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THE DIURNAL VARIATION OF DEEP CONVECTIVE CELLS IN TROPICAL CYCLONES UNDERGOING RAPID INTENSIFICATION

Jae-Deok Lee* and Chun-Chieh Wu
Department of Atmospheric Sciences, National Taiwan University, Taipei, Taiwan

1. INTRODUCTION

The rapid intensification (RI) event is an important scientific issue, as well as a very difficult problem, in tropical cyclone (TC) intensification. In general, the RI is defined as when the central pressure decreased by about 42 hPa or the maximum surface wind speed increased by over 30 kt within 24 h (Holliday and Thompson 1979; Kaplan and DeMaria 2003).

From many previous studies on RI, a common feature is that within TC inner-core region, deep convective cells are well identified. These deep convective cells have generally colder brightness temperature (BT) than that of peripheries (Browner et al. 1977; Gray and Jacobson 1977; Muramatsu 1983; Steranka et al. 1986; Heymsfield et al. 2001; Bedka et al. 2010; Guimond et al. 2010, 2016; Harnos and Nesbitt 2011; Jiang 2012; Kieper and Jiang 2012; Monette et al. 2012; Dunion et al. 2014). Once deep convective cells occur, it can largely contribute to the formation of cirrus clouds in the upper troposphere (Merritt and Wexler 1967). These thick clouds can play a role in providing warmer environment beneath that cloud regions. This could be one of the favorable conditions for the development of deep convective cells especially within eyewall region because the upper troposphere tends to be destabilized throughout nighttime by radiative cooling.

This study examines how the diurnal variation of deep convective cells serves as a precursor of RI with respect to five RI TCs (Nepartak 1st, Meranti 14th, Chaba 18th, Songda 20th, and Nockten 26th) in 2016.

2. DATA

In this study, deep convective cells and vertical wind shear are examined using Himawari-8 satellite imagery and ERA-Interim data. And for the better reliability with respect to best track, three different best tracks, i.e., Japan Meteorological Agency, Joint Typhoon Warning Center (JTWC), and Korea Meteorological Administration, respectively, are averaged. In order to convert 1-minute averaged maximum surface wind speed of JTWC to 10-minute averaged maximum surface wind speed, the equation used in international best track archive for climate stewardship has been applied, i.e., V10=V1×0.88.

3. THE DEFINITION OF ANVIL CORE AND AREA

Based on the 11.2 μm infrared channel, the anvil core and area have been defined as follows: for example, if BT ≤ 195 K, that area indicates the existence of anvil core. Meanwhile, if 195 K < BT ≤ 225 K, this area indicates anvil area.

4. THE RELATIONSHIP BETWEEN ANVIL CLOUDS AND TC INTENSIFICATION

Figure 1 shows the anvil core and area analyzed within 300 km radius with respect to five RI cases. On the tropical depression stage, most RI cases seem to have temporary and sporadic anvil core. This feature can be often found in any tropical depressions. However, after it becomes tropical storm intensity, the anvil core and area tend to be further organized and well maintained especially during nighttime. Although Songda has very small amount of anvil core percentage, it has comparable amount for anvil clouds (Fig. 1d). In other words, if one or several anvil cores exist, it may be enough to help TC intensification. This is designated as a first peak of the anvil cloud development. As a successive development, if there is a second peak during nighttime, all RI cases have undergone RI process. Meanwhile, the anvil area tends to be greatly expanded about 6 h after the anvil core development in the upper troposphere. As a result, such anvil area, which may also include cirrus clouds so-called “cirrus-shield”, is apt to be maximized during daytime. In this situation, the atmospheric columns beneath the thick

*Corresponding author address: Jae-Deok Lee, Department of Atmospheric Sciences (C403), National Taiwan University, Taiwan. E-mail: ruio1084@gmail.com

cloud region can be maintained as warmer environment due to latent heat release induced by deep convection. This may be effective for the destabilization in the upper troposphere during nighttime.

5. AN ANALYSIS OF MEAN BT WITH TC RADII

Figure 2 shows the results for mean brightness temperature according to TC radii. On the tropical depression stage, the inner-core region has warmer BT with small anvil cores (Figs. 1, 2). After 1 or 2 days, the inner-core BT has been significantly become colder than that of previous time. This period corresponds to the first peak of anvil core as shown in Fig. 1. During daytime, the large anvil area produced by anvil core during last nighttime is able to cover the inner-core as well as most eyewall area. Although BT has been slightly increased during daytime, the inner-core still remains cold enough, i.e., below 200 K (Fig. 2). With this environment, all RI cases have identically occurred on the second peak period mainly during nighttime. In addition, at the end of RI period, the R50 mean BT shows warmer BT environment. This warmer BT indicates the existence of small eye structure because the eye region has clear sky, which is normally high BT value.

6. CONCLUDING REMARKS

In this study, using Himawari-8 satellite imagery, the anvil core and area have been examined to see whether it can be an indicator for RI. Based on the current results, five RI cases satisfying two RI definitions show the same characteristic before the onset of RI and after the onset of RI. In the real atmosphere, the diurnal variation seems to have a large influence on the development of deep convection. Overall, five RI cases were also under weak or moderate vertical wind shear environment during the RI period (not shown). We think that this diurnal variation for anvil core and area is an important RI precursor if they show the first and second peak before and after the onset of RI under the favorable largescale environment.

7. REFERENCES

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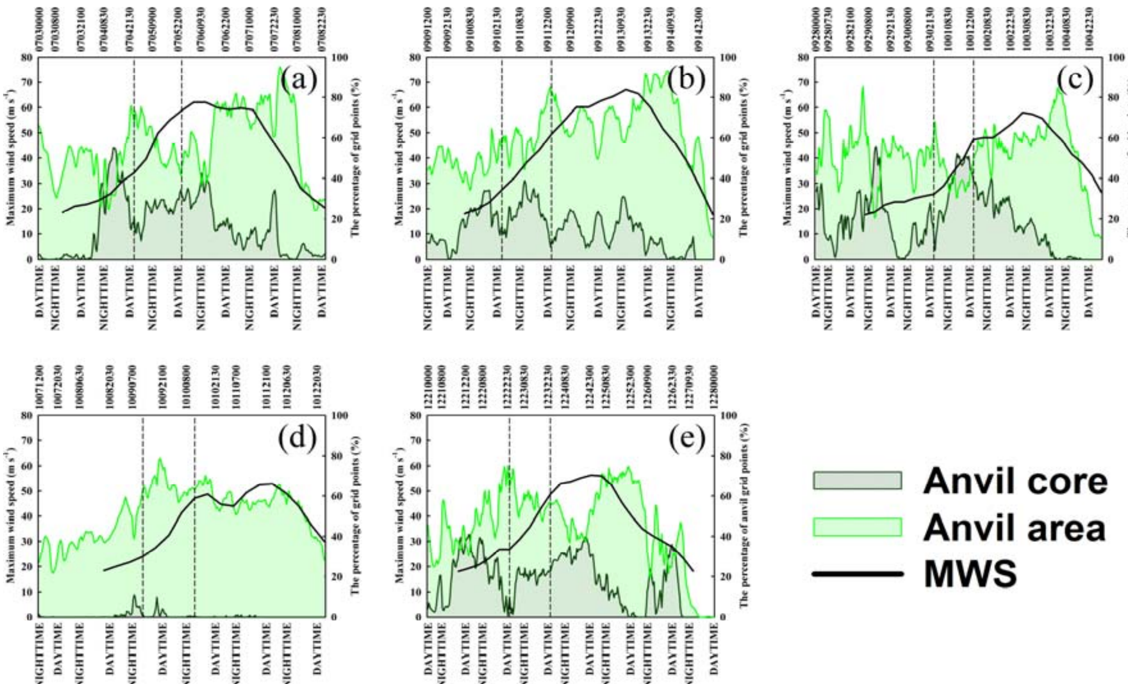

Fig. 1. The analyzed anvil core and area for RI TCs: (a) Nepartak (1st), (b) Meranti (14th), (c) Chaba (18th), (d) Songda (20th), and (e) Nockten (26th), respectively. The thick solid-line indicates 10 minutes averaged maximum surface wind. The vertical dashed-line indicates the RI period, i.e., 24 h.

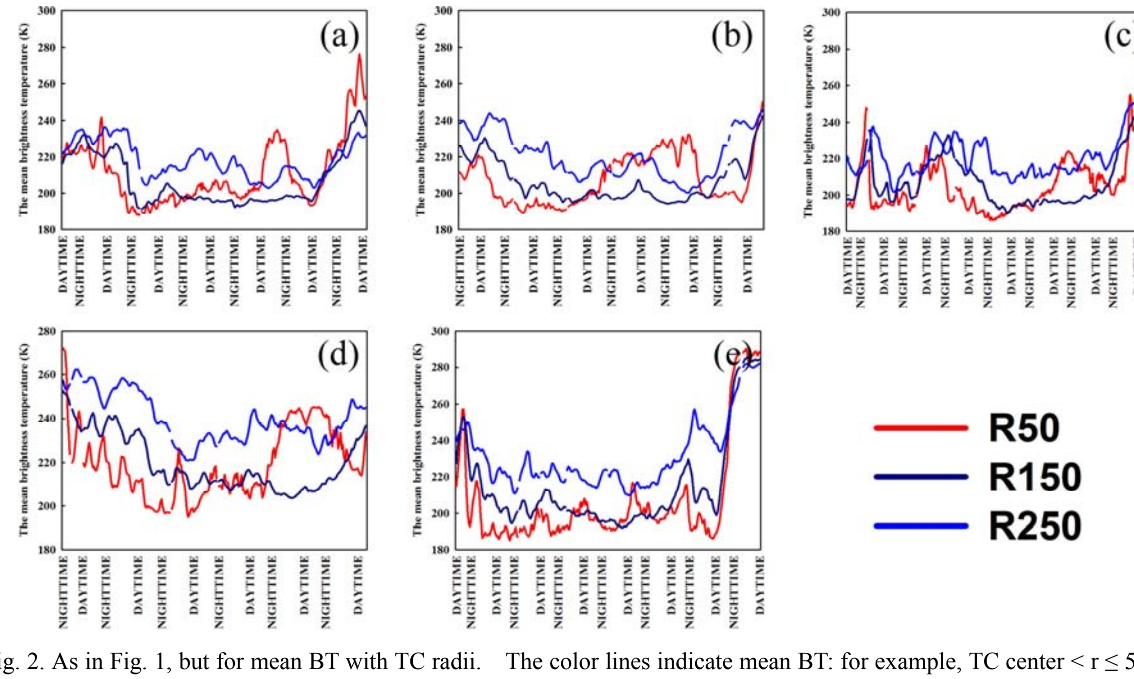

Fig. 2. As in Fig. 1, but for mean BT with TC radii. The color lines indicate mean BT: for example, TC center < r ≤ 50 km in red, 50 < r ≤150 km in dark blue, and 150 km < r ≤ 250 km in blue, respectively.