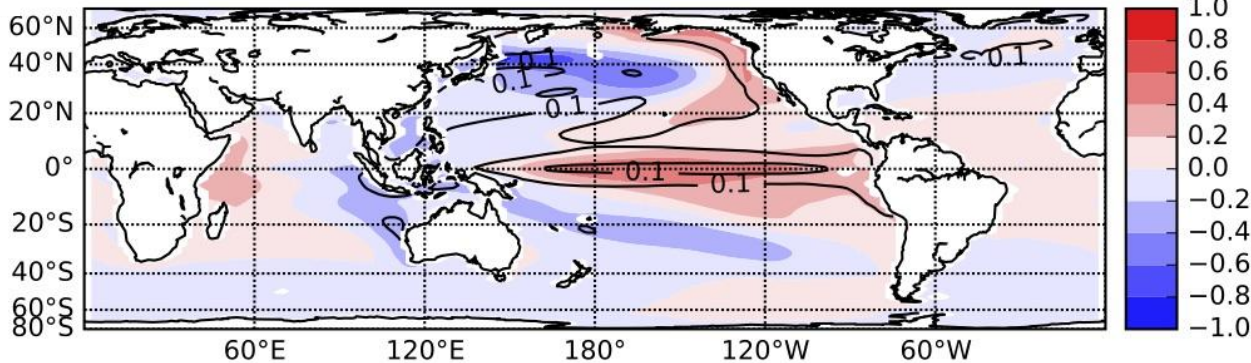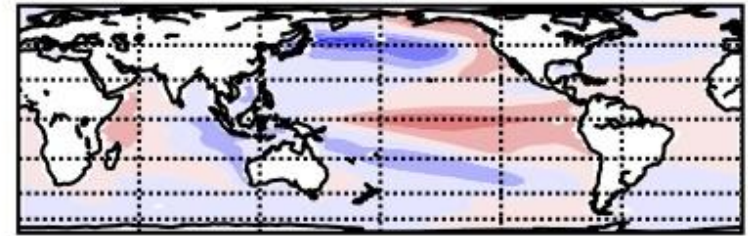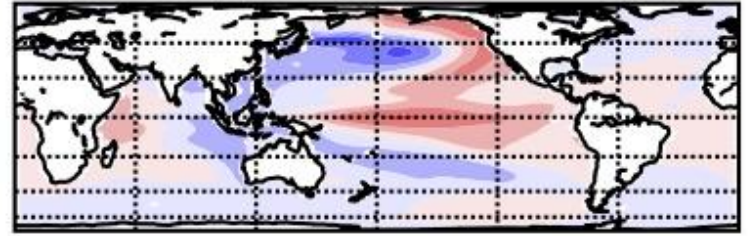# Using ensemble EOFs to identify ENSO precursors in the CESM

Naomi Goldenson
Andy Rhines
Cecilia Bitz
Malte Stuecker

CESM Workshop - June 2017

Motivation for Ensemble EOFs:

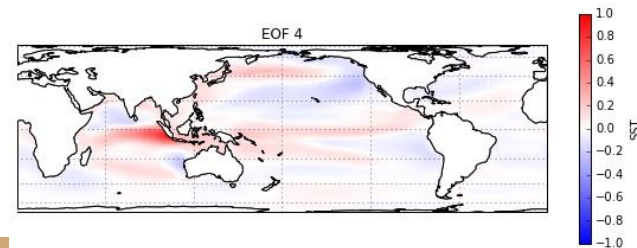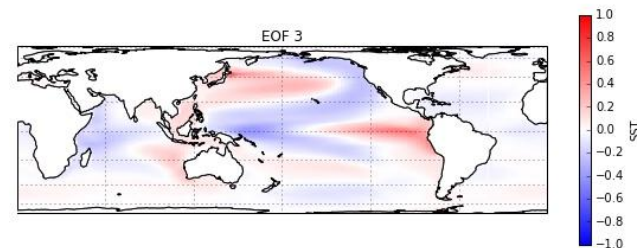The PDO, calculated separately for each member of the large ensemble, can vary quite a bit.
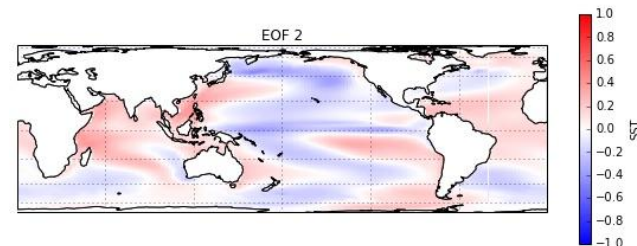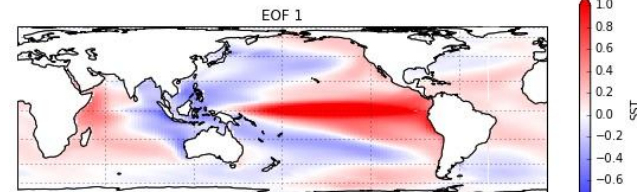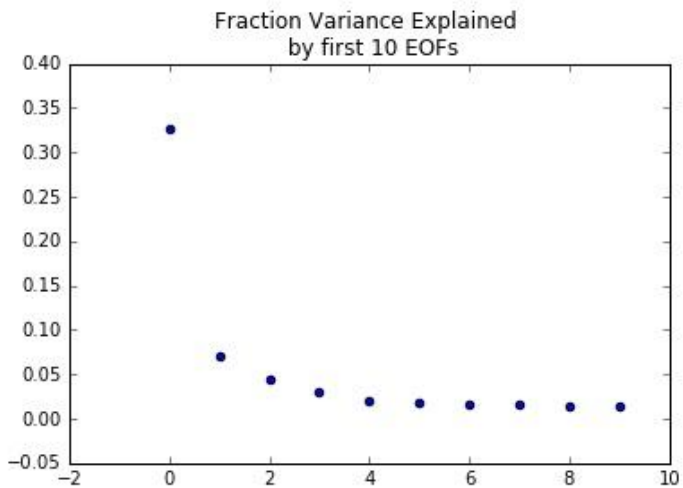
# Ensemble EOFs

We stack 40 members of the CESM large ensemble to find one consistent set of "ensemble EOFs".

- Global SSTs
- Ensemble mean trend removed
- Ensemble mean seasonal cycle removed from monthly data in blocks of 30 years.
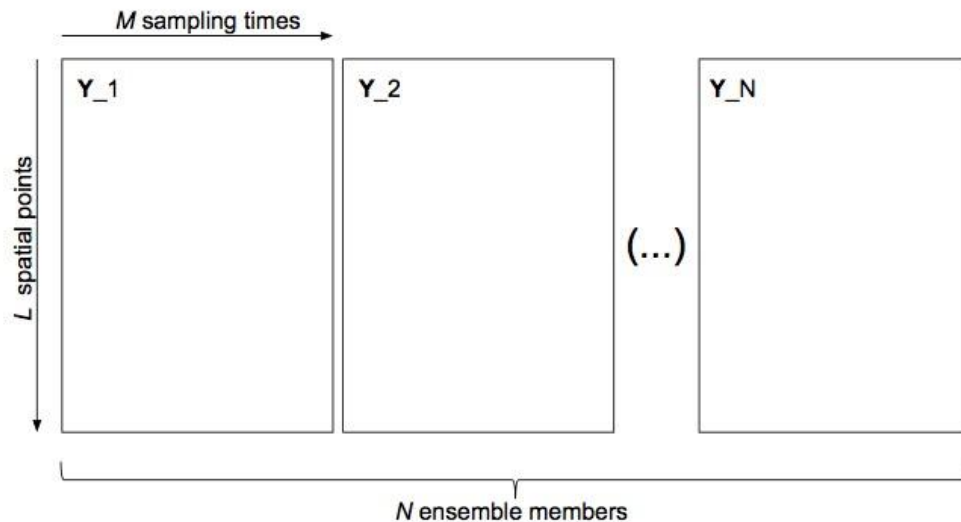
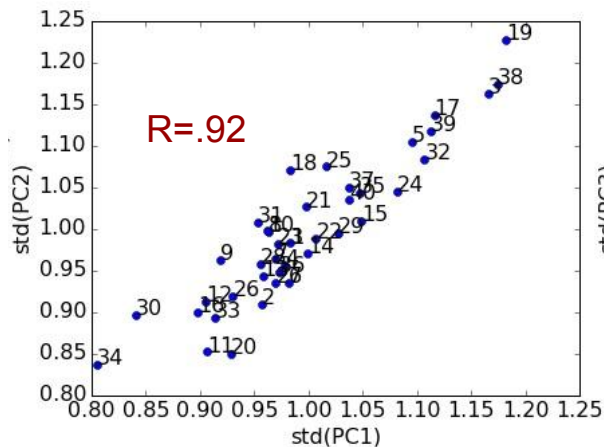# First few patterns: ENSO and ... ?
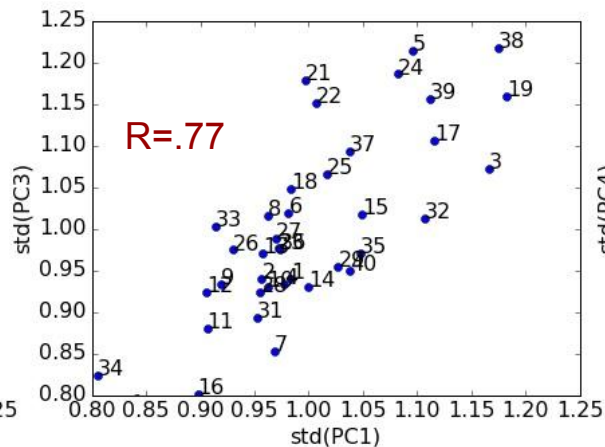
# "partial eigenvalues" across ensemble members

correlation between the magnitude of variance between…

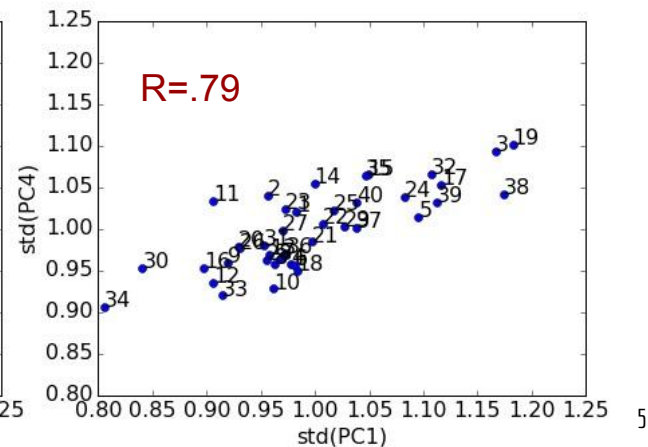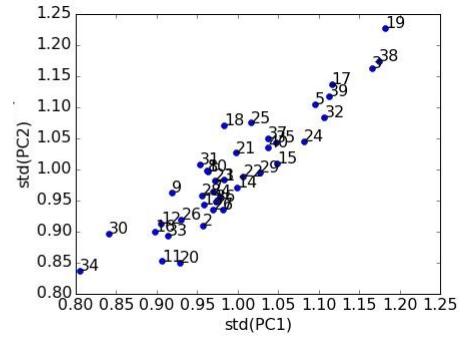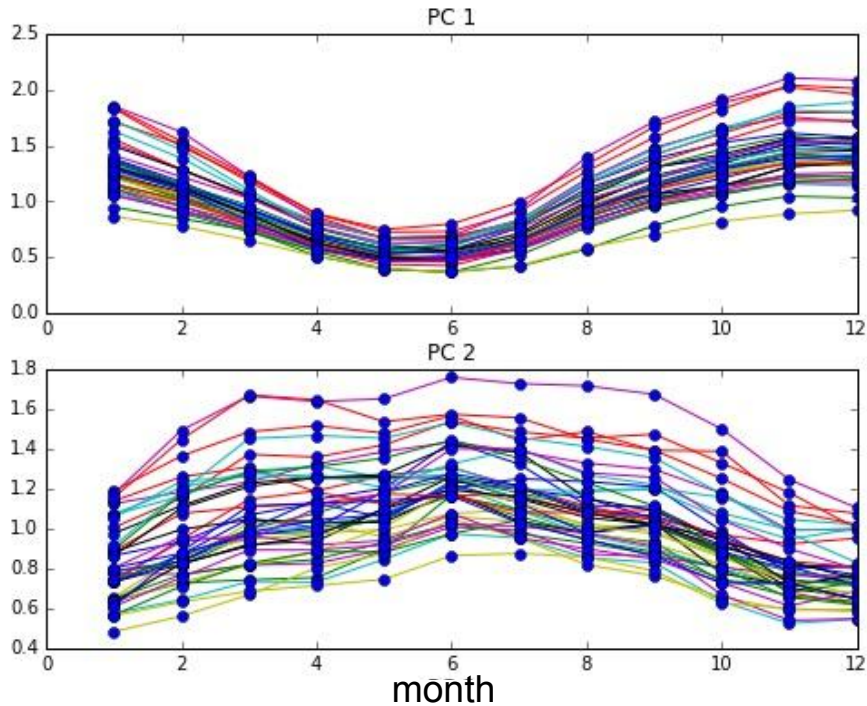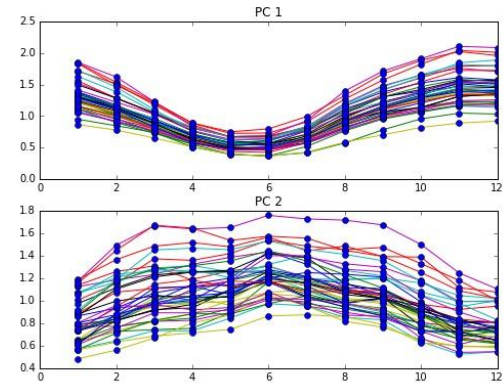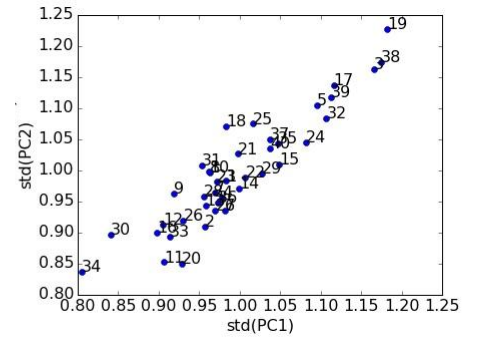|     | PC1 | PC2  | PC3  | PC4  |
|-----|-----|------|------|------|
| PC1 | 1   | 0.92 | 0.77 | 0.79 |
| PC2 |     | 1    | 0.77 | 0.65 |
| PC3 |     |      | 1    | 0.47 |

the 1st and 2nd PCs

the 1st and 3rd PCs
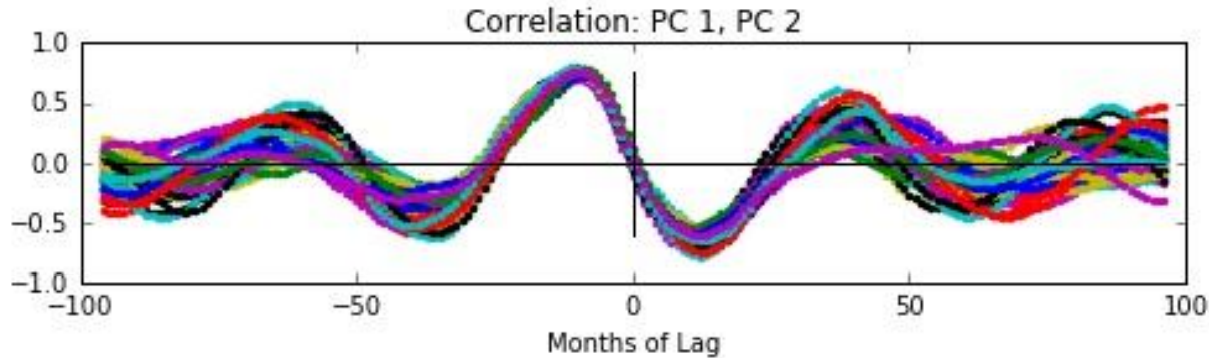
the 1st and 4th PCs

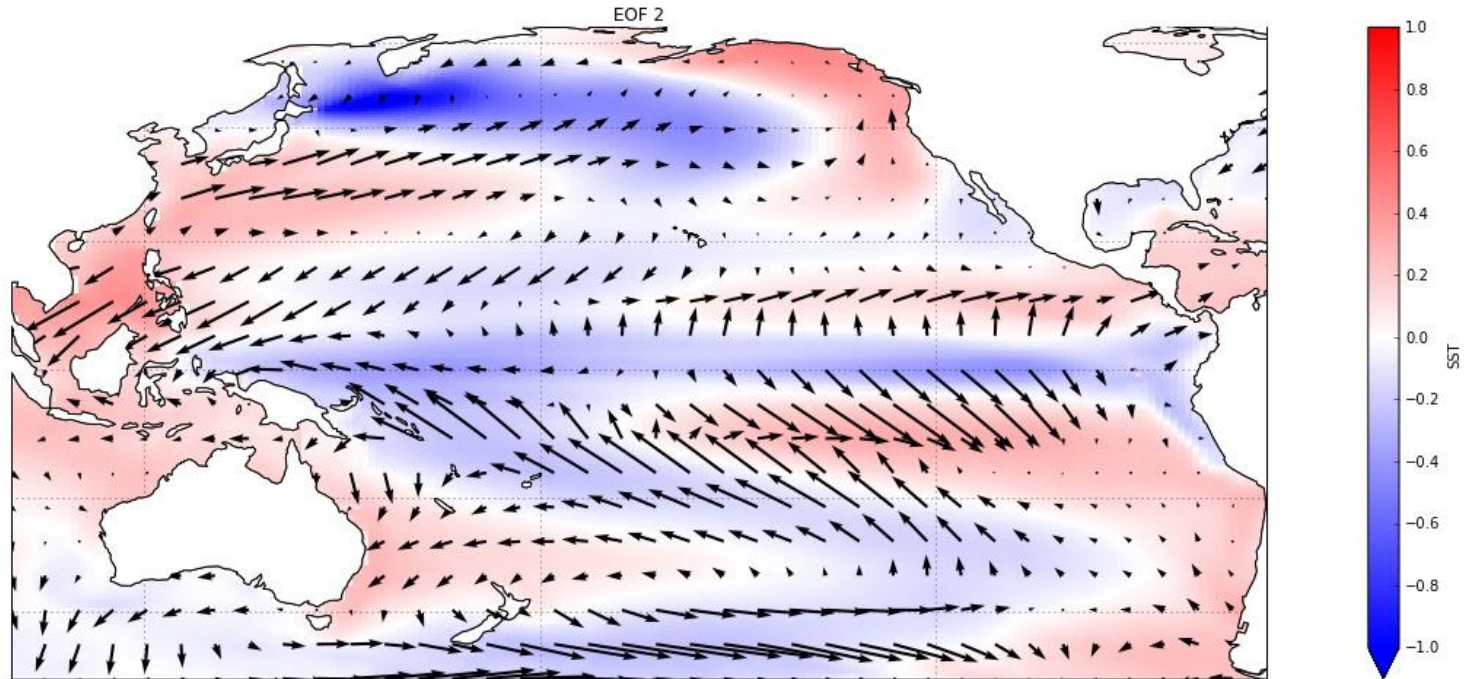# What is going on here?



PC2 has more variance in Northern summer

# What is going on here?



PC2 and PC1 and strongly
cross-correlated:

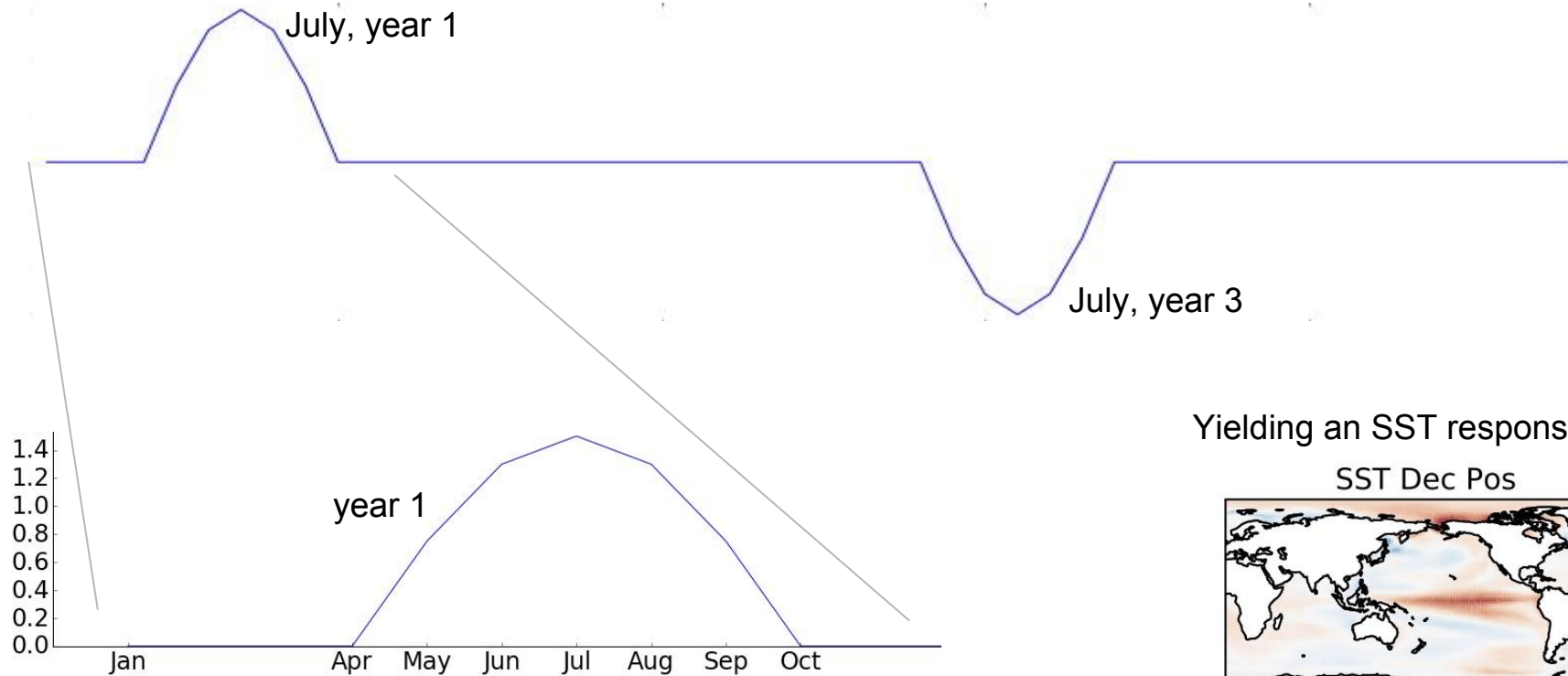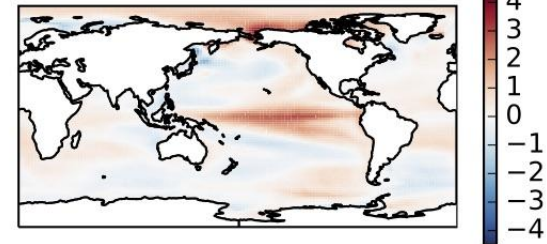# Can we induce an ENSO-like response?

We regress wind stress on PC2...
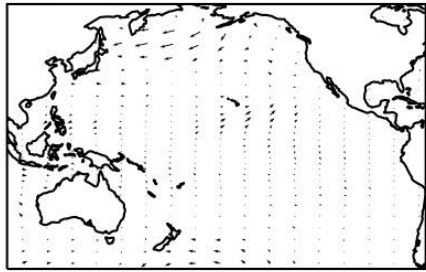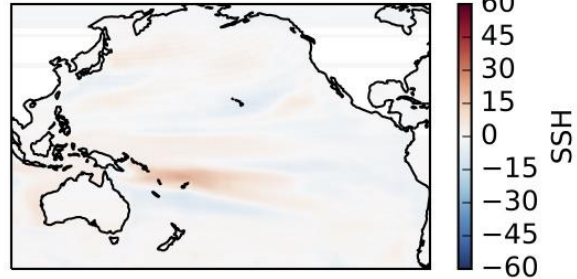
# ...and drive a cyclic anomaly from climatology

July, year 1

July, year 3

year 1

1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0

Jan    Apr  May  Jun  Jul  Aug  Sep  Oct

Yielding an SST response:



SST Dec Pos

4
3
2
1
0
−1
−2
−3
−4

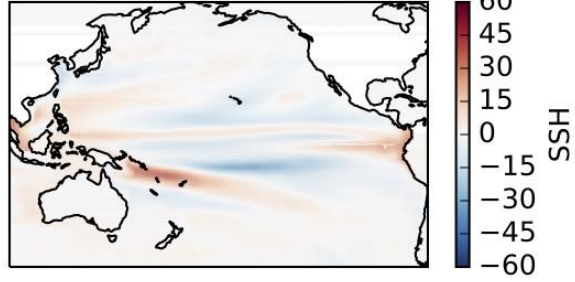Wind stress anom · SSH anom · SST anom
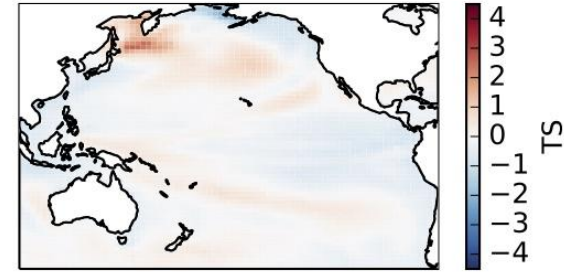
Composite anomalies, April, year 1 of 4 year cycle.
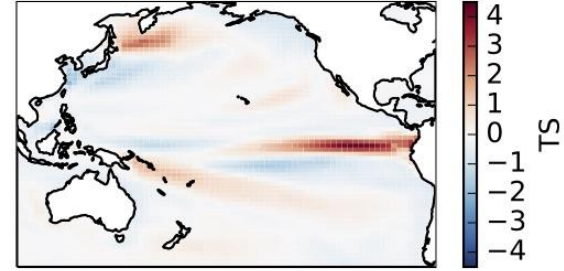
April
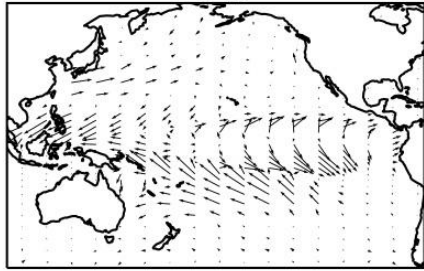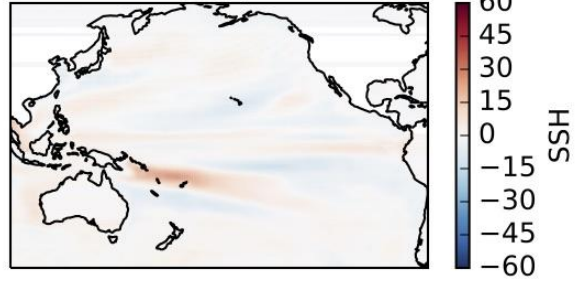
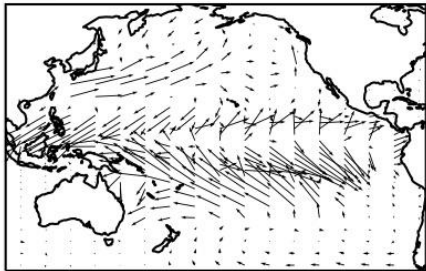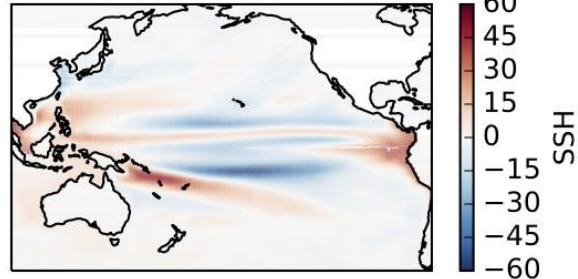Wind stress anom        SSH anom        SST anom
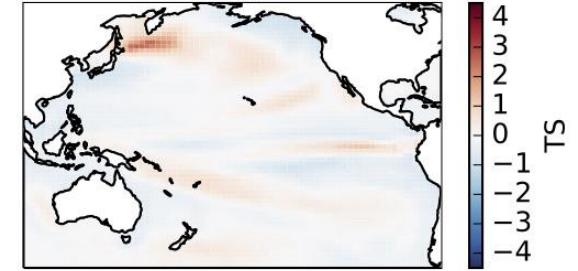
May
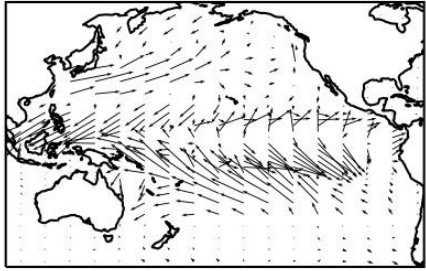
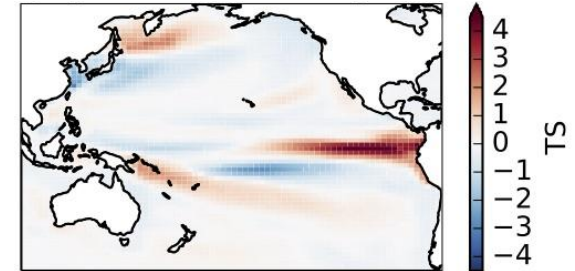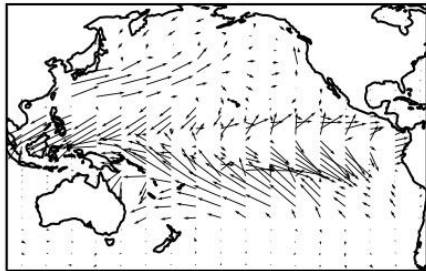| Wind stress anom | SSH anom | SST anom |

June

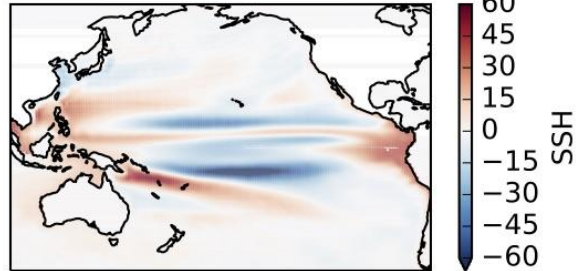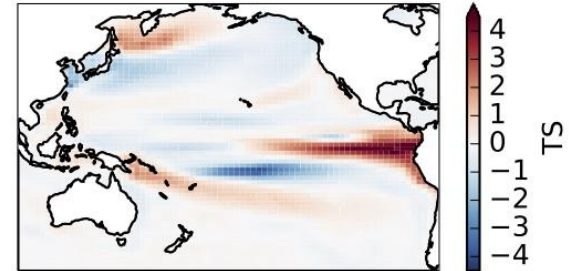Wind stress anom     SSH anom     SST anom
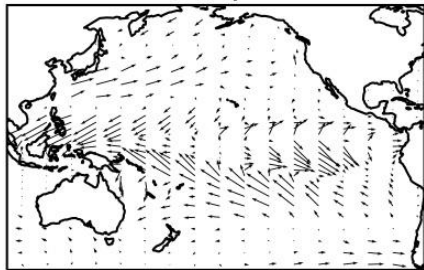
forcing is maximum

July
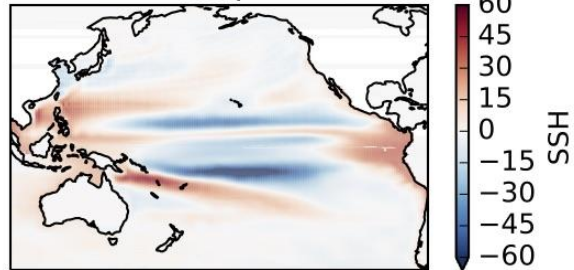
Wind stress anom          SSH anom          SST anom
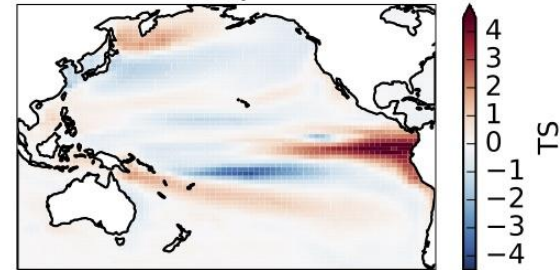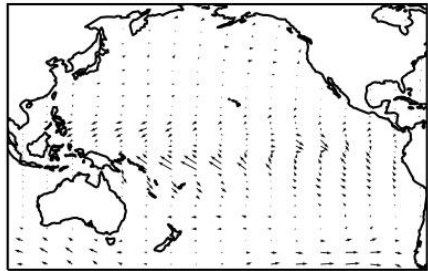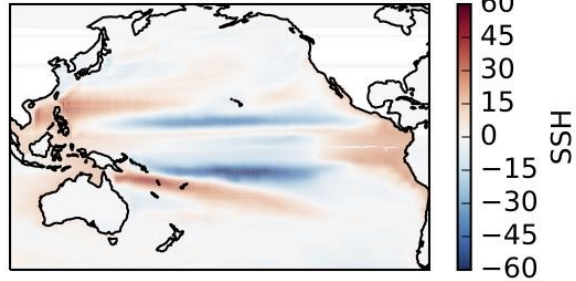
August

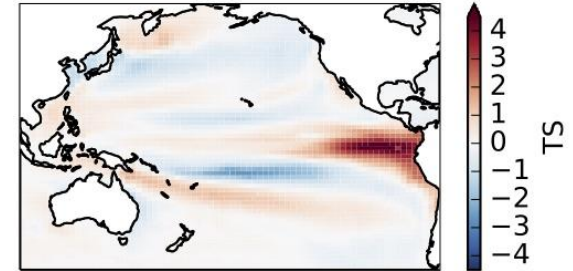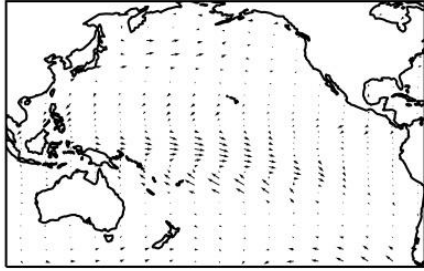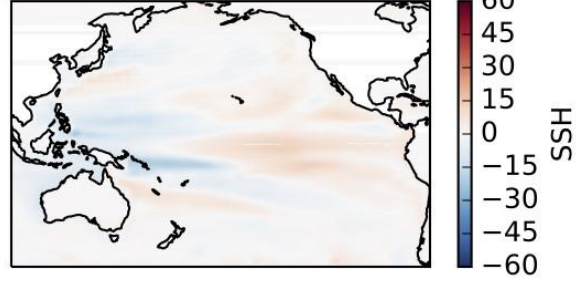Wind stress anom          SSH anom          SST anom
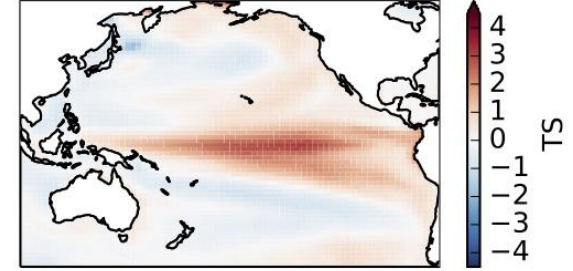
September

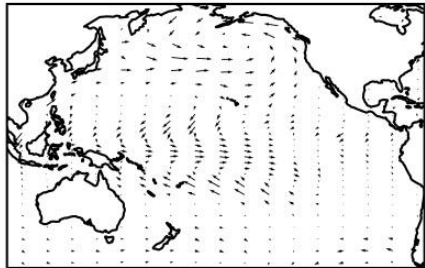Wind stress anom    SSH anom    SST anom

October

Wind stress anom  SSH anom  SST anom
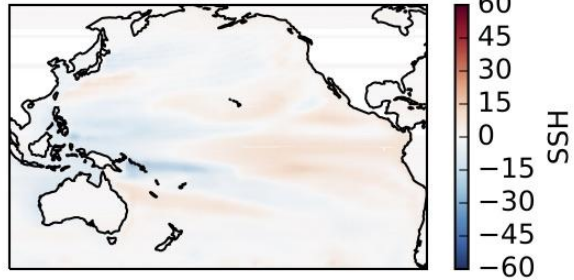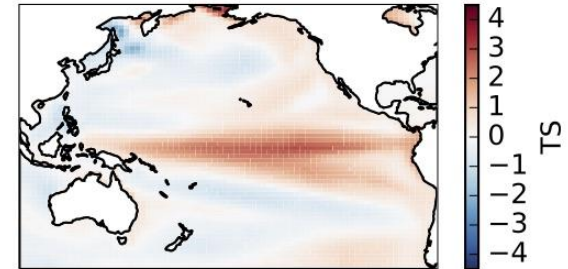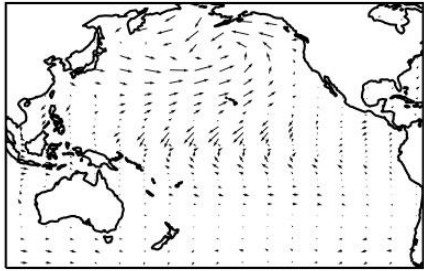
November

Wind stress anom     SSH anom     SST anom
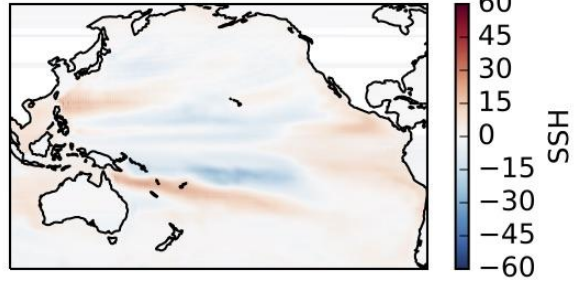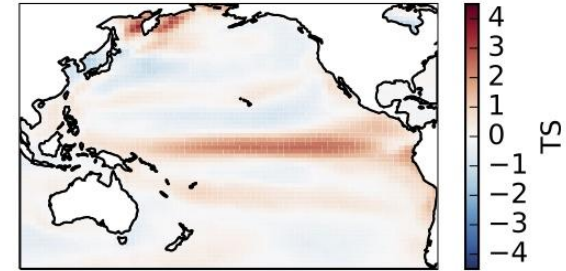
December

Wind stress anom          SSH anom          SST anom

January

# Summary

- Ensemble EOFs let us compare variance across ensemble members.

- Variance associated with precursor and decay of El Niño appears in EOFs after the 1st.

- These are not necessarily synonymous with physical patterns of SSTs that lead and lag El Niño.

- Wind stress associated with PC2, which leads PC1, can be used to generate an El Niño-like response.
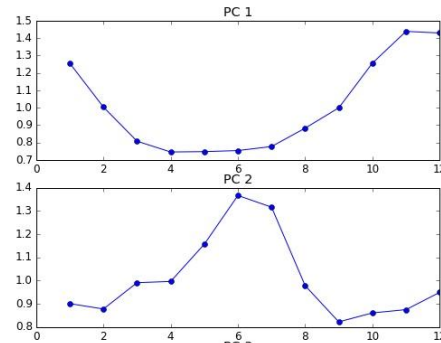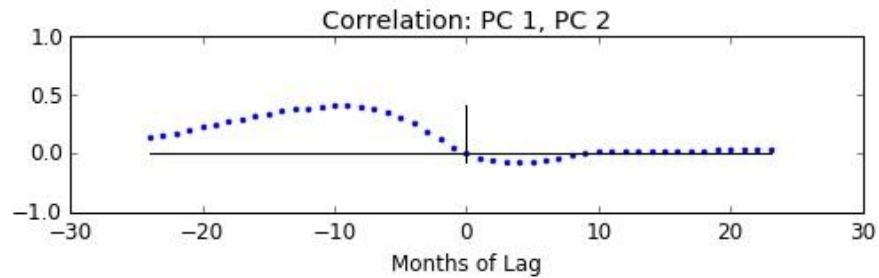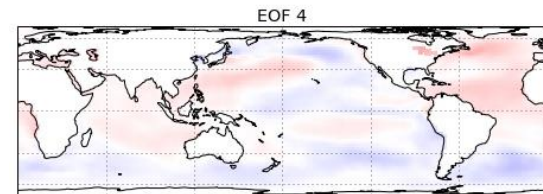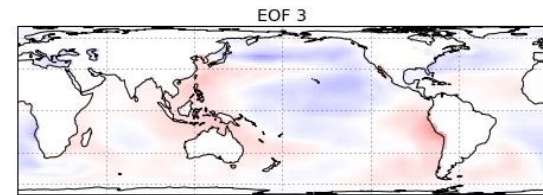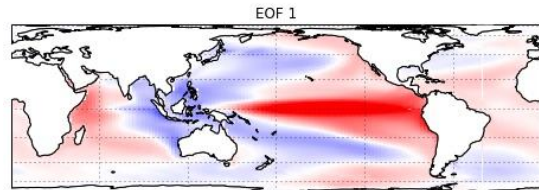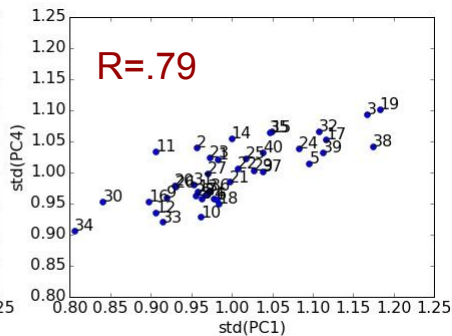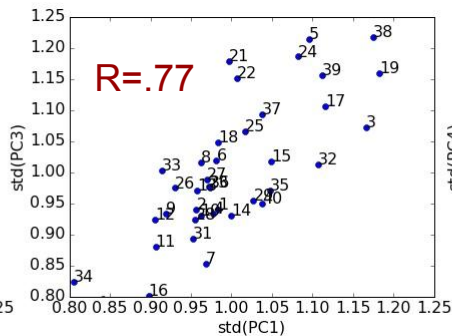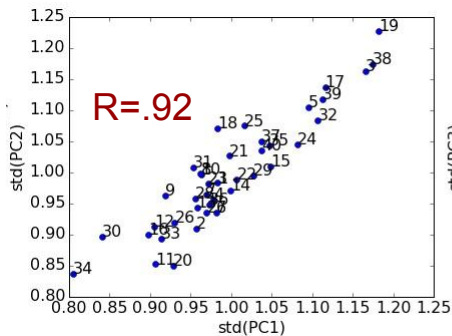
# Extra Slides
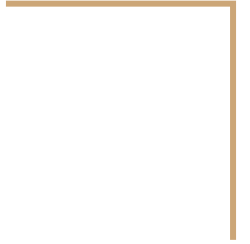
# To calculate EOFs on a very large matrix...

- where "very large" means  31200 x 20755 (it occupies 9.5 GB in a .csv file)

- Incremental PCA saves the day (Ross et al.)

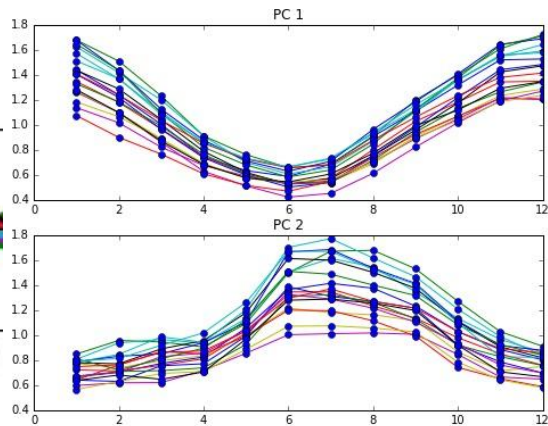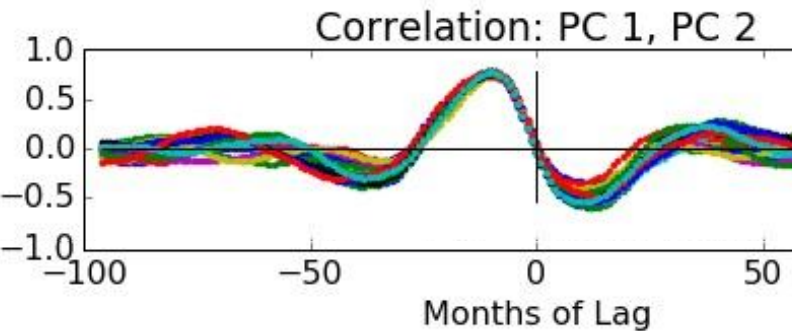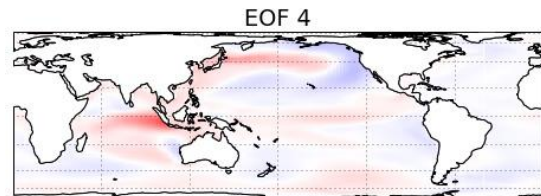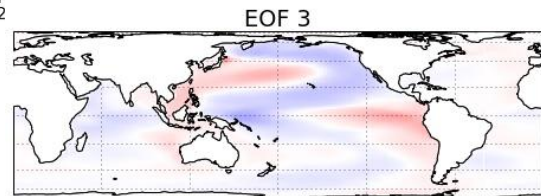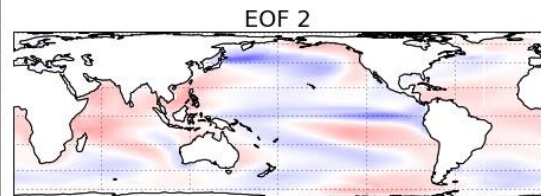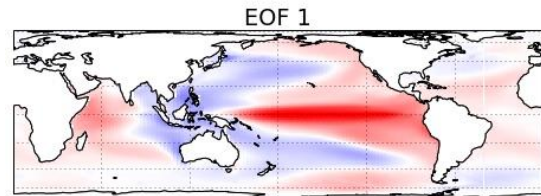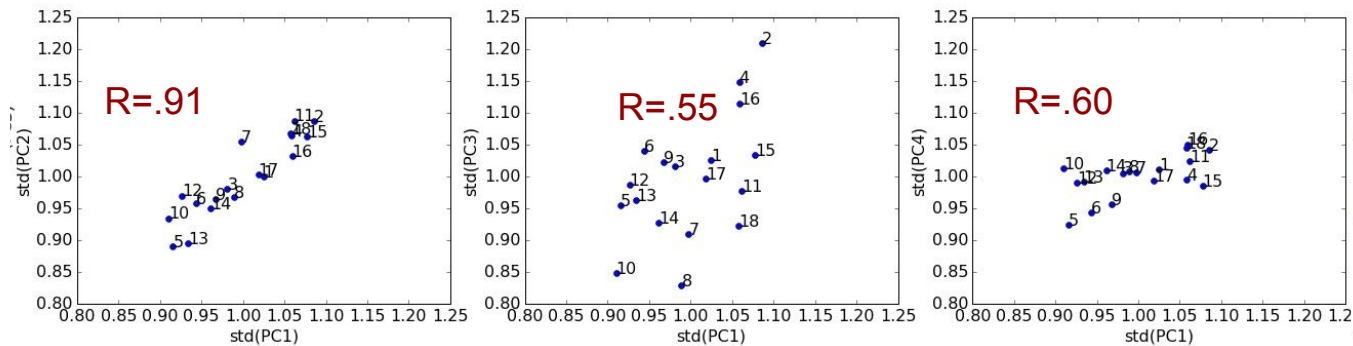- I use an implementation in the Python library: SciKit-Learn

# Observations (NOAA's ERSST)



EOF 1



EOF 2

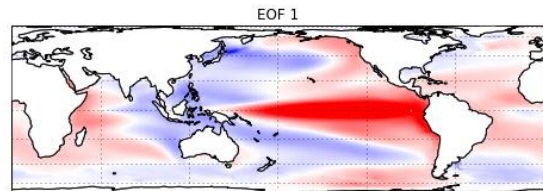

EOF 3



EOF 4



Correlation: PC 1, PC 2

Months of Lag



PC 1

PC 2
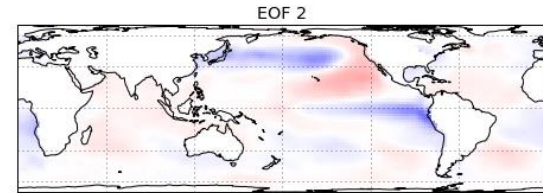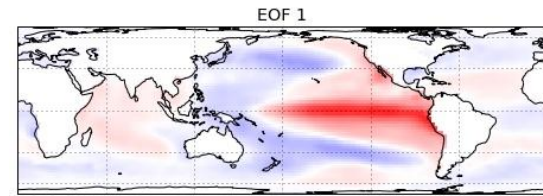
# CESM LE summary slide
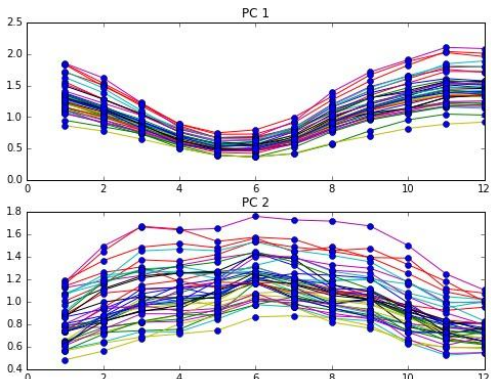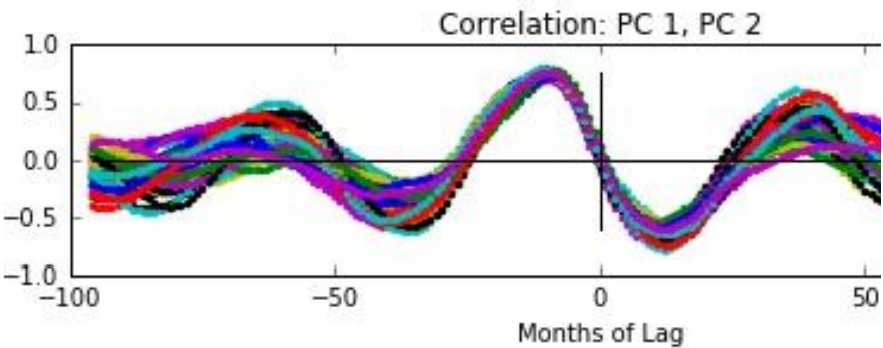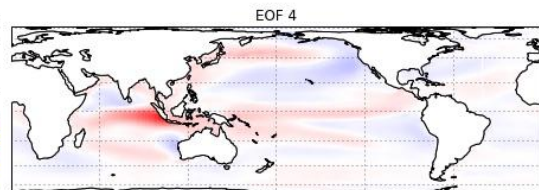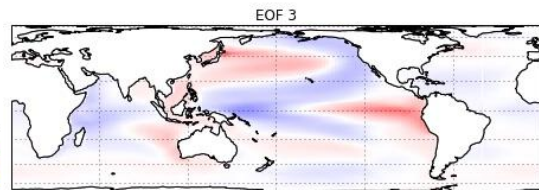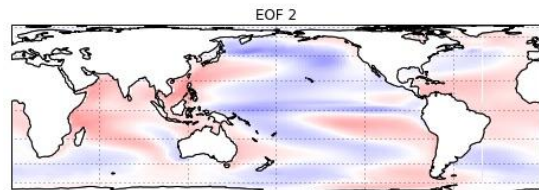
# The long control run of CESM.



R=.91

R=.55

R=.60

# The control run of CCSM4 2deg.
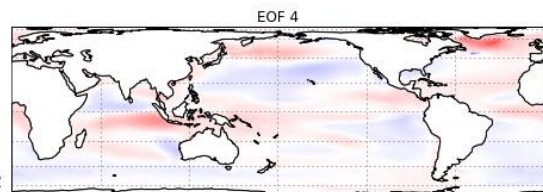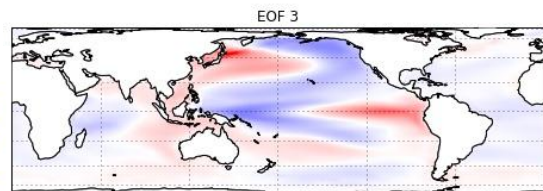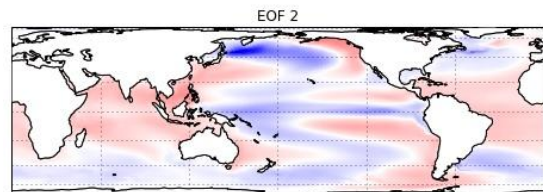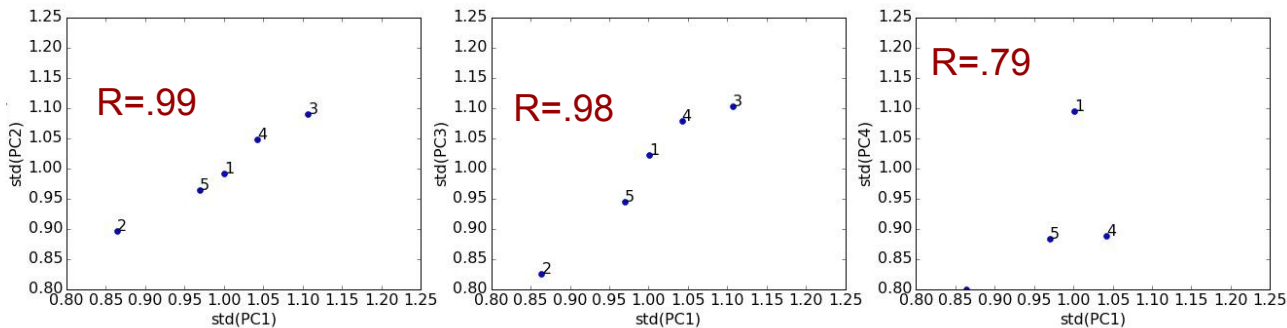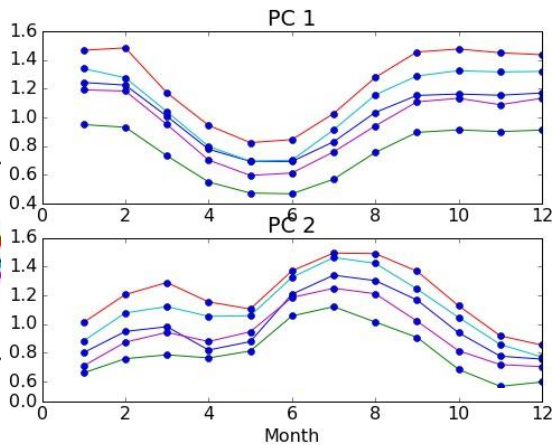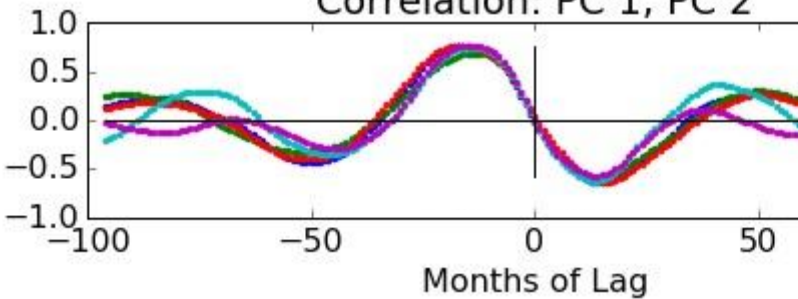
# Finding more physical patterns?



45° rotations