Climate and Oceans Support
Program in the Pacific

ACCESS-S Workshop

MODULE: Pacific climate drivers – focus on ENSO

Climate and Oceans Support Program in the Pacific

Topics in this module

- El Niño–Southern Oscillation (ENSO)
- (Madden–Julian Oscillation (MJO)) – covered by next speaker

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

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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.

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El Niño – Southern Oscillation (ENSO)

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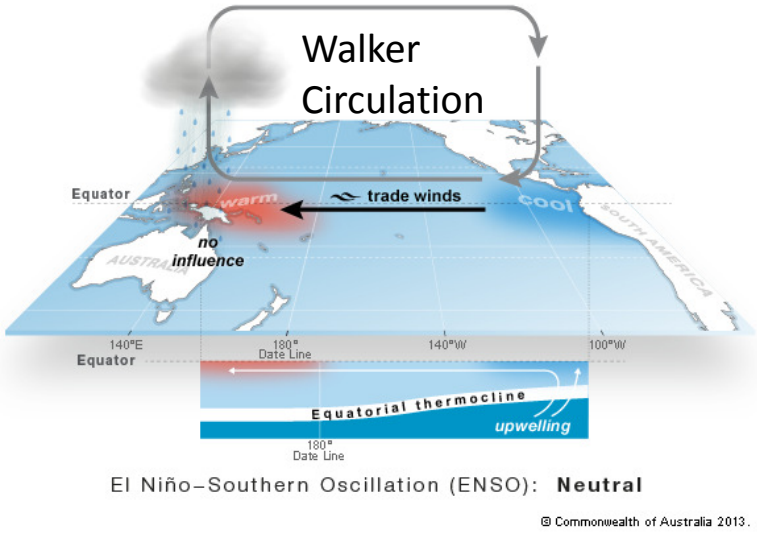
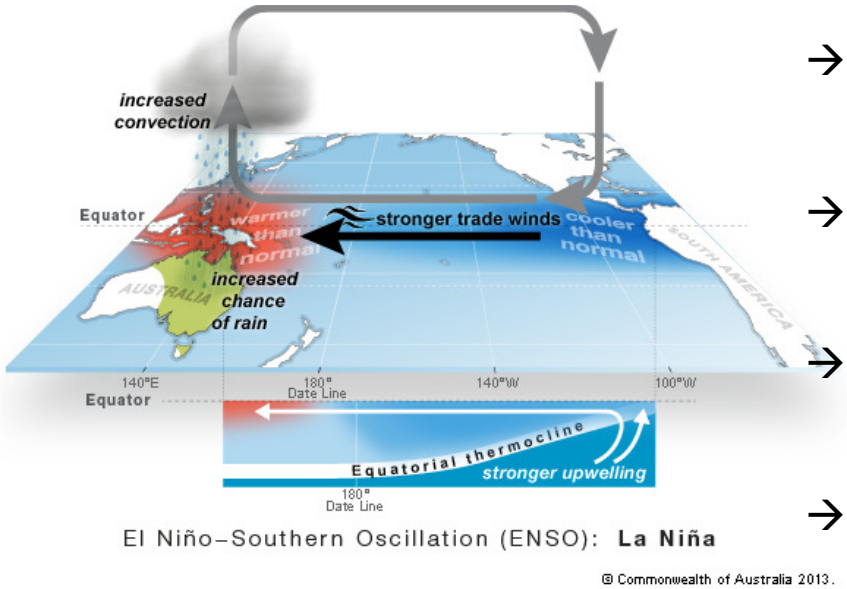
Circulation changes associated with La Niña

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)**

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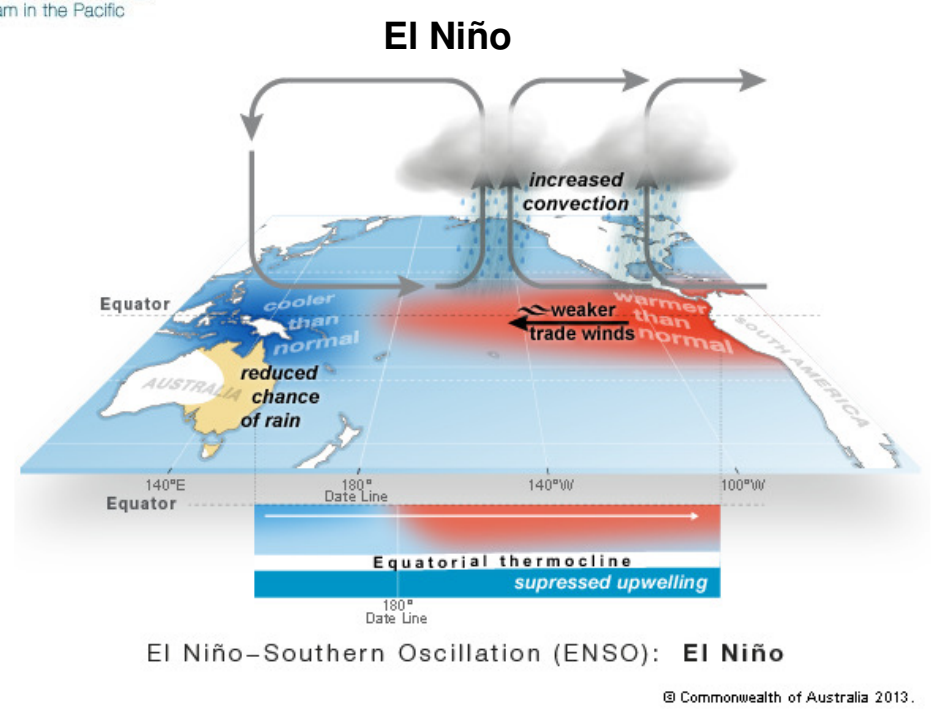
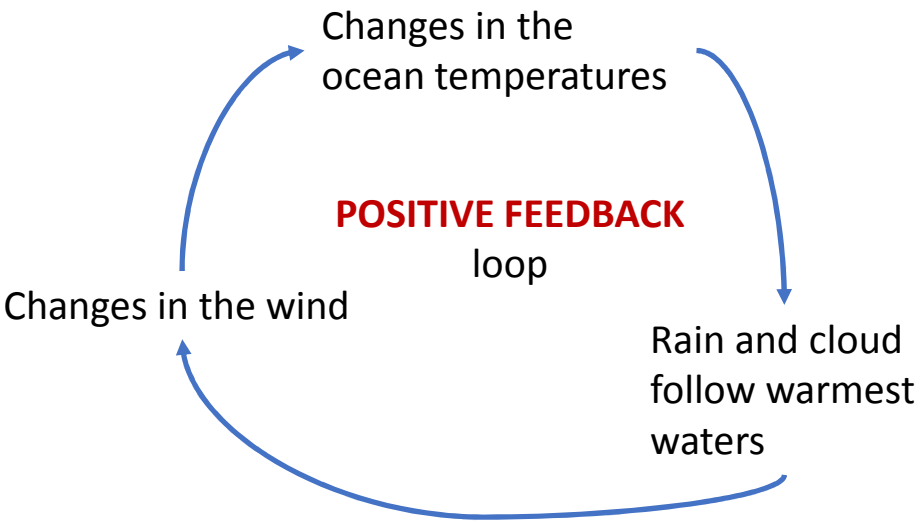
Circulation changes associated with El Niño





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.

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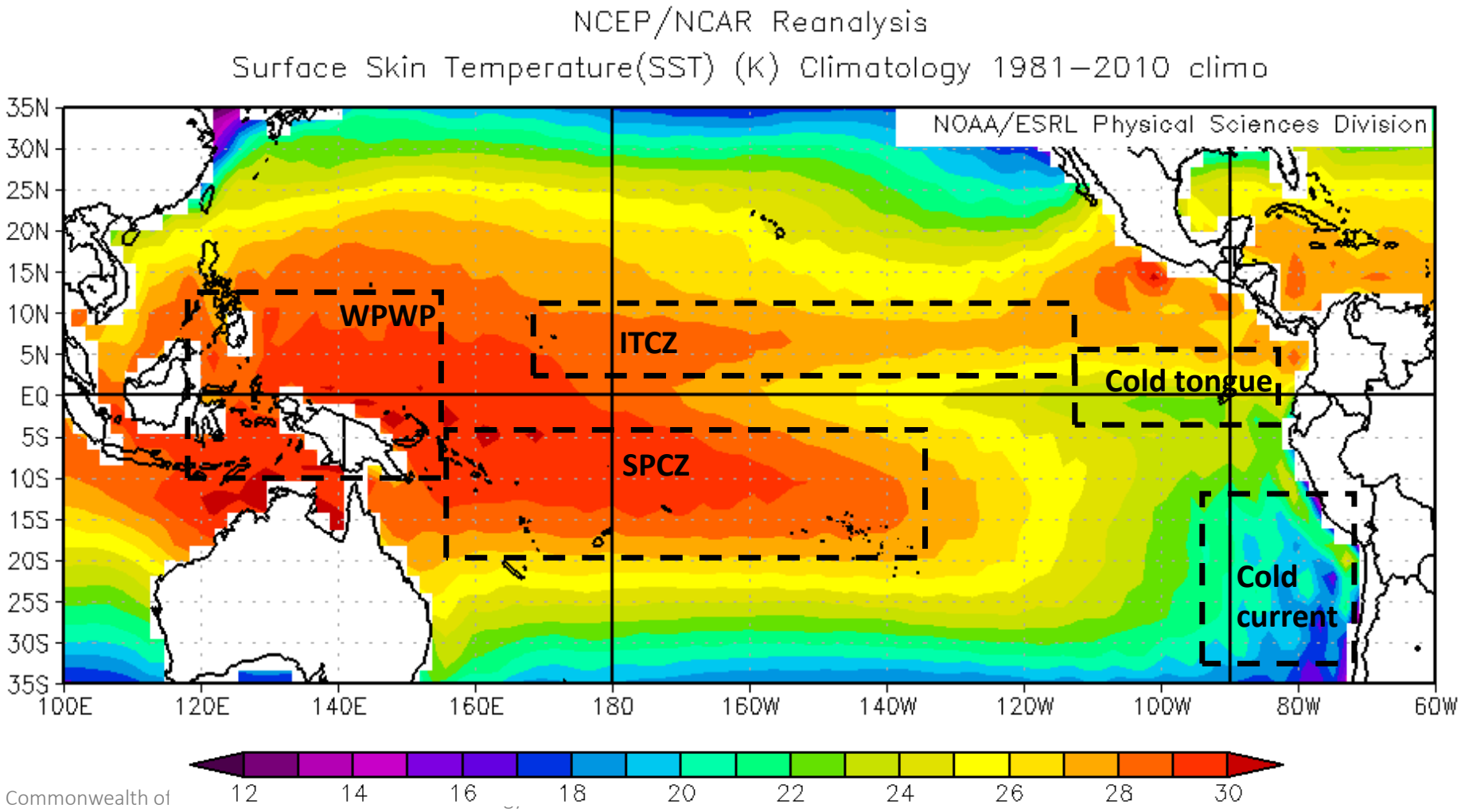
Average December Sea Surface Temperature (SST) pattern during a *neutral* ENSO phase



East equatorial Pacific is cooler than west

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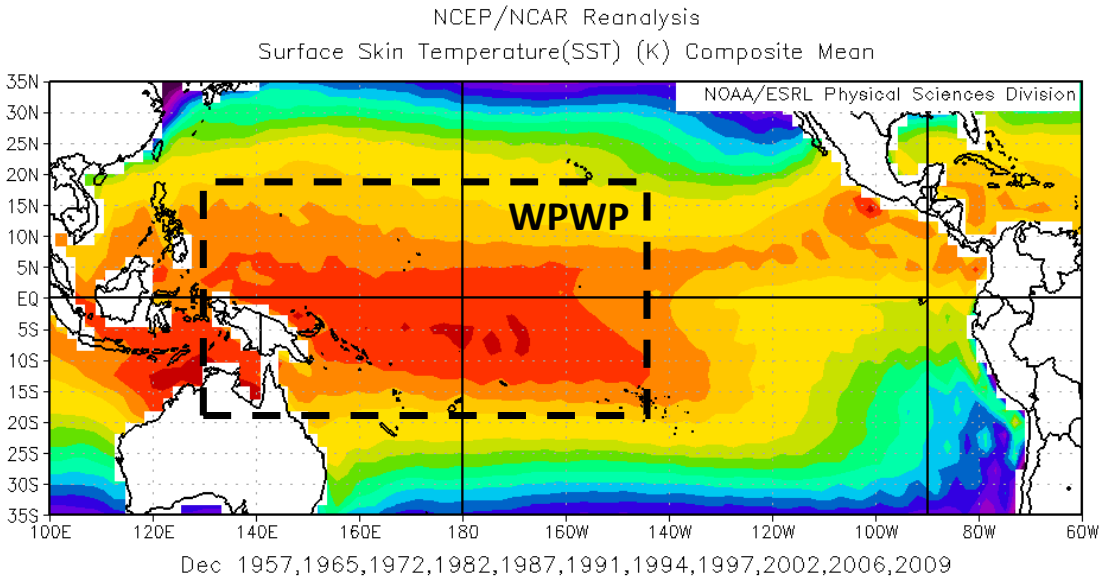
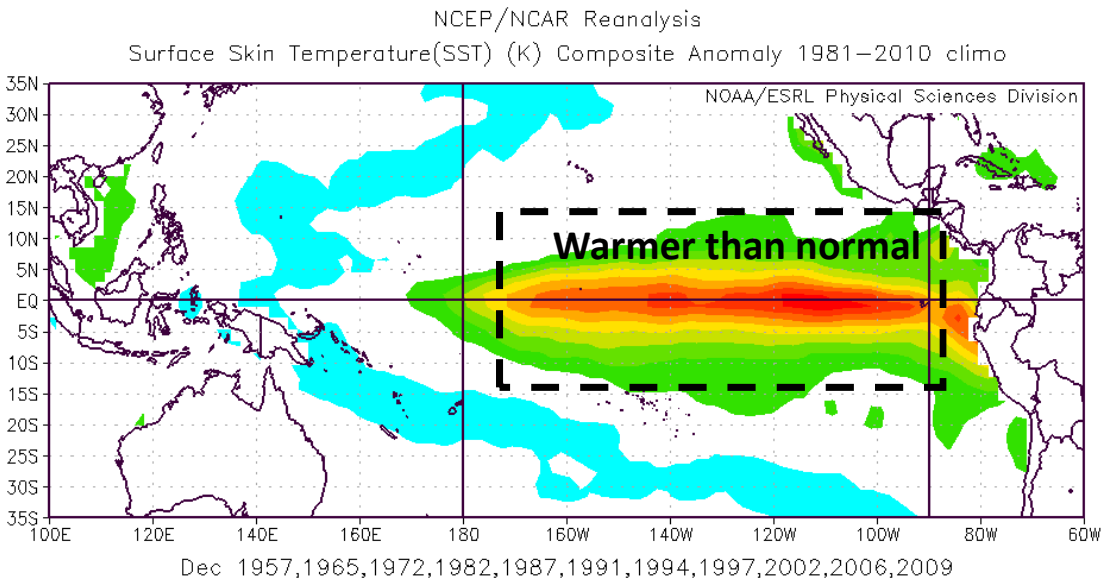
Average December Sea Surface Temperature patterns and anomaly during *El Niño*





Western Pacific Warm Pool has spread east into the central Pacific (29°C on equator 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

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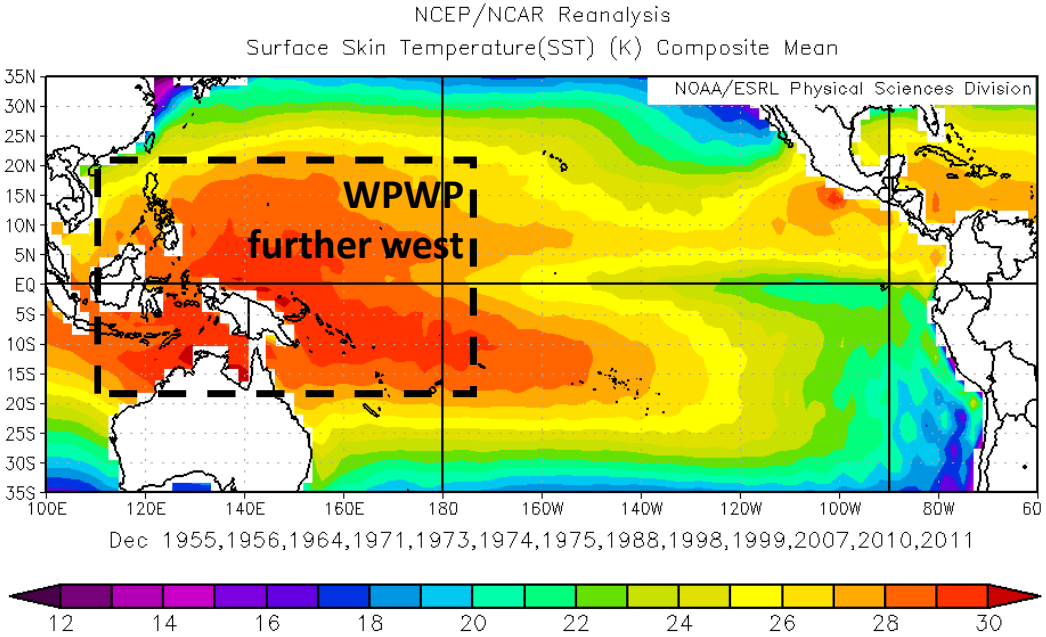
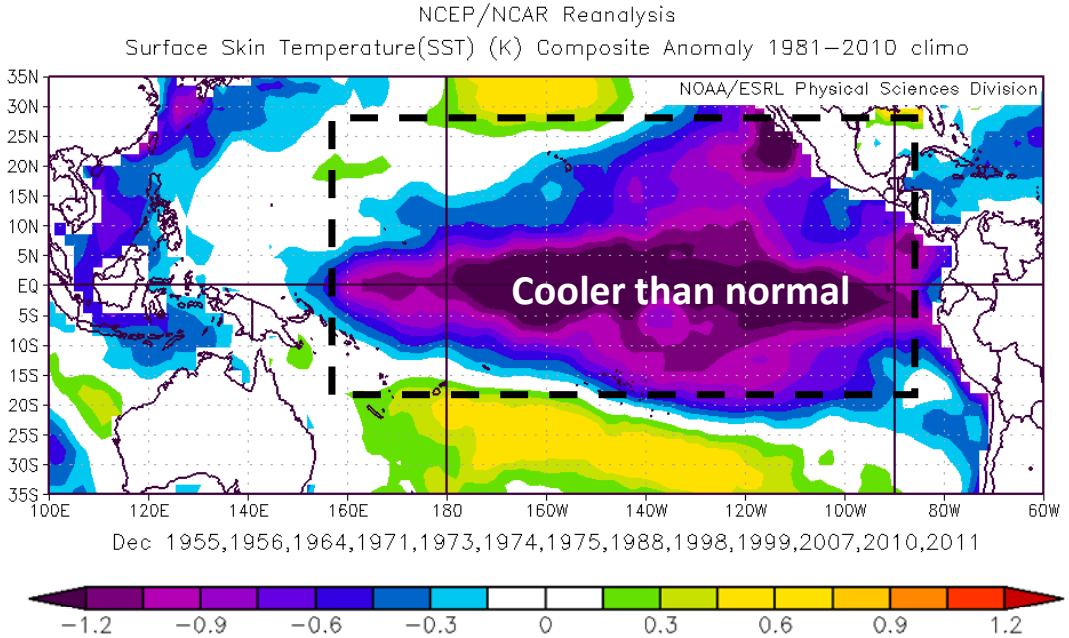
Average December Sea Surface Temperature patterns and anomaly during *La Niña*





Western Pacific Warm Pool has contracted to the far western Pacific. The water above 29°C on equator 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

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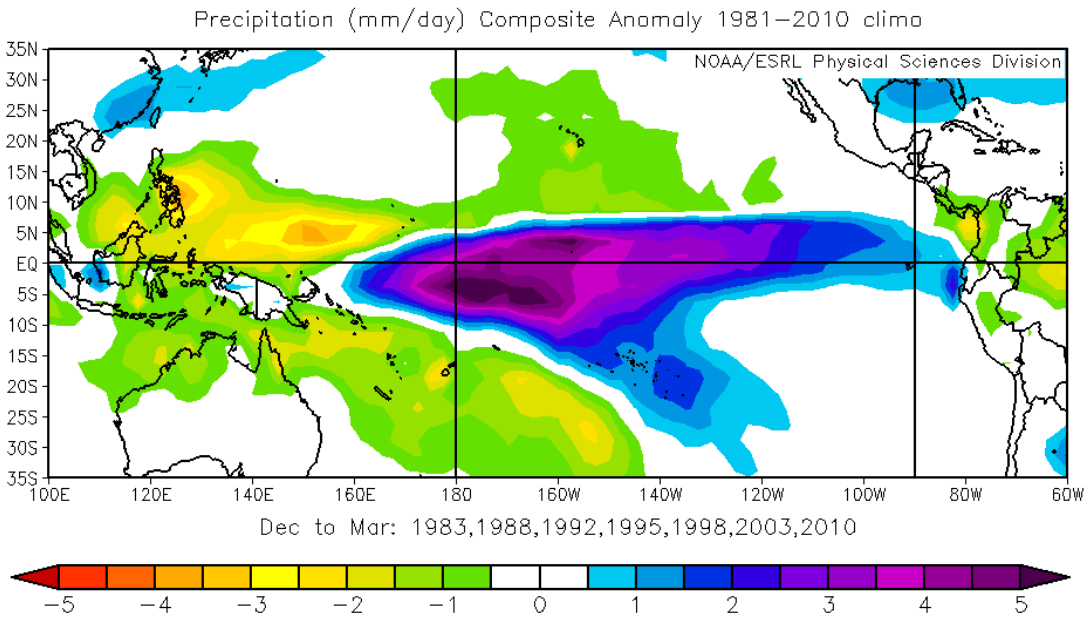
Average El Niño and La Niña rainfall patterns (mm/day) December - March

El Niño

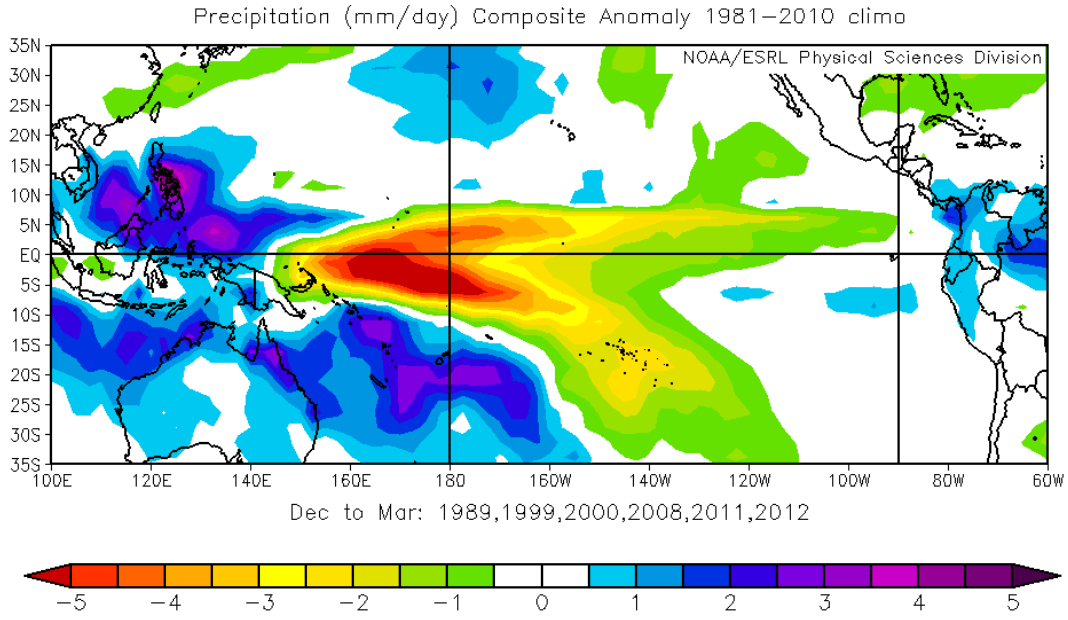


Rainfall ↑ across the **equatorial Pacific** east of 160°E over the anomalously warm water

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**

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El Niño – three different types
La Niña – one type

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.

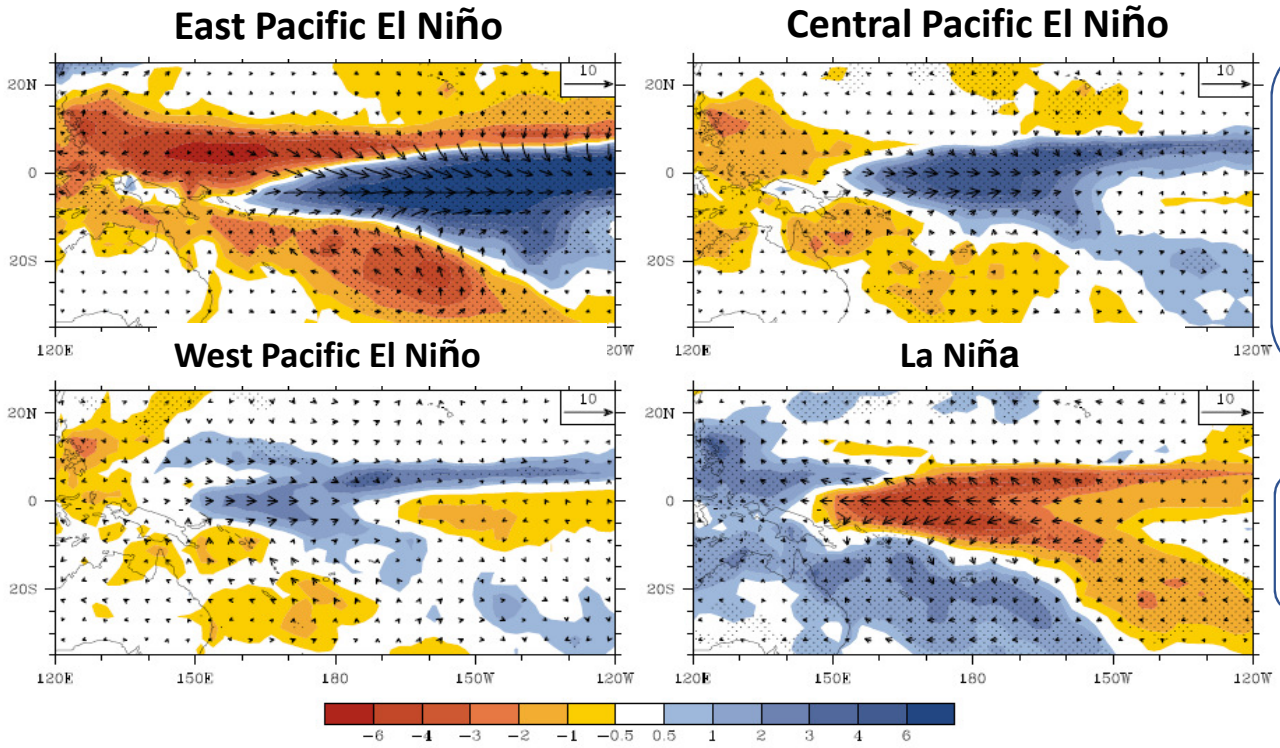

Figure 3: Mean Nov-Apr rainfall anomalies for the 3 El Niño types and for La Niña events. Arrows show the corresponding surface wind anomalies for Sep-Feb. Stippling denotes where the rainfall anomalies are statistically significantly different from zero at the 90% confidence level. Rainfall data are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

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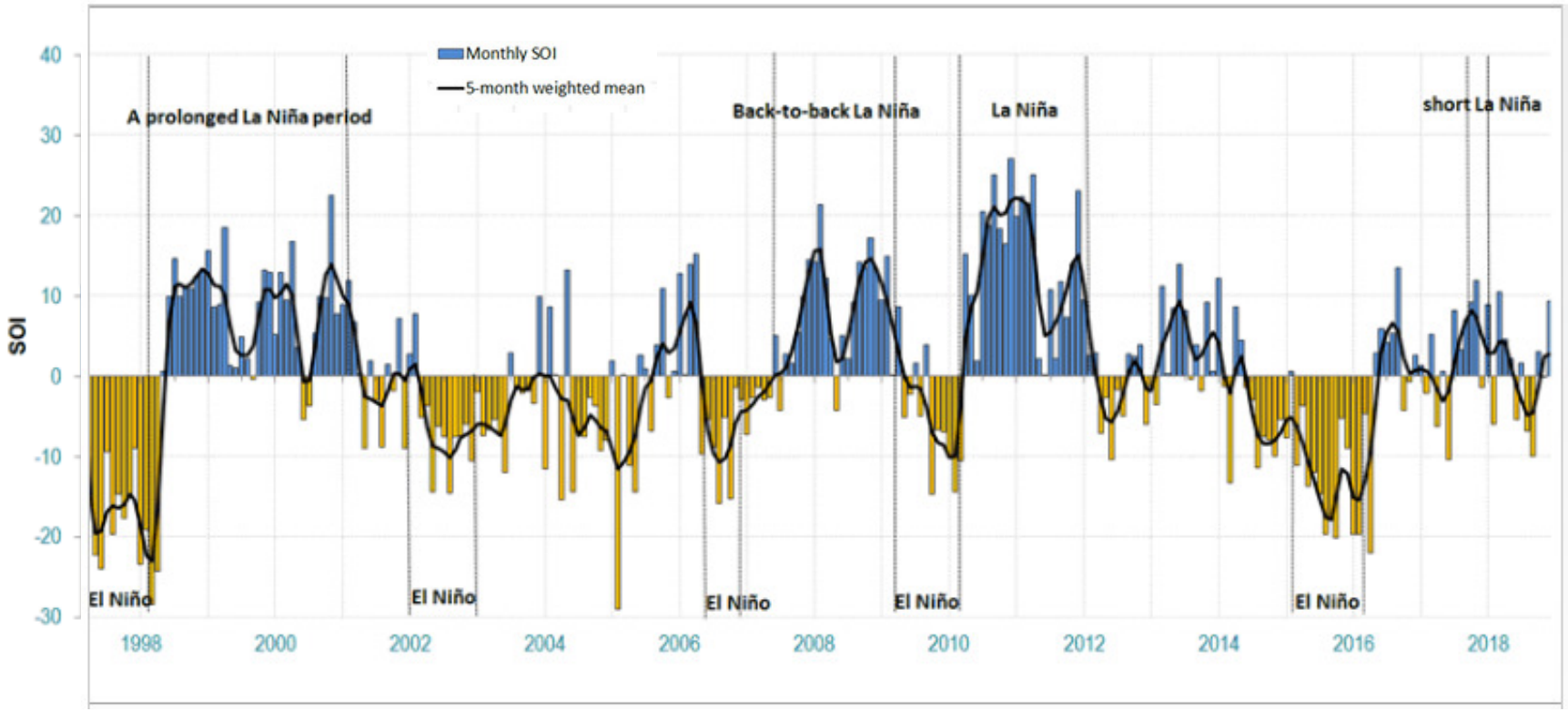
Tracking ENSO – Southern Oscillation Index (SOI)



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

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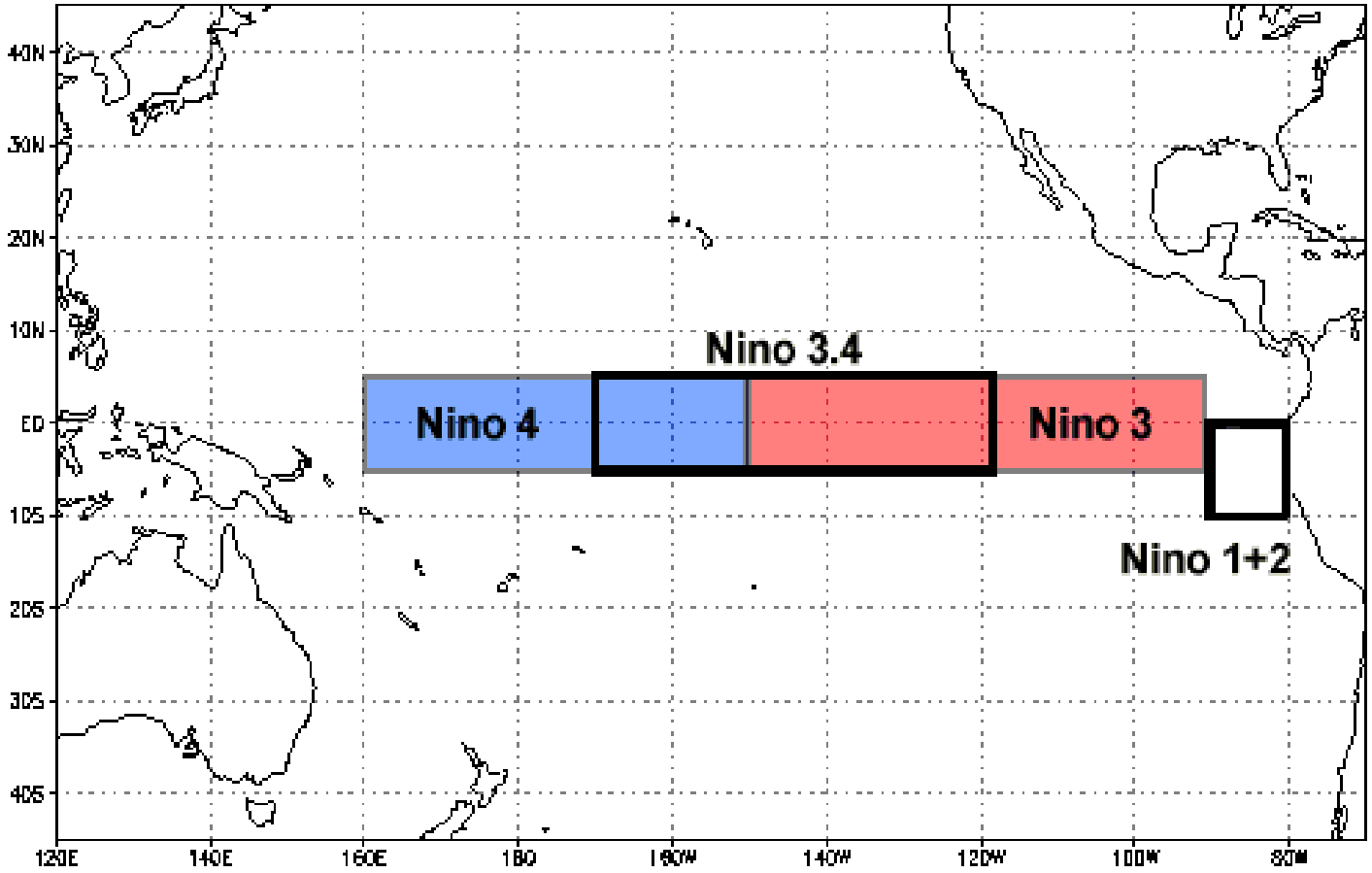
Tracking ENSO – Sea Surface Temperatures (NINO Indices)



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**

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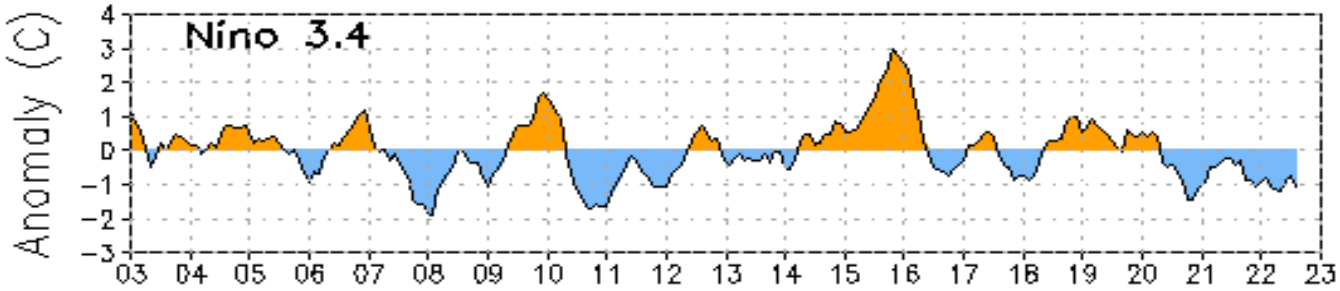
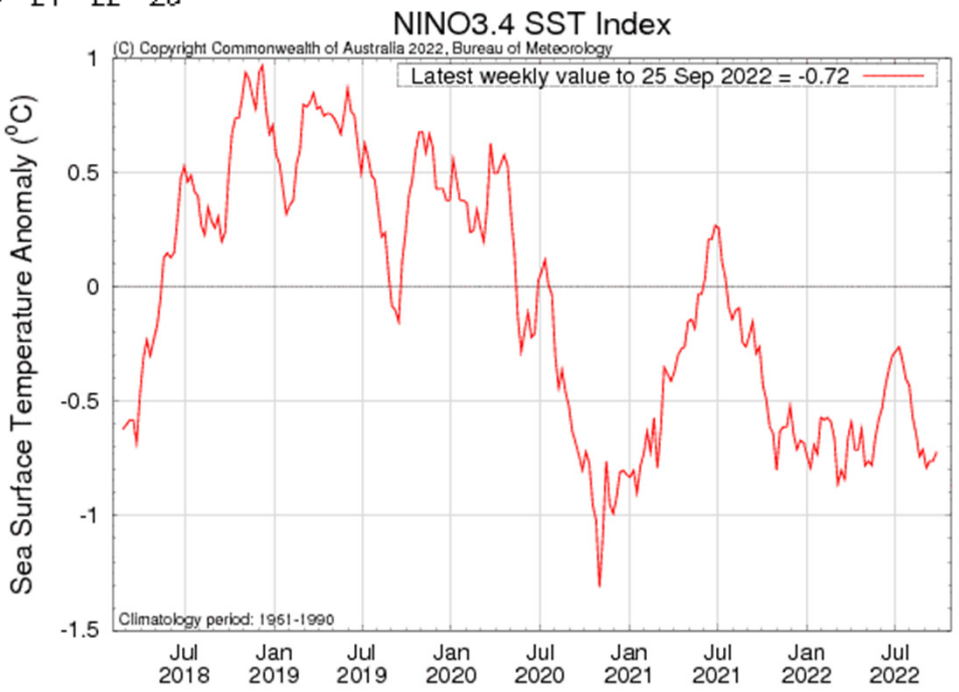
Tracking ENSO – NINO Indices

NINO3.4 (2003 – 2022)



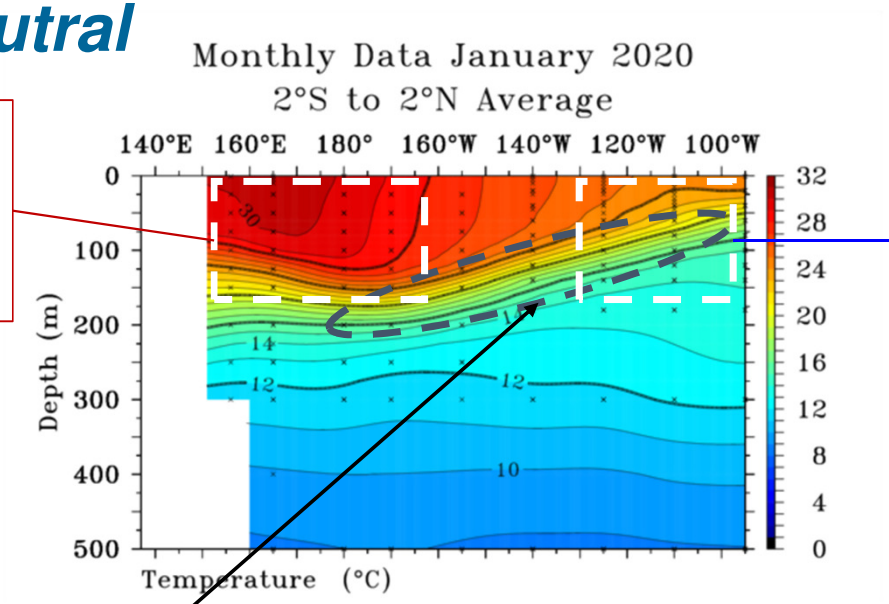
Above (from NOAA-CPC): gives long-term (20-year) perspective

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

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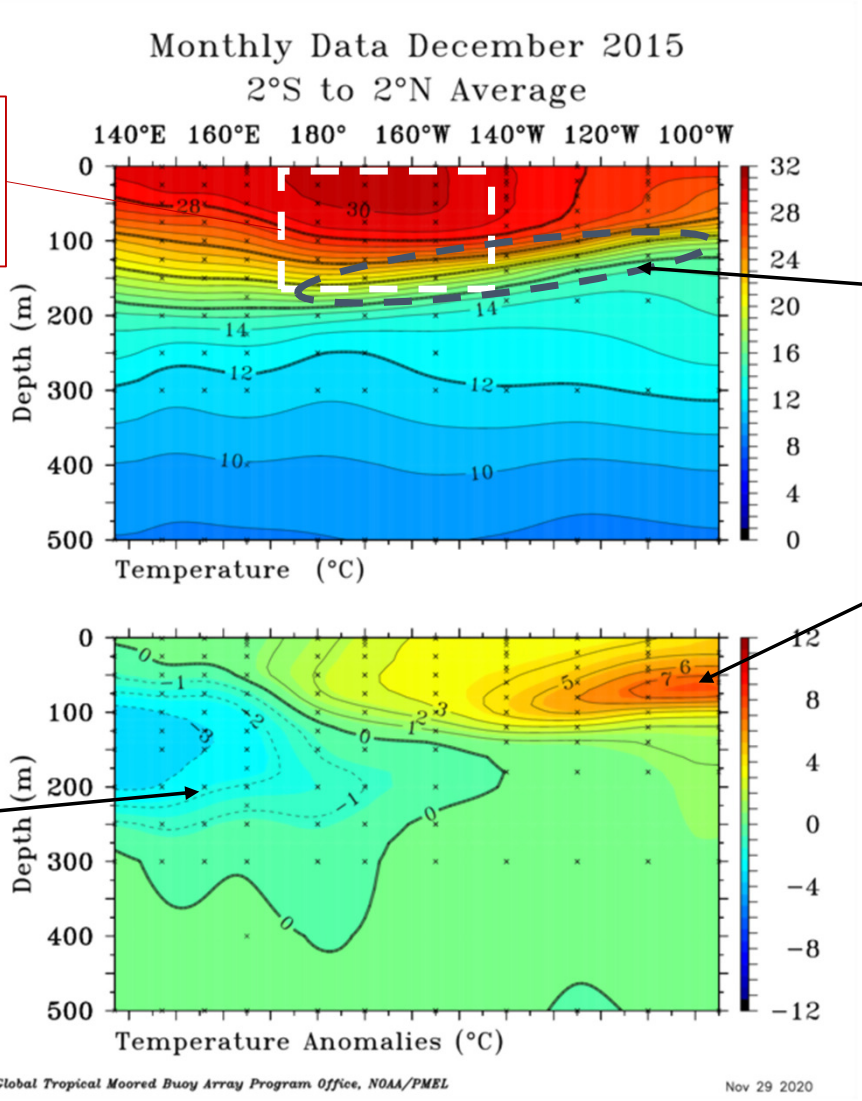
Warmest waters in central Pacific



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

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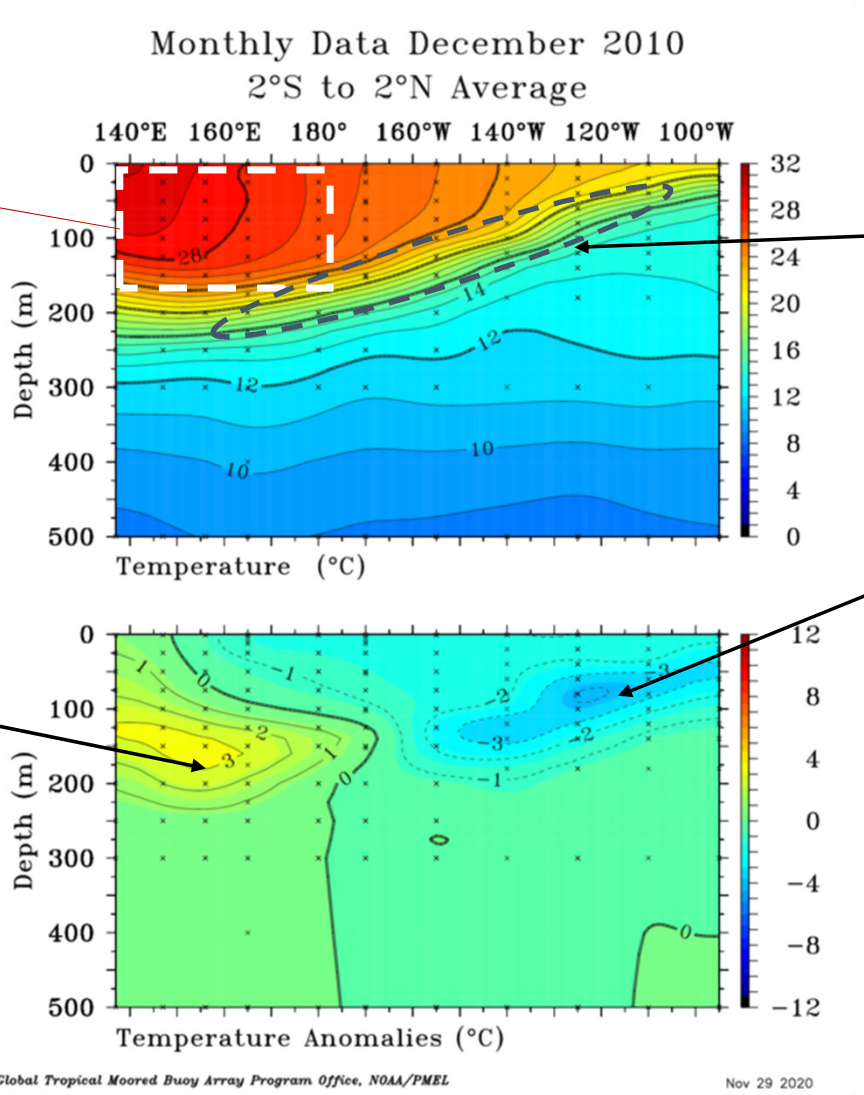
Warmest waters shifted to west



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

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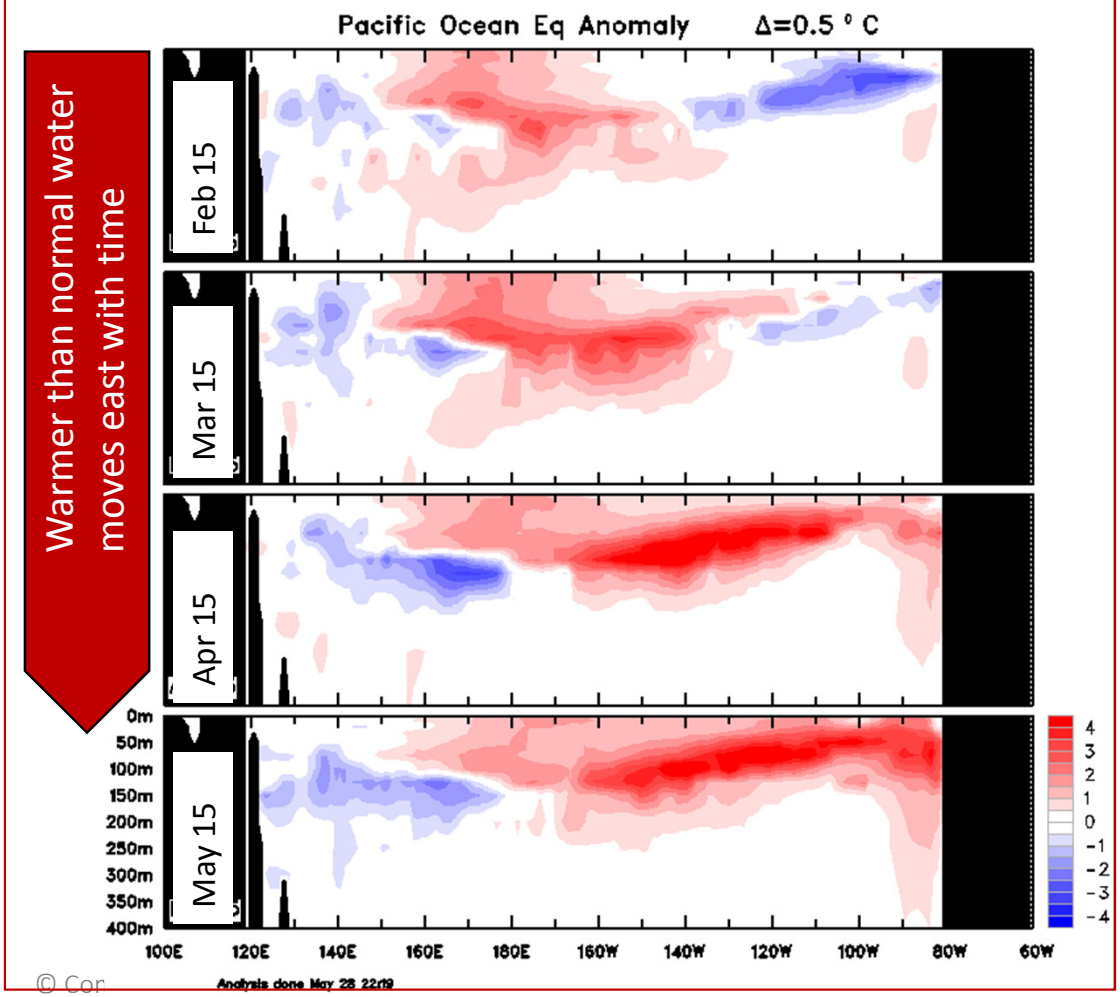
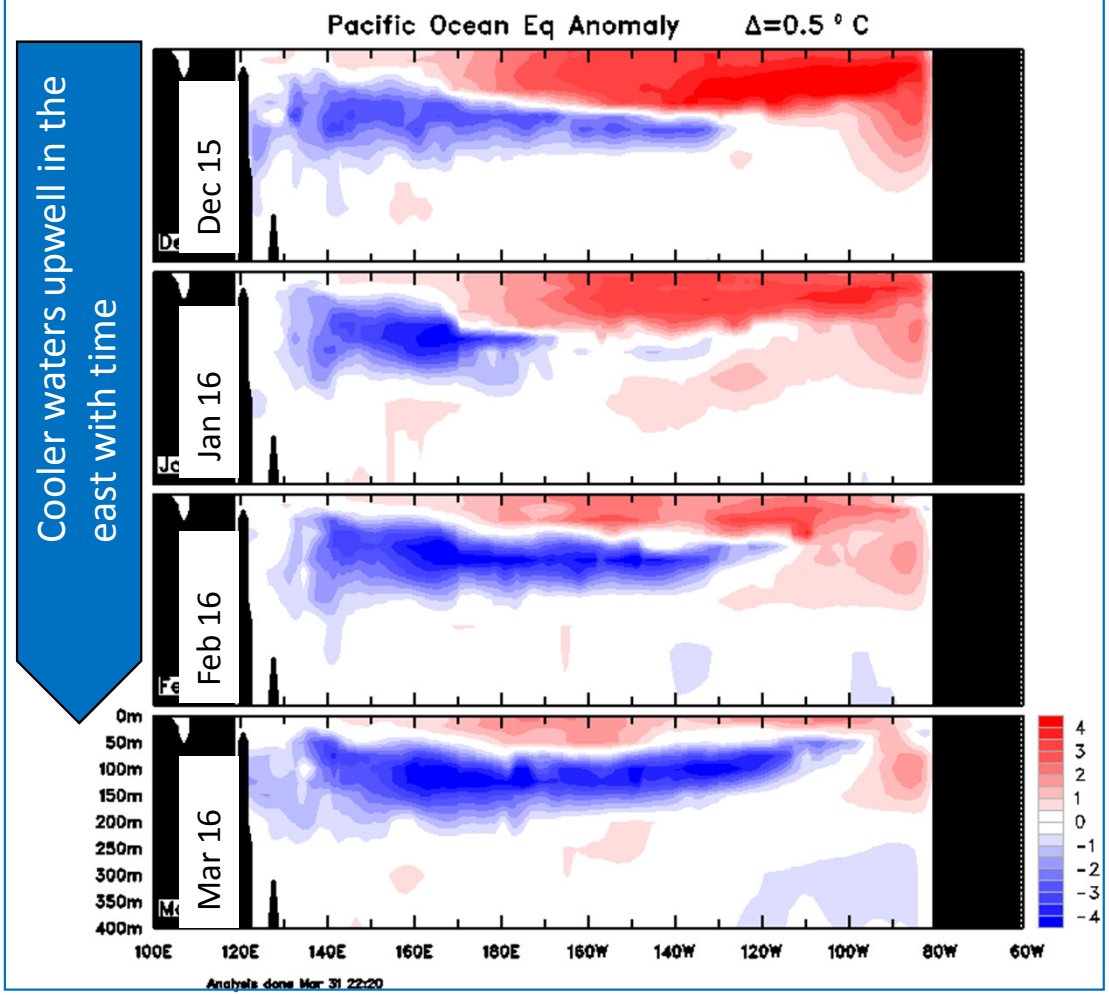
El Niño Development Phase



El Niño Decay Phase



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

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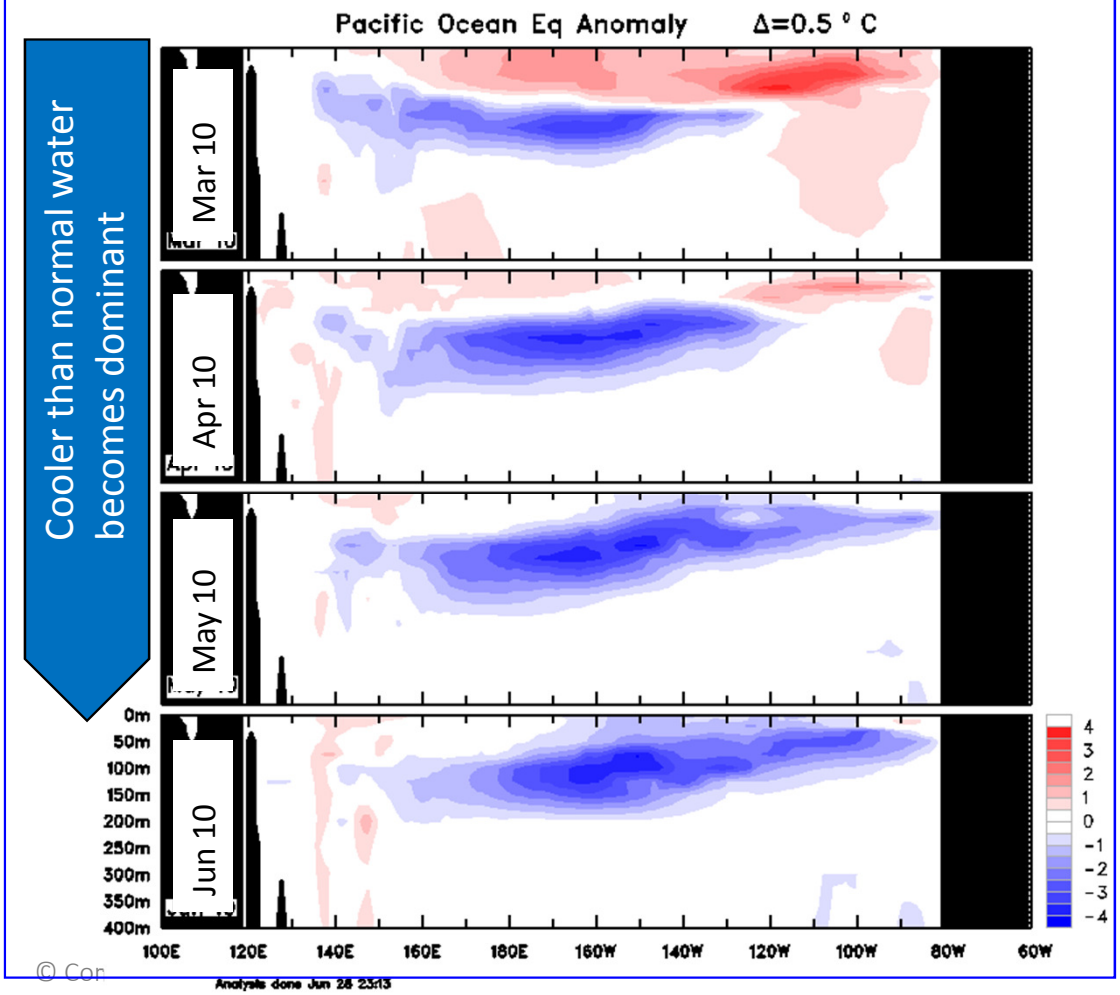
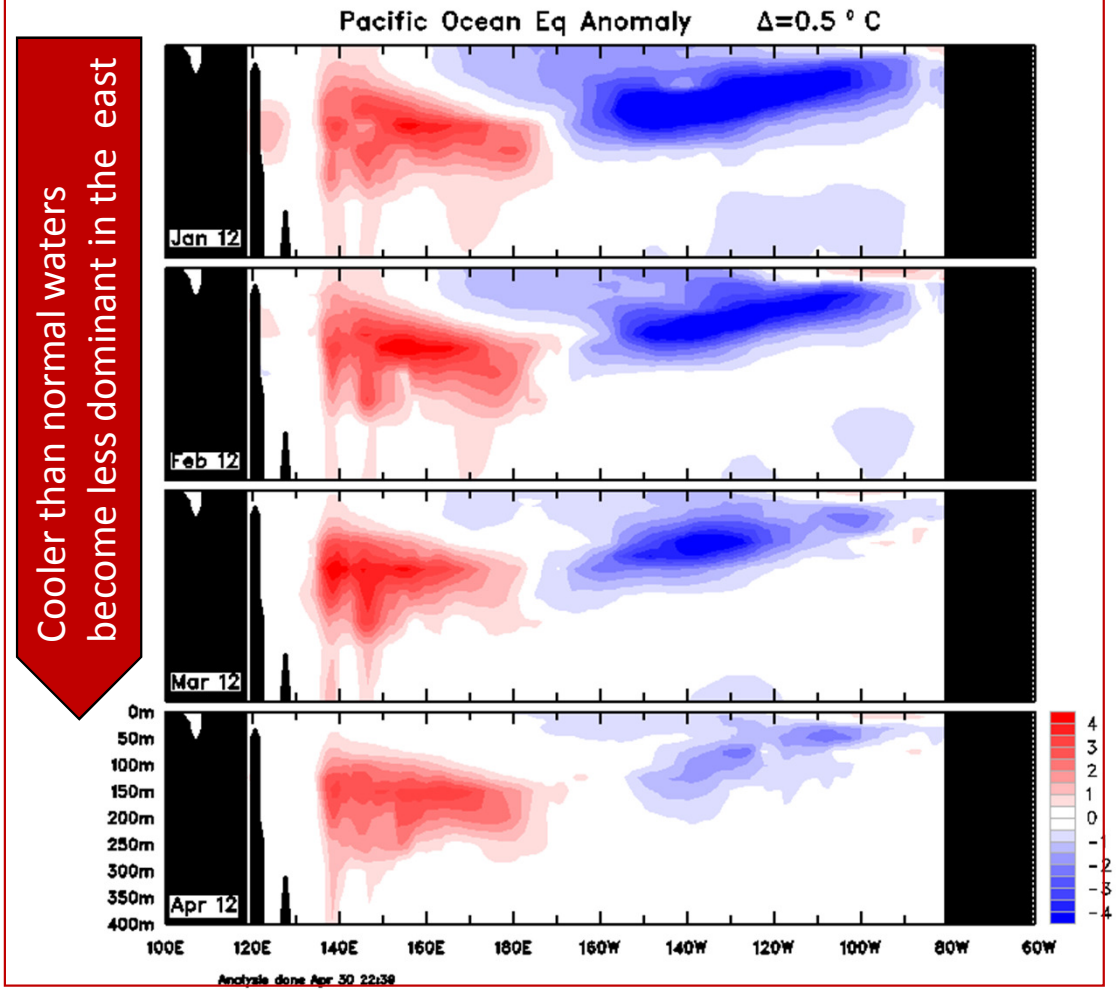
La Niña Development Phase



La Niña Decay Phase



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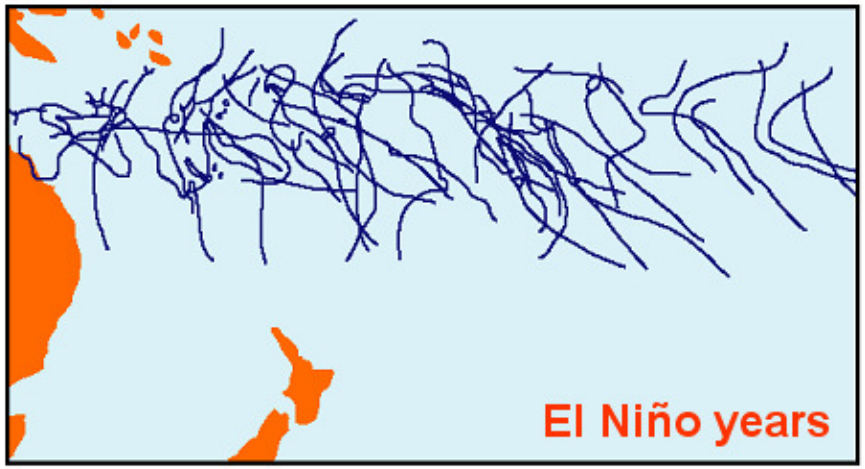
ENSO and Tropical Cyclones



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

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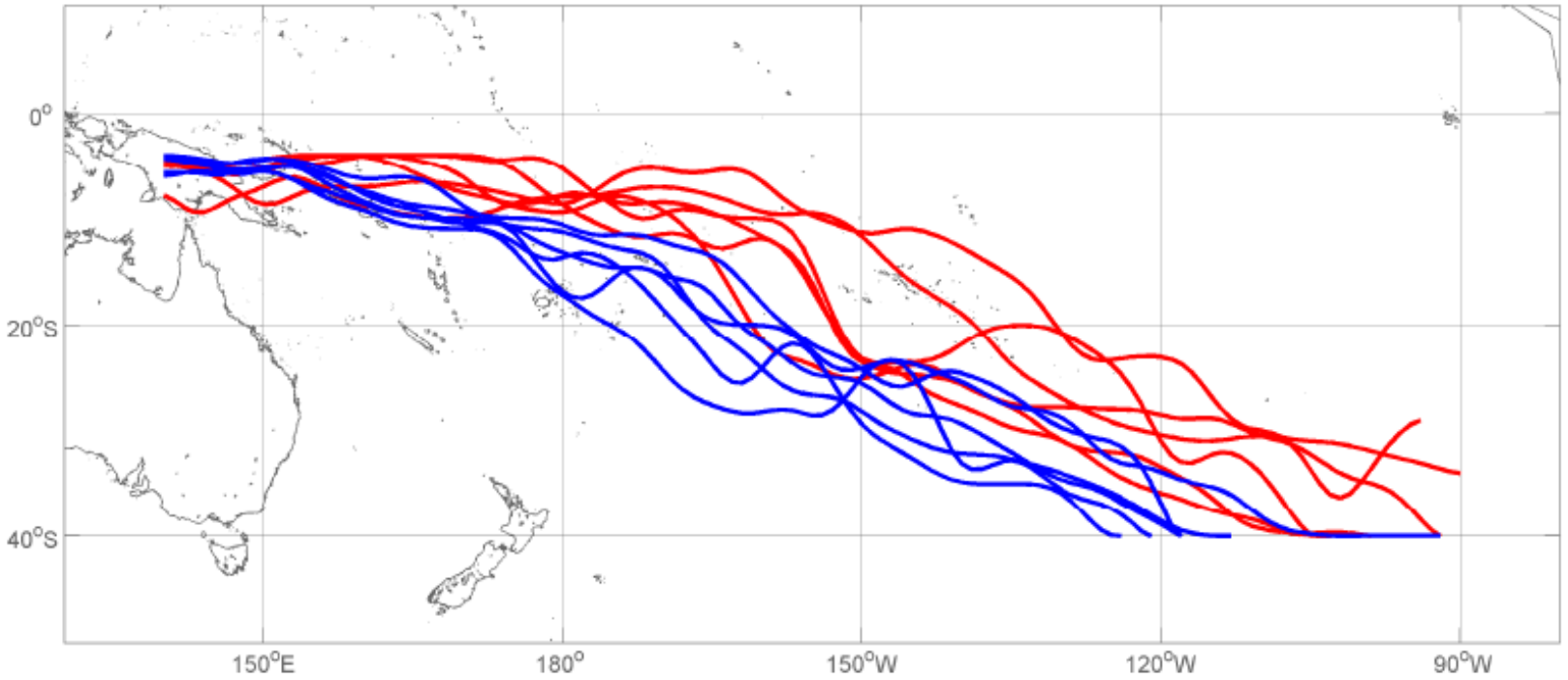
ENSO and the South Pacific Convergence Zone (SPCZ)
(from James Renwick & Brett Mullan, NIWA, N.Z.)



El Niño

La Niña

Shift in SPCZ position = large rainfall variability in affected countries

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Tracking & Monitoring ENSO Summary

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?

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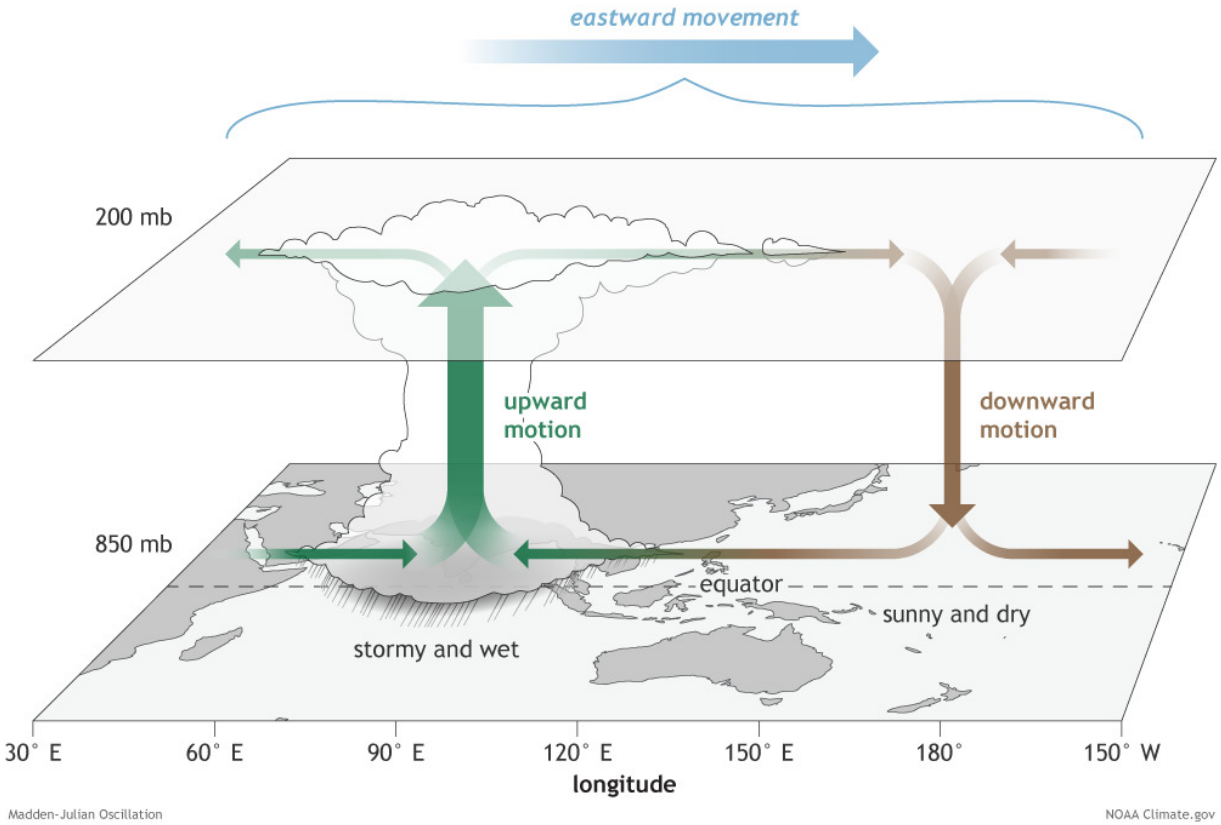
The Madden-Julian Oscillation (MJO)



- 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

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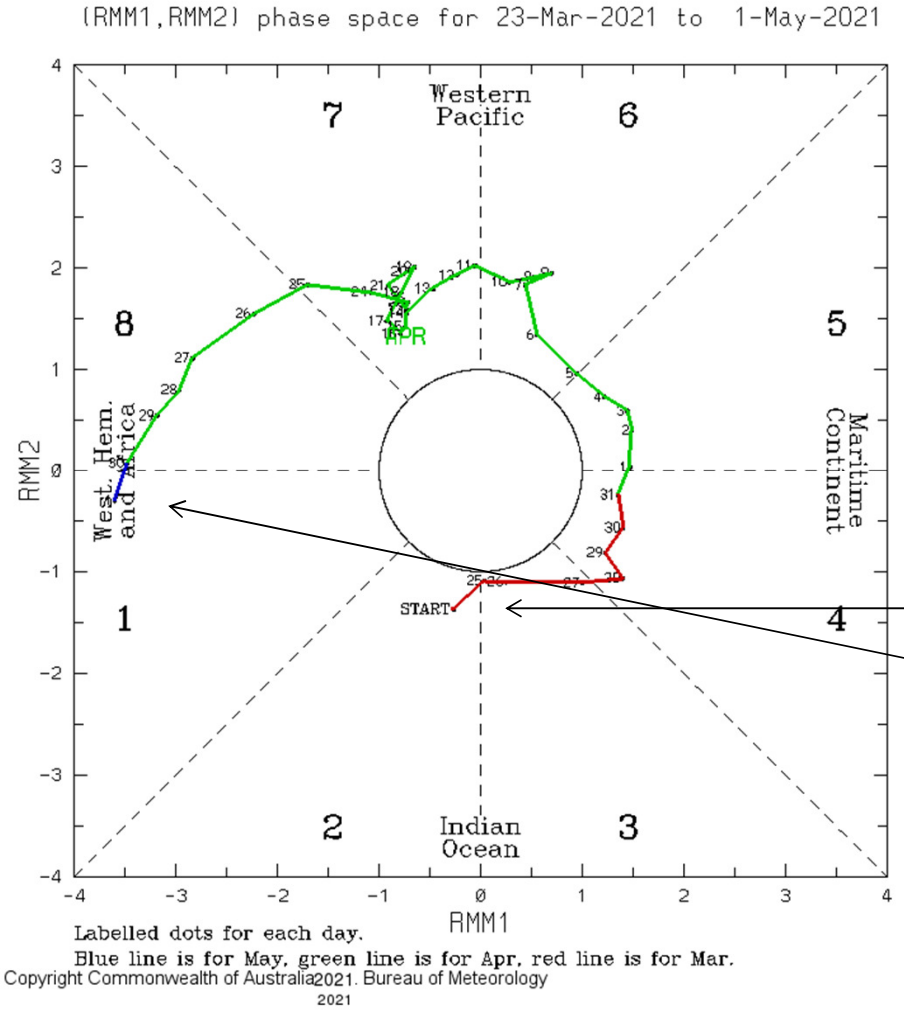
The Madden-Julian Oscillation (MJO)

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.

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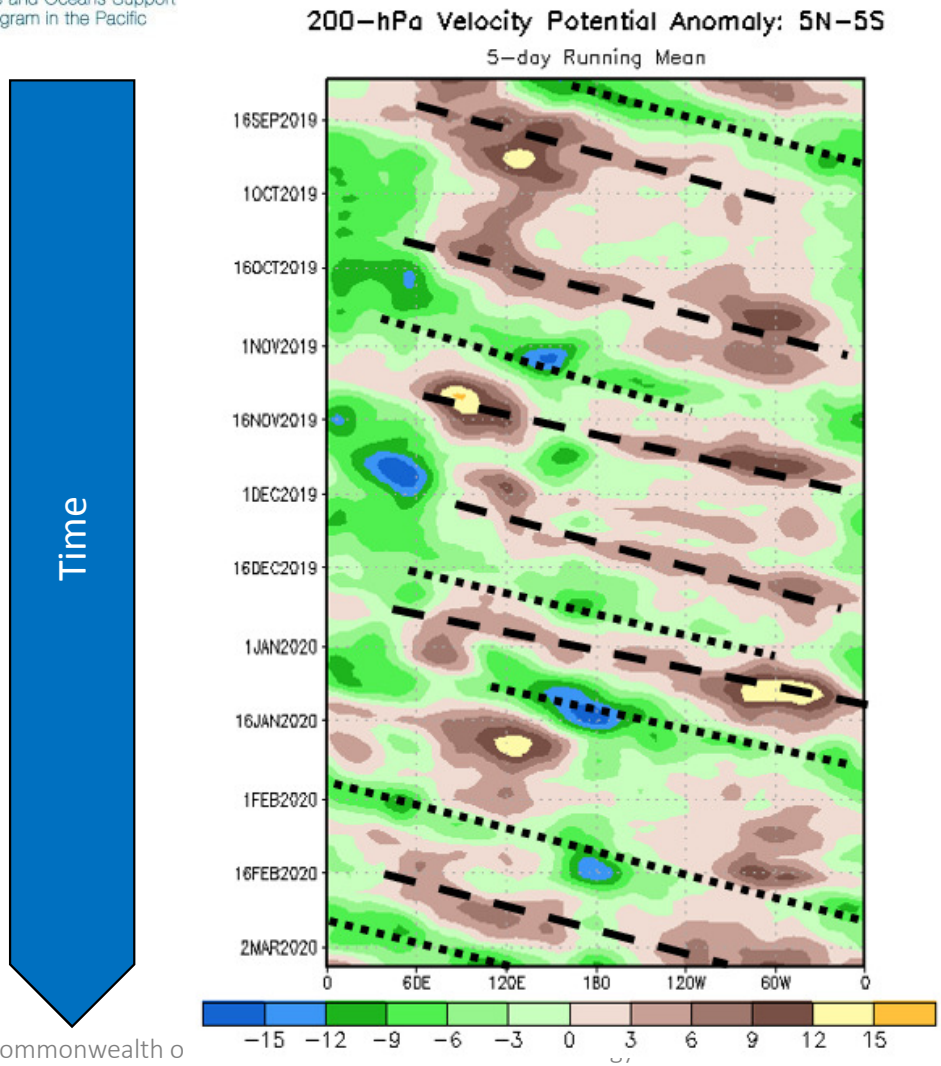
Monitoring the Madden-Julian Oscillation (MJO)



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

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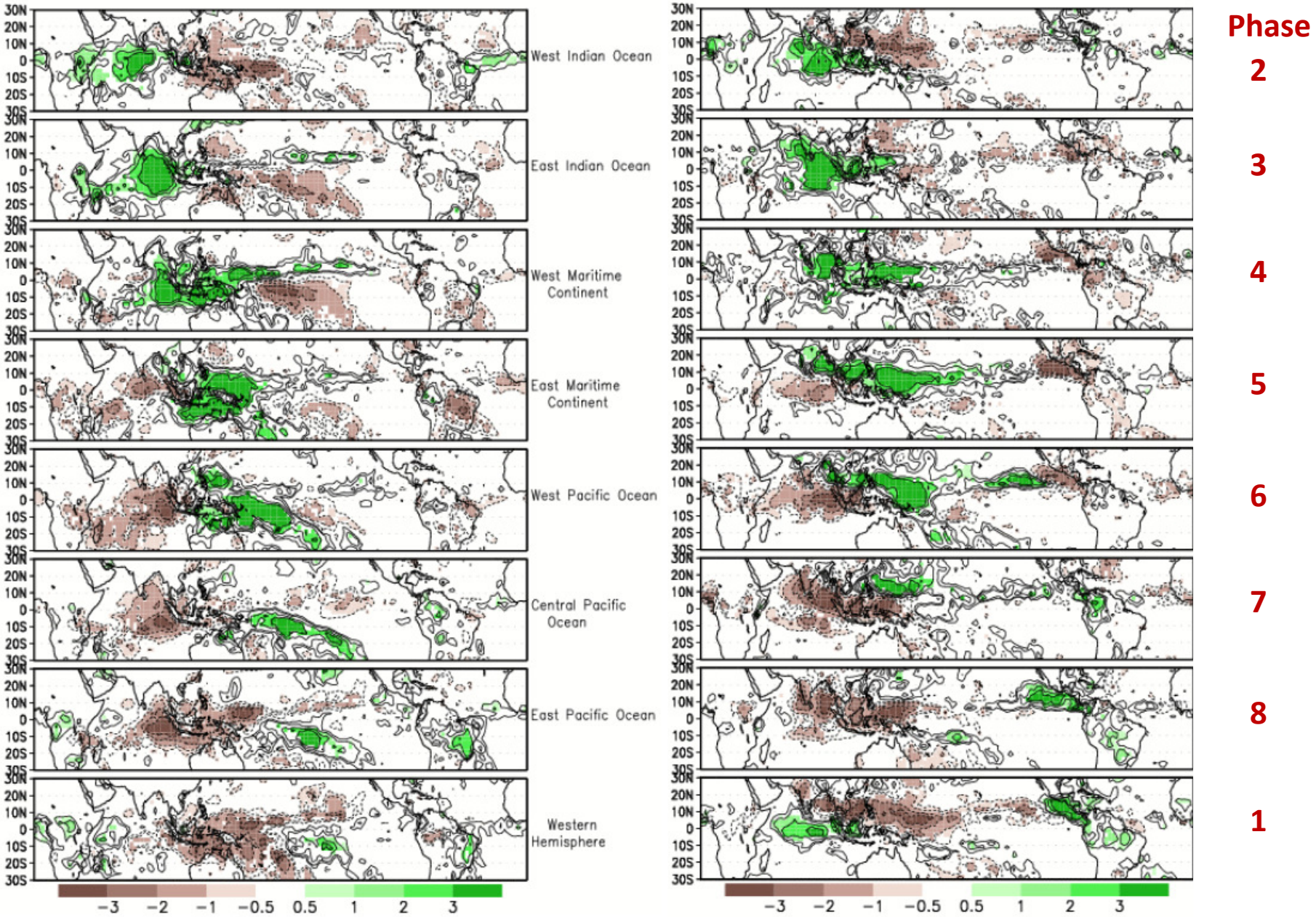
MJO Phase Averages

Left: Nov-March

Right: May-Sept

Units: Rain mm/day

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



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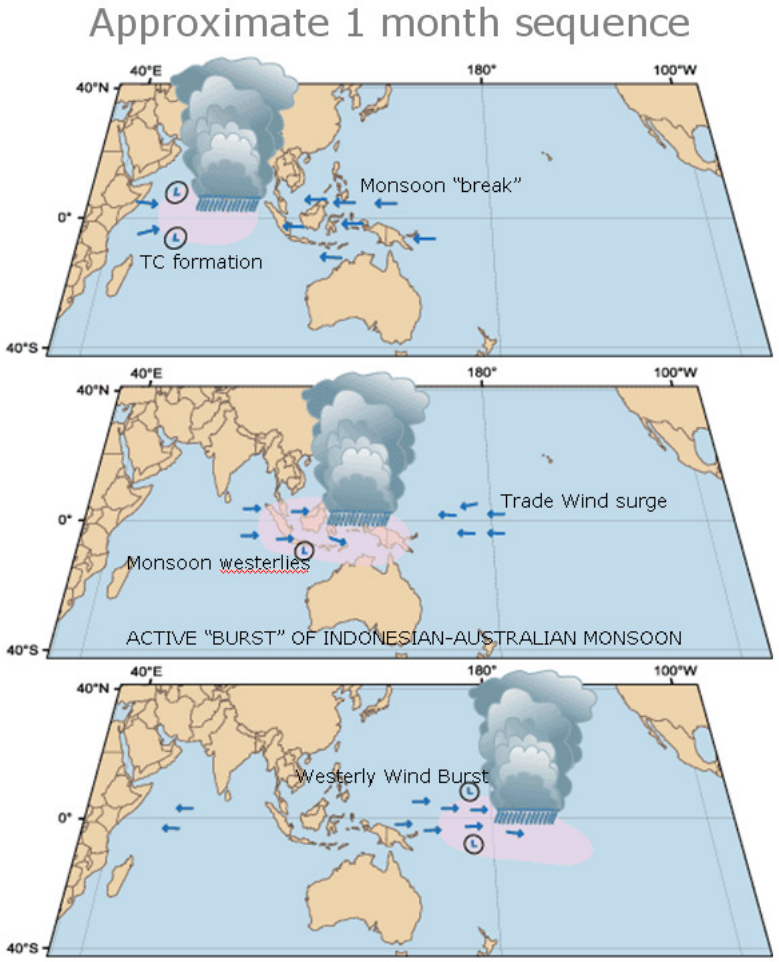
Madden-Julian Oscillation (MJO) summary

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?



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Indian Ocean Dipole (East Timor and PNG)

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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
- Indian Ocean Dipole (IOD)
  - Brief outline