

# Air-sea interaction: climate variability

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ATM2106

# Climate variability v.s. climate change

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- “**Climate variability**” : natural variability
  - Natural “modes” of variability
- “**Climate change**” : anthropogenic forcing
  - Due to man-made changes in greenhouse gases, land surfaces, species distributions, etc.

# Elements of the climate system

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- Sun
- Atmosphere
- Ocean
- Cryosphere (ice, snow)
- Land surface
- Biological and chemical cycles

# Climate forcing

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- **External forcing**
  - Earth orbit parameters (solar distance factors)
  - Solar luminosity
  - Moon orbit
  - Volcanoes and other geothermal sources
  - Greenhouse gases...

# Climate forcing

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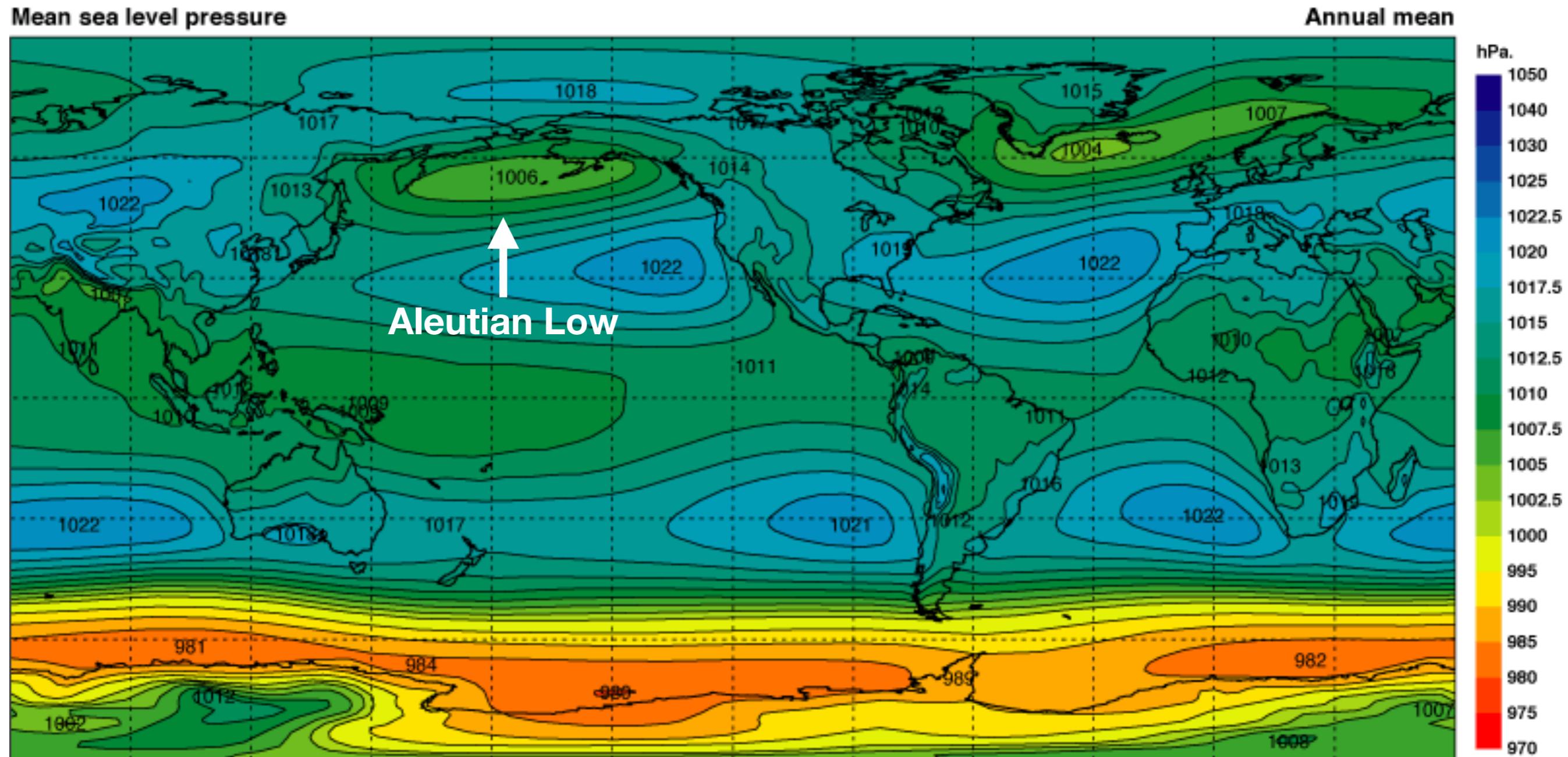
- **Internal forcing** : forcing between each element of the climate system
  - Wind forcing to the ocean
  - Ice extent forcing to the atmosphere or the ocean

# Natural climate modes with interannual to millennial time scales

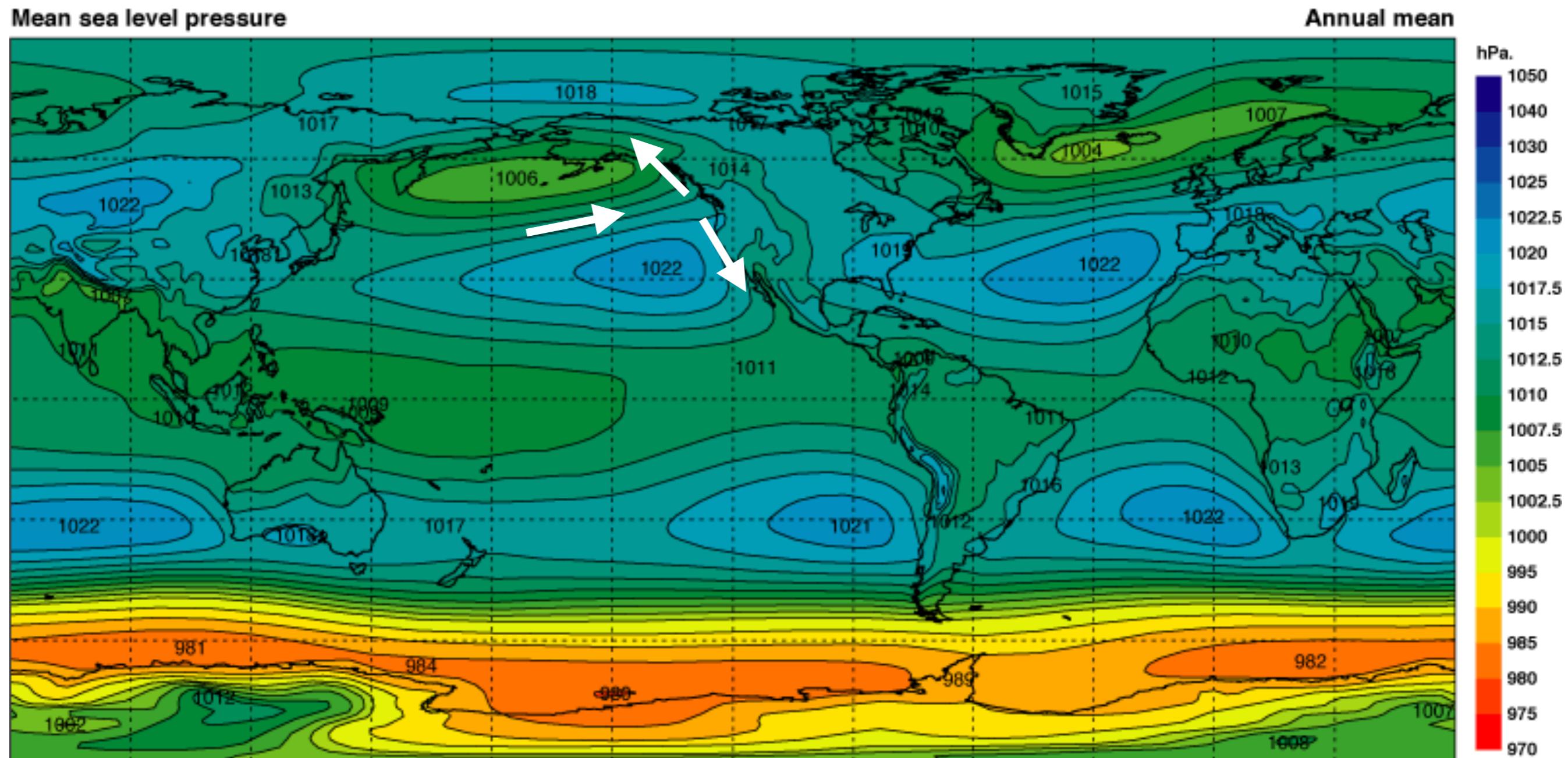
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- **Interannual : 1 year to 10 years**
  - ENSO
- **Decadal : 10 years to multiple decades**
  - Pacific Decadal Oscillation
  - North Atlantic Oscillation
  - Southern Annular Mode
- **Centennial : multiple hundreds years**

# Mean sea level pressure

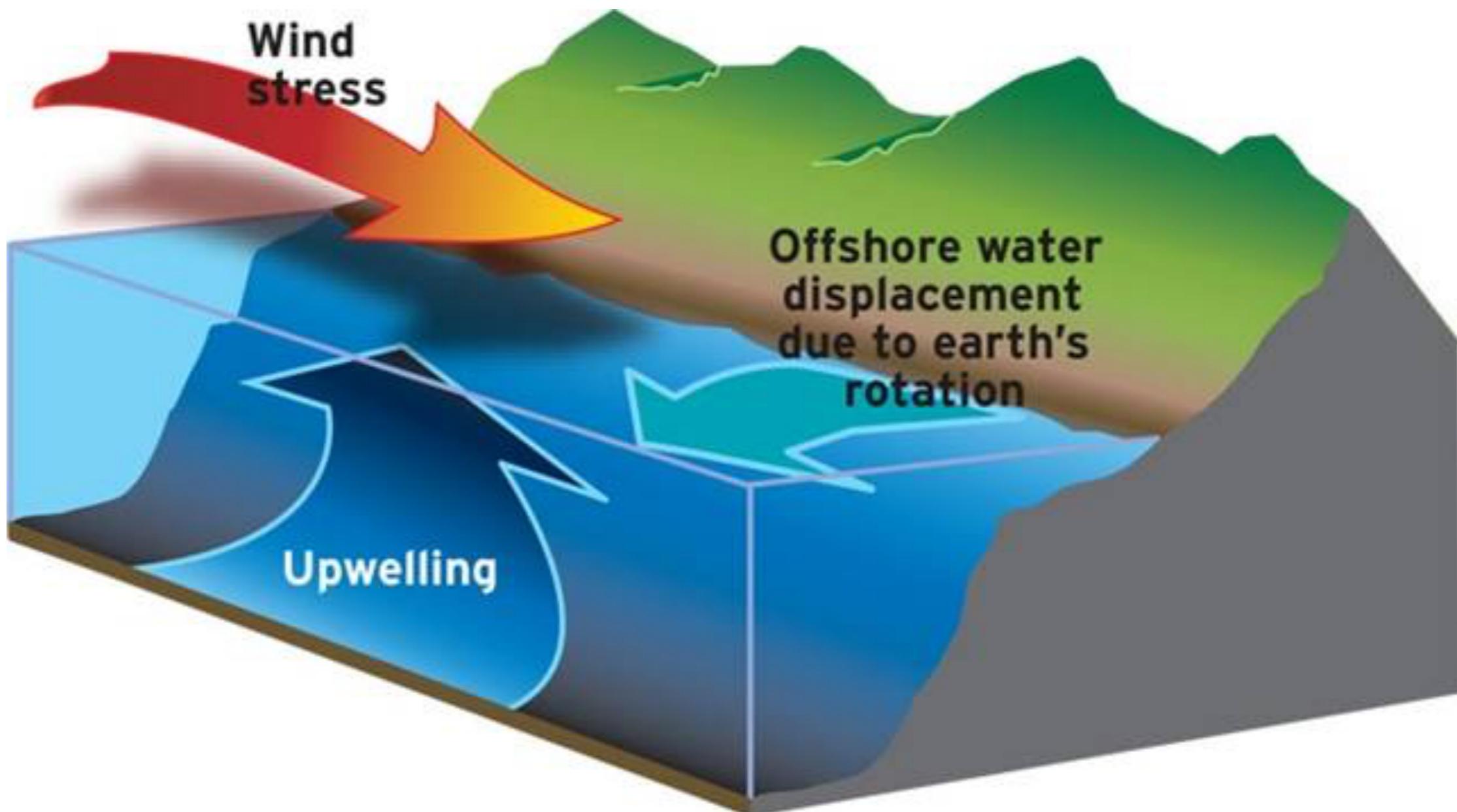


# Mean sea level pressure



# Coastal upwelling

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# Coastal upwelling

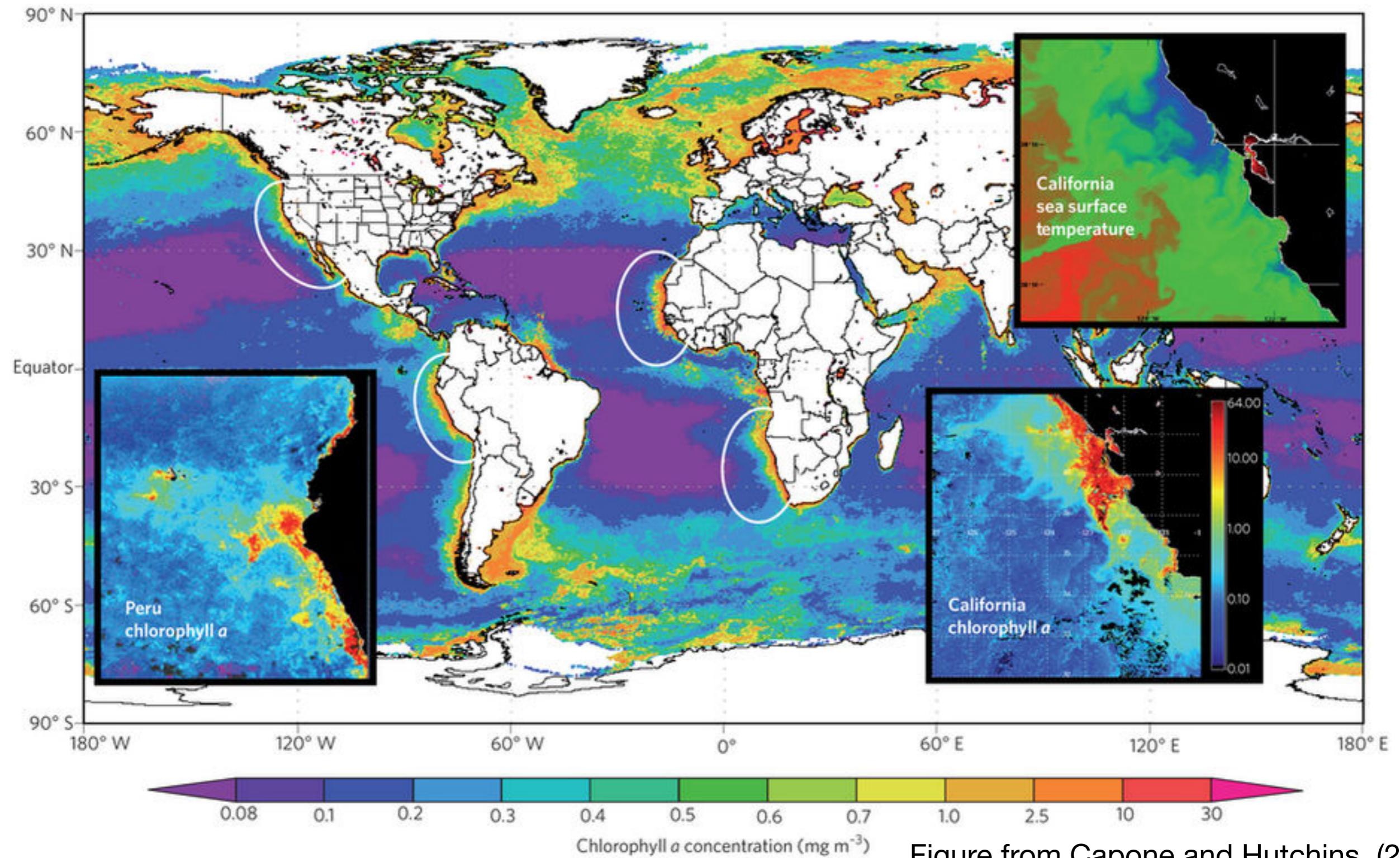
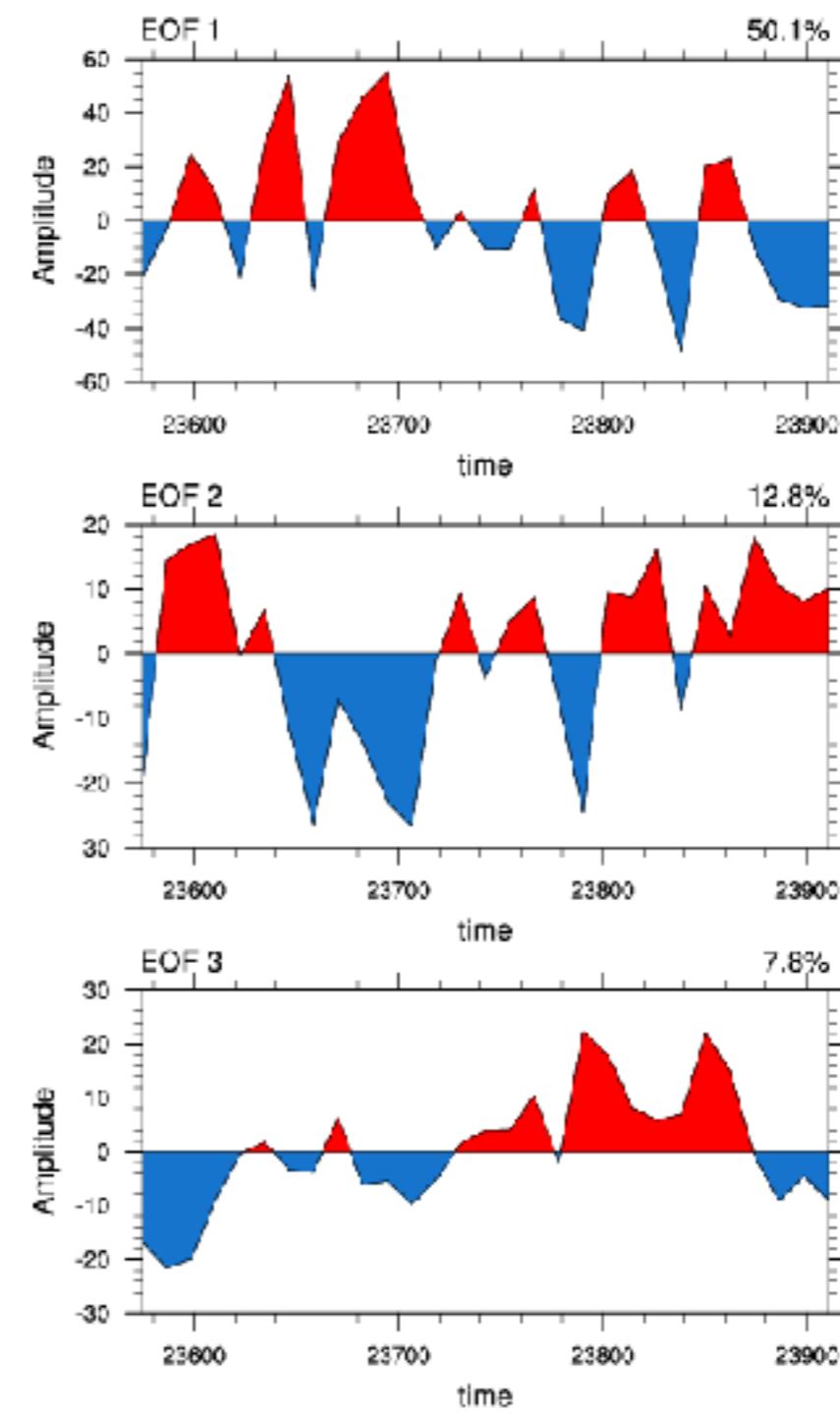
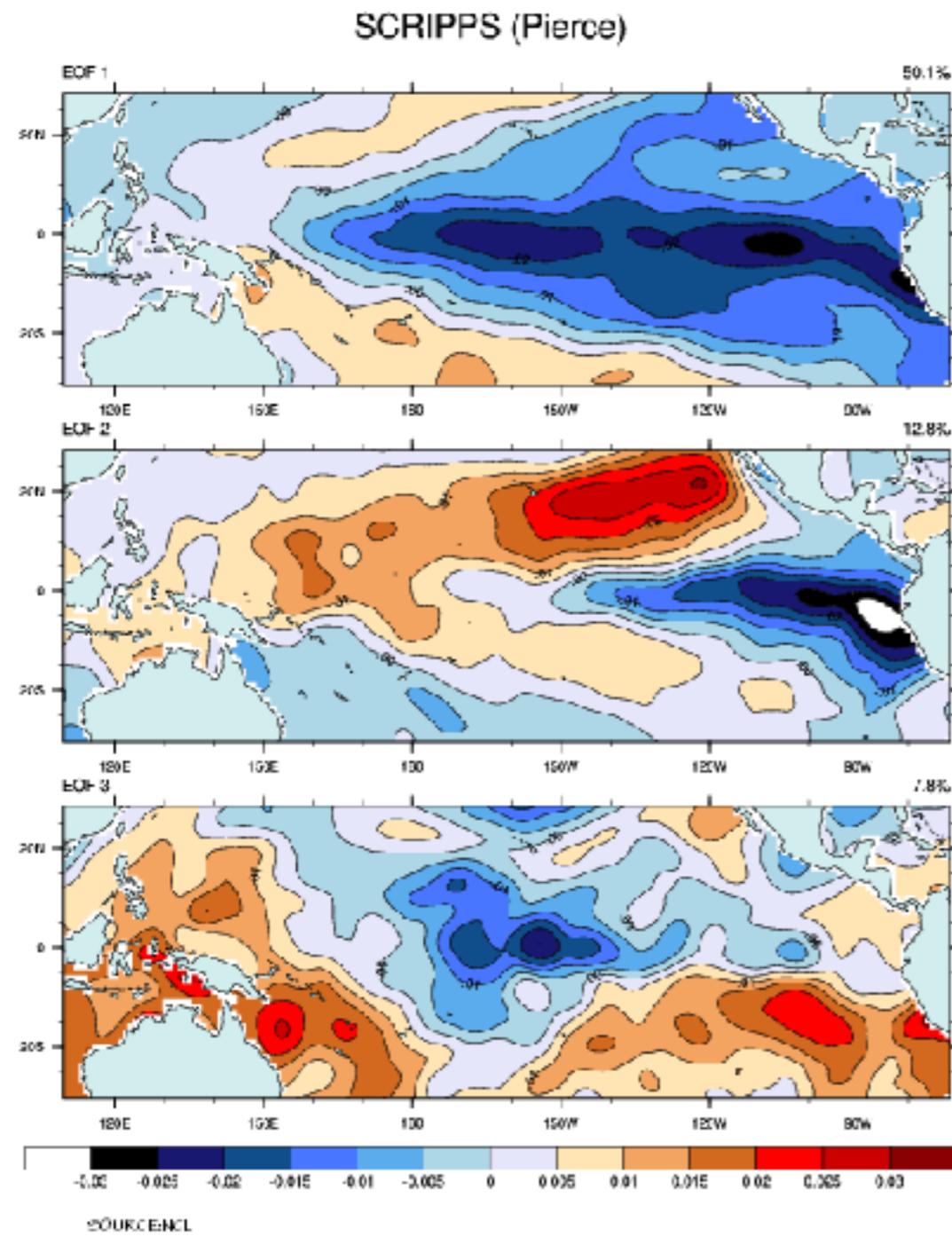


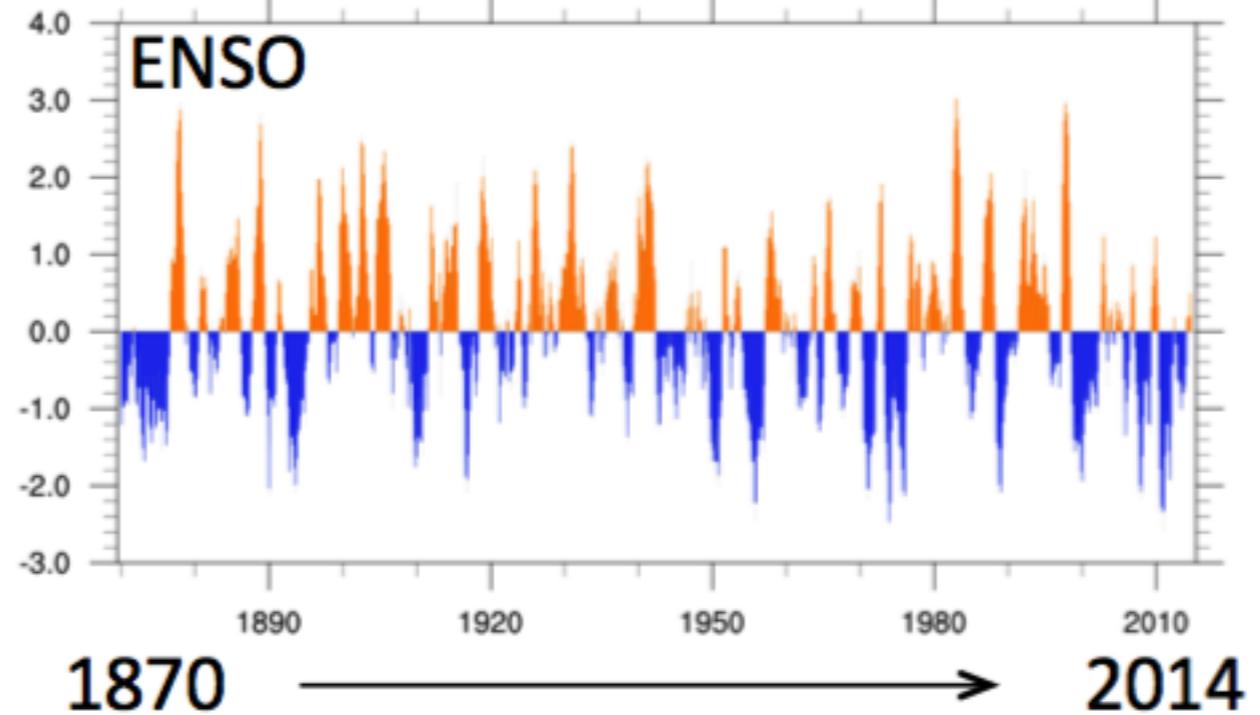
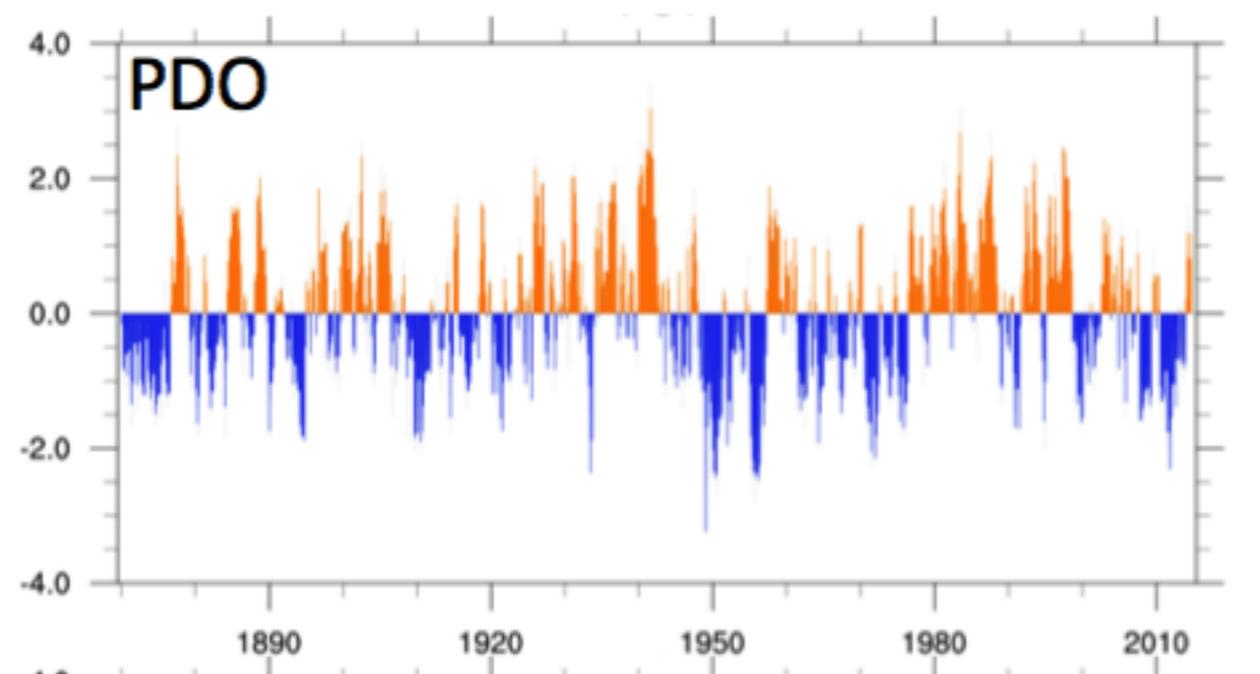
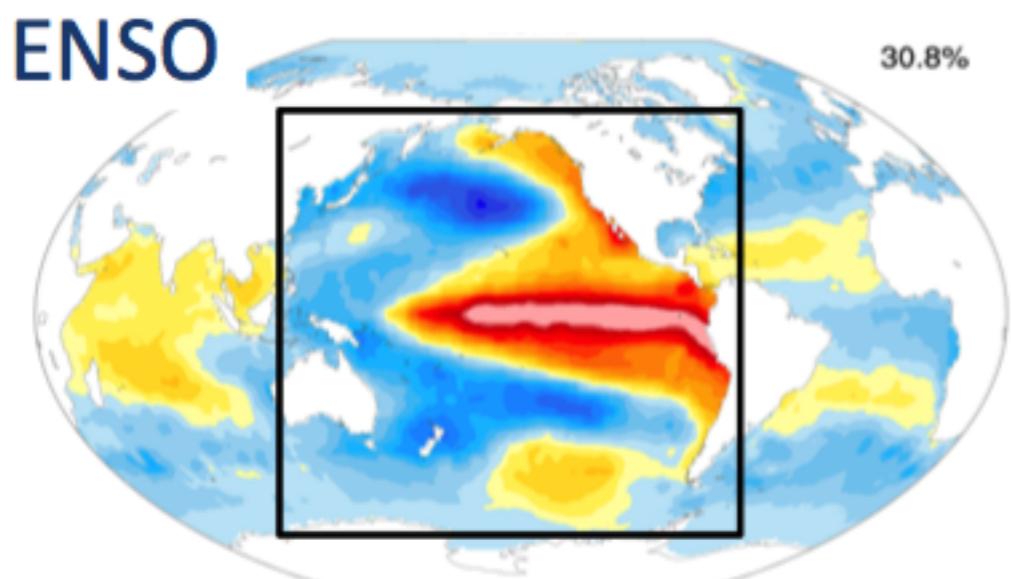
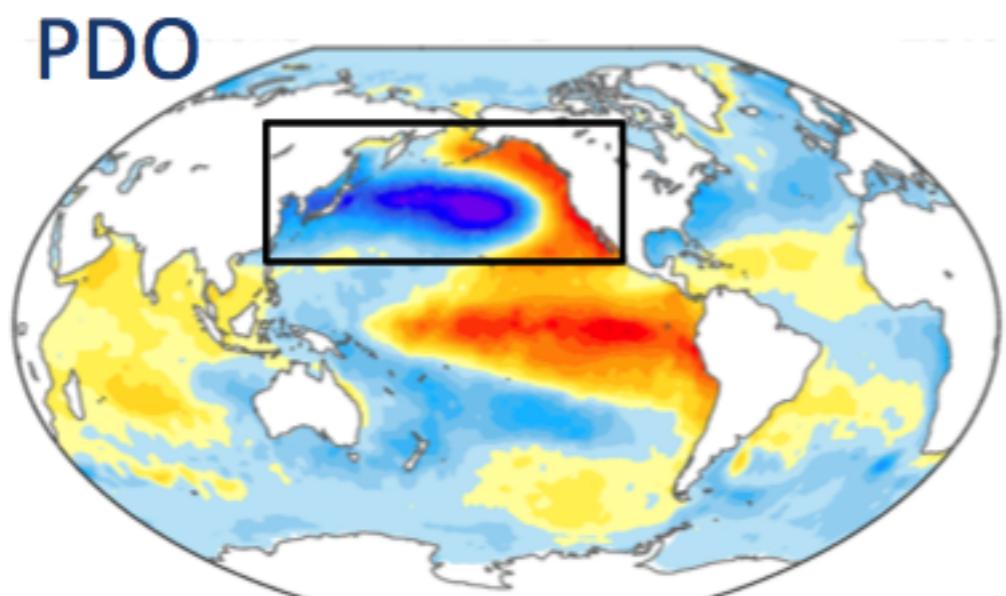
Figure from Capone and Hutchins, (2013)

# Empirical orthogonal function (EOF)



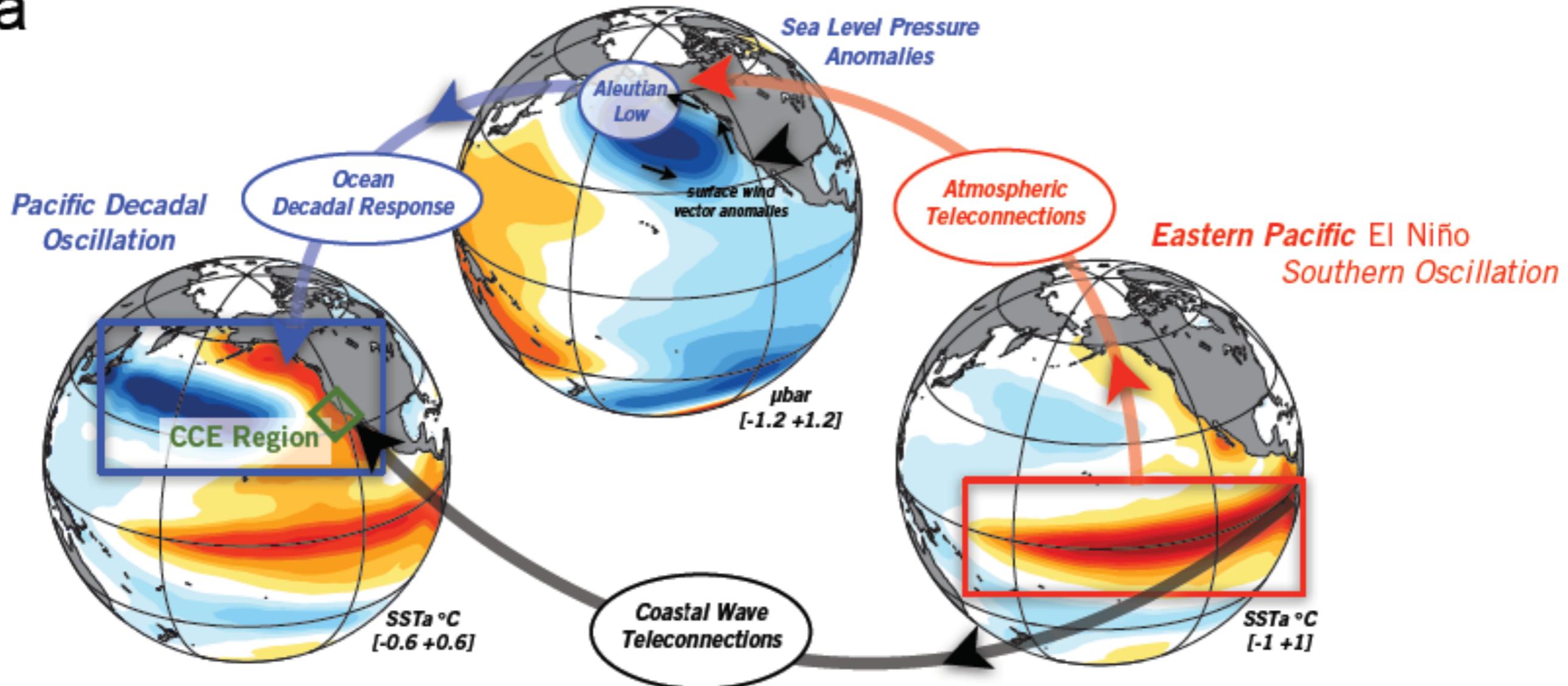
# EOF using sea surface temperature anomaly in the N. Pacific

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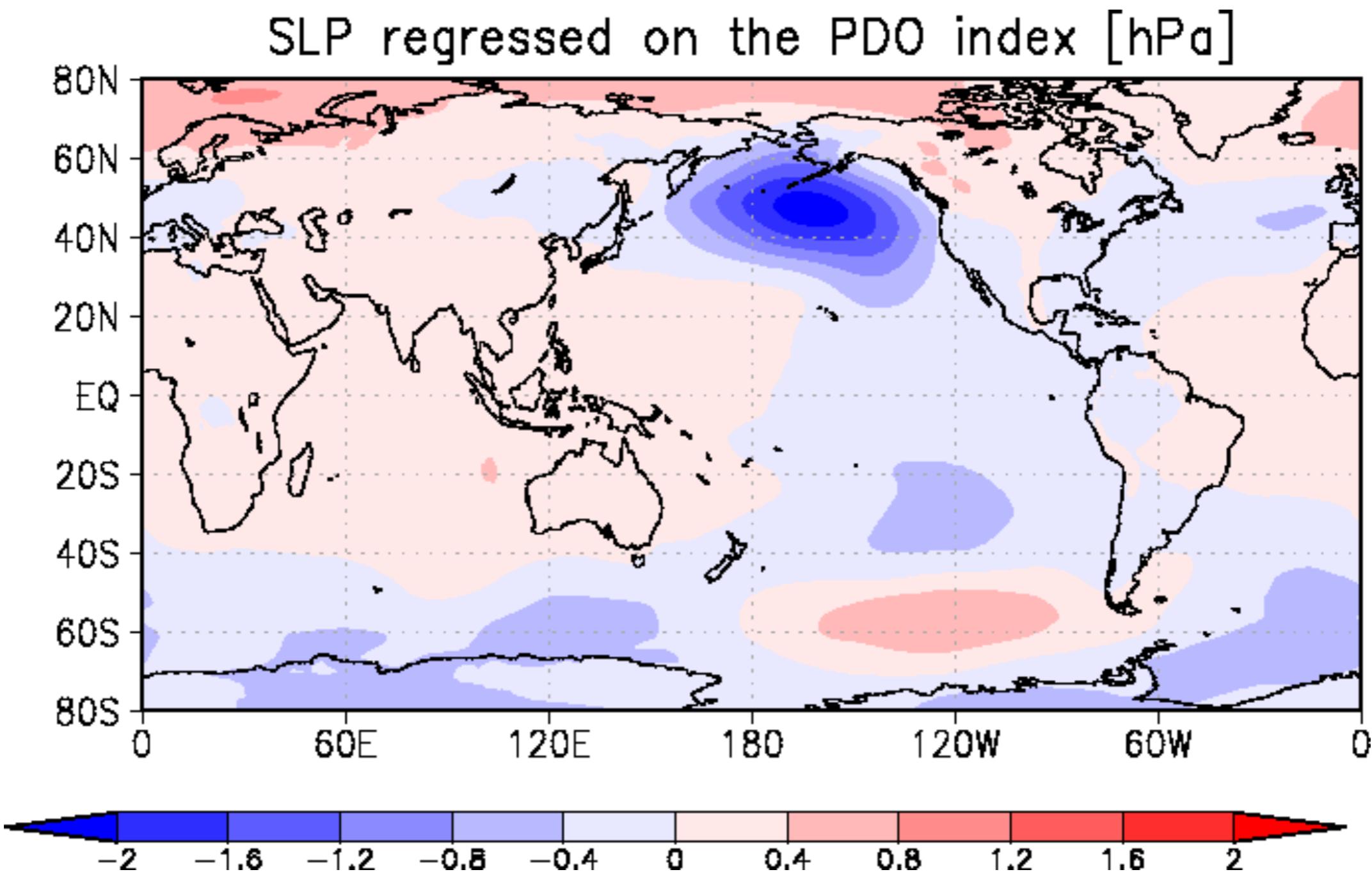
# Teleconnection

a

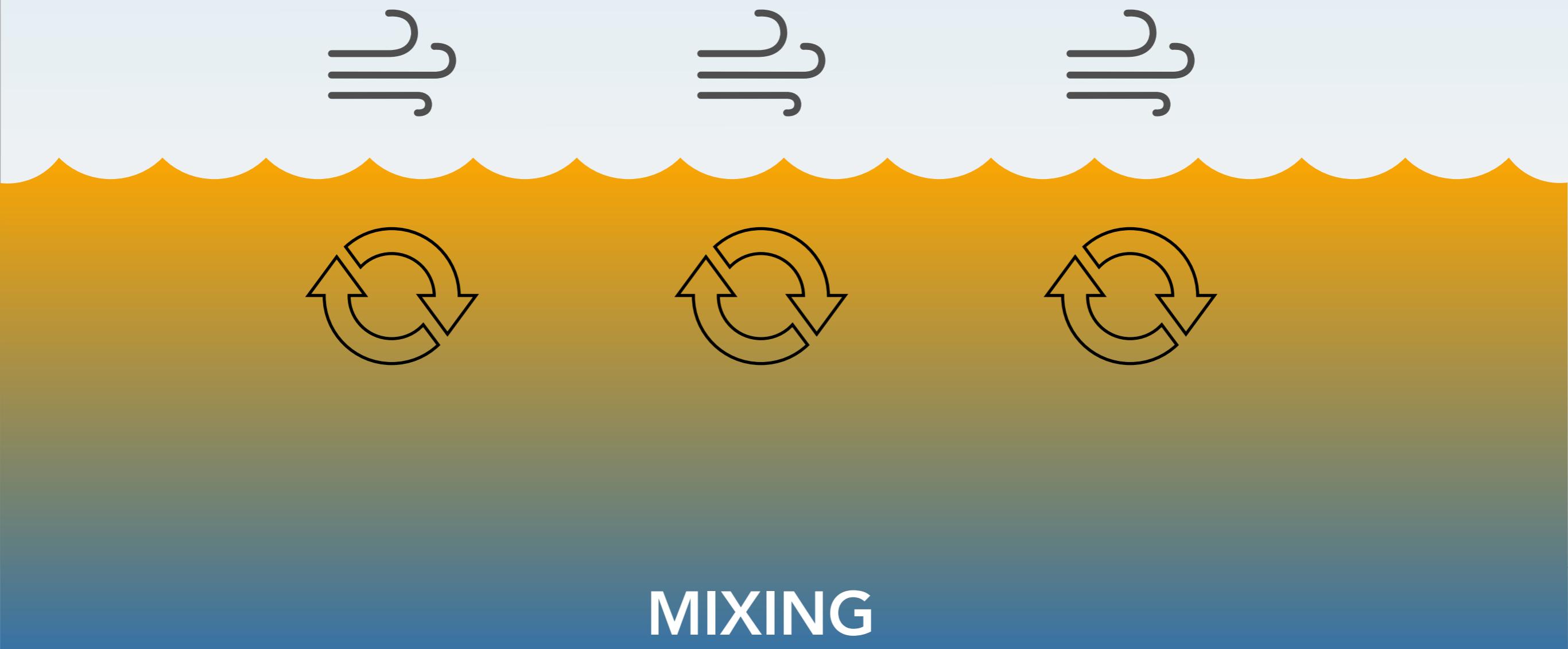


# Teleconnection

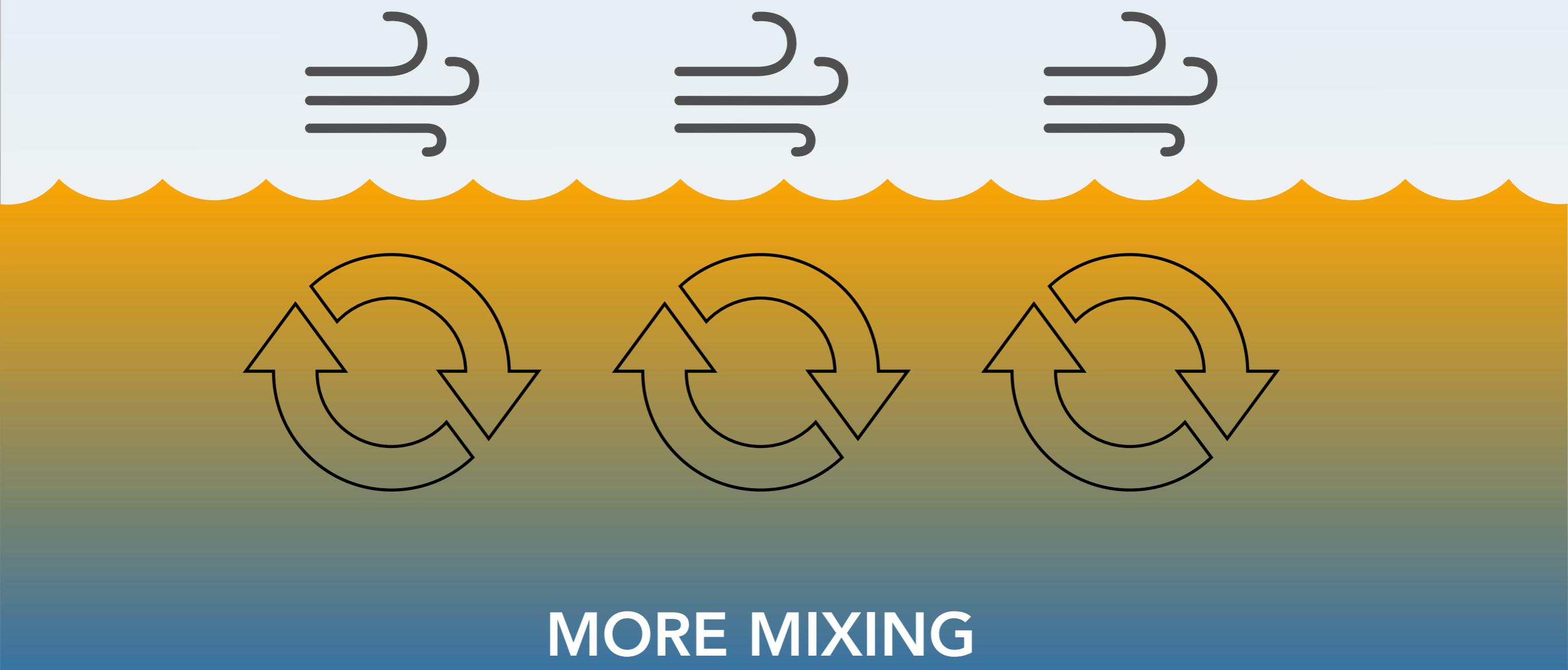
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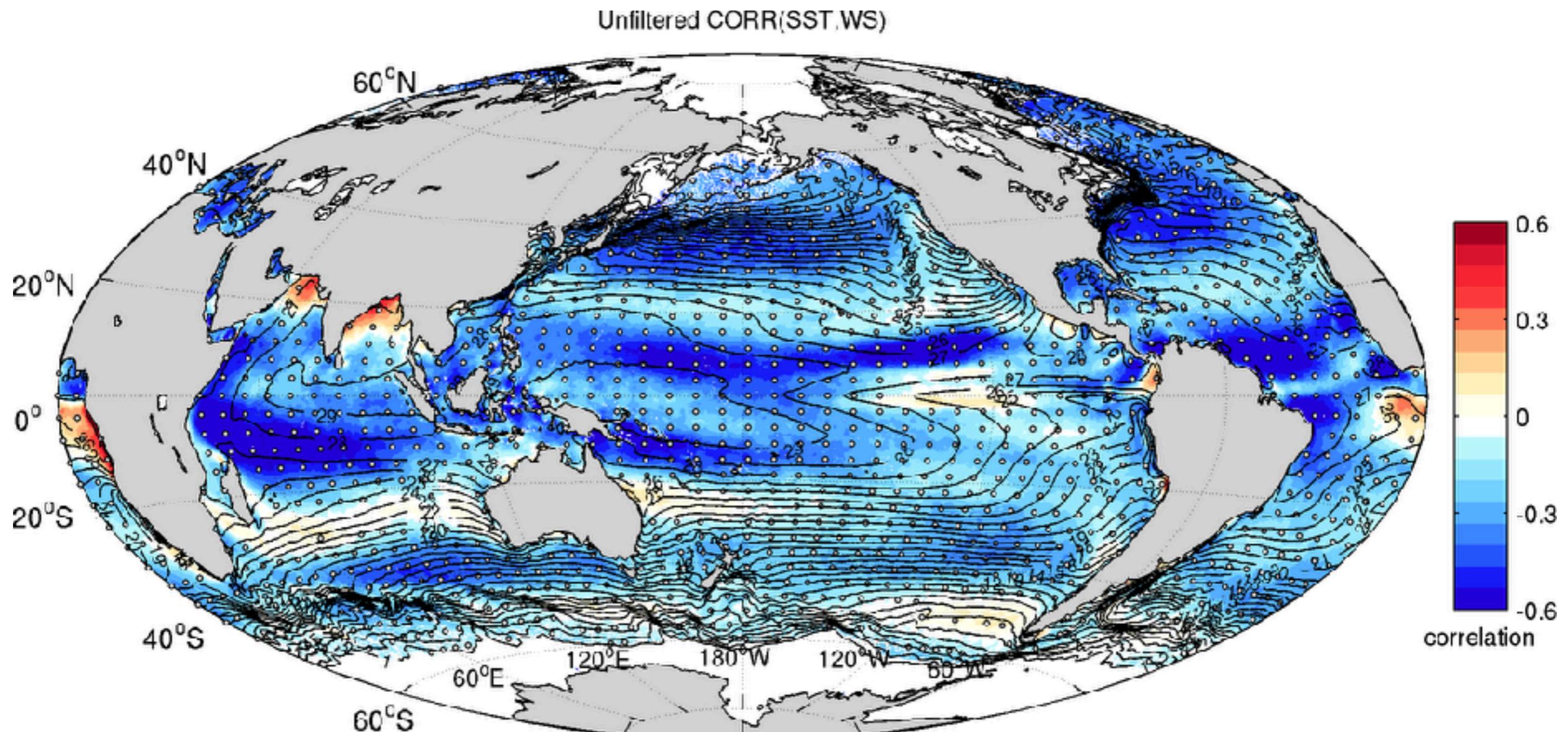
# WIND-SST IN LARGE SCALE



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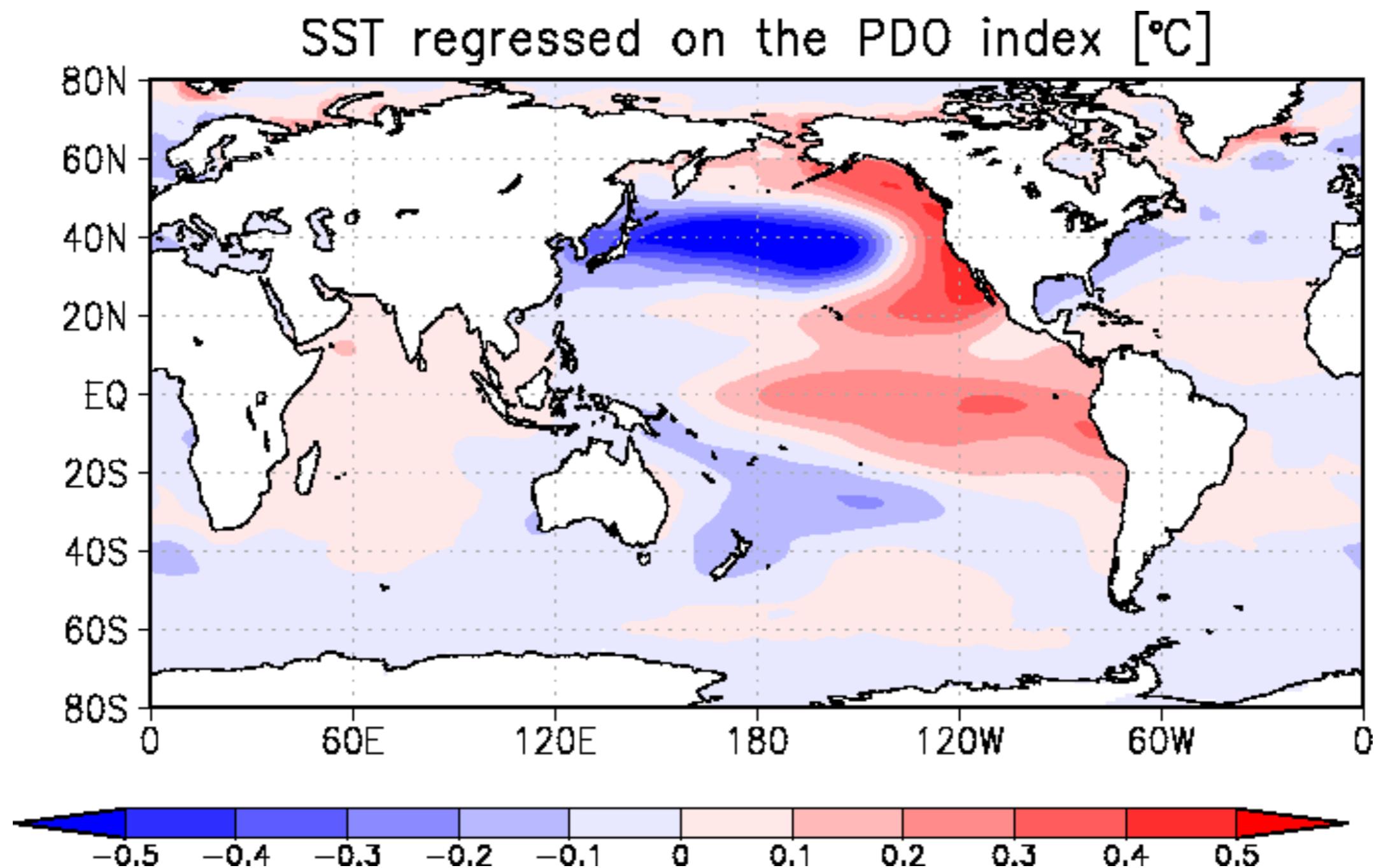
# Correlation between wind speed and SST



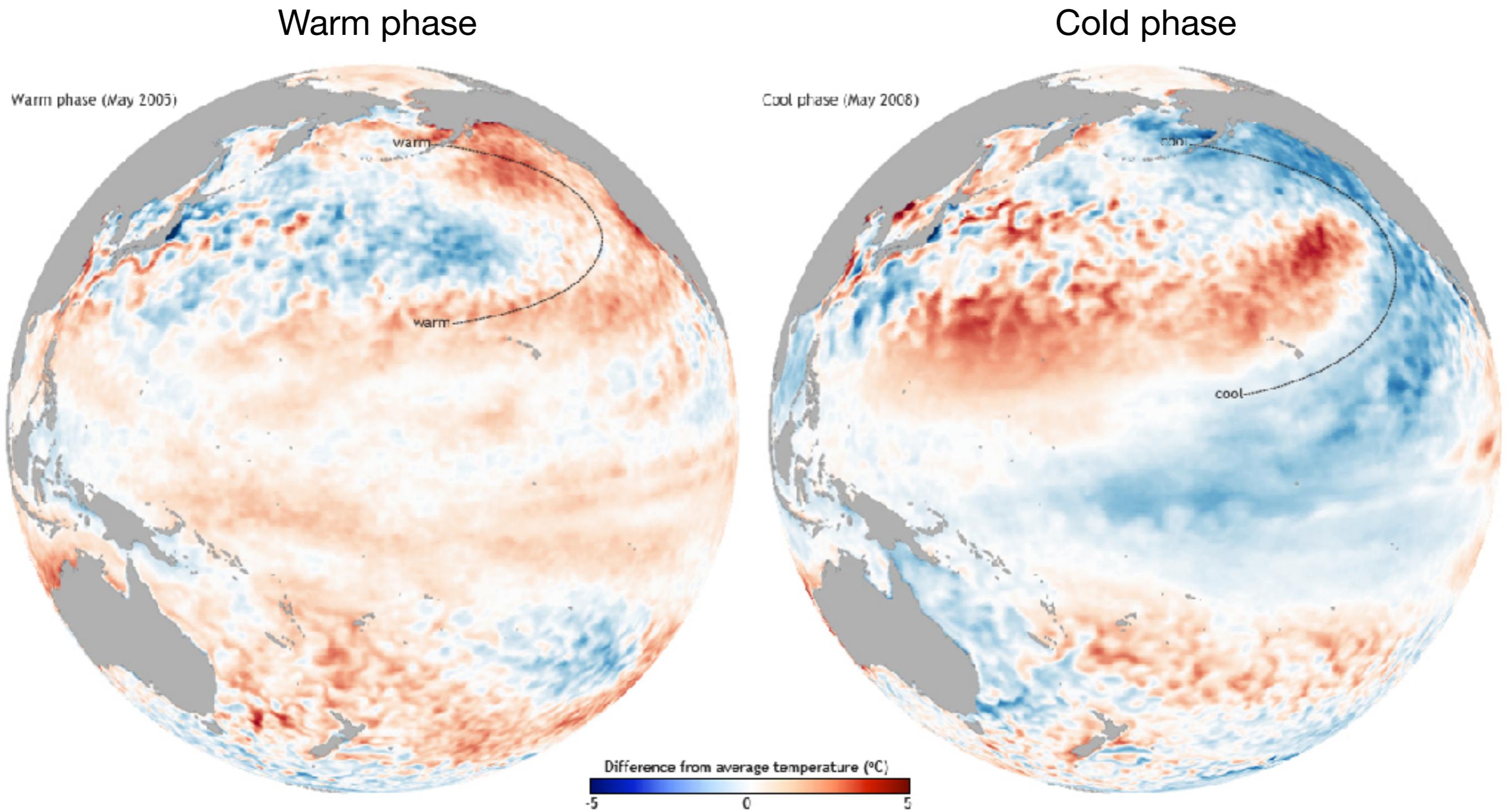
**Oceanic response to the atmosphere**

# Teleconnection

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# Pacific Decadal Oscillation

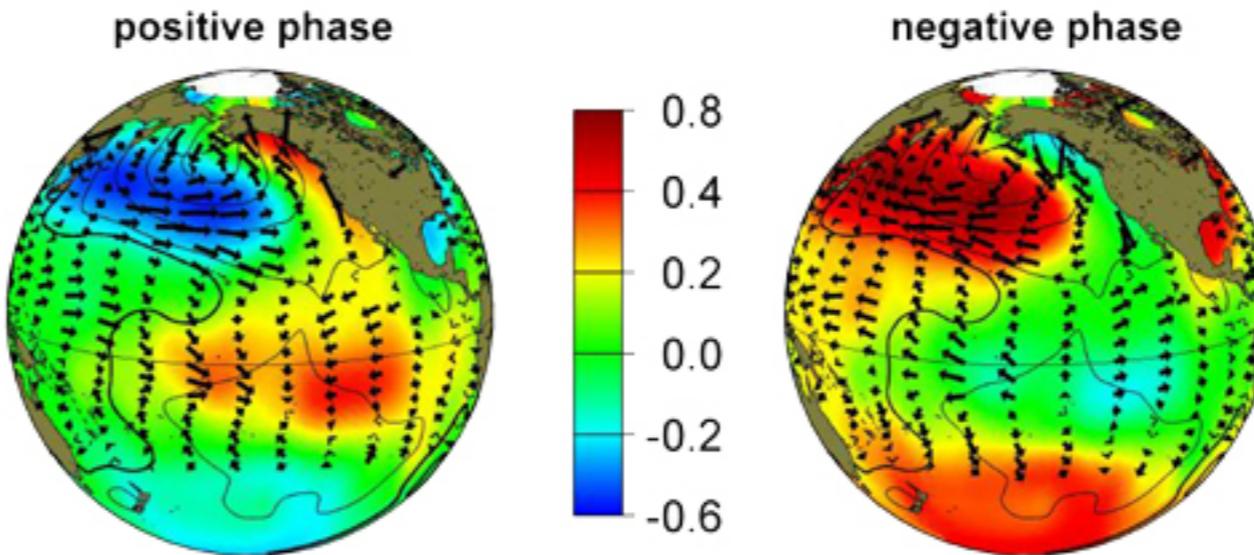


From [https://www.climate.gov/sites/default/files/HR\\_PDO2005-2008.jpg](https://www.climate.gov/sites/default/files/HR_PDO2005-2008.jpg)

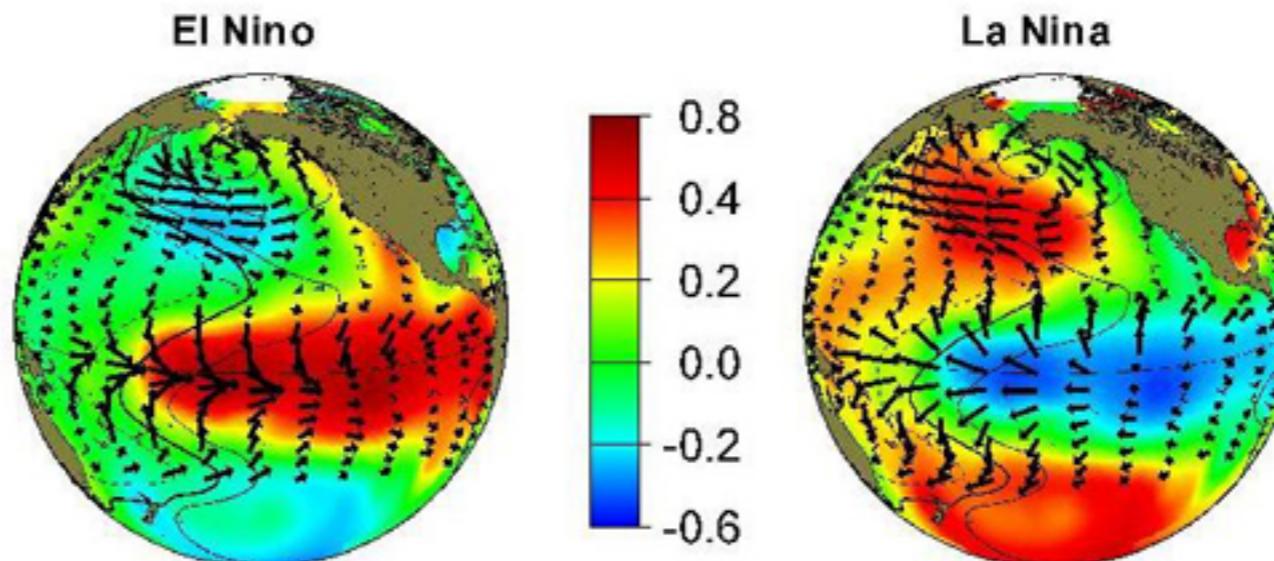
# PDO v.s. ENSO

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**Pacific Decadal Oscillation**



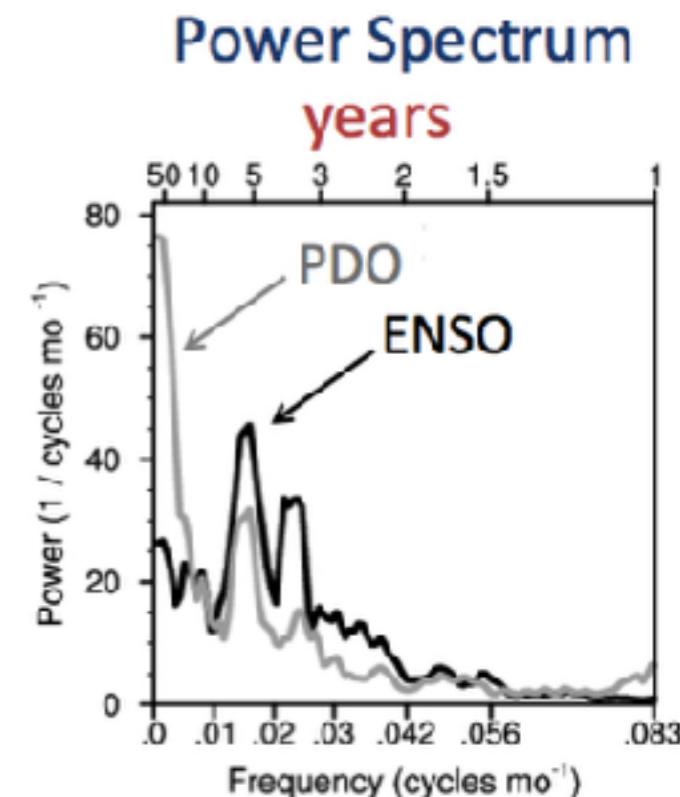
**El Nino Southern Oscillation**



# PDO v.s. ENSO

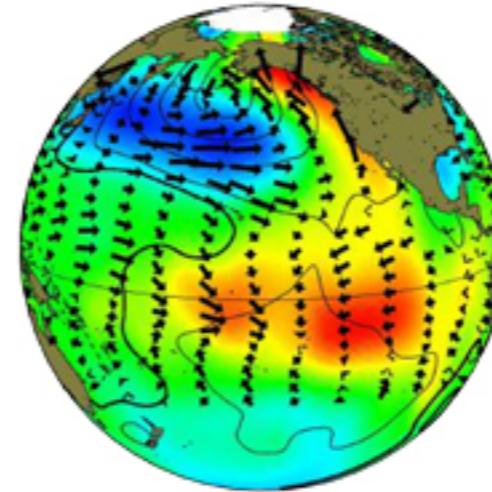
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- Time scale
  - PDO events persist for 20 to 30 years
  - ENSO events persist for 6 to 18 months
- The climate fingerprints
  - PDO in the North Pacific / North American sector
  - ENSO in the tropics

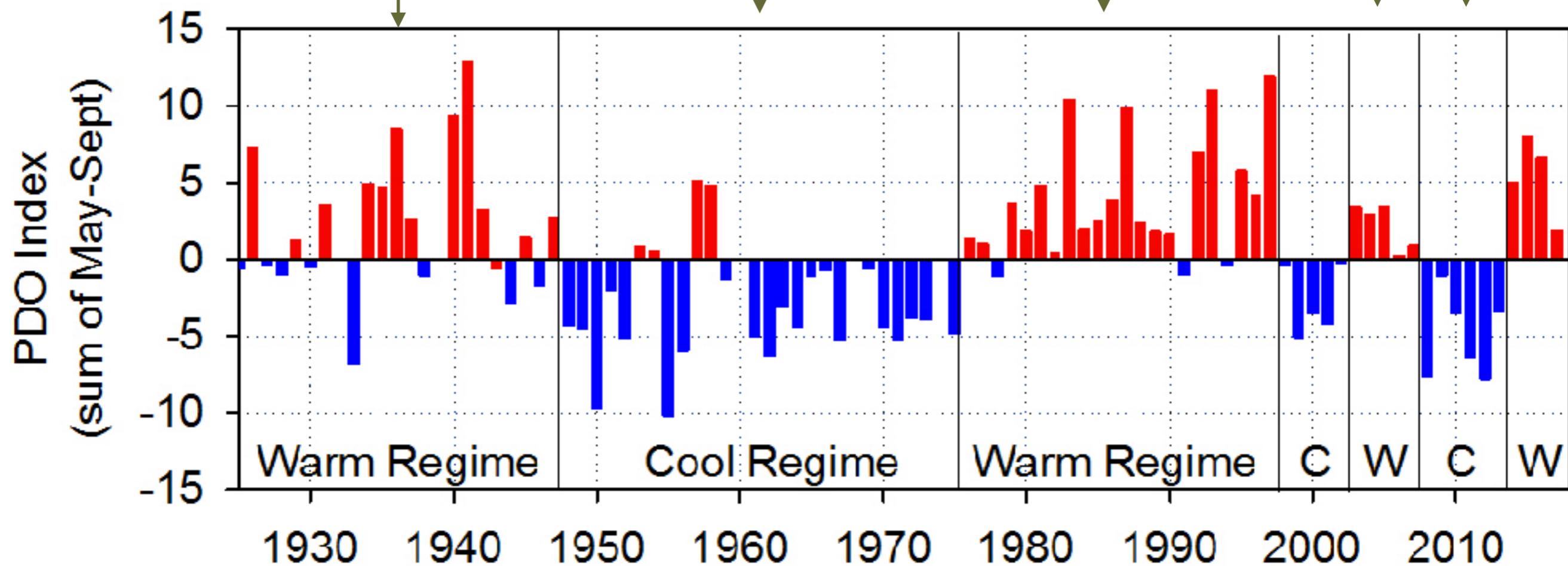
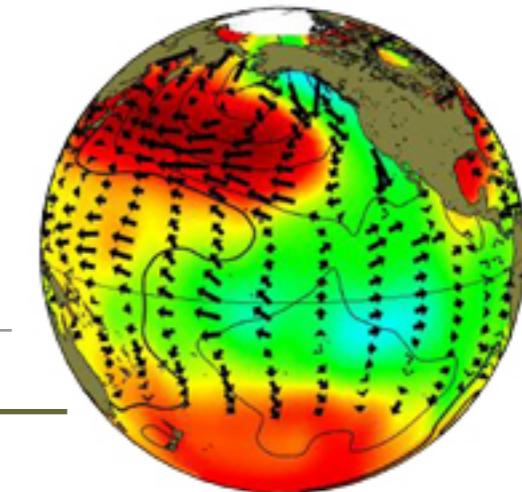


# PDO index

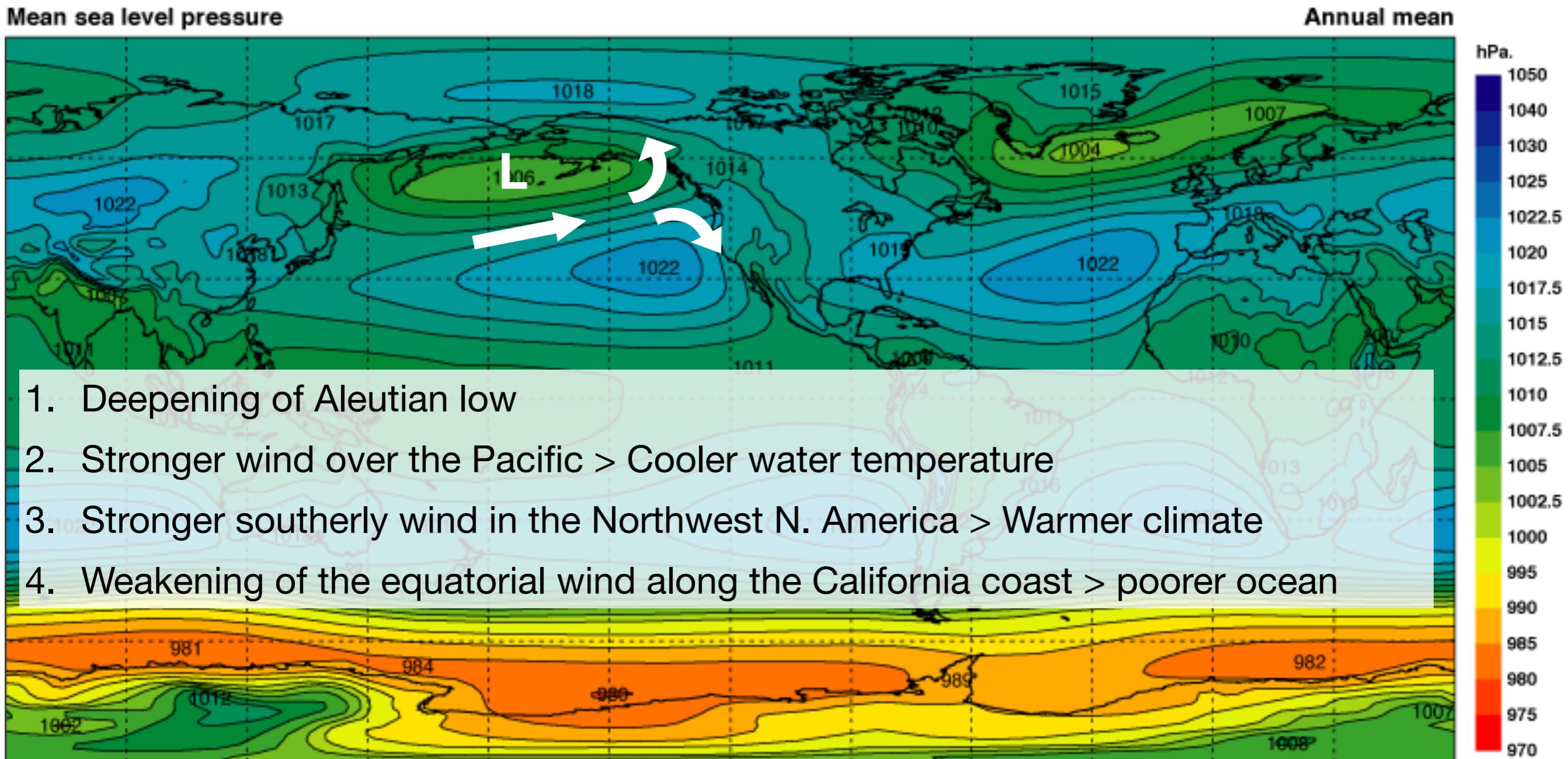
positive phase



negative phase



# Impact of a warm phase of PDO on climate



# Impact of PDO on climate

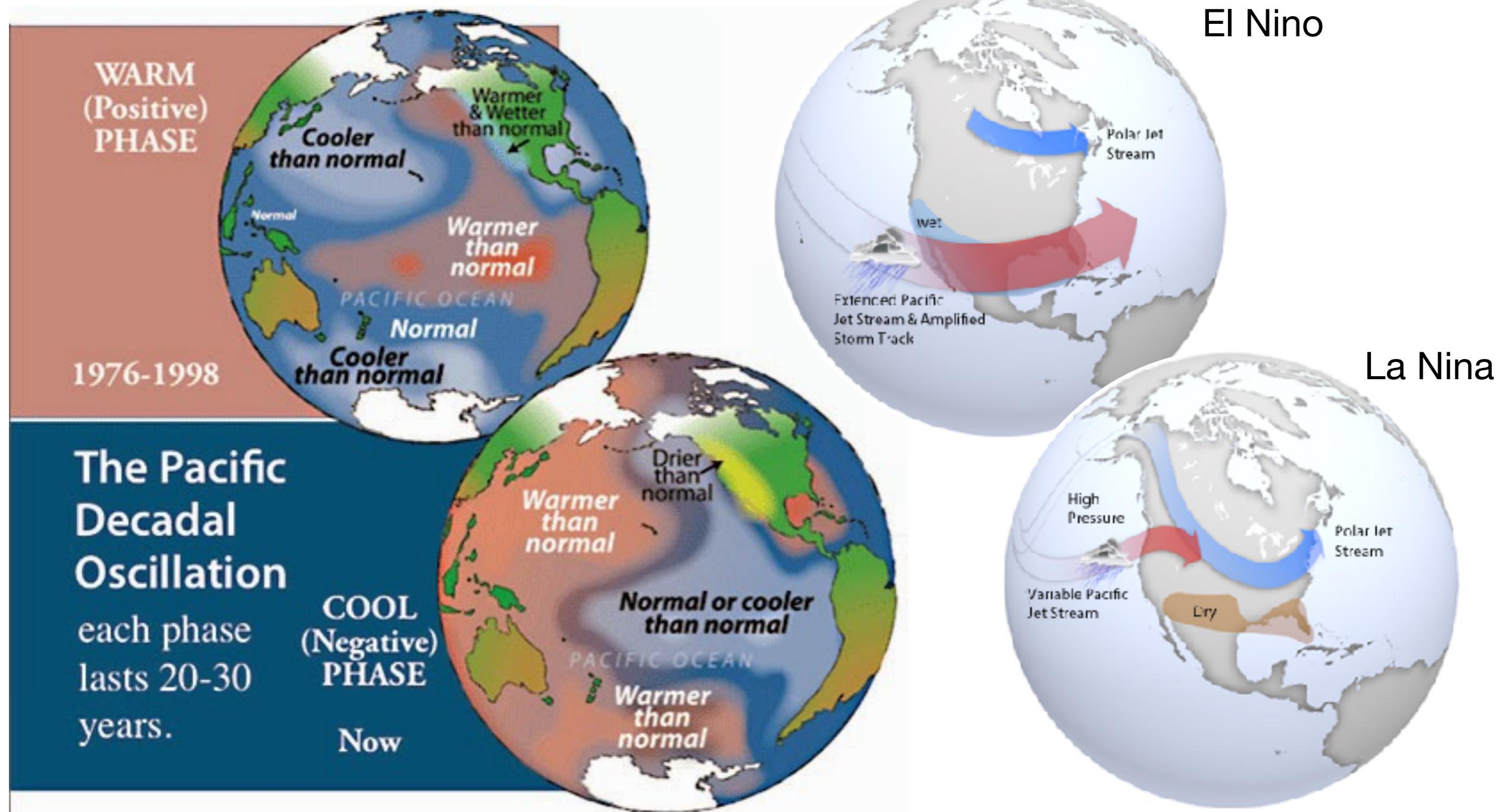


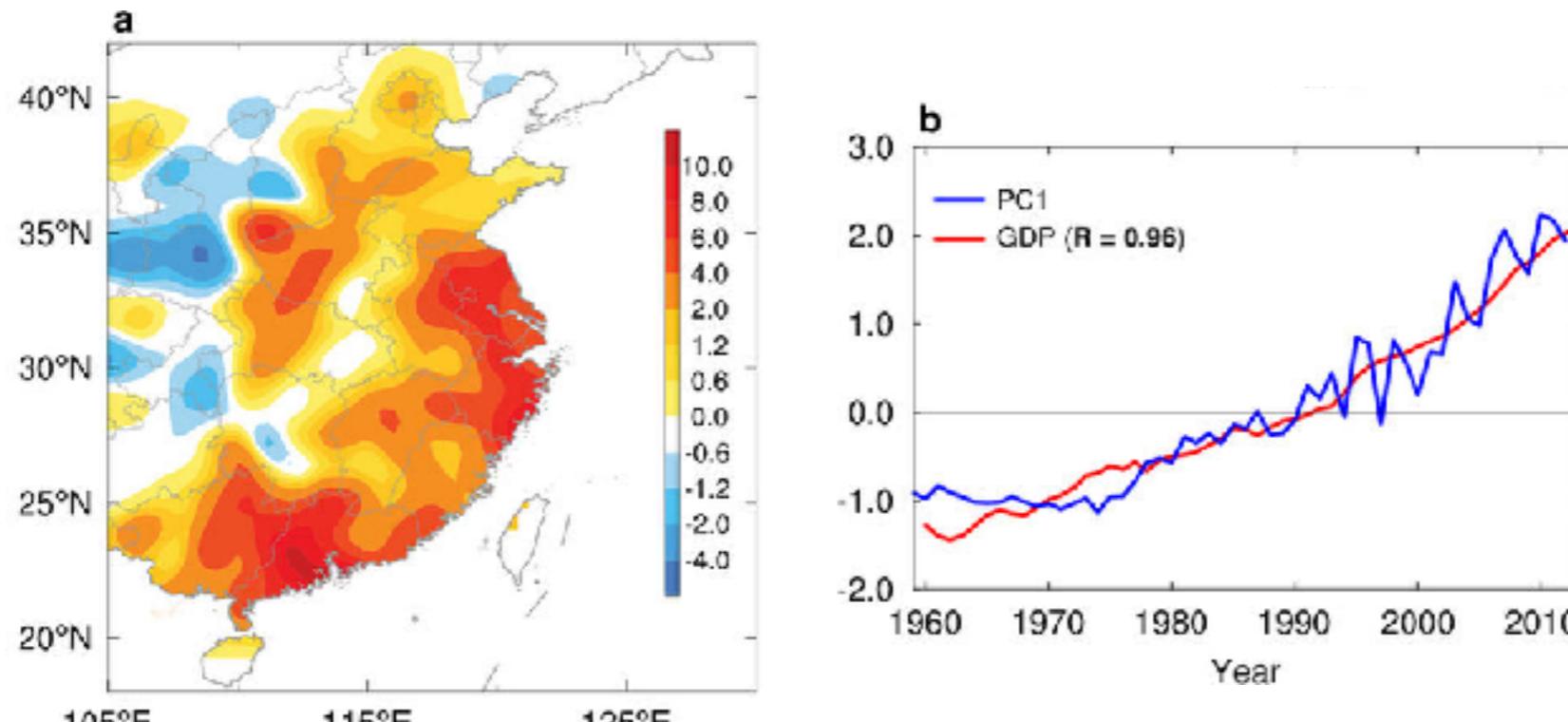
Figure from <http://the-mound-of-sound.blogspot.kr/2015/03/coming-soon-great-warming-spurt.html>  
And [https://www.climate.gov/sites/default/files/LosNinoshighpressure\\_0.jpg](https://www.climate.gov/sites/default/files/LosNinoshighpressure_0.jpg)

# PDO drivers

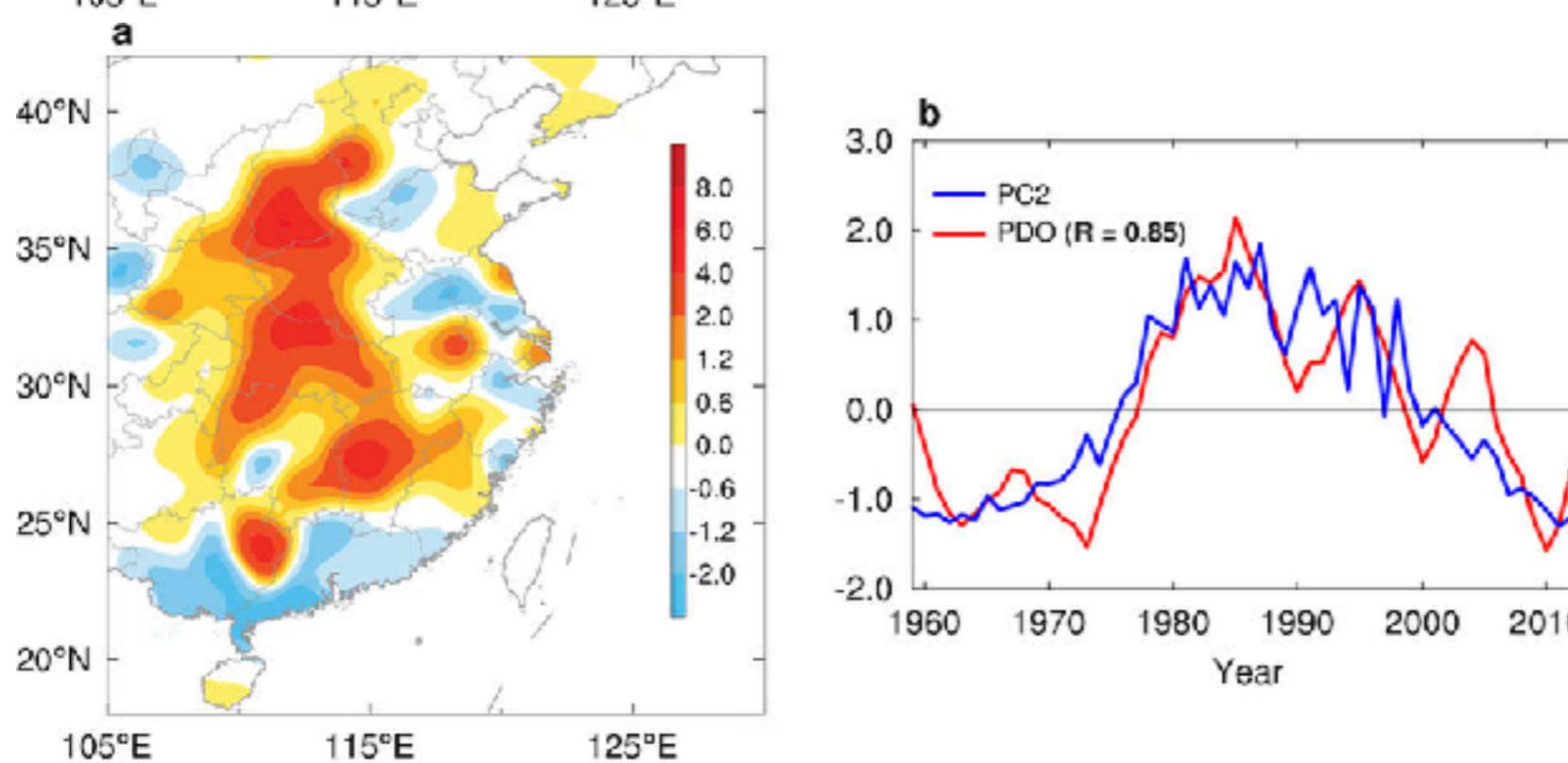
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- changes in **ocean surface heat fluxes and Ekman (wind-driven) transport related to the Aleutian low**
  - local unpredictable weather noise
  - remote forcing from interannual to decadal tropical variability (largely El Niño) via the “atmospheric bridge”
- **ocean memory**, or processes determining oceanic thermal inertia including “re-emergence”, that act to integrate this forcing and generate the decadal variability of the PDO
- **decadal changes in the Kuroshio-Oyashio current system**, forced by winds over the North Pacific driving westward propagating oceanic Rossby waves, manifested as SST anomalies along the subarctic front at about 40°N in the western Pacific ocean

# Impact of PDO on the climate of east Asia



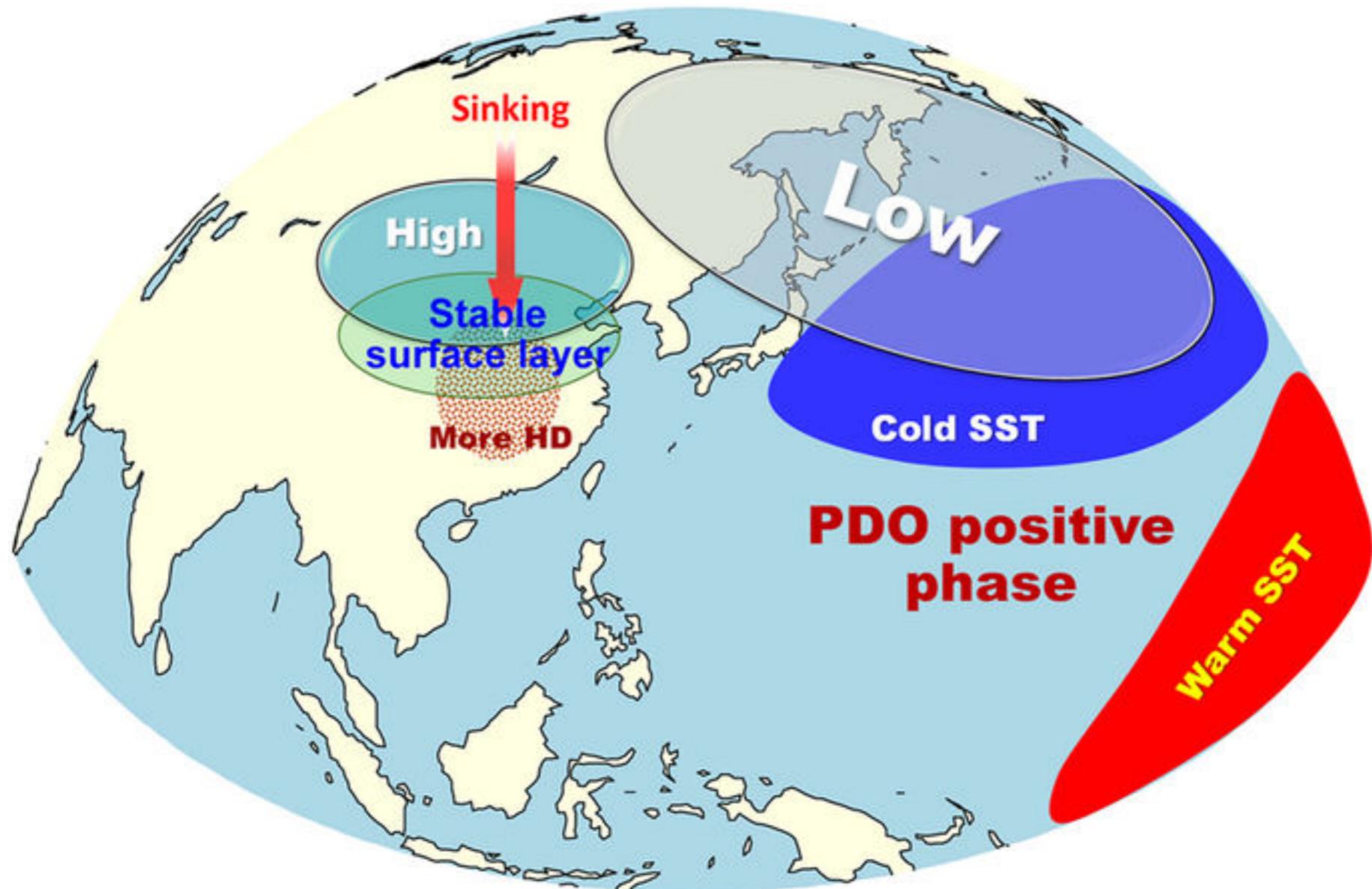
Haze day



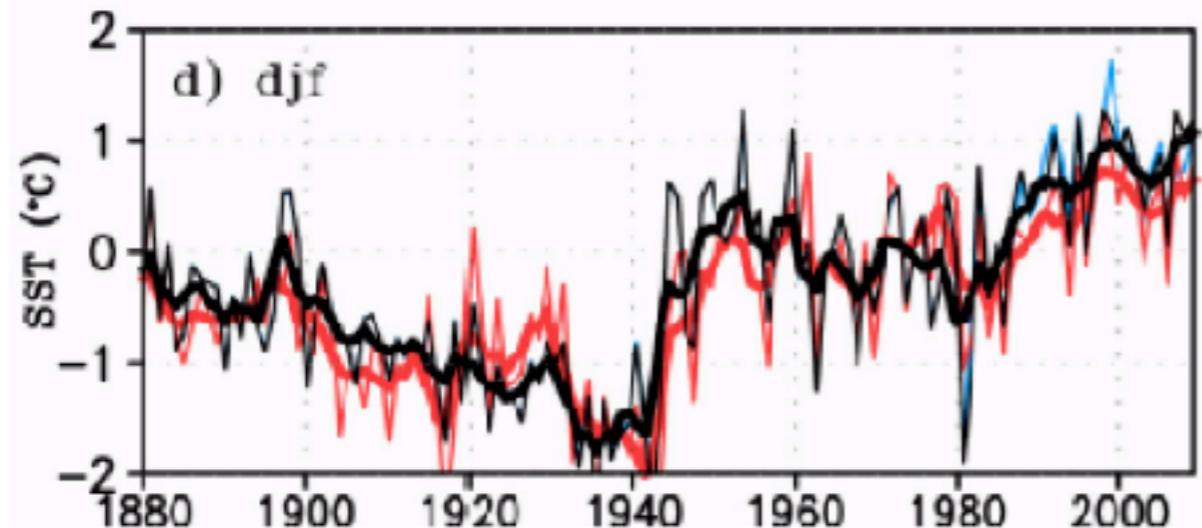
From Zhao et al., 2016

# Impact of PDO on the climate of east Asia

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# Impact of PDO on the climate of east Asia



Sea surface temperature near  
the Korean Peninsula

