Interpretation of the Climate Aspects and Indices discussed during the WMO RA-III/IV Regional Focus Monthly Sessions

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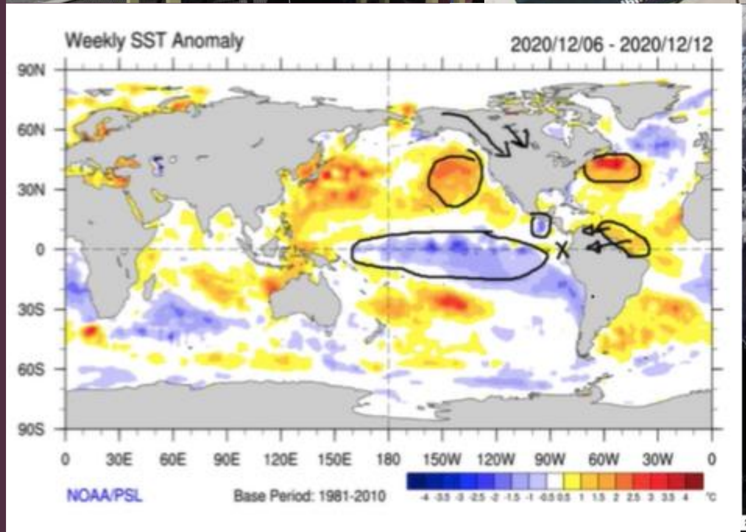
10 February 2021

WMO RA III-IV Regional Focus Group

- Since March 2004, the group conducts virtual **monthly weather and climate discussions** for the Americas and the Caribbean.

- **Collaborative effort:** CIRA, the WPC International Desks, the CIMH (Barbados), the University of Costa Rica, SMN Argentina and the Space Agency in Brazil.

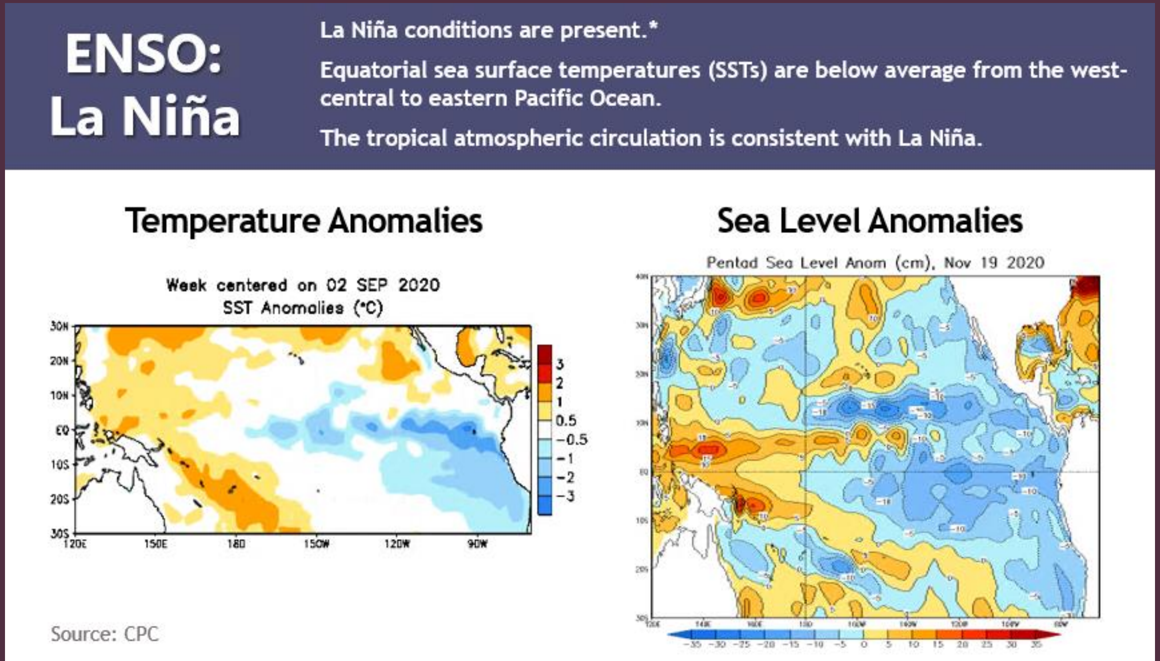
- **Bilingual:** English and Spanish

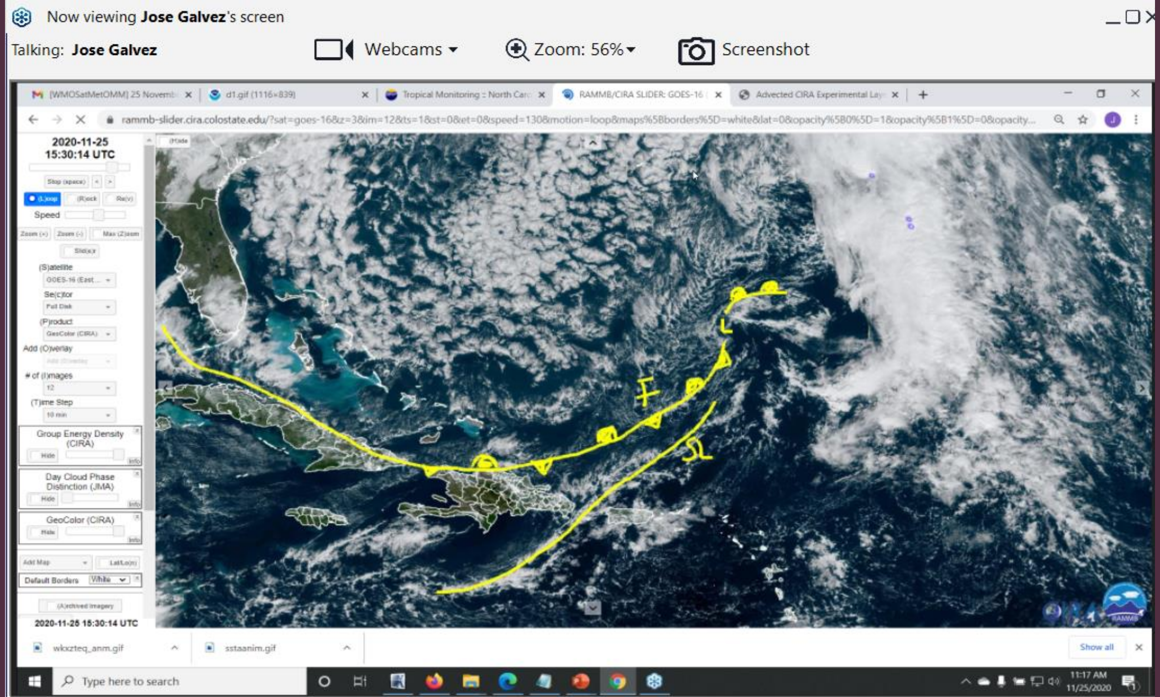


The Monthly Sessions

A typical session includes:

- Climate overview (Climate Aspects and Indices)
- Discussion of current weather
- Review of significant weather events that occurred during the past month
- Participant input on local and regional weather, and questions.





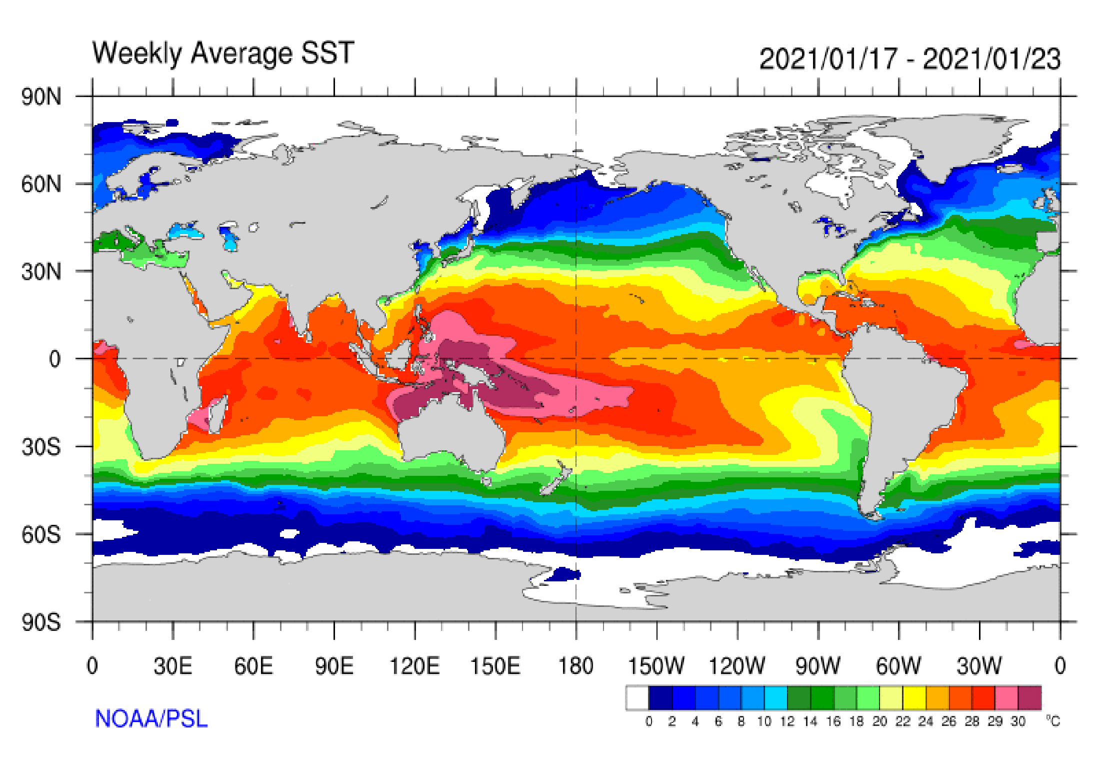
Outline of Today's Presentation

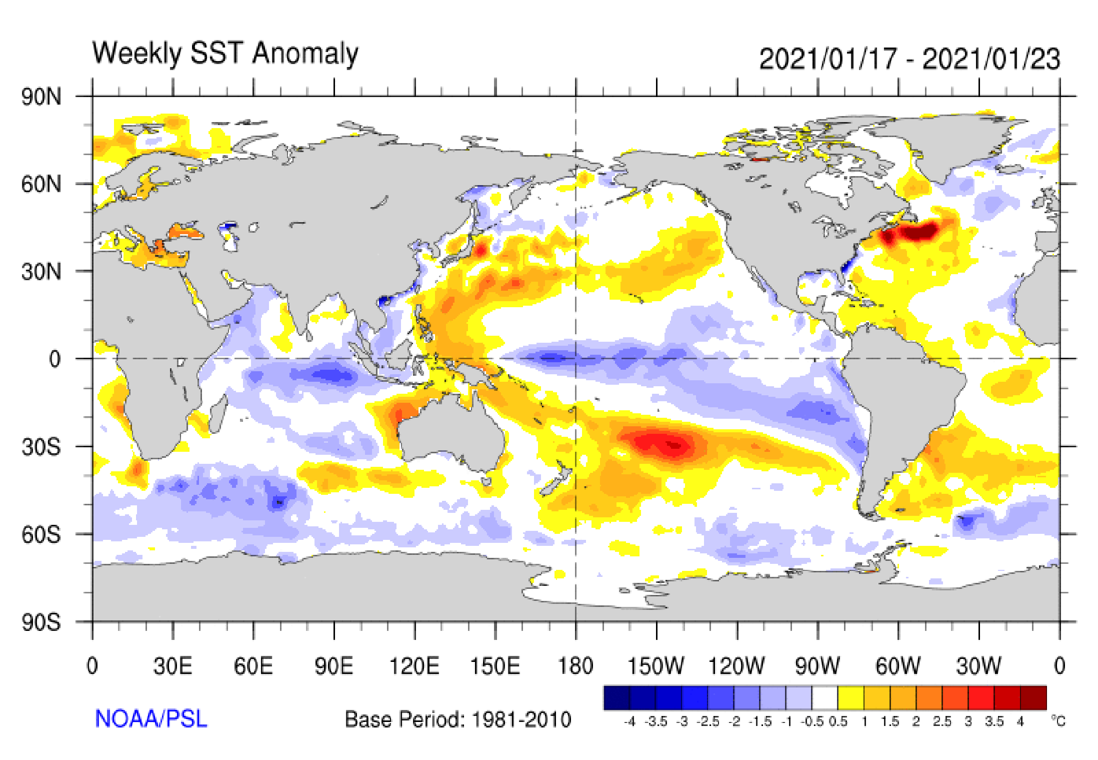
Review of some of the Climate Aspects and Indices

1. Sea Surface Temperatures and Anomalies
2. El Niño – Southern Oscillation (ENSO)
3. The Madden Julian Oscillation and Other Equatorial Perturbations – NCICS Web

Sea Surface Temperatures and Anomalies

Every session, we start with looking at sea surface temperatures and anomalies





Why is this important?

Source: https://psl.noaa.gov/map/clim/sst.shtml

Sea Surface Temperatures (SST) and Anomalies

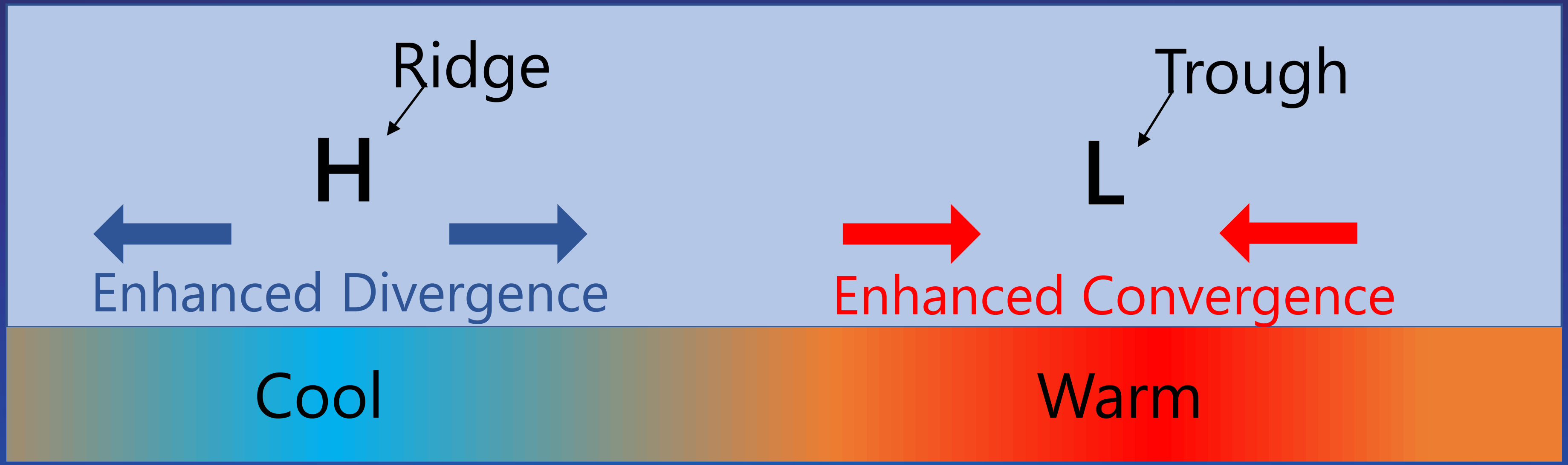
Importance

- Oceans cover most of the world, they have a strong influence on the weather and climate.
- Essential sources of heat and moisture.
- Ocean temperatures vary slowly, due to the high specific heat of water C_P (water warms and cools much slower than the air and terrain).

Slow-changing ocean temperatures are very useful for sub-seasonal and climate forecasting.

SST effects in the lower troposphere

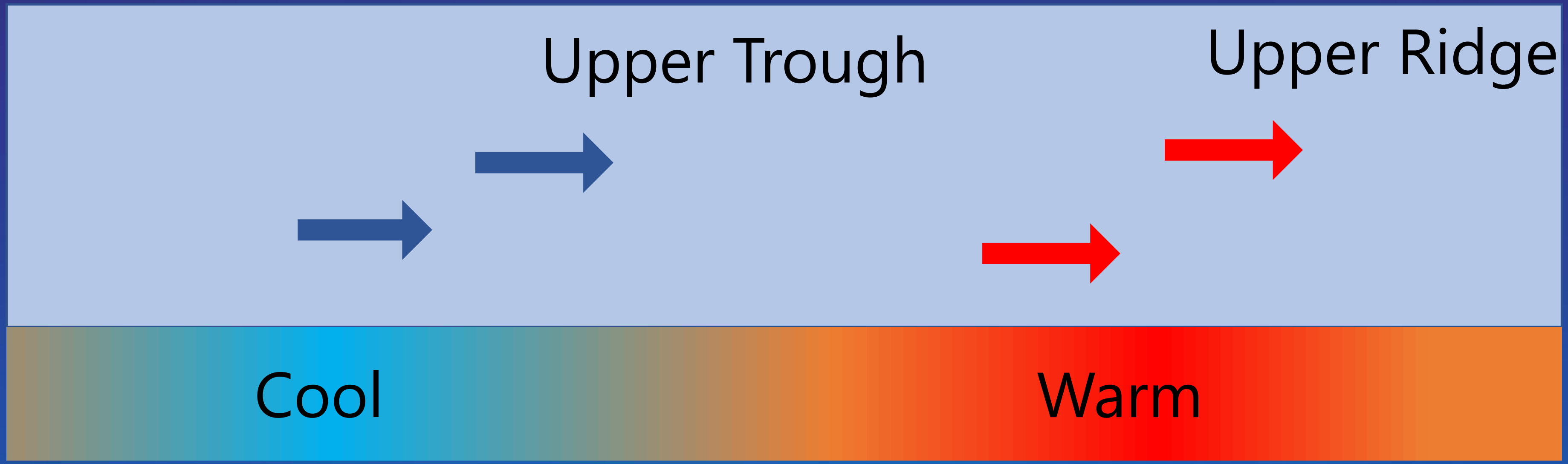
SSTs affect temperatures, pressures and circulations in the lower troposphere



Example: Migration/formation of the ITCZ during periods of weak synoptic forcing.

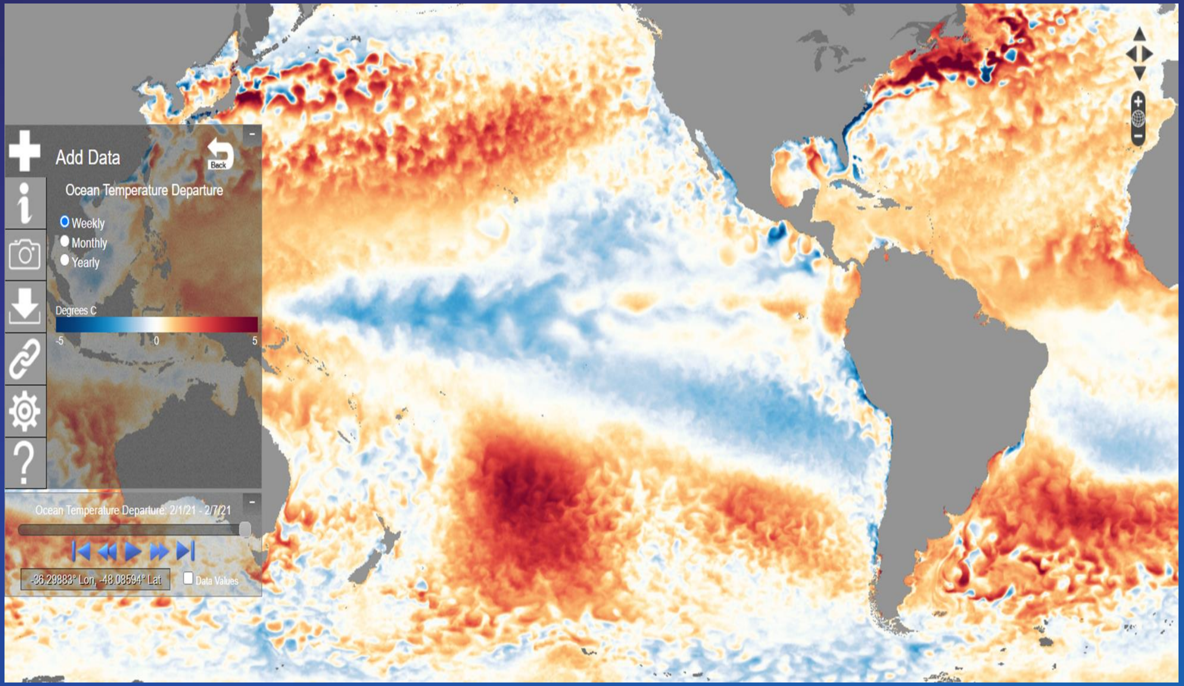
SST effects in the upper troposphere

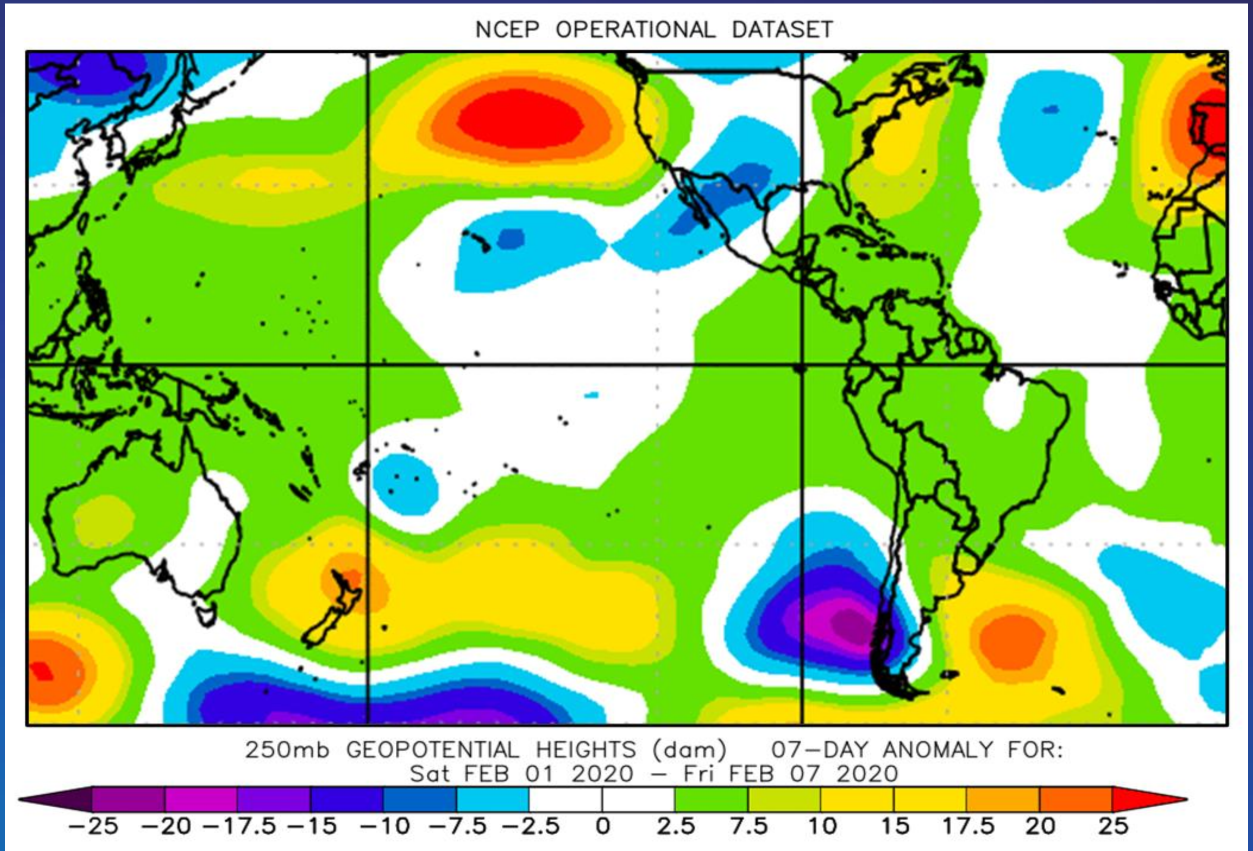
- In the upper troposphere, the effect is opposite and tends to shift downstream.
- Convection connects the lower and upper troposphere.



Where are anomalous troughs and ridges favored?

- Over/downstream from SST anomalies.
- Still, synoptic variability in the extratropics will sometimes overwhelm the influence of SST and anomalies.





How is sensible heat extracted from the ocean?

Heat flows from (to) the ocean by winds, when SSTs are warmer (cooler) than air

$$Q_{sen} = \rho_a C_p C_H U \underbrace{(T_{sea} - T_{air})}$$

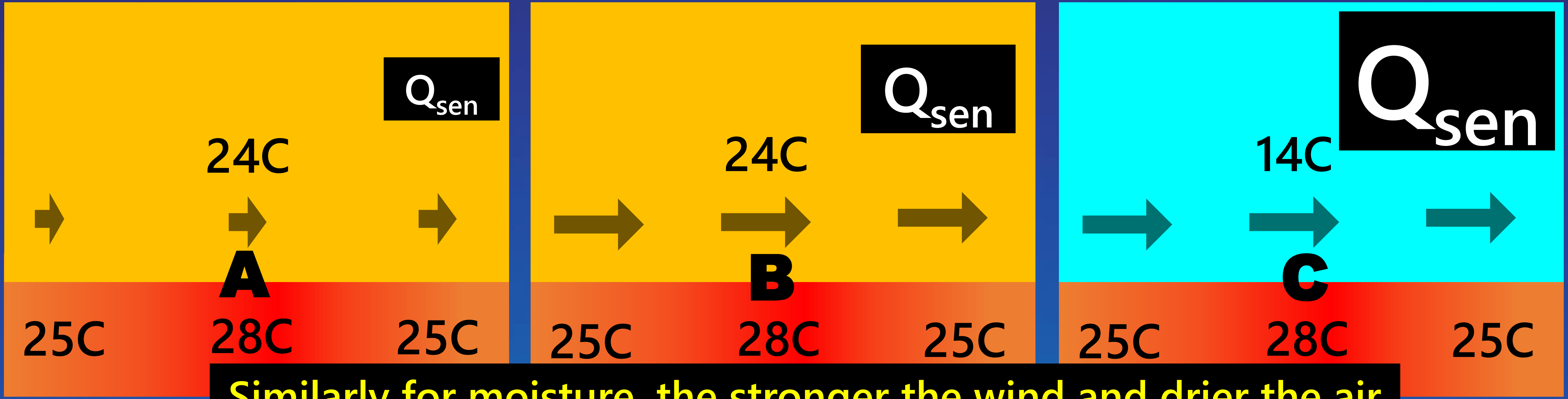
Air density

Air specific heat capacity

Turbulent exchange coefficient

Wind speed

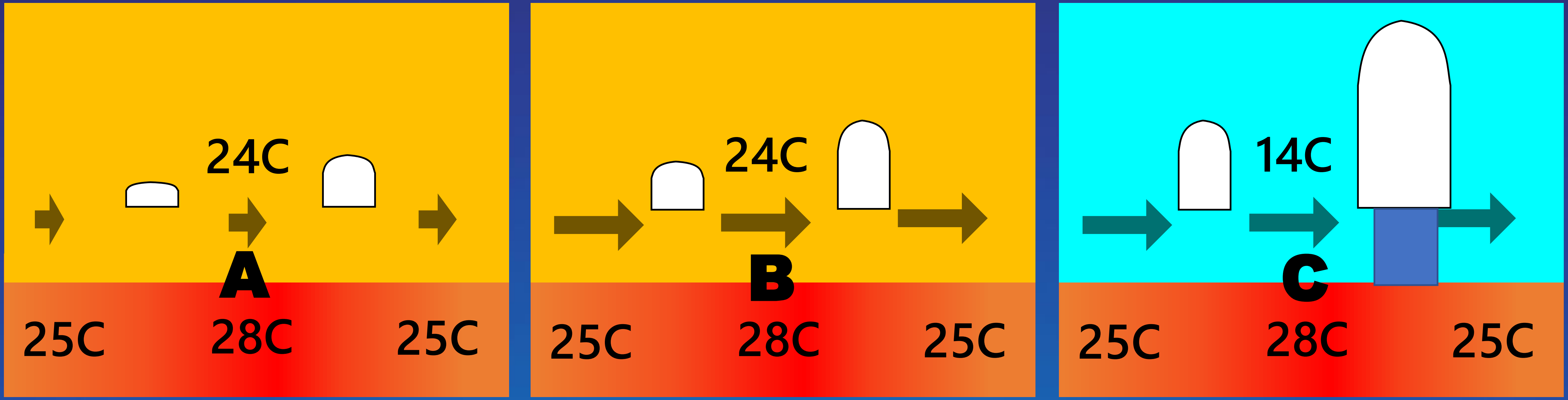
Sea-air temperature difference



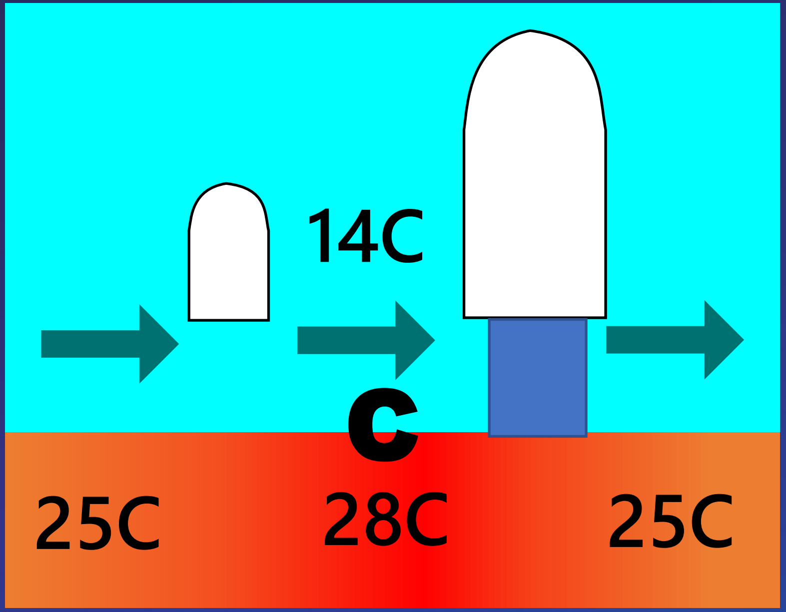
Similarly for moisture, the stronger the wind and drier the air mass, the larger the amounts of moisture extracted.

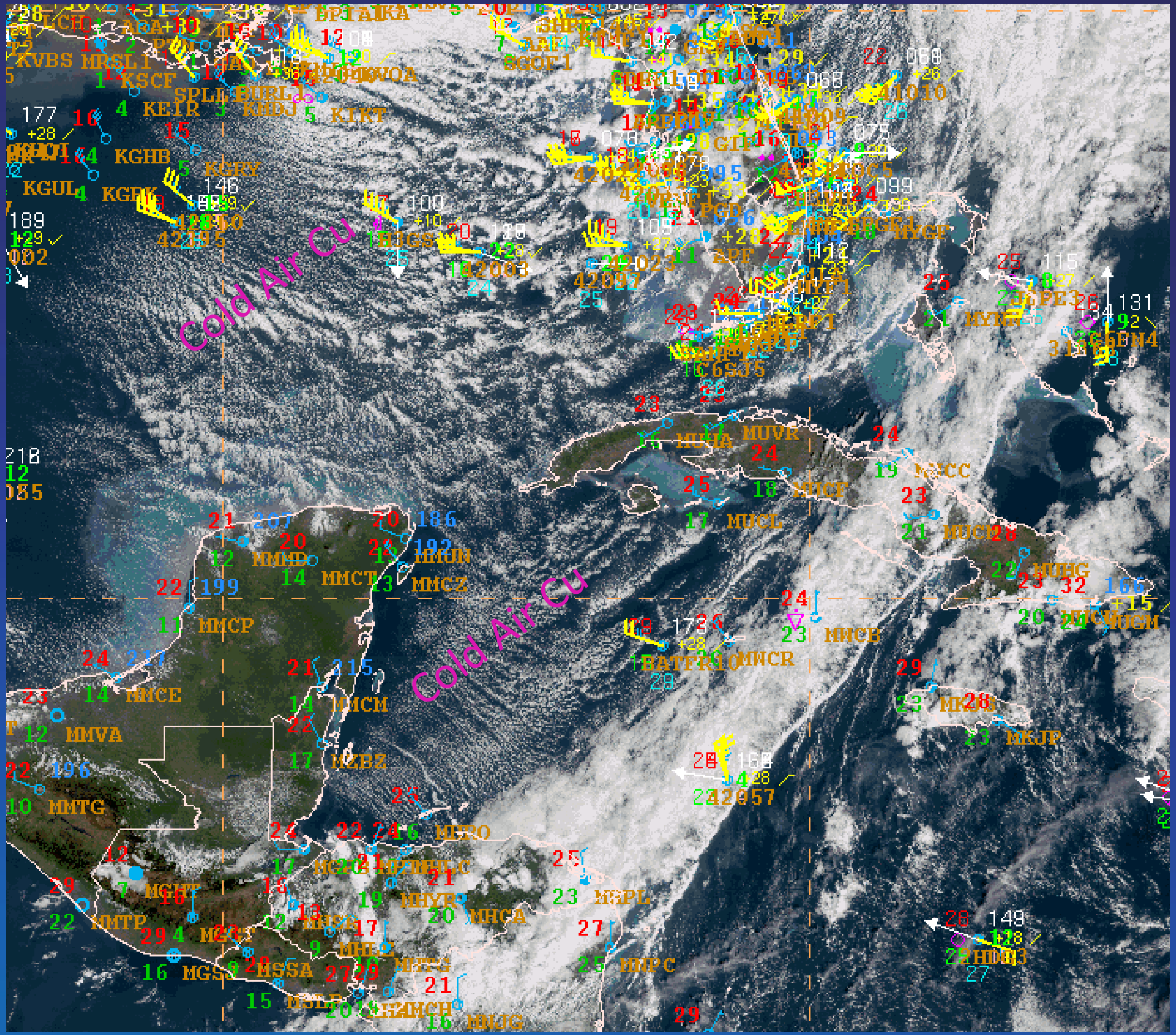
Which situation is the most unstable?

For instability: evaluate the largest decrease of temperature with height



Cold air cumulus



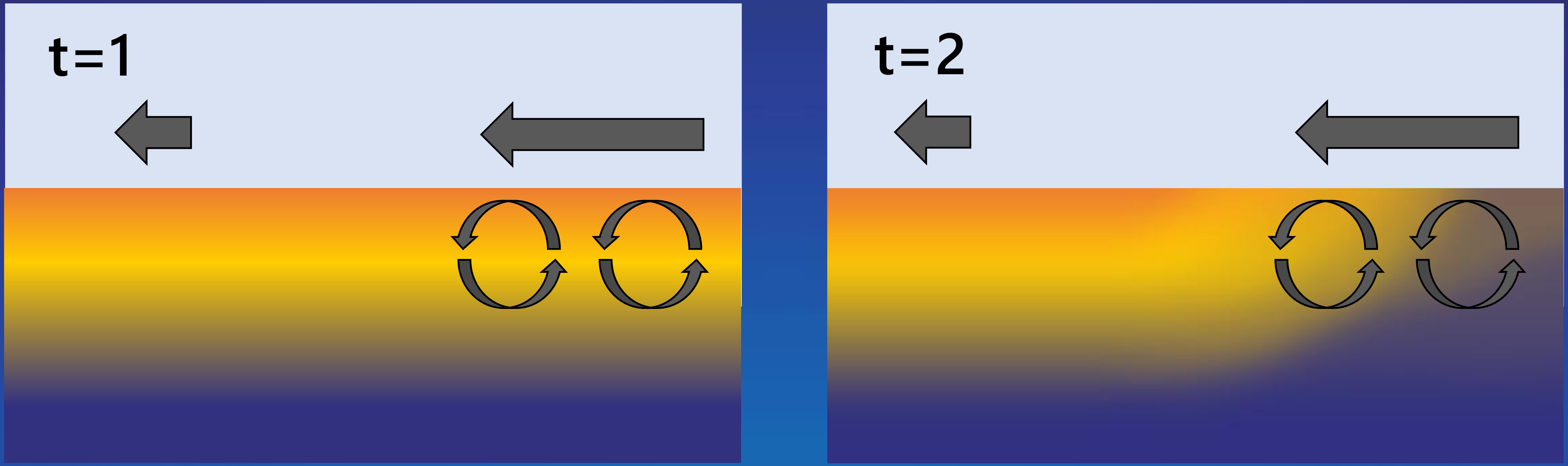


Following frontal passage, cold air advection over warmer waters favors convective instability. This triggers post frontal “cold air cumulus”
(Moderate Cu and Cu Congestus)

Strong winds can cool the ocean

- Turbulent Mixing with cooler water
- Ekman pumping (equator, coasts)
- Temperature of underlying layer matters

This is why we look into temperature anomalies in a layer as well



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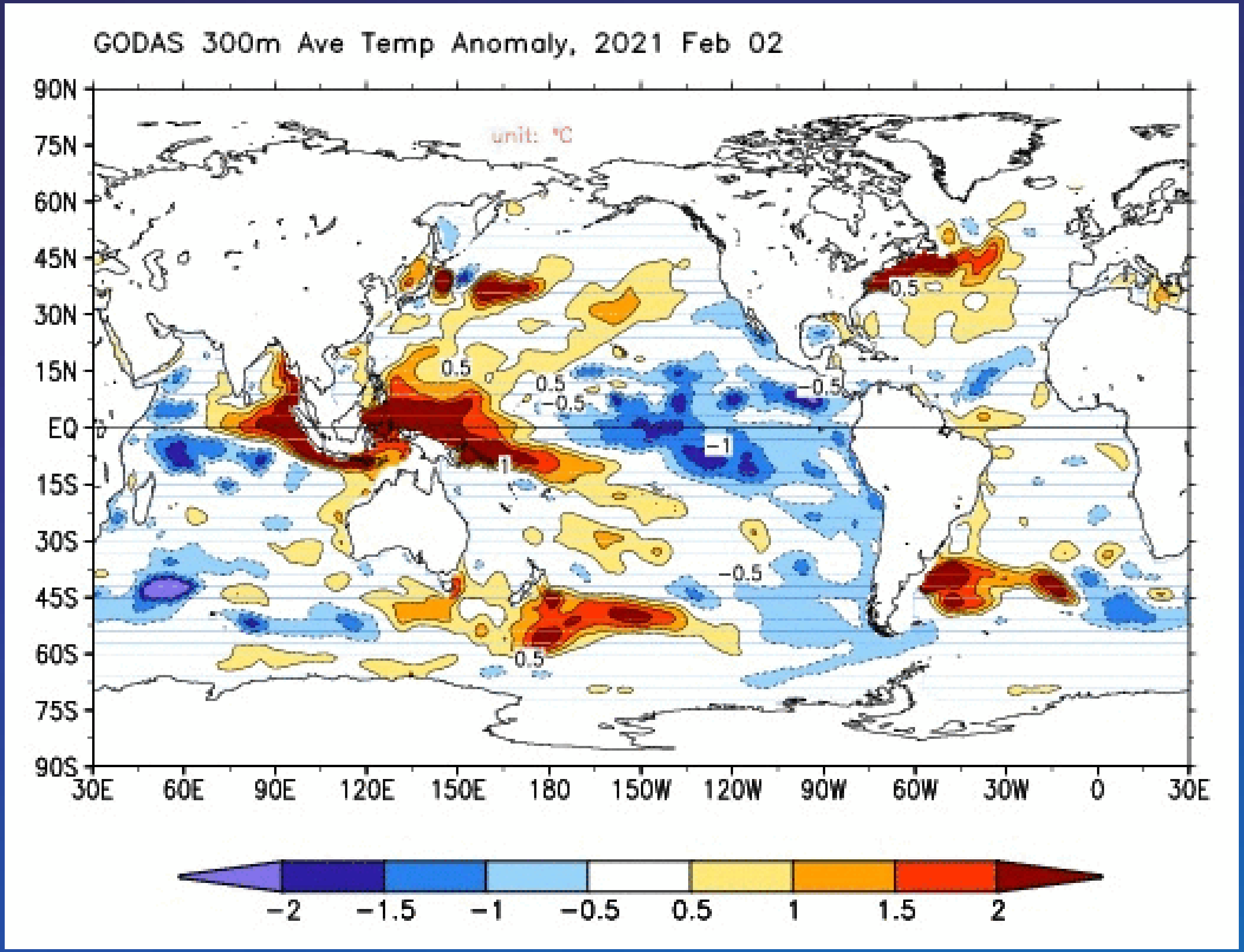
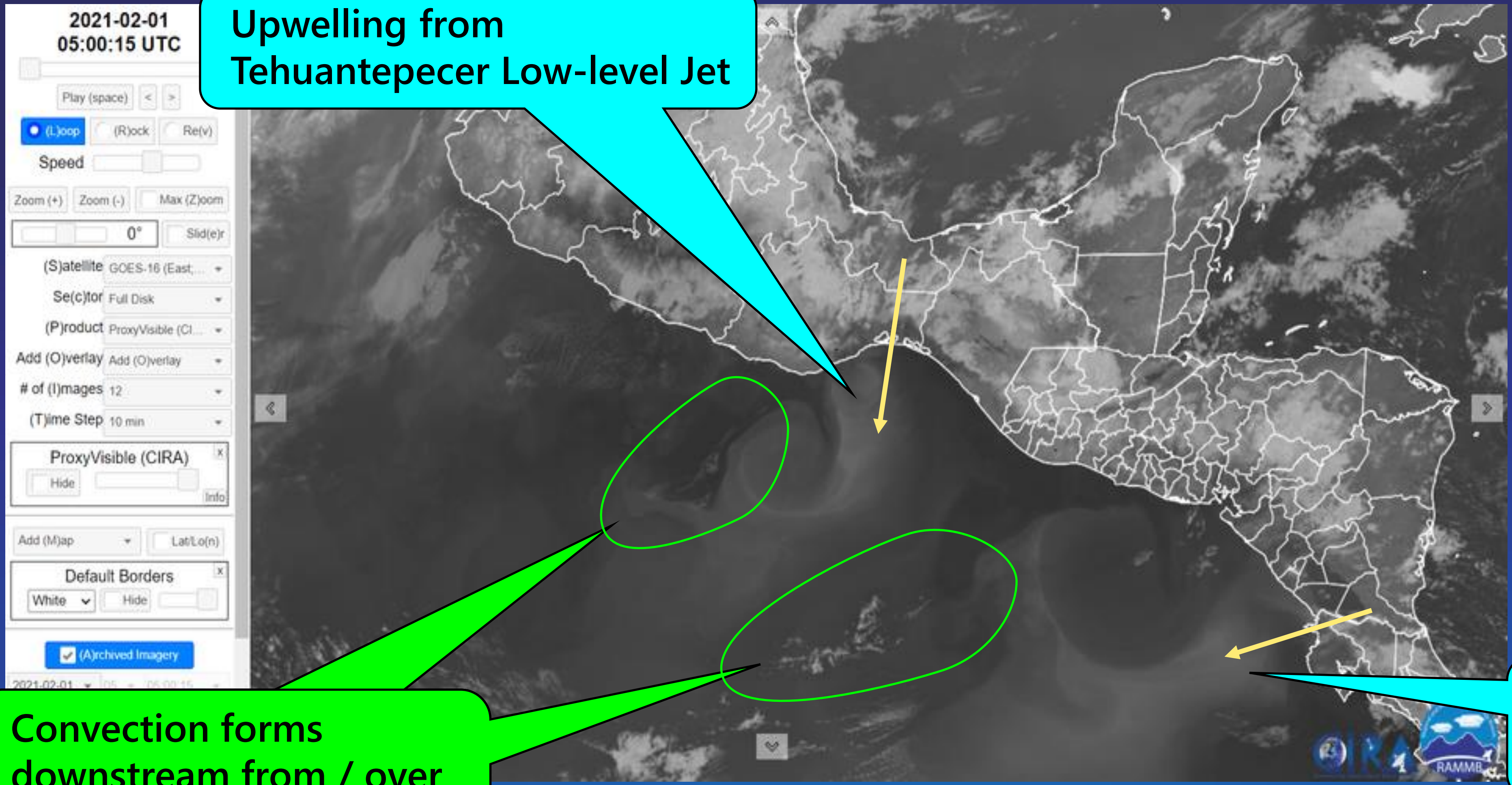


This is why we look into temperature anomalies in a layer as well

Deeper anomalies will take longer to dissipate. This is crucial for tropical cyclone strengthening

SST: Upwelling inhibits convection

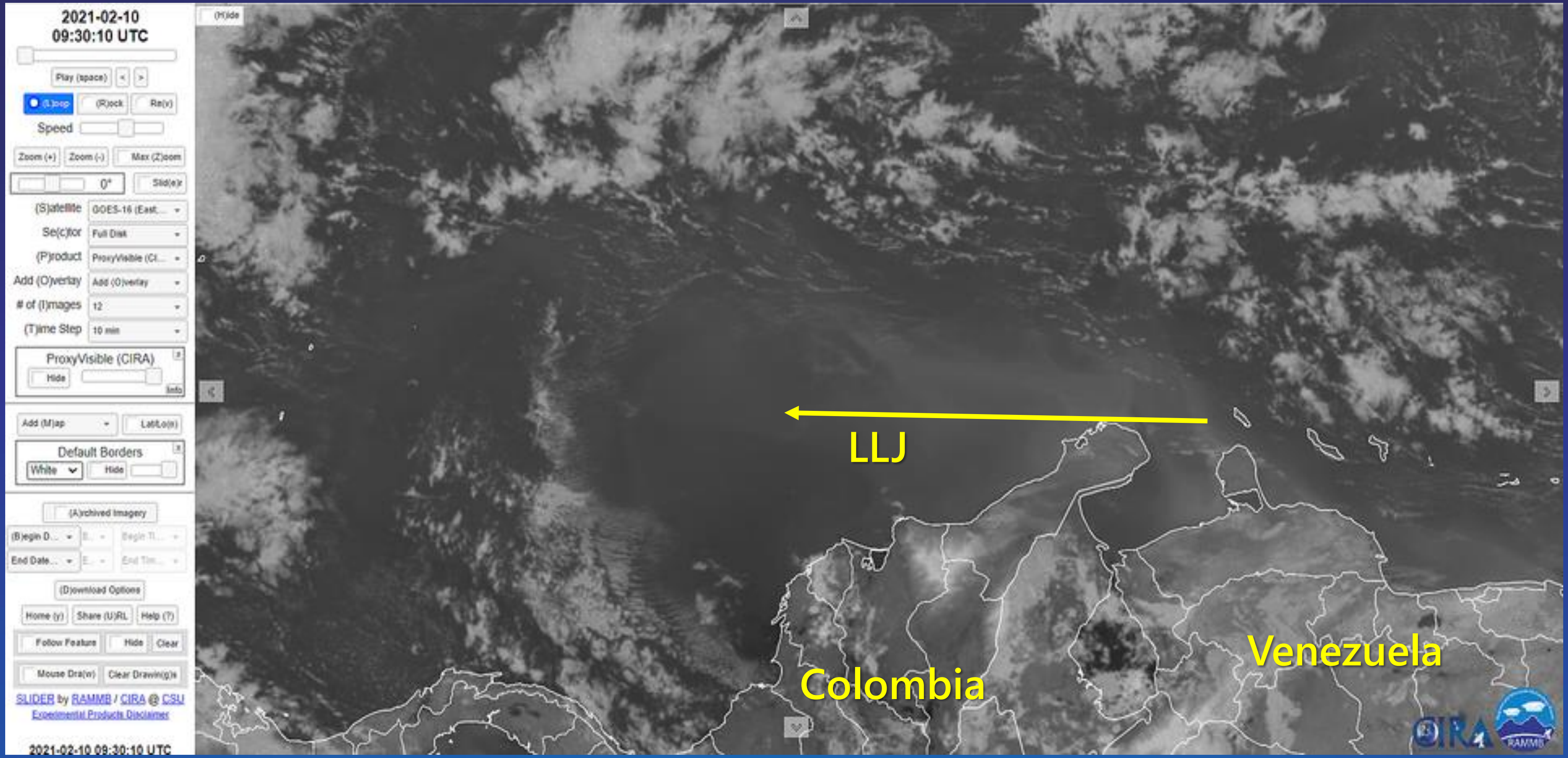


Upwelling from
Tehuantepecer Low-level Jet

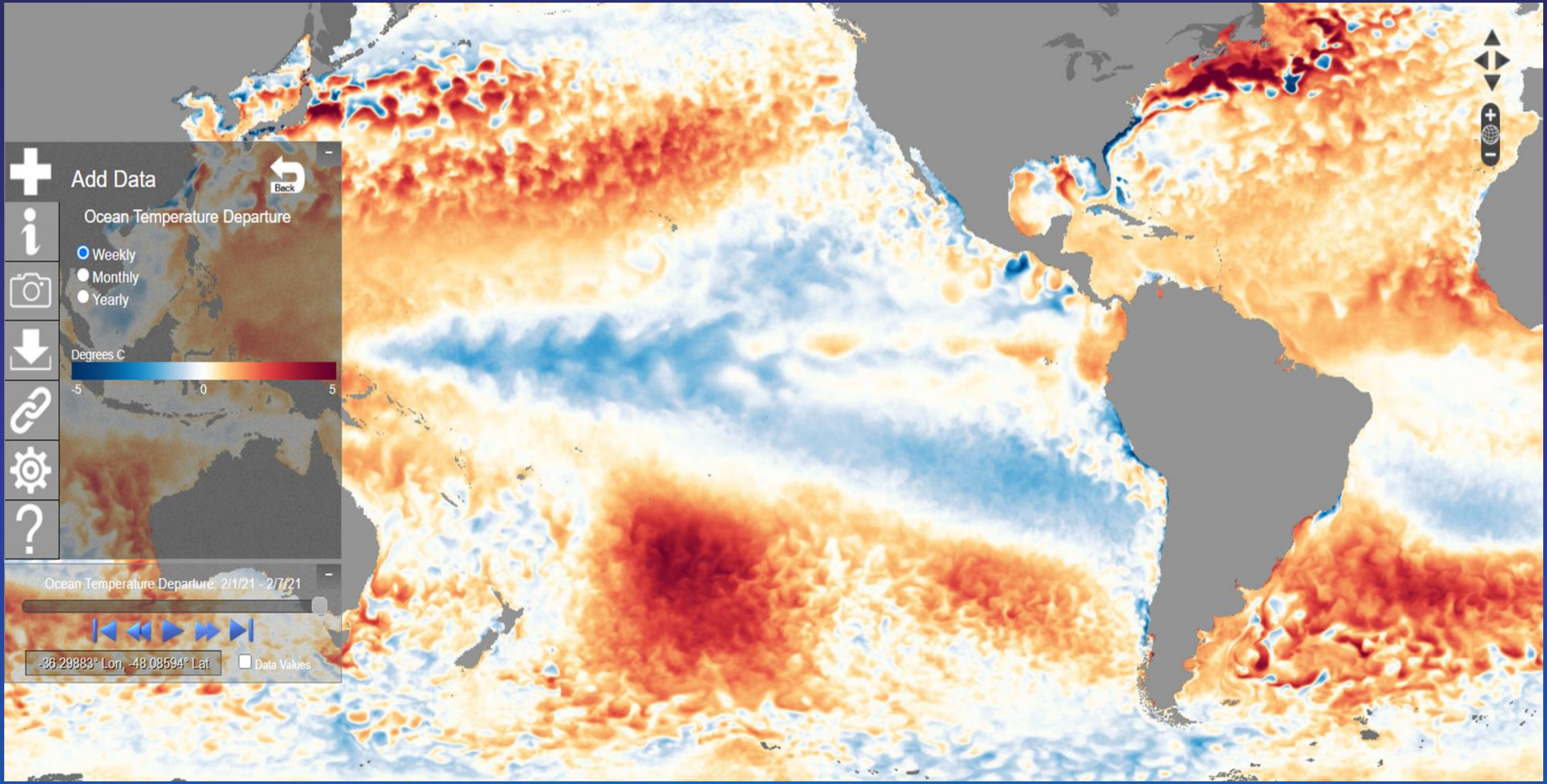
Convection forms
downstream from / over
warmer SSTs

Upwelling from
Papagayo Low-level Jet

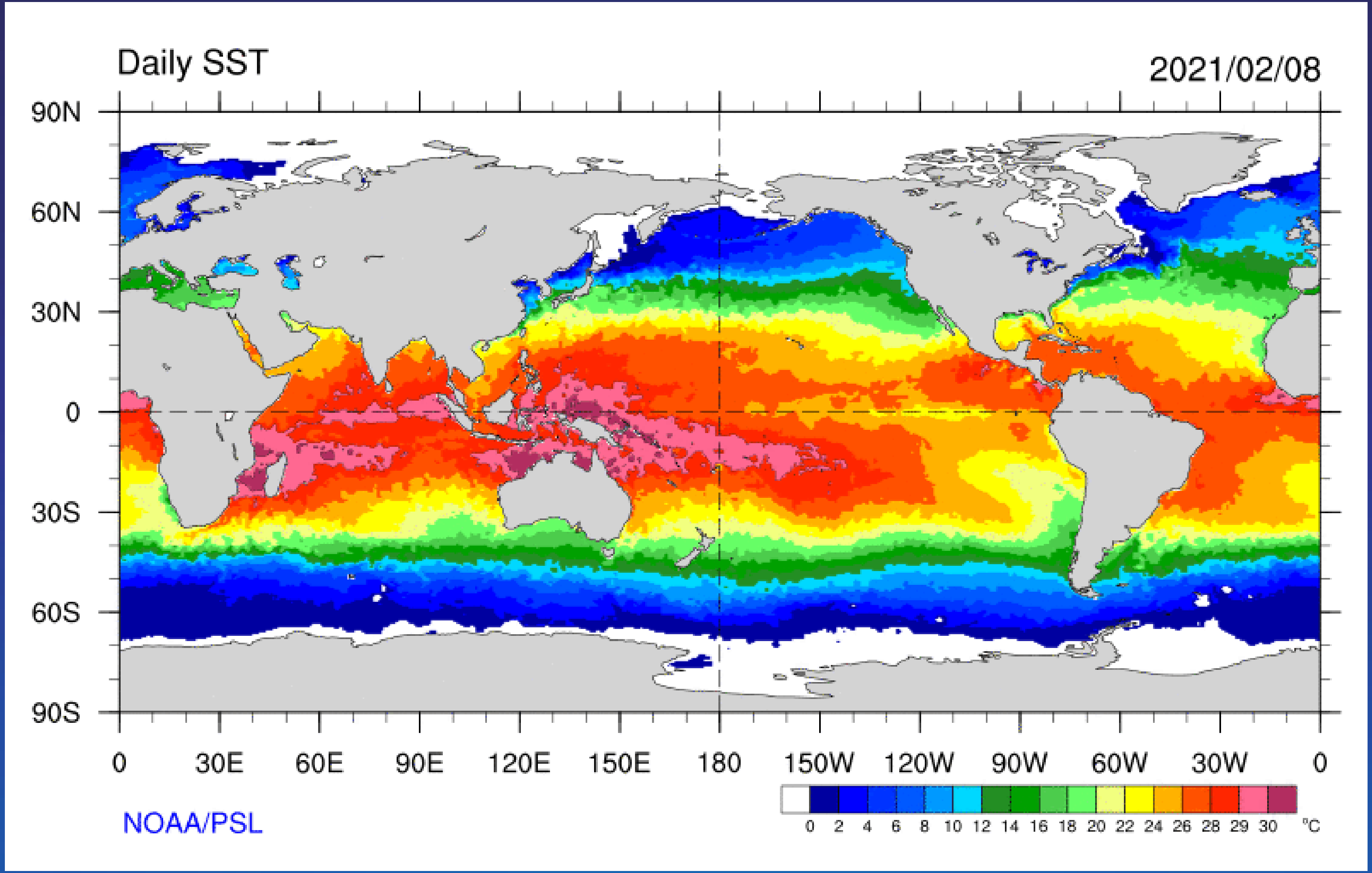
SST: Upwelling inhibits convection



Importance of anomalies



Current SST and Anomalies: Discussion



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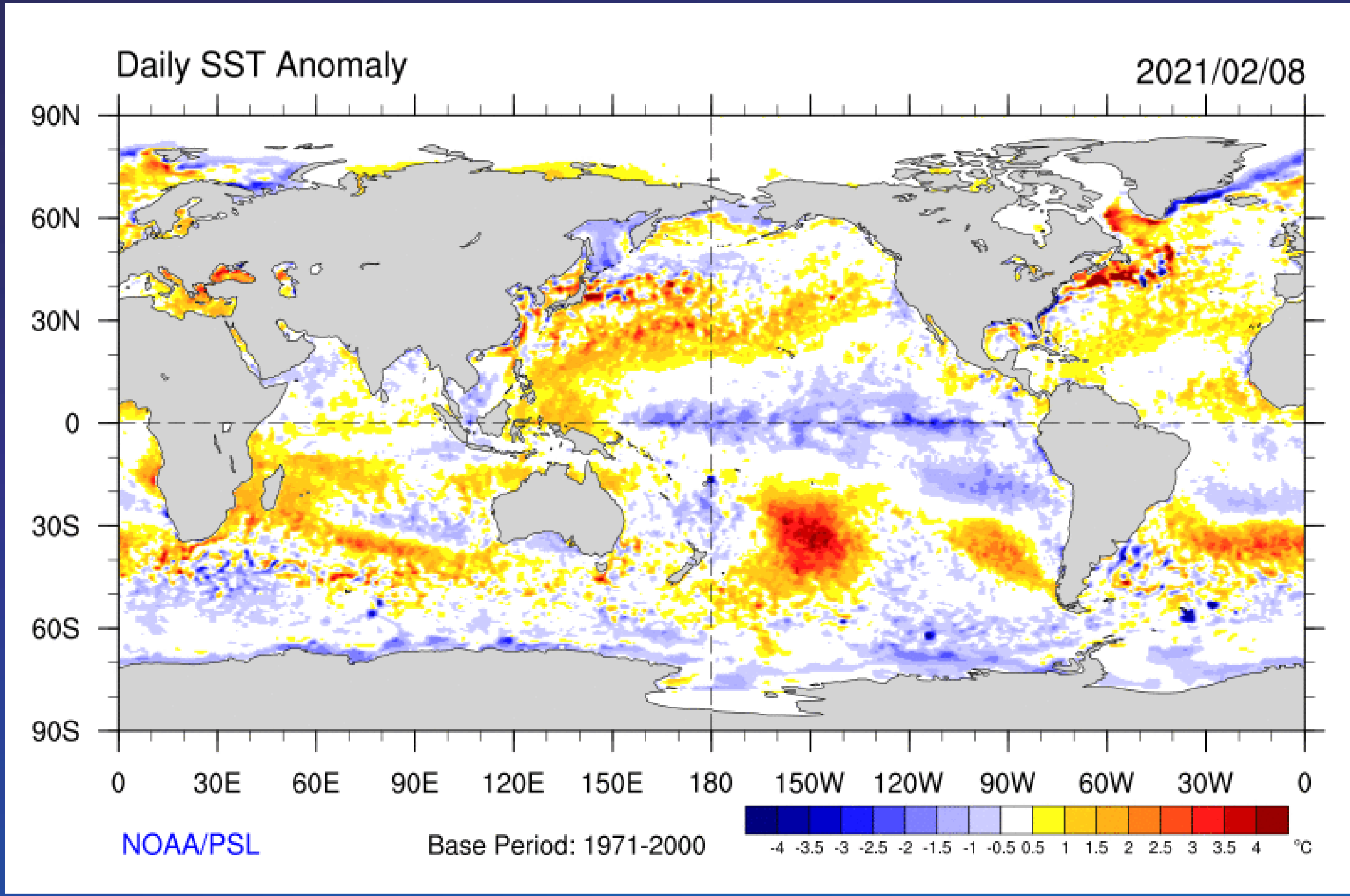

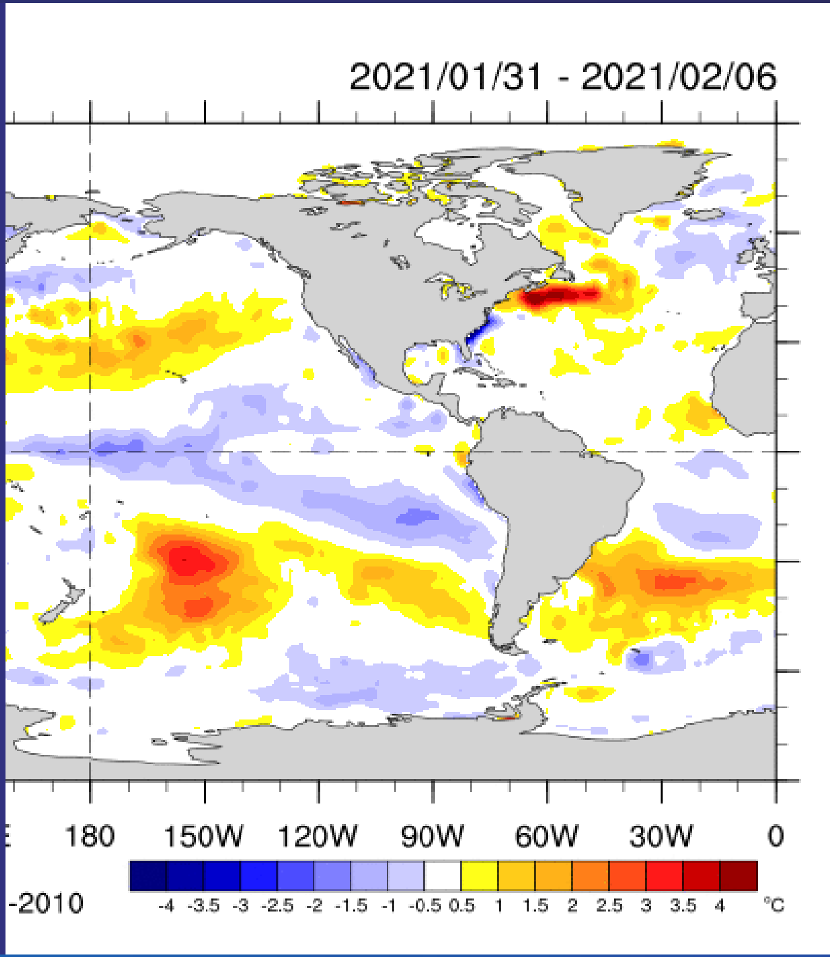

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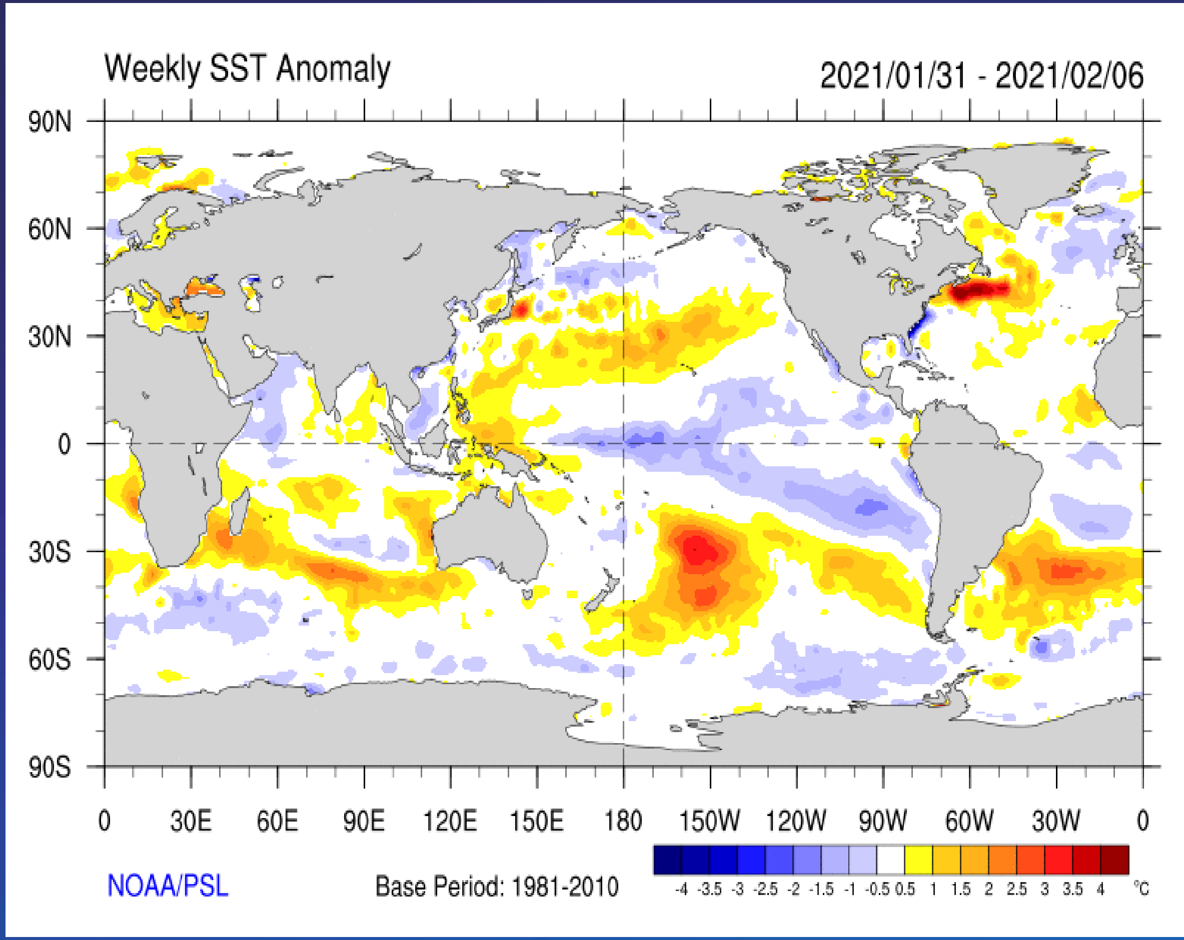
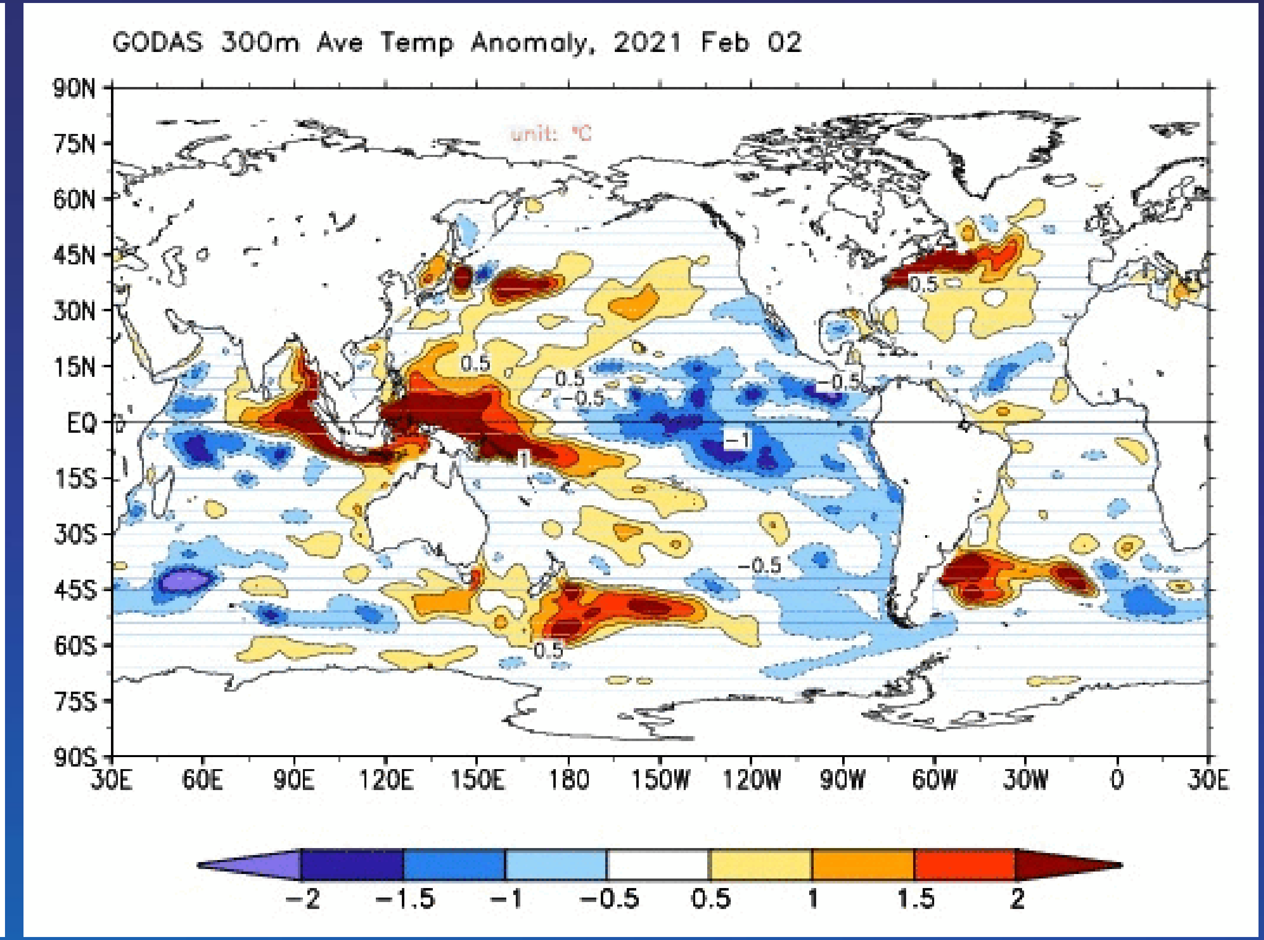




SST Resources

SST and anomalies, NOAA PSL: https://psl.noaa.gov/map/clim/sst.shtml

Layer Anomalies, CPC GODAS: https://www.cpc.ncep.noaa.gov/products/GODAS/

Other links:

NOAA OSPO SST (Office of Satellite and Product Operations): https://www.ospo.noaa.gov/Products/ocean/sst/contour/

NOAA OSPO SST Anomalies (Office of Satellite and Product Operations): https://www.ospo.noaa.gov/Products/ocean/sst/anomaly/index.html

NOAA NNVL SST Optimal Interpolation SST (OISST) Anomalies: https://www.nnvl.noaa.gov/view/globaldata.html#SSTA

GHRSST (Group for High Resolution Sea Surface Temperature): https://www.ghrsst.org/latest-sst-map/

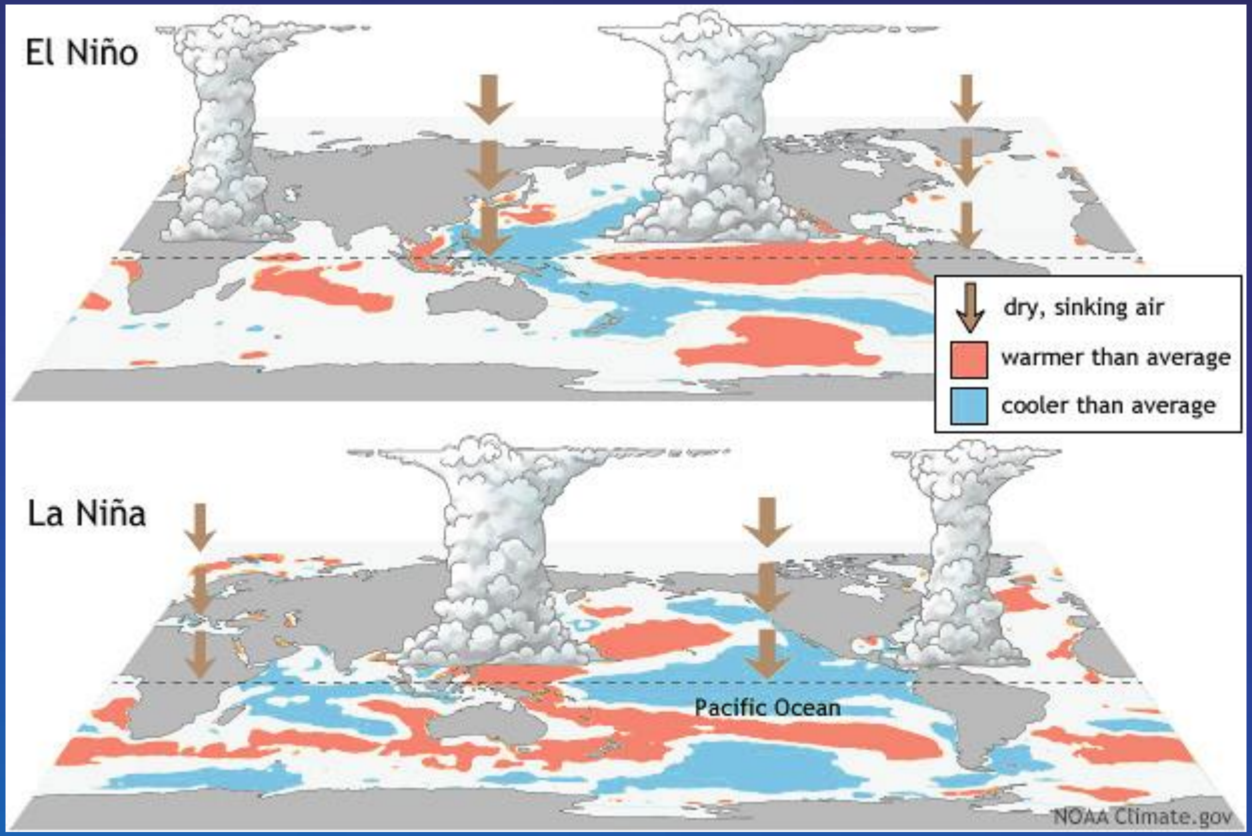
OSTIA (Operational Sea Surface Temperature and Ice Analysis), from the Met Office : http://ghrsst-pp.metoffice.gov.uk/ostia-website/index.html

NOAA Star Ocean Color Research Team – OCView: https://www.star.nesdis.noaa.gov/socd/mecb/color/ocview/ocview.html

El Niño-Southern Oscillation (ENSO)

Definition

- ENSO is a recurrent climate pattern across the Tropical Pacific.
- Consists of changes in many oceanic and atmospheric variables that persist during several months.
- Has 3 phases: El Niño (warm), La Niña (cool) and neutral.

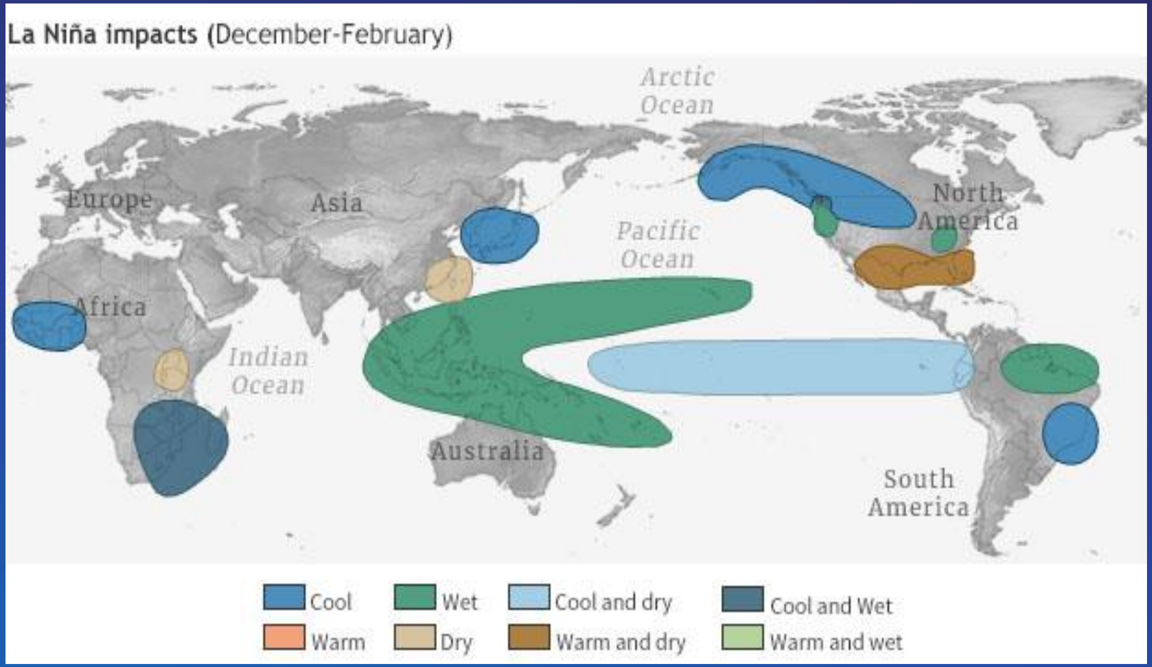


Source: Climate.gov

El Niño-Southern Oscillation (ENSO)

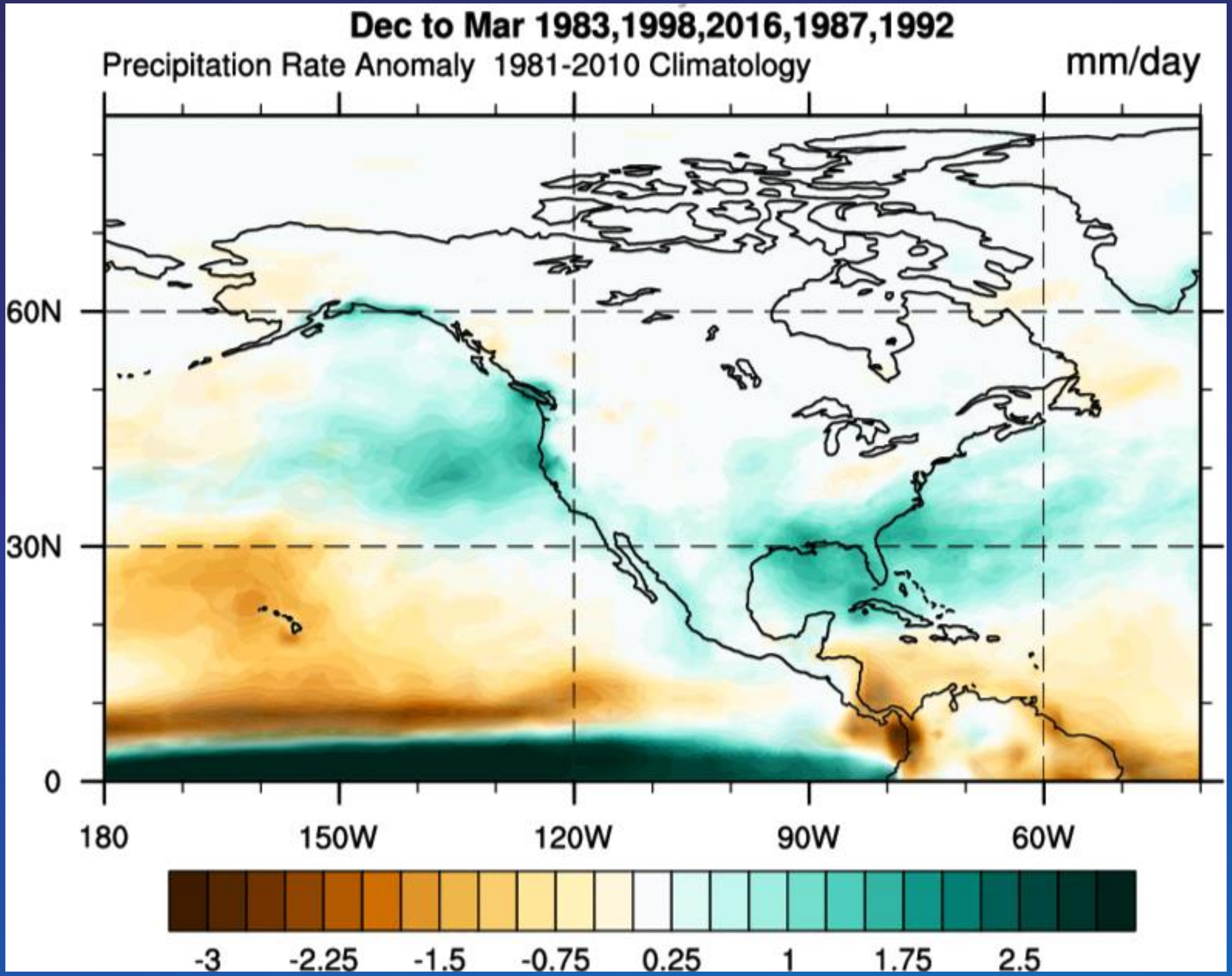
Great tool for Seasonal Forecasting around the Globe

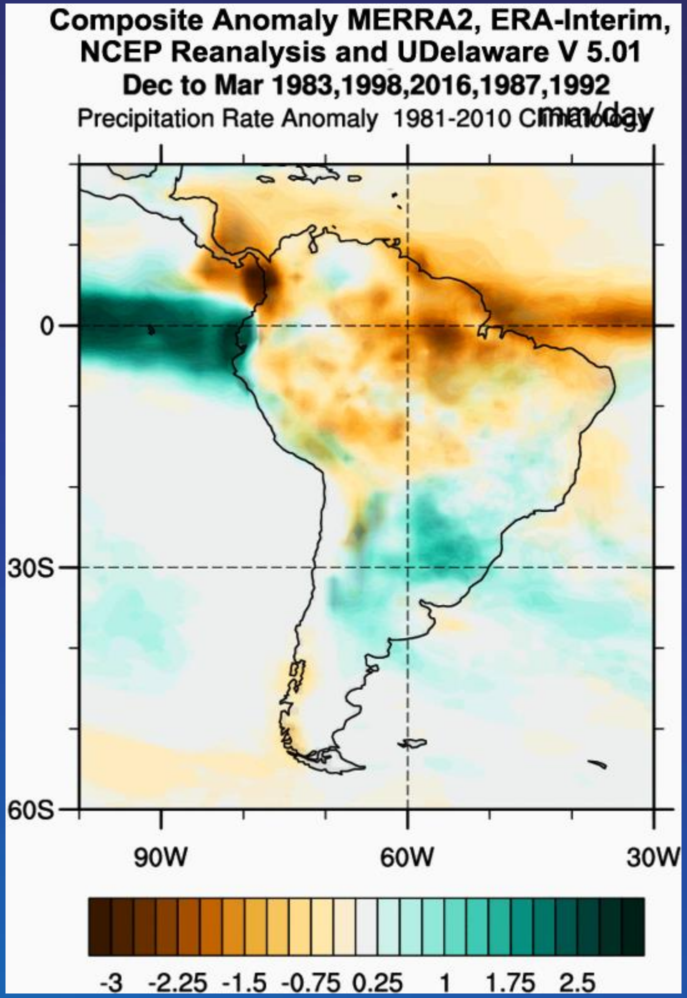
- ENSO has the ability to change the global atmospheric circulation, influencing temperature and precipitation globally.
- Excellent tool for seasonal forecasting, as we can predict ENSO's arrival many seasons in advance.



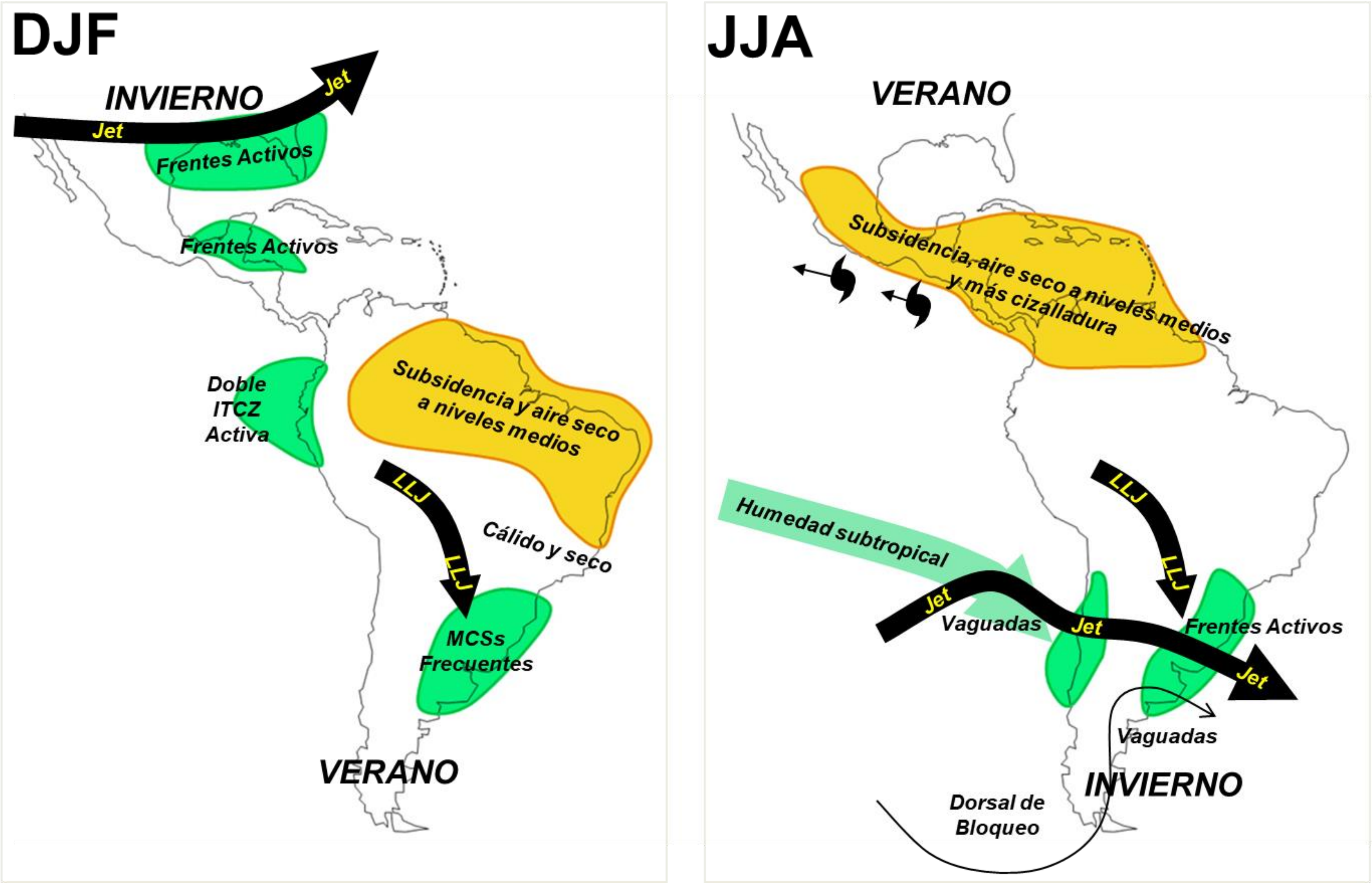
Source: Climate.gov

Warm ENSO Rainfall Anomalies





Warm ENSO Rainfall Anomalies



Poll Question #1

Which are generally true during La Niña? (1 or more)

a. More precipitation in NE South America

b. More precipitation in central Chile

c. More tropical cyclones in the Pacific

d. More tropical cyclones in the Caribbean

e. More precipitation in the Rio de La Plata region

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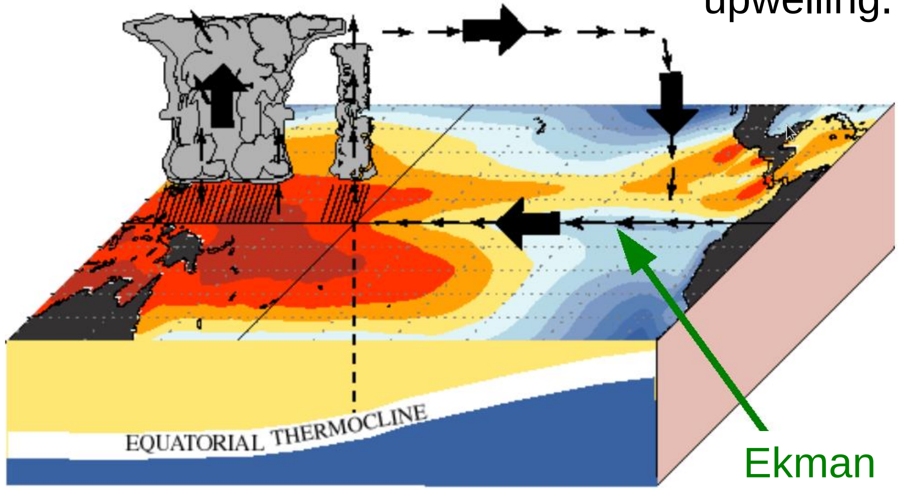
El Niño-Southern Oscillation (ENSO)

WARM WATERS
Easterly trades pile up warm water in the Western Pacific

COOL WATER
Trades transport cool waters from the south (Humboldt current) along South America, as well as cool waters from coastal upwelling. They favor equatorial upwelling.

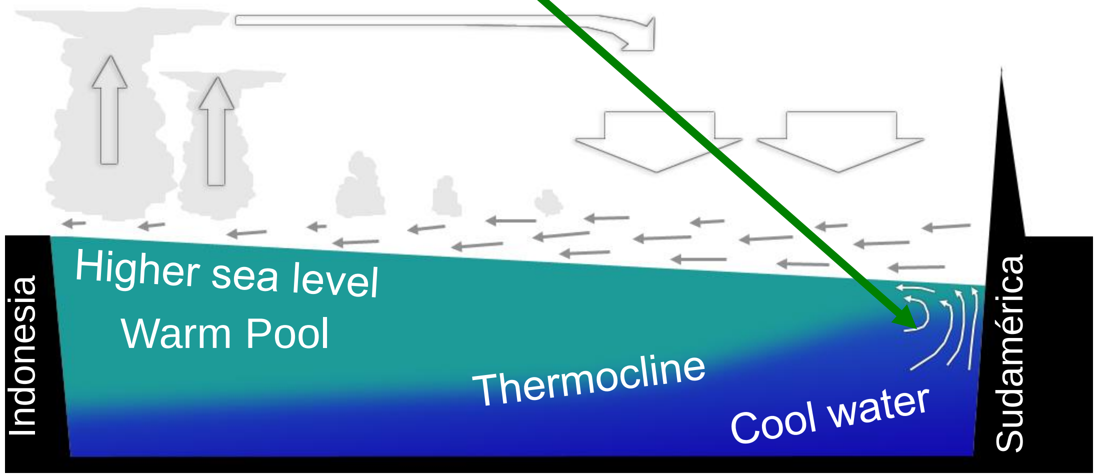
Normal



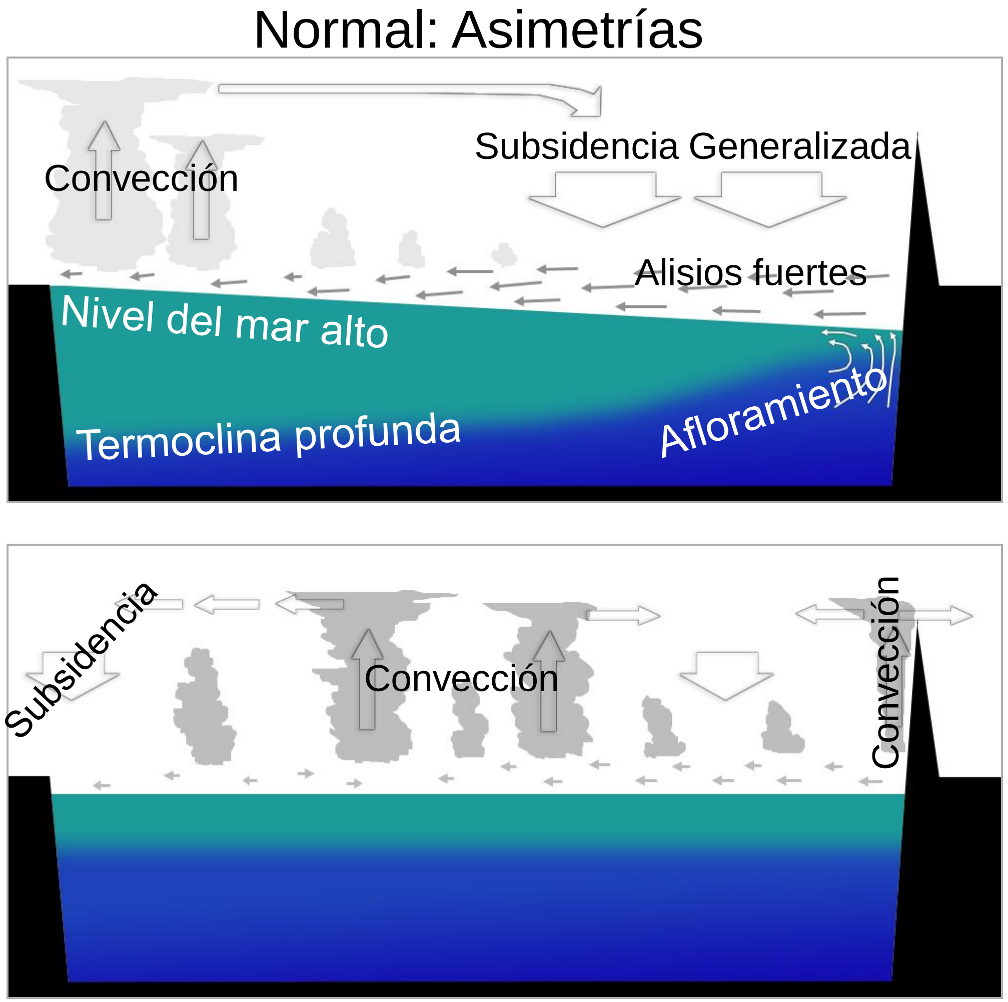
WALKER CIRCULATION
Subsiding branch of the Walker circulation enhances stability over the Eastern Pacific

Ekman
Upwelling

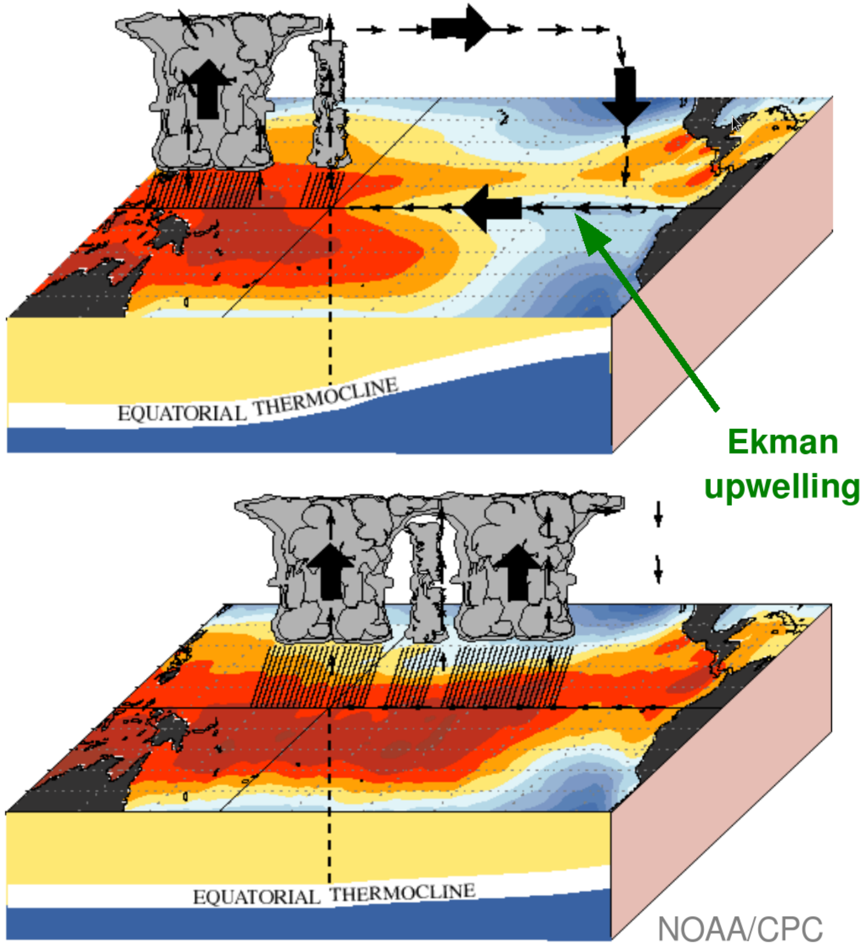
SEA LEVEL AND THERMOCLINE
- Higher sea level and deeper thermocline in Western Pacific.



Warm ENSO



Normal: Asimetrías
Convección
Subsidencia Generalizada
Alisios fuertes
Nivel del mar alto
Termoclina profunda
Afloramiento
Subsidencia
Convección
Convección



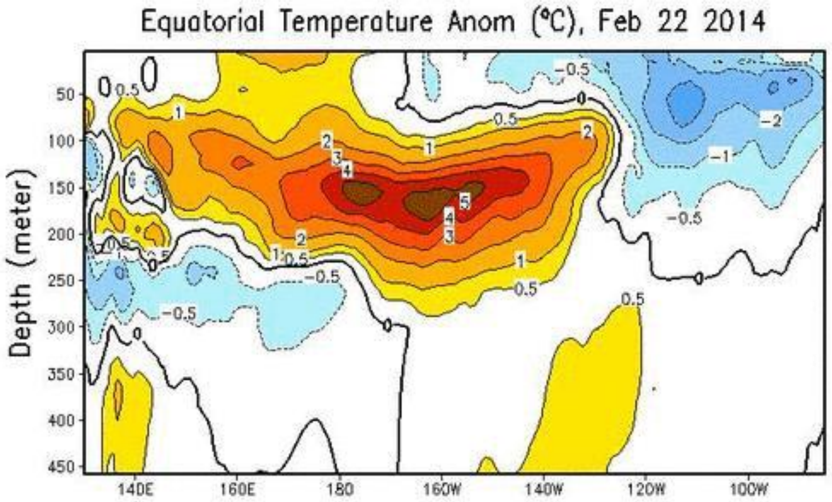
EQUATORIAL THERMOCLINE
Ekman upwelling
EQUATORIAL THERMOCLINE
NOAA/CPC

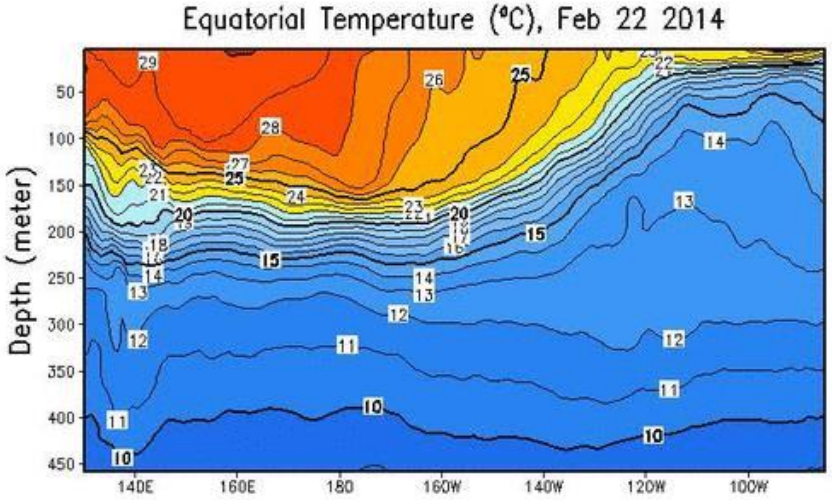
Ocean-Atmospheric Coupling

Occurs via interactions between surface winds and the ocean surface:

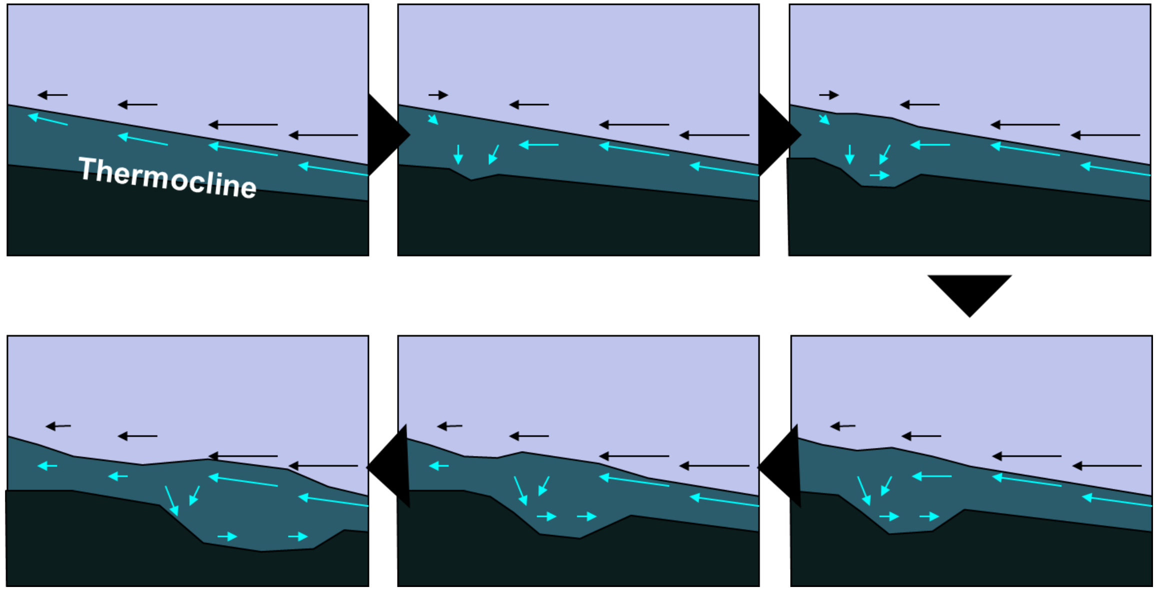
- Winds push currents
- Currents redistribute water masses
- The superficial temperature (SST) of water masses modifies atmospheric circulations

Oceanic Kelvin Wave Mechanism



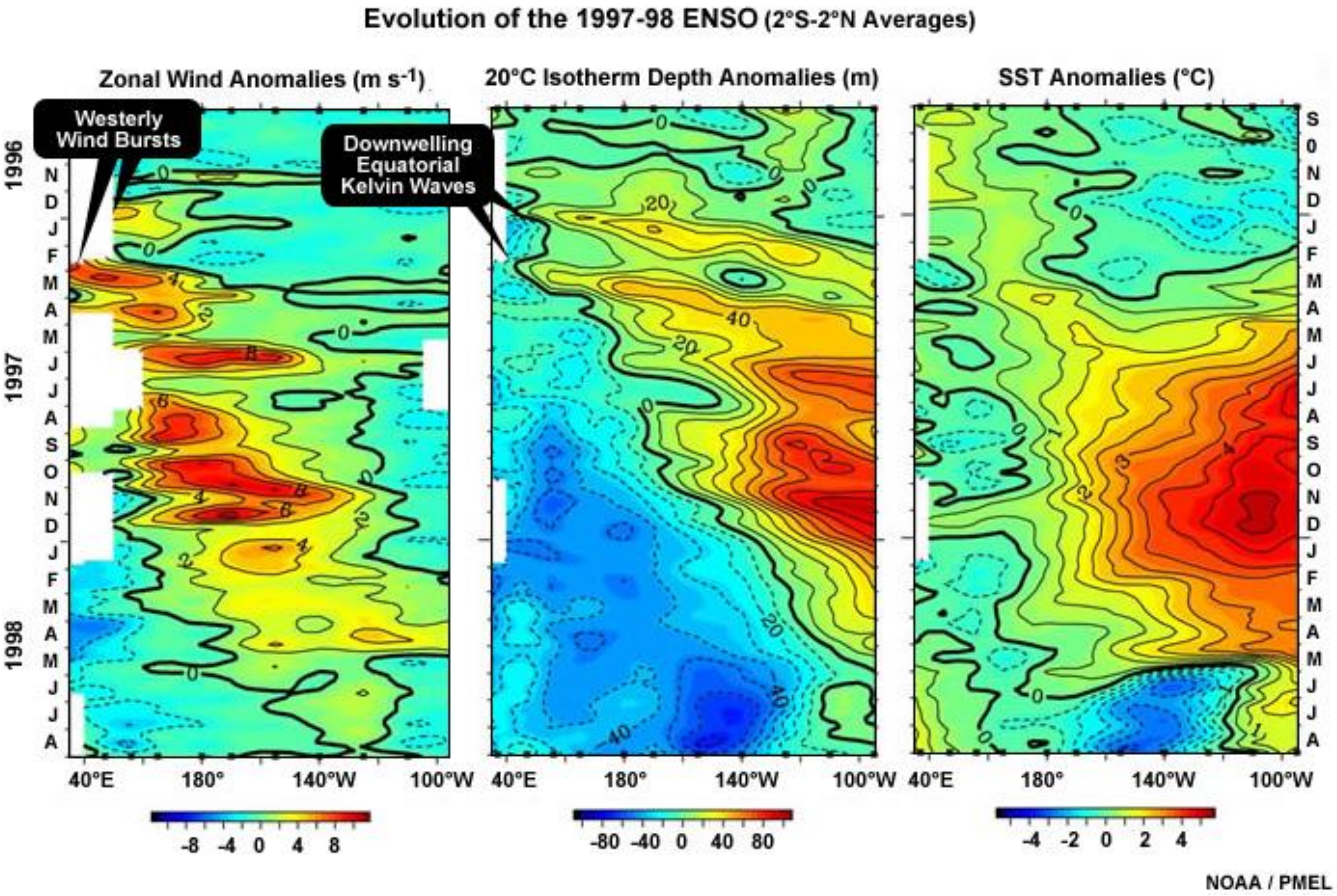


- Westerly wind bursts generate convergence when interacting with easterly trades
- Currents converge too, and generate a perturbation that propagates eastward along the equator
- This reflects in changes in sea-level and the depth of the thermocline.

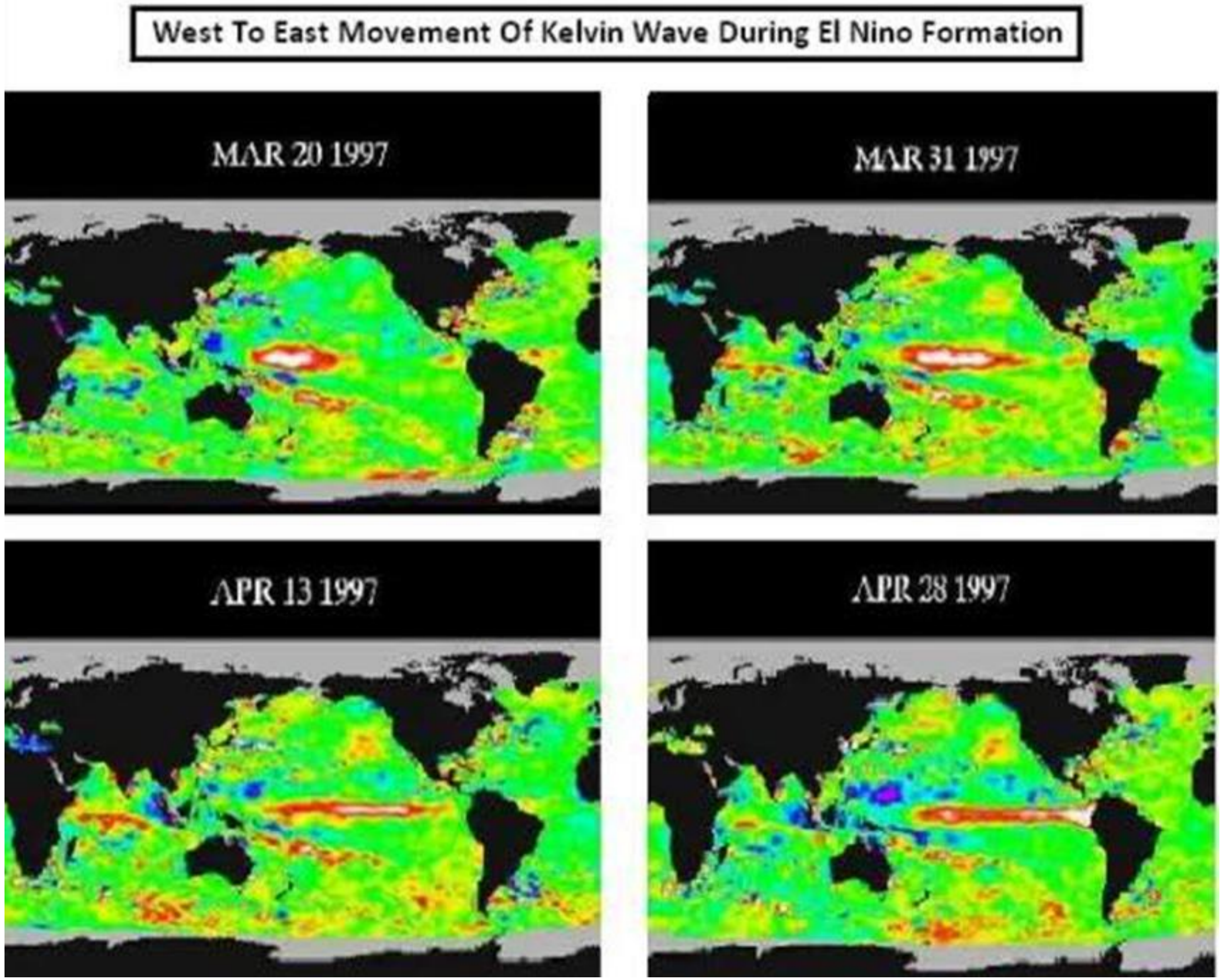


Evolution of the 1997 El Niño

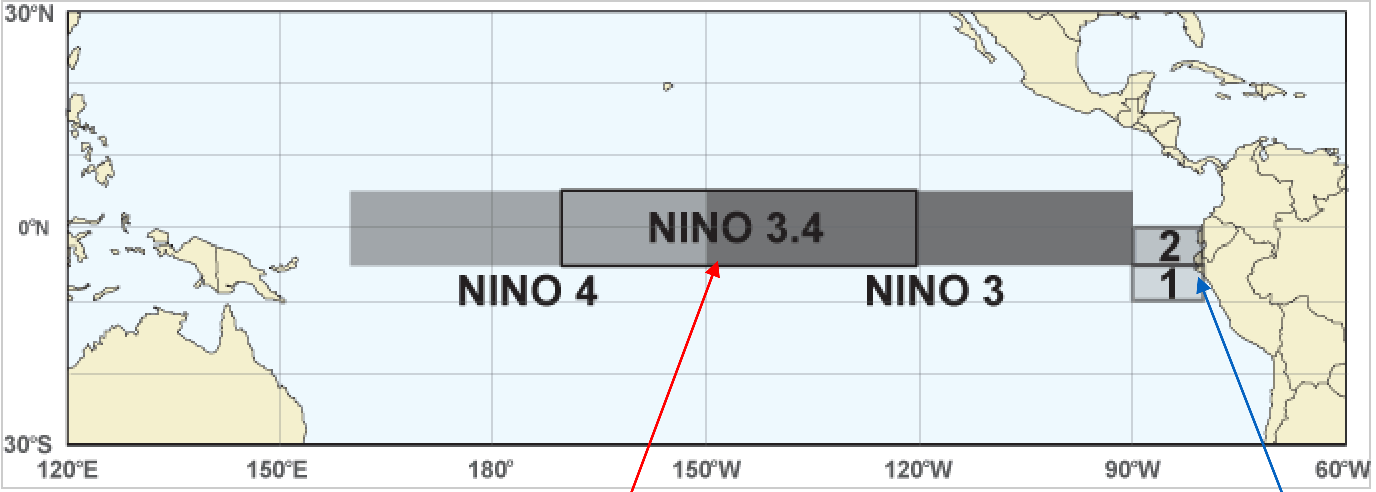
- Westerly wind bursts induce downwelling Kelvin Waves that reach the South American coast and warm up the ocean.
- Currents distribute warm air masses westward.



Kelvin Waves also reflect on sea level



Classification and Monitoring



Niño 3.4:

- Better predictability
- More influence on global impacts
- CPC/IRI use this region for monitoring and forecasting ENSO.

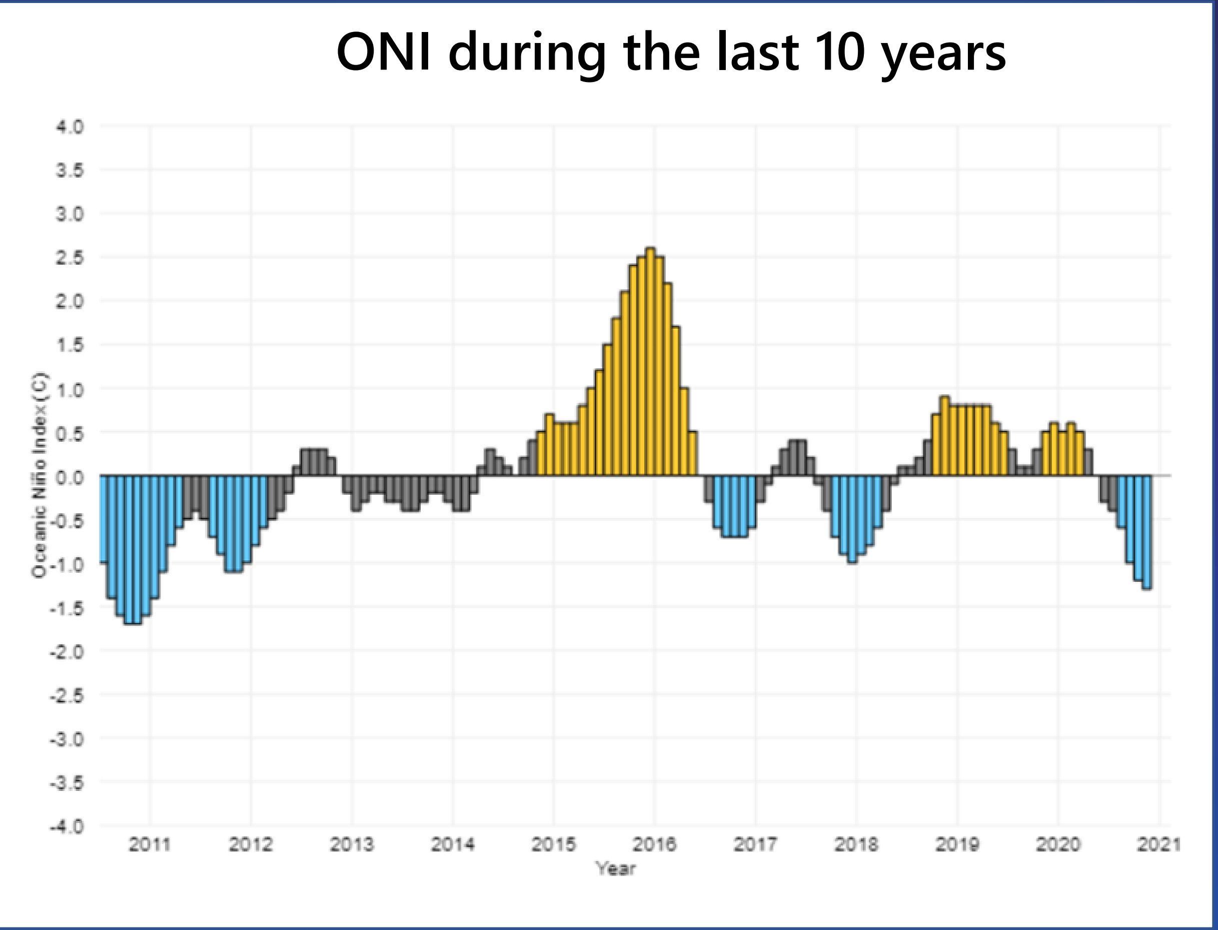
Niño 1+2:

- Affects directly the South American Coast
- Of special interest to Ecuador and Peru
- Hard to predict

Oceanic Niño Index (ONI)

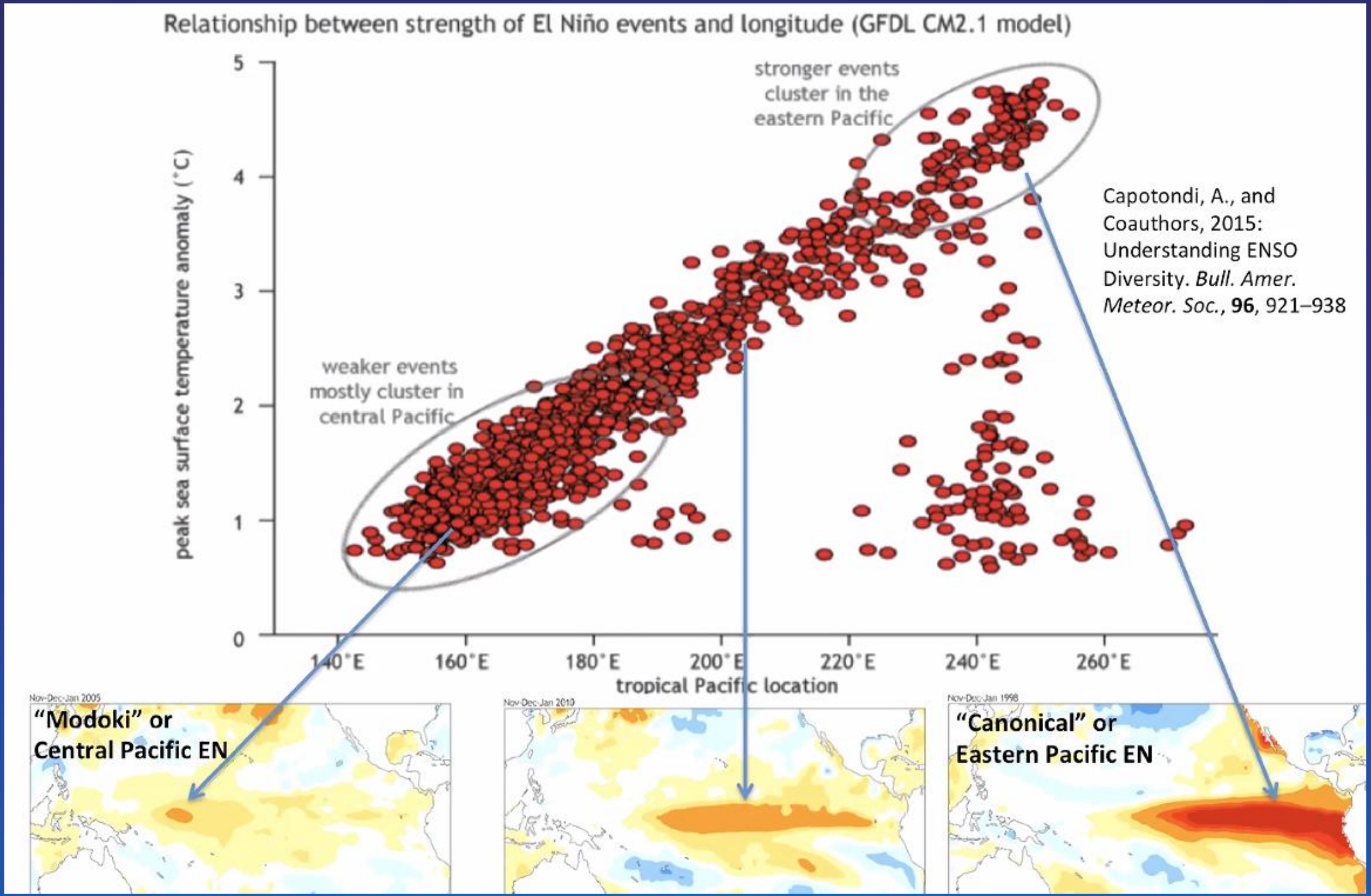
ONI Calculation:

1. Average the Niño 3.4 region SST for each month.
2. Average it with values from the previous and following months.
3. This running three-month average is compared to a 30-year average.



Source: https://www.climate.gov/news-features/understanding-climate/climate-variability-oceanic-ni%C3%B1o-index

ENSO "Flavors"



Capotondi, A., and Coauthors, 2015: Understanding ENSO Diversity. *Bull. Amer. Meteor. Soc.*, **96**, 921–938

Courtesy: Michelle L'Heureux.

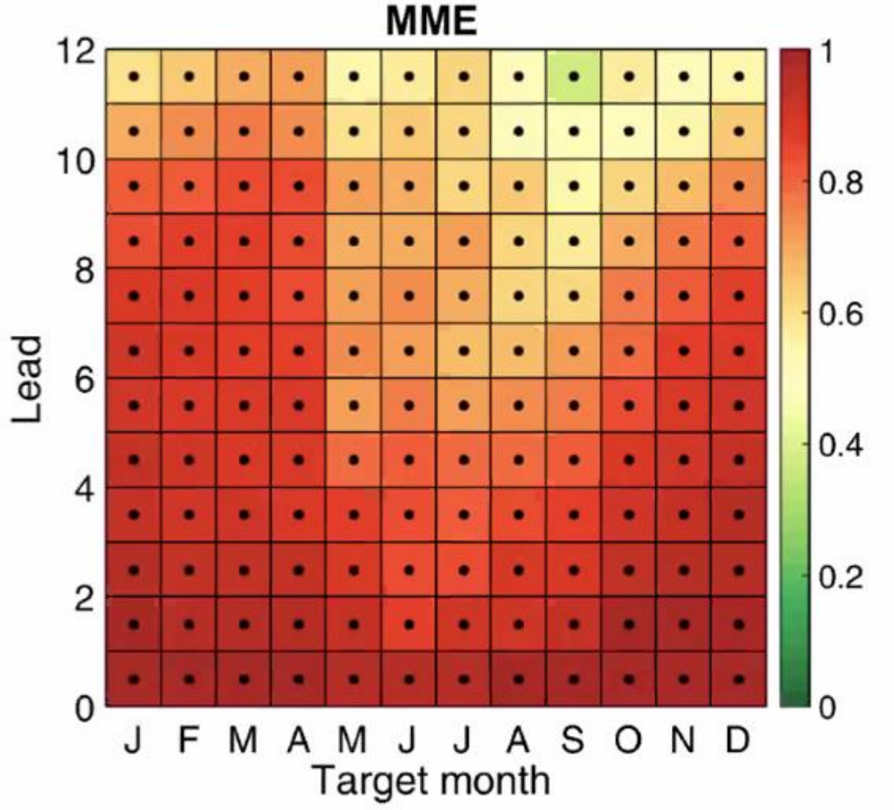
ENSO Predictability

ONI Calculation:

1. Average the Niño 3.4 region SST for each month.
2. Average it with values from the previous and following months.
3. This running three-month average is compared to a 30-year average.

Correlation coefficient (r) colorbar varies from…
No skill r=0 (green)
to
perfect skill r=1 (red)

r^2 = Explained Variance (%)



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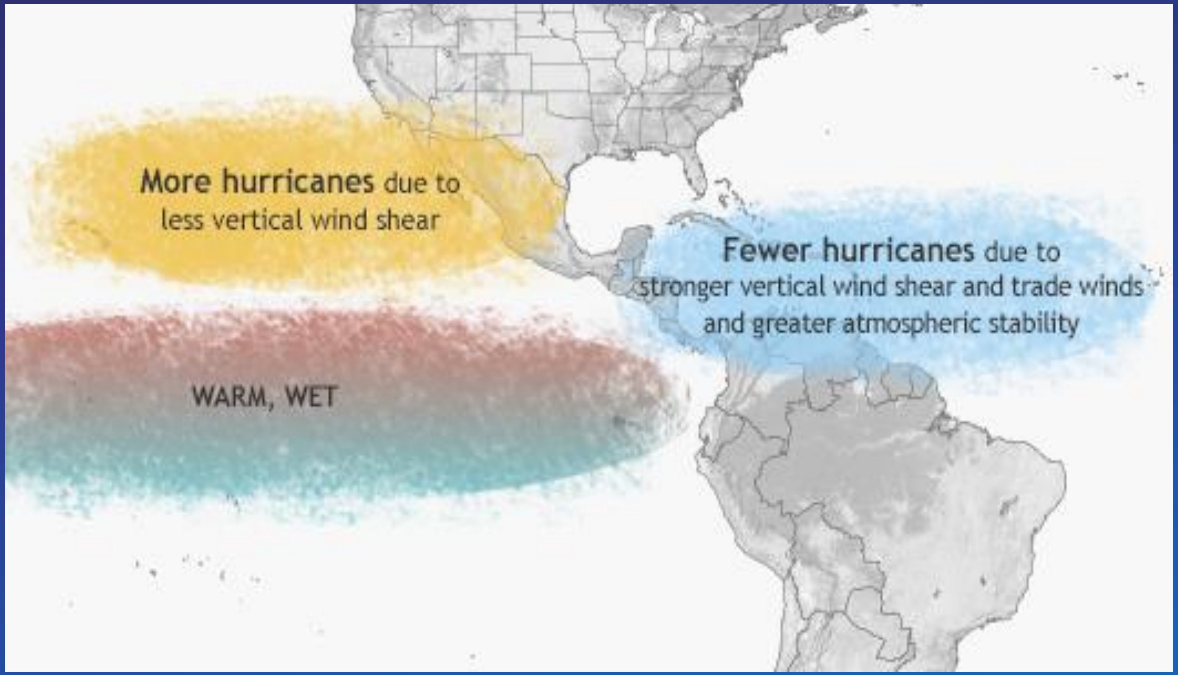
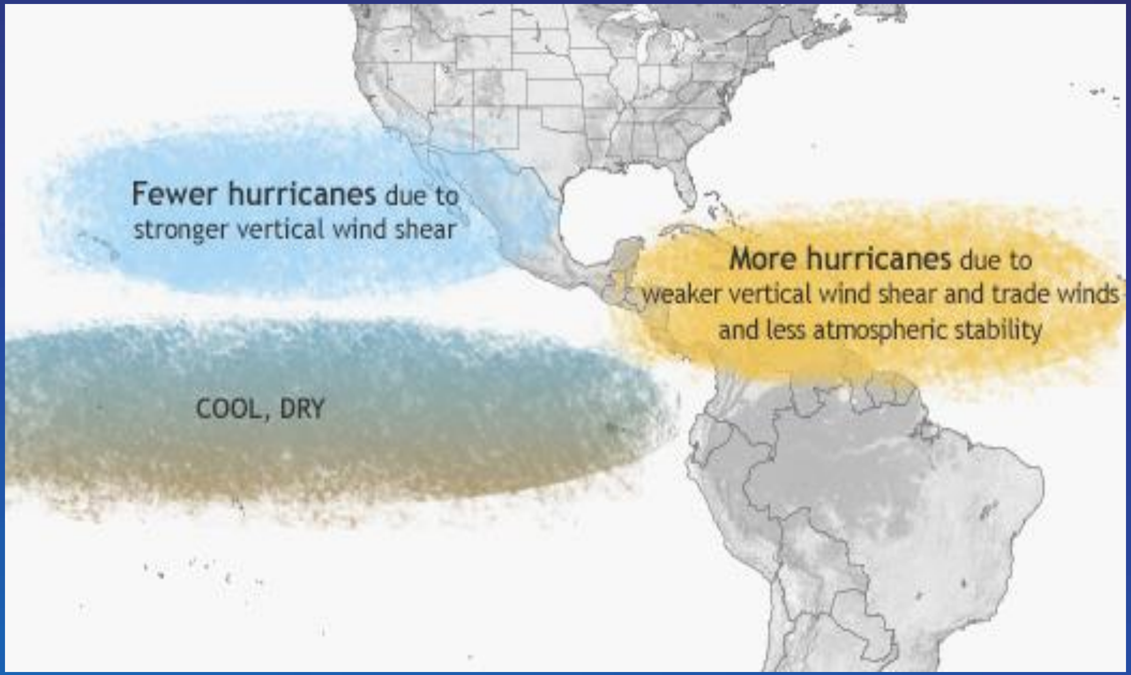
ENSO and Hurricanes

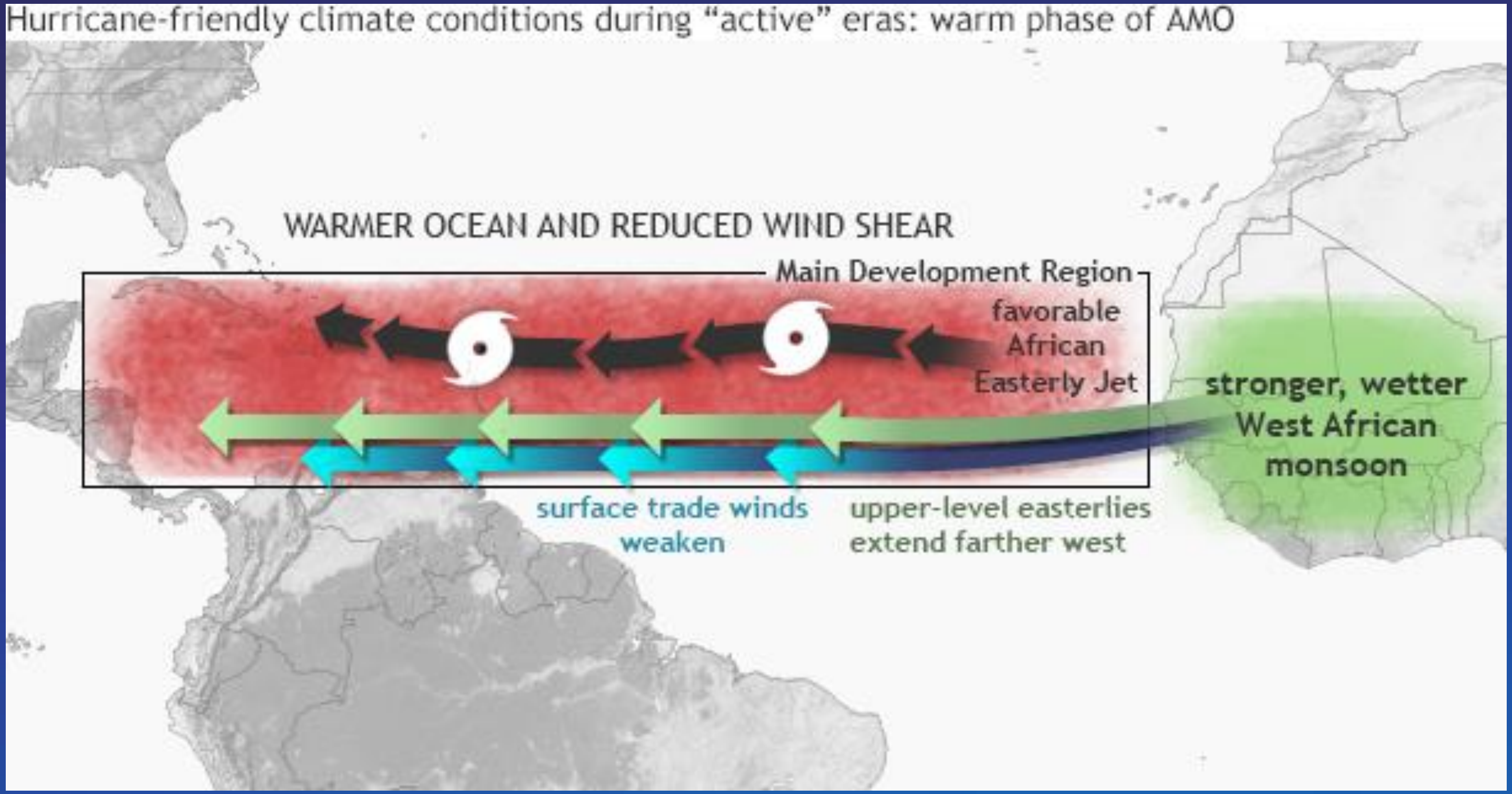
Great tool for Seasonal Forecasting around the Globe





ENSO and Hurricanes in the Atlantic

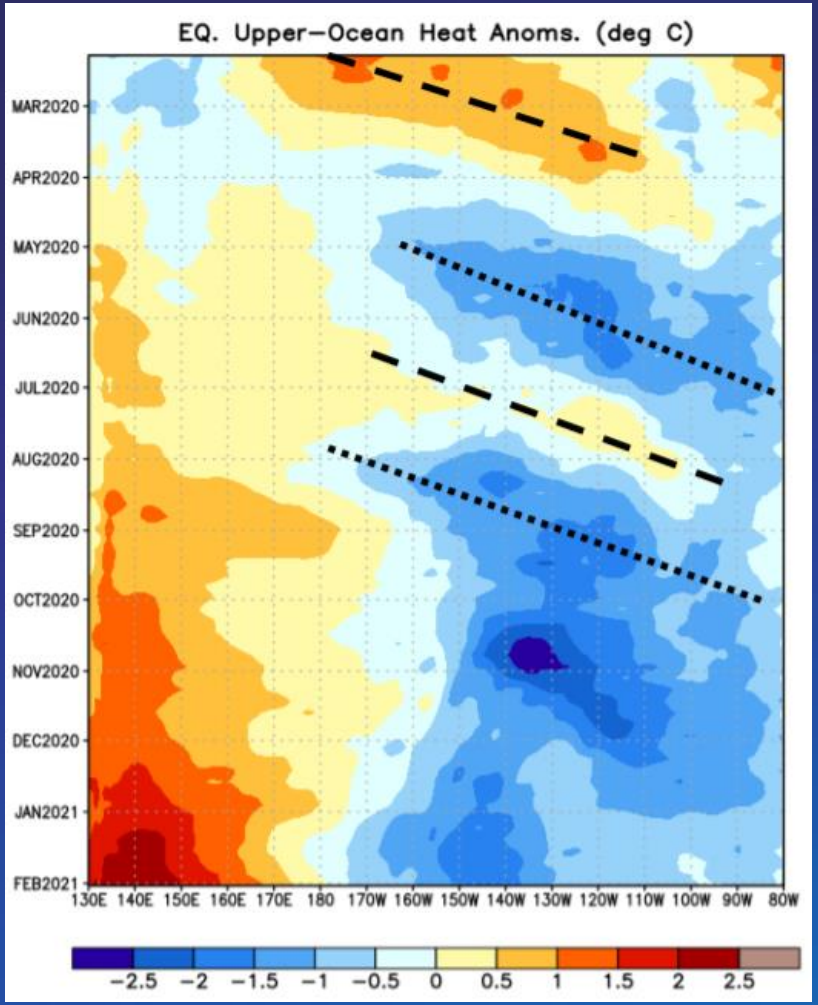
Cool ENSO and Warm Atlantic Multidecadal Oscillation (AMO)

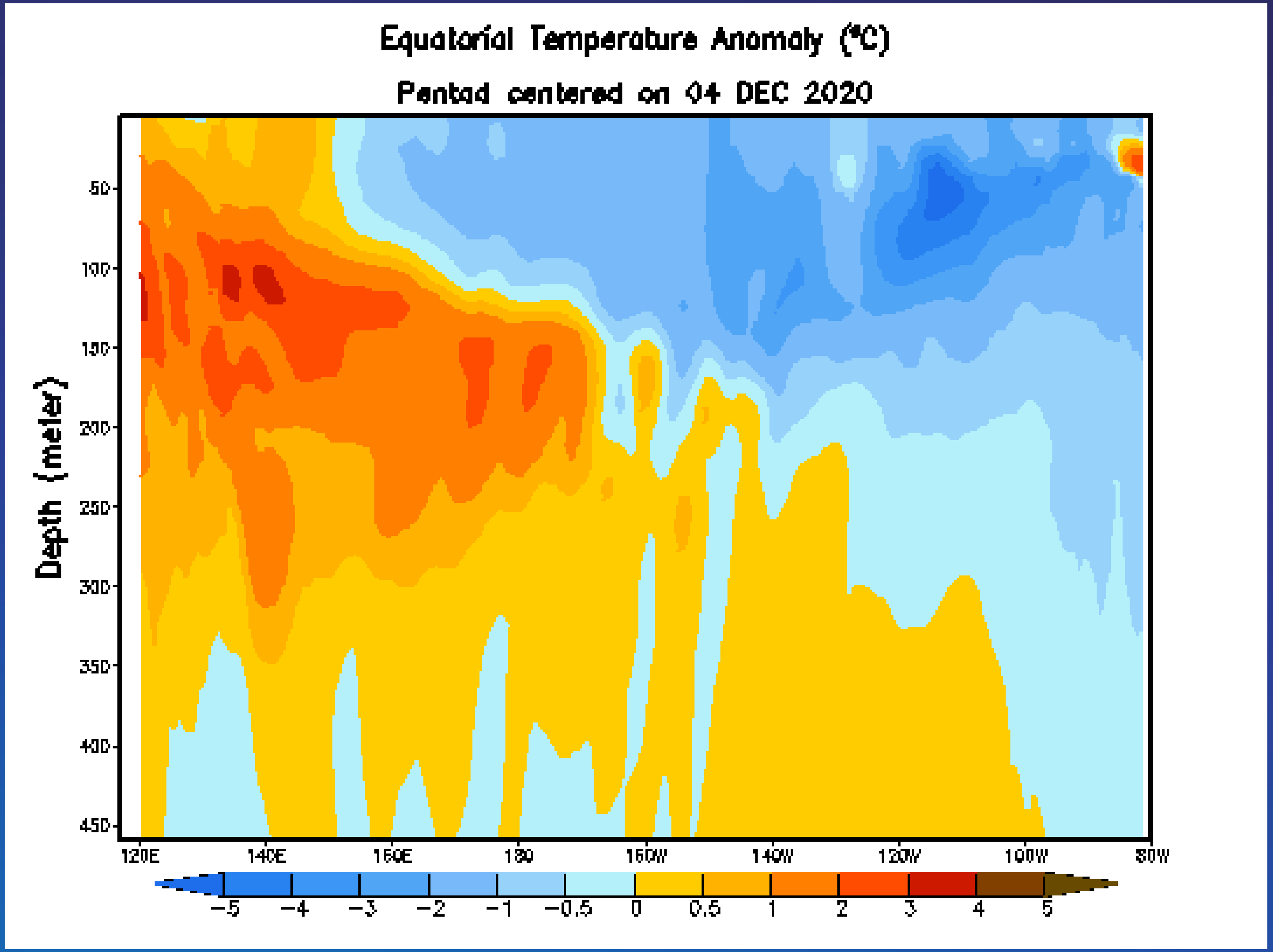


Warm phase of the AMO: Associates with warmer temperatures in the hurricane formation region

AMO: Goldenberg et al. 2001, Bell and Chelliah 2006.

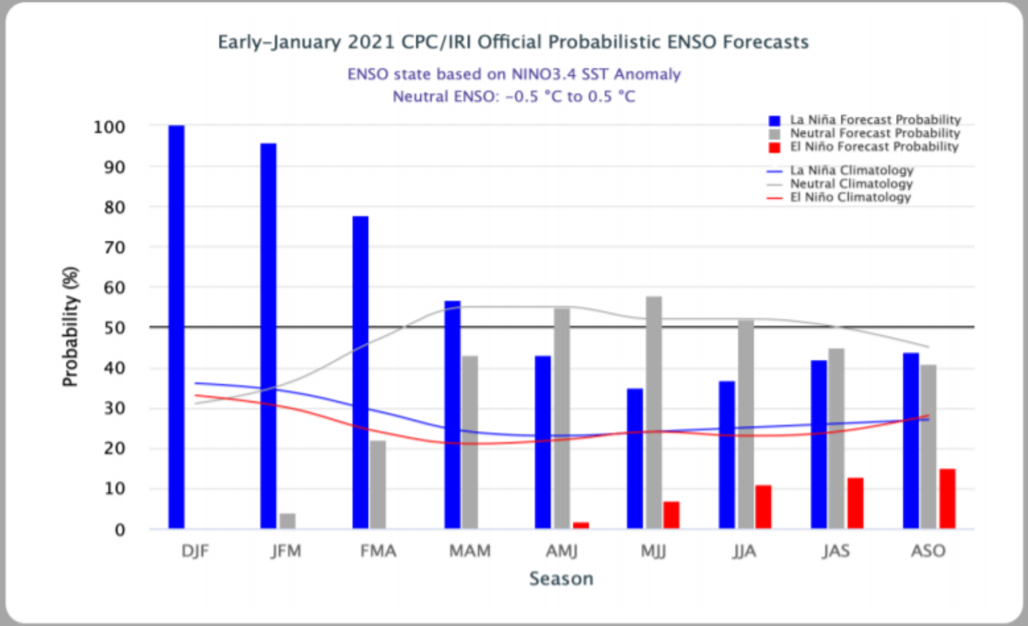
Current Conditions





Current Forecasts

The chances of La Niña are greater than 95% through January-March 2021, with a 55% chance of a transition to ENSO-neutral in April-June 2021.



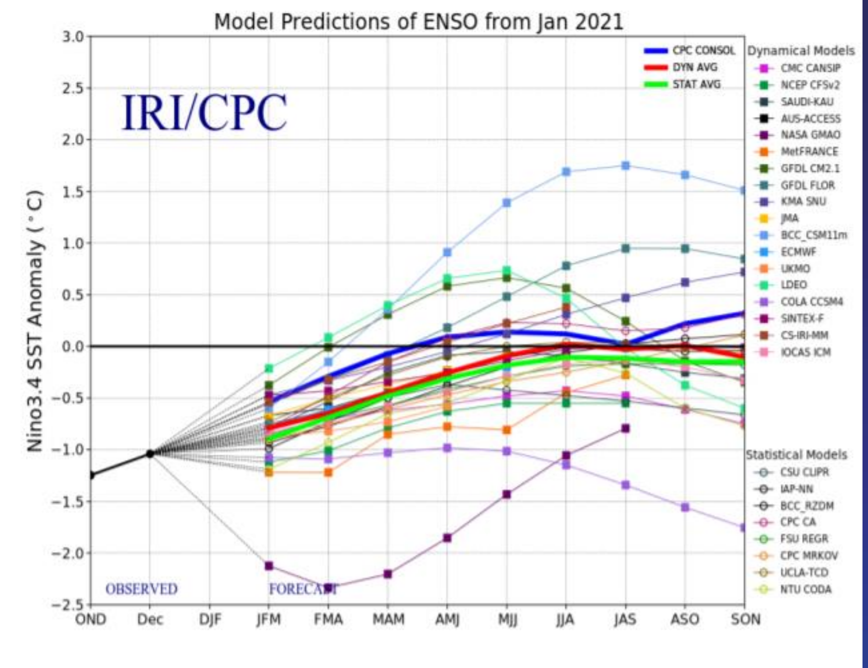


Figure provided by the International Research Institute (IRI) for Climate and Society (updated 19 January 2021).

Poll Question #2

In which time of the year is ENSO less predictable? (pick 1)

a. Northern hemisphere summer

b. Northern hemisphere fall

c. Northern hemisphere winter

d. Northern hemisphere spring

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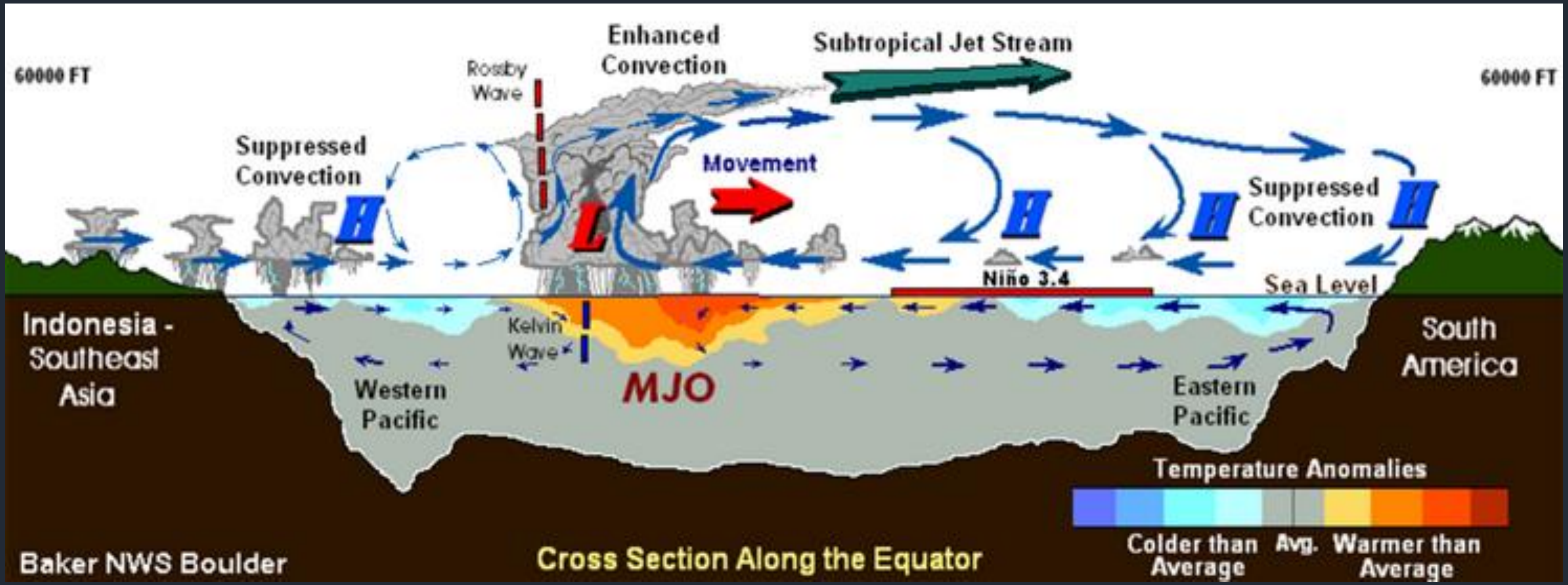
3. The Madden-Julian Oscillation (MJO)



The MJO is discussed in the Monthly Sessions

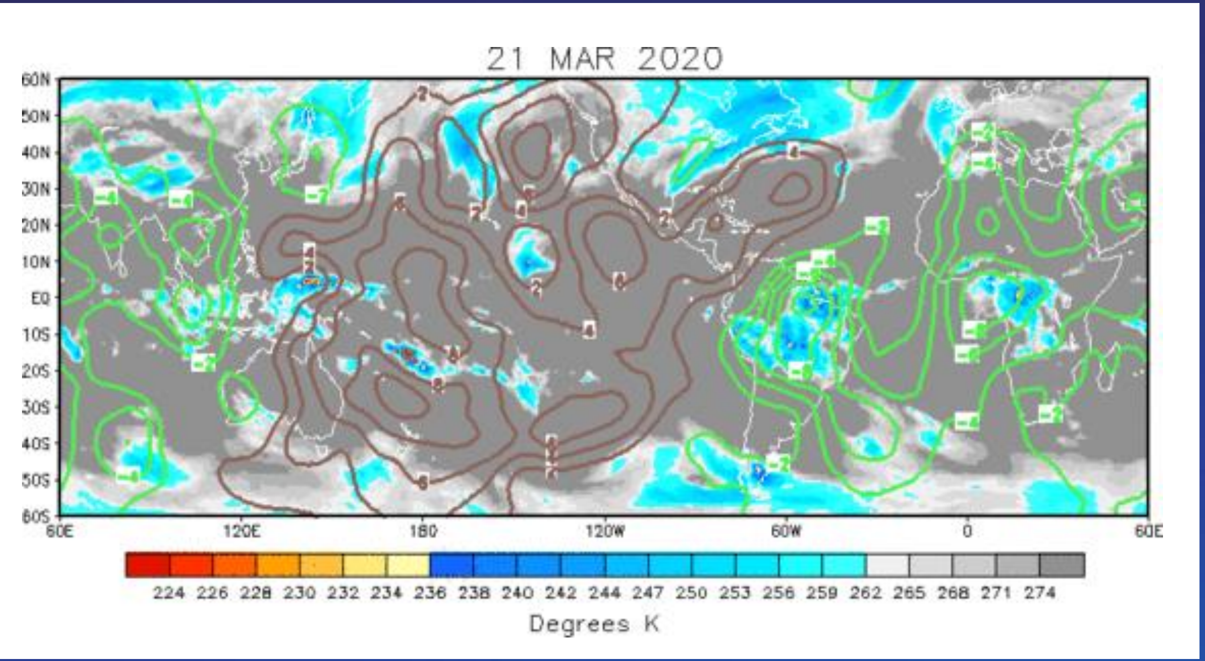


Fig. 200 hPa Velocity Potential (green=divergent or wet, brown=convergent or dry) propagating from west to east from late March through late April of 2020. Source: CPC.

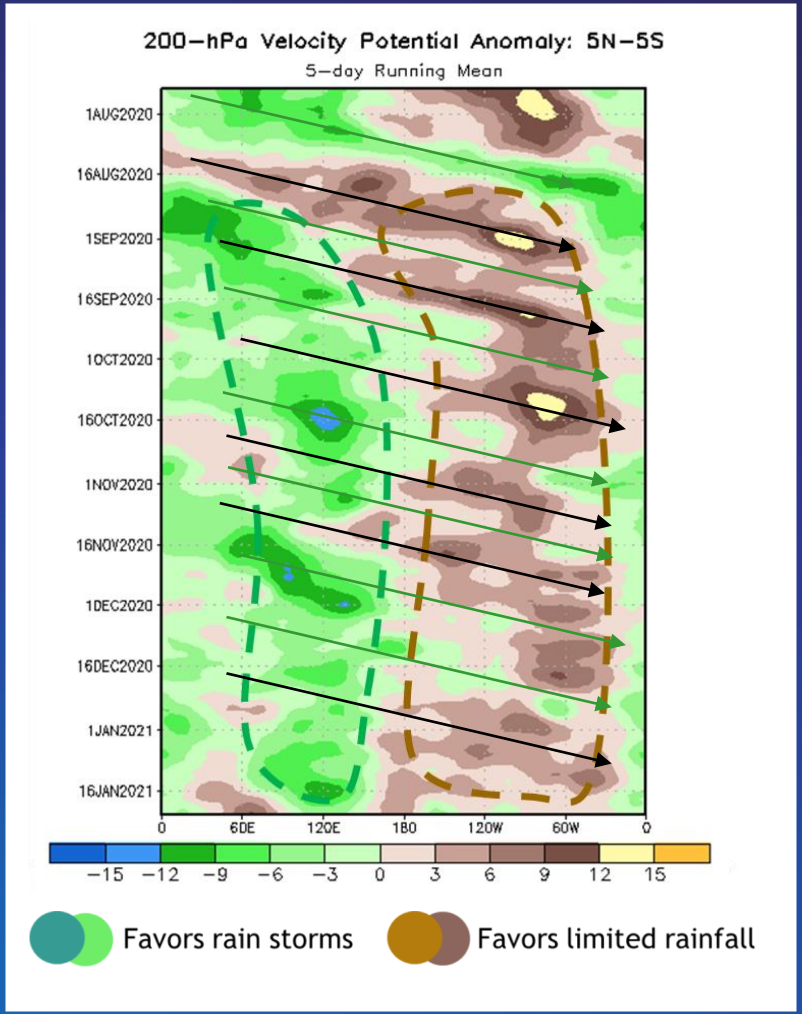


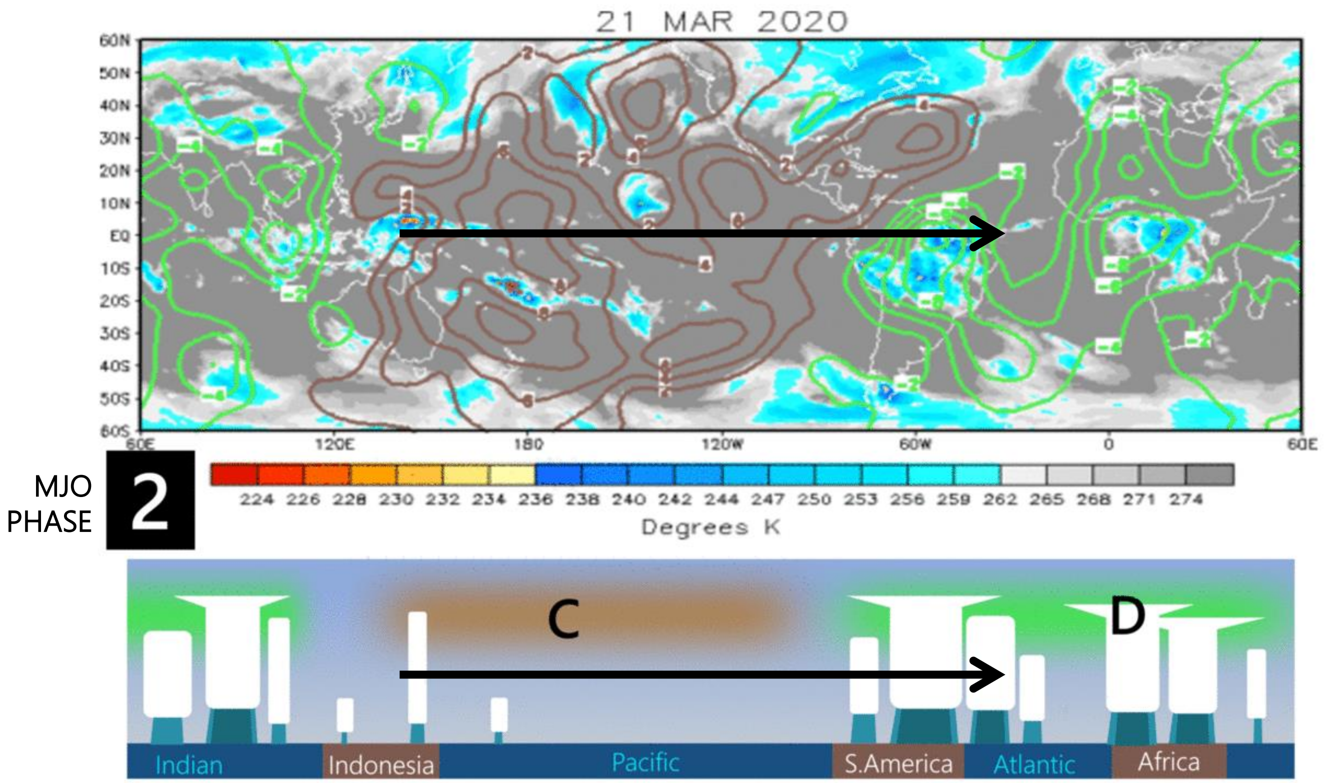
Fig. 200 hPa Velocity Potential Hovmoller diagram ▶

The Madden-Julian Oscillation (MJO)

Definition

- Eastward moving disturbance of clouds, rainfall, winds, and pressure that traverses the planet in the tropics and returns to its initial starting point in ~30 to 60 days.
- <u>Intraseasonal</u> tropical climate variability (i.e. varies on a week-to-week basis).

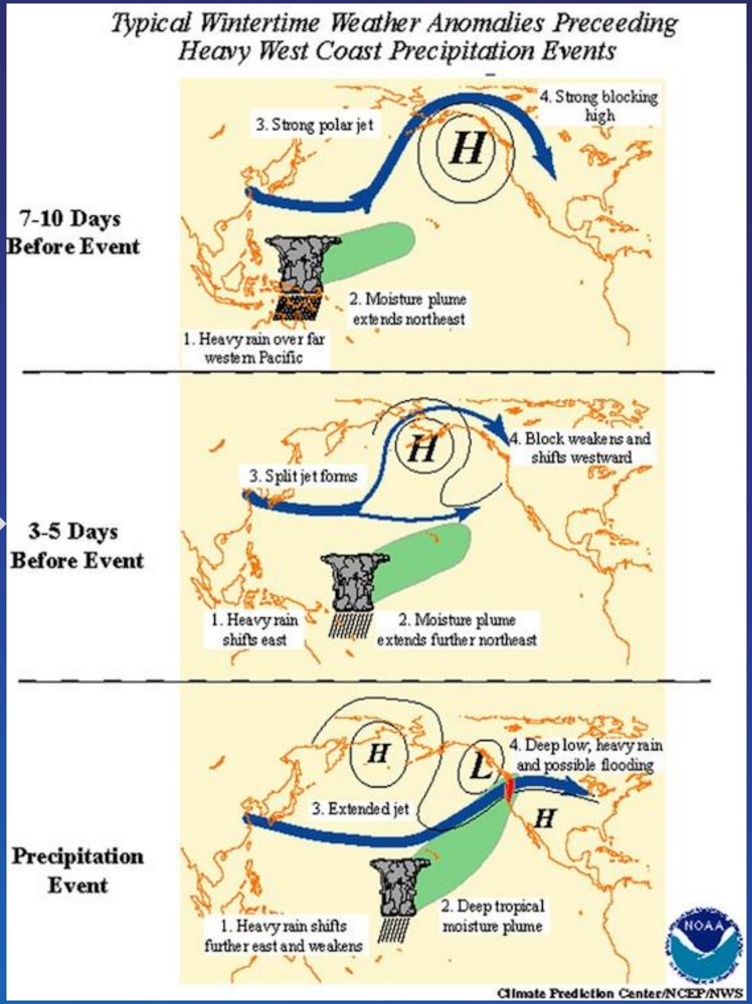
200 hPa Velocity Potential and Brightness Temperature (convection)



Convergent (C) / Divergent (D) and associated convection

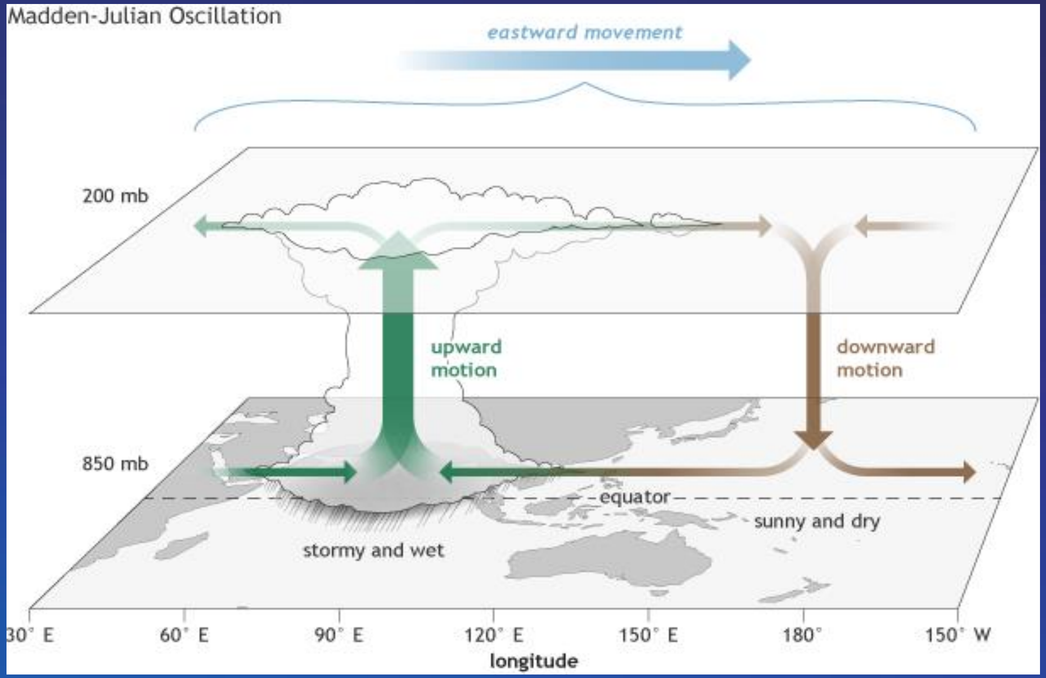
Importance of the MJO

- Key for the variability of precipitation in the tropics.
  - Upper divergent phase enhances deep convection and tropical cyclone intensity.
  - Upper convergent phase enhances easterly trades and regions of orographic forcing (e.g. Eastern Costa Rica)
- Affects the extra tropics too, via teleconnections (generation of Rossby Waves) and modulation of the subtropical jets.
- West tier of upper divergent phase enhances tropical cyclogenesis (low-level westerlies and less shear).



History of the MJO

- It was first noticed by Dr. Roland Madden and Dr. Paul Julian in the early 1970s, when they were studying tropical wind and pressure patterns.
- They noticed regular oscillations in winds between Singapore and Canton Island in the west central equatorial Pacific.
- Reference: (Madden and Julian, 1971; 1972; Zhang, 2005).



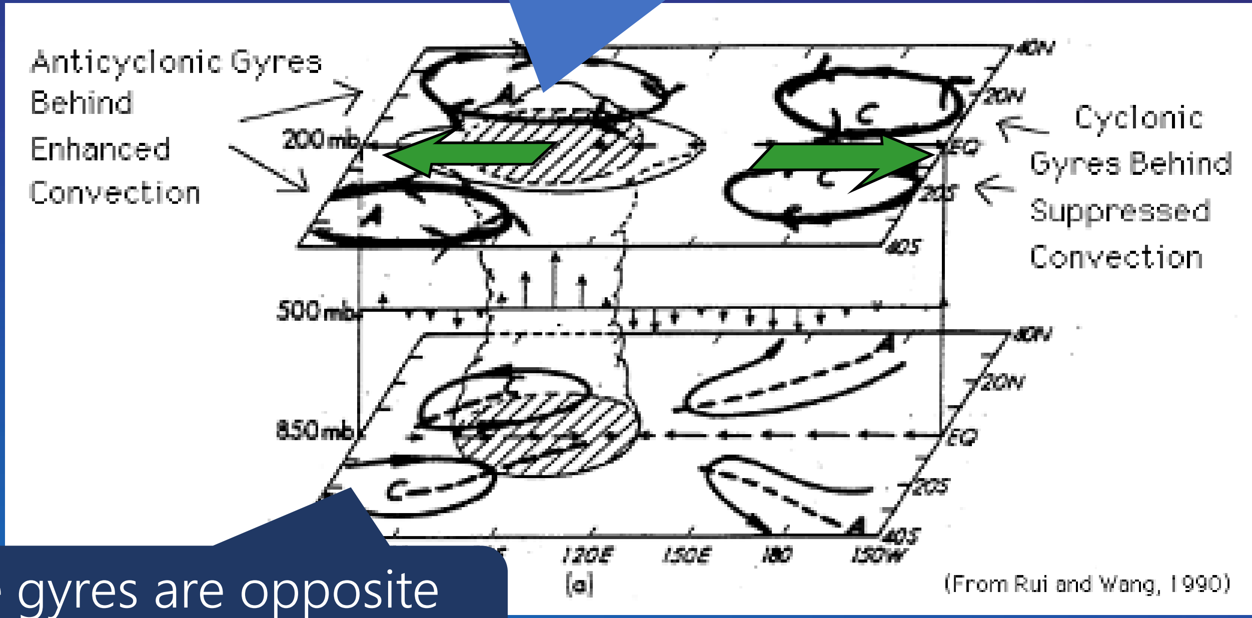
Source: CPC.

What triggers the MJO?

Strong convection that forms over warm equatorial waters (>27°C). Examples of triggers:

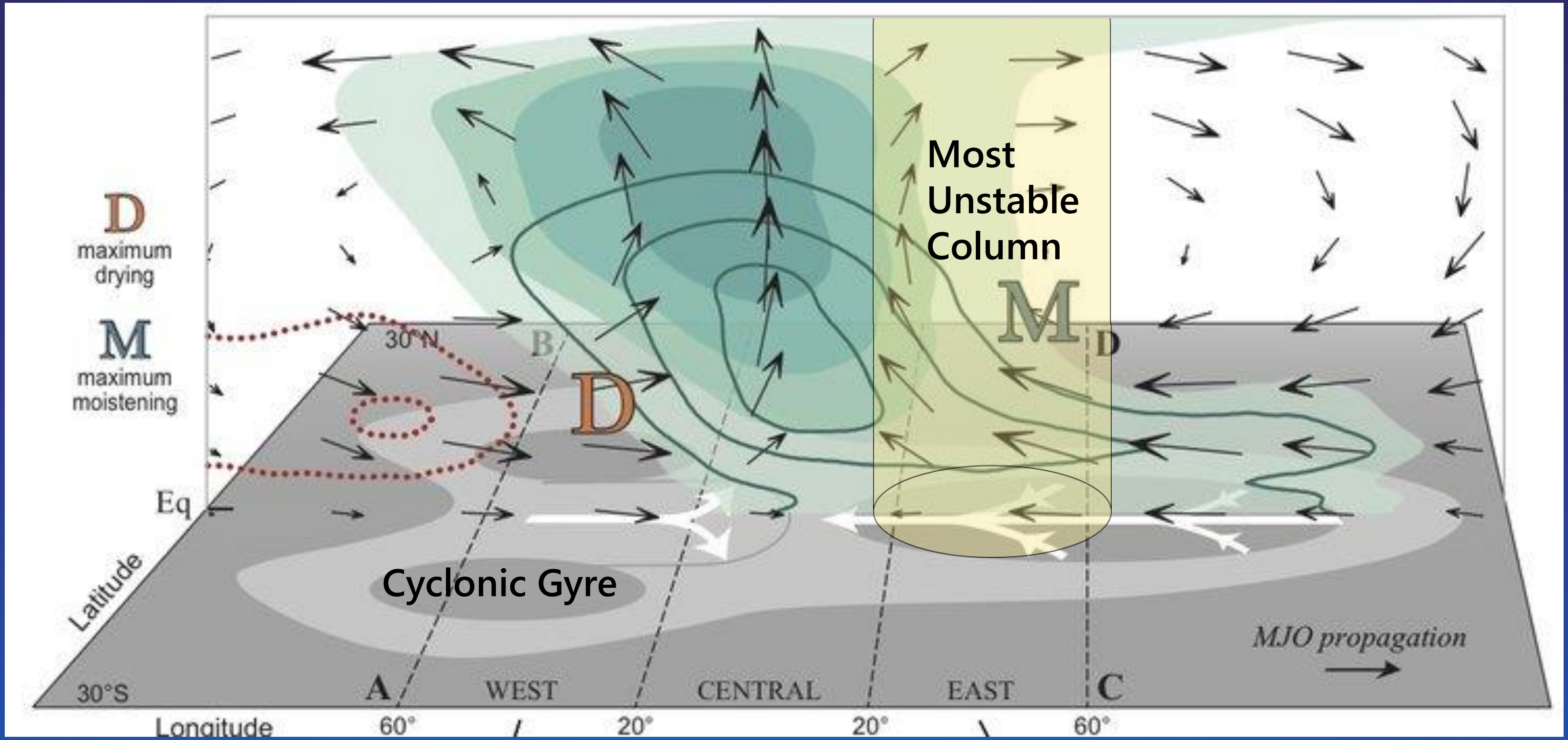
- Tropospheric Kelvin Wave
- Upper troughs/upper jets
- Low-level westerly wind bursts
- Mesoscale Convective System (MCS)
- Dry air intrusions over ITCZ located away from the equator
- Arriving MJO pulse, etc…

Latent heat release from strong convection generates gyres, symmetric to the equator, due to Geostrophic Adjustment



Surface gyres are opposite and weaker

Structure of the MJO



Source: Adames and Wallace (2015)

How does the MJO Propagate?

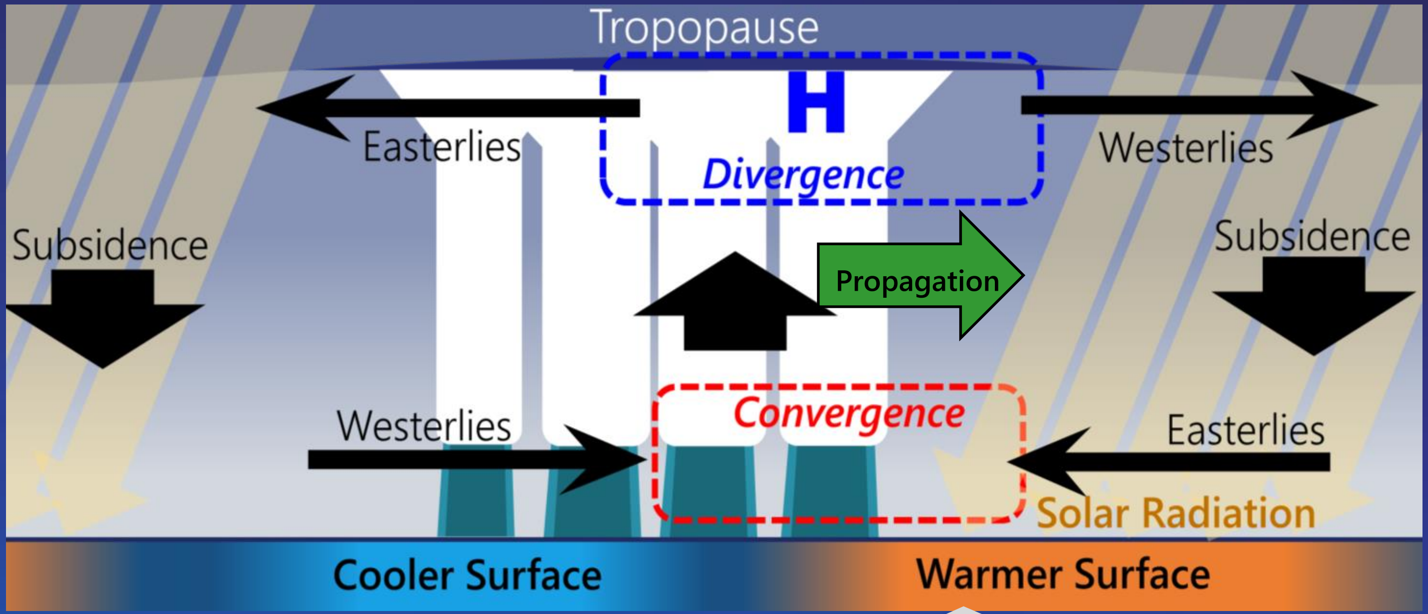
Propagates eastward.

Driven by equatorially trapped waves (Kelvin and Rossby waves) and by atmospheric-ocean coupling (AOC).

AOC: East of the convection…

a. Horizontal gyres favor upper divergence and ascent.

b. Subsidence and solar radiation favor surface warming, thus destabilization.



Location favorable for new convection due AOC: EAST of the MJO convection

Sources: CPC, https://asr.science.energy.gov/news/thematic-highlights/post/6234

Poll Question #3

What does the MJO convection produce in the upper troposphere, right over it? (1 or more)

a. A ridge

b. A trough

c. A perturbation in the tropopause

d. A warming (stabilizes the layer)

Poll Question #3

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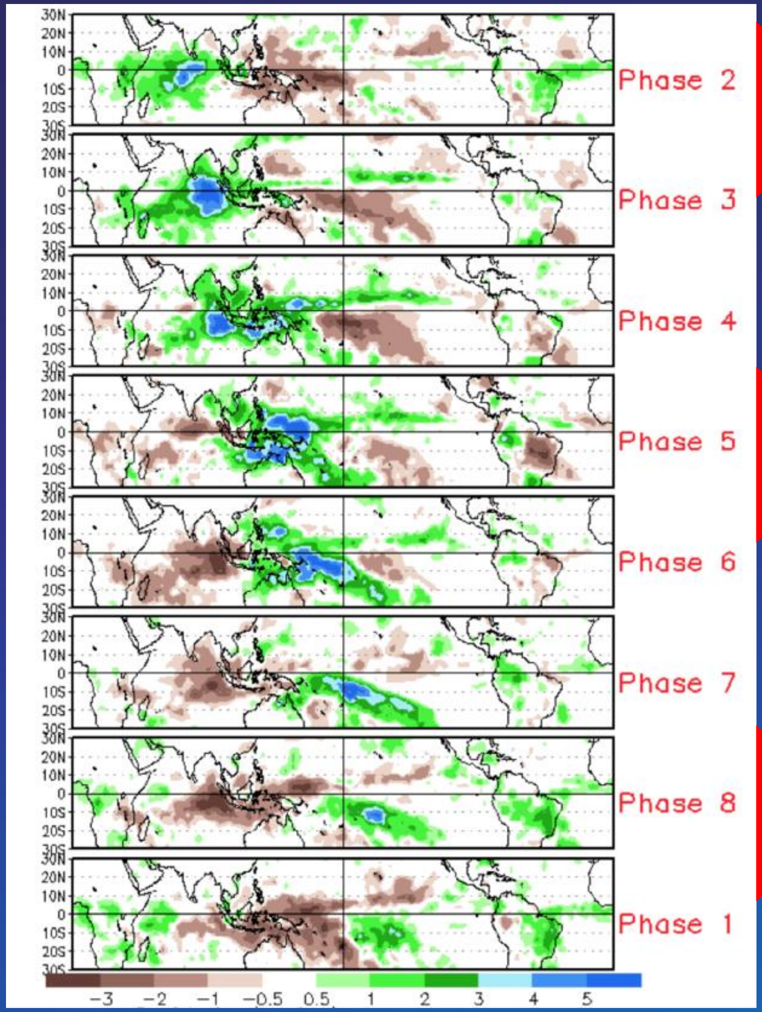
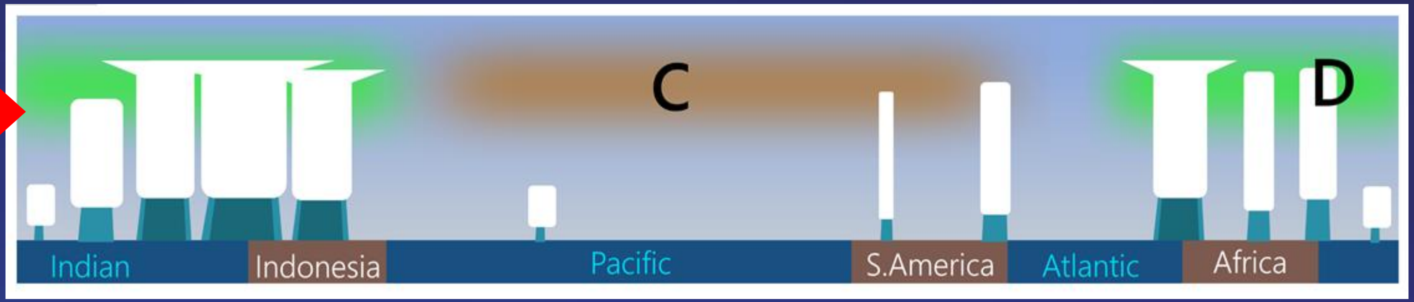
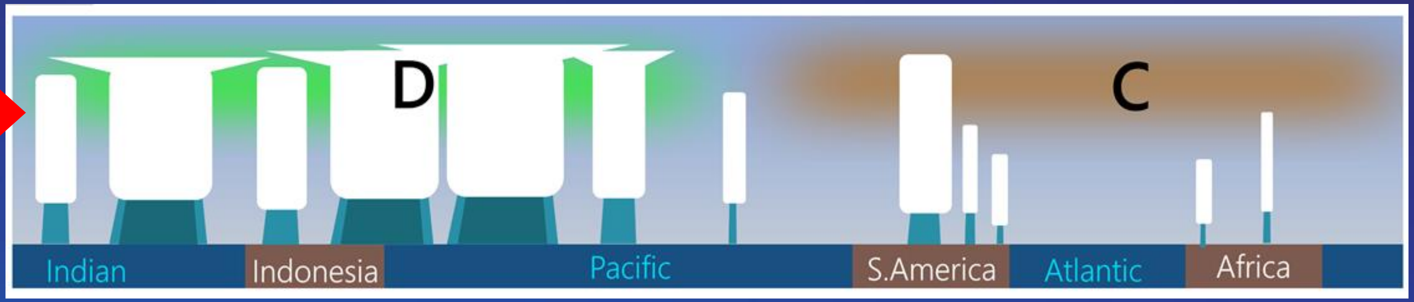
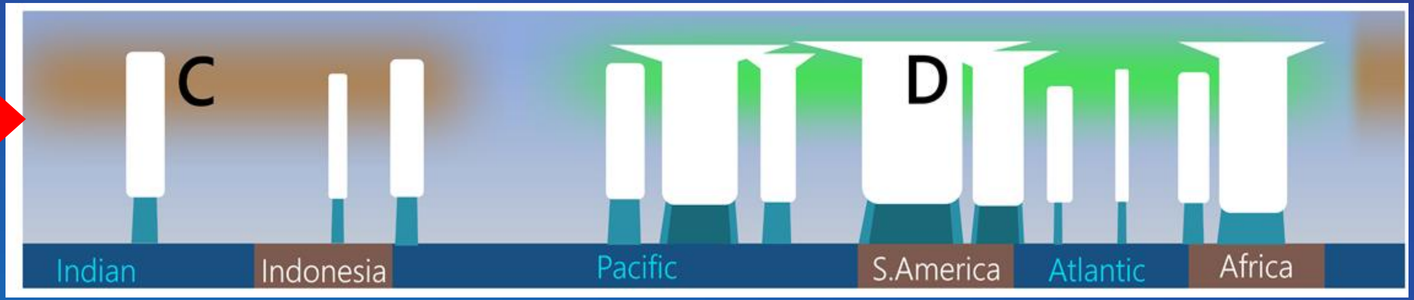
Phases of the MJO









MJO Propagation

Evaluate:

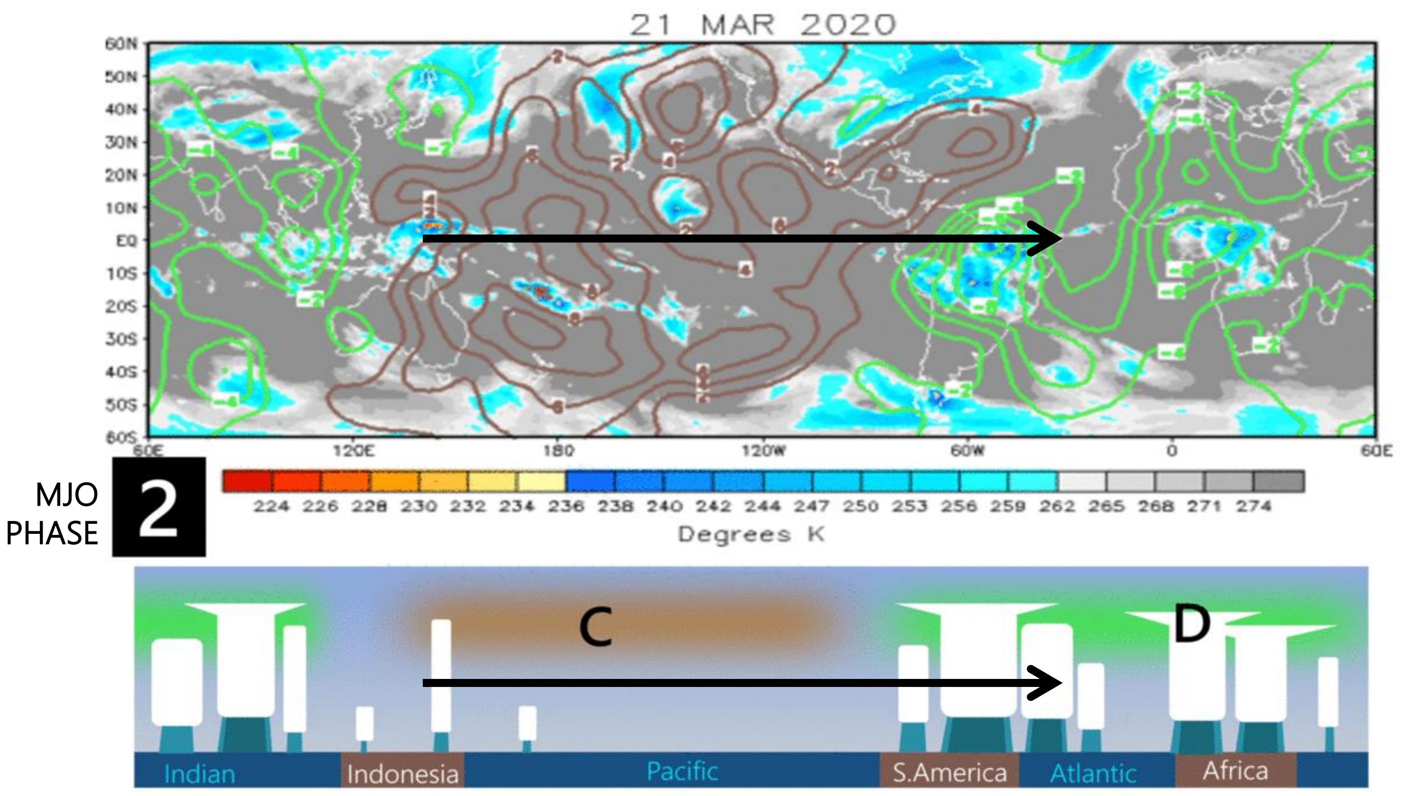
- Is propagation uniform?
  No

- What could cause anomalies in propagation?

Convection

- Terrain
- ENSO/SSTs
- Synoptic features
- Other atmospheric oscillations

200 hPa Velocity Potential and Brightness Temperature (convection)



Convergent (C) / Divergent (D) and associated convection

Poll Question #4

The upper convergent phase of the MJO associates with… (1 or more)

a. Weakening of the easterly trades

b. Acceleration of the easterly trades

c. Enhanced vertical wind shear in the Caribbean

d. Enhanced moisture convergence and rainfall in Eastern Costa Rica

e. Low-level westerlies

Poll Question #4

The upper convergent phase of the MJO associates with… (1 or more)

a. Weakening of the easterly trades

b. Acceleration of the easterly trades

c. Enhanced vertical wind shear in the Caribbean

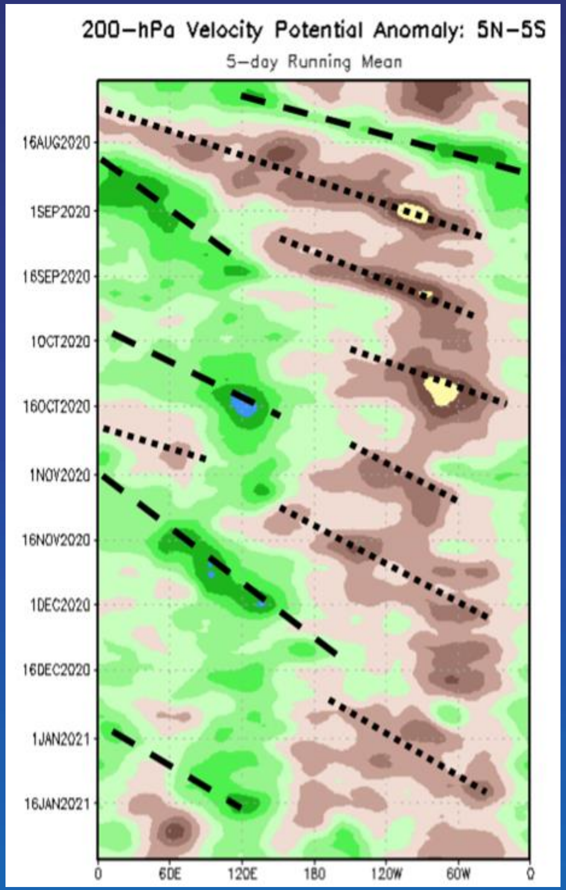
d. Enhanced moisture convergence and rainfall in Eastern Costa Rica

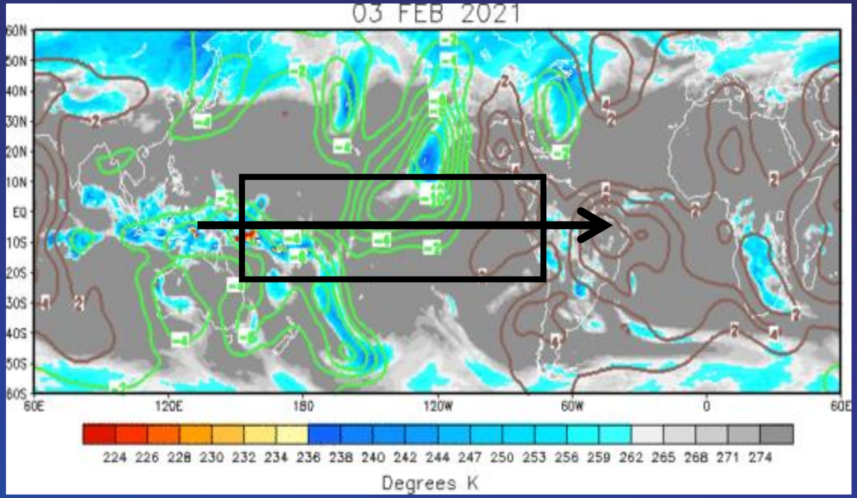
e. Low-level westerlies

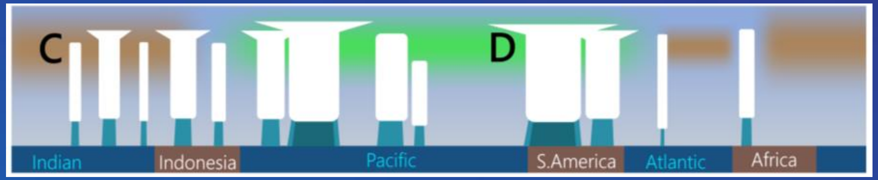
MJO Forecasts

We need to look for:

1. Is the MJO organized?
2. What is its current propagation speed?
   - How long it takes to go around the globe?
3. What phase is the MJO at?
4. Consider Different models
   - Weight to models that have been resolving the MJO best, and that are coherent with the expected propagation.

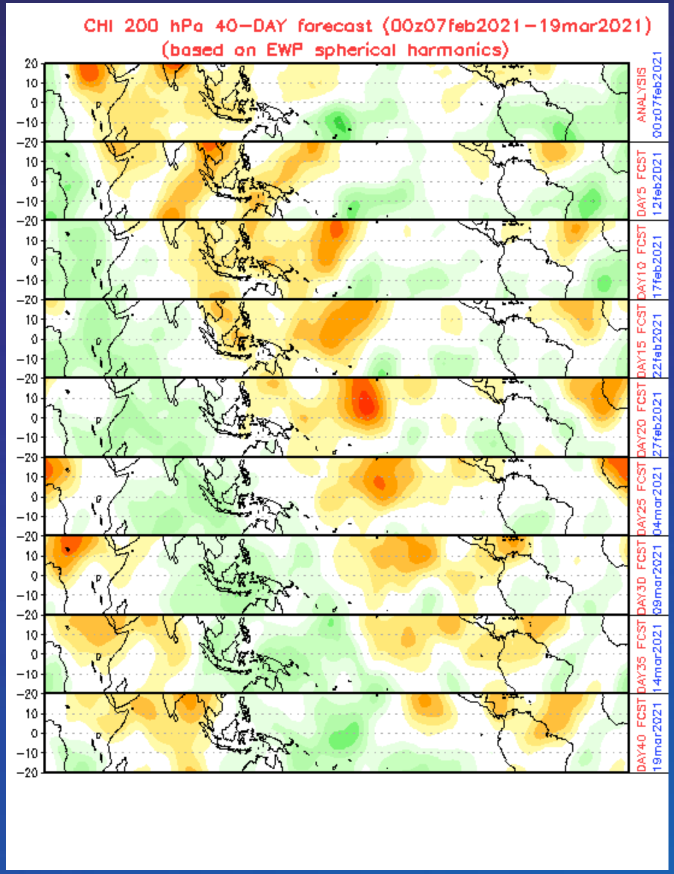


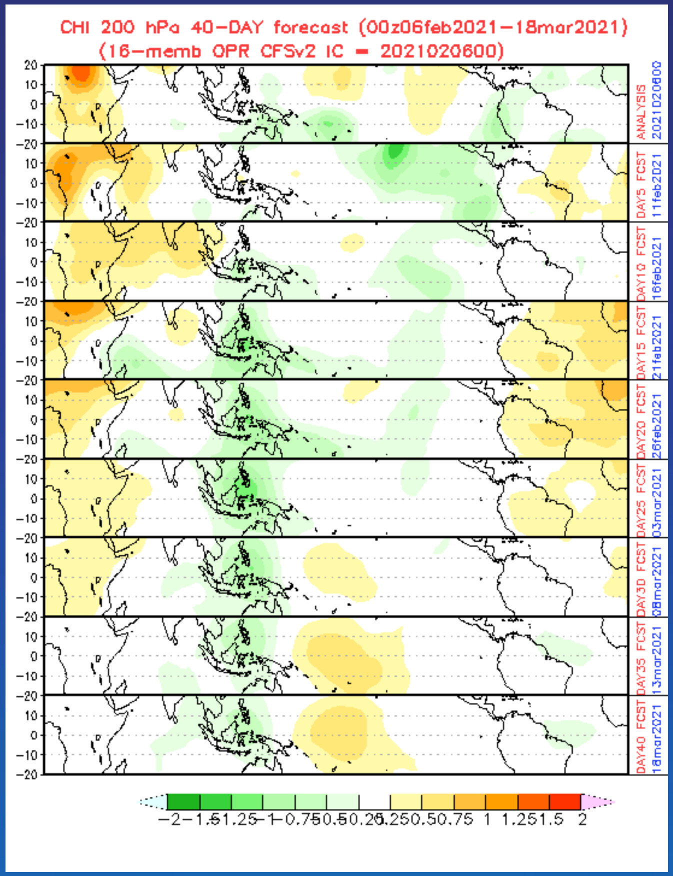


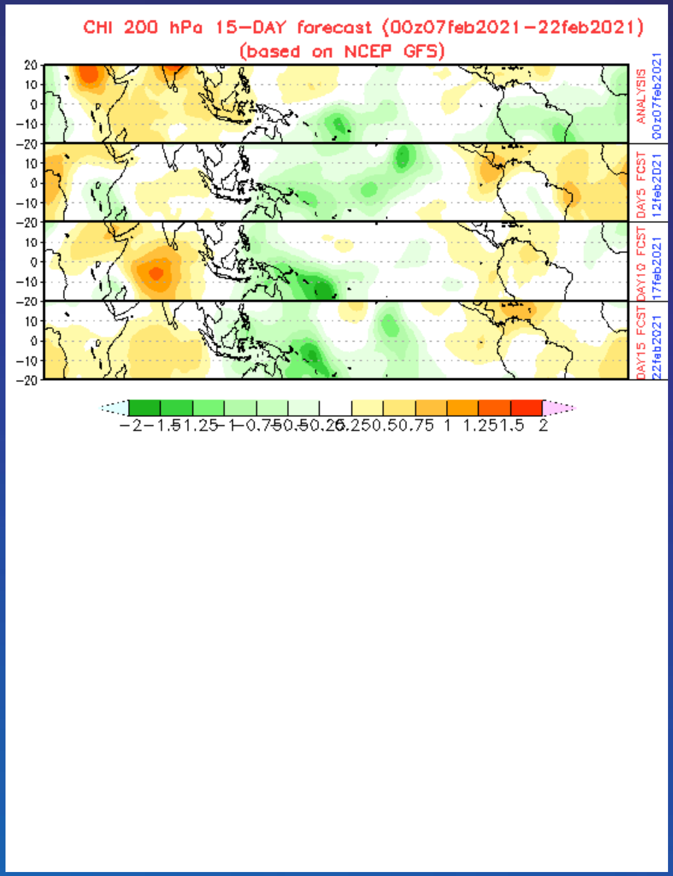


Forecasting the MJO

4. Consider Different Models

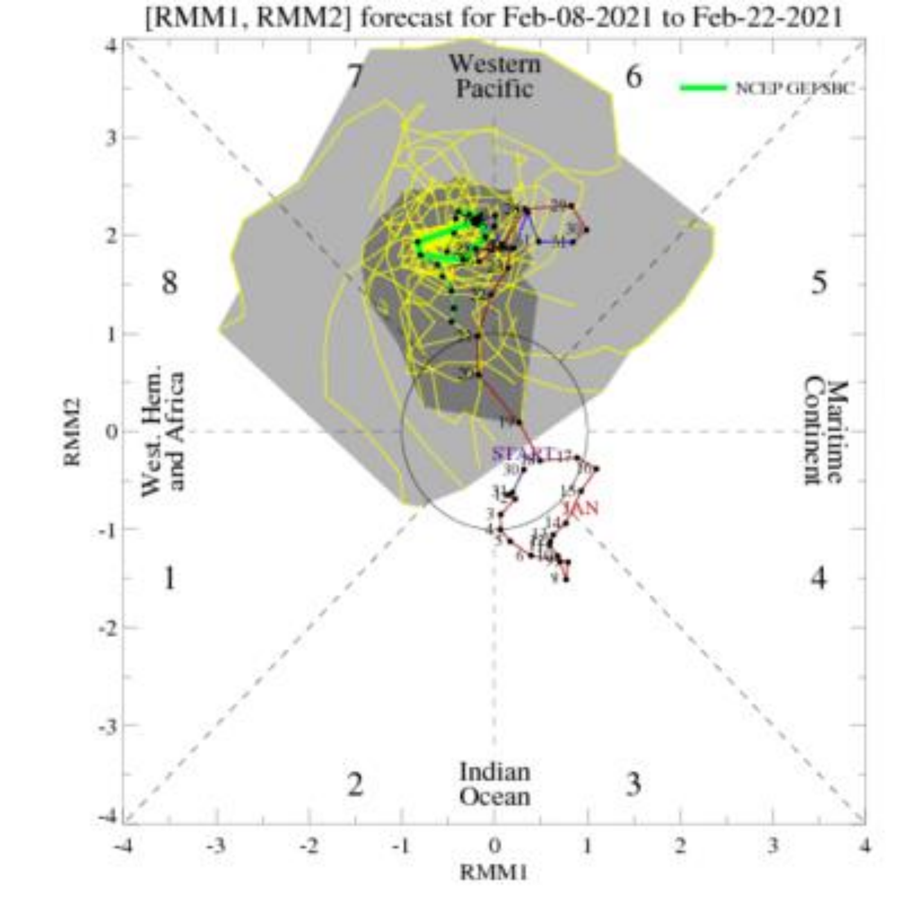






Forecasting the MJO

Phase Diagram



- Not often shown in the Monthly Sessions due to time limitations and complex interpretation.

- Provides insight on MJO Phase and degree of organization:

  a) Inside circle: disorganized

  b) Outside the circle: Organized

  c) Numbers are the MJO Phase

Resource: https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml#for

MJO Resources

NOAA's Climate Prediction Center MJO page:

https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml

Some MJO References

- Madden R. and P. Julian, 1971: Detection of a 40-50 day oscillation in the zonal wind in the tropical Pacific, J. Atmos. Sci., 28, 702-708.
- Madden R. and P. Julian, 1972: Description of global-scale circulation cells in the tropics with a 40-50 day period. J. Atmos. Sci., 29, 1109-1123.
- https://www.climate.gov/news-features/blogs/enso/what-mjo-and-why-do-we-care

Poll Question #5

What tier of the MJO favors tropical cyclogenesis in the Americas the most? (pick 1)

a. Center tier of the upper divergent phase

b. Center tier of the upper convergent phase

c. Eastern tier of the upper divergent phase

d. Western tier of the upper divergent phase

Poll Question #5

What tier of the MJO favors tropical cyclogenesis in the Americas the most? (pick 1)

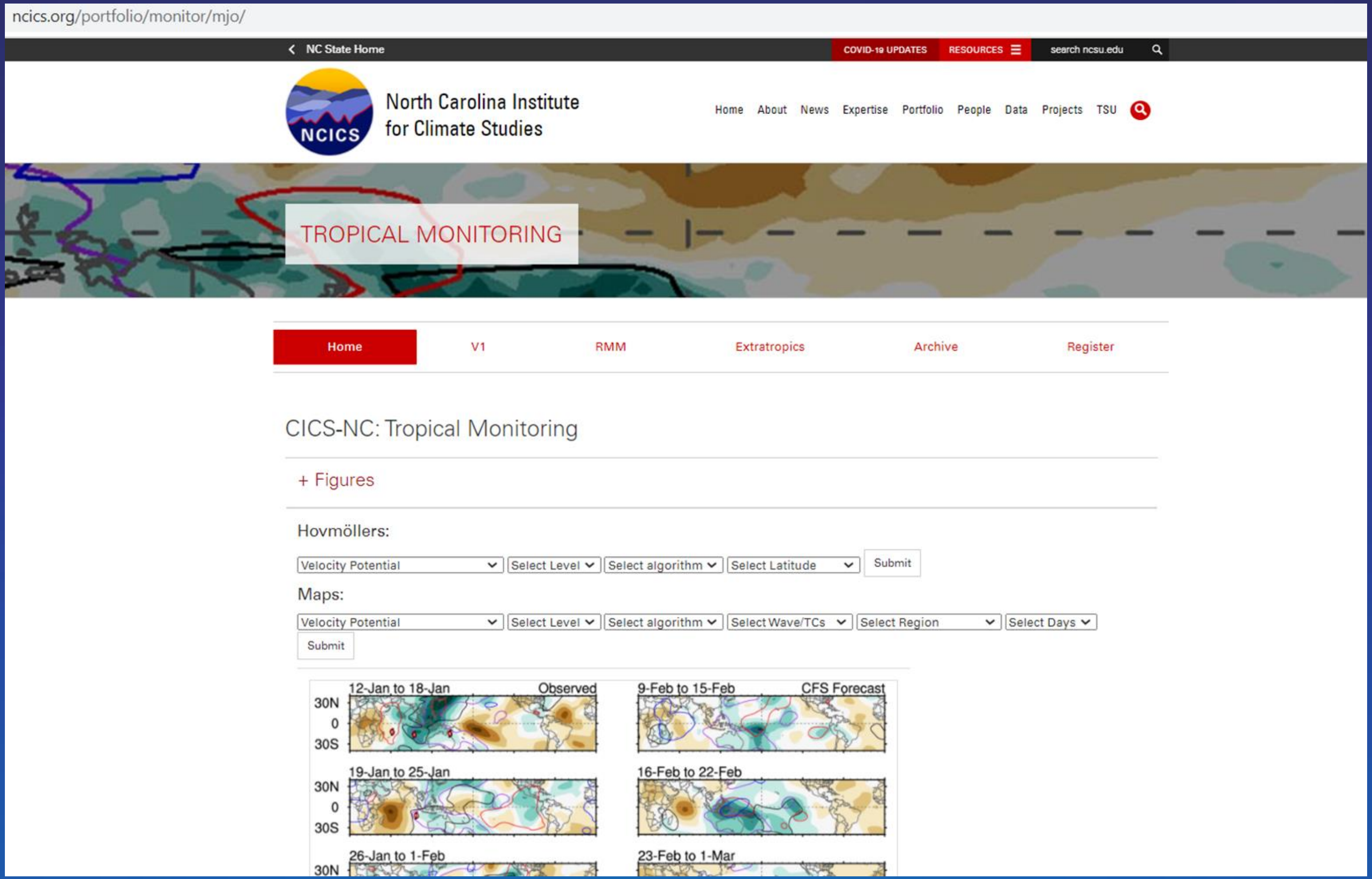
a. Center tier of the upper divergent phase

b. Center tier of the upper convergent phase

c. Eastern tier of the upper divergent phase

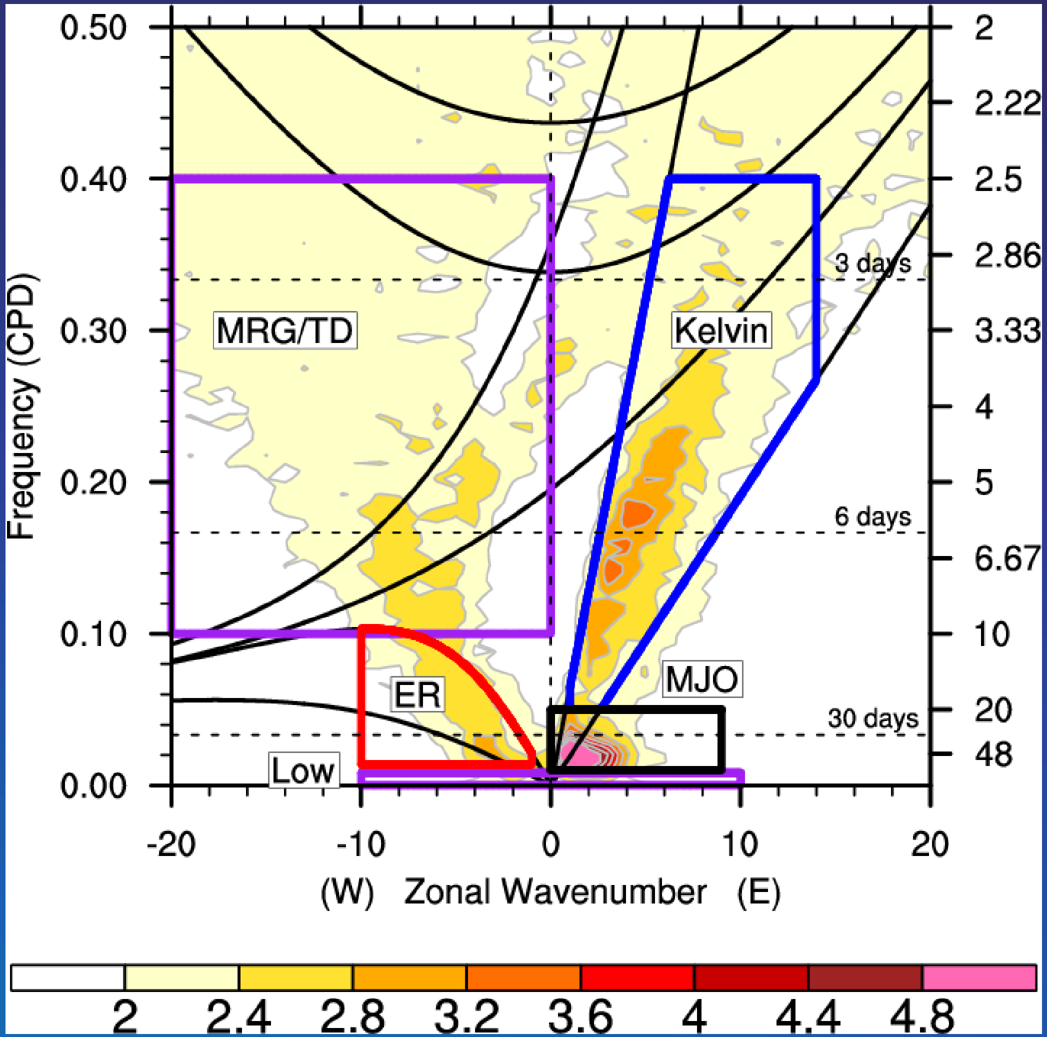
d. Western tier of the upper divergent phase

Equatorial Tropospheric Perturbations



Equatorial Tropospheric Perturbations

Wheeler and Weickmann (2001) developed a method for filtering OLR in real-time to identify, track, and predict the MJO and equatorial waves.



Poll Question #6

Which system propagates faster? (pick one)

a. Oceanic Kelvin Wave

b. The MJO

c. Tropospheric Kelvin Wave

d. Tropical Waves

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Which system propagates faster? (pick one)

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Poll Question #7

What increases the risk of a hurricane becoming strong? (1 or more)

a. Divergent phase of the MJO

b. Deep-layer warm anomalies in the ocean

c. Reduced vertical shear

d. High precipitable water/column moisture

e. A large circulation

Poll Question #7

What increases the risk of a hurricane becoming strong? (1 or more)

- a. Divergent phase of the MJO
- b. Deep-layer warm anomalies in the ocean
- c. Reduced vertical shear
- d. High precipitable water/column moisture
- e. A large circulation