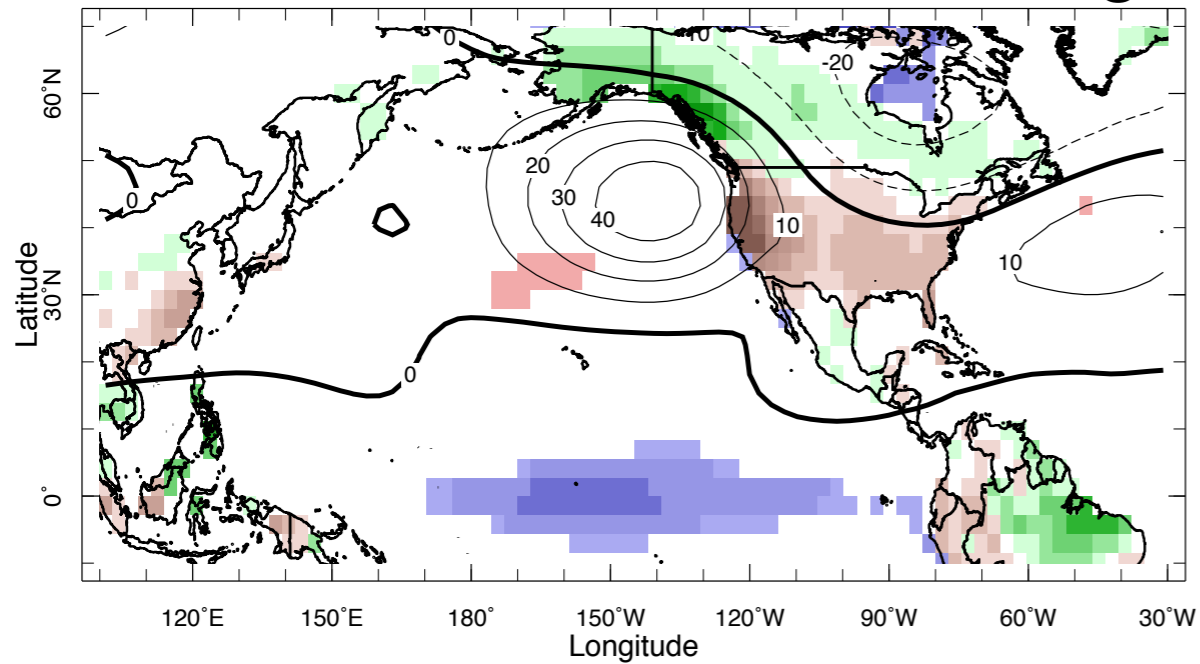
zlev 0.0 meters Pressure 200.0 mb



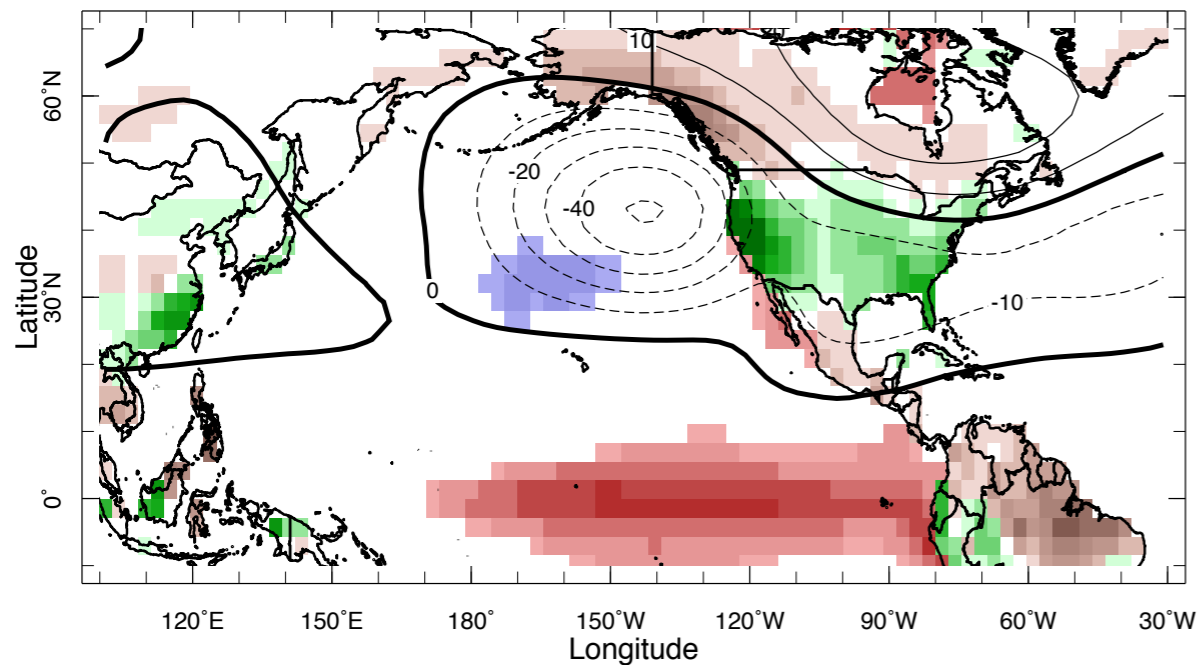
Dry and wet CA winters in the ECHAM4.5 and CCM3 models

ECHAM 4.5 Winter CA Precip(land), SSTA(ocean), 500mb Height(contour) GOGA Winter CA Precip(land), SSTA(ocean), 500mb Height(contour)

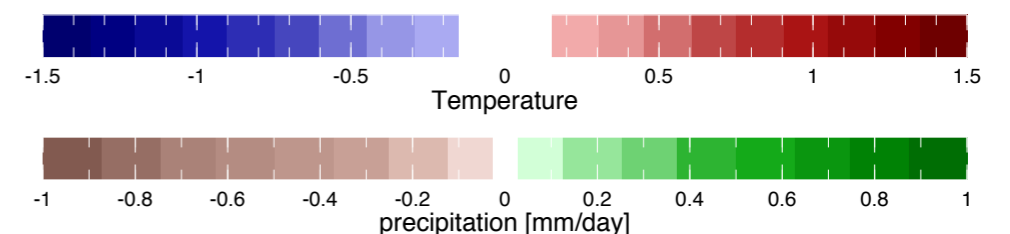
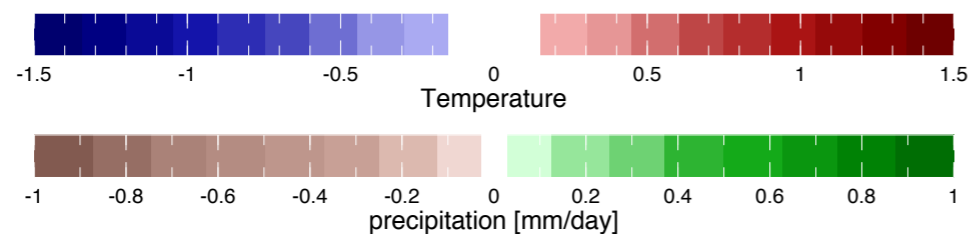
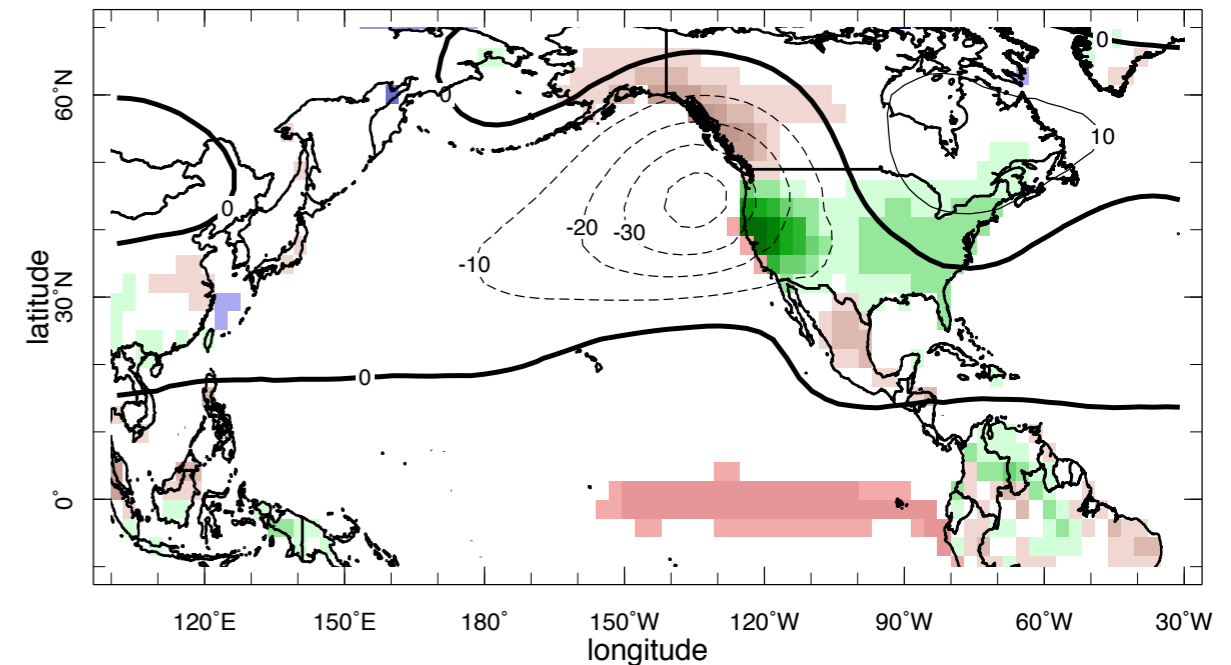
(A) Dry Years less right ... more right? (A) Dry Years



ECHAM4.5 (B) Wet Years

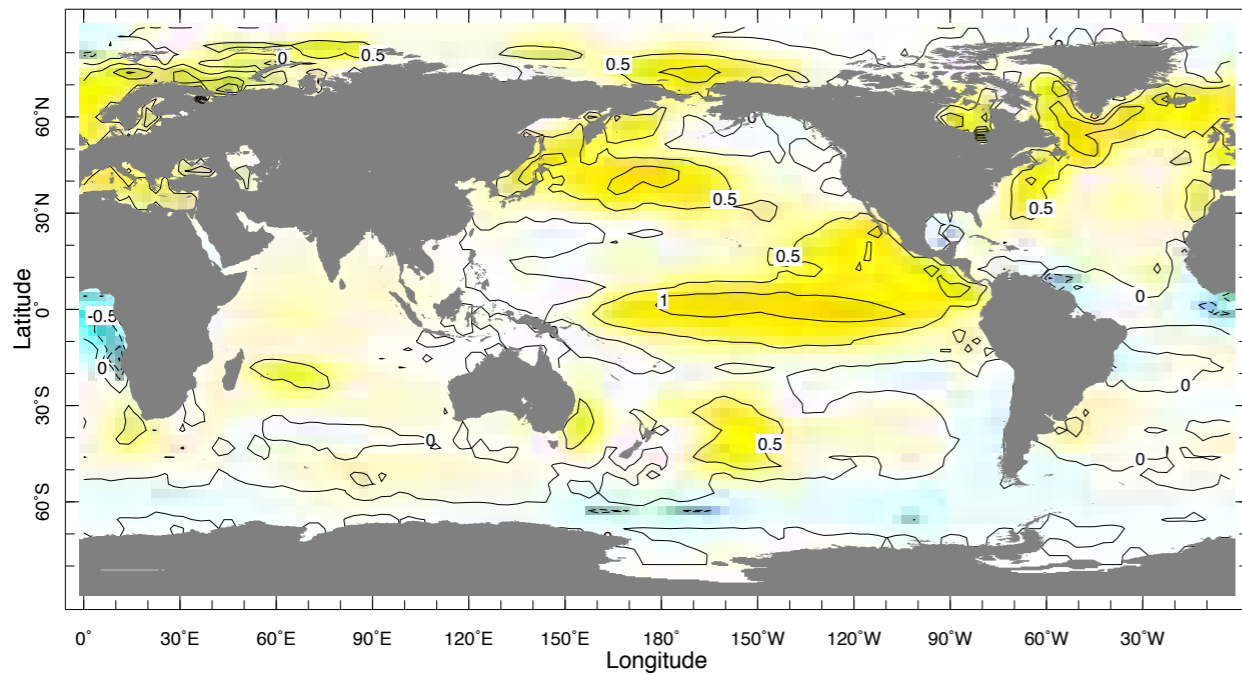


CCM3 (B) Wet Years

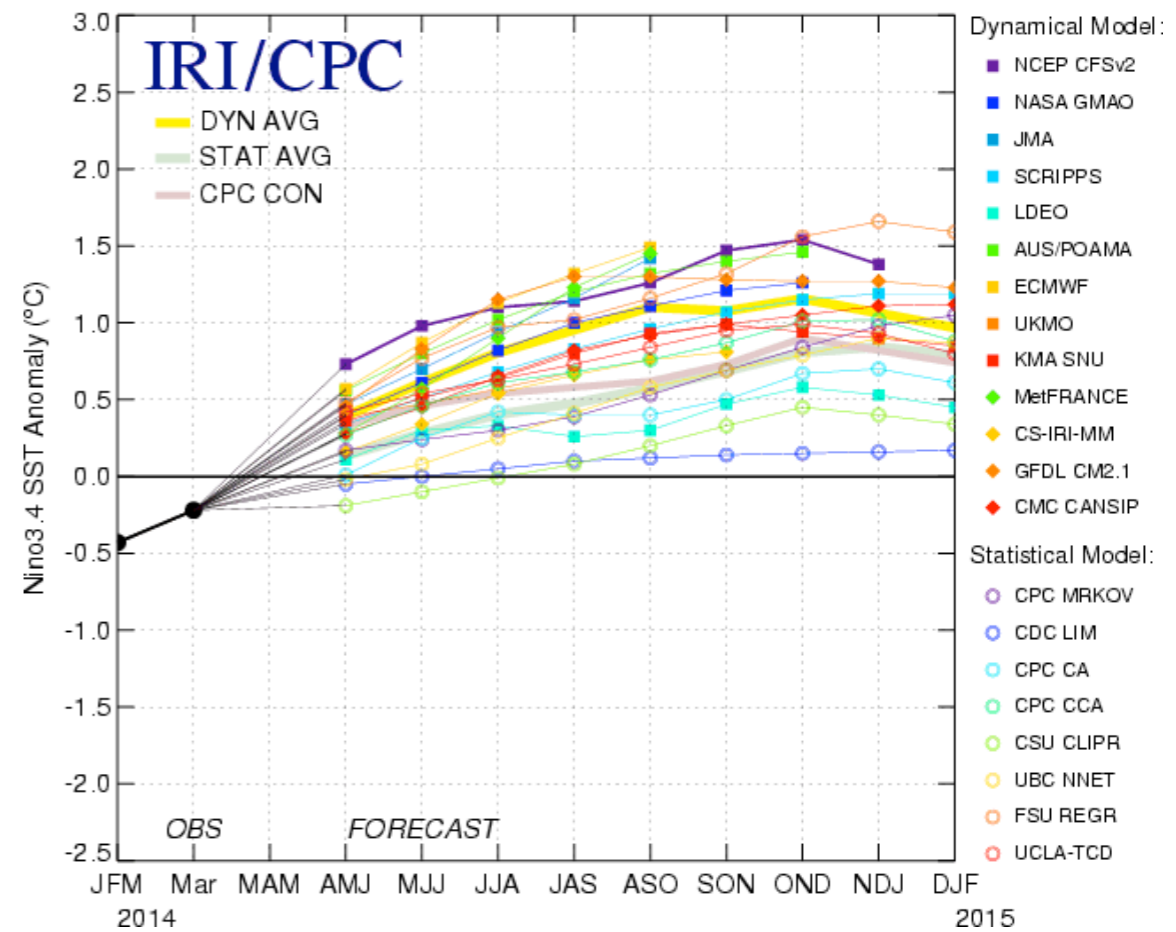


Modest El Nino predicted for winter 2014/15

Oct-Dec 2014 IRI seasonal Forecast SSTA issued 0000 1 May 2014

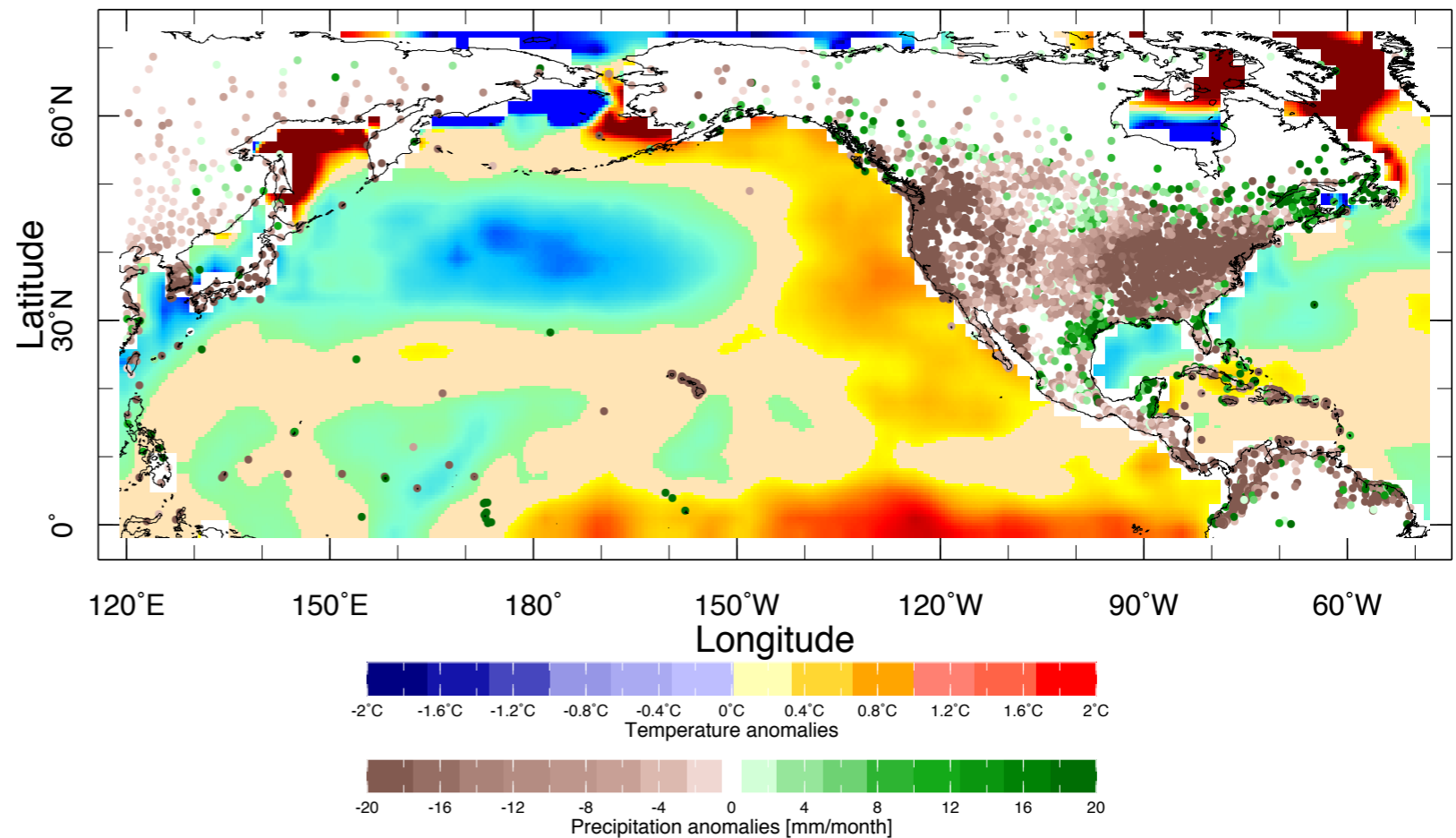


Mid-Apr 2014 Plume of Model ENSO Predictions



(b) DJF 1976/1977

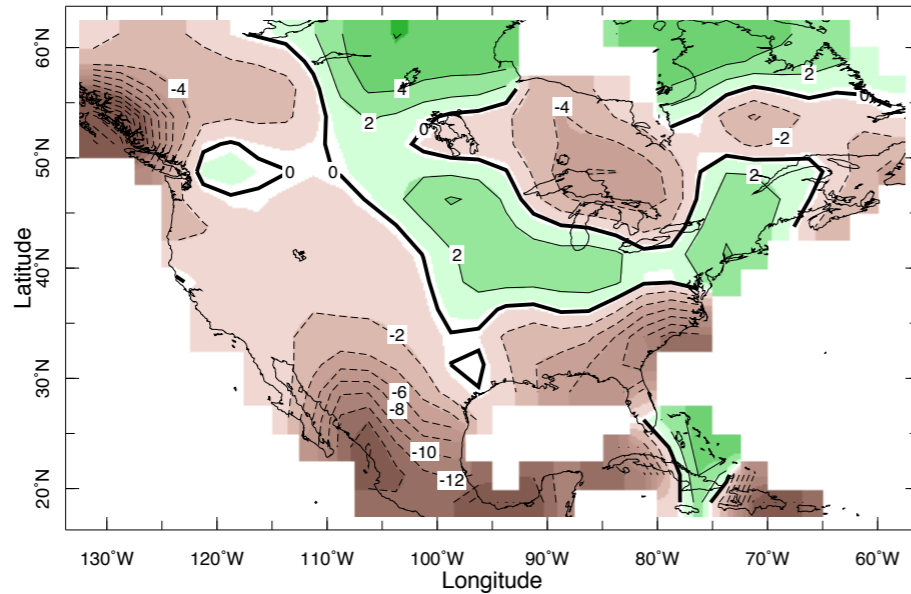
but beware!
 1976/77 was a
 strong El Nino
and a drought in
 California



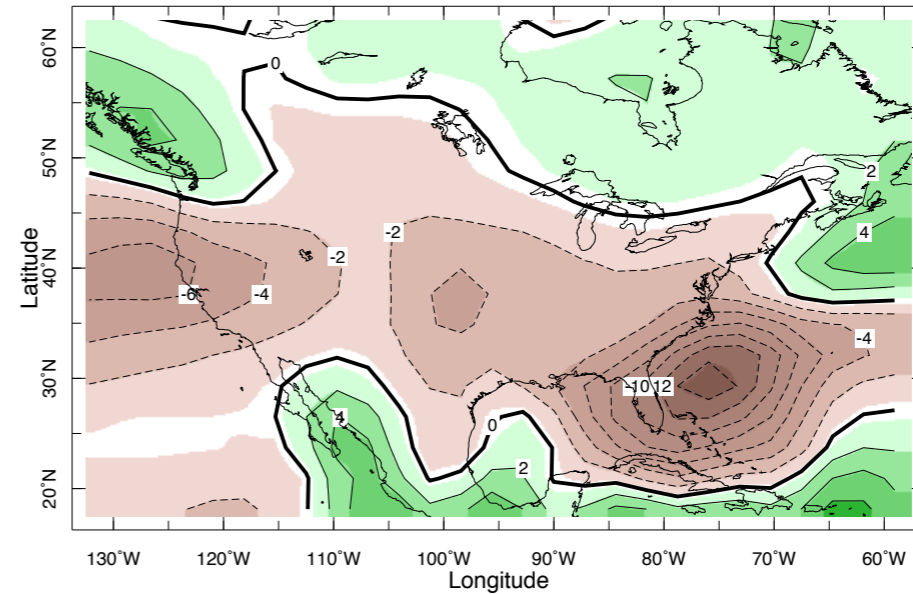
Two most recent dry winters might not have been strongly ocean forced, the 97/98 shift in to more La Nina-like tropical Pacific state has favored drying across southwest North America

Precipitation (Sep 1998 to Dec 2012) - (Jan 1948 to Aug 1998)

Observed

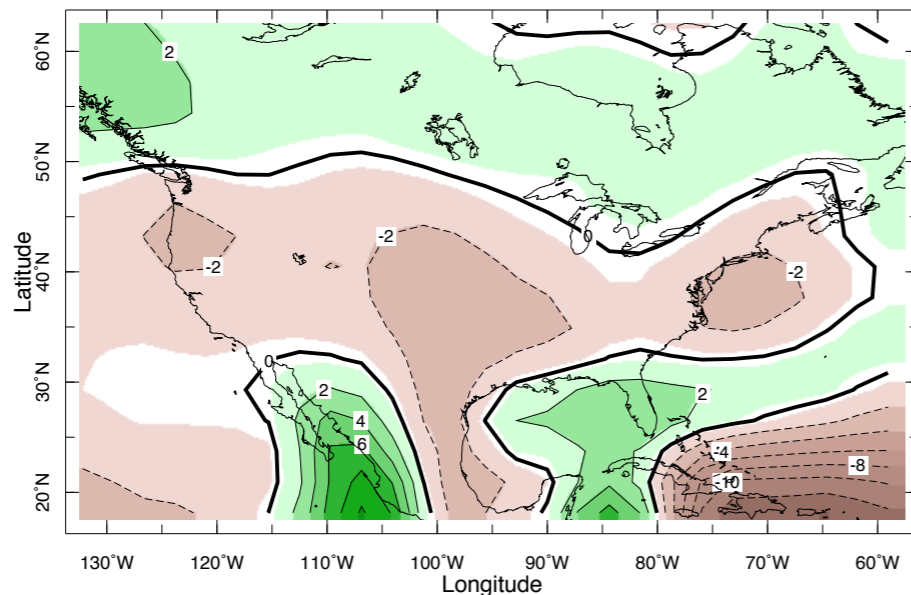


GOGA Model

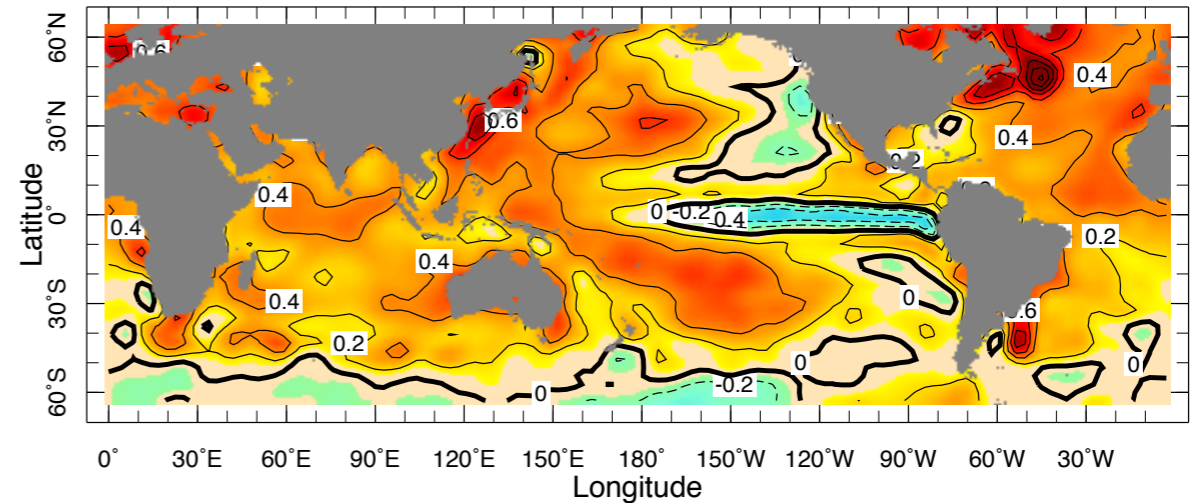


global
SST
forcing

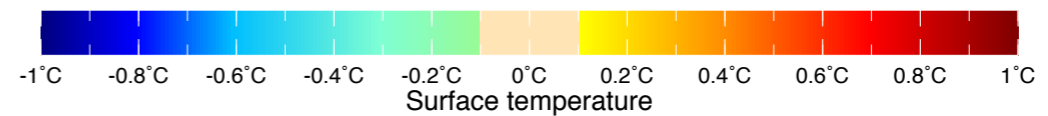
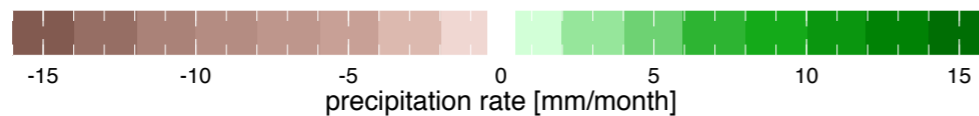
POGA-ML Model



Observed Sea Surface Temperature



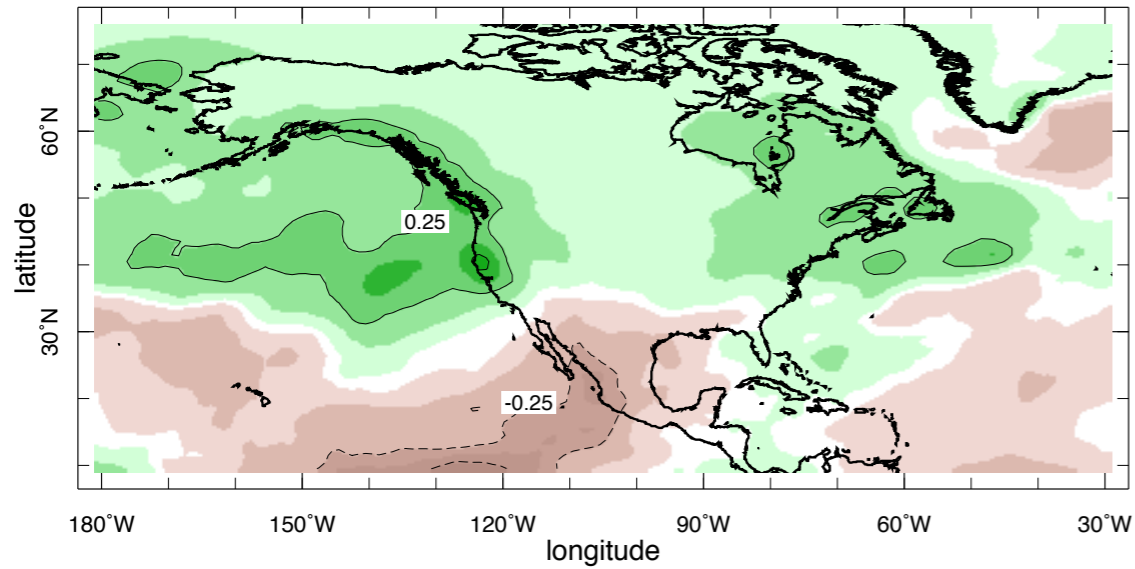
tropical
Pacific
SST
forcing
only



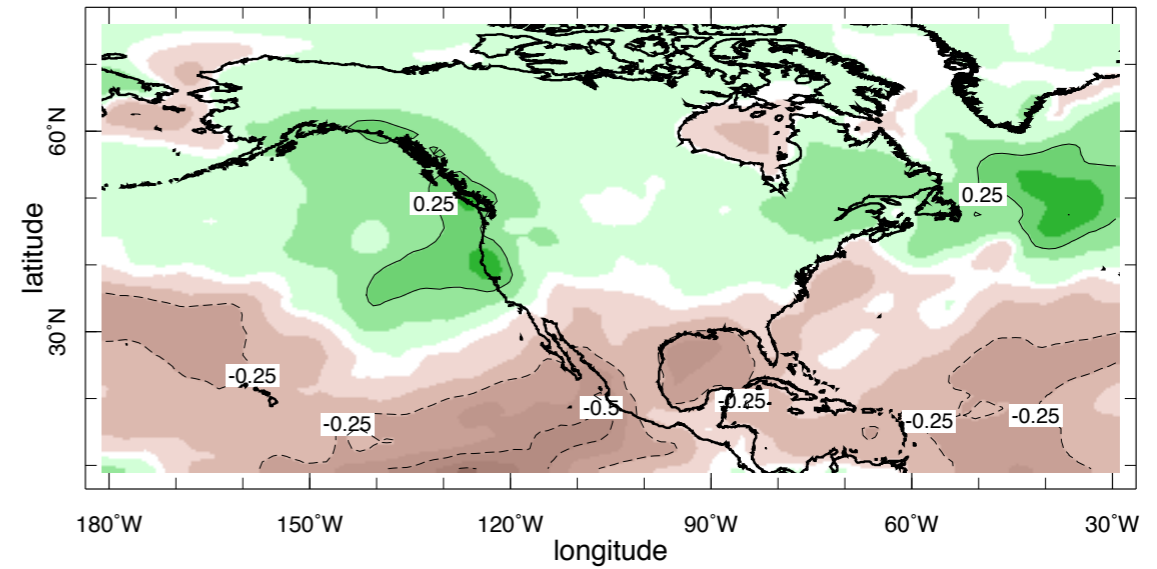
Climate models project for California wetter winters/ drier springs due to rising greenhouse gases

CMIP5, (2021-2040) - (1979-2005)

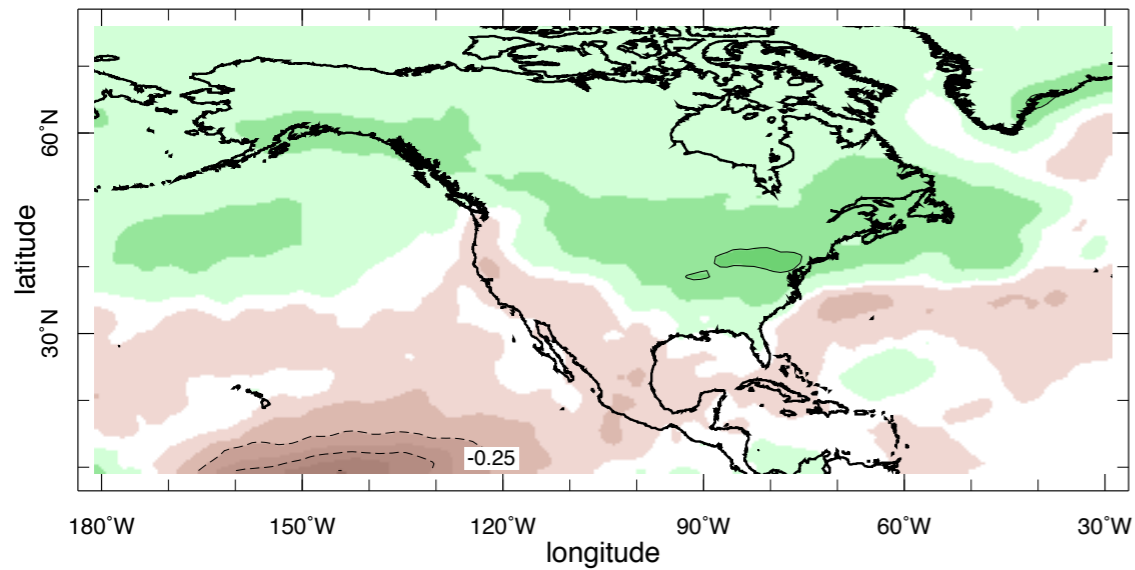
$\Delta \bar{P}$ DJF



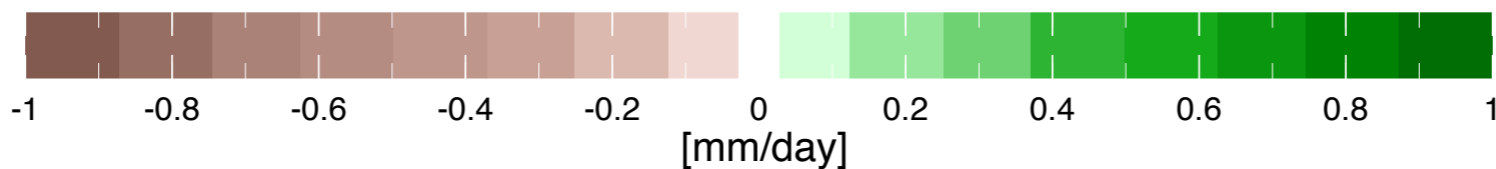
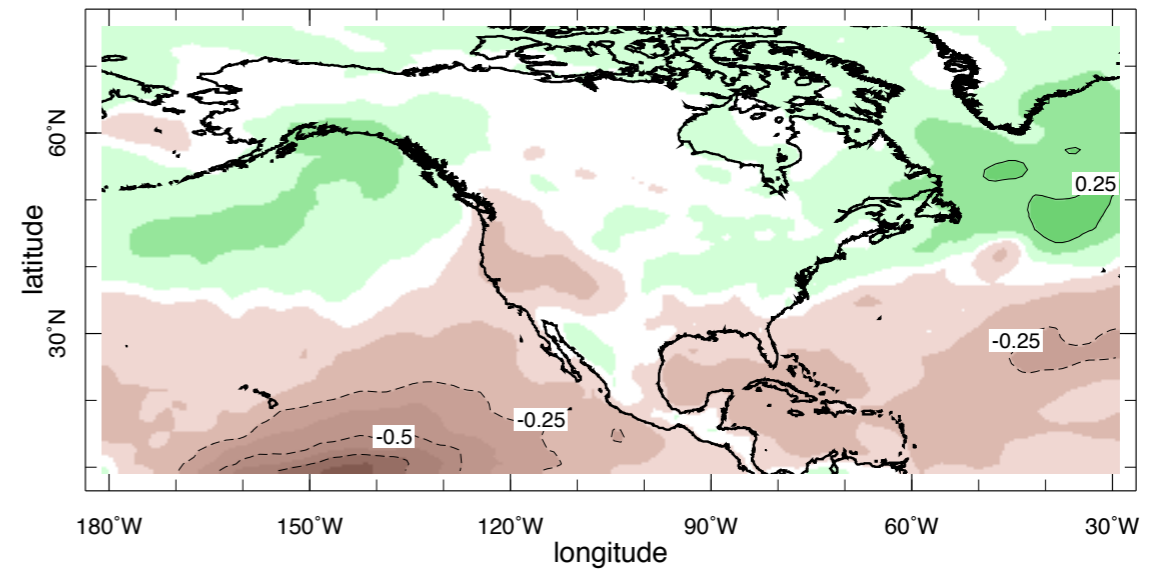
$\Delta(\bar{P} - \bar{E})$ DJF



$\Delta \bar{P}$ MAM



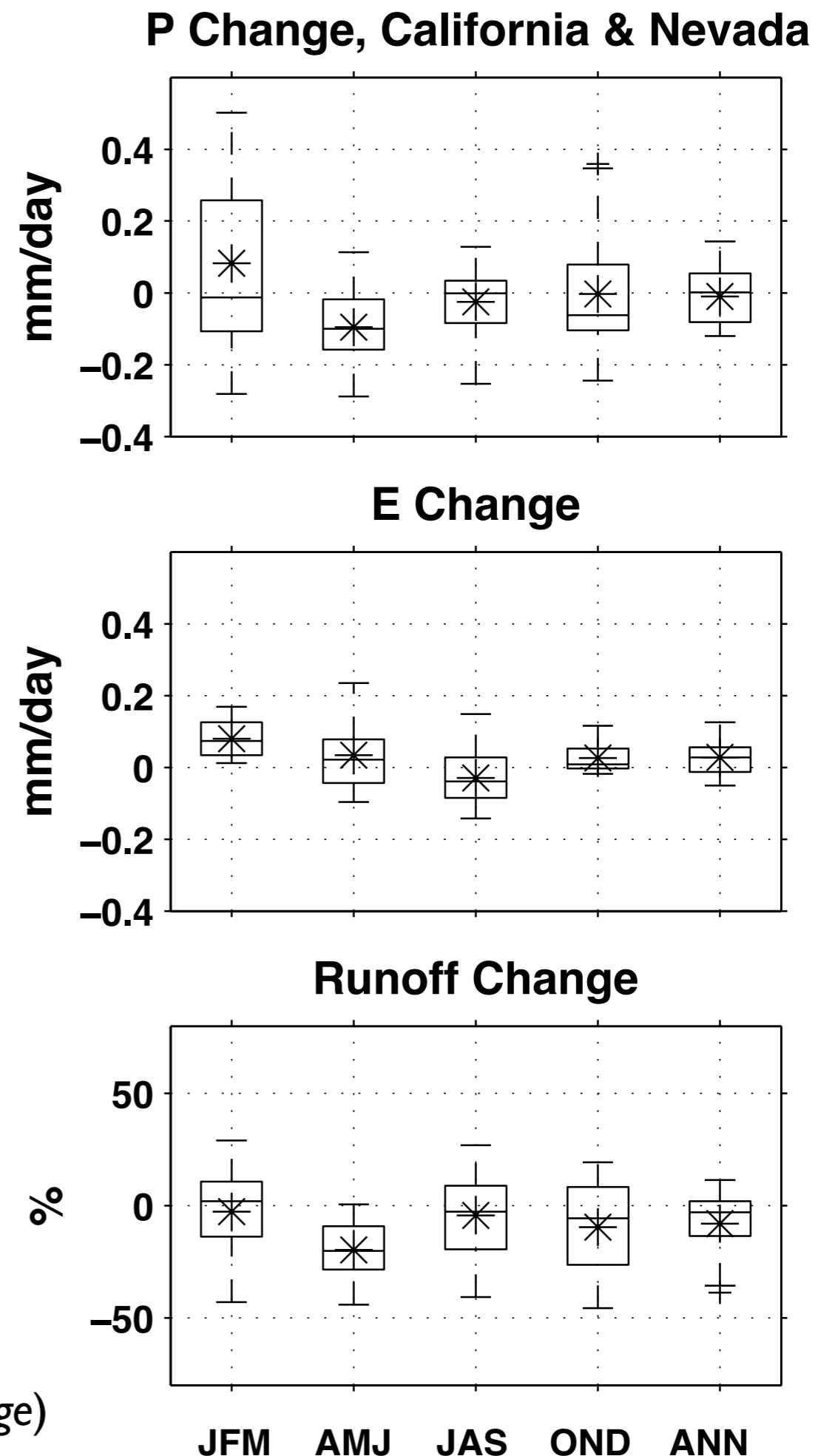
$\Delta(\bar{P} - \bar{E})$ MAM



Most recent climate models project for 2021-2040, due to rising greenhouse gases:

- an increase in winter precipitation
- a decrease in spring precipitation
- an increase in winter evaporation/ET
- a strong drop in spring runoff

Seager et al. (2013, *Nature Climate Change*)



Conclusions

The 2013/14 winter drought caused by an unusually persistent anomalous ridge centered just off the west coast.

California droughts this serious have occurred before. No clear precipitation trends.

Droughts largely related to internal atmosphere variability but wet winters tend to be El Nino winters. Link not strong: 1976/77 was both an El Nino winter and a drought!

Not clear that winter 2013/14 drought was strongly forced by ocean surface temperature. More modeling and observational work to prove yes or no. 1997/98 (presumed natural) shift in Pacific Ocean has favored dry conditions in SW since then.

Models project rising GHGs will cause an increase in winter precipitation for central to northern CA and a decrease in spring. 2012/13/14 winter precipitation decline is not consistent with human-induced climate change.

But, as years go by, increased winter evaporation/evapotranspiration plus spring precipitation decline will cause a spring runoff decline and stress CA water resources.