



Workshop, May 18, 2022



# Atmospheric Drivers in California Precipitation Transitions

## Potential Predictability of Southwest US Precipitation: Role of tropical and high-latitude variability

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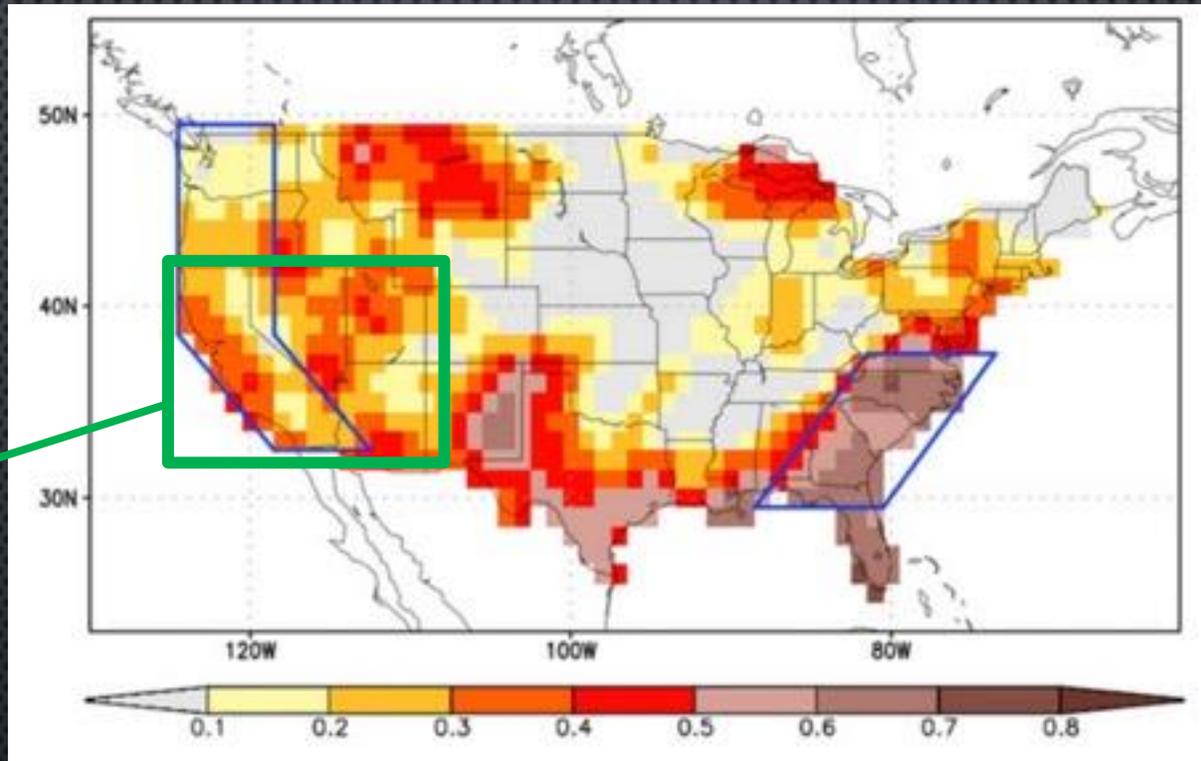
University of California Irvine





## Research Question

Southwest US domain



Skill of CFSv2 seasonal forecasts for predicting DJF precipitation (hindcasts 1982-2010).  
From Kumar and Chen (2020). Kumar and Chen (2020).

**What would be the benefit of improving seasonal forecasts in the tropics and the high-latitudes?**

# The atmospheric model : WACCM

## The Whole Community Climate Atmospheric Model (WACCM)

- WACCM4 1.9° x 2.5° horizontal grid, 66 vertical levels, up to 140 km
- Specified chemistry, External forcing (GHGs, etc) follows historical values
- Prescribed QBO

## Experiments

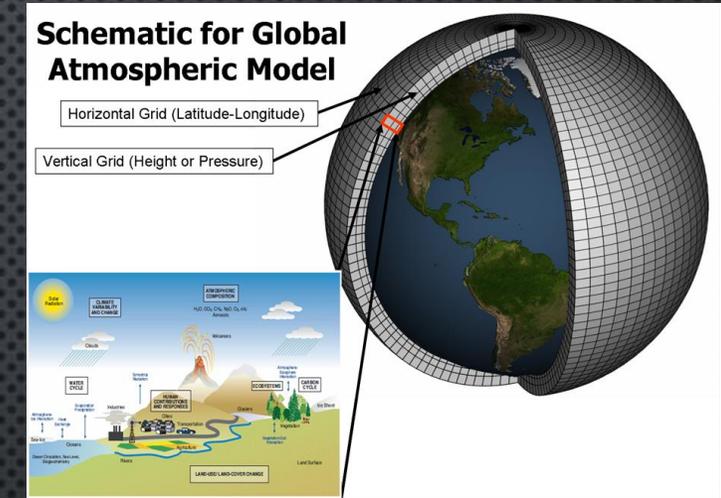
### Four types of experiments over 1980-2016

- 1) Prescribed observed SST/SIC : **AMIP**
- 2) AMIP with prescribed tropical variability : **AMIP-TROP**
- 3) AMIP with prescribed high-latitude variability : **AMIP-HL**
- 4) AMIP with prescribed tropical and high-latitude variability : **AMIP-TRHL**

**AMIP**

**AMIP-plus**

**10 ensemble members per experiment**

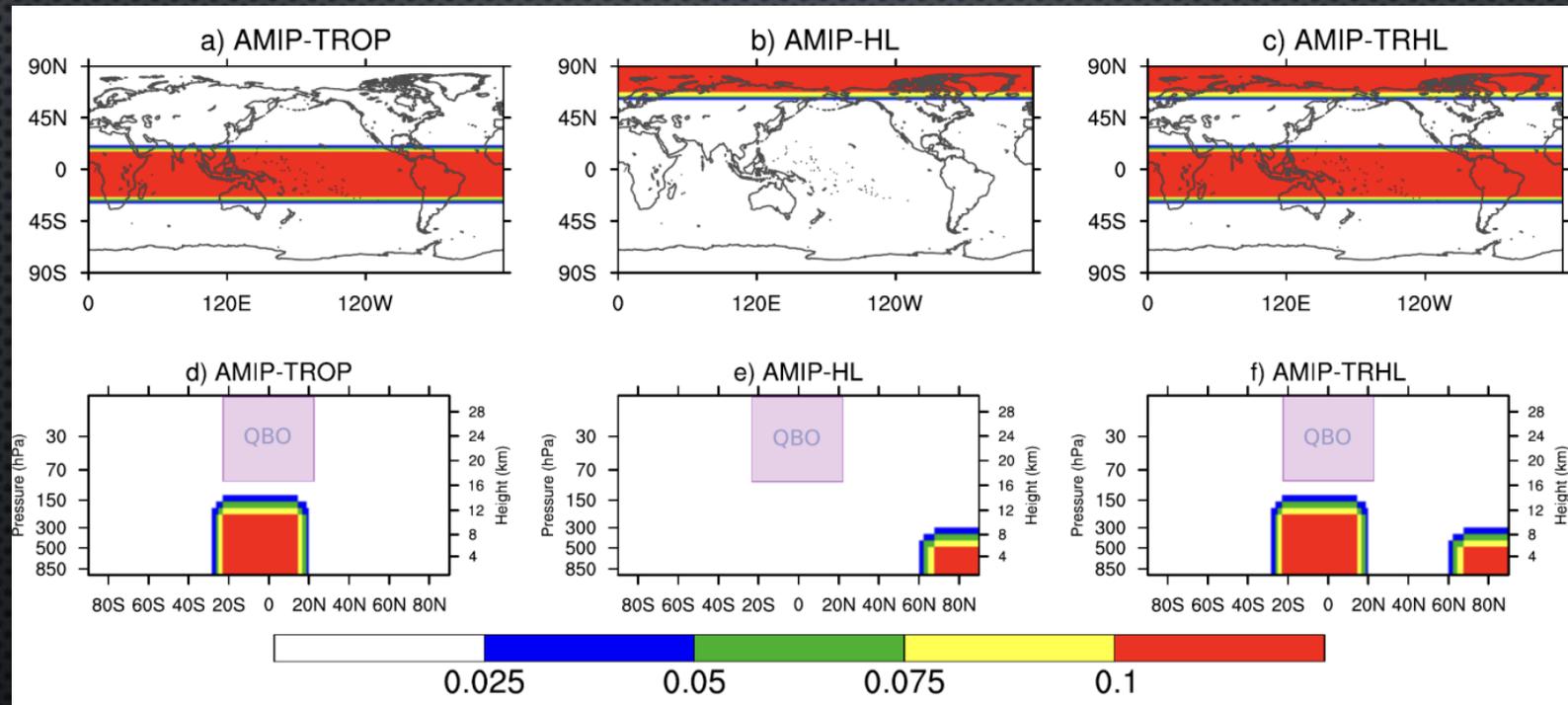




# Experimental setup for AMIP-plus experiments

Nudging of  $u$ ,  $v$ ,  $T$  & sfc  $p$  toward MERRA-2:

$$X_{\text{REF}} = \text{AMIP}_{\text{Clim-3hourly}} + \text{MERRA2}_{\text{anom-3hourly}}$$



Value of the nudging coefficient along the horizontal and vertical in : a) and d) AMIP-TROP ; b) and e) AMIP-HL ; c) and f) AMIP-TRHL. The relaxation strength is linearly decreased from 0.1 to 0 at the edges of the nudging domain. The purple rectangle in the pressure versus latitude plots indicates the domain of relaxation of the QBO (horizontal wind only, and a nudging time coefficient of 10 days).



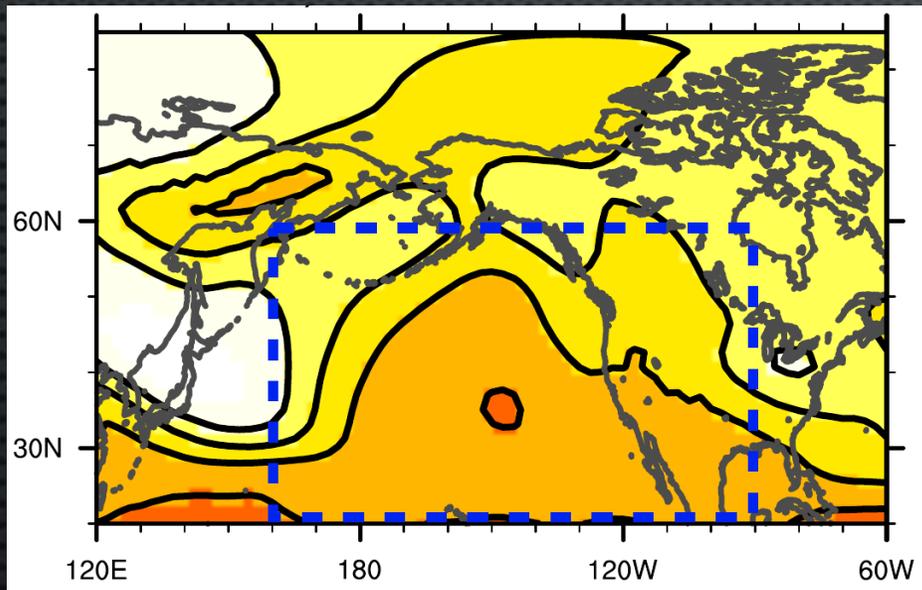
# Results



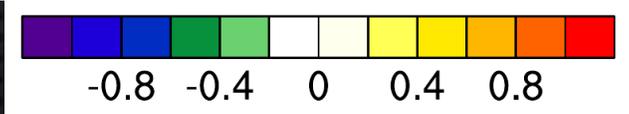
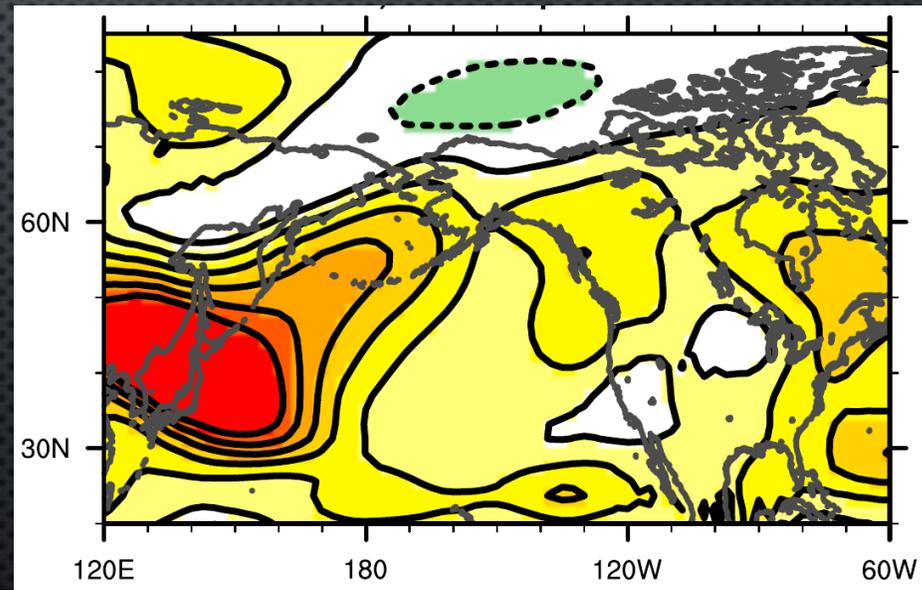
# Representation of the North Pacific atmospheric variability in each experiment

Skill in Z500 (versus MERRA-2)

AMIP (SST only)



Additional skill in AMIP-TROP



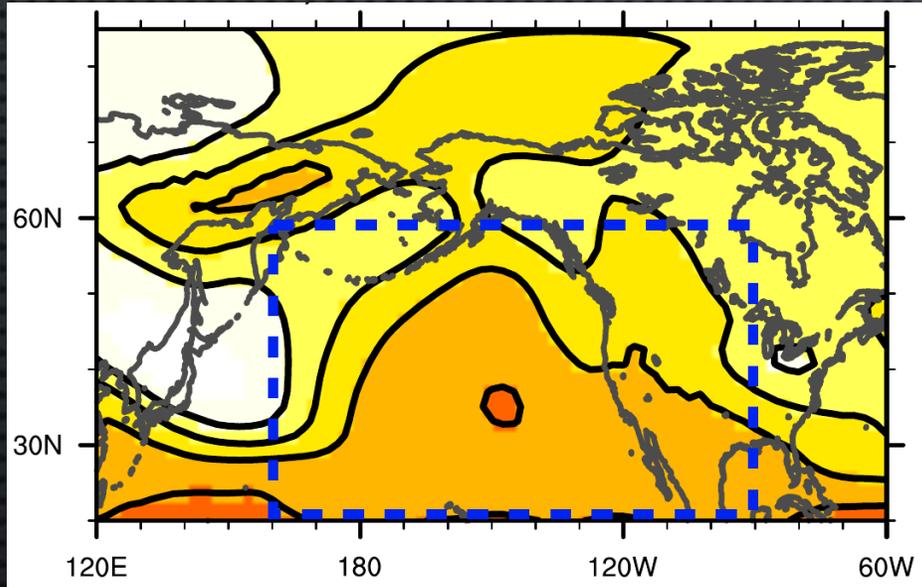
Grid-point correlations of NDJFM Z500 anomalies with MERRA-2 (1980-2016)



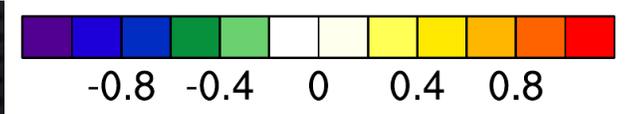
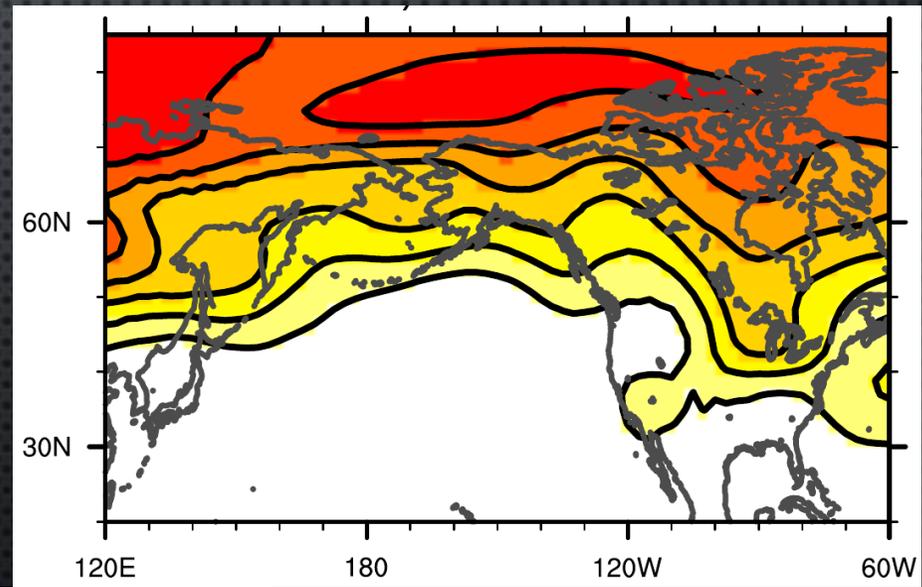
# Representation of the North Pacific atmospheric variability in each experiment

Skill in Z500 (versus MERRA-2)

AMIP (SST only)



Additional skill in AMIP-TRHL



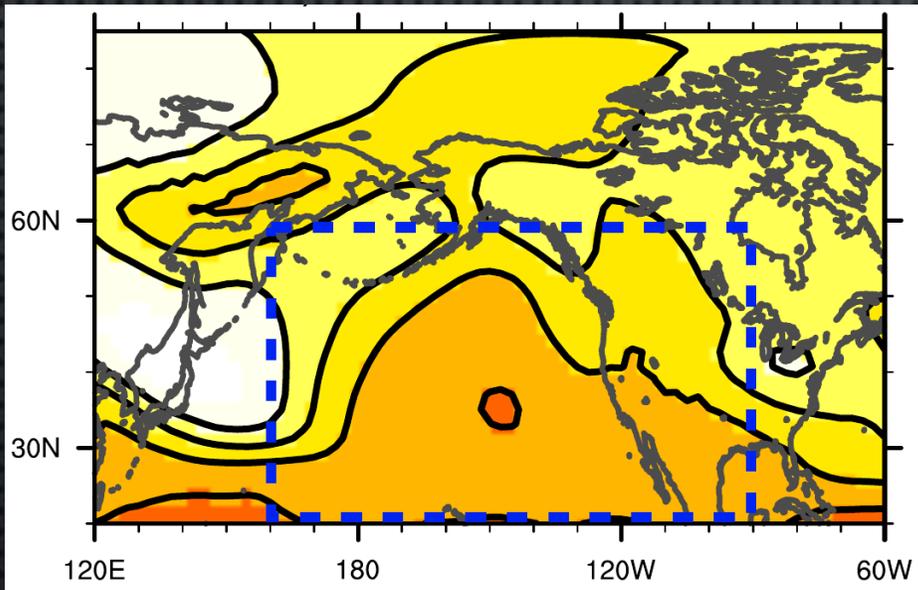
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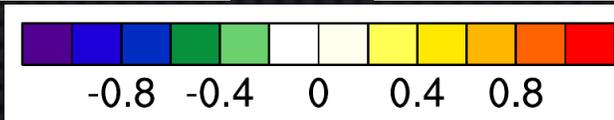
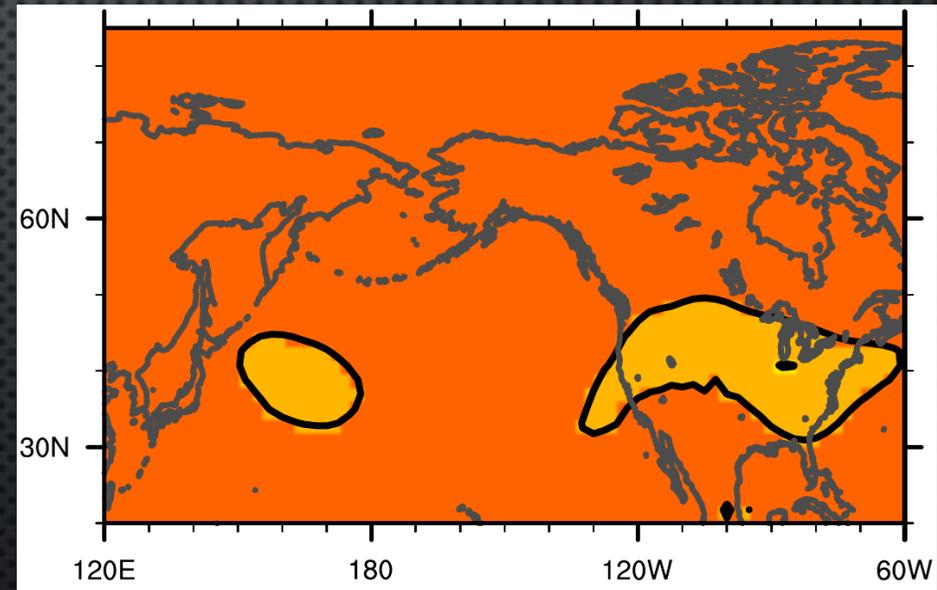
# Representation of the North Pacific atmospheric variability in each experiment

Skill in Z500 (versus MERRA-2)

AMIP (SST only)



Total skill in AMIP-TRHL



Grid-point correlation of NDJFM Z500 anomalies with MERRA-2 (1980-2016)

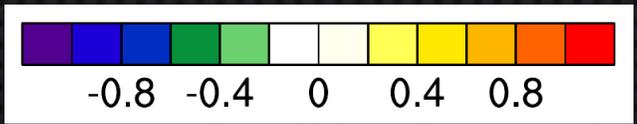
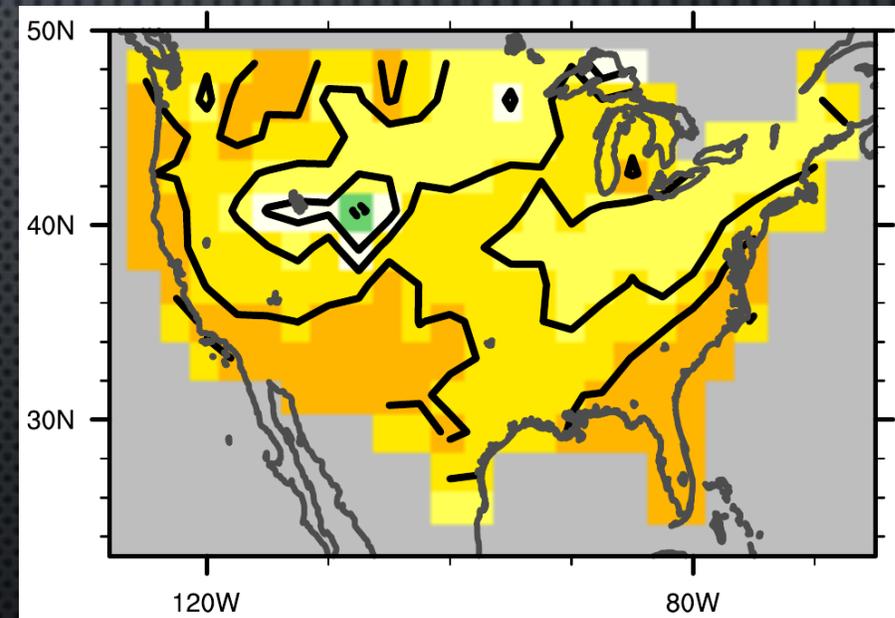
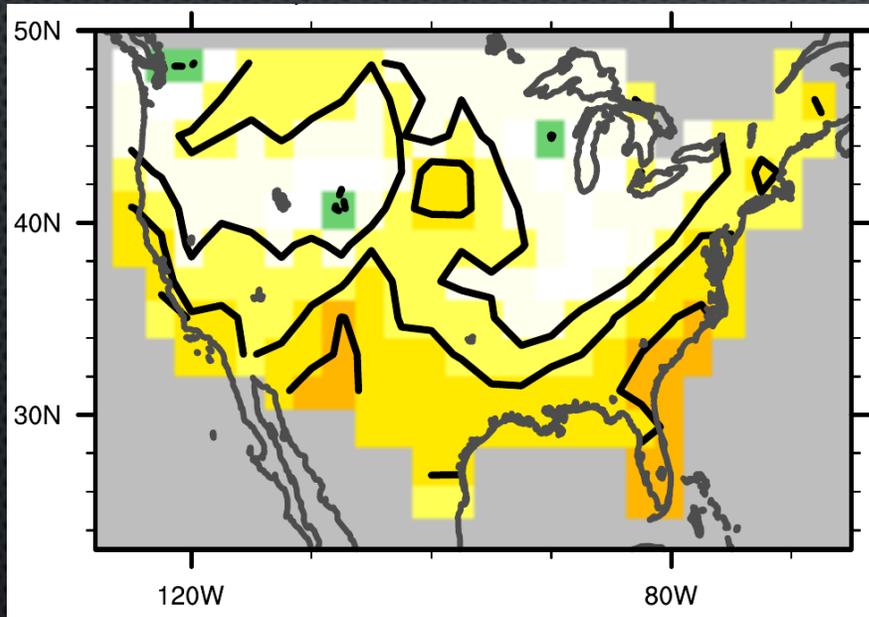


# Representation of US precipitation

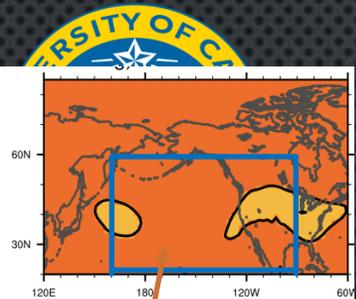
Skill in precipitation (versus CPC)

AMIP (SST only)

Total skill in AMIP-TRHL



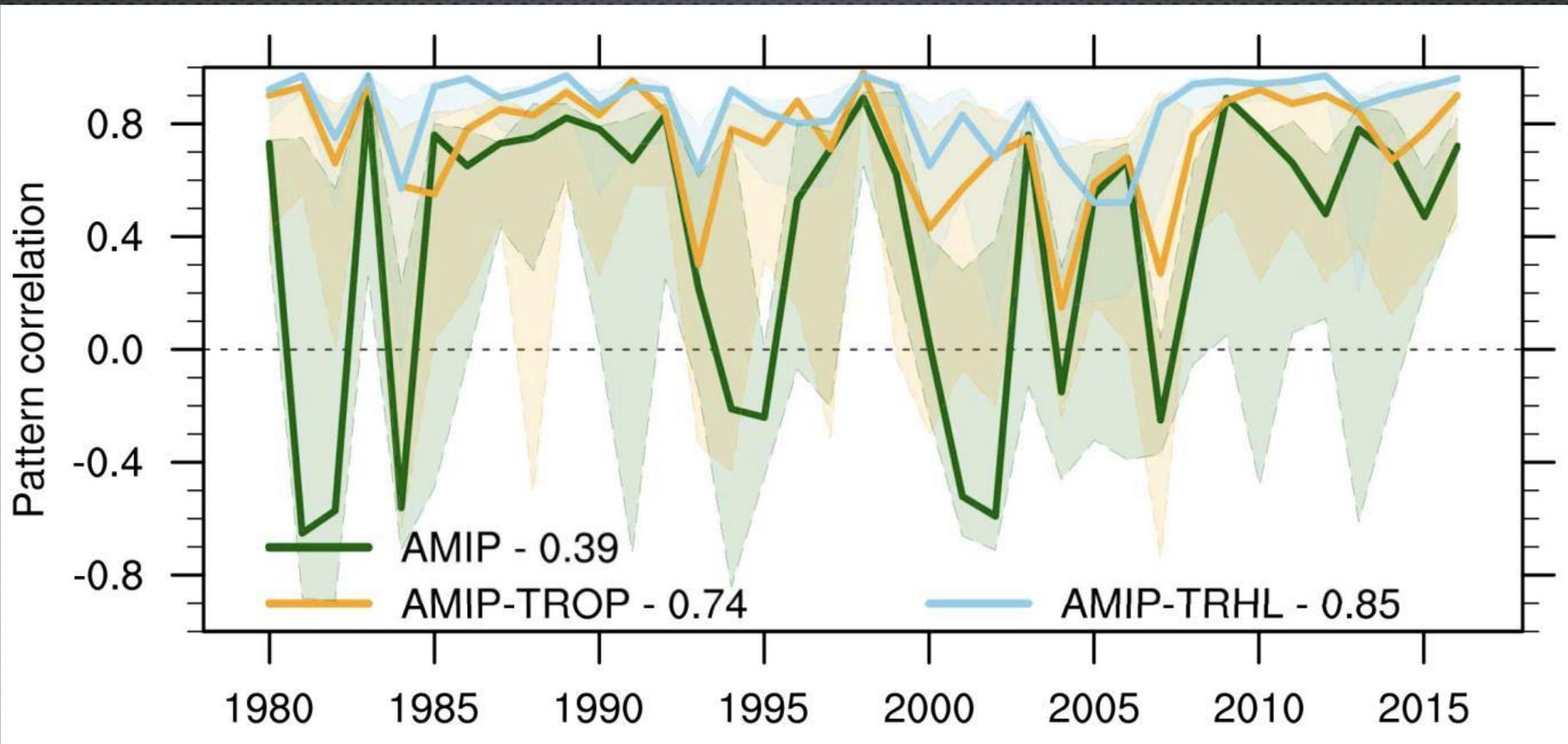
Grid-point correlation of NDJFM P anomalies with CPC (1980-2016)



# Timeseries of “skill” in the North Pacific

AMIP, AMIP-TROP (tropics nudged) and AMIP-TRHL (tropics and Arctic nudged)

North-Pacific/  
North America  
domain  
  
[160°E /90°W;  
20°N/60°N]



Pattern correlation of Z500 anomalies in the North Pacific - North America domain [160°E/90°W,20°N/60°N] between MERRA-2 and ensemble means of AMIP (green), AMIP-TROP (orange) and AMIP-TRHL (blue) and MERRA-2, for each NDJFM season of 1980-2016. For each experiment, the envelope represents max/min values of the spatial correlation among the 10 ensemble members.



## Decompose into different timescales using daily data

Synoptic (1-10 days), S2S (10-90 days), Interannual (1-5 years), Multiyear (>5 years)

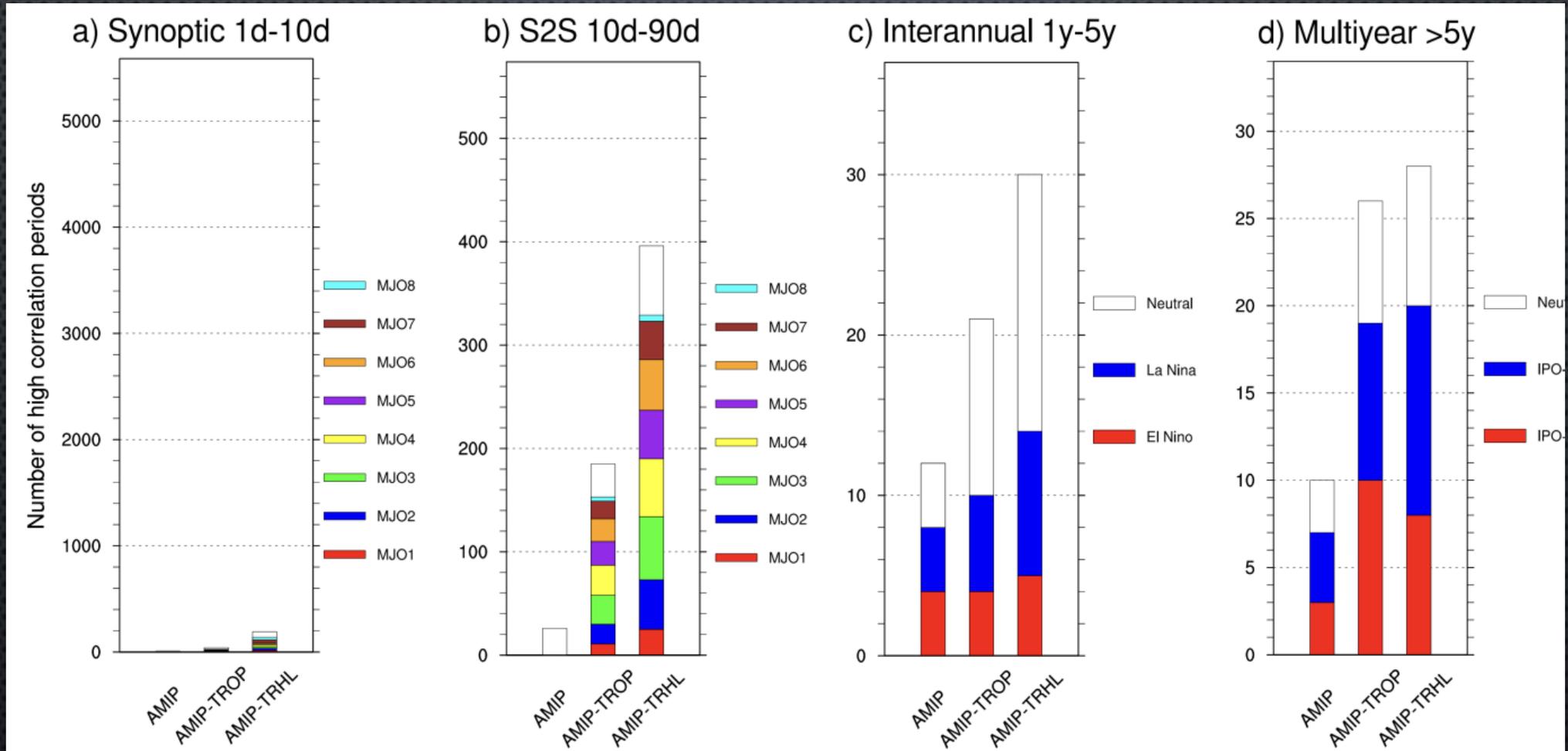
Compute pattern correlations between the observed and simulated Z500 anomaly in the NP-NA domain, after time filtering the daily data

If the correlation is greater than 0.7, the event is classified as *accurately represented* in the experiment.

Composite by phases of MJO (synoptic, S2S), ENSO (interannual) and IPO (multiyear)



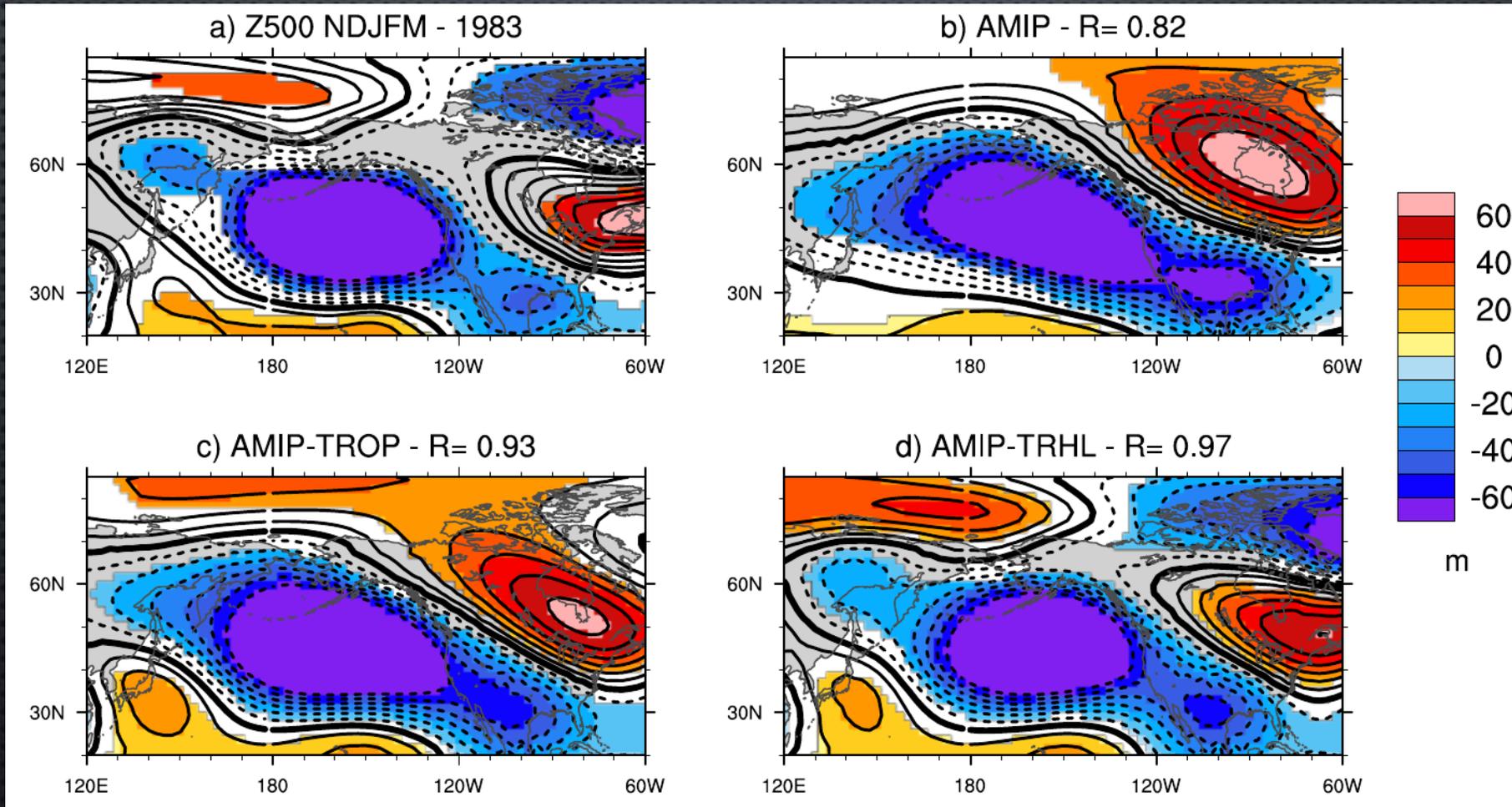
# Counts of periods of accurate representation of NP-NA circulation patterns



Count of periods of accurate representation of the North Pacific circulation pattern in AMIP, AMIP-TROP and AMIP-TRHL, for a) the synoptic (1d-10d) timescale (5587 NDJFM days over 1980-2016) ; b) the S2S (10d-90d) timescale (574 pentads) ; c) the interannual (1y-5y) timescale (37 years) ; d) the multiyear timescale (37 years with 5-yr lowpass filter, i.e. 33 years). Events of "accurate representation" are based on a spatial correlation of Z500 anomalies, in the ensemble mean of experiments versus reanalysis, greater than 0.7.



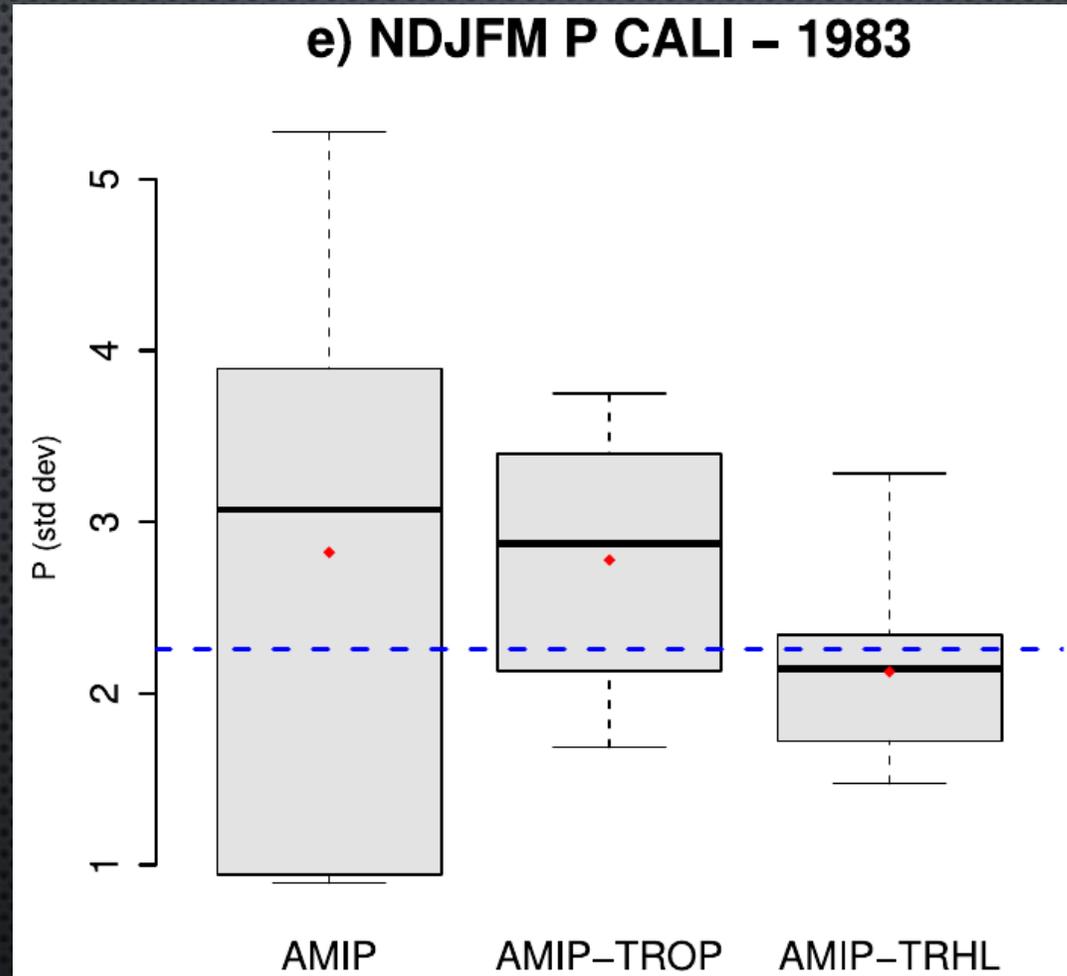
# 1983 : A "typical" El Niño year



Z500 anomalies in NDJFM 1983, in : a) MERRA2, b) AMIP, c) AMIP-TROP and d) AMIP-TRHL.



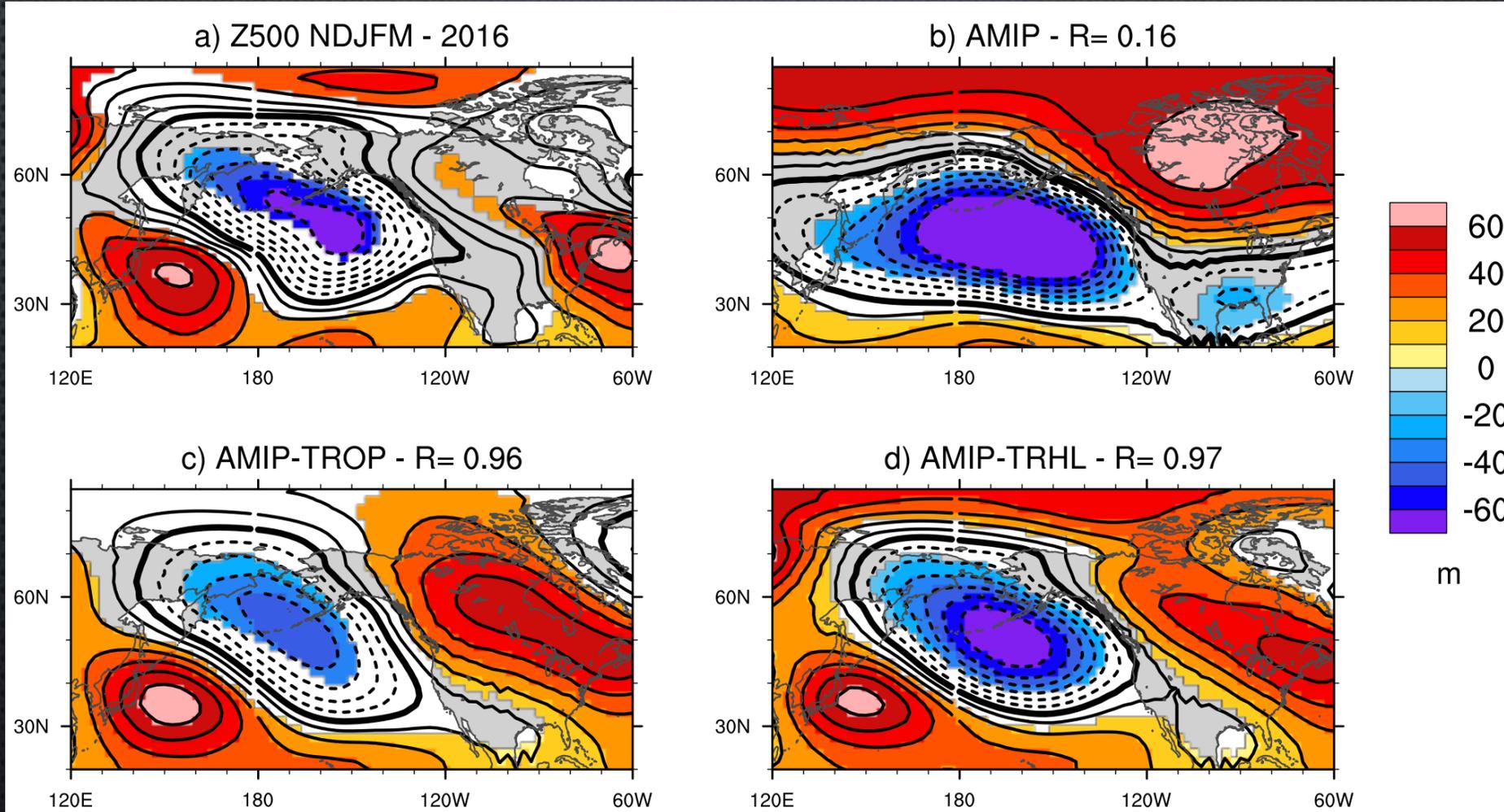
# 1983 : A "typical" El Niño year



Boxplot-whisker representation of the 10-member distribution of NDJFM 1983 CA rainfall anomalies [124°W/116°W, 32°N/42°N] in AMIP, AMIP-TROP and AMIP-TRHL. The boxplot indicates the median, upper and lower quartile of the distribution. The whiskers indicate the minimum and maximum values. The ensemble mean is marked by a red diamond. The horizontal dashed blue line indicates the observed value.



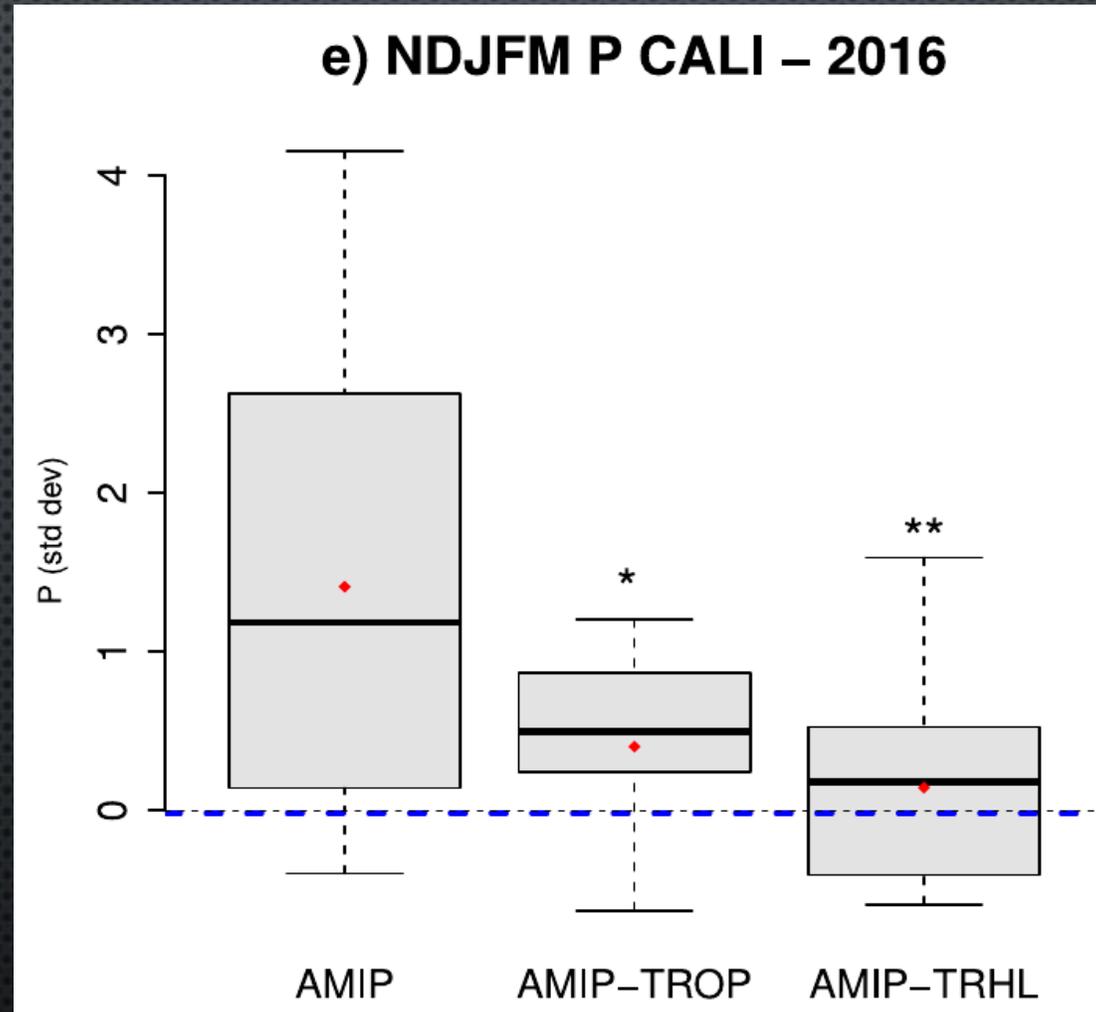
# The 2016 El Niño "bust"



Z500 anomalies in NDJFM 2016, in : a) MERRA2, b) AMIP, c) AMIP-TROP and d) AMIP-TRHL.



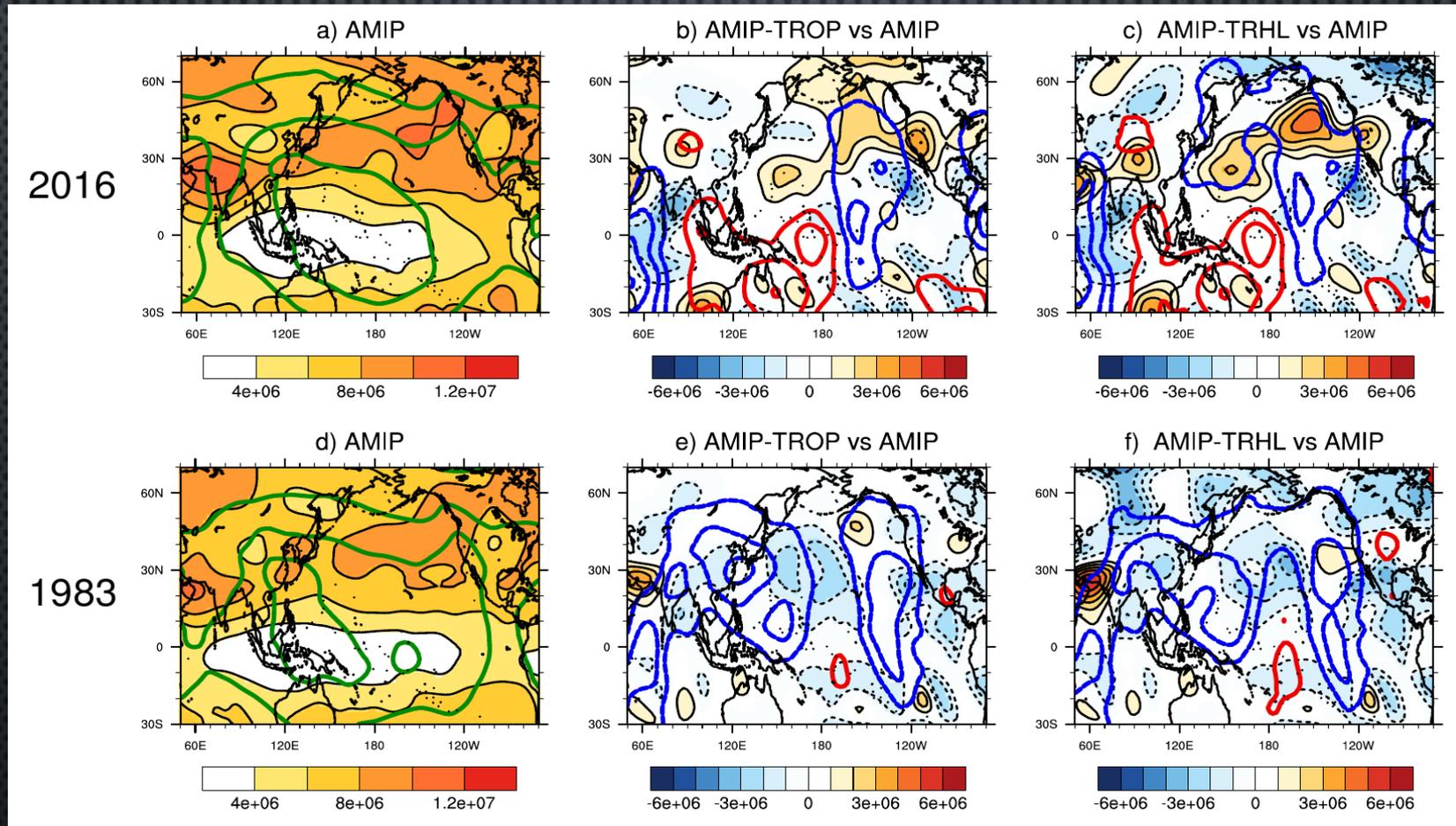
## The 2016 El Niño “bust”



Boxplot-whisker representation of the 10-member distribution of NDJFM 2016 CA rainfall anomalies [124°W/116°W, 32°N/42°N] in AMIP, AMIP-TROP and AMIP-TRHL. The boxplot indicates the median, upper and lower quartile of the distribution. The whiskers indicate the minimum and maximum values. The ensemble mean is marked by a red diamond. The horizontal dashed blue line indicates the observed value.



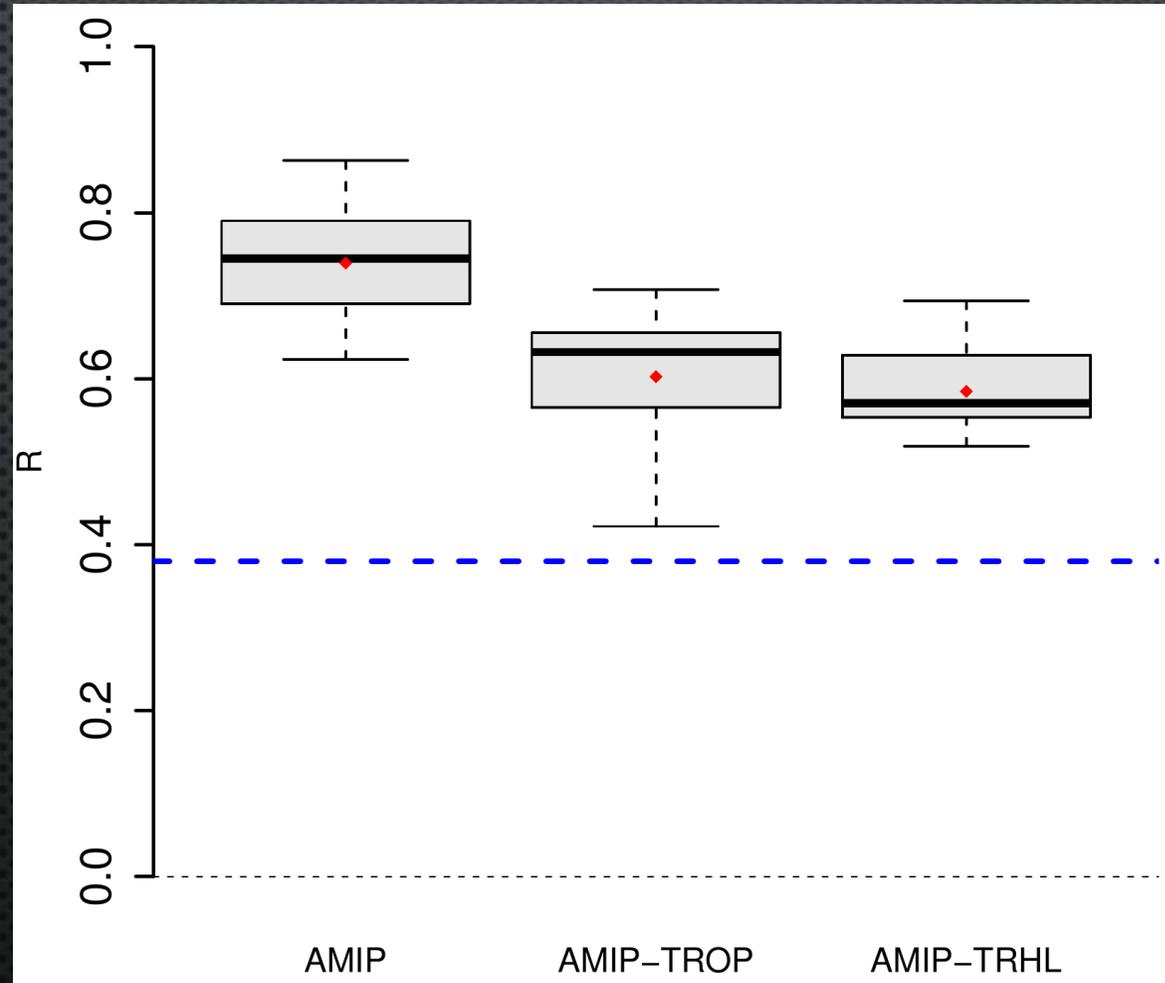
# Greater S2S variability in 2016 versus 1983



NDJFM standard deviation of subseasonal (10d-90d) 850 hPa velocity potential (green, blue and red contours, kg/s) and 250 hPa streamfunction (shading, kg/s) in (Top) 2016 : a) AMIP, contour interval for VP850 :  $5 \cdot 10^{-5}$  kg/s. b) AMIP-TROP minus AMIP difference. Contour interval for VP850 :  $2.5 \cdot 10^{-5}$  kg/s (blue is negative, red is positive). c) Same as b) but for AMIP-TRHL. (Bottom) 1983 ; d-f) Same as a)-c) but for year 1983.



# More realistic tropical variability weakens the ENSO teleconnection in the model



Comparison of the ENSO teleconnection in observations and the AMIP experiments (1980-2016).



# Summary: Take-away points

- Tropical variability exerts a strong influence on the North Pacific North America atmospheric circulation, from S2S to decadal time scales. Imposing high-latitude variability further increases the skill of the model.
- This means that improving predictability in the tropics and high-latitudes will benefit predictions of the Southwest US precipitation at S2S, seasonal, and decadal time scales.
- Signal at one time scale may be a source of noise at another. We find that high S2S activity (MJO) in the tropics may disrupt the ENSO teleconnection and be detrimental for seasonal predictions. Further work is ongoing to explore this question in climate model large ensembles.

## References

- Peings, Y., Lim, Y., & Magnusdottir, G. (2022) Potential predictability of Southwest US rainfall : role of tropical and high-latitude variability, *Journal of Climate*, 35, <https://doi.org/10.1175/JCLI-D-21-0775.s1>
- Lim, Y., Peings, Y., & Magnusdottir, G. (2021). The role of atmospheric drivers in a sudden transition of California precipitation in the 2012/13 winter. *Journal of Geophysical Research: Atmospheres*, 126, e2021JD035028. <https://doi.org/10.1029/2021JD035028>
- Sena, A T, Peings, Y, & Magnusdottir, G. (2022). Effect of the Quasi-biennial Oscillation on the Madden Julian Oscillation teleconnections in the Southern Hemisphere, *Geophys. Res. Lett.*,49, <https://doi.org/10.1029/2021GL096105>

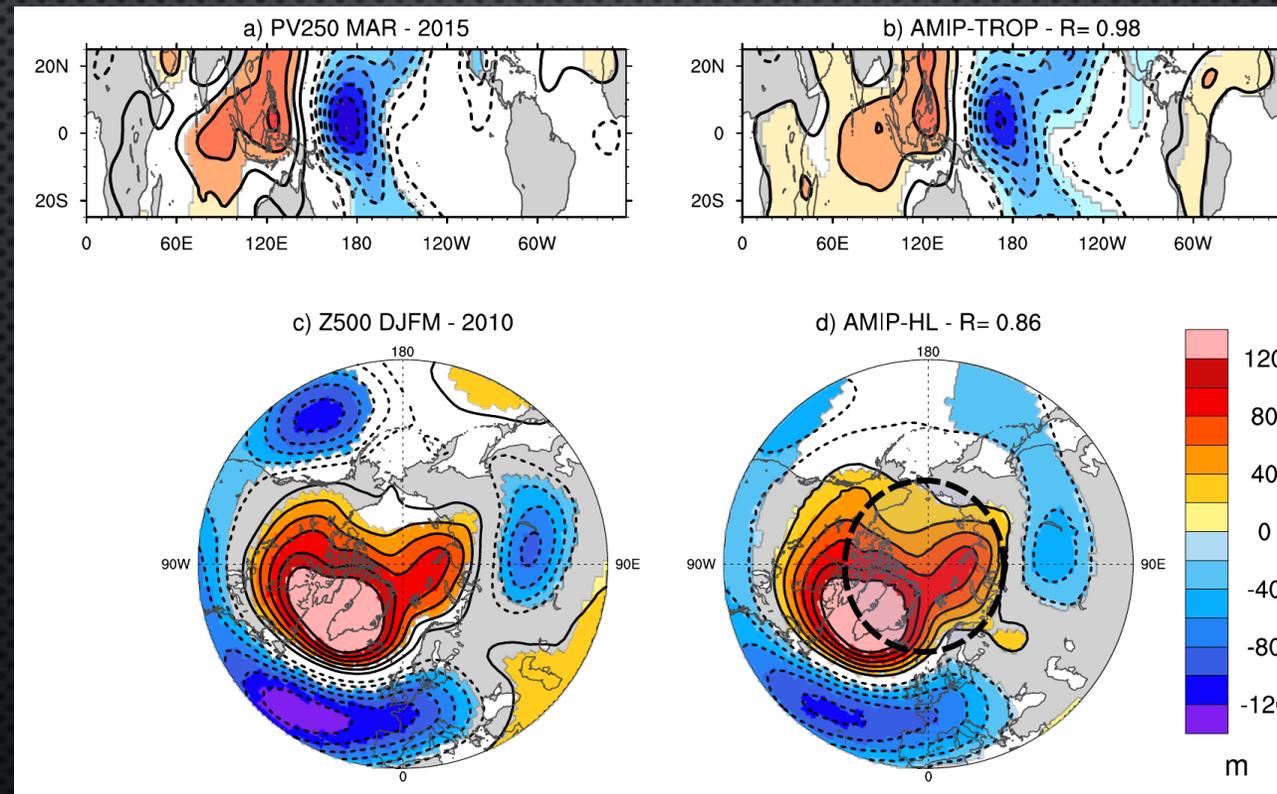




# Nudging the atmosphere towards MERRA-2 fields



- In the nudging domain, the T, U, V and surface pressure are nudged towards a reference state :
- $X_{REF} = AMIP_{clim-3hourly} + MERRA2_{anom-3hourly}$
- 
- At each grid point of the nudging domain,  $X_{t+1} = X_t + k*(X_t - X_{REF})$  , with k nudging coefficient



Verification of nudging efficiency

