Why seasonal prediction of California winter precipitation is challenging?

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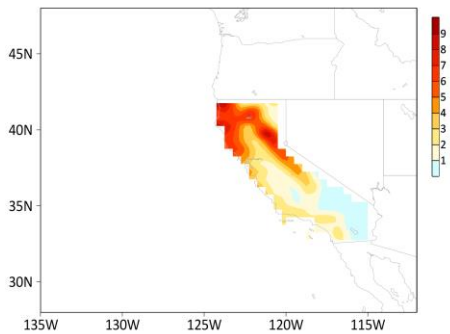
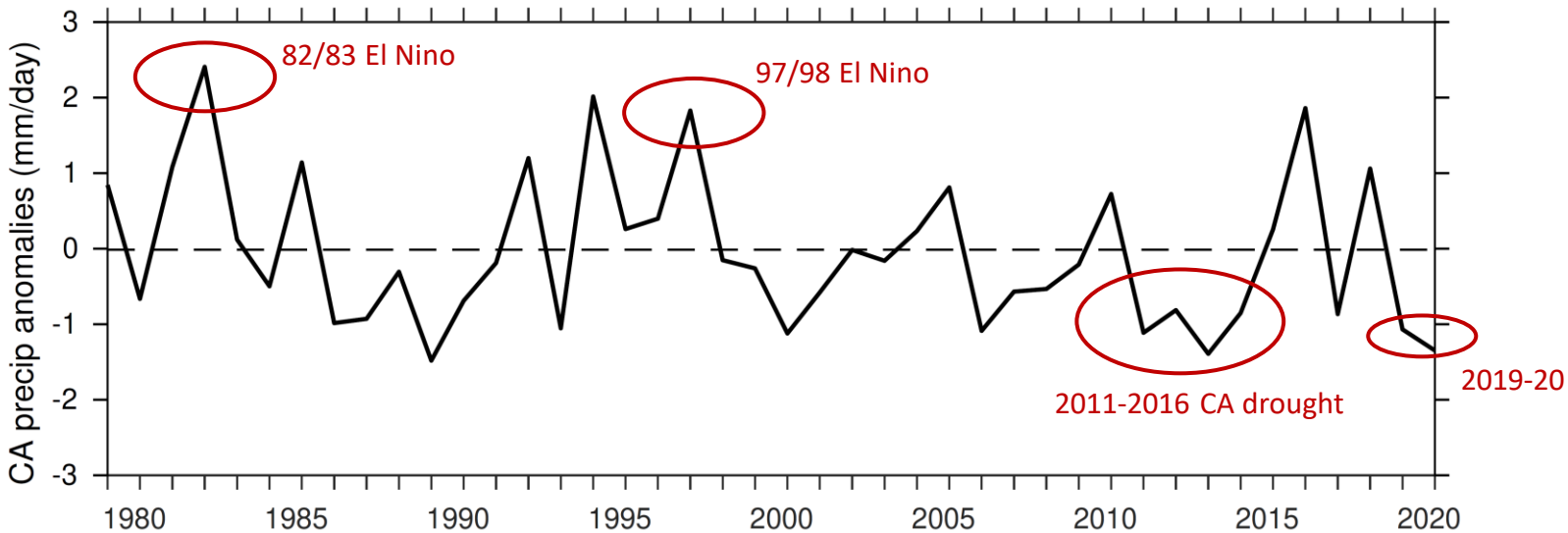
CALIFORNIA DEPARTMENT OF
WATER RESOURCES

A focus on CA precipitation



Winter mean (Nov-Mar) precipitation over CA

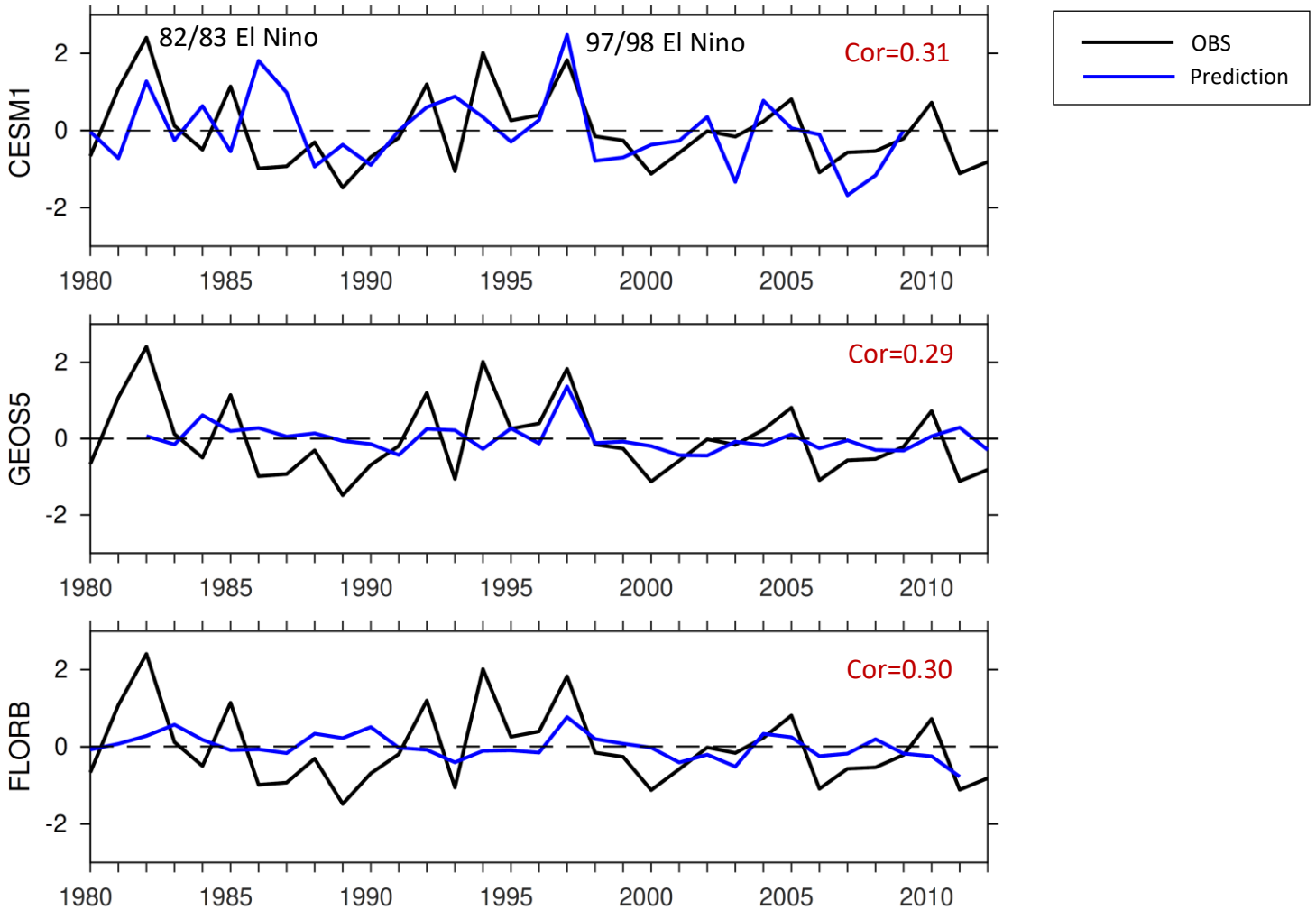
Year-to-year variability of winter (Nov-Mar) CA precipitation anomalies



Are these peaks and valleys predictable at a useful lead time?
What should our expectations be?

Seasonal prediction of Nov-Mar CA rainfall anomalies in NMME models

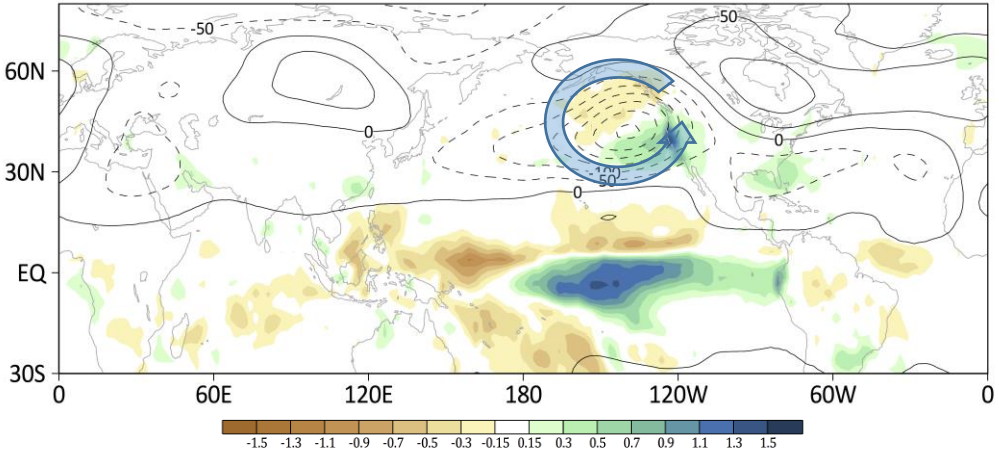
(Initialized on Oct. 01 of each year)



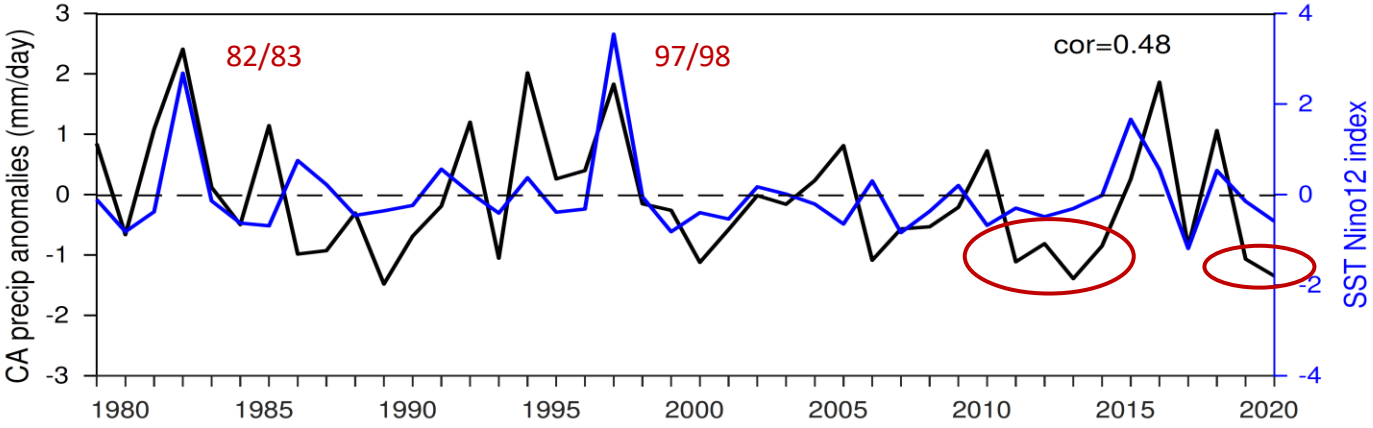
Present-day, global dynamical models can skillfully predict *Pacific Ocean* El Nino/La Nina months in advance. However, they demonstrate little predictive skill for mid-latitudes, even in the most impacted regions.

Large-scale patterns associated with interannual winter CA precipitation

Z500 (Contours), Precipitation (Shading)



Correlation between CA precipitation and El Nino index (maximum with Nino12)

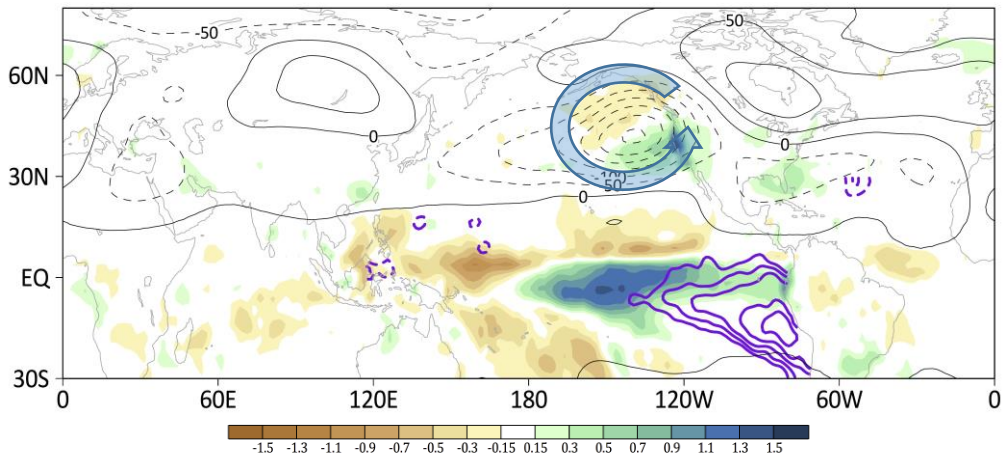


- El Nino only explains ~ 25% of interannual CA precipitation variability.

Based on correlating historical data, even a perfect El Nino / La Nina prediction would seem to only lead to skillful predictions of about 25% of CA precipitation variability.

Large-scale patterns associated with interannual winter CA precipitation

Z500 (Contours), Precipitation (Shading), Purple (SST)



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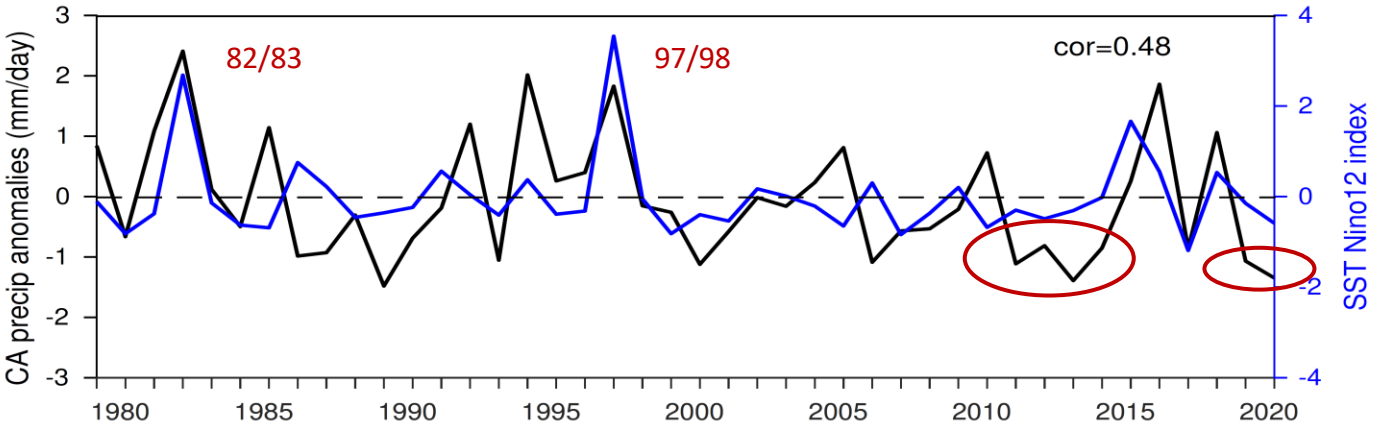

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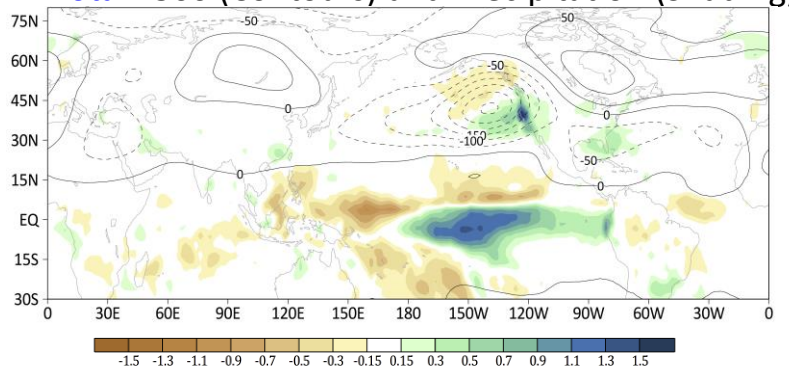
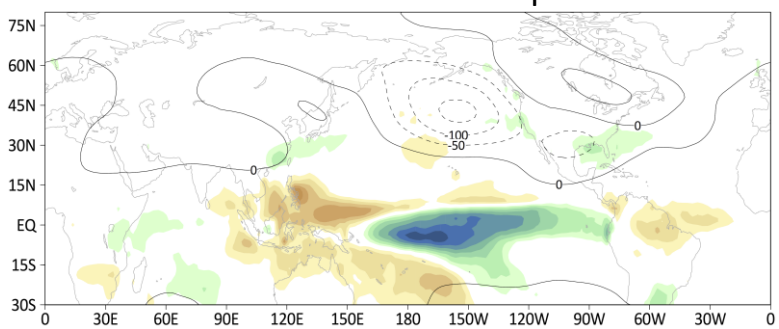
Based on correlating historical data, even a perfect El Nino / La Nina prediction would seem to only lead to skillful predictions of about 25% of CA precipitation variability.

Separating large-scale patterns associated with winter CA precipitation

A. Total Z500 (Contours) and Precipitation (Shading)

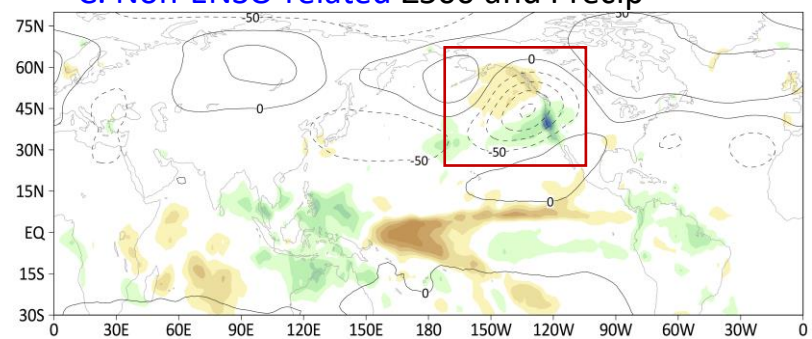


B. ENSO-related Z500 and Precip



Nino 12 index

C. Non-ENSO-related Z500 and Precip



Pacific_Z500ne index

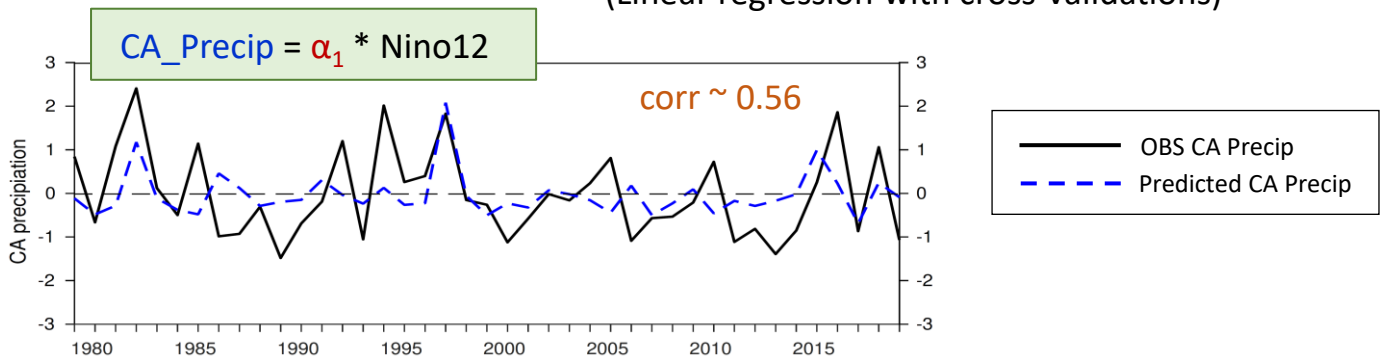
(Projection of winter mean ENSO-removed z500' onto the circulation pattern in the box region)

Circulation associated with CA precipitation is separated into an ENSO related component and a component independent from ENSO (Pacific Z500ne index), with a dominant role for CA precipitation from the latter.

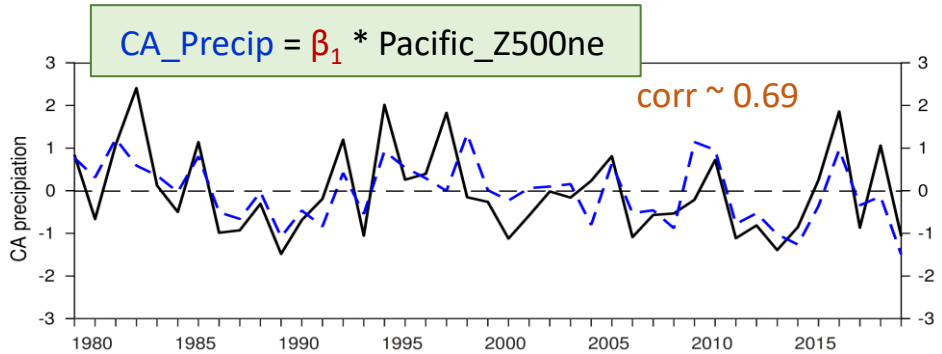
Prediction of CA Precip assuming perfect ENSO and Pacific_Z500ne predictions

(Linear regression with cross-validations)

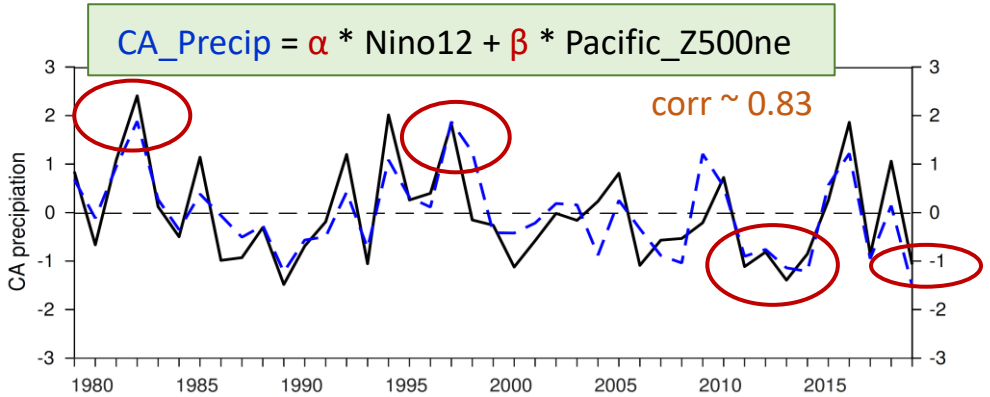
ENSO



Pacific Z500ne



ENSO + Pacific Z500ne

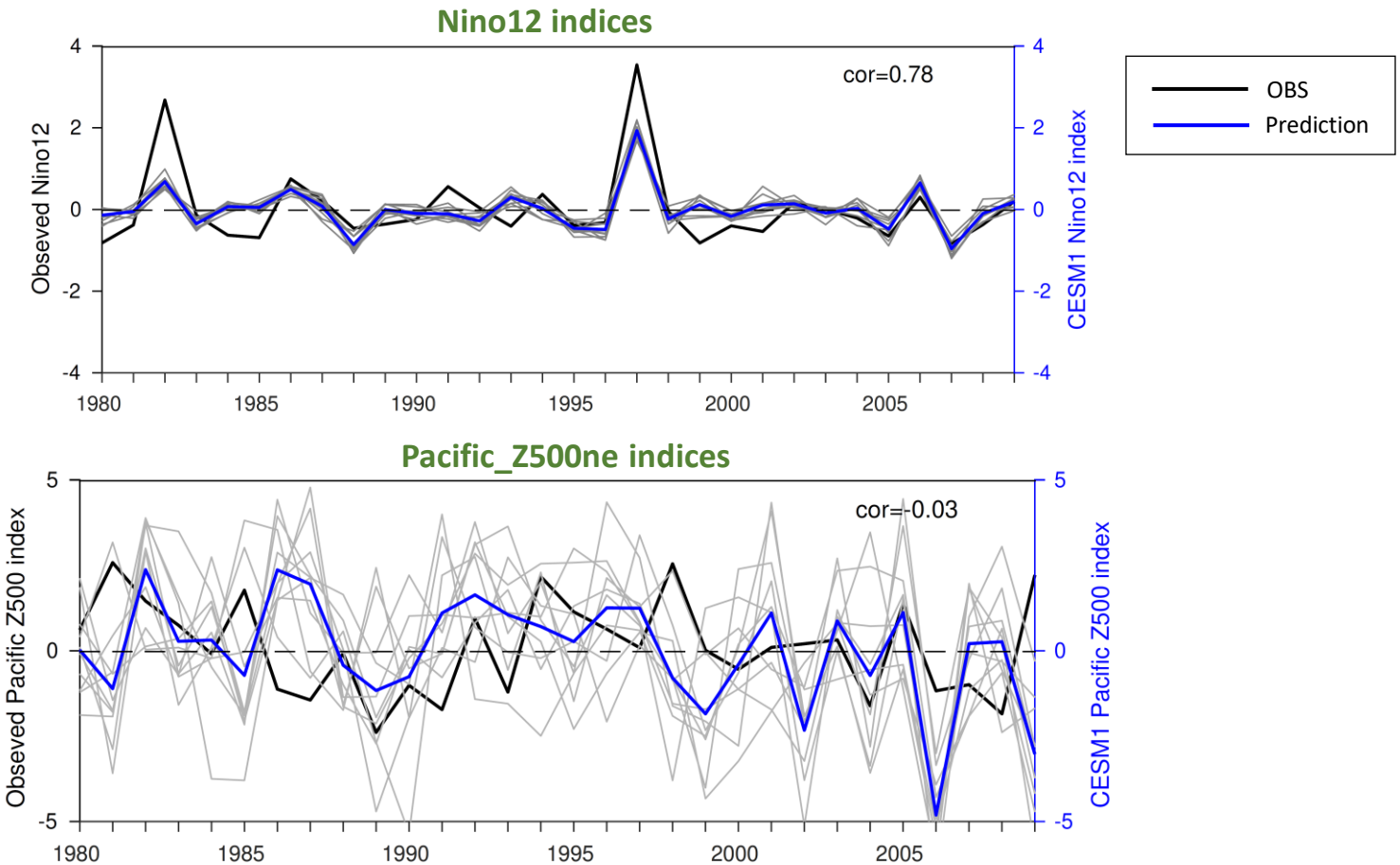


CA precipitation can be well predicted assuming perfect predictions of El Nino and the Pacific Z500ne index. The key question becomes: how predictable are the El Nino and the Pacific Z500ne index seasons ahead?

How predictable are El Nino and Pacific_Z500ne indices in coupled dynamical models?

Winter (Nov-Mar) predictions based on NMME models - CESM1 (initialized on Oct. 1)

(**Blue**: 10-member mean; **Grey:** each model member forecast)



Very similar results are found based on other NMME models.

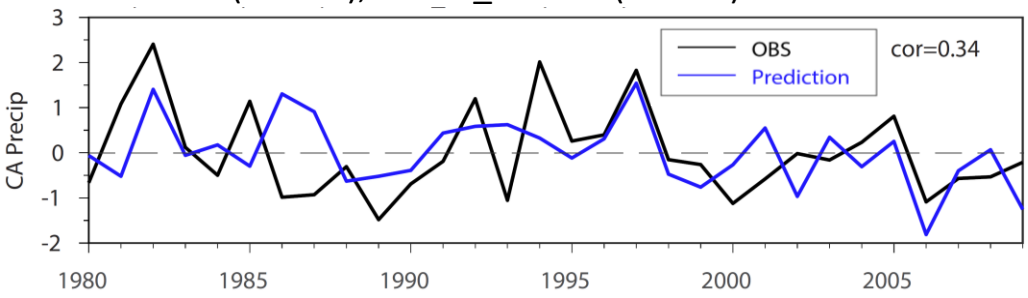
Dynamical prediction models have high skill for *tropical Pacific* El Nino, but almost no skill for circulation independent from ENSO (Pacific Z500ne), leading to an overall low prediction skill for CA precipitation.

Statistical prediction of CA Precip using NMME winter predictions of Nino12 and Z500ne

$$CA\_Precip = \alpha * Nino12 + \beta * Pacific\_Z500ne$$

Statistical-dynamical hybrid approach

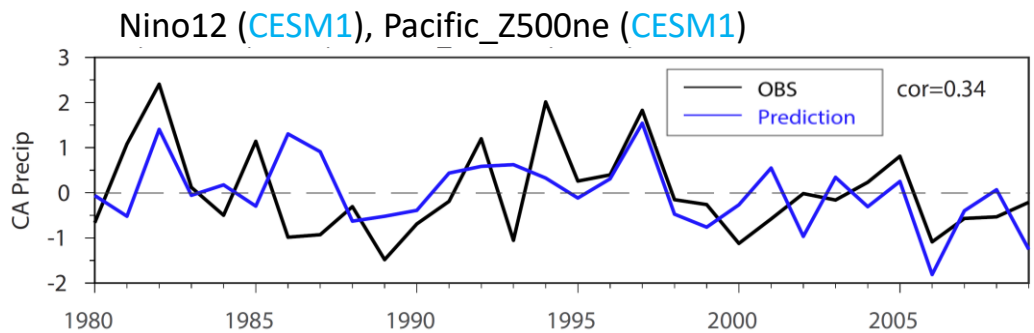
Nino12 (CESM1), Pacific_Z500ne (CESM1)



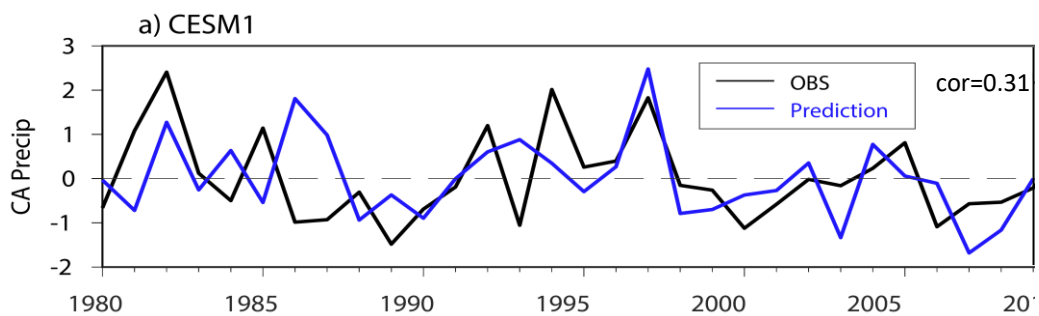
Statistical prediction of CA Precip using NMME winter predictions of Nino12 and Z500ne

CA_Precip = α * Nino12 + β * Pacific_Z500ne

Statistical-dynamical hybrid approach



Dynamical prediction



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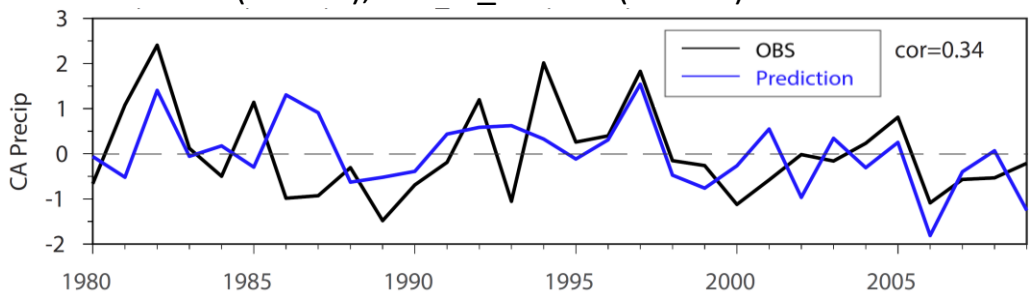
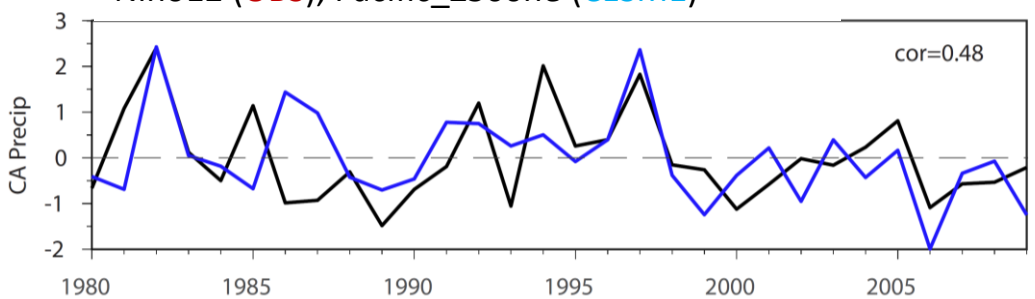
Statistical-dynamical hybrid approach

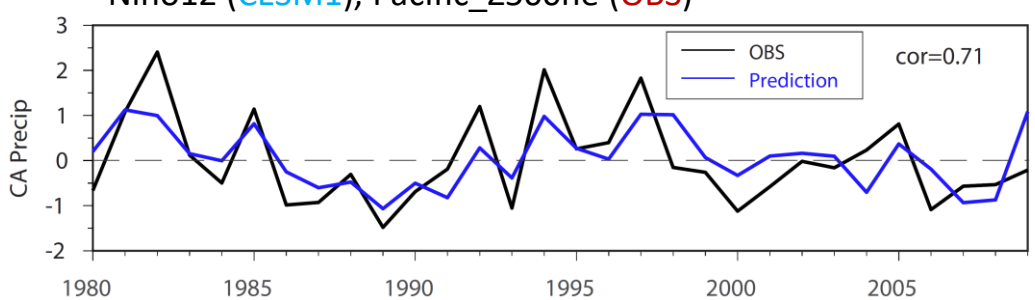
Nino12 (CESM1), Pacific_Z500ne (CESM1)



Nino12 (OBS), Pacific_Z500ne (CESM1)



Nino12 (CESM1), Pacific_Z500ne (OBS)

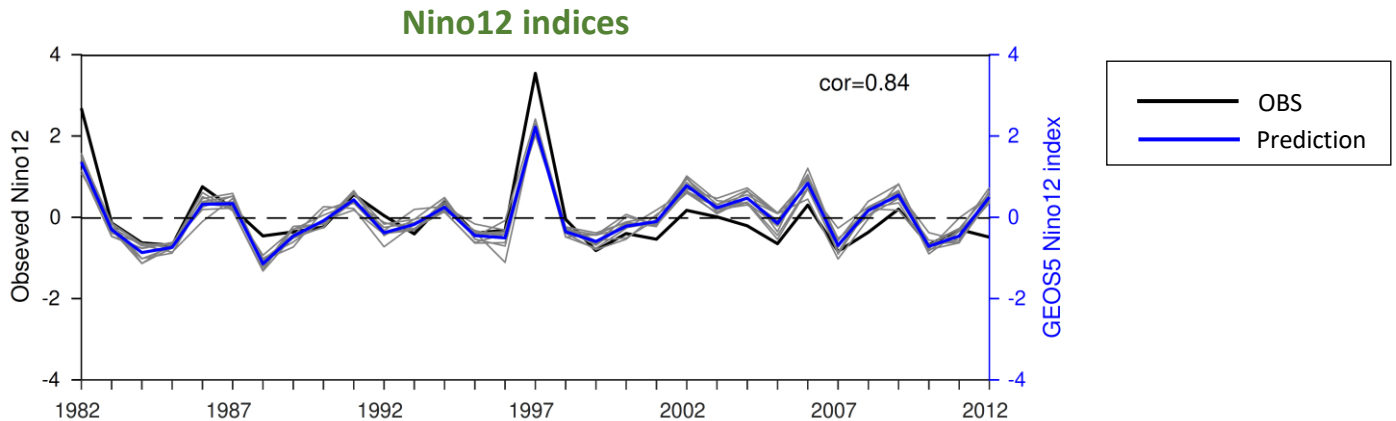


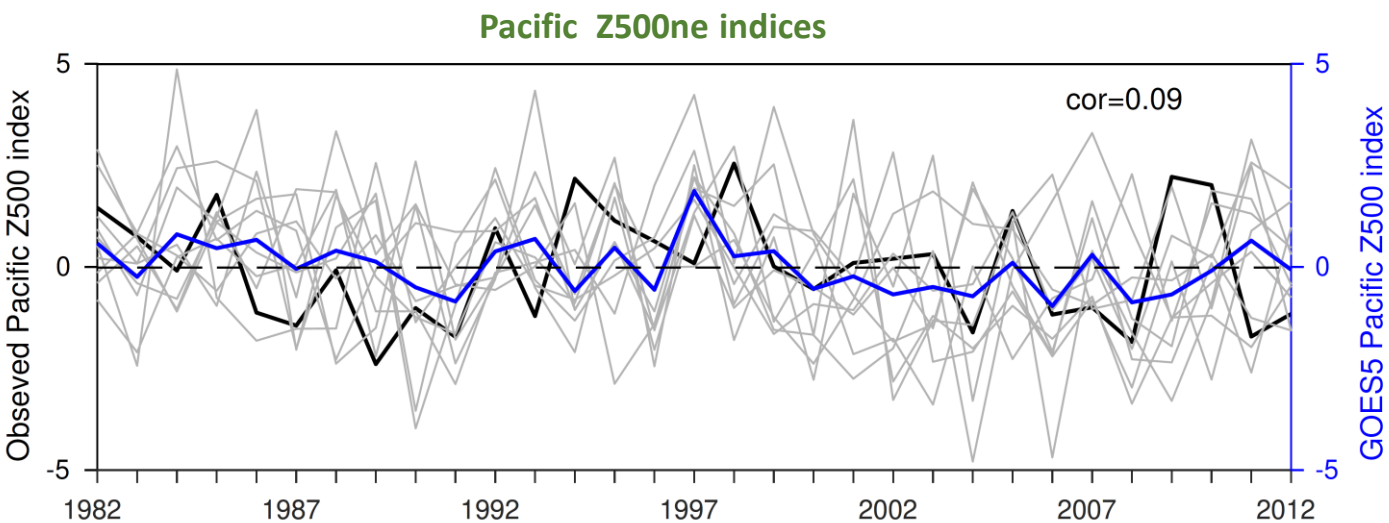
Accurate prediction of ENSO-independent circulation (Pac_Z500ne) is crucial for skillful CA Precip prediction.

Predicted El Nino and Pacific_Z500ne indices in GEOS5

Winter (Nov-Mar) predictions based on NMME models – GEOS5 (initialized on Oct. 1)

(**Blue**: 10-member mean; **Grey:** each model member forecast)

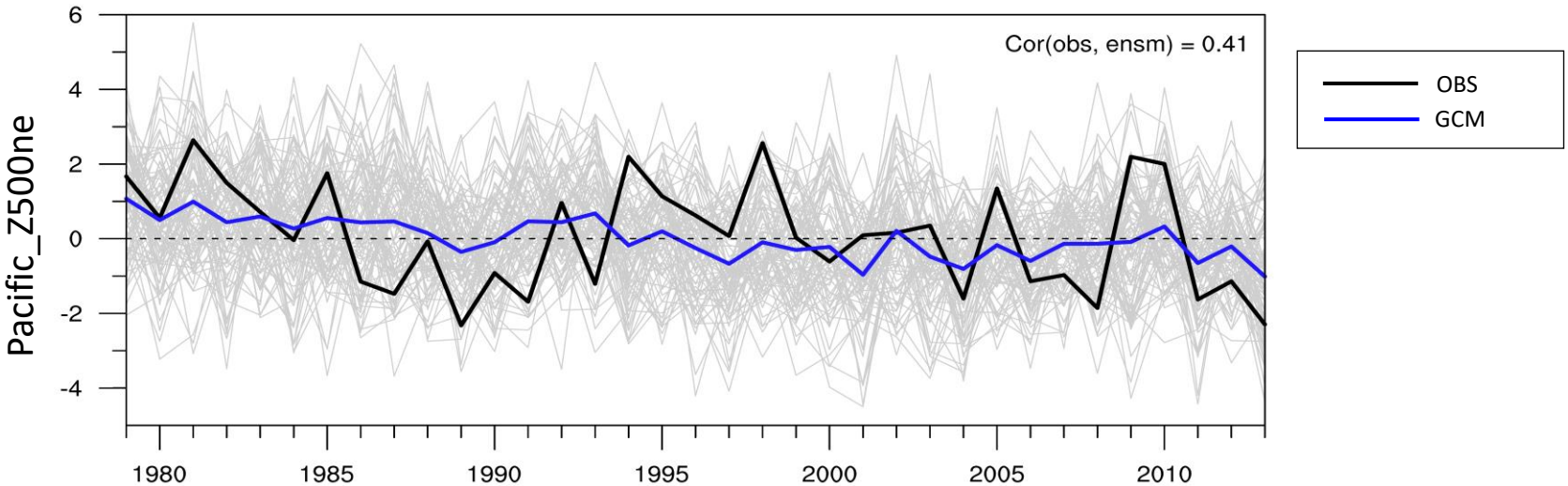




Similar results in GEOS5: high skill for *tropical Pacific* El Nino, but almost no skill for circulation anomalies independent from ENSO (Pacific_Z500ne).

A further test on predictability of the Pacific_Z500ne index: Perfect SST/sea ice forcing

Pacific_Z500ne indices in OBS and AGCM simulations (96 members / 8 GCMs)



Forced by the same observed SST/sea ice in AGCMs, large spreads in simulated Pacific Z500ne indices among 96 model members suggest prediction of CA precipitation greatly challenging.

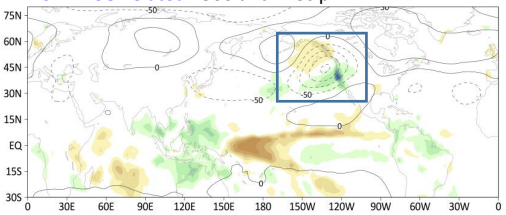
AGCMs from the NOAA Facility for Climate Assessments (FACTS) Project

AMIP: observed monthly SST and Sea ice during 1979-2014

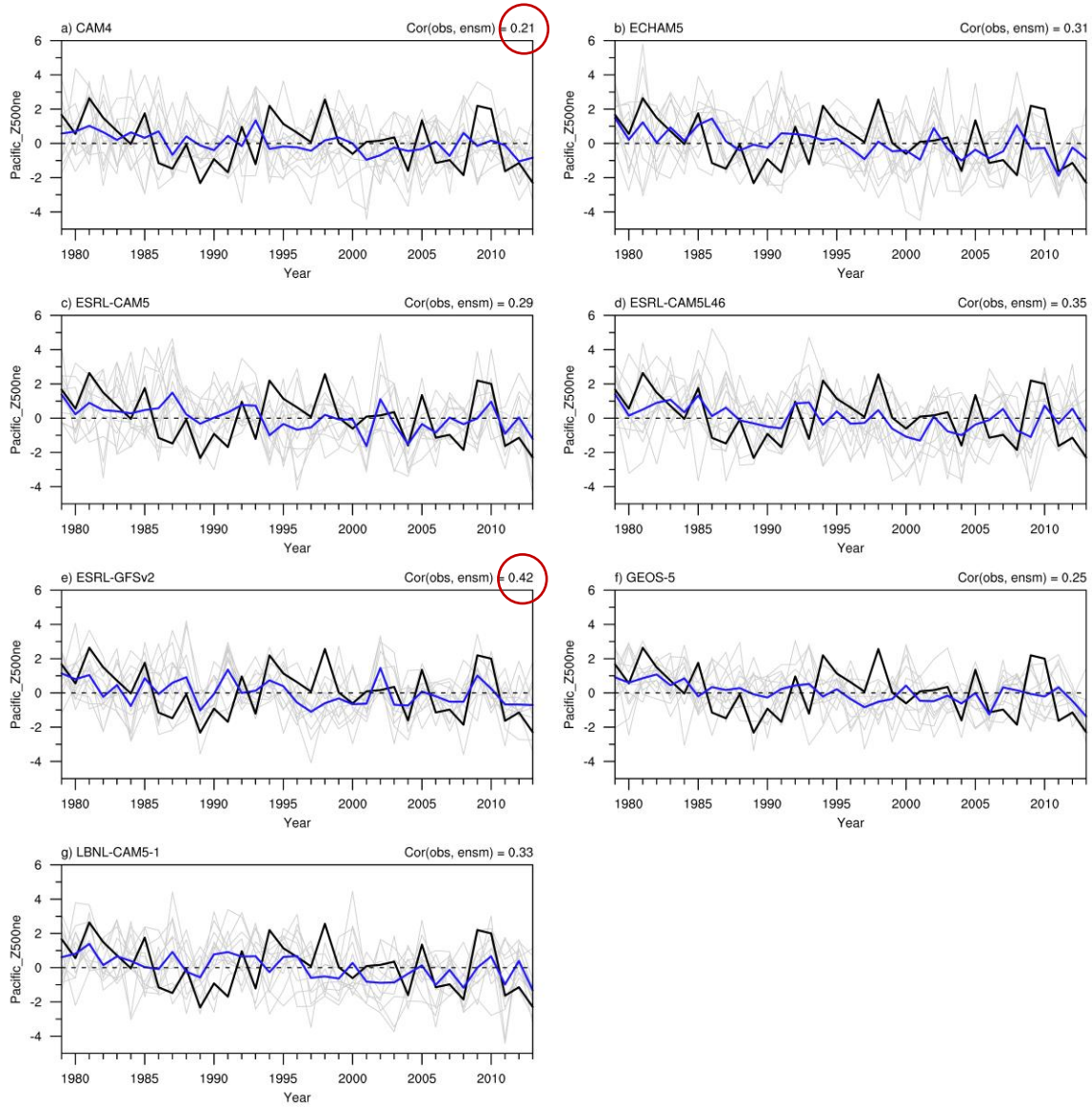
TABLE 1. Description of FACTS AGCMs analyzed in this study.

Model name	Institute	Ensemble size	Horizontal resolution (longitude × latitude)
AM3	Geophysical Fluid Dynamics Laboratory (GFDL)	17	1.9°×1.9°
CAM4	National Center for Atmospheric Research (NCAR)	20	1°×1°
ECHAM5	Max Planck Institute for Meteorology (MPI)	50	0.75°×0.75°
ESRL-CAM5	National Center for Atmospheric Research (NCAR)	40	1°×1°
ESRL-CAM5L46	National Center for Atmospheric Research (NCAR)	16	1°×1°
ESRL-GFSv2	NOAA/NWS Environmental Modeling Center (EMC)	50	1°×1°
GEOS-5	NASA Goddard Space Flight Center (GSFC)	12	1.25°×1°
LBNL-CAM5	National Center for Atmospheric Research (NCAR)	50	1°×1°

Non-ENSO-related Z500 and Precip



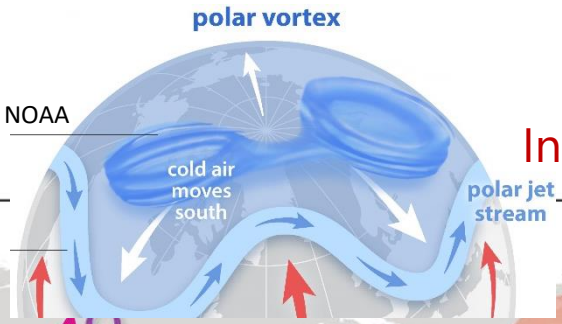
Pacific_Z500ne indices in OBS and individual AGCM simulations (12 members each)



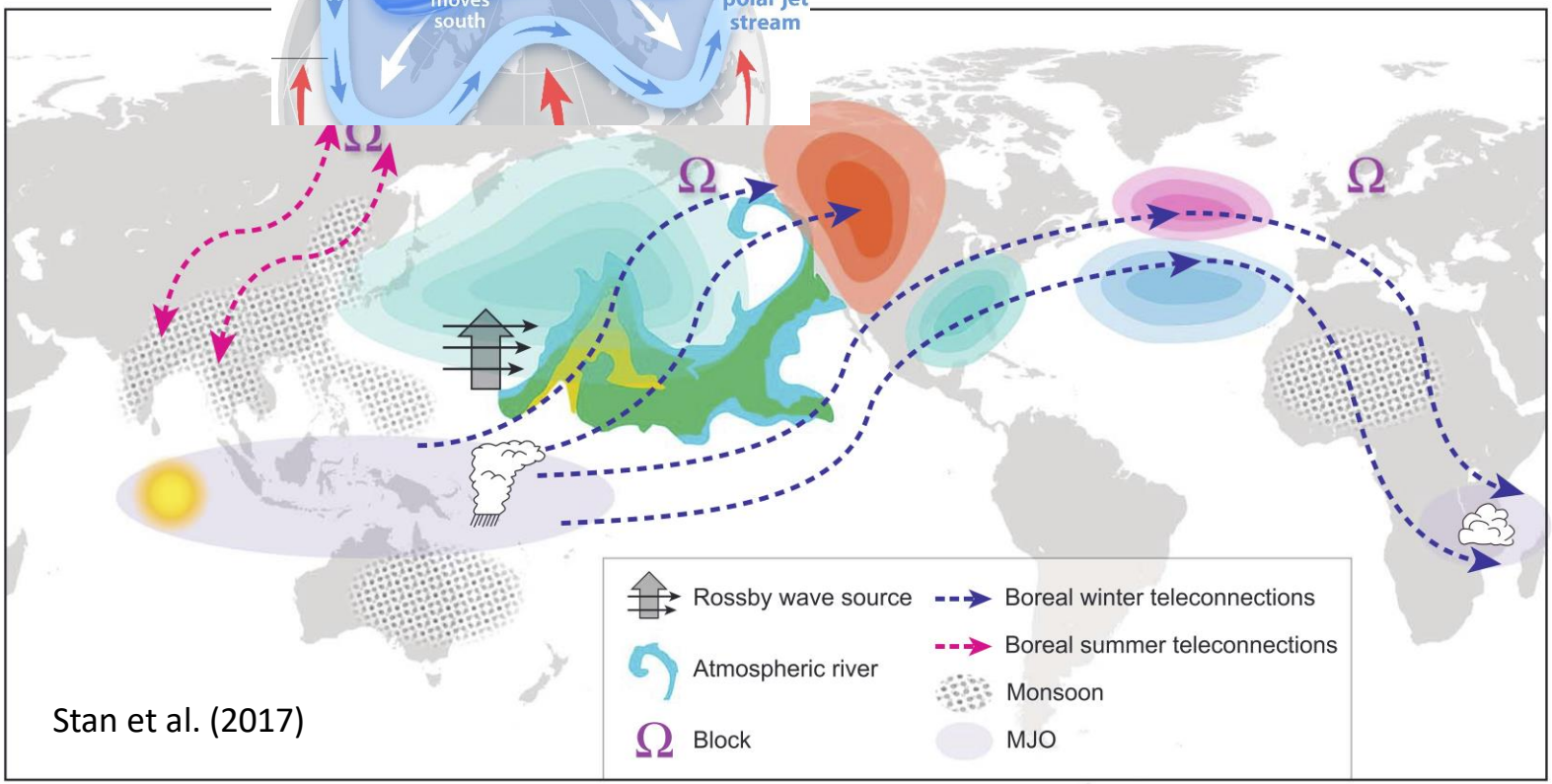
Forced Pacific_Z500ne variability exhibits variations in different AGCMs, suggesting predictability derived by the “Perfect model approach” could also be underestimated due to model deficiencies.

Urgent need to identify underexploited predictability sources for seasonal prediction of CA precipitation

Courtesy: NOAA



Influences from both Tropics & Arctic



Stan et al. (2017)

- ❑ Tropical convective variability (MJO, etc) and teleconnection patterns (e.g., 2015/16 El Nino)
- ❑ Arctic sea-ice variability and tropospheric/stratospheric Rossby-wave responses
- ❑ Troposphere-stratospheric interaction (both Arctic and tropics, e.g., QBO-MJO connection).

"Global cloud-resolving high-top models"

Summary:

- The observed year-to-year variability of CA winter precipitation can be separated into two components, one associated with the tropical SST variability, i.e., ENSO, and another with anomalous circulation near the west coast US, with a more dominant influence on CA winter precipitation from the latter.
- While skillful predictions for ENSO can be achieved, low prediction skill for CA winter precipitation is largely due to limited skill of anomalous Pacific circulation independent from ENSO as suggested by NMME predictions and multi-GCM simulations.
- Improved understanding of processes driving the non-ENSO related Pacific anomalous circulation associated with CA precipitation, and investigation of its precursors in large-scale conditions, are critical towards a breakthrough in predicting CA precipitation.

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