Feedbacks:
Oceans and El Niño

EES 3310/5310
Global Climate Change
Jonathan Gilligan

Class #9: Monday Sept. 10 2018

Feedback Mathematics

Stefan-Boltzmann Feedback

Bare rock:

- $I_{\text{out}} = \epsilon \sigma T^4$
- $f_{\text{SB}} = -3.2\ \text{Wm}^{-2}\text{K}^{-1}$
- Forcing: $Q_{\text{forcing}} = I_{\text{in}} - I_{\text{out}} = +1\ \text{Wm}^{-2}$
- $\Delta T = -Q_{\text{forcing}} / f$

$$\Delta T = \frac{-1\ \text{Wm}^{-2}}{-3.2\ \text{Wm}^{-2}\text{K}^{-1}} = +0.32\ \text{K}$$

Positive & Negative Feedback

Positive & Negative Feedback

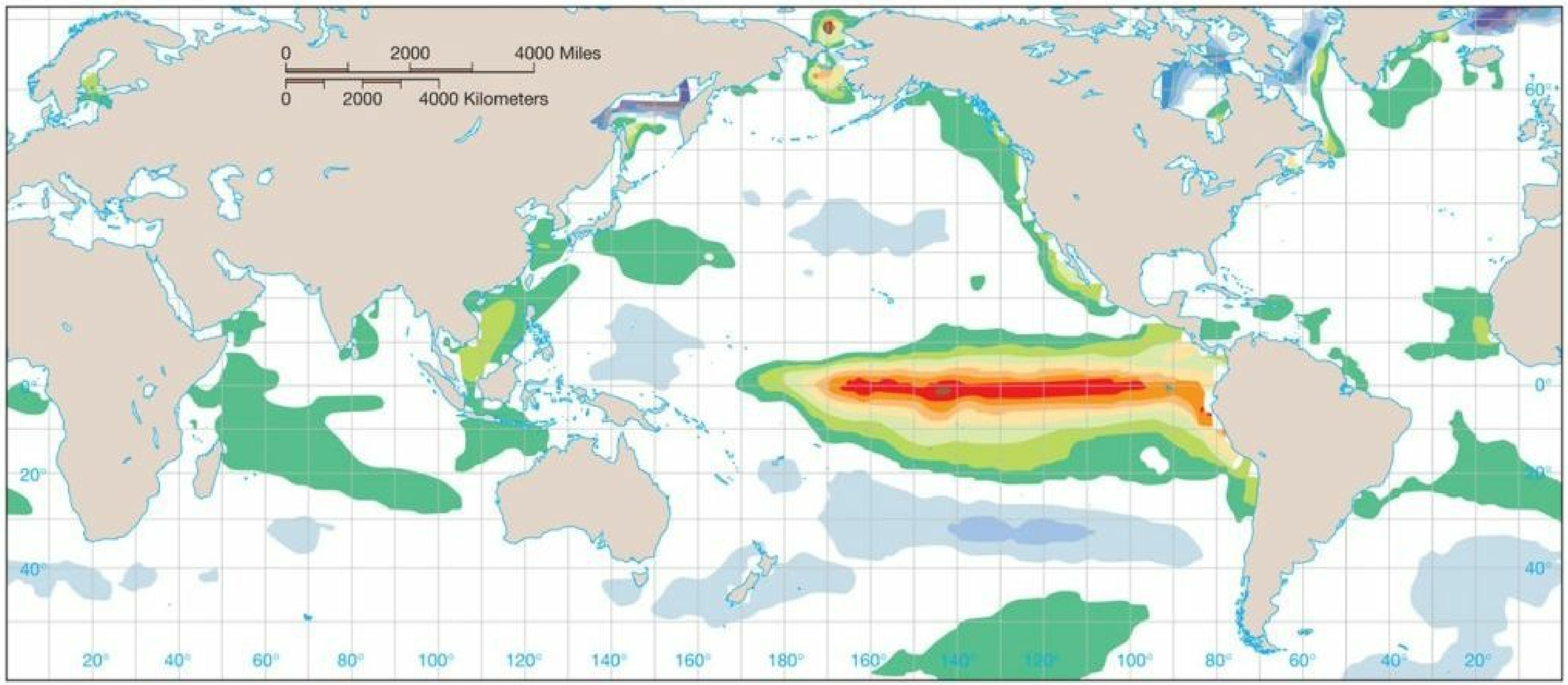
- Total feedback: $f = f_0 + f_1 + f_2 + \cdots$
- $f_0 = f_{SB}$: Stefan-Boltzmann
- Other feedbacks $f_1, f_2, \cdots$:
  - Positive ($f_i > 0$): amplifies temperature change
    - Warmings $\rightarrow$ hotter
    - Coolings $\rightarrow$ colder
  - Negative ($f_i < 0$): diminishes temperature change
    - Warmings $\rightarrow$ milder
    - Coolings $\rightarrow$ milder

Amplification

$$a = \frac{f_0}{f} = \frac{f_0}{f_0 + f_1 + f_2 + \cdots}$$
$$f_0 = f_{\mathrm{SB}} = \text{Stefan-Boltzmann feedback}$$

$$\Delta T = \frac{-Q_{\text{forcing}}}{f}$$
$$= a \times \frac{-Q_{\text{forcing}}}{f_0}$$

- $a > 1$: net feedback is positive:
  - more severe warmings, coolings.
- $a < 1$: net feedback is negative:
  - milder warmings, coolings.

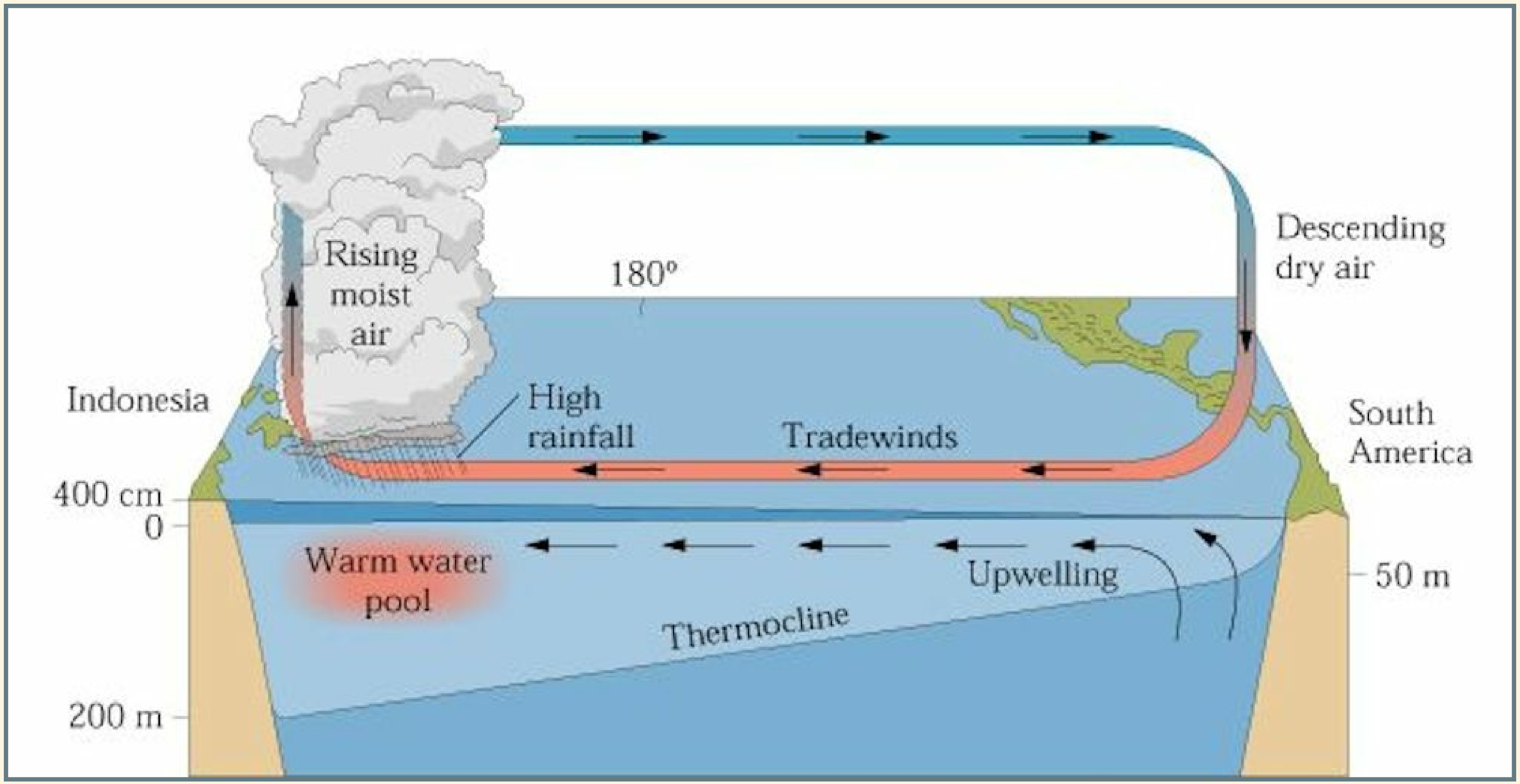


Sea Surface Temperature Composite Anomaly, November to March

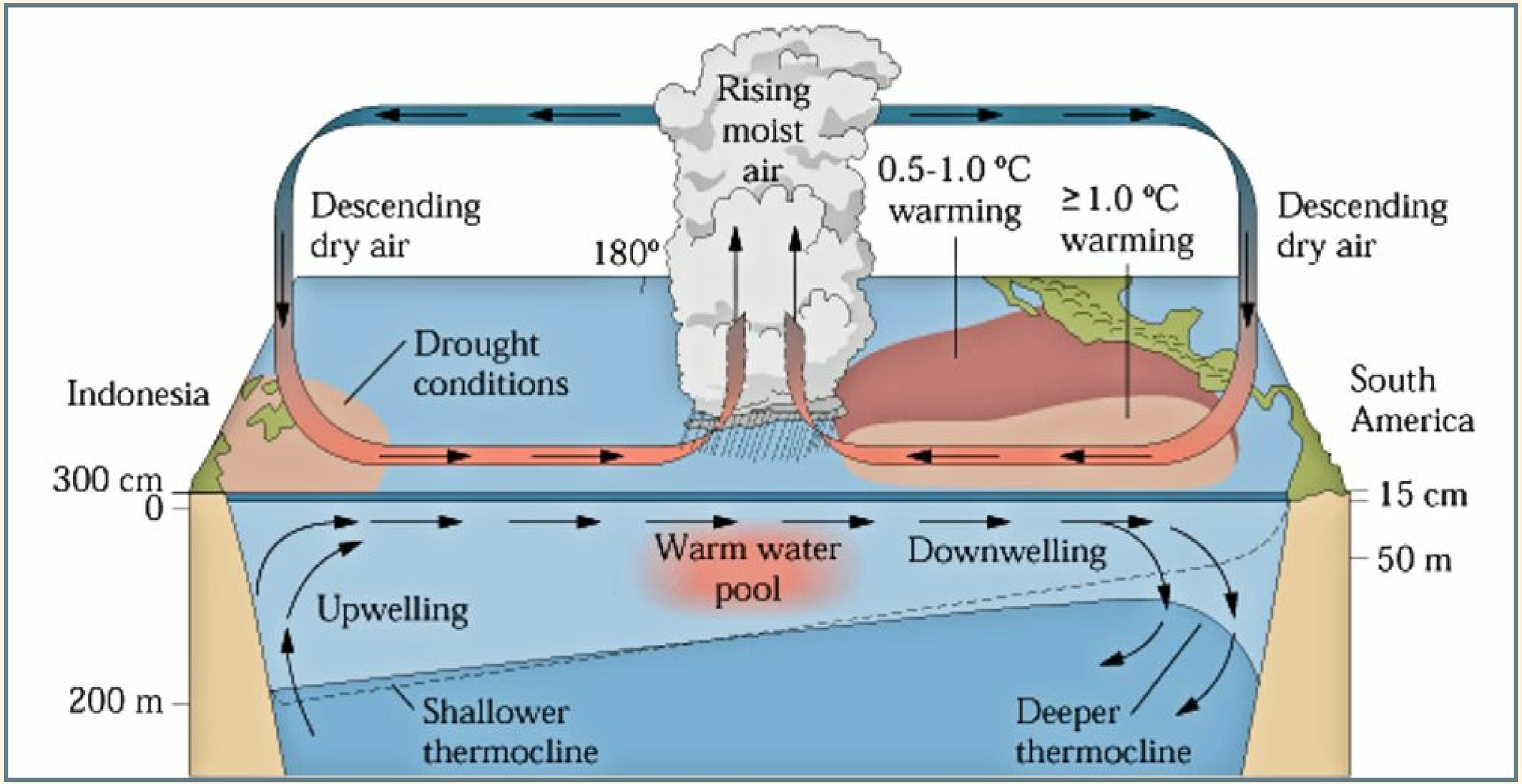
1958, 1966, 1973, 1983, 1987, 1992, 1996, 1998

-2.0 °C -1.5 °C 1.0 °C -0.5 °C 0.0 °C 0.5 °C 1.0 °C 1.5 °C 2.0 °C

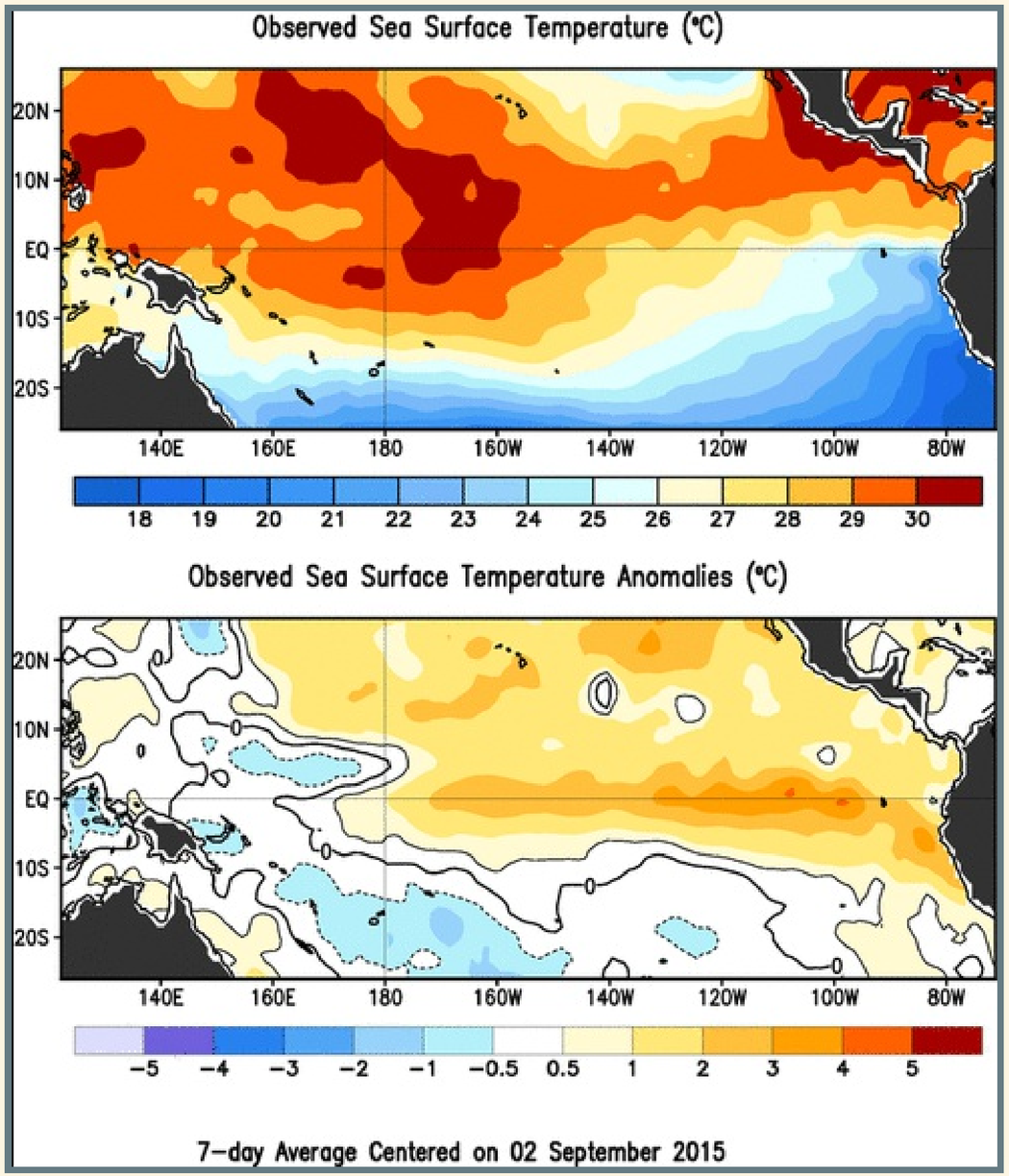
Normal Conditions



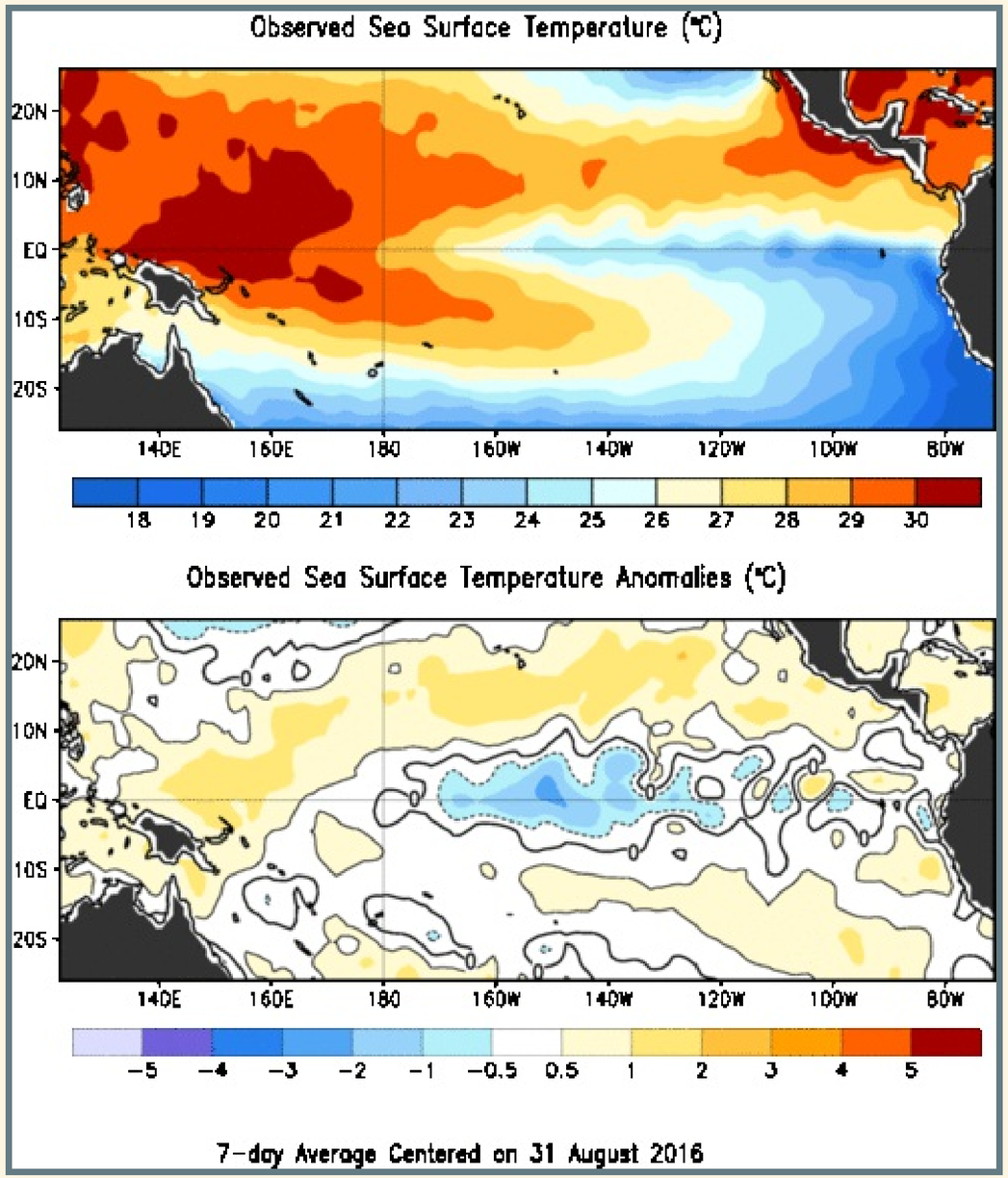
El Niño


Rising
moist
air
Descending
dry air
180°
0.5-1.0 °C
warming
≥ 1.0 °C
warming
Descending
dry air
Drought
conditions
Indonesia
South
America
300 cm
0
15 cm
50 m
Warm water
pool
Downwelling
Upwelling
200 m
Shallower
thermocline
Deeper
thermocline

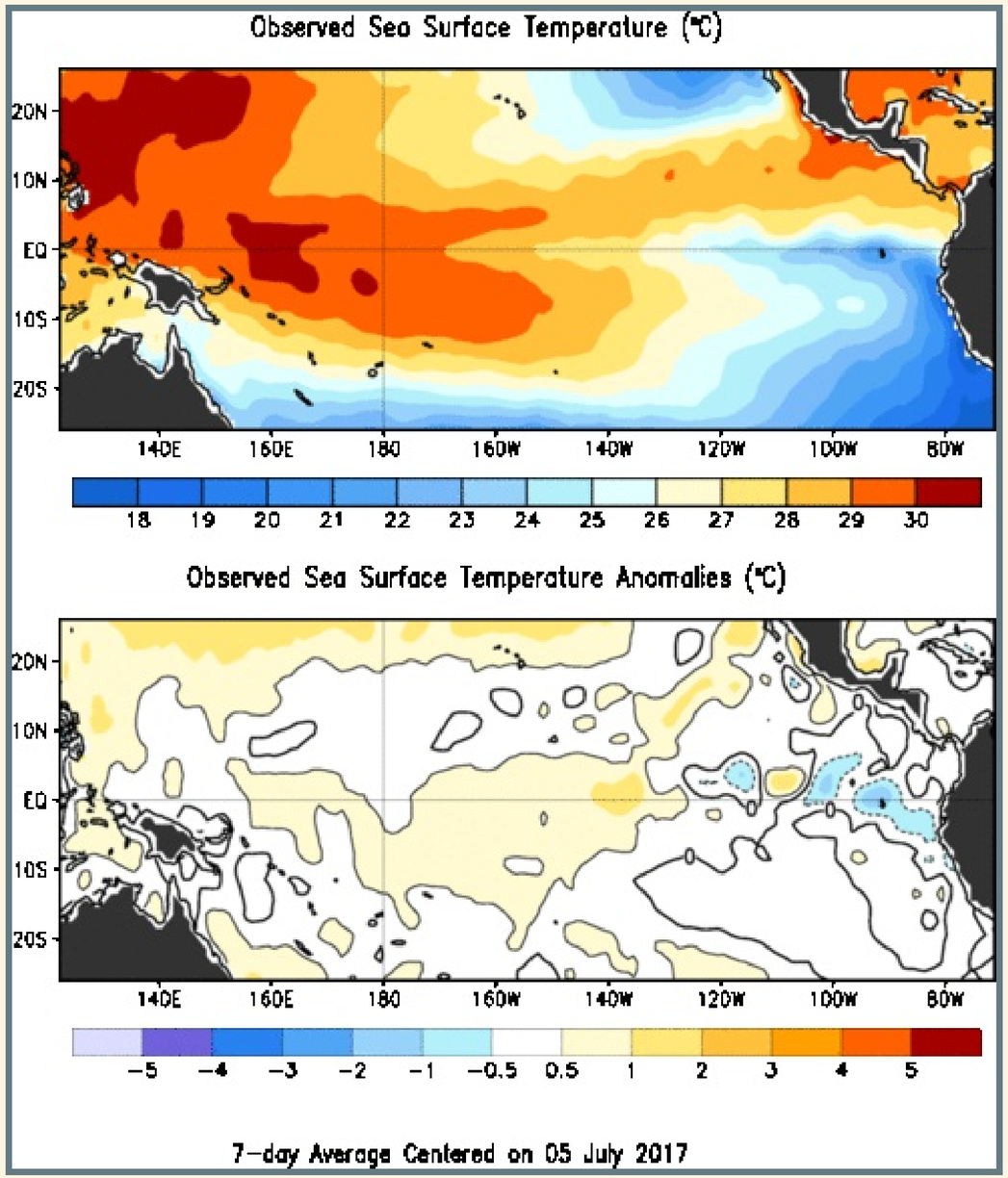
Aug.-Sept. 2015



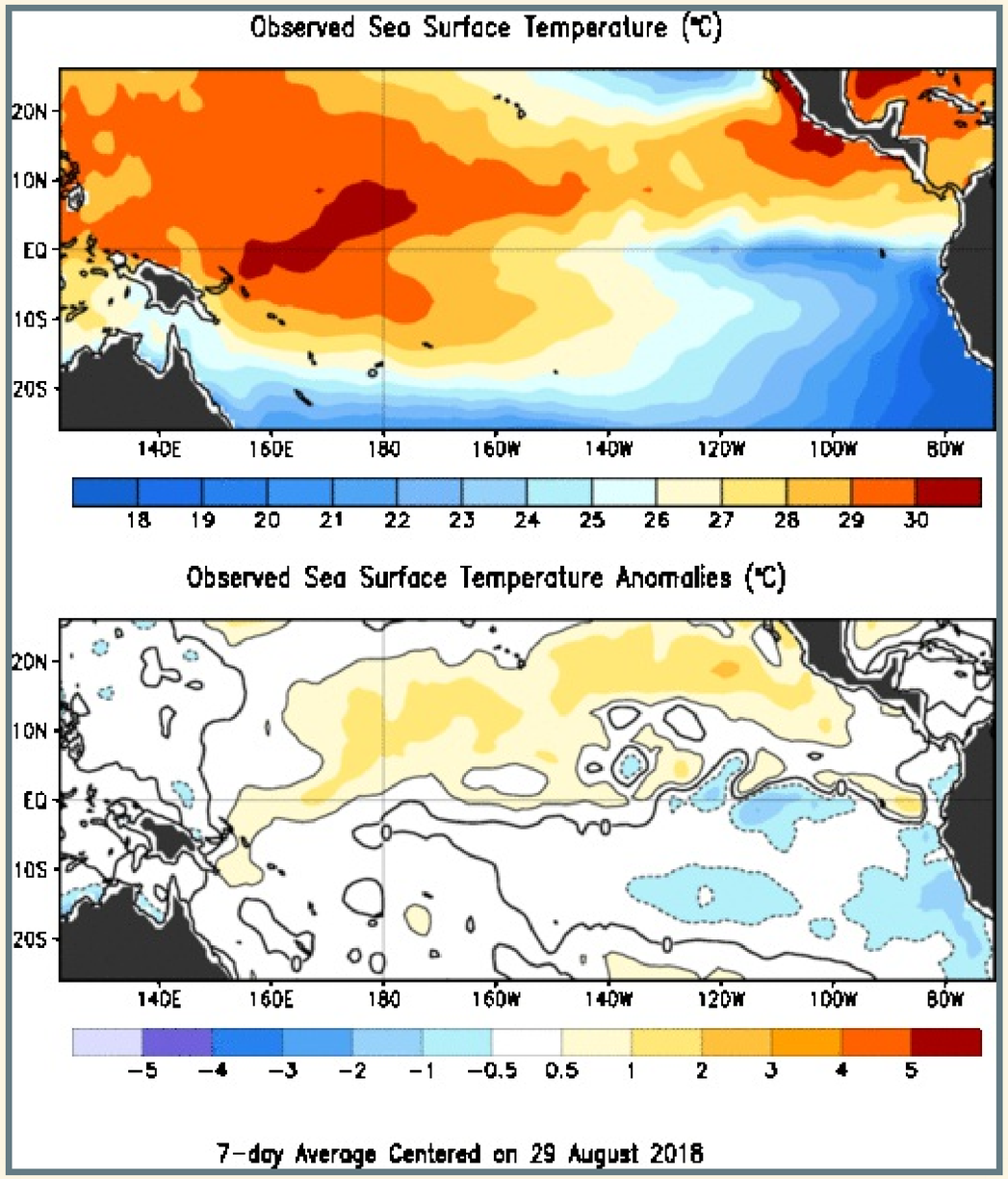
Aug.-Sept. in 2016



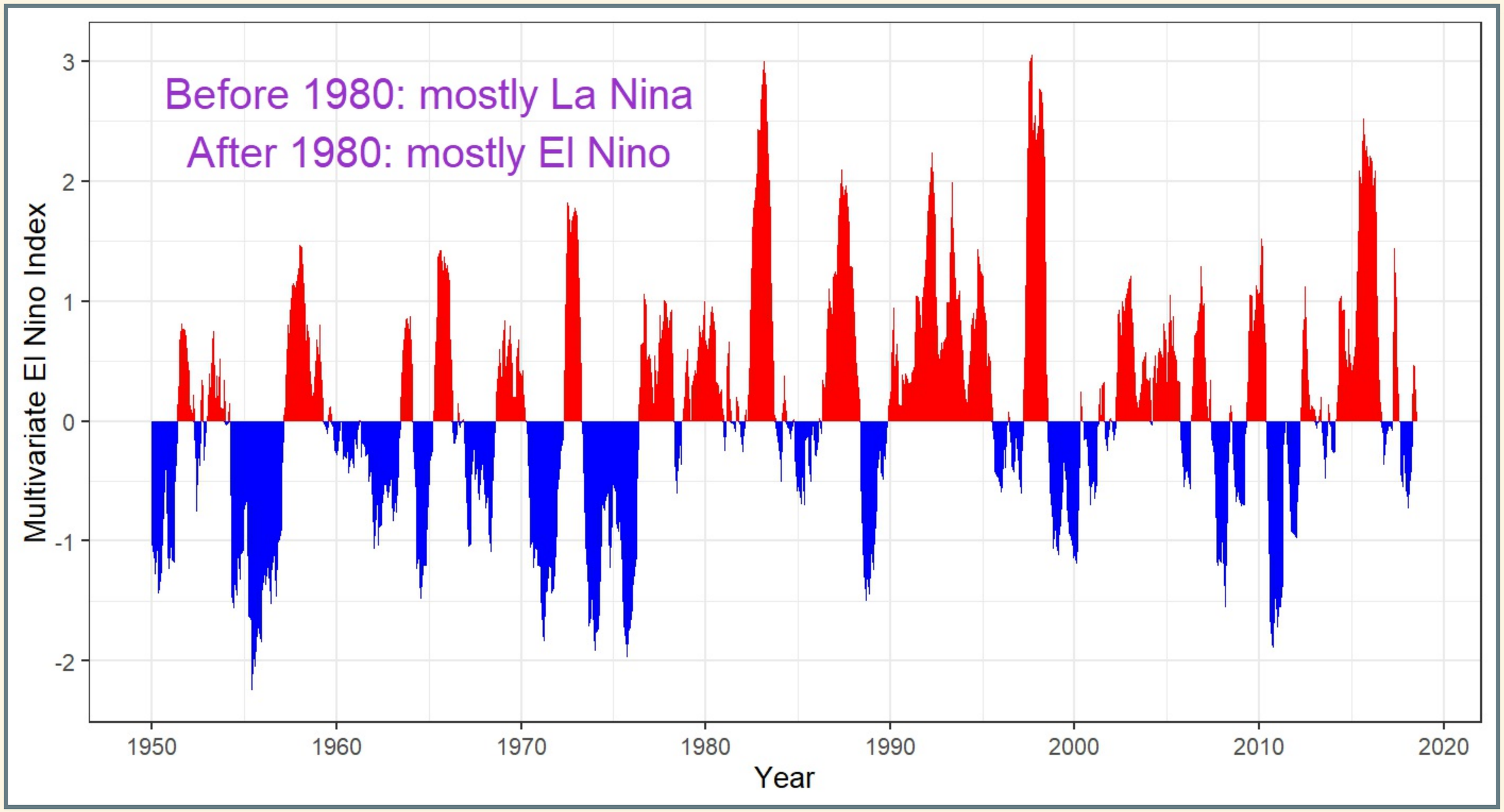
Jul. in 2017


Observed Sea Surface Temperature (°C)
20N
10N
EQ
10S
20S
140E
160E
180
160W
140W
120W
100W
80W
18
19
20
21
22
23
24
25
26
27
28
29
30
Observed Sea Surface Temperature Anomalies (°C)
20N
10N
EQ
10S
20S
140E
160E
180
160W
140W
120W
100W
80W
−5
−4
−3
−2
−1
−0.5
0.5
1
2
3
4
5
7−day Average Centered on 05 July 2017

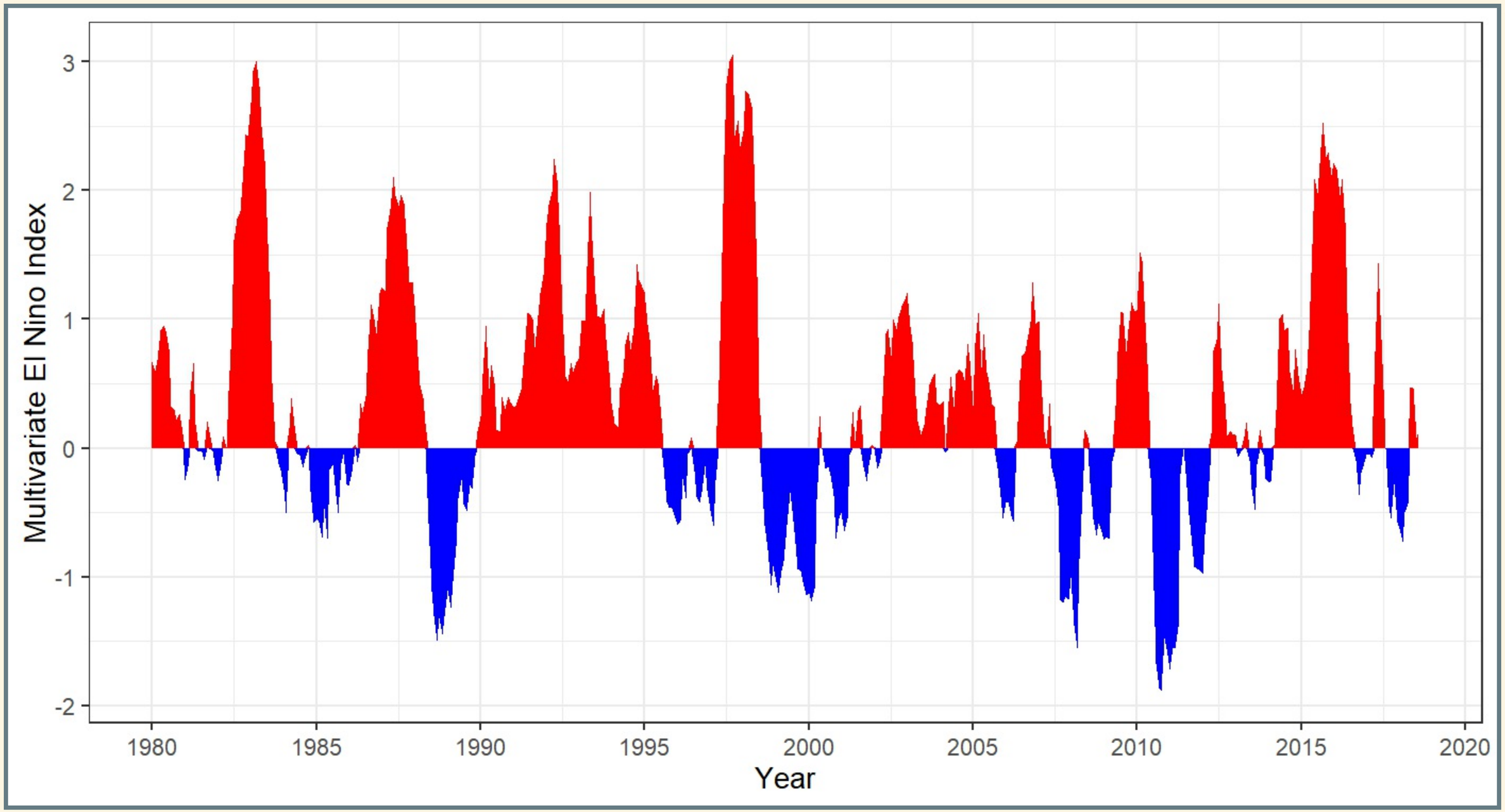
Aug.-Sept. in 2018



Historical Record



Recent Times



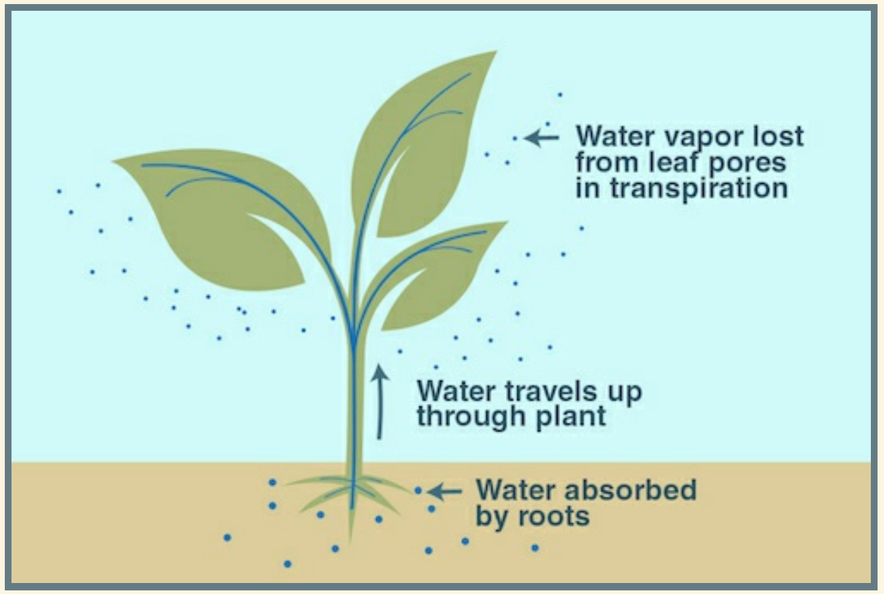
Climate Connection

- El Niño phase:
  - Hotter sea-surface
  - More evaporation
  - Bigger greenhouse effect
  - Higher global air temperatures
  - Incoming heat goes into air more than ocean
- La Niña phase:
  - Cooler sea-surface
  - Less water vapor
  - Smaller greenhouse effect
  - Cooler global air temperatures
  - Incoming heat mostly absorbed by ocean

Biosphere Feedbacks

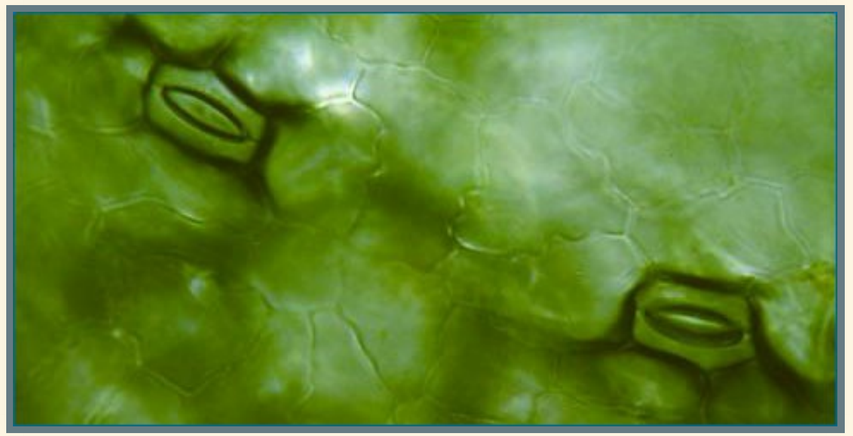
Hydrological Cycle

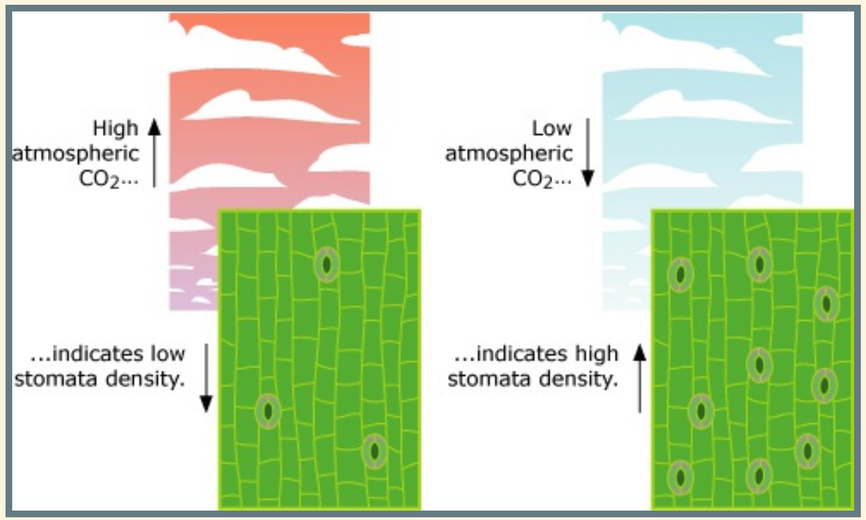
- Transpiration in plants:
  - Roots take water from ground
  - Leaves emit water vapor
  - This can be a significant source of water vapor



Hydrological Cycle

- Transpiration occurs through "stomata" in leaves
- Tradeoff stomata:
  - Allow plant to get CO_2
  - Cause plant to lose water
- More CO_2 in atmosphere:
  - Fewer stomata
  - Less transpiration

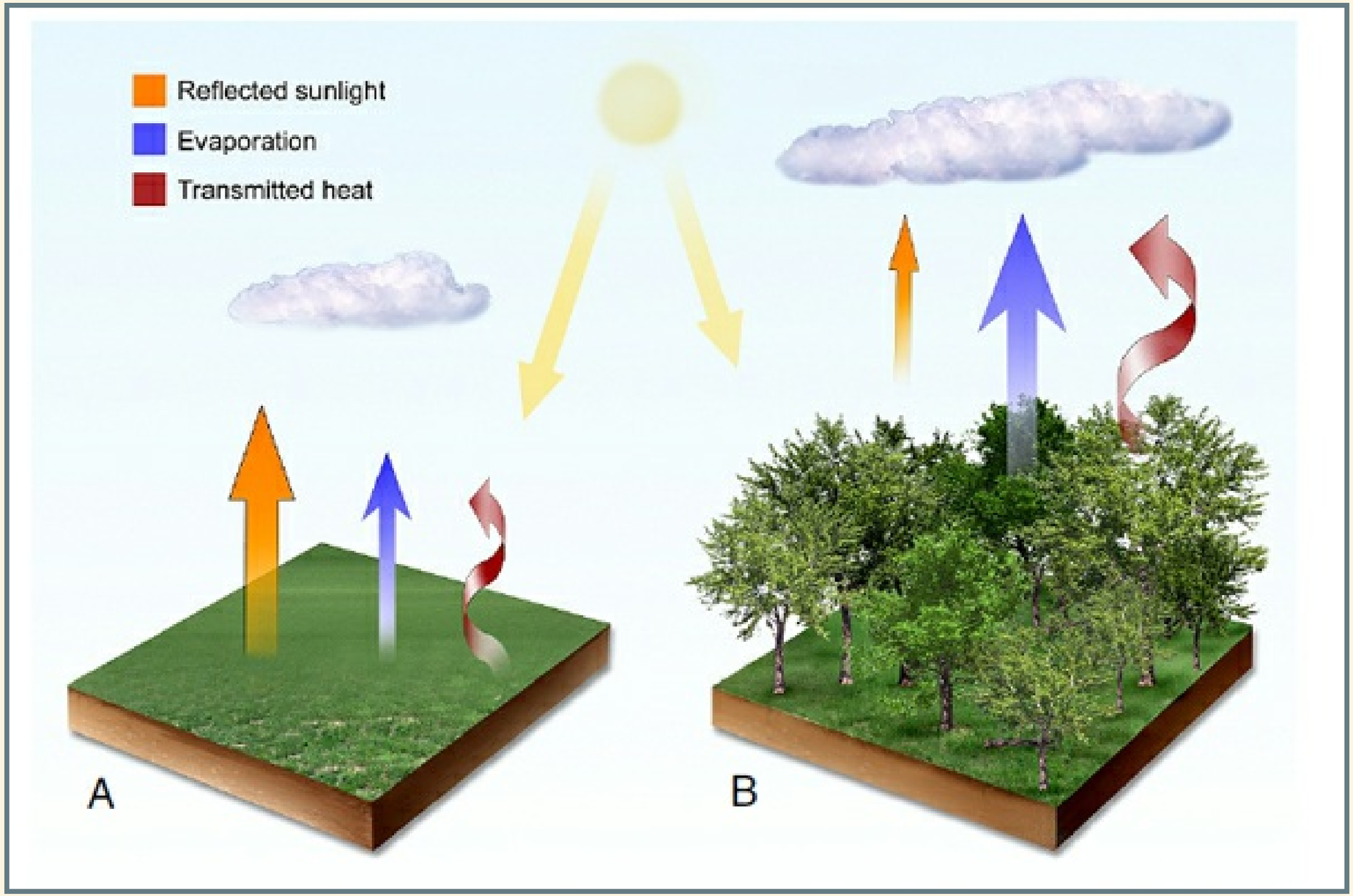




Albedo

- Trees have dark leaves
- Boral forests (near arctic) expand as temperature rises, decrease albedo
- If tropical/temperate forests turn to grassland, albedo rises (cooling)

Forests vs. Grasslands



Carbon Cycle

- Dead organic matter in ground (leaves, roots, etc.) stores carbon
- Warming temperatures accelerate decomposition
  - Bacterial/fungal metabolism
- Huge amounts of dead organic matter in arctic tundra & permafrost
  - Concerns about runaway greenhouse gas emission as ground thaws & warms