

Air-sea interaction: #2

Natural climate variability

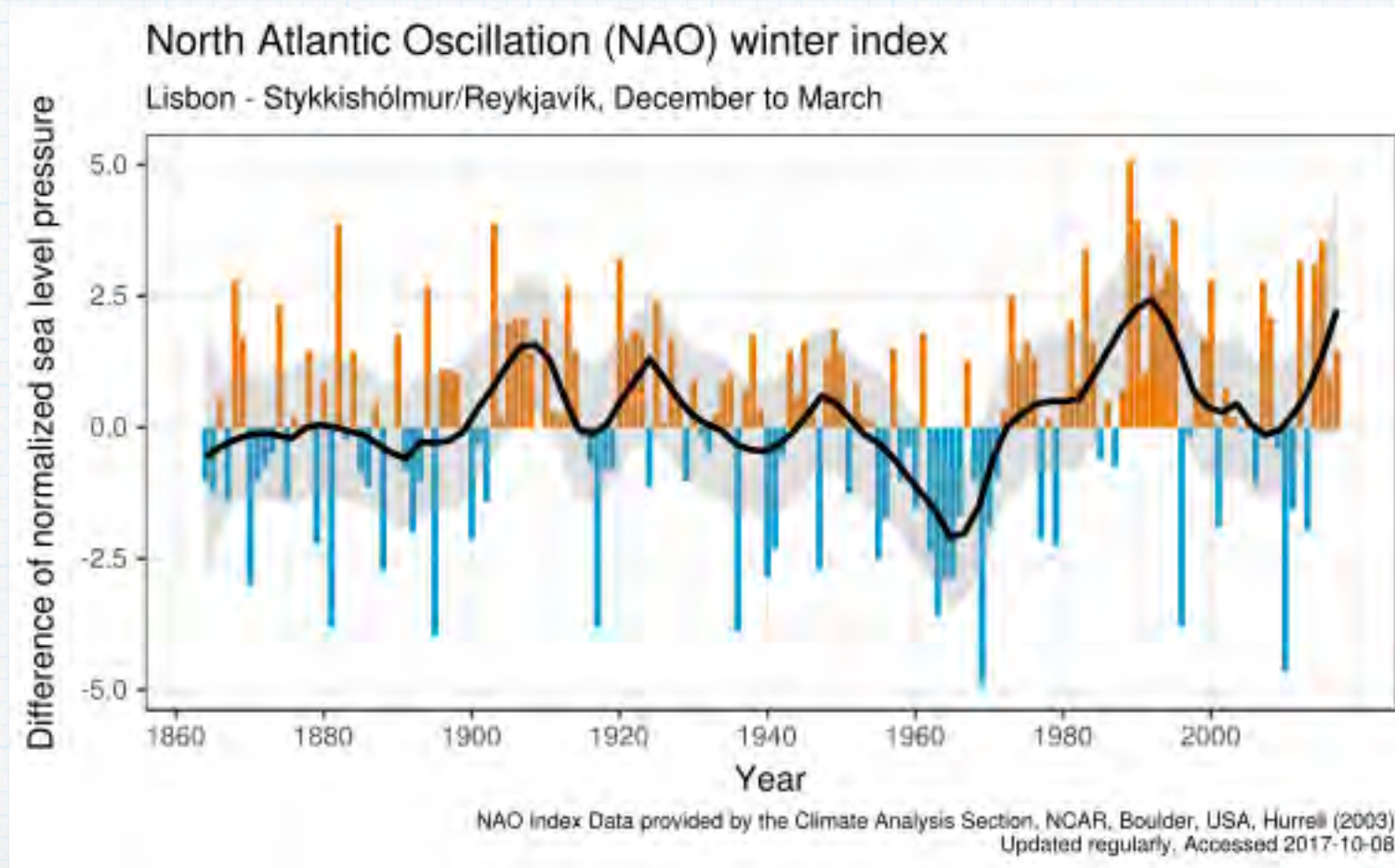
Natural climate modes with interannual to millennial time scales

- **Interannual : 1 year to 10 years**
 - ENSO
- **Decadal : 10 years to multiple decades**
 - **Pacific Decadal Oscillation**
 - **North Atlantic Oscillation**
 - Atlantic Multi-decadal Oscillation
 - **Southern Annular Mode**

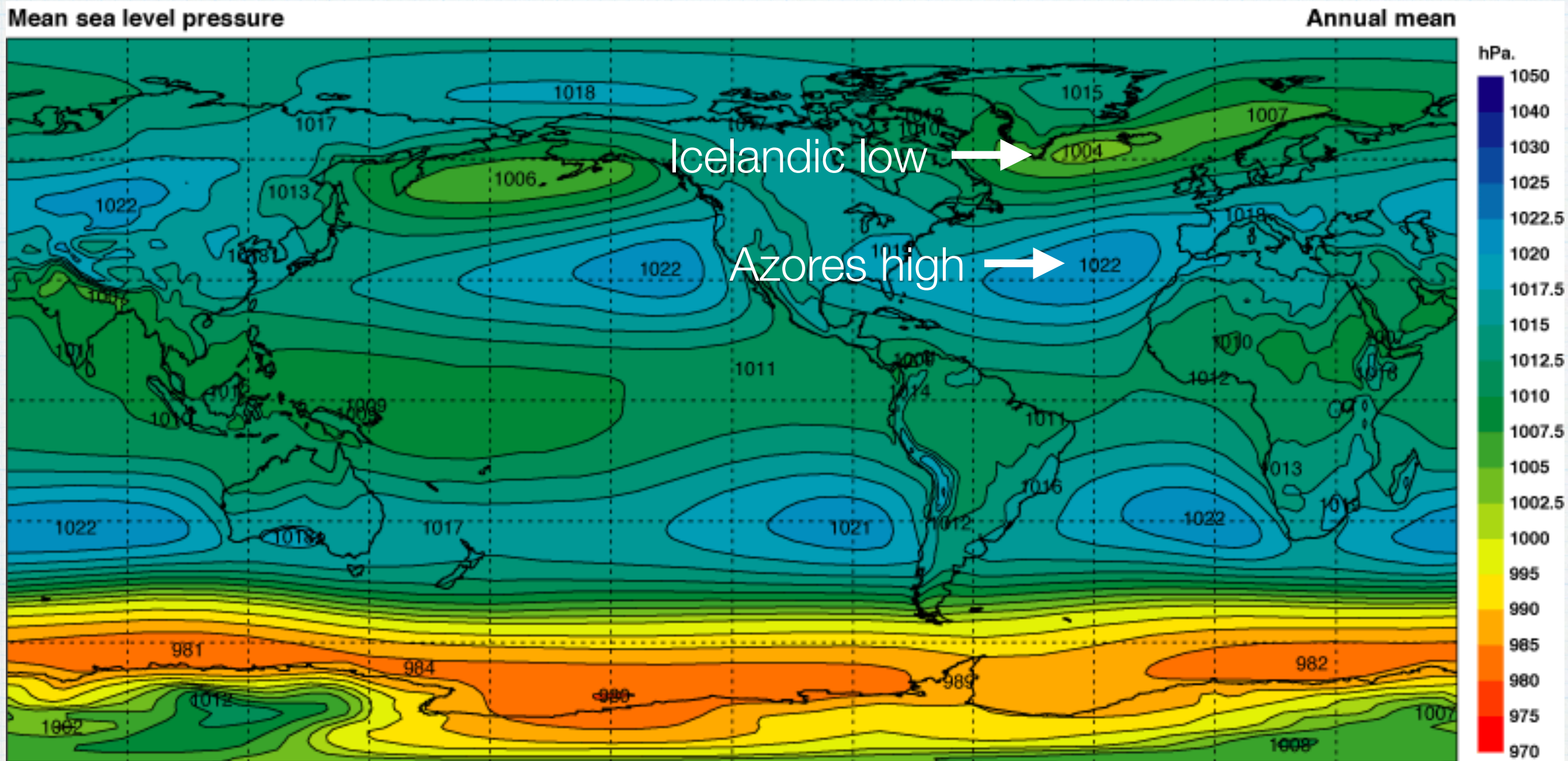
North Atlantic Oscillation (NAO)

- A reversal of sea level pressure over the North Atlantic
- It has an effect on the weather in Europe and along the east coast of North America.

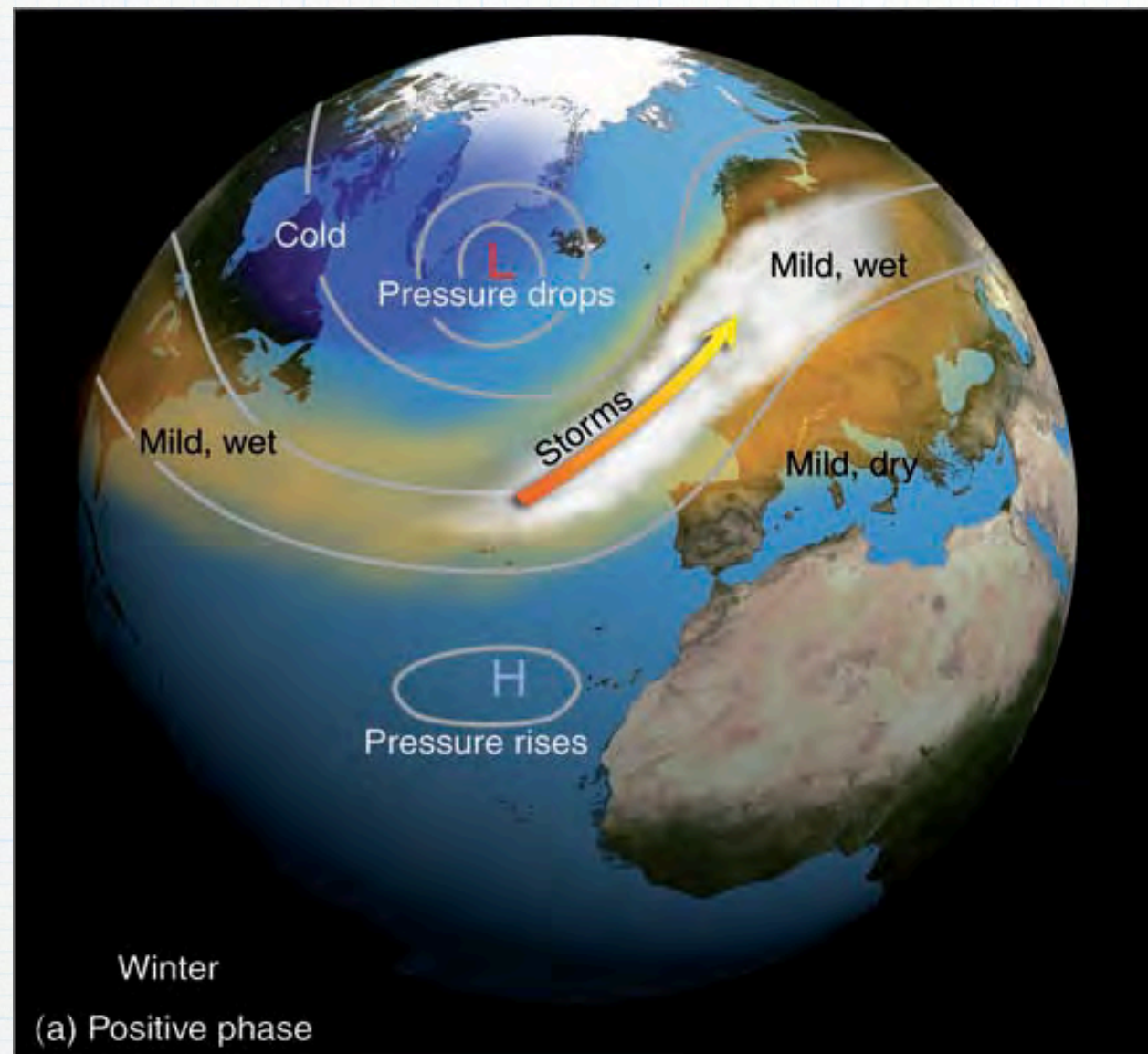
$$\text{SLP}_{\text{Portugal}} - \text{SLP}_{\text{Iceland}}$$



Impact of NAO on the climate



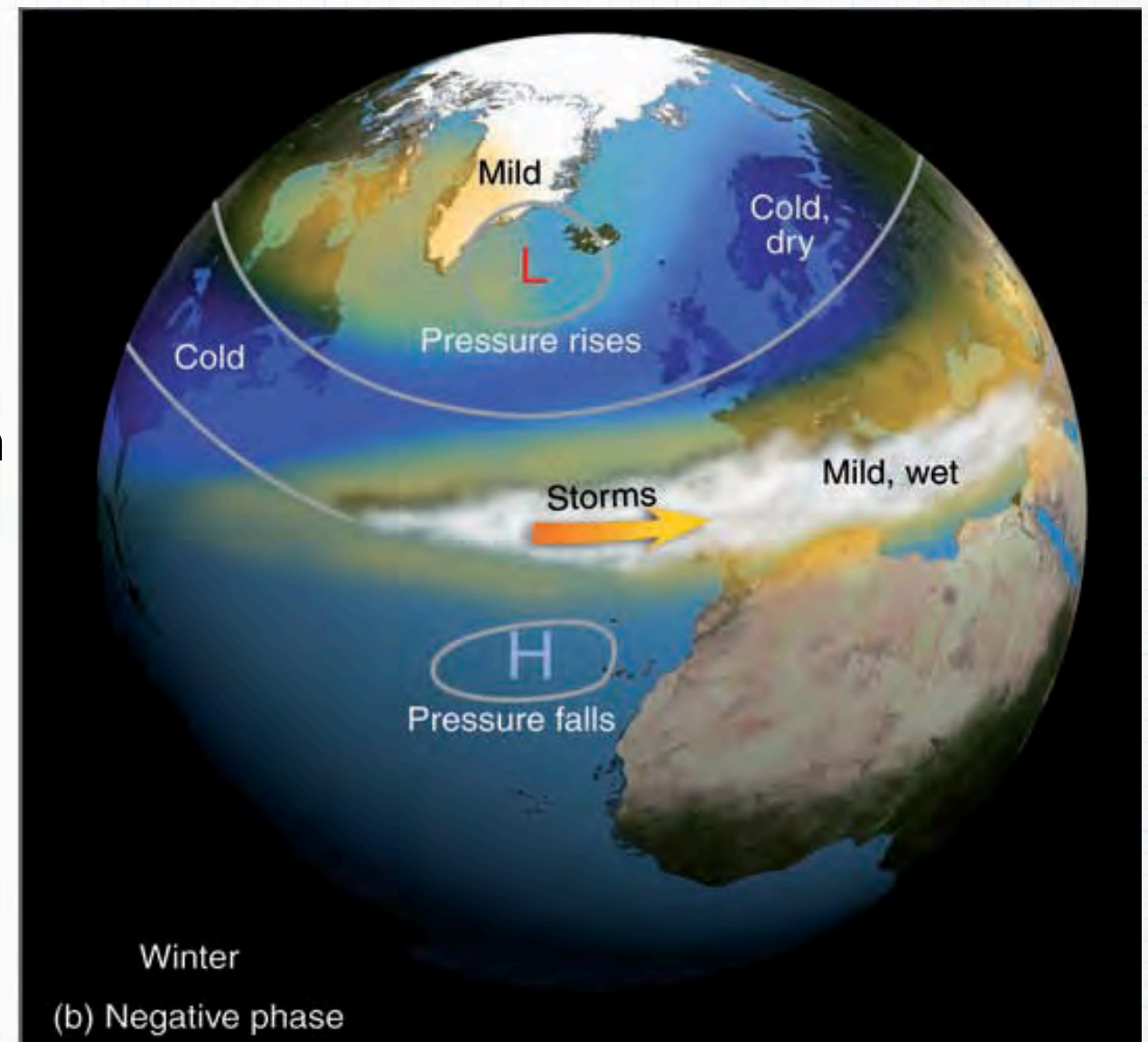
The climate during the positive phase of the NAO



- The pressure gradient increases in north-south direction
- Stronger westerly winds
- The strong westerlies direct strong storms into northern Europe
- Wet and mild climate in the northern Europe
- Wet and mild climate in the eastern US, but cold and dry in the northern Canada and Greenland

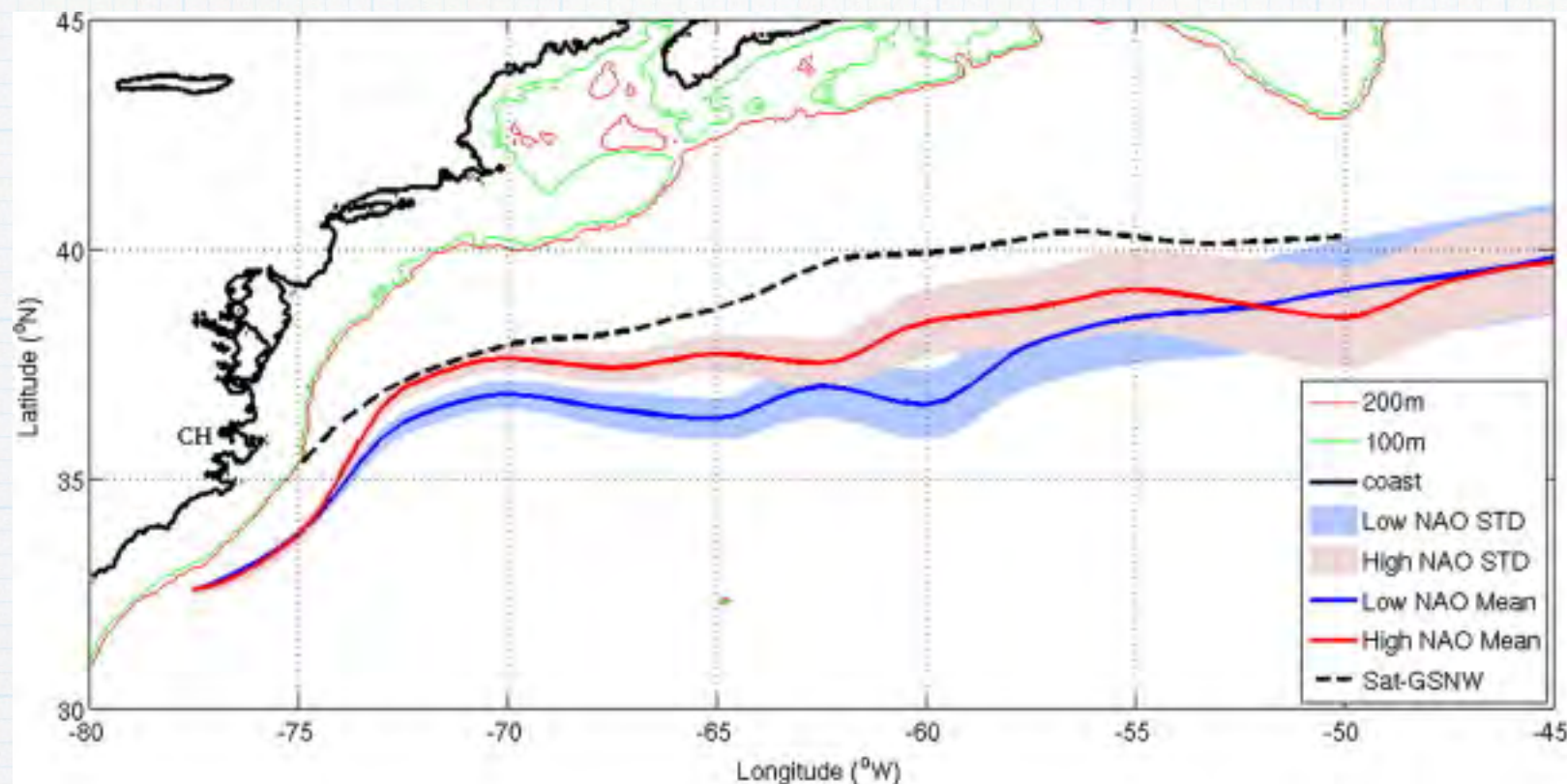
The climate during the negative phase of the NAO

- The Icelandic low rises while pressure drops near the Azores high.
- The reduced pressure gradient
- Weaker westerlies
- Fewer and weaker winter storms travel the more west-east direction.
- Wet and mild climate in the southern Europe and in the Mediterranean Sea.
- The winters in Northern Europe are usually cold and dry.
- The winters long the east coast of North America are also cold and dry.



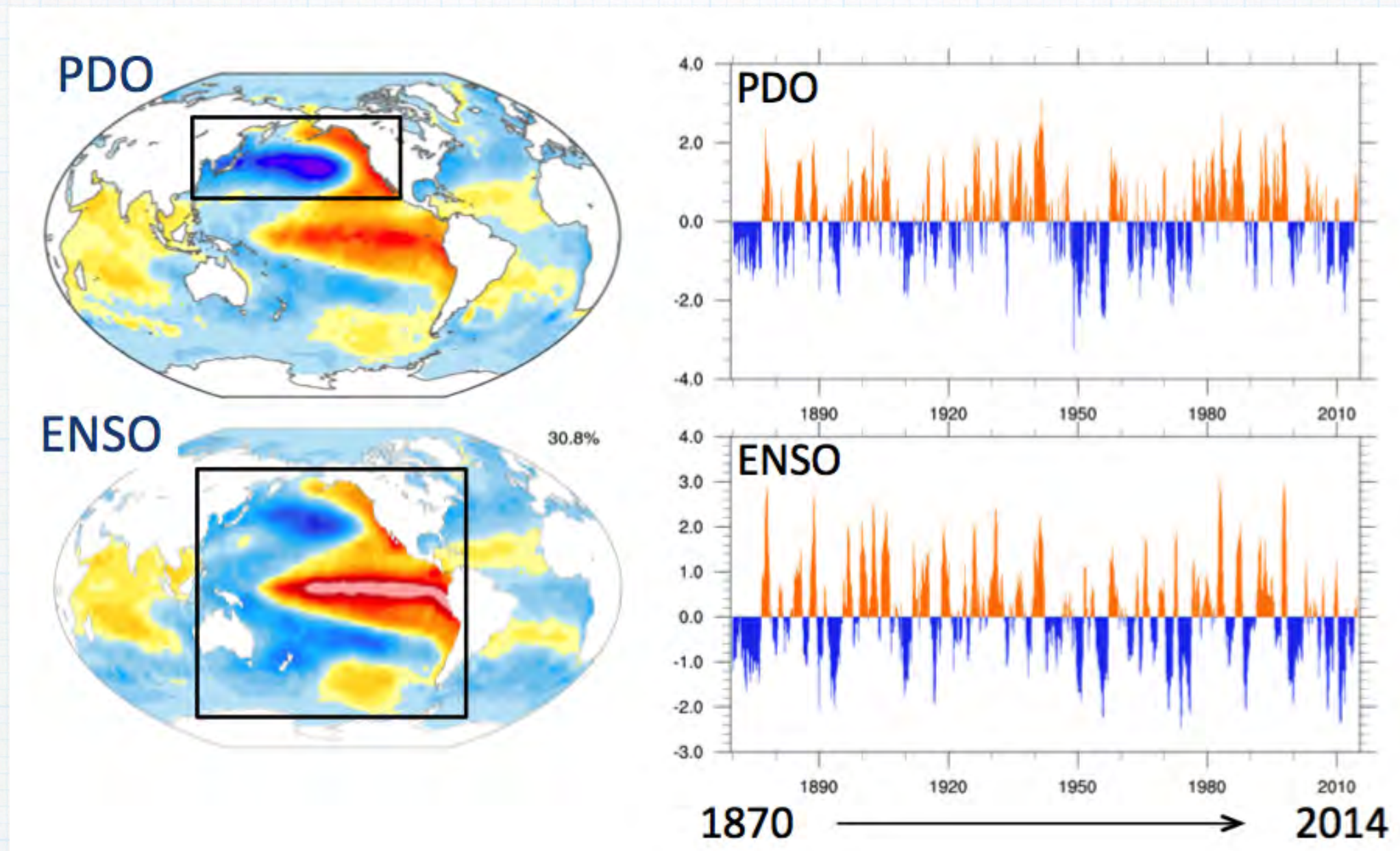
NAO and the ocean

- Positive NAO
 - Stronger SST gradient
 - The Gulf Stream tends to be stronger and closer to the coast
- Negative NAO
 - Weaker SST gradient
 - The Gulf Stream follows a more southerly track.



Pacific Decadal Oscillation

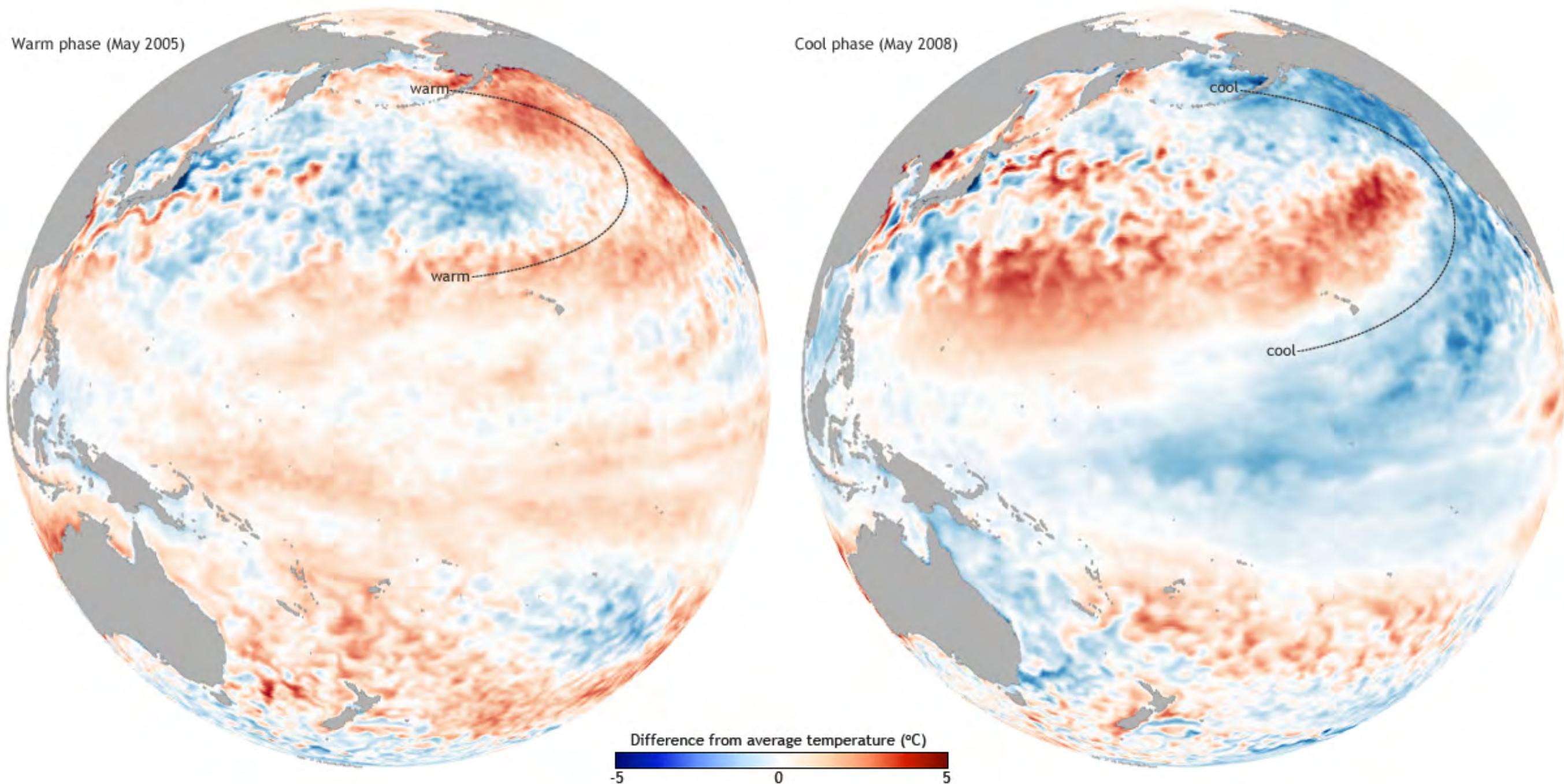
- A variability with a period of about 20 years in the North Pacific



Pacific Decadal Oscillation

Warm phase

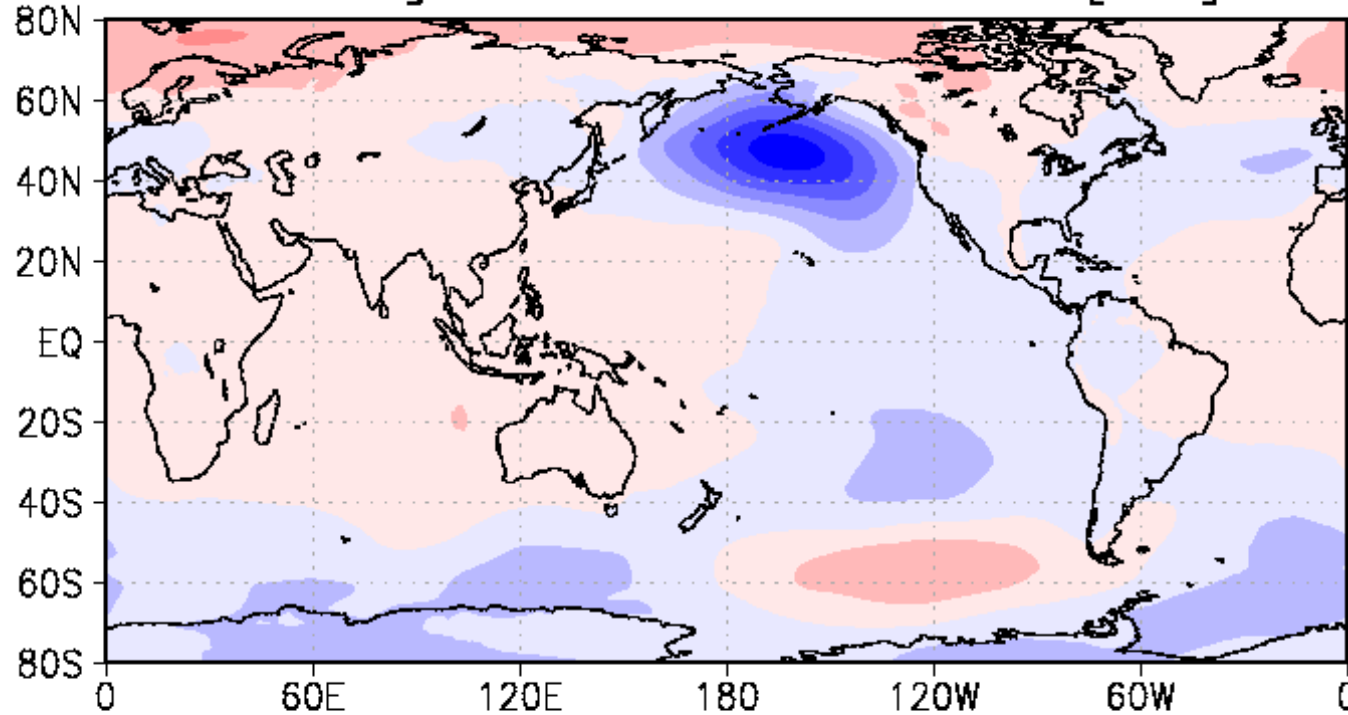
Cold phase



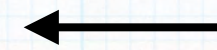
From https://www.climate.gov/sites/default/files/HR_PD02005-2008.jpg

PDO and air-sea interaction

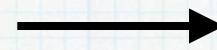
SLP regressed on the PDO index [hPa]



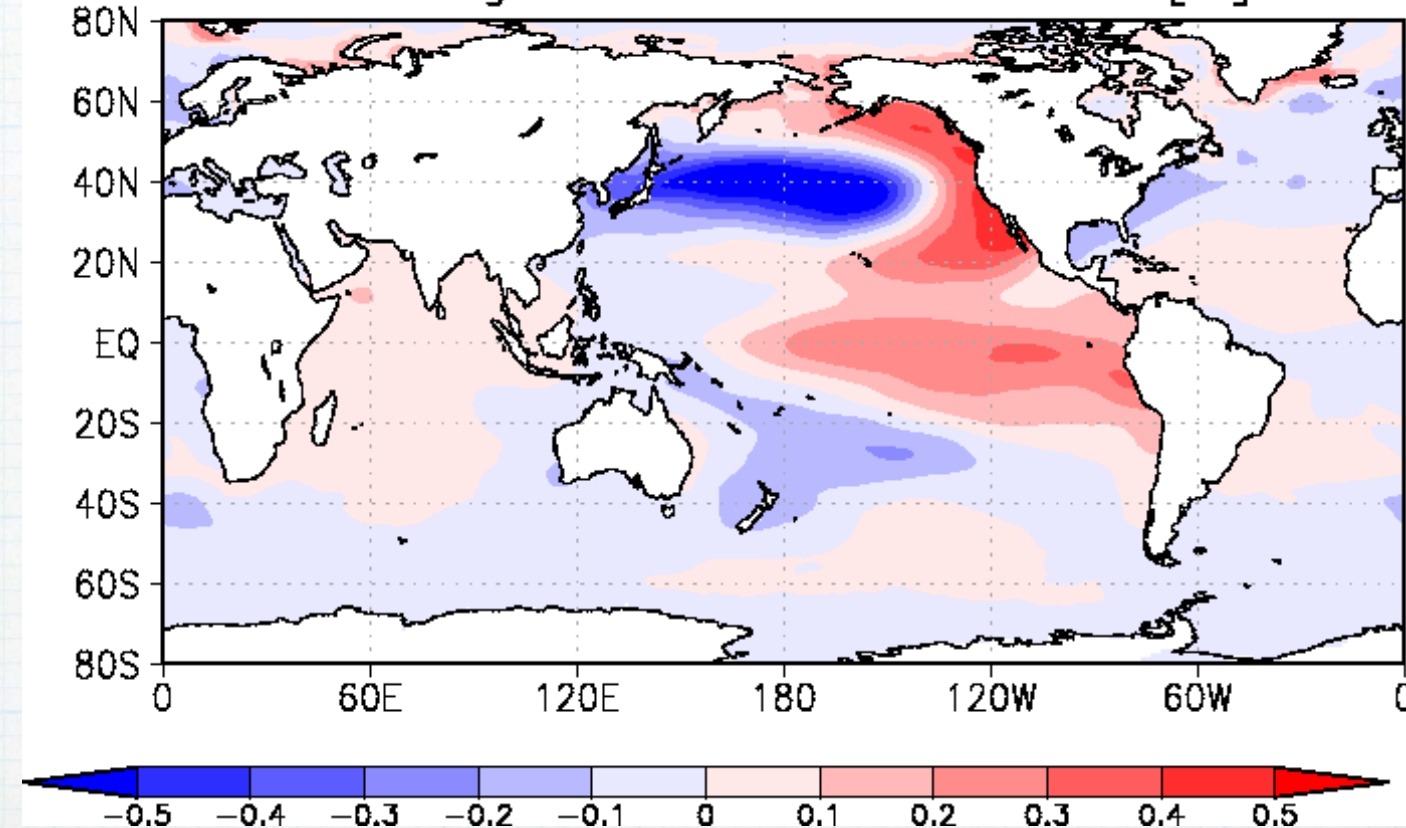
Sea level pressure
anomaly in the warm
phase of PDO



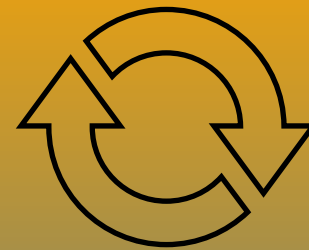
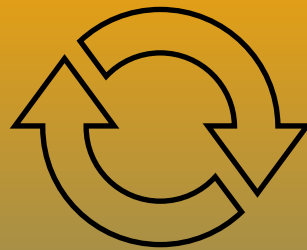
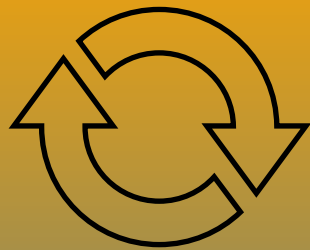
Sea surface temperature
anomaly in the warm
phase of PDO



SST regressed on the PDO index [°C]

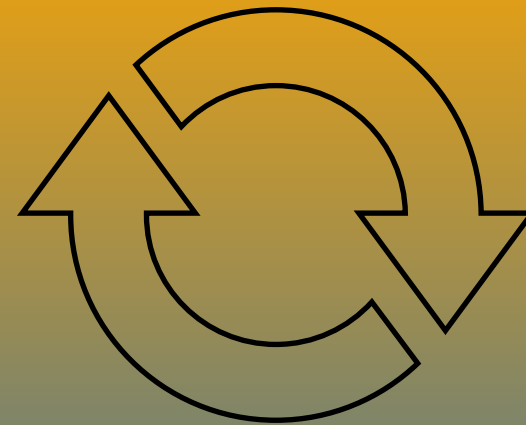
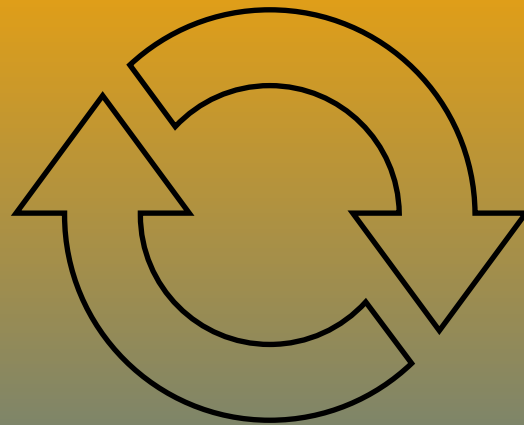
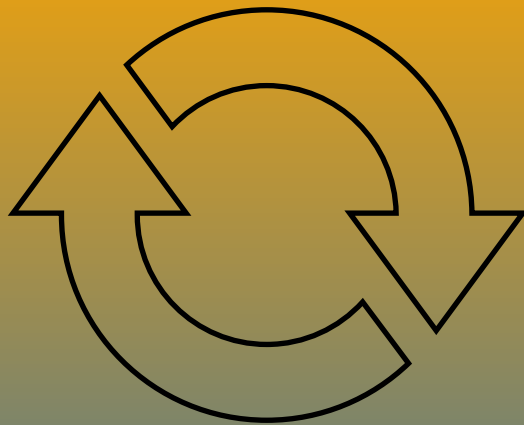
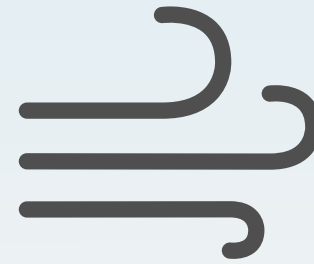
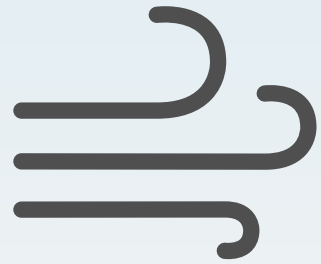


wind-SST in large scale



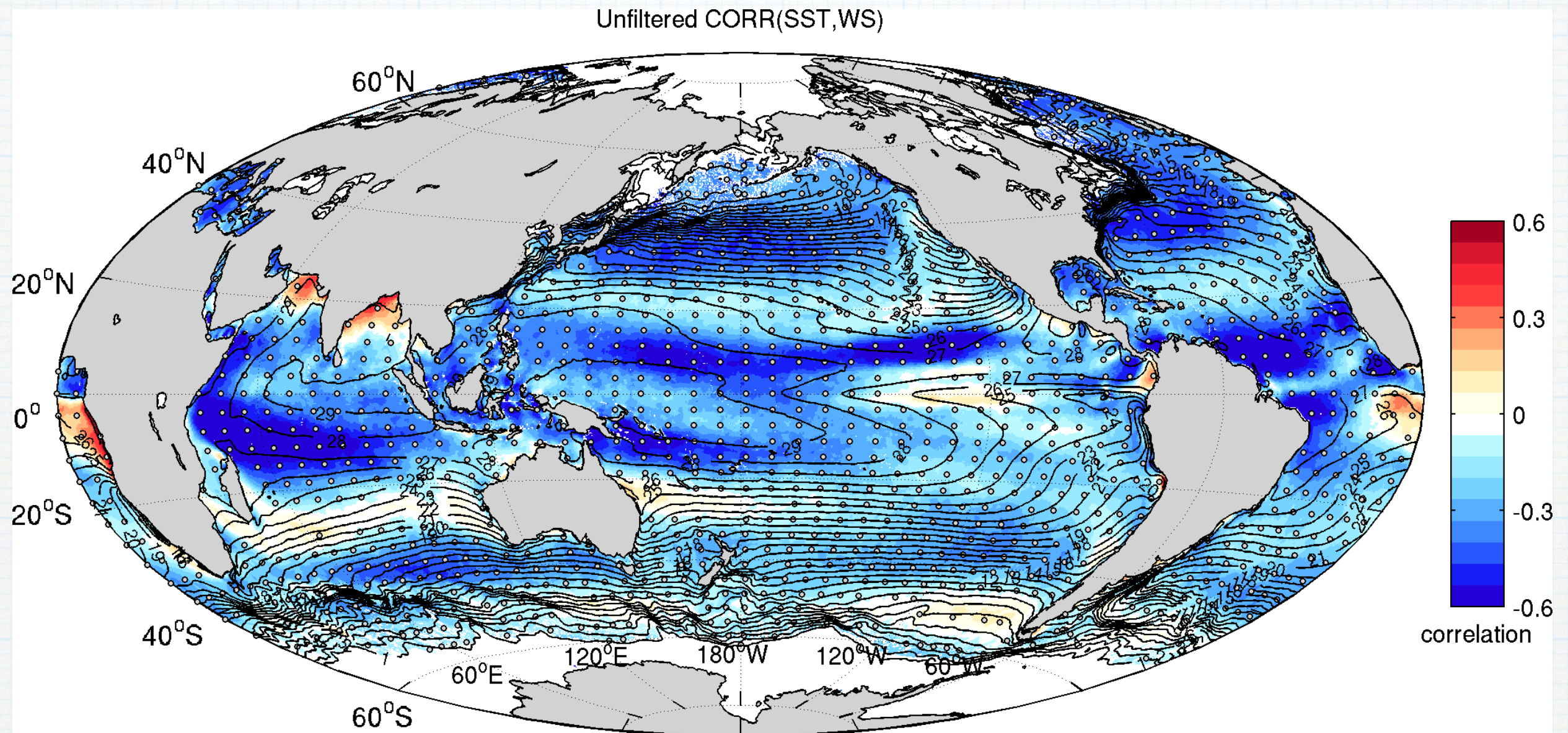
MIXING

wind-SST in large scale



MORE MIXING

Correlation between wind speed and SST



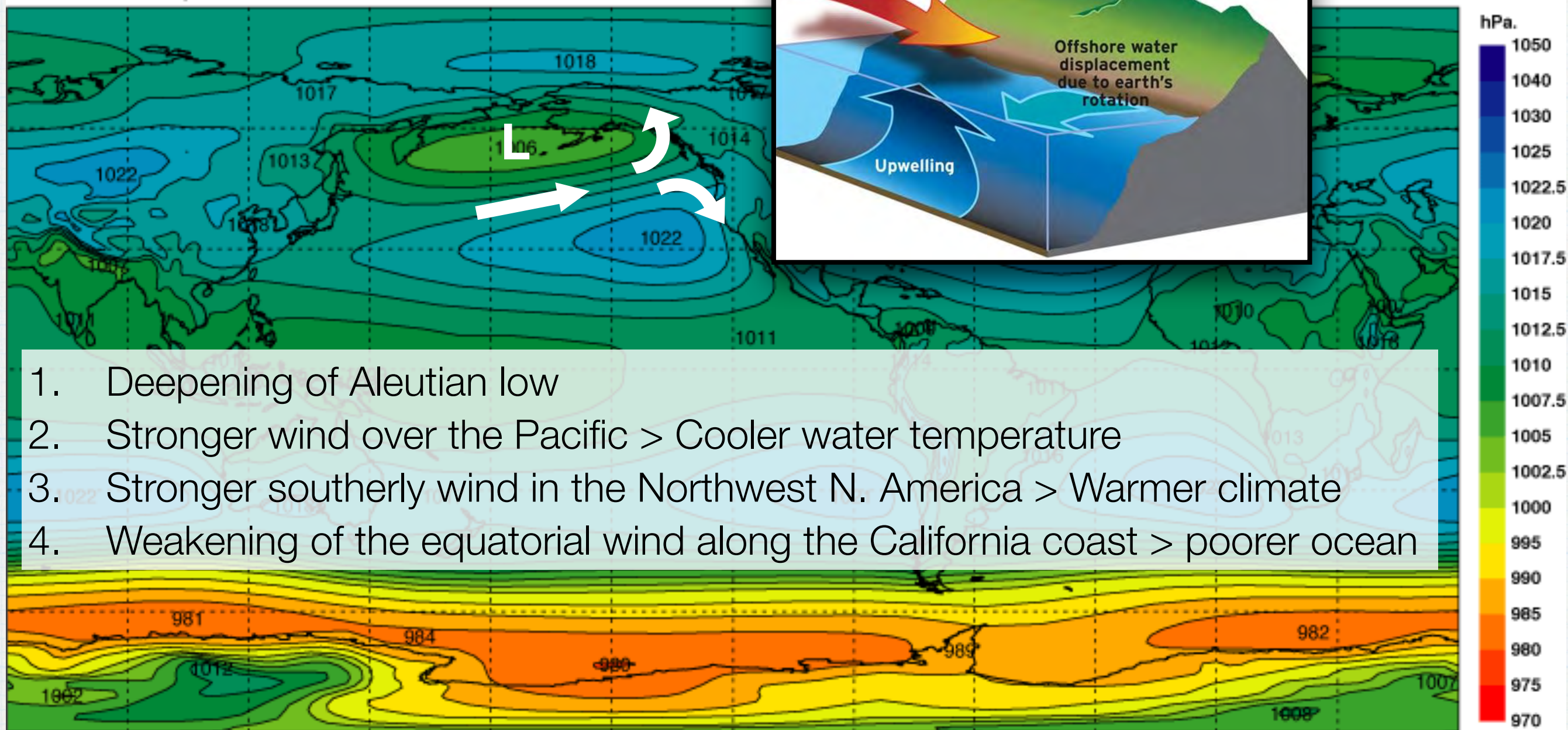
Oceanic response to the atmosphere

2000-2009 satellite wind and SST data

A credit to Dr. Hyodae Seo (WHOI)

Impact of a warm phase of PDO on climate

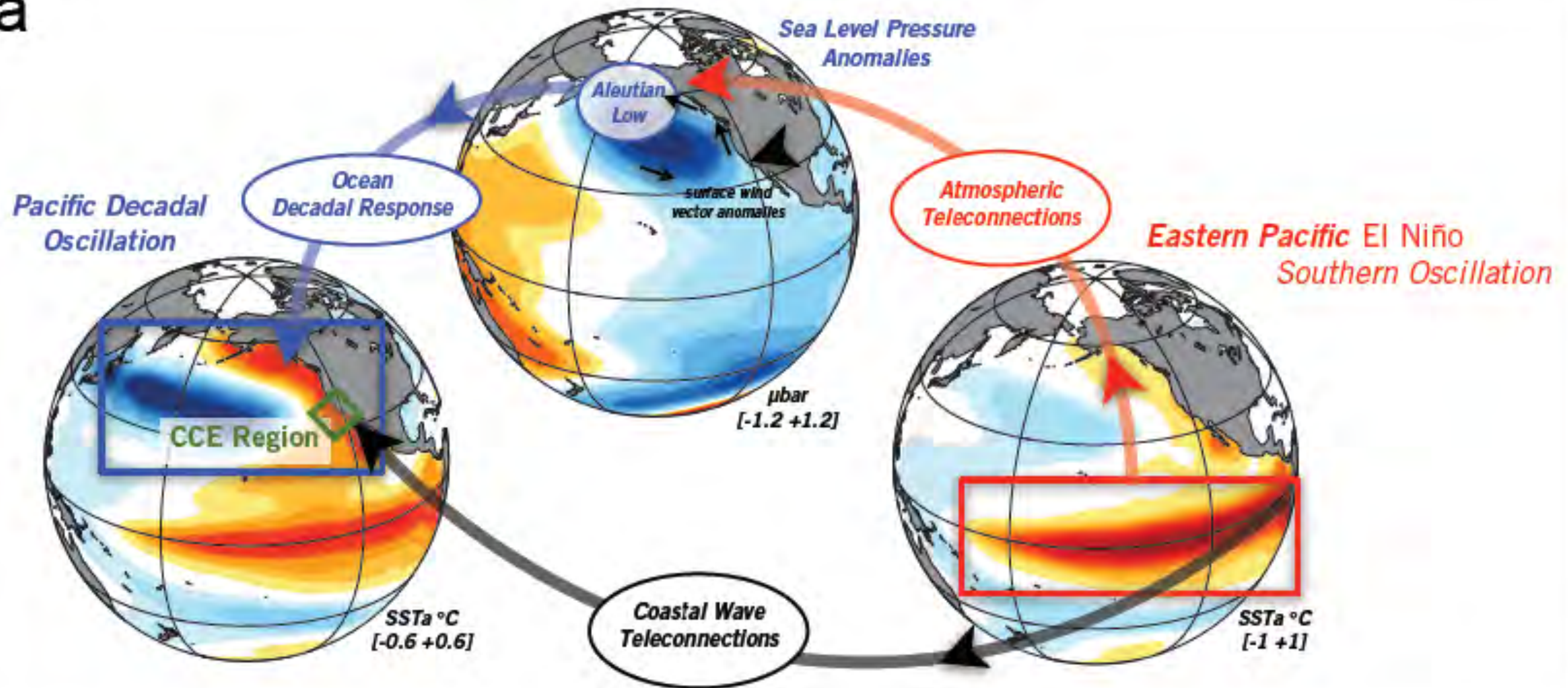
Mean sea level pressure



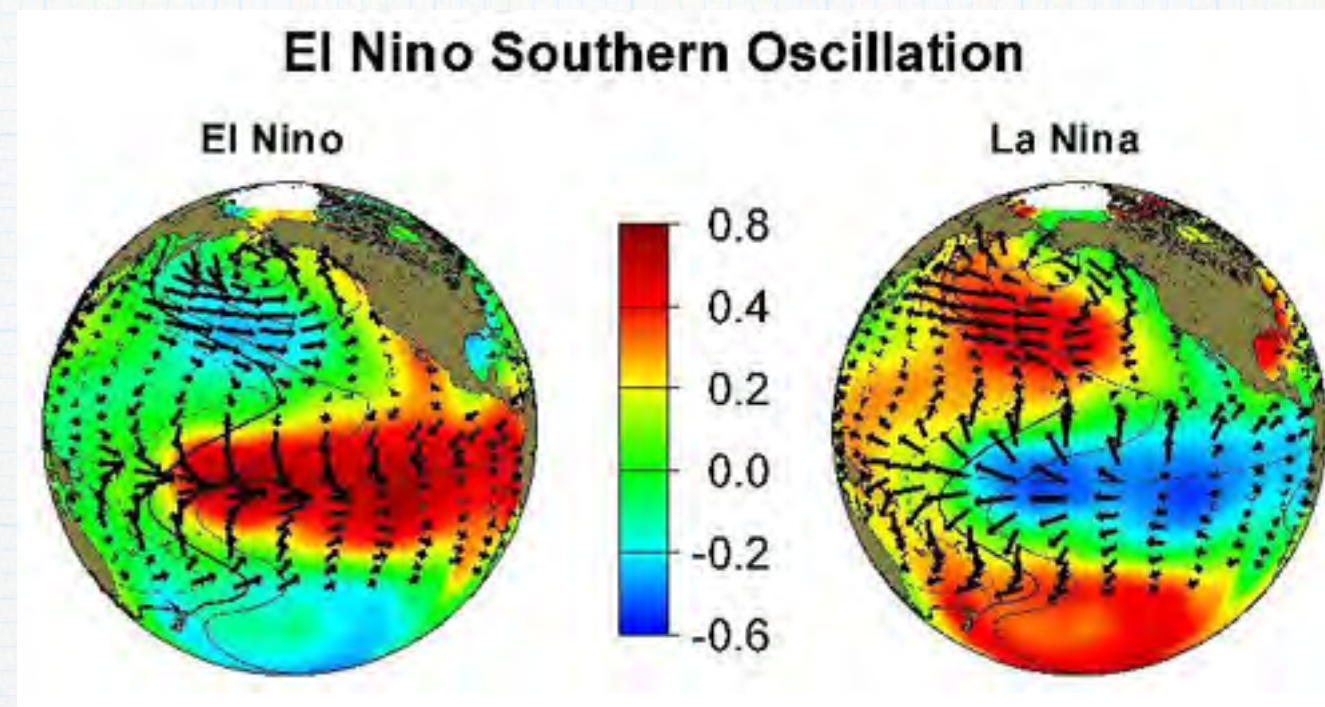
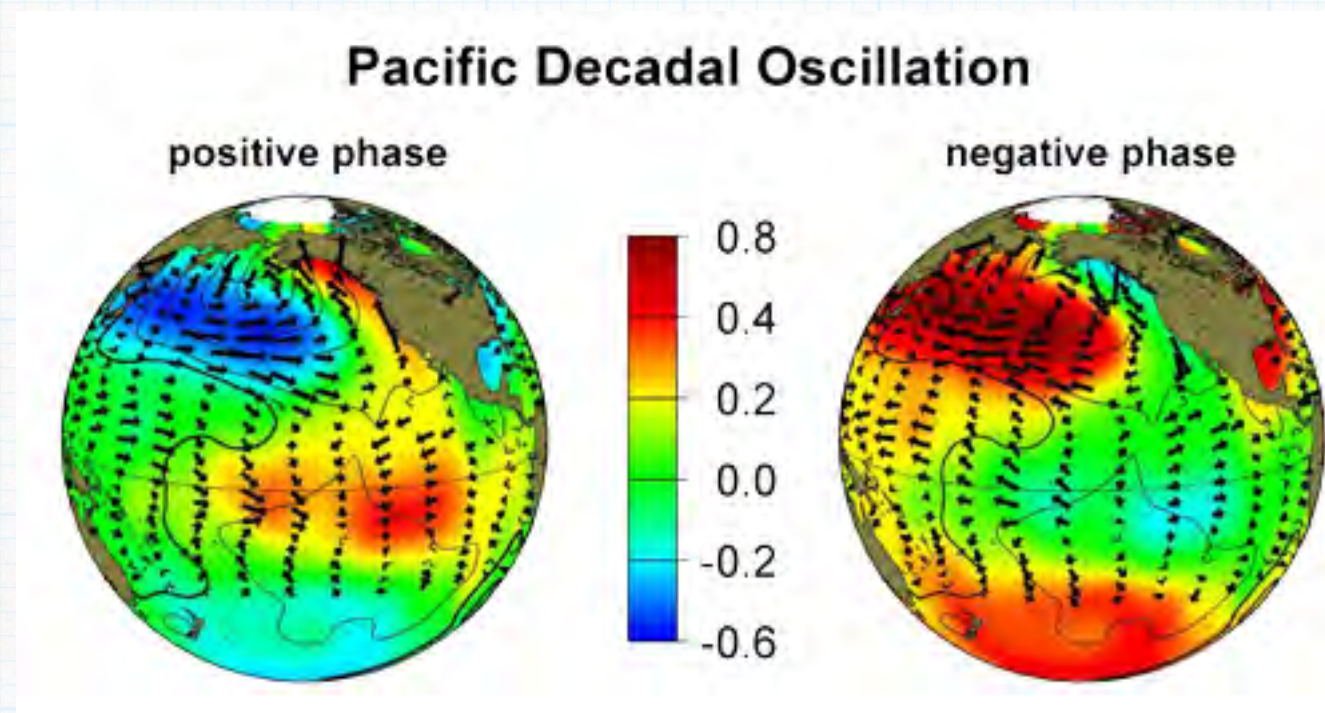
1. Deepening of Aleutian low
2. Stronger wind over the Pacific > Cooler water temperature
3. Stronger southerly wind in the Northwest N. America > Warmer climate
4. Weakening of the equatorial wind along the California coast > poorer ocean

Teleconnection

a

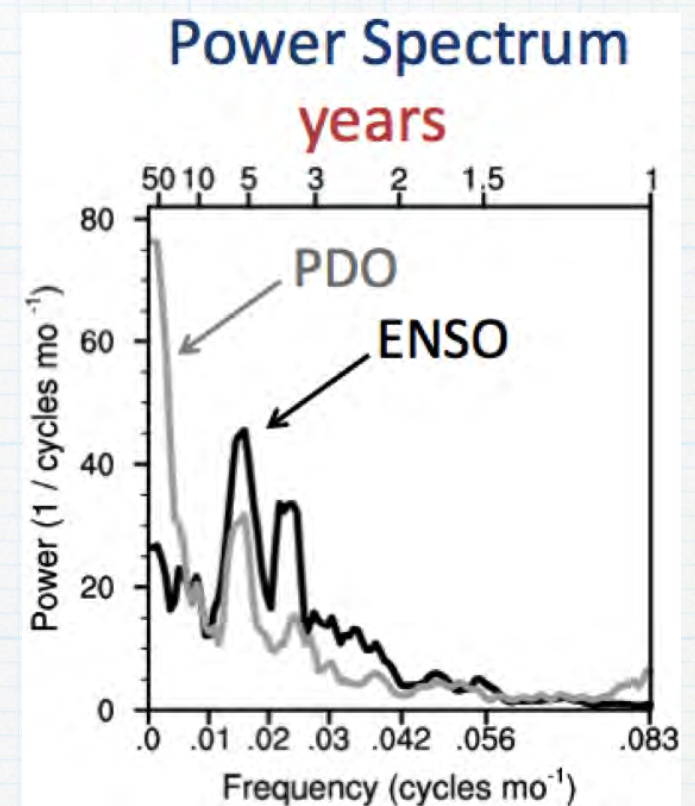


PDO v.s. ENSO



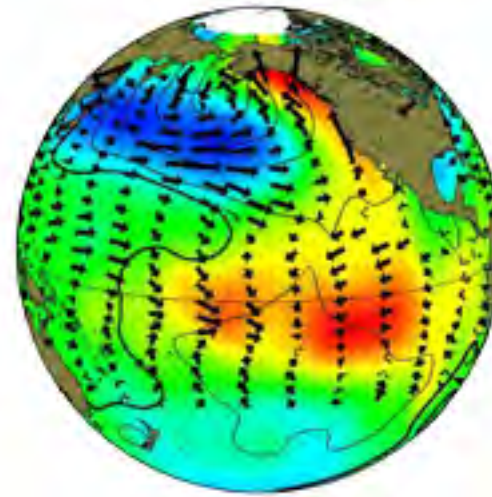
PDO v.s. ENSO

- Time scale
 - PDO events persist for 20 to 30 years
 - ENSO events persist for 6 to 18 months
- The climate fingerprints
 - PDO in the North Pacific / North American sector
 - ENSO in the tropics

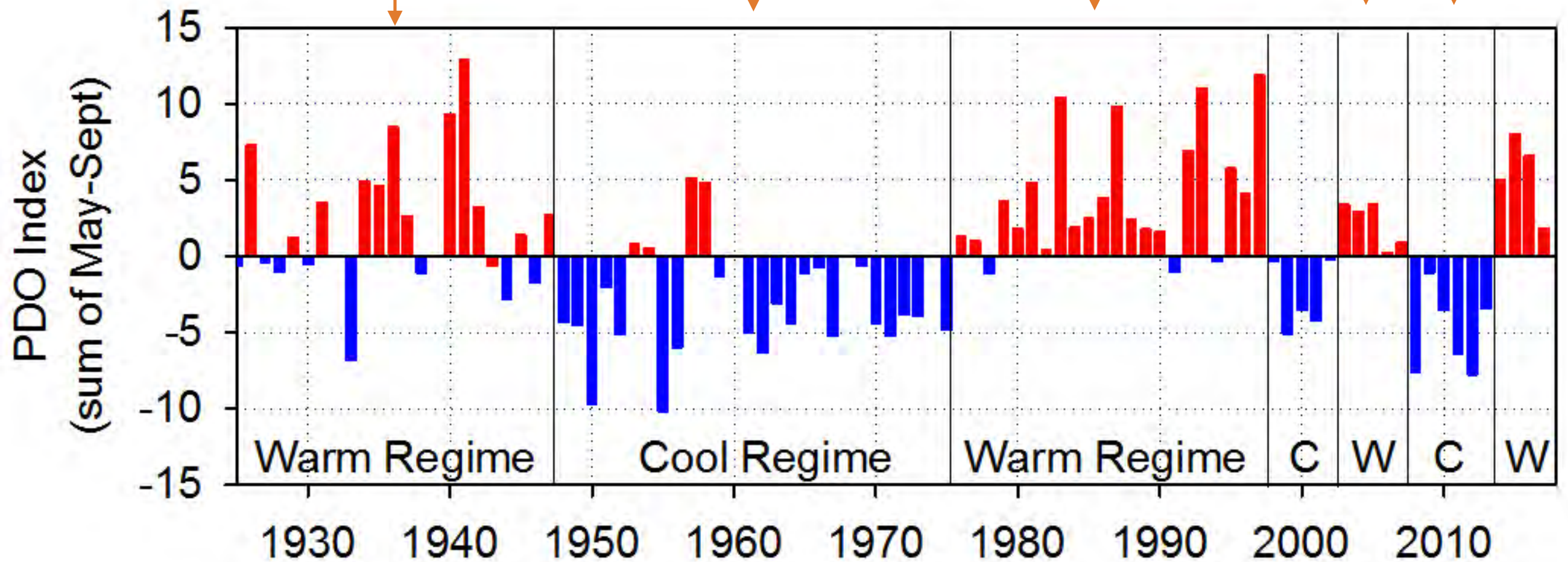
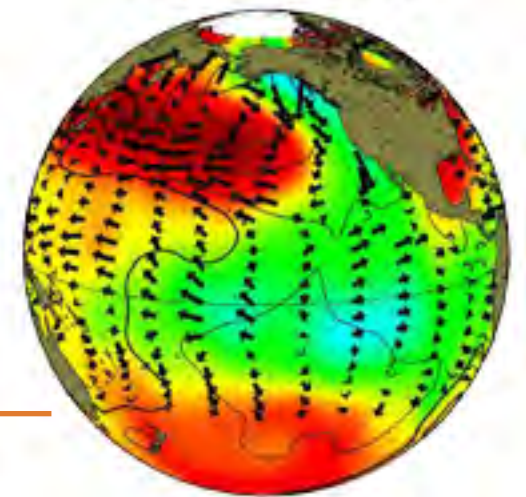


PDO index

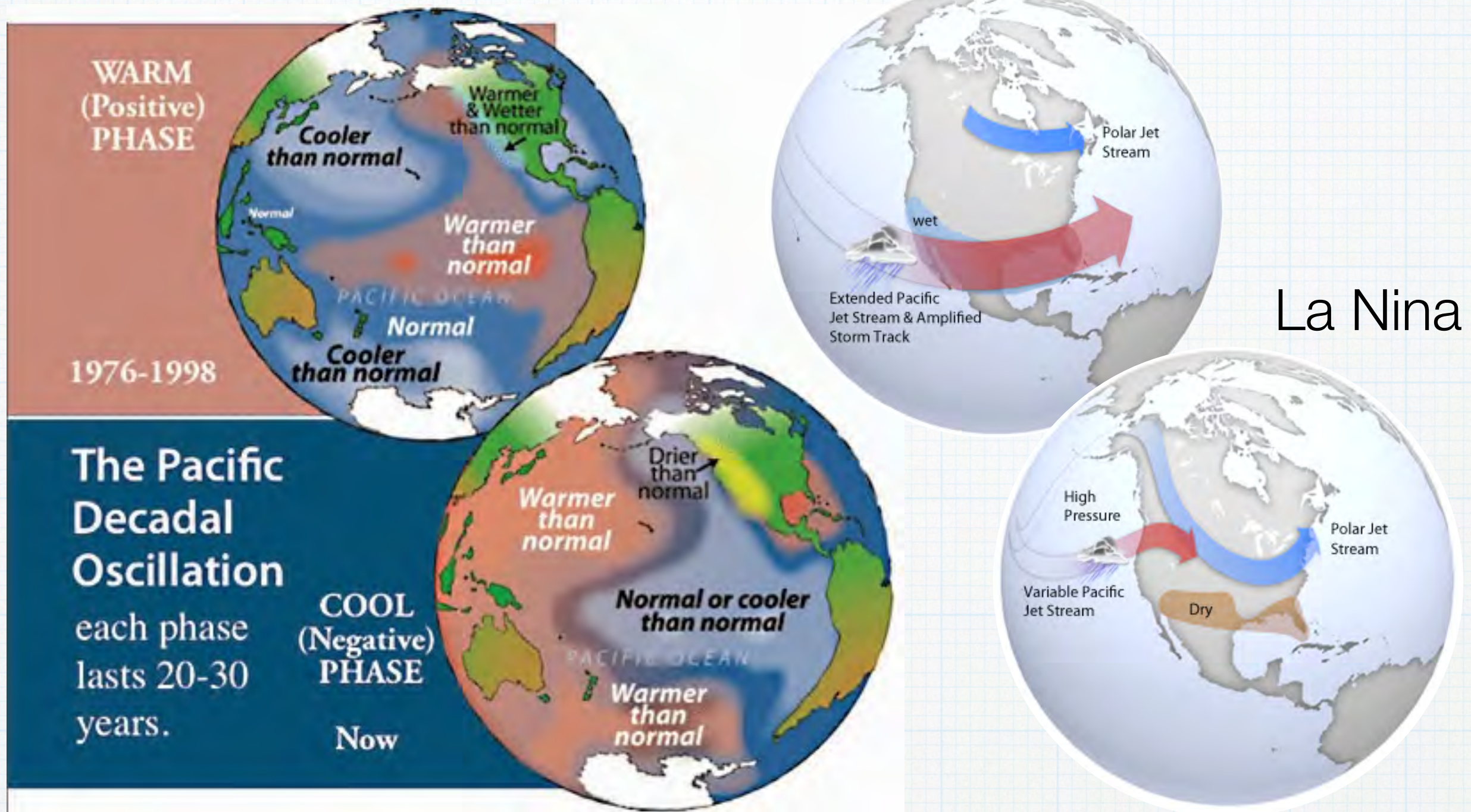
positive phase



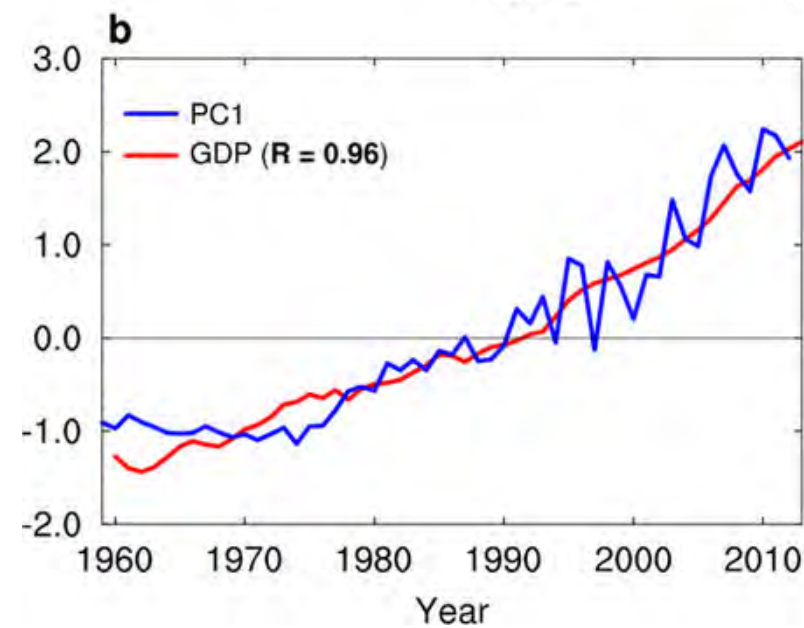
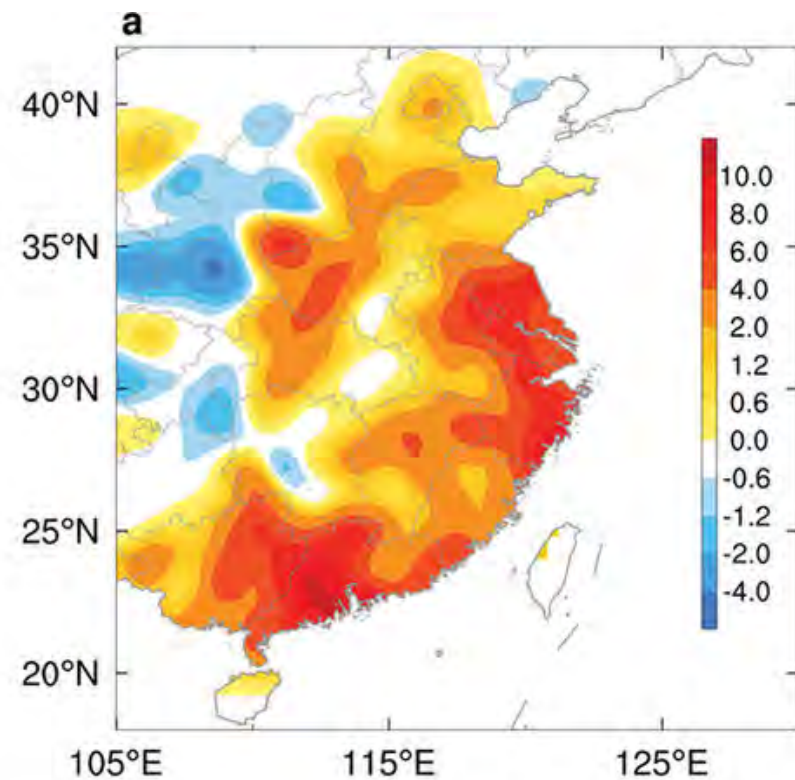
negative phase



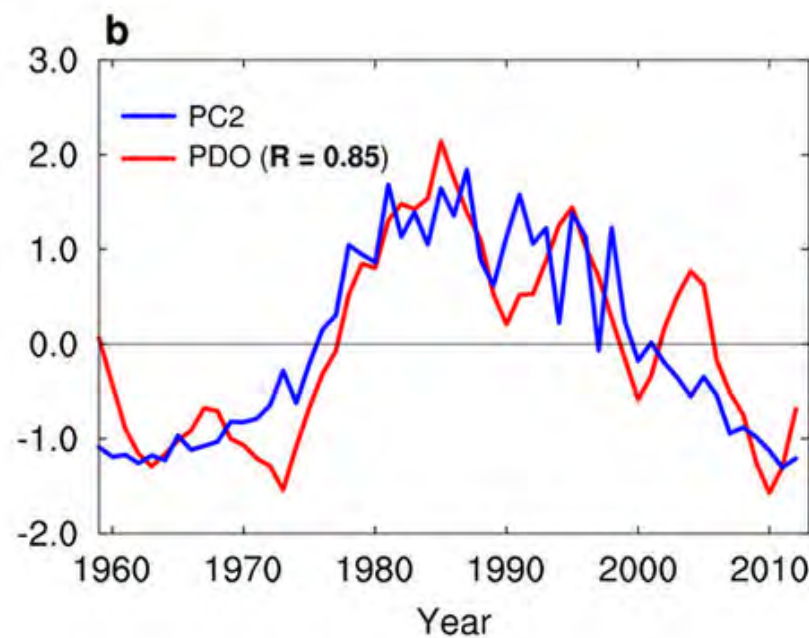
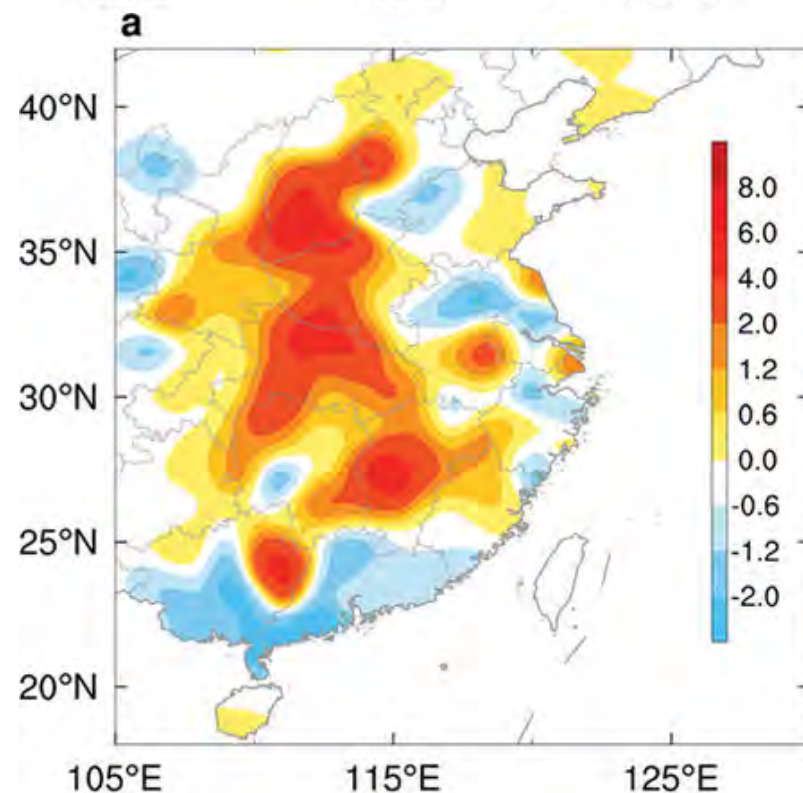
Impact of PDO on climate



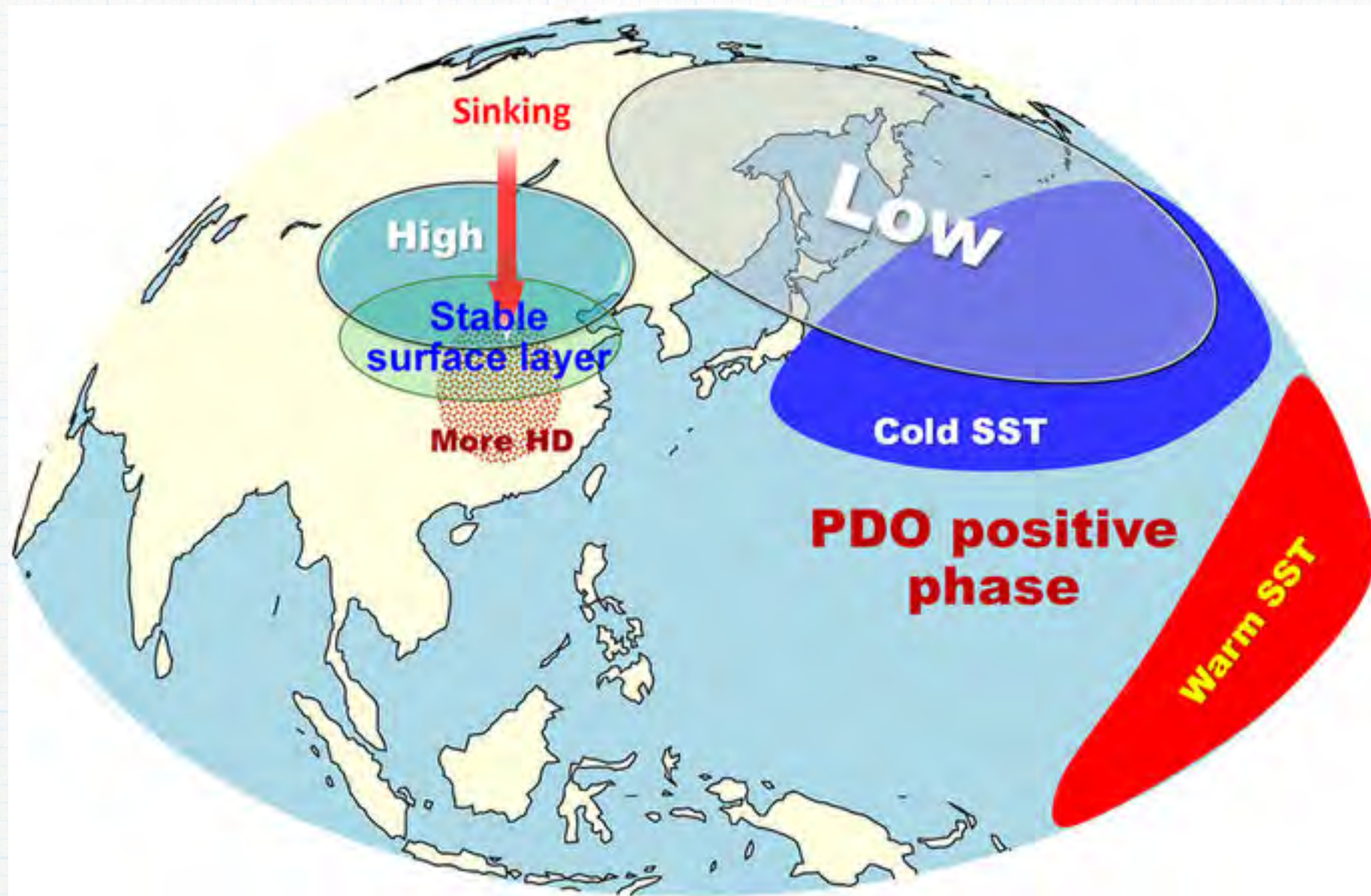
Impact of PDO on the climate of east Asia



Haze day

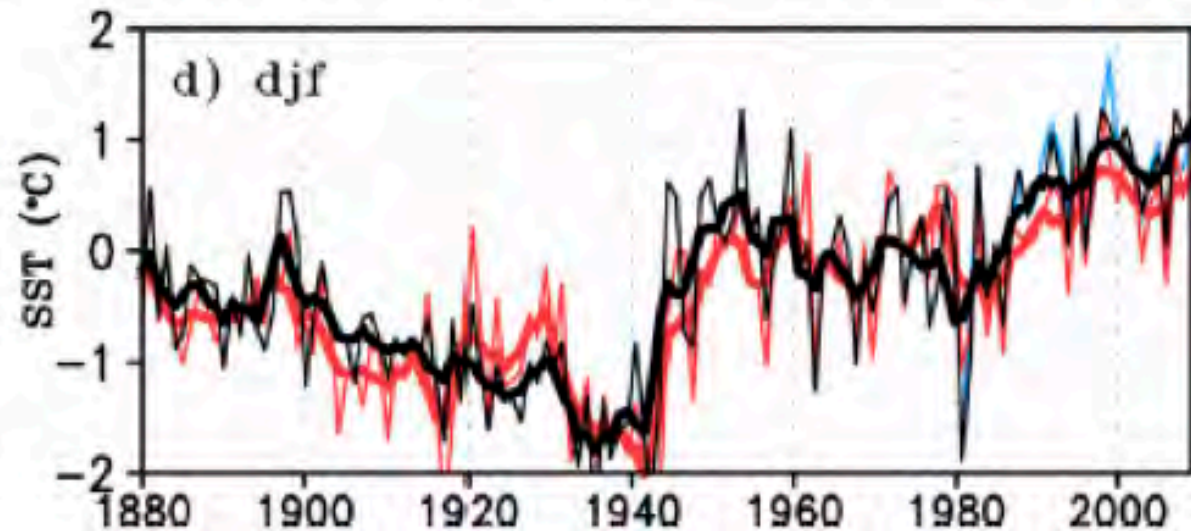


Impact of PDO on the climate of east Asia

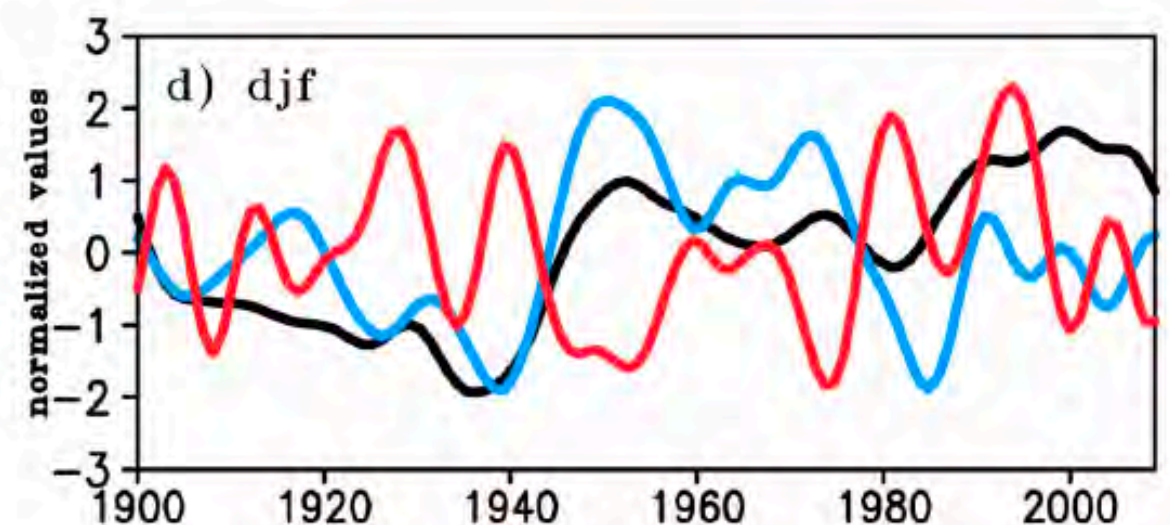
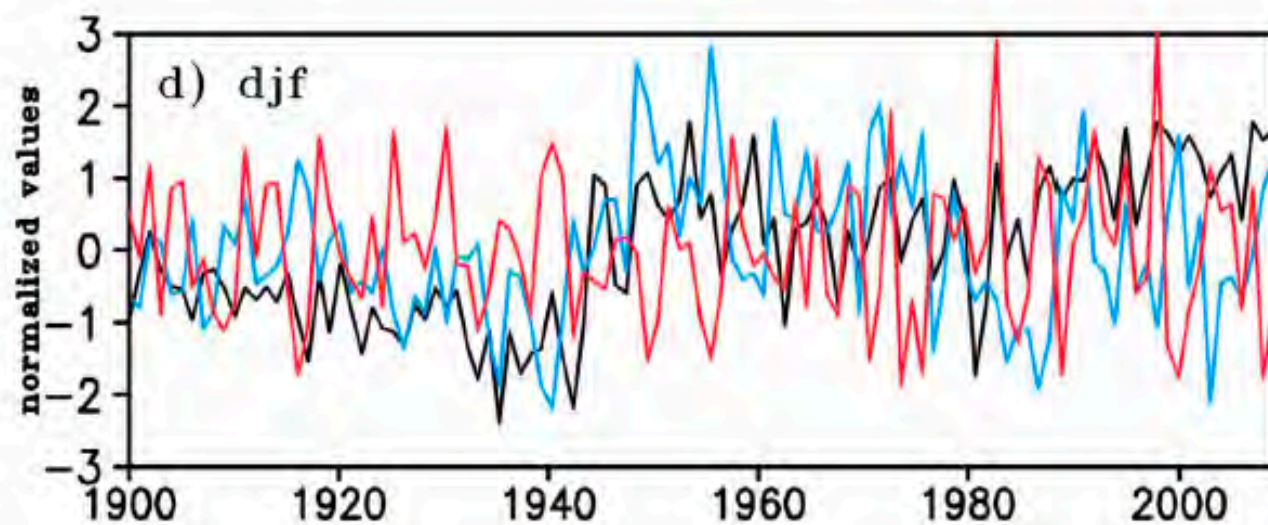


Impact of PDO on the climate of east Asia

Sea surface temperature near the Korean Peninsula



- Black : SST anomaly
- Blue : $-1 \times (\text{PDO index})$
- Red : ENSO index



Southern Annular Mode (SAM) or Antarctic Oscillation

- A low frequency mode of atmospheric variability
- Expressed as the north-south movement of the westerly winds
- As the westerly winds change the location, so does the storm track and precipitation
- Two phases : A positive or a negative phase
- Southern Annular Mode (SAM) can last several weeks, but changes phases quickly and unpredictably.

Southern Annular Mode (SAM) or Antarctic Oscillation

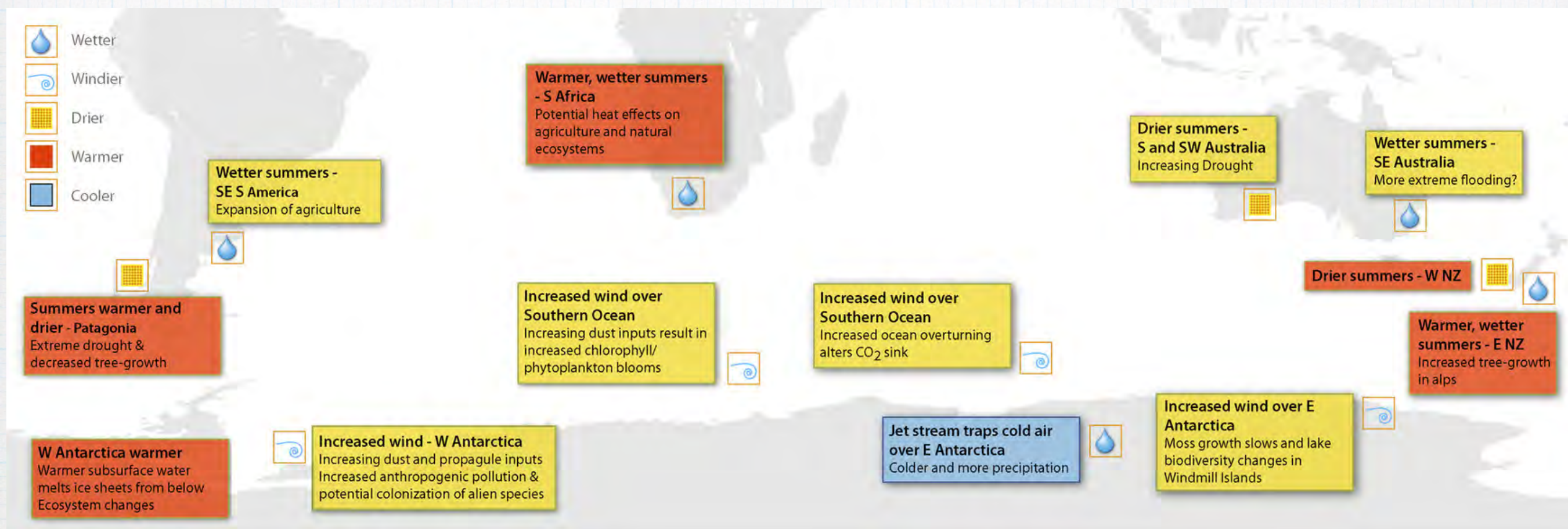
- The index of SAM is defined as the difference of zonally-averaged sea-level pressure between the latitude of 40°S and 65°S
- A negative SAM phase (less pressure difference) has an equatorward shift of the westerly winds.
 - More storm activities over Australia and New Zealand.
 - Decreases in temperature there
- During a positive SAM phase (greater pressure difference), strong westerly winds shift towards Antarctica.
 - Less rain over Australia and New Zealand
 - Warmer weather there

The impact of SAM on the weather



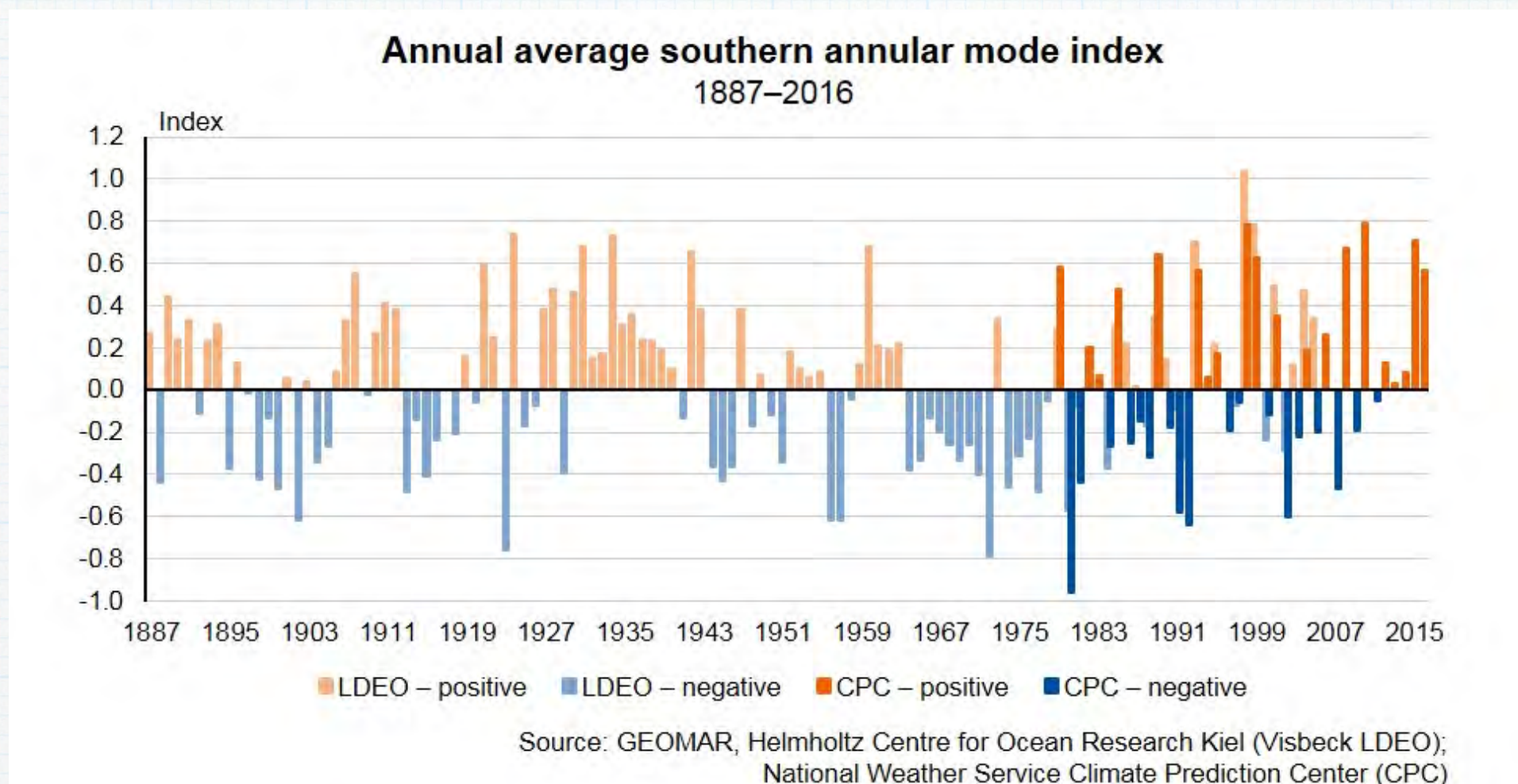
SAM

The impact of SAM on the weather



Southern Annular Mode

- SAM values can vary widely over time periods of weeks or months.
- The Southern Annular Mode (SAM) has been increasing (becoming more positive) since 1970.



From http://archive.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Atmosphere-and-climate/southern-annular-mode.aspx

Southern Annular Mode

