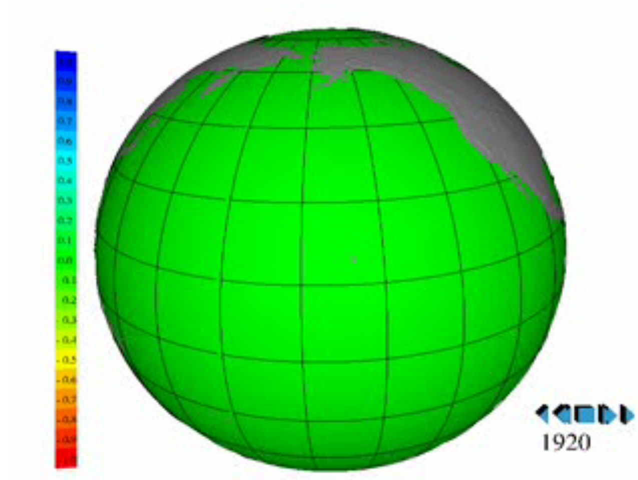
Pacific Decadal Oscillation I



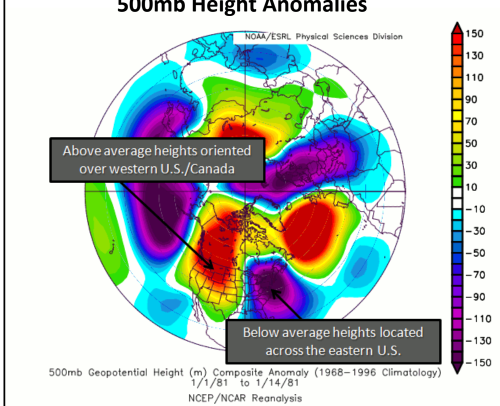
First– some important terms!

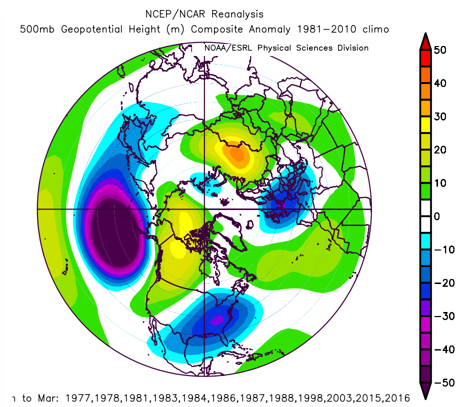
PNA vs PDO vs IPO vs NPGO?!

PDV: "Pacific Decadal Variability"

Pacific/North American Pattern

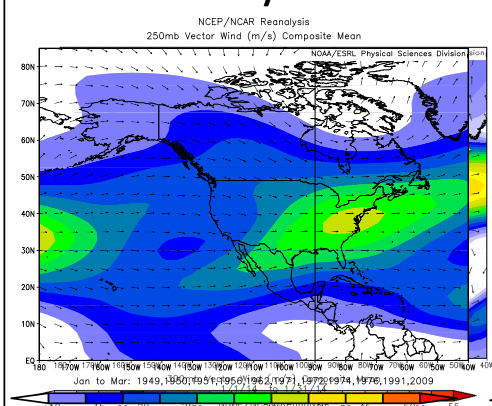
500mb Height Anomalies

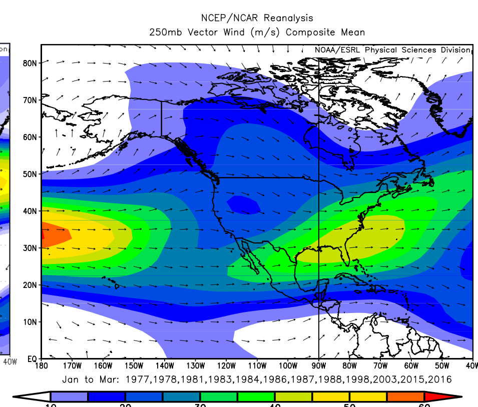




Positive phase of the PNA

Pacific/North American Pattern

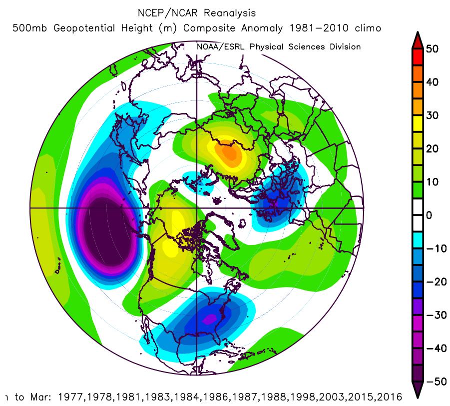




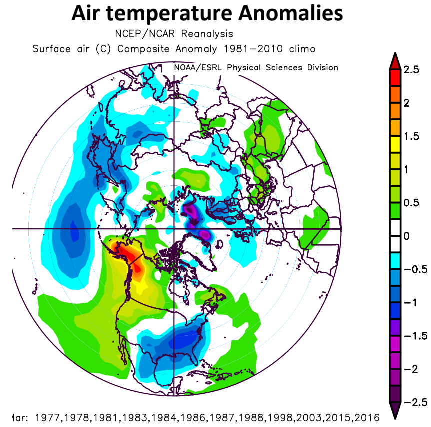
Positive phase of the PNA

Pacific/North American Pattern

500mb Height Anomalies



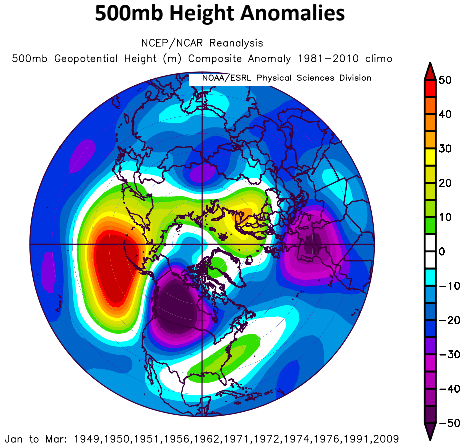
Air temperature Anomalies



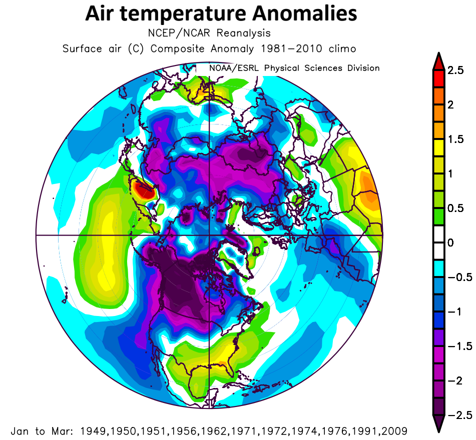
Positive phase of the PNA

Pacific/North American Pattern

500mb Height Anomalies



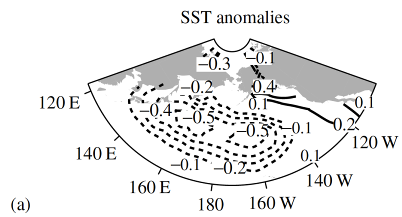
Air temperature Anomalies



Negative phase of the PNA

Pacific Decadal Oscillation

- leading Empirical Orthogonal Function (EOF) of monthly SST anomalies north of 20°N (Mantua et al. 1997)
- pattern is similar to ENSO, but with larger amplitudes in mid-latitudes rather than low-latitudes and a broader width of equatorial anomalies than those of ENSOs

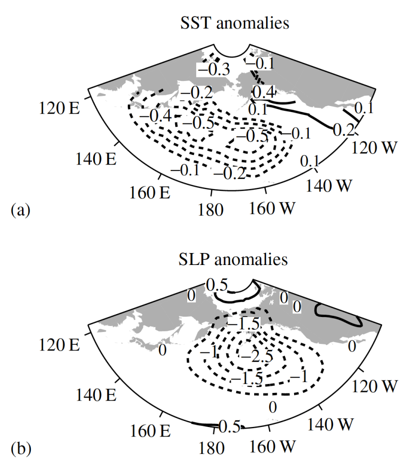


Mantua 2002

Pacific Decadal Oscillation

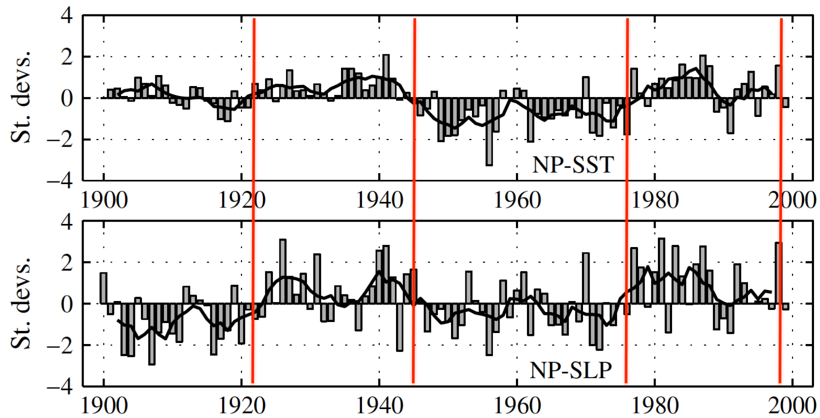
- Atmosphere co-varies with the PDO index in central North Pacific:

  cool SST anomalies → deepened Aleutian Low & enhanced westerlies in the (associated w/ the PNA pattern)



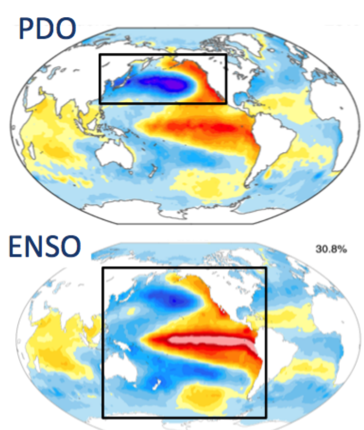
Mantua 2002

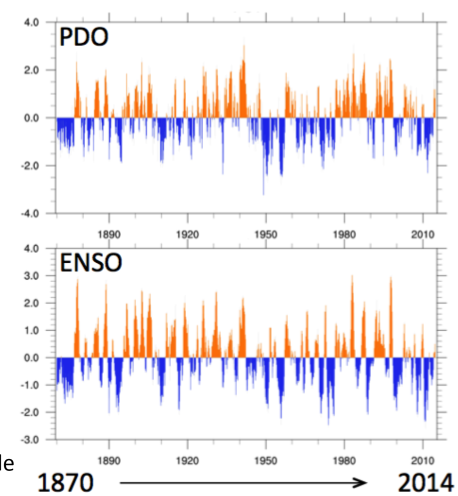
Pacific Decadal Oscillation index



Mantua 2002

PDO vs ENSO





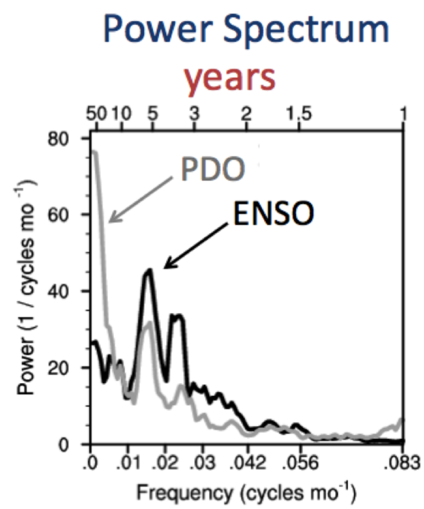
C. Deser, UCAR/NCAR Climate data guide

Decadal modulation of interannual teleconnections

Timescale dependent signatures

- Dominant timescales (e.g. Mantua and Hare 2002 PDO review):
  - Bi-decadal (20-yr) oscillation
  - Penta-decadal (50–70-yr) oscillation

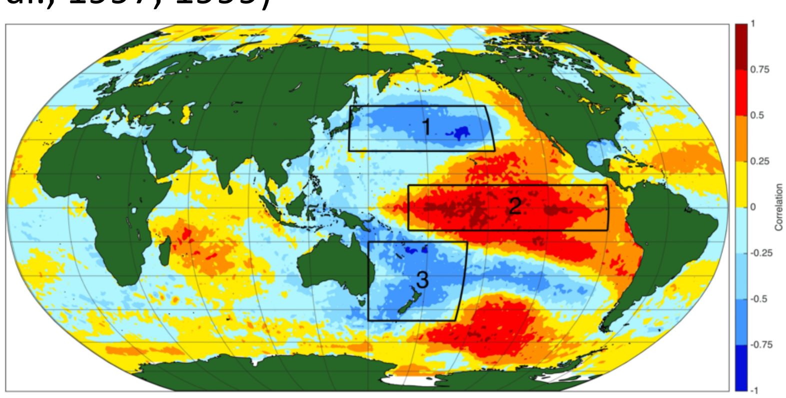
[Minor quasi-decadal (10-yr) peak also observed in some (e.g. Wang et al. 2011)]



Adapted from Deser et al. (2012)

Interdecadal Pacific Oscillation

- The full Pacific extension of the PDO (Power et al., 1997, 1999)



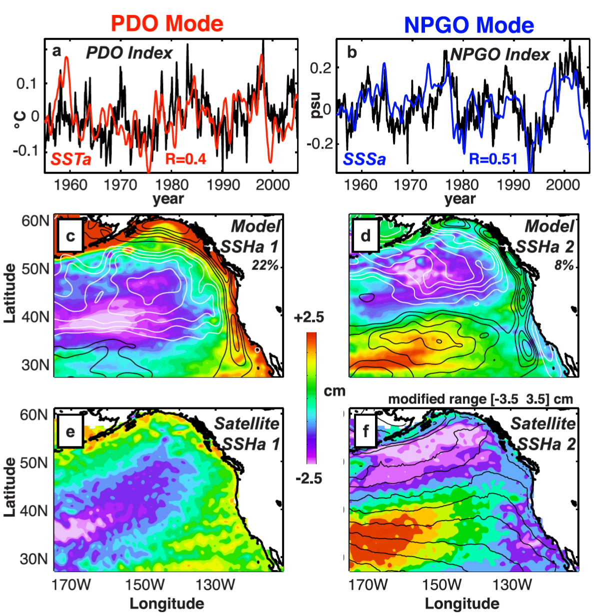
Tripole index of the IPO; Henley et al. 2015

North Pacific Gyre Oscillation

- EOF2 of SST & SSH anomalies in the North Pacific (PDO is EOF1)
- Statistically independent of the PDO
- reflects changes in wind stress, in particular the winds that force coastal upwelling
- Strengthening since 1993– in response to global warming?

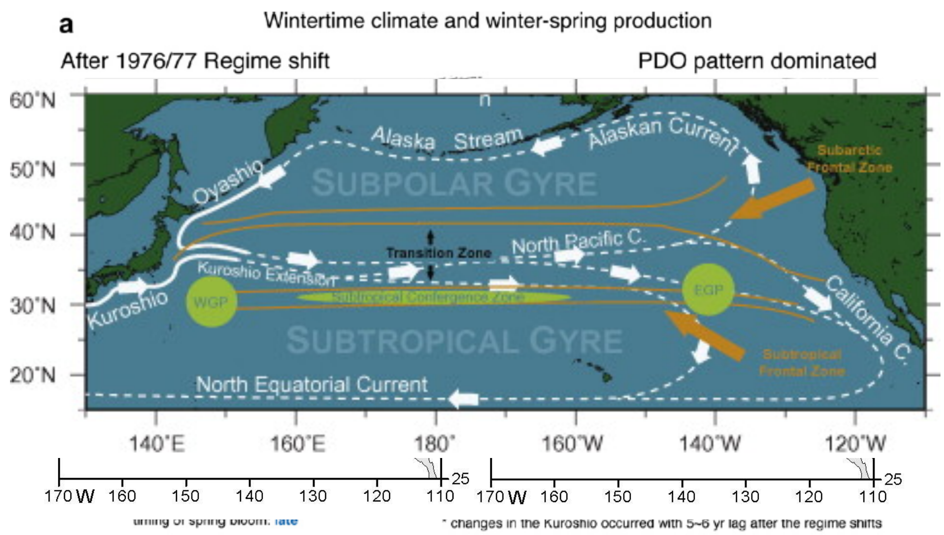
Di Lorenzo et al. 2008

NPGO vs PDO

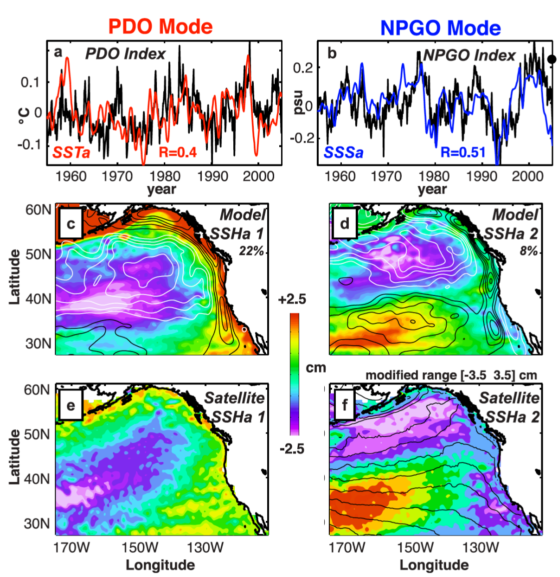


Di Lorenzo et al. 2008

NPGO vs PDO



NPGO vs PDO

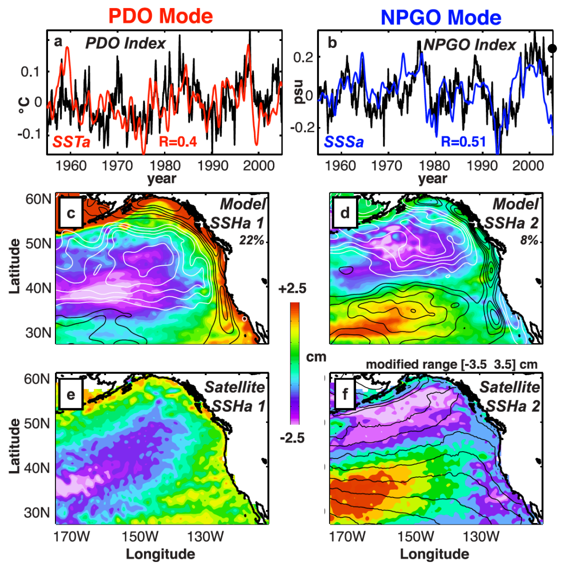


PDO:

- Subpolar gyre expands while Subptropical gyre contracts
  - North Pacific Current shifts south
  - Stronger Alaskan Gyre
  - Stronger Alaska current
  - Weakened CA current

Di Lorenzo et al. 2008

NPGO vs PDO



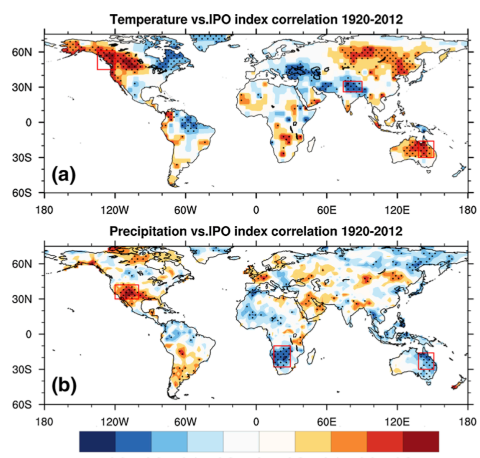
NPGO:

- Subpolar and AND Subtropical gyre intensified
  - North Pacific Current intensifies
  - Stronger Alaska current
  - Stronger CA current

Di Lorenzo et al. 2008

Global teleconnections

- air-temperature anomalies due to PDO are generally similar to those connected to ENSO
- POS PDO/IPO:
  - Higher wintertime temperature over Alaska and western Canada and the Pacific Northwest
  - Cooler temperature in Mexico and the southeastern US
  - Increased rain and river runoff in the coastal ranges of Alaska, and in the southwestern US and Mexico
  - precipitation in Canada and Siberia is reduced
- absolute correlations of precipitations onto the PDO index are generally smaller than those of temperatures



Dong and Dai 2015

Impact on NA precipitation

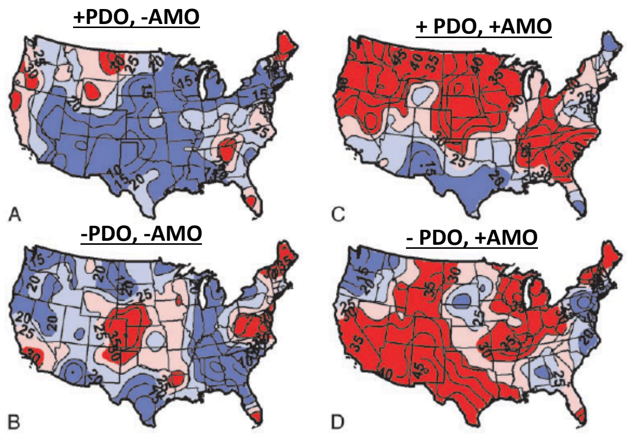


Fig. 5. Drought frequency (in percent of years) for positive and negative regimes of the PDO and AMO. (*A*) Positive PDO, negative AMO. (*B*) Negative PDO negative AMO. (*C*) Positive PDO, positive AMO. (*D*) Negative PDO, positive AMO.

McCabe et al. 2004

Decadal modulation of interannual (ENSO) teleconnections

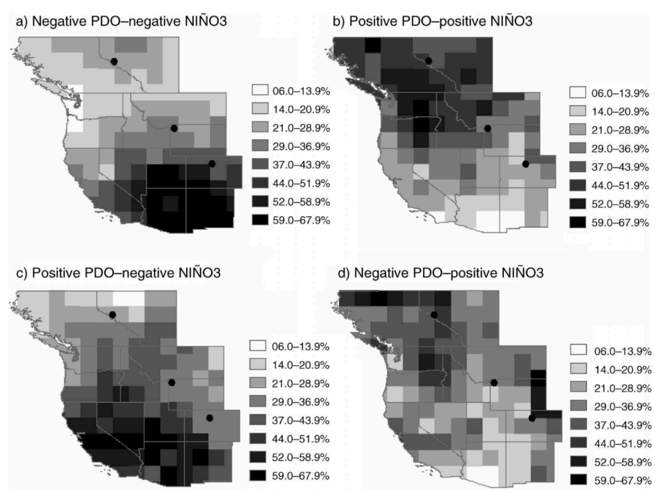
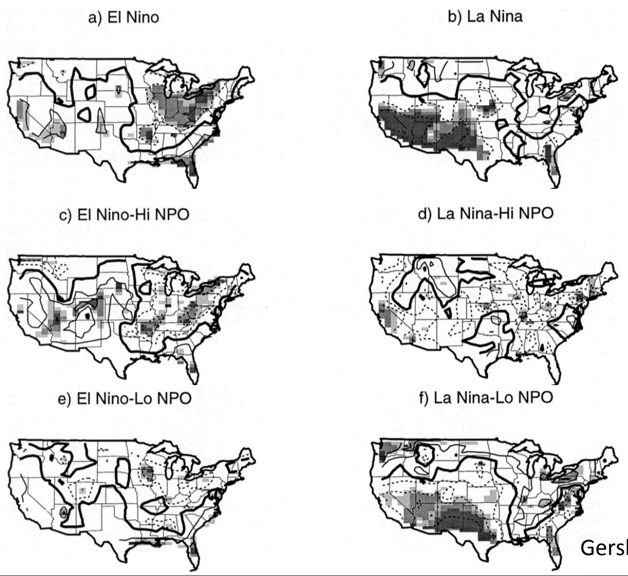


FIG. 7. Maps depicting the percentages of years classified as extreme drought (first-quartile PDSI) during the four categorical combinations of the PDO and ENSO phases across the western United States and Canada. The three study areas are represented by solid circles.

Schoennagel et al (2005)

Decadal modulation of interannual (ENSO) teleconnnections



Gershunov and Barnett (1998)

Mechanisms

- Why so important/why do we care?

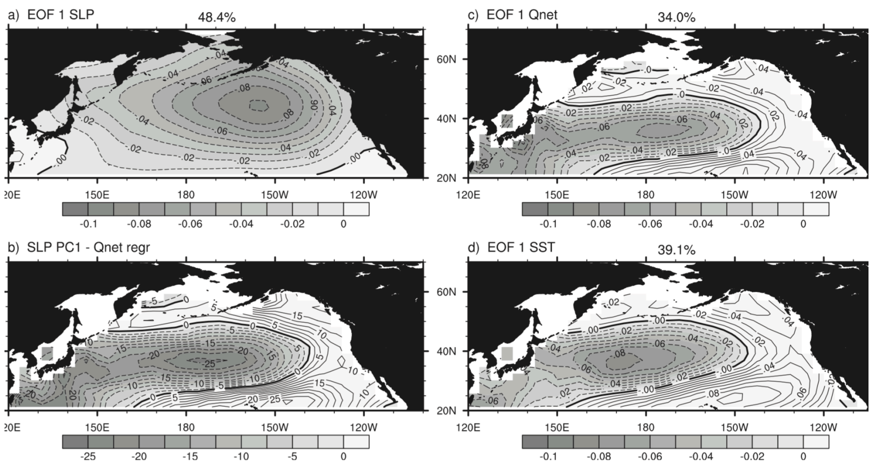
Mechanisms

- Why so important/why do we care?
  - Predictions
  - Response to decadal forcing

Mechanisms

- Null hypothesis: Decadal scale variability in the North Pacific can be explained by memory in the system and atmospheric noise.
- Extra-tropically or tropically forced?

Noise + memory == PDV?



Alexander 2010

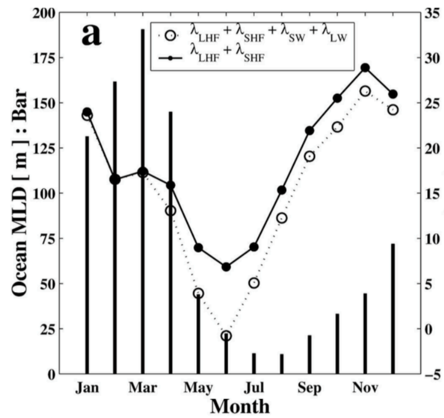
Mechanisms for memory

- Recall that the oceans store much more heat than the atmosphere
  - Heat content of the upper 2.5 m of ocean ≈ to that of the entire atmosphere above it
- This means that the oceans have much more memory than the atmosphere
- Ocean mixed layer (20-300m) temperature anomalies can be sustained for several months

Mechanisms for memory

1. Cloud—SST feedback;

Cool SSTs in NP → More stable atmosphere → more stratiform clouds in NP → more cooling



Park et al., 2006

Mechanisms for memory

2. Reemergence Mechanism

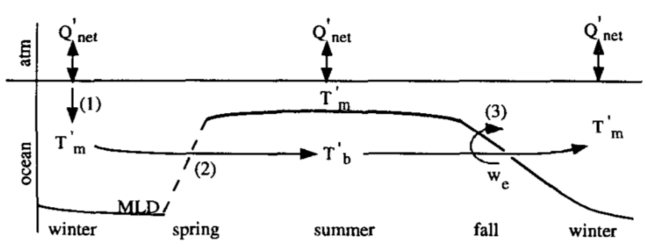
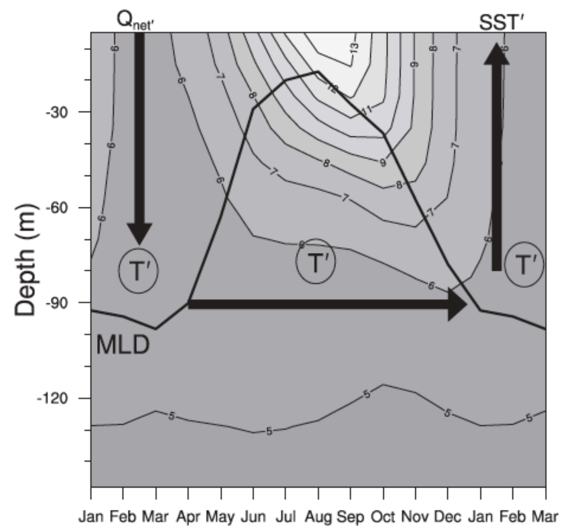


FIG. 1. Schematic diagram of the Namias and Born hypothesis. 1) Anomalous atmospheric forcing (Q'_{net}) in winter creates a temperature anomaly (T'_m) over a deep mixed layer; 2) the temperature anomaly remains beneath the mixed layer (T'_b) when the mixed layer reforms (dashed line) close to the surface in spring; 3) the sub–mixed layer temperature anomaly is entrained (w_e) into the mixed layer in the following fall/winter, influencing the surface temperature.

Alexander and Deser 1995

Mechanisms for memory

2. Reemergence Mechanism

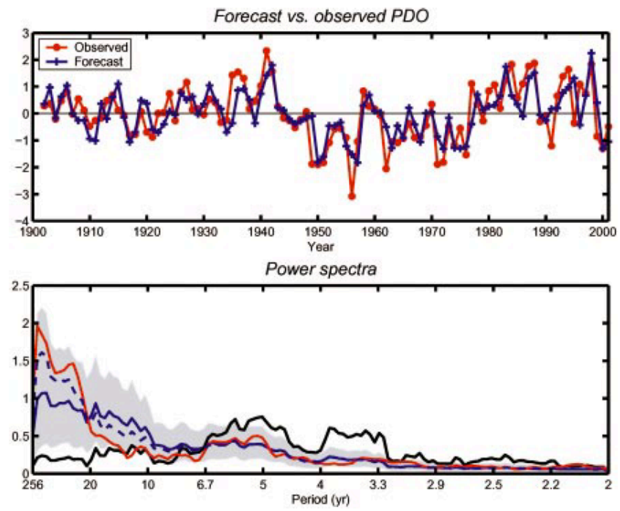


Mechanisms for memory

3. Many more…. (see review by Alexander 2010)

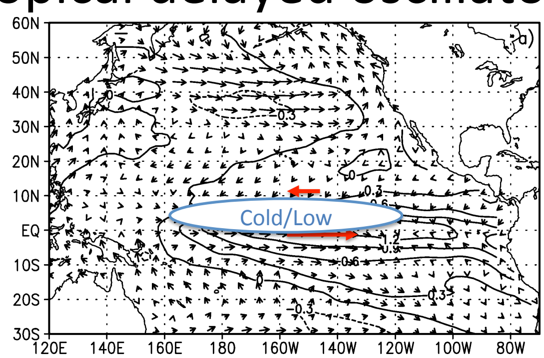
Role of the tropics?

PDO can be reproduced with ***tropical variability*** + ***stochastic atm forcing*** in mid-latitudes + ***reemergence mechanism***



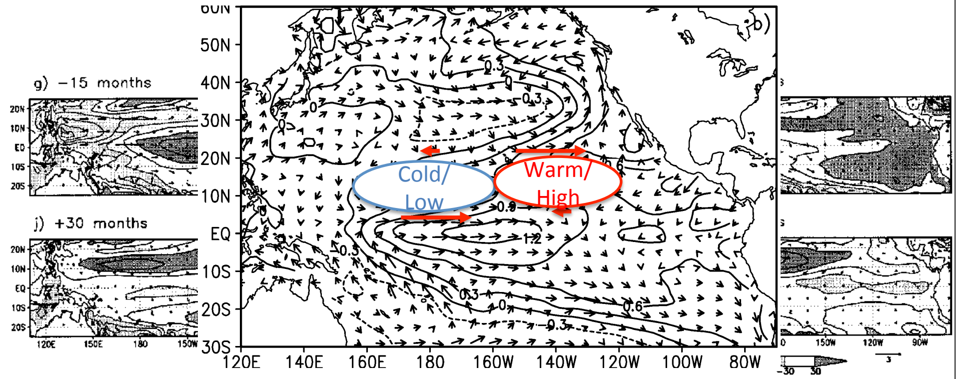
Newman et al. (2003)

Tropical delayed oscillator



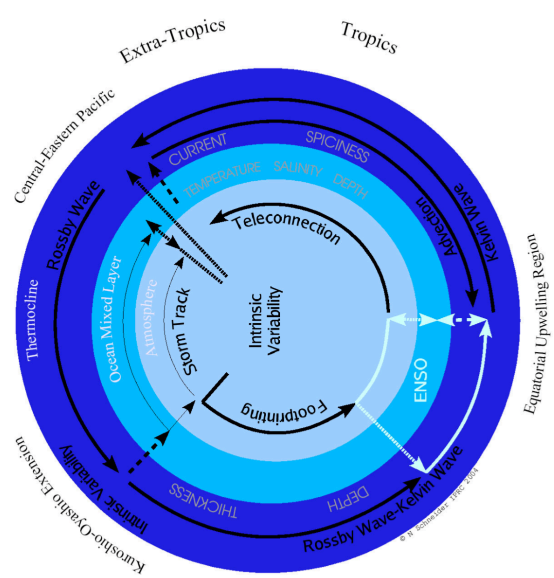
- The communication of the equatorial and extra-equatorial regions of the ocean via waves allow for the existence of a basin-scale mode of variability:
  - Anomalous mass of an extra-equatorial Rossby wave generates equatorial Kelvin wave
  - Accomplished through integrated mass transport towards ("charging") or away ("discharging") from equator
  - Figure after Wang, Jin, and Wang, 2003 Part II

Delayed oscillator review



Decadal variability in the tropics involve a delayed oscillator mechanism similar to that described for ENSO, but with slower Rossby waves at higher latitudes (Kirtman 1997) or of higher vertical mode number (Liu et al. 2002). Figure after Manabe and Knutson 1998

Mechanism schematic summary



Minobe et al. 2004

Predictability

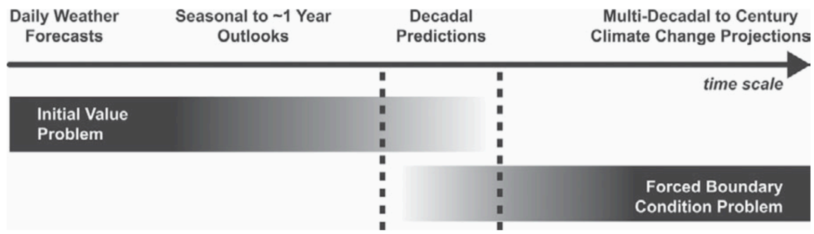
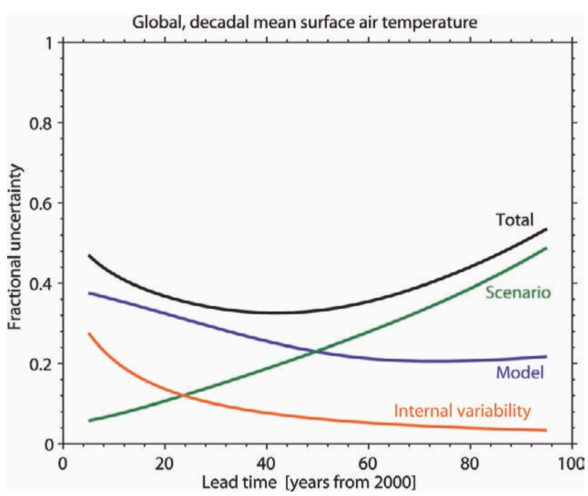


FIG. 2. Schematic illustrating progression from initial value problems with daily weather forecasts at one end, and multidecadal to century projections as a forced boundary condition problem at the other, with seasonal and decadal prediction in between.

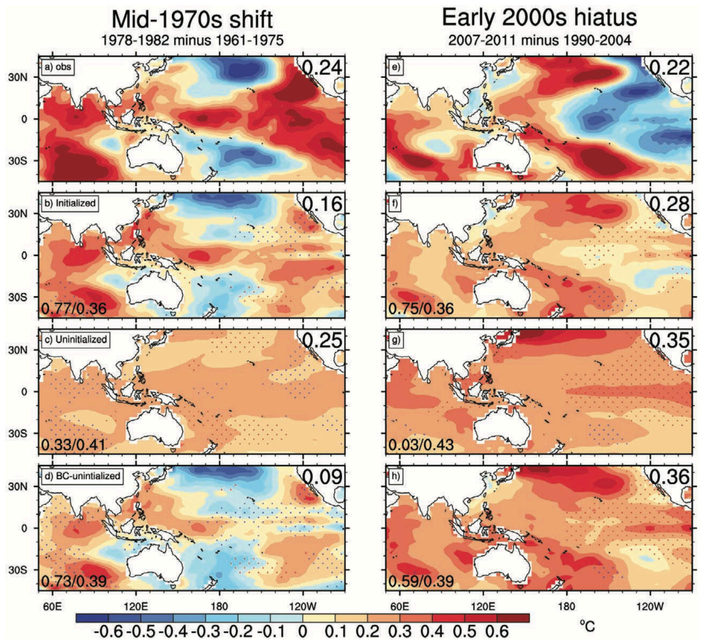
Meehl et al. 2009

Sources of uncertainty



Meehl et al. 2009

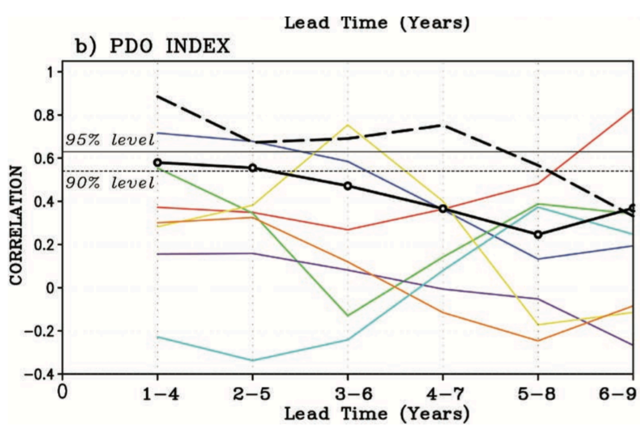
Predictability



Meehl et al. 2014

Predictability

Still limited to a few years in advance



Meehl et al. 2014