SMALL SCALE CLOUD ACTIVITY IN MARITIME CONTINENT AND WESTERN PACIFIC USING SATELLITE DATA

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ABSTRACT

Using the geostationary satellite (GMS) data, we identified each cloud system over the tropical Pacific and around the maritime continent. The systems were further categorized as over land, over coast and over ocean. The Tropical Rainfall Measuring Mission (TRMM) data over the cloud systems were picked up and statistical characteristics of precipitation such as storm height in terms of cloud system evolution was revealed. The rainfall was the maximum at the time of TBB minimum or earlier. Vertical development was significant over coast area, while remarkable horizontal expansion appeared over land. Precipitation ice and the storm height showed differences among land, coast, and ocean.

Keywords-TRMM; GMS; cloud

1. INTRODUCTION

Tropical precipitation activity, particularly in the maritime continent and western Pacific, is the primary driving force of the general circulation, and the study of the tropical cloud/precipitation system is essential for understanding the climate system. Satellite data help much for the study of the cloud/precipitation activity thanks to the global scale coverage and long-term monitoring. The Tropical Rainfall Measuring Mission (TRMM) satellite is equipped with a precipitation radar (PR), and three-dimensional rain structure measurement was realized (Kummerow et al. 2000). The power of PR could be enhanced using other satellite data such as GMS which observe clouds hourly.

This paper describes the evolution of cloud systems observed by GMS over the maritime continent and the tropical western Pacific using cloud tracking method. The TRMM data matched with cloud systems identified by GMS data were incorporated, and the characteristics of rain rate, storm height, etc. with cloud evolution stage were investigated.

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2. EVOLUTION OF CLOUD SYSTEM

First, we identified the cloud system using the blackbody brightness temperature (TBB) which relates to cloud height. In this study we used 235 K as the threshold according to GPI (Arkin and Meisner 1987). Clouds which has the rain area (less than 235 K) of more than 1,963 km (corresponding to a circle with a radius of 25 km) were picked up. Hereafter we call the area as the cold cloud area. We also applied the split window technique (Inoue 1987) which utilizes the difference of TBB due to water vapor. The analysis was performed over a rectangular region of 90E-180E and 20S-20N including the maritime continent and par of tropical western Pacific, and the period is year 2000. The cloud systems were tracked in GMS hourly cloud data using the minimum speed technique (Machodo et al. 1998). We stratified the cloud systems into the open ocean, land, coast, and coastal sea types. After identify the location of the cloud systems, the distribution of the gravity centers (center rate), the cloud coverage (cloud rate), and the locations of the occurrence, split occurrence, merge, dissipation are made. The grid size is 0.1 degree for cover rate and 0.5 degrees for others. The total number of the cloud system appeared in the analysis region in 2000 was 290,717. First, we picked up only systems which did not experience any splitting or merging (non-split/non-merge convective system). The number of these systems was 81,314 and the fraction was about 28 %. The numbers of cloud systems over land, ocean, coast, and coastal sea (hereafter “sea”) are 4,250, 16,660, 24,520, and 21,324, respectively. The fraction of number of the systems which moved from one region to another region was only 6 % which were not used in the analysis.

Figures 1 shows the minimum TBB in the system, the cloud area, an the mean TBB gradient in 10 km at the edge for the elapse time after occurrence as functions of elapse time in hour for systems with lifetime of 1-6 hours. The time t=0 means the occurrence, and the dissipation is depicted by small circles. The minimum TBB is estimated for five hours before occurrence and after dissipation. Other parameters are set to zero for five hours before occurrence and after dissipation. The minimum TBB becomes significant two hours before occurrence and takes the minimum in the beginning phase of the cloud evolution for every region. After taking the minimum, TBB slowly increases and takes slightly higher temperature at the dissipation time than at the occurrence. This fact indicates that the cloud system, first, evolve vertically, and after taking the highest top, it becomes gradually lower. The variation of the minimum TBB is large in the order of the coast, land, sea and ocean. This is partly because the background (cloud free) TBB is high over the land. The difference of TBB is more significant for the longer lifetime cloudy systems, and maximum 5 K difference appeared between over the ocean and the coast.

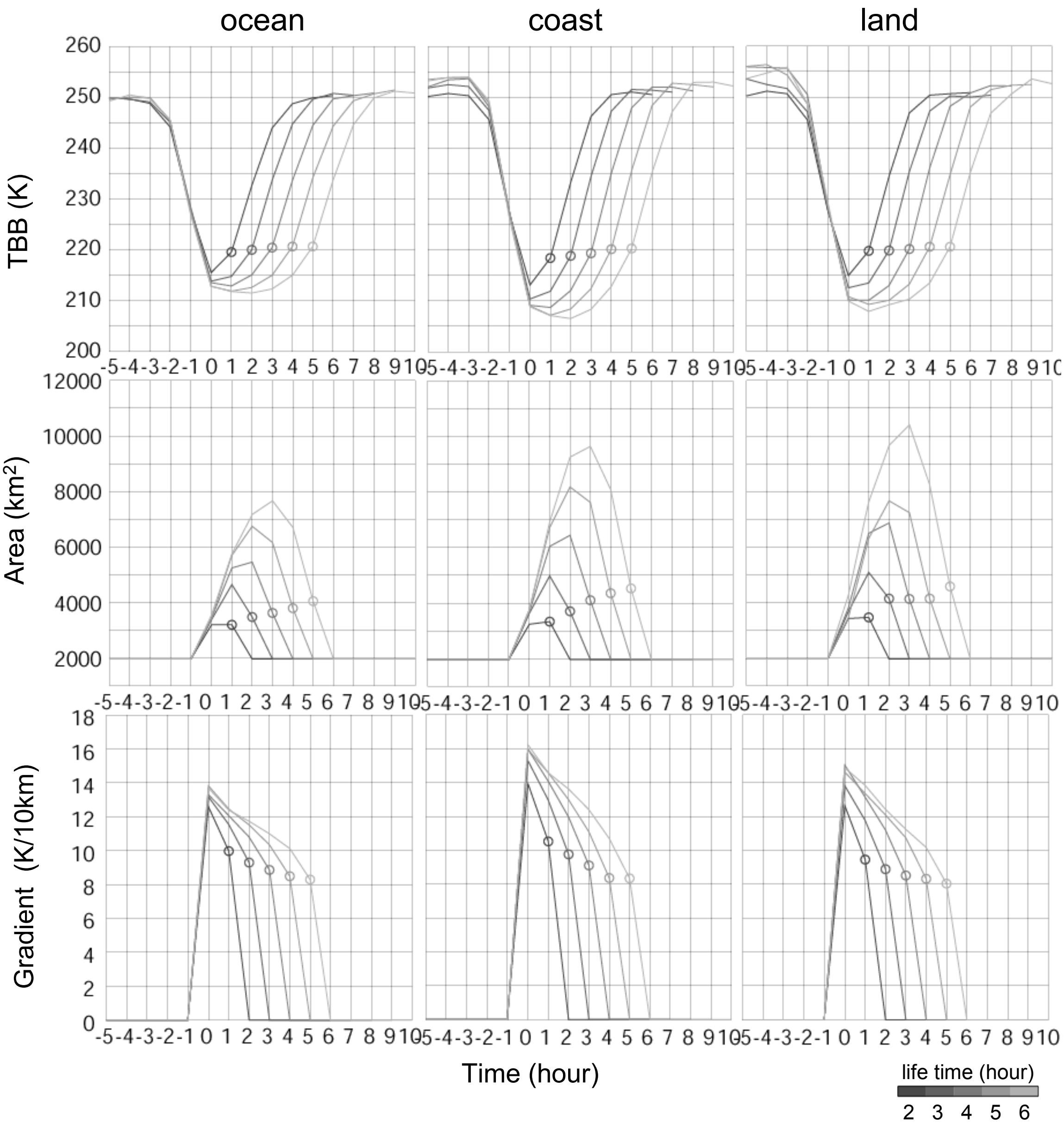

Figure 1. Variations of TBB, area and TBB gradient at the edge for non-split/non-merge cloud systems for each lifetime.

On the contrary to the minimum TBB, the cloud area is maximum at the middle of the lifetime, and the profile of time variation has a symmetrical shape. The gradient of TBB can be an index representing the vertical cloud shape. The high gradient indicates a columnar shape, and low gradient indicates a horizontal extended shape. The figure tells that the cloud system evolves from vertically sharp shape to flatter shape. The gradient is high at the beginning period and low in the dissipating period for systems with long lifetime. In addition, the time change rate of the gradient is small in the middle of its lifetime for systems with a lifetime of more than four hours. The order of the gradient at the beginning phase is the coast, land, sea, and ocean from great to small, while it is the coast, sea, ocean, and land in the dissipating phase. This indicates that the horizontal change is great over the land and vertical change is great over the ocean.

The characteristics that TBB is minimal at the beginning phase, the area size is maximal in the middle, and the gradient is maximal at the beginning and minimal in the dissipating phase was found general independent of the land, ocean, and others. In other words, all non-split/non-merge systems first rapidly grow vertically, expand horizontally, and finally dissipate in thin and smooth shape.

This evolution is similar as that Machodo et al. 1998 reported. As the lifetime is longer, the minimum TBB is the lower, and the cloud top is higher. This is followed by a large size expansion. The TBB gradient at the maximum size slowly changes. For the longer lifetime system, the slowness is more significant. When the area is maximum, TBB gradually increases. This suggests that the anvil contributes much to the increase of the area for the long lifetime systems. In addition, the difference among the regions is bigger for longer lifetime systems.

3. CONVECTIVE STAGE AND PRECIPITATION

Here, we will show the precipitation and evolution stage of cloud systems using GMS and TRMM data. The sample number is particularly small for TRMM PR due to the poor frequent observation of TRMM and the narrow swath of PR.

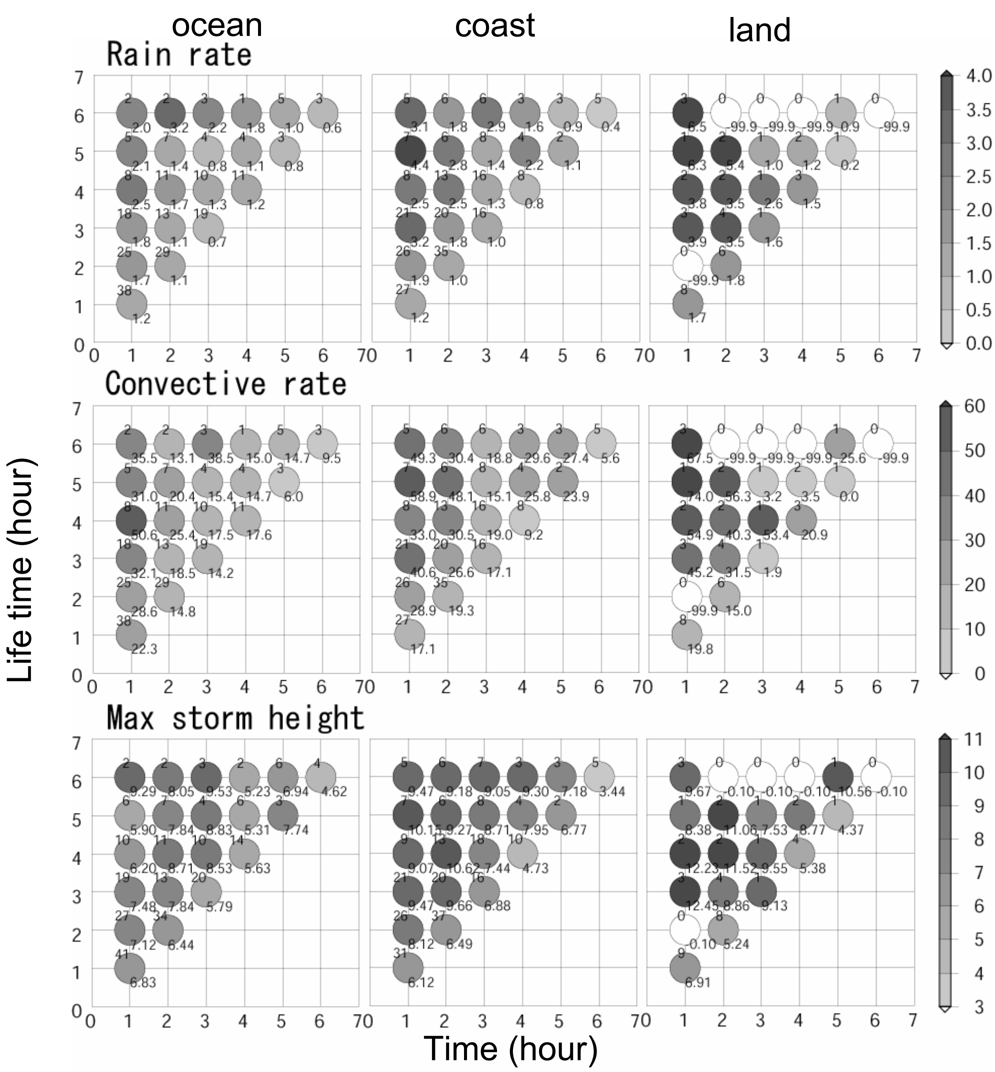

Figure 2. Rainrate, convective rain rate, max storm height for cloud system with several lifetimes derived from TRMM PR.

The mean of rainrates, cloud water content, cloud ice amount, and ice precipitation for each lifetime was investigated. The mean was taken for the rain-conditioned cases. It should be noted that the mean values are taken from the snapshot data of TRMM instead of continuously following data for each system. The rainrates are first strong and decrease, and at the same elapse time, rainrates are stronger for longer lifetime systems. The mean rainrates in the order of over the coast, land, sea and ocean from strong to weak. Though the TMI rain retrieval is less accurate over the land and coast area than over the ocean, the above tendency appeared for all regions. The cloud water content, liquid precipitation amount, and solid precipitation amount also show the characteristics that they are strong for long lifetime systems and decrease as the time elapses. The exceptions are the solid precipitation amounts over ocean and sea which changed only little during the lifetime, while the solid precipitation amounts over the land and coast changed much during the lifetimes, and the solid precipitation amount over land is greater than over coast. The liquid precipitation amounts over the land and coast are nearly nothing. This may be due to the difficulty of TMI rain retrieval over the land region.

The same analysis for the rainrate, storm height, and the fraction of convective rain amount obtained from the PR data are shown in Fig. 2. Since the storm height varies much in the cold cloud region, the maximum storm height instead of mean storm height in each cold cloud region are averaged over many systems. The number of samples over land is very few and the result may be erroneous. The rainrate variation seems similar to that by TMI though it is not so clear. The rainrate over the coast is larger than over ocean or sea. The fraction of convective rain amount shows the same tendency as the rainrate, that is, the rainrate is maximum at the beginning of the lifetime and gradually decreases after that. In other words, a cloud system starts as a convective system. After that the system horizontally expands and stratiform rain becomes dominant with decreasing rainrate. Rikenbach 1999 examined squall lines observed by ground-based radars and GMS during the Tropical Ocean Global Atmosphere Coupled Ocean-Atmosphere Response Experiment (TOGA COARE). He pointed out that rainfall is associated with low TBB which then separated from the precipitating region. The time when the size is maximum appeared in the decaying period and stratiform rain is dominant. In his cases, the cloud system consisted of several developing and decaying convective systems on a squall line. Though, in our study, we did not separate this systems by the shapes, Rickenbach's result supports our results on the precipitation and cloud evolution. The storm height is high when the rain is strong for coast, while this is not the case for ocean or sea. This indicates that the horizontally spread stratiform precipitating cloud is maintained for ocean and sea during the lifetime. Over the coast, the vertical growth and decay of the cloud system is rapid, and the temporal variation of the fraction also varied largely.

4. CONCLUSION

We showed the cloud system characteristics and its relationship with sea surface conditions using satellite data. The advancement of the satellite observation makes many different data available. To address the cloud system characteristics in many aspects, the combination of these satellite data is now very effective and also essential.

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