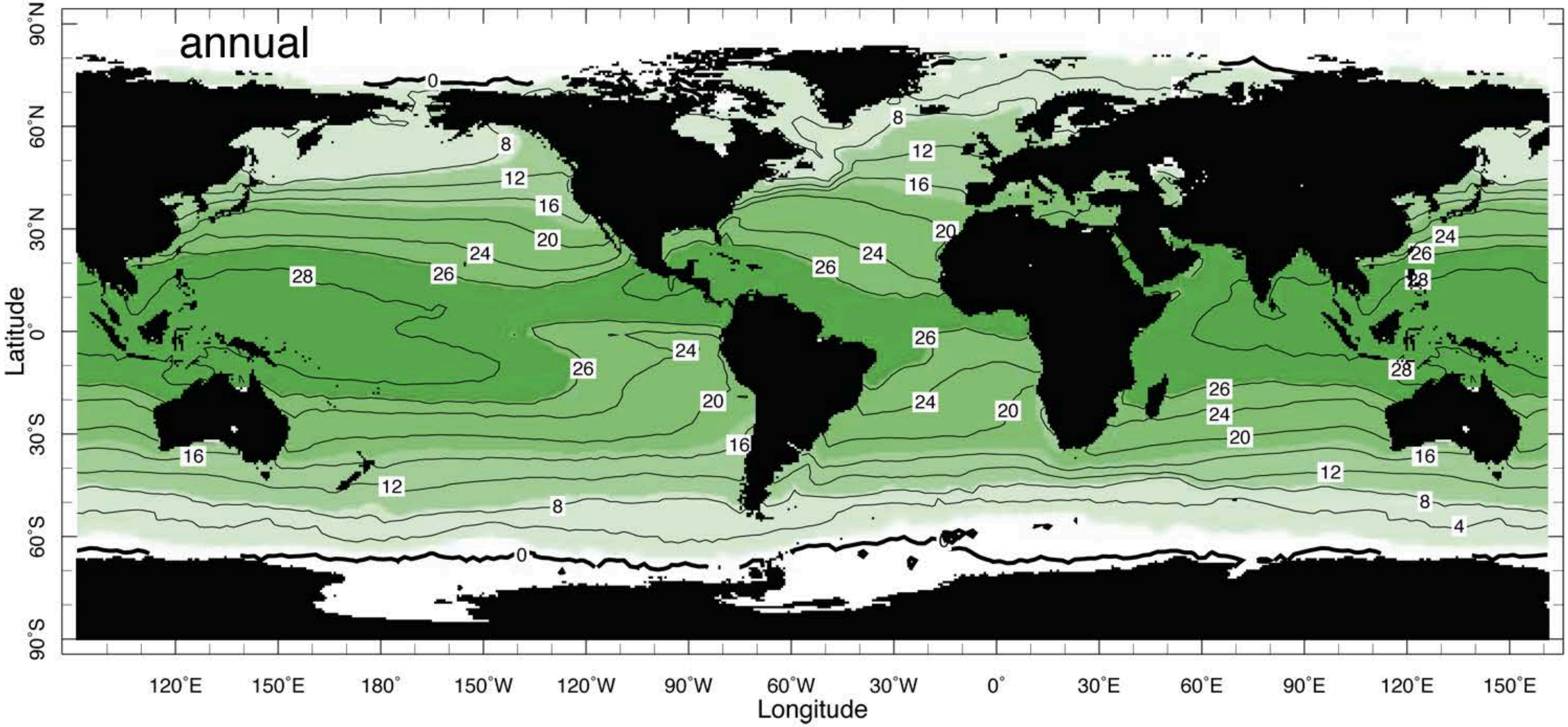
Air-sea interaction: El Nino and La Nina

ATM2106

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

Sea Surface Temperature (ºC)



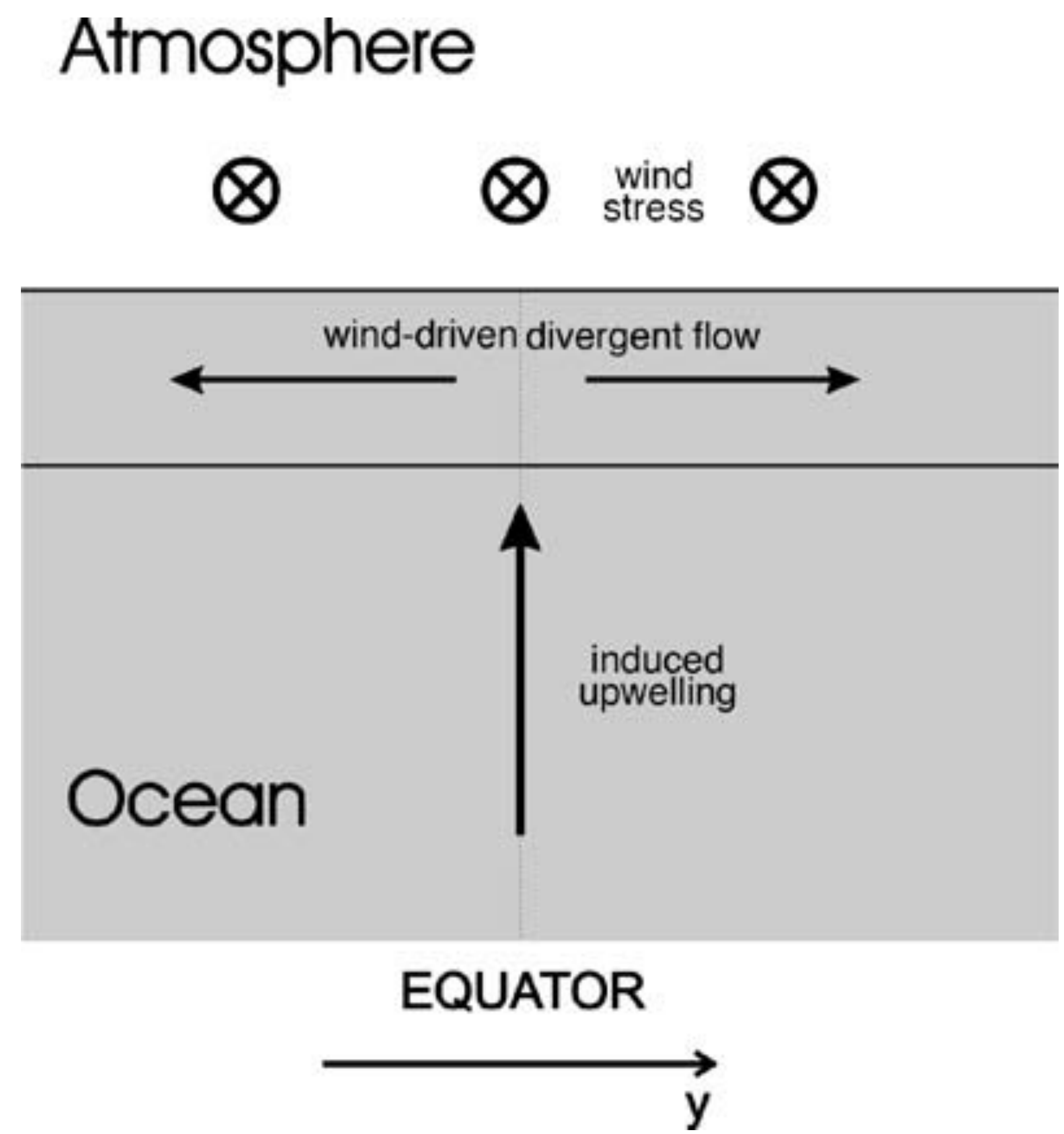
Divergence of the water at the equator

$$\beta V = \frac{1}{\rho_{ref}} \left(\frac{\partial \tau_{wind,y}}{\partial x} - \frac{\partial \tau_{wind,x}}{\partial y} \right)$$

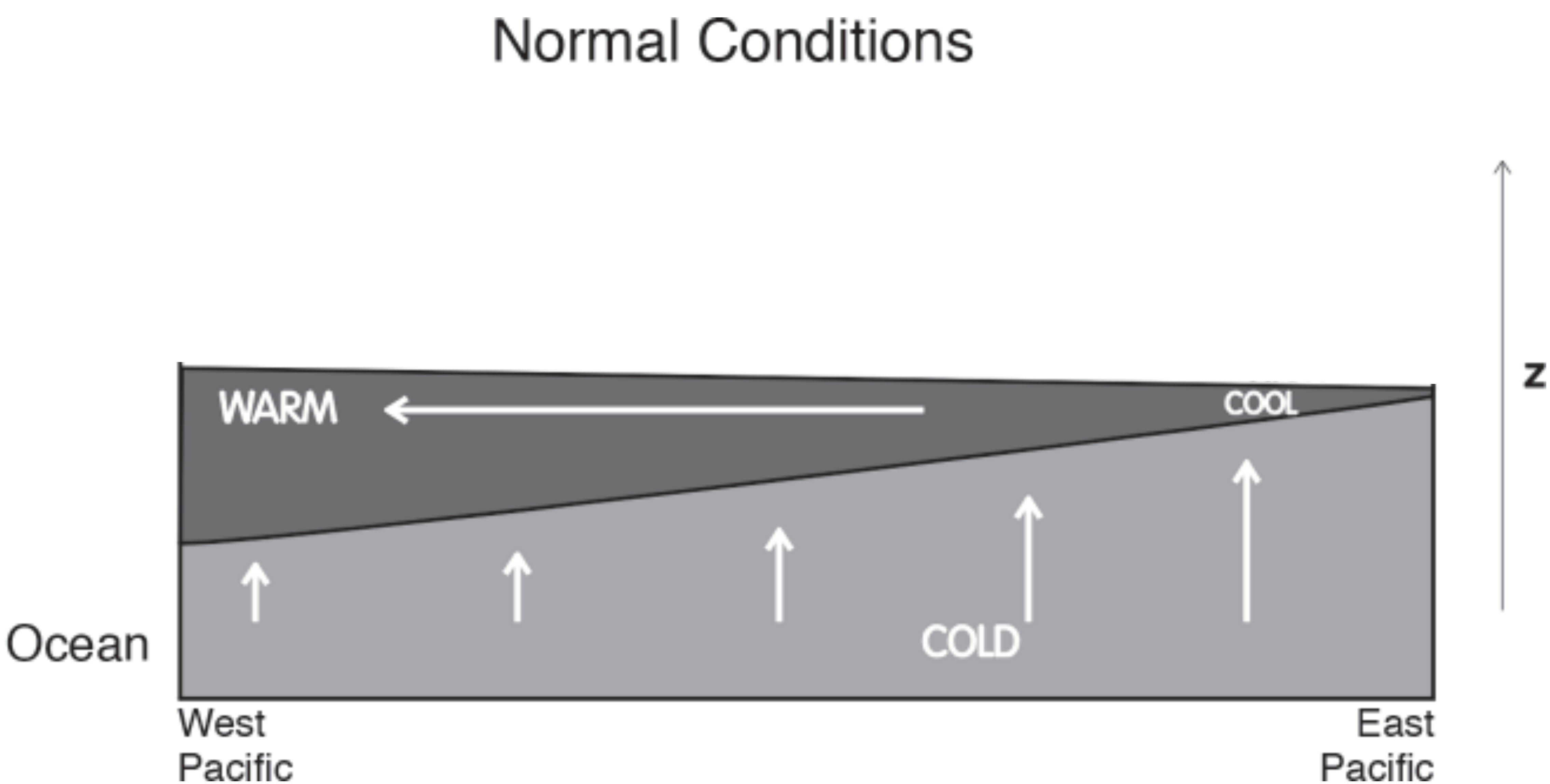
$$\beta V = -\frac{1}{\rho_{ref}} \frac{\partial \tau_x}{\partial y}$$

$\beta > 0$ In the northern hemisphere

$\beta < 0$ In the southern hemisphere

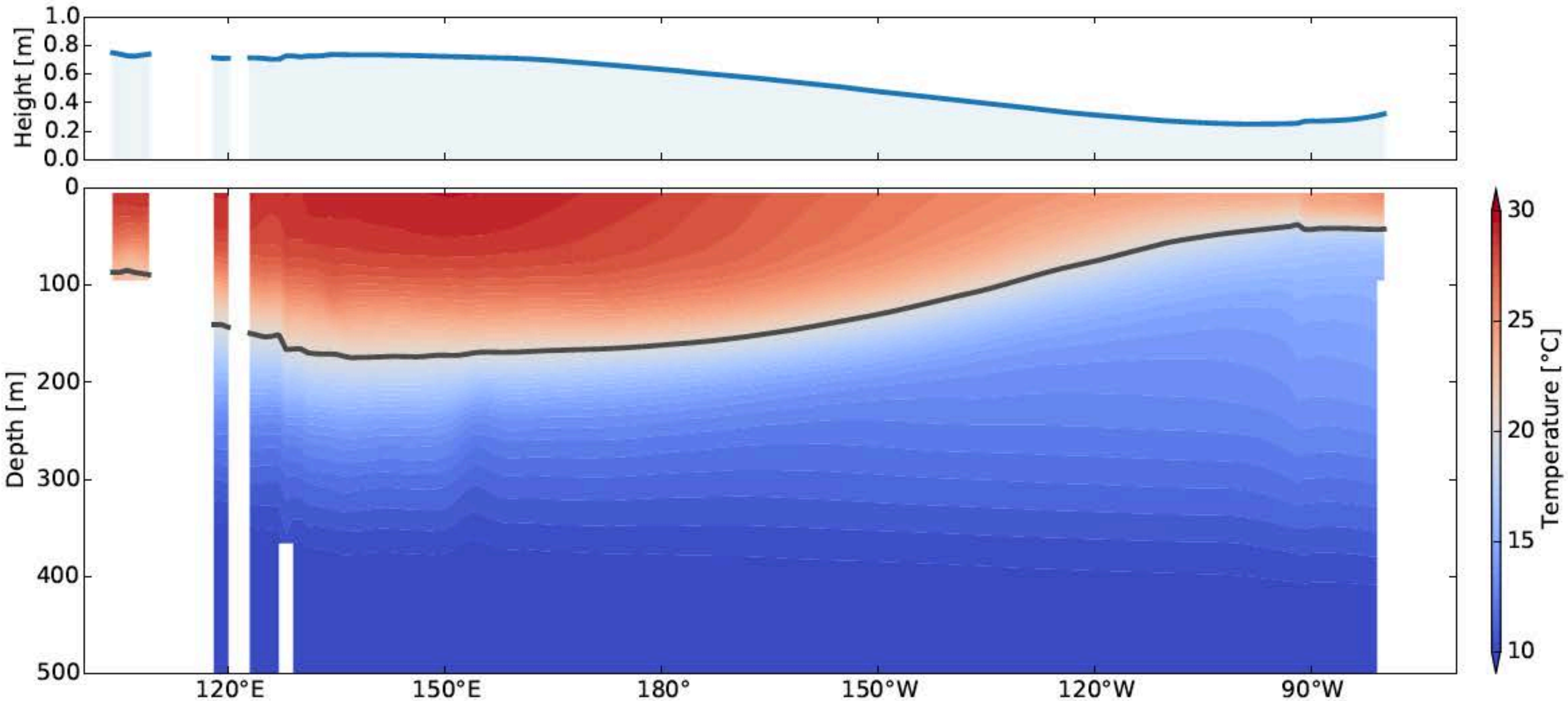


Upwelling along the equator



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

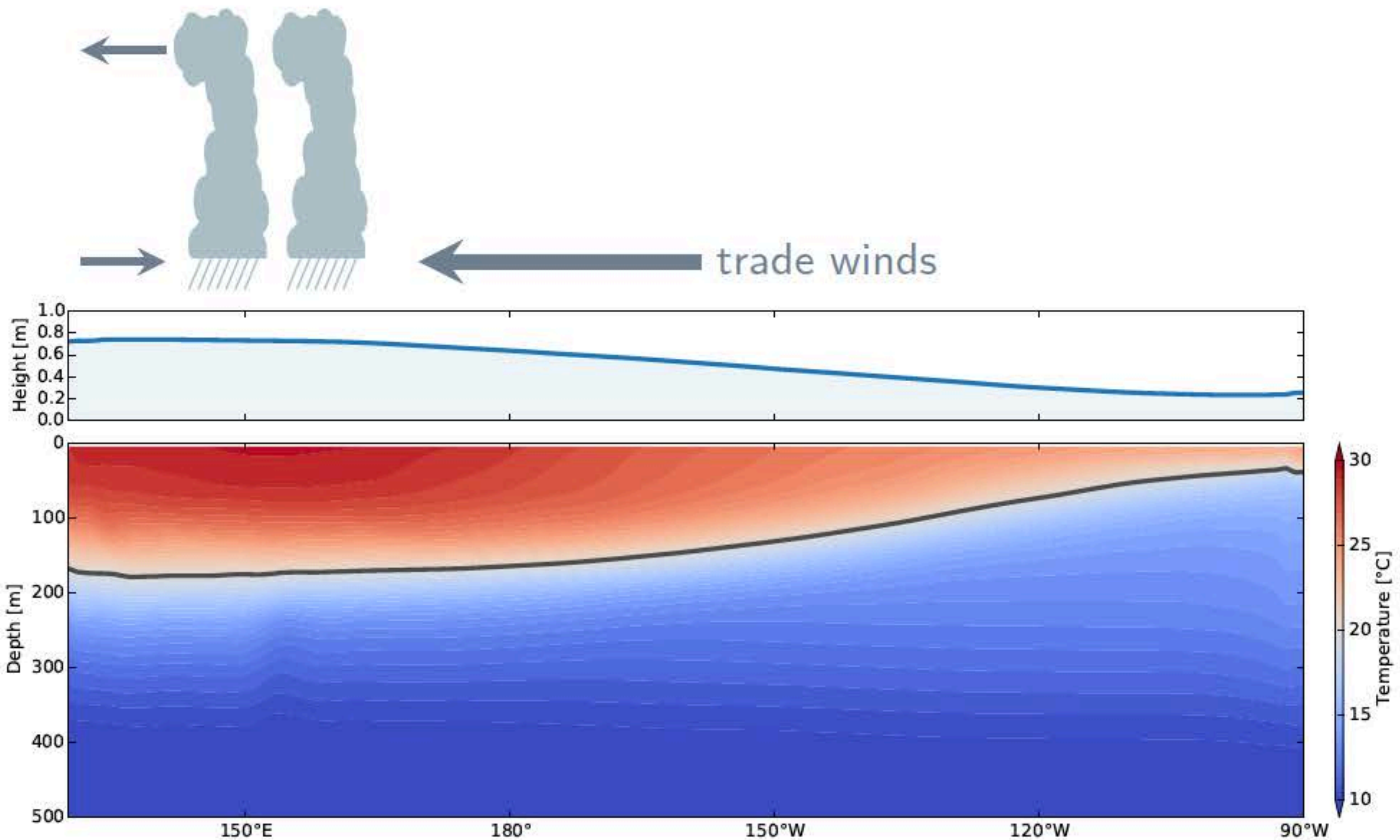


data from C

Slide by Jonathan Wright

Normal conditions

Convection is located over the Western Pacific warm pool



Slide by Jonathan Wright

Normal conditions

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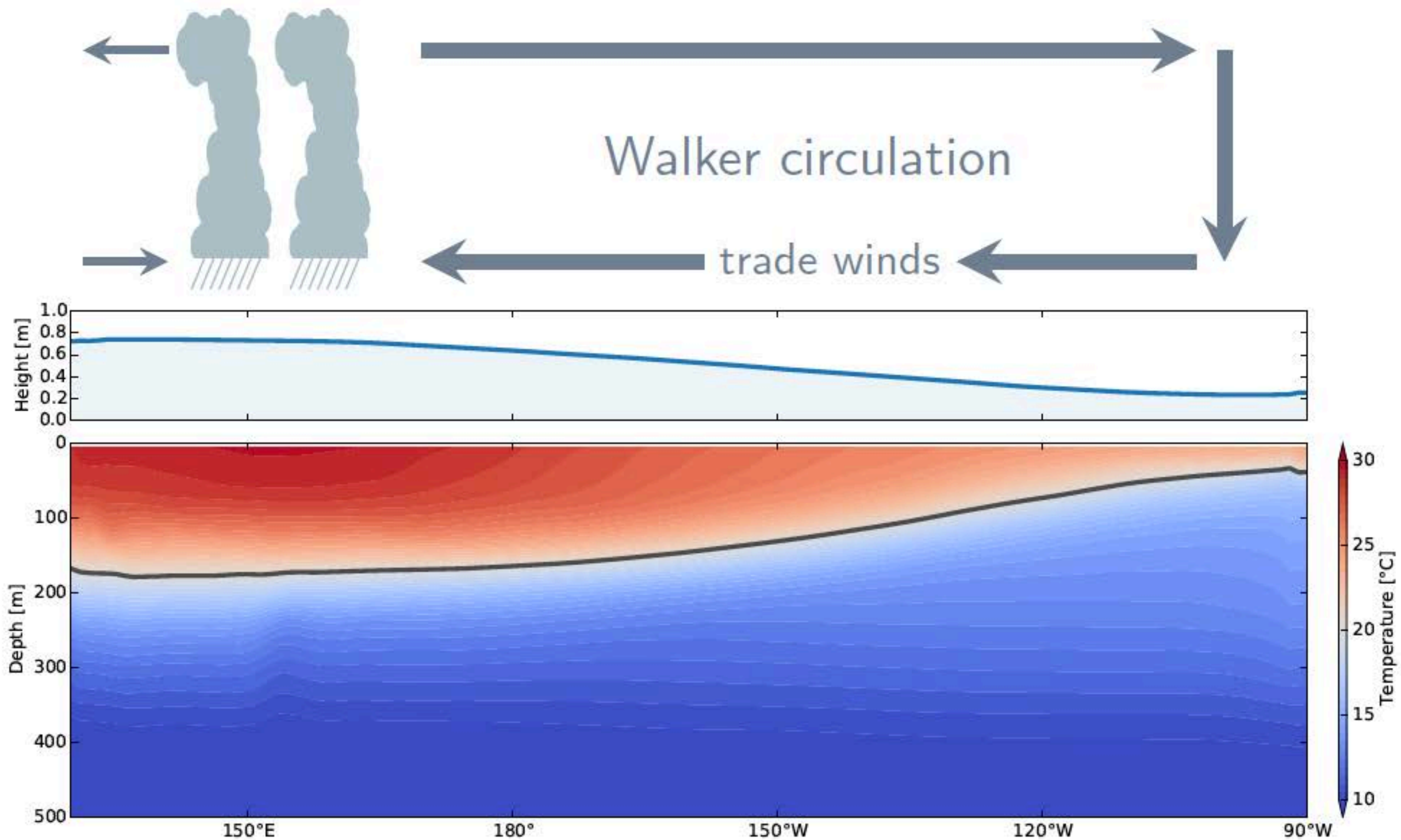

Slide by Jonathan Wright

Normal conditions

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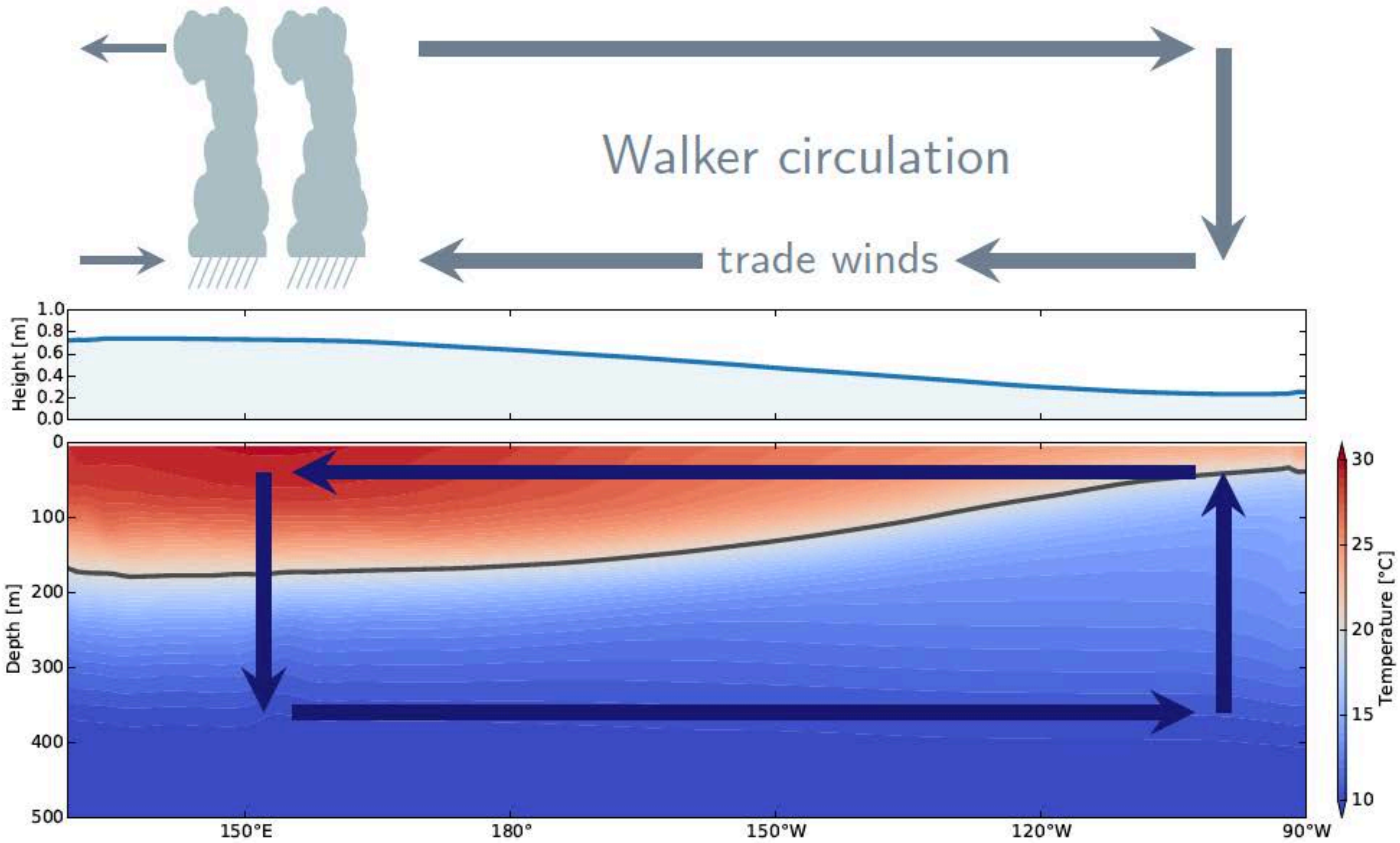
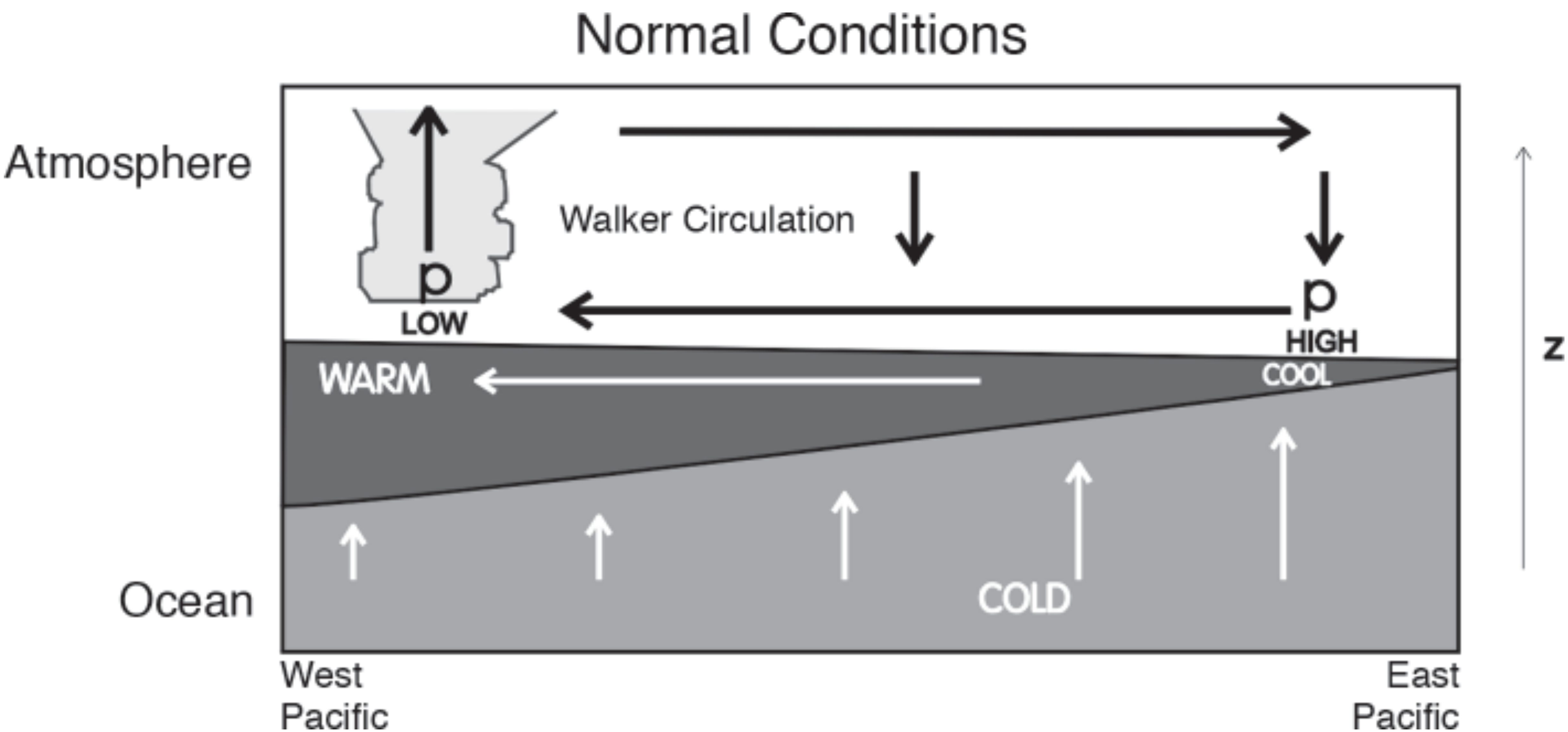


Slide by Jonathan Wright

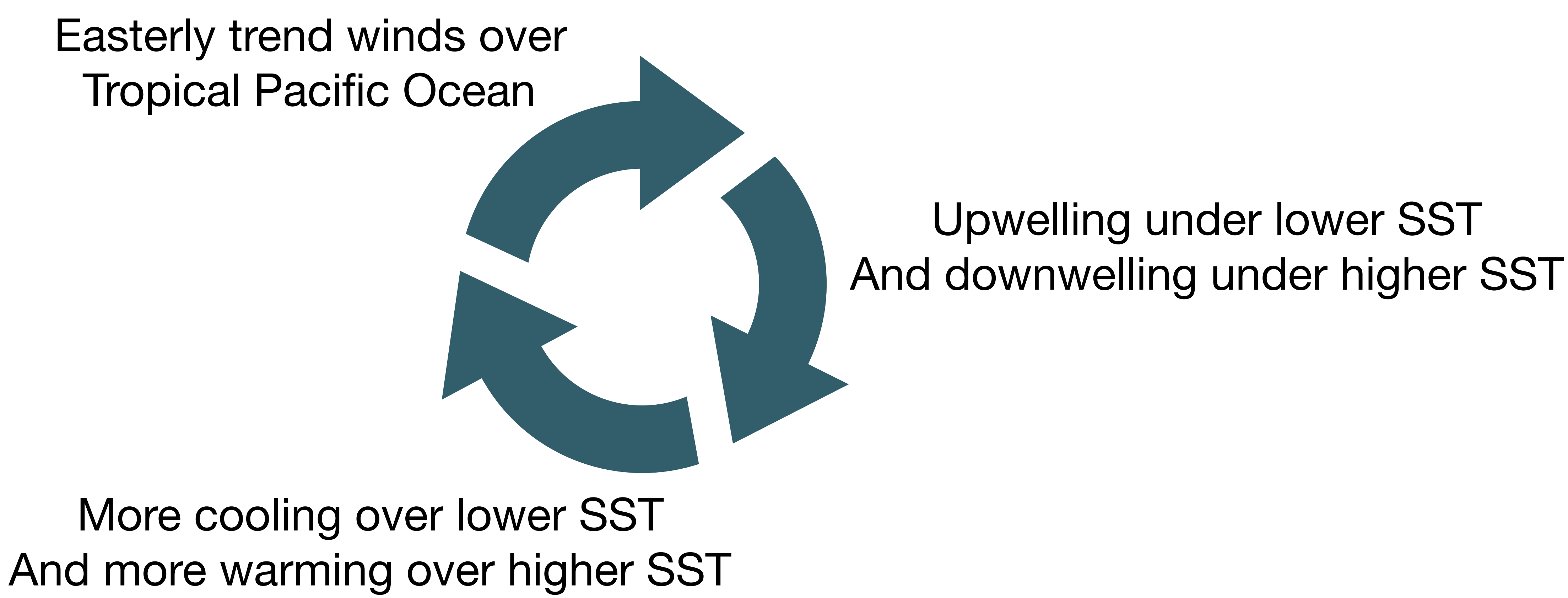
Normal conditions



The Bjerknes feedback

Slide by Jonathan Wright

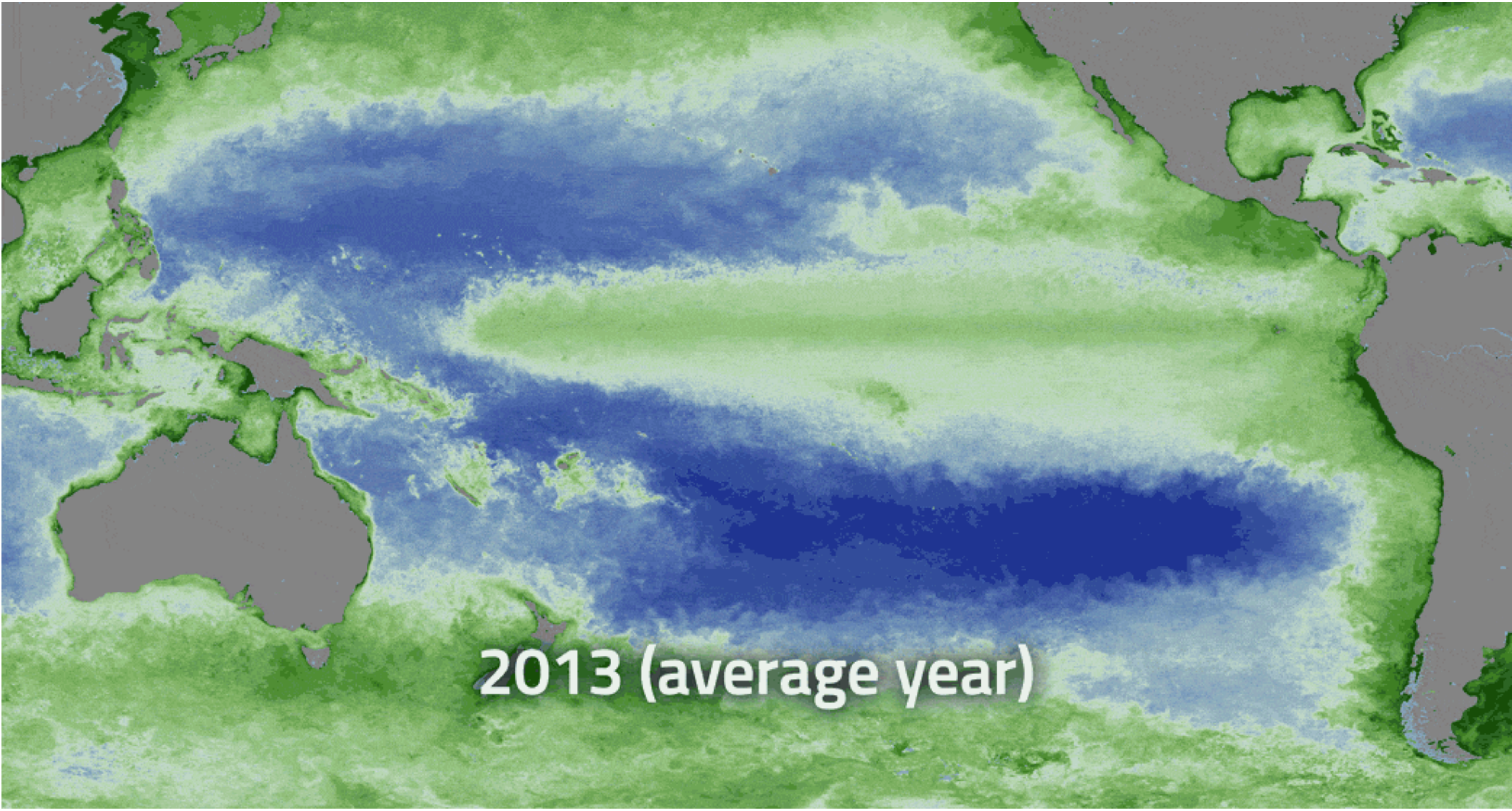
1. Winds flow from low SST to high SST ...
2. which causes upwelling under low SST and downwelling under high SST ...
3. which enhances cooling in the region of low SST and warming in the region of high SST ...
4. which strengthens the winds that flow from low SST to high SST



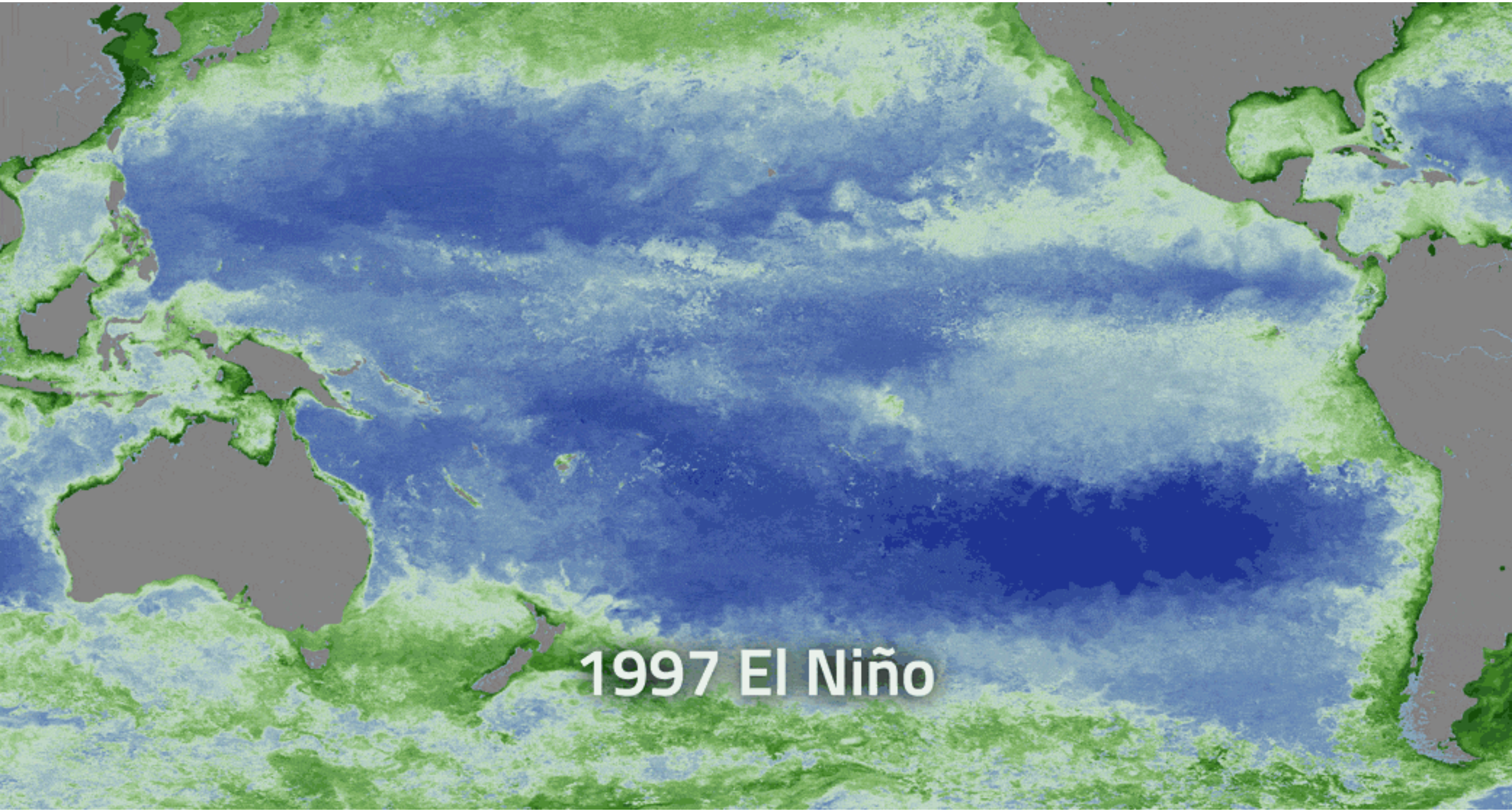
Interannually varying climate in the tropics

- 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

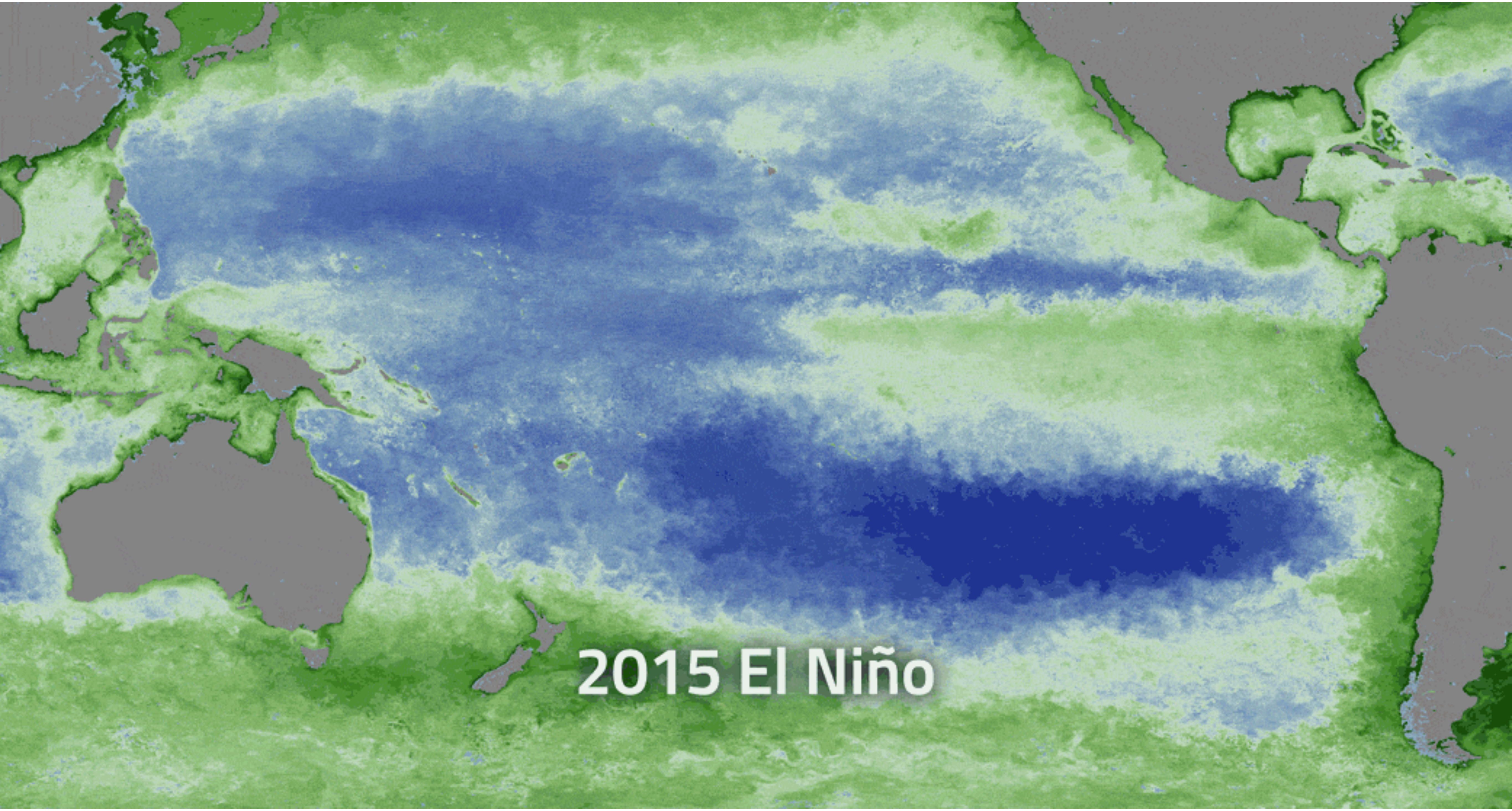
Satellite chlorophyll

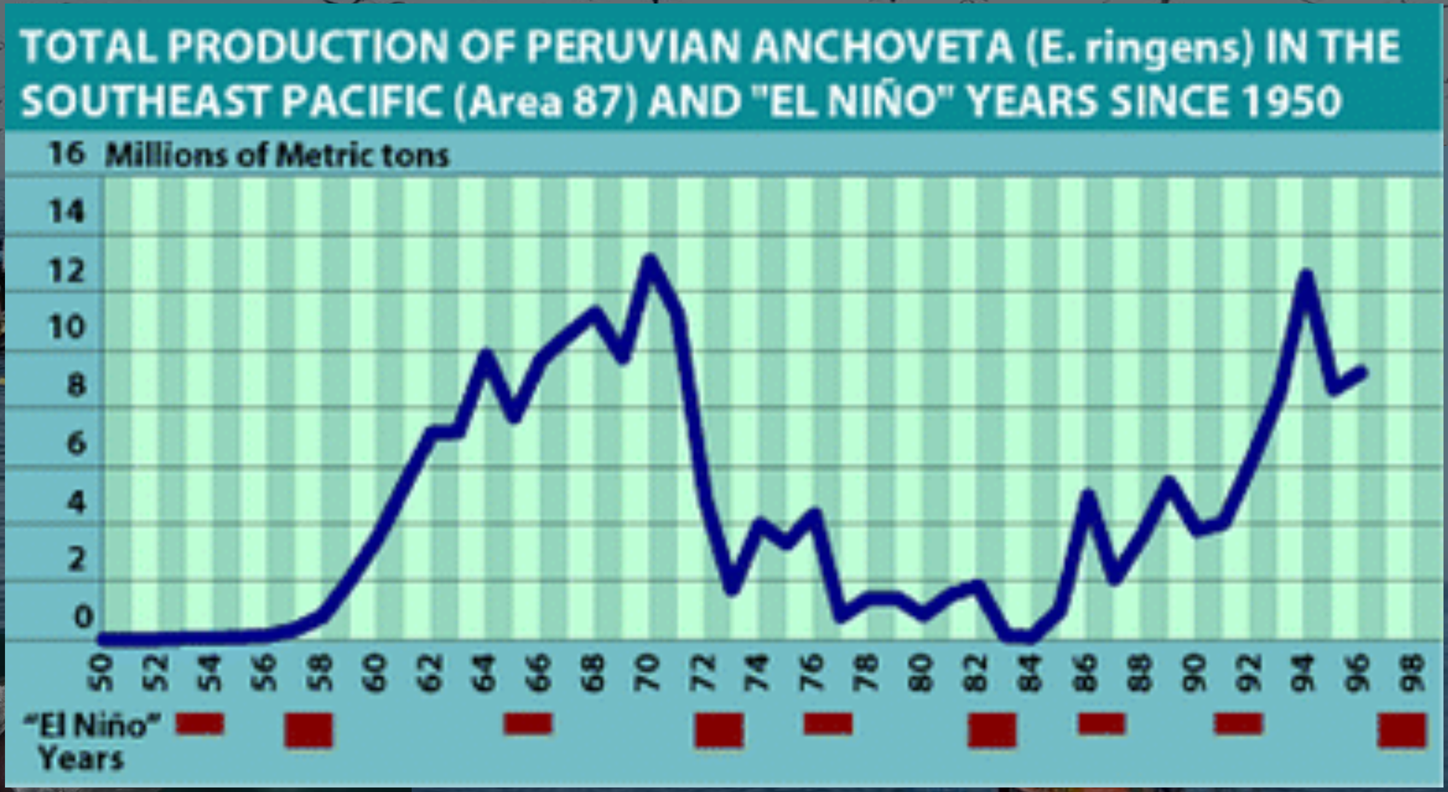


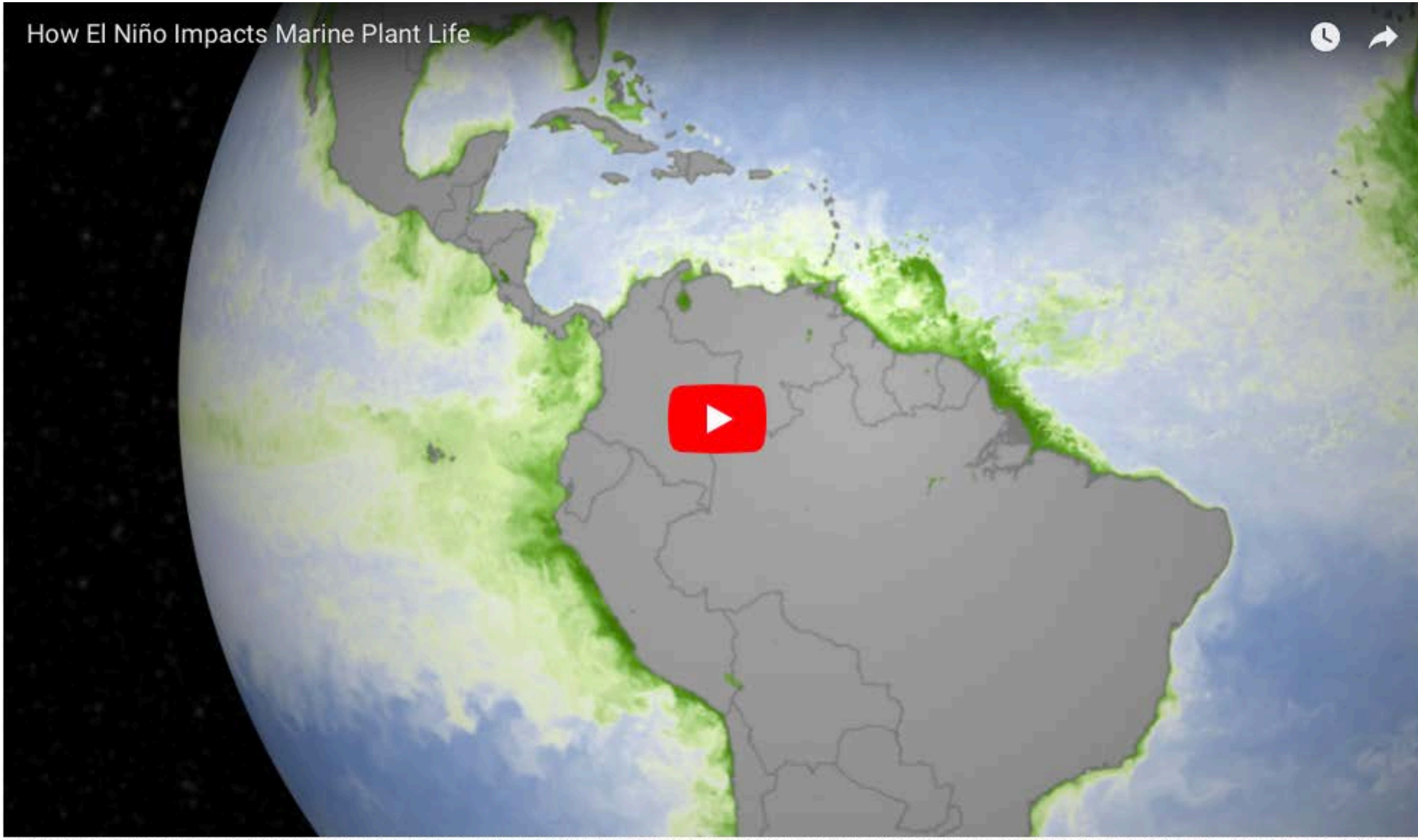
Satellite chlorophyll



Satellite chlorophyll




TOTAL PRODUCTION OF PERUVIAN ANCHOVETA (E. ringens) IN THE SOUTHEAST PACIFIC (Area 87) AND "EL NIÑO" YEARS SINCE 1950
16 Millions of Metric tons
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

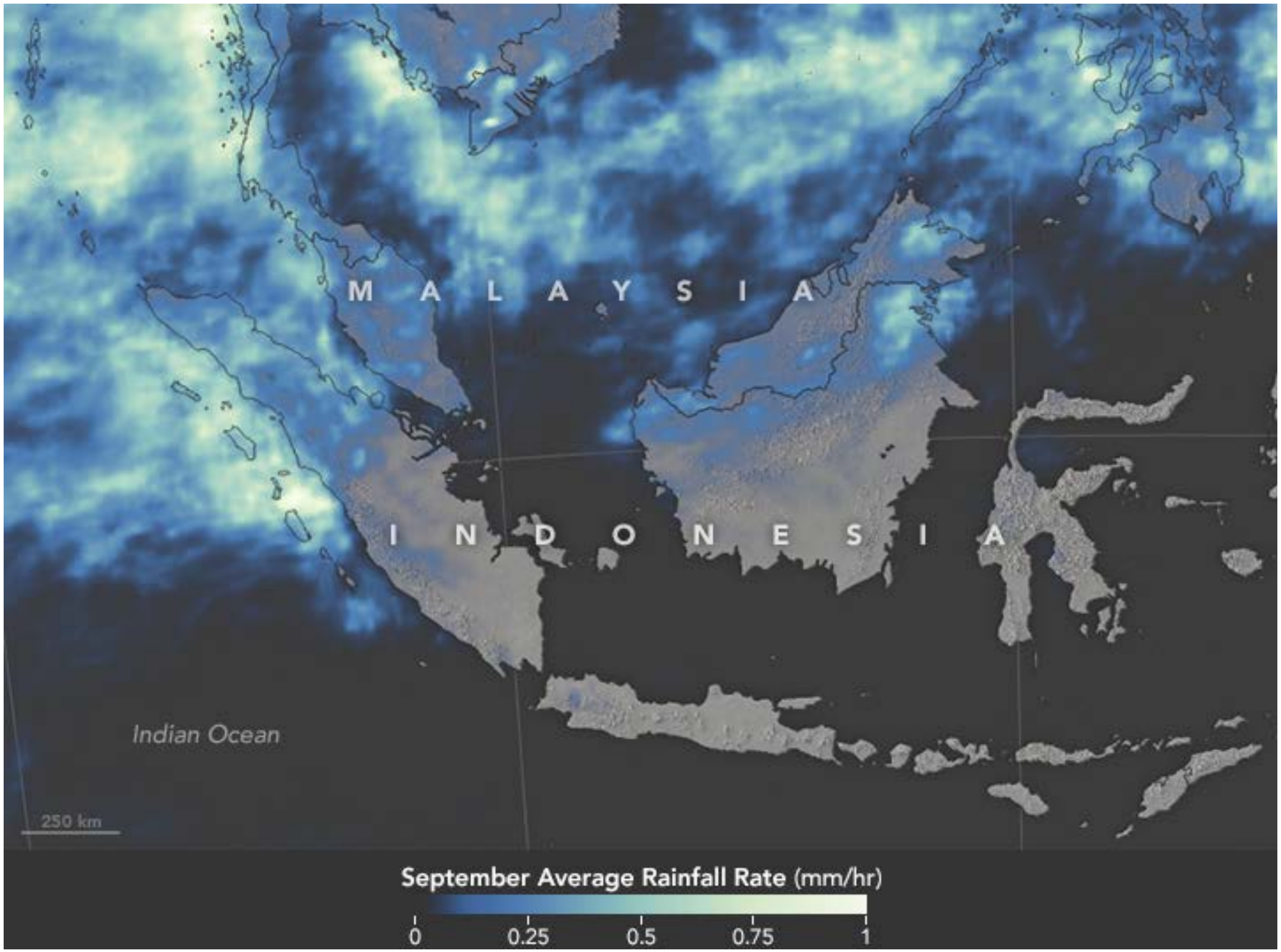


El Niño years can have a big impact on the littlest plants in the ocean, and NASA scientists are studying the relationship between the two. Ocean color maps, based on a month's worth of satellite data, show El Niño's impact on phytoplankton.

This video is public domain and can be downloaded at the Scientific Visualization Studio

https://youtu.be/sh2KhliHD9A

2015 September

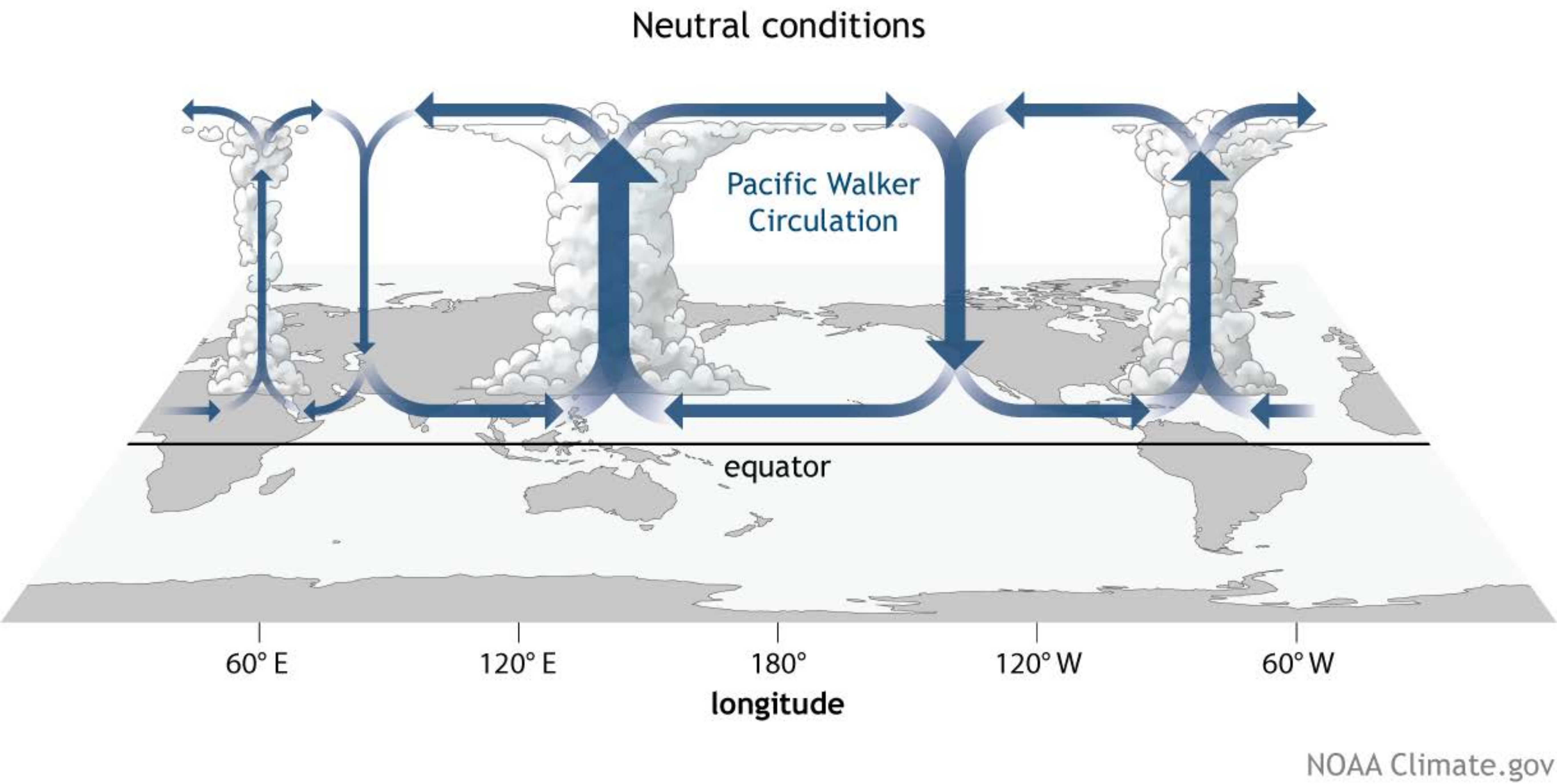


Credits: NASA

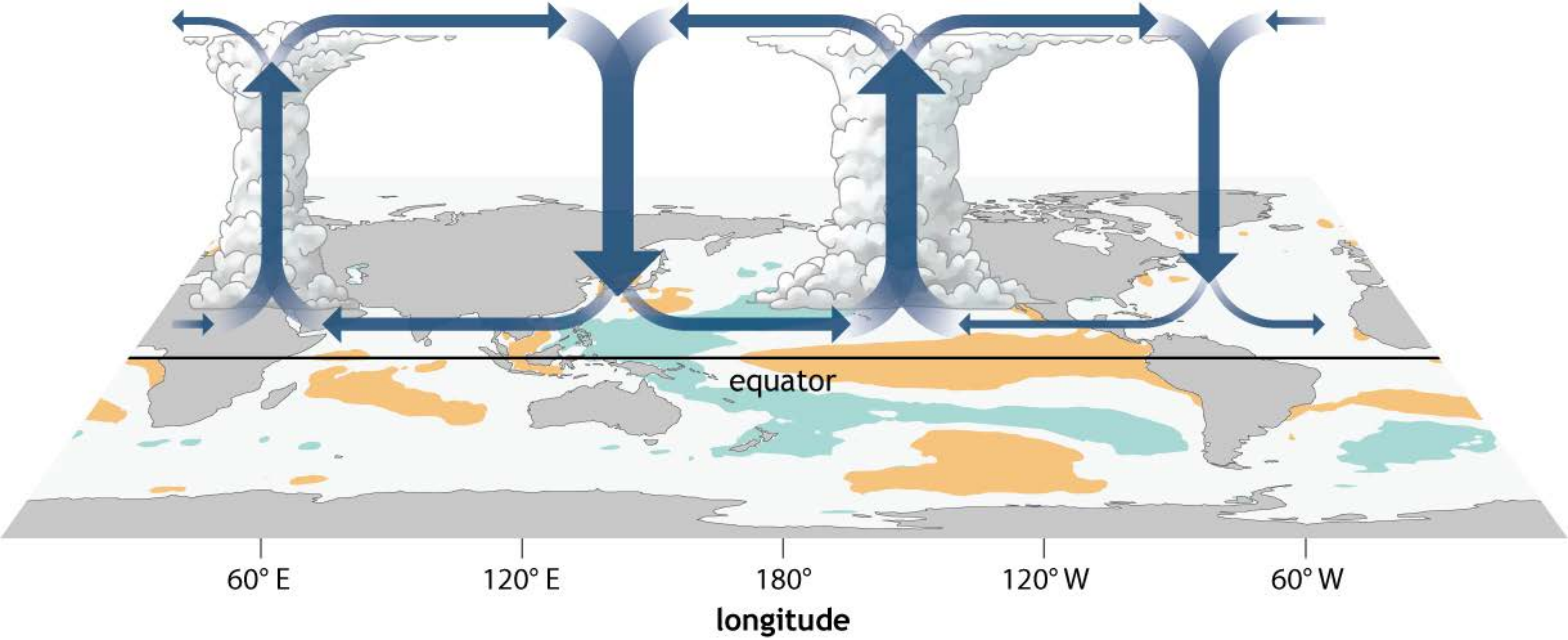
2015 September

Credits: NASA

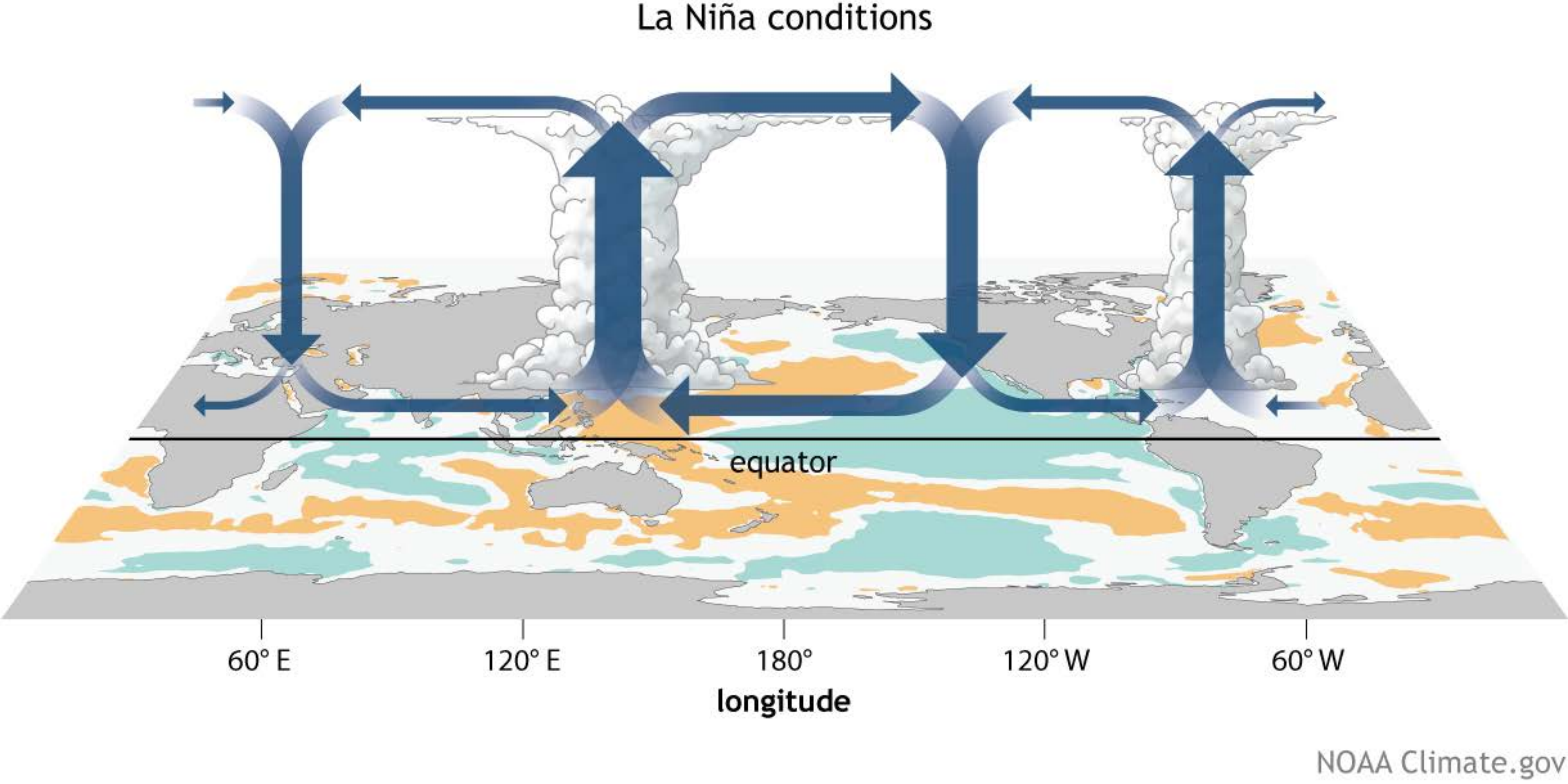
Credits: NASA

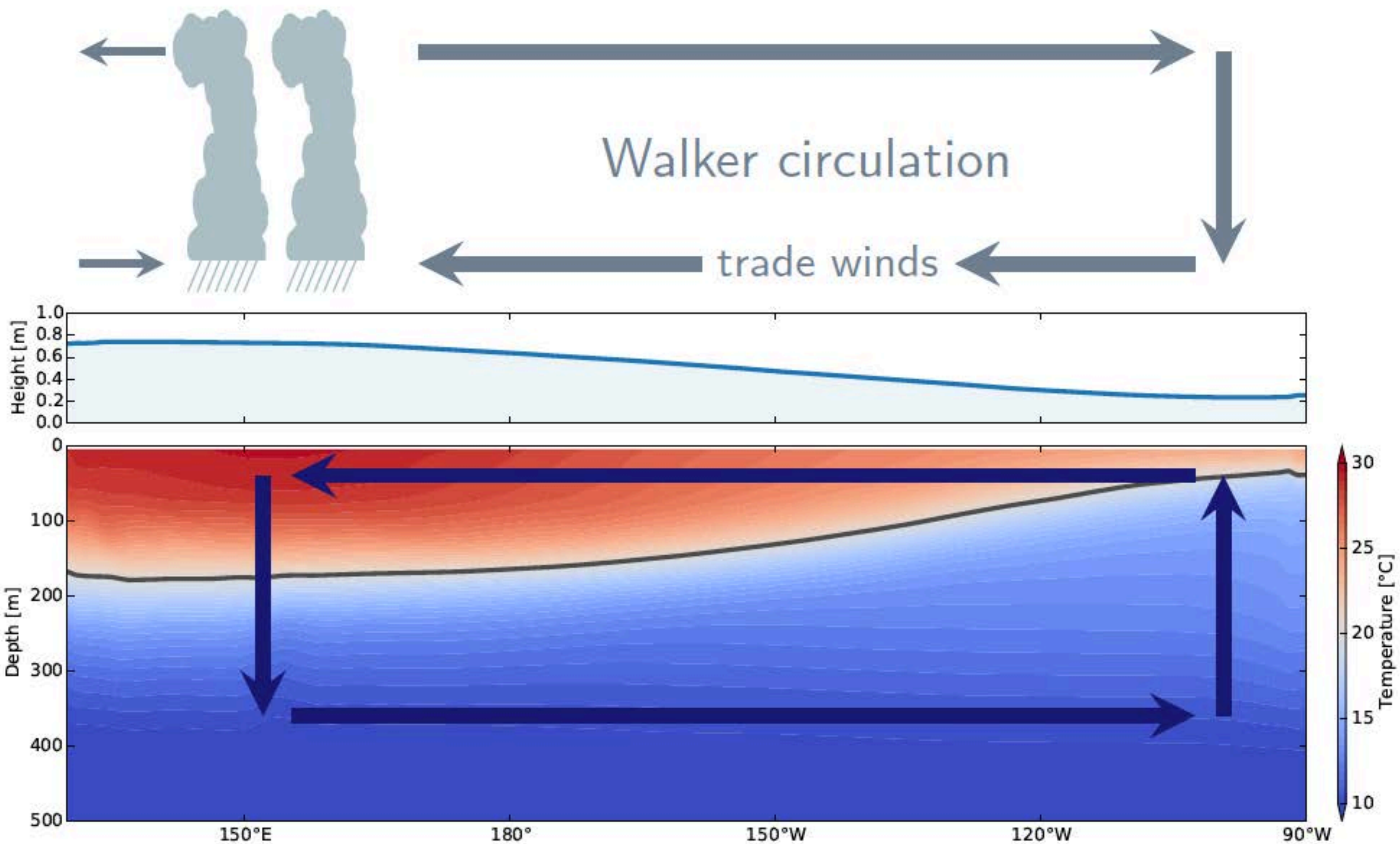

Neutral conditions
Pacific Walker Circulation
equator
60° E
120° E
180°
120° W
60° W
longitude
NOAA Climate.gov

El Niño conditions

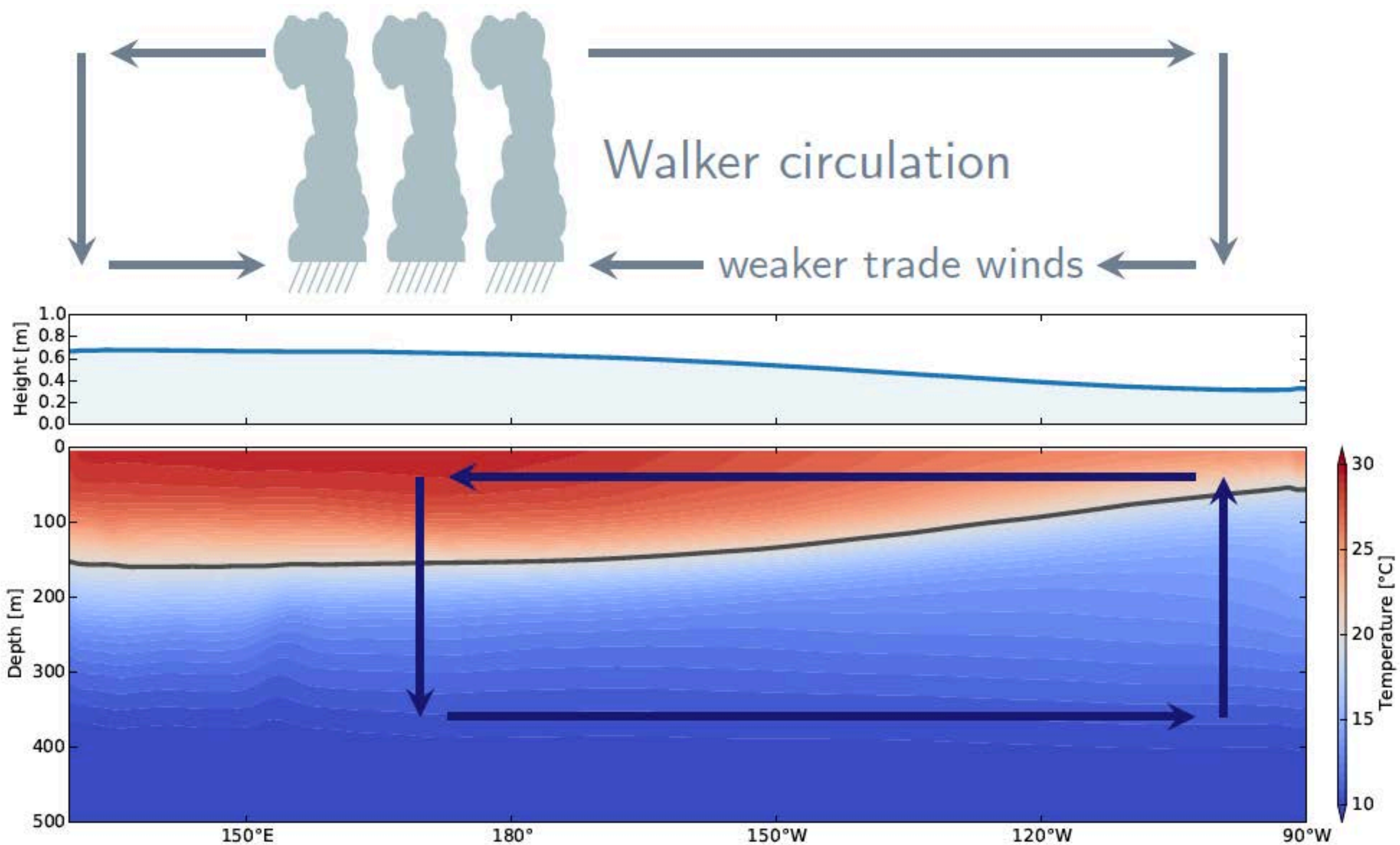


NOAA Climate.gov


La Niña conditions
equator
60° E
120° E
180°
120° W
60° W
longitude
NOAA Climate.gov



Slide by Jonathan Wright



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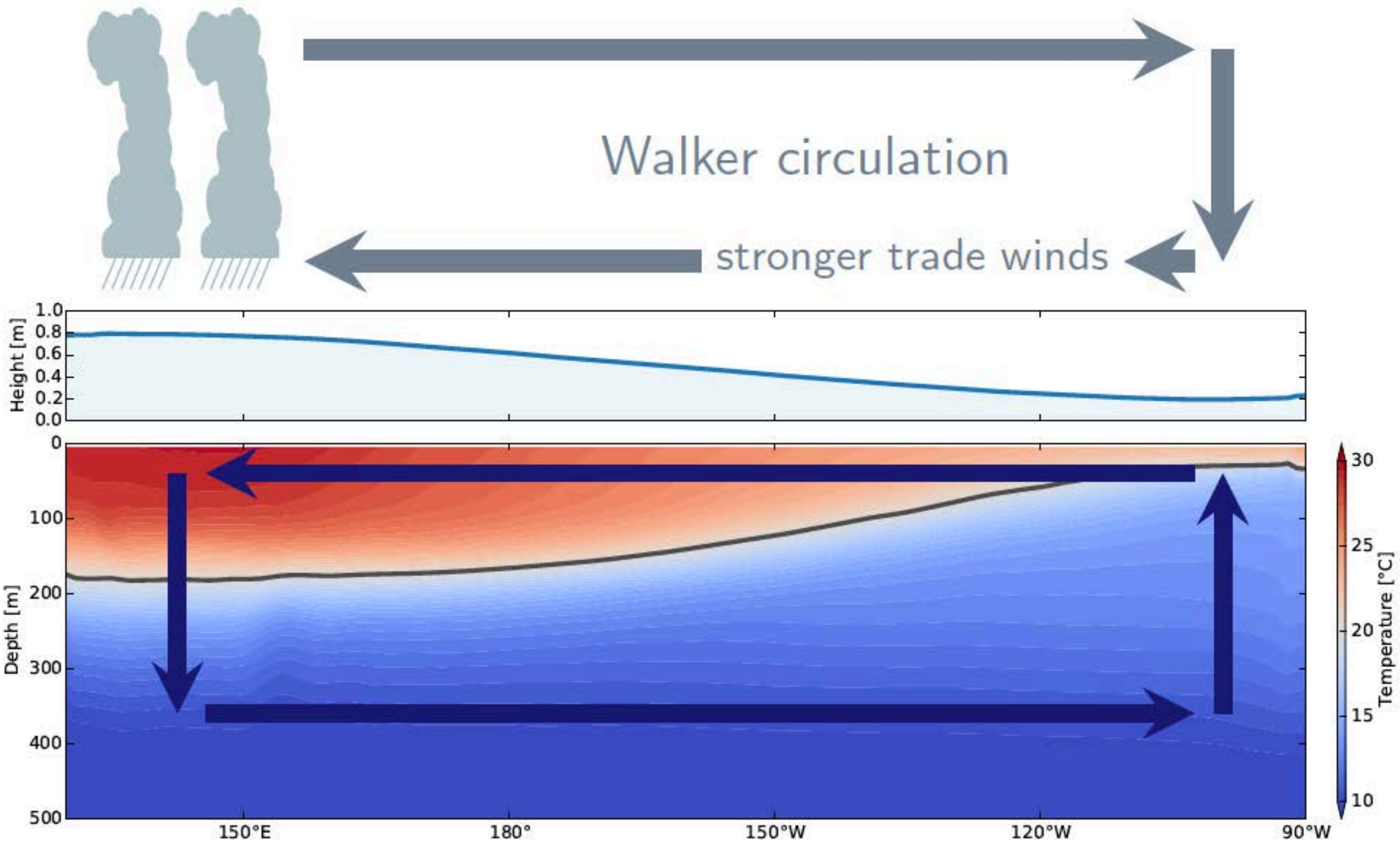
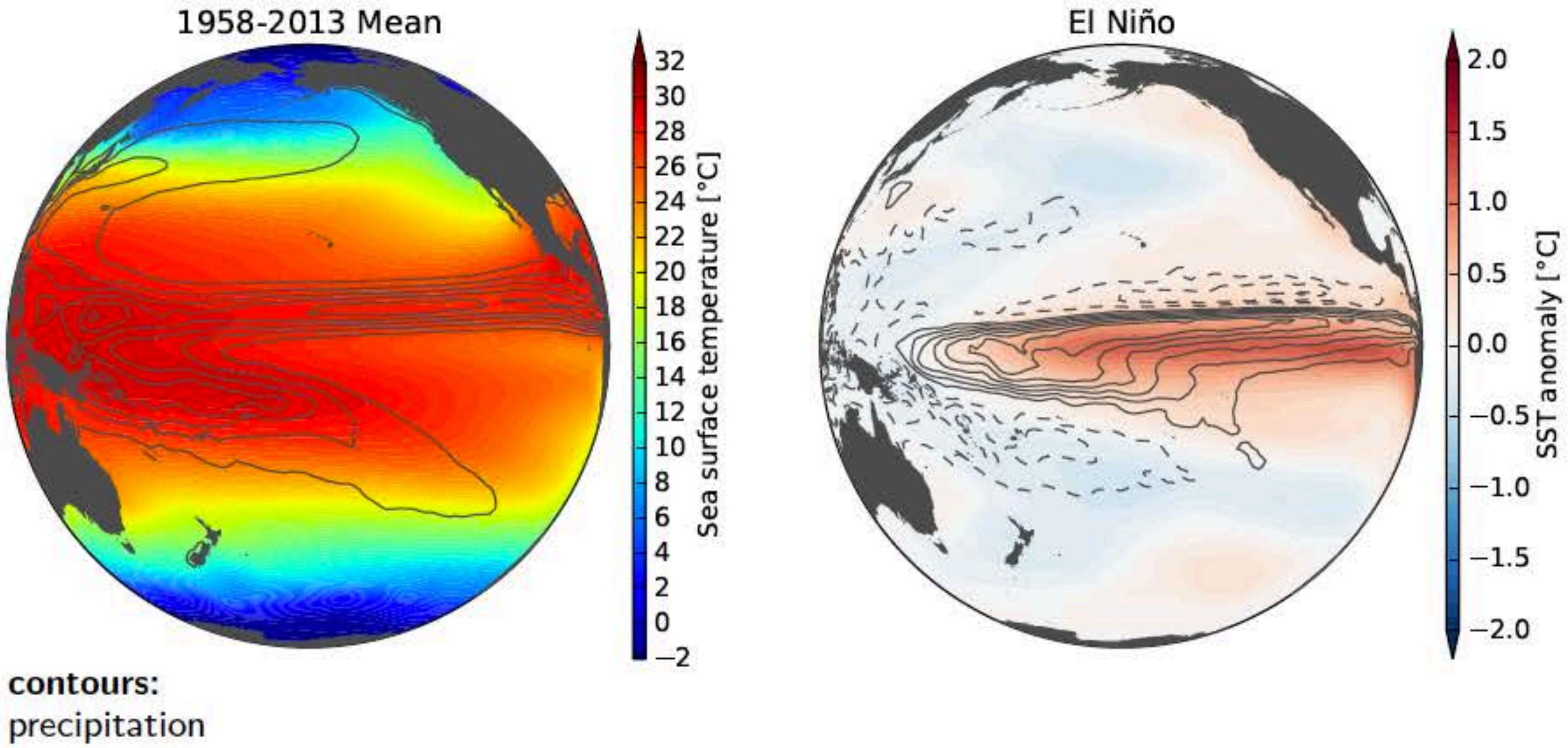


Slide by Jonathan Wright

Air-sea interaction

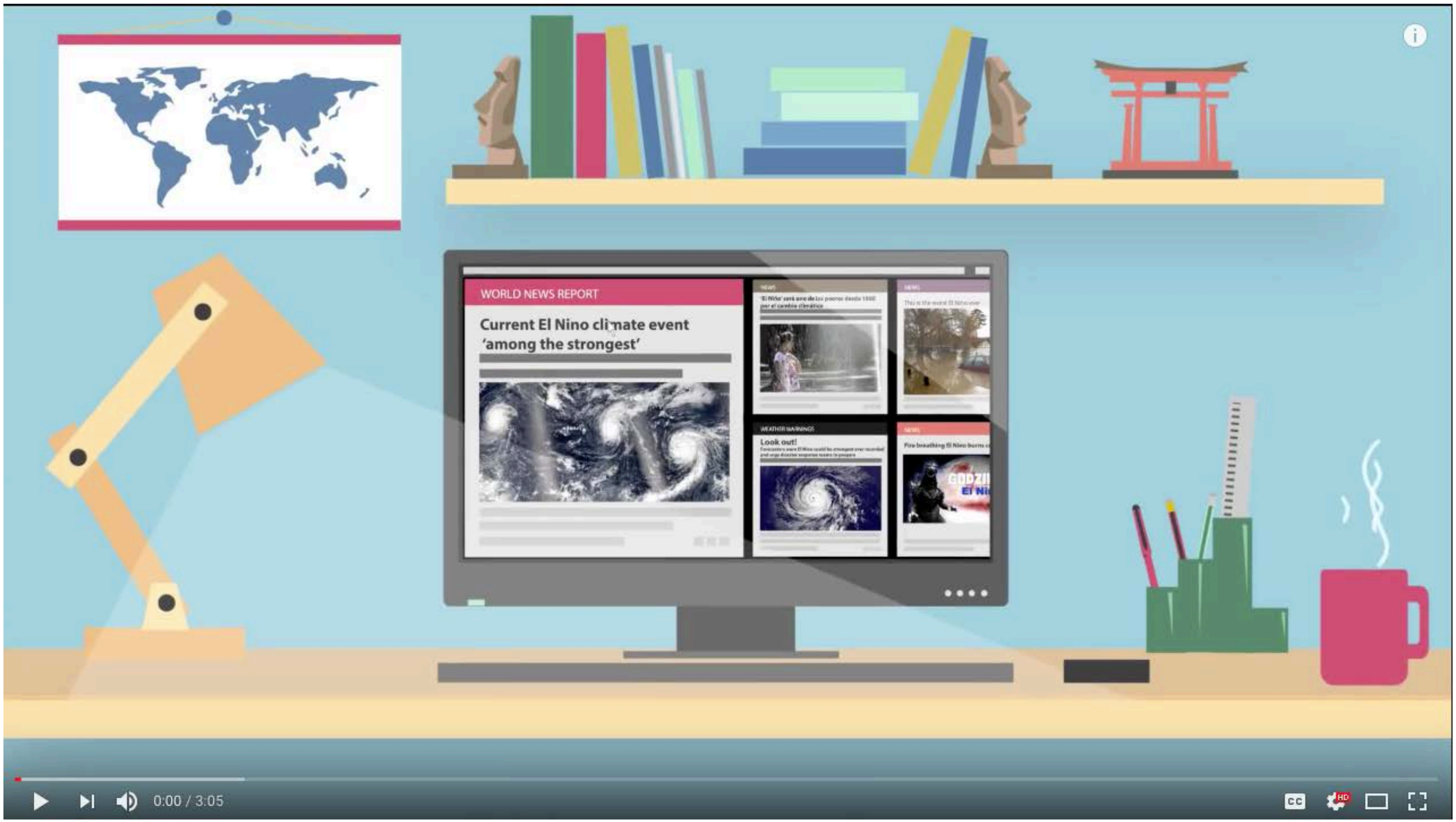
- ENSO-related SST anomalies lead to precipitation anomalies in the equatorial Pacific
- Dynamic changes associated with the precipitation anomalies dominate outside of the equatorial Pacific



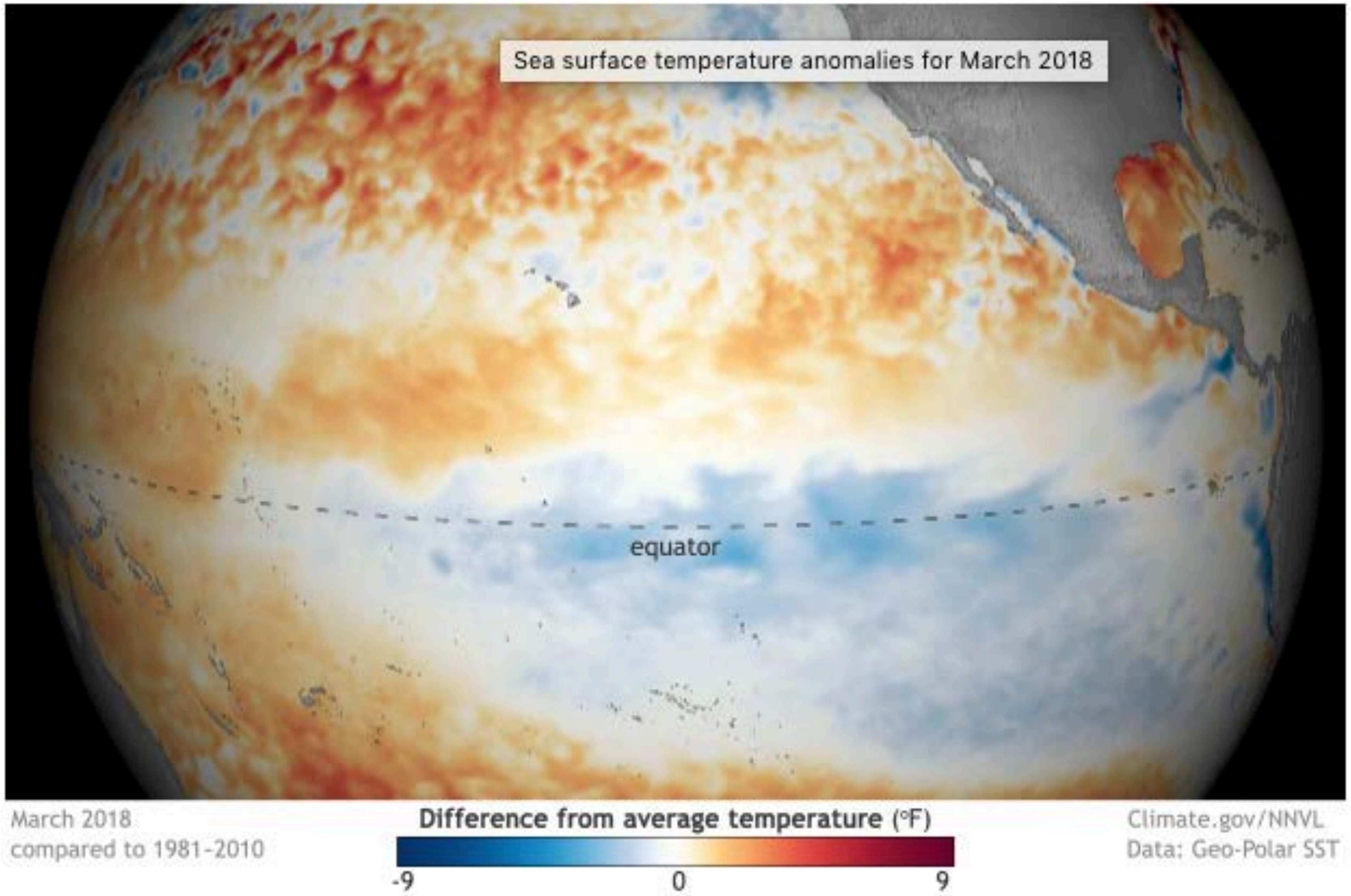
data from COBE & JRA-55

Slide by Jonathan Wright

The El Nino of 2015-2016



https://youtu.be/v92Iqihct98


Sea surface temperature anomalies for March 2018
equator
March 2018
compared to 1981-2010
Difference from average temperature (°F)
-9
0
9
Climate.gov/NNVL
Data: Geo-Polar SST

From NOAA NWS

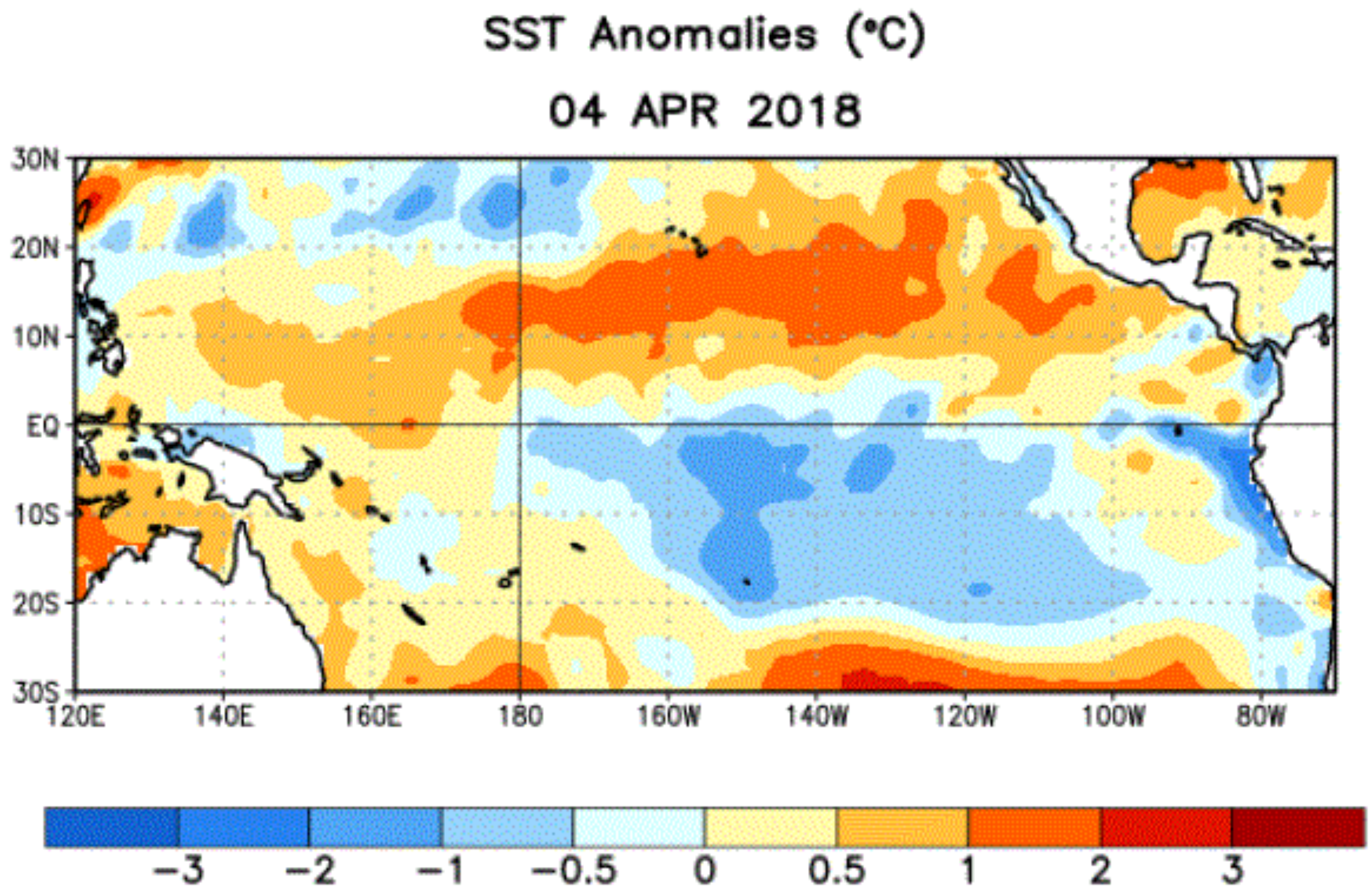


Figure 1. Average sea surface temperature (SST) anomalies (°C) for the week centered on 4 April 2018. Anomalies are computed with respect to the 1981-2010 base period weekly means.

From NOAA NWS

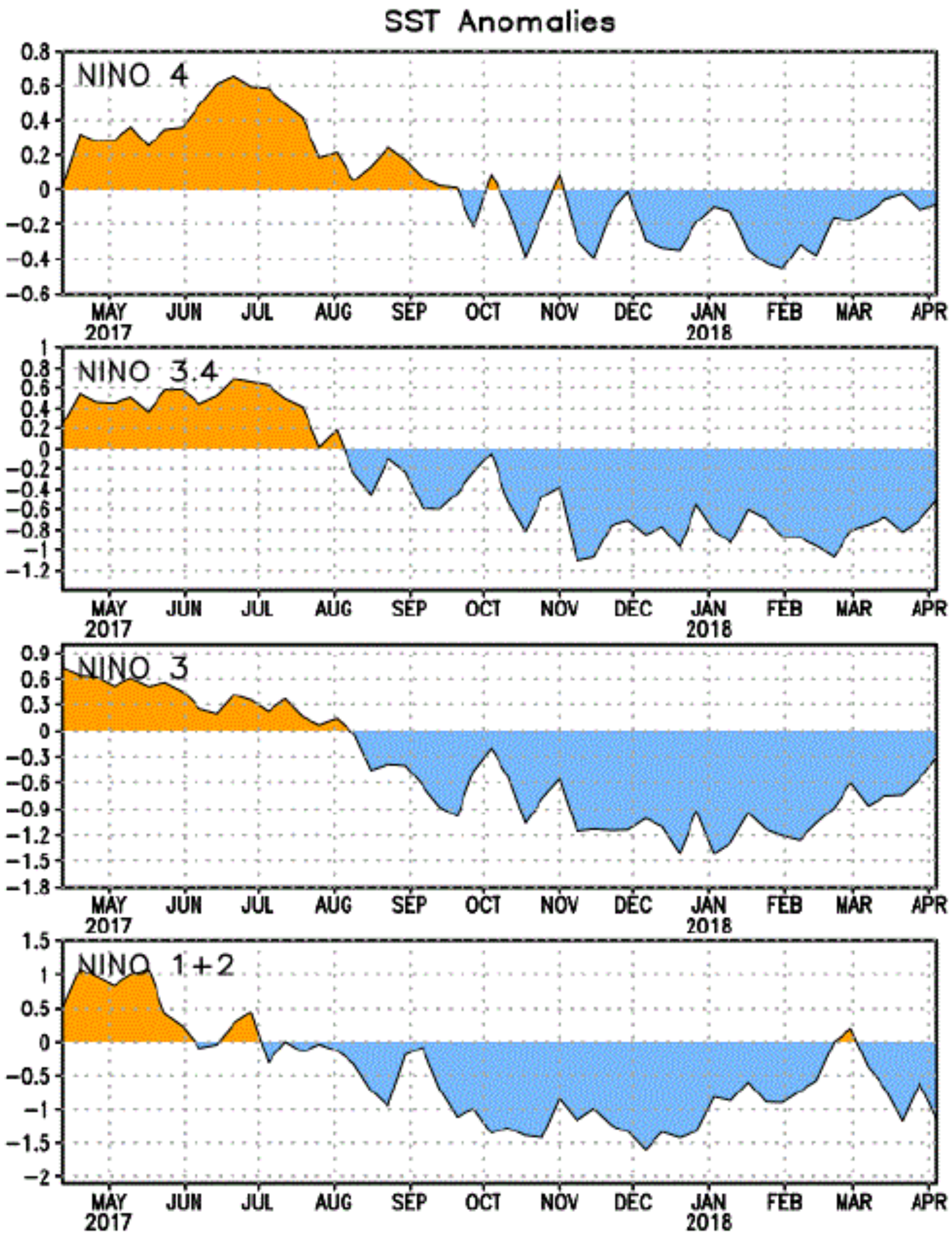


Figure 2. Time series of area-averaged sea surface temperature (SST) anomalies (°C) in the Niño regions [Niño-1+2 (0°-10°S, 90°W-80°W), Niño-3 (5°N-5°S, 150°W-90°W), Niño-3.4 (5°N-5°S, 170°W-120°W), Niño-4 (5ºN-5ºS , 150ºW-160ºE]. SST anomalies are departures from the 1981-2010 base period weekly means.

Prediction

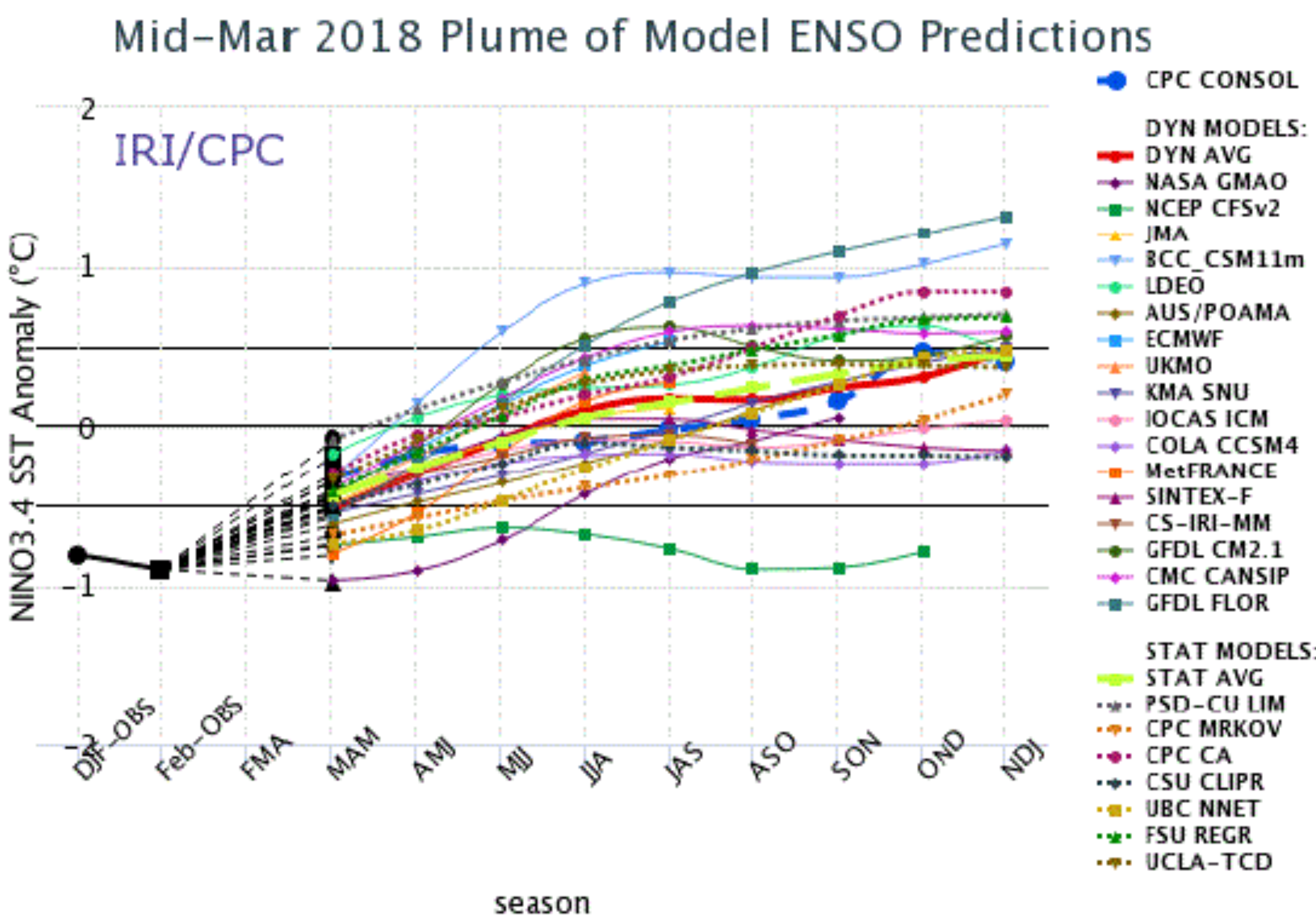
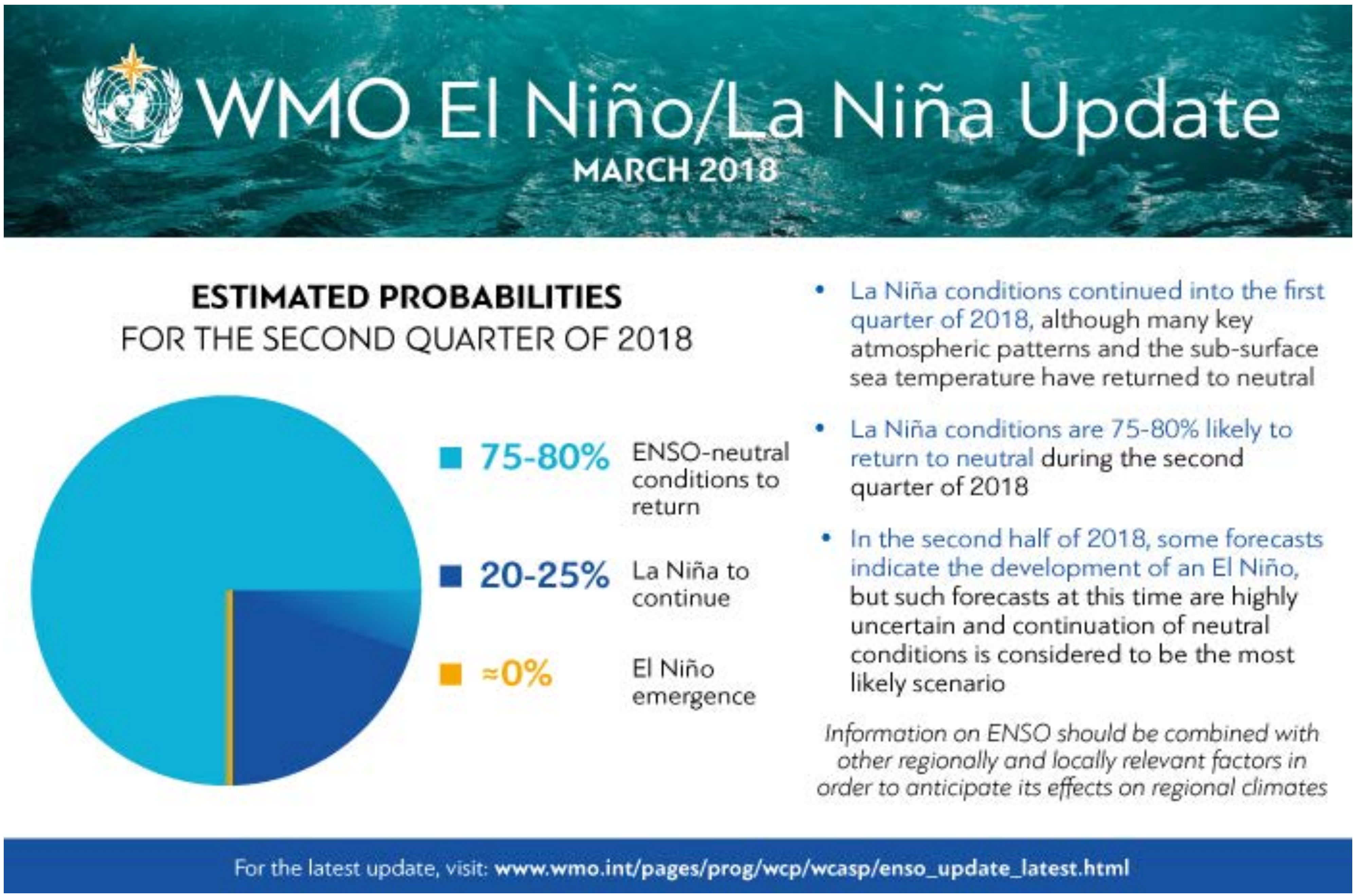


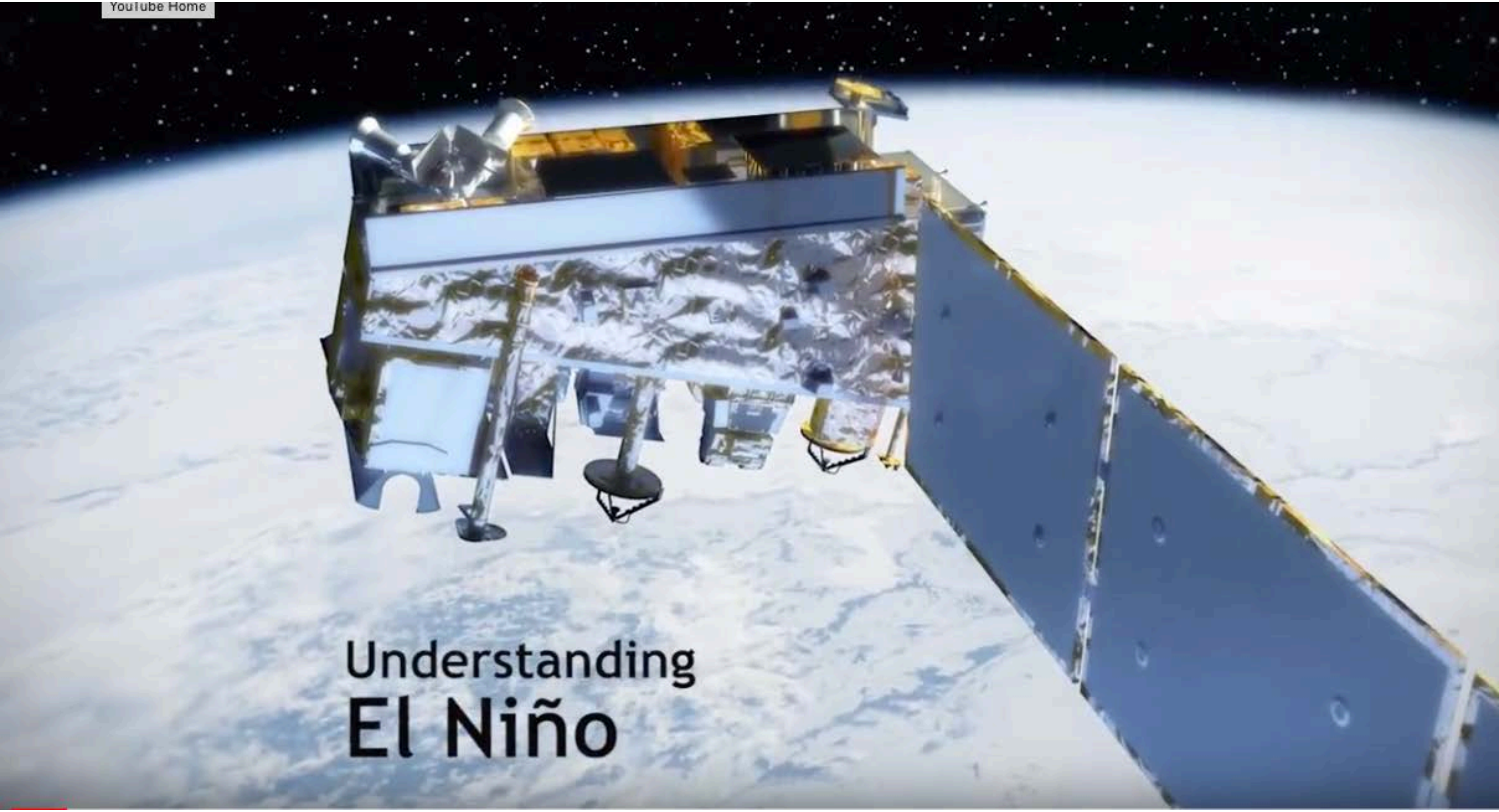
Figure 6. Forecasts of sea surface temperature (SST) anomalies for the Niño 3.4 region (5°N-5°S, 120°W-170°W). Figure updated 19 March 2018.

From NOAA NWS

Prediction



WMO El Niño/La Niña Update
MARCH 2018
ESTIMATED PROBABILITIES
FOR THE SECOND QUARTER OF 2018
75-80% ENSO-neutral conditions to return
20-25% La Niña to continue
≈0% El Niño emergence
La Niña conditions continued into the first quarter of 2018, although many key atmospheric patterns and the sub-surface sea temperature have returned to neutral
La Niña conditions are 75-80% likely to return to neutral during the second quarter of 2018
In the second half of 2018, some forecasts indicate the development of an El Niño, but such forecasts at this time are highly uncertain and continuation of neutral conditions is considered to be the most likely scenario
Information on ENSO should be combined with other regionally and locally relevant factors in order to anticipate its effects on regional climates
For the latest update, visit: www.wmo.int/pages/prog/wcp/wcasp/enso_update_latest.html



https://youtu.be/_Tuou_QcgxI

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

↓

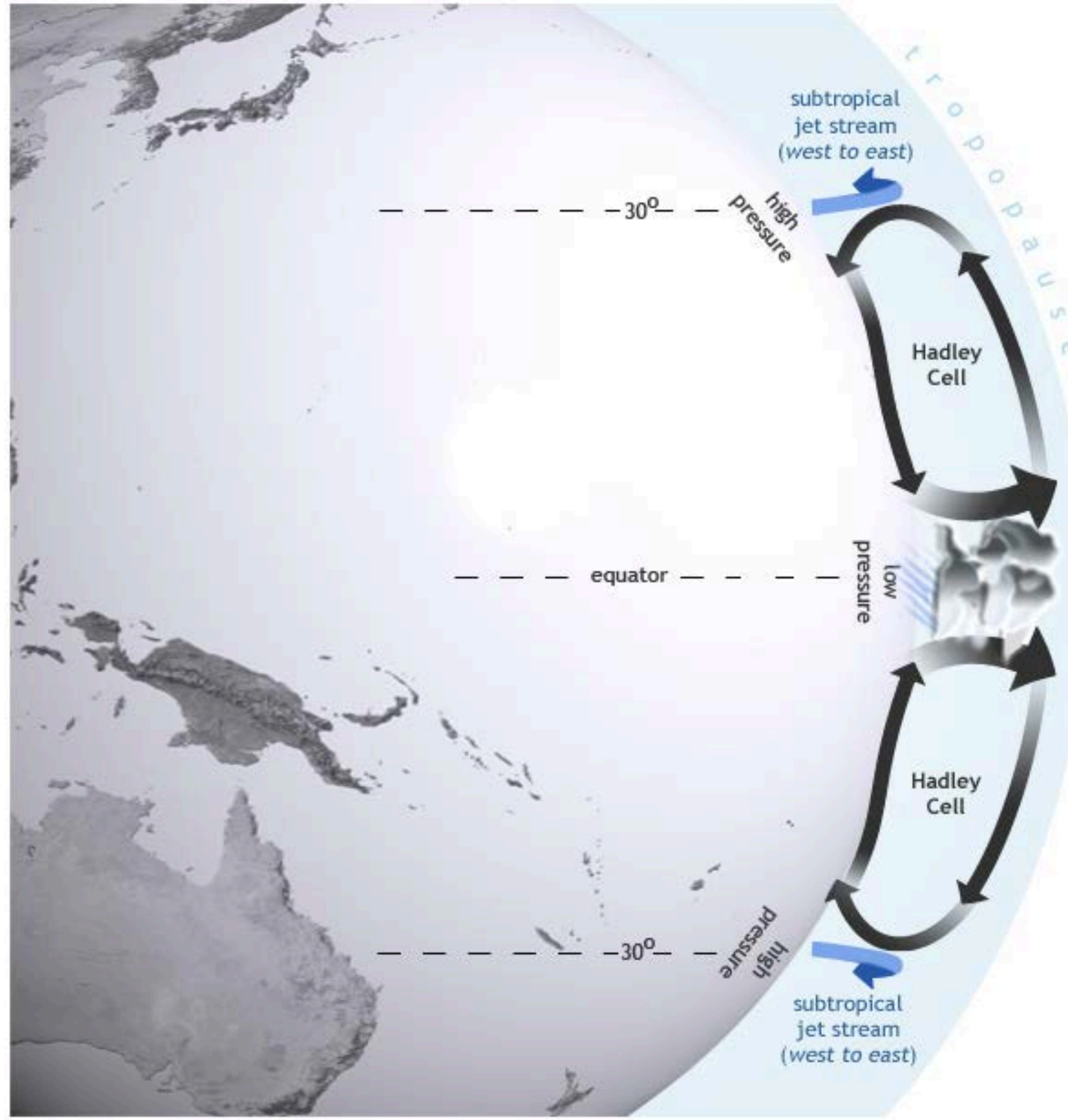
Convection and precipitation, Latent heat release

↓

Stronger Hadley circulation

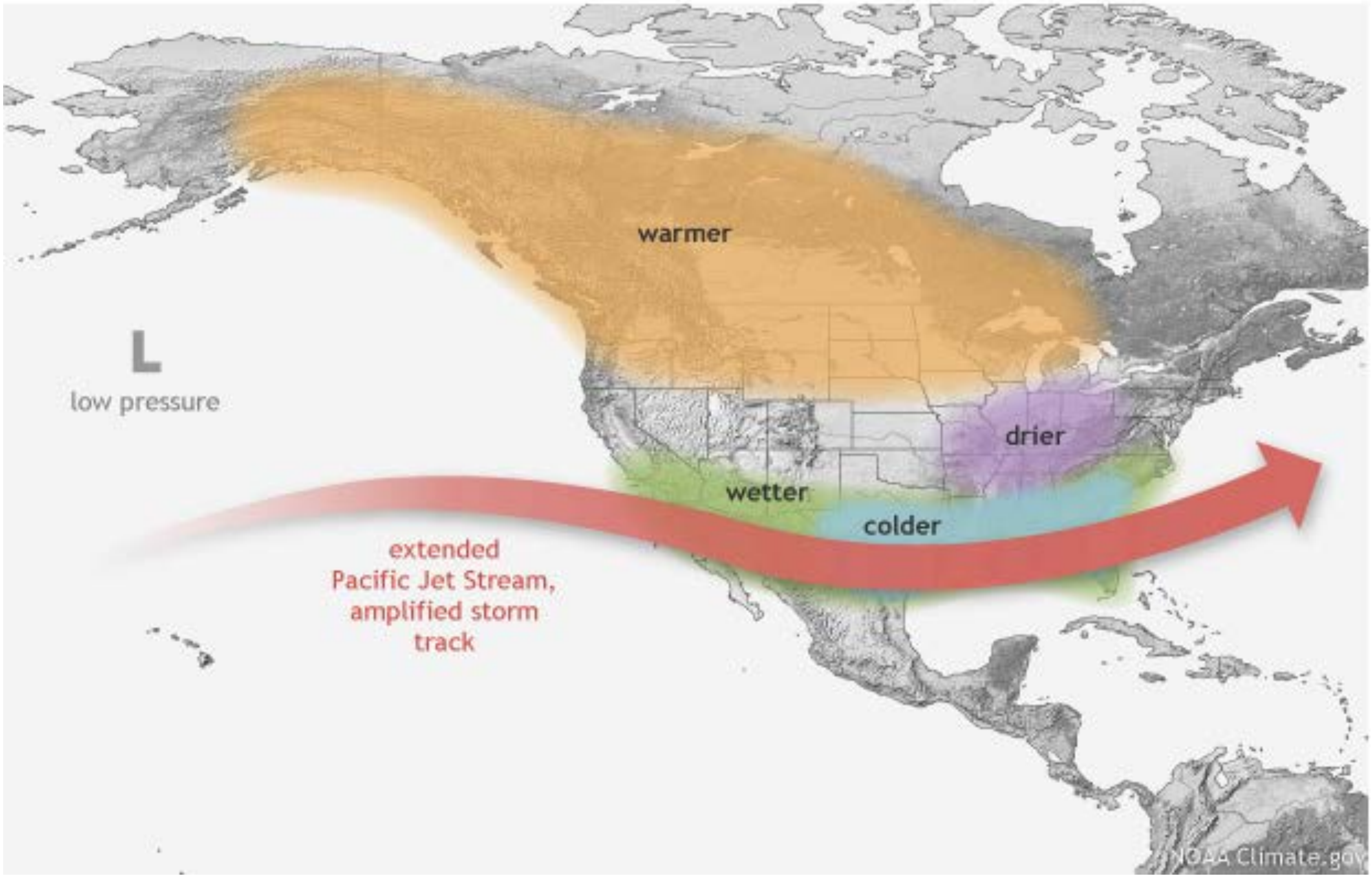
↓

Stronger Hadley circulation, affecting jet stream

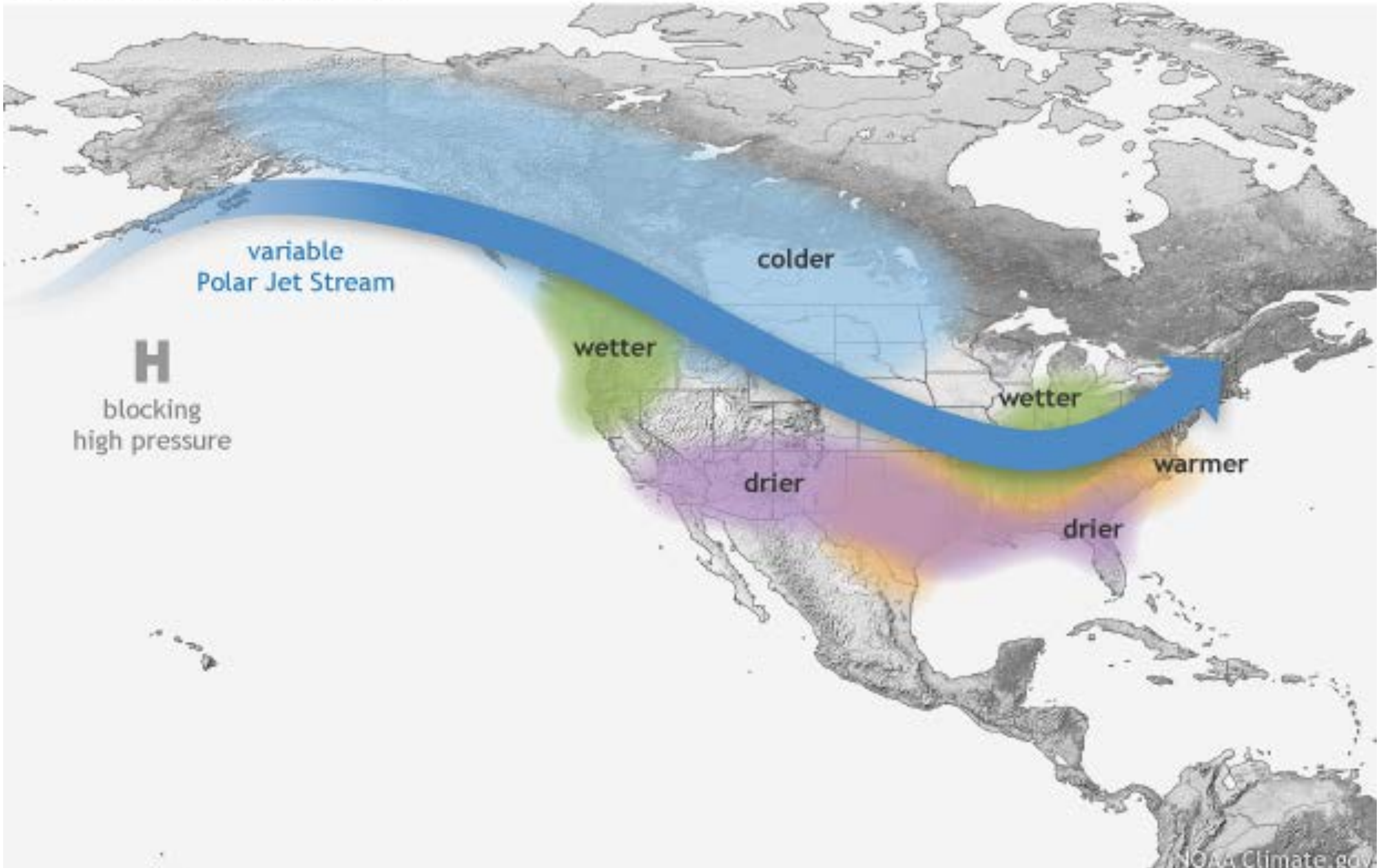


El Niño influences global atmospheric circulation by intensifying the Hadley circulation, in which heat is transferred from the Earth's surface to the upper atmosphere through convection and latent heating. Map by NOAA Climate.gov.

WINTER EL NIÑO PATTERN

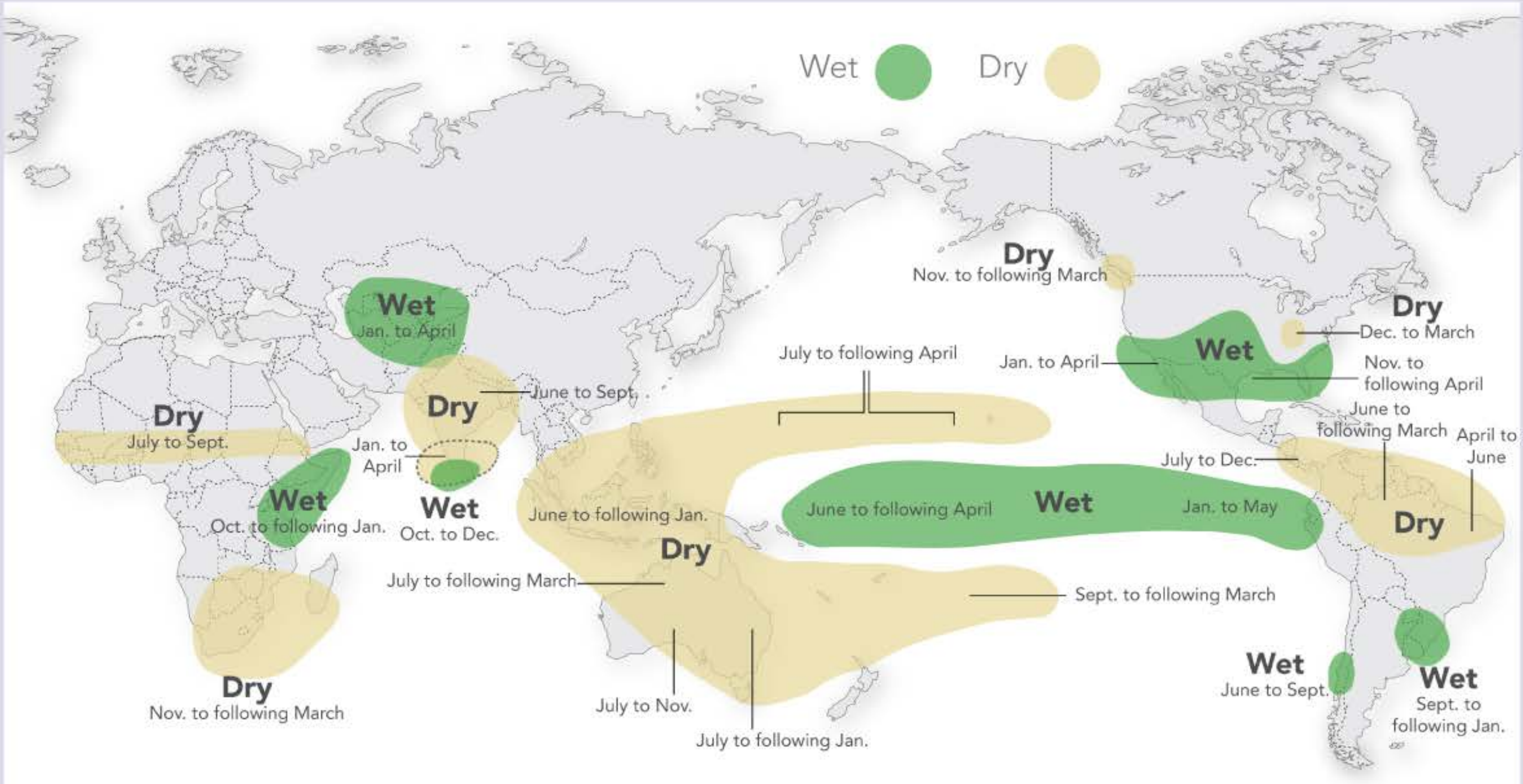


WINTER LA NIÑA PATTERN



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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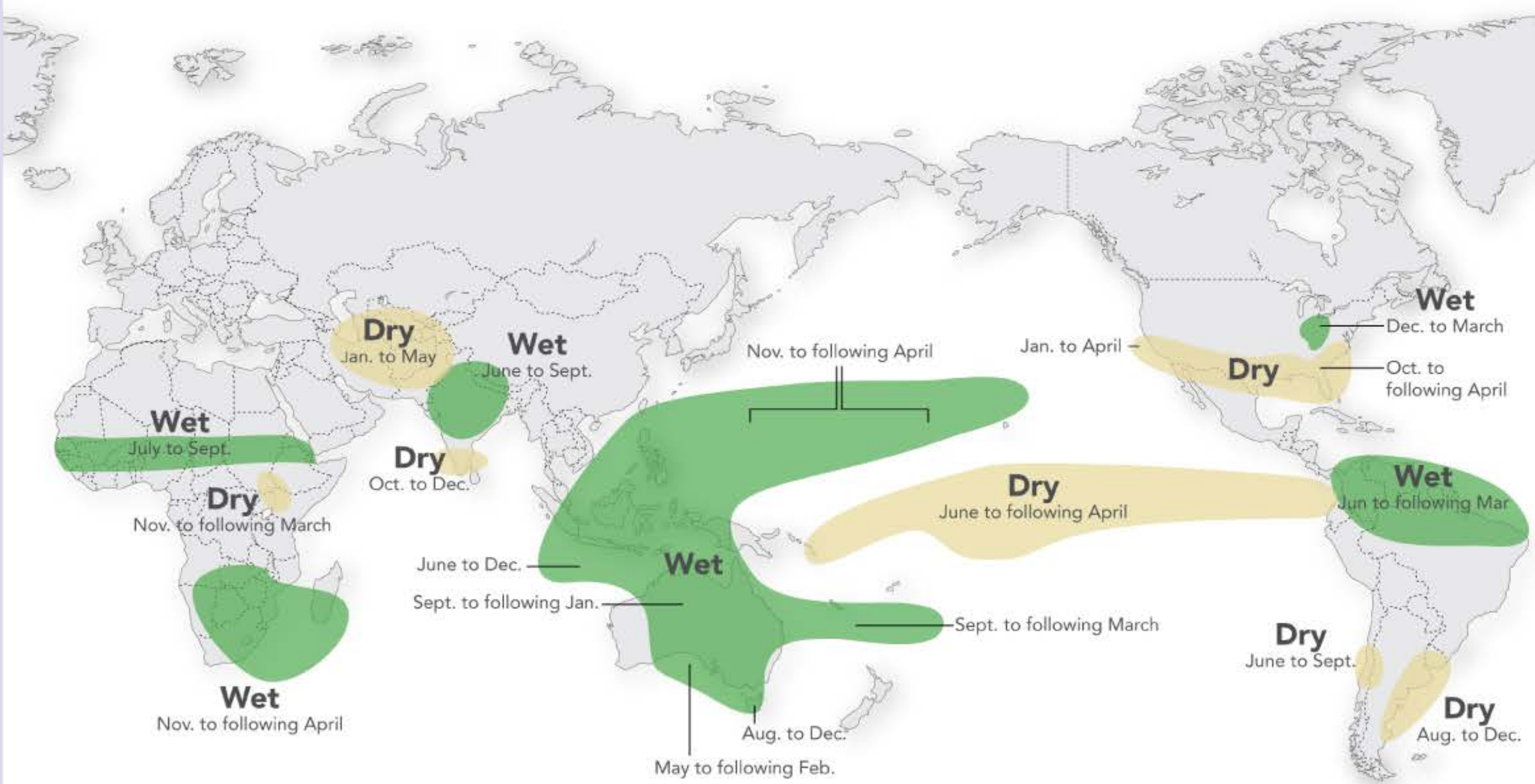

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Sources:

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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Agriculture

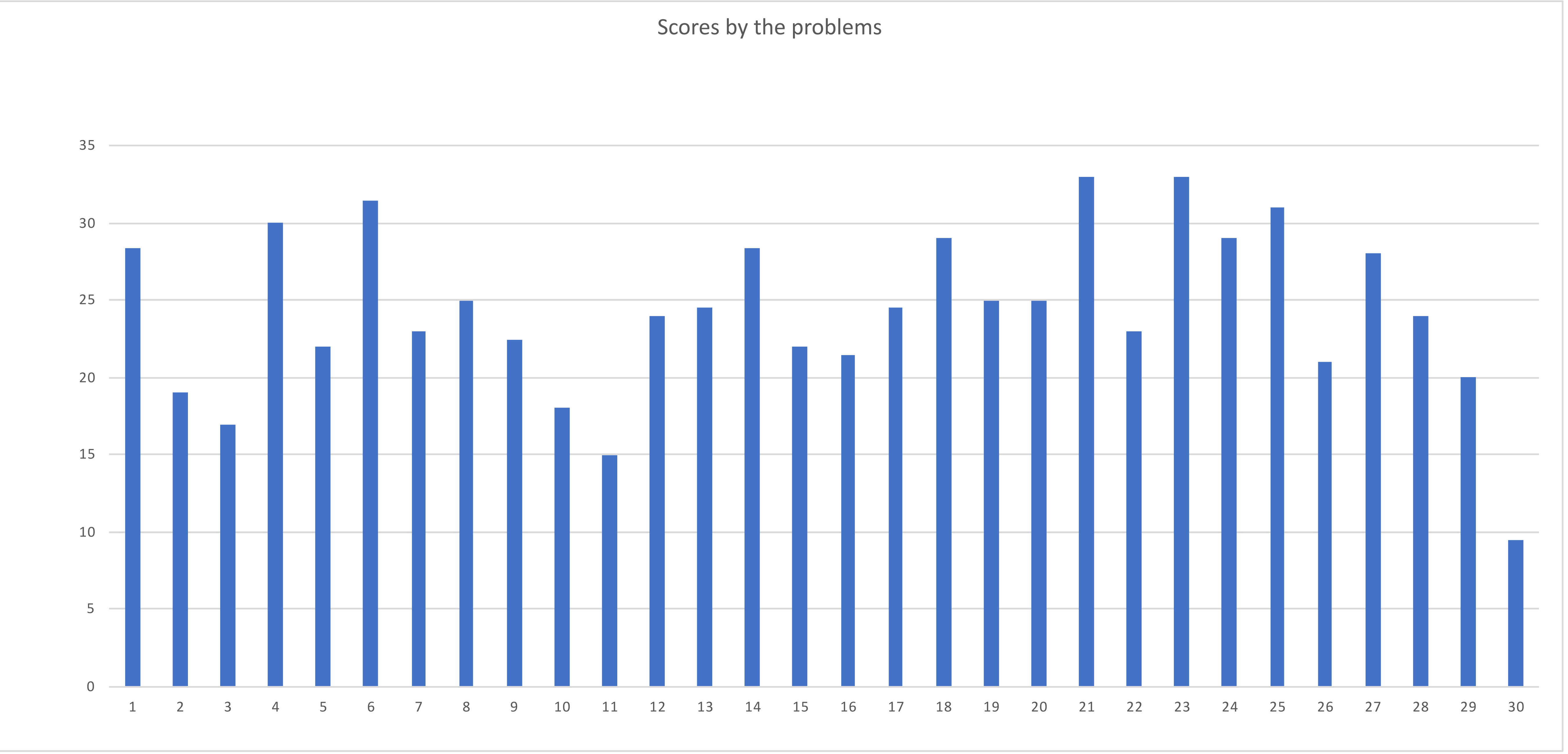
- El Ninos tend to result in more summer crops in the Northern Hemisphere, especially in US and Canada (more precipitation)

- The negative impact on tropical agriculture, particularly in Indonesia and parts of Latin America.

Energy

- El Ninos tend to suppress Atlantic hurricanes, which is good for oil and gas production in Gulf of Mexico.

- El Ninos leads to warmer winter in the USA, decreasing the demand for energy.



Scores by the problems
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