JP3J.15 TRANSITION OF THE RAINFALL CHARACTERISTICS RELATED TO THE MOISTENING OF LAND SURFACE OVER THE CENTRAL TIBETAN PLATEAU DURING GAME-TIBET IOP

Hiroyuki Yamada[1] and Hiroshi Uyeda[1,2]
[1] Japan Agency for Marine-Earth Science and Technology, Yokosuka, Kanagawa, Japan
[2] Hydrospheric Atmospheric Research Center, Nagoya University, Nagoya, Japan

1. INTRODUCTION

The Tibetan Plateau is characterized by large convective activity and its marked diurnal variation during the summer monsoon season (from June to August). The tropospheric heating over the plateau due to the latent heat release from deep convective clouds plays an important role in the maintenance of the Asian summer monsoon circulation (Luo and Yanai 1984; Ueda and Yasunari 1998). These convective clouds usually develop in the daytime due to the thermal instability resulting from the strong heating of the plateau surface (Kuo and Qian 1981; Yanai et al. 1992).

It is expected that the land-surface conditions, such as soil moisture and vegetation, have a large impact for the development of the convective clouds and associated rainfall. The surface condition may control the ratio of the sensible heat flux to latent one (i.e., Bowen ratio) and may influence the boundary-layer conditions (such as temperature and humidity) and the development of convective clouds. The convective rainfall can be influenced by the boundary layer because precipitation particles falling from the clouds can evaporate within this layer as long as the layer is not saturate.

To demonstrate the sensitivity of convective precipitation for the land-surface conditions, simultaneous observations on the land surface, precipitation clouds, and rainfall, were conducted over the Tibetan Plateau during the summer season of 1998, as a part of the GAME-Tibet project (GAME: GEWEX Asian Monsoon Experiment; GEWEX is the Global Energy and Water Cycle Experiment). Using the observational data, this paper describes the characteristics of monsoon rainfall and focuses on their significant transition that occurred three weeks after the onset of deep convective activity. The important point is that this transition occurred when the increase in soil moisture content and activation of vegetation (short grasses) were observed within the radar observational area.

2. OBSERVATION

A Doppler radar was placed in the grassland over the central plateau (91.9°E, 31.4°N, 4590 m above sea level: ASL). A radiosonde station, four surface meteorological stations, and a raingauge network were installed within the radar observational area. An intensive observation was made from 27 May to 19 September 1998.

3. CHANGES IN THE SURFACE CONDITIONS

To show the evidence that a remarkable change in the land-surface conditions was delayed from the time of the monsoon onset, time series of the echo-top height and the surface conditions is shown in Fig. 1. A dramatic rise of the echo-top from 12 to 16 km ASL in mid-June indicates the frequent development of deep convective clouds after the onset of the summer monsoon. In the onset phase, although the increases of air temperature and humidity near the surface (Fig. 1b-c) is clear; however, the soil moisture content (Fig. 1d) kept decreasing until it increased significantly in early July. This evidence indicates that the plateau surface was not moistened in the first three weeks of the monsoon period whereas deep convective clouds frequently develop over it. After the moistening of the land, near-surface air became moist (Fig. 1c). Activation of grass in the moistening stage was observed by a video camera (not shown).

---

* *Corresponding author address:* Hiroyuki Yamada, Japan Agency for Marine-Earth Science and Technology, Yokosuka, Kanagawa 237-0061, Japan; e-mail: yamada@jamstec.go.jp.

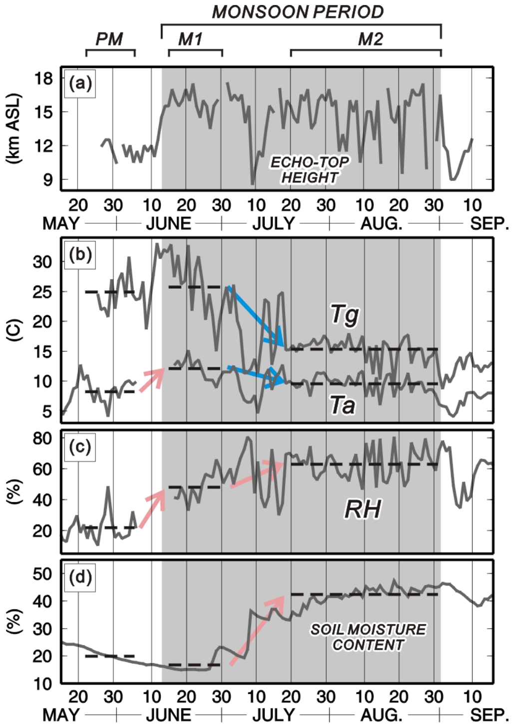

Fig. 1 *(a) Time series of the daily maximum of the 10-dBZ echo-top height in the analysis area between 15 May and 15 September, 1998. (b-d) Time series of the ground surface (Tg), surface air temperature (Ta), air relative humidity (RH), and soil moisture content at 0.04 m below the surface, observed at Amdo station. Dashed lines show the mean value within three sub-periods (i.e., PM, M1, and M2), and arrows show the trend in between two of the sub-periods.*

4. CHANGES IN THE RAINFALL AMOUNT

Ueno et al. (2001) shows a remarkable increase in the monthly rainfall from June (51 mm) to July (134 mm). Since the monsoon rainfall over the plateau relates not only to thermal instability but also to large-scale frontal disturbances, the present study separated all of rainfalls into three categories according to the synoptic-scale conditions. Figure 2 shows the rainfall characteristics of the three types. One of them, termed as "UH-type," characterized by no frontal disturbance but the presence of a surface heat low and a Tibetan upper high, shows a significant increase in the daily rainfall amount from June to August, while there was no such marked increase in the other two types (i.e., TR and NL types). The clear increase in the UH-type rainfall implies that processes other than solar heating are responsible for the trend because UH-type rains are related to the convective rainfall during the development of a surface heat low.

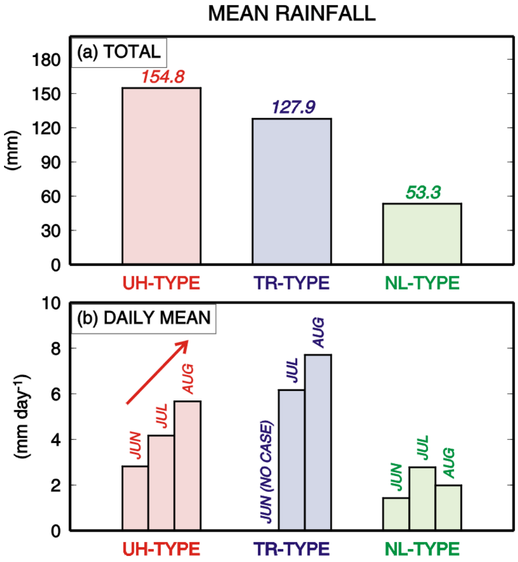

Fig. 2 *(a) Total amount of mean rainfall in the analysis area, accumulated for the UH-, TR-, and NL-type rain events during the monsoon period. (b) Daily-mean rainfall for each type in the summer months.*

5. CHARACTERISTICS OF UH-TYPE RAIN

To clarify the cause of the increase in the UH-type rainfall, the relationship between rainfall and radar echoes was investigated. Figure 3 shows the histograms of hourly rainfall in June and July. These histograms include all of the cases (hours) in which convective echoes were observed over the rain gauges. "No-rain case" means the hour that observed rainfall was 0 mm whereas convective echoes passed over the rain gauge. It is noteworthy that the frequency of no-rain events decreased from June to July, while that of light-rain events (i.e., 0-2 mm) increased. These results show that, in June, there were a considerable number of cases in which precipitation particles from convective clouds did not reach the ground.

The analysis using upper-air sounding data (not shown) demonstrated that the sub-cloud layer in June were deeper and drier than that in July, and suitable for the evaporation of precipitation particles. The

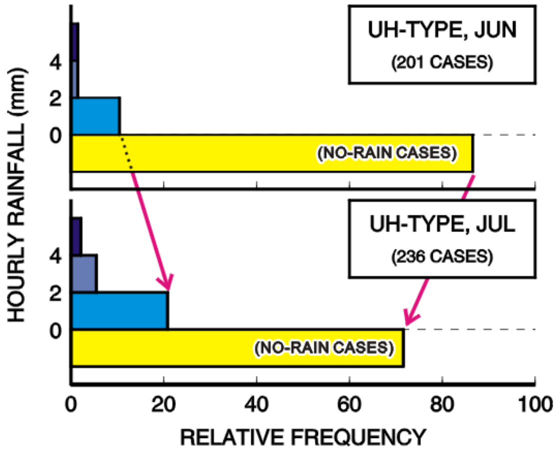

Fig. 3 *Histograms of hourly amounts of convection-related rainfall during UH-type rainy days in June and July. The number of cases means the total hours that convective-related rainfall were detected in each month at the seven surface stations within the radar observational area.*

sub-cloud layer conditions favorable for the evaporation were also demonstrated by examining the frequency of temperature drop larger than 5 Kelvin in an hour related to the passage of convective clouds (not shown). The frequency was higher in June than July, suggesting the dry environment in June.

6. SUMMARY

According to the results, a conceptual model on the transition of rainfall characteristics in early July can be illustrated as Fig. 4. Both the moistening of the ground and the activation of grass cause the decrease in sensible heat and increase in latent heat, which affect to the depth and wetness of the sub-cloud layer. The sub-cloud layer becoming shallow and wet provides the unfavorable condition for the evaporation of precipitation particles, and yields the transition of rainfall characteristics. These results, therefore, indicate the plateau surface has a significant impact upon the modification of the rainfall characteristics during the summer monsoon season.

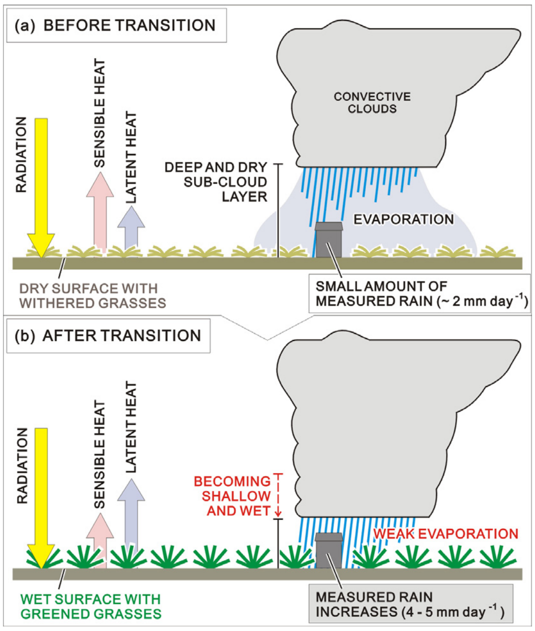

Fig. 4 *Schematic illustration showing the transition of the UH-type rainfall characteristics due to the moistening of the plateau surface.*

REFERENCES

Kuo, H. L., and Y. F. Qian, 1981: Influence of the Tibetan Plateau on cumulative and diurnal changes of weather and climate in summer. *Mon. Wea. Rev.*, **109**, 2337-2356.

Luo, H., and M. Yanai, 1984: The large-scale circulation and heat sources over the Tibetan Plateau and surrounding areas during the early summer of 1979. Part II: Heat and moisture budgets. *Mon. Wea. Rev.*, **112**, 966-989.

Ueda, H., and T. Yasunari, 1998: Role of warming over the Tibetan Plateau in early onset of the summer monsoon over the Bay of Bengal and the South China Sea. *J. Meteor. Soc. Japan*, **76**, 1-12.

Ueno, K., H. Fujii, H. Yamada, and L. Liu, 2001: Weak and frequent monsoon precipitation over the Tibetan Plateau. J. Meteor. Soc. Japan, 79, 419-434.

Yanai, M., C. Li, and Z. Song, 1992: Seasonal heating of the Tibetan Plateau and its effects on the evolution of the Asian Summer monsoon. *J. Meteor. Soc. Japan*, **70**, 319-351.