NOAA RESEARCH • ESRL • PHYSICAL SCIENCES DIVISION

The Processes Underlying the Pacific Decadal Oscillation

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Science Review
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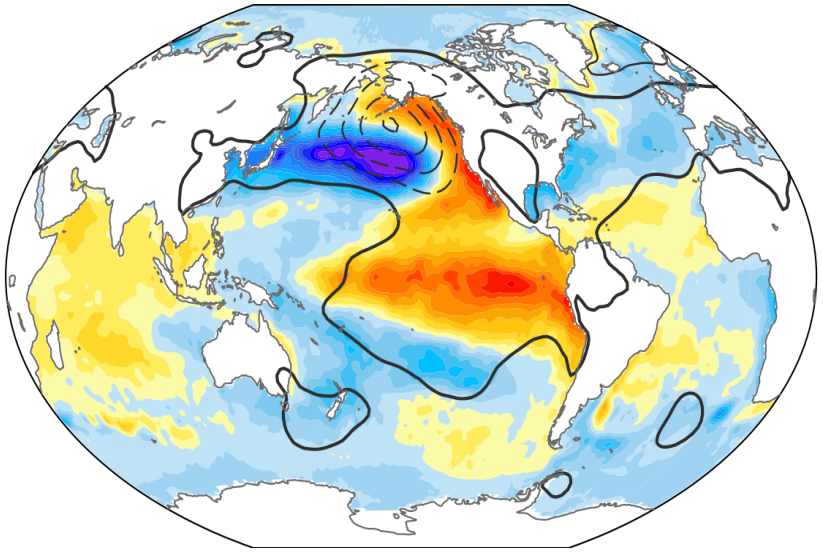
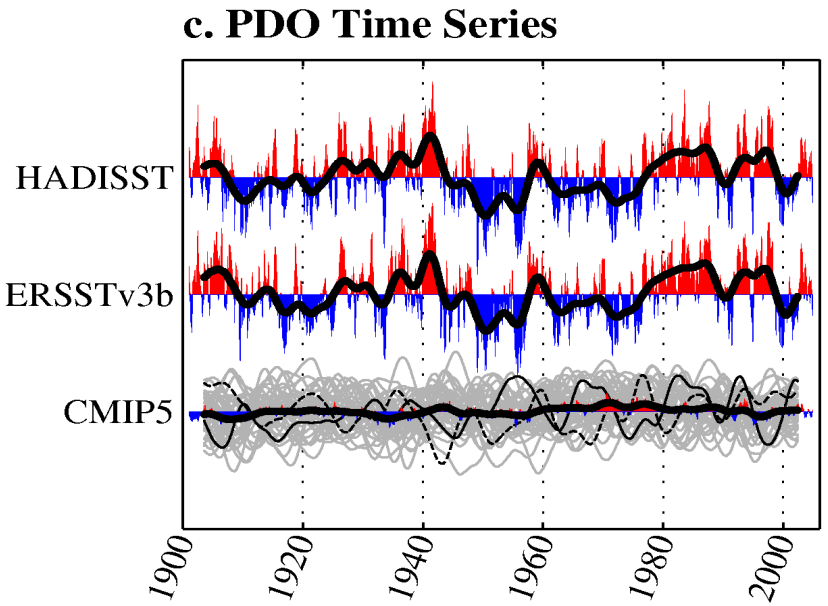
Why study the PDO?

- Leading pattern of SST variability in the North Pacific (> 20°N)
- Associated with climate, ecosystem and hydrologic fluctuations
- Develop a process understanding - key to prediction and applications



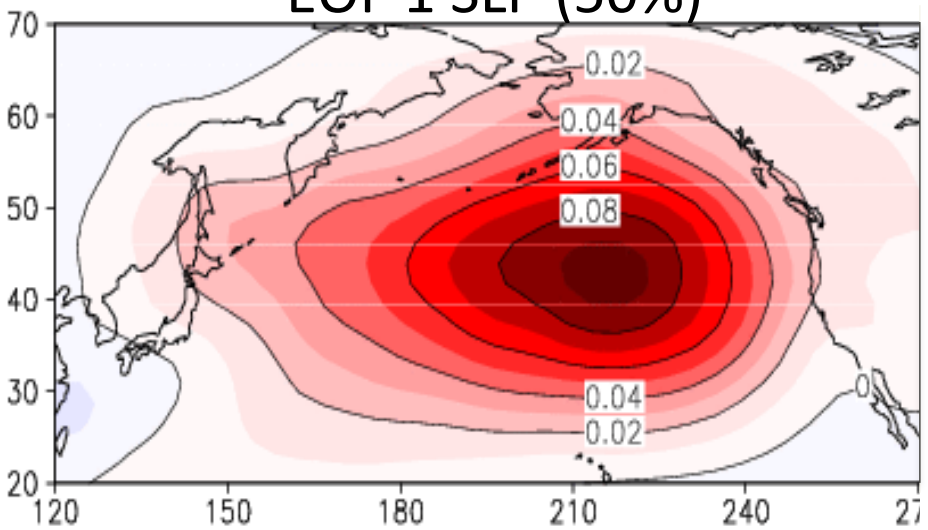


Newman, Alexander et al., 2015; BAMS, submit.

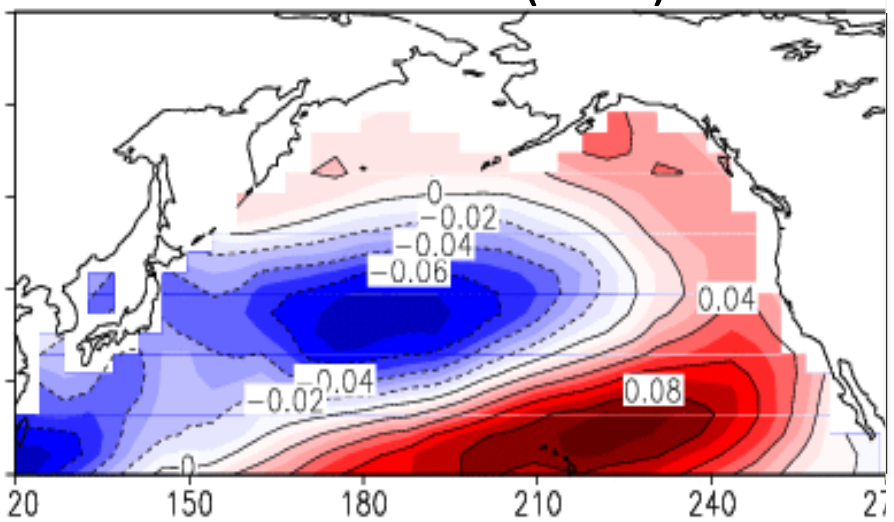
Random Forcing Aleutian Low Variability

- Ocean is a simple slab no currents thus no ENSO or ocean gyres
- Leading pattern => changes in strength of the Aleutian Low
- Changes in surface fluxes forces ocean
- Ocean integrates flux forcing creates SST anomalies that resemble the PDO

EOF 1 SLP (50%)



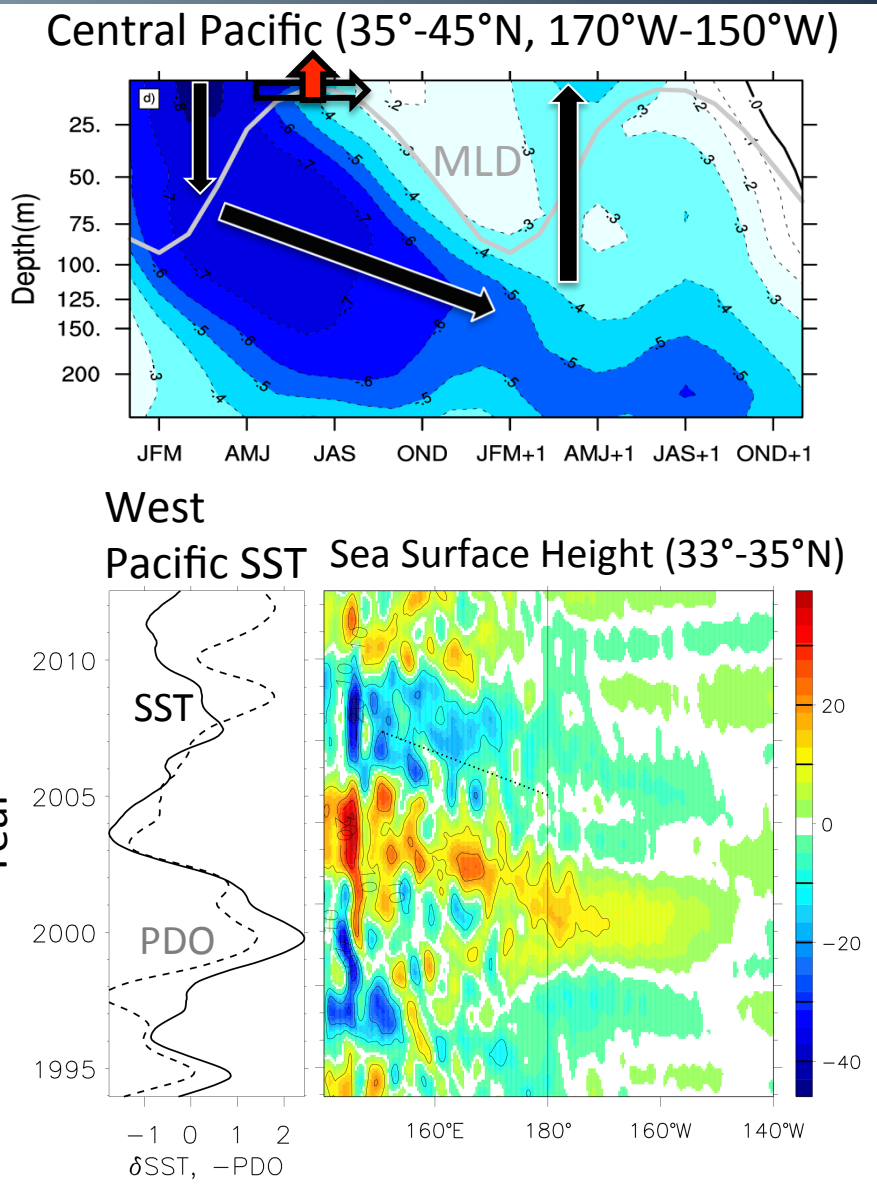
EOF 1 SST (34%)



Alexander, 2010; AGU Monograph Chapter

Midlatitude Ocean Processes

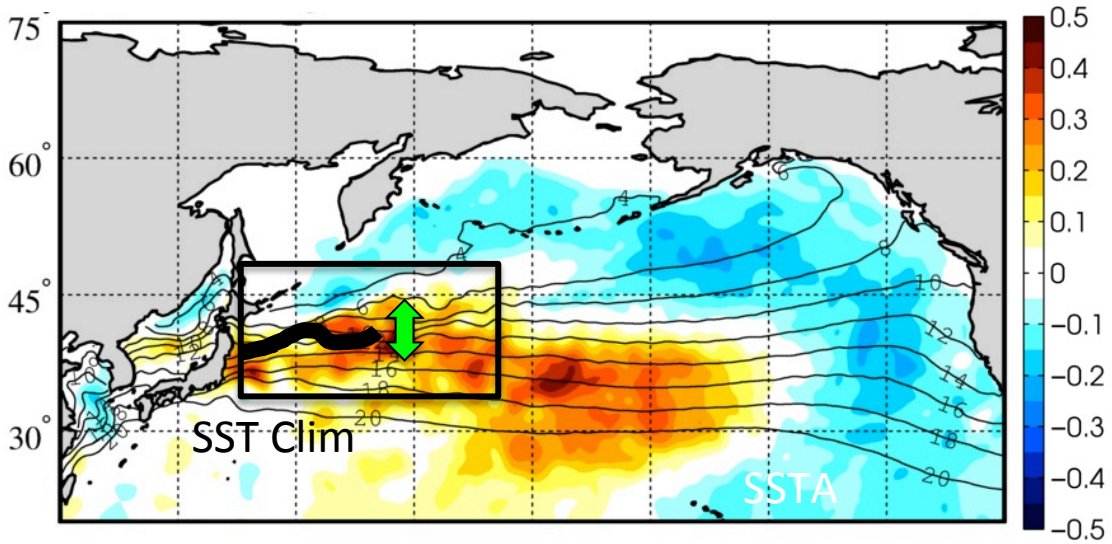
- Reemergence
  - Acts to "lengthen" ENSO & random atmospheric forcing
- Wind generated Ocean Rossby waves
  - Impacts SST near Japan, along the Kuroshio-Oyashio Extension (KOE) front



Newman, Alexander et al., 2015; BAMS, submitted

Kuroshio-Oyashio frontal variability

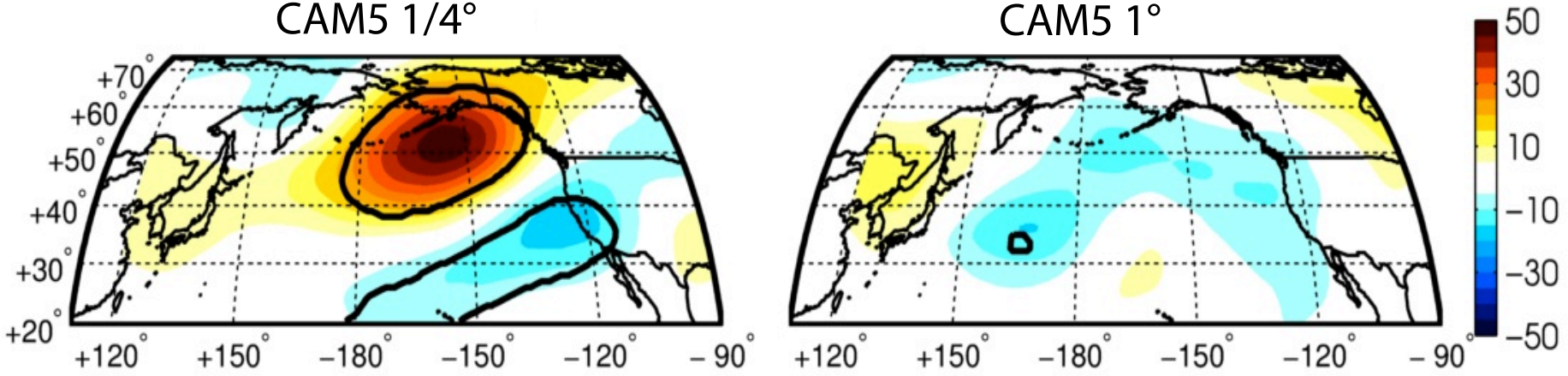
- SST anomalies and the atmospheric response to the frontal anomalies in an atmospheric model



300 hPa height (m)

CAM5 1/4°

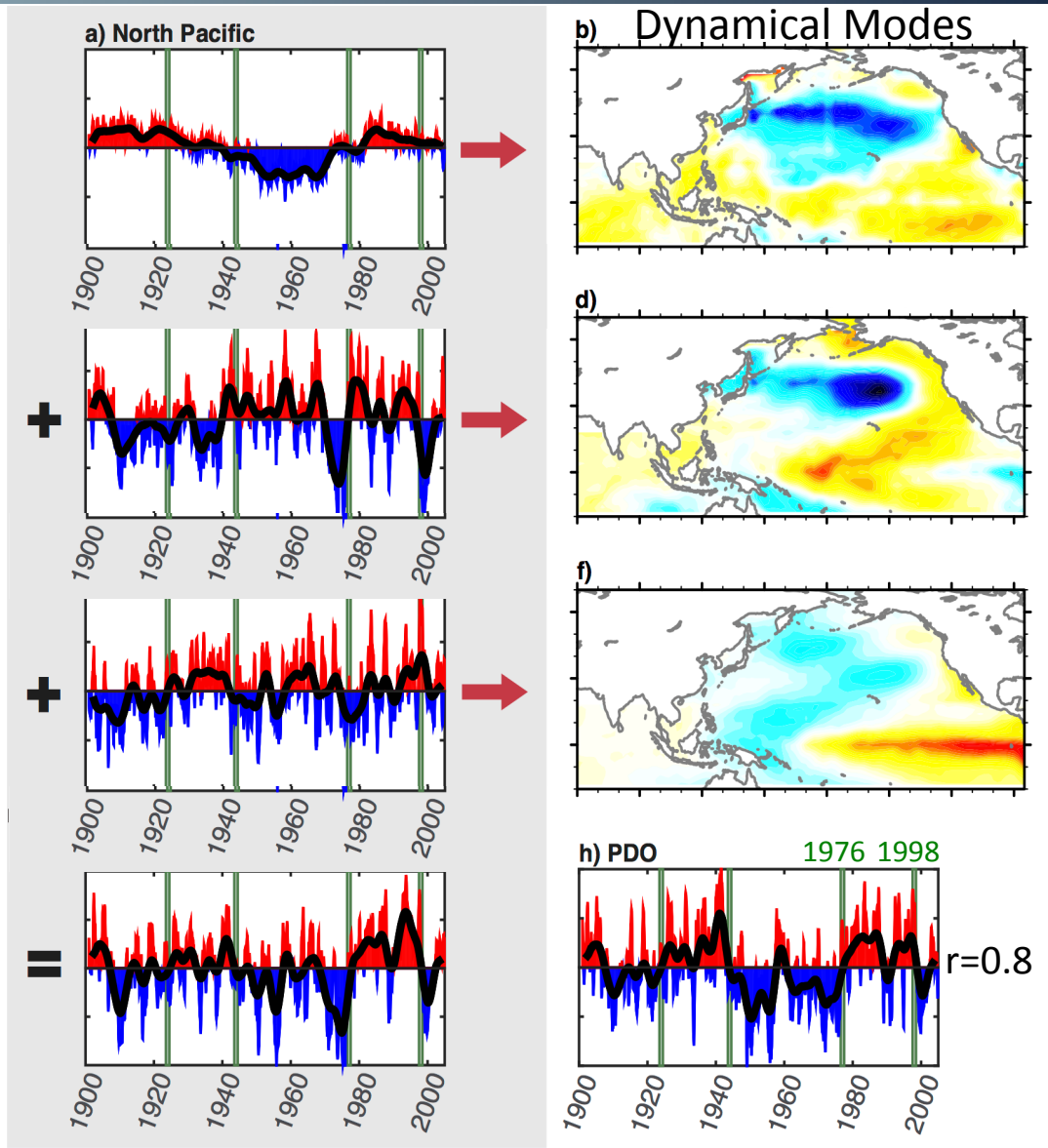
CAM5 1°



 Smirnov, Newman, Alexander et al., 2015; J. Climate

Building the PDO

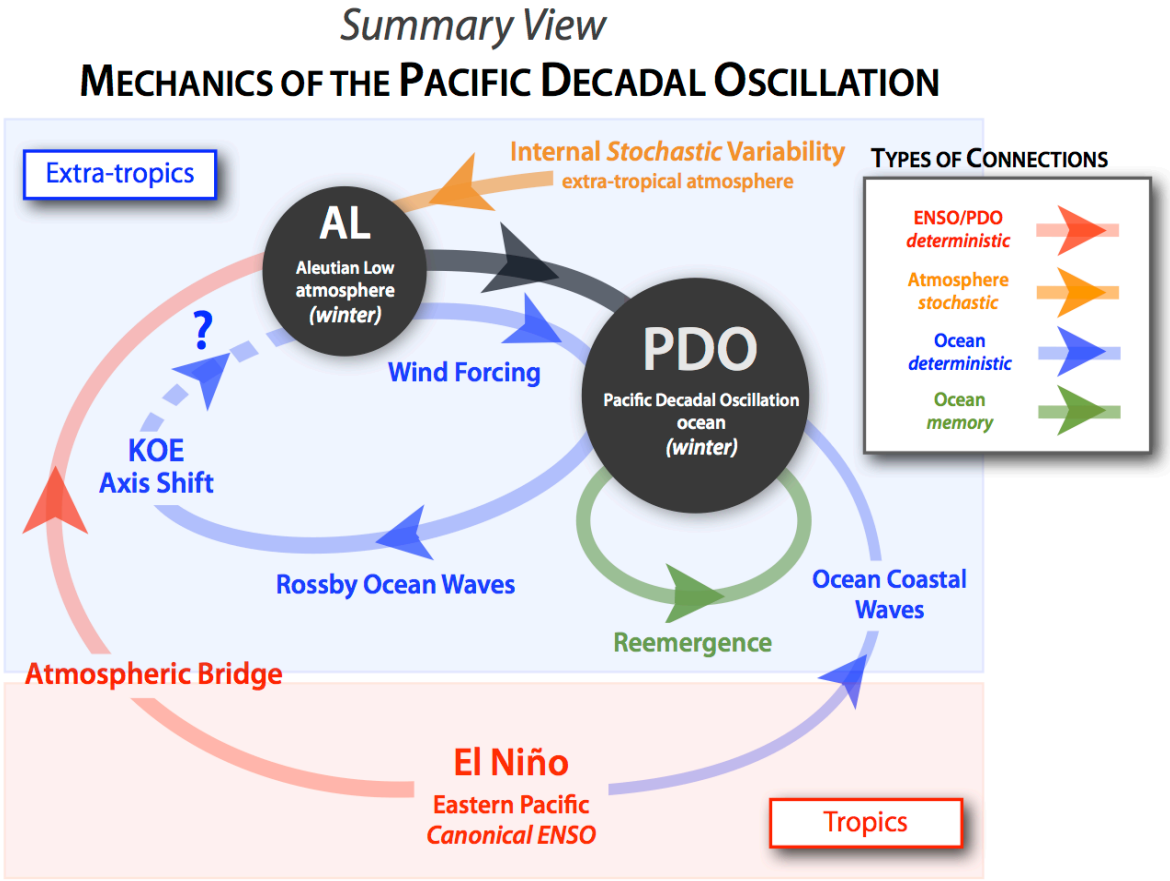
- Empirical Model (LIM)
- Leading Pacific dynamical modes
  - Not EOFs, not orthogonal
- Time series show projection of each mode onto the PDO



Newman, Alexander et al., 2015; BAMS, submitted

Summary and Conclusions

- Processes:
- Atmospheric Bridge (ENSO)
- Random forcing
- Reemergence
- Ocean Rossby waves & ocean fronts
- Atmospheric response to KOE SST anomalies?



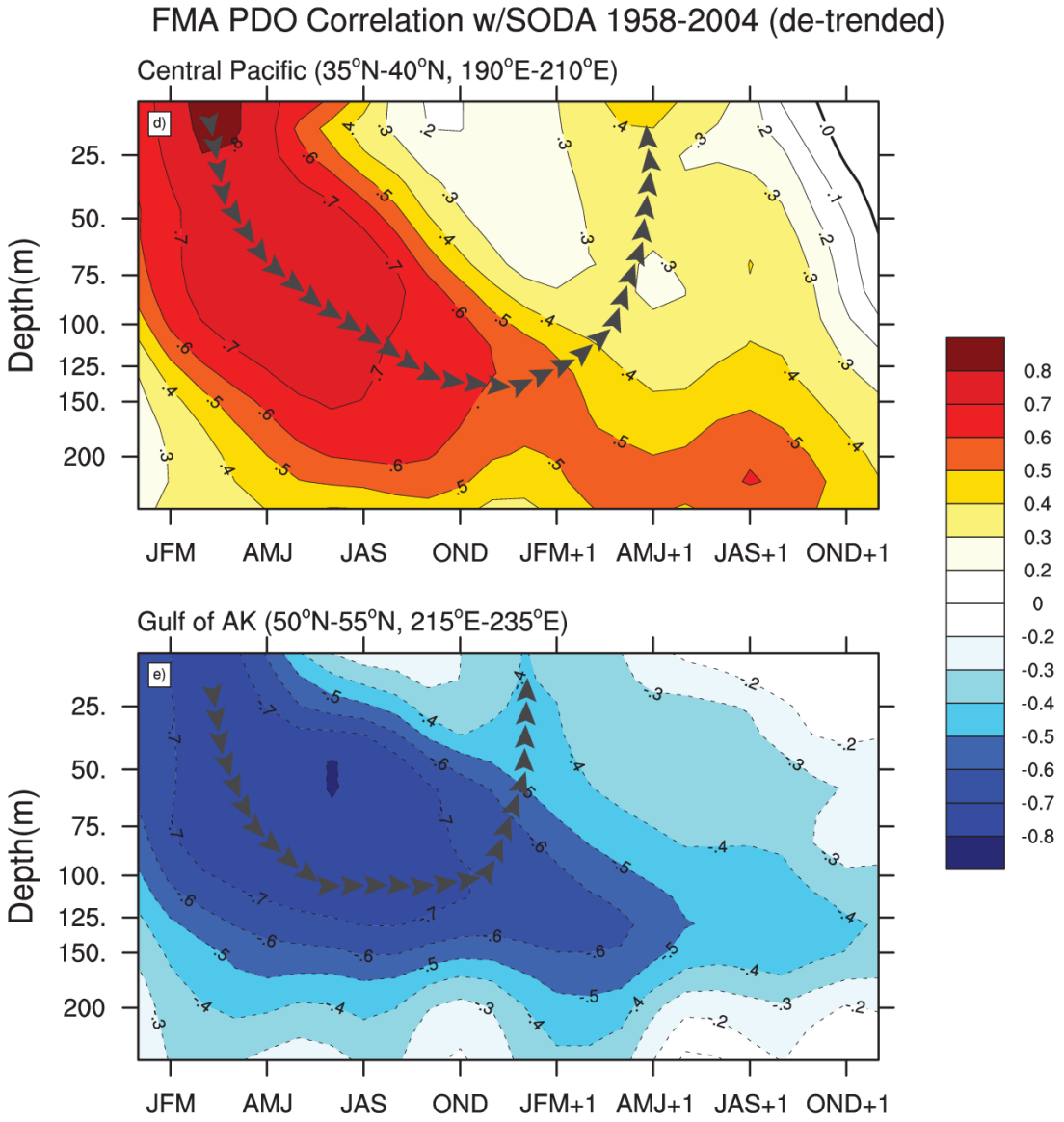
 Newman, Alexander et al., 2015; BAMS, submitted

Additional slides

"Re-emergence" : SST anomalies can recur in consecutive winters in the extratropics

Acts to lengthen ENSO and Random Aleutian Low forcing

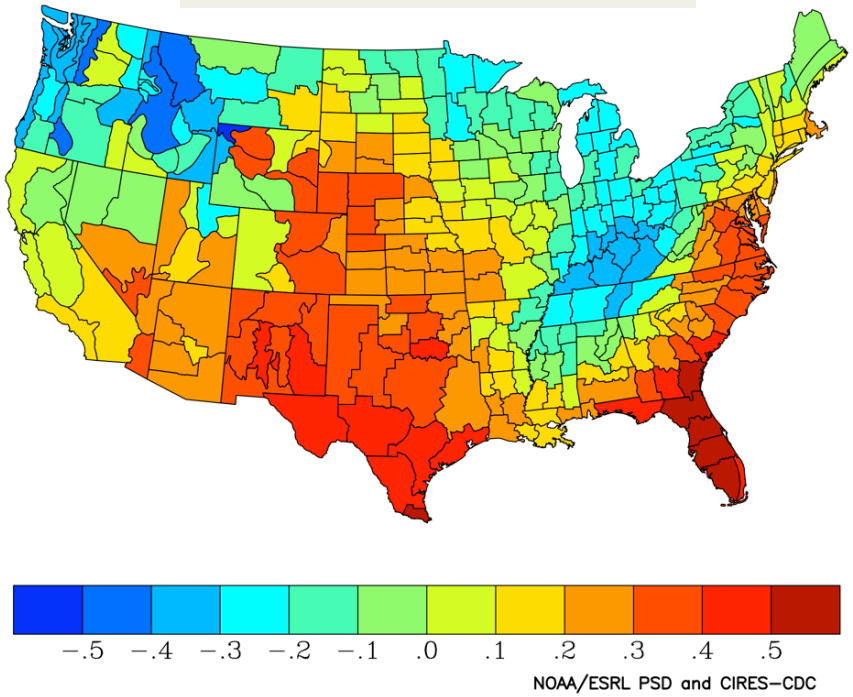
Depth vs. time cross-section of ocean temperature anomalies (°C) in two regions, correlated on the PDO (1958-2004)



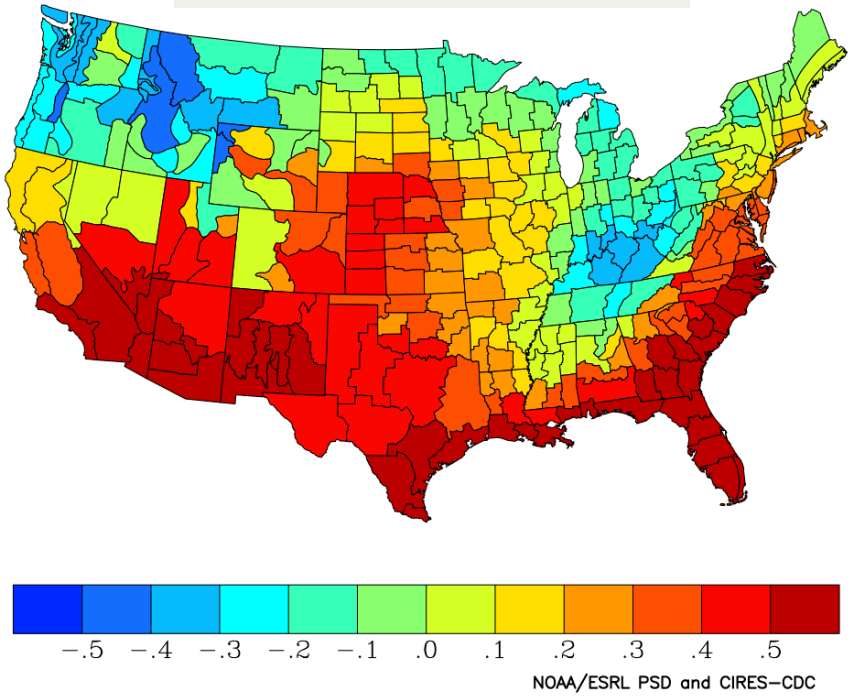
Newman, Alexander et al., 2015; BAMS, submitted.

PDO and ENSO "climate signals" are not independent

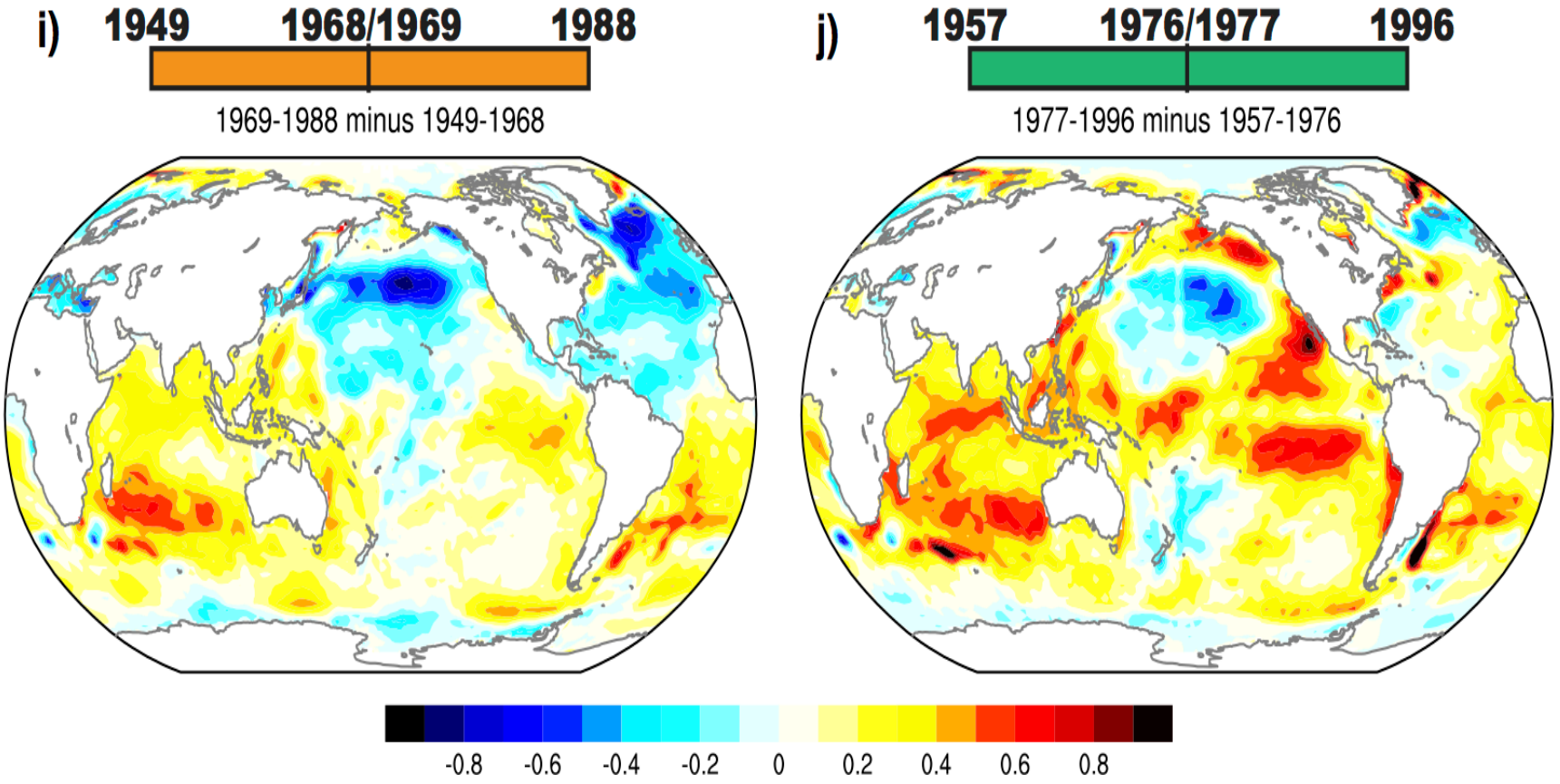
Nov-Mar precipitation correlated with PDO



Nov-Mar precipitation correlated with ENSO



Epoch differences in SST

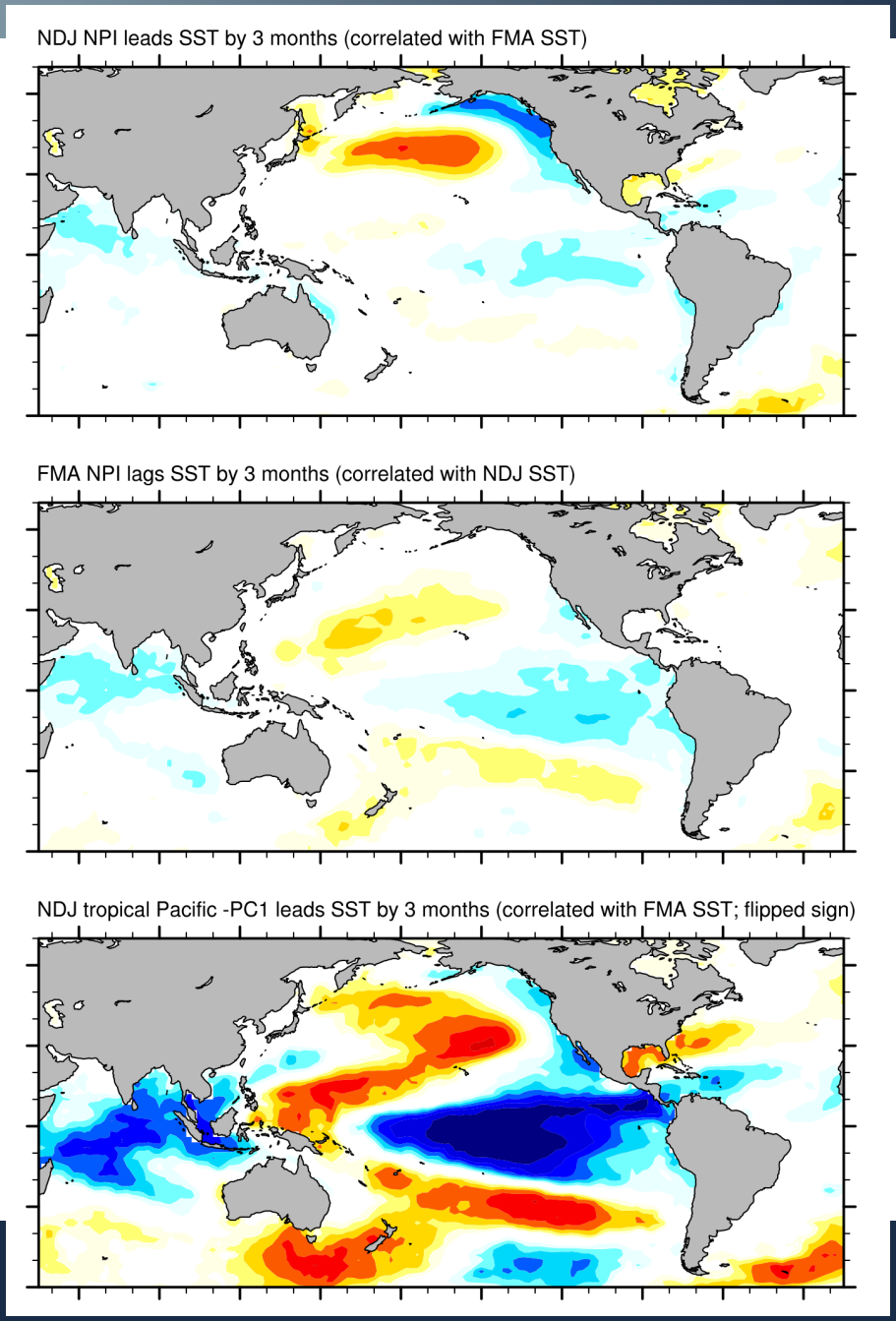


Local and remote forcing of the PDO

Top: atmosphere (NPI) leads SST by three months

Middle: SST leads NPI by three months

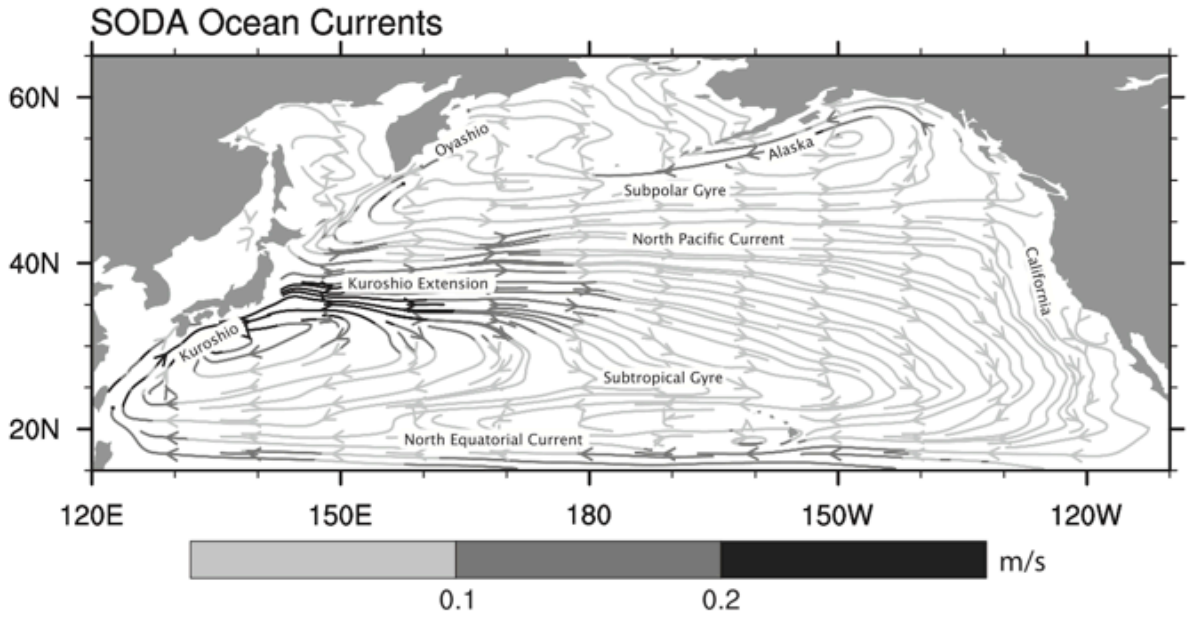
Bottom: ENSO index leads SST by three months

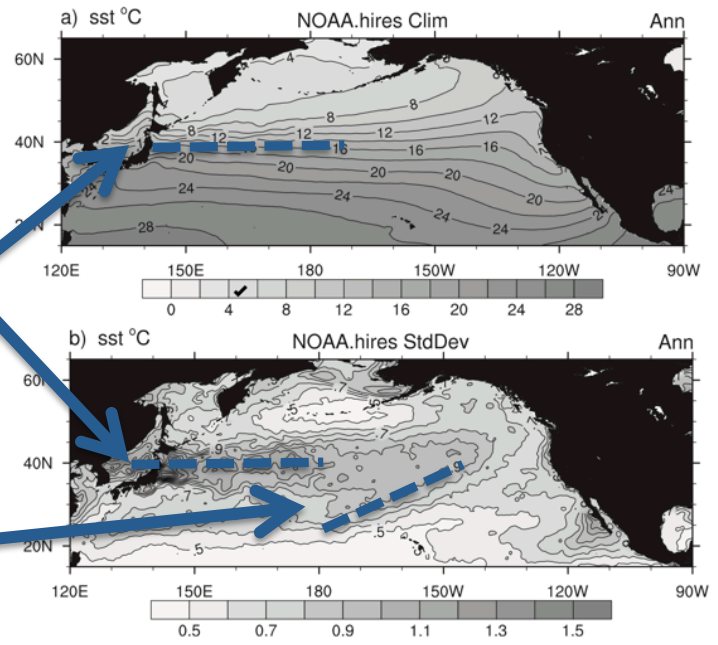


Pacific Ocean currents and variability

Kuroshio-Oyashio Extension (KOE) system is a key component of the North Pacific ocean-atmosphere system

Shifts in the subarctic SST front are associated with longer time scales (westward propagating Rossby waves)





Subarctic front

Subtropical front

Removing tropically-forced portion of the PDO yields "internal" North Pacific SST mode

Top: Leading pattern of North Pacific variability (PDO)

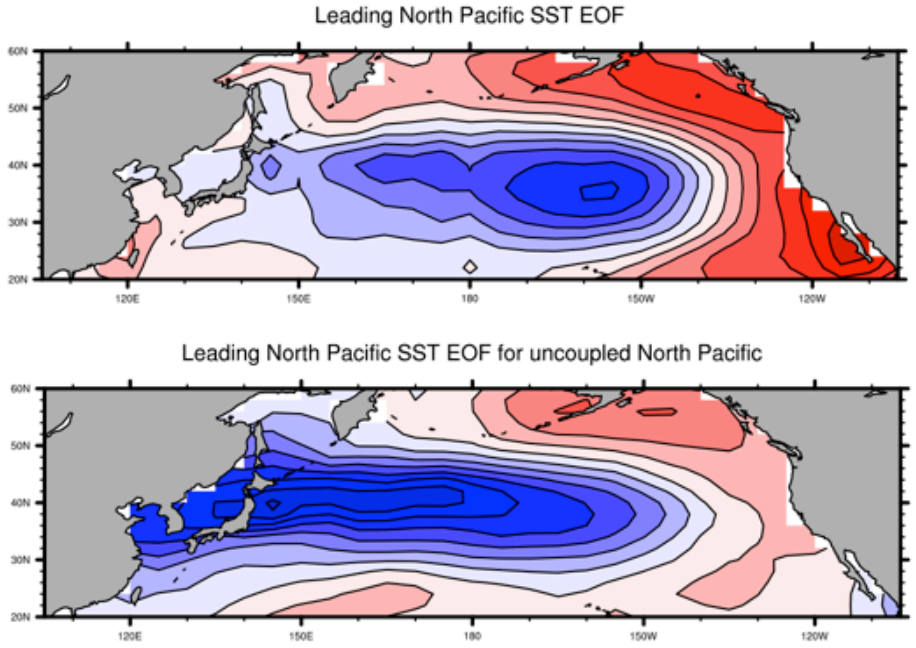
Bottom: Leading pattern of "internal" North Pacific seasonal variability (after uncoupling Tropics and North Pacific dynamics within **B**)

Multivariate AR1 model (LIM):

$$d\mathbf{x}/dt = \mathbf{B}\mathbf{x} + \mathbf{F}_s$$

Determined from observations, where **x** represents seasonal mean anomalies (1958-2008) of

- **Tropical Pacific** [SST, thermocline depth]
- **North Pacific** [SST, mixed layer temp (30-100m)]



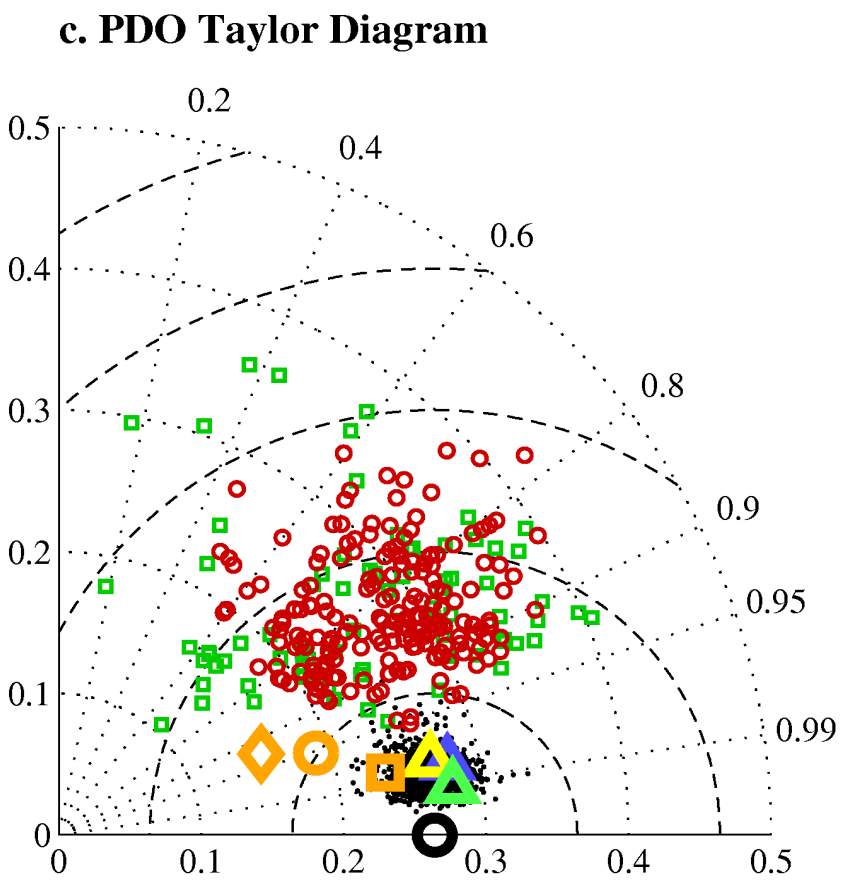
ENSO-PDO representation in CMIP5

Taylor diagram compares PDO determined from HadISST, 1901-2004, to

- CMIP3 : green
- CMIP5: red
- Black dots: 50-yr Monte Carlo subsampling
- Triangles: other data sets

Key result:

- Models reproduce a PDO EOF but none reproduce PDO well



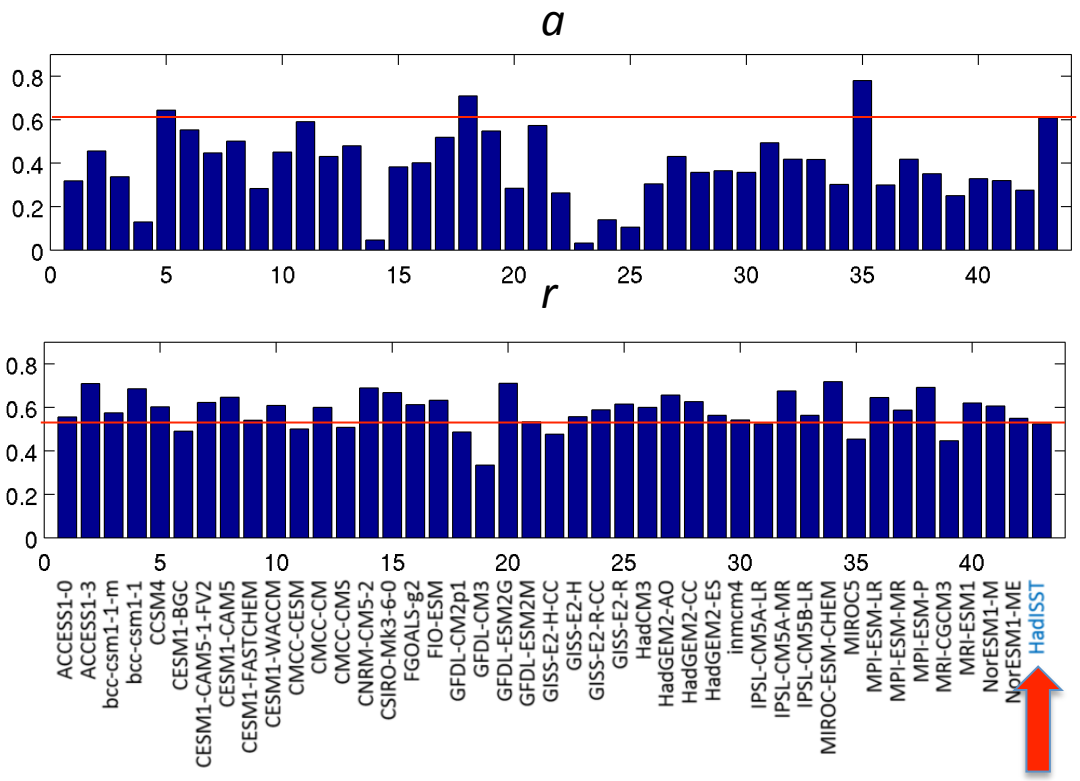
ENSO-PDO representation in CMIP5

$$PDO(n) = r\,PDO(n-1) + a\,PC1_{Tropics}(n) + b\,PC2_{Tropics}(n) + e$$

Fitting (simpler) AR1 model to observations and CMIP5 models, 1901-2004

Key results:

- Most models reproduce PDO EOF
- Almost all models underestimate tropical forcing of PDO (*a*)
- Most models (slightly) overestimate *r*



PDO/ENSO spectra

Gray shading: 1000 1000-yr LIM (multivariate AR1) realizations

CMIP5 spectra lies within confidence interval (a-c)

PDO paleo reconstructions