STUDY ON THE PRECIPITATION CHARACTERISTICS AROUND THE HIMALAYAS USING TRMM PR DATA

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Abstract

The presented study deals with the climatological features of the diurnal cycle of precipitation around the Himalayas by utilizing fine resolution data by Precipitation Radar (PR). Threshold based precipitation characteristics exhibit the dominance of light rainfall around the Himalayas. The enhanced midnight-early morning precipitation and its broadening and movement are noticed over the south-facing slopes of the Himalayas during the summer monsoon season. The GEWEX Asian Monsoon Experiment (GAME) Reanalysis data are utilized to understand atmospheric system.

Keywords: diurnal cycle, Himalayas, TRMM PR, GAME Reanalysis

1. Introduction

The study of precipitation variability around the Himalayas is of primary importance, particularly because of its impact on social and economic activities, such as agricultural production, land use, flood prediction and water resources management. To the authors' knowledge, precipitation regime has not been well studied around the Himalayas, where annual precipitation is as much as 300-400 cm over the south-facing slopes of the Nepal Himalayas (Shrestha 2000; Barros et al. 2000) and there appears strong variability over the diurnal cycle with nocturnal peak in rainfall during the summer monsoon season (Barros and Lang 2003). One of the studies with cloud field showed strong diurnal variation during pre-monsoon season (May, 1998) over the south-facing slopes of the eastern Himalayas (Kurosaki and Kimura 2002). However, the fine details of these variations in the widespread range of the Himalayas are not understood. There is not yet a concensus on what process (es) control the diurnal cycle of precipitation around the Himalayas.

The Tropical Rainfall Measuring Mission (TRMM) satellite is invaluable as a direct precipitation measure from space, but samples a particular location infrequently. The use of Precipitation Radar (PR) onboard the TRMM satellite provides nearly homogenous dataset with horizontal resolution of 4.3 km covering the entire region. High resolution enables us to investigate spatial and temporal variability of precipitation.

In this paper, we use PR2A25 v5.0 'Near-surface rainfall rate' dataset. Near-surface rainfall was accumulated and binned to hourly local times with 0.05 deg. grid. For all the grids, total rain amount and rain conditioned rain rate were calculated for each season for the 5-yr period 1998-2002. In addition, we took reference of histogram produced for the PR near-surface stratiform and convective mean daily rainfall amount around the Himalayan region during the summer monsoon season (F. Furuzawa, Nagoya University) which shows peculiar characteristics (e.g., stratiform and convective show almost similar distribution around 120-130 mm day^{-1}, beyond that convective shows wider distribution). We choose threshold of $<=5$ mm h^{-1}(120 mm day^{-1}) as light rain and >5 mm h^{-1} as moderate to heavy rain. We make use of accumulation over 3 h or 6 h of local time considering the sampling constraint with PR observations. We will also utilize the GEWEX Asian Monsoon Experiment (GAME) reanalyzed fields (ftp://hydro.iis.u-tokyo.ac.jp/GAME/). Areas of emphasis include: near-surface monsoon precipitation diurnal cycle, its spatial variability, and atmospheric system.

2. Results and Discussion

2.1 Diurnal variation

To begin, we will examine spatial and temporal variability of rainfall occurrence by area averaging over the south-facing slopes of the Himalayas (readers are referred to Bhatt and Nakamura (2004) for area description) over 5 years (1998-2002) during 3-hours intervals for four meteorological seasons (shown in Fig. 1). There appears pronounced diurnal cycle with afternoon maximum during March-Apr-May (MAM). Noted features include: midnight-early morning peak during June-July-August (JJA), and daytime peaks during September-October-November (SON) and December-January-February (DJF). These results reveal spatial and seasonal variability, with daytime northward progression of precipitation. More interestingly, midnight-early morning peak appears during JJA only. The horizontal distributions of mean conditional rain rate also exhibit similar behavior (shown only for 12-18 LT in Fig. 2). The ridge-valley gradients show that pre-monsoon rainfall appears intense over the ridges as compared to the summer monsoon season.

We next present the horizontal distributions of near-surface rainfall during the summer monsoon season. An example of the JJA light mean conditional rain rate over 5 years (1998-2002) during 3-hours intervals is shown in Fig. 3. The large scale precipitation features associated with layout of the mountain peaks over the south-facing slopes of the Himalayas do not appear clearly between 6-12 LT. The broadening of the rainband can be seen especially in after-midnight hours in this region. Between 0-3 LT, narrower rainband appears along the south slopes (at high elevations) of the Himalayas. More interestingly, it broadens along slope region and moves with time to W/SW direction. It can be seen clearly in the western Himalayas. Turning to daytime (12-15 LT), a narrower rainband appears nearly at the same place. It appears widespread between 15-18 LT in the entire slope region of the Himalayas. Between 18-21 LT, the rainband become most narrowest and localize near to the High Himalayas. The principal features are similar to those found in previous studies (Barros and Lang 2003; Ueno et al. 2001). However, midnight-early morning southward shift in precipitation is one of the new findings. Relative to light rain, moderate to heavy rain has few samples. We produced horizontal distributions with 6-hour accumulations (not shown). The spatial preference is almost similar of light rain rate. The total rain distribution also exhibit similar behavior (not shown). The foothill region of the Himalayas shows maximum rain activity and intense rainfall between 6-12 LT. Compared to light rain, horizontal distributions of moderate to heavy rain rate exhibits a stronger diurnal variation over south-facing slopes of the Himalayas. Overall, daytime northward and midnight-early morning southward shift in precipitation appear. Such a substantial seasonal variability and dominant midnight-early morning tendency warrant further analysis on atmospheric system.

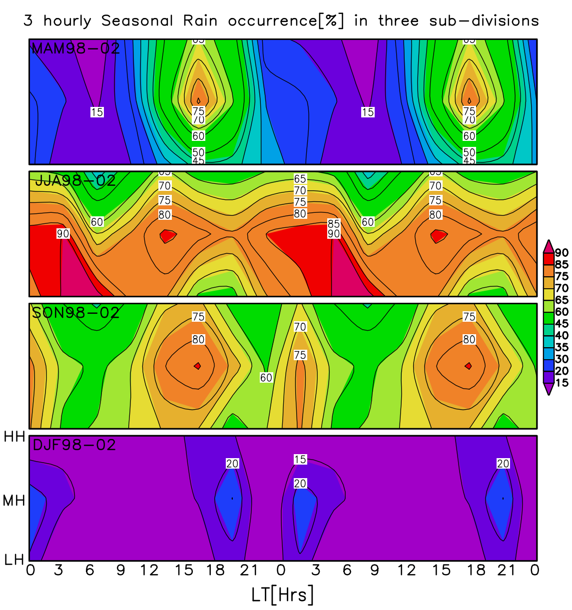

Fig. 1: Seasonal variation of rainfall occurrence in three climatic divisions over the south-facing slopes of the Himalayas for eight time periods of a day. For clarity, the diurnal cycle is repeated.

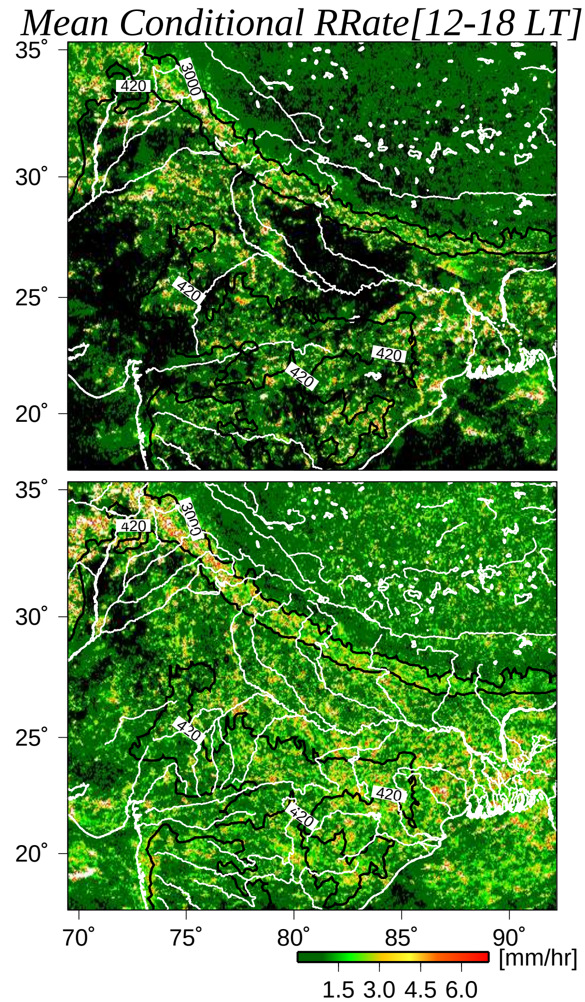

Fig. 2: Horizontal distributions of near-surface mean conditional rain rate for pre-monsoon period (upper panel) and summer monsoon period (lower panel).

2.2 Circulation and Thermodynamic Diagnostics

The GAME has provided reanalyzed fields covering the atmospheric system during the intensive observation period, Mar.-Oct. 1998. We used climatological variables (e.g. wind, moisture, temperature) which are available at 6 hour interval with 0.5 deg. x 0.5 deg. grid for 17 atmospheric levels. A good representation of mesoscale cannot be expected using these dataset due to the complex terrains in this region. Necessarily, data period is not long enough to obtain climatological mean values.

Wind is one of the important factors in the diurnal cycle as it governs the transport and distribution of moisture. The climatological mean wind in the lower atmosphere exhibit S/SE flow during JJAS with strong cyclonic tendency during midnight-early morning and W/SW flow during Apr-May (see Fig. 4) around the south slopes of the Himalayas. Also shown are the diurnal cycle of thermodynamic variables. Moisture information can be used to access precipitation potential. The diurnal cycle of mean relative humidity and air temperature show enhanced moisture and nighttime cooling in the atmosphere during midnight-early morning in the vicinity of the south-facing slopes of the Himalayas (see 700 hPa distribution for JJAS). From a thermodynamic perspective, midnight-early morning precipitation is no more a surprise. The daytime enhanced moisture in the vicinity of the Himalayas during Apr-May also resembles well with precipitation characteristics in this region. The Reanalysis shows relatively stronger diurnal variation of temperature during JJAS as compared to Apr-May in the lower atmosphere. We also examined the vertical structure of the monsoon circulation by creating height-latitude sections of moisture flux divergence (not shown). Midnight-early morning moisture convergence in the lower atmosphere is noticed in the vicinity of the Himalayas. There is a clear diurnal cycle of moisture in the northern Indian continent, foothill region and near to the Himalayas. Also, there appears stronger meridional wind. All these tendencies are conducive to convection and precipitation. The Reanalysis reveals a diurnal cycle that is coherent with precipitation diurnal cycle around the Himalayas. But the atmosphere revealed by GAME reanalysis should be considered robust. So far, the question as to which mechanism dominates the physics behind midnight-early morning southward shift remains an open one. We are now investigating underlying mechanism.

3 Concluding Remarks

The climatological features of the diurnal cycle are investigated using fine resolution PR data around the Himalayas. The results reveal spatial and seasonal variability. The south-facing slopes of the Himalayas are noticed somewhat unique with midnight-early morning precipitation during the summer monsoon season. Also midnight-early morning precipitation broadening and movement are noticed in this season. There appears strong diurnal variation of precipitation with afternoon maximum during the pre-monsoon season. Threshold based precipitation characteristics exhibits the dominance of light rainfall around the Himalayas during the summer monsoon season. The moderate to heavy rain exhibits relatively stronger diurnal cycle over south-facing slopes of the Himalayas. The climatological diagnostic studies from GAME Reanalysis suggest a robust atmospheric system and provides an impression that the dirunal variations in atmospheric state is important in driving the diurnal cycle of precipitation over the south-facing slopes of the Himalayas. However, interaction between mountain-forced gravity waves and thermodynamics of the Himalayan atmosphere may be important for midnight-early morning precipitation. For south-southwestward shift in precipitation, development and propogation of density current may be important. The work is underway to support these hypotheses.

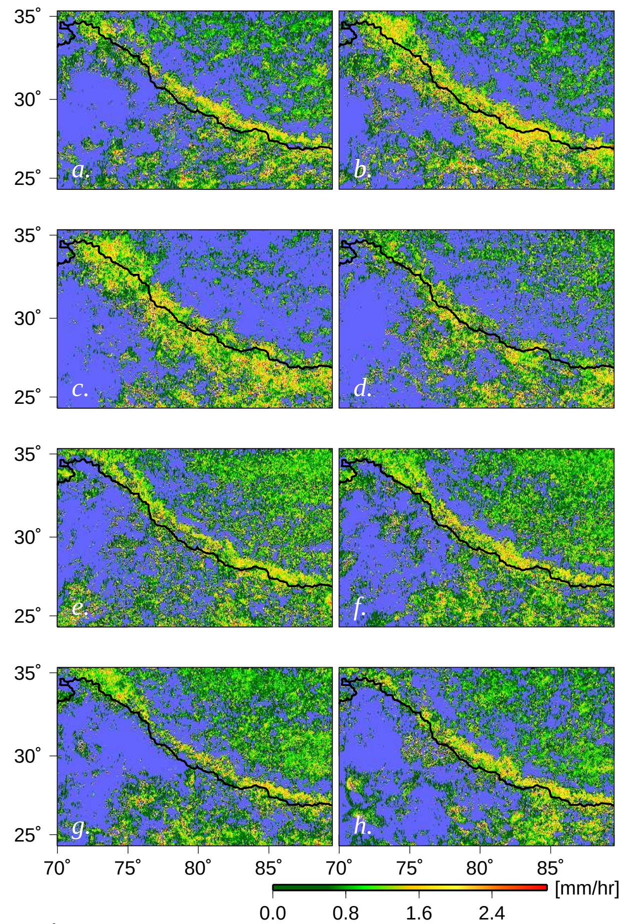

Fig. 3: Mean three hourly light conditional rain rate(mm/hr) distribution for JJA of 5-year period 1998-2002. Panels a) through h) refer to 0-3 LT, 3-6 LT, 6-9 LT, 9-12 LT, 12-15 LT, 15-18 LT, 18-21 LT, 21-24 LT, respectively.

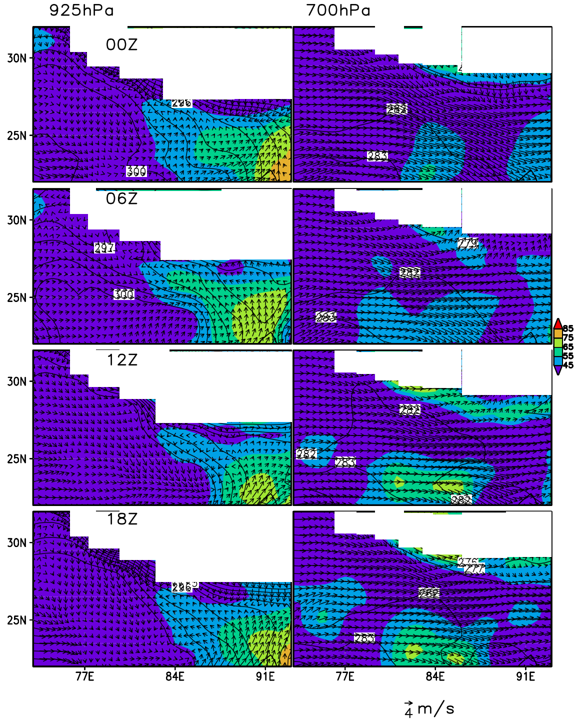

Fig. 4: The climatological mean wind diurnal cycle for lower atmosphere around the Himalayas. Also shown are mean relative humidity (shaded) and temperature (solid contour) from GAME Reanalysis during Apr-May, 1998.

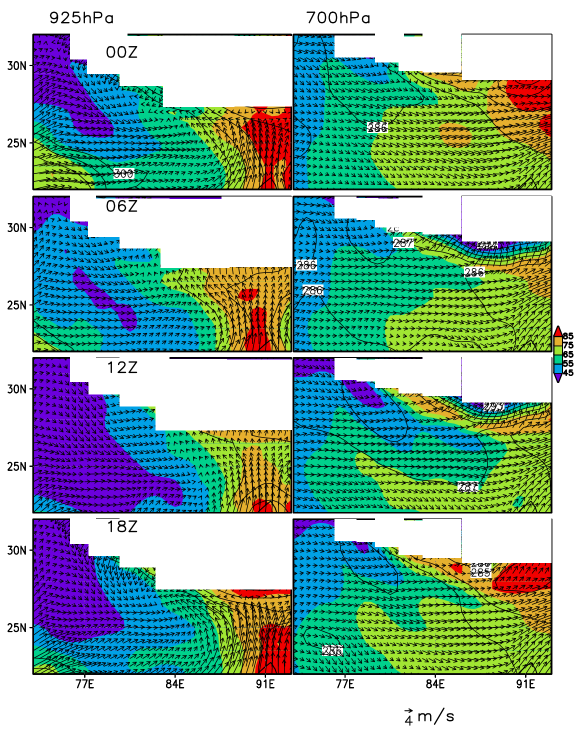

Fig. 5: As in Fig. 4 but for June-July-August-September, 1998.

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