Walker Circulation, El Niño-Southern Oscillation (ENSO)

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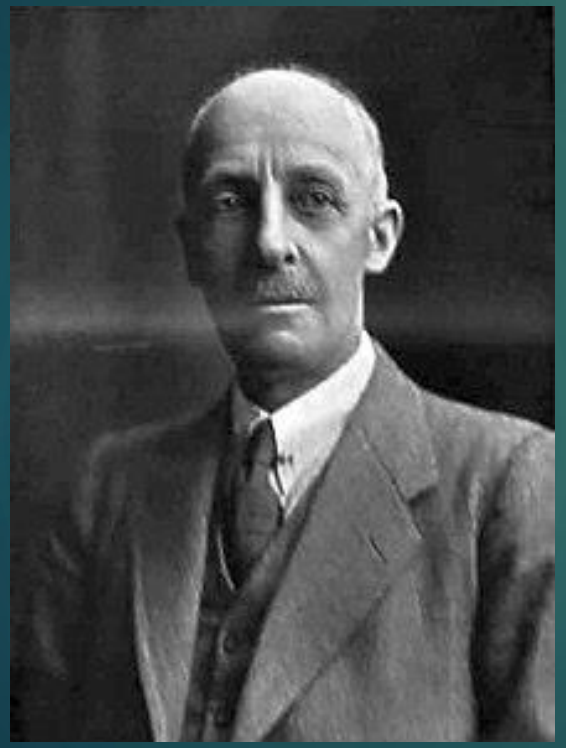
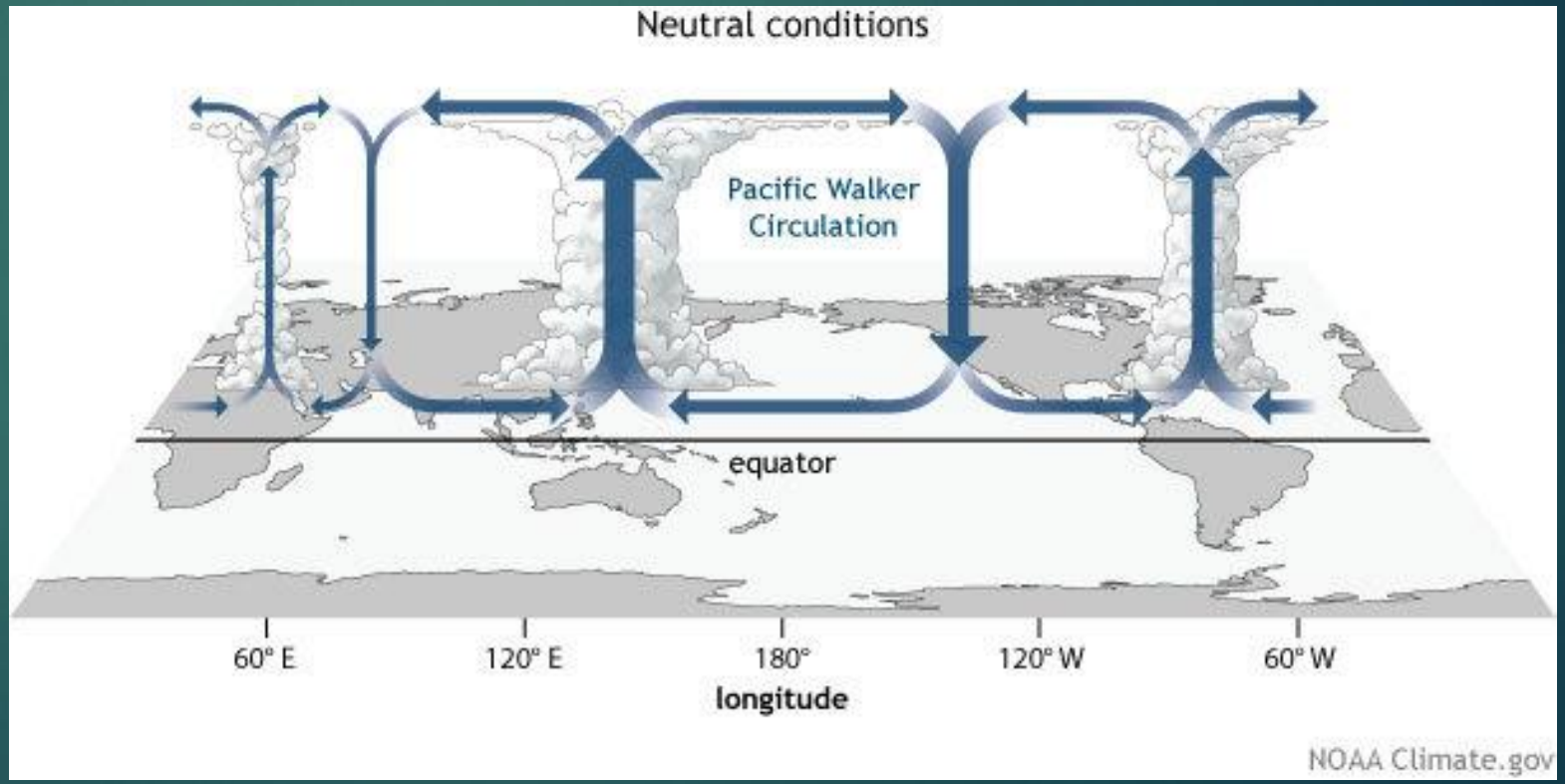
1. Walker Circulation

Typical east west circulation of tropical winds is called walker circulation (**G .T . Walker in 1922-23**). Walker Circulation is a zonal convective cell of air circulation, which is formed due to development of pressure gradient from **east to west in the equatorial pacific ocean**.



(1868 – 1958)



2. El Niño: Historical Context

- **El Niño** (Spanish for "**the Child**" in reference to **baby Jesus**) = warm surface current in equatorial eastern Pacific that occurs periodically around **Christmastime**
- El Niño, as a **oceanic phenomenon** along the **coasts of northern Peru and Ecuador,** has been documented since the **1500s**.
- Originally, the term El Niño was used to describe the **annual appearance of warm waters** along the coast of northern Peru around **Christmastime.**
- Camilo Carrillo used the word EL Nino in 1892 at Geographical Society Congress (Lima Peru).
- In some years the warm waters appeared earlier and lasted longer. Eventually, the term El Niño was applied to the **periods of anomalous warming**.
- The stronger events disrupted local fish and bird populations.

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2. Southern Oscillation (SO): Historical Context

- Beginning in the late 1800s scientists began to describe **large-scale pressure fluctuations.**
- Sir **Gilbert Walker** and **colleagues** extended the early studies and determined that a **global-scale pressure fluctuation** (the Southern Oscillation) is related to rainfall anomalies in many areas of the Tropics (e.g., India and South America).
- The **SO** was used as the basis for seasonal rainfall predictions (ca 1930s).

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2.1 Why Oscillation!

- Walker Circulation is a zonal convective cell of air circulation, which is formed due to development of pressure gradient from **east to west in the equatorial pacific ocean**.
- After two or three years this general condition of **east-west pressure gradient is revised**. (The **pressure gradient becomes from the west to east**)
- Thus there are oscillation in pressure gradient and air circulation after the interval of 2 – 3 years. **Walker called such oscillation as southern oscillation.**
- Walker circulation and southern oscillation are driven by the **sea surface pressure gradient** from the equatorial eastern pacific ocean to the equatorial western pacific ocean. (Sea surface pressure gradient depends on the **sea surface Temperature**)
- By **October-November** the low air pressure of the tropical western pacific is shifted to the **tropical eastern pacific** causing **weakening of trade winds**.

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2.2 Discovery of the "El Niño- Southern Oscillation (ENSO)"

- El Niño and the Southern Oscillation were studied as **separate phenomena** until the 1950s-1960s.
- Important works by **Berlage (1956) and J. Bjerknes (late 1960s)** demonstrated a link between the two phenomena.
- Studies at that time also showed that the **anomalous warming** of the **Ocean waters** during El Niño extended over a large portion of the equatorial Pacific.

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3. ENSO: A Coupled Ocean-Atmosphere Cycle

ENSO is a "coupled" phenomenon: atmosphere drives the ocean and the ocean drives the atmosphere.

"Positive Feedback" between ocean and atmosphere.

Example:

Weaker equatorial trade winds → cold water upwelling in the east will decrease → surface warming of the ocean → reduced east-west temperature gradient → Weaker equatorial trade winds

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4. El Niño/ Low Southern Oscillation Phase VS. La Niña/ High Southern Oscillation Phase

Signals in Tropical Pacific:

- Sea surface temperatures (SSTs)
- Precipitation
- Sea Level Pressure
- The Southern Oscillation (High vs. Low Phases)
- Low-level Winds and Thermocline Depth

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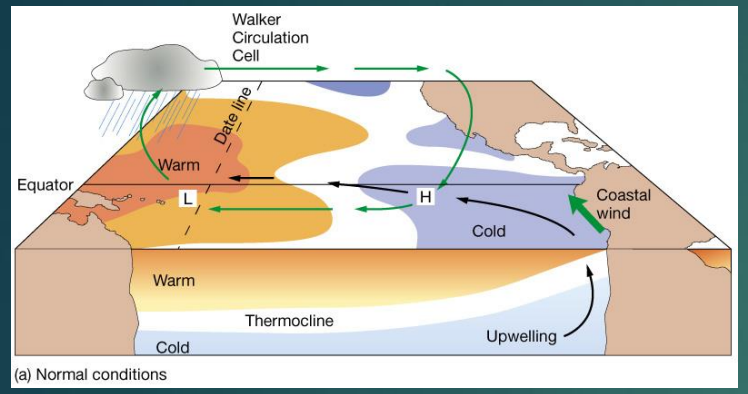
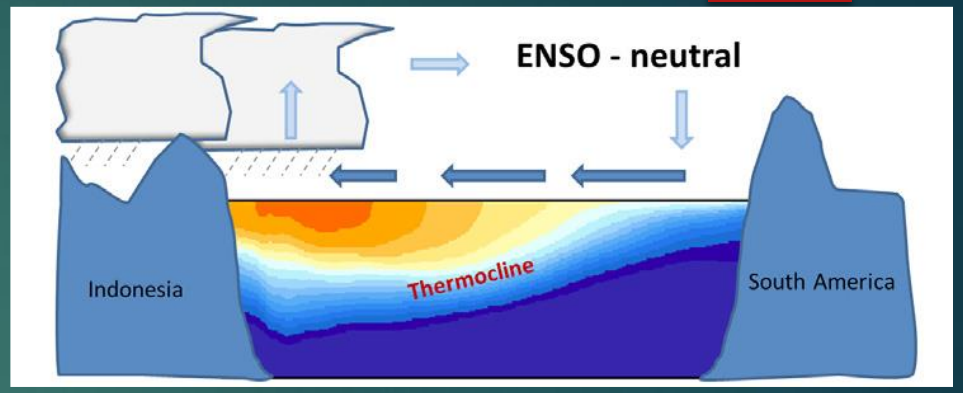
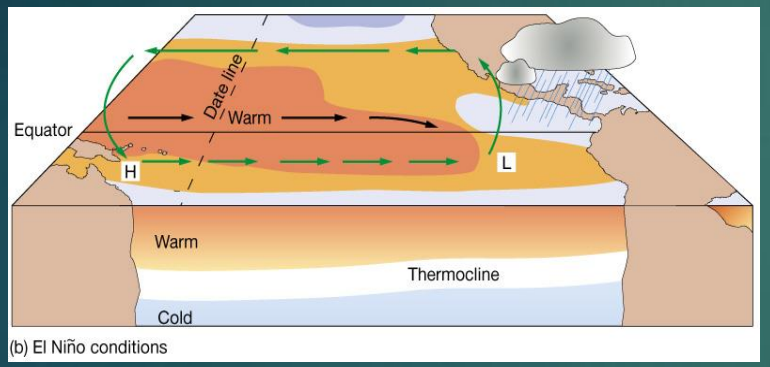
4.1 Phases of ENSO

https://www.youtube.com/watch?v=tyPq86yM_Ic

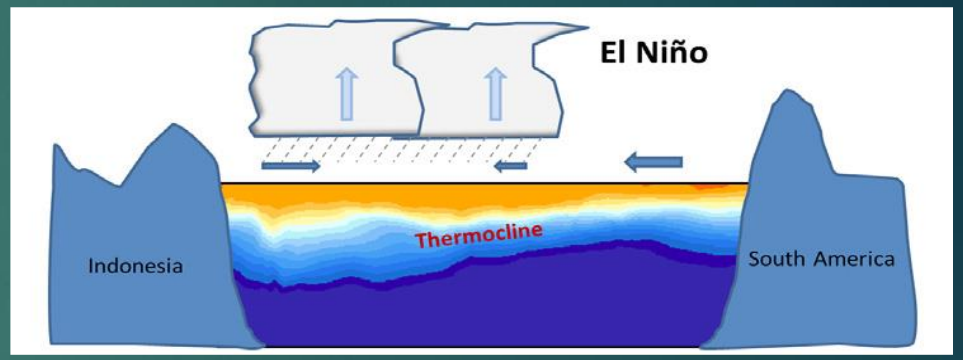


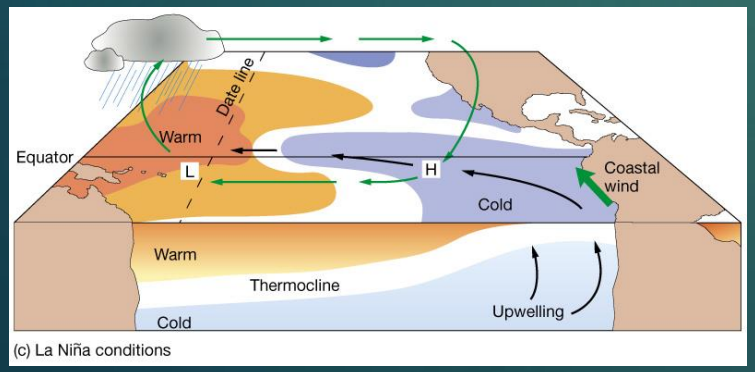
Normal Condition



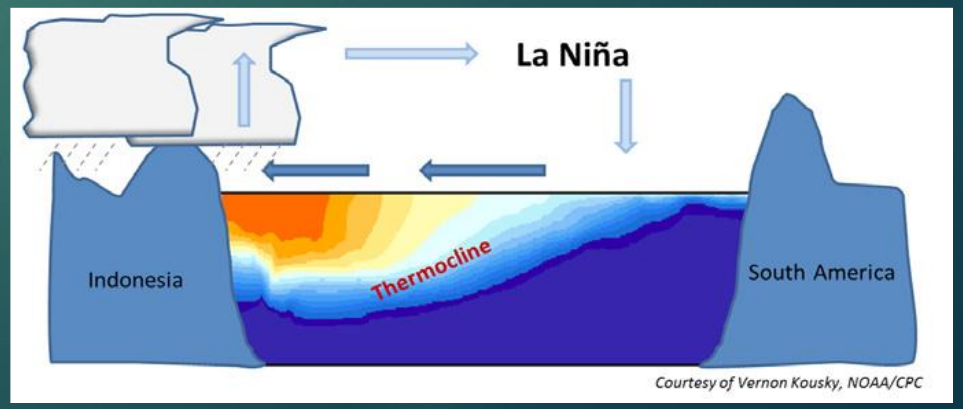


El Nino Condition





La Nina Condition



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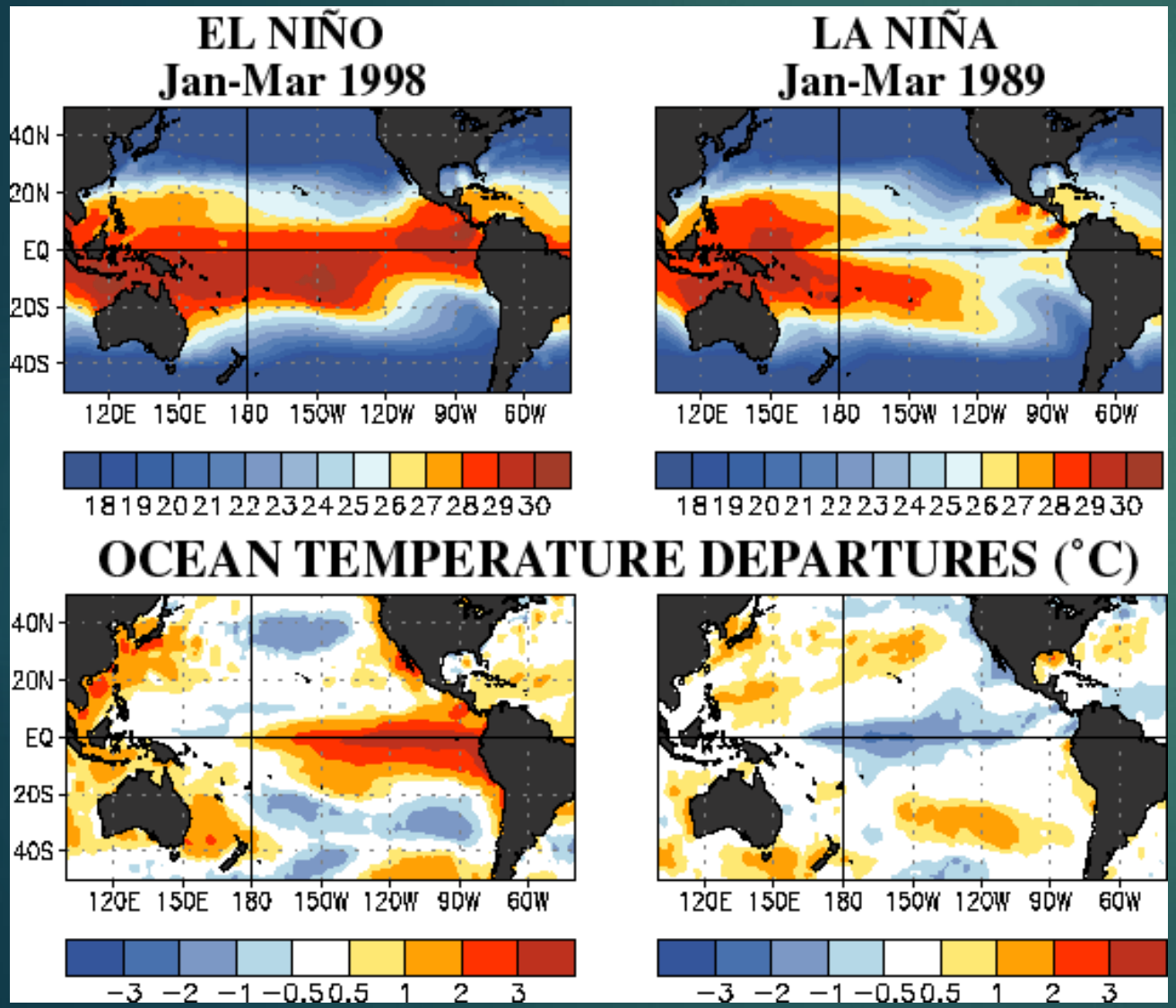
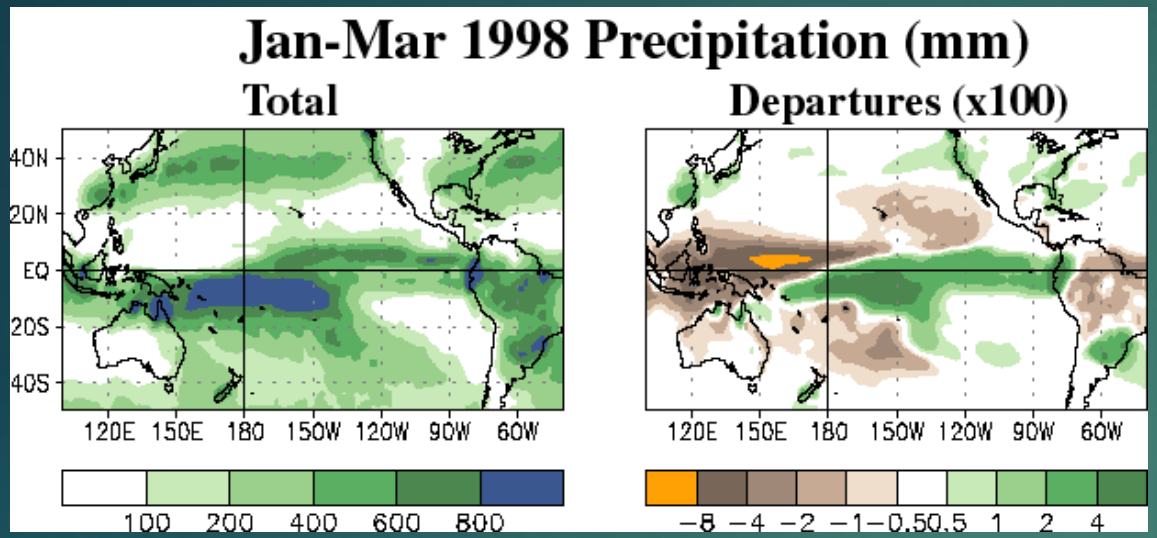
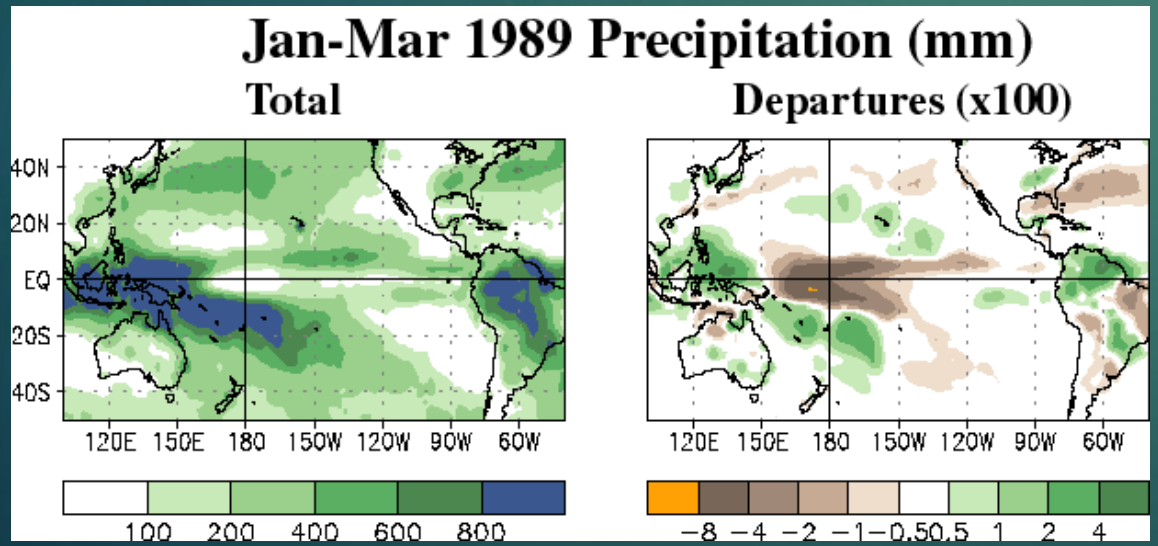
4.2 Sea Surface Temperatures



- Equatorial cold tongue is weaker than average or absent during El Niño, resulting in positive SST anomalies.
- Equatorial cold tongue is stronger than average during La Niña, resulting in negative SST anomalies.

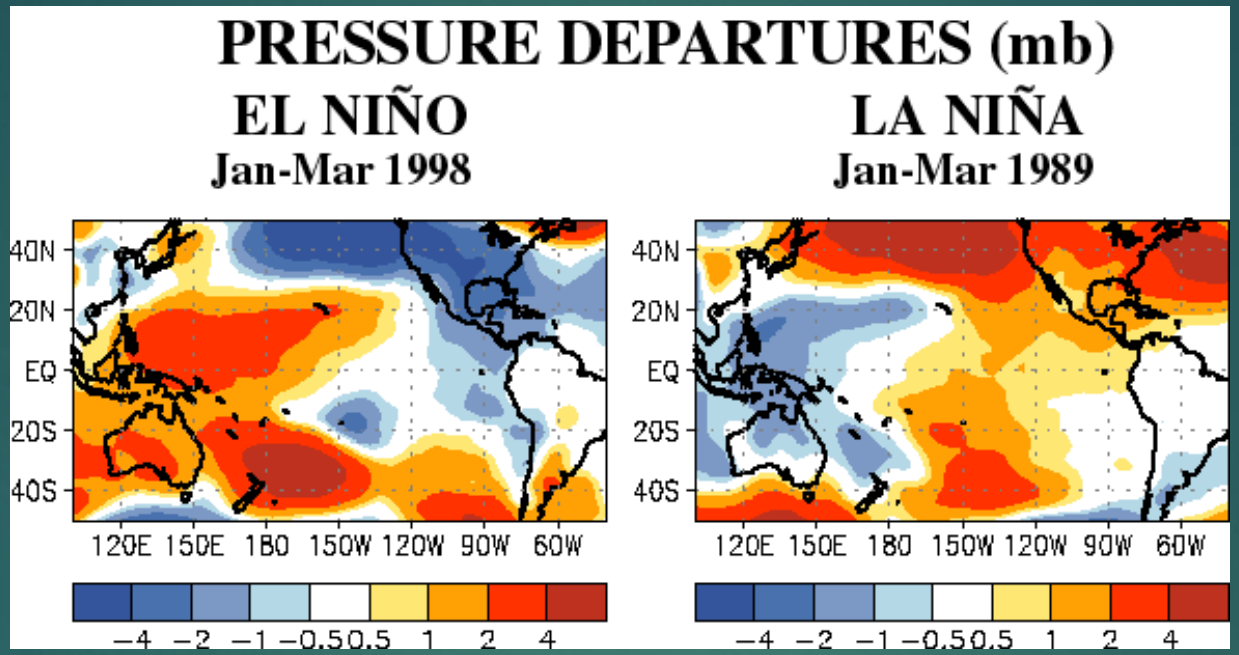
4.3 Precipitation





- Enhanced rainfall occurs over warmer-than-average waters during El Niño.
- Reduced rainfall occurs over colder-than-average waters during La Niña.

4.4 Sea Level Pressure



El Niño: Positive SLP anomalies over the western tropical Pacific, Indonesia and Australia. Negative SLP anomalies over eastern tropical Pacific, middle and high latitudes of the North Pacific, and over U.S. Opposite pattern for La Niña. The pressure see-saw between the eastern and western tropical Pacific is known as the Southern Oscillation.

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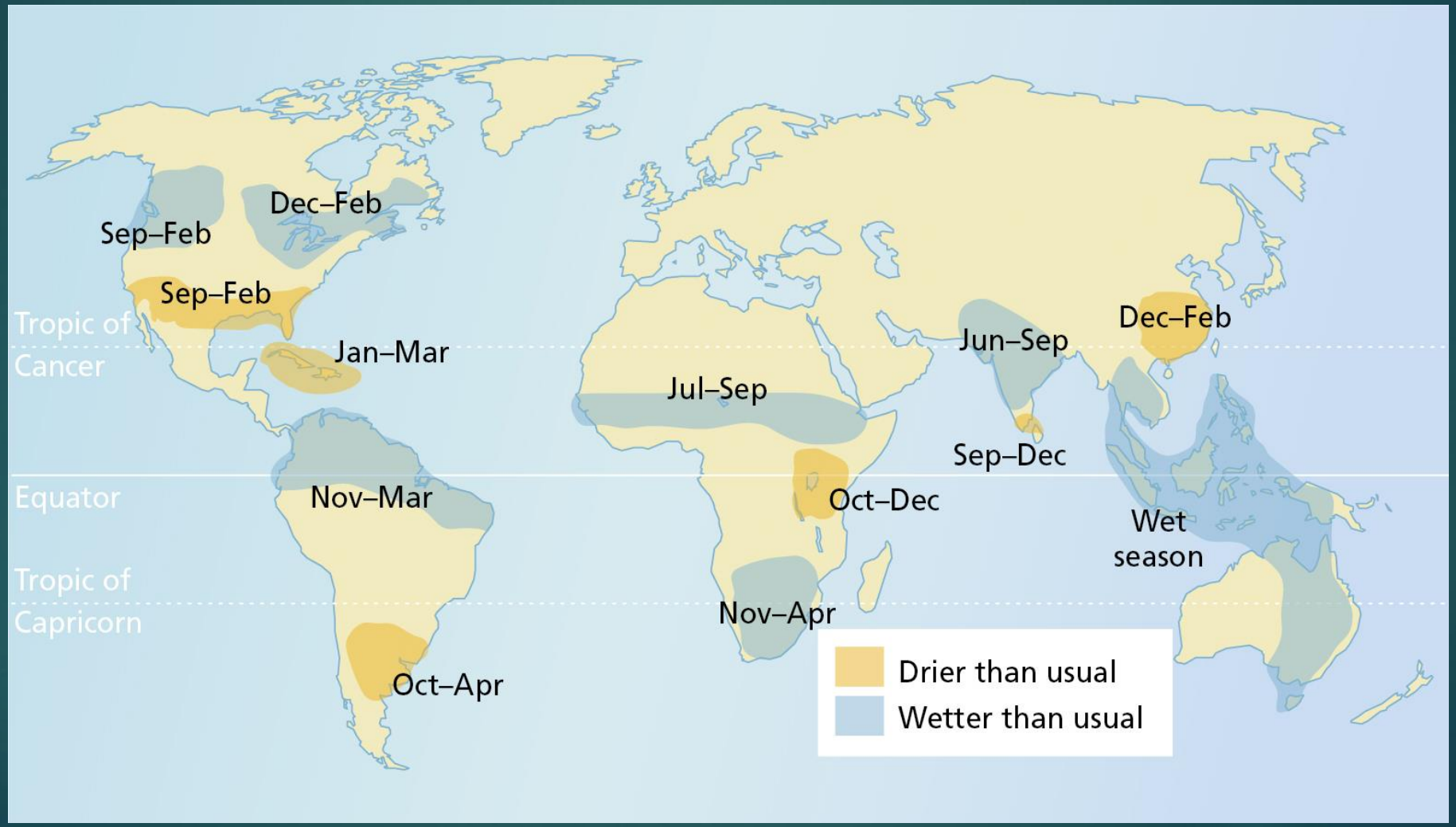
4.5 Global changes to rainfall and drought in a La Niña year



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5. Impact of El-Nino

- In **South America**, there are a variety of impacts:
  - an increased possibility of flooding on the western coast of northern South America
  - drier conditions east of the Andes, in Amazonia
  - wetter conditions in southern Brazil and northern Argentina

- In **Australia** and the **western Pacific basin**:
  - weaker monsoons across much of Asia
  - reduction in number and intensity of tropical storms
  - an increase in wildfires with the drier conditions

Impact of La-Nina

- A variety of global phenomena have been linked to La Niña events:
- flooding in Queensland, Australia in 2010/11 – more than 80 people were killed
- heavy snowstorms in northern USA/southern Canada in 2010
- strong tornadoes in the southern USA in 2011
- increases in transmissible diseases in wetter areas, e.g. malaria in southeast Asia and Australian encephalitis (or Murray Valley encephalitis), in southeast Australia

6. Monitoring Tools

Surface and subsurface ocean temperatures

- Sea-level Pressure (Southern Oscillation Index – SOI)
- Oceanic Niño Index (ONI)
- Low-level and upper-level atmospheric wind

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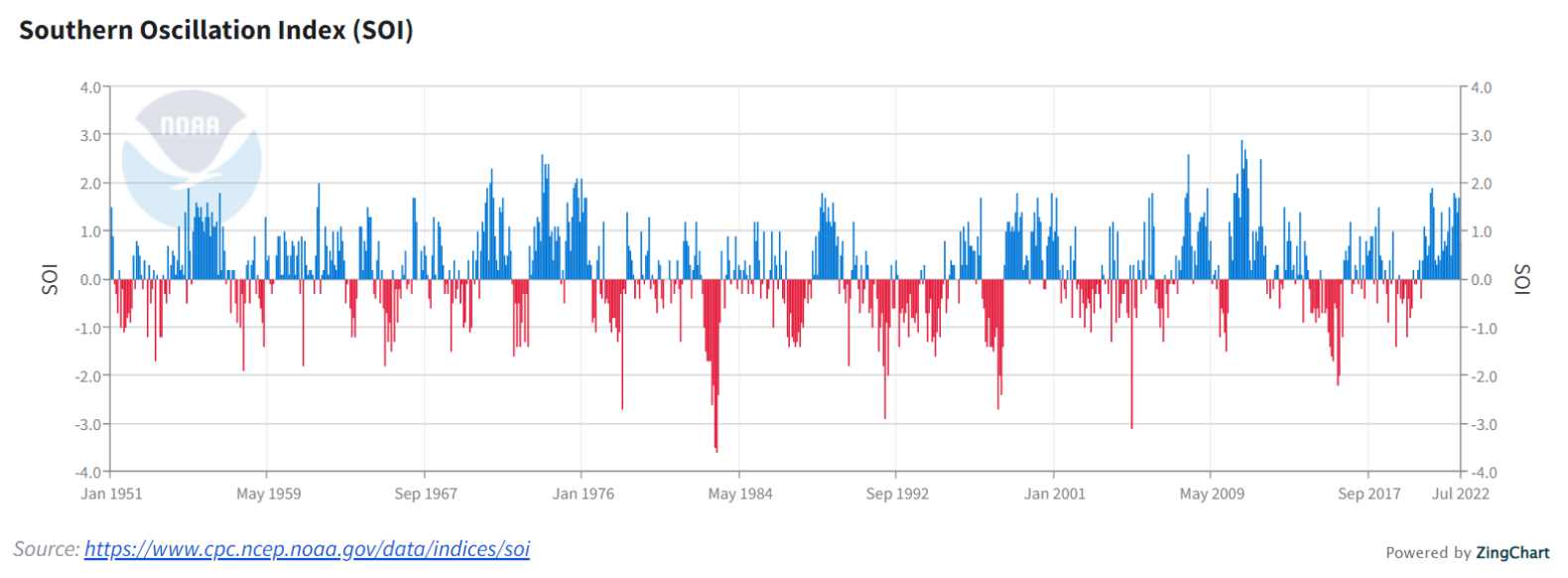
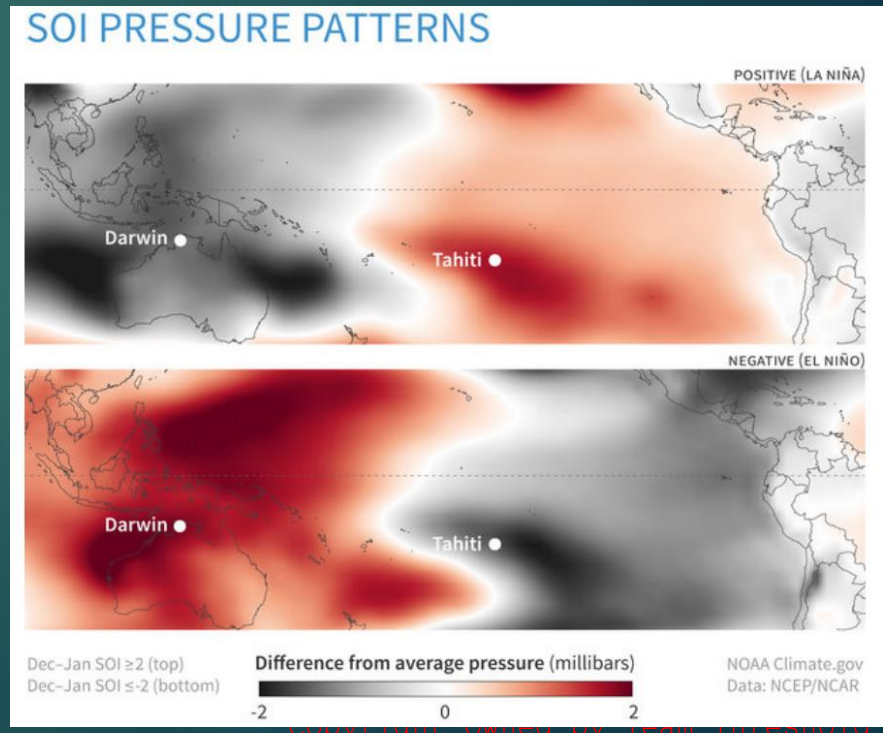
The Southern Oscillation Index (SOI)

- The Southern Oscillation Index (SOI) is a measure of the intensity or strength of the Walker Circulation. It is one of the key atmospheric indices for gauging the strength of El Niño and La Niña events and their potential impacts on the Australian region.
- The SOI measures the difference in surface air pressure between **Tahiti and Darwin**.
- Sustained **positive SOI values indicate a La Niña** event while sustained **negative values indicate an El Niño.**



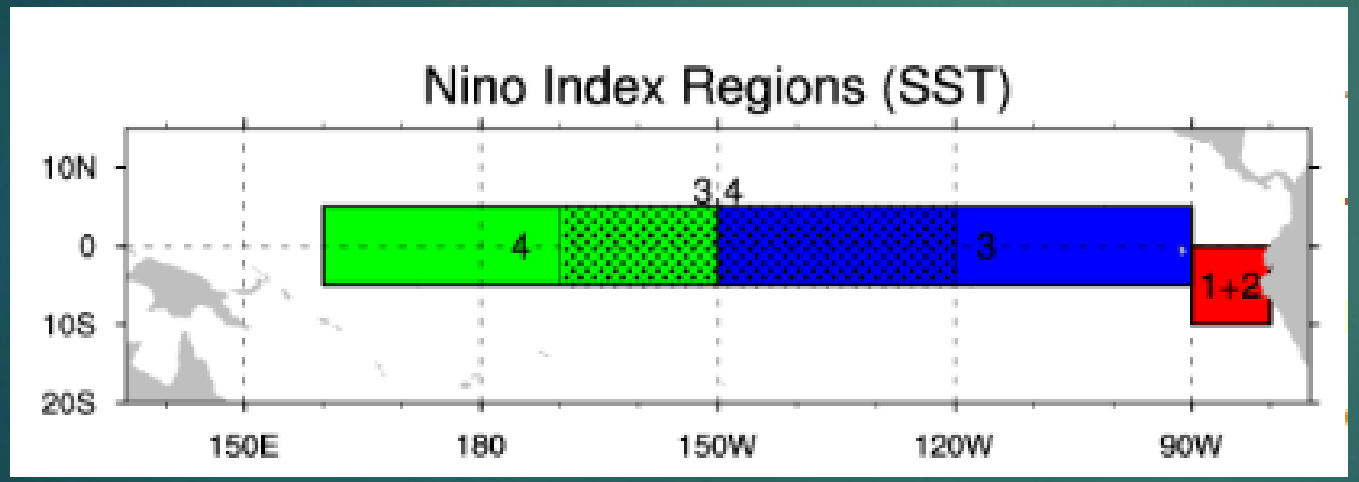


Other Index

The Niño 3.4 index and the **Oceanic Niño Index** (ONI) are the most commonly used indices to define El Niño and La Niña events.

El Niño: characterized by a *positive ONI* greater than or equal to +0.5°C.

La Niña: characterized by a *negative ONI* less than or equal to −0.5°C.



- Niño 1+2 (0-10S, 90W-80W)
- Niño 3 (5N-5S, 150W-90W)
- Niño 3.4 (5N-5S, 170W-120W)
- **ONI (5N-5S, 170W-120W)**
- Niño 4 (5N-5S, 160E-150W)

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Thank You