JP3J.13 DIURNAL VARIATION OF THREE-DIMENSIONAL RADAR ECHOES AND THEIR POSSIBLE ROLE OF PRECONDITIONING THE ATMOSPHERIC HUMIDITY

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1. Introduction

Preconditioning the atmosphere humidity is essential for the development of organized convective systems constituting the active part of Madden Julian Oscillation (MJO), and also it is one of the supposed processes initiating MJO (Blade and Hartmann, 1993). However, for the mechanism of preconditioning by cumulus convections studies are limited. For example, Johnson et al. (1999) introduced that shallow and congestus clouds are frequently observed in the inactive phase of MJO, which are coincided with the moistening of the lower troposphere.

IORGC/JAMSTEC conducted an intensive observation at Republic of Palau (7 N, 134 E) from December 2004 to January 2005 using triple Doppler radars including R/V Mirai. During the observation, a mass of isolated convective cells was frequently observed, which was followed by an appearance of organized convective systems. The appearance of isolated convections showed clear diurnal variation. Therefore, by investigating the behavior of the isolated convections following topics will be revealed, as (1) the developing mechanism of organized convective systems, (2) the role of diurnal variation of isolated convections for the development of organized convective systems, and (3) the moistening mechanism by convections. Johnson et al.(1999) categorize observed radar echoes into three categories by their echo top height. However, in this study we categorize them by their horizontal extent. Time series of the number of categorized radar echoes features are investigated focusing on their diurnal variations in relation with the lower tropospheric humidity to study the moistening process of lower troposphere by cumulus convections.

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2. Data

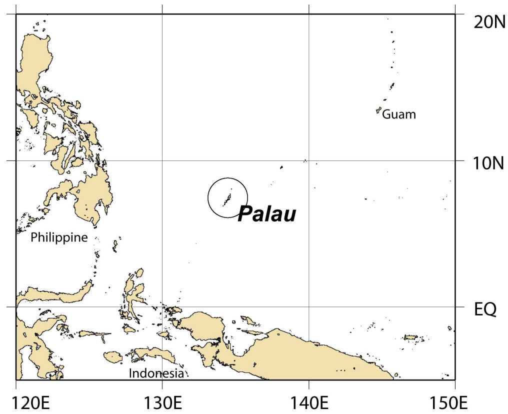

Figure 1. Map of the observation area. A center circle indicates radar range installed at Republic of Palau.

Data used in this study are from intensive observation at Republic of Palau (7 N, 134 E) from December 10th 2004 to January 15th 2005. A x-band radar installed at a hill of a Palau island observed three-dimensional distribution of raindrops within a range of 150 km as in Figure 1 with beam width of 1.2 degree in 7.5 minutes interval. One convective feature is defined from a mass of radar echo at 3 km height in Cartesian coordinate. The convective features are categorized into three categories depend on their horizontal area at 3 km height. Equivalent diameter is defined here from a diameter in which the area of echo is converted as area of a circle. Those with their equivalent diameter less than 10 km but at least more than 5 km^2 are “Isolate convections”, equivalent diameter between 10km to 30 km are “slightly organized convections”, and equivalent diameter with more than 30 km are “organized convections”.

The observed days are classified into convectively disturbed period and undisturbed period as well as Sui et al. (1997). Because the behavior of convections in disturbed phase is quite different with undisturbed phase. In this study, days with total radar echo area is more than 6000 km^2 (10 % of the total observation area) are defined as disturbed phase.

Data from radiosonde launched 8 times a day from R/V Mirai are used to detect atmospheric environment.

3. Results

Figure 2 shows Hovmoller diagram of TBB temperature from GOES satellite. The observation period is characterized by a passage of MJO active phase from late December to middle January, but from 5th to 9th January the convections are suppressed even inside the active phase of MJO. At December 23rd a cloud cluster coupled with westward moving Rossby wave has passed.

Johnson et al. (1999) studied the number of convections categorized with their echo top height in a time scale of one month and showed shallow convections and congestus clouds preconditioned the lower troposphere. In this study we will discuss phenomena of mush shorter time scale, because observation period is only a month and the observation site is rather apart from the equator (7N) in which the effect of MJO is weak.

A daily-averaged time series of the number of convective features is shown in Figure 3 similar as figure 9 of Johnson et al. (1999). Organized convections with their equivalent diameter is more than 30 km are increased during convectively disturbed period with Rossby wave or MJO has passed as in Figure 2. On the other hand, isolated convections is always in substantial number, especially in the inactive phase of MJO before December 27th.

Next focusing on December 15th to 20th during the inactive phase of MJO, around 16th isolate convections show their peak number, then 18th to 19th slightly organized convections increase their number coincided with the increase of organized convections. As well as the middle December, the January 3rd to 9th when convections are suppressed, first isolated or slightly organized convections increase their number, after that organized convections increase. In this period, total precipitable water is quickly decreased suggesting an intrusion of dry air. From Figure 3, the number of convective features increased in smaller features first and organized features at last within about 5 day period.

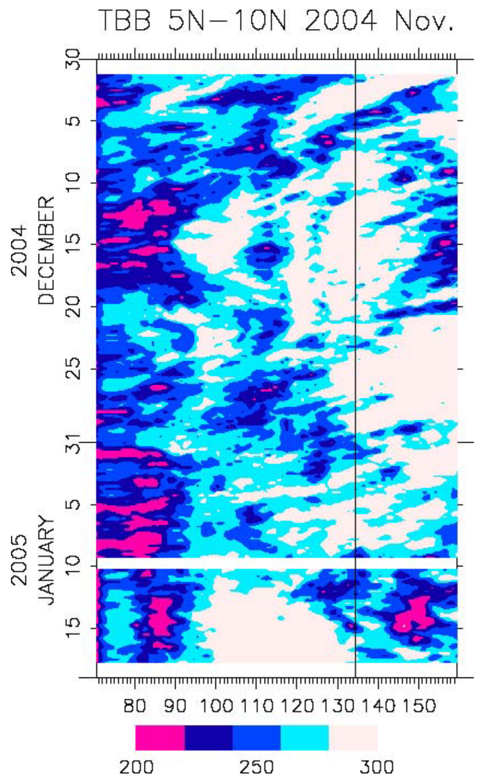

Figure 2. Hovmoller diagram from GOES satellite Tbb temperature. Tbb temperature is the average from 5 N to 10 N. A vertical solid line indicates the observation longitude of 134 E.

Figure 4 indicating not averaged time series of convective features shows quite significant diurnal variations in each category. Especially in the 5 to 6 days period from undisturbed to disturbed period mentioned above, diurnal variation of isolated convection is quite clear, and they usually increased the number in the nighttime shown in pink color in the figure.

Figure 5 shows clipped time series from Figure 4 with tropospheric relative humidity profiles focusing

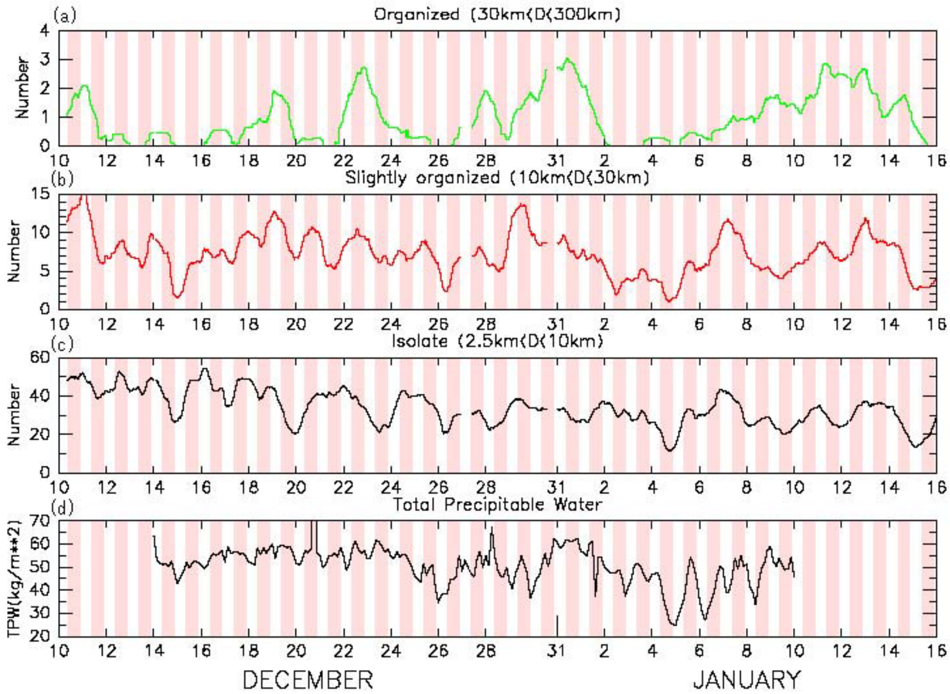

Figure 3. Daily-averaged number of convective features in three categories of (a) organized, (b) slightly organized, (c) isolate, and (d) total precipitable water from radiosonde launched at R/V Mirai. Pink color shades indicate nighttime.

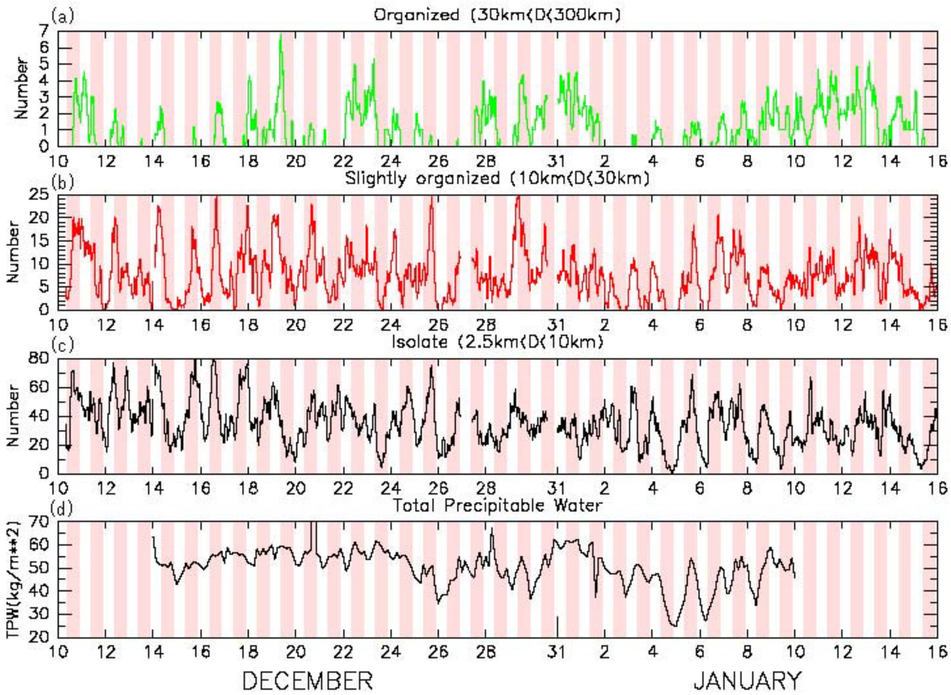

Figure 4. Same as figure 3. except for not averaged variation of convective features.

on the period mentioned above. From undisturbed to

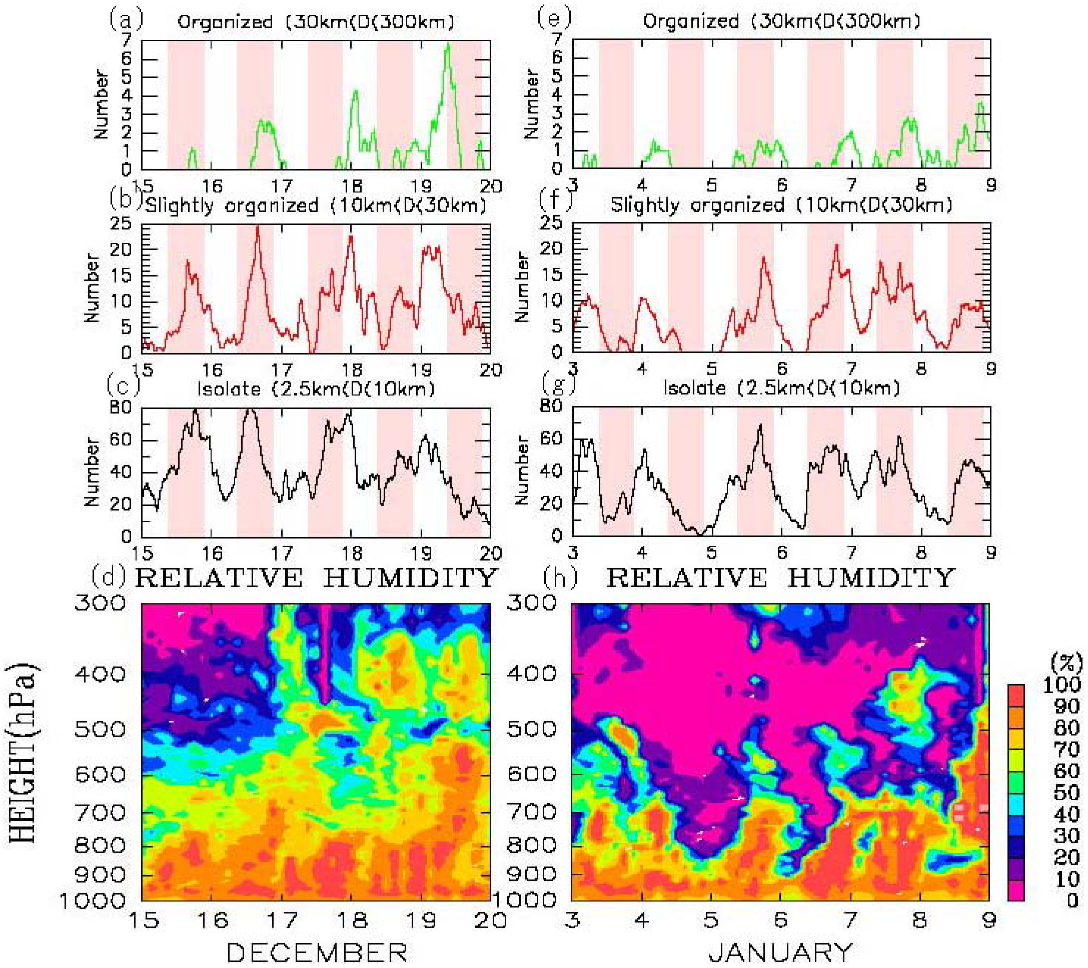

Figure 5. Clipped convective features number variation with relative humidity profile. Upper three panels indicate number of features as well as Figure 4. The lowest panels show relative humidity profiles from radiosonde.

disturbed period, first isolate convections show clear diurnal variations with their maximum in the night time, then slightly organized convections increase simultaneously with isolated convections or a little later. Those variations are seemed to synchronize with lower tropospheric humidity (Figure 5 (d), (h)). After that organized convections increased day by day. In Figure 5(g) January 3rd and 4th the isolate convections have their maximum in daytime, however, it supposed to be affected by a dry air intrusion at the time.

The relationship between number of convective features and lower tropospheric humidity is confirmed in Figure 6 by lagged correlation analysis. Figure 6(a) shows significant simultaneous correlation between isolate / slightly organized convections and specific humidity at 850 hPa. Figure 6(b) shows the specific humidity increases 3 to 6 hours after the appearance of isolate / slightly organized convections. In both figures correlations for isolate convections are much clearer than for slightly organized convections. There is no significant correlation with specific humidity above 600hPa (not shown). It can be understood that in convectively undisturbed period isolate (slightly organized) convection significantly affect lower tropospheric moistening. Simultaneous increase at 850hPa and a little delayed increase of humidity at 700hPa are consistent with Figure 5(d) and (h) which is tilted to the right in the figure.

Diurnal variations of convective features are shown in Figure 7. As noted in Sui et al. (1997),

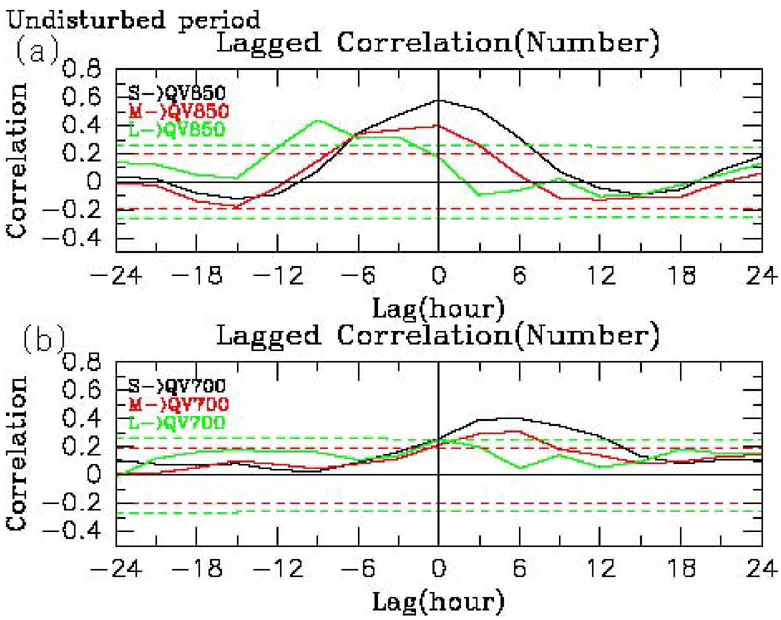

Figure 6. Lagged correlation between number of convective features and lower tropospheric specific humidity at 850hPa(a) and 700hPa (b). Horizontal broken lines indicate confidence level of 95% with colors of each element.

diurnal variations have different mechanism between convectively disturbed and undisturbed periods that can be recognized in Figure 4. This figure shows diurnal variation of convectively undisturbed period. Diurnal variations of isolate and slightly organized convections have first peak at 3 a.m. in late midnight and second peak at 3 p.m. in the afternoon. For organized convection its peaks are not clear. From this results, we speculate that in convectively undisturbed period isolate / slightly organized convections increased in midnight, which moistens the lower troposphere. After that organized convections can appear. After several days of moistening by isolate / slightly organized convections in midnight, organized convections can develop much larger.

4. Discussion

This study has shown that the diurnal variation of isolate or slightly organized convective features is closely connected with lower tropospheric humidity increase. However, one uncertainty remains that the increase of lower tropospheric humidity is the effect of local convective activity or the effect of the large scale advection. The studied area has its diameter of 300 km, which is slightly smaller than a distance of air mass travel in a day in this region. However, we

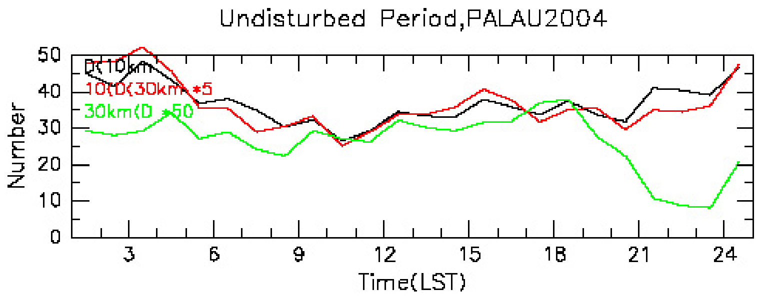

Figure.7 Diurnal variation of number of convective features in each category of isolate (black), slightly organized (red), and organized (green). For easy to understand, slightly organized and organized are multiplied by 5 and 20, respectively.

consider the increase of lower tropospheric humidity is the result of the local convective activity in the following two reasons. First, since in this region in the tropics thermodynamic field is usually horizontally homogeneous in the scale of a few hundred kilometers, what happens in the observation area within 150 km radius most likely happen as well as around the observation area. Second, the correlation in Figure 6 will represent what synchronizes most with the lower tropospheric humidity. It is not understandable that large scale advection of moist air comes in phase with the diurnal variation of isolated convections. Therefore, it can be said that the lower tropospheric humidity increase is caused by the isolate or slightly organized convective activities.

In this study the importance of the diurnal variation of isolated convections for lower tropospheric humidity increase in convectively undisturbed periods. It is important for numerical simulation of convectively undisturbed period. To describe the isolated convections of about 10 km^2 in mean size, the diameter is less than 4 km. To simulate the isolated convections numerical models with the horizontal grid spacing less than 1km is needed.

5. Summary

The number of convective features in three categories with their horizontal extent is investigated with lower tropospheric humidity. The time series of the number of convective features show clear diurnal variations in the convectively undisturbed period. The diurnal variation of isolated and slightly organized convections have maximum in late midnight, and they have the effect of moistening the lower troposphere. As they moisten the lower troposphere day by day, organized convections increase their number until convectively disturbed period. This diurnal variation of isolated convections is appeared to play important role for preconditioning the lower tropospheric humidity.

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