MJO-induced Warm Pool Eastward Extension and Onset of El Niño

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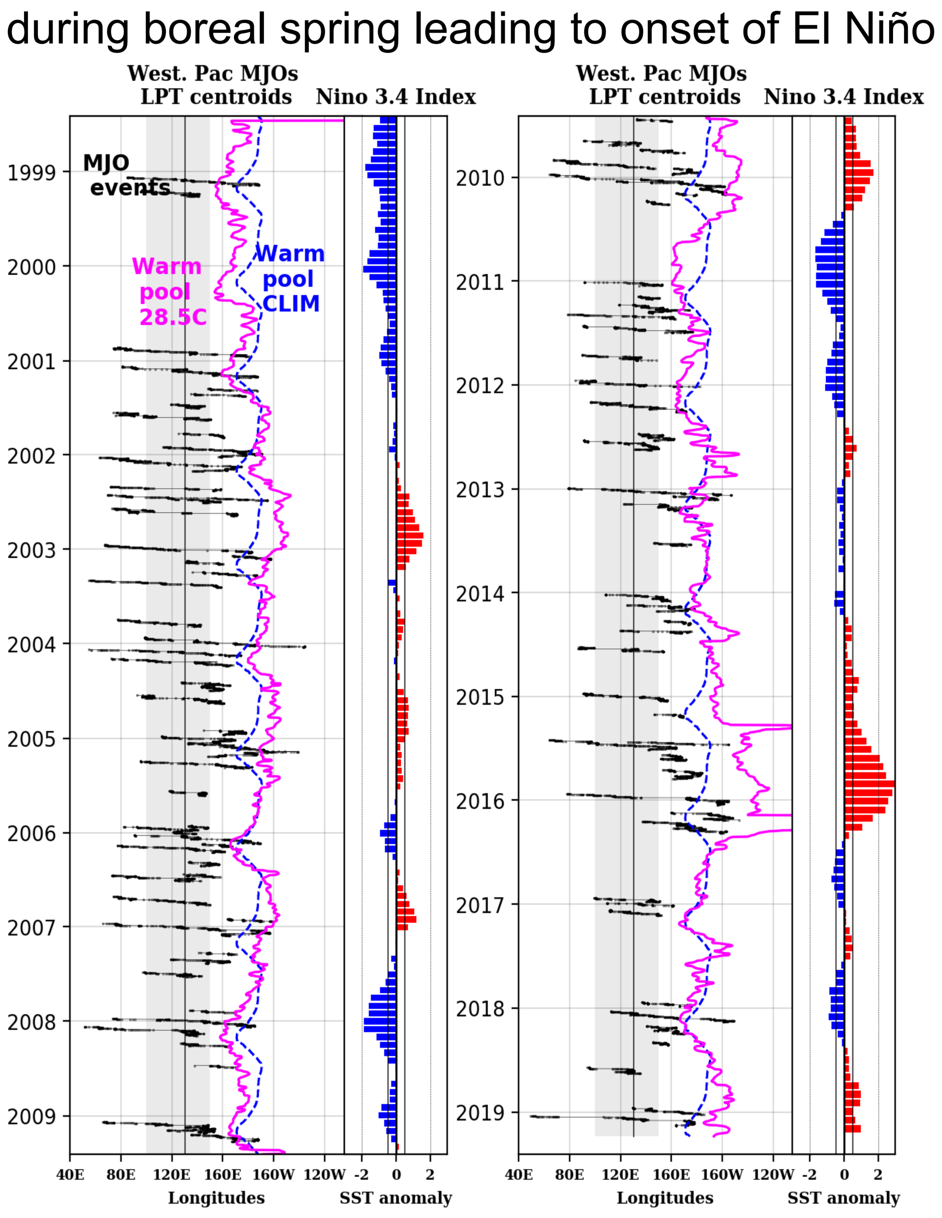
1. Motivation

- The eastern edge of equatorial warm pool (WP) shows large eastward and westward displacements from its climatological position associated with ENSO (Delcroix and Picaut, 1998) with some high-frequency variability (Fig. 1).
- Anomalous WP eastward extensions often occur after MJO event(s), especially during boreal spring leading to onset of El Niño events.



Science questions:

1. *How does the MJO affect the WP?*
2. *What is the physical mechanism(s) through which the MJO influence the onset of El Niño?*

Research objectives:

a) To quantify MJO-induced WP eastward extension and its time and spatial scales
b) Understand the relationship between MJO rain and westerly winds and the WP
c) Investigate the impact of the MJO on the upper ocean leading up to the onset of El Niño.

Figure 1. *MJO LPT (black, total of 99 events into W. Pac.), eastern edge of warm pool 28.5°C (magenta) and annual climatology (blue dashed), Nino3.4 index (+/- red/blue).*

2. Data and Methodology

Data:

- Rain: TRMM Multi-Satellite Precipitation Analysis (TMPA, 3-hrly, 0.25°, 1998/06 to 2019/03)
- Surface winds at 10m: Cross-Calibrated Multi-Platform (CCMP) and ASCAT (0.25°, 1998/06 to 2019/03)
- SST: Optimum Interpolation Sea Surface Temperature (OISST,daily,0.25°,1998/06 to 2019/04)
- Salinity, temperature, rain rates and zonal winds at the TRITON mooring at 156E, 0.
- Barrier layer thickness: ARGO floats from http://www.argo.ucsd.edu/.
- Mixed layer depth, temperature and salinity: ARGO floats http://www.jamstec.go.jp/e/.
- Zonal surface currents: OSCAR (5days,1/3°,1998/06 to 2019/03).

Methods:

MJO identification: Large-scale precipitation tracking (LPT, Kerns and Chen 2016, 2019) Track 12 mm/day rainfall (spatially filtered 3-day accumulation) at least 10 days. Here we only include MJO LPT that propagated into W. Pacific (130E) with centroids between 15S – 15N.

Post-MJO warm pool structure and evolution:

- WP defined by 28.5˚C *isotherm*
- Track in time post-MJO until eastern edge (5˚S-5˚N), reaches its east-most position *allowing temporary retreats (< 2 deg.,& <5 days).*

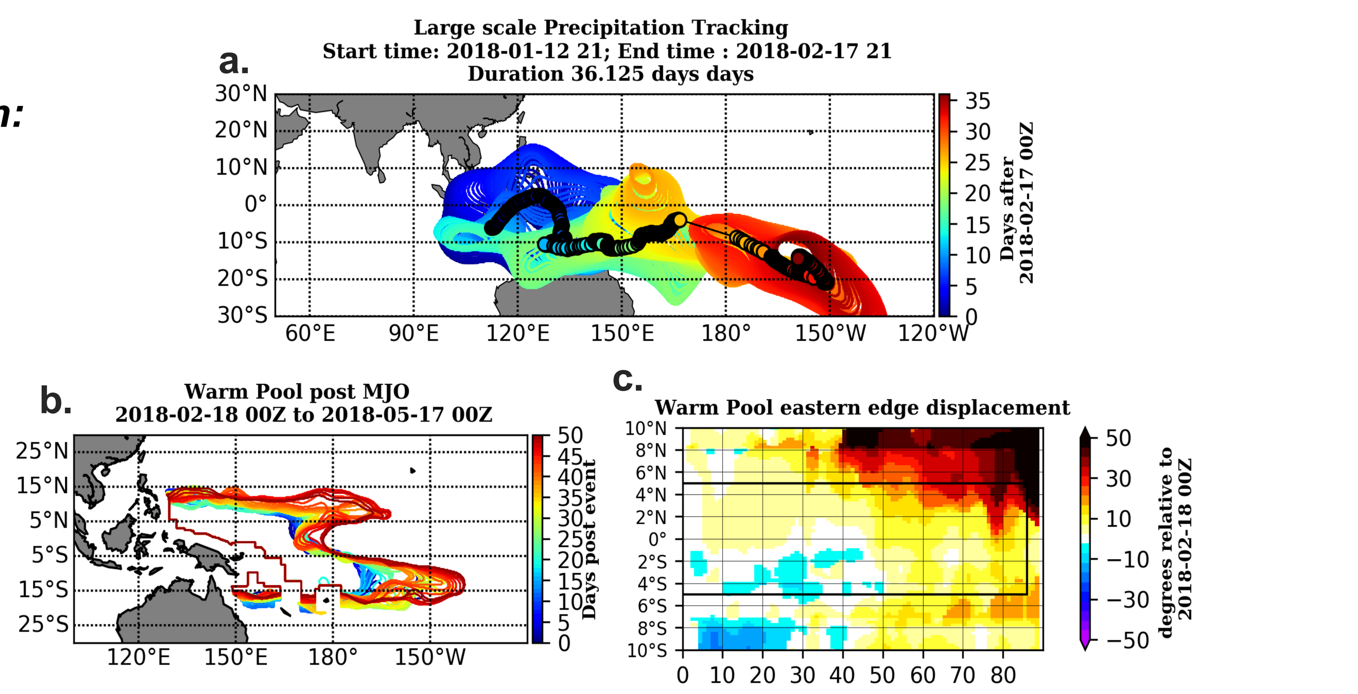


Figure 2. *a. MJO LPT 3-hourly contour and centroids in time (days, color). b. WP (28.5˚C contour) in time (days, color) post MJO. c. WPEE (degrees relative to WP on 2018-05-17 from 10°S to 10°N. Black box makes the time period of WPEE, which reached its easternmost longitude within 5°S–5°N.*

3a. Post-MJO Warm Pool Eastward Extension (WPEE)

- 65% (64 out of 99) MJO events had a significant impact on WPEE (Fig. 3a)
- WPEE (~1,000 km) occurs mostly during the 1st 15 days post MJO (Fig. 3b,c)
- Strong MJOs (~20%) can sustain WPEE 25 days post-MJO
- WPEE speed is ~0.8 m/s, similar to wind-forced eastward equatorial currents (Yoshida 1959), but slower than oceanic Kelvin waves (~2 m/s)

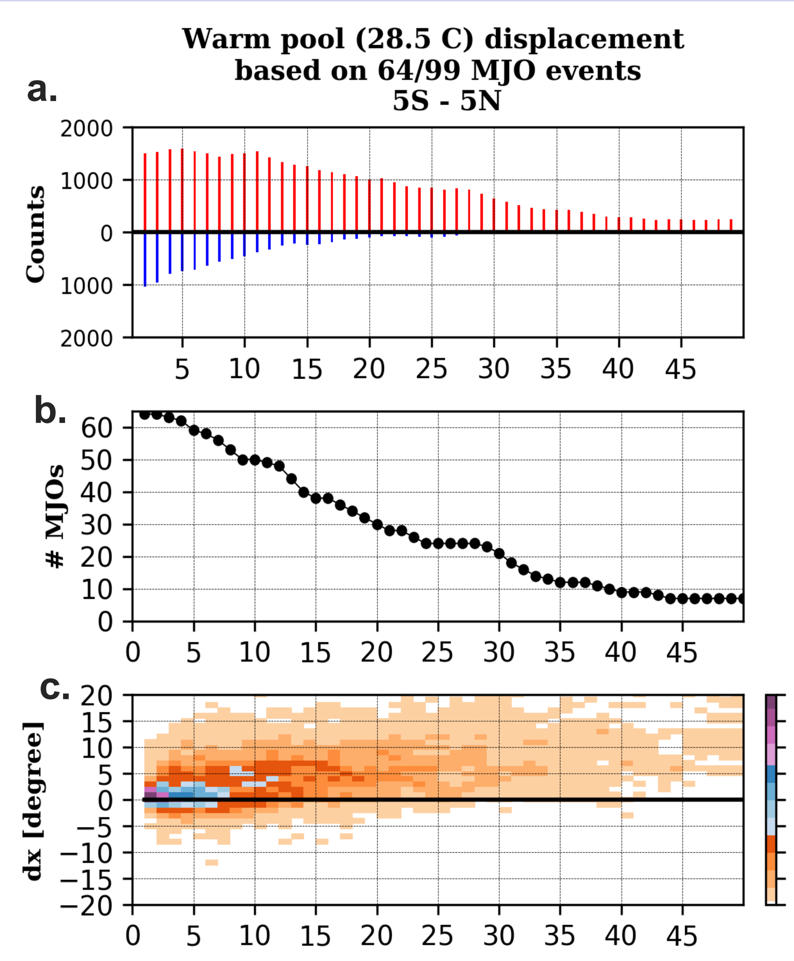
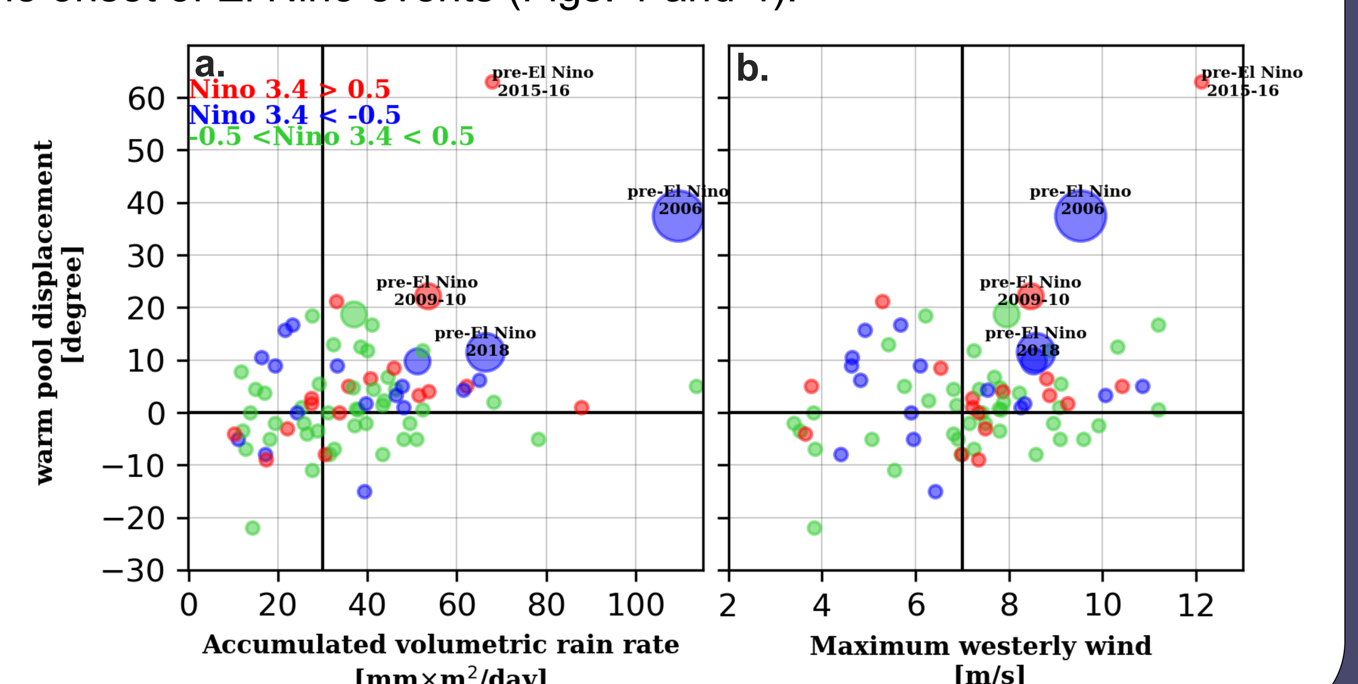


Figure 3. a*. Number of eastward (red) and westward (blue) WP displacement area within 5°S–5°N as a function of post-MJO days.* ***b****. Number of MJO events contributing to the zonal displacement in a.* ***c****. Frequency distribution of the WP eastward extension (colors) for each day post-MJO events.*

3b. MJO Rain and Wind in relation to WPEE

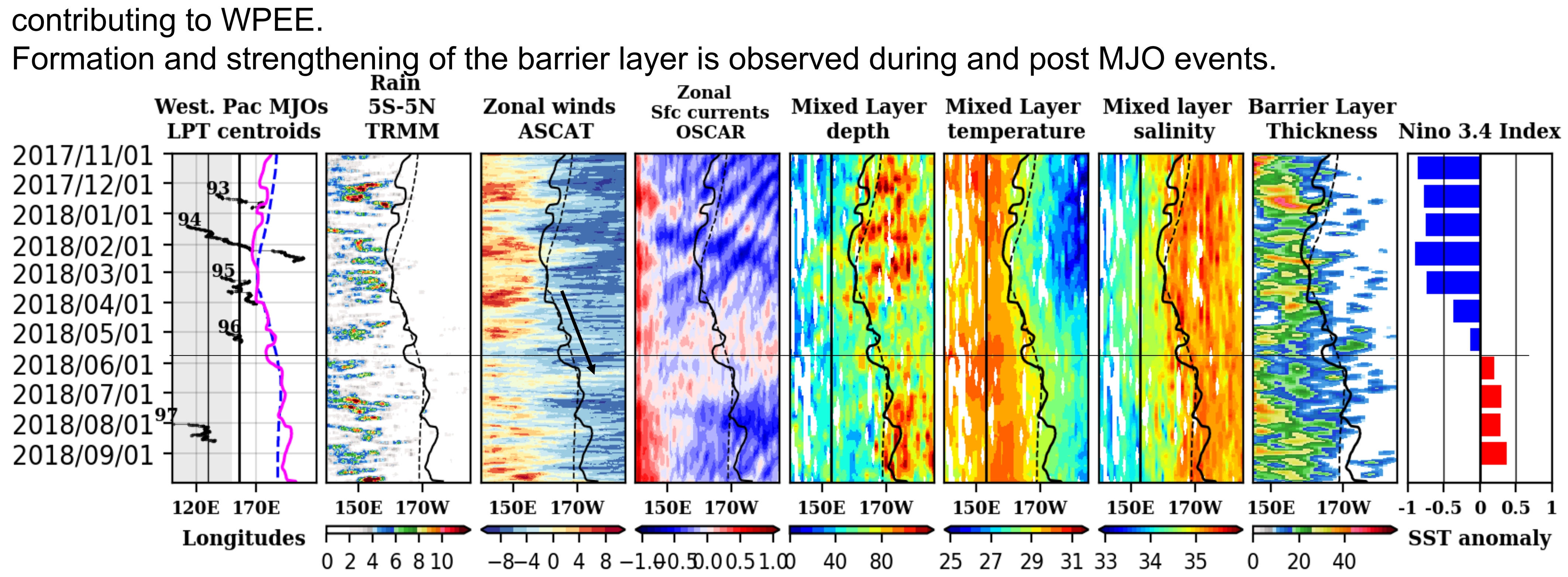
- WPEE generally increases with the amount of rainfall and strength of westerly winds associated with the MJO (Fig. 4)
- Large WPEE is associated with strong MJOs with heavy rainfall (accumulated volumetric rain rates > 30 $mm \times m^2/day$ and strong westerly winds (> 7 m/s)
- Some major WPEEs (> 10 deg.) are associated with multiple strong MJO events that occurred right before the onset of El Niño events (Figs. 1 and 4).

Figure 4. *WPEE (in degree) post MJO varies with:* ***a.*** *Accumulated volumetric rain rate during the MJO in the west equatorial Pacific (east of 130E),* ***b.*** *Maximum equatorial (5˚S-5˚N) westerly wind during the MJO in the W. Pac. Circle size is proportional to number of MJO events that produced one continuous WPEE.* ***Note:*** *MJO events during declared El Niño events are not considered.*



3c. Impact of the MJO on upper ocean leading up to the onset of El Niño

- The MJO affects upper ocean through momentum, heat and freshwater fluxes. The mixed layer deepens and its salinity and temperature decreases (Figs. 5, 6).
- Strong westerly winds force surface zonal currents and induce oceanic Kelvin waves. Post-MJO surface heating and horizontal thermal advection increase SST to the east of the MJO contributing to WPEE.
- Formation and strengthening of the barrier layer is observed during and post MJO events.



Transition to onset of El Niño 2018

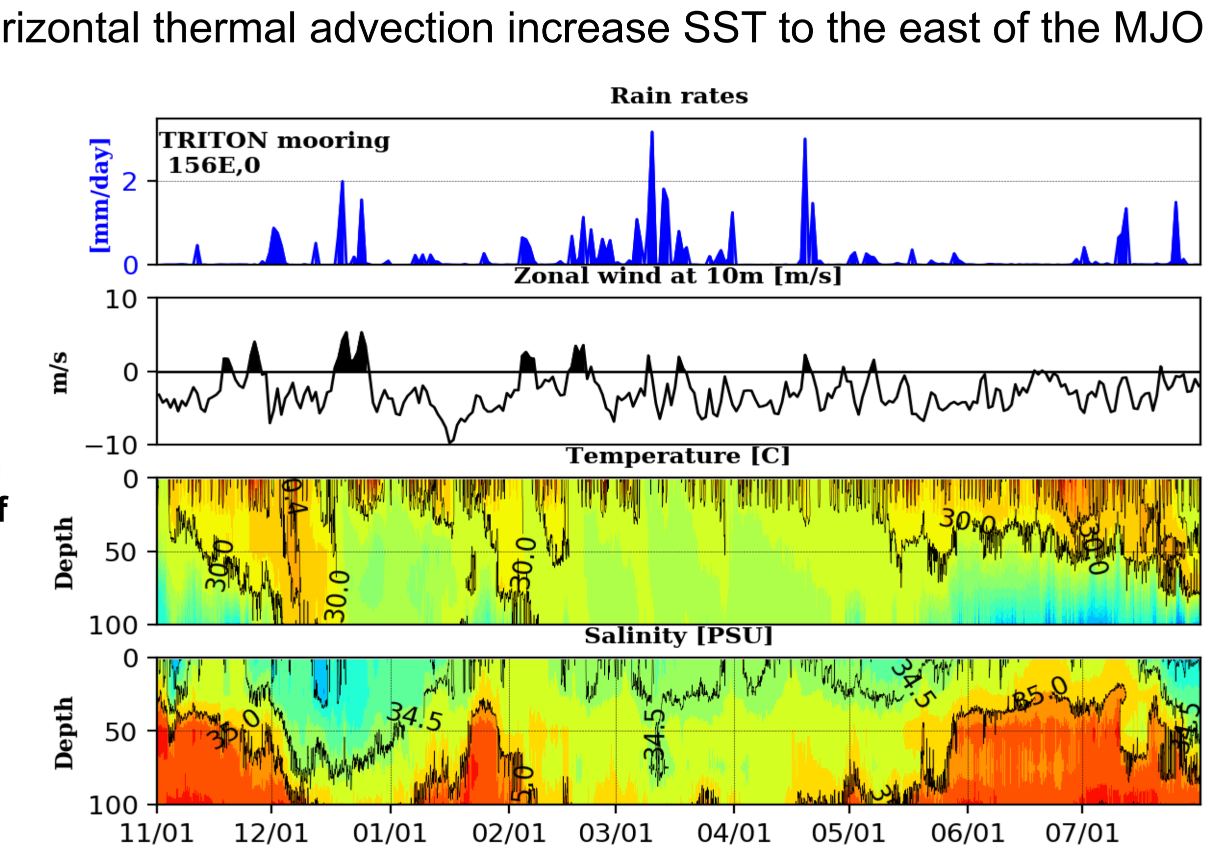


Figure 5*: Left-right: MJO and WP, averaged 5˚S-5˚N time-long. sections of daily rainfall, zonal surface winds, zonal surface currents, mixed layer depth, temperature, and salinity, barrier layer thickness and Niño 3.4 monthly anomaly. Vertical black lines marks 156E.*

Figure 6. *Top-bottom: Daily rain rates, surface winds, hourly depth– time section of temperature and salinity at 156E, 0.*

4. Summary and Future work

Summary: **1)** Satellite observations of SST (OISST) and precipitation (TRMM-GPM) show that ~65% MJO events over W Pac from 1998-2019 had a significant impact on WPEE (from 100's km to more than 2,000 km) occurring mostly during the 1st 15 days post MJO, but can extend beyond 25 days in major and/or multiple MJO events.
2) Large WPEE is often associated with strong and/or consecutive MJO events with heavy precipitation and strong westerly winds prior to the onset of El Niño.
3) Upper ocean warming and barrier layer are observed post MJO, which are important to WPEE.

Future work: We conduct coupled atmosphere-ocean model simulations of the MJO and post-MJO events to better understand the physical mechanism(s) responsible for WPEE, especially prior to the onset of El Niño.

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