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Use of TRMM in determining the climatic characteristics of rainfall over Bangladesh

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Abstract

Five years of data from 1998 to 2002 of TRMM-3B42 version 5 (V5), 3B43 V5, 3B42 version 6 (V6), 3B43 V6, and the Bangladesh Meteorological Department rain-gauge network were analyzed to understand the climatic characteristics of rainfall over Bangladesh. TRMM-PR 2A25 data were used to obtain the precipitation field of the convection events. Daily rainfall measured by TRMM V5 3B42 was compared to that of rain-gauge values from pre-monsoon to post-monsoon months (March–November). The time sequence patterns of the daily rainfall determined by the V5 3B42 and those from rain gauges were remarkably similar. The spatial and temporal averages of rainfall revealed good estimations of rainfall: during March to November, the V5 3B42- and rain gauge-estimated daily rainfall was 8.12 and 8.34 mm, respectively. In annual scale, TRMM V5 3B42-, V5 3B43-, V6 3B42-, V6 3B43- and rain-gauge estimated rainfall was 6.9, 6.4, 6.6, 6.8 and 7.1 mm/day, respectively. The average percentage of rainy days determined by V5 3B42 data with respect to the rain-gauge value was 96%. TRMM is useful for estimating the average values of rainfall in Bangladesh. The prominent difference between rainfall estimated by rain-gauge and V5 3B42 was found to be period- and location-dependent. The V5 3B42 overestimated the rainfall during the pre-monsoon period and in dry regions but underestimated it during the monsoon period and in wet regions. The reason for the differences according to season and locations is considered to be the vertical cross section of convection obtained by TRMM-PR 2A25 data. The rainfall overestimation in pre-monsoon and underestimation in monsoon period measured by V5 3B42 is reduced to reasonable amount by V6 3B42 and V6 3B43. In this manner, the merit of using TRMM data for climatological studies of rainfall over Bangladesh is shown.

Keywords: Precipitation; Monsoon; Tropical Rainfall Measuring Mission; Rain gauge

1. Introduction

The Tropical Rainfall Measuring Mission (TRMM), cosponsored by the National Aeronautics and Space Administration (NASA) of the U.S.A. and the Japan Aerospace Exploration Agency (JAXA, previously known as the National Space Development Agency, or NASDA), has collected data since November 1997 (Kummerow et al., 2000). Tropical rainfall, which falls between 35°N and 35°S, comprises more than two-thirds of global rainfall. TRMM is a long-term research program designed to study the Earth's land, oceans, air, ice, and life as a total system. Previous estimates of tropical precipitation were usually made on the basis of climate prediction models and the occasional inclusion of very sparse surface rain gauges (RNGs) and/or relatively few measurements from satellite sensors. The TRMM satellite allows these measurements to be made in a focused manner. TRMM is NASA's first mission dedicated to observing and understanding tropical rainfall and how it affects the global climate (Simpson et al., 1988; Wolff et al., 2005). The TRMM spacecraft fills an enormous void in the ability to estimate worldwide precipitation because ground-based radars that measure precipitation cover a very small part of the planet. Ground-based radars cover only small percent of the area covered by TRMM, said Kummerow (http://www.xs4all.nl/~carlkop/tropmis.html) and RNGs are limited to specific geographic points. The TRMM Ground Validation (GV)

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Program began in the late 1980s and has yielded a wealth of data and resources for validating TRMM satellite estimates by providing rainfall products for four sites: Darwin, Australia (DARW); Houston, Texas (HSTN); Kwajalein, Republic of the Marshall Islands (KWAJ); and Melbourne, Florida (MELB). Wolff et al. (2005) provide extensive details on the TRMM GV program, site descriptions, algorithms, and data processing. For years, other groups studied various locations to validate TRMM data, such as Ikai and Nakamura (2003), who calculated rain rates over the Ocean, Nicholson et al. (2003), who validated TRMM rainfall for West Africa, and Barros et al. (2000), who studied a monsoon case in Nepal. TRMM mission is officially extended up to 2009 and in the mean time focus has begun on planning for the Global Precipitation Measurement (GPM) GV program. The GPM satellite will commence operations in 2010. The main goal of the TRMM GV program is to provide rain estimates at various sites throughout the globe in order to compare with and hopefully help to improve GPM satellite retrievals. Unfortunately, so far, there has been no research done to validate TRMM data over Bangladesh. This paper describes how accurately the TRMM satellite can determine surface rainfall in Bangladesh. In Bangladesh, RNG data are the only representation of precipitation throughout the country. Inadequate RNG networks throughout the country sometimes provide incomplete information on the distribution of rainfall. The use of remote sensing data in estimating rainfall in Bangladesh, thus, offers an exciting opportunity. Neither RNGs nor satellite-based estimates are perfect indicators of rainfall (Nicholson et al., 2003). Morrissey and Greene (1993) and Xie and Arkin (1995, 1996) show in their examinations that all satellite estimates have non-negligible biases when compared with concurrent *in situ* observations. With RNGs, biases are introduced by gauge type, maintenance, and placement (Legates & Willmott, 1990; Sevruk, 1982) as well as by spatial sampling (Huffman et al., 1995, 1997; Morrissey et al., 1995; Rudolf et al., 1994). Xie and Arkin (1995) concluded that these are small when compared with the bias in satellite estimates. Even when these biases are included in the measurements, RNG rainfall is used as a ground-based rainfall measurement.

In and around Bangladesh, the rainy season is divided into three periods: (a) pre-monsoon (March–May), (b) monsoon (June–September), and (c) post-monsoon (October–November). In Bangladesh, about 20%, 62.5%, 15.5%, and 2% of the annual rainfall (~2700 mm) occurs during pre-monsoon, monsoon, post-monsoon, and winter periods, respectively (Islam & Uyeda, 2005). Research conducted on the estimation of rainfall in Bangladesh using remote sensing data remains inadequate. Recently, Ohsawa et al. (2001) studied the relationship of infrared brightness temperature (TBB) of cloud top heights from GMS (Geostationary Meteorological Satellite) data to RNG rainfall in Bangladesh. As mentioned above, very little validation work has been conducted on the rainfall estimated by TRMM over Bangladesh, and the GPM GV is an on-going project. A number of researchers are working on the development of instrumentation and algorithms for GPM. Information about the distribution of rainfall and the structure of precipitation systems from a heavy-rainfall region, such as Bangladesh, is important for these developers. In this work, attempts have been made to compare the rainfall determined by TRMM 3B42 products, which is the combination of TRMM Precipitation Radar (PR) and TRMM Microwave Imager (TMI), with the values of ground-based RNGs throughout Bangladesh. Pre-monsoon, monsoon, and post-monsoon rain rates have distinctive features in Bangladesh as well as in parts of Asia that experience monsoons. These are also obtained from TRMM 3B42, TRMM-PR 2A25, and RNG data. Radar PPI scans data from the Bangladesh Meteorological Department (BMD) are used to support the TRMM-PR horizontal images.

2. Data and methods

Rainfall data for 3-h periods from 1998 to 2002, measured and collected by the Bangladesh Meteorological Department (BMD), were used to prepare the RNG rainfall data. In this purpose, the metadata chart of BMD was utilized to avoid the random error such as mistake in data transfer through radio link. Even though, RNG data were missing at WMO station #41960 (90.36E, 22.33N) in 1998 and WMO station #41963 (91.07E, 22.30N) in 2000. Area of Bangladesh (88.05°–92.74°E and 20.67°–26.63°N) is 147570 km^2, where BMD placed 31 rain gauges throughout the country. TRMM produced a daily 1° × 1° microwave-calibrated IR rain estimate (TRMM Science Data and Information System (TSDIS) 3B42). The daily data from TRMM V5 3B42 products estimated gridded rainfall of 1° × 1° resolution for the same analysis period. The V5 3B43 product is produced by merging the monthly accumulation of daily V5 3B42 with the monthly accumulated Climate Assessment and Monitoring System (CAMS) or Global Precipitation Climatology Centre (GPCC) rain-gauge analysis (3A45) (Huffman et al., 1995). The V6 3B42 is a 3 hourly 0.25° product based on multi-satellite precipitation analysis (Huffman et al., 2004). The multi-satellite and gauge analysis are merged (Huffman et al., 1997) to create a post-real-time satellite–gauge monthly product, which is the TRMM product V6 3B43. The RNG values were not uniformly gridded because the RNGs of BMD are not positioned at uniform grid distances. Therefore, the comparison between rainfall estimated by TRMM V5 3B42 and that measured by RNG was performed on a point-to-point basis, i.e., one RNG must be in a TRMM data grid box. The analysis period of 1998–2002 was chosen because it was the only one with a full complement of data for the TRMM and the collected RNGs rainfall in Bangladesh. In the analysis, the entire rainy period of March–November has been accounted for, which is nearly the complete rain period of Bangladesh, with 98% of the total annual precipitation. Except for 2A25 and 3B43, 3B42 products are available for each day of the 5-year analysis period. Five types of analyses were carried out. First, the mean rainfall field for March to November (MAMJJASON) was prepared for the V5 3B42 dataset. Second, day-to-day comparisons of rainfall for five well-separated and selected stations throughout Bangladesh were conducted. The 0-mm rainfall within 3-h periods has been accounted to calculate the daily rainfall amount. Third, point-to-point comparisons of rain climates were obtained from the TRMM V5 3B42 and RNG datasets for the