A Study on the Hot Events in the Western Equatorial Pacific - Their Characteristics, Mechanisms and Interactions with the Pacific Warm Pool

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論 文 内 容 要 旨

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学位論文の 題　　目	A Study on the Hot Events in the Western Equatorial Pacific – Their Characteristics, Mechanisms and Interactions with the Pacific Warm Pool （西部太平洋赤道域におけるホット・ イベントに関する研究- それらの特性、メカニズム、そして太平洋暖水プールとの相互作用）		

論 文 要 旨

The western equatorial Pacific is potential for the Hot Event (HE) study since the previous study showed that among the equatorial regions, most of HEs occurred in this area. Moreover, it is also known as an important area for oceanography and climatology since the warmest equatorial pool, which is responsible to transport heat and water vapor to the higher latitude is located in this area. Therefore, the investigation of HE in the western equatorial Pacific can give a better understanding of their characteristics and mechanisms as well as their interactions with the Pacific warm pool.

Chapter 1 introduces the research backgrounds of the high SST in the western equatorial Pacific and the summary of the previous HE study. The previous studies on the high SST in the western equatorial Pacific were mainly focused on the seasonal, intraseasonal, and interannual variations. HE phenomena correspond to the occurrence of very high SST (>30°C) with a short time scale (< a month). These phenomena are sensitive to the measurements bias/errors and sparsely occur because of their requirement on the particular mechanisms for their formation. Therefore, the appropriate dataset and method are needed to capture their occurrence. The previous studies of HE used the optimally interpolated daily SST data with a spatial resolution of 0.1° × 0.1° merging the infrared and microwave satellite SSTs to detect HEs. They also developed a method called the time-dependent threshold, a SST threshold which follows the interanual variation of SST in the equatorial oceans. They found 31 HE cases during 10 years observation in the equatorial region which were generated by the condition of high solar radiation and low wind speed. In some cases the high solar radiation generated during the HE occurrence is associated with a sub-surface high SST anomaly during El Niňo event controlled by the "remote convection" mechanism. However, their studies cannot reveal the relation between HEs and the long-term SST pattern in the warm pool due to the limited HE case numbers. This relation becomes the important issues for the present HE study. This short period variability of SST may have the climatic consequences if accumulated and then affected the long-term statistic pattern in the warm pool.

I examined the performance of three global SST datasets and evaluated the previous HE detection method in Chapter 2. Three global SST datasets which have the same temporal and spatial resolution i.e., daily and 0.25° grid interval were examined against the SSTs obtained from the TAO/TRITON buoys in detecting HE. After the analysis of Power Spectral Density, probability test and comparison with the original AMSR-E snapshots, NGSST-O-Global-V2.0a was chosen for investigating HE in the western equatorial Pacific. The two microwave sensors composing NGSST-O-Global-V2.0a, significantly improve the observation coverage and the diurnal correction on the processing of NGSST-O-Global-V2.0a reduces the errors arising from merging observations at different times. The method used by the previous study has a limitation for detecting HE in the cold season. Improving new detection method which is free from seasonal effect, I defined an HE as a connected region with a SST higher than the space-time dependent threshold of about 30°C, with a minimum areal size of 2×10^6 km, and a duration period longer than 6 days.

Chapter 3 conducts the climatological study of HE in the western equatorial Pacific. During 9 years observation from 2003 to 2011, I found 71 HE cases which have characteristics as follows : a mean

areal size of 6.30×10^6 km^2, a mean period of 18.14 days, a mean amplitude of 0.33 °C, and a mean speed of development (decay) of 0.28 (0.31) $\times 10^6$ km^2/day. They were distributed within the equatorial band to subtropical Pacific (20°S to 30°N) and extended eastward to 150°W. They frequently occurred along the northern coasts of New Guinea and the Solomon Islands, with an eastward extension to 180°E. Their distribution also exhibited seasonal variation. The observed distribution of the HE occurrences indicates that the HE formation is statistically related to the formation of the Pacific warm pool via the long-term SST. Higher occurrence rates of HE correspond to higher climatological SSTs. For the HE mechanisms, I found that although high solar radiation of more than ~200 W/m^2 was required, wind speeds lower than ~4 m/s become the key for the HE occurrence in the western equatorial Pacific. In areas where wind speeds are low, latent heat loss are reduced and high SSTs occur, leading to the occurrence of HEs.

The atmospheric variability during the development and decay stage of HE is described in Chapter 4. The HE development in the western equatorial Pacific is indicated by positive anomaly of solar radiation from its climatology while its decay is denoted by the anomaly of surface wind direction. During the development stage, the solar radiation (wind speed) in the HE area is much more enhanced (reduced) than during the decay stage. The theory of 'remote convection' is proven for the formation mechanisms of HE occurred in the late May 2003 (i.e., HE030528). Moreover, the high solar radiation during the development stage of HE is partly contributed by the suppressed phase of the MJO in the western equatorial Pacific. I also found the indication of the air-sea-land interaction process which generates the strong westerly wind during the decay of HE030528. Surface wind plays important role to influence the variability of solar radiation during the HE occurrence by controlling the water vapor supply in the upper troposphere through surface evaporation and surface convergence variation. Thus, surface wind becomes the key factor for the HE occurrence in the western equatorial Pacific.

Chapter 5 focuses on the oceanic variability during the development and decay stage of HE. The west side of the Pacific warm pool is characterized by the warm and relatively stable thermal structure. These characteristics may become the anvil for the HE occurrence so that the highest occurrence rate of HE is found in this area. The occurrence of HE in the western equatorial Pacific can be identified by the trapezoidal shape of the thermal structure change in the mixed layer which is described as follows: during the development stage, the higher temperature is accumulated at the surface layer while during the decay stage, the temperature at the surface (deeper layer) decrease (increase). This trapezoidal shape is formed by the heat accumulation at the surface layer under the condition of high solar radiation and low wind speed during the development stage. During the decay stage, high latent heat loss and the transport of sensible heat to the deeper water column occur under the condition of low solar radiation and strong wind speed. These mechanisms may contribute to maintain the warm mixed layer in the Pacific warm pool. Since surface winds control heat accumulation at the surface layer and heat distribution in the mixed layer by influencing current speed, current divergence and latent heat flux, surface winds become the key factor for the HE occurrence and the formation of the thermal structure in the Pacific warm pool.

The general conclusions and remarks are mentioned in chapter 6. Future studies of HE are directed to investigate : 1) the mechanisms governing the characteristics of HE detected in the western equatorial Pacific (duration, amplitude, areal size, and speed of development and decay), 2) further analysis of the HE-MJO-tropical cyclone relationship, 3) the role of HE in governing the mixed layer temperature variations involving all possible factors such as subduction, entrainment lateral mixing and also interannual background, 4) the possible mechanisms of rainfall on influencing the HE occurrence and 5) the possible effect of HEs on influencing the global climate.

論 文 目 次

論文審査の結果の要旨

西部太平洋赤道域の太平洋暖水プールに関して多くの研究が行われてきたが、用いられた海面水温(SST)データは解像度が荒く、エルニーニョなどの大規模構造の季節変動や年々変動などに焦点が当てられていた。本研究では、近年精力的に整備された最新観測システムに基づく高解像度解析データを用いて、この海域に特徴的な 30 度を超える超高 SST 短期変動現象（ホット・イベントと呼ぶ、以下 HE）の特性、メカニズム、そして太平洋暖水プールとの相互作用を明らかにした。

新しく開発した時空間依存しきい値により、継続して出現する約 30 度以上の SST を持つ連続した広域海面として、2003-11 年間に 71 個の HE を検出した。その平均面積は 6.30 百万平方キロメートル、平均継続日数 18.14 日、平均 SST は 30.33 度であった。個々の HE の面積時系列から、新たに HE 発達期と減衰期を定義した。

ニューギニアとソロモン諸島に接し、東へ 180E のあたりまで伸びる海域に、HE が頻発することがわかった。この海域は、気候学的に定義された、SST が 28 度以上の暖水プール海域と一致した。

HE 発達期には、大気上層の下降流によって雲の発生が抑えられ、晴天で無風の条件が整い、海面に入射する短波放射が卓越し、海面での潜熱フラックスが押さえられ、海洋表層が加熱され、SST が急速に上昇する。この事実は、これまでの研究とよく整合する。一方、この海域では、無風の条件がより重要であることが示された。

HE 減衰期には、風速が強くなり、海面から大気に向かう海面熱フラックスが増加し、その影響が大気上層に及び、雲が発生し、短波放射が海面に入射しなくなり、HE 域の SST が急速に降下してイベントは終了する。その際、海洋下層への顕熱輸送がおこり、混合層深度が増加する。HE の発達・減衰に伴うこのような海洋混合層内の時間発展は、台形的鉛直温度構造と名付けられた。暖水プールは HE 発生基盤として機能するとともに、HE 減衰期に下層に供給される顕熱は暖水プールの形成・維持に大きく寄与していると考えられる。

太平洋暖水プールの気候学的側面が、最新の大気海洋観測システムから得られる情報に基づいて新たに定義された広域短期変動現象によって説明できることを実証し、今後の大気海洋相互作用の研究に大きな指針を与えた本研究は、申請者が自立して研究活動を行うに必要な高度な研究能力と学識を有することを示している。よって、WIRASATRIYA 提出の博士論文は、博士（理学）の学位論文として合格と認める。