

# Air-sea interaction: #2

## Natural climate variability



# Natural climate modes with interannual to millennial time scales

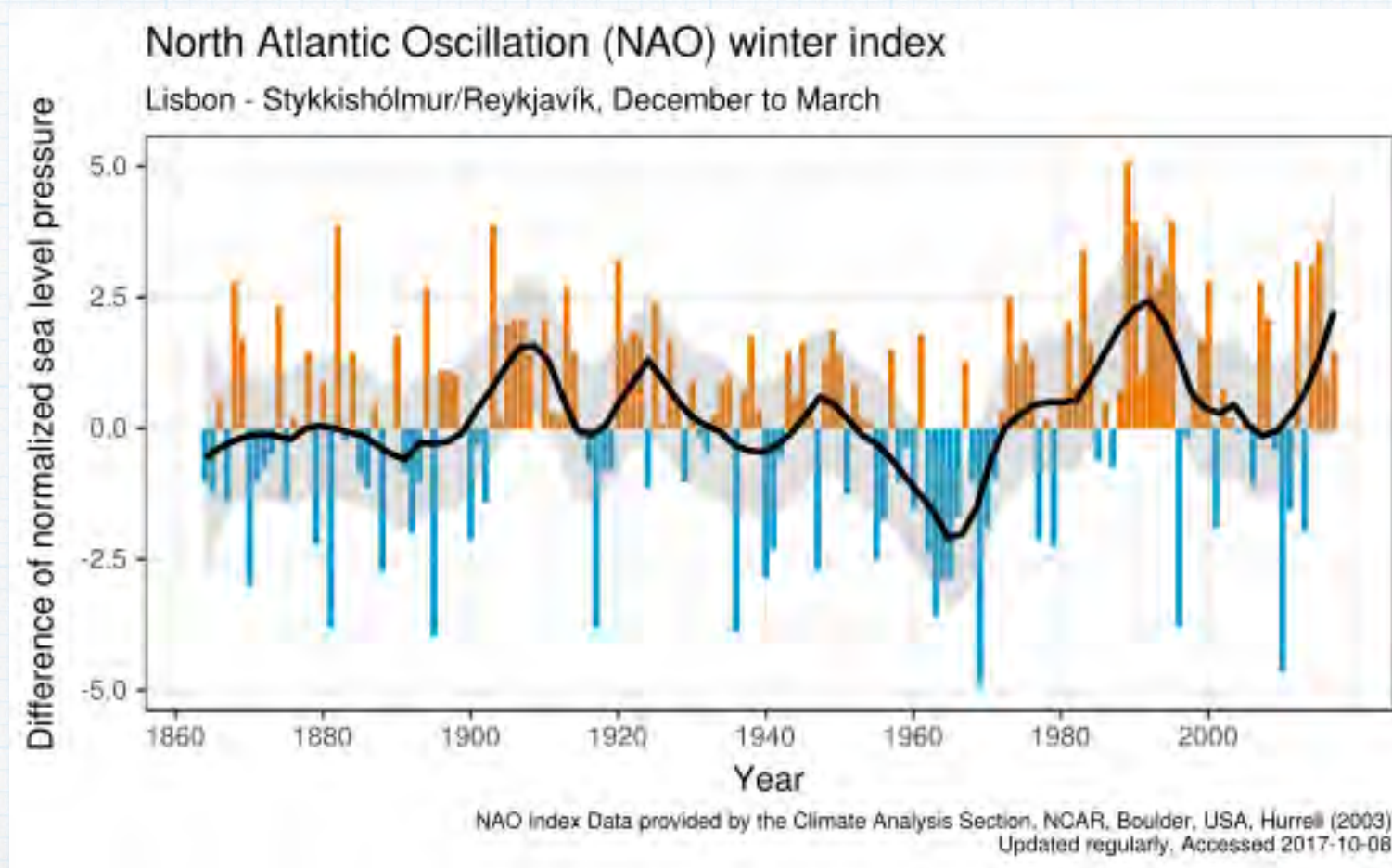
- **Interannual : 1 year to 10 years**
  - ENSO
- **Decadal : 10 years to multiple decades**
  - **Pacific Decadal Oscillation**
  - **North Atlantic Oscillation**
  - Atlantic Multi-decadal Oscillation
  - **Southern Annular Mode**



# 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.

$SLP_{\text{Portugal}} - SLP_{\text{Iceland}}$

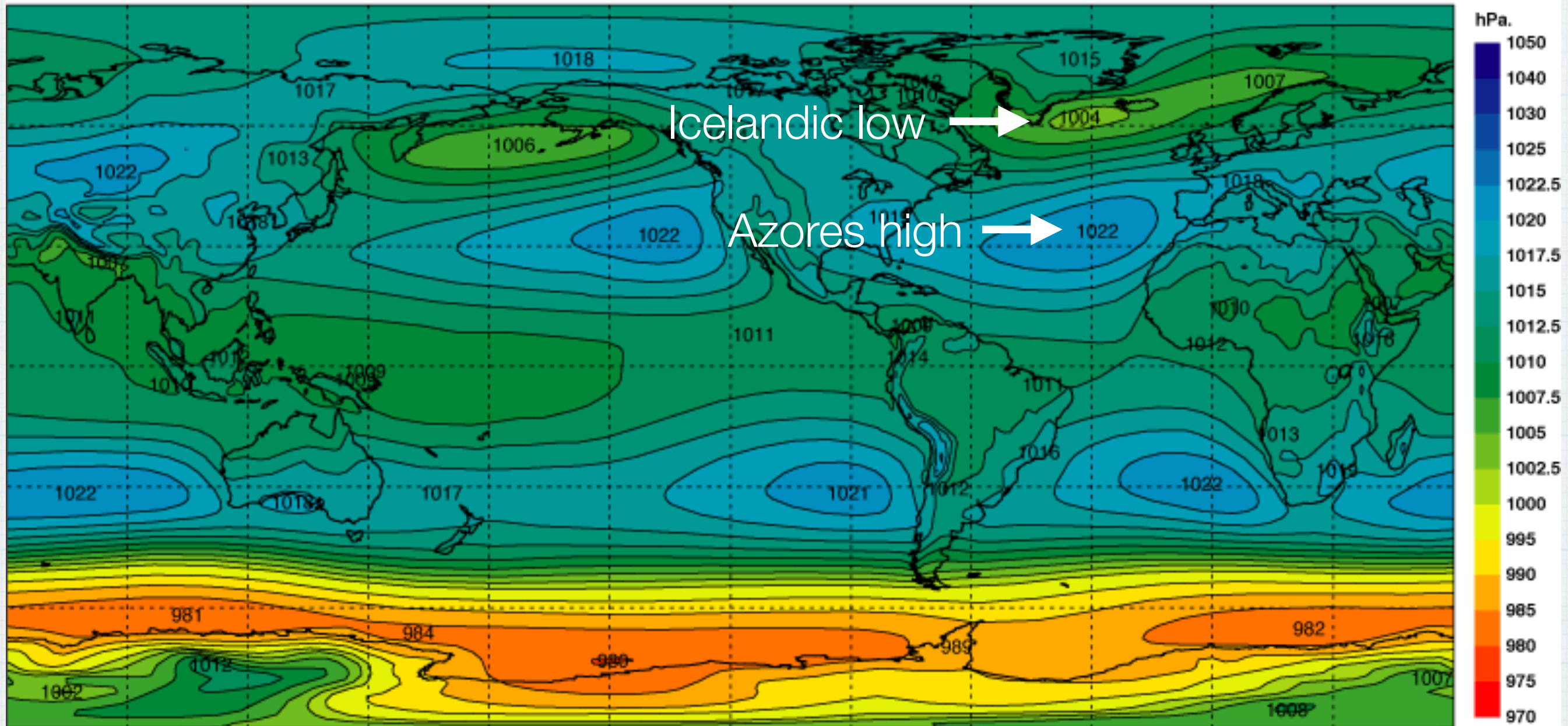




# Impact of NAO on the climate

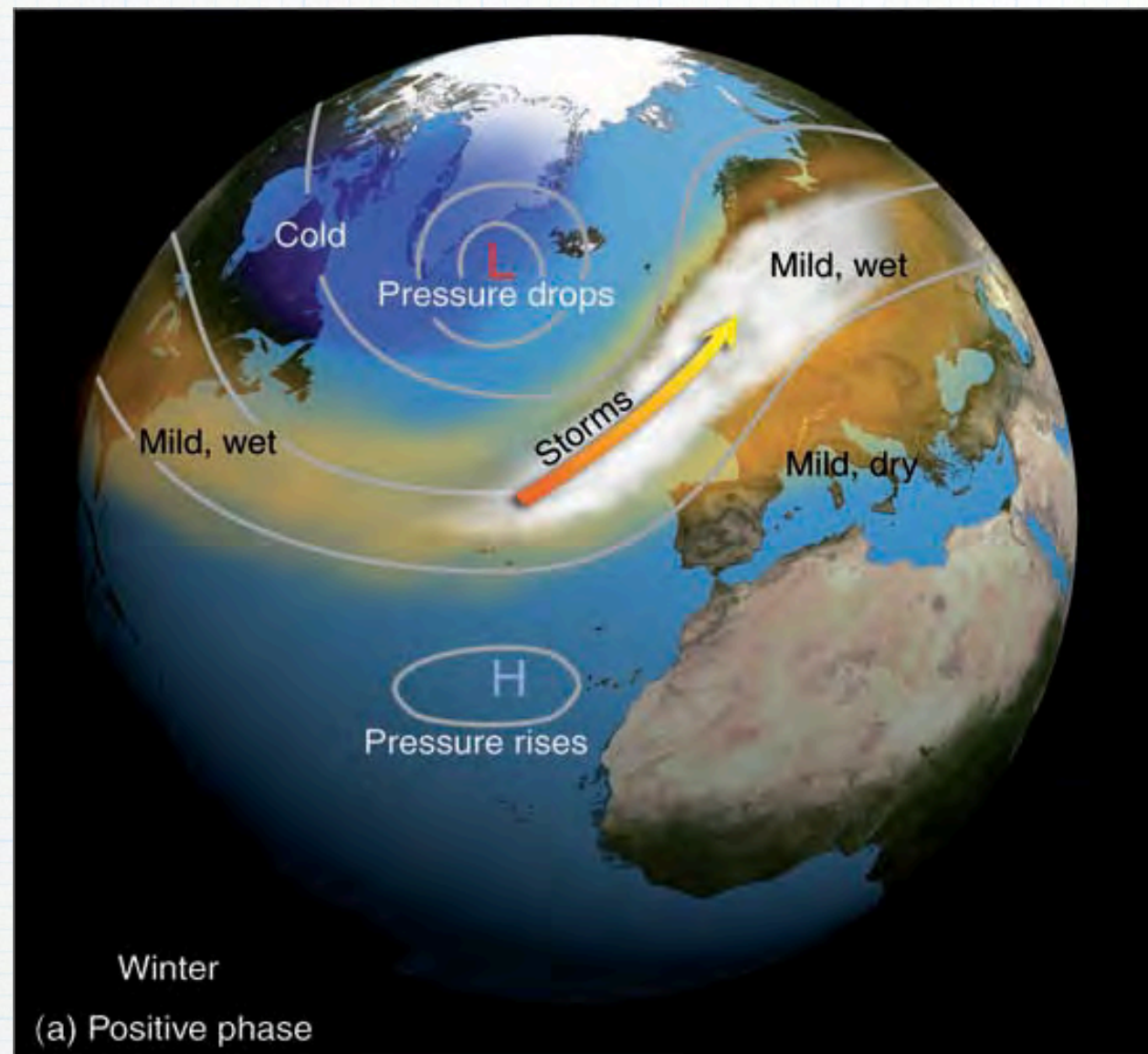
Mean sea level pressure

Annual mean





# The climate during the positive phase of the NAO

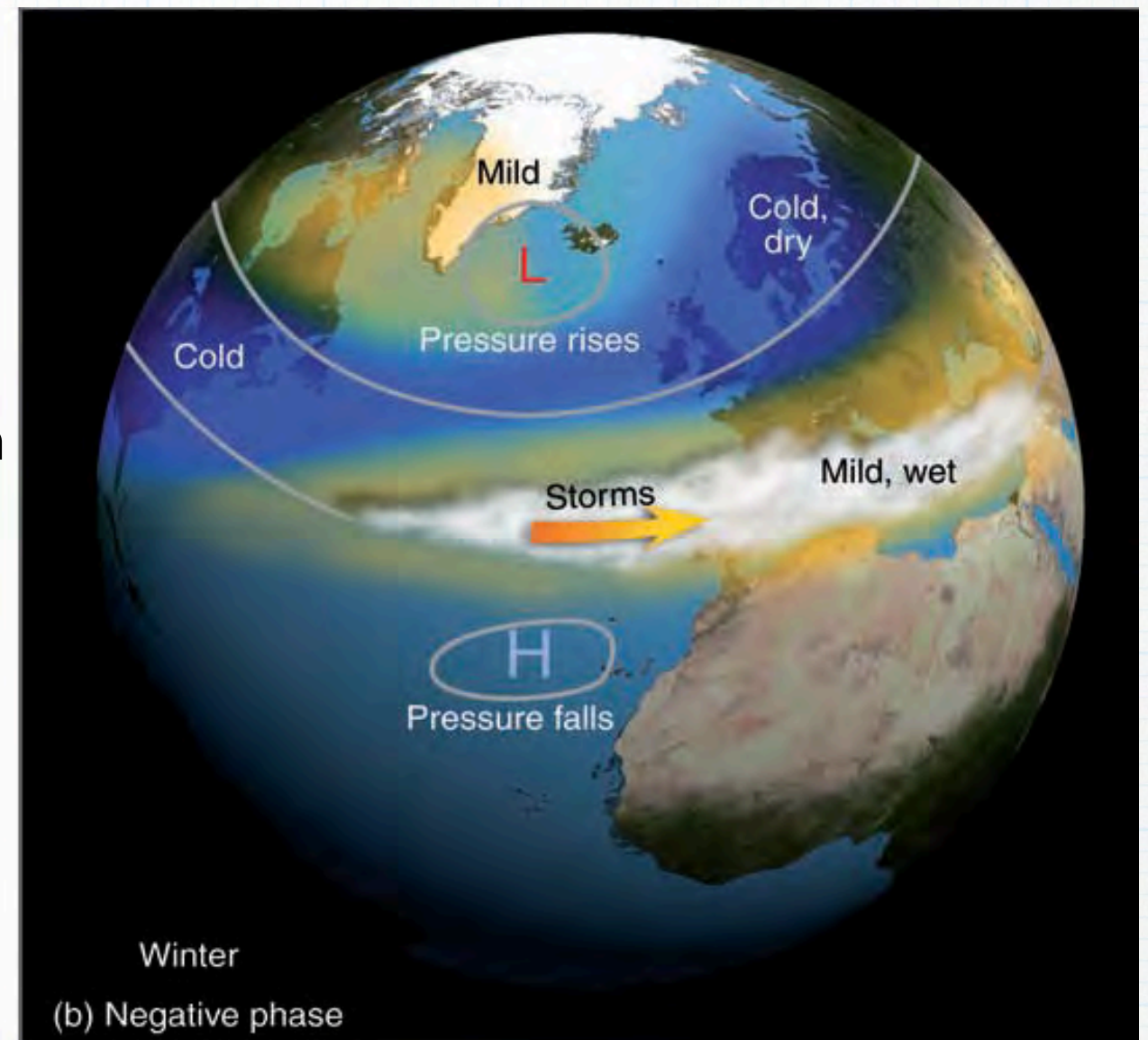


- The pressure gradient increases in north-south direction
- Stronger westerly winds
- The strong westerlies direct strong storms into northern Europe
- Wet and mild climate in the northern Europe
- Wet and mild climate in the eastern US, but cold and dry in the northern Canada and Greenland



# The climate during the negative phase of the NAO

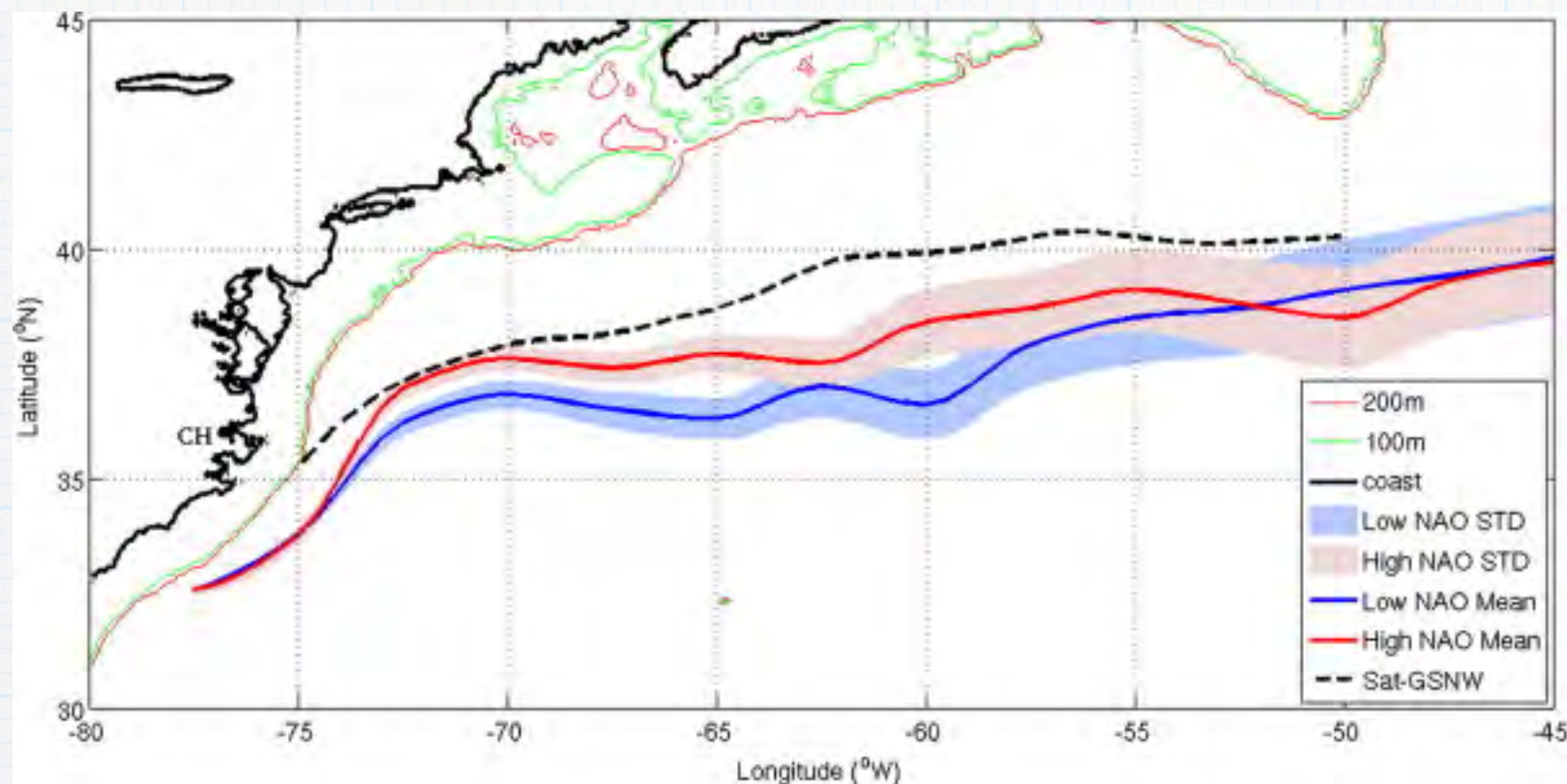
- The Icelandic low rises while pressure drops near the Azores high.
- The reduced pressure gradient
- Weaker westerlies
- Fewer and weaker winter storms travel the more west-east direction.
- Wet and mild climate in the southern Europe and in the Mediterranean Sea.
- The winters in Northern Europe are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





# NAO and the ocean

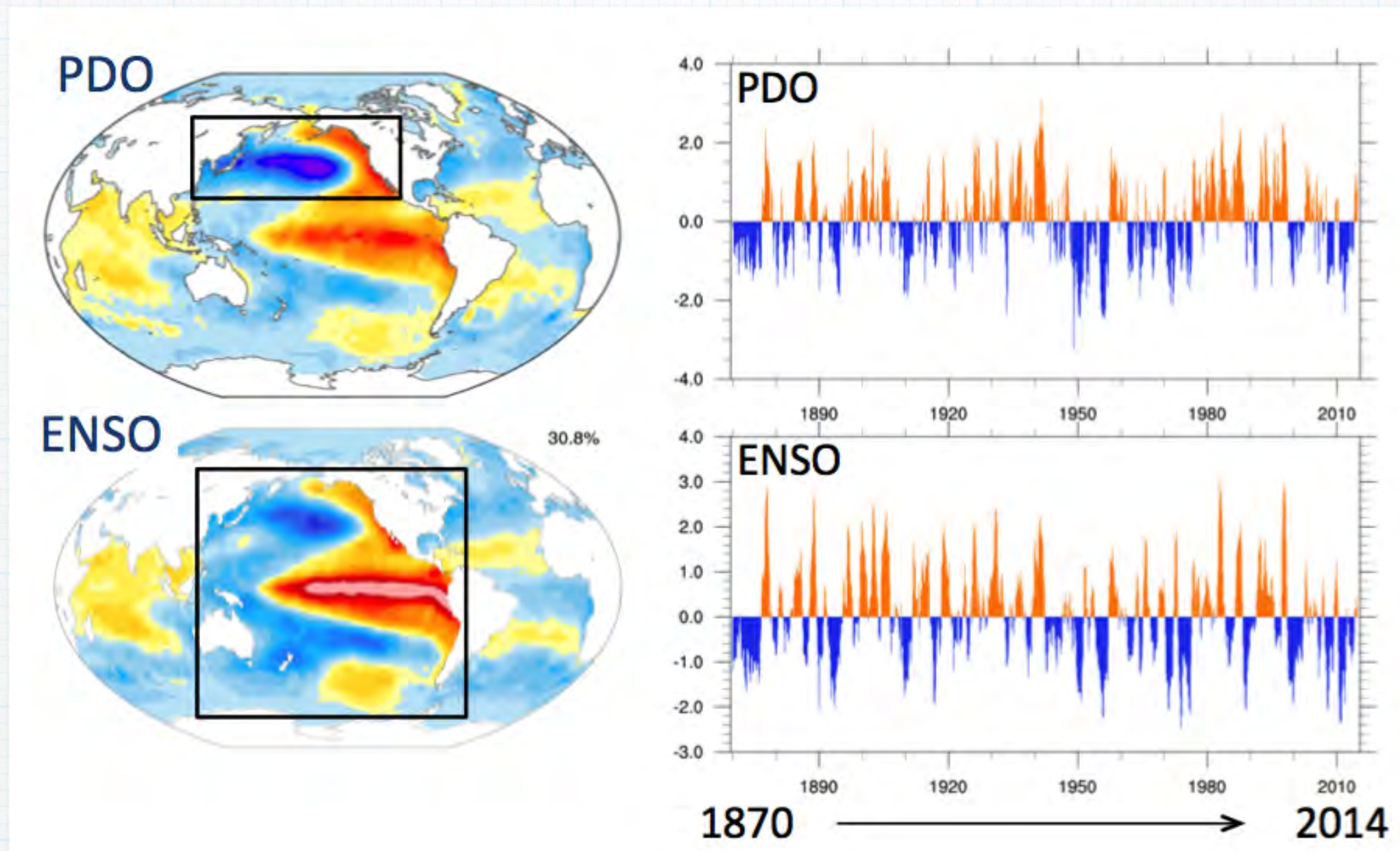
- Positive NAO
  - Stronger SST gradient
  - The Gulf Stream tends to be stronger and closer to the coast
- Negative NAO
  - Weaker SST gradient
  - The Gulf Stream follows a more southerly track.





# Pacific Decadal Oscillation

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

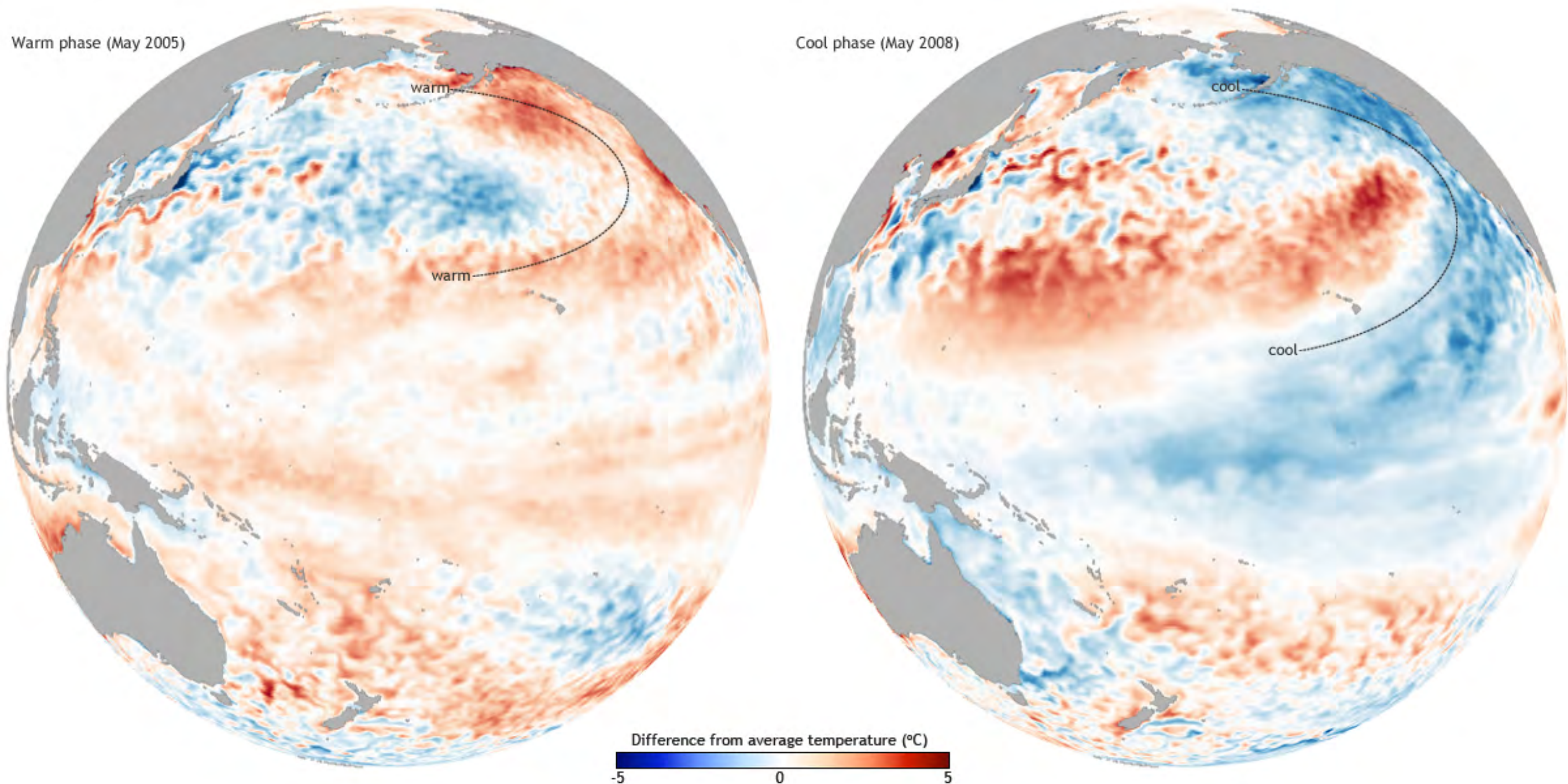




# Pacific Decadal Oscillation

Warm phase

Cold phase

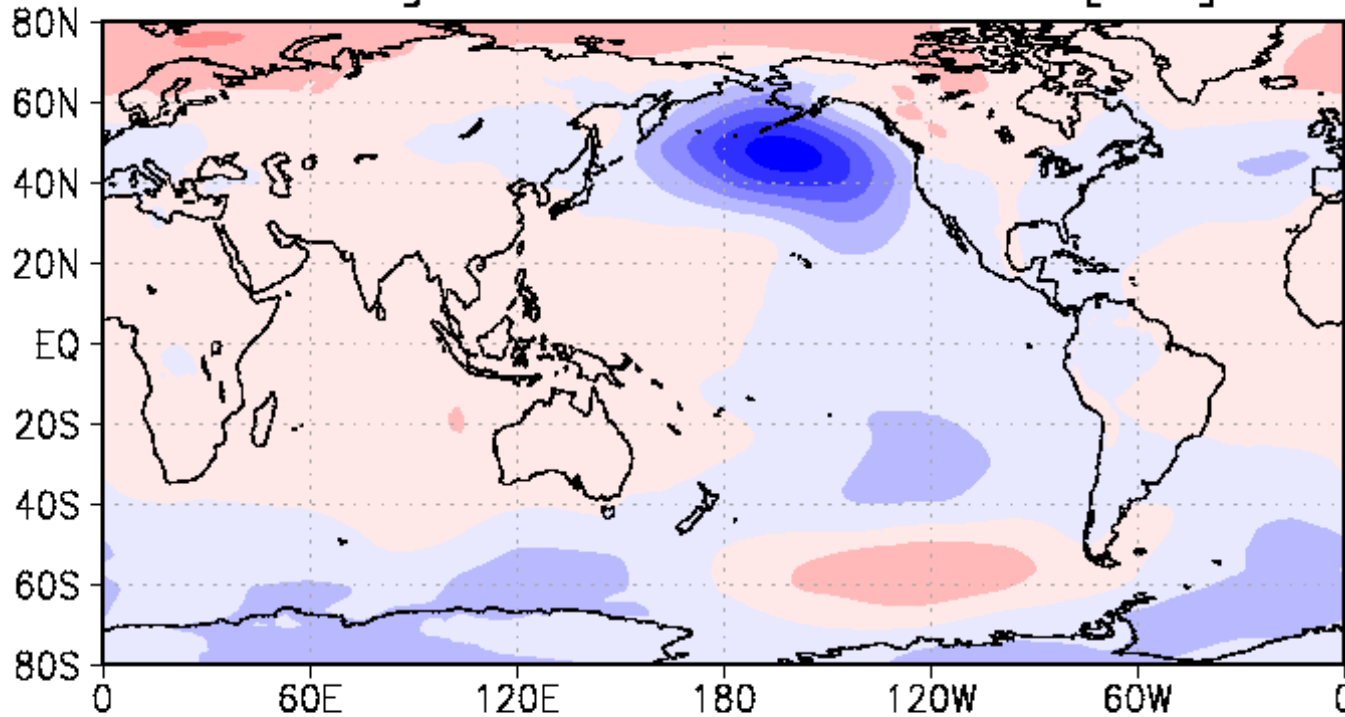


From [https://www.climate.gov/sites/default/files/HR\\_PD02005-2008.jpg](https://www.climate.gov/sites/default/files/HR_PD02005-2008.jpg)



# PDO and air-sea interaction

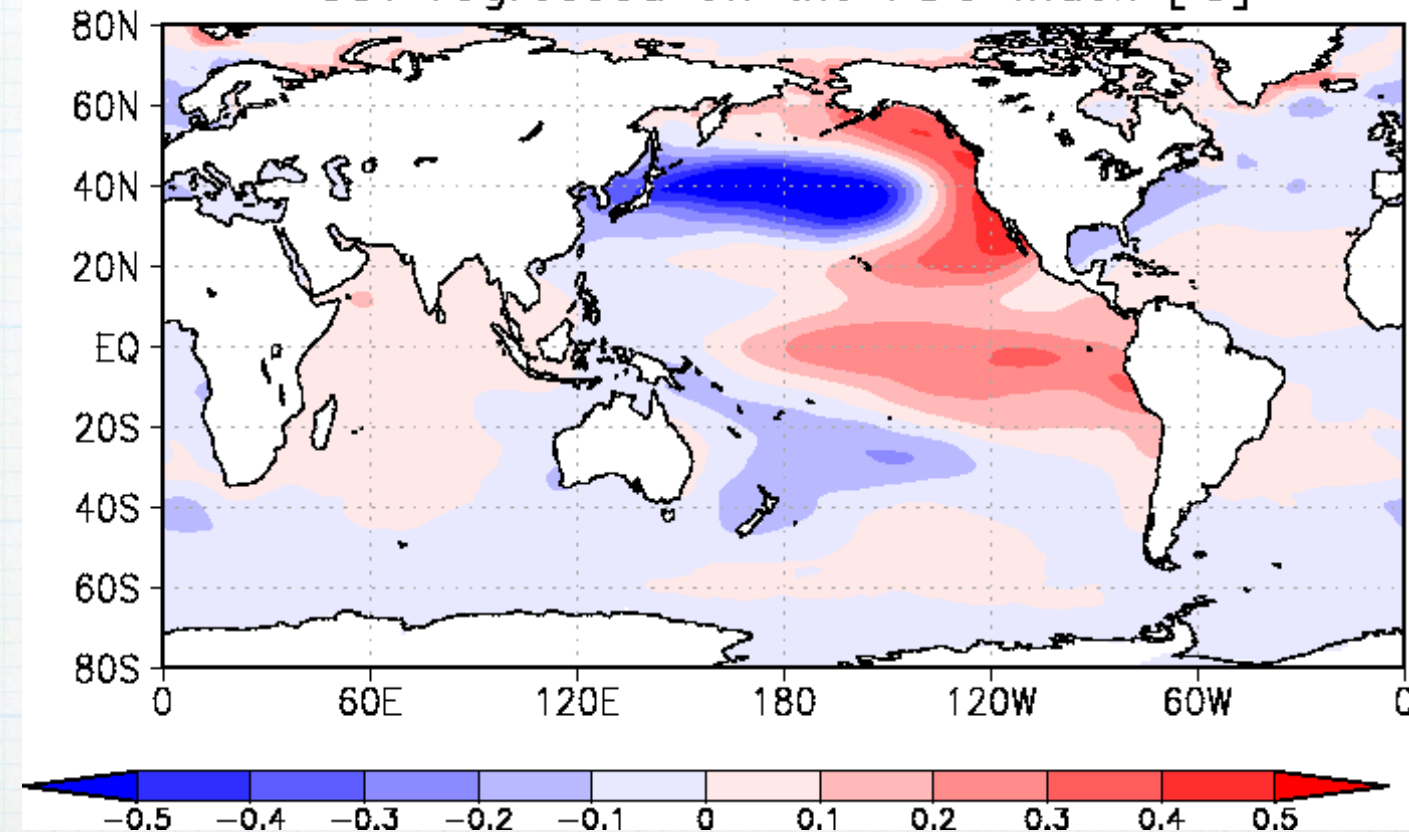
SLP regressed on the PDO index [hPa]



← Sea level pressure anomaly in the warm phase of PDO

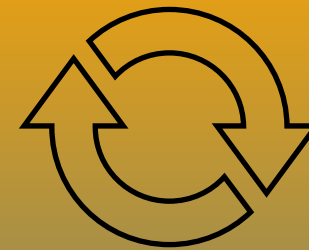
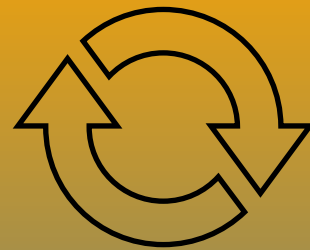
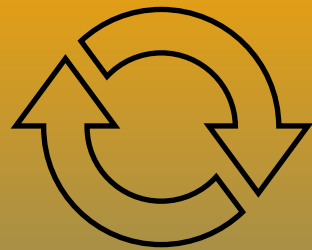
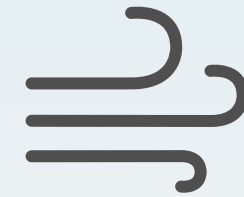
Sea surface temperature anomaly in the warm phase of PDO →

SST regressed on the PDO index [°C]





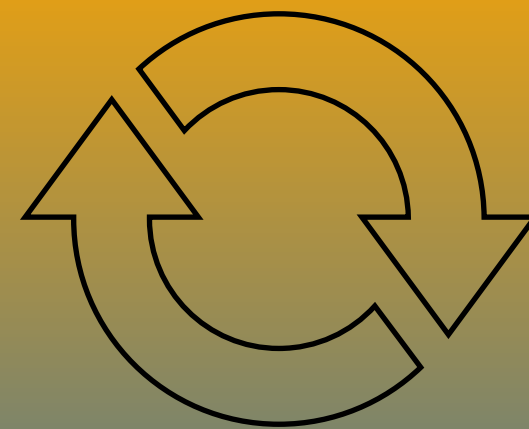
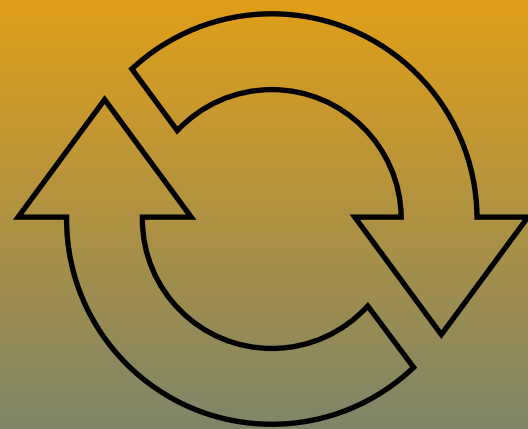
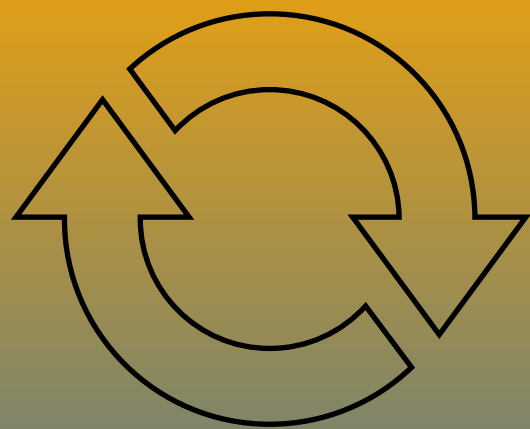
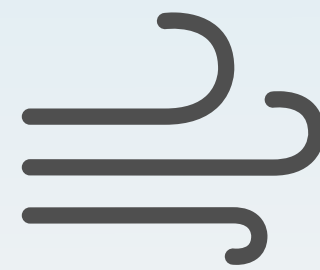
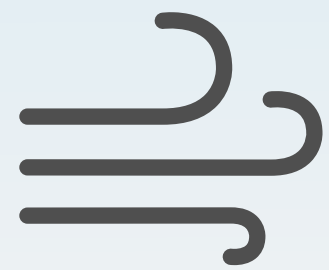
# wind-SST in large scale



**MIXING**



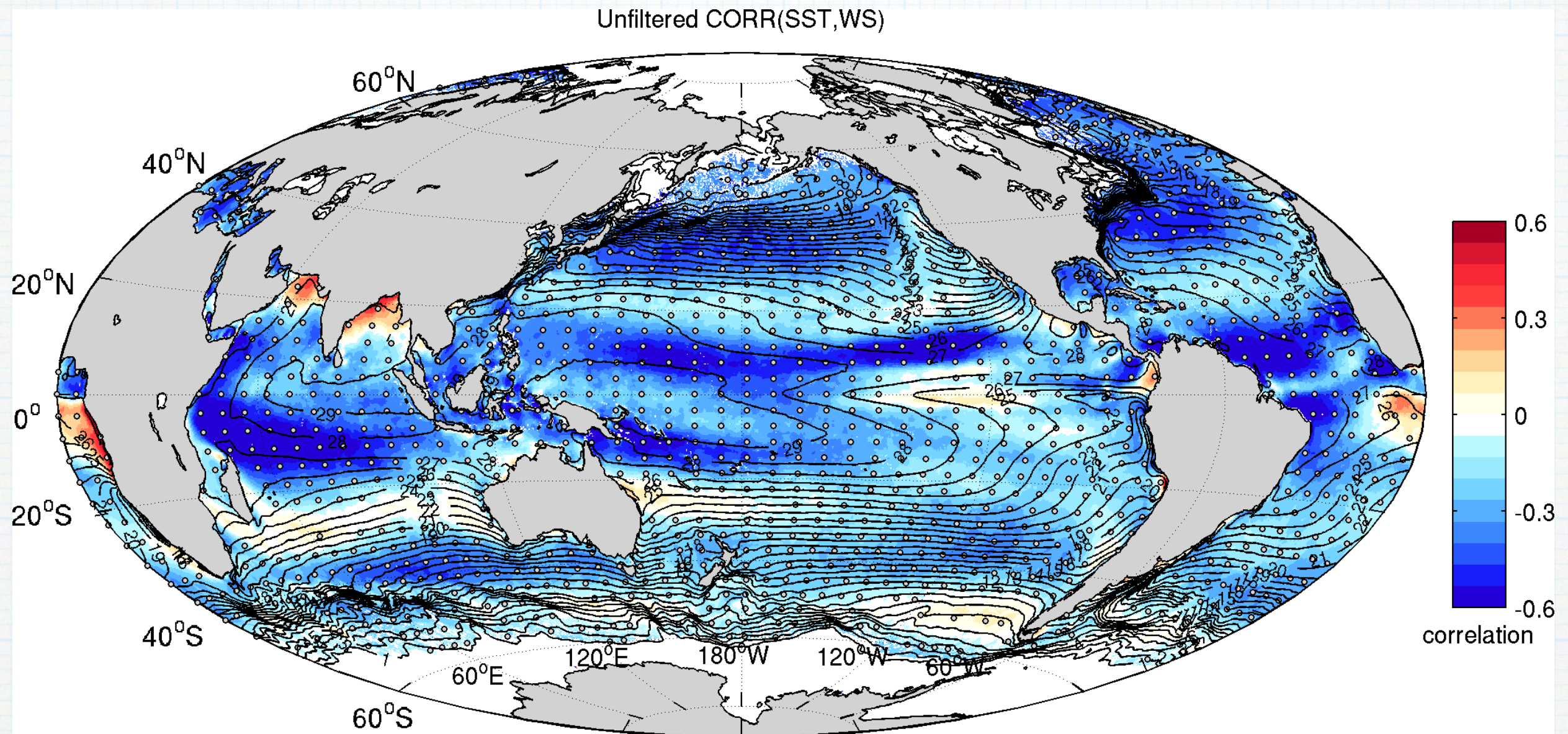
# wind-SST in large scale



**MORE MIXING**



# Correlation between wind speed and SST



**Oceanic response to the atmosphere**

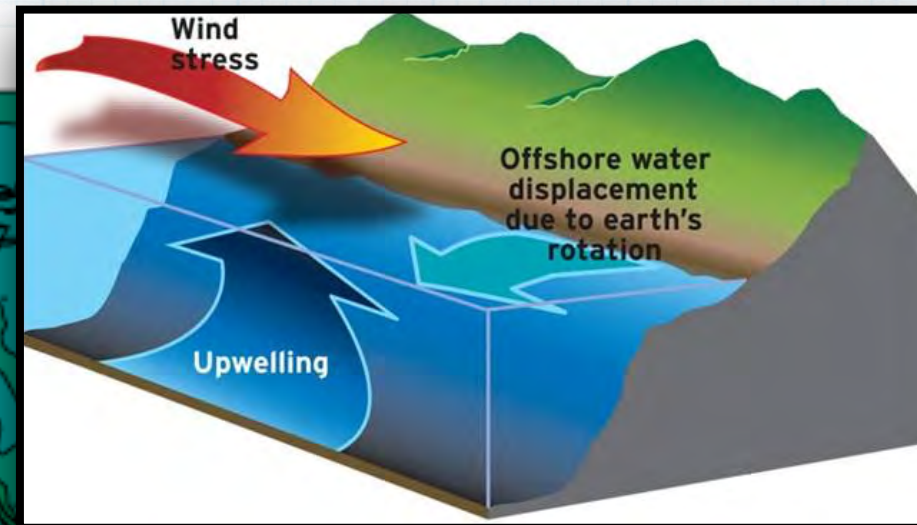
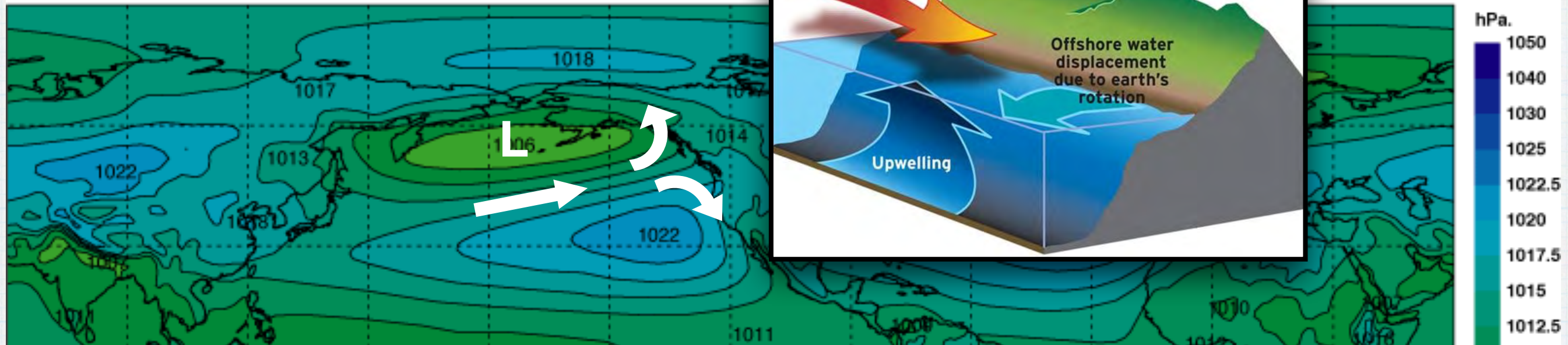
2000-2009 satellite wind and SST data

A credit to Dr. Hyodae Seo (WHOI)

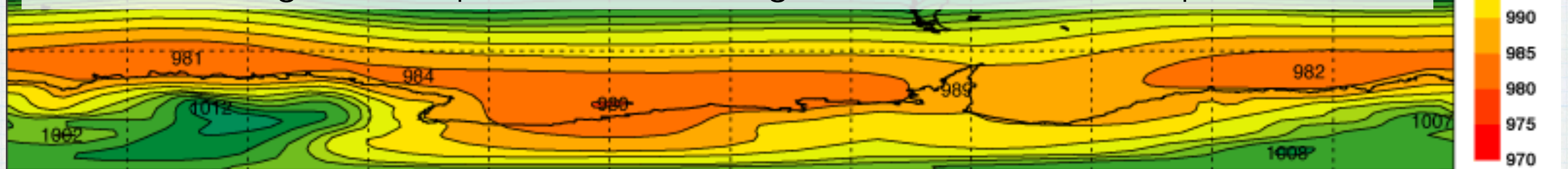


# Impact of a warm phase of PDO on climate

Mean sea level pressure



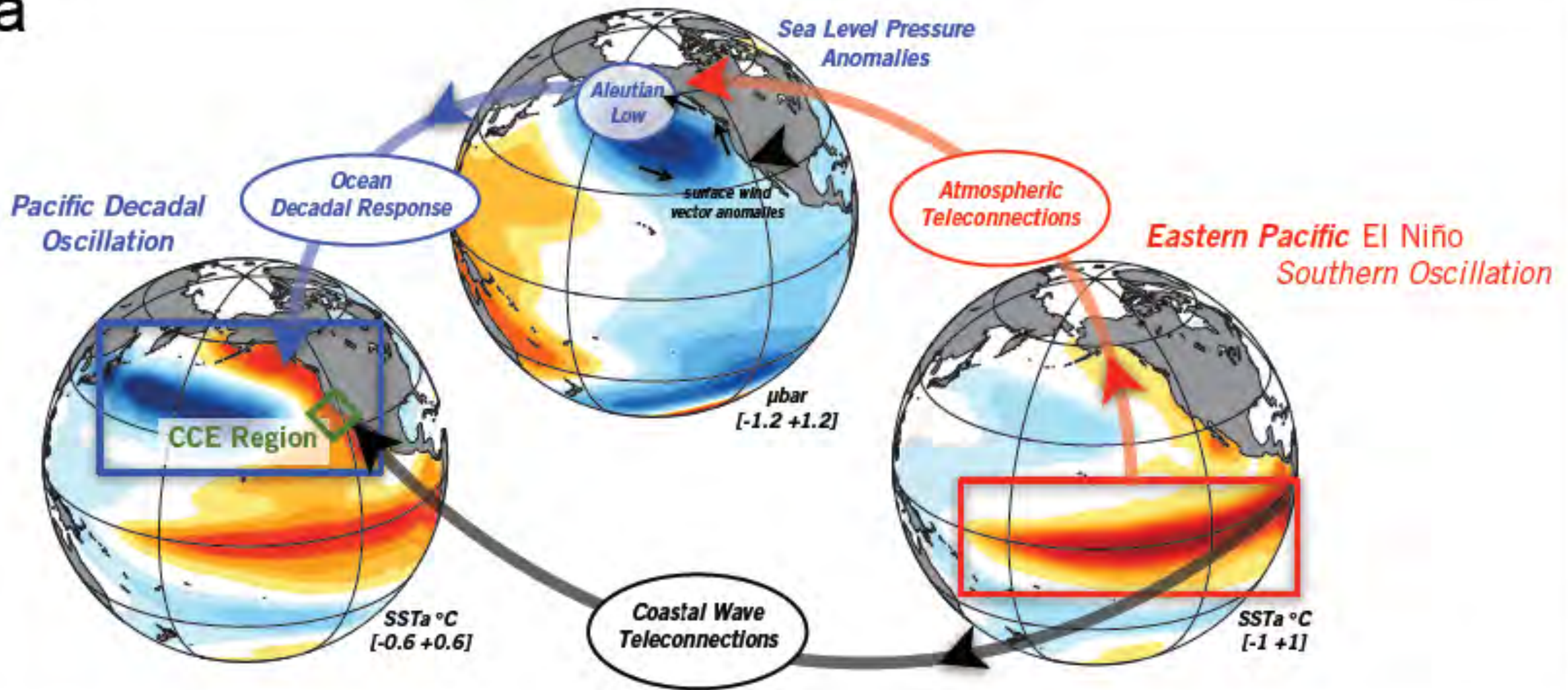
1. Deepening of Aleutian low
2. Stronger wind over the Pacific > Cooler water temperature
3. Stronger southerly wind in the Northwest N. America > Warmer climate
4. Weakening of the equatorial wind along the California coast > poorer ocean





# Teleconnection

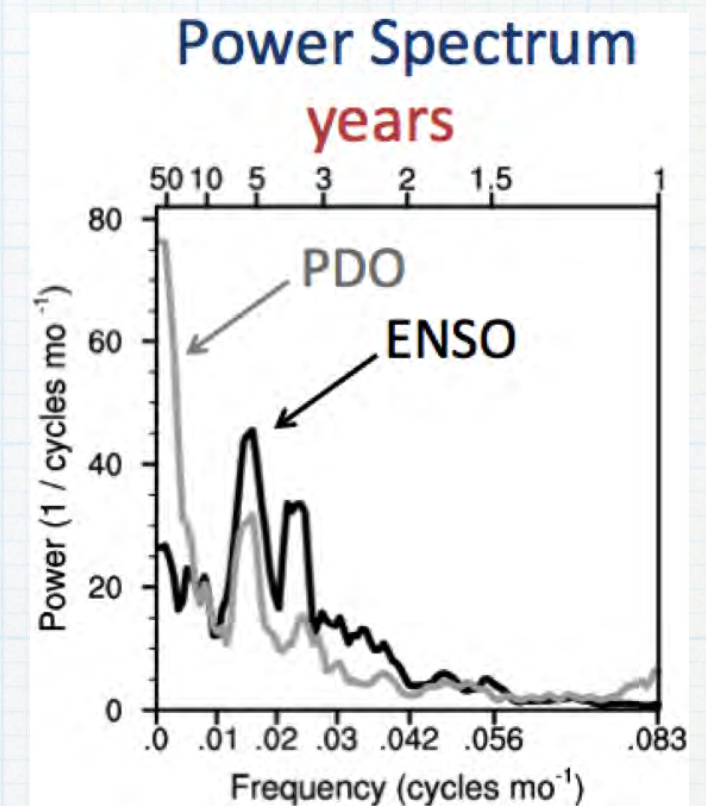
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# PDO v.s. ENSO

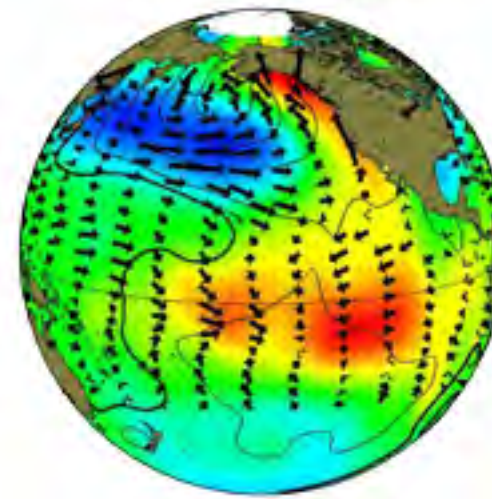
- Time scale
  - PDO events persist for 20 to 30 years
  - ENSO events persist for 6 to 18 months
- The climate fingerprints
  - PDO in the North Pacific / North American sector
  - ENSO in the tropics



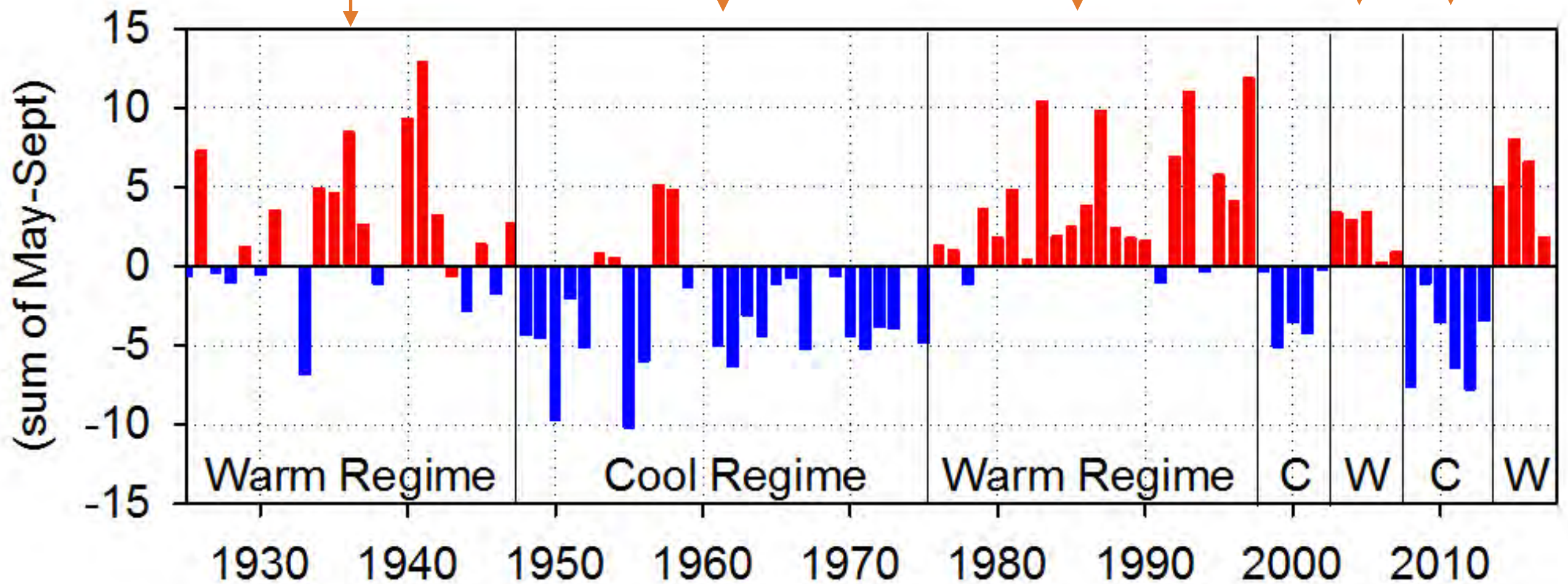
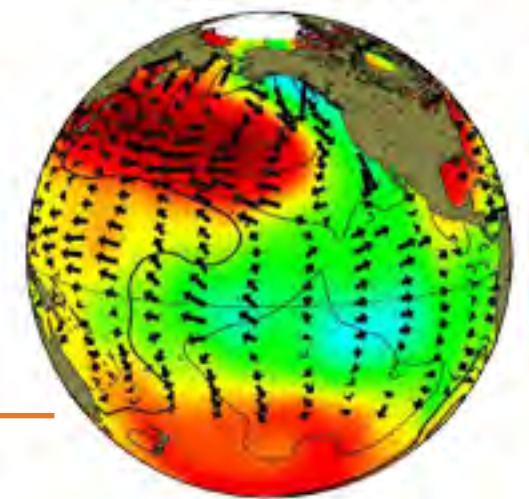


# PDO index

positive phase



negative phase





# Impact of PDO on climate

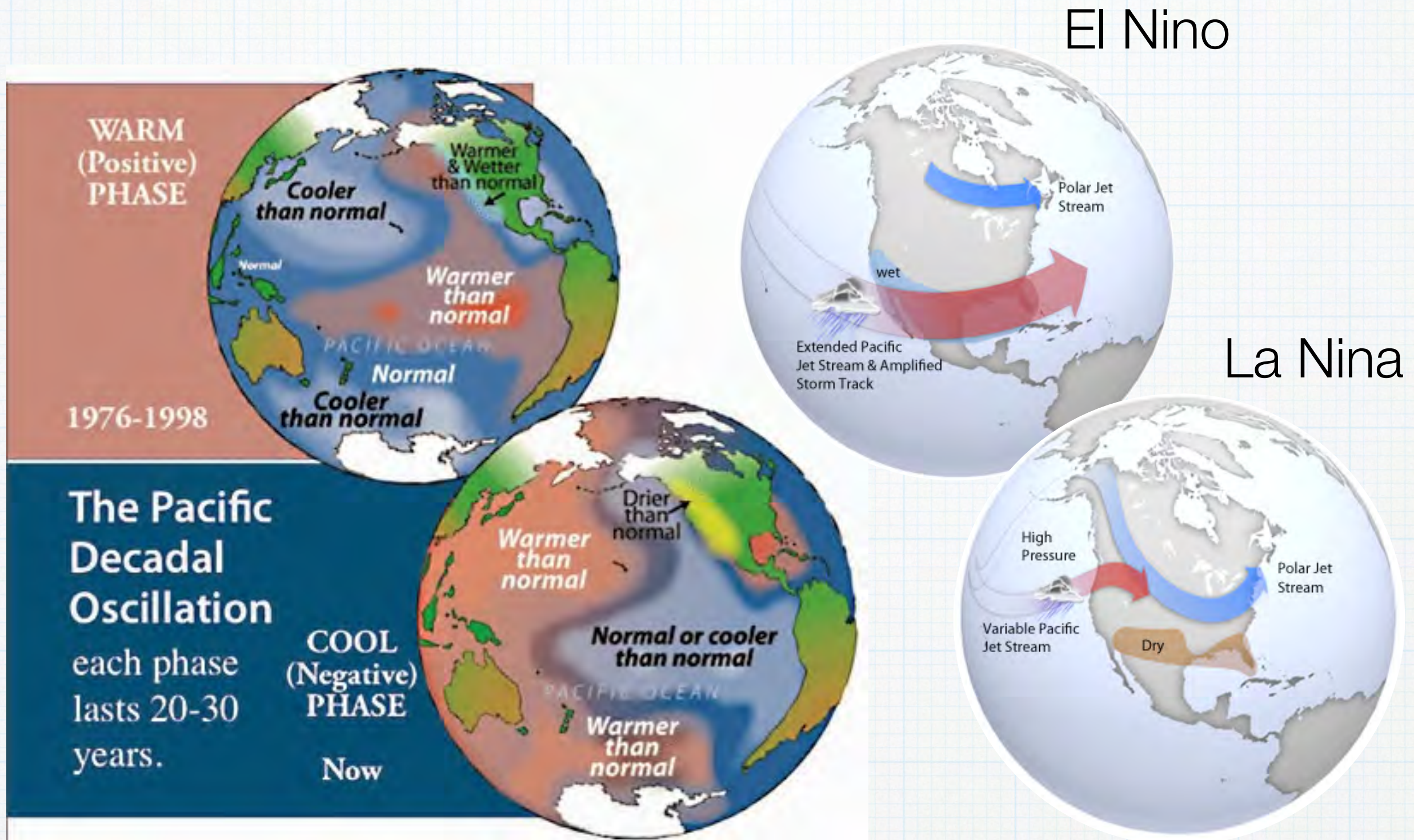


Figure from <http://the-mound-of-sound.blogspot.kr/2015/03/coming-soon-great-warming-spurt.html>  
And [https://www.climate.gov/sites/default/files/LosNinoshighpressure\\_0.jpg](https://www.climate.gov/sites/default/files/LosNinoshighpressure_0.jpg)



# 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  $40^{\circ}\text{S}$  and  $65^{\circ}\text{S}$
- 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



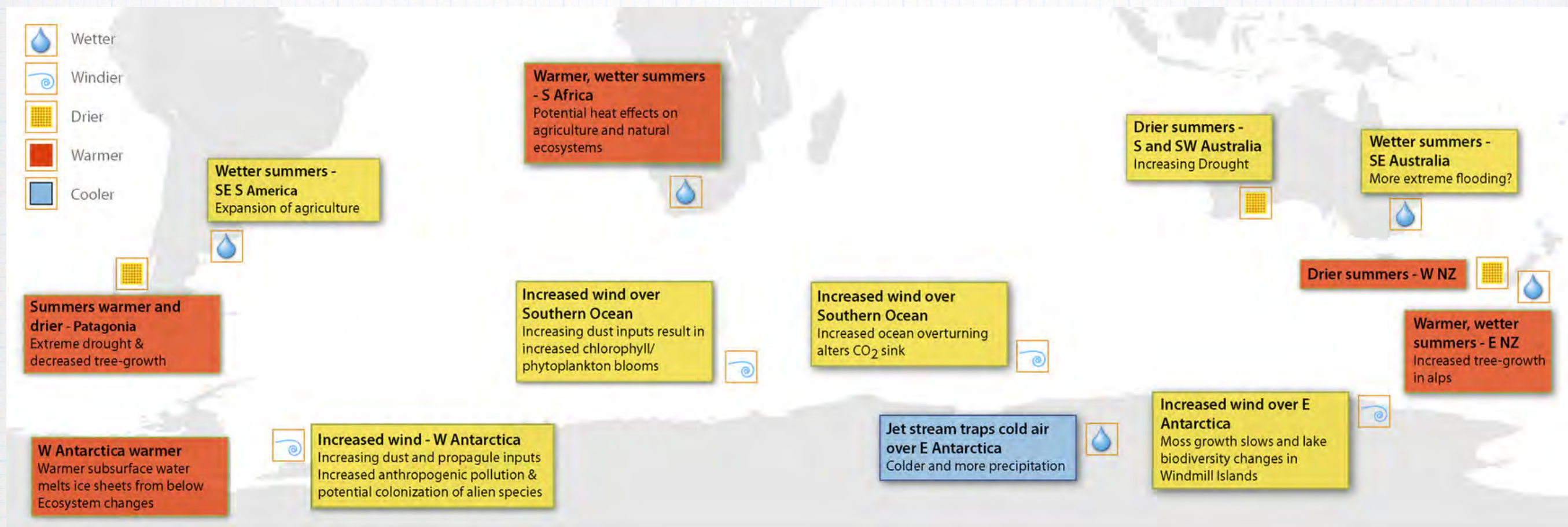
# The impact of SAM on the weather



**SAM**



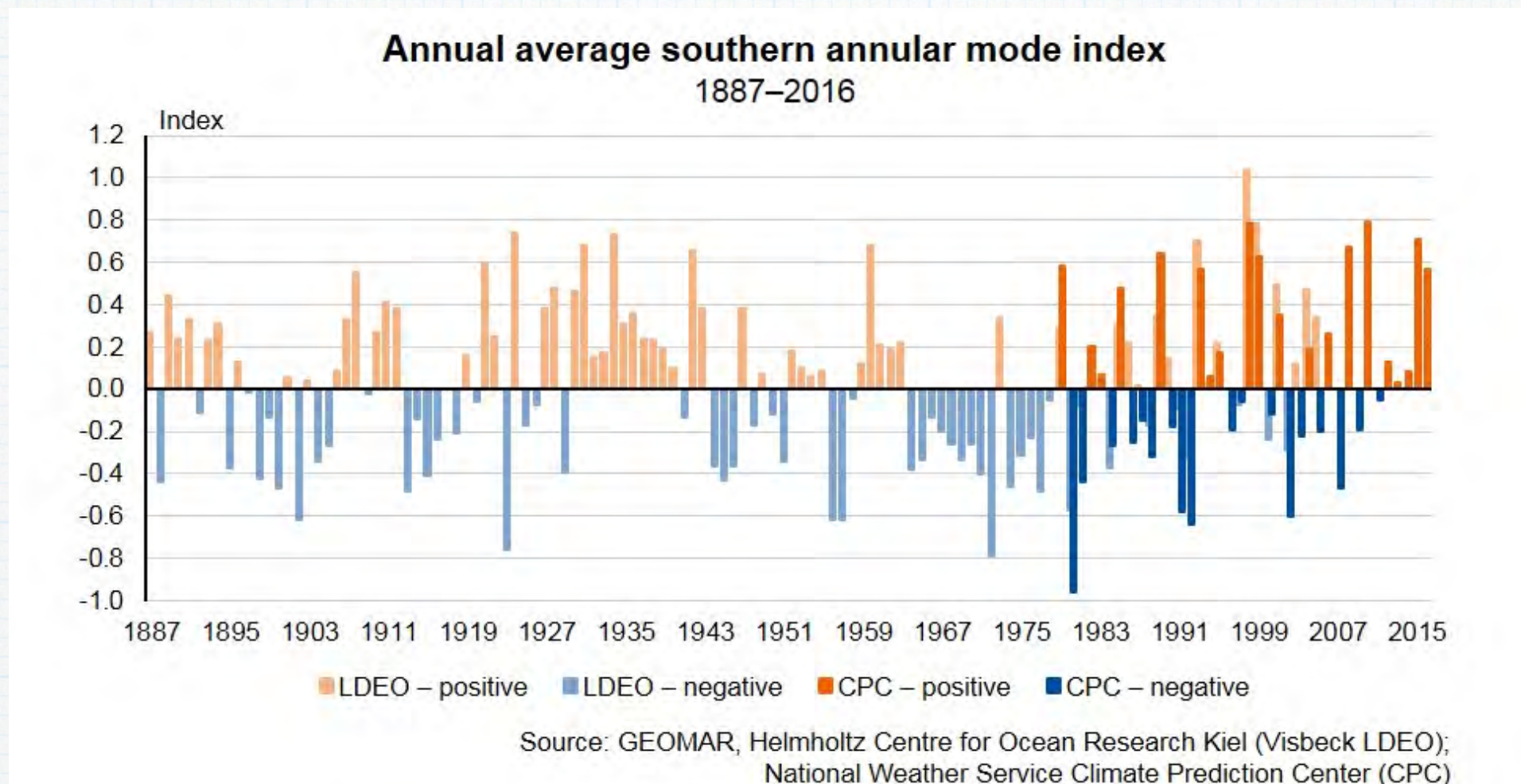
# The impact of SAM on the weather





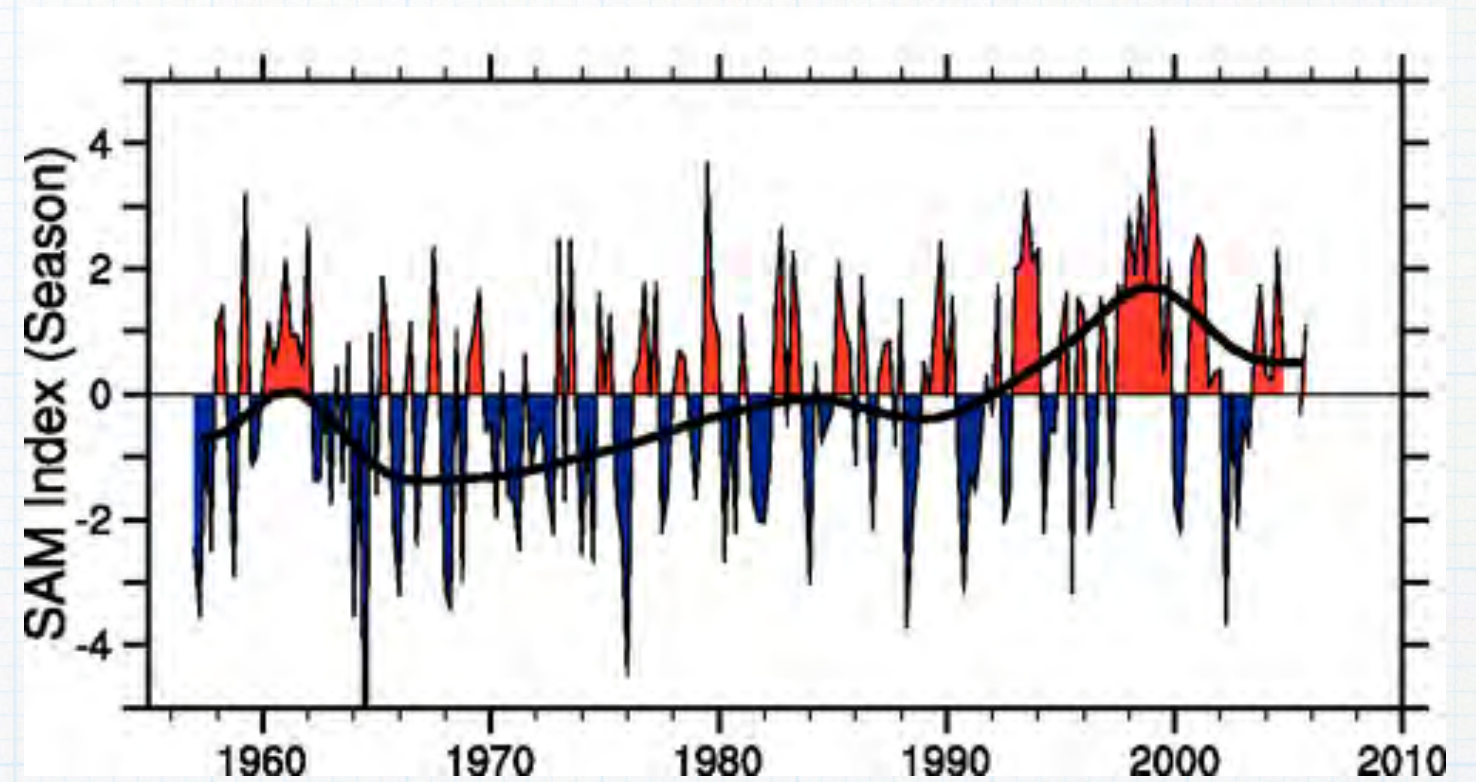
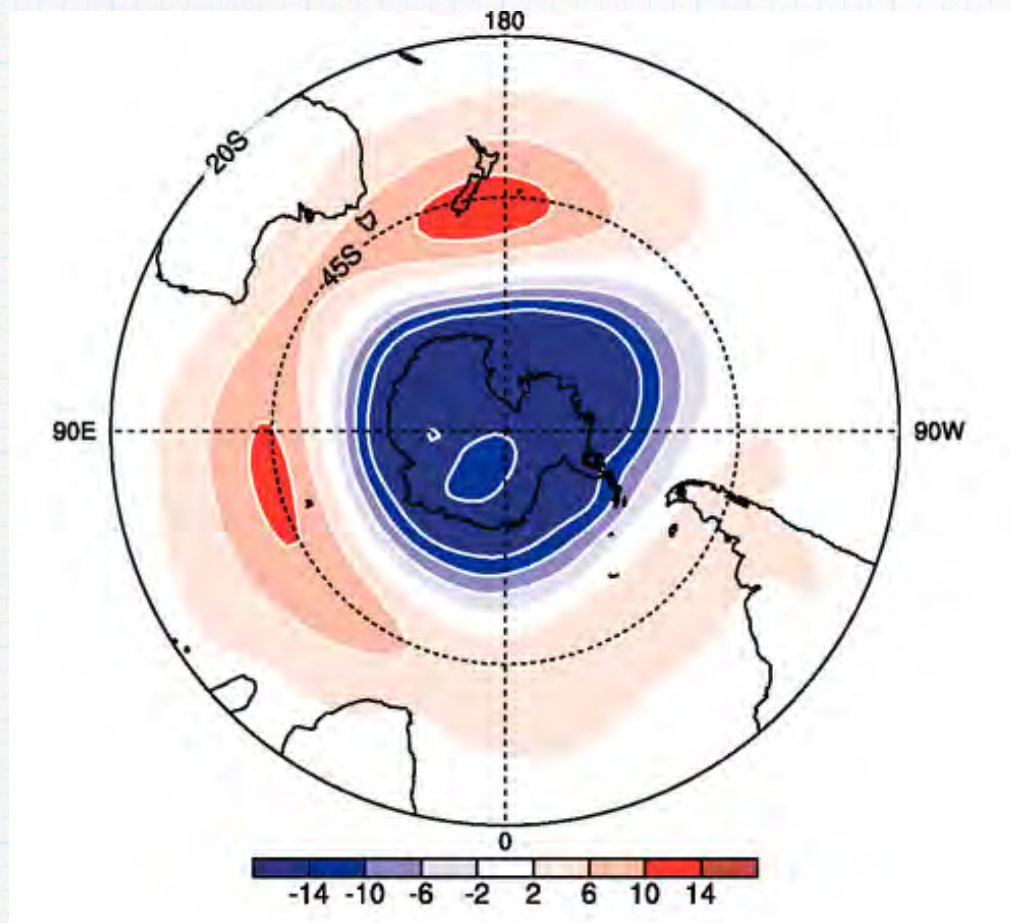
# Southern Annular Mode

- 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.





# Southern Annular Mode





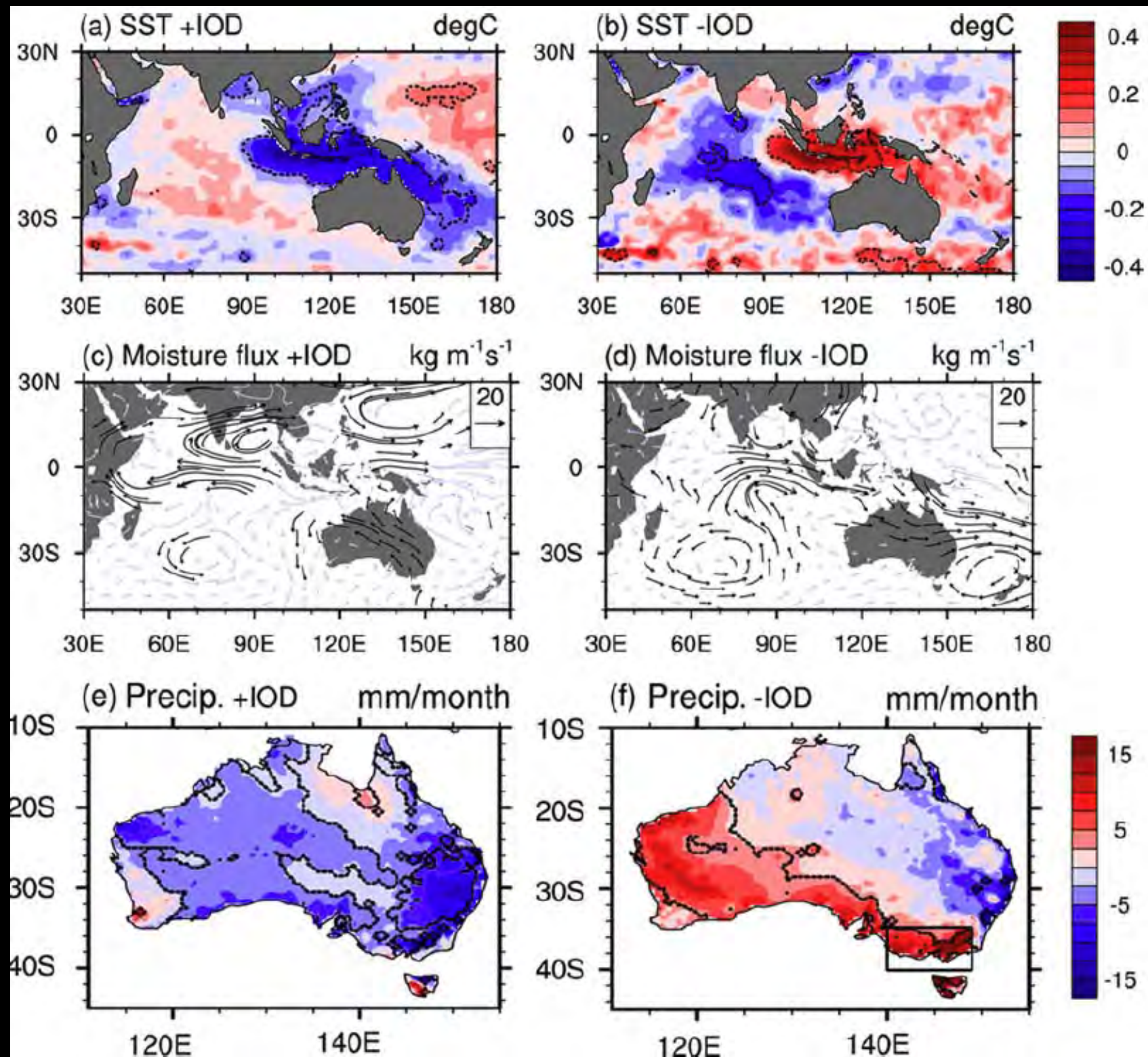
# Indian Ocean Dipole (IOD)

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- Difference between sea surface temperatures of the tropical western and eastern Indian Ocean.
- It affects the weather in Australia and Africa.
- [Video](#)

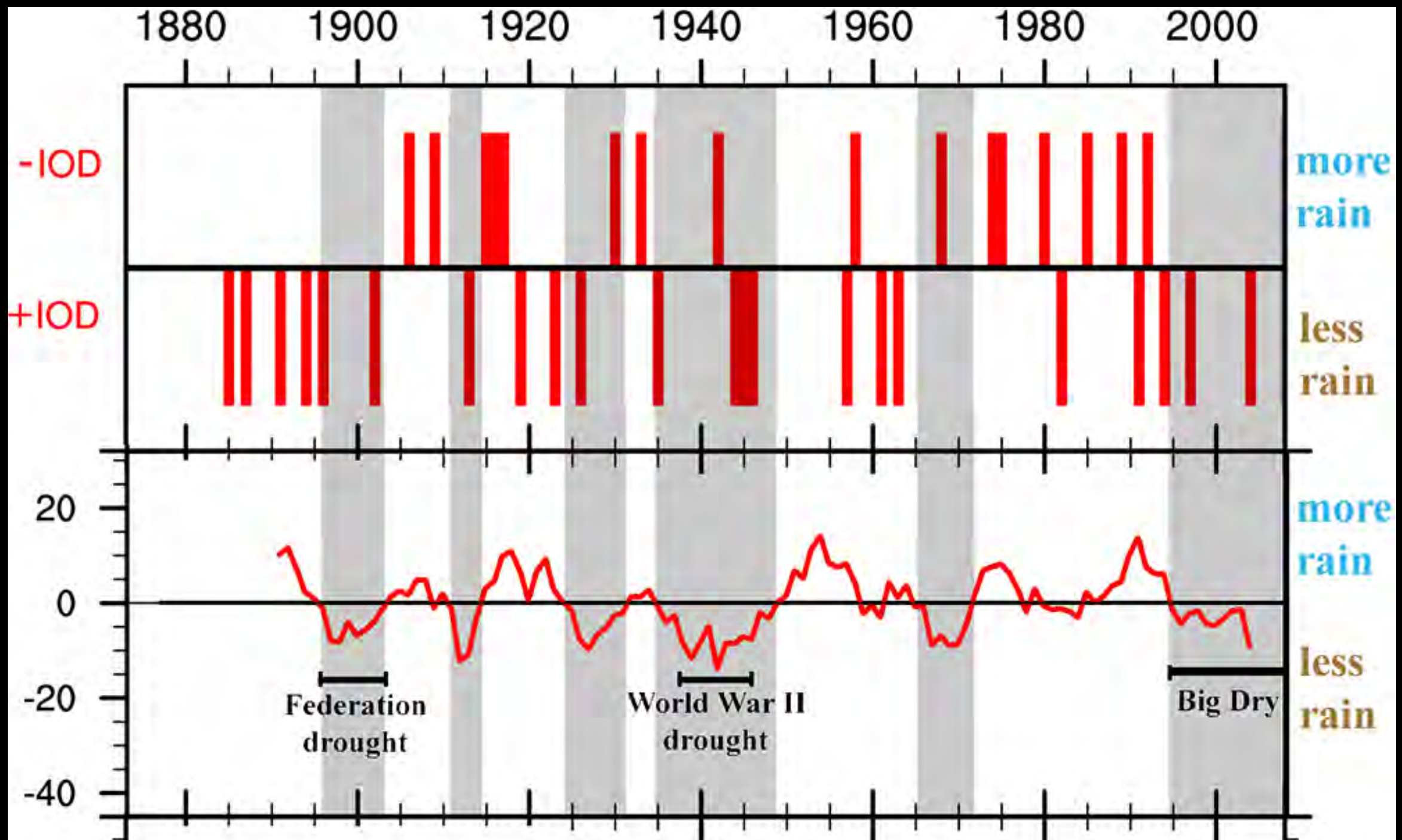


# IOD and climate patterns





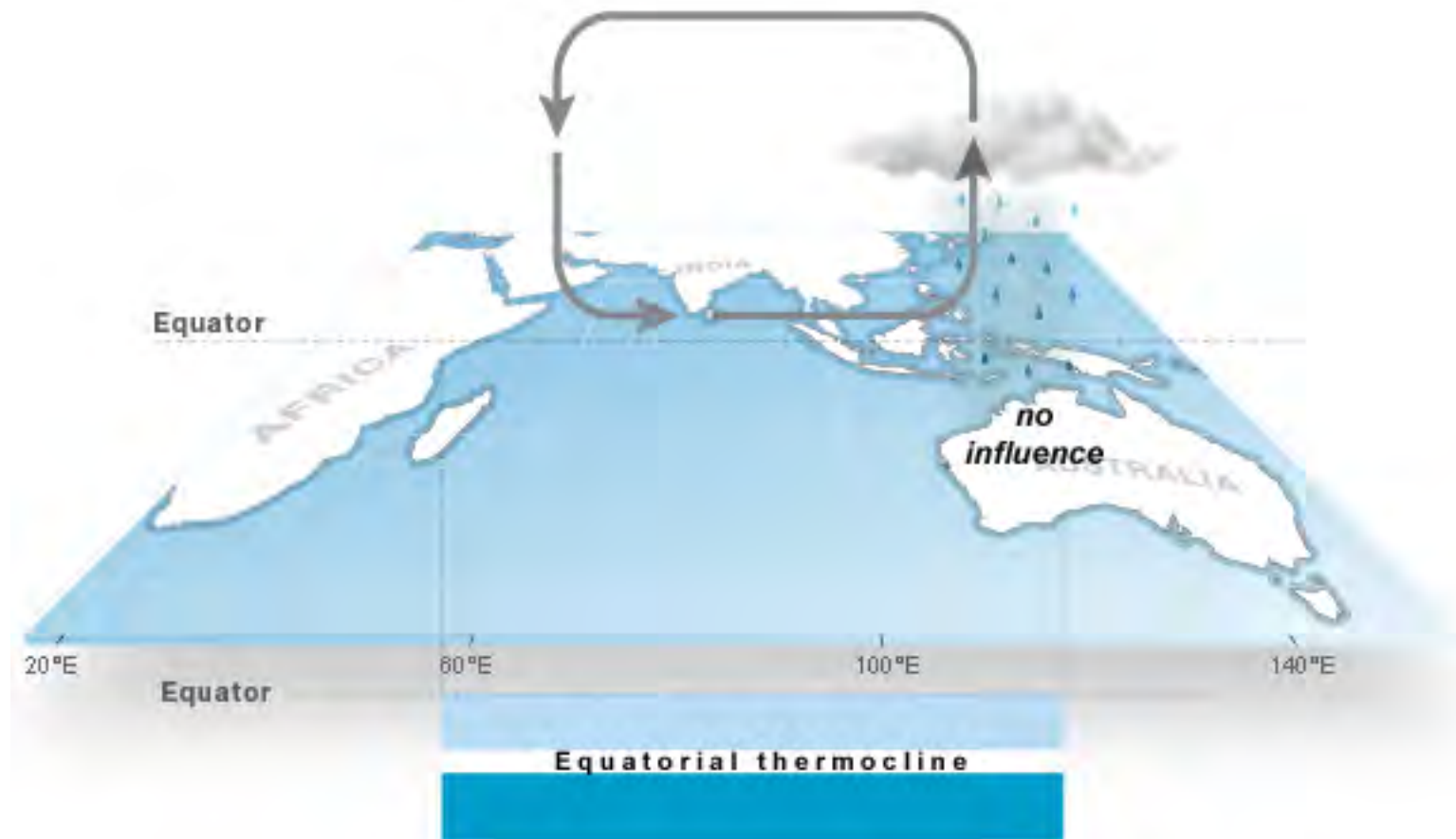
# IOD and precipitation over Australia





# IOD : #1. Neutral phase

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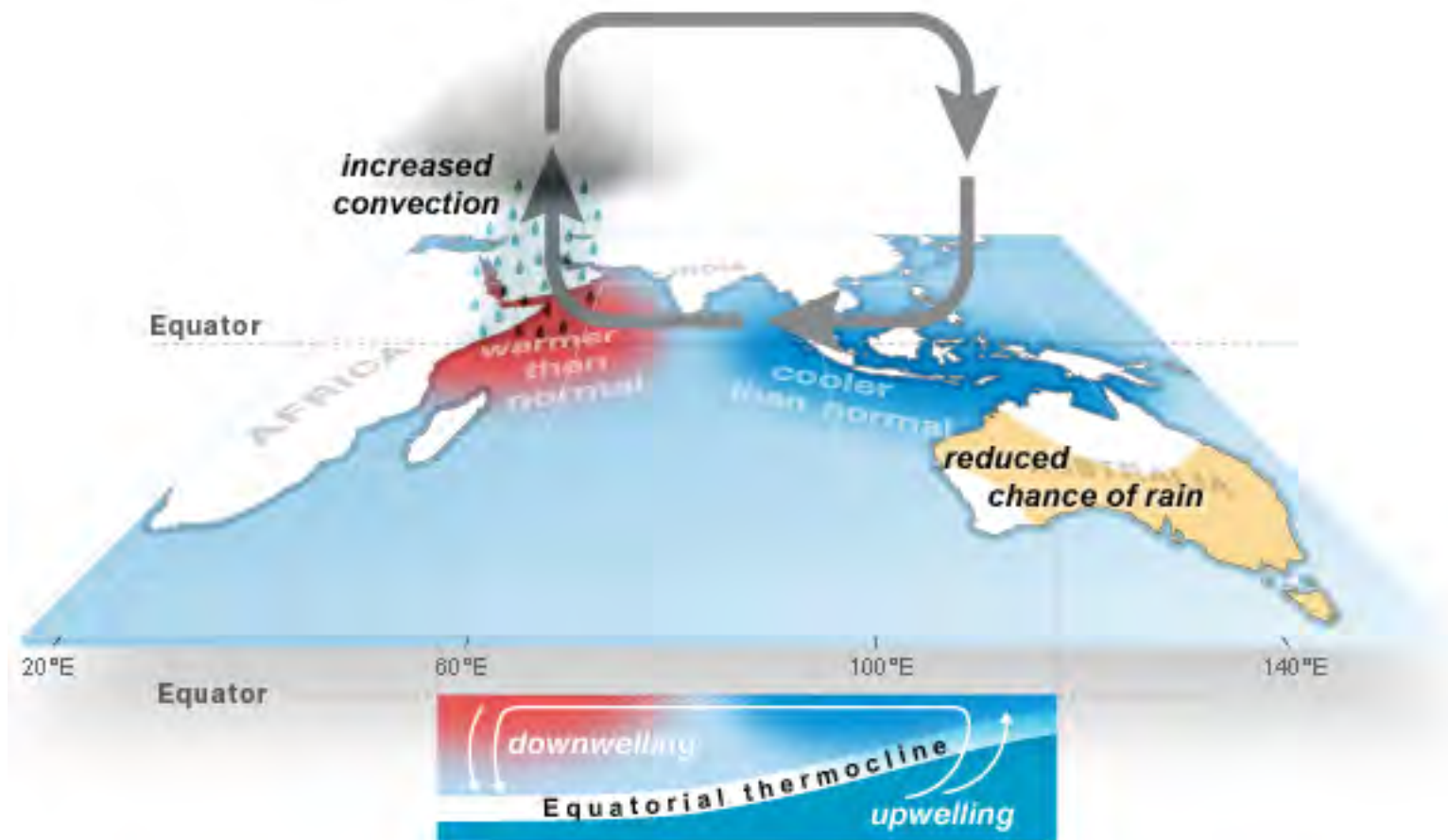


Indian Ocean Dipole (IOD): **Neutral phase**



# IOD : #2. Positive phase

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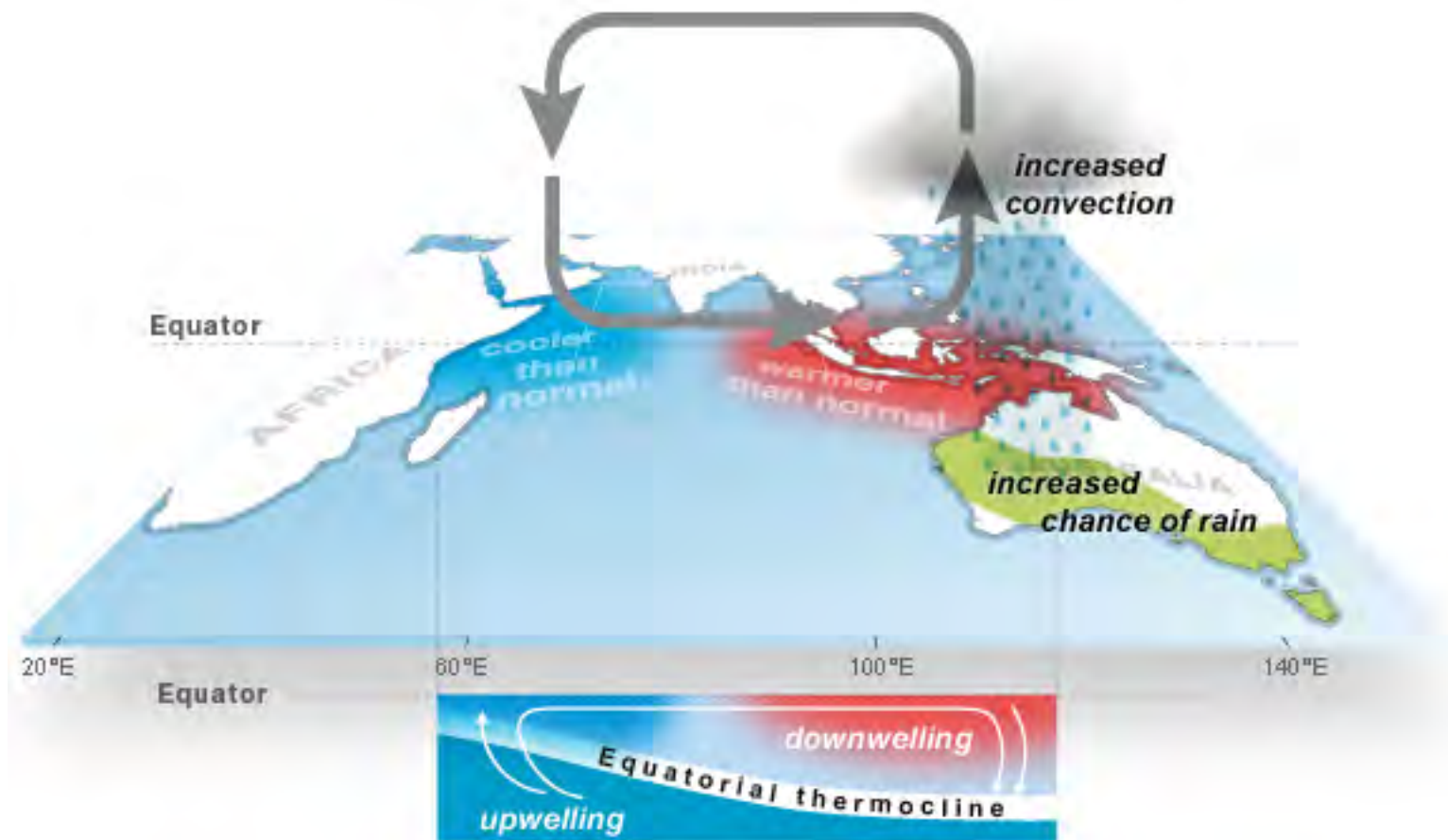


Indian Ocean Dipole (IOD): **Positive phase**



# IOD : #3. Negative phase

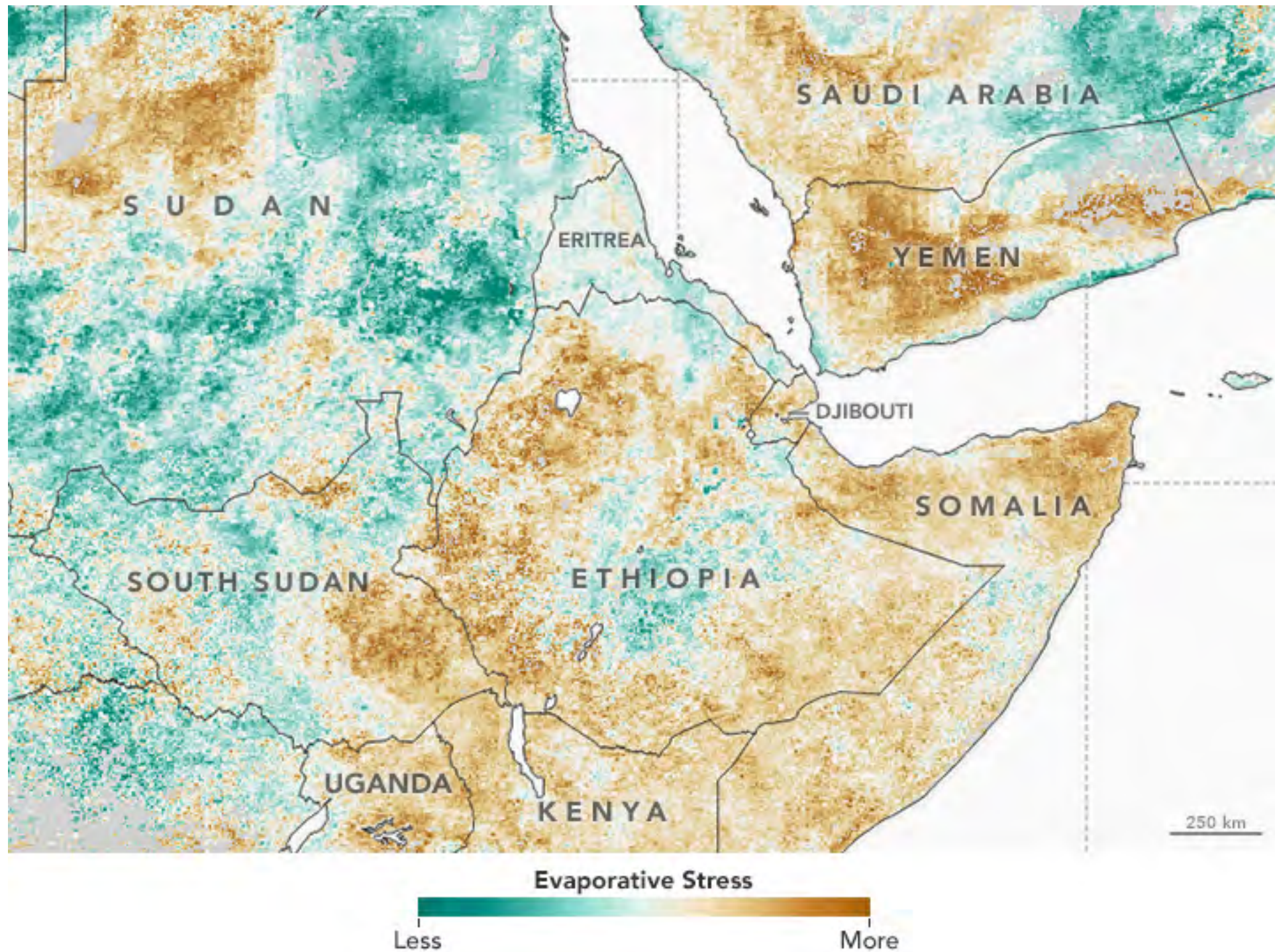
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Indian Ocean Dipole (IOD): **Negative phase**



# Precipitation over Eastern Africa



From <https://earthobservatory.nasa.gov/NaturalHazards/view.php?id=89735>



# Precipitation over Eastern Africa

“The current drought is tied to the **weak La Niña** conditions that emerged in the Pacific in 2016. La Niña shifts ocean temperatures and air pressure over the Pacific Ocean, with effects that ripple through weather patterns around the world. One of those effects is a reduction in rainfall in East Africa. The influence of La Niña was likely amplified by patches of unusually cool water in the western Indian Ocean and unusually warm water in the eastern part of the basin. This configuration—what meteorologists call the **negative phase of the Indian Ocean Dipole**—reduces rains in East Africa and increases them in Malaysia.”

