Decadal prediction in the Pacific region

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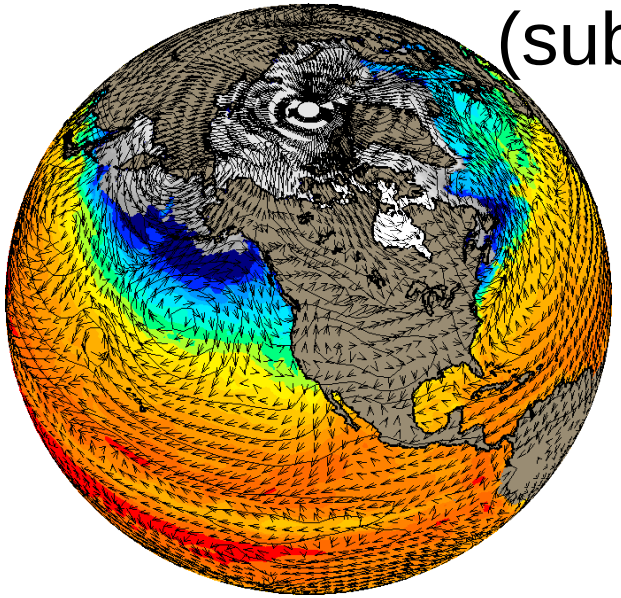
(submitted to J. Climate)



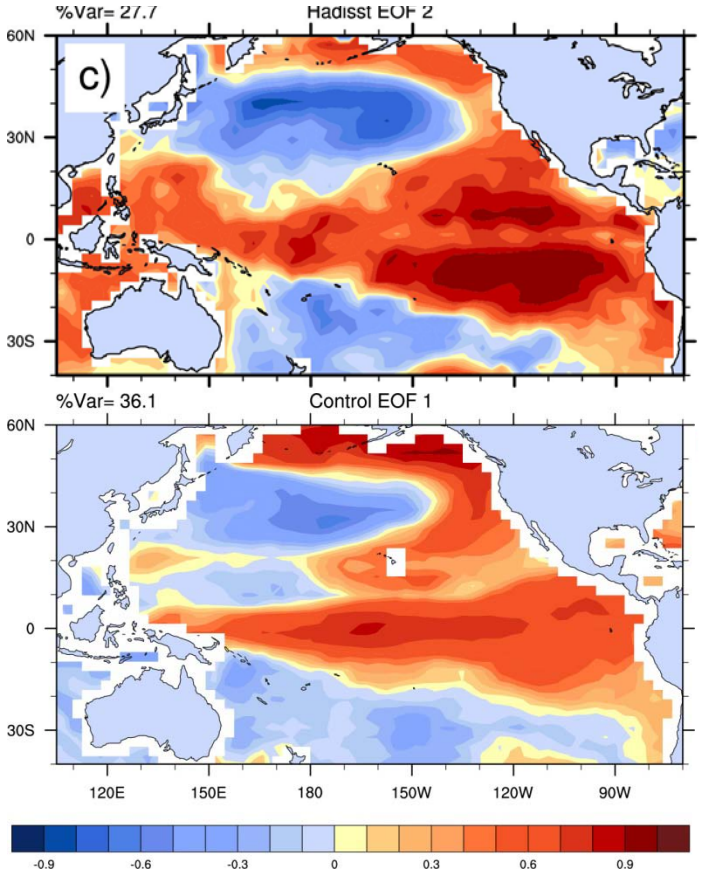
NCAR

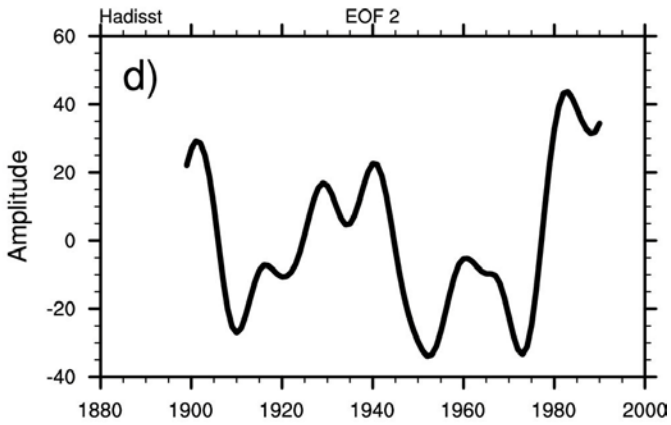
Decadal Prediction

Factors that influence decadal prediction in the Pacific:

1. Climate change commitment
2. External forcing (e.g. increasing GHGs)
3. Internally generated variability (e.g. IPO/PDO)

The Pacific Decadal Oscillation (PDO) or Interdecadal Pacific Oscillation (IPO)

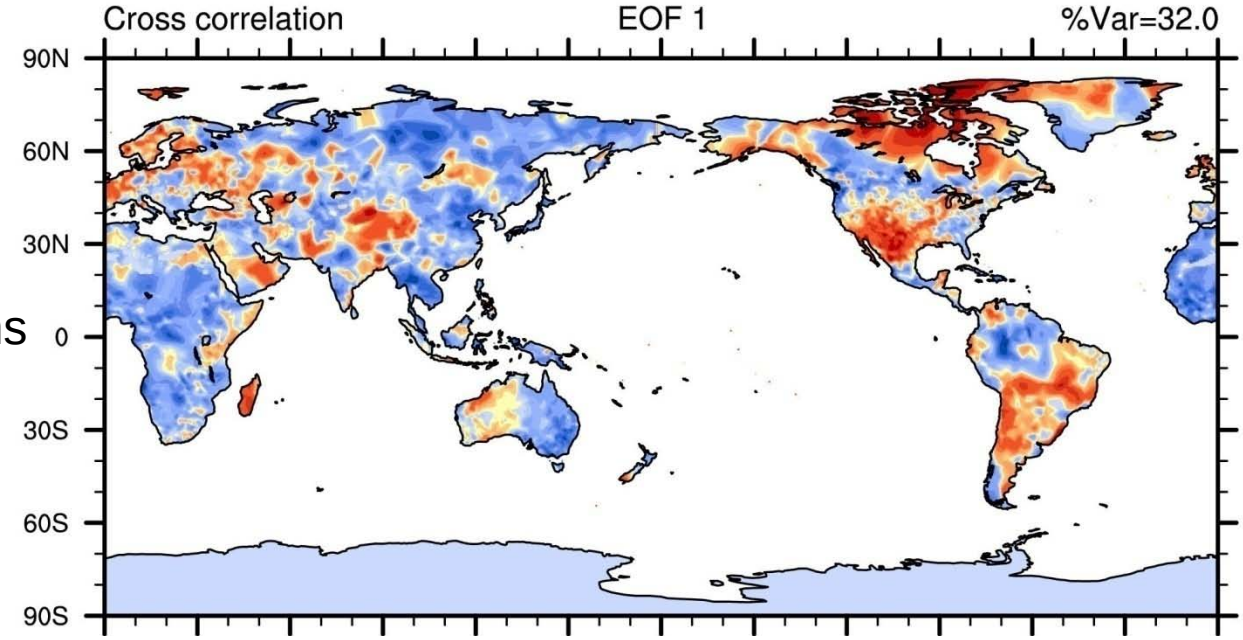




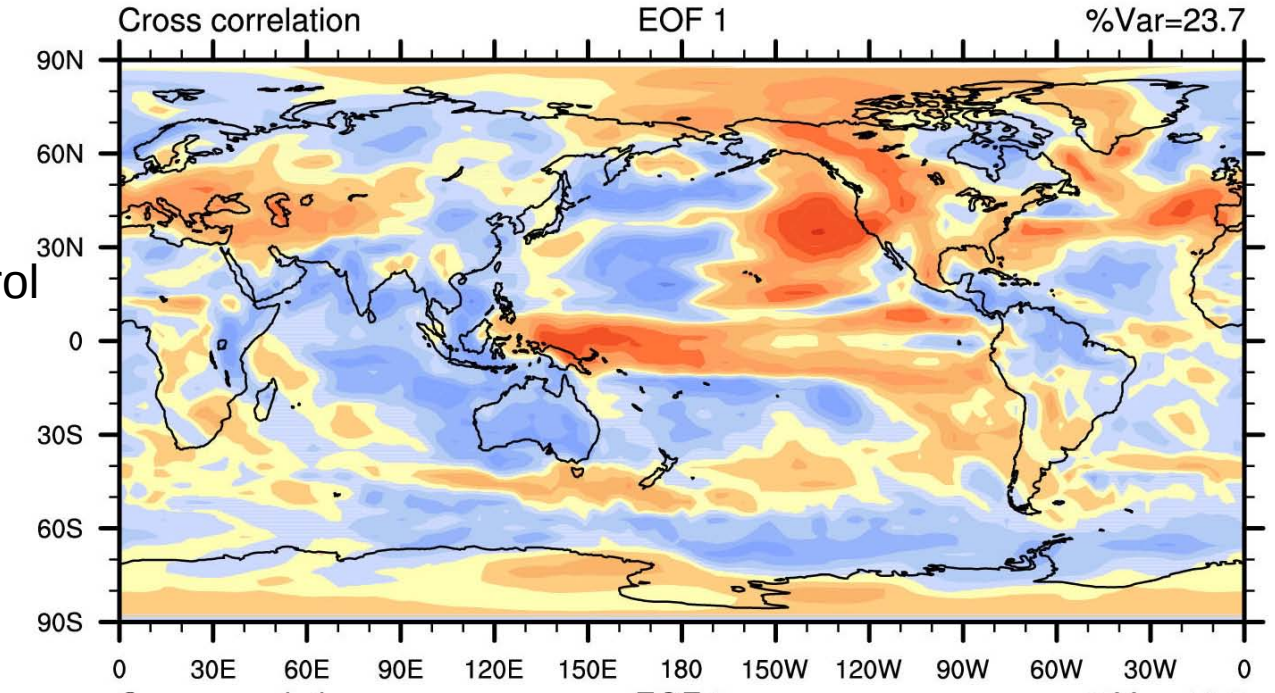
The observed IPO pattern resembles “inherent” decadal pattern from unforced model control run (pattern correlation= +0.63)

IPO correlated with low pass filtered precipitation

Observations

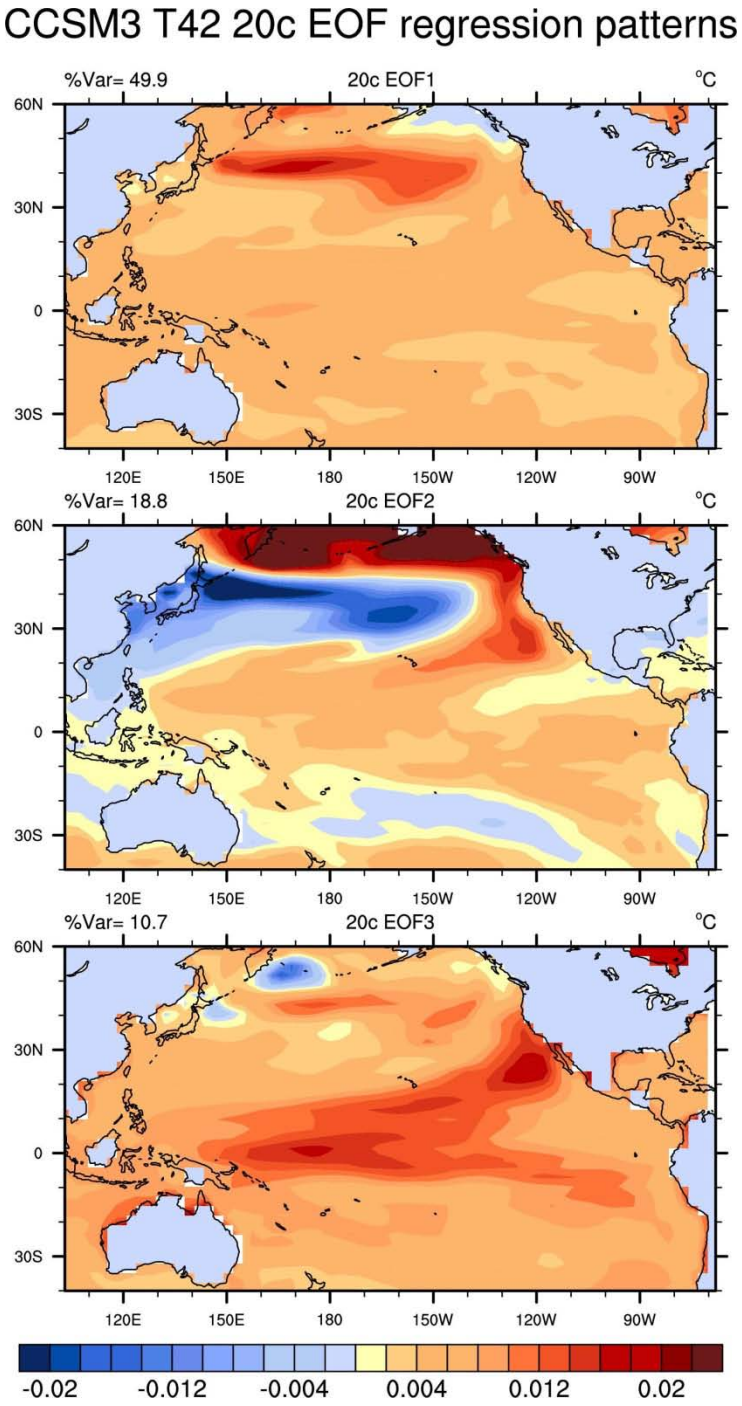


Model control



Single member, 20th century all-forcings, T42

Regress PC time series back on original data and show patterns for first three EOFs (in units of °C)



A “perfect model” decadal prediction of Pacific SST and associated precipitation anomalies

(CCSM3.0, T42, “large ensemble”, atmospheric initial state perturbed with same ocean initial state at year 2000; one reference, 29 ensemble members run to 2061)

For decadal predictions of Pacific SSTs, there is time to adjust predictions to past conditions and still have predictive capability

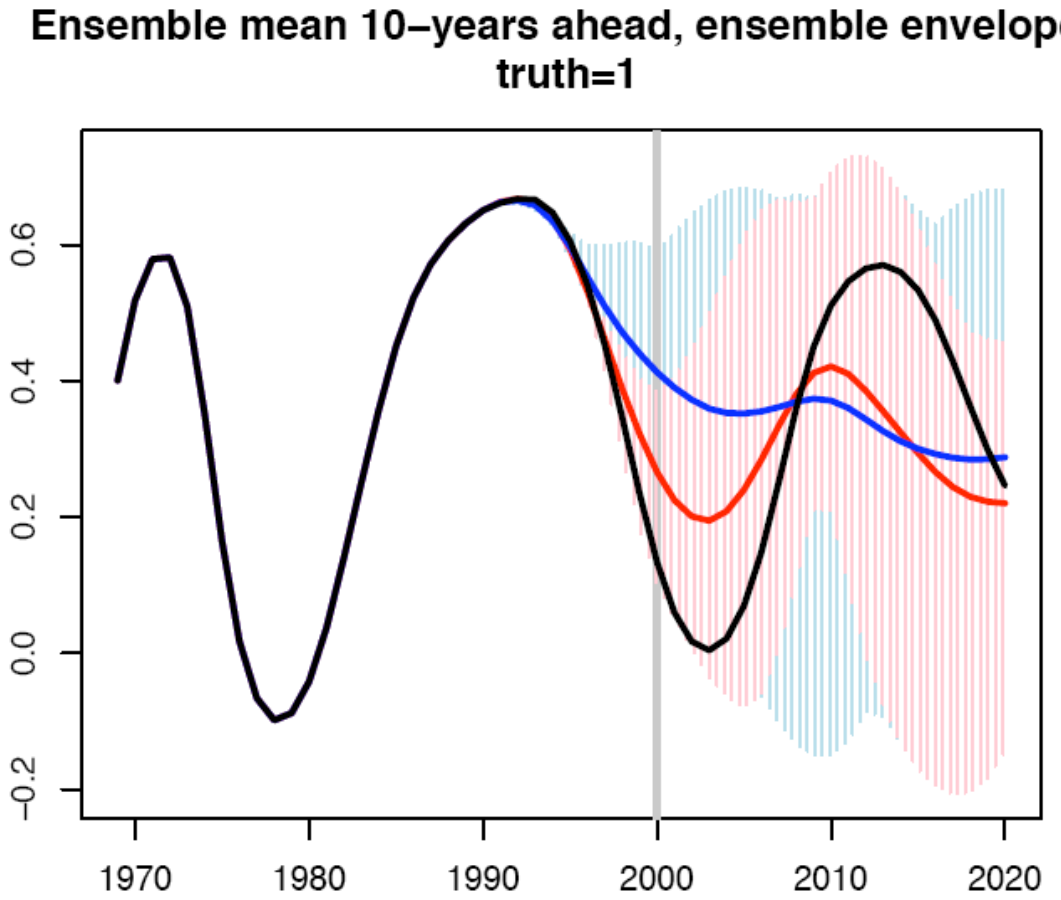
All data is low pass filtered, so assume we are in the year 2010 and want to have a decadal outlook for the period centered on 2020. Initialize an ensemble of predictions at the year 2000, and select a subset of ensemble members based on the year 2000 to 2010 spread (low pass filter will include years 1991-2009, so at year 2000 there will already be spread of ensembles); then track that subset past “present” year of 2010 out to 2020

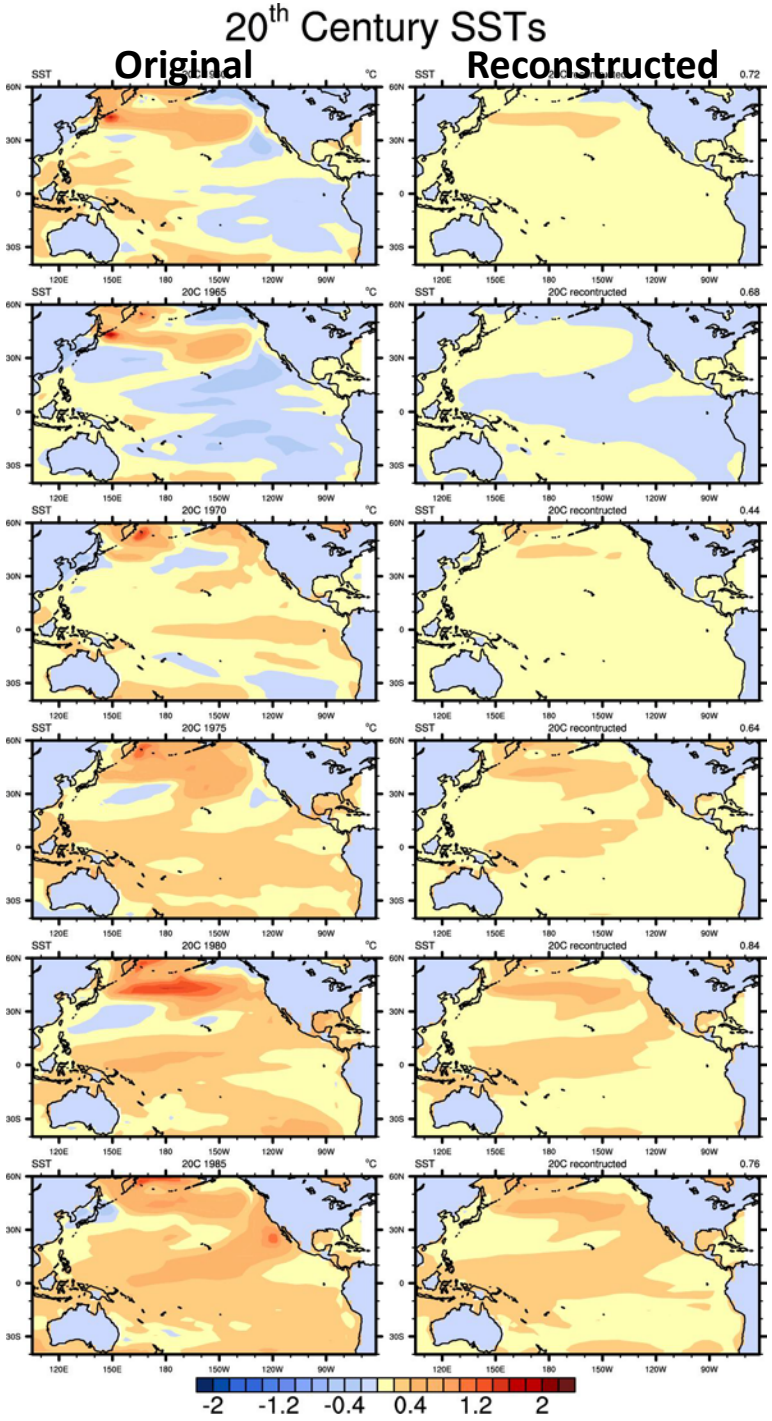
Premise: a subset of selected ensembles will track the future better than the ensemble members that deviate from the target early in the period

Pattern correlation time series of 20C EOF2 with each future ensemble member

Select subset of ensemble members that best capture the IPO (EOF2) evolution by calculating Euclidean distance from each ensemble member to reference (“truth”) in the 10 years 1991 to 2000

Sum distances and pick best 9 (7 to 9 are about the same); from 2000 to 2020, the summed distanced for the reduced ensemble is less than summed distance for the full ensemble





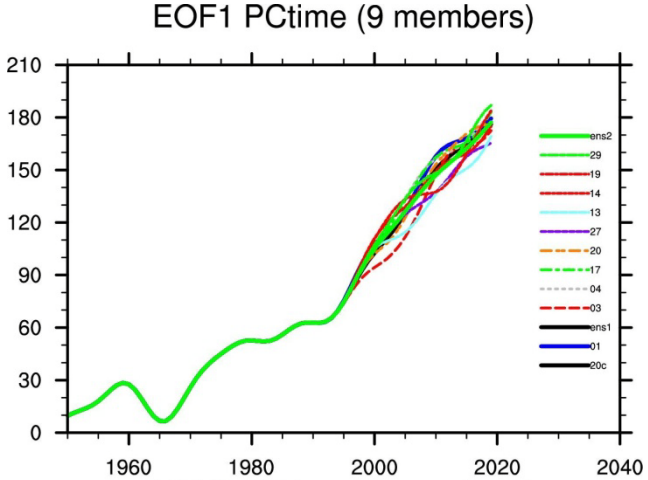
Reconstructed SST anomaly patterns for 20th century from first three EOFs compared to full SST anomalies

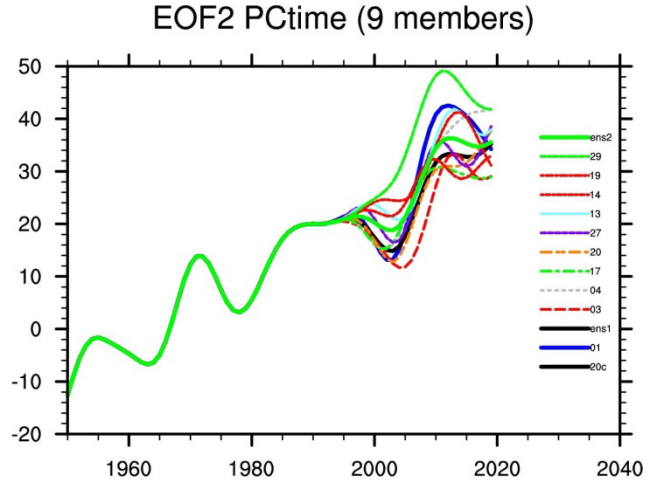
Regress 20C EOFs onto future ensemble member SSTs, calculate future PC time series

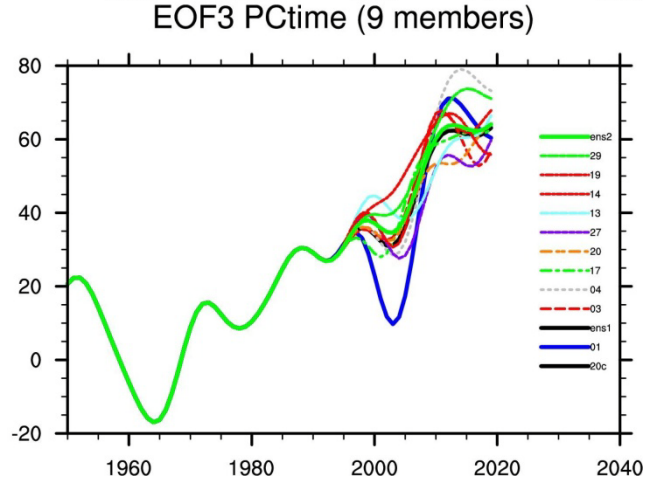
Reduced ensemble PC time series for first three EOFs compared to the reference

Next, project future PC time series onto 20C SST regression patterns

sum first three regression patterns and get predicted SST anomalies, and compare to reference re-constructed SST anomalies for future



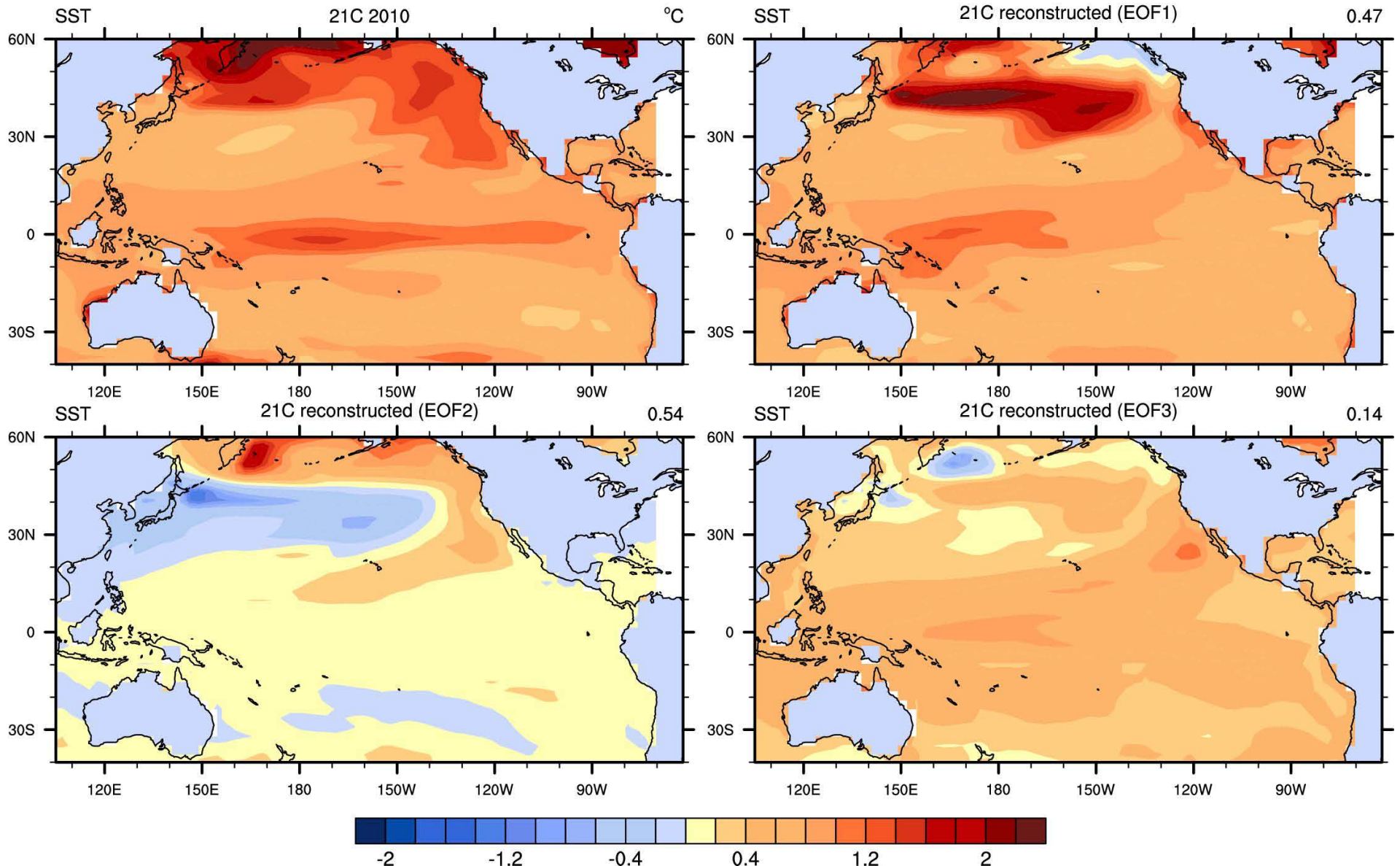




Contributions from first three EOFs to total predicted SST anomaly pattern for 2010

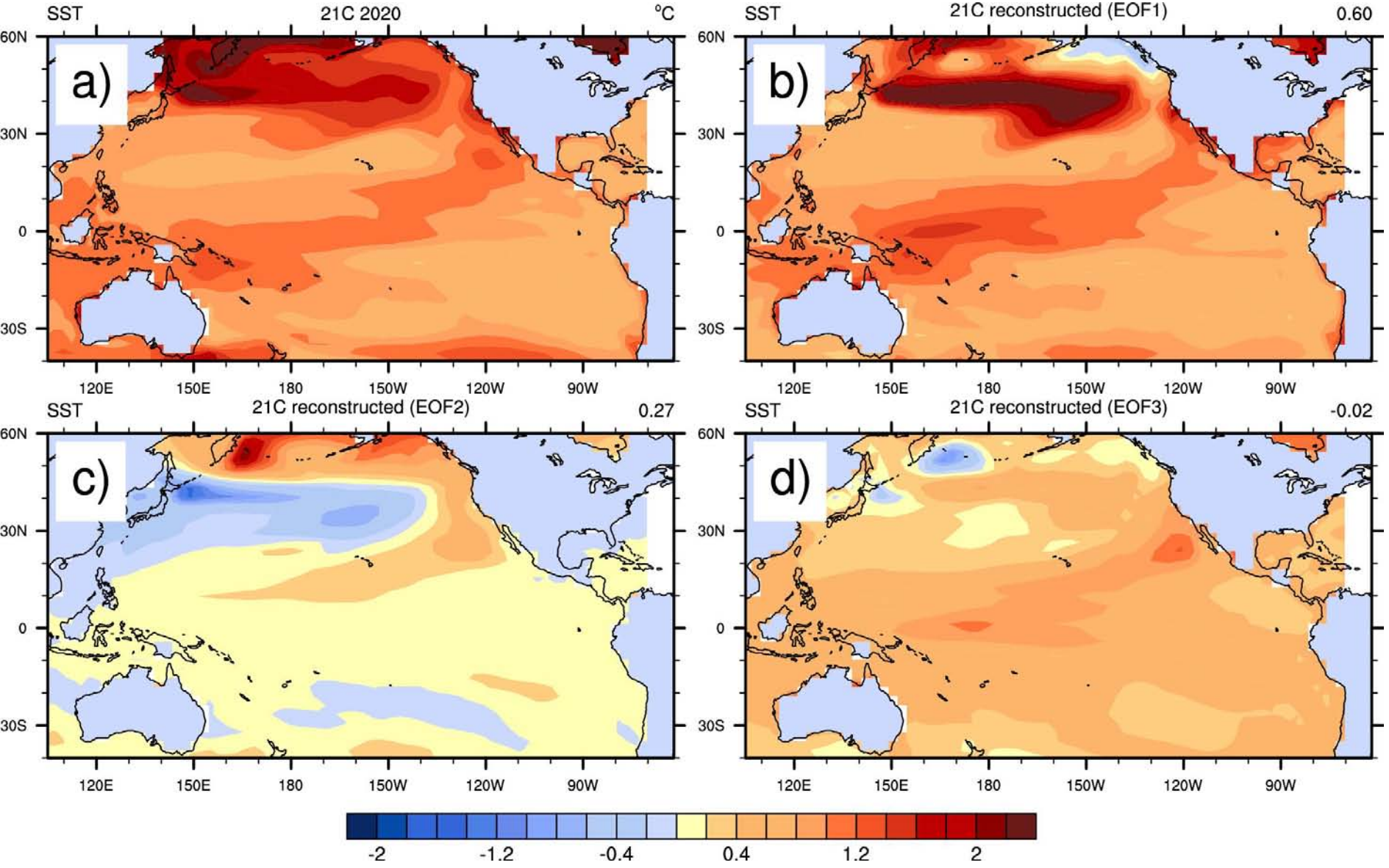
EOF1 (forced trend) = 0.47; EOF2 (IPO) = 0.54

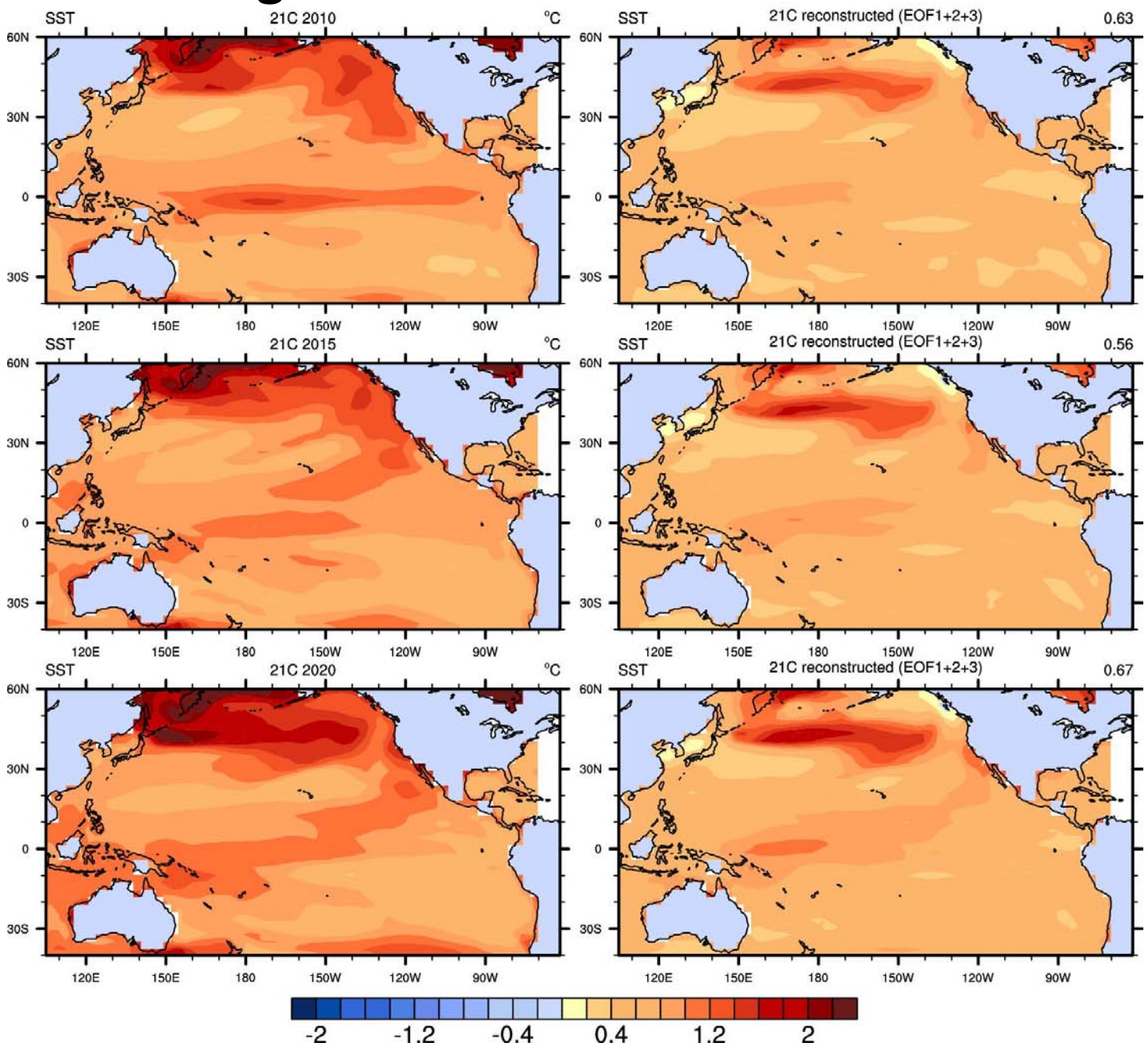
Ensemble reconstructed (°C)



Contributions from first three EOFs to total predicted SST anomaly pattern for 2020

EOF1 (forced trend) = 0.60; EOF2 (IPO) = 0.27





Pattern correlations

2010:

+0.63

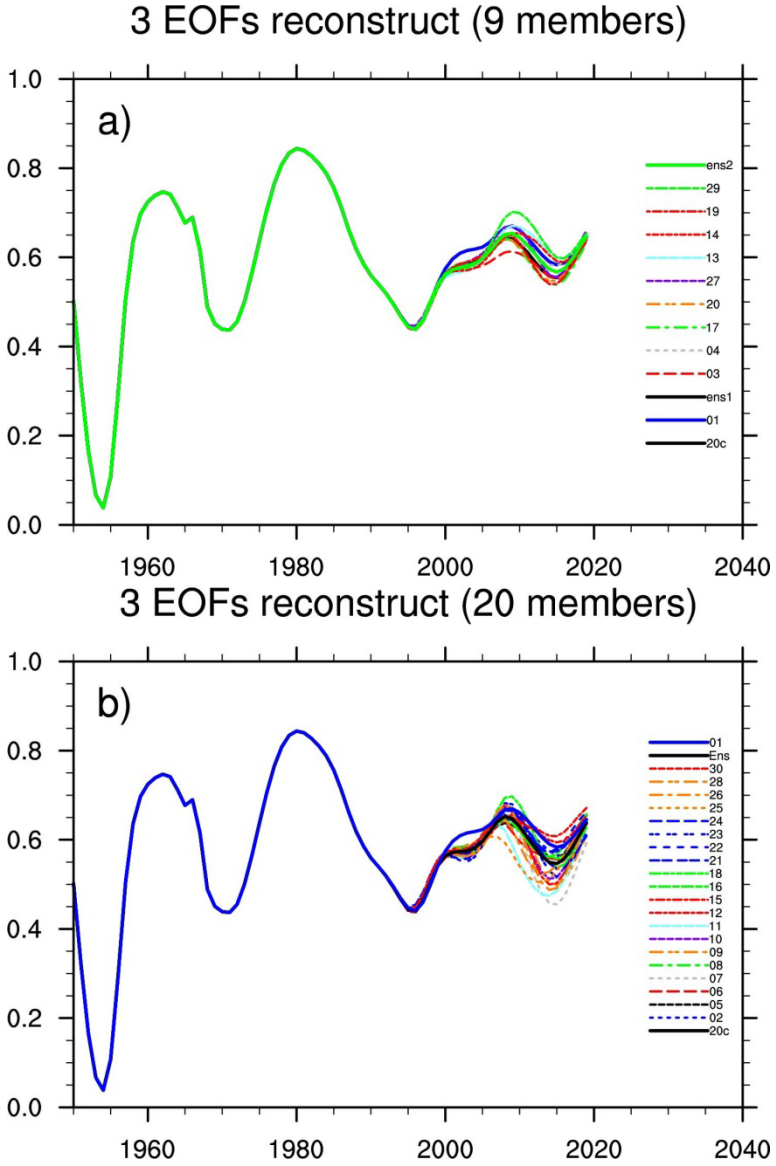
2015:

+0.56

2020:

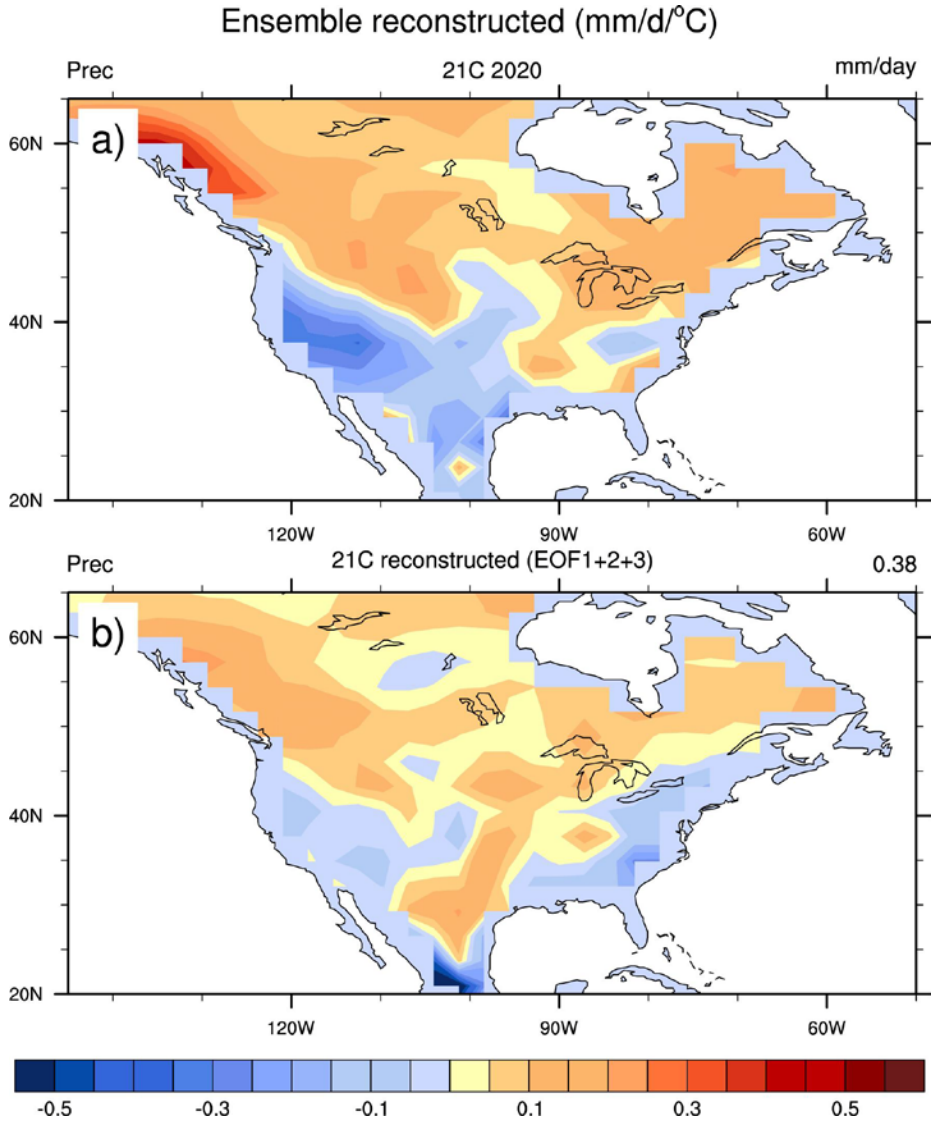
+0.67

The reduced ensemble tracks the reference with less spread than the other members (spread at 2020 for reduced ensemble = 0.03; for other 20 members = 0.08; reduced ensemble spread significant at 97.4% level calculated from random combinations of 9 member spreads from full ensemble)



Use PC time series from SST EOFs and regress onto precipitation to re-construct precipitation anomaly patterns

Precipitation outlook for the ~18 years centered on 2020:



Reference

Prediction

(anomaly pattern correlation = +0.38)

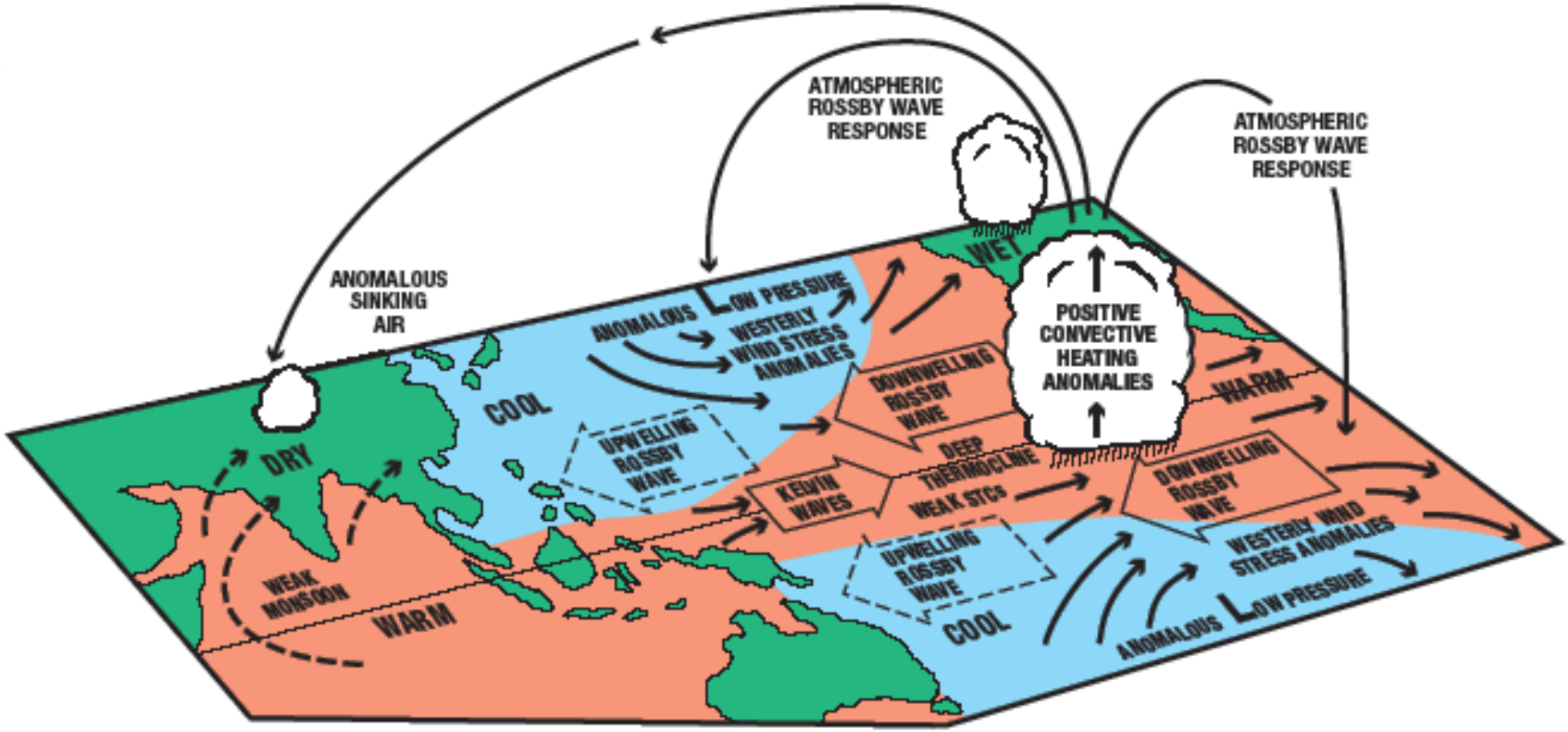
Conclusions

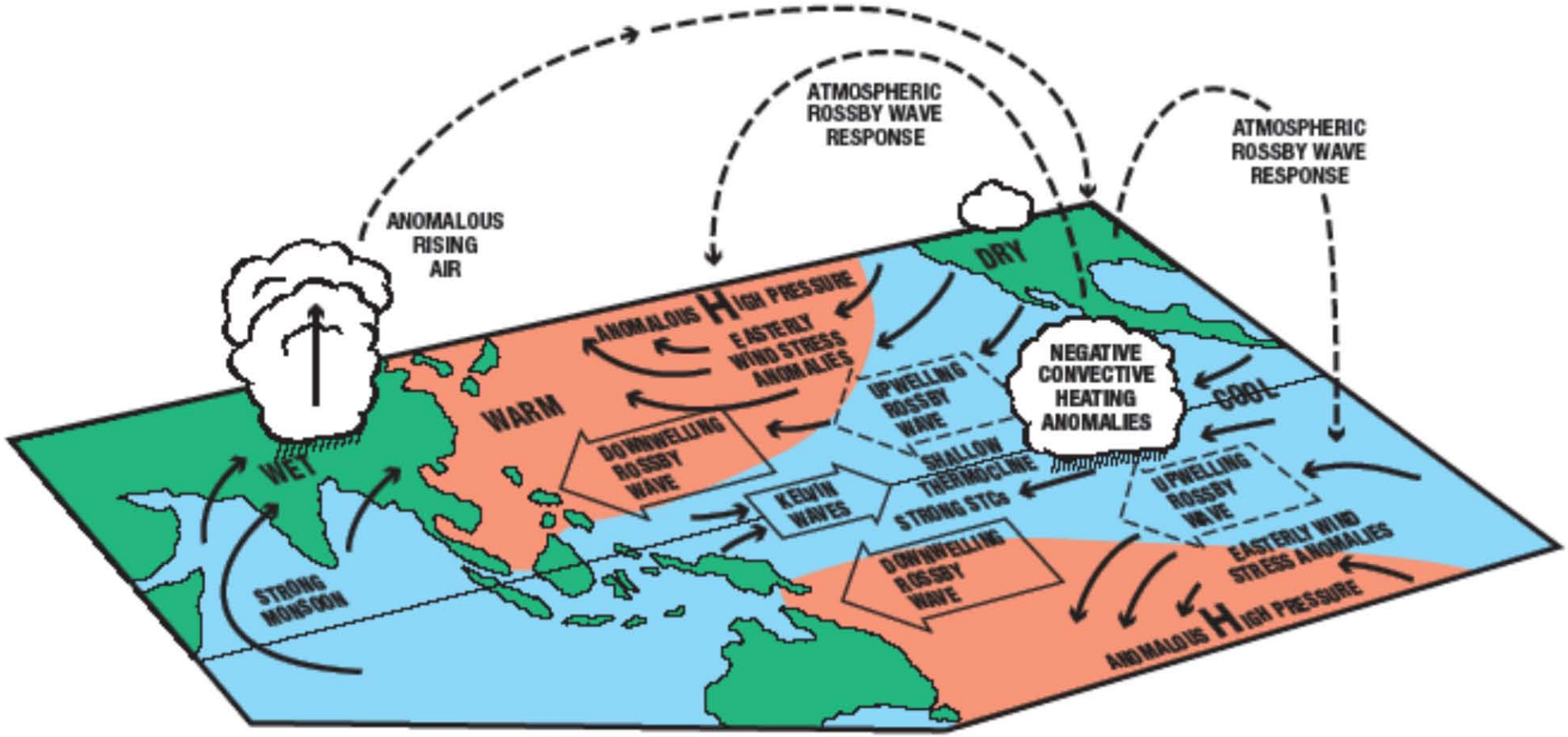
1. IPO is dominant internally generated SST pattern in the Pacific; if future time evolution could be predicted, it could contribute to increased decadal regional predictive skill

2. Perfect model reference simulation and 29 ensemble members: using past information early in the prediction period, subselect members that continue to track target evolution of EOF2 (IPO); use first three EOFs and PC time series to construct future SST and precipitation patterns; some skill for Pacific SST predictions (pattern correlations greater than +0.5), and qualitative skill for pattern of predicted precipitation over western North America

3. IPO has largest contribution to predicted SST pattern at 2010, but by 2020 more Pacific decadal predictability is forced trend

Mechanism for IPO (multi-decadal SST) and associated precipitation variability in the Indo-Pacific region (Meehl, G. A., and A. Hu, 2006, *Journal of Climate,* **19**, 1605–1623.)



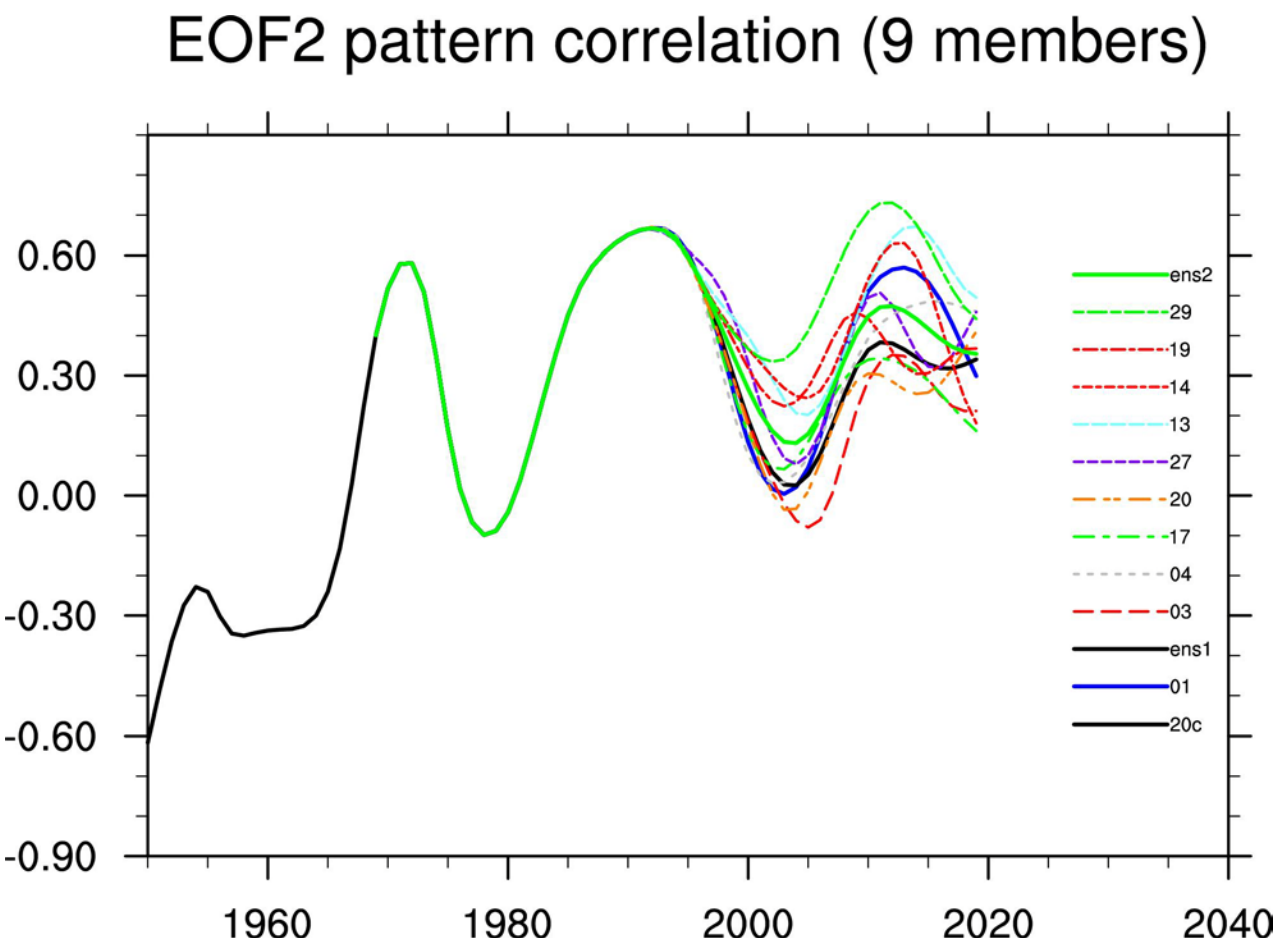

ATMOSPHERIC ROSSBY WAVE RESPONSE
ATMOSPHERIC ROSSBY WAVE RESPONSE
ANOMALOUS RISING AIR
DRY
ANOMALOUS HIGH PRESSURE
EASTERLY WIND STRESS ANOMALIES
WARM
UPWELLING ROSSBY WAVE
NEGATIVE CONVECTIVE HEATING ANOMALIES
COOL
WET
DOWNWELLING ROSSBY WAVE
KELVIN WAVES
SHALLOW THERMOCLINE
STRONG STCs
UPWELLING ROSSBY WAVE
STRONG MONSOON
DOWNWELLING ROSSBY WAVE
EASTERLY WIND STRESS ANOMALIES
ANOMALOUS HIGH PRESSURE

Can the time evolution of the IPO increase regional predictive skill?

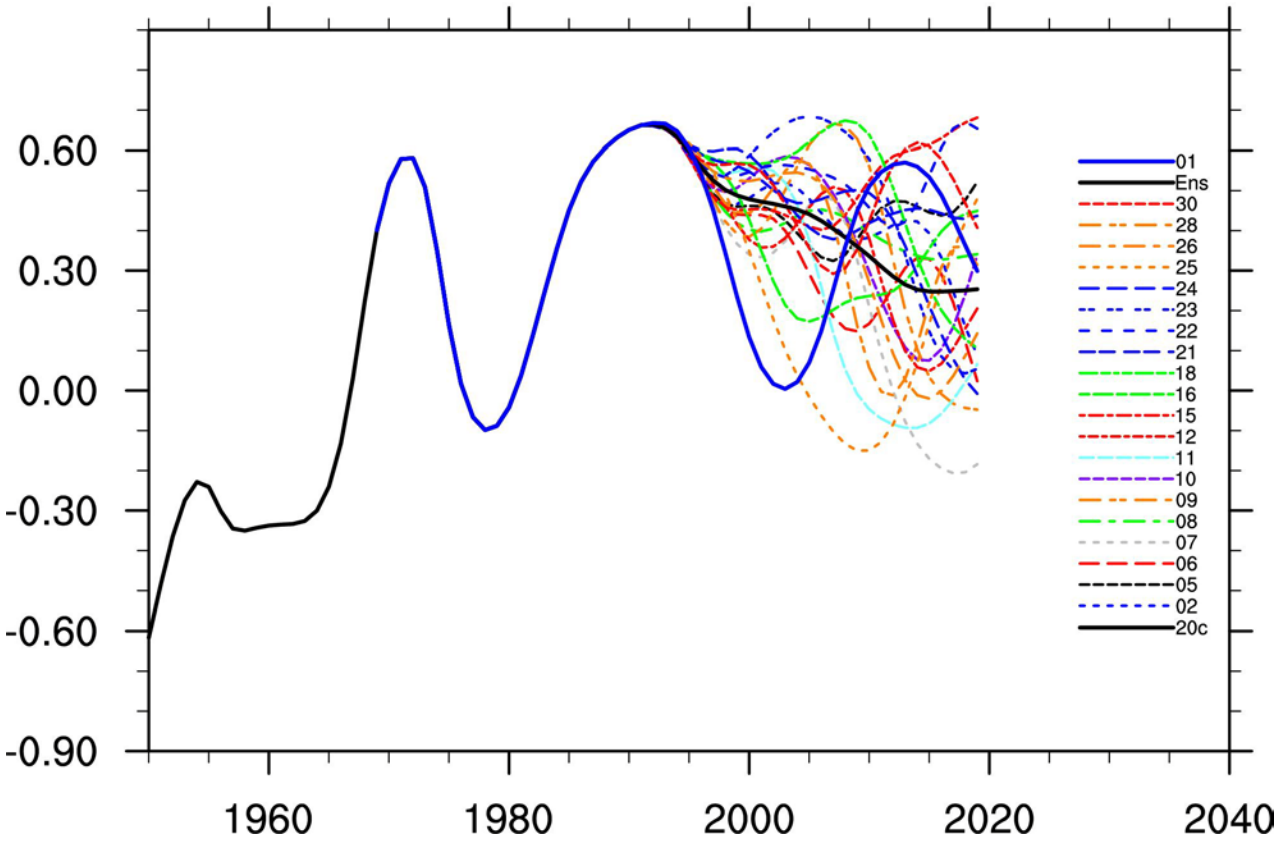
Compute EOF2 as IPO index and perform pattern correlation of this index with 29 future ensemble members using one as the perfect model or reference

(CCSM3.0, T42, atmospheric initial state perturbed with same ocean initial state at year 2000; one reference, 29 ensemble members run to 2061)

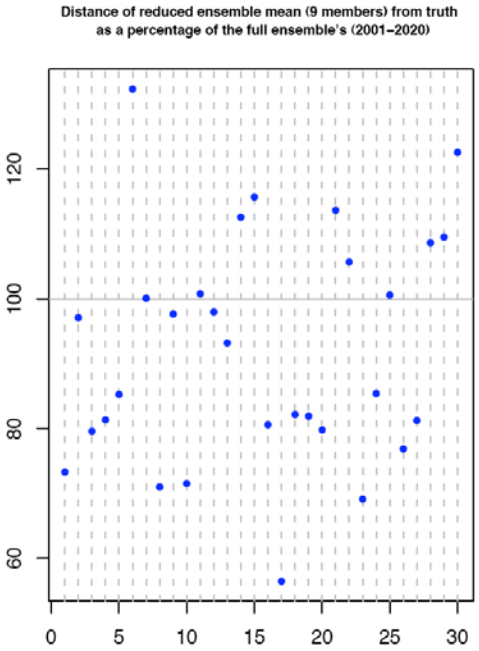
IPO index (EOF2) for the Pacific

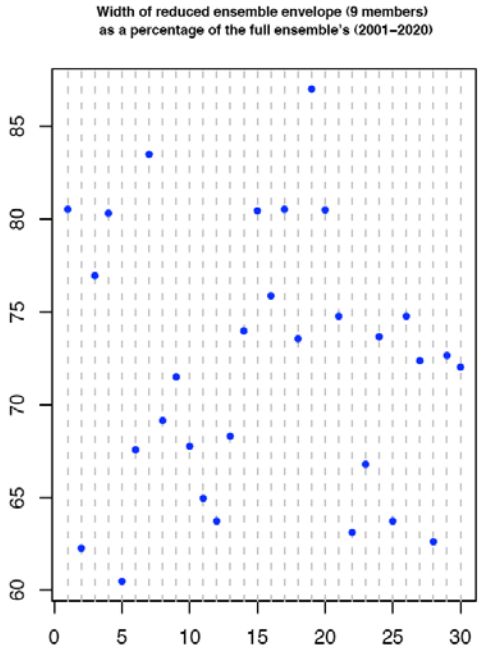


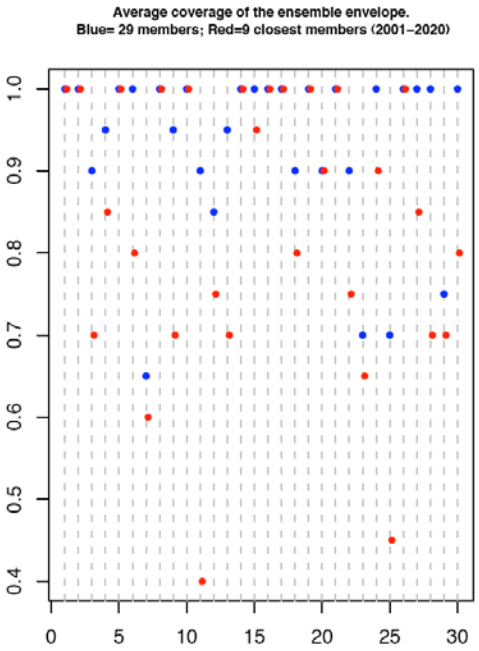
9 out of 29 members (31%) show some predictive skill out to 20 years


EOF2 pattern correlation (20 members)
0.60
0.30
0.00
-0.30
-0.60
-0.90
1960
1980
2000
2020
2040
01
Ens
30
28
26
25
24
23
22
21
18
16
15
12
11
10
09
08
07
06
05
02
20c

1. Low pass filter all model data (center year represents about 20 year average)
2. Calculate EOFs for 20th century
3. Derive PC time series for first three EOFs
4. Regress PC time series against original data and calculate regression patterns of SST re-constructed from first three EOFs for 20th century
5. Assume % variance does not change in future, get future PC time series using 20th century EOFs and future re-constructed SST anomaly patterns relative to 20th century
6. Select 9 best ensemble members based on distance from target at year 2000 (reference year is 2010)
7. Use 9 best PC time series to regress against the pattern of each EOF, then sum the first three to get total contribution of first 3 EOFs to the anomaly of each year as a prediction to 2020
8. Correlate those patterns with target SST anomalies as prediction verification at year 2020
9. Use SST EOF PC time series to regress against precipitation data







Upper left: for first 10 years after 1991, compute Euclidean distance from the reference in each year for each ensemble member; add distances and pick best 7-9 (number makes little difference); distance between reduced ensemble and reference (and full ensemble) after 2010, sum the distances, compute the ratio, if value below 100 the reduced ensemble is closer to reference than full ensemble

Upper left: for first 10 years after 2000, compute Euclidean distance from the reference in each year for each ensemble member; add distances and pick best 7-9 (number makes little difference); distance between reduced ensemble and reference (and full ensemble) after 2010, sum the distances, compute the ratio, if value below 100 the reduced ensemble is closer to reference than full ensemble

Upper right: for each year compute the range of the reduced ensemble, divided by the summed range of the full ensemble; the lower the ratio the better the reduced ensemble

Lower left: compute how many times the reference is outside the range of either the reduced or full ensemble; 1.0 means the reference is always captured by the spread of the ensemble (two dots for each case, one for the full ensemble (blue) and one for reduced (red))

Time series shows reduced ensemble range (red) compared to full ensemble range (blue) and reference (black)

CMIP5 Decadal Predictability/Prediction Experiments

Draft from WGCM meeting, September, 2008