Air-sea interaction: El Nino and La Nina
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
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

Ocean

West Pacific

East Pacific

WARM → COLD → COOL

z
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
Normal conditions

Convection is located over the Western Pacific warm pool

Slide by Jonathan Wright
Normal conditions

Convection is located over the Western Pacific warm pool

Walker circulation

trade winds
Normal conditions

Convection is located over the Western Pacific warm pool

Walker circulation

trade winds
Normal conditions

Atmosphere

Normal Conditions

Ocean

West Pacific

East Pacific

Walker Circulation

p LOW

p HIGH

WARM

COLD

z
The Bjerknes feedback

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

Easterly trend winds over Tropical Pacific Ocean

Upwelling under lower SST And downwelling under higher SST

More cooling over lower SST And more warming over higher 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

2013 (average year)
Satellite chlorophyll

2015 El Niño
TOTAL PRODUCTION OF PERUVIAN ANCHOVETA (E. ringens) IN THE SOUTHEAST PACIFIC (Area 87) AND "EL NIÑO" YEARS SINCE 1950

16 Millions of Metric tons

“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
Walker circulation

Weaker trade winds
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
The El Nino of 2015-2016

https://youtu.be/v92Iqihct98
Sea surface temperature anomalies for March 2018

Difference from average temperature (°F)

March 2018 compared to 1981-2010

Data: Geo-Polar SST
Climate.gov/NNVL
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.
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 (5°N-5°S, 150°W-160°E)]. SST anomalies are departures from the 1981-2010 base period weekly means.
Prediction

Mid-Mar 2018 Plume of Model ENSO Predictions

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.
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/wcap/enso_update_latest.html
Understanding
El Niño

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

low pressure

extended
Pacific Jet Stream,
amplified storm track

warmer
drier
colder
wetter
WINTER LA NIÑA PATTERN

variable Polar Jet Stream

blocking high pressure

colder

wetter

warmer
drier

drier
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/ens/o/

Sources:
La Niña and Rainfall

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

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Sources:
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