

Air-sea interaction: climate variability 2

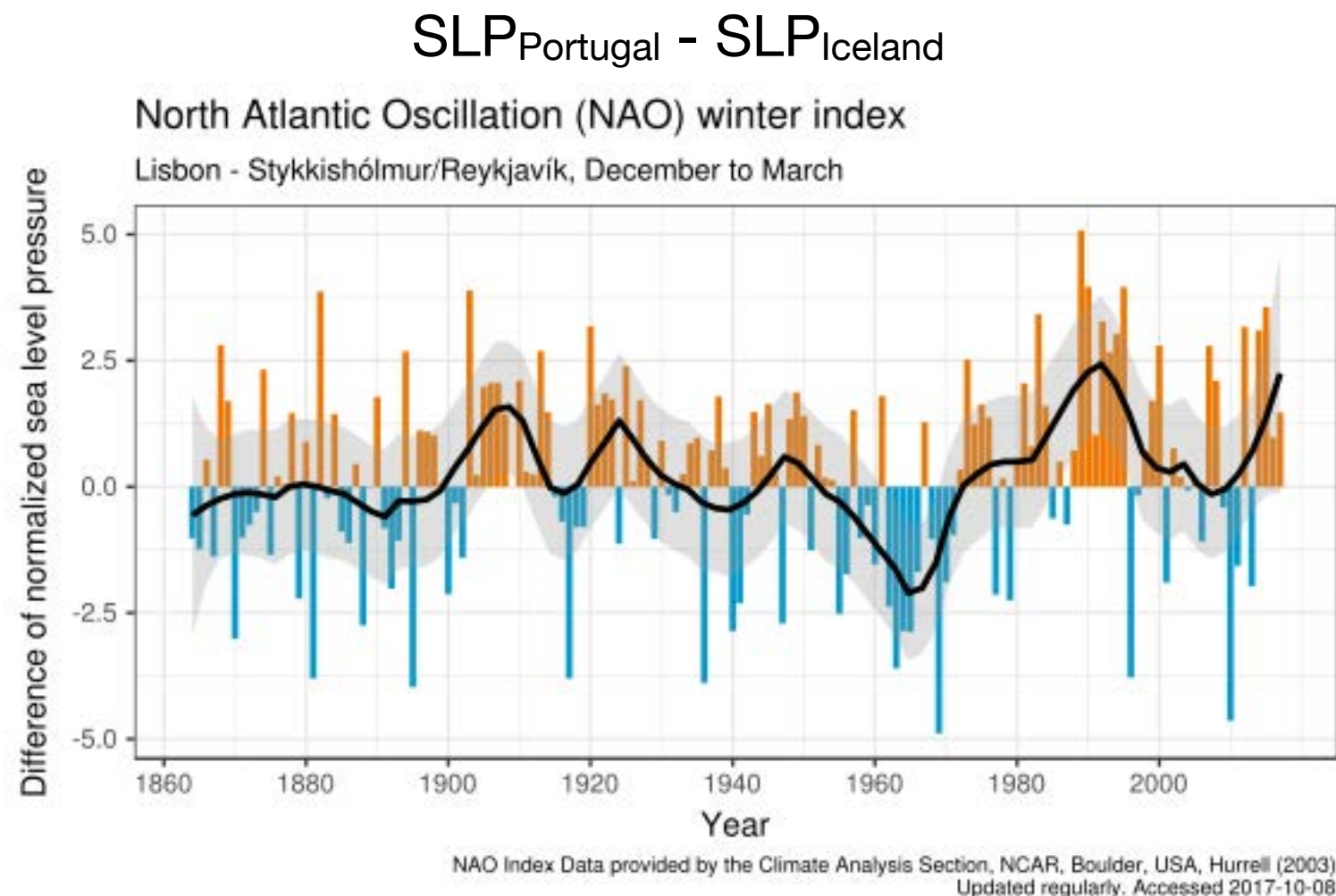
ATM2106

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)

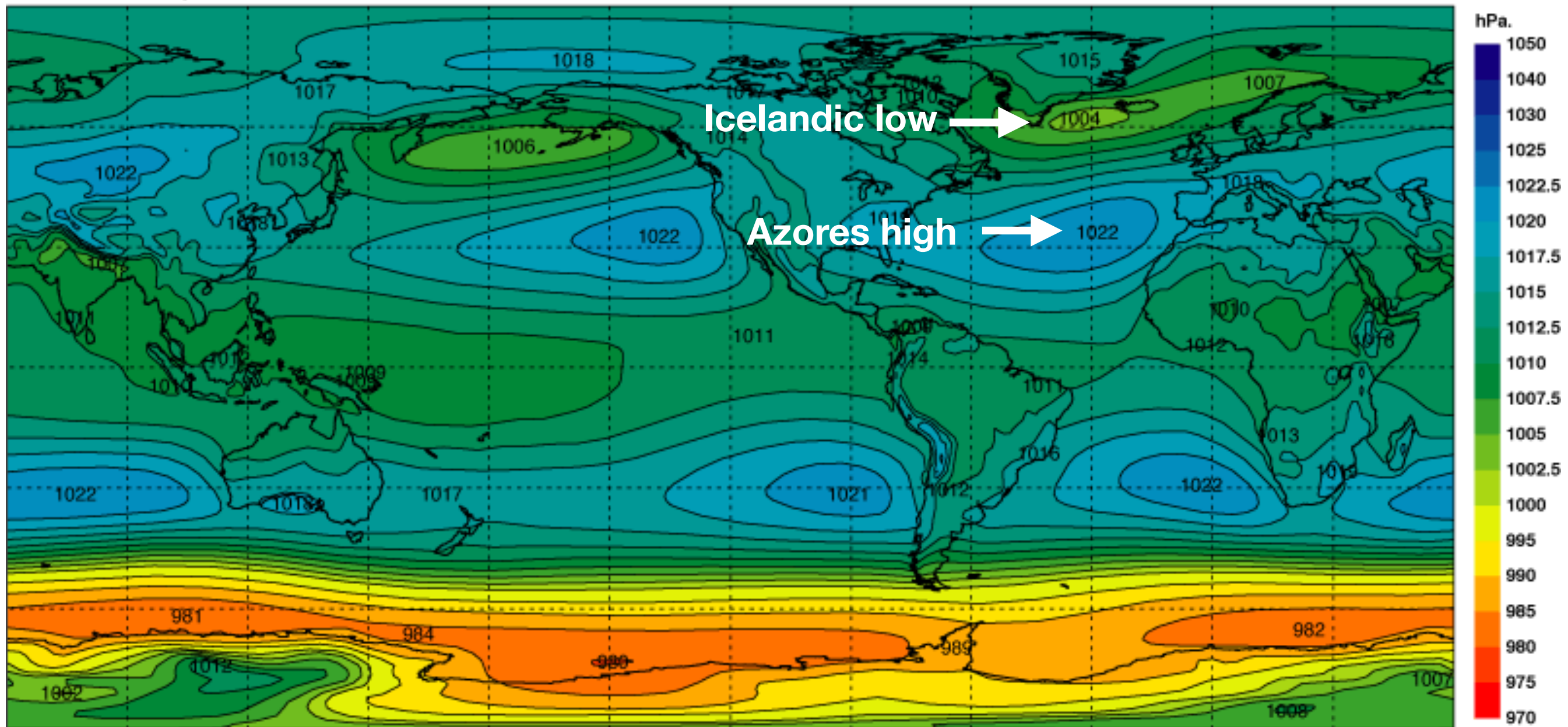
- A reversal of sea level pressure over the North Atlantic
- It has an effect on the weather in Europe and along the east coast of North America.



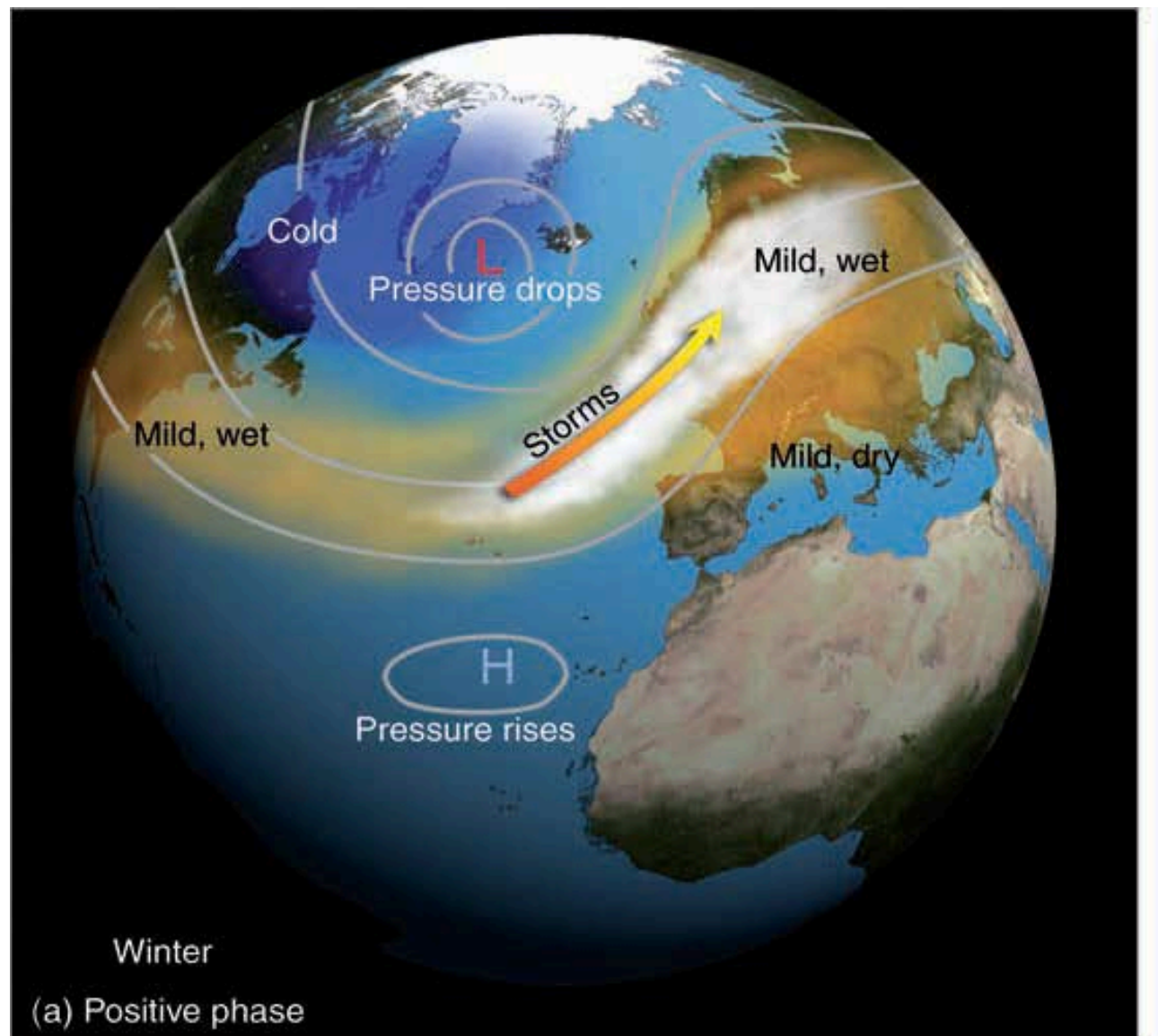
Impact of NAO on the climate

Mean sea level pressure

Annual mean



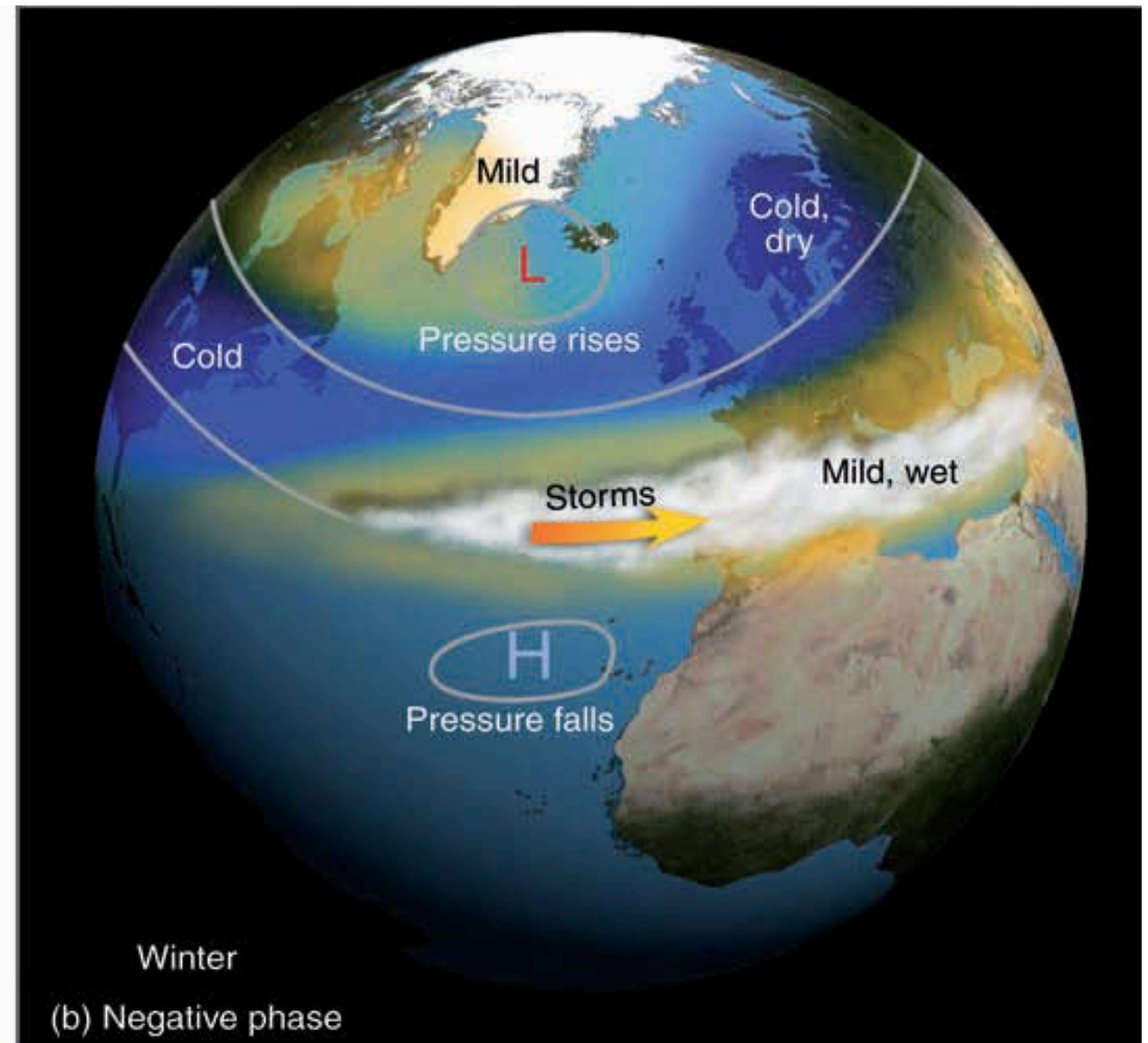
The climate during the positive phase of the NAO



- 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

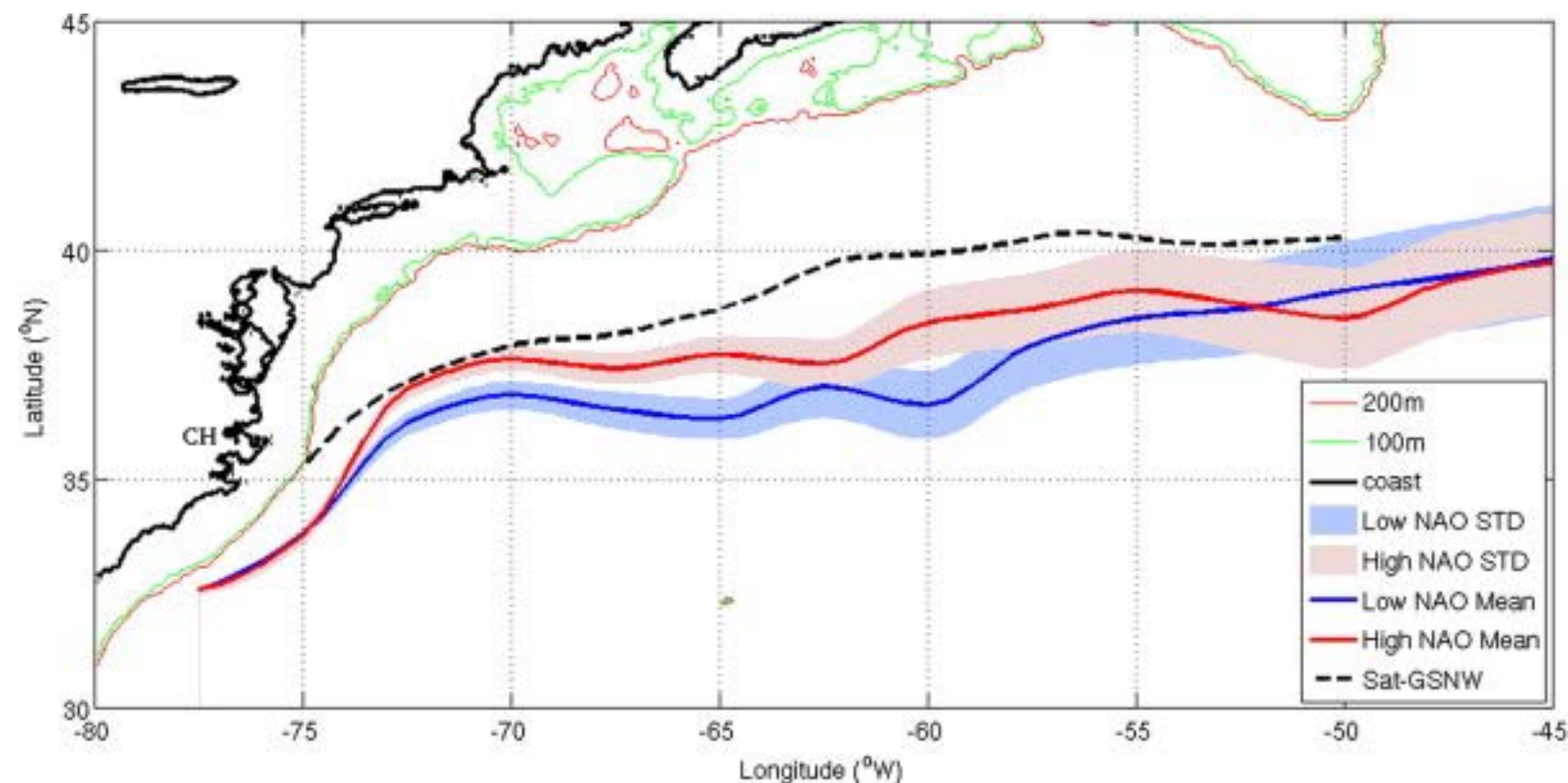
The climate during the negative phase of the NAO

- 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.



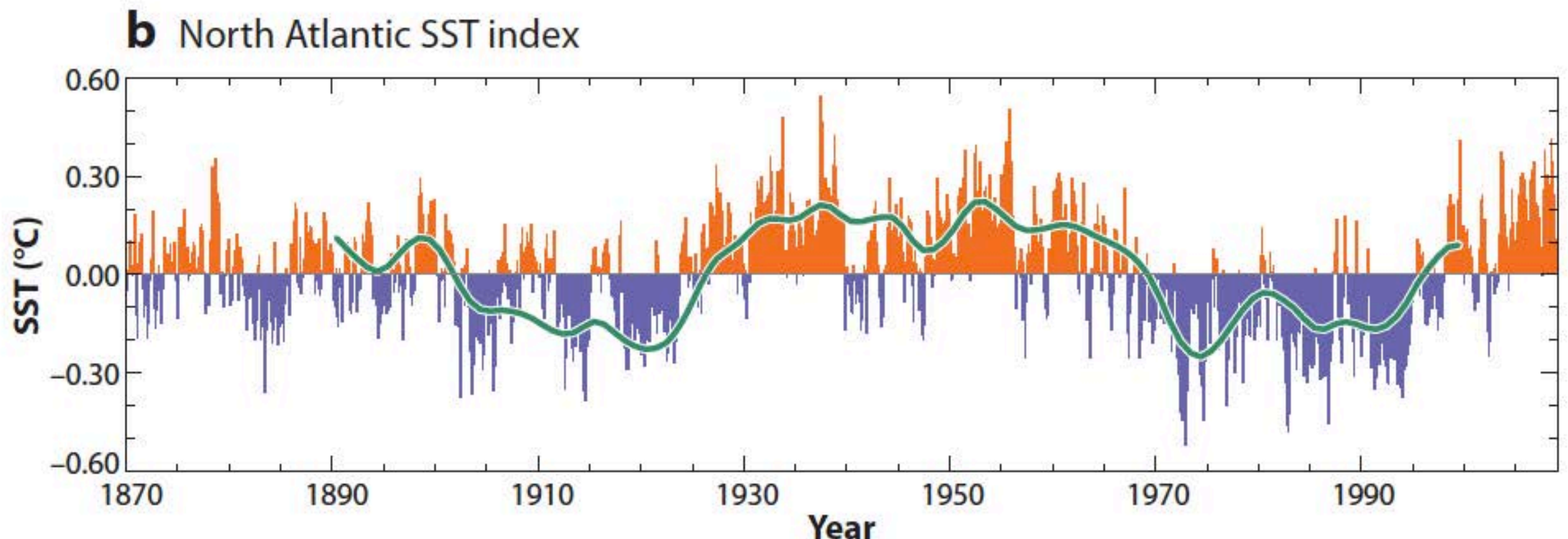
NAO and the ocean

- 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.



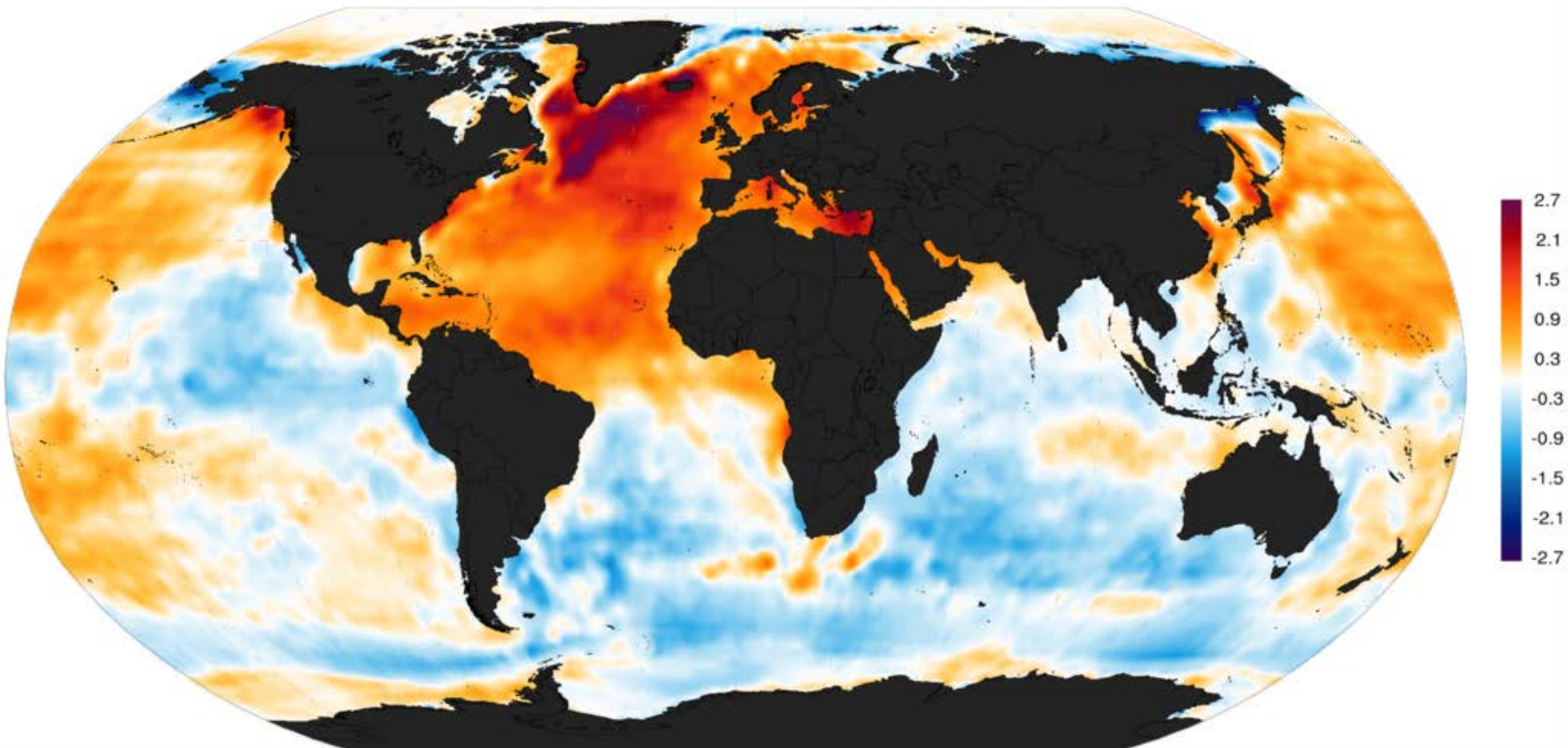
Atlantic Multi-decadal Oscillation (AMO)

- Sea surface temperatures (SST) in the North Atlantic undergo slow variations with a period on the order of 65-80 years. \Rightarrow Atlantic Multi-decadal Oscillation (AMO)



Atlantic Multi-decadal Oscillation (AMO)

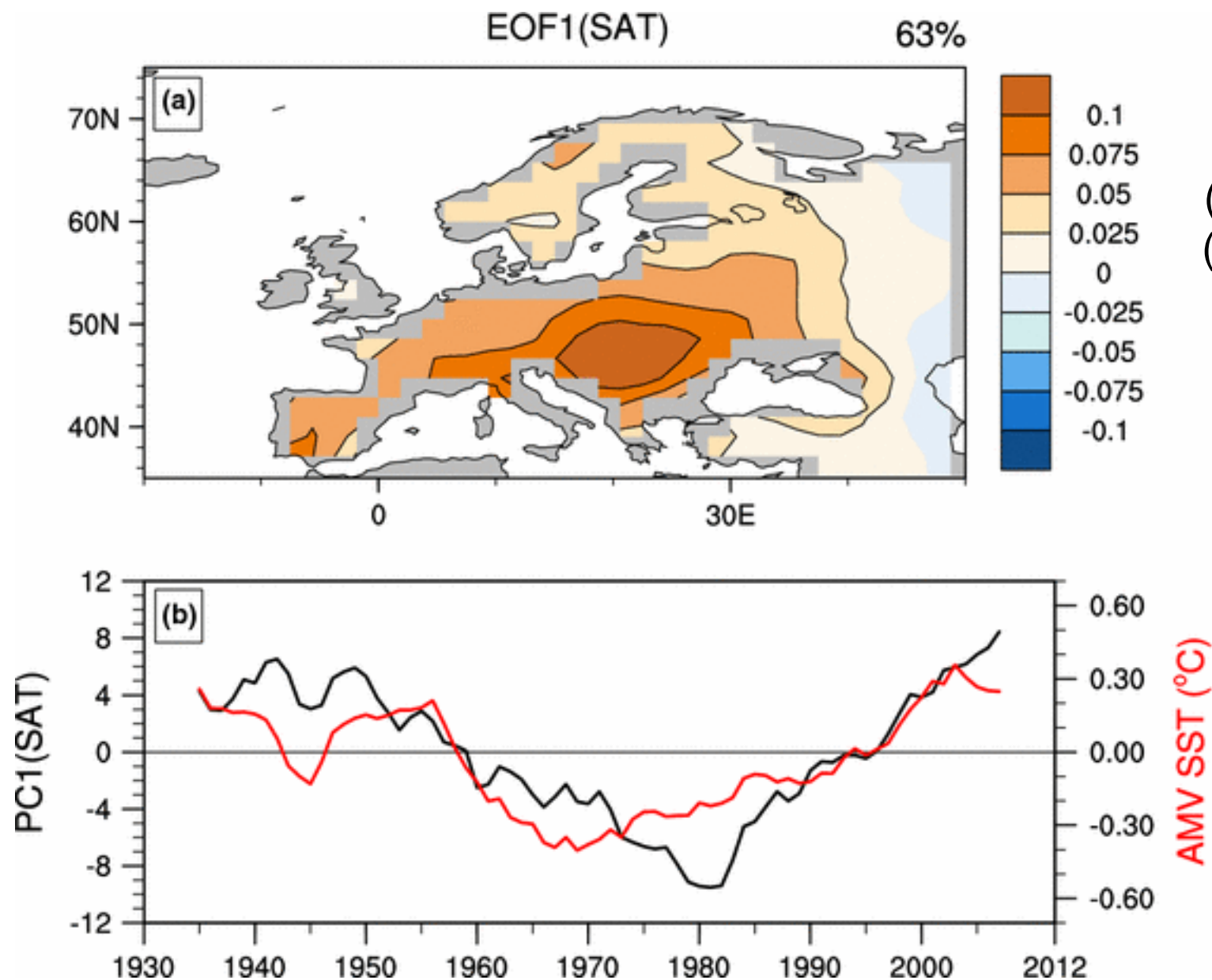
SST anomaly / AMO index



From https://commons.wikimedia.org/wiki/File:AMO_Pattern.png

Impact of AMO on the climate in Europe:

1. summer temperature

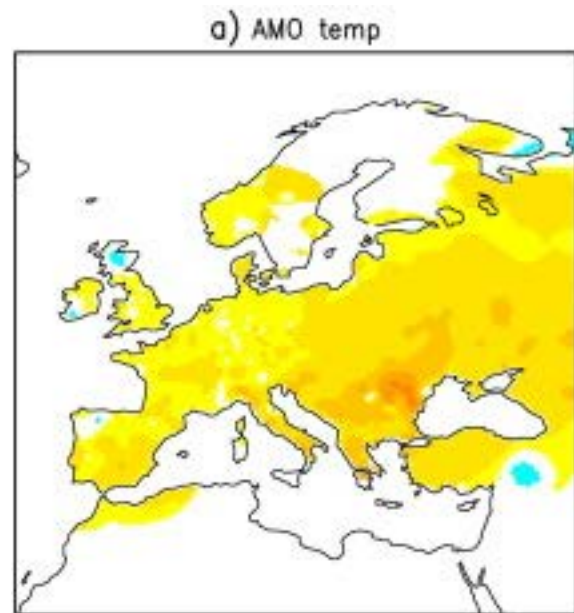


(a) Summer (JJA) 2 m air temperature in °C (11 years running mean) for the time period 1930–2012.

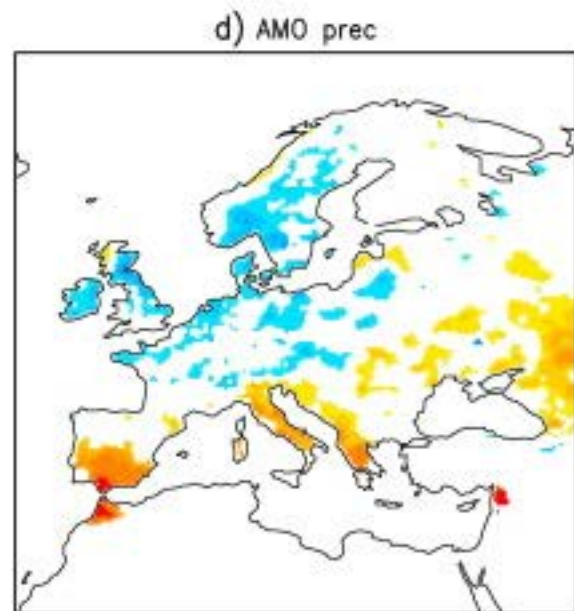
First principal component (PC1) of EOF SAT (*black*) with AMV index (*red*) which is constructed on the basis of the averaged SST (in °C) over the region 35°N–50°N and 7.5°W–75°W

Impact of AMO on the climate in Europe:

2. summer rainfall



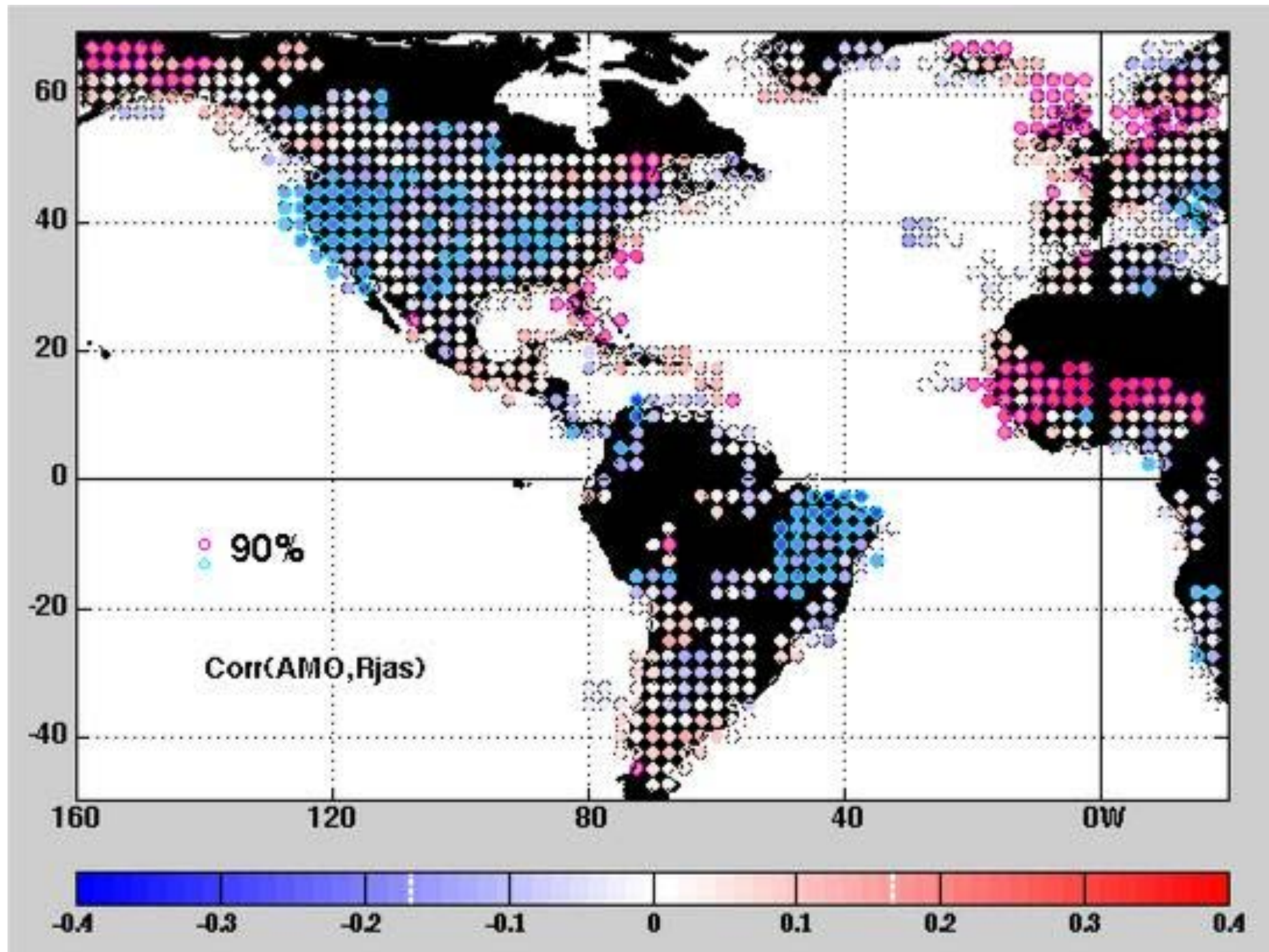
($T_{AMO+} - T_{AMO-}$) in summer with respect to 1950-2012



($Precip_{AMO+} - Precip_{AMO-}$) in summer with respect to 1950-2012

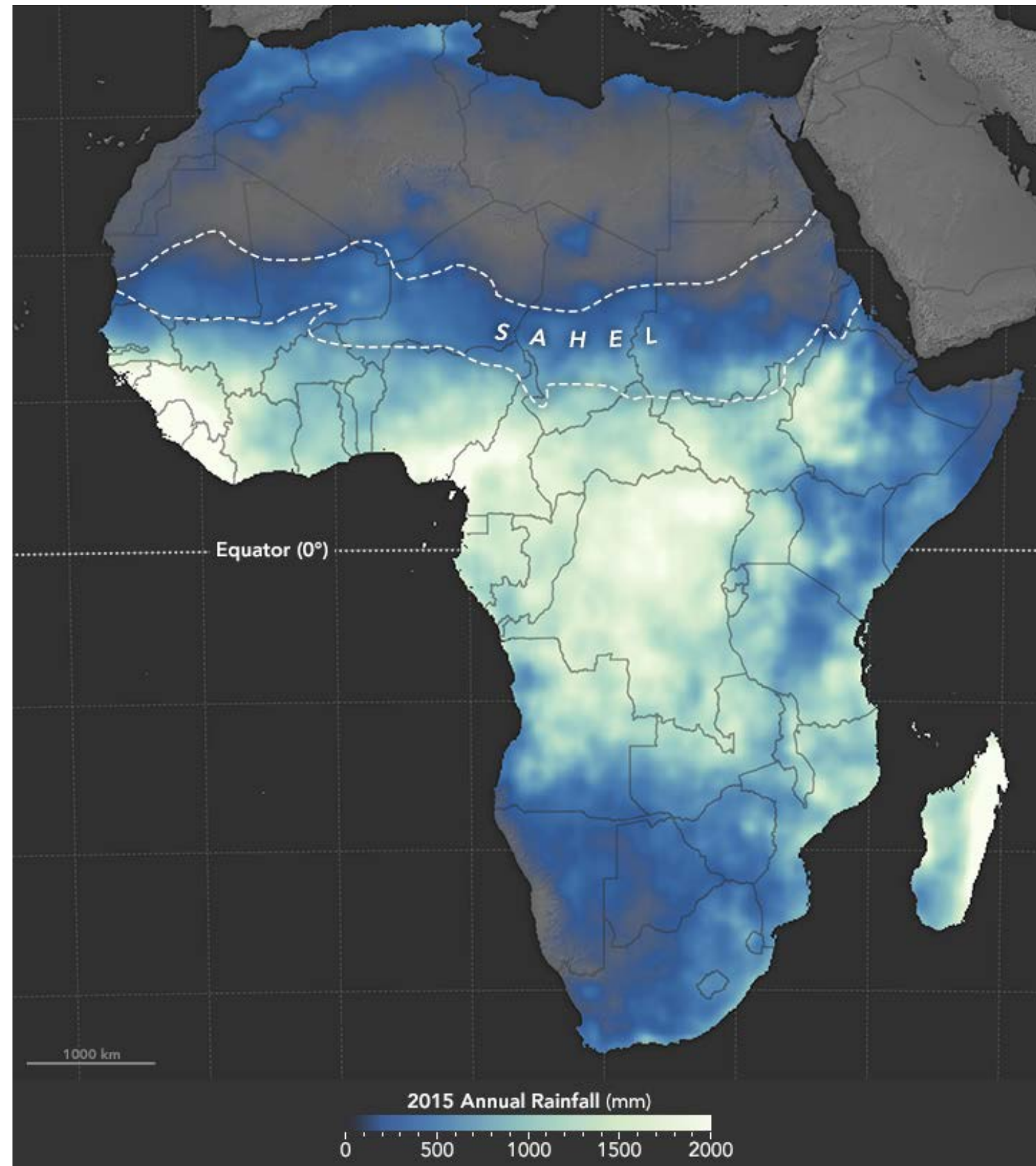


Impact of AMO on the climate in N. America: summer rainfall



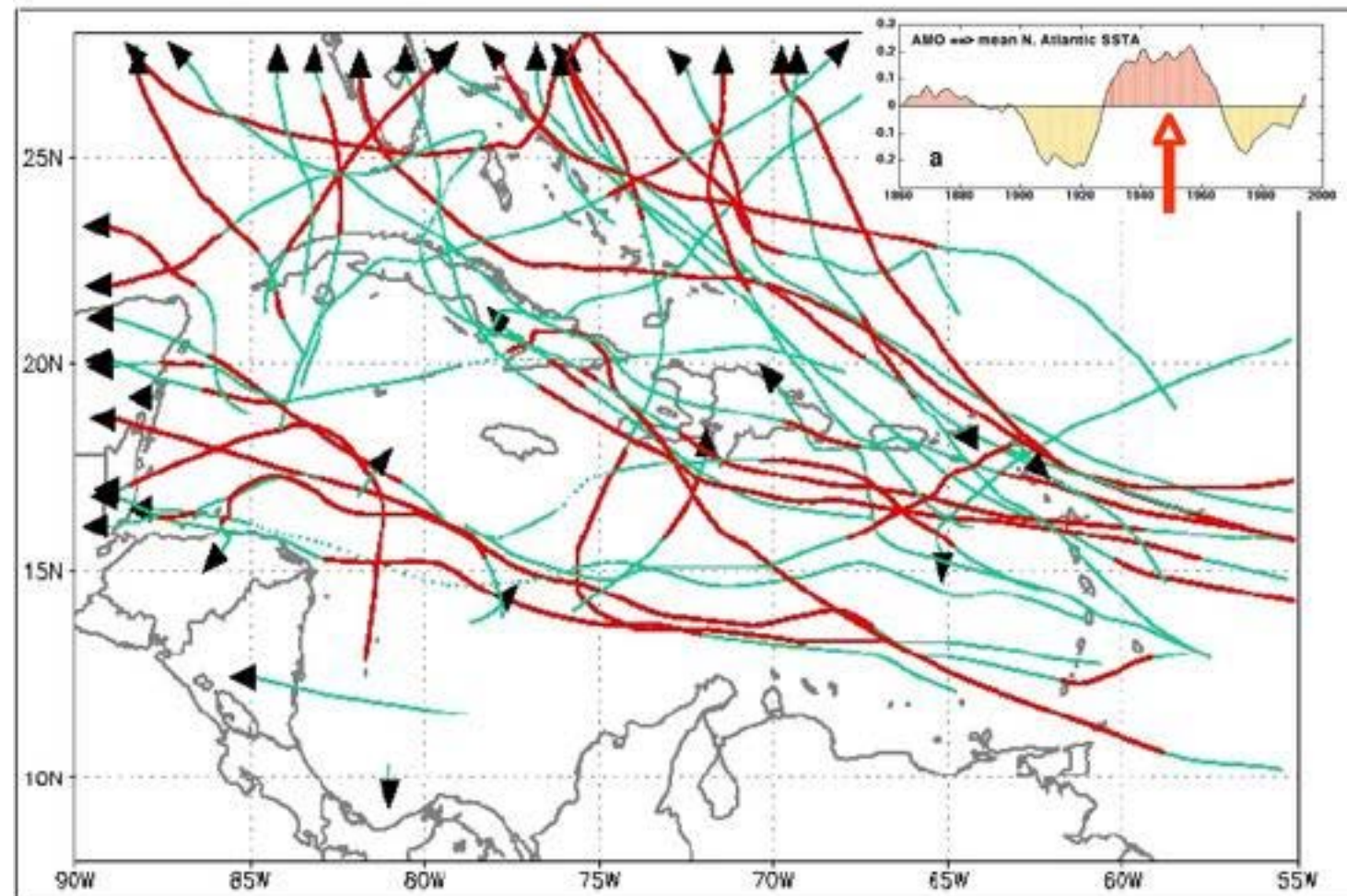
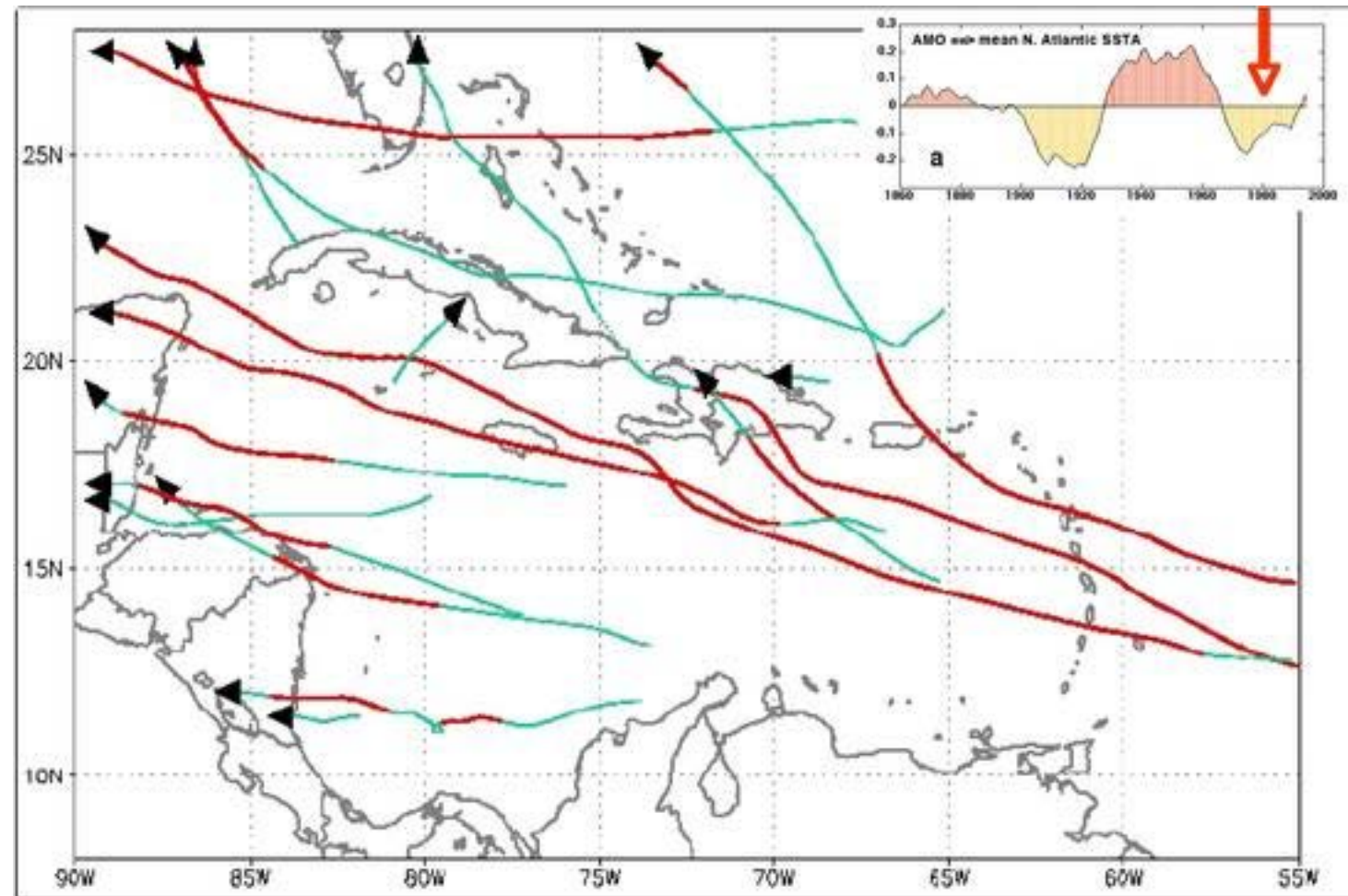
AMO and rains over the Sahel, Africa

- Being placed at the boundary between the dry and wet climate.
- Most farms entirely depend on rainfall for watering the crops.
- A few dry years can easily lead to food shortages and famine.
- In 1980s with a negative AMO phase, millions of people lost their lives during droughts in Kenya and Ethiopia.



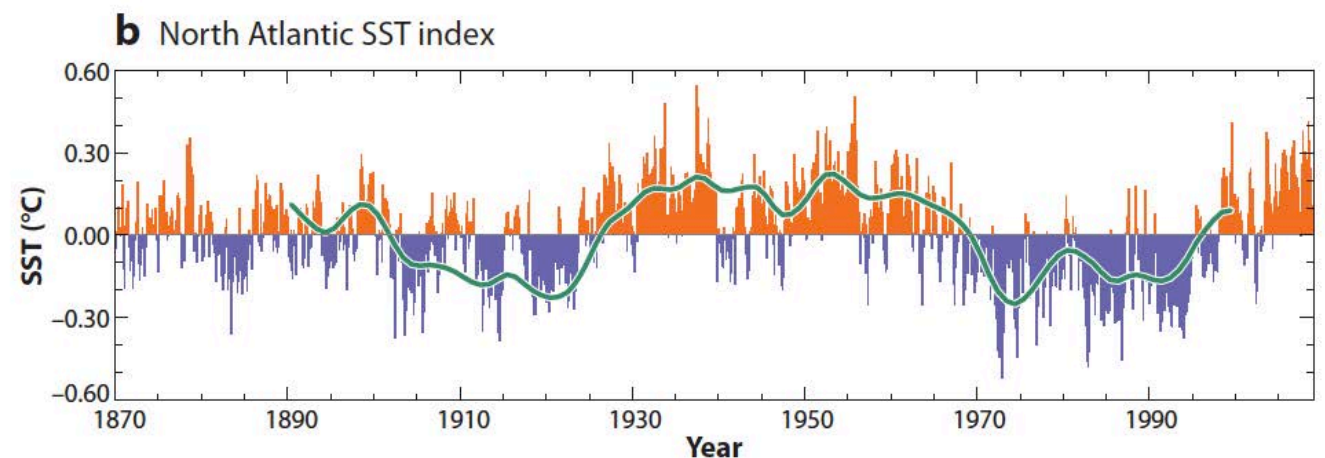
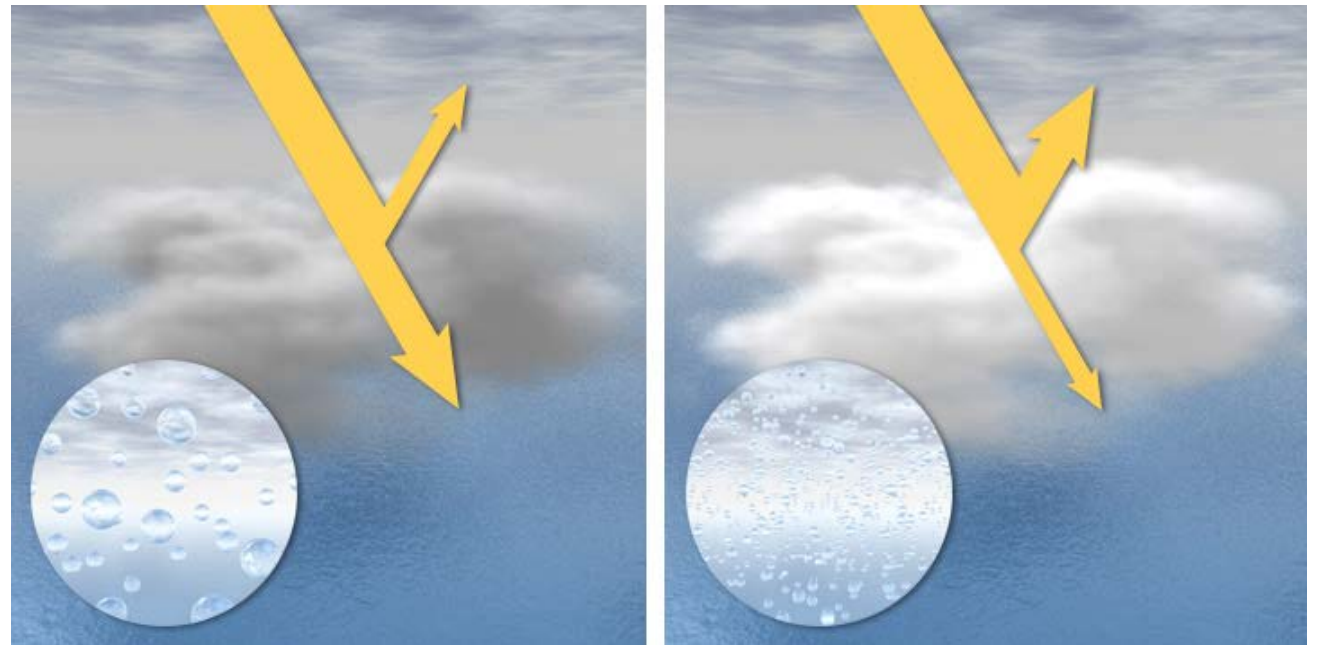
AMO and hurricanes

- Tracks of tropical storms associated with AMO.
- More tropical storms (almost double in number) when AMO is positive.
- Warmer sea surface temperature during the positive phase of AMO can provide more energy to tropical storms.



What are drivers for AMO?

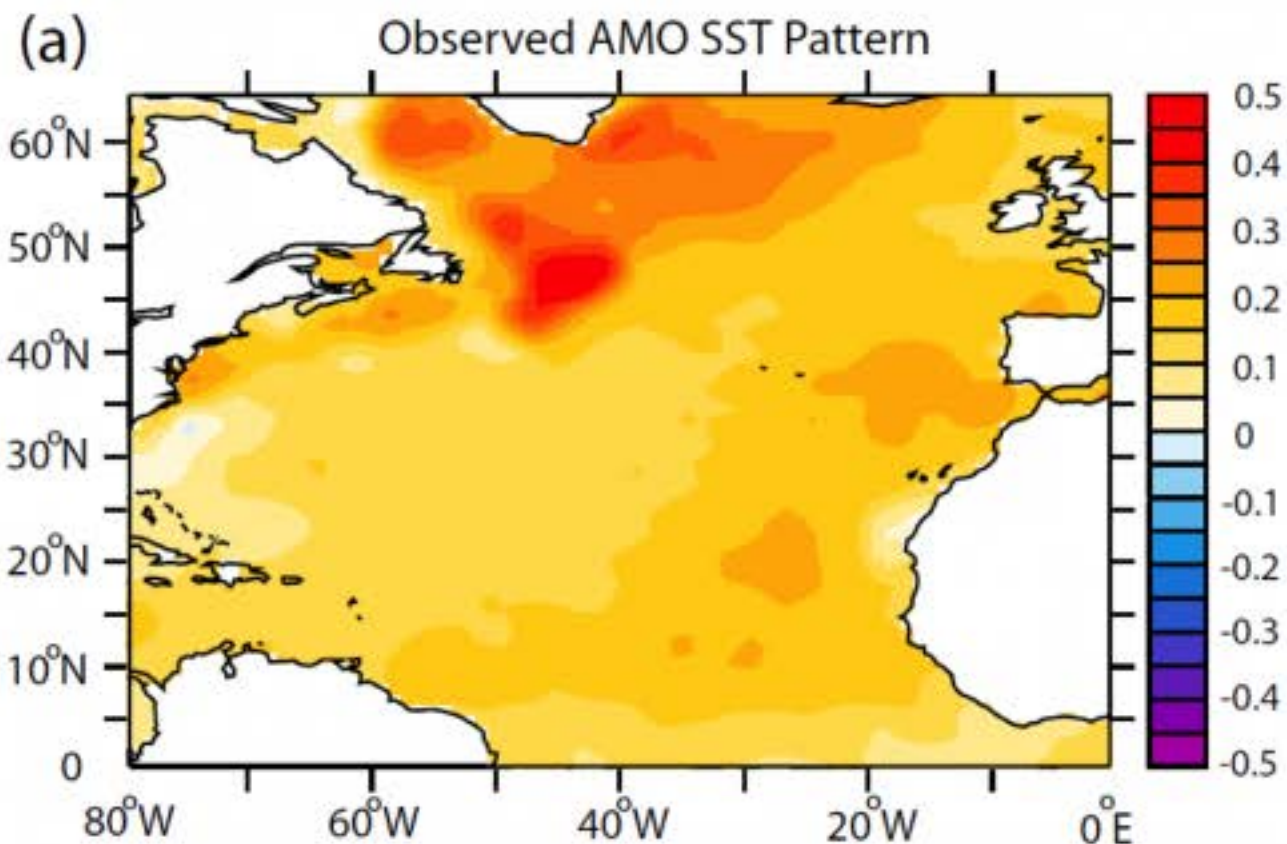
- Natural phenomenon driven by ocean currents.
- Aerosol?
 - Indirect effect
 - Volcanic eruptions
 - Clean air regulation



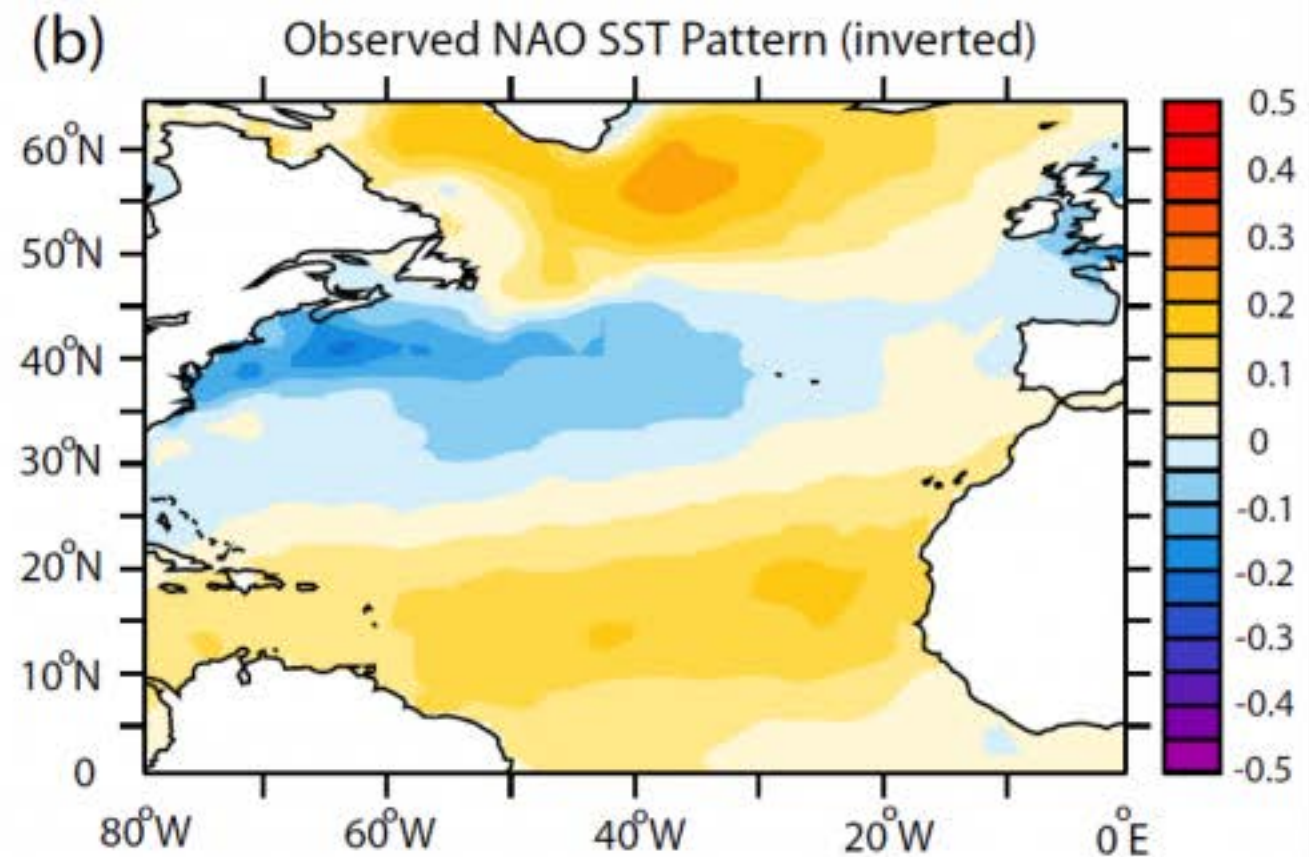
Atlantic Multi-decadal Oscillation

- The SST-based AMO index provides a simple way to describe multidecadal climate variability in the N. Atlantic.
- It is associated with important climate impacts, such as the multidecadal variability of Atlantic Hurricane activity, North American and European summer climate, northern hemispheric mean surface temperature, and Arctic sea ice anomalies.
- The AMO pattern is robust across different datasets (i.e. HadISST, ERSST, Kapan SST)

AMO v.s. NAO



AMO SST pattern using
HadISST dataset (Rayner et al.
2013) for the period 1870-2015.

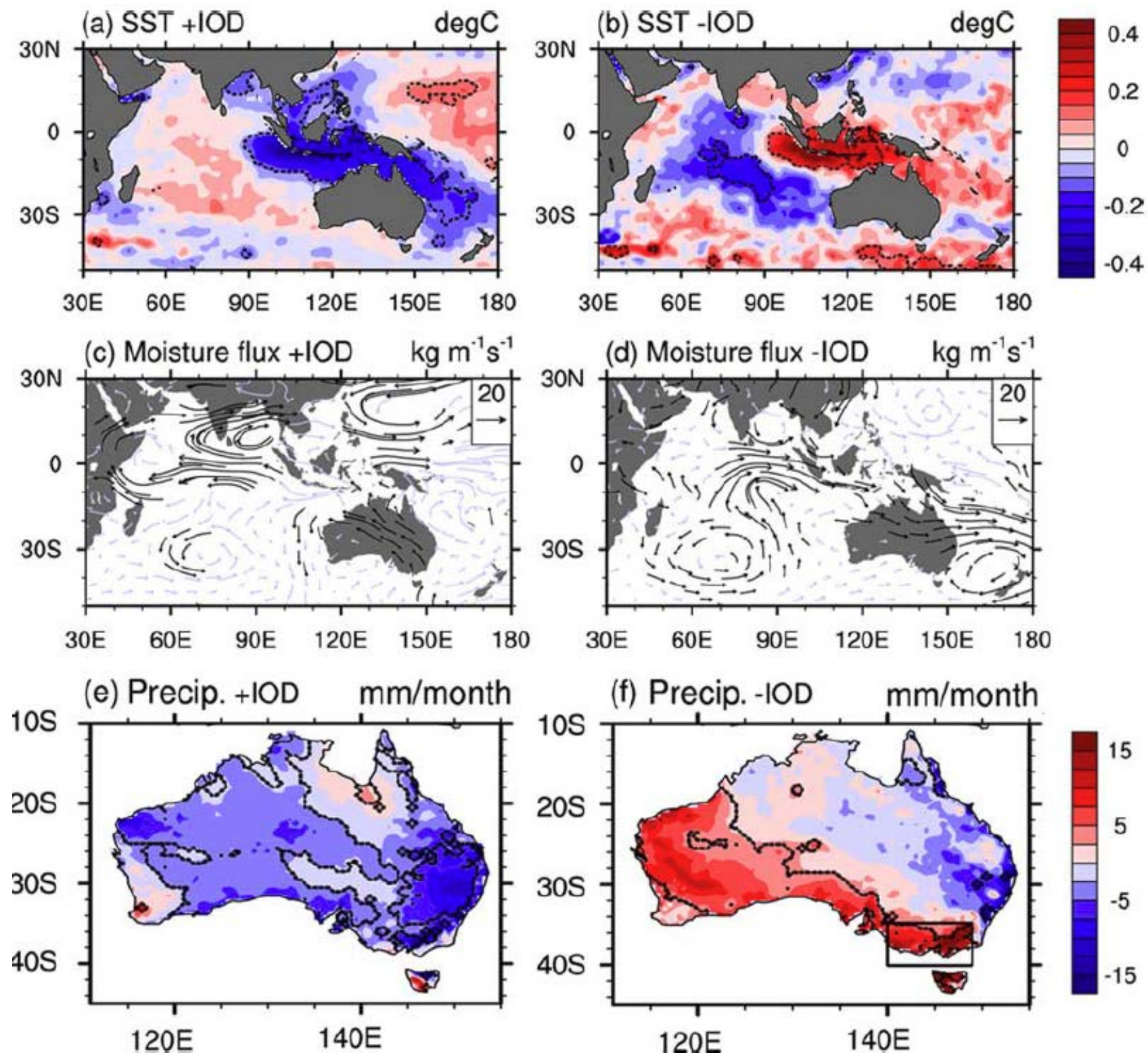


NAO SST pattern using HadISST dataset
(Hurrell Station-Based DJFM NAO Index)
for the period 1870-2015.

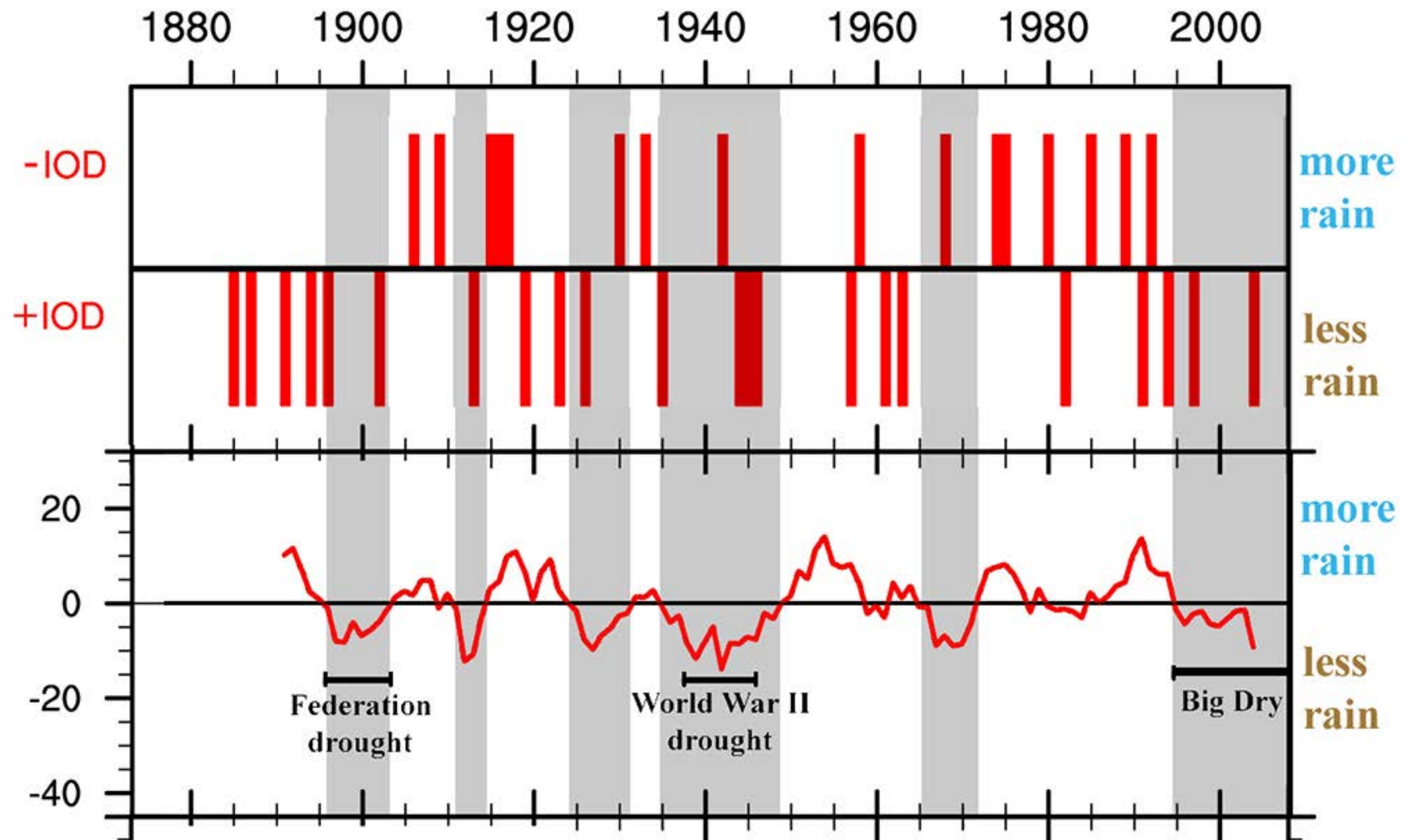
Indian Ocean Dipole (IOD)

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

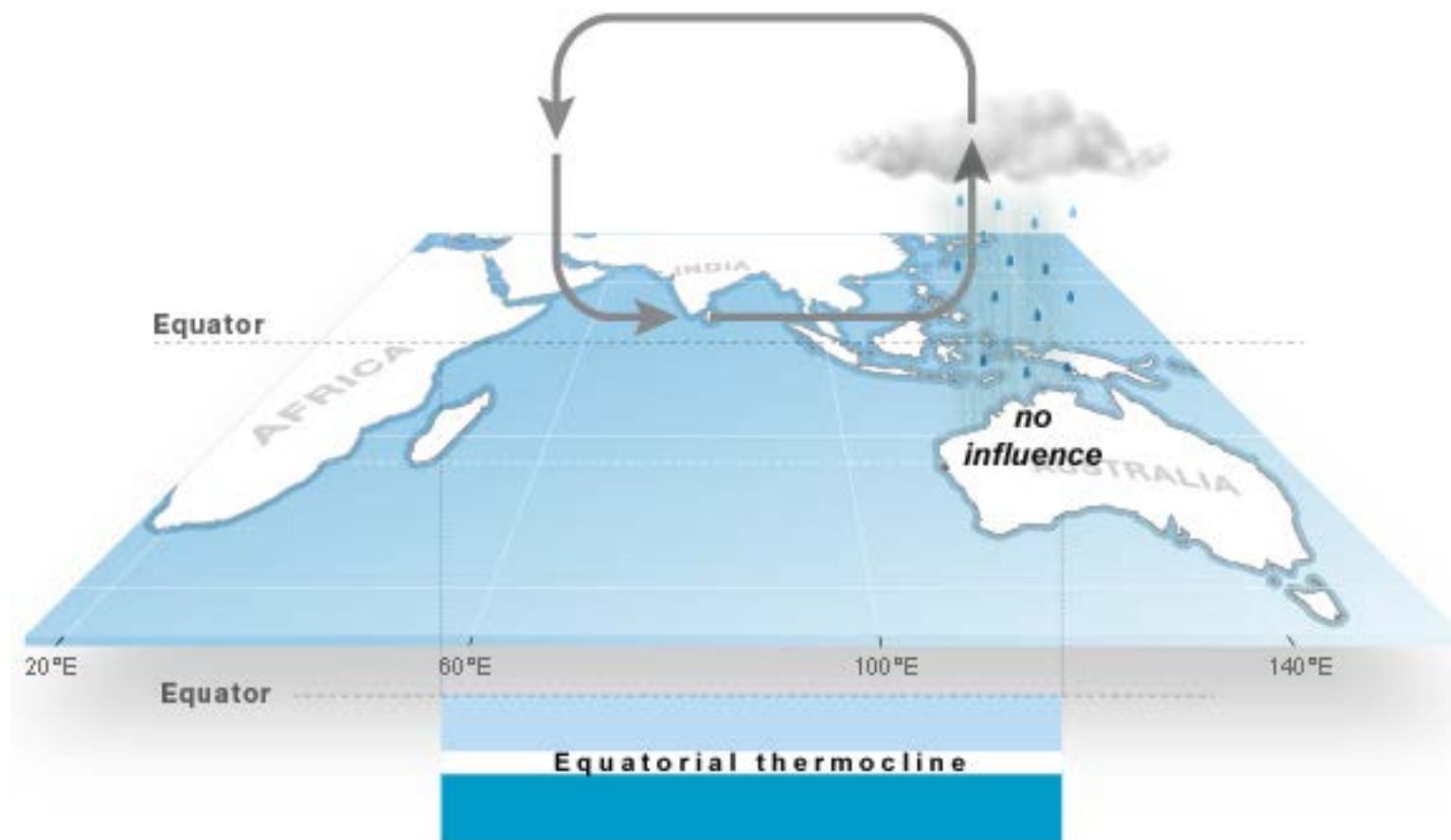
IOD and climate patterns



IOD and precipitation over Australia

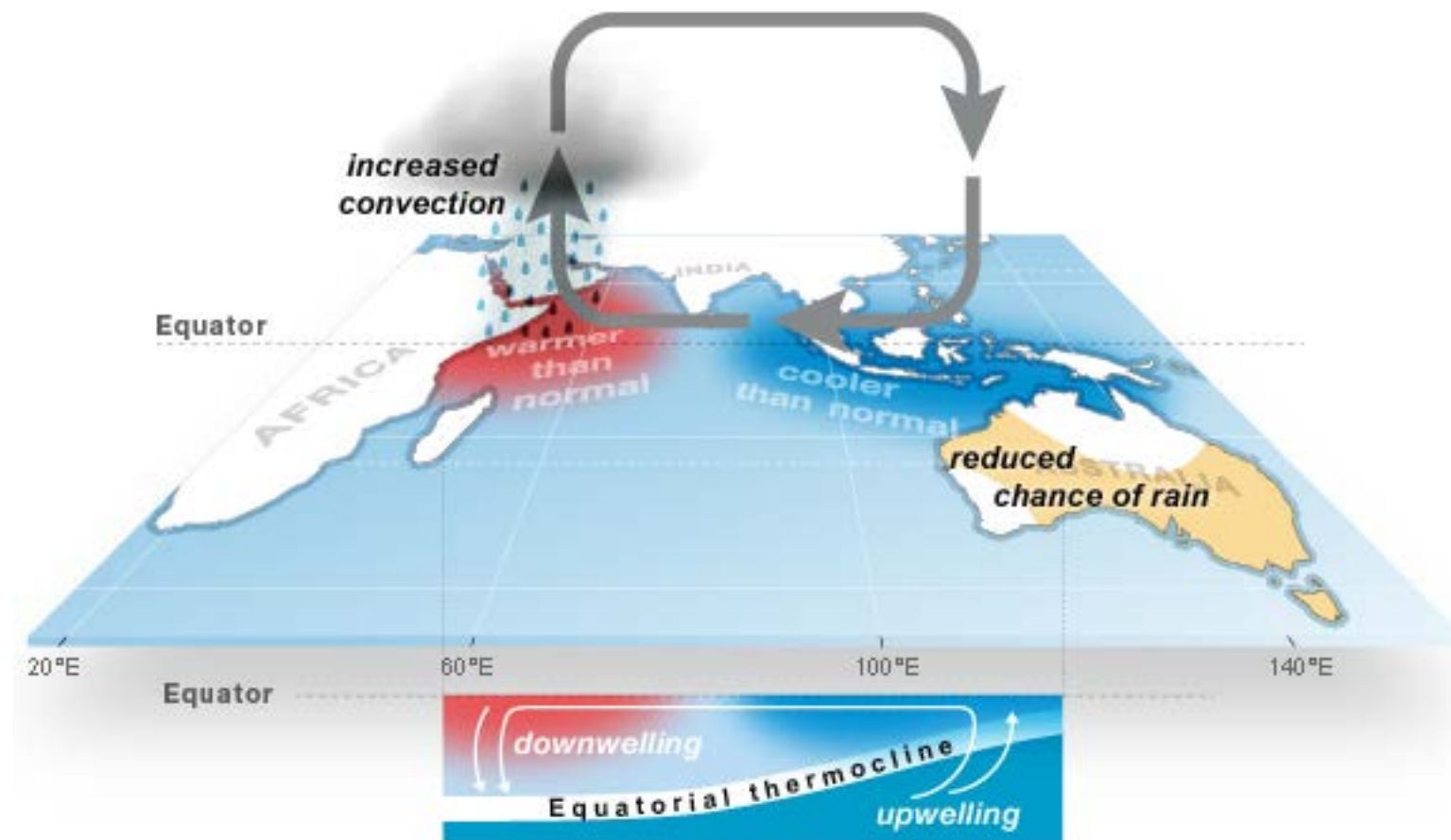


IOD : #1. Neutral phase



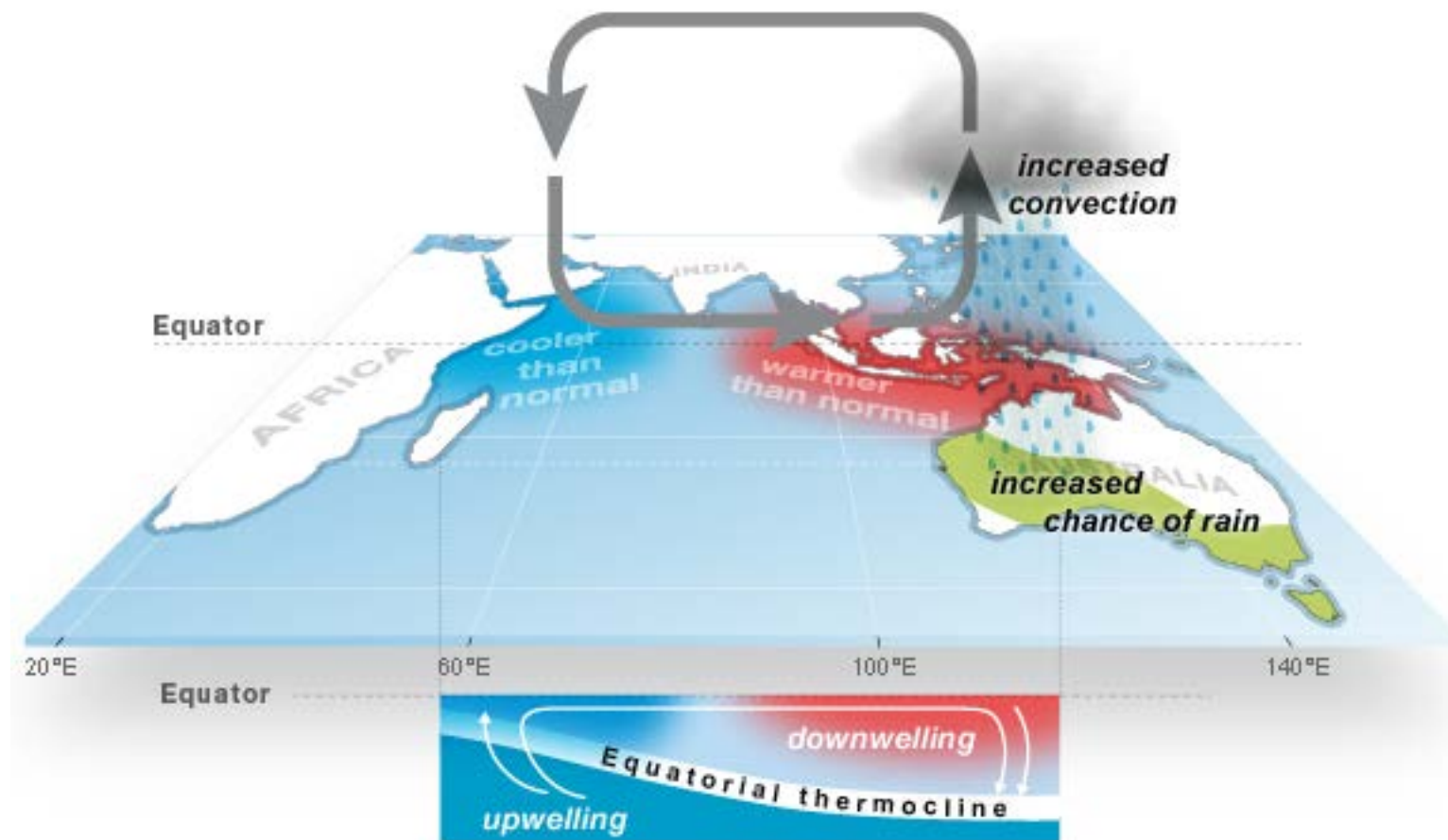
Indian Ocean Dipole (IOD): **Neutral phase**

IOD : #2. Positive phase



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

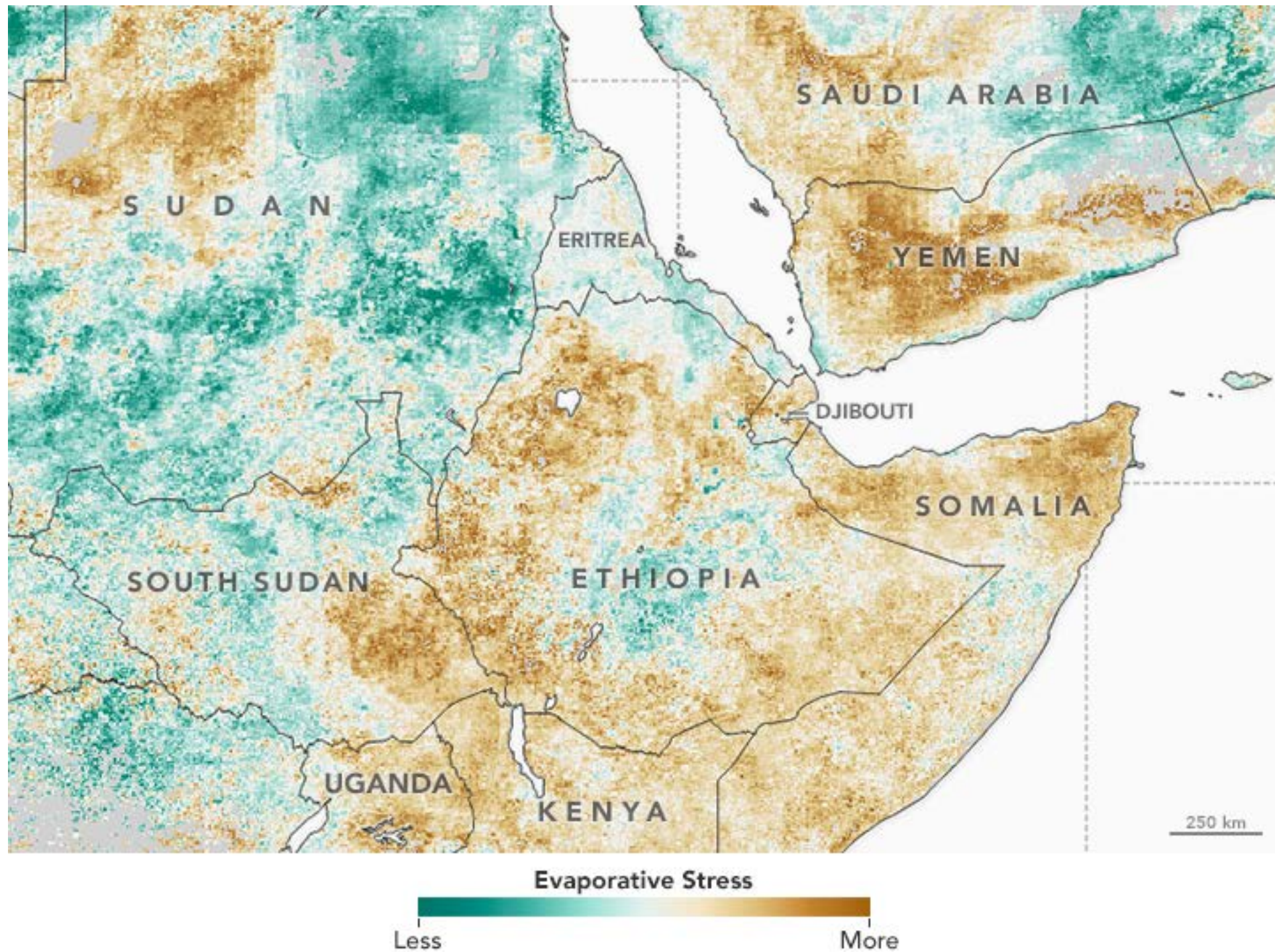
IOD : #3. Negative phase



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

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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 positive phase of the **Indian Ocean Dipole**—reduces rains in East Africa and increases them in Malaysia.”

