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The Influence of Madden Julian Oscillation on the Formation of the Hot Event in the Western Equatorial Pacific

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Abstract. Hot event (HE) is the high SST phenomena higher than about 30°C, occur in an area of more than 2×10^6 km^2 and last for a period more than 6 days. HE develops only under the condition of high solar radiation and low wind speed. The indication of the relation between HE and MJO has been described in the previous study for one HE case. In the present study, the more case of MJO-HE relation is collected for the period of 2003-2011 and the possible mechanisms is examined. New Generation Sea Surface Temperature for Open Ocean (NGSST-O-Global-V2.0a) was used to identify HEs. Precipitation from TRMM were bandpass filtered with cut off period of 30-60 days for MJO identification. Observation data from TAO/TRITON buoy were used for investigating the possible mechanism of MJO-HE relation. Off 48 HE cases located along the equatorial band, the development of 29 HE cases was related to the suppressed phase of MJO whereas the high solar radiation occurred. High precipitation during the active phase of MJO may contribute to stabilize the upper mixed layer. The stable upper water column fasten the heating process during the suppressed phase of MJO, generating HE.

Keyword: Hot Event, MJO, freshening effect

1. Introduction

Sea surface temperature (SST) is a fundamental parameter for the air-sea interaction processes. In the tropical region, SSTs distribution is negatively skewed which shows the different atmospheric processes before and after 29.5°C Before 29.5°C, the deep convection represented by the highly reflective cloud (HRC) increase following SST. Conversely, after 29.5°C the convection decrease as the SST increase [1]. For decades, study on SSTs were focused on the high SSTs less than 29.5°C since it has significant influence on the climate system. The high possibility of the rain formation occurs under the condition of SSTs between 26 and 29.5°C. For example, typhoon is generated under the condition of SSTs> 26°C [e.g., 2]. Moreover, [3] emphasized that the deep convections frequently occur when their bottom SST is higher than 28°C. Investigations on SSTs higher than 30°C were rarely conducted due to the requirement of high spatial and temporal resolution of SST dataset i.e. daily and less than 0.25° grid resolution. The signal of SSTs higher than 30°C may be dissembled in

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the lower resolution of SST dataset. Thus, many aspects of high SSTs phenomena in the tropics are still left to be observed.

The investigation of short timescale and high SST phenomena (i.e. less than a month and higher than 30°C) called Hot Event (HE) in the tropical region have been conducted by [4, 5, 6, 7, 8, 9, 10, 11]. They used daily satellite based SST data with grid interval of less than 0.25°×0.25°. They found that HE occur under the condition of low wind speed and high solar radiation associated with high diurnal SST amplitude. Through observation of 10 years SST data, [4] found 31 HEs distributed in whole equatorial region. Satellite SSTs has systematic positive bias against buoy SSTs for the SSTs higher than 30°C due to the large in-situ diurnal SST [5]. Therefore, [10, 11] used diurnally corrected SST dataset for the investigation of HE in the western equatorial Pacific. Through observation of 9 years SST data, [10] found 71 HEs distributed in the western equatorial Pacific. In the case study of HE began at 28 May 2003 called HE030528, [11] found that the development of HE030528 was related to the subsidence air over HE area induced by the deep convection at the northern and southern side of HE area which created tropospheric flywheel effect.

In the larger scale, the subsidence air over HE area may be influenced by the suppressed phase of the Madden Julian Oscillation (MJO). MJO is the overturning global circulation connecting the region of strong deep convection with high precipitation known as the active phase and the region of weak deep convection with low precipitation known as the suppressed phase. This circulation moves eastward with the speed of 5 m/s and period of 30-90 days [12]. The development stage of HE030528 was related to the suppressed phase of MJO [11]. However, one case study cannot represent the general relation between HE and MJO. Thus, this paper is aimed to identify the more cases of HE-MJO relation and investigating the possible mechanisms.

2. Material and Method

2.1. Material

We used the daily New Generation Sea Surface Temperature for Open Ocean (NGSST-O-Global-V2.0a) to identify HEs in the western equatorial Pacific [13]. This SST data has applied diurnal correction to reduce positive bias against buoy SST as described in [5]. This dataset also has been examined for HE identification [10]. The grid interval of the data is 0.25°×0.25°. The bias (root mean square error) against 1 m depth temperature measured by TAO/TRITON buoys in the western equatorial Pacific is -0.107°C (0.428°C).

MJO was observed by using precipitation data. We used The Tropical Rainfall Measuring Mission (TRMM), the daily data of satellite based global gridded precipitation with the grid interval of 0.25°×0.25°. This rain rate products are derived using the algorithm described in [14] and its validation is described by [15].

For investigating the mechanisms underlying the MJO-HE relation, we used observational measurements from the TAO/TRITON buoys [16] located at the western equatorial Pacific. The parameters were SST, solar radiation, and surface salinity. Since the data consist of 6 quality grades, only the highest and default quality were used in the analysis.

2.2. Method

HE is defined as a connected region with a SST higher than the space-time dependent threshold (~30°C), an areal size larger than 2×10^6 km, and lasting for a period longer than 6 days. The detail detection method for HEs is explained in [10]. Following the track of MJO, the present study used 48 HE cases located along the equatorial band identified by [10]. For capturing MJO signal, precipitation data from TRMM was filtered with cut-off period of 30-60 days and presented in Hovmöller diagram. The relation between HE and MJO was indicated by the coincident event between the suppressed phase of MJO and the development stage of HE.

3. Result and Discussion

3.1. Identification of MJO-HE relation

For detecting MJO signal, [11] used vertical pressure velocity data from JRA-55 without any filtering process which made the MJO signal was noisy. In this study we used satellite based precipitation data and then filtered with cut-off period of 30-60 days. The result is shown in Hovmöller diagram (Fig. 1). The active (suppressed) phase of MJO signal is clearly shown by eastward movement of positive (negative) precipitation. Every year, about 8 MJO events were identified passing the western equatorial Pacific during 2003-2011.

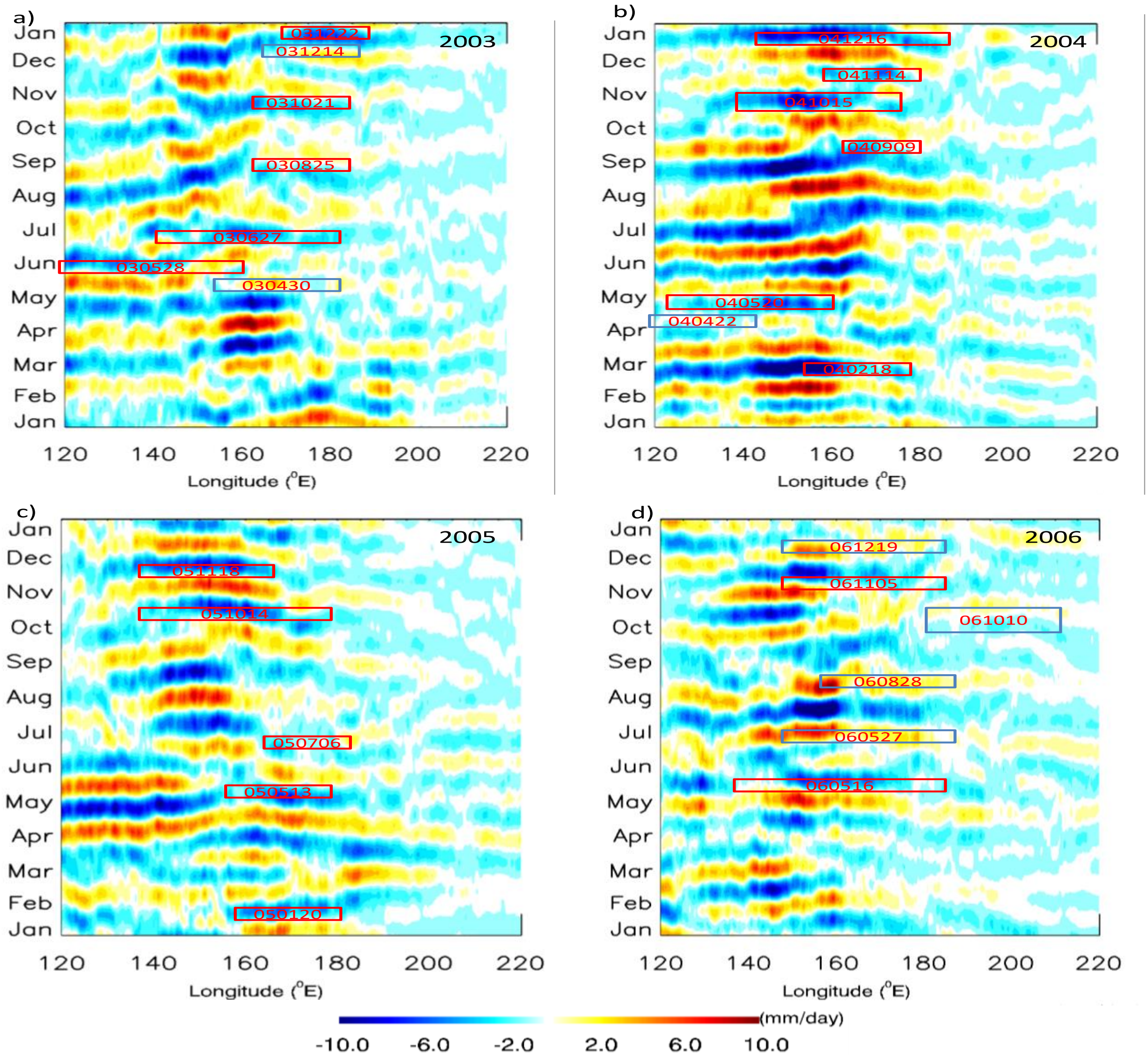


Fig. 1. Hovmöller diagram (5°S-5°N) of precipitation after filtering with cutting period from 30 to 60 days. Red and blue boxes denote the coincidence of HE to suppressed phase and active phase of MJO respectively. HE cases are taken from [10].

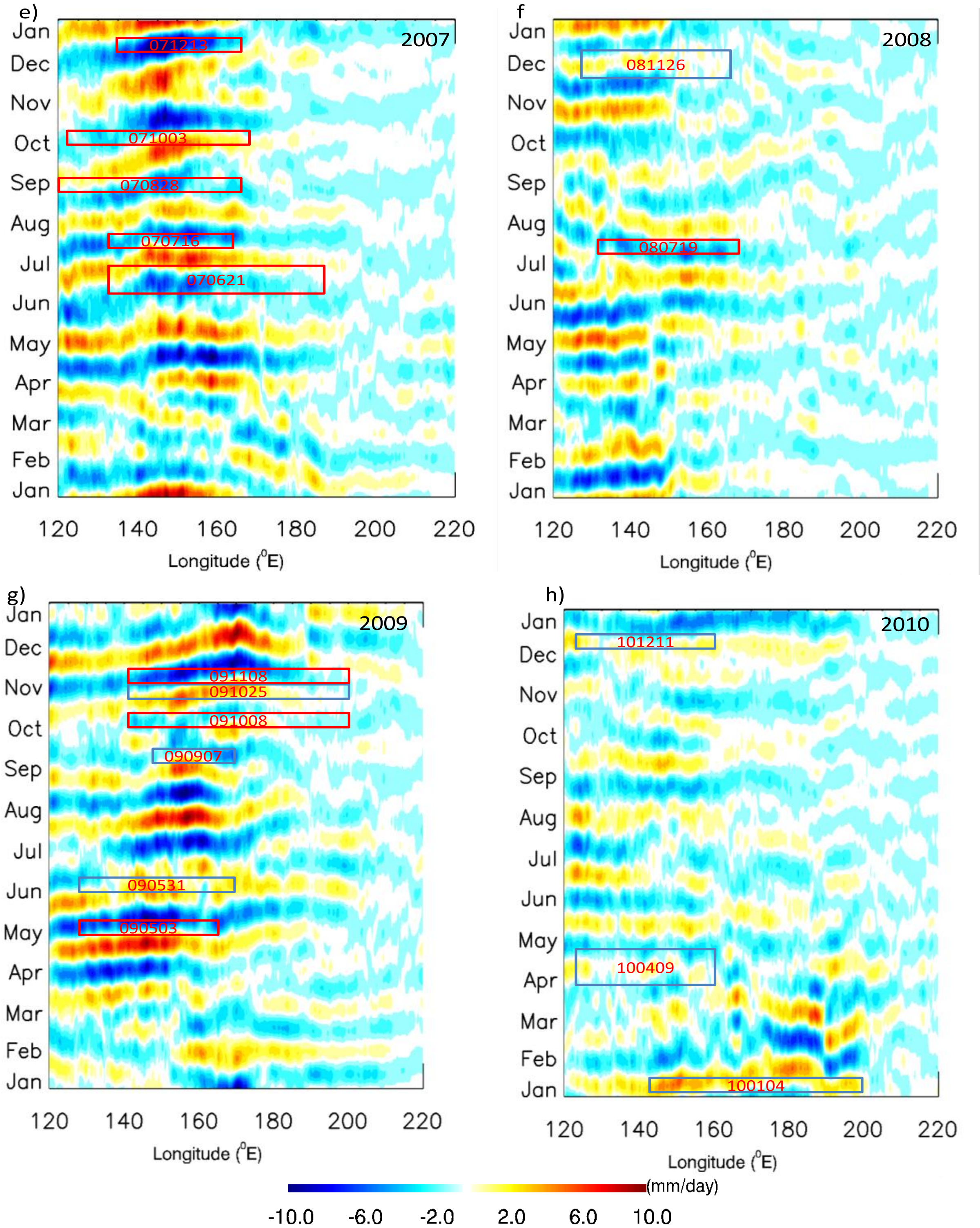


Fig. 1. Continues

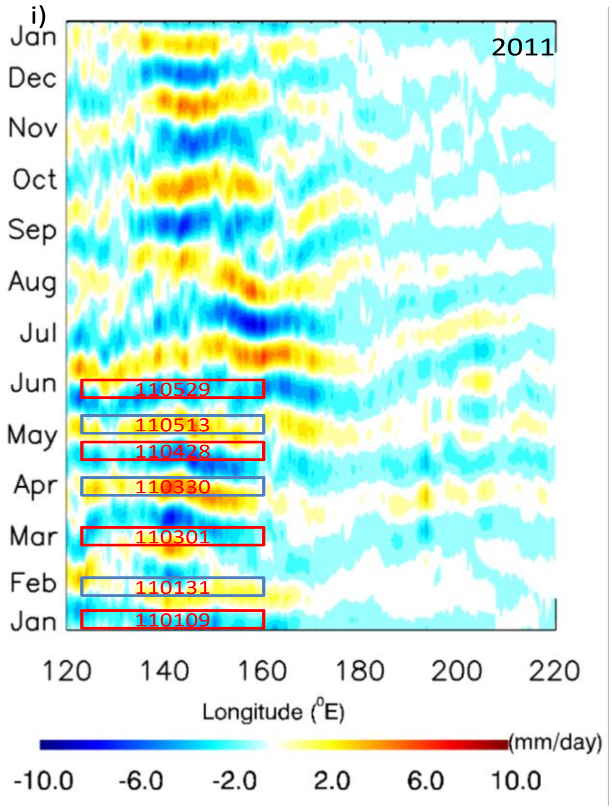


Fig. 1. Continues.

The oceanic response on MJO event has been observed by many researchers. The fluctuation of SST related to MJO is vary e.g. 0.25°C [17], 0.5°C [18, 19] and even higher i.e, 2°C [20, 21]. Figure 2 shows the evidence of increasing SSTs during the suppressed phase of MJOs. Through case study of HE030528, [11] found the increase of SST about 0.5°C during the suppressed phase of MJO.

The relation between MJO and HE was indicated by the coincide event between the period of suppressed phase of MJO and the period of the development stage of HE denoted by the red box (Fig.1). The blue boxes denote the development stages of HEs that do not coincide with the suppressed phases of MJOs. Off 48 HE cases during 2003-2011, we identified 29 cases of the development stage of HE coincide with the suppressed phase of MJO. This number is much more than the number of the HE generated by the positive anomaly of subsurface temperature during El Niño as identified by [6] i.e., 3 cases during 1993-2003. Thus, the influence of MJO to the development of HE is more frequent than ENSO.

3.2. Possible mechanism of MJO-HE relation.

The mechanisms on how HE developed and decayed was exposed by [11] in terms of climatological analysis and case study. Solar radiation variability due to the remote convection mechanisms and surface wind speed variability influenced by the topography determine the development and decay stage of HE. In the present study, the higher solar radiation due to the subsidence air during the suppressed phase of MJO were the most prominent signal on how MJO influence the HE development. These phenomena occurred for all HEs related to MJO. Moreover, we also introduce precipitation as a new parameter affecting HE development.

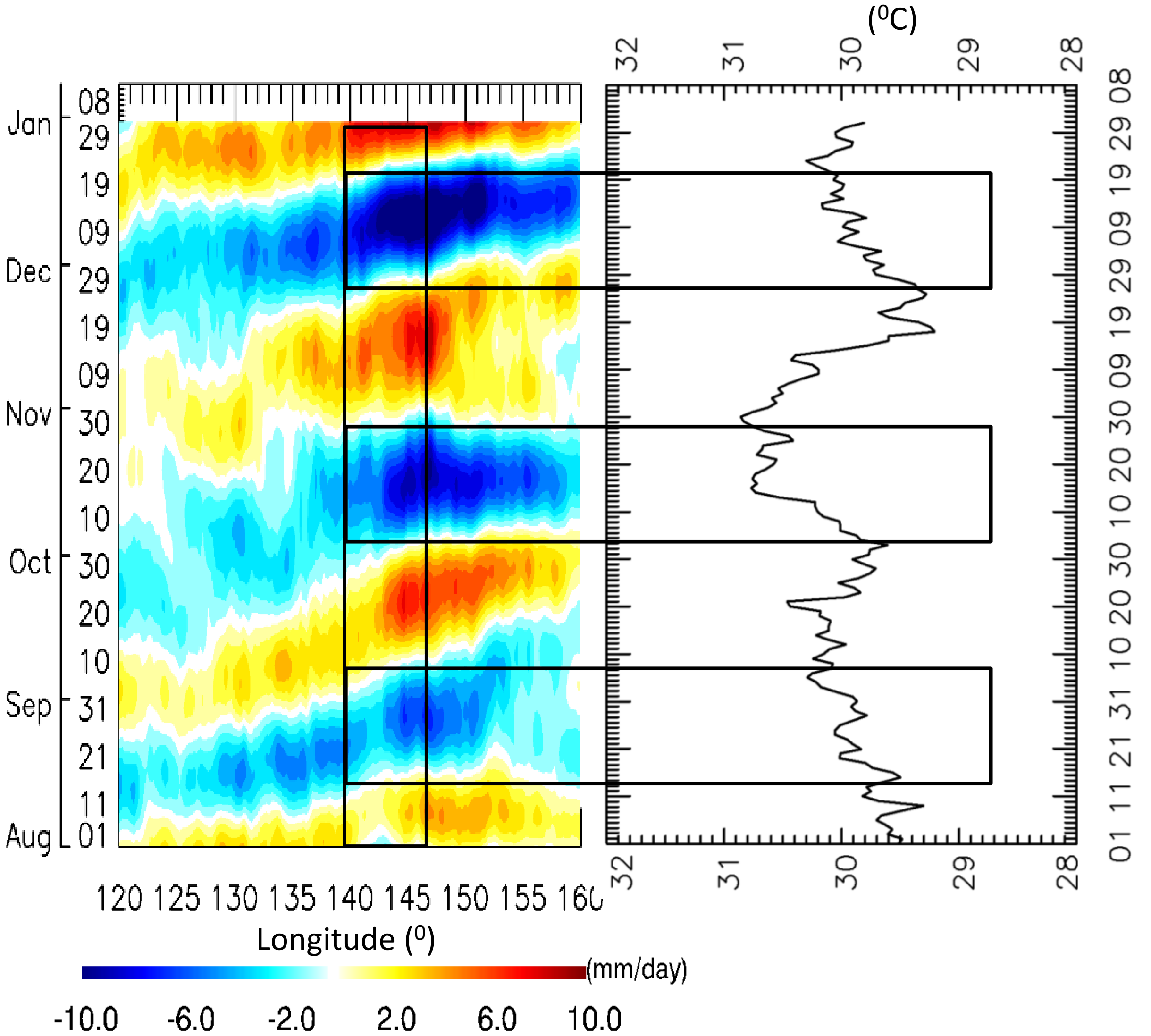
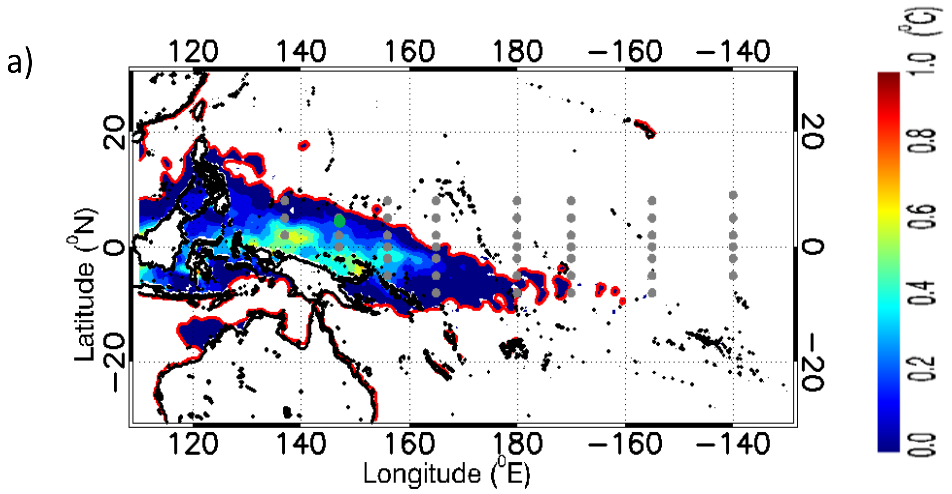


Fig. 2. Hovmöller diagram (5°S-5°N) of precipitation after filtering with cutting period from 30 to 60 days (left figure) and the corresponding mean SST value inside the black box (right figure).

MJO influence the SST through the buoyancy flux into the ocean. It increases (decreases) with surface warming by solar radiation (cooling by latent heat flux and nighttime infrared radiation) and freshening (salinizing) by precipitation (evaporation) [12]. In the present study, the influence of freshwater flux was examined for the development of HE090503. HE090503 is one of HE cases related to MJO event. The amplitude map is shown in Fig. 3a. Figure 3b shows the Hovmöller diagram of filtered precipitation and time series of SST, solar radiation and salinity observed by TAO/TRITON buoy at 147°E, 5°N denoted by the green dot in Fig. 3a. The active phase of MJO was indicated by the positive filtered precipitation in the Hovmöller diagram, lower and fluctuated solar radiation and the decrease of salinity in the time series data. The decrease of salinity denoted the freshening process. The suppressed phase of MJO was indicated by the negative filtered precipitation in the Howmoller diagram and the increasing solar radiation in the time series data. Salinity remained low in this period. This period coincided to the increasing SST which indicated the development stage of HE. The freshening process during the active phase of MJO may stabilize the water column, prevented the mechanical mixing,



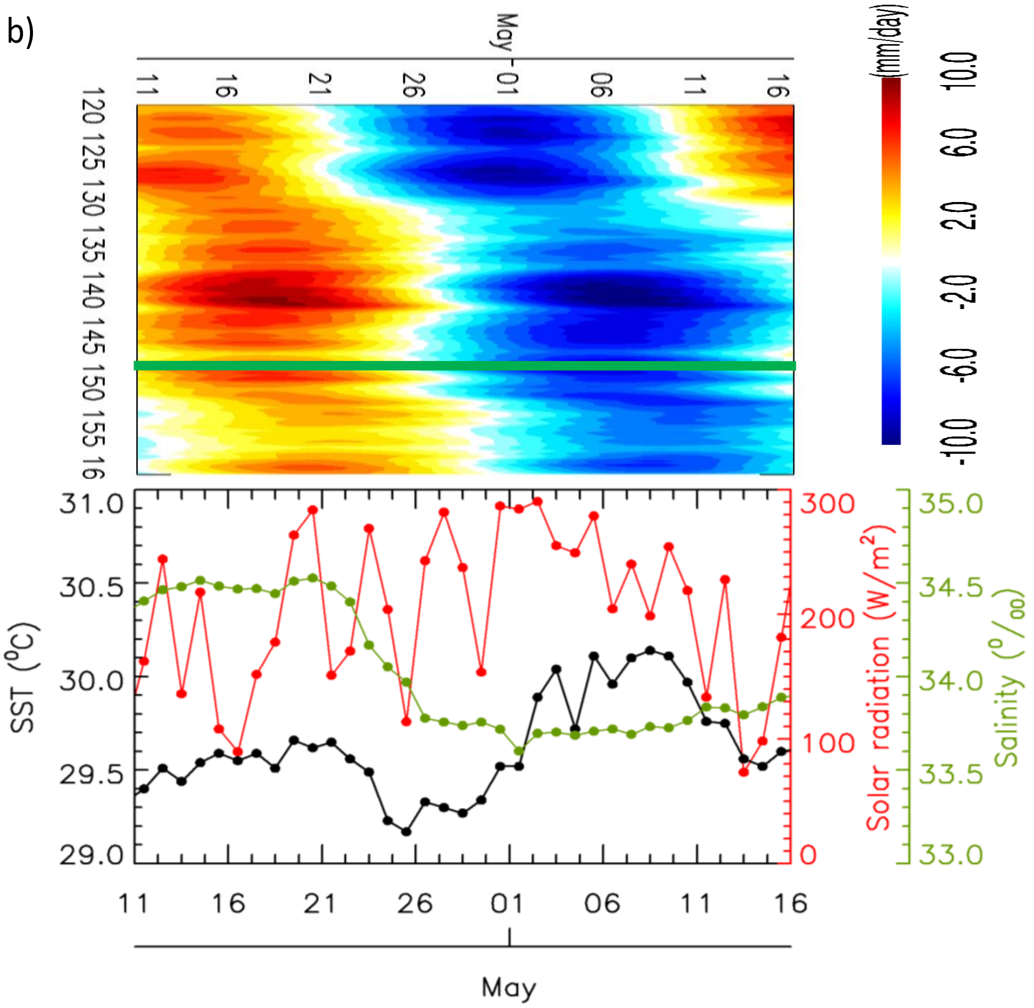


Fig. 3. (a) The amplitude map of HE090503. Amplitude map is the composite of daily amplitude throughout the period of HE090503. Daily amplitude is calculated by subtracting daily SSTs from space-time dependent threshold as shown in [10]. The green dot is the position of TAO/TROTON buoy used in the time series analysis of Fig. 3b. (b) The Hovmöller diagram of 2°N-7°S of TRMM filtered precipitation and the time series of SST, solar radiation and surface salinity of TAO/TROTON buoy at 5°N, 147°E. The green line in Hovmöller diagram points 147°E.

fastened the warming in the sea surface, and generating HE. Thus, beside high solar radiation during the suppressed phase of MJO, this study firstly shows the contribution of high precipitation during the active phase of MJO to the development of HE by stabilizing the upper water column. However, this phenomena occurred only in some cases. Strong oceanic processes, such as horizontal advection by ocean currents, cold water entrainment at the bottom of the mixed layer or the effect of the diurnal cycle may blurred the mixed layer responses to MJO forcing [12]. Thus, the stabilizing effect of precipitation were dissembled in some other HE cases.

4. Conclusion

The study of the influence of Madden Julian Oscillation on the formation of the Hot Event in the western equatorial Pacific can be concluded as follows :

a. Off 48 HE cases located along the equatorial band during 2003-2011, the development of 29 HE cases was related to the suppressed phase of MJO.
b. The high solar radiation due to the subsidence air during the suppressed phase of MJO were the most prominent factor on how MJO influence the HE development.
c. The high precipitation during the active phase of MJO may contribute to HE development by stabilizing the upper mixed layer. The stable upper water column fastened the heating process during the suppressed phase of MJO, generating HE.

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