Journal Club – Dec. 15th 2020

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machine learning in climate science

Journal Club

Distinct Patterns of Tropical Pacific SST Anomaly and Their Impacts on North American Climate

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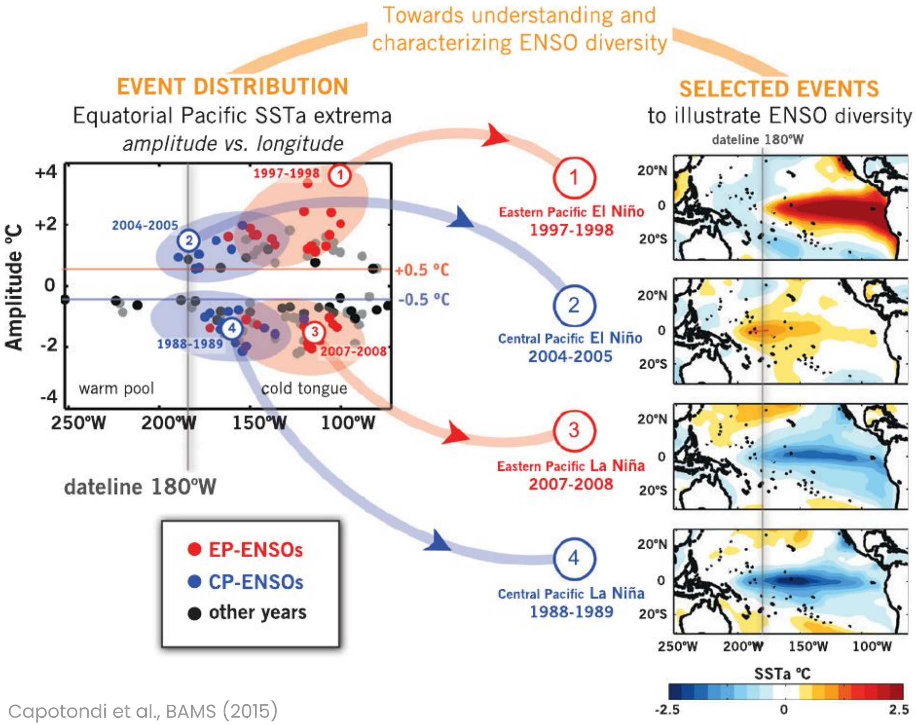
Motivation

“each ENSO event is unique in its SST anomaly pattern and climate response”

Capotondi et al., BAMS (2015)



Capotondi et al., BAMS (2015)

Main Question

“each ENSO event is unique in its SST anomaly pattern and climate response”

Capotondi et al., BAMS (2015)

Can we still distinguish different ENSO types and estimate their impact on North America?

Datasets

Datasets used in boreal winter (DJF) from 1901 - 2010

Sea surface temperature:

- Monthly SST from HadISST

Precipitation:

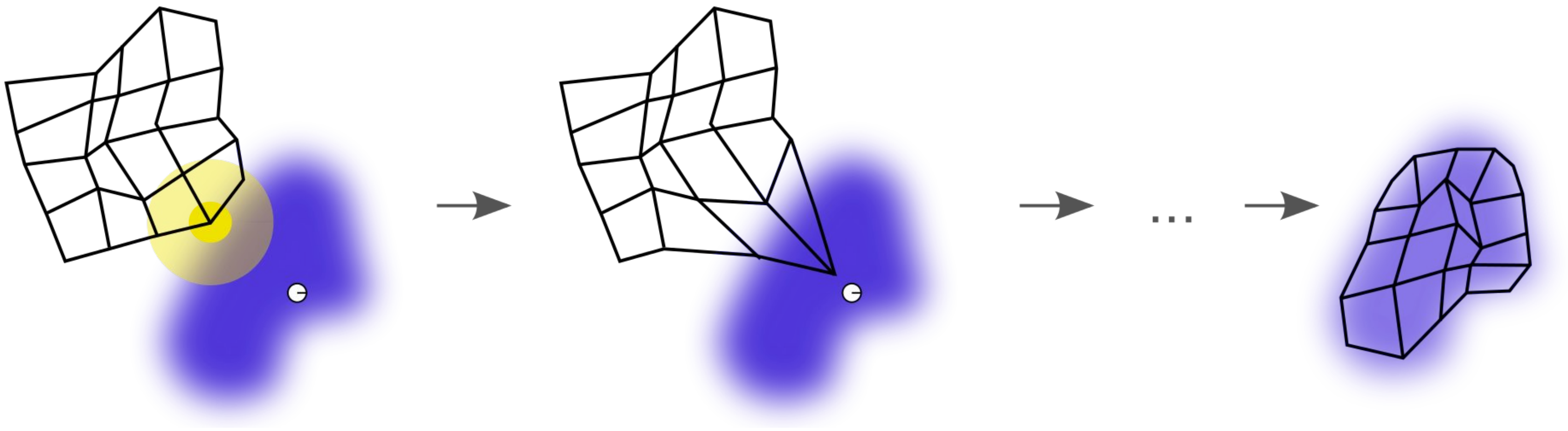
- Climate Research Unit (CRU): Monthly precipitation and temperature over land
- Global Precipitation Climatology Center (GPCC): Global land precipitation

Temperature and Pressure:

- Twentieth Century Reanalysis (20CRv2): Pressure data
- ECMWF's atmospheric reanalysis (ERA20C): Temperature and pressure reanalysis
- NOAA outgoing longwave radiation (OLR)

Self-organizing maps

Unsupervised learning method for dimensionality reduction



Wikipedia

Discretized representation of the input space, called Kohonen map

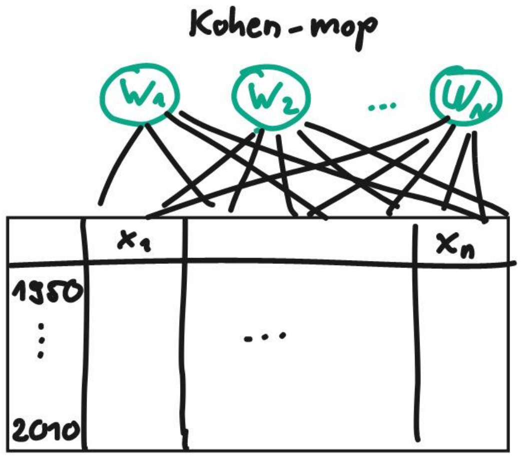
Self-organizing maps

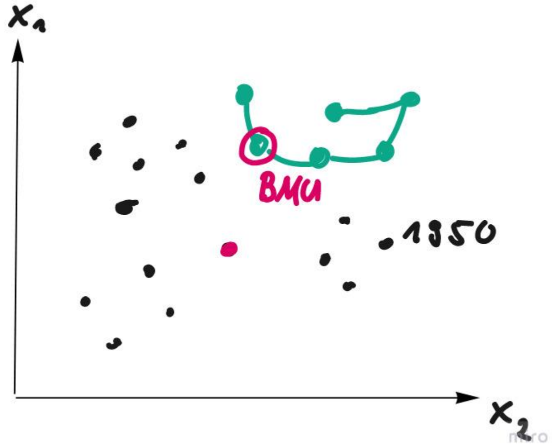
Randomly initialize weight vectors

while units move:

1. randomly select datapoint
2. compute winning neuron (Best Matching Unit)
3. update BMU and neighbors

$$W_{t+1} = W_t + \eta_t L_t (X_t - W_t)$$





SOM: Find number of clusters

False discovery rate:

Field significant approach which determines whether two cluster patterns are statistically distinguishable.

FDR between cluster i and j:

1. P-values (two-sided) of mean composites
2. Evaluate distribution of M p-values

$$p_{\mathrm{FDR}} = \max_{m=1,\ldots,M}\left[p_{(m)} : p_{(m)} \leq q\left(\frac{m}{M}\right)\right].$$

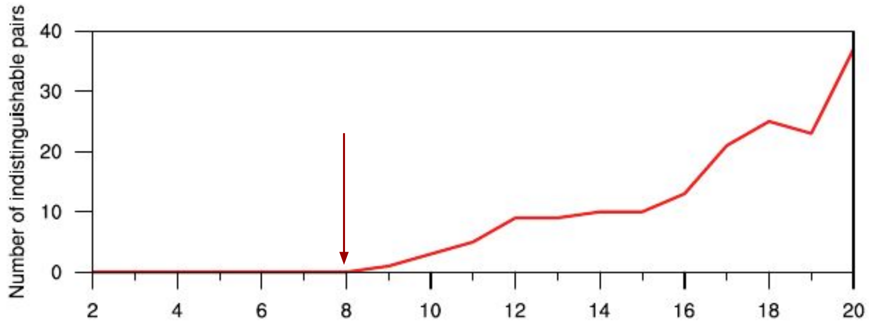


FIG. 1. The number of SOM SST cluster pattern pairs that are indistinguishable at the 95% confidence level. The horizontal axis indicates the number of SOM patterns K from 2 to 20.

SOM patterns

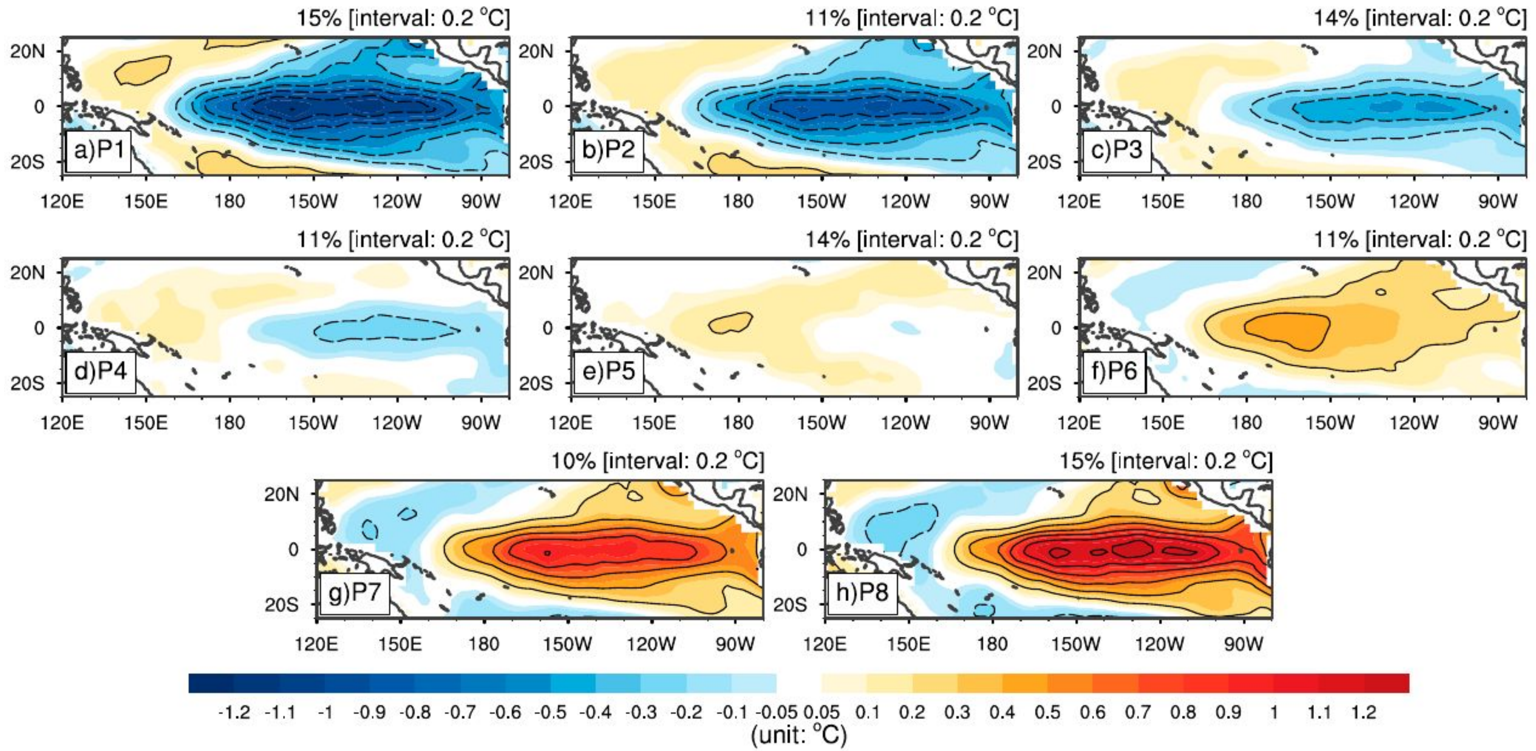
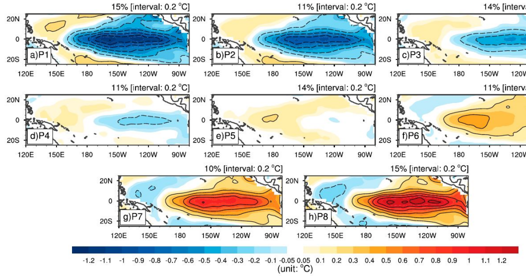


FIG. 2. The spatial distribution of eight SOM patterns (°C). The percentage to the top right of each map refers to the frequency of occurrence of the pattern for the 1901–2010 period.

ENSO time series



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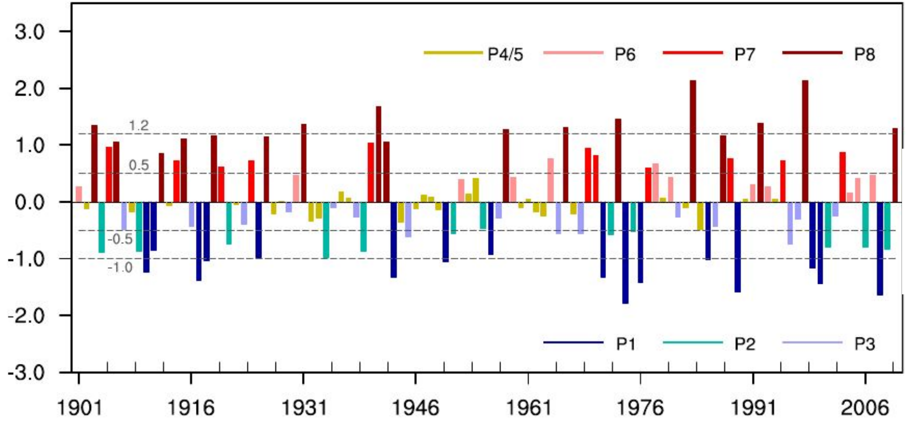
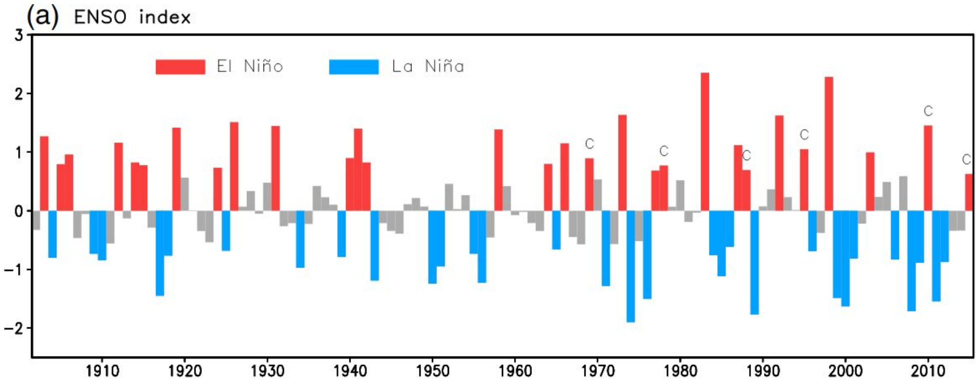


FIG. 3. The time series of DJF-mean Niño-3.4 index (°C) from 1901 to 2010 color-coded according to each year's corresponding SOM pattern identification. Warm colors, cold colors, and yellow bars indicate El Niño–like, La Niña–like, and near-normal patterns, respectively. The dashed gray lines indicate the threshold Niño-3.4 values for El Niño (+0.5°C), La Niña (−0.5°C), strong El Niño (+1.2°C), and strong La Niña (−1.0°C) used in this study.



Nguyen et al., Int, Jour. of Climat. (2020)

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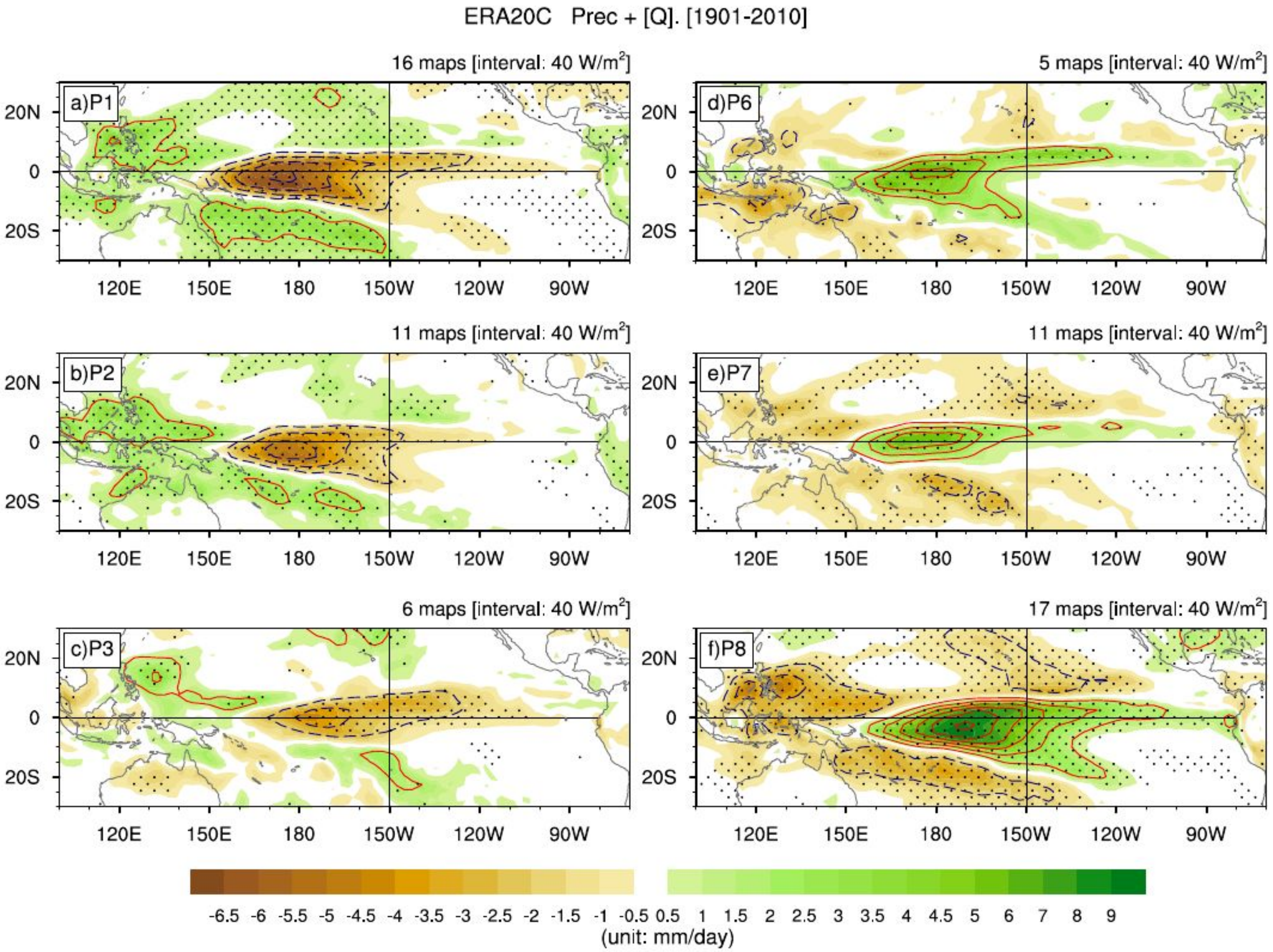
Precipitation anomalies



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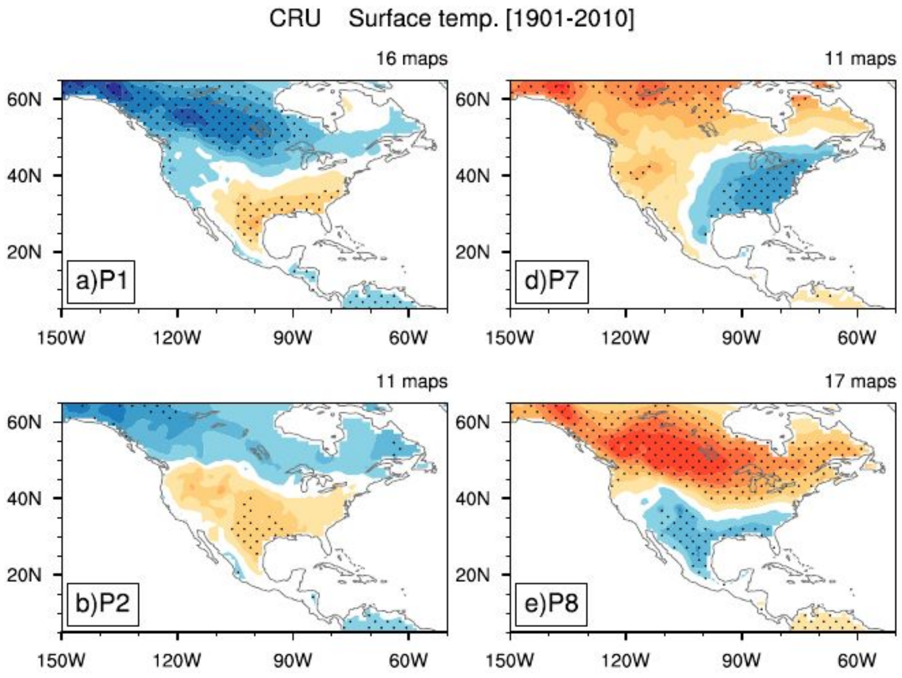
Impact on North America



DJF-mean temperature anomalies

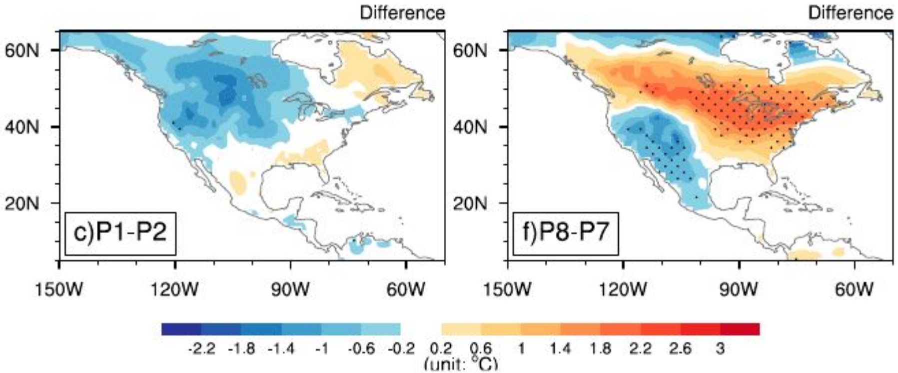
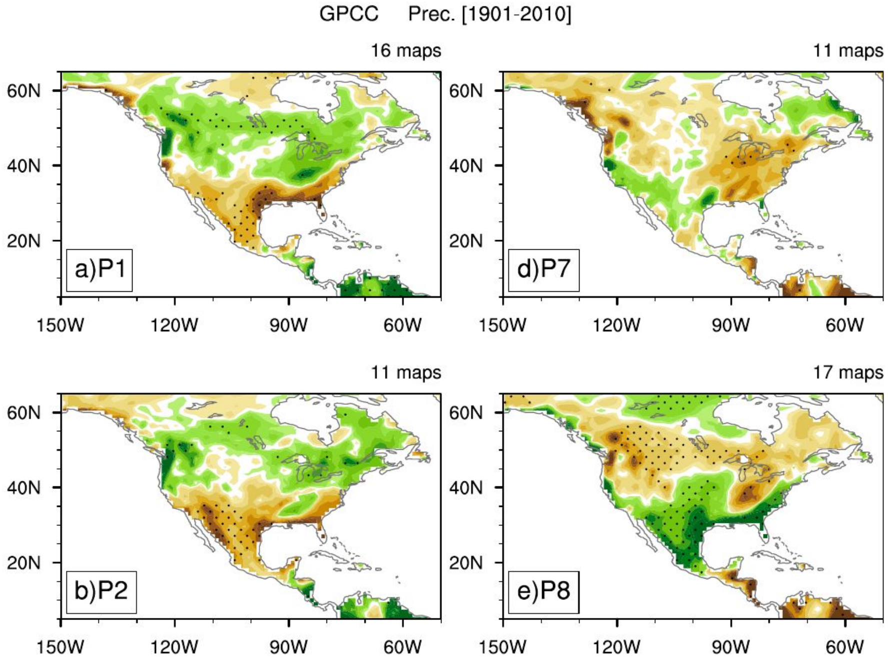


FIG. 7. Composite maps of the DJF-mean surface temperature anomalies over North America (°C) for (left) the two La Niña patterns (P1 and P2) and their differences and (right) the two El Niño (P7 and P8) patterns and their differences, based on CRU observational data for the period 1901–2010. Stippling indicates values at or above the 90% confidence level using the two-tailed nonparametric Monte Carlo bootstrap statistical significance test.

Impact on North America



DJF-mean precipitation anomalies

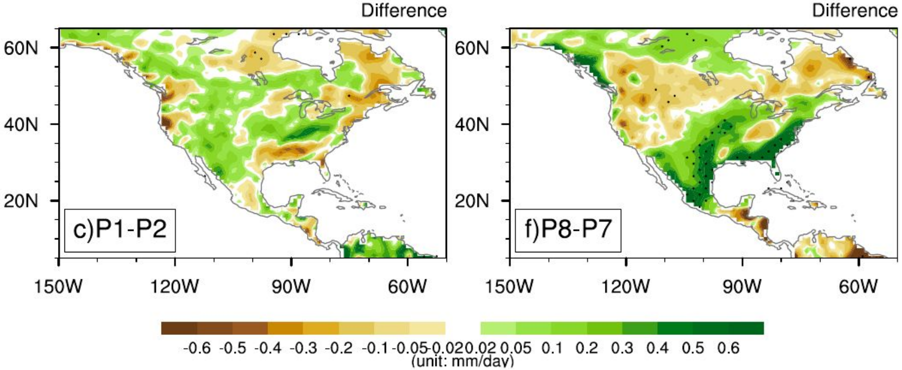
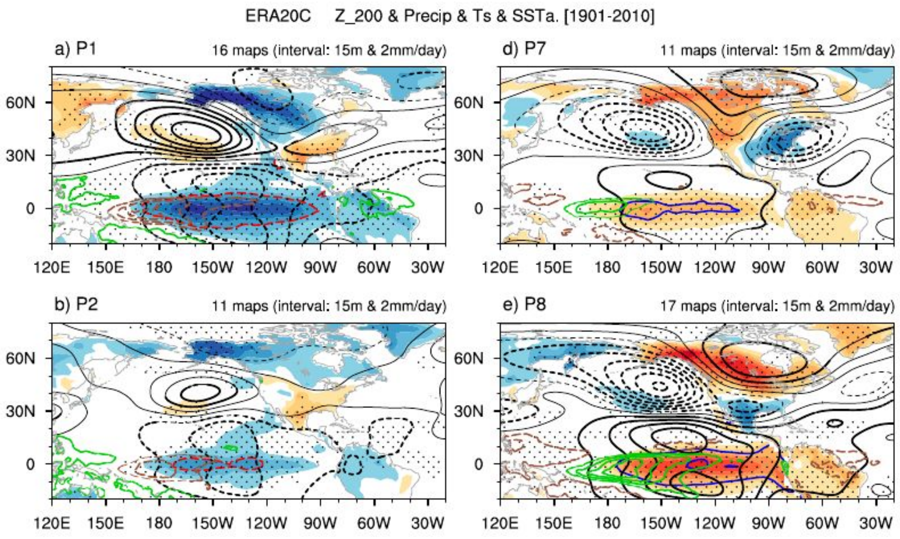


FIG. 9. As in Fig. 7, but for precipitation composites based on GPCC dataset for the period of 1901–2010.

Impact on North America



DJF-mean geopotential height, temperature and precipitation

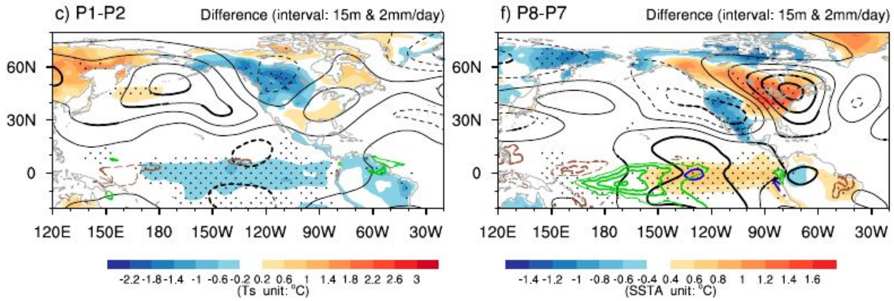


FIG. 8. Composite maps of the DJF-mean geopotential height anomalies at 200 hPa (black contours; interval: 15 m) and precipitation anomalies (brown and green contours; interval: 2 mm day^{-1}) for (a),(b) the two La Niña patterns and (c) their differences and (d),(e) the two El Niño patterns and (f) their differences. The shading represents surface temperature anomaly over land (°C) and SST anomaly over the oceans (°C). The blue and red contours show the SST anomaly of ±0.8° and ±1.6°C. The thick contours and stippling indicate values at or above the 90% confidence level using the two-tailed nonparametric Monte Carlo bootstrap statistical significance test. All the variables, except SST (from HadISST), were derived from ERA20C for the period of 1901–2010.

SST-forced components

Comparing model ensemble (CAM4/5) to observation responses

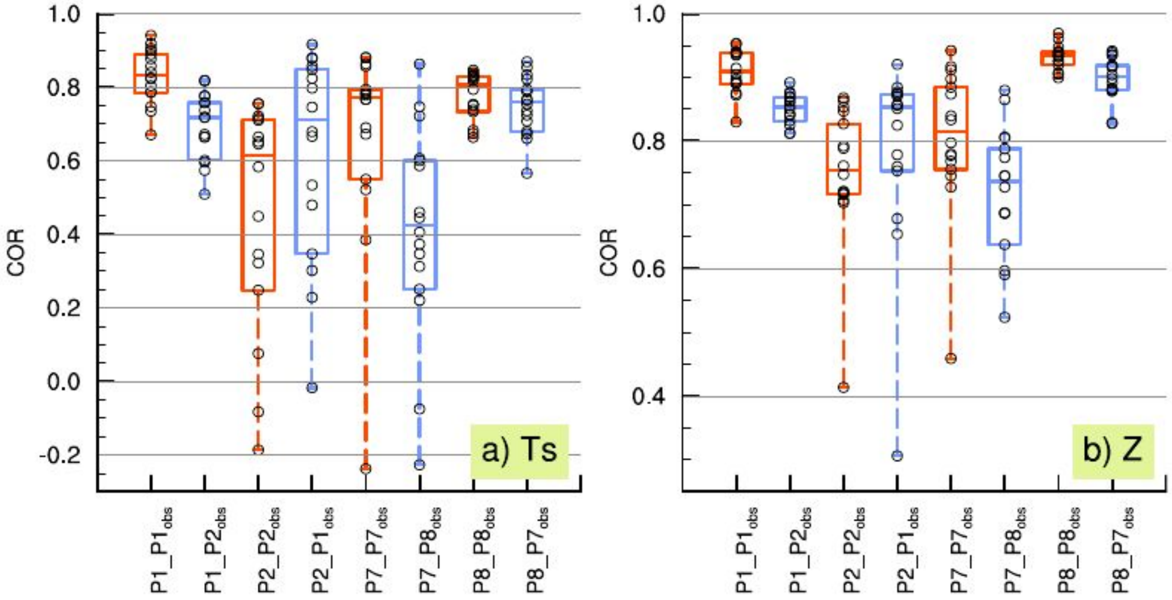


FIG. 13. Box plot of the spatial correlation coefficients of (left) surface temperature and (right) 200-hPa geopotential height composites with hollow circles, indicating the spatial correlation between the observation and each ensemble member for each of the four patterns (P1 and P2, P7 and P8). The red (blue) box represents the correlation coefficients between the same (cross) patterns.

Take home message

1. Self-organizing maps are an alternative to PCA due to nonlinearity and robustness

2. ENSO classification is useful to understand ENSO dynamics and impacts but “each ENSO event is unique in its SST anomaly pattern and climate response”