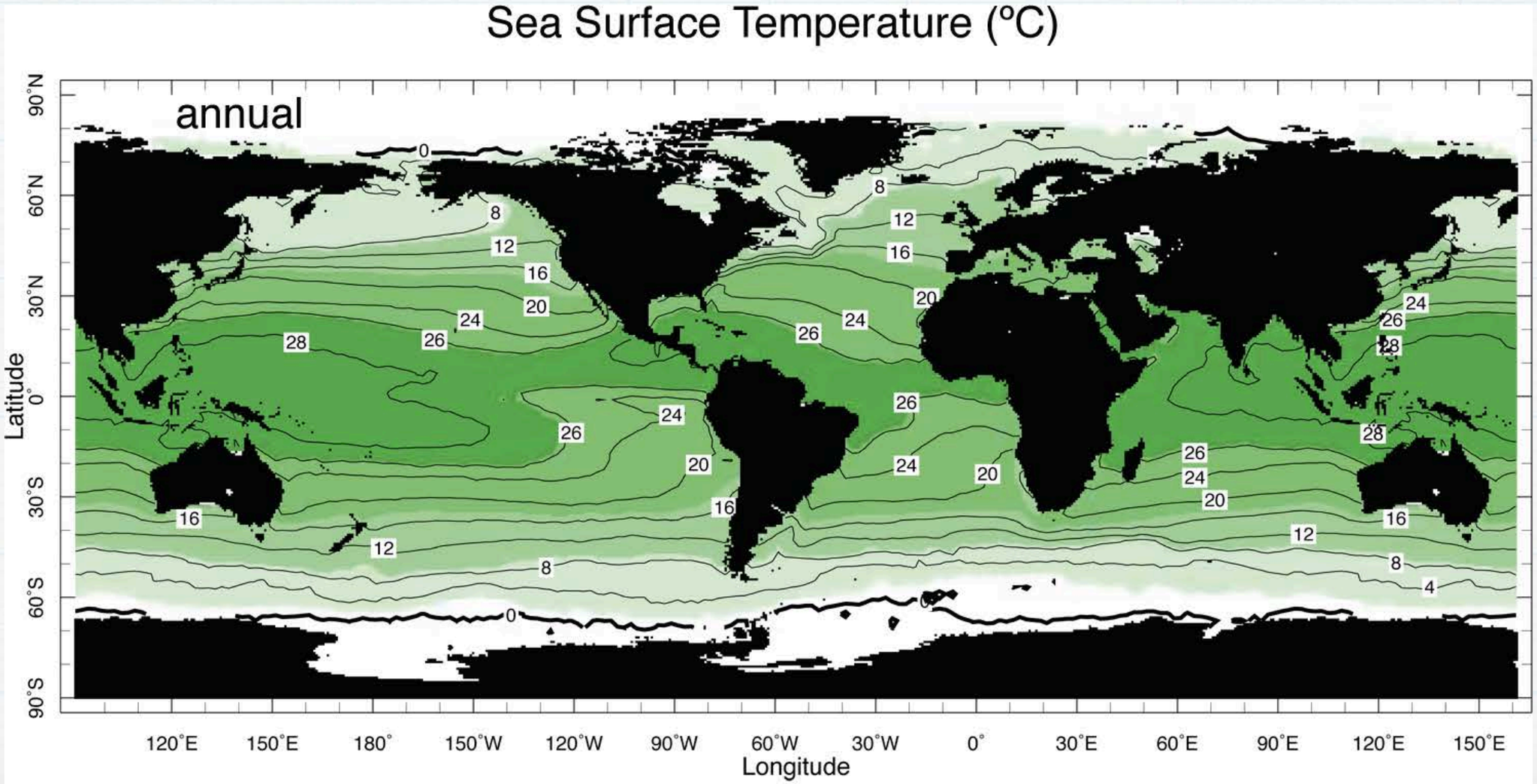
Air-sea interaction: #1 Natural climate variability

El Niño and the Southern Oscillation

- In tropical latitudes, changes in SST and tropical air temperatures and wind are more in phase with one another.
- The ocean is active, meaning that SST changes can modulate the atmospheric states.
- Occasional failures of the Indian monsoon (extensive droughts in Indonesia and much of Australia) occurs with unusual rainfall and wind patterns across the equatorial Pacific Ocean as fa as South America.
- A known phenomenon for a long time, for example by Charles Darwin during *Voyage of the Beagle* (1831~1836)
- Named as *Southern Oscillation* by Gilbert Walker
- El Niño, a warmer surface waters in the eastern equatorial Pacific

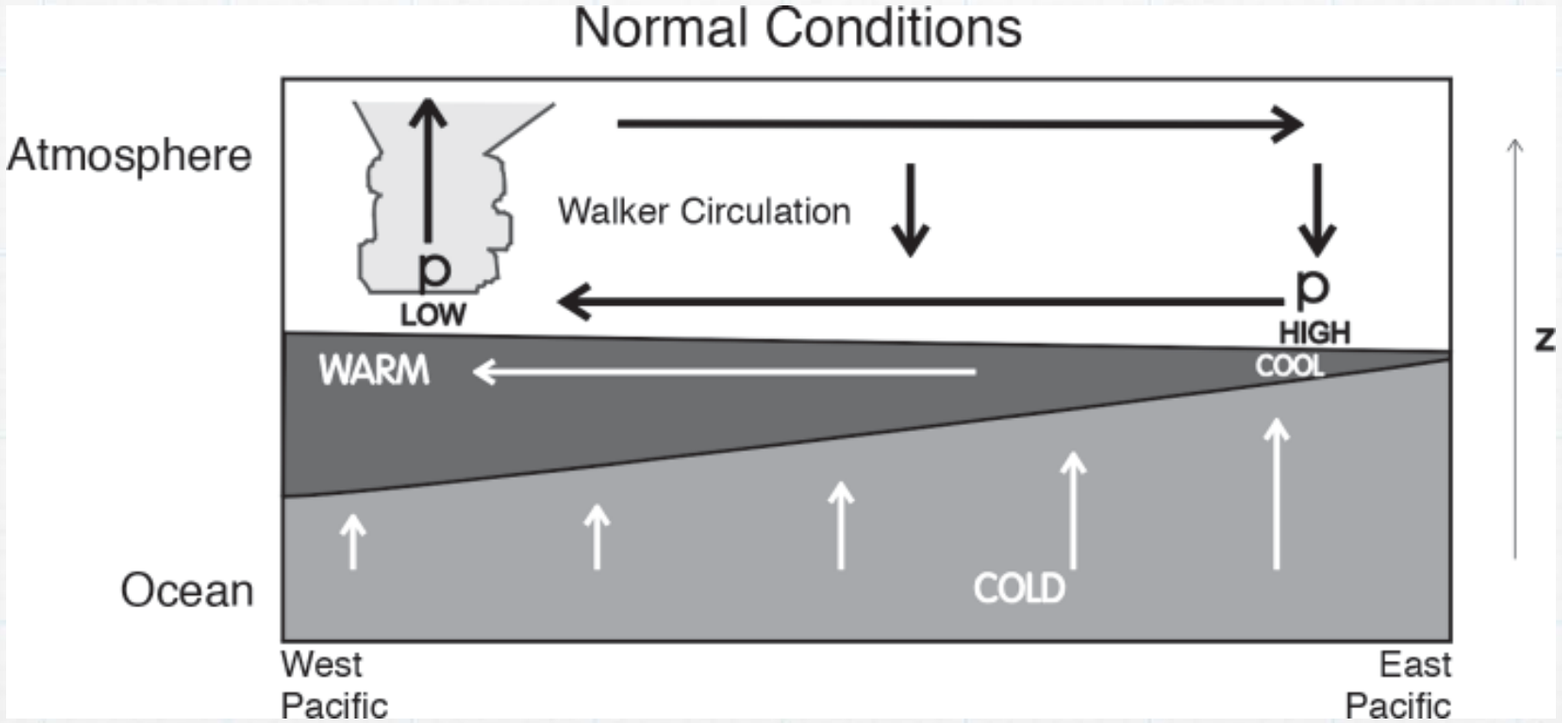
Normally…

- Wet climate in Indonesia
- Warm sea surface temperature in the western equatorial Pacific (Warm pool)
- Relatively colder sea surface temperature near Peru (Cold tongue))
- Trade wind from the east to the west



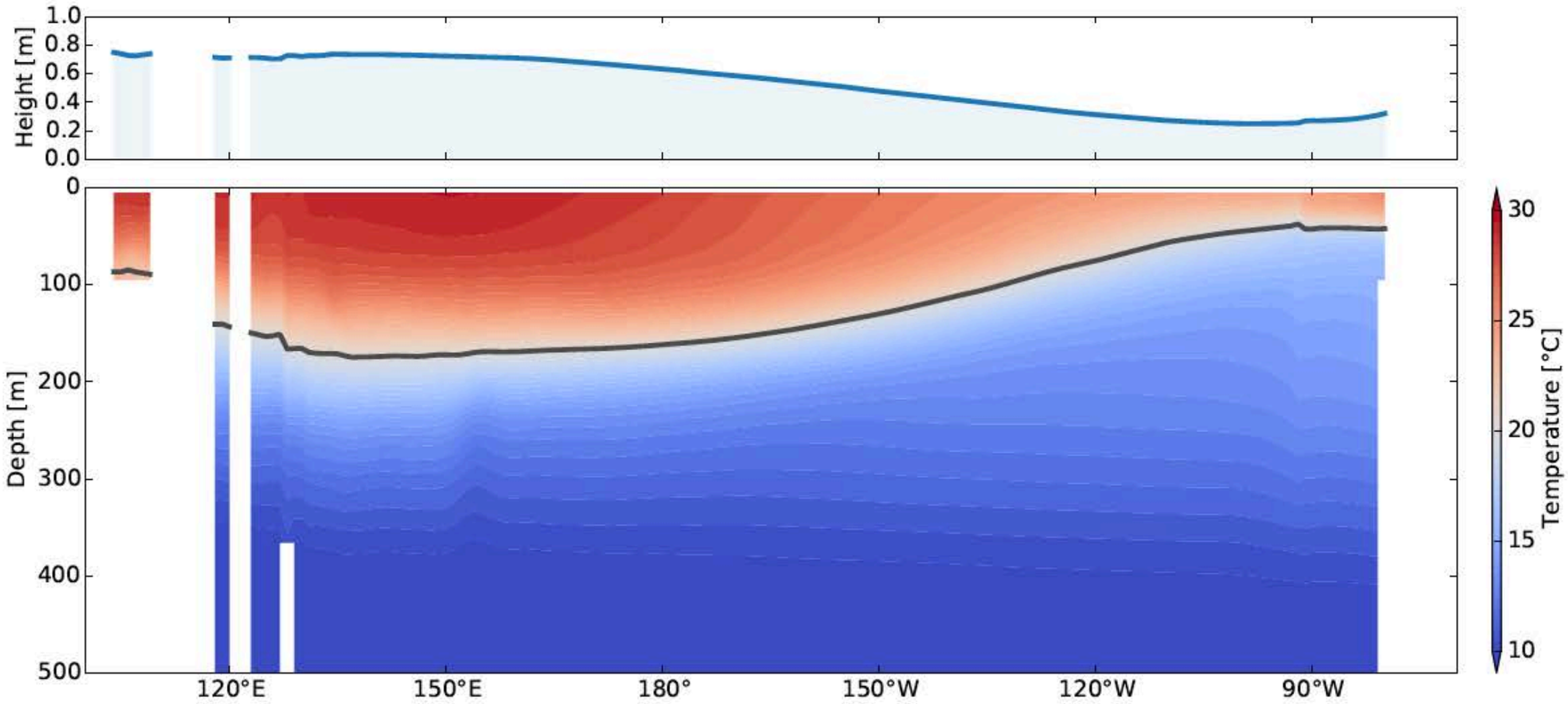
Upwelling along the equator

- The tropical Pacific Ocean is bounded to the east and west.
  - Thermocline is deeper in the west and shallower in the east.
- The “cold tongue” in the east, and the “warm pool” in the west.



Normal conditions

- Sea surface height is 40–50 cm higher in the west than in the east
- The thermocline (indicated by the 20°C isotherm) is ∼135 m deeper in the west than in the east

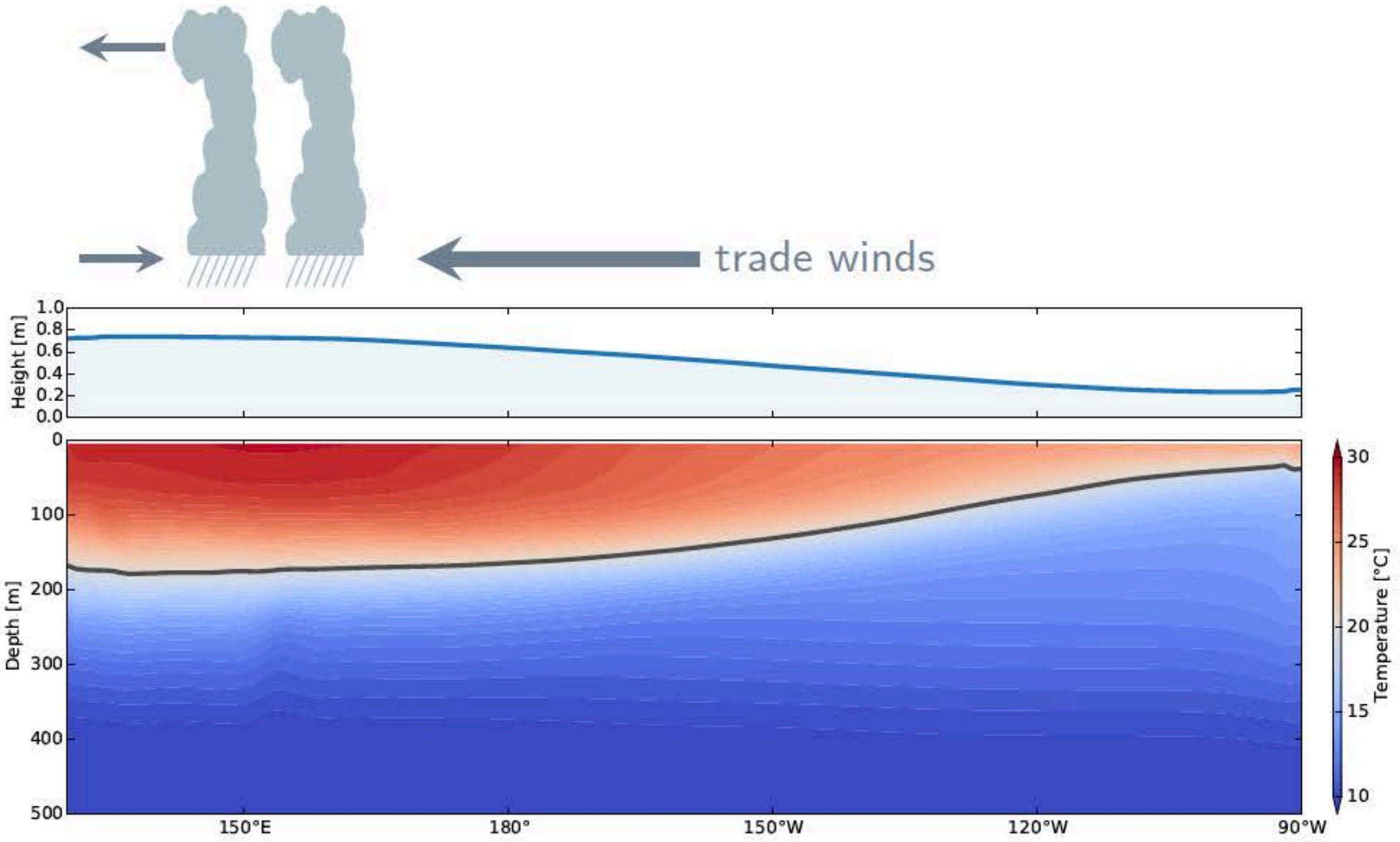


data from C

Slide by Jonathan Wright

Normal conditions

Convection is located over the Western Pacific warm pool



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Normal conditions

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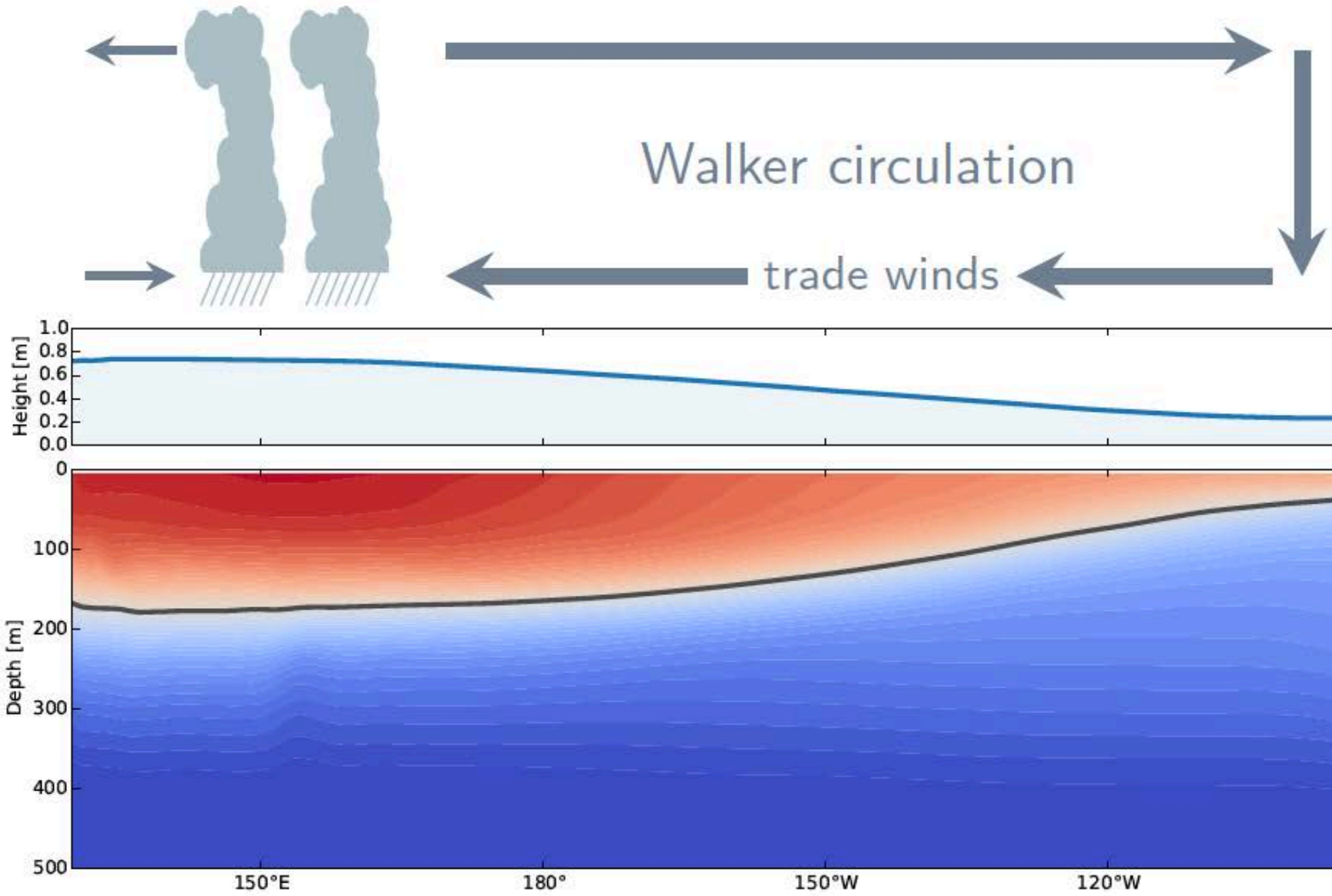

Slide by Jonathan Wright

Normal conditions

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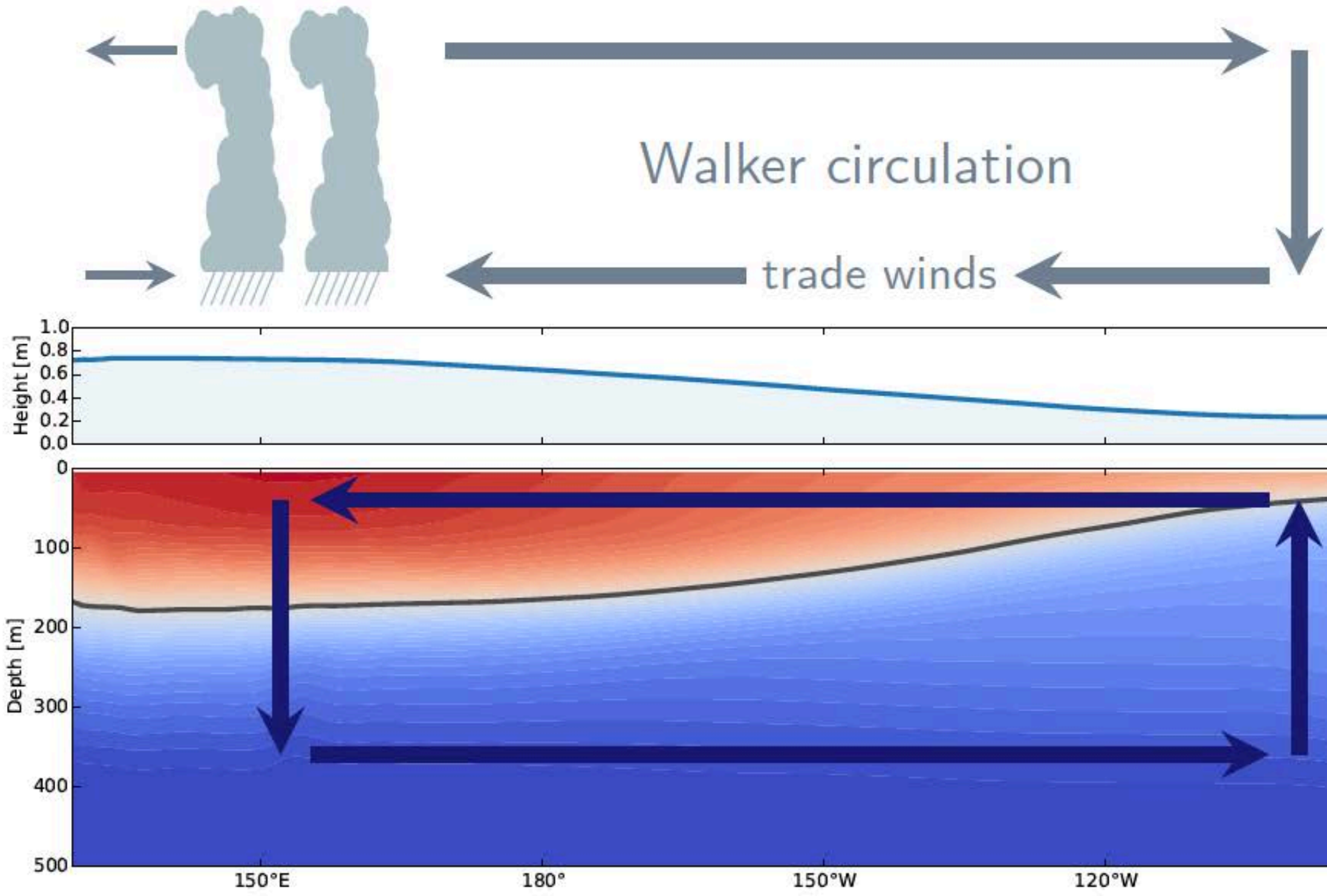
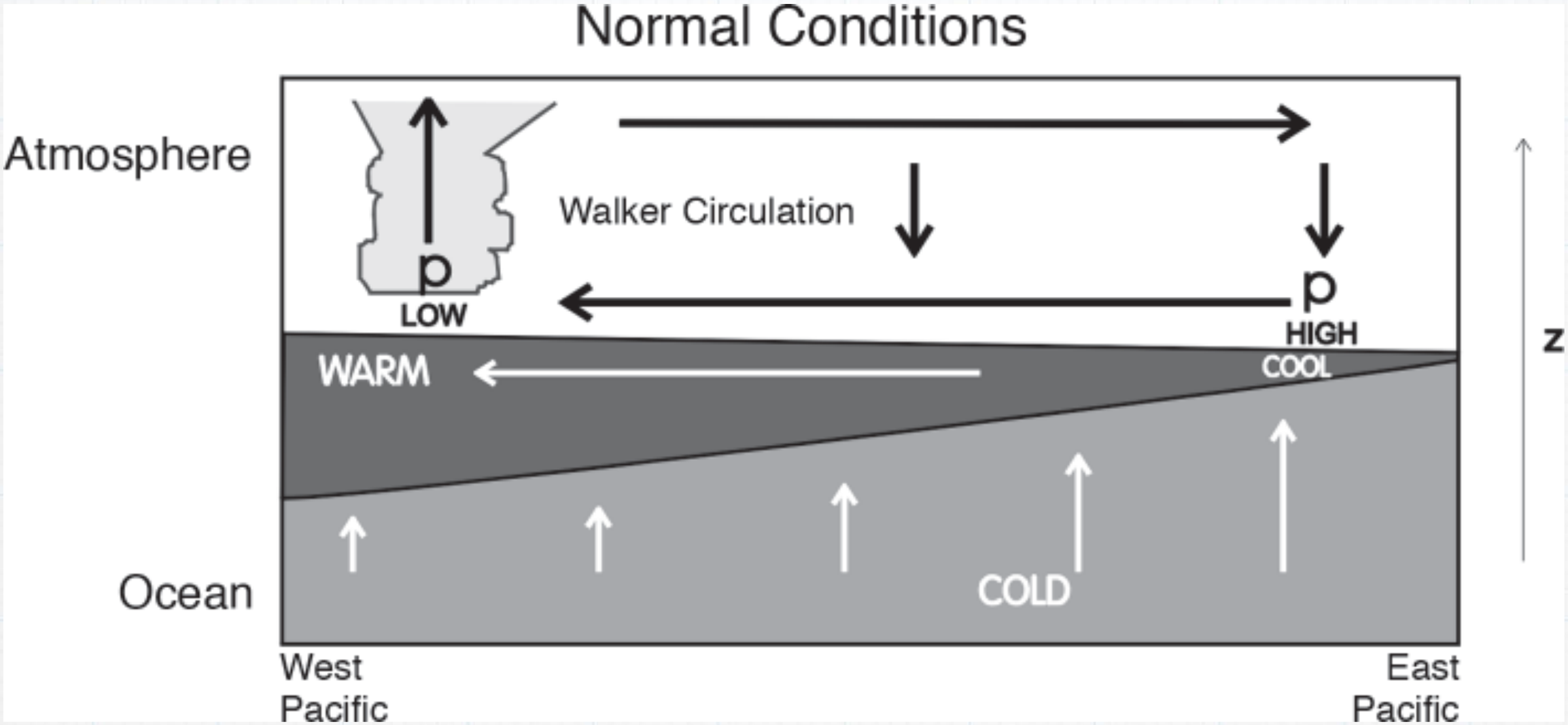


Slide by Jonathan Wright

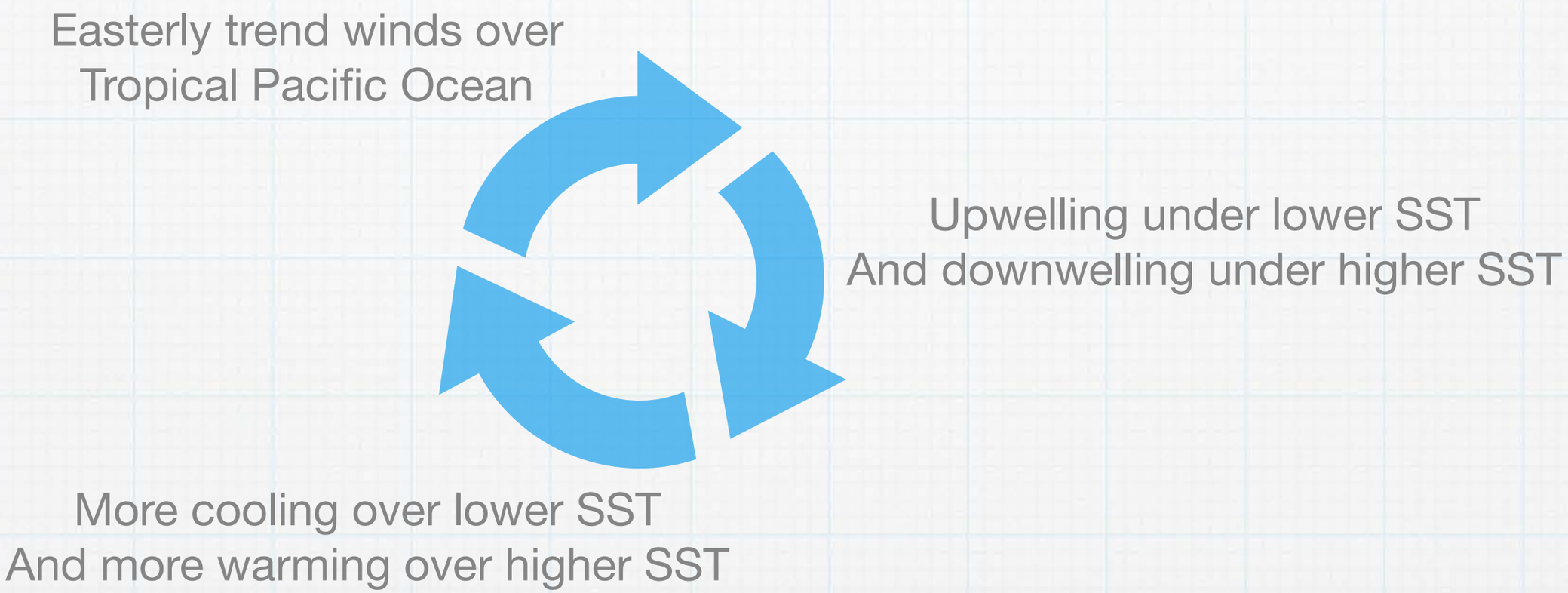
Normal conditions



The Bjerknes feedback

Slide by Jonathan Wright

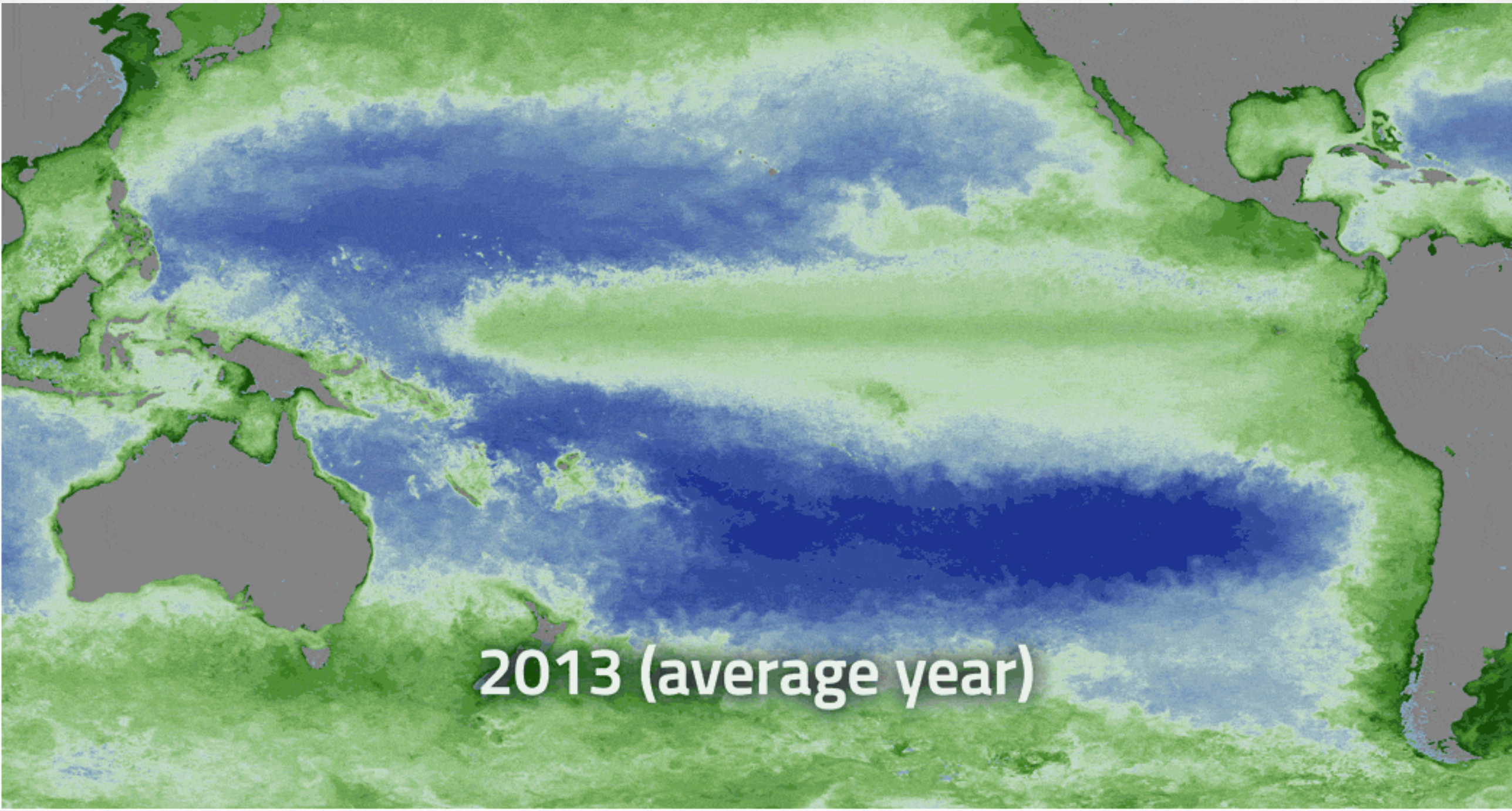
1. Winds flow from low SST to high SST ...
2. which causes upwelling under low SST and downwelling under high SST ...
3. which enhances cooling in the region of low SST and warming in the region of high SST ...
4. which strengthens the winds that flow from low SST to high SST



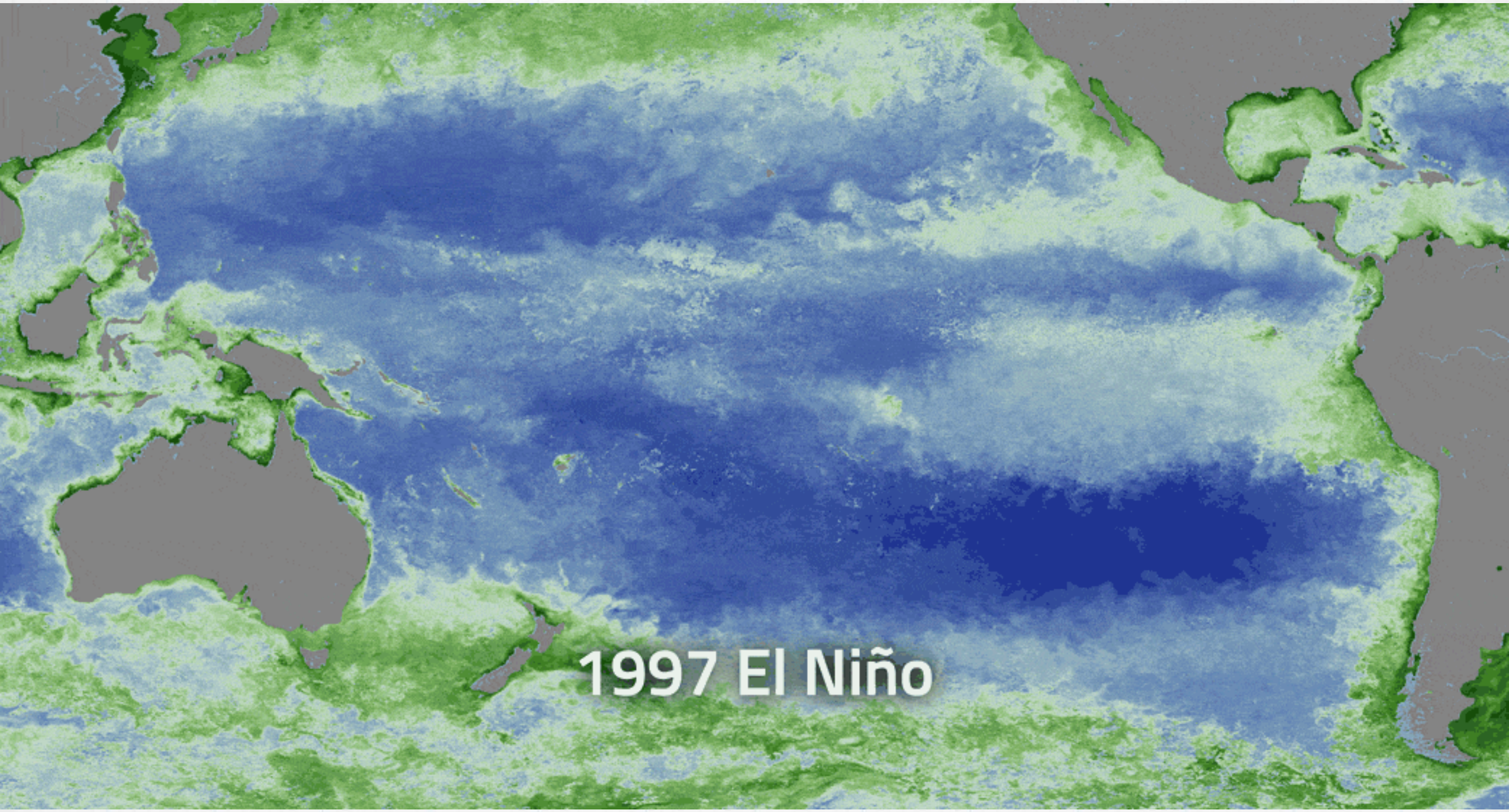
Interannually varying climate in the tropics

- Failures of the Indian monsoon
- Extensive droughts in Indonesia and much of Australia
- Unusual rainfall and wind patterns
- Warm surface water temperature in the eastern Pacific
- Poor fishing

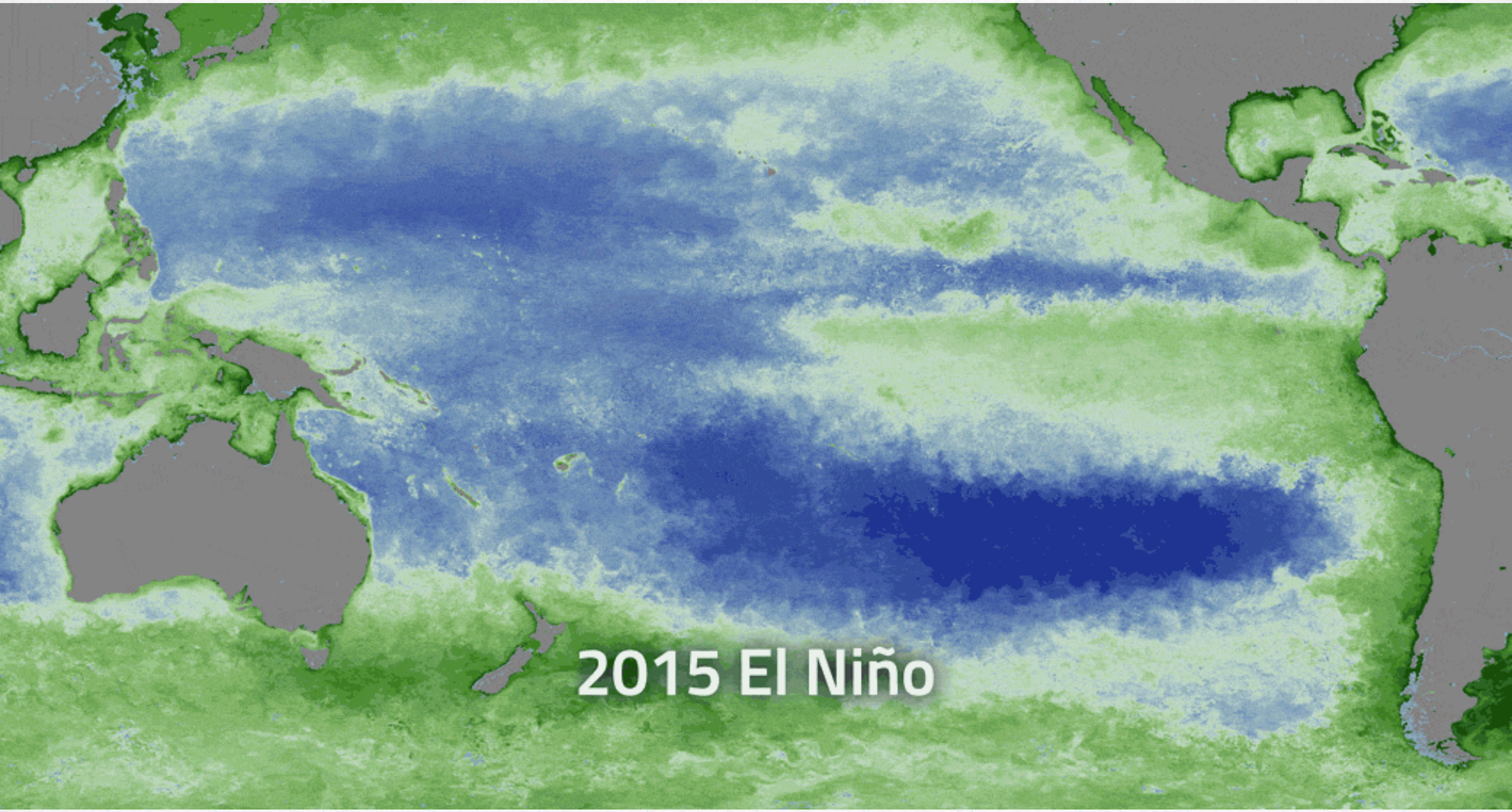
Satellite chlorophyll



Satellite chlorophyll

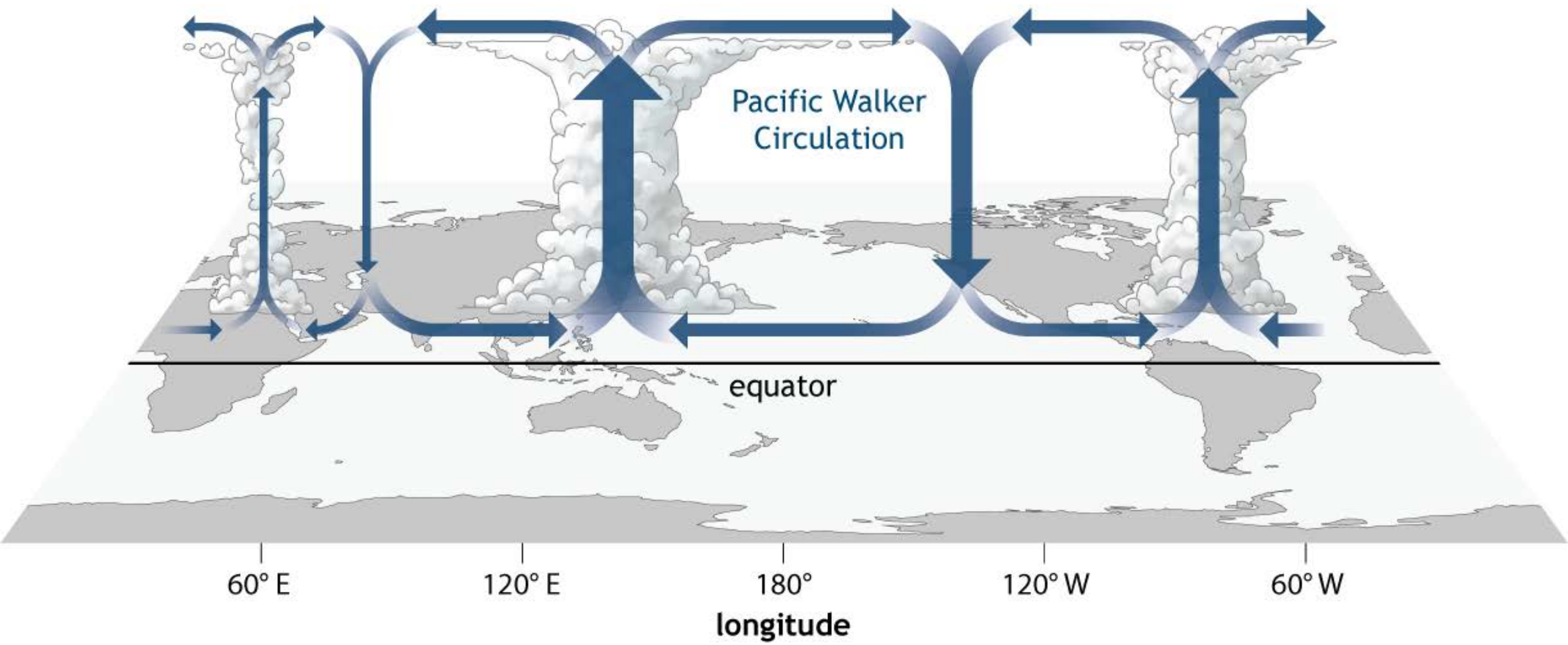


Satellite chlorophyll



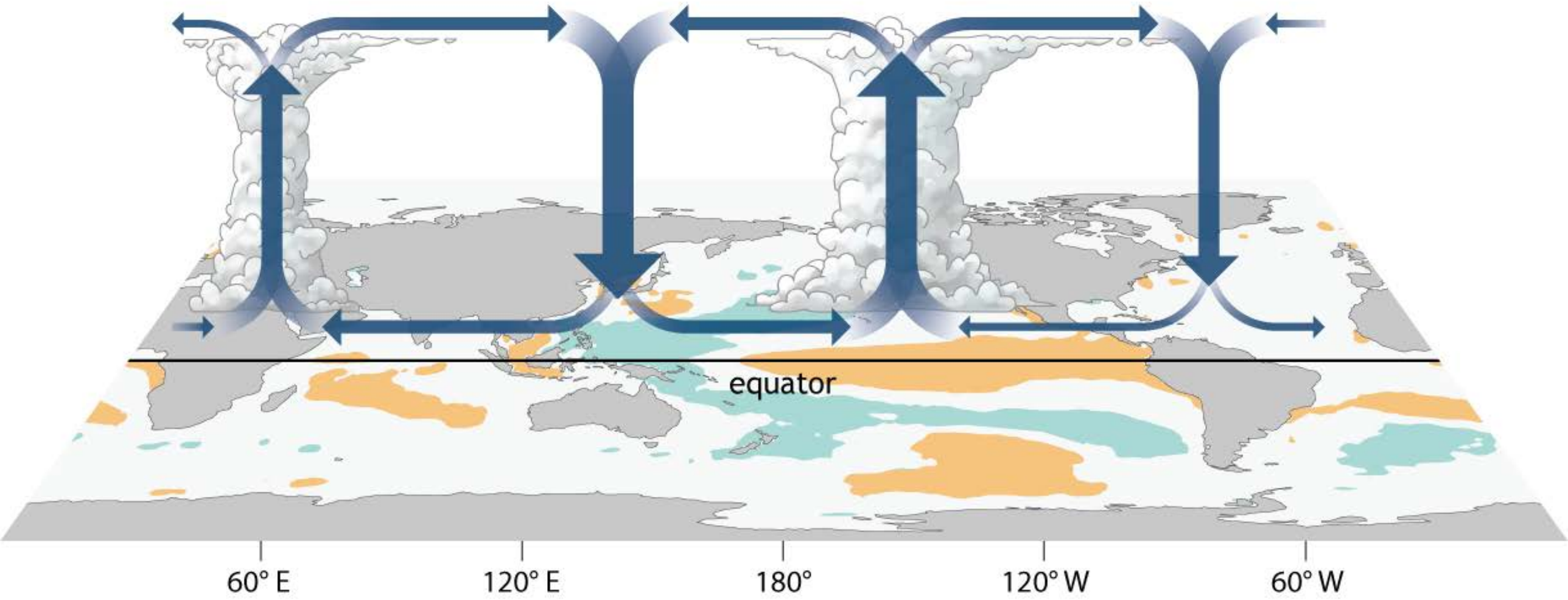

TOTAL PRODUCTION OF PERUVIAN ANCHOVETA (E. ringens) IN THE SOUTHEAST PACIFIC (Area 87) AND "EL NIÑO" YEARS SINCE 1950
Millions of Metric tons
16
14
12
10
8
6
4
2
0
50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98
"El Niño" Years

Neutral conditions



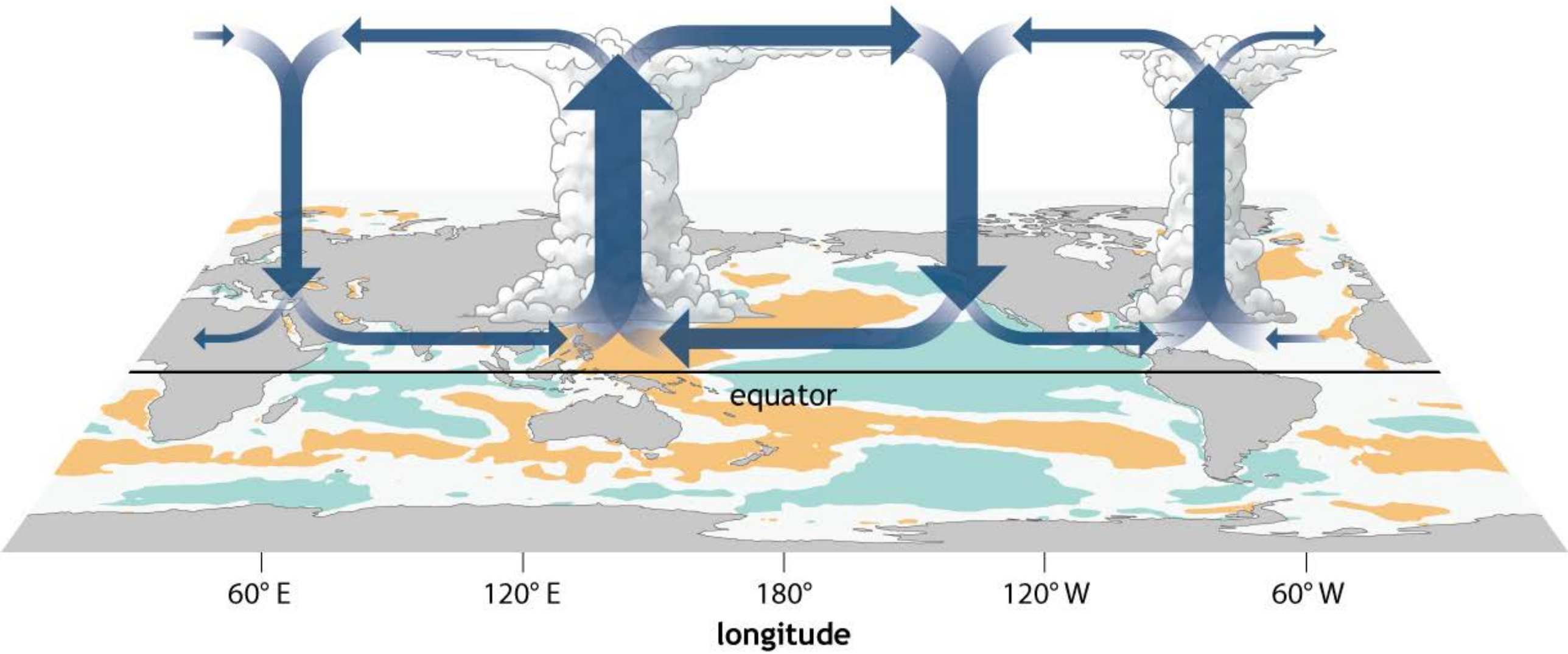
NOAA Climate.gov

El Niño conditions

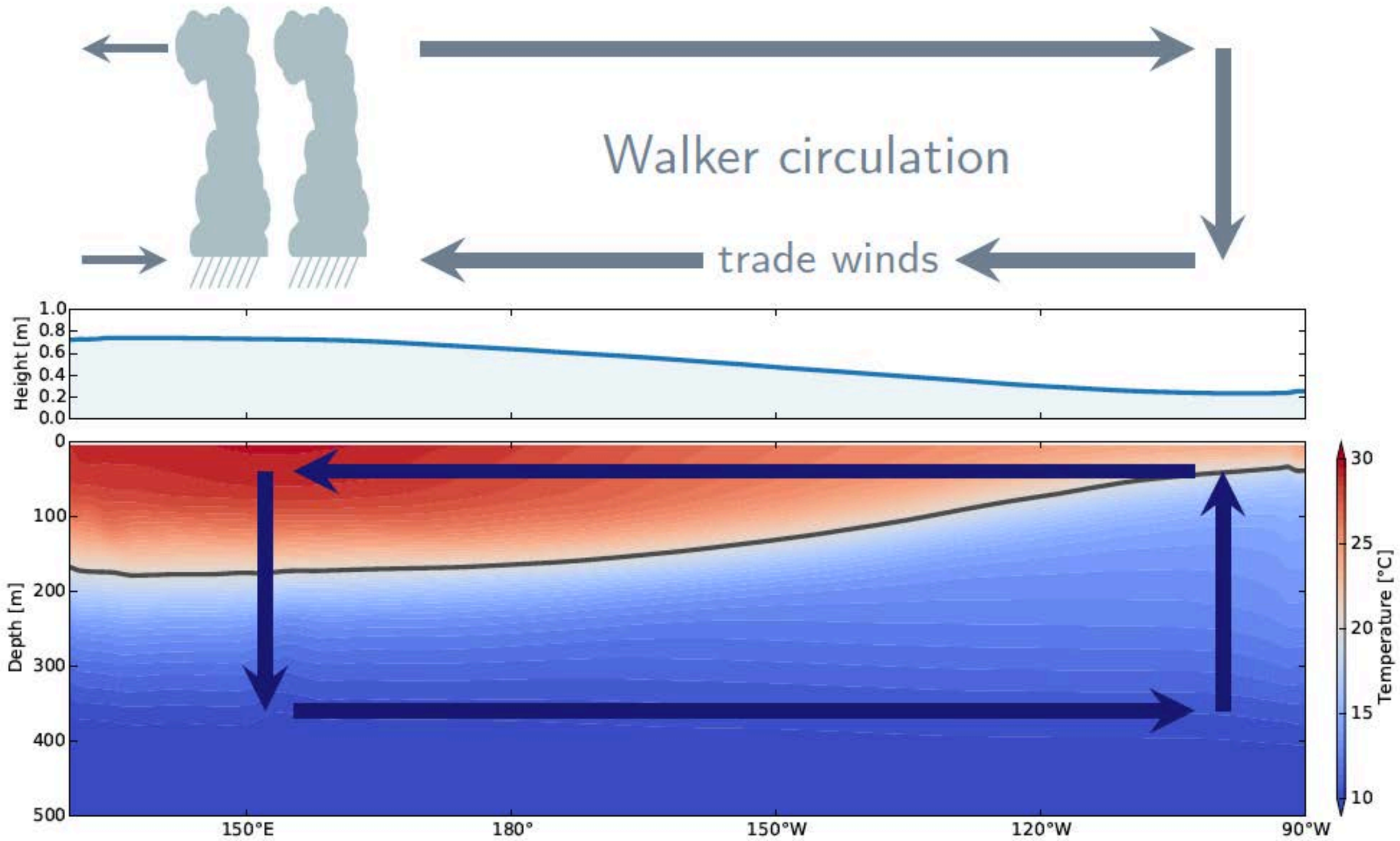


NOAA Climate.gov

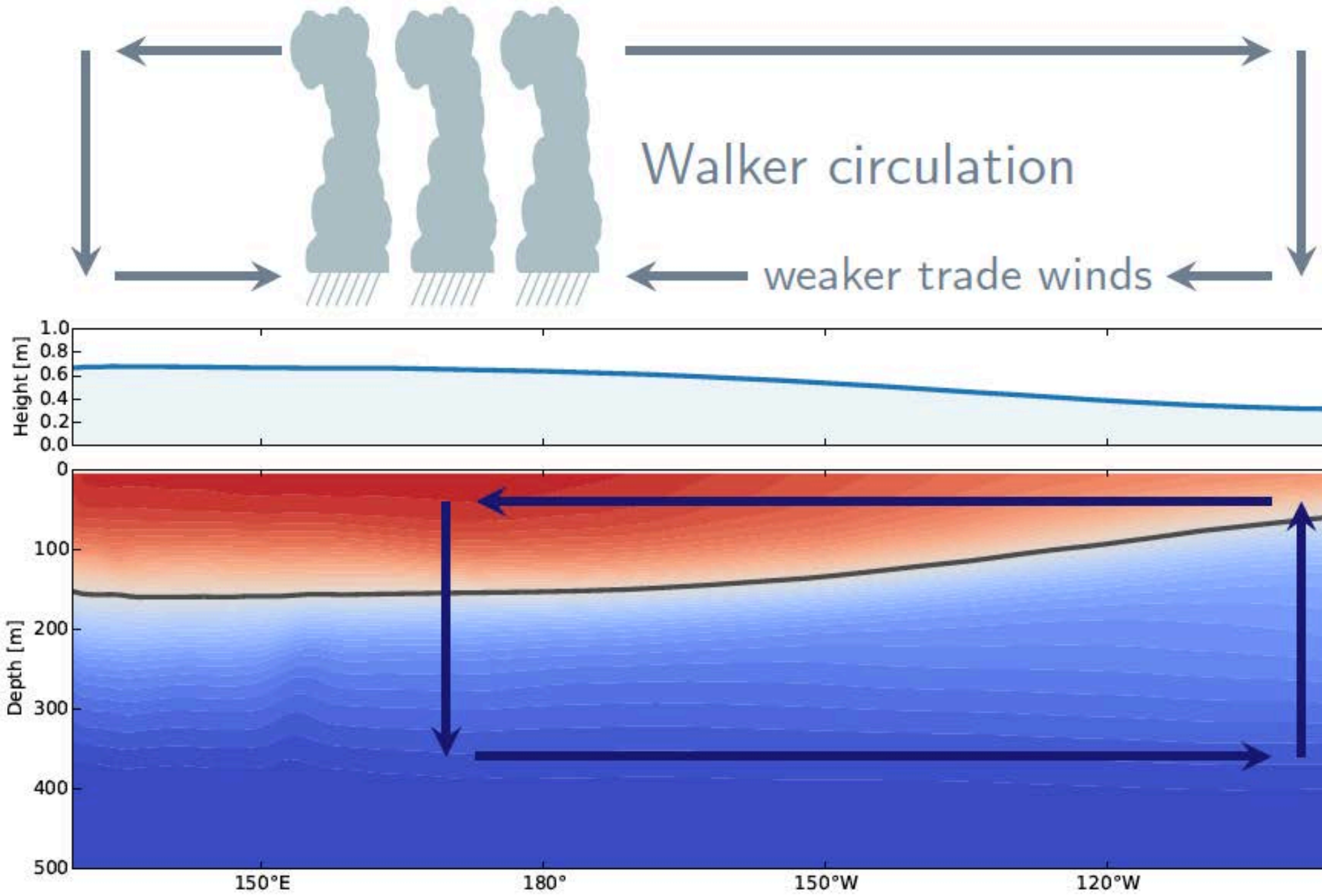
La Niña conditions



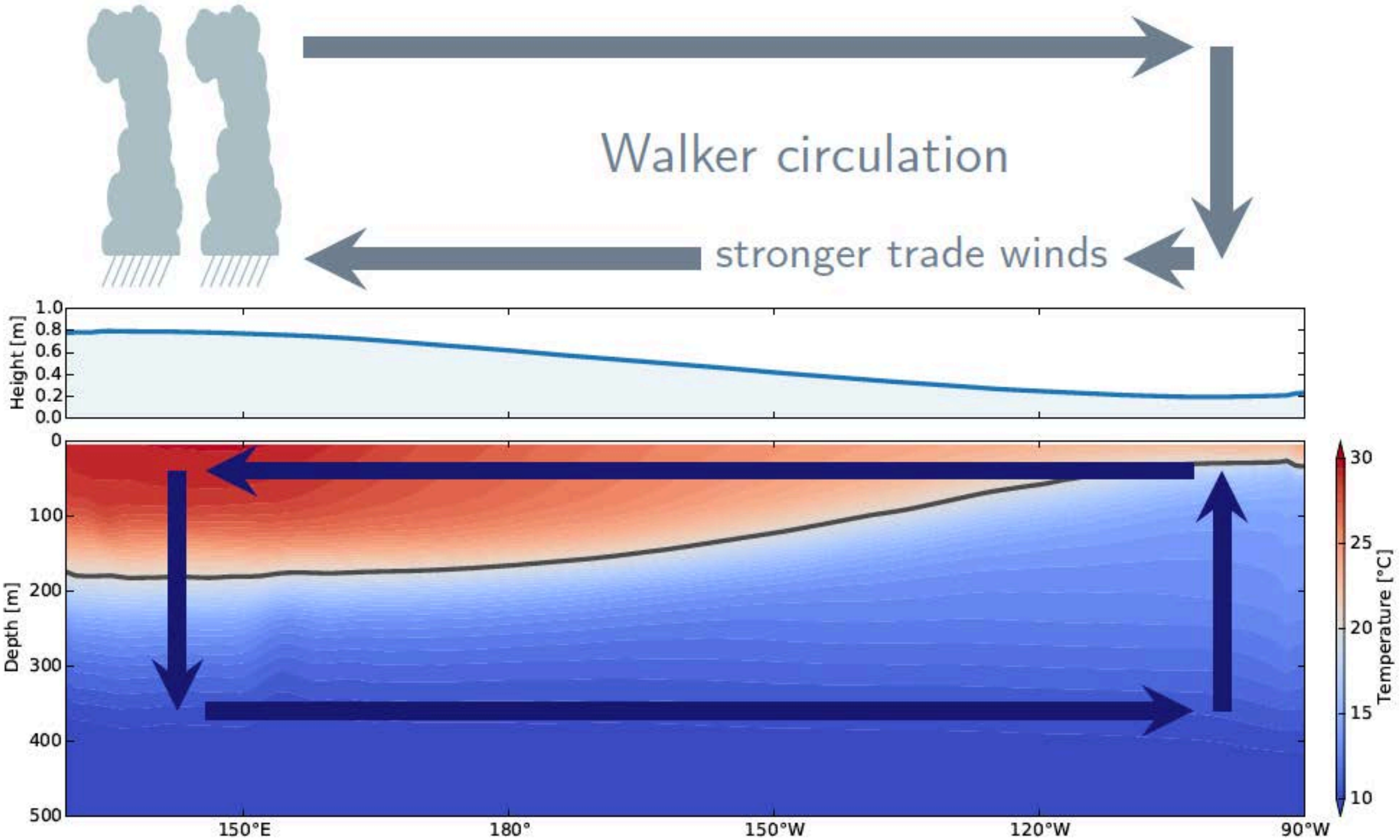
NOAA Climate.gov



Slide by Jonathan Wright

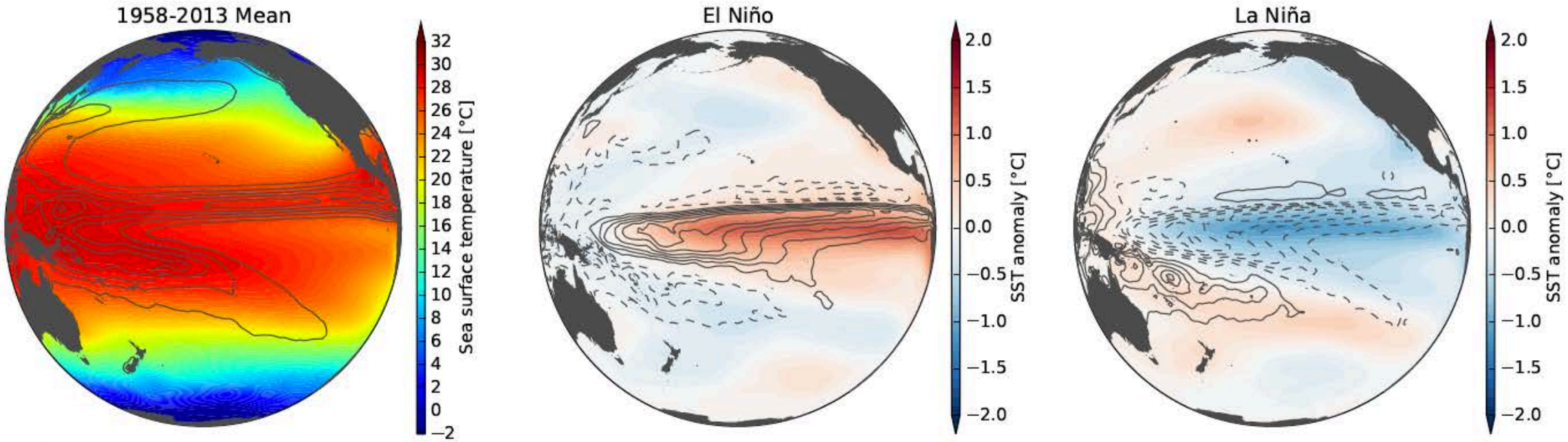


Slide by Jonathan Wright



Slide by Jonathan Wright

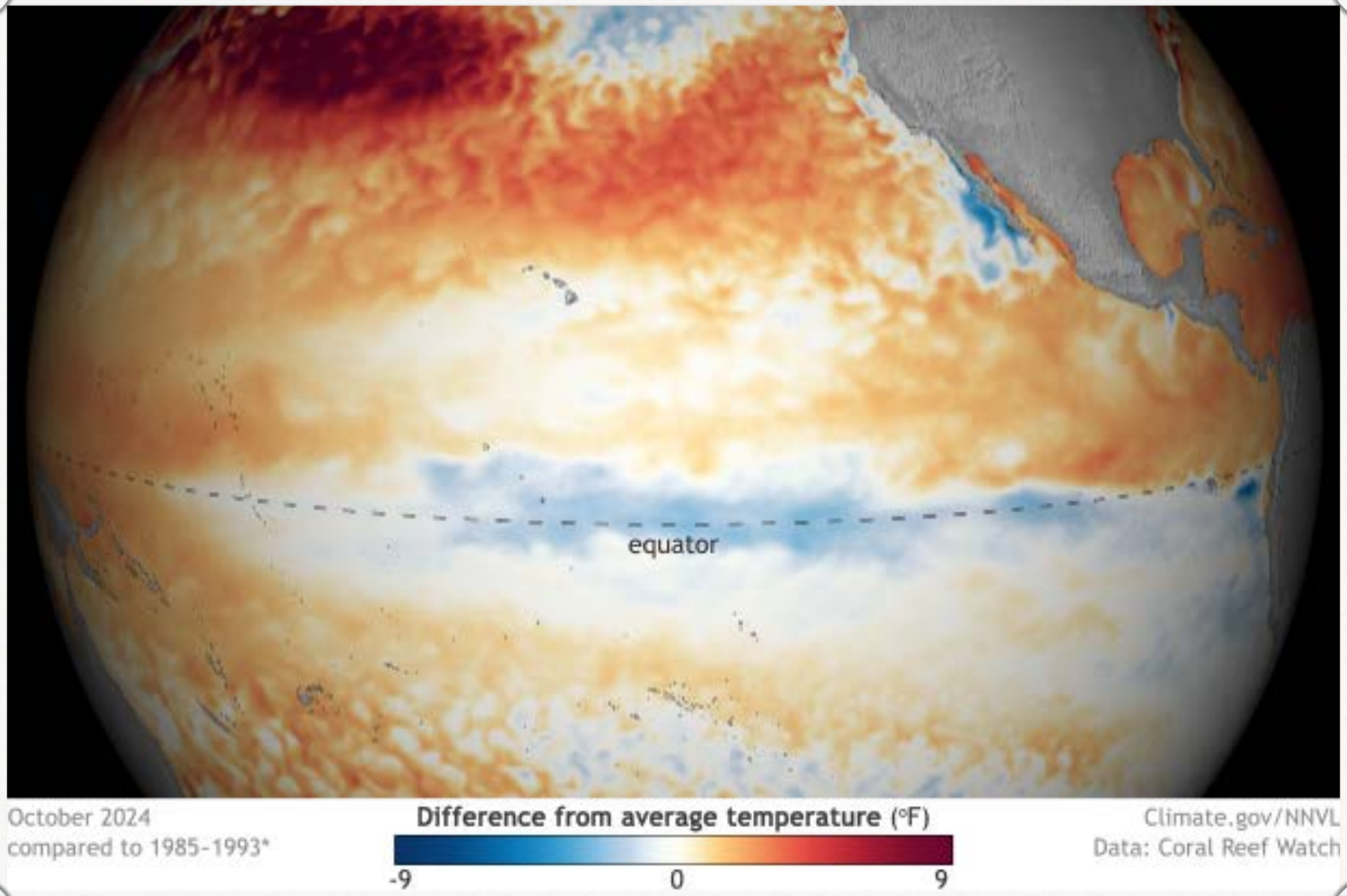
- ENSO-related SST anomalies lead to precipitation anomalies in the equatorial Pacific
- Dynamic changes associated with the precipitation anomalies dominate outside of the equatorial Pacific



contours:
precipitation

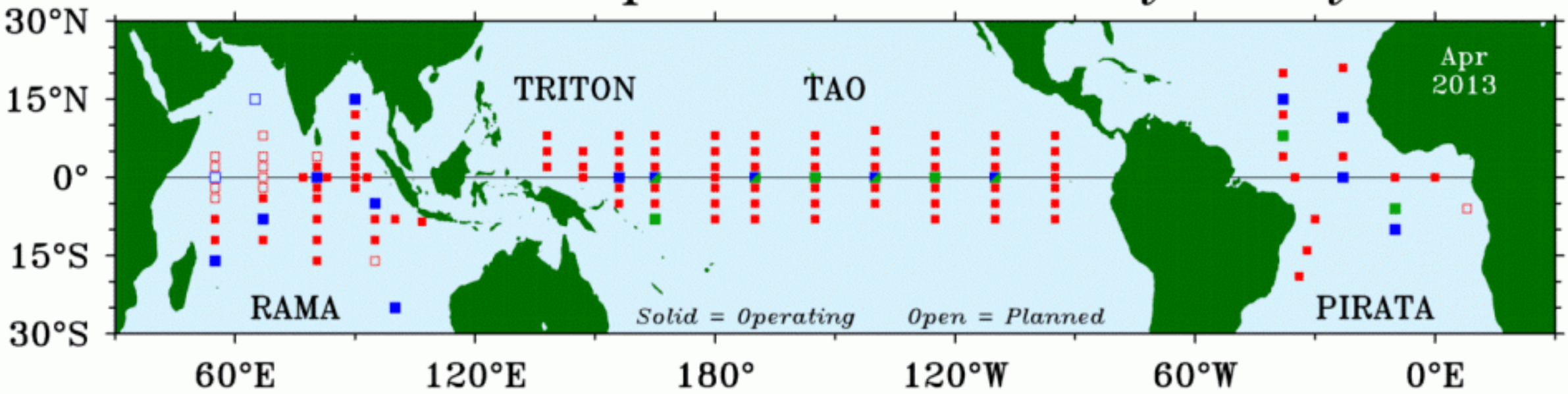
data from COBE & JRA-55

Slide by Jonathan Wright

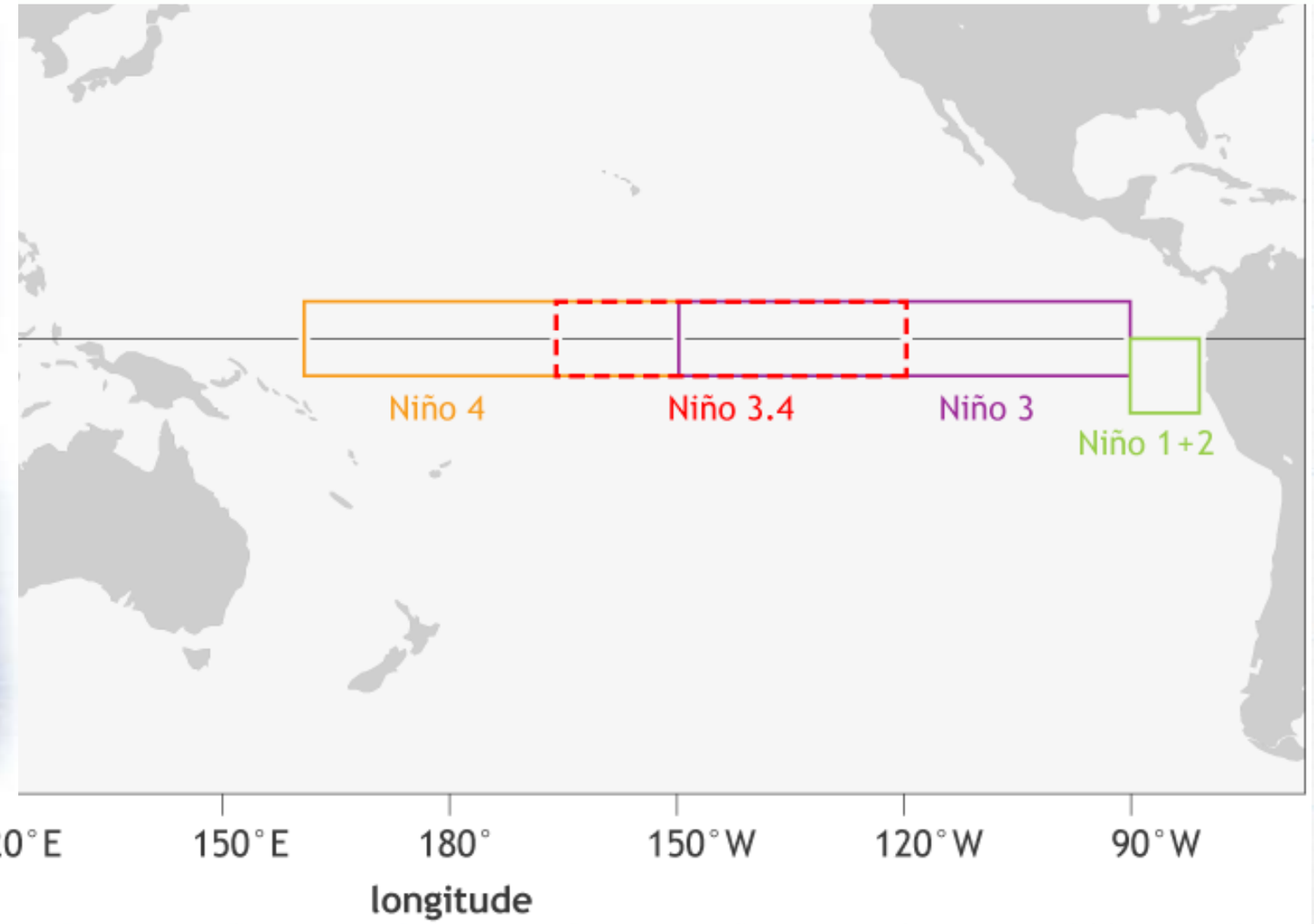


"There's a 57% chance La Niña will develop soon. This is late for La Niña to arrive, and it's very likely to be a weak event at most. However, even a weak event can influence temperature, rain, and snow patterns across the world."

Global Tropical Moored Buoy Array

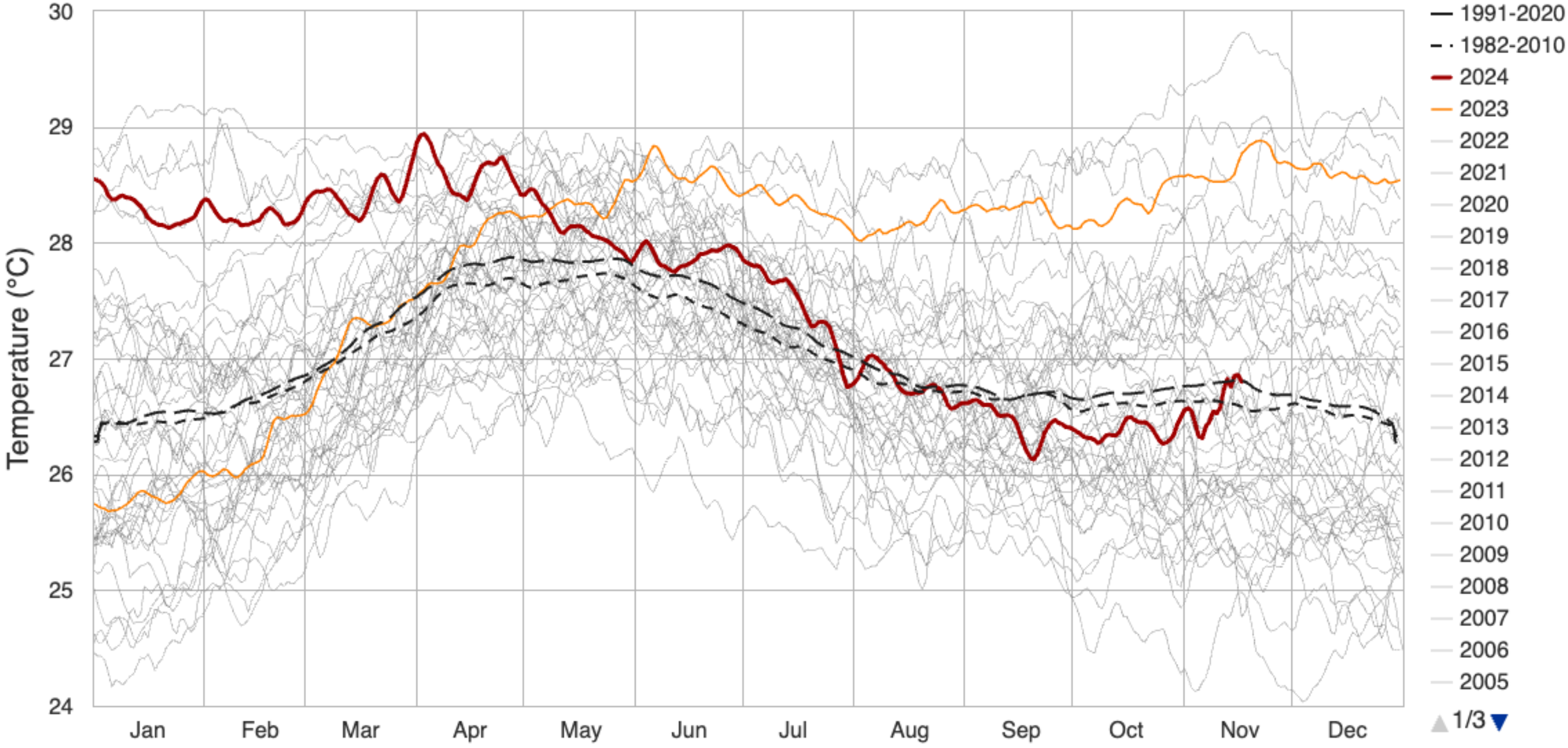


TAO Project Office, NOAA/PMEL



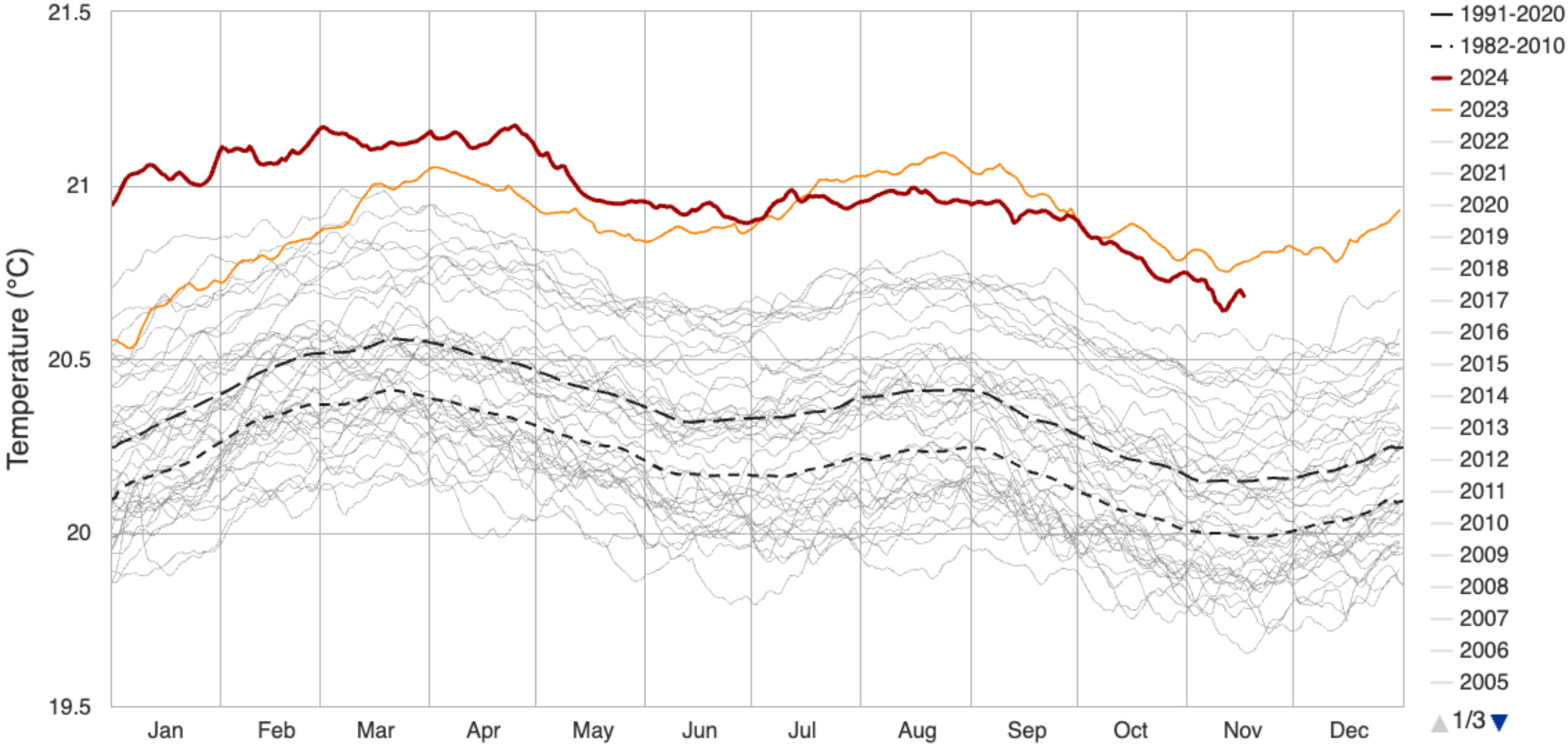
Daily Sea Surface Temperature, Niño 3.4 (5°S–5°N, 120–170°W)

Dataset: NOAA OISST V2.1 | Image Credit: ClimateReanalyzer.org, Climate Change Institute, University of Maine



Daily Sea Surface Temperature, World (60°S–60°N, 0–360°E)

Dataset: NOAA OISST V2.1 I Image Credit: ClimateReanalyzer.org, Climate Change Institute, University of Maine

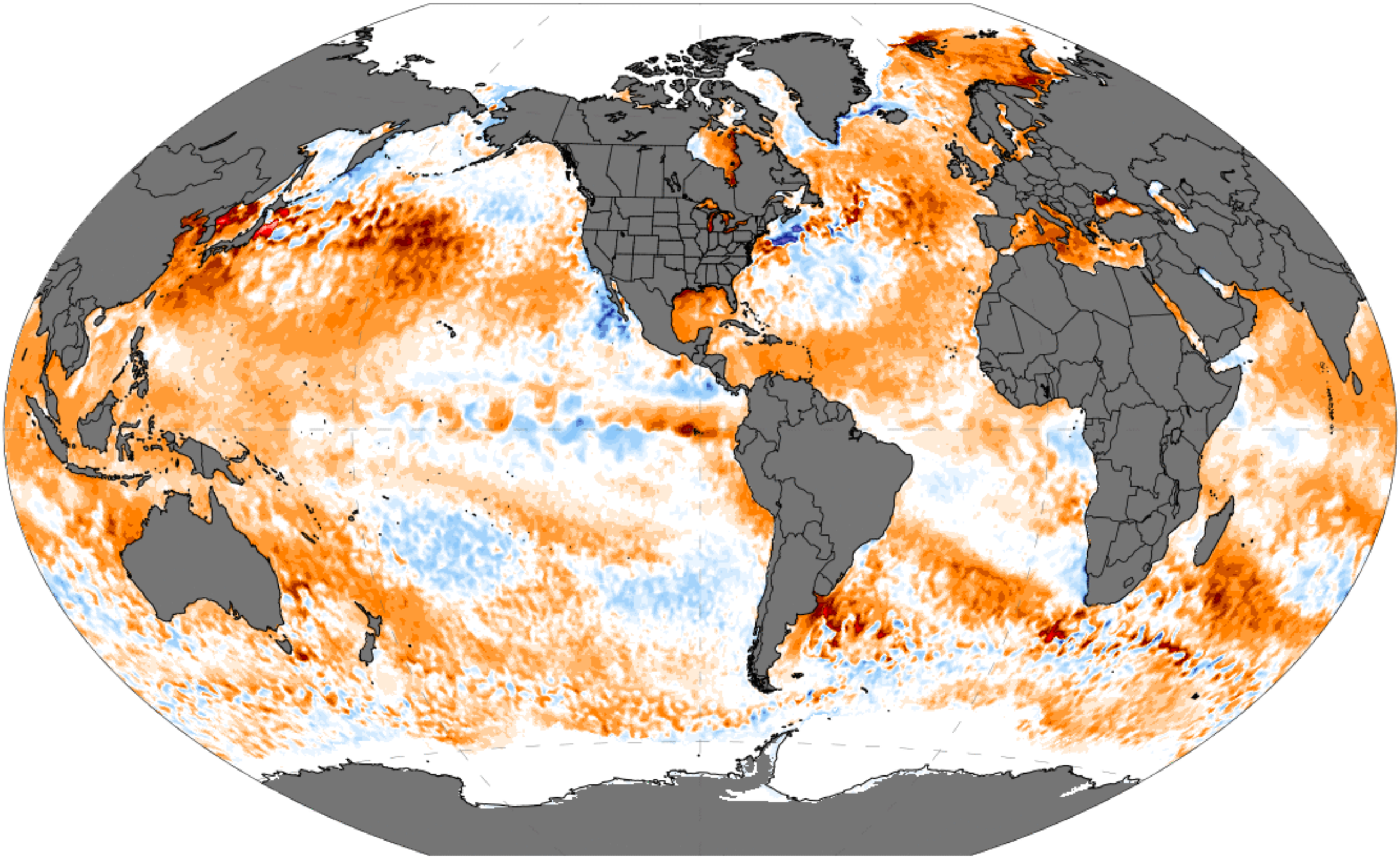


NOAA OISST V2.1 SST Anomaly (°C) [1991-2020 baseline]

Sat, Nov 16, 2024 | preliminary

ClimateReanalyzer.org

Climate Change Institute | University of Maine



-9 -7 -5 -4 -3 -2 -1 -0.5 0 0.5 1 2 3 4 5 7 9

Is it El Niño conditions?

Start here

Is the monthly Niño-3.4 SST ≥ 0.5°C?

NO

YES

Think the Niño-3.4 SST will stay ≥ 0.5°C for the next several seasons?

NO

YES

What does the atmosphere look like?

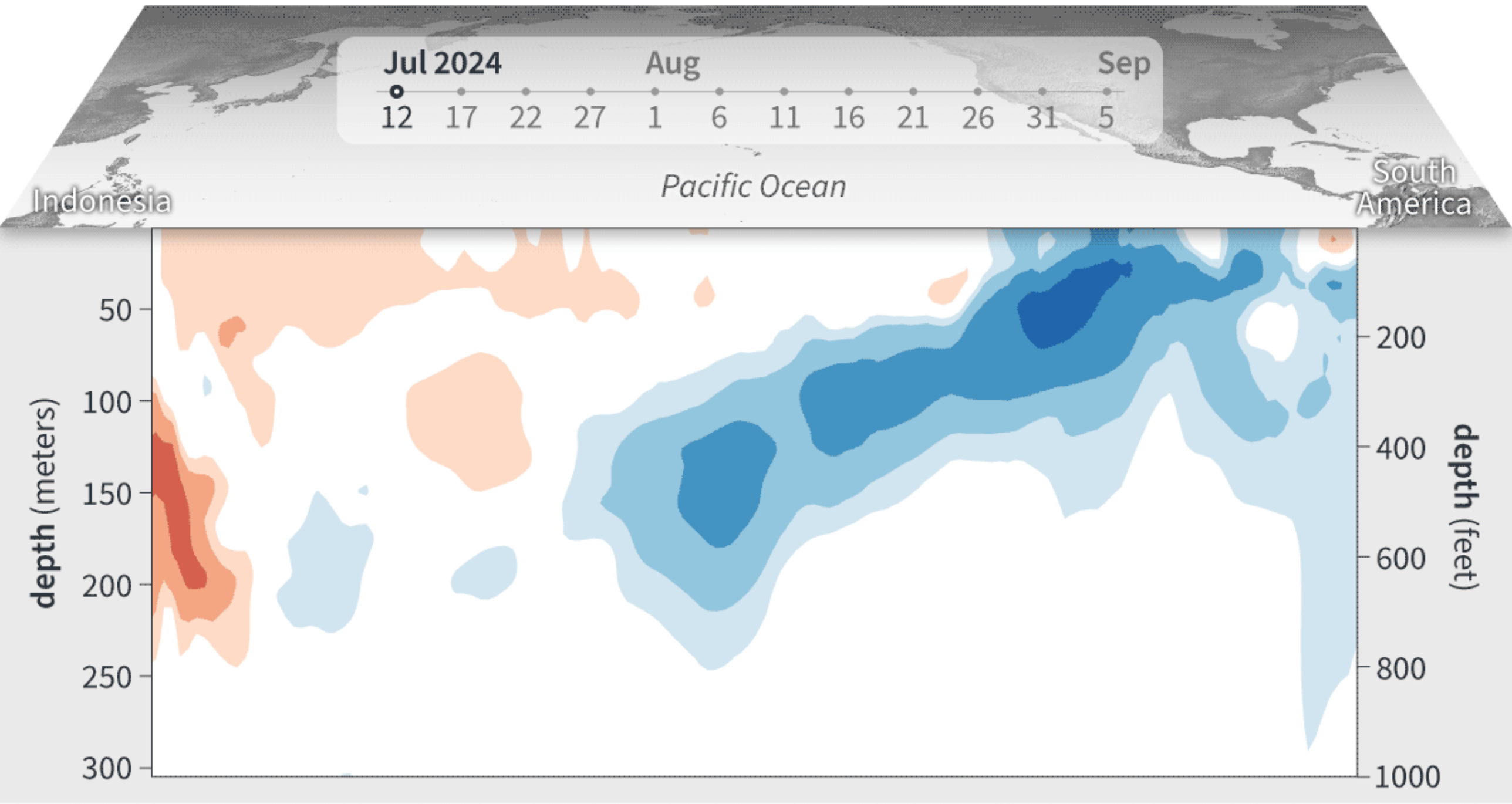
Insufficient indications of a weaker Walker circulation

Indications of a weaker Walker circulation (such as more rain over the central Pacific, less rain over Indonesia)

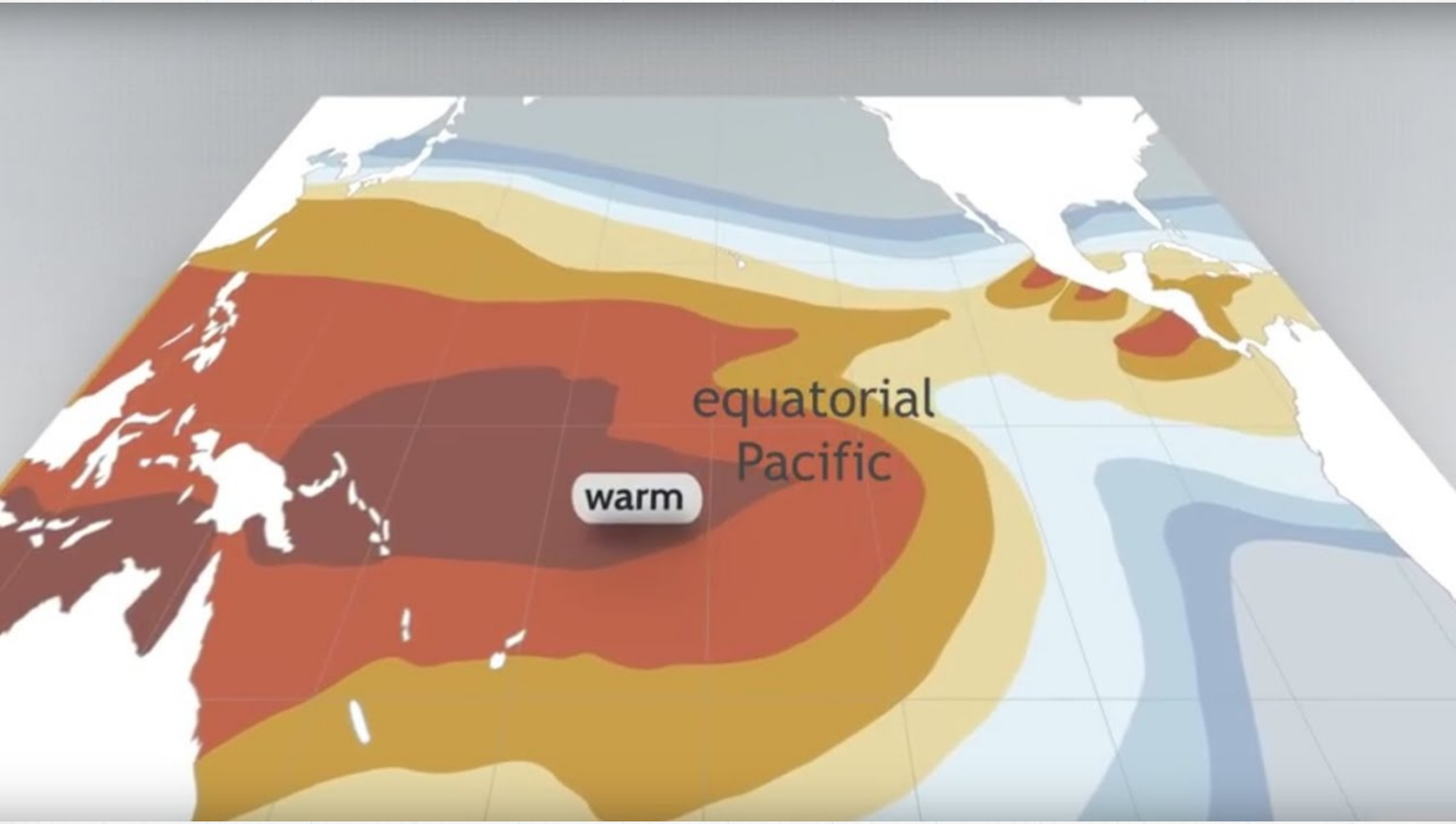
NOPE!

El Niño conditions!

Cold water continues to lurk beneath the surface in eastern Pacific



NOAA Climate.gov
Data: CPC


equatorial
Pacific
warm

ENSO arises from changes across the tropical Pacific Ocean. So why does ENSO affect the climate over sizable portions of the globe?

Warmer SST in the central and eastern tropical Pacific Ocean

↓

Warmer air, more moisture

↓

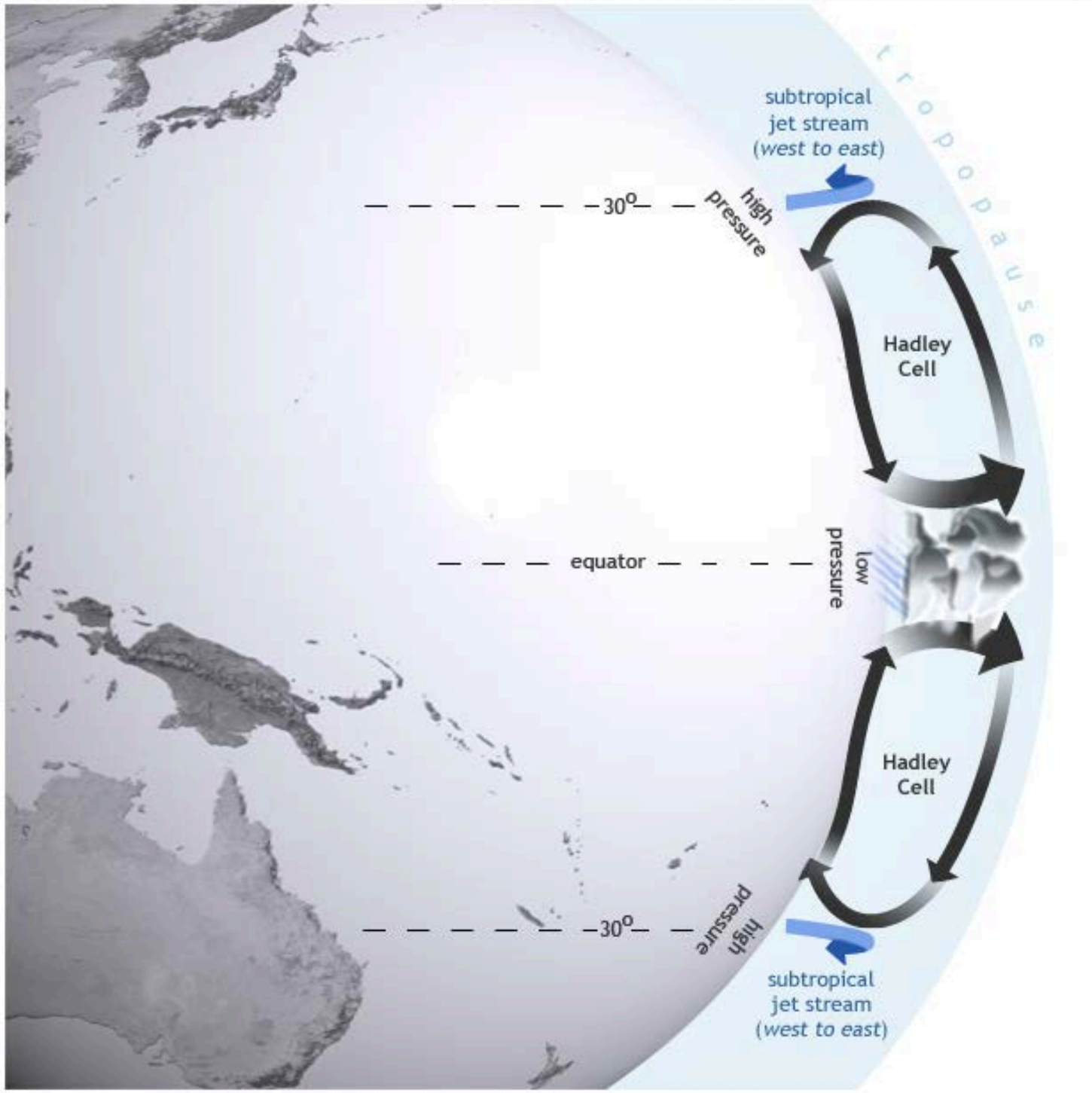
Convection and precipitation, Latent heat release

↓

Stronger Hadley circulation

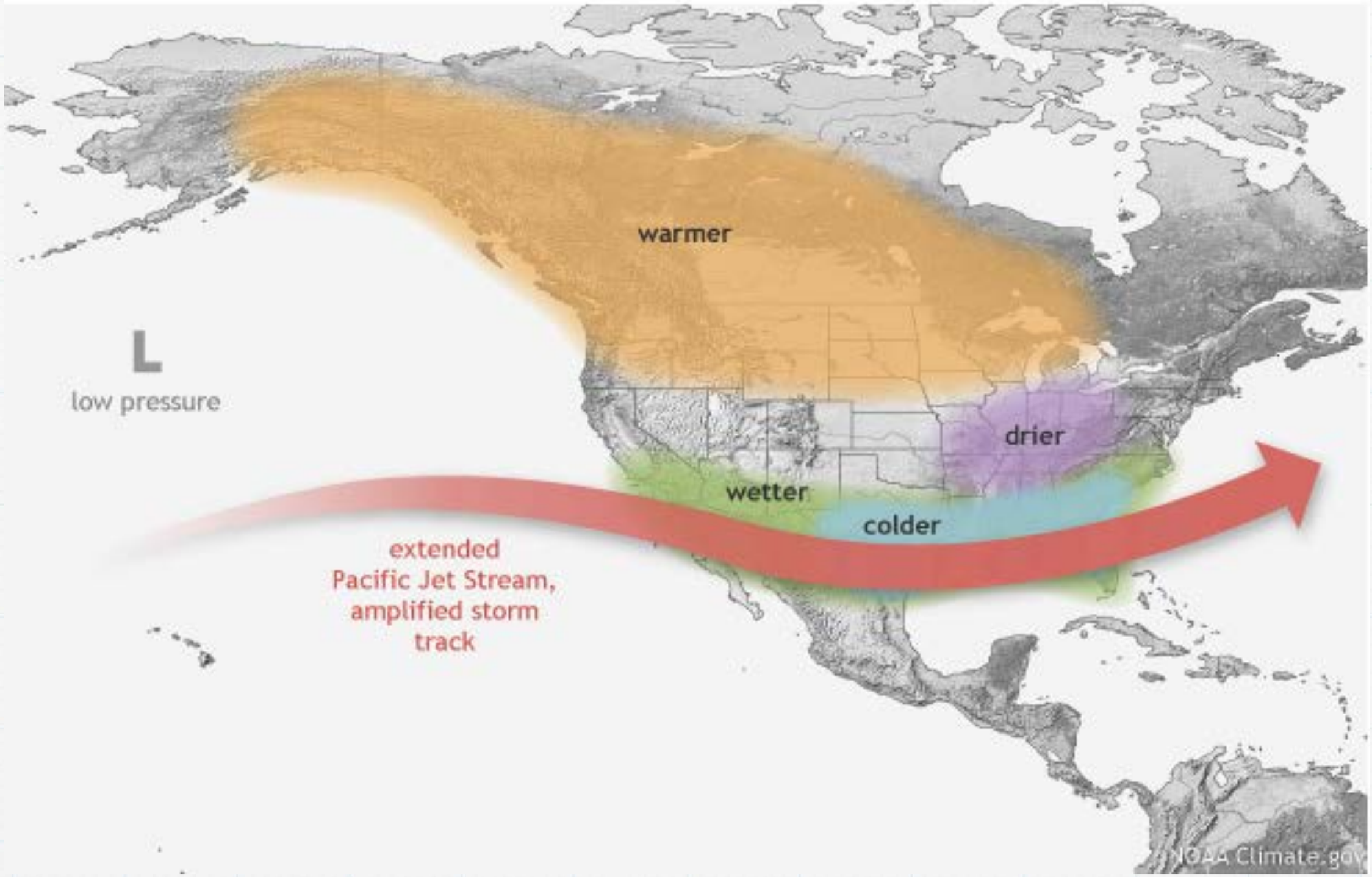
↓

Stronger Hadley circulation, affecting jet stream

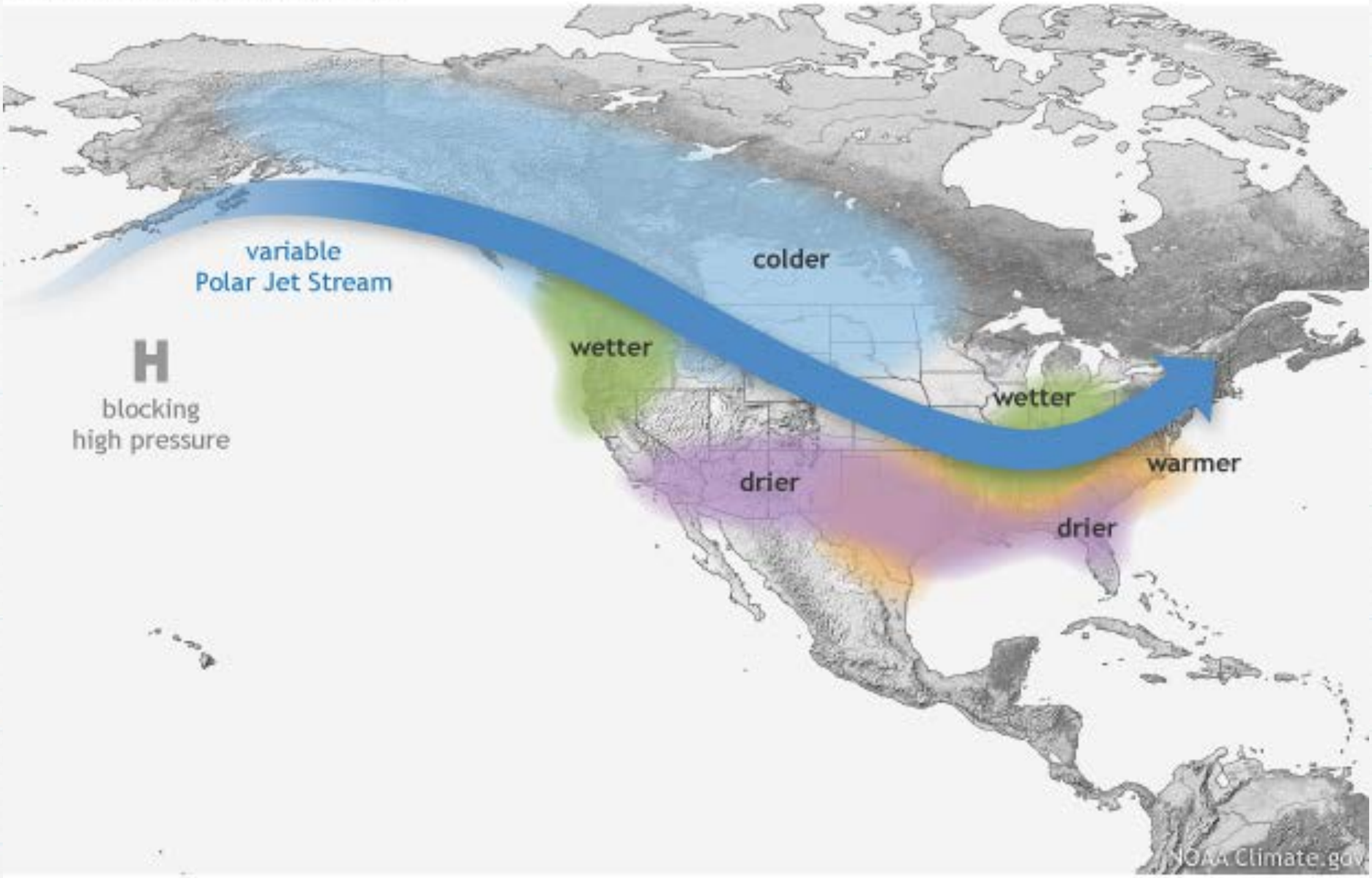


El Niño influences global atmospheric circulation by intensifying the Hadley circulation, in which heat is transferred from the Earth's surface to the upper atmosphere through convection and latent heating. Map by NOAA Climate.gov.

WINTER EL NIÑO PATTERN

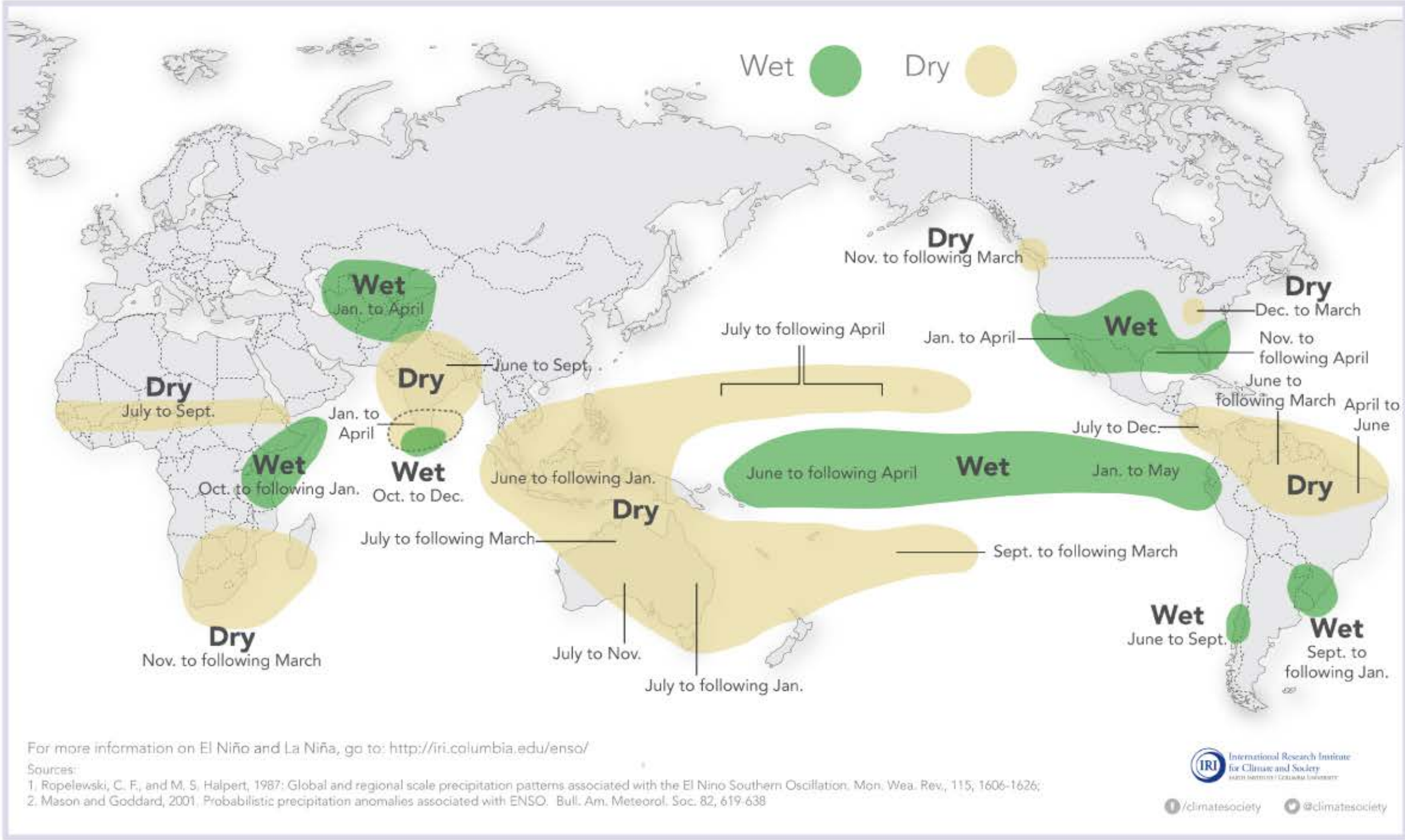


WINTER LA NIÑA PATTERN



El Niño and Rainfall

El Niño conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. Although they vary somewhat from one El Niño to the next, the strongest shifts remain fairly consistent in the regions and seasons shown on the map below.



For more information on El Niño and La Niña, go to: http://iri.columbia.edu/enso/

Sources:
1. Ropelewski, C. F., and M. S. Halpert, 1987: Global and regional scale precipitation patterns associated with the El Nino Southern Oscillation. Mon. Wea. Rev., 115, 1606-1626;
2. Mason and Goddard, 2001. Probabilistic precipitation anomalies associated with ENSO. Bull. Am. Meteorol. Soc. 82, 619-638

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La Niña and Rainfall

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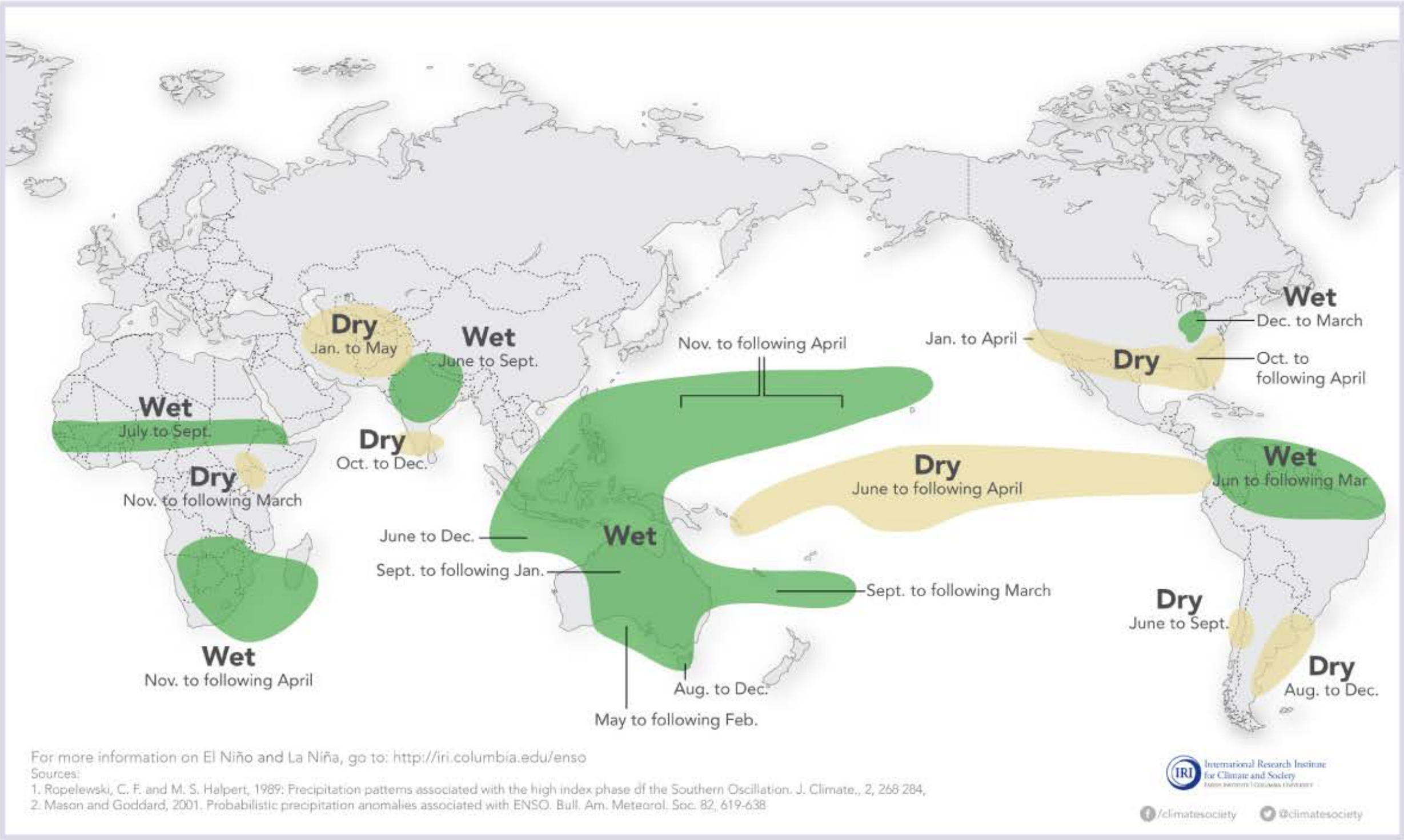

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Sources:
1. Ropelewski, C. F. and M. S. Halpert, 1989: Precipitation patterns associated with the high index phase of the Southern Oscillation. J. Climate., 2, 268 284,
2. Mason and Goddard, 2001. Probabilistic precipitation anomalies associated with ENSO. Bull. Am. Meteorol. Soc. 82, 619-638

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