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Diurnal variation of precipitation over Himalayan region

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Abstract

The diurnal cycle of precipitation is one of the strongest components of variability of precipitation. The study was focused on diurnal variation of precipitation normal to the Himalayan range using the Tropical Rain Measuring Mission (TRMM) Precipitation Radar (PR), instantaneous data over the period 1998- 2002. Gtopo30 (Digital elevation map (DEM) with spatial resolution 30 was used for study topographic height. During June, July and August late night /morning rainfall is dominated over the slope and foothill of mountains, while afternoon/ evening rainfall dominated over Tibetan Plateau and Deccan Plateau. Foothill of the mountain and Deccan Plateau is characterized by convective rainfall where as Tibetan plateau and slope of the mountain is characterized by stratiform rainfall. It is also noticed that rainfall shifts southward during morning period.

Introduction

Generally, in tropical regions, the diurnal variation of rain is significant. The maritime continent, the afternoon rain dominates over land and morning rain dominates over ocean near the coast (e.g Dai 2001).So far, almost all studies on the diurnal variation of precipitation in and around Himalayan regions are using visible/infrared cloud data. Exceptions are campaign experiments, such as, the GEWEX Asian Monsoon Experiment-Tibet (GAME-Tibet) (e.g. Shimizu et al. 2001, Uyeda et al. 2001) or the Monsoon Himalayan Precipitation Experiment (MOHPREX) (Barros & Lang 2002). Data to study the variability of precipitation and the dynamics of precipitation processes in the middle and high Himalayas are still very scarce. There is no operational weather radar or radiosonde networks and the existing rain gauges are not enough for the study. This fact obstructs the detailed study on the precipitation activity in this region.

The Tropical Rainfall Measuring Mission (TRMM) satellite equipped with the first space borne Precipitation Radar (PR) was launched in 1997. In addition, TRMM is in a non-sun synchronous orbit, which gives us a unique opportunity to observe the diurnal variation of rain directly in a large scale. One of the disadvantages of the radar is its narrow swath (about 220 km).

There exist a lot of literatures on the diurnal variation of precipitation. However, only few reports exist on the diurnal variation of rain over Himalayan regions because of the lack of good data sets.

Data and Methodology

TRMM revolves into a circular orbit of altitude 350 km, inclination angle 35 and revolution period of 90 minutes. The orbit altitude was changed to 402.5 km in August 2001 because of a satellite reentry problem. Its non-sun synchronous orbit ranges between 35 degrees north and 35 degrees south of the equator, allowing TRMM to fly over each position on the Earth's surface at a different local time each day.

PR (Precipitation Radar) is the primary instrument onboard TRMM operating 13.8 GHz. PR antenna scans in the cross-track direction over ±17 degrees (215-km swath at the surface). It consists of 49 scanning angle bins with an interval of 0.71 degrees. The spatial horizontal resolution is about 4.3 km at nadir. The vertical profiles are given with 80 bins every 250 m.

TRMM standard products are provided by NASA and NASDA, consist of Level 1 data, Level 2 data and Level 3 data. The Level 1 is the data sets attached ancillary data and geo-referencing data to measured raw data (Level 0), and is processed to be sensor-dependent physical units. Level 2 data consists of meteorological parameters (e.g. rainfall rate) derived from the Level 1 data using various algorithms and it is produced as 2- or 3- dimensional rain map along the TRMM PR swath. (Iguchi et al. 1998, Kummerow et al. 1998).

The PR2A25 convective stratiform algorithm determines whether the echo is convective or stratiform based on the vertical profile of reflectivity (from which the bright band, echo top height, and maximum reflectivity in the vertical profile are identified) and the horizontal variability of the echo. The PR convictive-statiform algorithm also assigns echo to a category called "other" when the echo does not fall to either convective or stratiform. Because of the small fraction of the other category and its very small contribution to total rain (< 0.2% when using the 17 dBZ threshold), only convective and stratiform rain types were taken into consideration (Nitta et al. 1994)

For the study of general characteristics and diurnal variation of precipitation TRMM/ PR data called 2A25 version 5 instantaneous data for 1998- 2002 were used. In order to obtain climatological characteristics, gridded data of 0.1 degrees (longitude) by 0.1 degrees (latitude) were generated for 24 local hour slots. The Global 30 Arc Second Elevation DATA Set (GTOPO30) produced by the Earth Resources Observation Systems (EROS) Data Center of the U.S. Geological Survey was used to obtain the topographical map. The resolution is 1 km in horizontal and 1 m in vertical. For this study data were averaged over 0.1° x 0.1° grids.

The study was concentrated mainly over Himalayan region which characterized by a complex geologic structure, snowcapped peaks, large valley glaciers, deep river gorges, high plateaus etc. As orography directly influence the precipitation (Murakami 1987) the study is done for rainfall normal to the Himalayan Range within 82° to 86° East (Fig. 1) for data period 1998-2002.

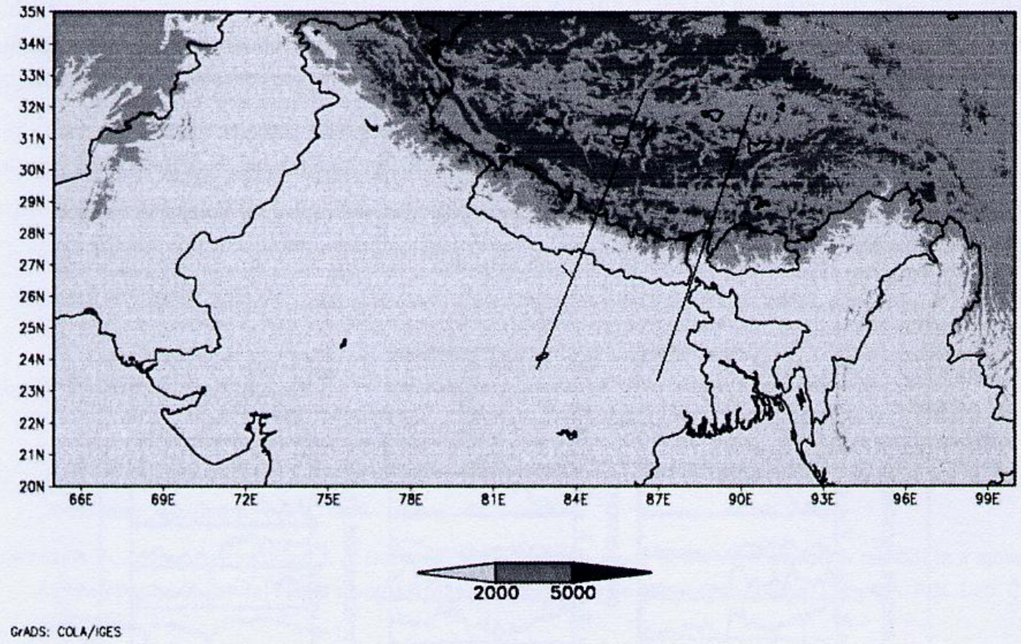

Fig. 1: Investigated region (altitude intervals in m a.s.l.)

Results

As June, July and August receives highest amount of rainfall over the Himalayan region (Singh 2003) a detail study is done for the season to reduce sampling error For the study of diurnal variation of rain the day was divided into 8 periods of 3 hour duration as: late night (0-2 LT), early morning (3-5 LT), morning (6-8 LT), late morning (9-11 LT), early afternoon (12-14 LT), late afternoon (15-17 LT), evening (18- 20 LT), and night (21-23 LT).

Fig. 2a shows the three-hourly distribution of rainfall(mm/month) from Local time (0-2) to local time (21- 23) respectively from second column to bottom. Fig. 2b and 2c express similar but for rain and convective rain fraction percentages. The first column of each figure expresses topographic height (m). Fig. 2a depicts that during morning period rainfall is concentrated over slope and foothill of mountain. It seems that during early morning period local time (3- 5) and late morning period (6-8), rain region (rainfall amount) shifted to southward. Then during early afternoon period rainfall dissipates all over the region. Again rainfall appears over Deccan plateau, Tibetan plateau and slope of the mountain during late afternoon and evening period. The figure shows that slope of the mountain receives rainfall almost all the time period. Fig. 2b shows that rain fraction is found high over slope and foothill of mountain during late night, early morning and morning period. Rain fraction also shifts to southward during early morning period and late morning period. Rain fraction is found high over Deccan and Tibetan plateau during early afternoon, afternoon and evening period. According to Fig. 2c convective rain fraction is more than 50% over foothill of mountain and Deccan plateau during all the time. Convective rain fraction is found more than 50% over Tibetan plateau during late afternoon period. But over slope of the mountain convective rain fraction is found less than 50% almost all the time period.

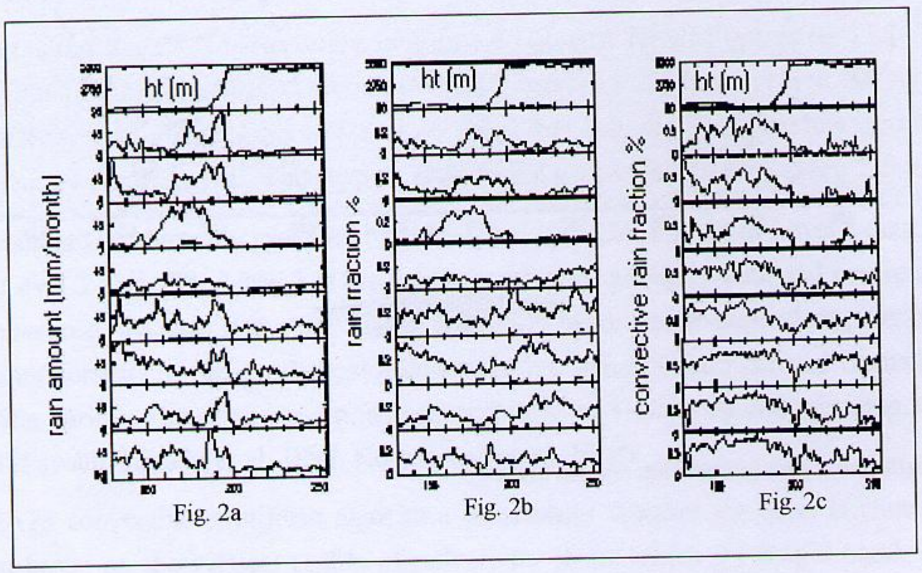

Fig. 2: a: 3-hourly distribution of rainfall (mm/month) from local time (0-2) to (21-23) from second column from the top. First column is for topography height (m); b: same as a but for rain fraction (%), c: same as a but for convective rain fraction

Discussion and conclusion

Though PR has poor sampling some interesting features are revealed: India sub-continent, Himalayan mountain range and the Tibetan Plateau have peculiar diurnal variations of cloud activity. Over the Tibetan Plateau and most of the Deccan Plateau there is strong afternoon and evening cloud activity. On the other hand, the southern foot of the Himalayan mountain range shows morning cloud activity. The morning cloud activity region seems to be extended to mountainous terrains in Indochina peninsula (Ohsawa et al. 2001). This is in agreement with own results according to which the Tibetan and Deccan plateaux are dominated by afternoon and evening rainfall whereas in the Himalayan foothills morning rainfall prevails. Ueno et al. (2001) suggest that the differential heating between the plateau and the surrounding region at the same level also produces mountain and valley-breeze type circulation on a large scale, with denser air diverging from the plateau and descending night and warm air ascending over the plateau and along the slopes during the day (Ueno et al. 2001).

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