Climate and Oceans Support Program in the Pacific

ACCESS-S Workshop

MODULE: Pacific climate drivers

Topics in this module

- El Niño–Southern Oscillation (ENSO)
- Madden–Julian Oscillation (MJO)

Expected learning outcomes

- Understanding of the main climate drivers that affect the Pacific

These outcomes are important for understanding and interpreting ACCESS-S outputs and products such as the tropical cyclone outlook and ENSO

El Niño – Southern Oscillation (ENSO)

ENSO is the dominant driver of natural climate variability.

ENSO is strongly linked to the seasonal cycle; this is the source of the predictability.

El Niño = broad scale warming of water in the central and eastern tropical Pacific Ocean.

La Niña = a broad scale cooling of water in the central and eastern tropical Pacific Ocean.

Rain often occurs over the warmest waters.

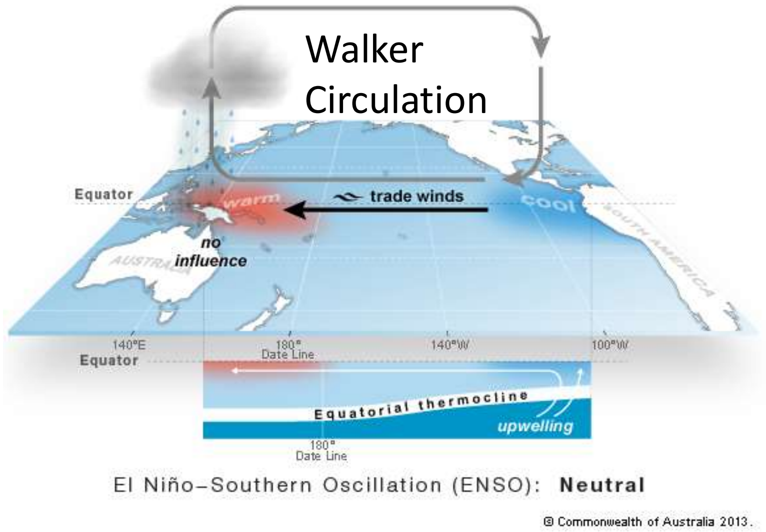
El Niño – Southern Oscillation (ENSO)

Video - https://www.climatekelpie.com.au/index.php/climatedogs/

Circulation changes associated with La Niña

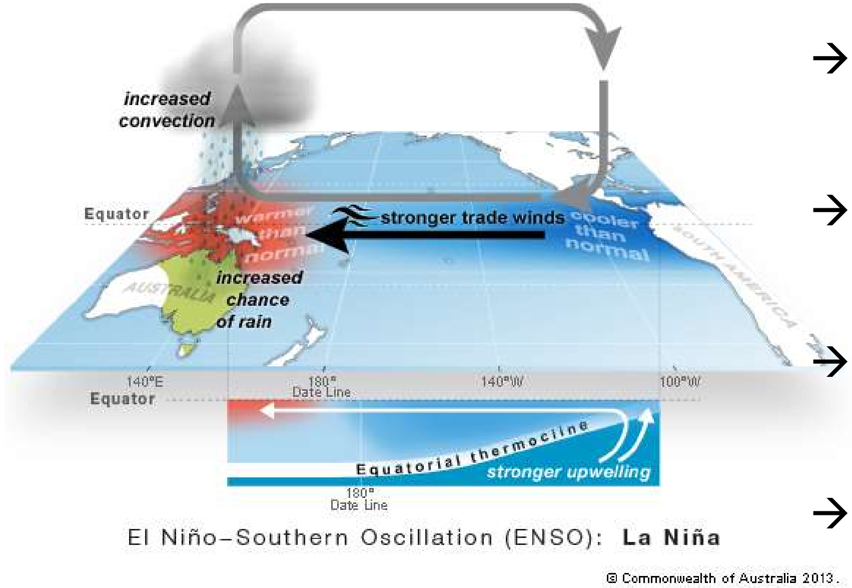
Climate and Oceans Support Program in the Pacific

Neutral



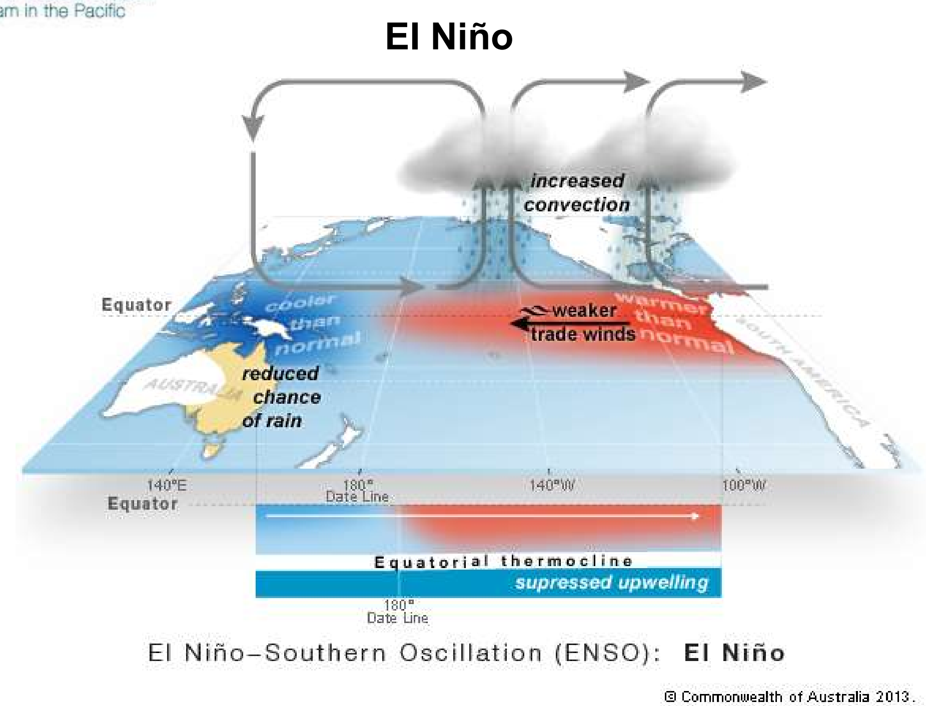
Warmer waters in the west, cooler waters in the east.

La Niña



- → **Walker Circulation** becomes stronger and moves west during La Niña
- → Rain and cloud follows Western Pacific Warm Pool
- → Stronger trade winds increase upwelling in eastern Pacific.
- → Equatorial Pacific **Cold Tongue develops and strengthens**
- → Bringing increased temperature contrast between west and east along the equator
- → Atmosphere and ocean act together in sync (**COUPLED)**

Circulation changes associated with El Niño



Changes in the ocean temperatures

POSITIVE FEEDBACK
loop

Changes in the wind

Rain and cloud follow warmest waters

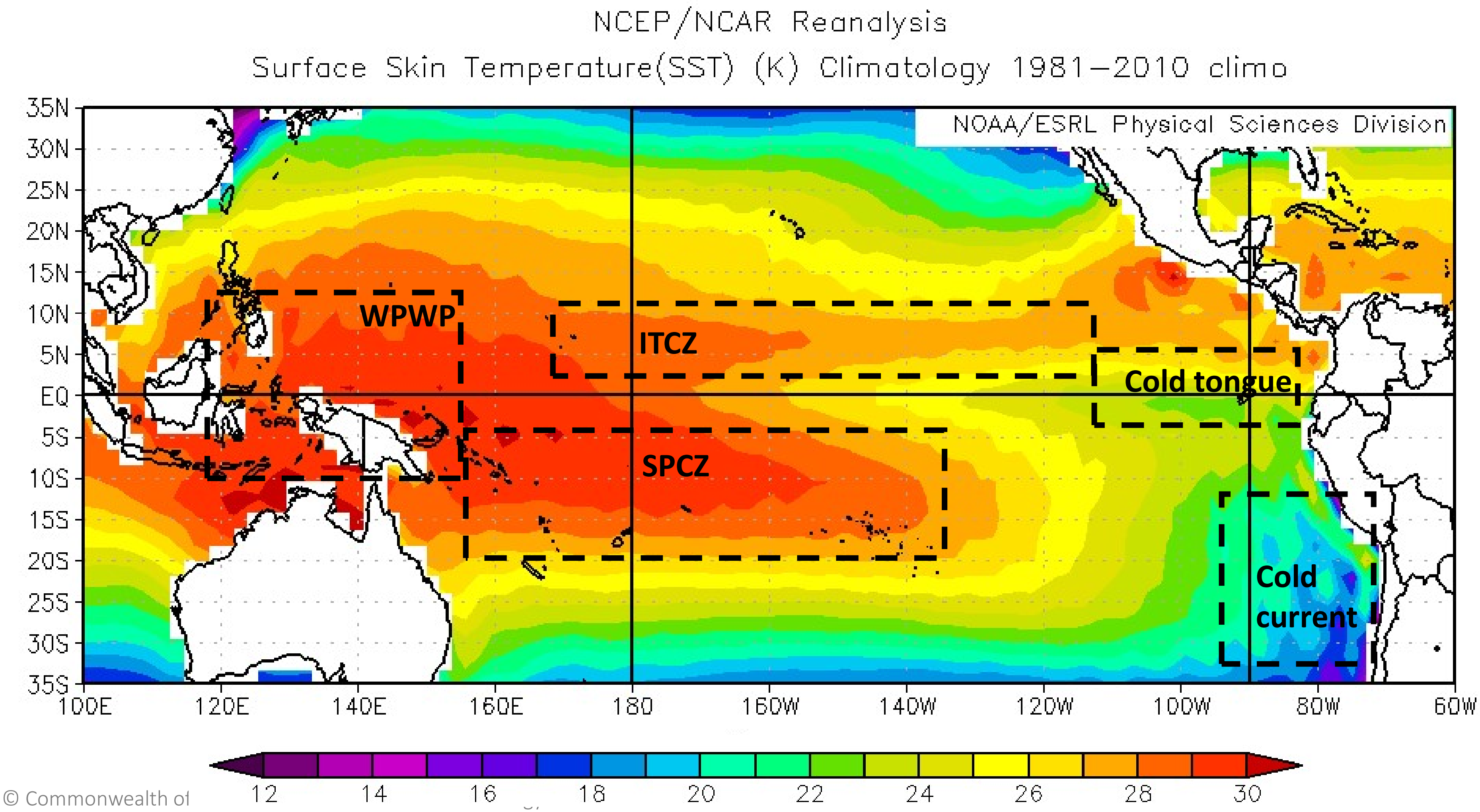
Walker Circulation weakens, moves east and sometimes reverses during an El Niño

The **Western Pacific Warm Pool** moves east, dragging the cloud and rain with it

ENSO events develop in autumn to winter and decay in summer.

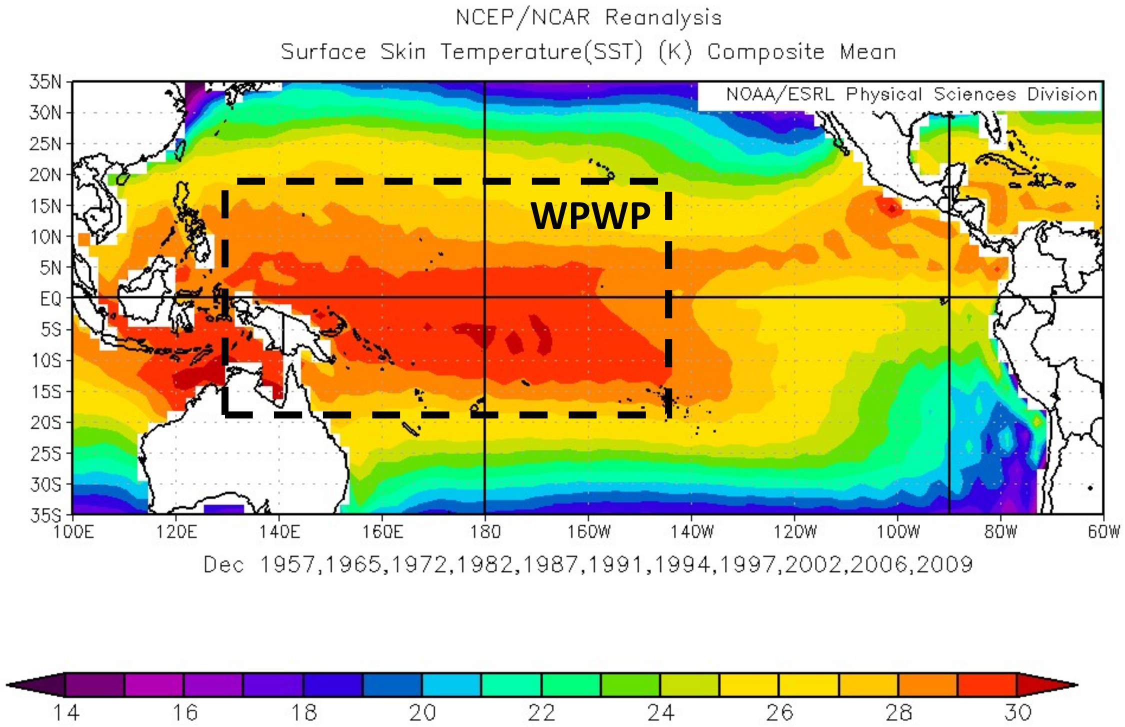
ENSO lifecycle is a source of predictability in the Pacific.

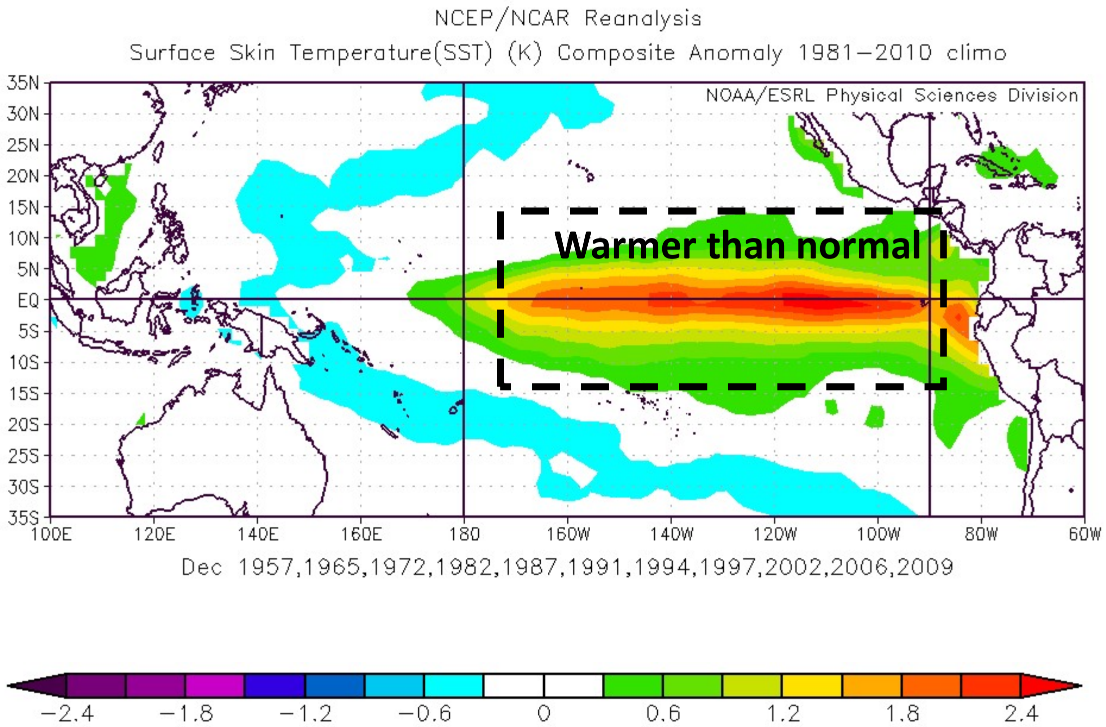
Average December Sea Surface Temperature (SST) pattern during a *neutral* ENSO phase



East equatorial Pacific is cooler than west

Average December Sea Surface Temperature patterns and anomaly during *El Niño*





Western Pacific Warm Pool has spread east into the central Pacific (29°C east of 160°W)

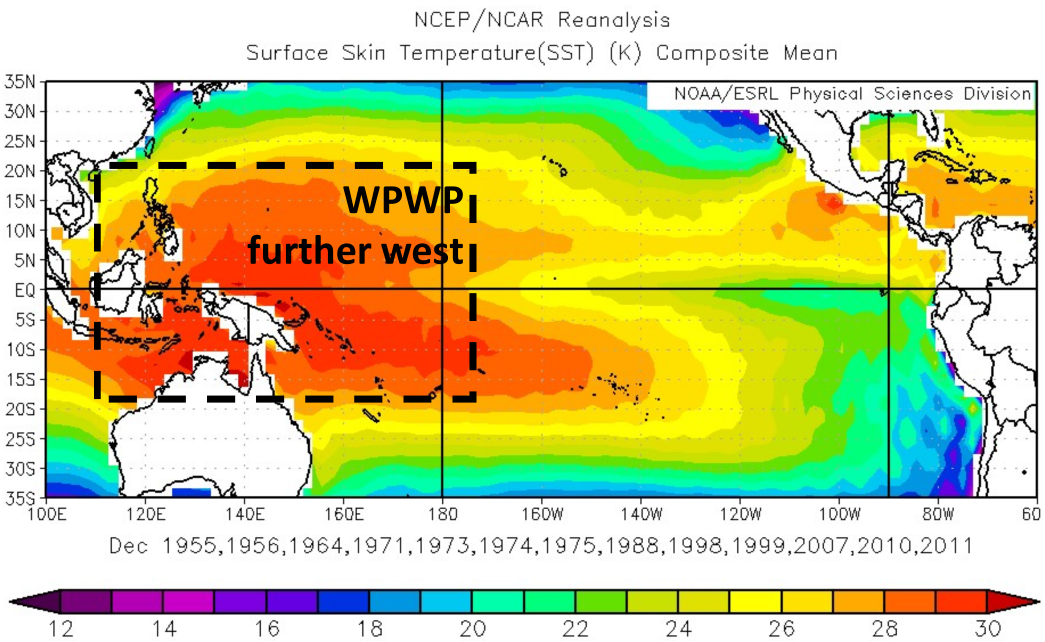
Temperature difference between east and west equatorial Pacific is about 4°C

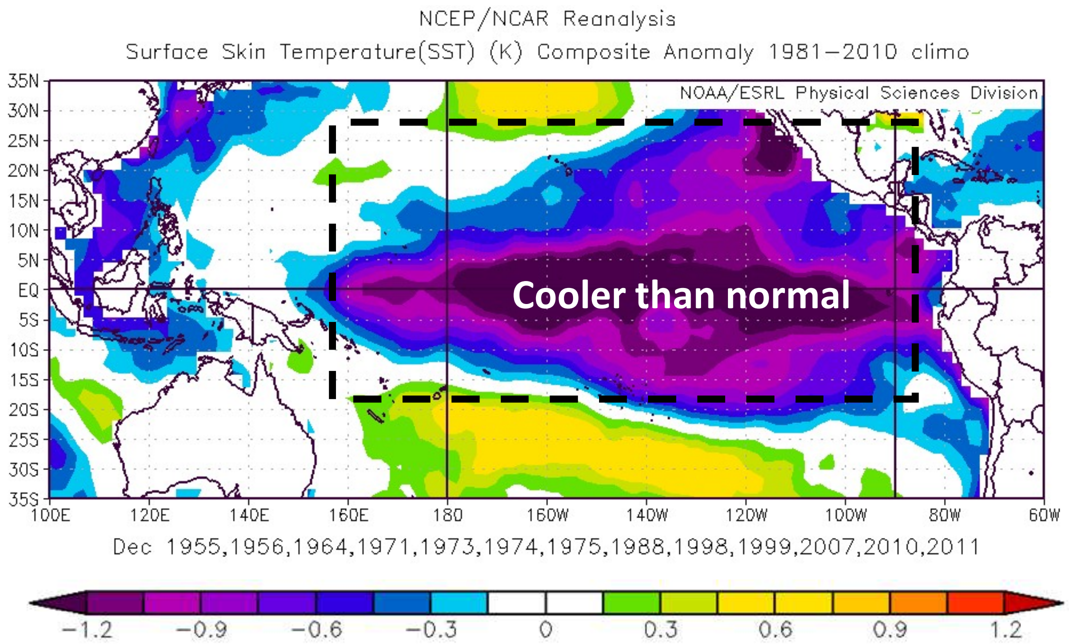
Sea Surface Temperatures in the central and eastern Pacific are typically **above normal**

Boomerang-shaped region of **cooler water** to the west around the warm equatorial waters

Climate and Oceans Support Program in the Pacific

Average December Sea Surface Temperature patterns and anomaly during *La Niña*





Western Pacific Warm Pool has contracted to the far western Pacific. The water above 29°C is more than 40° of longitude west compared to El Niño average.

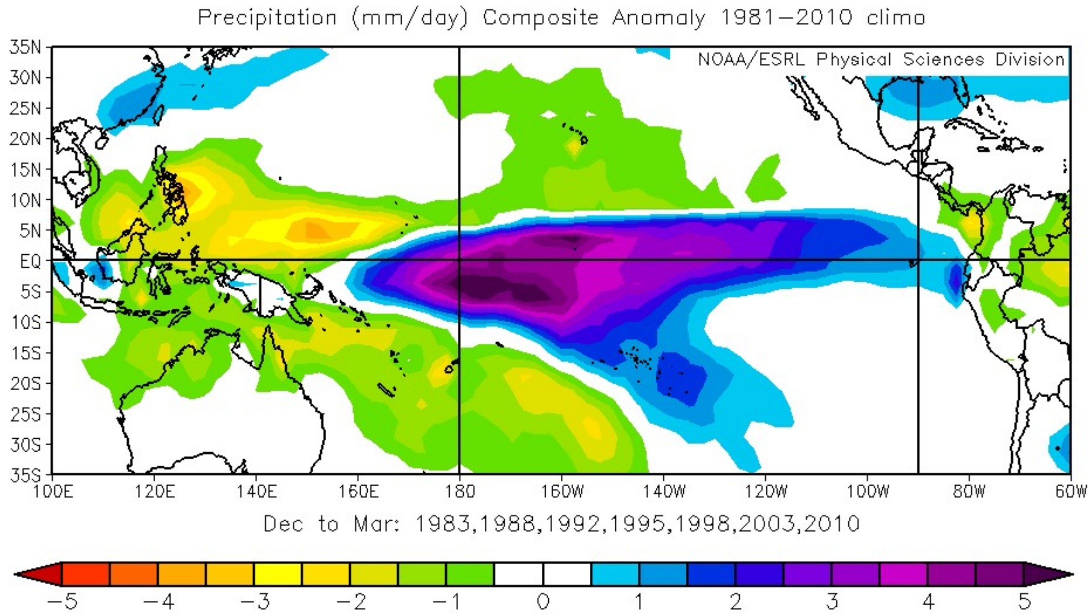
Equatorial Pacific **Cold Tongue is stronger** and further west

Sea Surface Temperatures are typically **below normal** within about 15° of the equator, east of 160°E. Almost the reverse of El Niño but not symmetrical.

Boomerang-shaped region of **warmer water** wrapping around the cool equatorial waters

Average El Niño and La Niña rainfall patterns (mm/day) December - March

El Niño

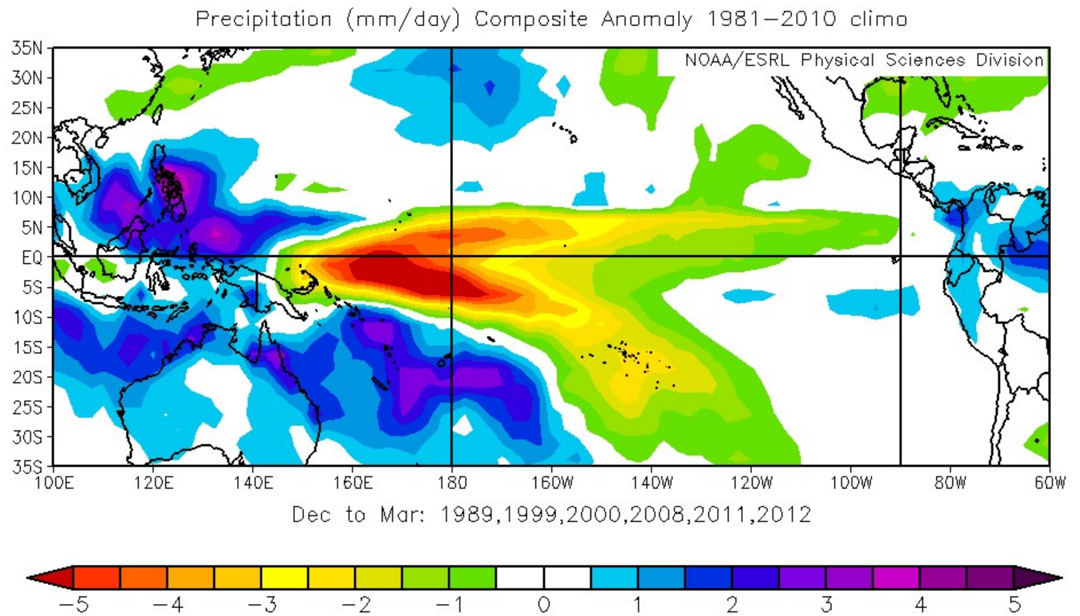


Rainfall ↑ across the **equatorial Pacific** east of 160°E over the anomalously warm water

Rainfall ↓ southwest and **northwest** Pacific, **Maritime Continent** and **northern Australia**

ITCZ is shifted **south**, **SPCZ** is shifted **northeast**

La Niña



Rainfall ↓ across much of the **equatorial Pacific** east of 150°E over the anomalously cool water

Rainfall ↑ southwest and **northwest** Pacific, **Maritime Continent** and **much of Australia**

ITCZ is shifted **north**, **SPCZ** is shifted **southwest**

El Niño – three different types
La Niña – one type

Climate and Oceans Support Program in the Pacific

East Pacific (classic) El Niño: large ‘wedge’ of higher than normal rainfall emerging from South America coast with boomerang of low rainfall to the west

West Pacific El Niño: higher than normal rainfall extending further north and west than for central Pacific event. Generally the weakest of the 3 types.

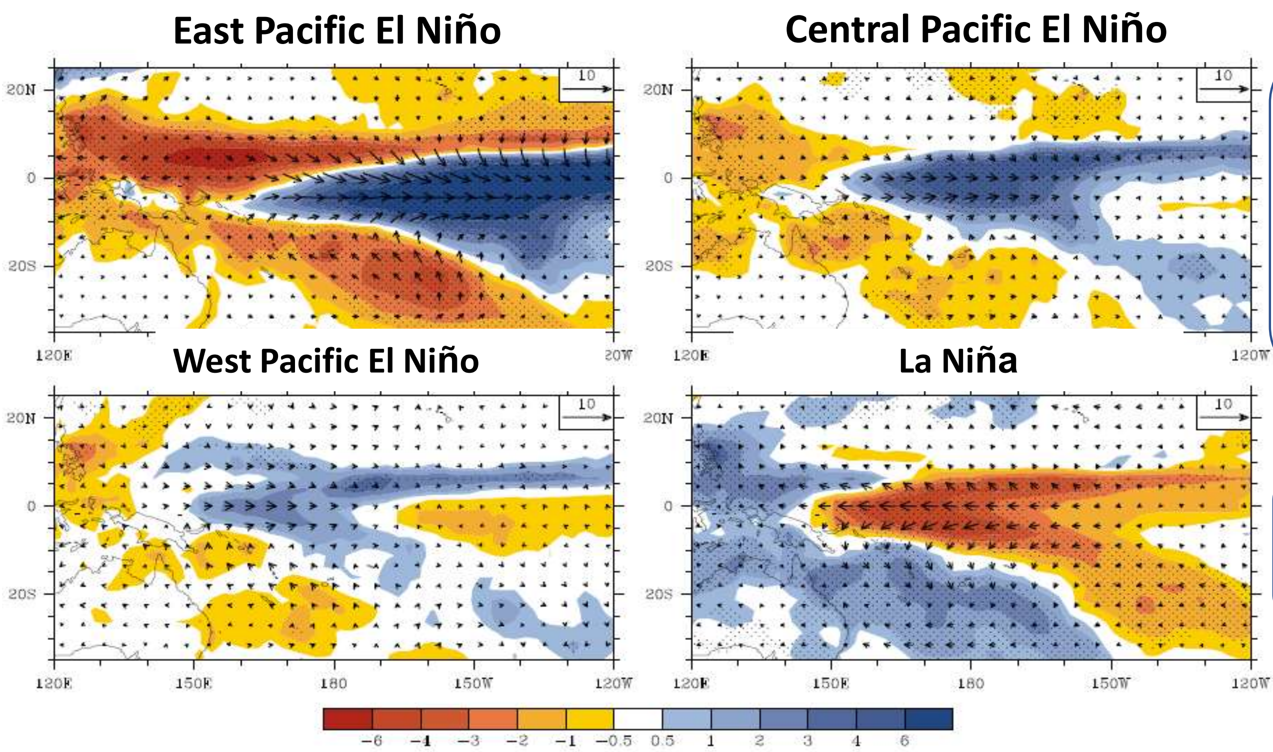


Figure 3: Mean Nov-Apr rainfall anomalies for the 3 El Niño types and for La Niña events. Arrows show the corresponding surface wind anomalies for Sep-Feb. Stippling denotes where the rainfall anomalies are statistically significantly different from zero at the 90% confidence level. Rainfall data are from the GPCP analysis and wind data are from the ERA-Interim reanalysis, 1979-2010.

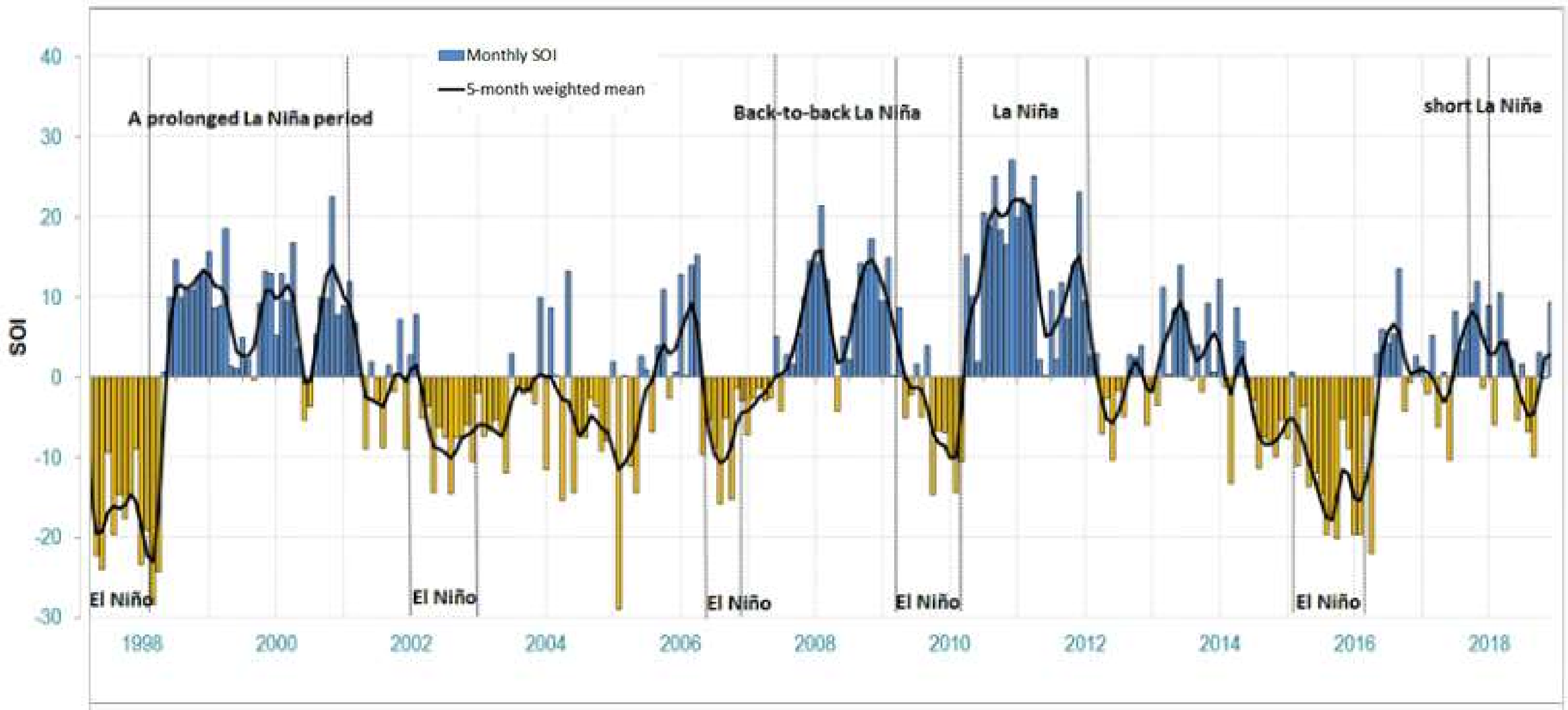
Central Pacific El Niño: ‘Modoki’ El Niño with increased rainfall in the centre of the Pacific

La Niña generally has one form

The type of ENSO event affects where rainfall will occur

Tracking ENSO – Southern Oscillation Index (SOI)

Climate and Oceans Support Program in the Pacific



Difference in air pressure between Tahiti and Darwin

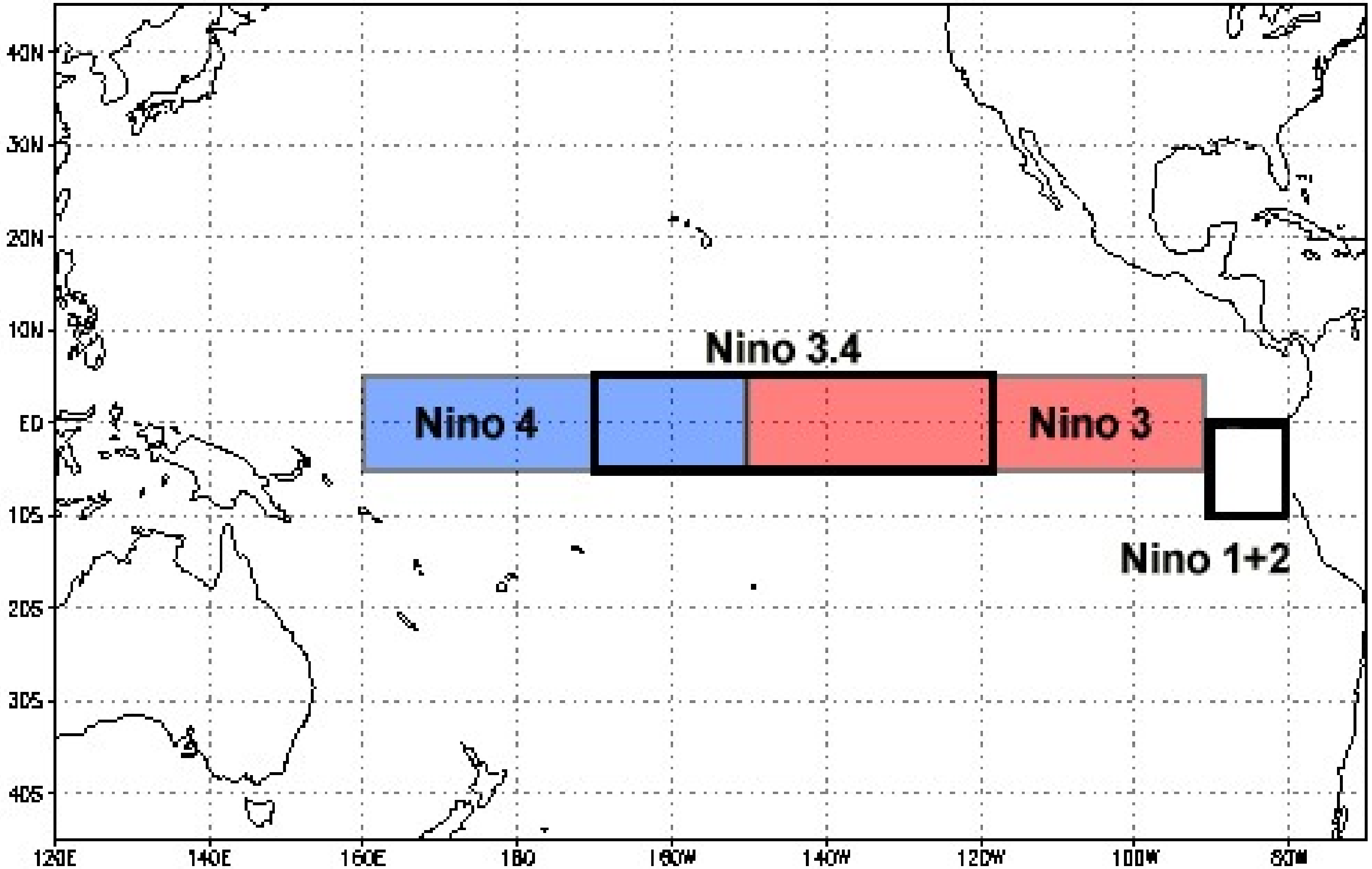
SOI is a sign of the Walker Circulation

Sustained SOI of +7 → La Niña

Sustained SOI of −7 → El Niño

Understanding SOI = understand ENSO event

Tracking ENSO – Sea Surface Temperatures (NINO Indices)



One way ENSO is monitored is by looking at particular areas of the Pacific Ocean

The **NINO indices** give a summary of the equatorial **Sea Surface Temperatures (SSTs)**, and the state of ENSO

The SST anomaly in the box is averaged.

Thresholds for El Niño and La Niña events are about **+0.8°C** and **–0.8°C** respectively, for **NINO3** and **NINO3.4**

NINO3.4 is most commonly used for **tracking ENSO**

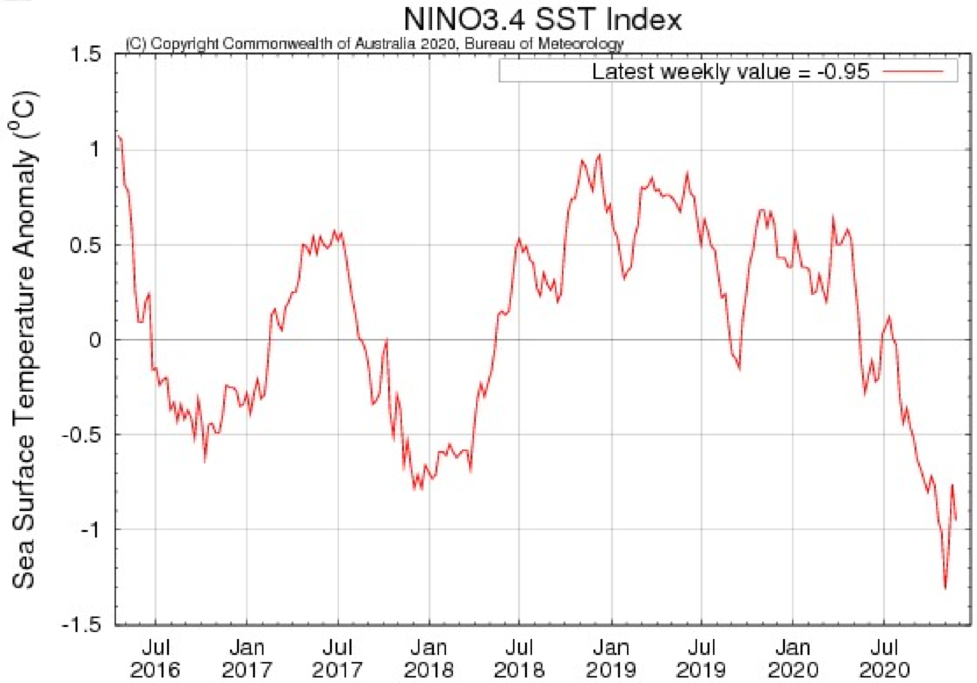
Tracking ENSO – NINO Indices

Climate and Oceans Support Program in the Pacific

NINO3.4 (2002 – 2021)

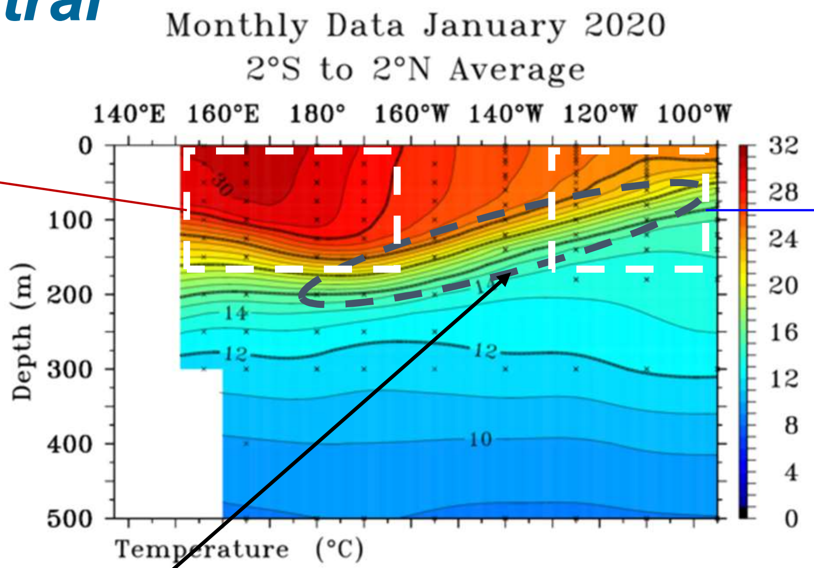
Above (from NOAA-CPC): gives long-term (20-year) perspective

Right (from BoM): gives recent (4-year) perspective



Tracking ENSO – Sub-surface temperatures
ENSO *neutral*

Warm waters *deeper* in west 29°C at 100m depth



Warm waters *shallow* in east 15°C at 100m depth

Strongest temperature gradient (i.e. isotherms are bunched together) is called the **thermocline –** the 20°C isotherm sits very close to the middle of the thermocline

Thermocline: is deepest in the west and shallowest in the east, so that it slopes upwards from west to east

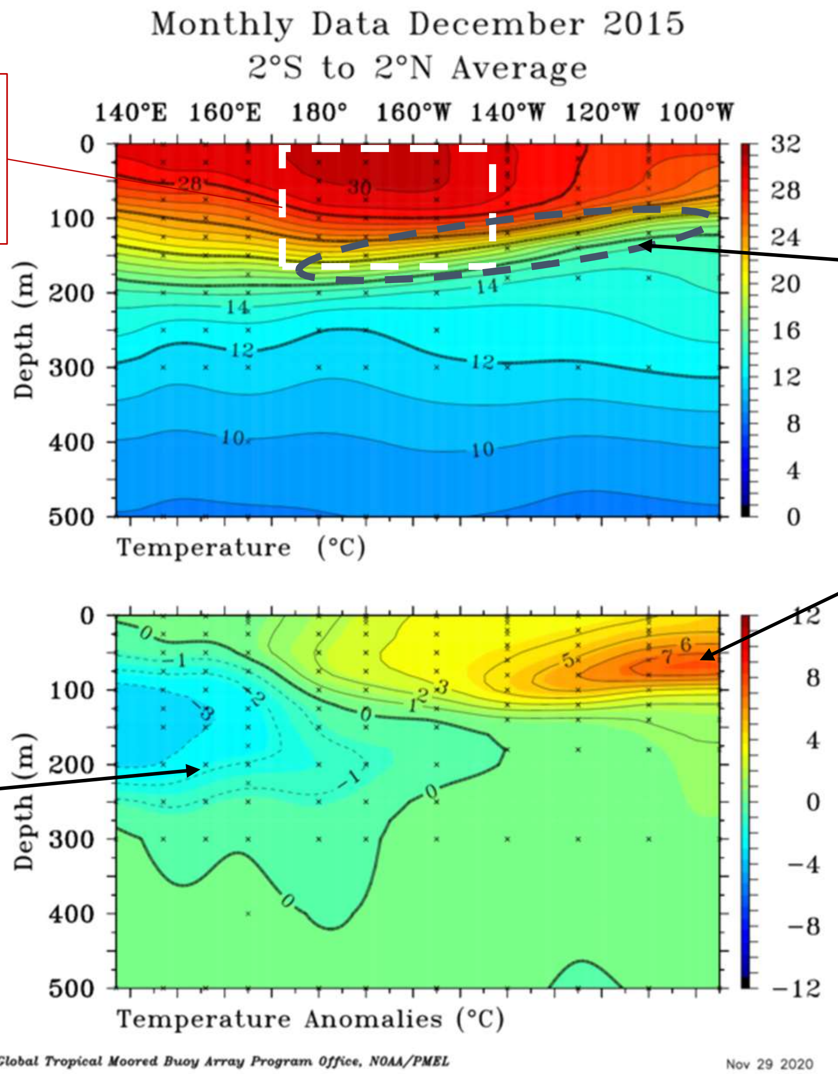
Sub-surface temperature profile from Global Tropical Moored Buoy Array

Tracking ENSO – Sub-surface temperatures

El Niño

Climate and Oceans Support Program in the Pacific

Warmest waters in central Pacific



Thermocline is **flatter than average** shallower in west and deeper in east. Warm water has moved into the eastern Pacific.

Strong positive temperature anomalies in the eastern Pacific are a typical signature of a mature strong El Niño

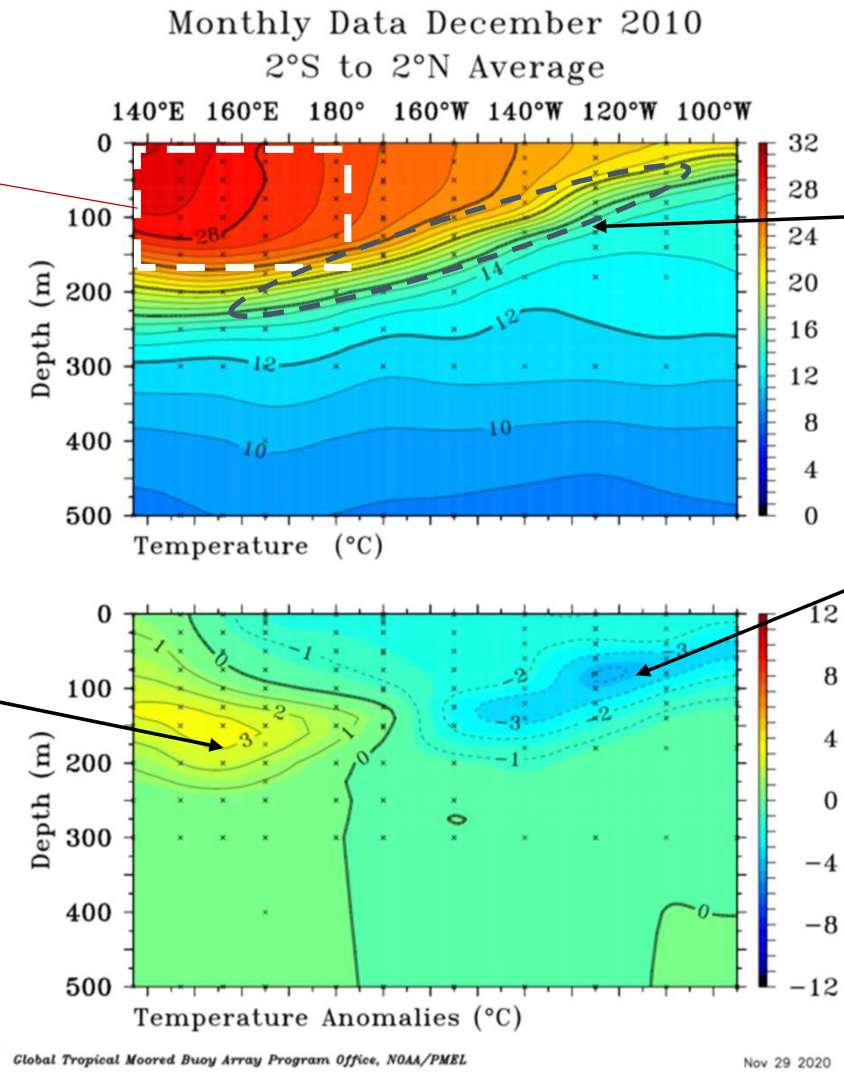
Negative temperature anomalies developing in the west and undercutting the positive anomalies are another typical sub-surface sign of El Niño

Strong El Niño: December 2015

Tracking ENSO – Sub-surface temperatures *La Niña*

Climate and Oceans Support Program in the Pacific

Warmest waters shifted to west



Thermocline is **steeper than average** deeper in west and shallower. Cool water is upwelling in east.

Strong negative temperature anomalies in the eastern Pacific are a typical signature of a mature strong La Niña

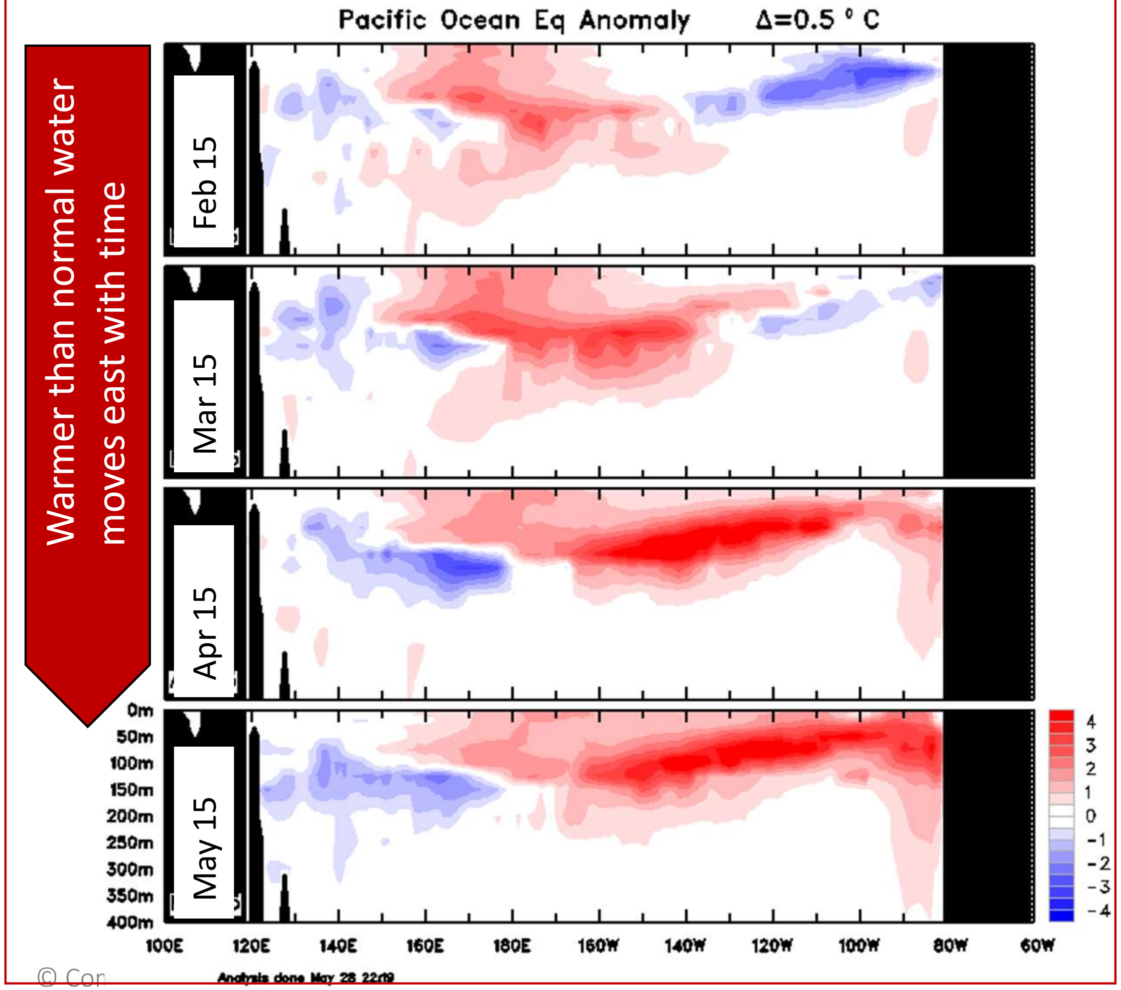
Positive temperature anomalies developing in the west and undercutting the negative anomalies are another typical sub-surface sign of La Niña

Strong La Niña: December 2010

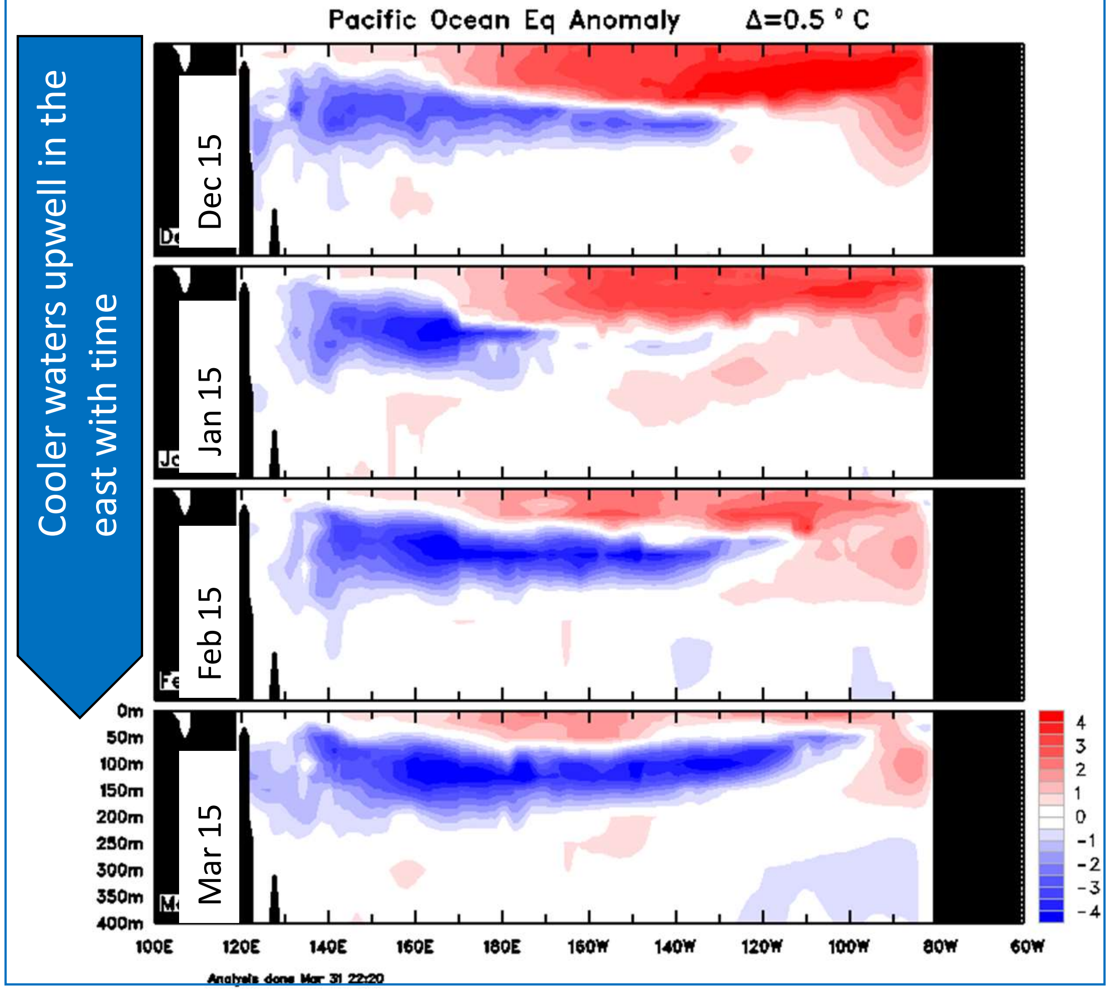
El Niño: four-month sequences development and decay: sub-surface temperature

Climate and Oceans Support Program in the Pacific

El Niño Development Phase



El Niño Decay Phase

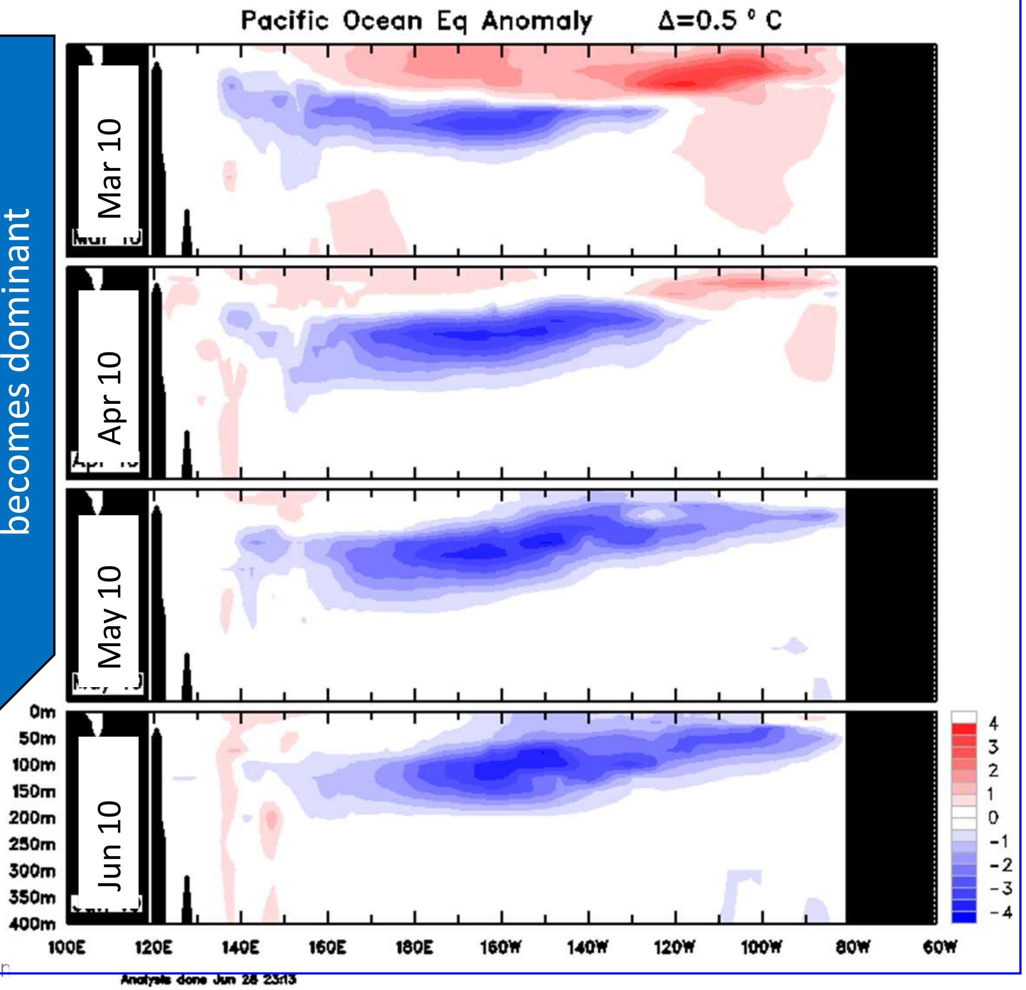


La Niña: four-month sequences, development and decay: sub-surface temperatures

Climate and Oceans Support Program in the Pacific

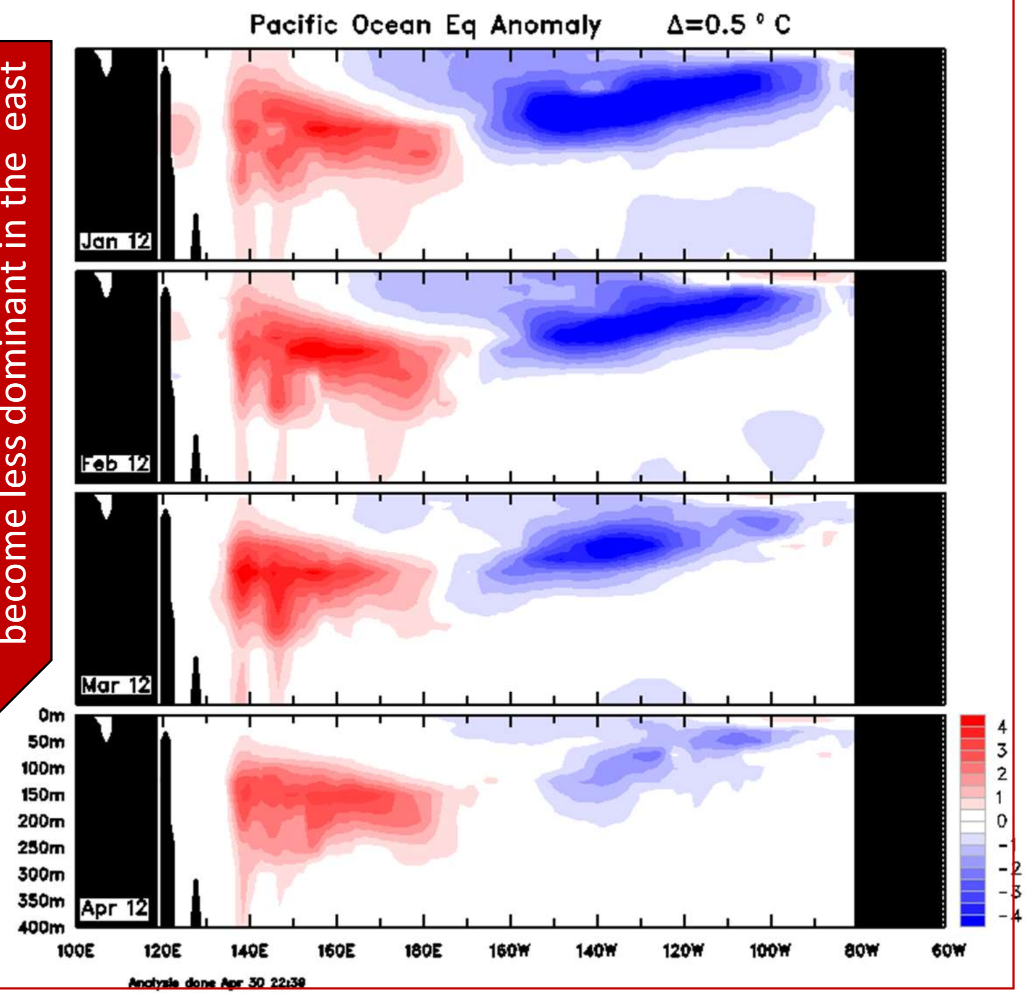
La Niña Development Phase

Cooler than normal water becomes dominant

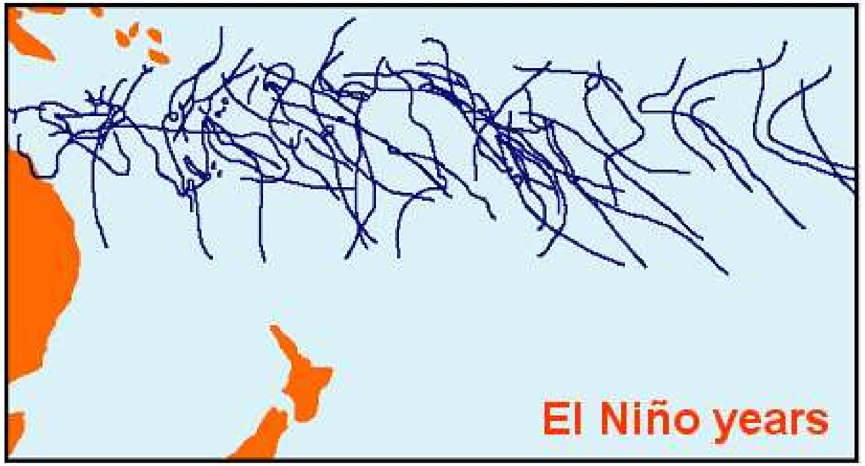


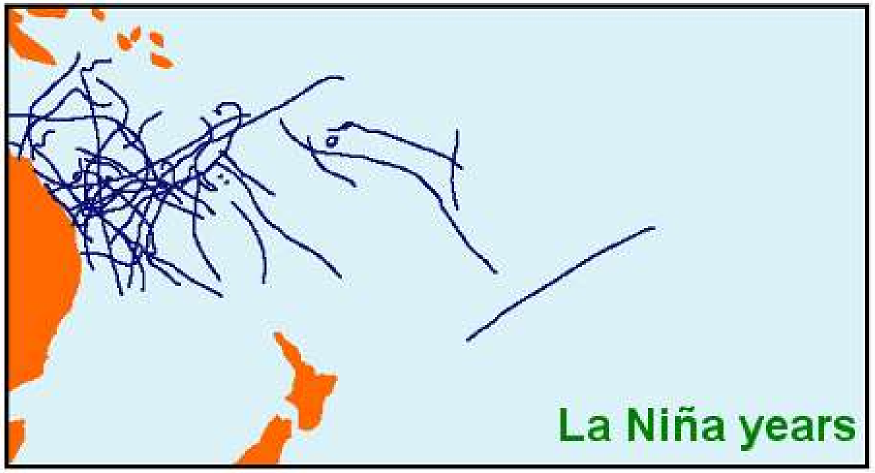
La Niña Decay Phase

Cooler than normal waters become less dominant in the east



ENSO and Tropical Cyclones





Cyclogenesis requires Sea Surface Temperatures (SSTs) higher than 26.5°C

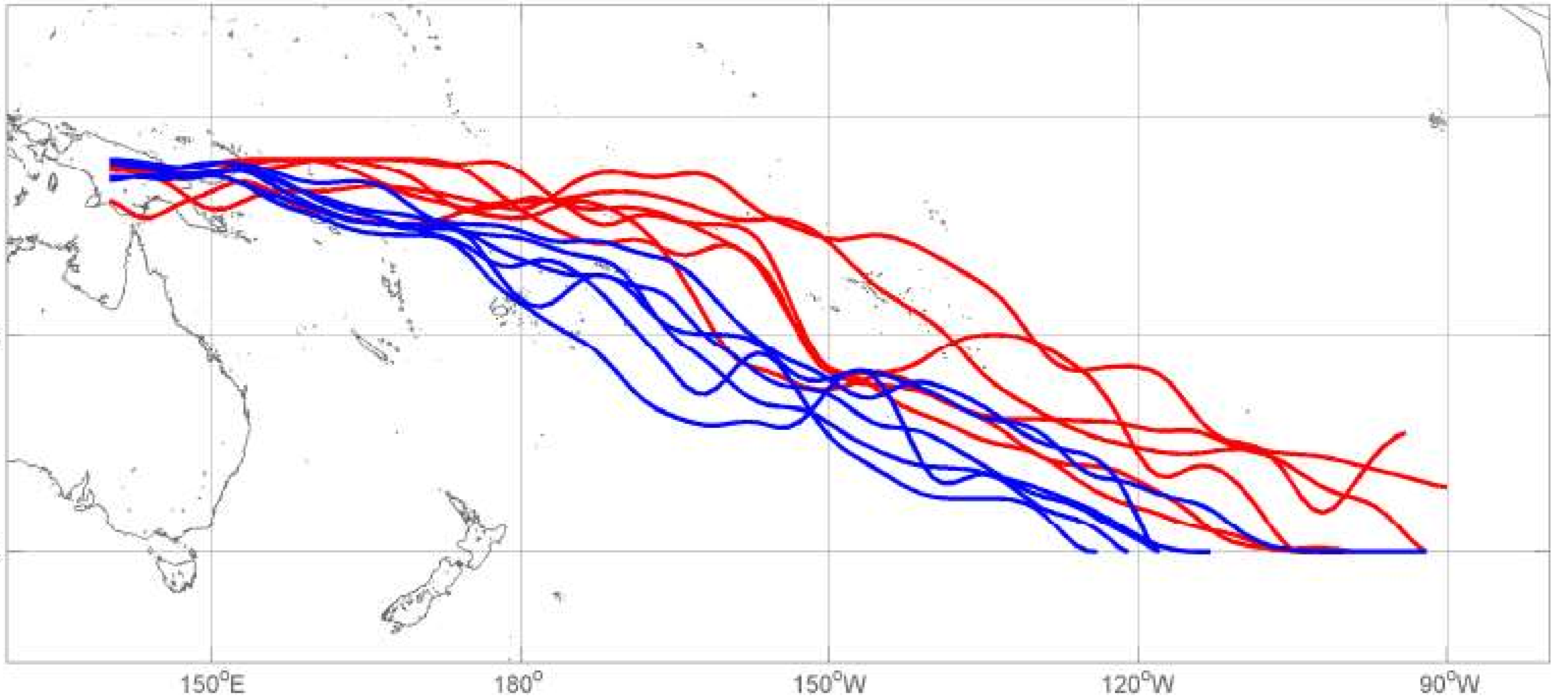
Intensity of cyclones linked to **higher SSTs**

El Niño: higher SSTs in Central Pacific, increased cyclogenesis in this region = Tropical Cyclones spread out

La Niña: cyclogenesis region pushed into Western Pacific due to lower SSTs in Central Pacific = Tropical Cyclones closer together

Climate and Oceans Support Program in the Pacific

ENSO and the South Pacific Convergence Zone (SPCZ)
(from James Renwick & Brett Mullan, NIWA, N.Z.)



El Niño

La Niña

Shift in SPCZ position = large rainfall variability in affected countries

Tracking & Monitoring ENSO Summary

Climate and Oceans Support Program in the Pacific

El Niño:

• The Walker Circulation and trade winds weaken.

• Ocean temperatures become warmer than average in the central and eastern Pacific.

• The Southern Oscillation Index (SOI) remains negative for several consecutive months.

• Cloud and rainfall increase over the central and east Pacific. Decreases in the west - over Australia, Indonesia, Solomon Islands etc.

La Niña:

• The Walker Circulation and trade winds strengthen.

• Ocean temperatures become cooler than average in the central and eastern Pacific.

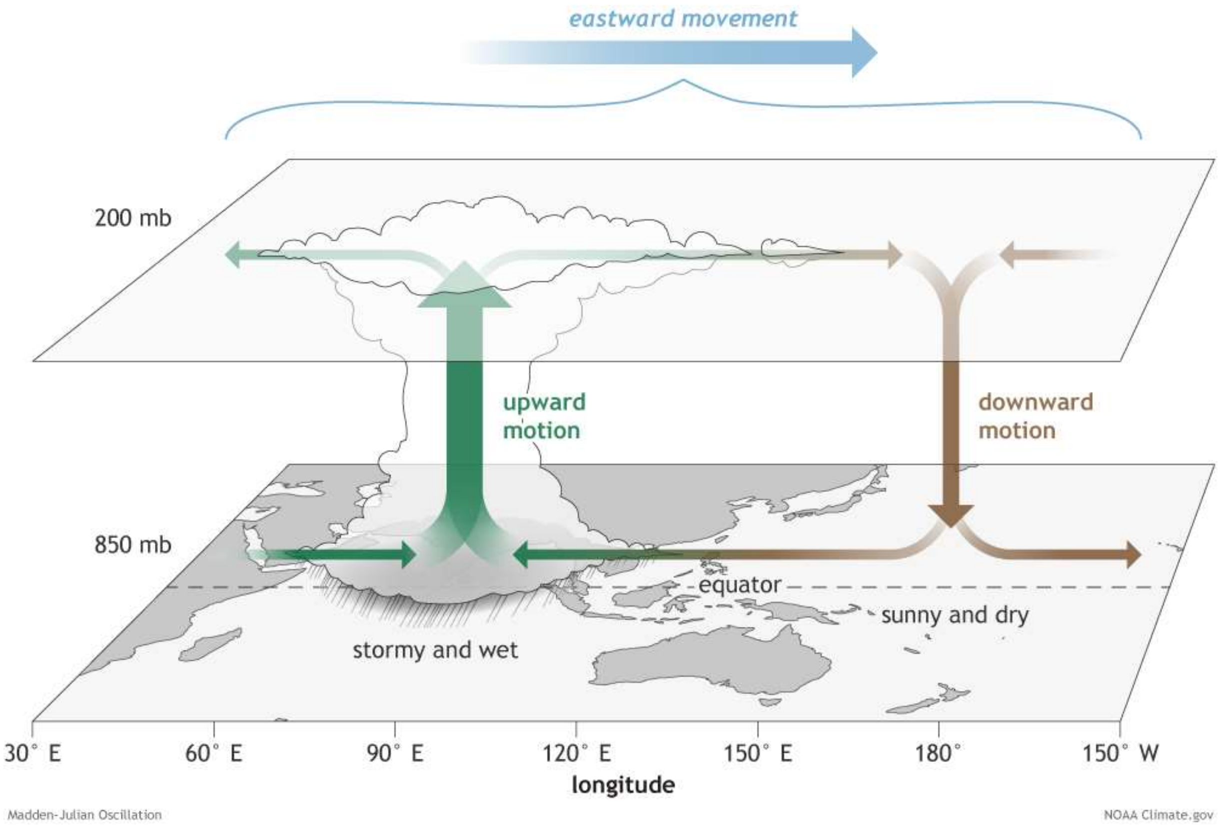
• The Southern Oscillation Index (SOI) remains positive for several consecutive months.

• Cloud and rainfall decrease over the central and east Pacific. Increases in the west - over Australia, Indonesia, Solomon Islands etc.

Discussion questions

- Why are there multiple ways to track ENSO?
- What role do the trade winds have in sea surface temperatures and rainfall?
- How would you plan for a La Niña event?
- Would your country have more tropical cyclones during El Niño or La Niña?

The Madden-Julian Oscillation (MJO)

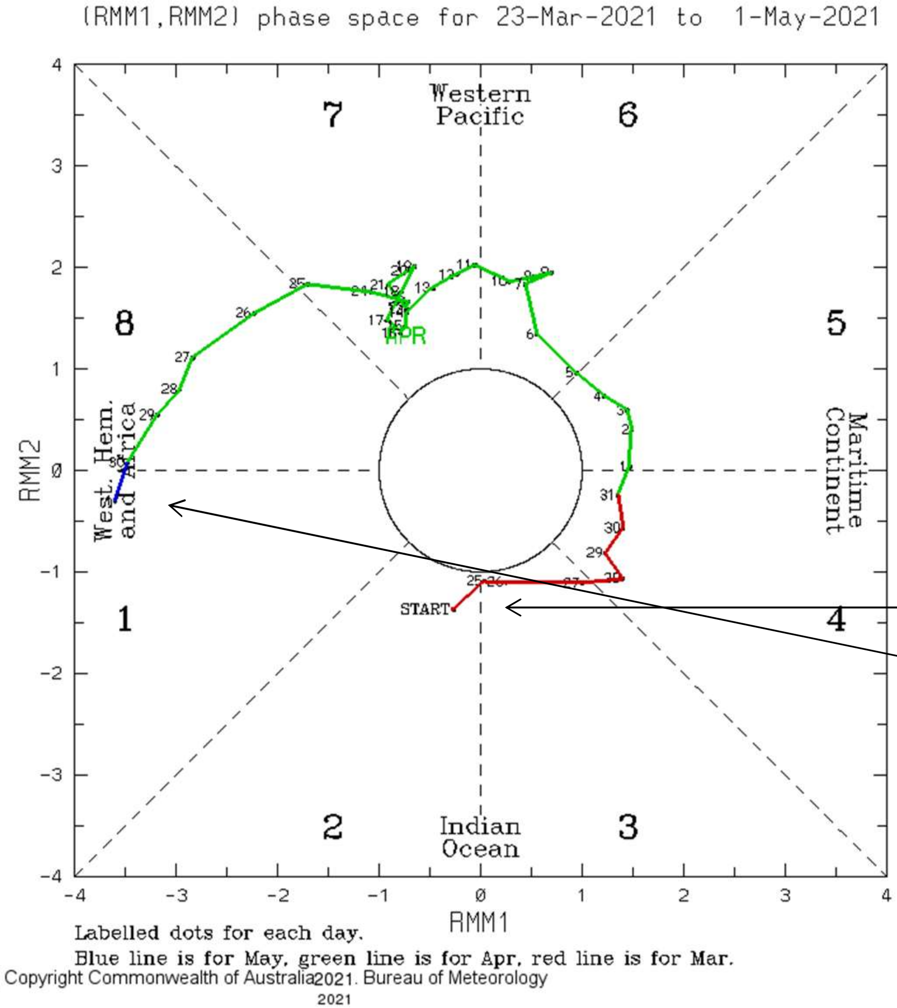


- Starts over western Indian Ocean and moves east over the western and central tropical Pacific.
- Features enhanced rainfall followed by a dry phase
- Cycle around the globe lasts 30–60 days
- **Brings active and break phases of the monsoon or wet season**
- **Increased chance of Tropical Cyclones**
- Winds from MJO can help El Niño development
- More active in southern summer/autumn

The Madden-Julian Oscillation (MJO)

Video - https://www.climatekelpie.com.au/index.php/climatedogs/

Monitoring Madden-Julian Oscillation (MJO)

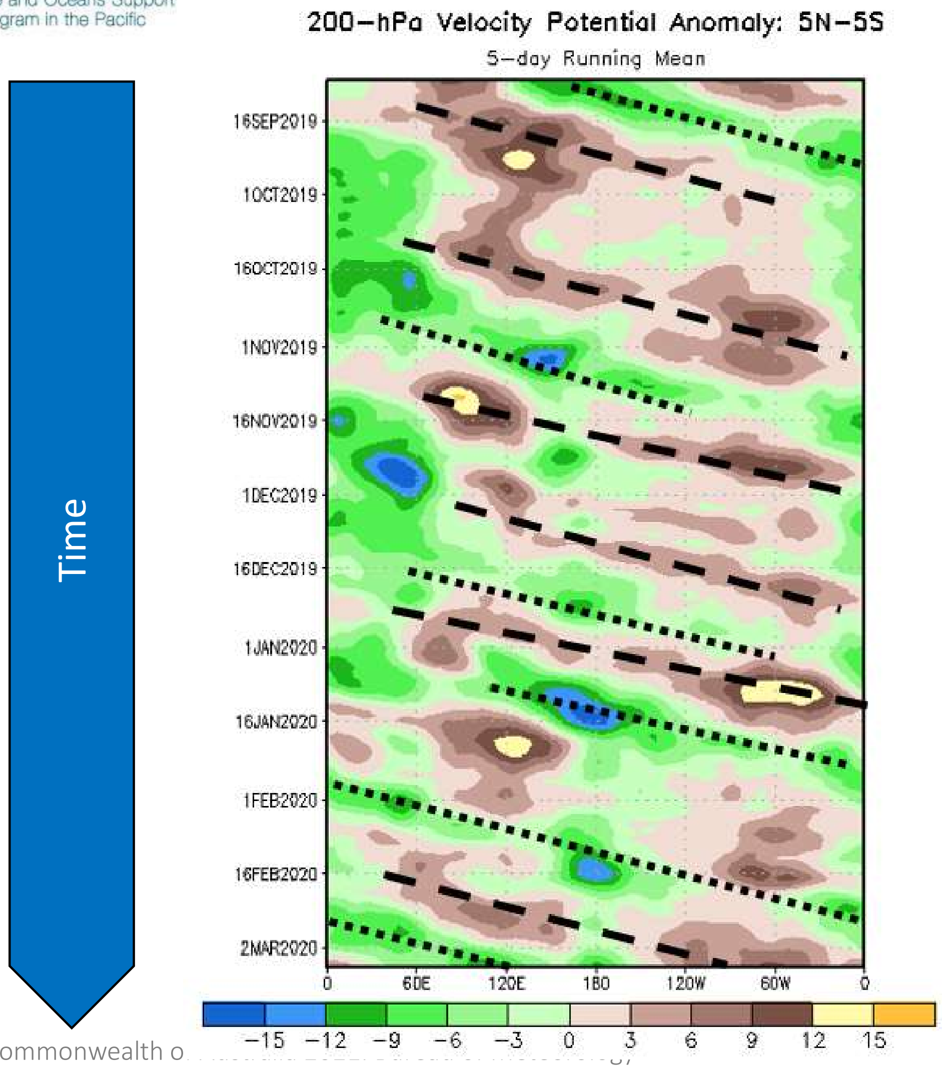


MJO Phase Diagram – 40 days

- Uses wind and cloud observations
- Daily strength of wind and cloud are calculated and plotted as a point on diagram. The **small numbers** are the **dates**. **New colour** for **each month**.
- An **active** period of the MJO is when the points form an **anti-clockwise** spiral **outside** the centre circle.
- The centre circle represents a weak or non-existent MJO signal. This example is a weak MJO
- The edges of the diagram represents stronger MJO. This is an example of a strong MJO.

Climate and Oceans Support Program in the Pacific

Monitoring the Madden-Julian Oscillation (MJO)



MJO Time-Longitude Plot

Brown/Yellow = **less cloud** and rain than normal

Green/Blue = **more cloud** and rain than normal

Time runs down the page

Areas of high or suppressed convection move from west to east through time

Dotted black lines show the **propagation of active** (wet) phase of the MJO

Dashed black lines show the **propagation of inactive** (dry) phase of the MJO

200 hPa Velocity Potential is related to the amount of convergence or divergence high in the atmosphere

Climate and Oceans Support Program in the Pacific

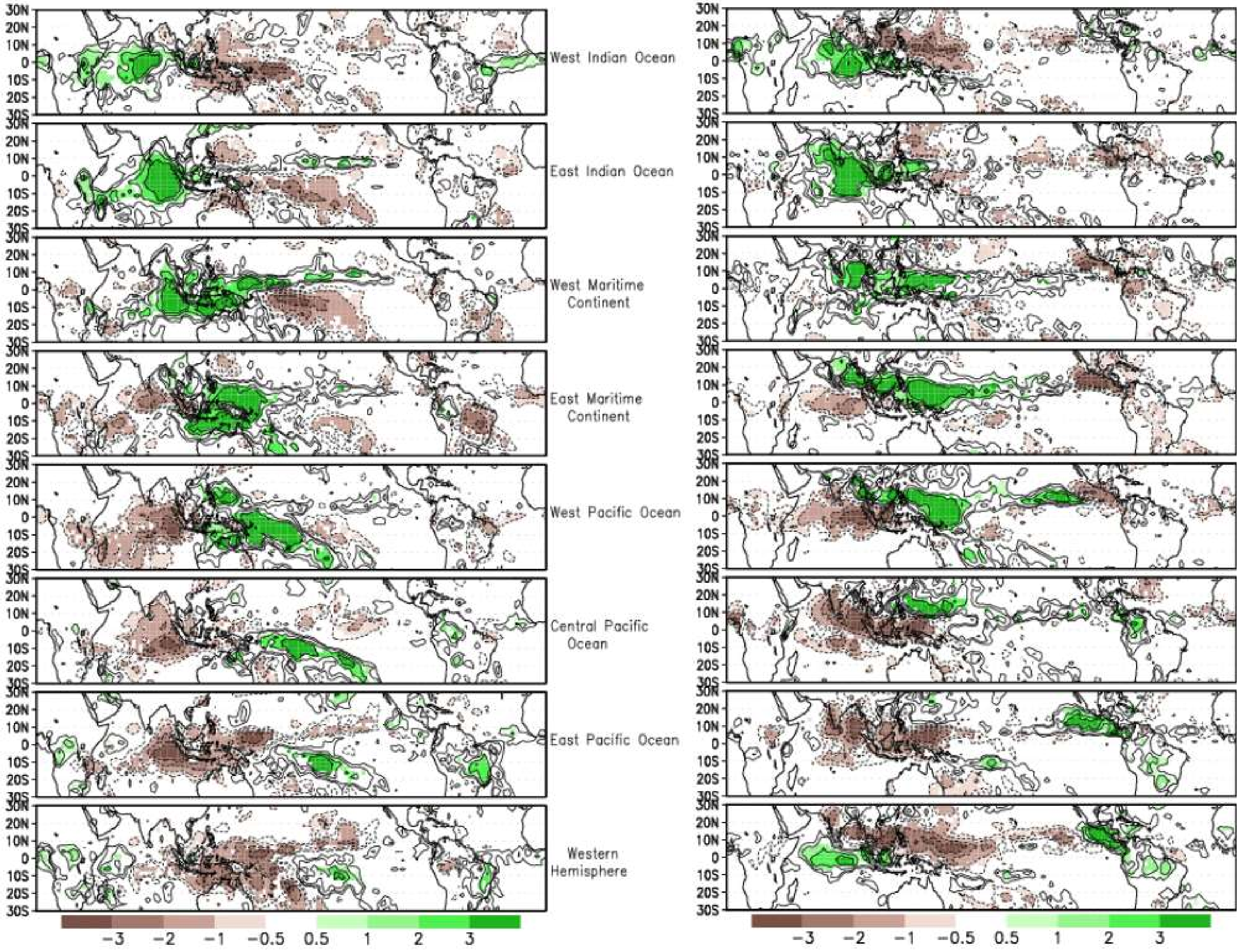
MJO Phase Averages

Left: Nov-March

Right: May-Sept

Units: Rain mm/day

Areas of higher rainfall move east with areas suppressed rainfall following behind



Phase

2

3

4

5

6

7

8

1

Madden-Julian Oscillation (MJO) summary

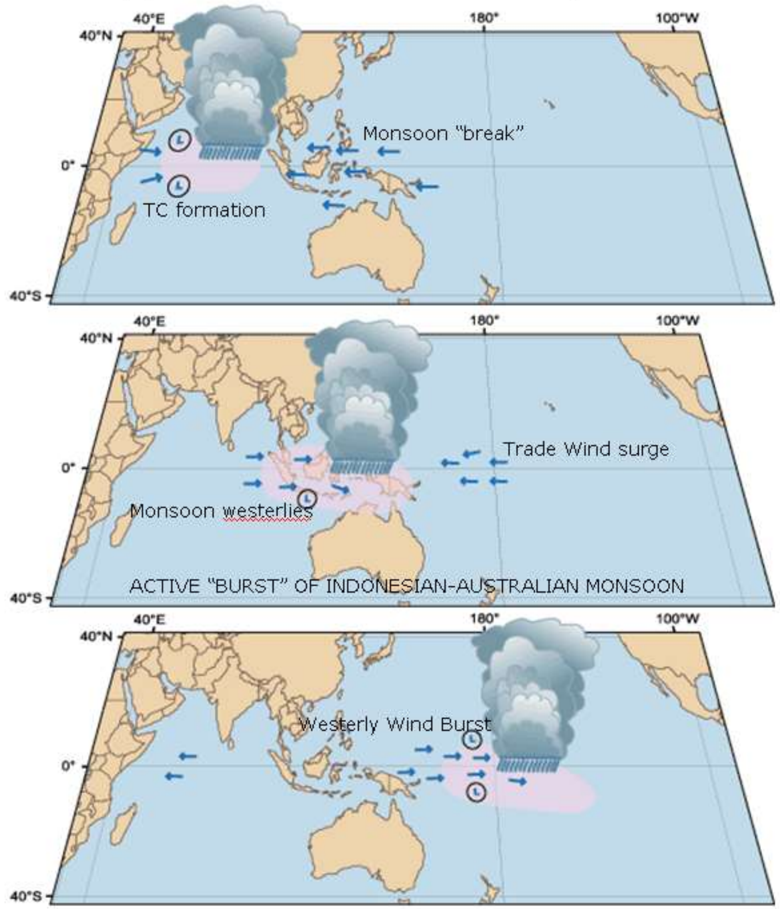
Topics covered

- MJO moves from west to east around tropics
- MJO has a 30-60 day cycle
- Tracking MJO with phase diagram

Discussion questions

- How can the position and strength of the MJO affect tropical rainfall?

Approximate 1 month sequence



Indian Ocean Dipole (East Timor and PNG)

Video - https://www.climatekelpie.com.au/index.php/climatedogs/

Pacific climate module summary

- El Niño Southern Oscillation (ENSO)
  - Sea surface temperatures
  - Rainfall
  - Tracking
  - ENSO and Tropical Cyclones
  - ENSO and (SPCZ)
- Madden-Julian Oscillation (MJO
  - Monitoring MJO
  - MJO Phases