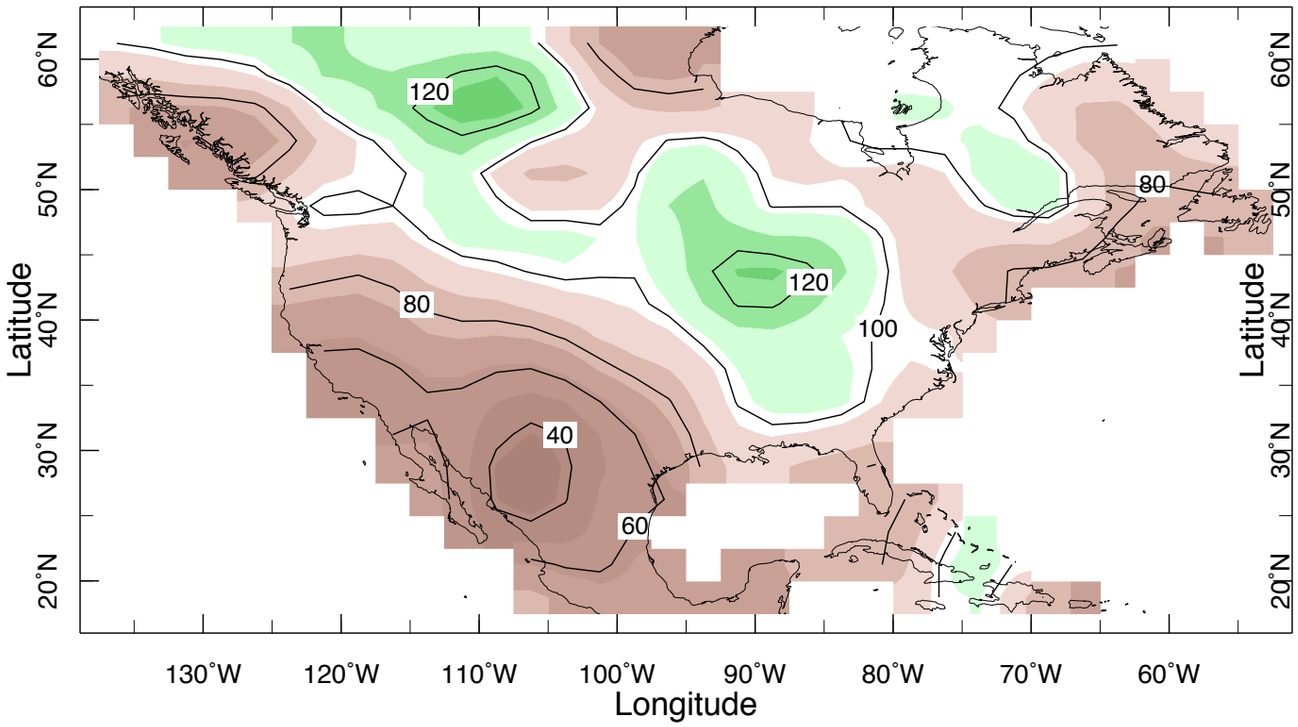
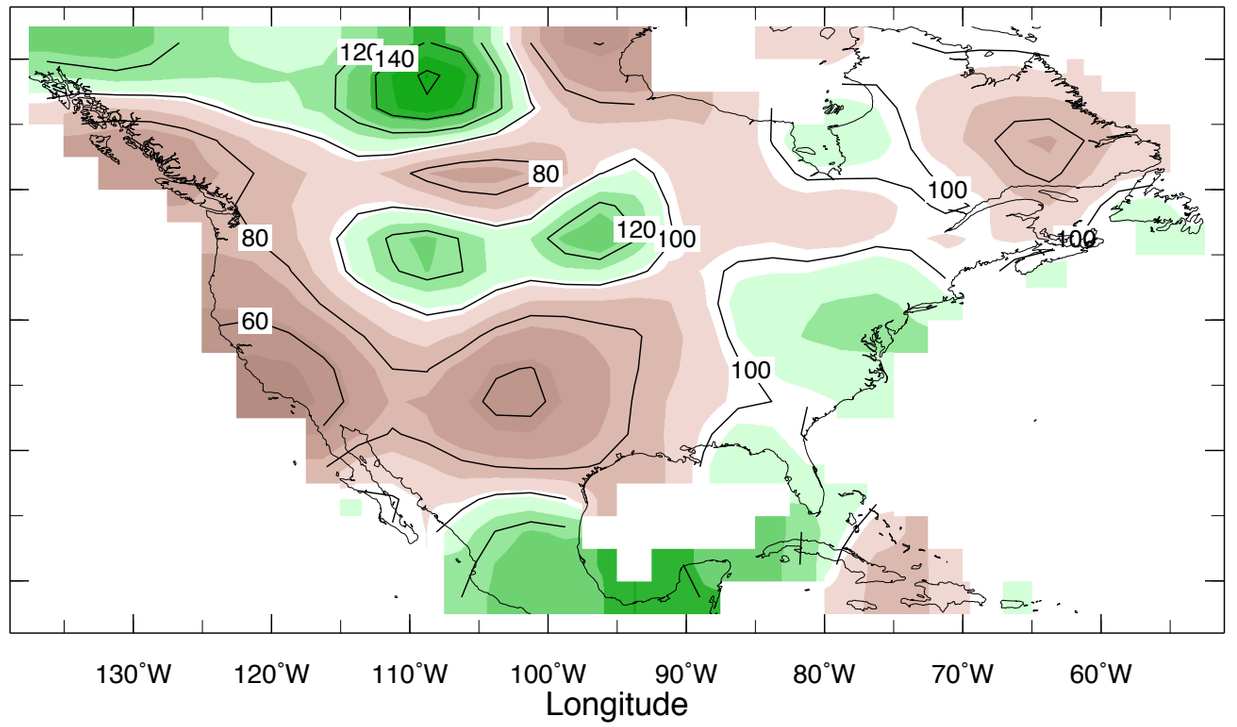
Causes of the 2011-14 California Drought:

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



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NOAA Drought Task Force

Observational data:

NOAA Climate Division precipitation, Jan 1895 to Apr 2014

Various SST products

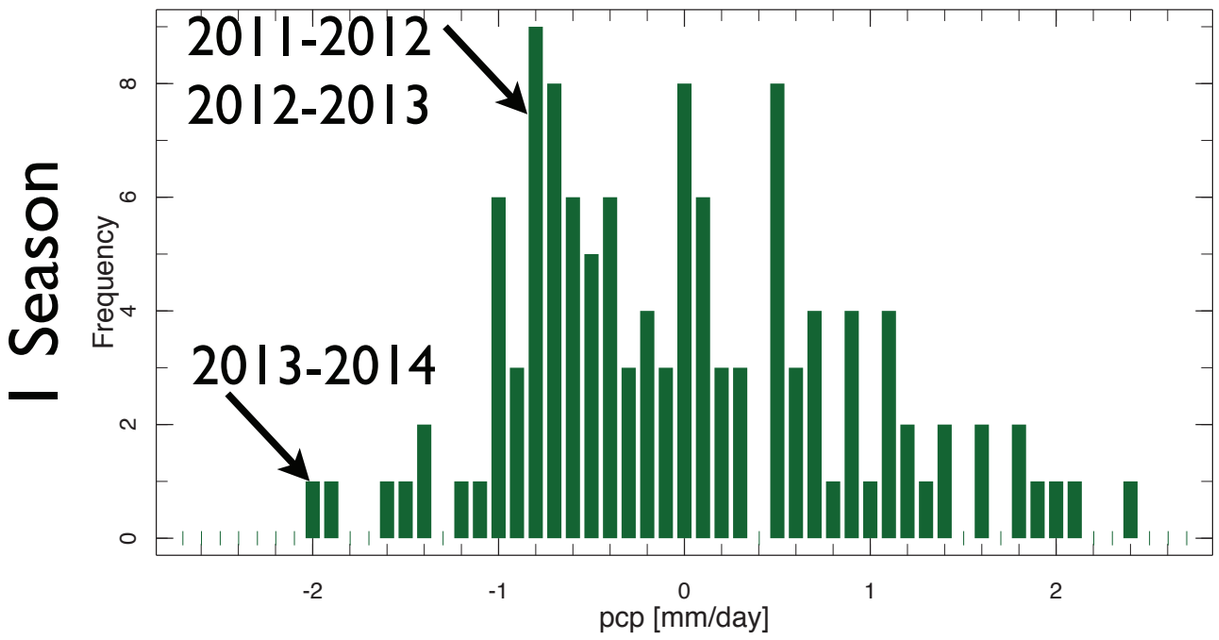
NCEP-NCAR Reanalysis 1949 to Apr 2014

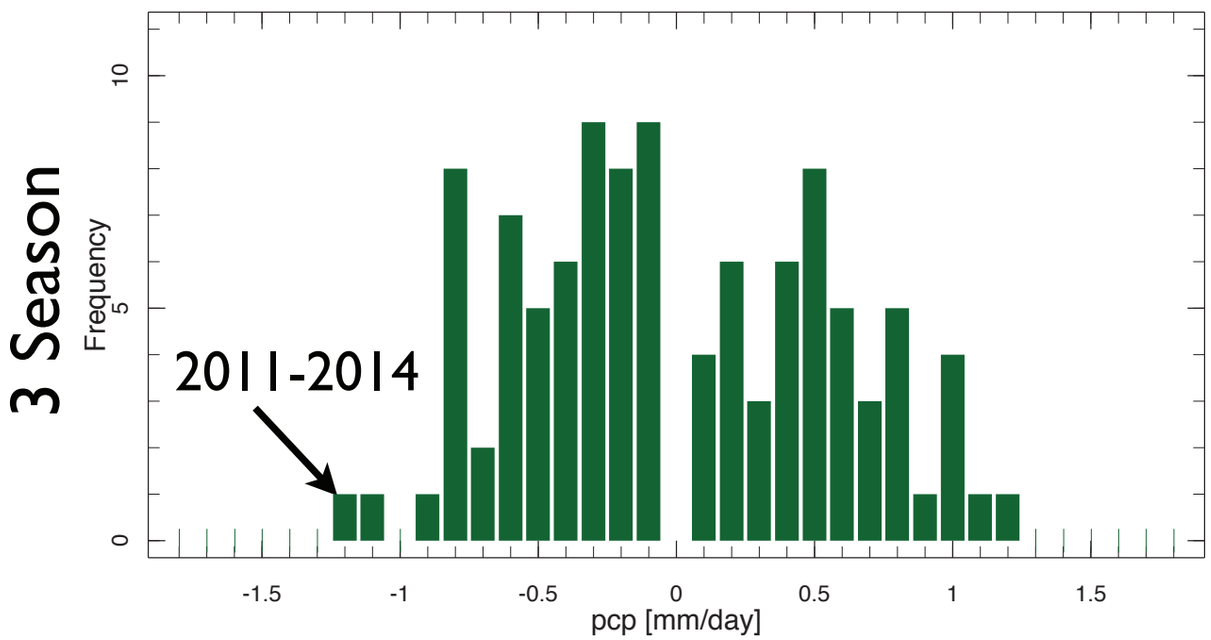
Models:

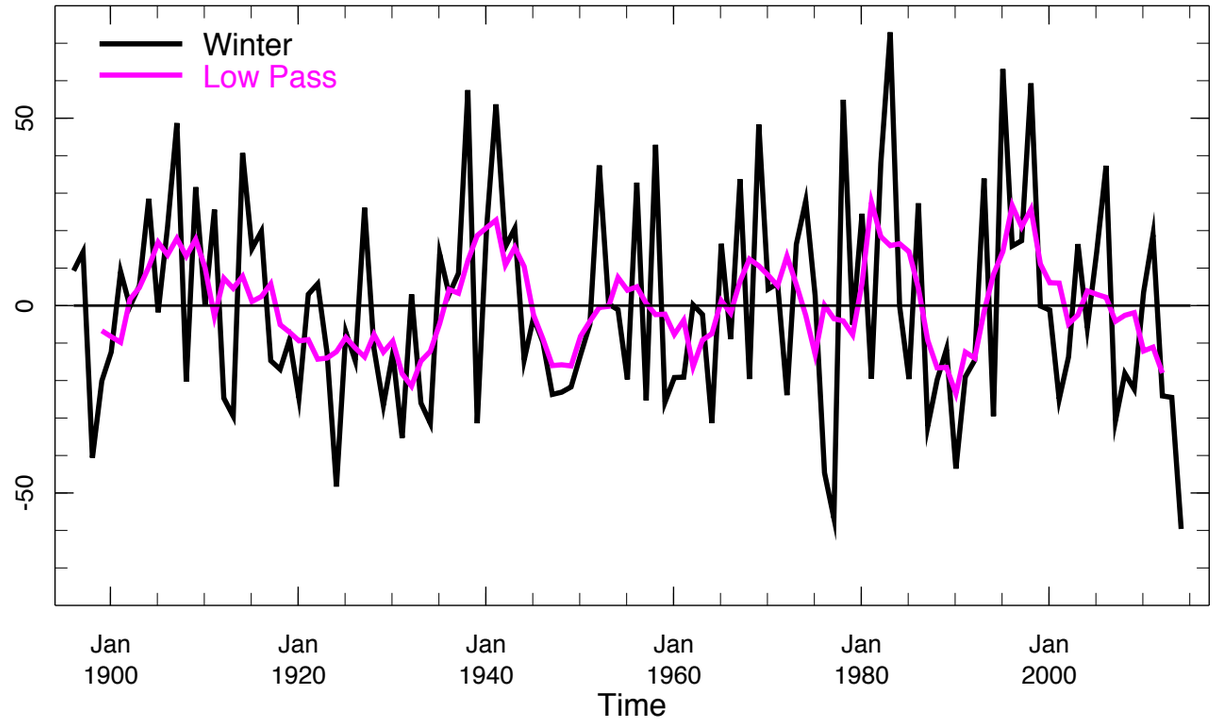
Seven SST-forced GCMs

CCM3, CAM4, ESRL CFSv2, NCEP CFSv2, NASA GEOS-5, ECHAM4.5, ECHAM5

CA Winter Climate Division Precipitation







California has a rich history of droughts. Current drought appears as one of many such events both in terms of amplitude and duration, but it is the worst.

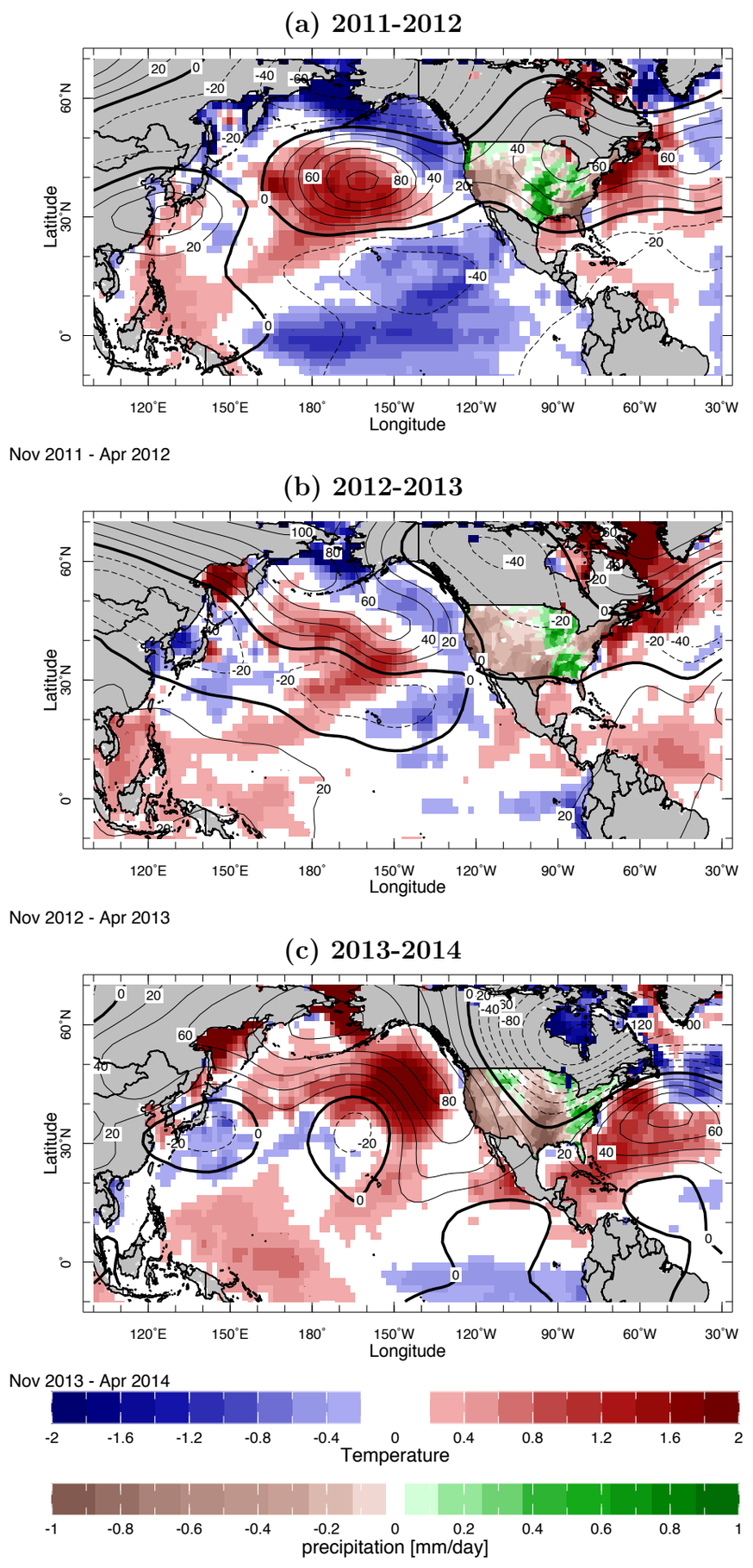
Last 3 winters 200mb heights, SST, U.S. precipitation

2011/12 looks like a La Nina

2012/13 ENSO neutral, North Pacific ridge

2013/14 warm west tropical Pacific, North Pacific-west coast ridge

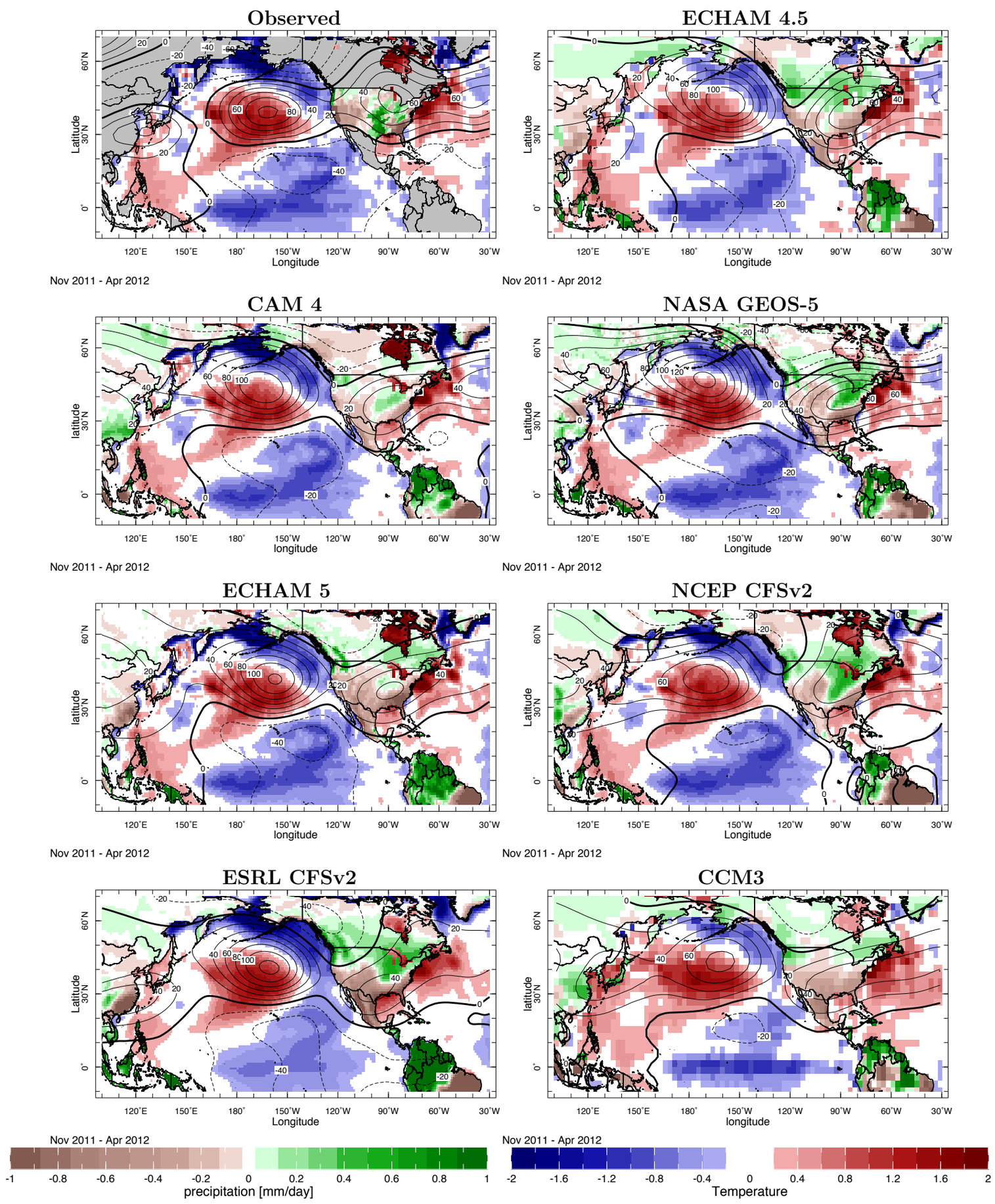
In all three CA/west coast was dry



Observed and model ensemble means for winter **2011/12**

Models respond in classic La Nina style

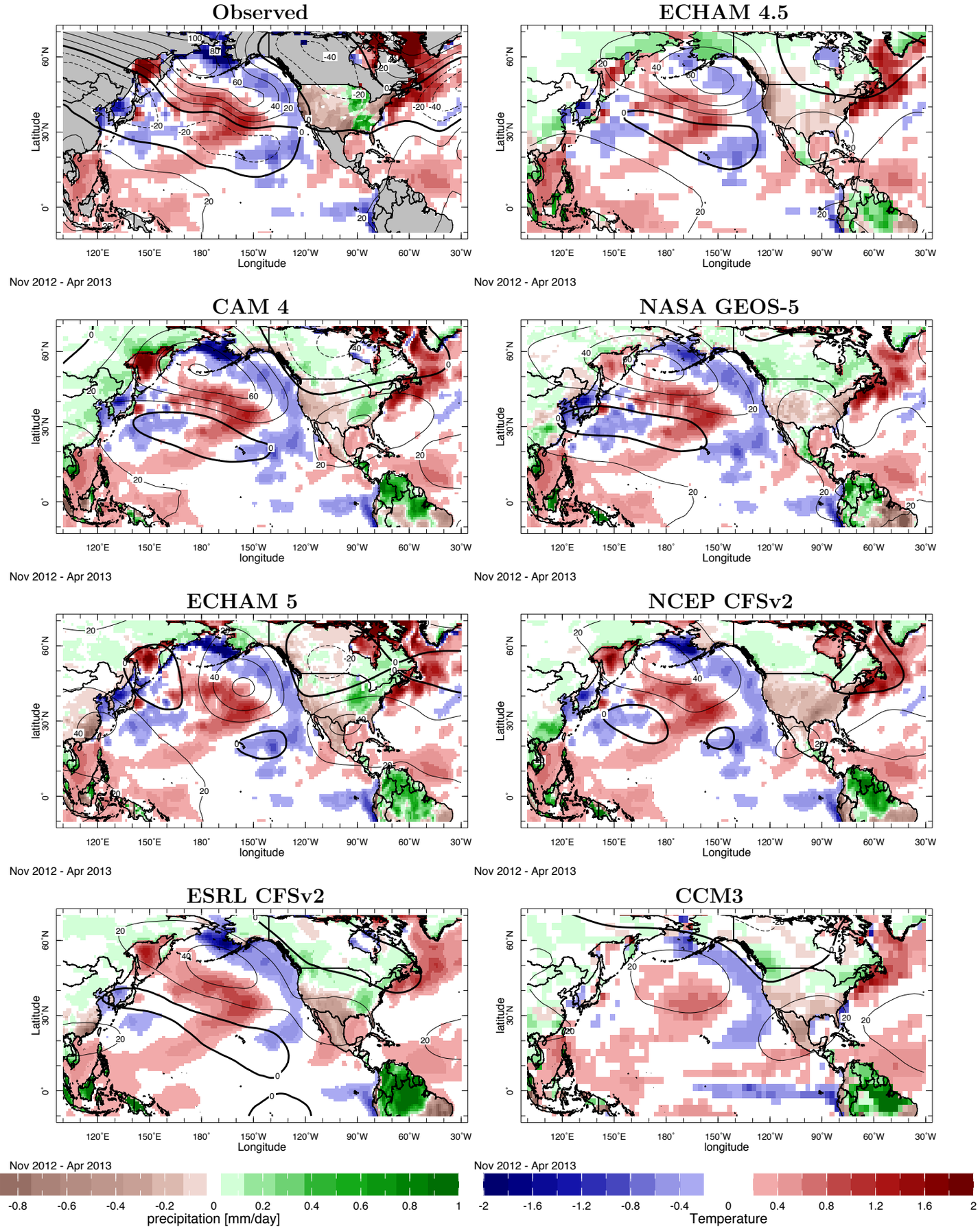
All models have CA dry



Observed and model ensemble means for winter **2012/13**

Several models have some success at reproducing North Pacific to west U.S. ridge

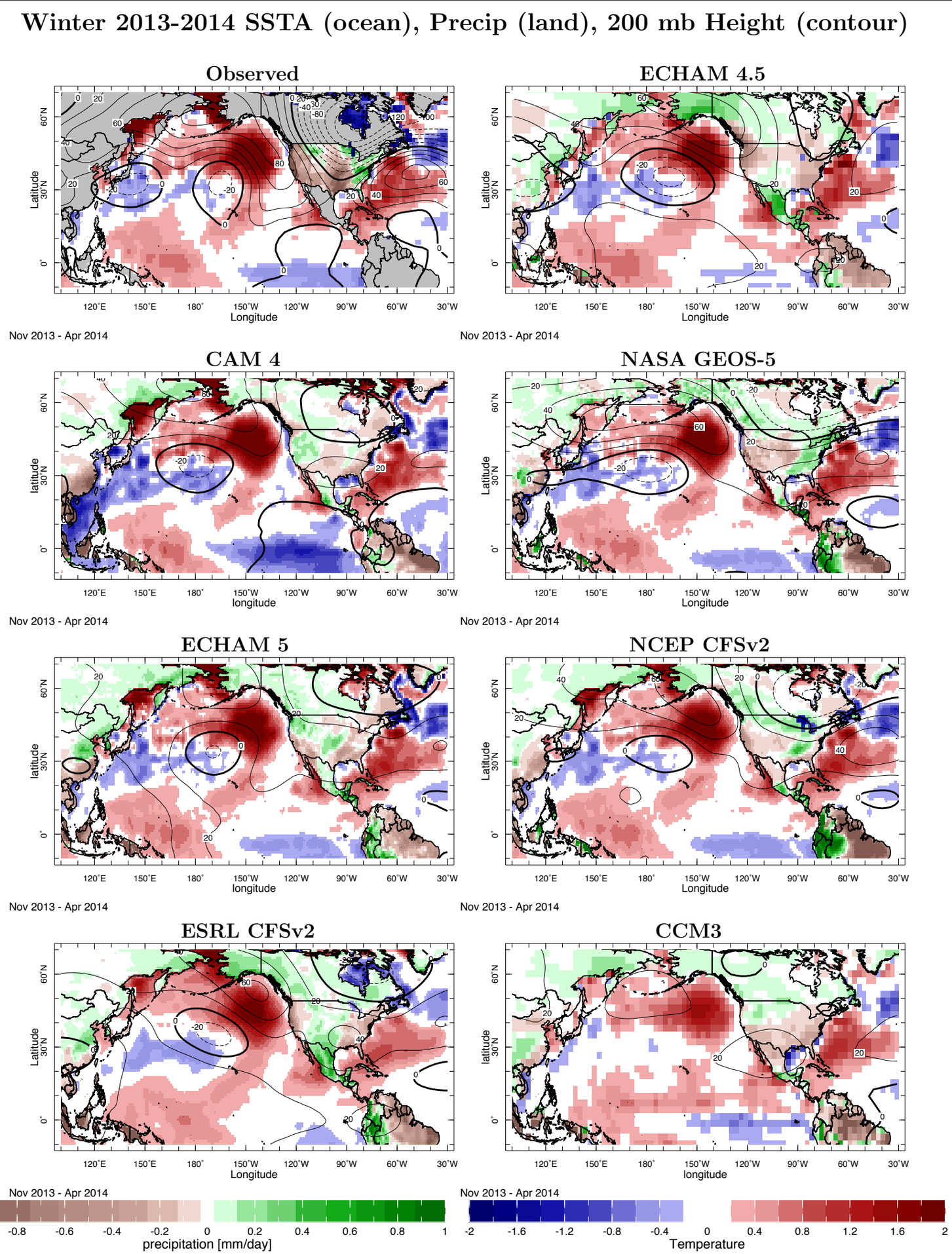
All models have CA dry



Observed and model ensemble means for winter **2013/14**

Six models reproduce North Pacific to west U.S. ridge

Six models have CA dry



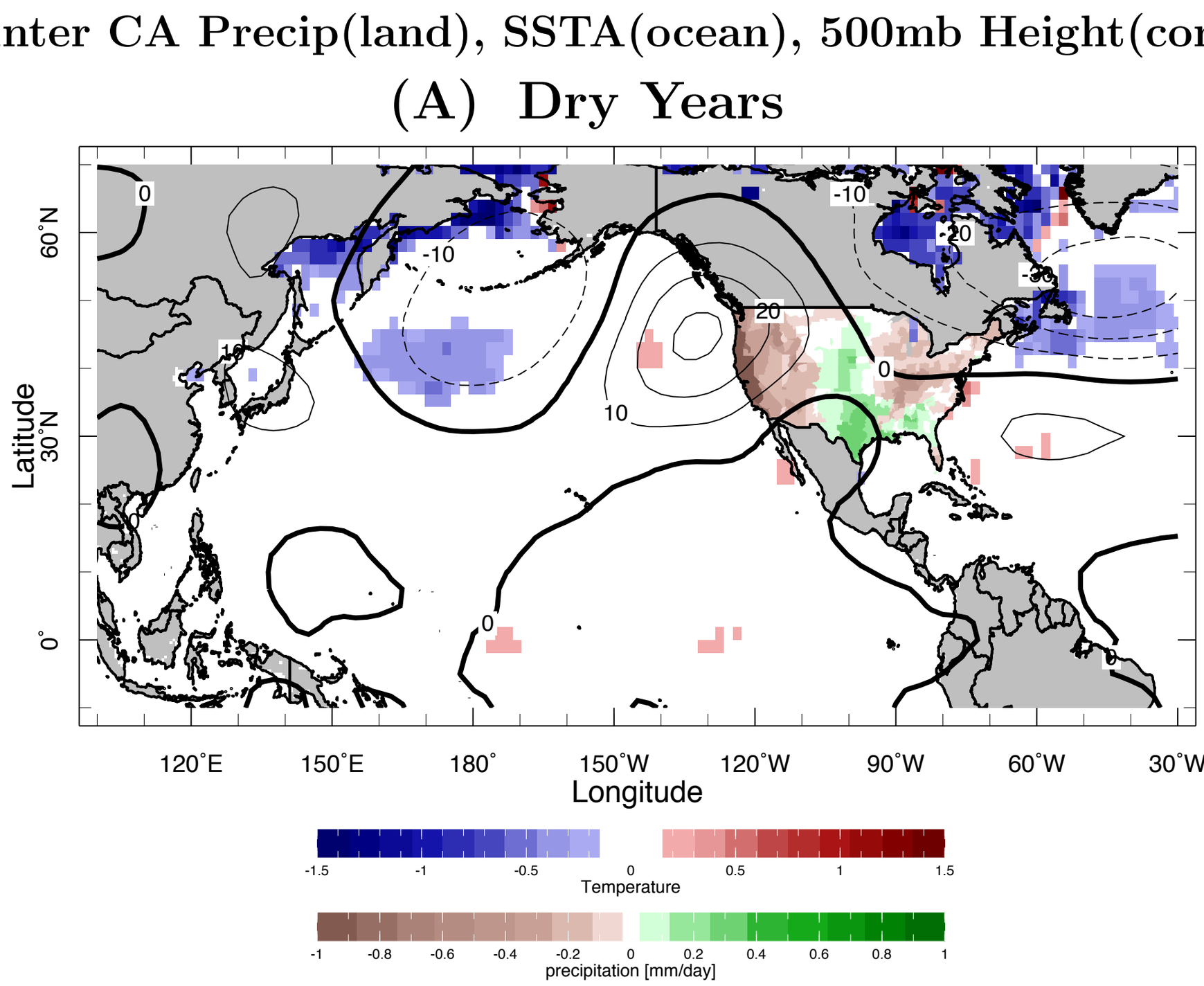
Models forced with observed SSTs for the last 3 winters produce high pressure over west coast and a dry west coast, including CA.

2011/12 is a La Nina but in 2012/13 and 2013/14 models are picking up non-La Nina SST forcing

20 of 21 (3 years * 7 models) modeled winters have CA dry

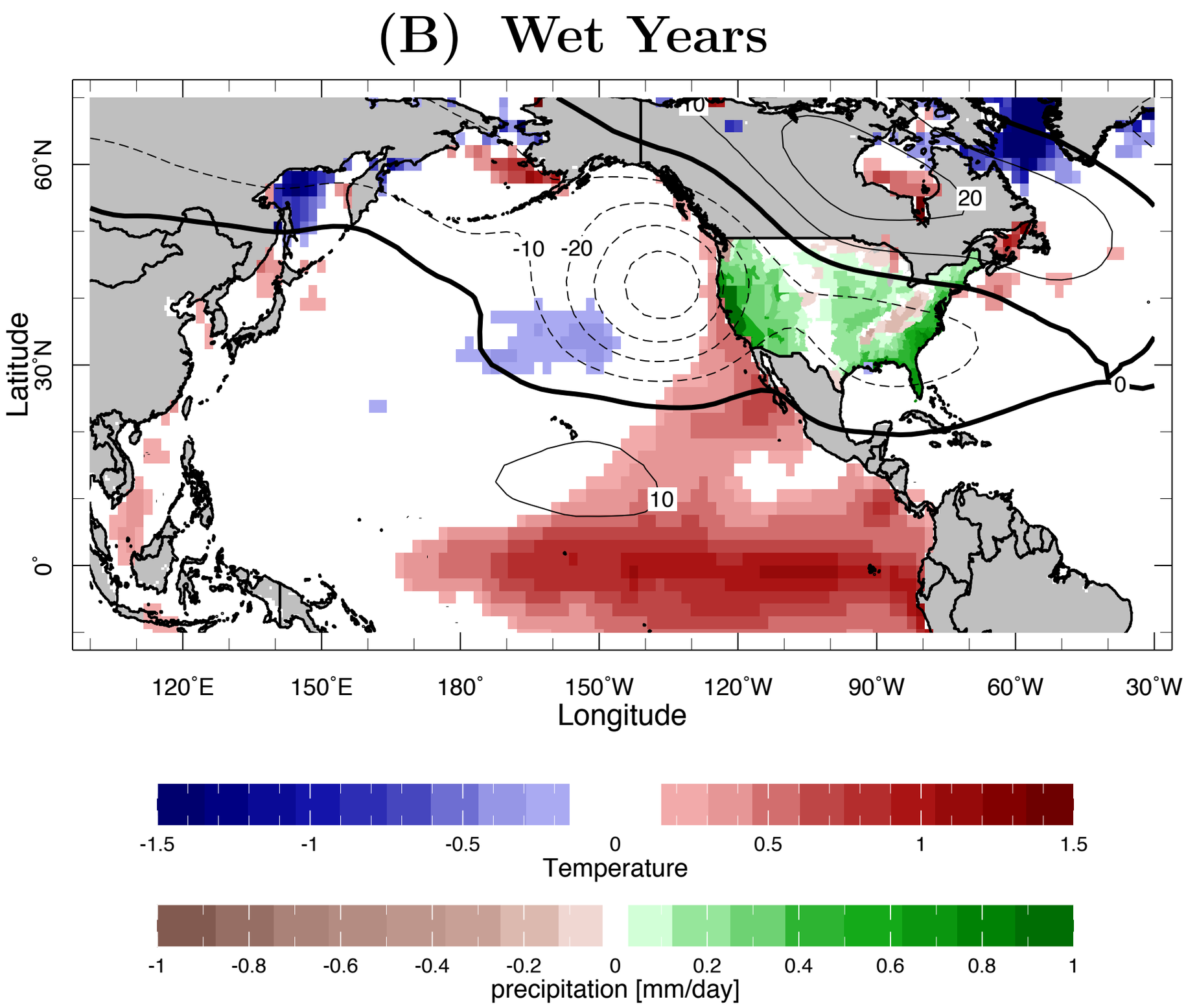
The modeled high and P deficit are, however, weaker than observed

No surprise SST-forced models do not fully capture CA *P* variability



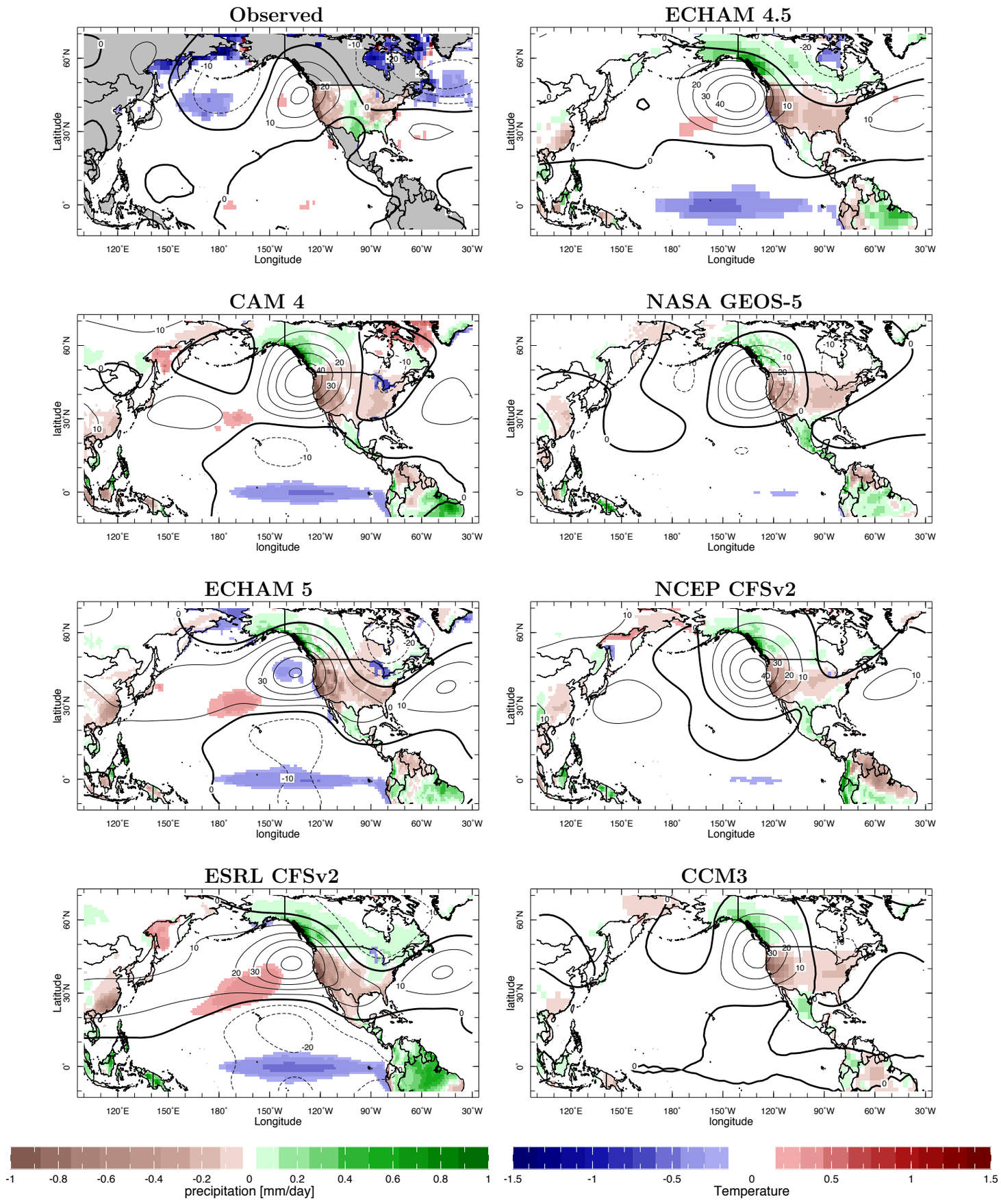
A composite of observed CA dry winters shows the off-coast ridge but no impressive sea surface temperature anomalies

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

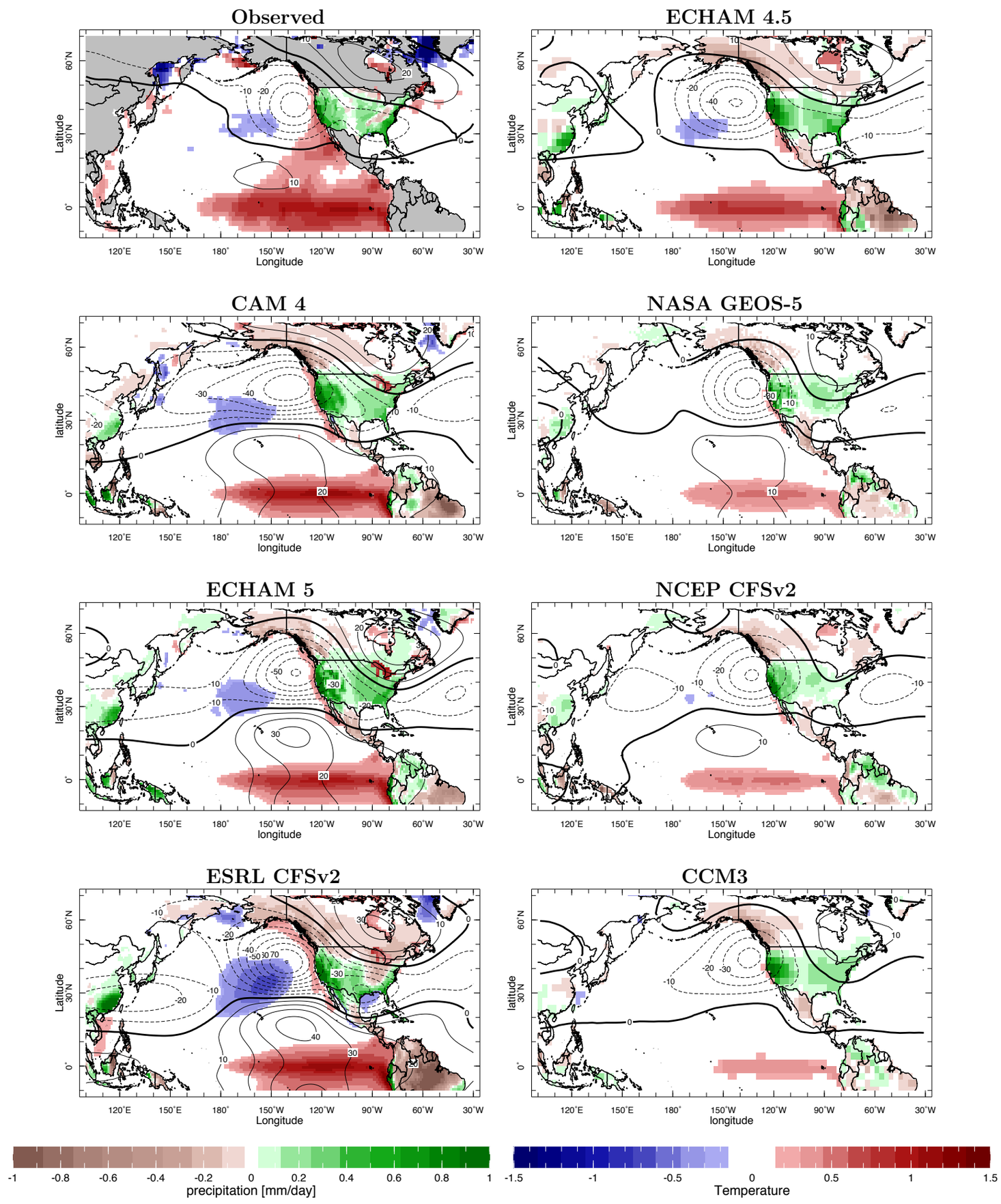


Some models (ECHAM4.5, ESRL CFSv2) appear to have too strong of a La Nina-CA dry relation.

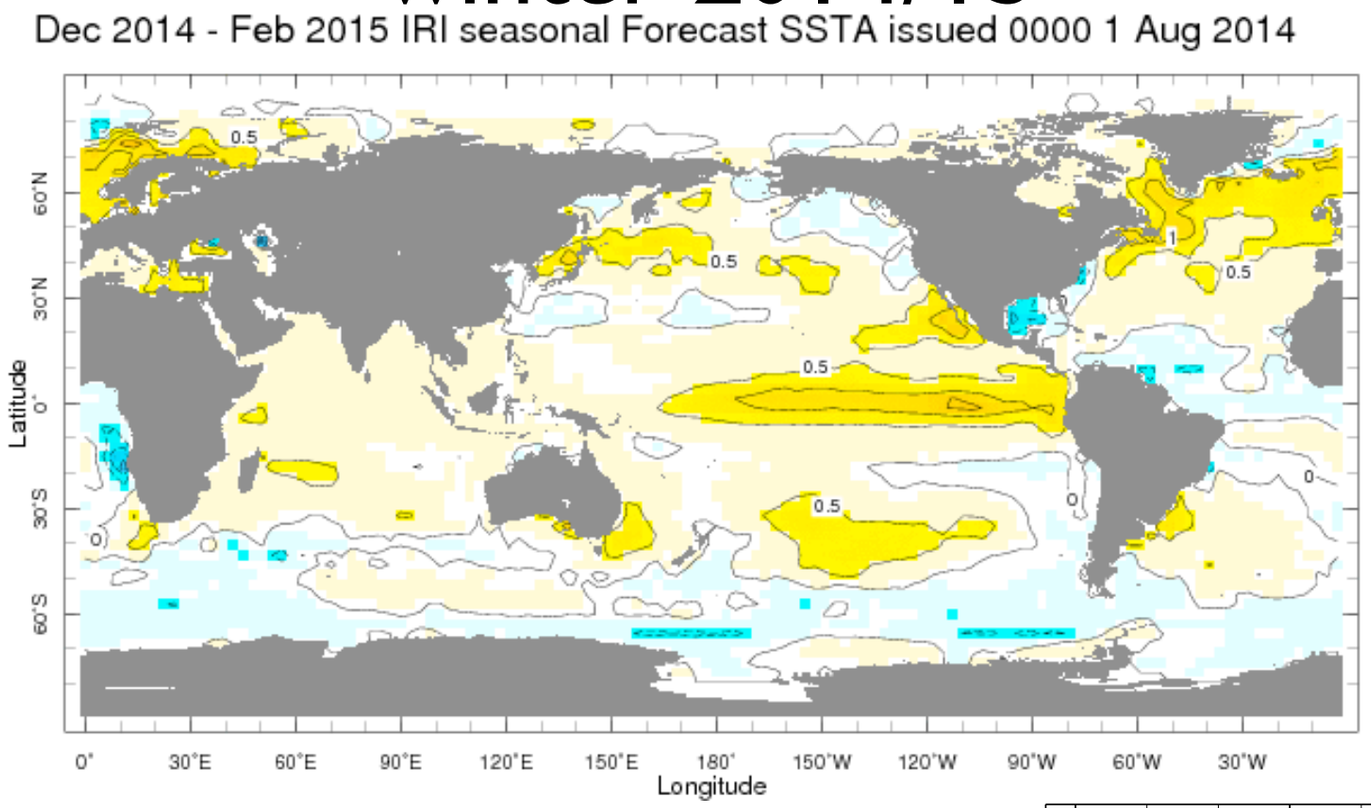
Other models (GEOS-5, CCM3) seem to correctly link CA-dry winters to internal atmosphere variability.

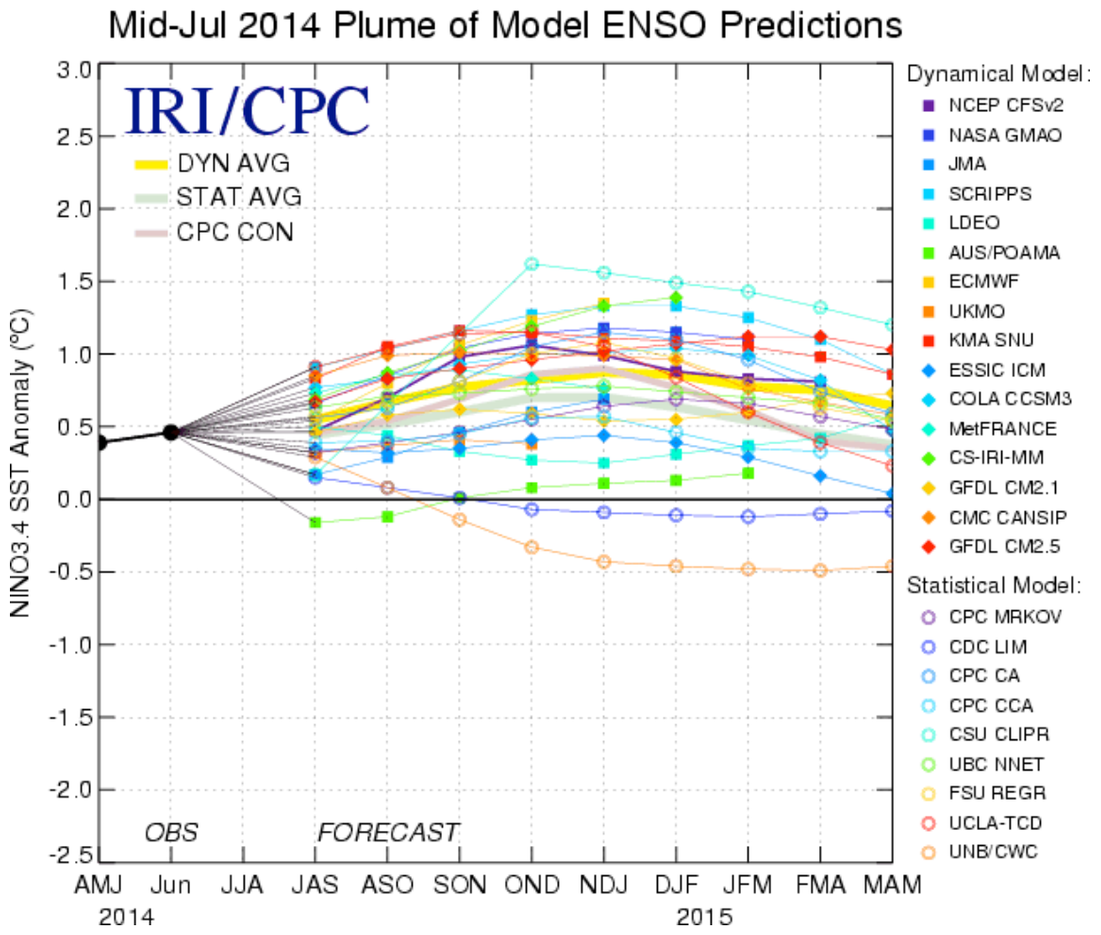


All models correctly link wet CA winters to El Nino, though with varying strengths of relation. I.e. models capture the nonlinearity of CA-SST relations.



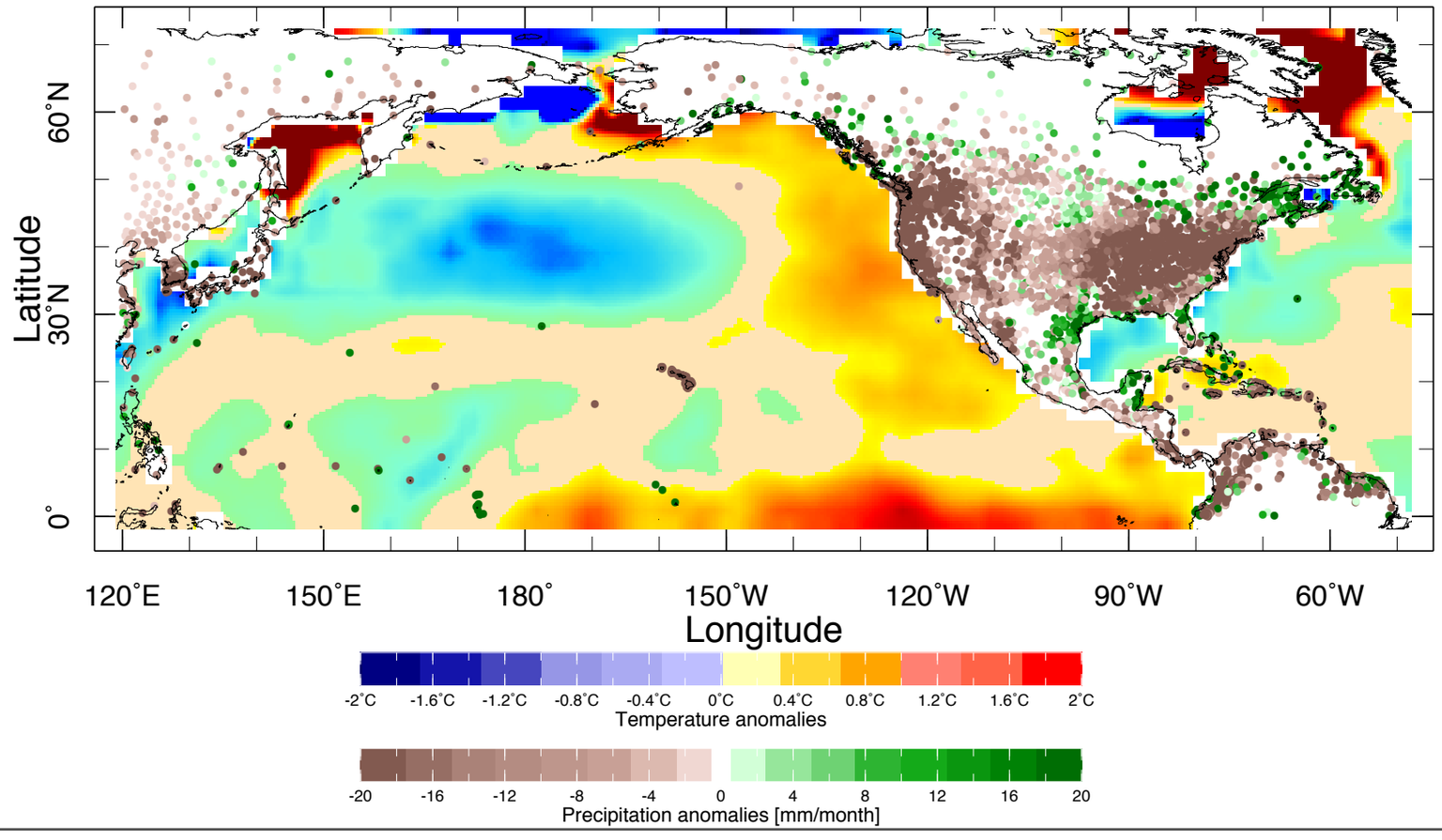
Modest El Nino predicted for winter 2014/15





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

(b) DJF 1976/1977



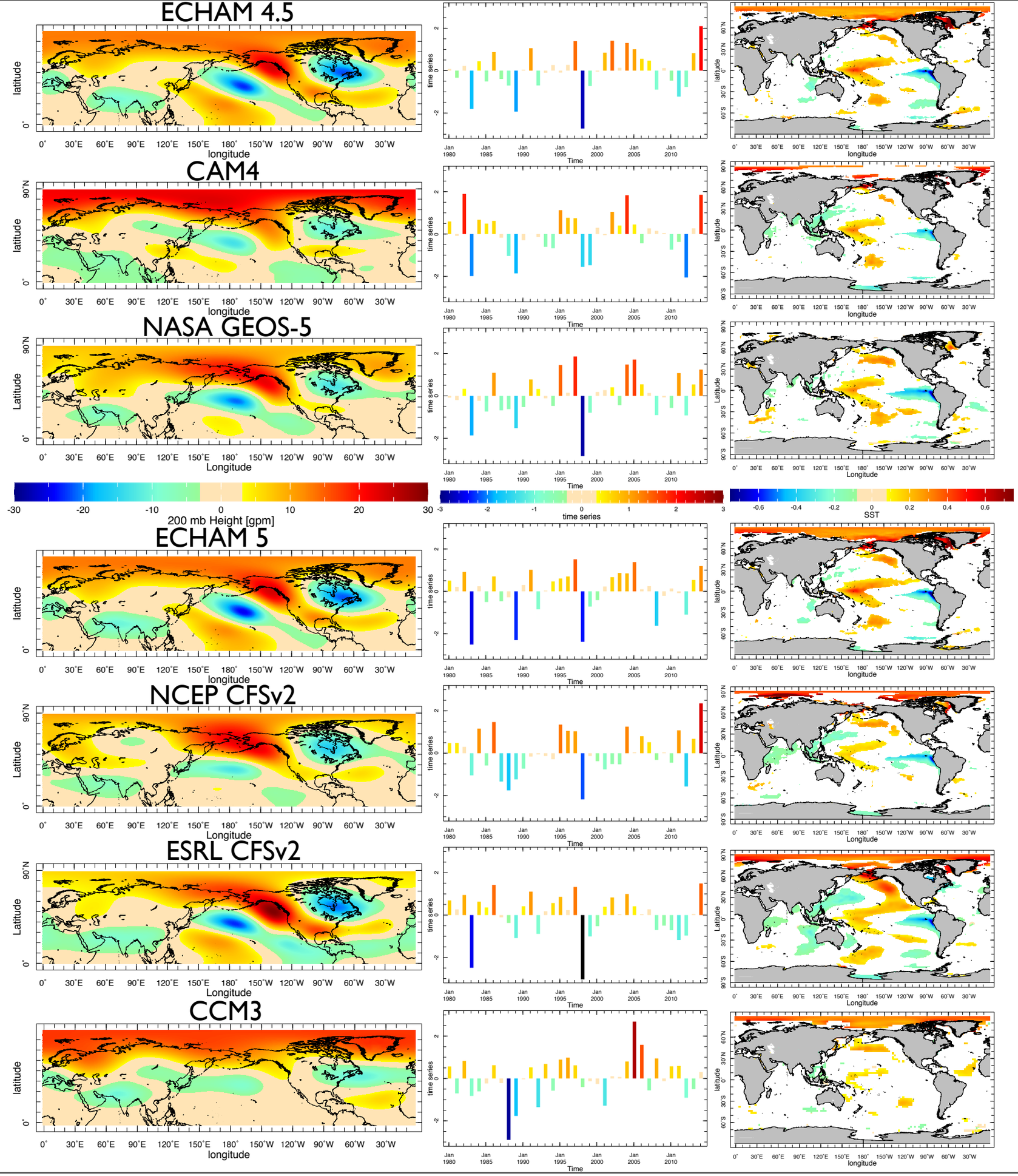
But what is the SST-forced component the models picked up, especially for 2013/14?

To check, perform EOF decomposition of Nov-Apr 200mb height for 0-90N, 1979 to 2014 (common period of the models)

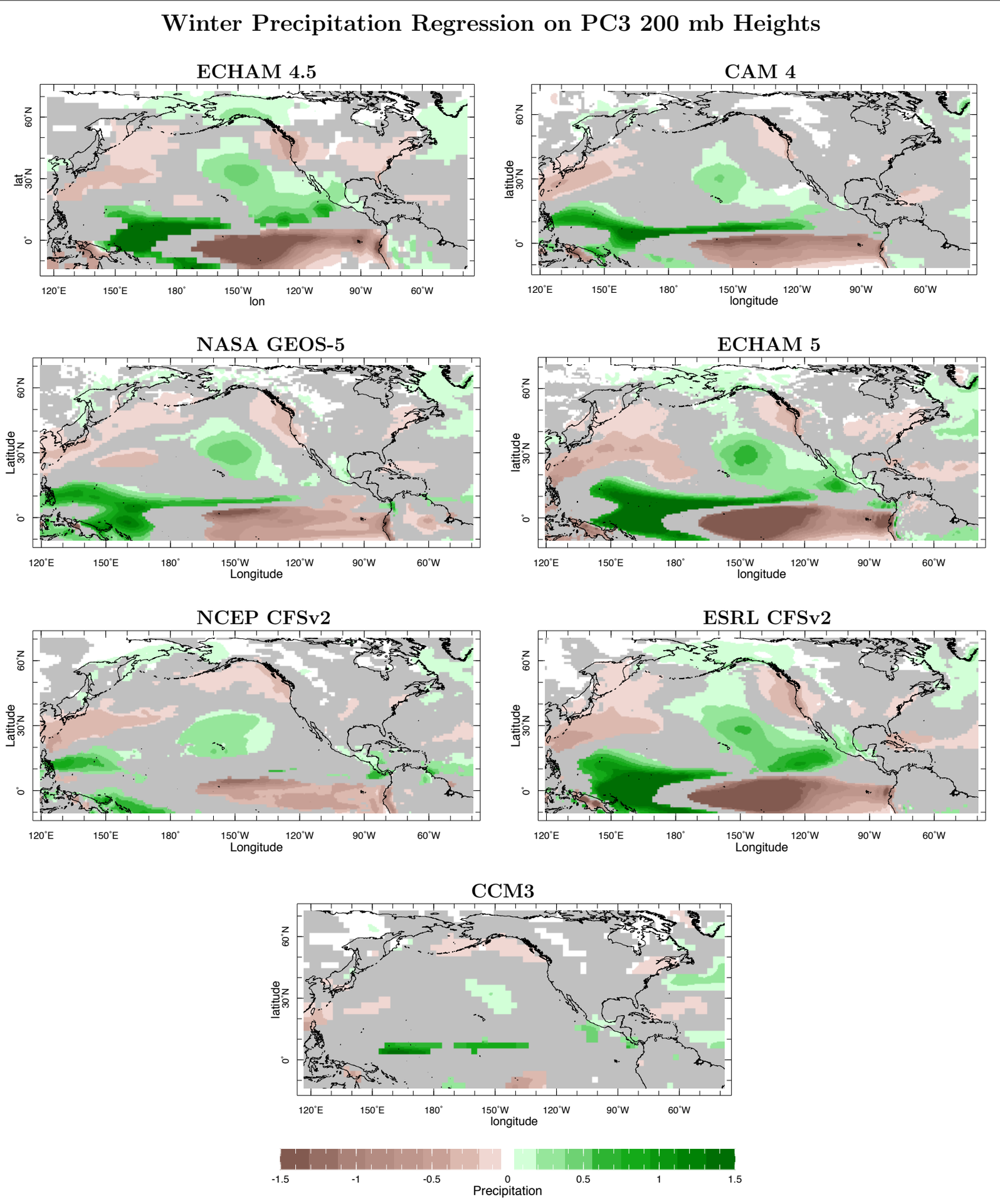
EOF/PC 1 --- ENSO
EOF/PC 2 --- decadal ENSO/PDV/trend

EOF/PC 3 has a wave train arching from tropical west Pacific to N. America with west coast ridge.
Correlates with warm west tropical Pacific.
Mode of internal SST-forced climate variability, well expressed in 2013/14

The SST-gradient/west coast ridge SST-forced mode in 7 models. 200mb height pattern, time series, SST regression (shown where significant)

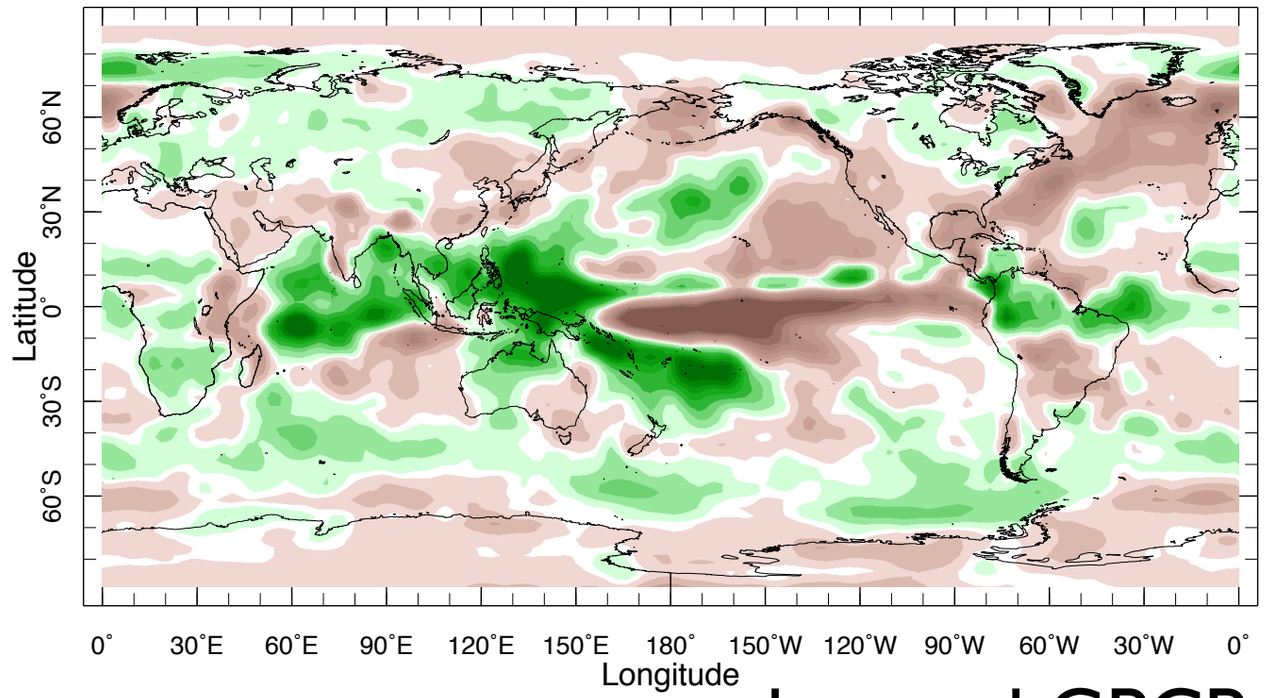


Ensemble mean *P* regressed onto PC3, shown where 90% significant. Wet west tropical Pacific, dry US west coast.

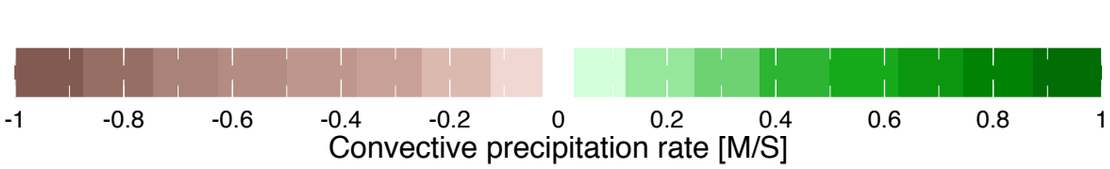


In addition .....1999-2009 minus 1979-1998 precipitation shift

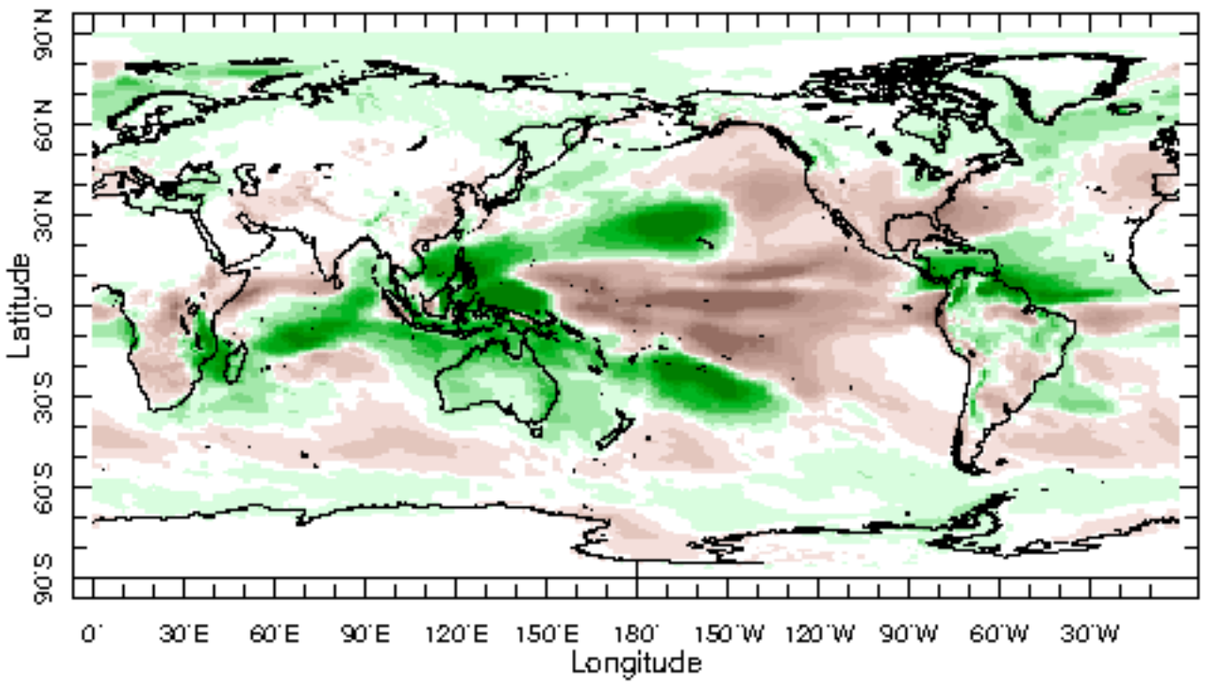
Two most recent dry winters partly SST forced but the 97/98 shift to more La Nina-like tropical Pacific state has also favored drying across southwest North America



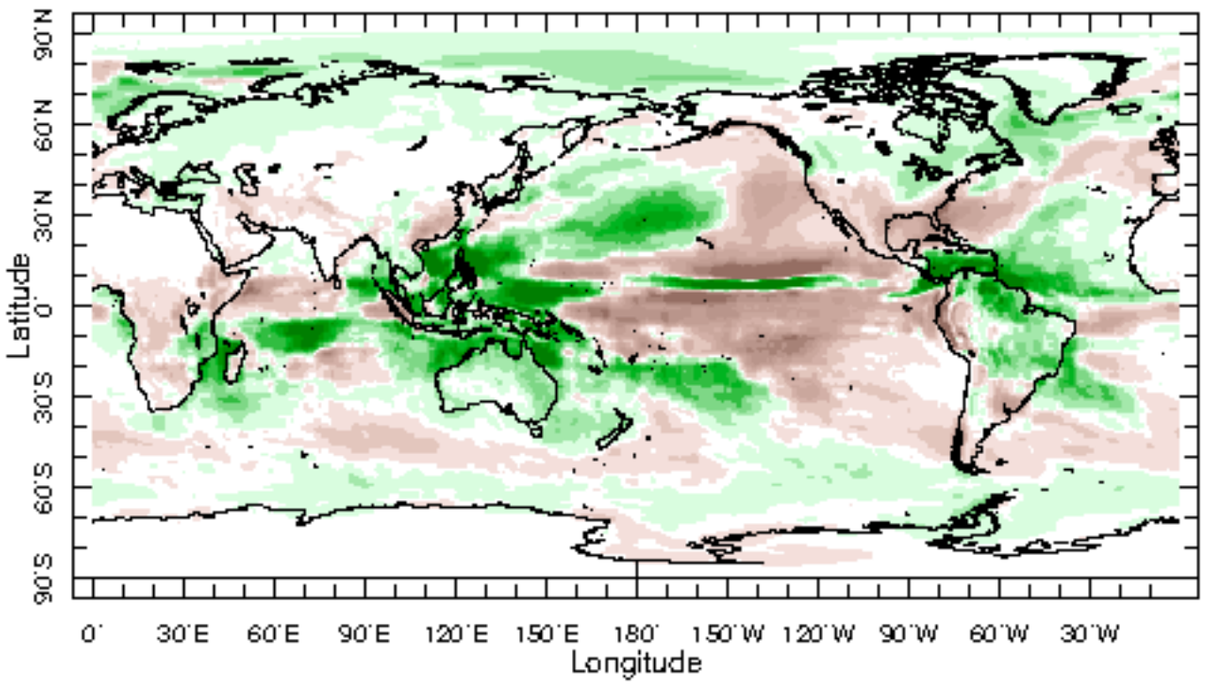
observed GPCP



GEOS-5



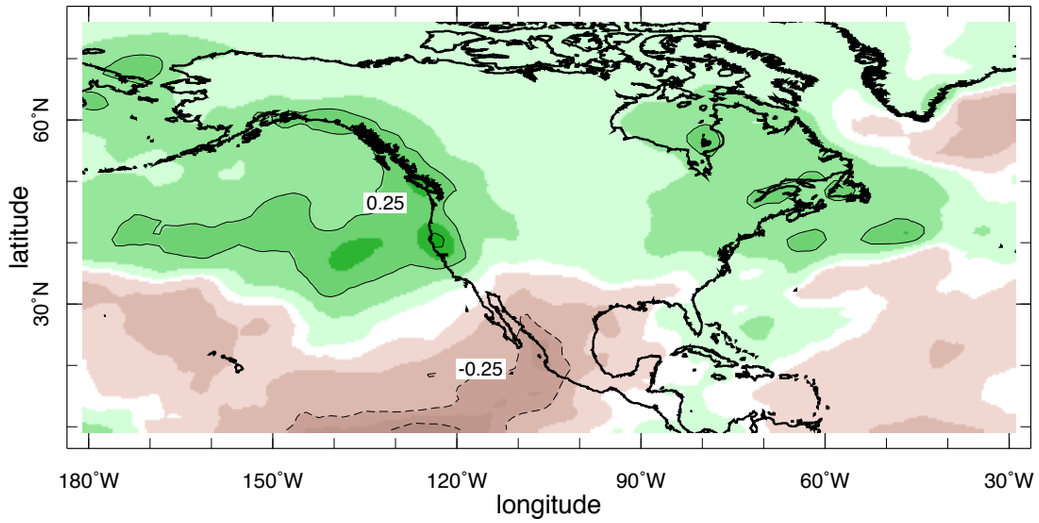
NCEP CFSv2



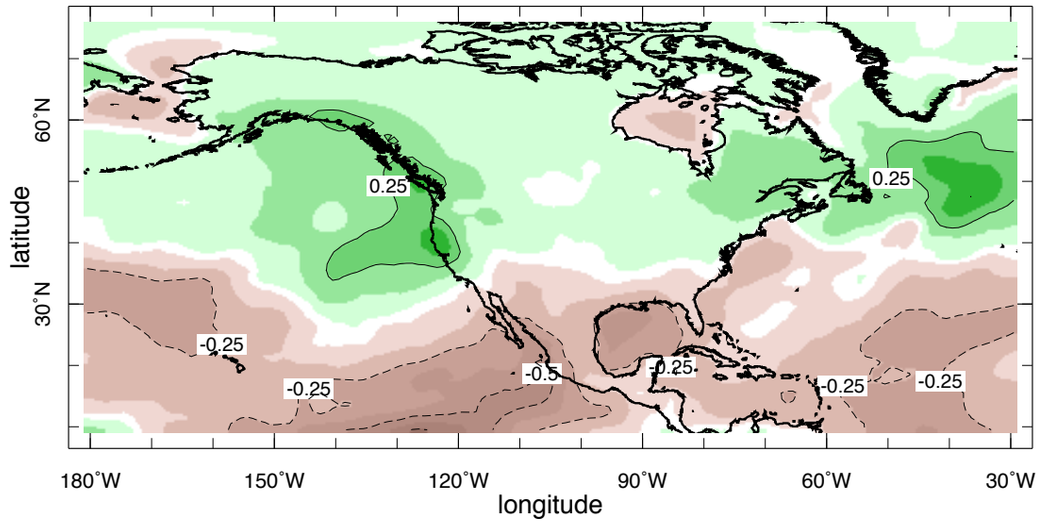
Climate models project for California wetter winters/drier springs due to rising greenhouse gases. For DJF, wet-getting-wetter and wave response with southwesterly anomaly at coast.

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

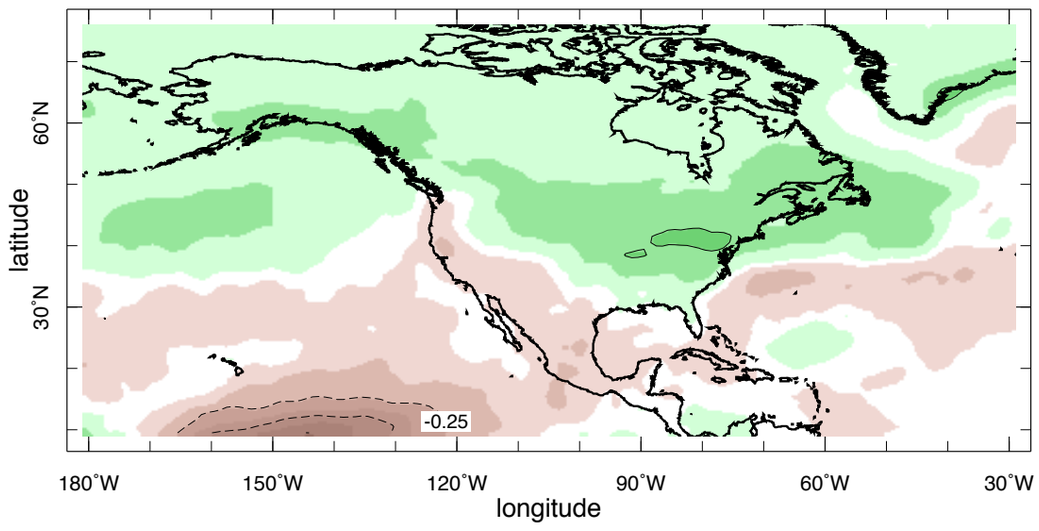
$\Delta\overline{\overline{P}}$ DJF



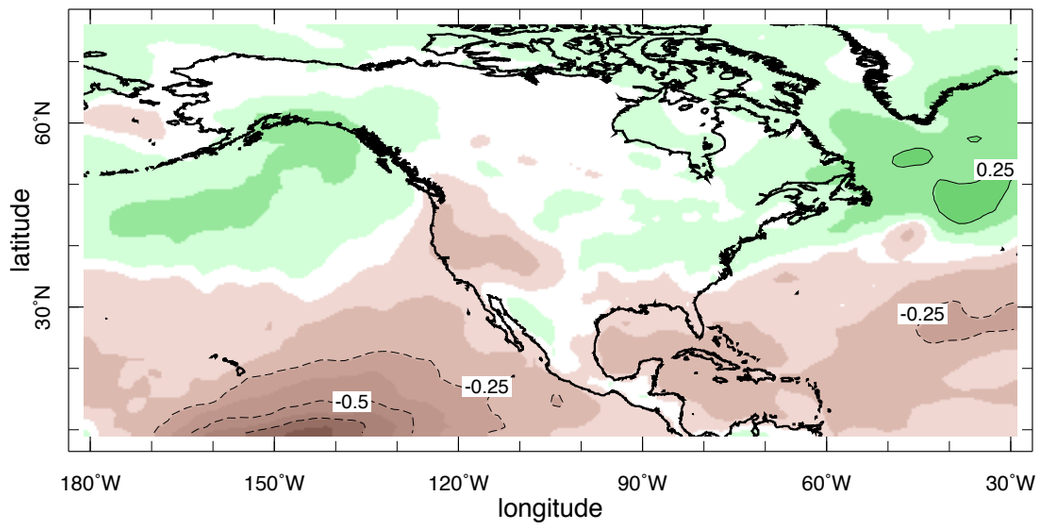
$\Delta(\overline{\overline{P}} - \overline{\overline{E}})$ DJF

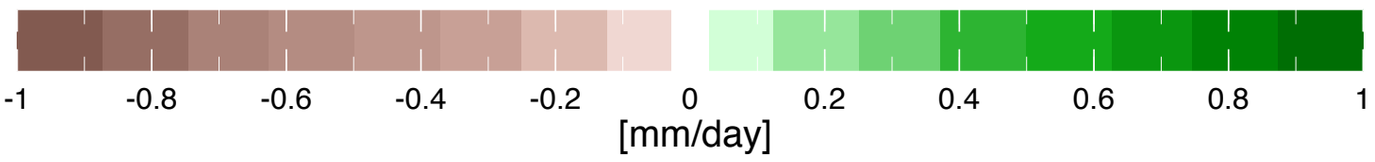


$\Delta\overline{\overline{P}}$ MAM



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





Conclusions

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

California droughts almost this serious have occurred before. No clear 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!

Winter 2013/14 drought was in part forced by warm tropical west Pacific SST anomaly. This is related to EOF3 of SST-forced variability (#1 ENSO #2 PDV/trend) but with in general low variance explained tho' strong in 2013/14.

1997/98 (presumed natural) shift in Pacific Ocean has favored dry conditions in SW since.

Models project rising GHGs will cause an increase in winter precipitation for central to northern CA and a decrease in spring. Winter precipitation decline is not consistent with human-induced climate change (which is not to belittle the very real climate chnage problems CA faces).