MEASUREMENTS OF WATER VAPOR AND RAINFALL OVER INDIAN OCEAN AND SUB-CONTINENT WITH A TERRA-MODIS AND TRMM

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ABSTRACT

The south-west monsoon seasonal variations of the water vapor and rainfall over the Indian subcontinent and oceans are studied using microwave (MW) and near-Infrared (NIR) satellite measurements on monthly scales. The total precipitable water (TPW) derived from multi channel imaging data acquired with the Moderate Resolution Imaging Spectrometer (MODIS) on the Terra Spacecraft and rainfall data from merged infrared estimates calibrated against Tropical Rainfall Measuring Mission (TRMM) microwave data respectively are used. Since TPW is an important link connecting the various components of the hydrological cycle, its variability with rainfall on monthly scales have been used to meet this objective in the present study during the three successive contrasting good (normal), bad (drought) and good (normal) south-west monsoon years of 2001 to 2003 respectively.

1. INTRODUCTION

The motivation for the present study is to understand varying properties of moisture and rainfall over regions where conventional data are sparse. Ultimately, it is intended to take advantage of the relatively complete and consistent coverage, as well as continuity in sampling, associated with these two datasets obtained from most advanced satellite measurements. Separate TPW retrievals from MODIS measurements, along with rainfall retrievals from Tropical Rainfall Measuring Mission (TRMM) measurements, are used to characterize the monsoon strengths during successive good-bad and good monsoon years.

2. DATA USED

The data products of Terra-MODIS and TRMM have been used in the present study. MODIS was launched aboard the Terra and Aqua satellite on 1999 and 2002, respectively as part of NASA's Earth Observing System (EOS) mission. MODIS derived atmospheric and ocean products, includes numerous aspects of earth's atmosphere, land, oceans, and crysphere, with a concentration on water in the earth's system-[1-2]. Among the 36 channels, several NIR channels located within and around 0.94-um water vapor band are used for remote sensing of column water vapor amounts over clear land of the globe, and above clouds both over land and ocean[3].
The TRMM satellite, a joint project between the United States and Japan and the first spacecraft designed to monitor rain over the tropics, was launched on November 27, 1997. TRMM provides instantaneous rainfall data uniquely from various sensors. However, for more temporal and spatial coverage at finer scales, IR merged TRMM rainfall products[4] has been used that are produced operationally as 3B-42 products on 1^0 x 1^0 latitude-longitude grid on various temporal scales.

3. RESULTS AND DISCUSSIONS:

Precipitating systems of all kinds feed mostly on the moisture already in the atmosphere at the time the system develops, and precipitation occurs through convergence of available moisture on the scale of the system. Hence, the atmospheric moisture content directly affects rainfall rates. In order to examine the variations and the complete flow patterns of the moisture from Indian ocean, Arabian Sea and Bay of Bengal to Indian land masses and rainfall over India and adjoining areas, characterising good and bad monsoon are revealed for all the three years. However for brevity we show only a few results.
Fig 1(a-c) shows the water vapor distribution during July month of 2001-2003 years over the study area. In all the figures TPW exhibits notable geographical distribution that are consistent with the

patterns of a normal south-west monsoon circulation associated with the strength of reversal in the winds proceeding across the center of the Arabian Sea and onto the Indian Subcontinent. The flow across the Arabian sea within southwest monsoon takes the form of an intense low-level jet, known as the Findlater jet which typically bifurcates before it reaches the Indian coast into two branches which are denoted as the Somali and Split jet. The placement and time dependence of this split is important in setting the strength of the monsoon over India. Seasonal march of the water vapour leading to the establishment of the Indian summer monsoon is clearly depicted by its propagation from both the Arabian Sea and head Bay of Bengal to the Indian Land mass during the year 2001 and 2003 (Fig. 1a, c). However there is seen a severe break in moisture transport in July during 2002 (Fig. 1b) which shows very dry conditions almost all over India and adjoining oceanic regions well depicted by MODIS data

The Tropical Convergence Zone field got totally isolated from the bay of Bengal branch of Findlater jet from July showing lack of moisture support to the main landmasses. The drought signatures of year 2002 in monthly scale thus produces highly contrasting behavior in the TPW, shifting from a largely meridionally-oriented moisture transports (from Indian ocean, Arabian Sea and Bay of Bengal to Indian regions) to a largely zonally-oriented shift (in central east equatorial Indian Ocean) explain why the drought could be commenced in July 2002 compared to other two adjoining good monsoon years. MODIS-TPW is effective in capturing these important details embedded in its full-coverage.

Fig 2 (a-c) shows the simultaneous rainfall distribution during the same period. The rainfall is well spread all over India in July during the normal years which is consistent with the well build up moisture fields in land and surrounding ocean in this month shown in MODIS-TPW. The high rainfall along the normal depression tracks from Bay of Bengal to north and central India is well characterised in association with the entrained moisture fields during July. The rainfall patterns in Gujarat, Rajasthan and S-W Indian regions are also consistent with impact of moisture from Arabian Sea region.

There is seen a severe break in moisture transport in July during 2002 which shows very dry conditions almost all over India and adjoining oceanic regions well depicted by MODIS data (Fig 2b). The TCZ field got totally isolated from the bay of Bengal branch of Findlater jet from July showing lack of moisture support to the main landmasses. This clearly corroborates with the TRMM rainfall patterns in Fig. 2b in July when except north-eastern regions the deficit of rainfall in the whole India is well characterised.

Furthermore, the northward propagation patterns are known to be signatures of the monsoon performances[5] through the analysis of propagation of cloud bands. We have attempted to explain through the Hovmoller diagrams. The abscissa in Fig. 2 is latitude and the ordinate is in the monthly time scale. Both the parameters are able to characterise the performance of god-bad-good situations corresponding to the respective three monsoon years. The complete break situation in water vapor transport from Arabian Sea is clearly prominent than the Bay of Bengal branch during 2002 indicating the drought situation followed by deficit in rainfall[6]. The normal propagation during 2001 and 2003 are well indicative of respective normal monsoons. The simultaneous northward propagation pattern of rainfall does indicates the strengths of the respective monsoons clearly corroborating with the TPW. However present study opens new avenues to understand varying properties of moisture and rainfall over the region on optimum temporal scales for better assessment of the monsoon progress and its performance.

ACKNOWLEDGEMENTS

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Fig. 1 TPW and Rainfall from MODIS and TRMM from 2001 to 2003 for July month

MODIS-TPW July 2001-2003 (a-c) **TRMM-Rainfall (mm) July 2001-2003 (a-c)**

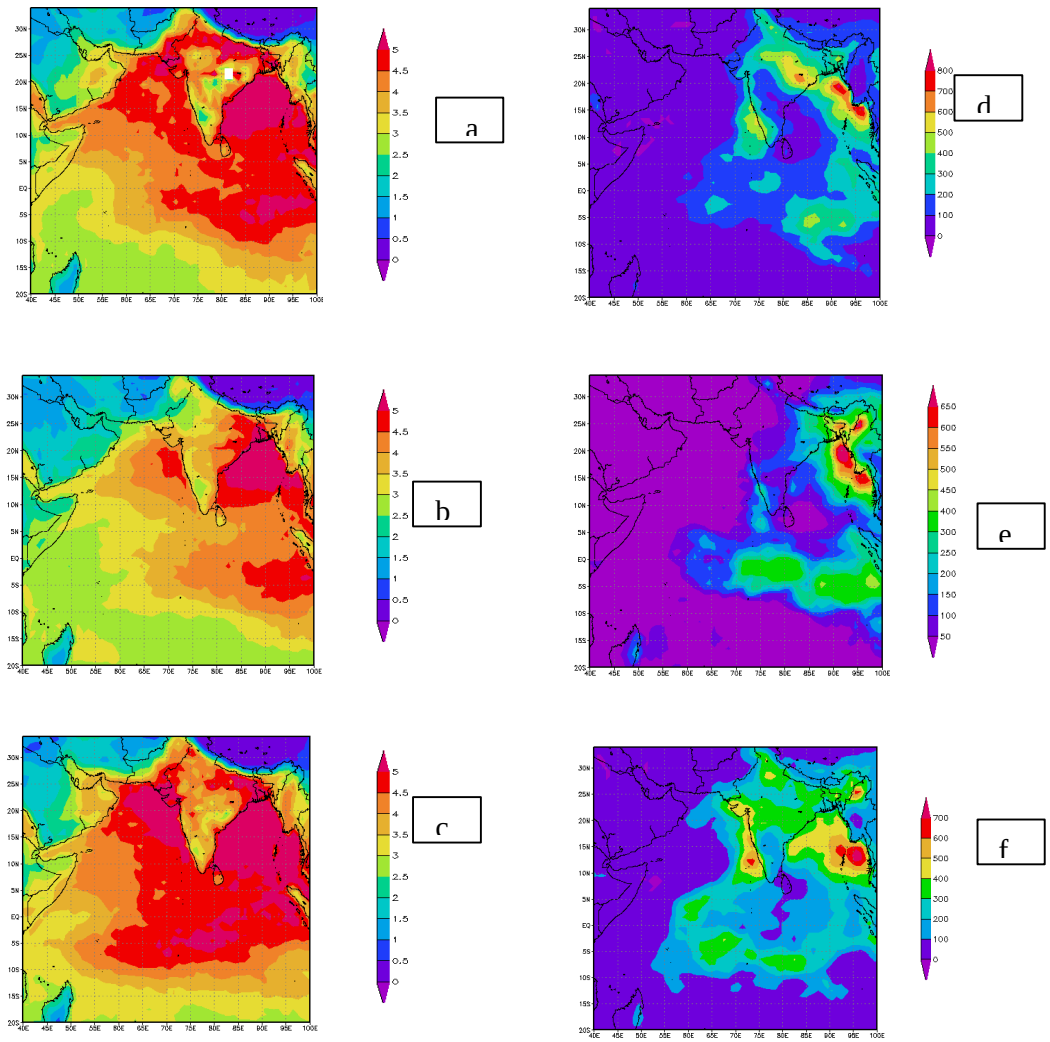
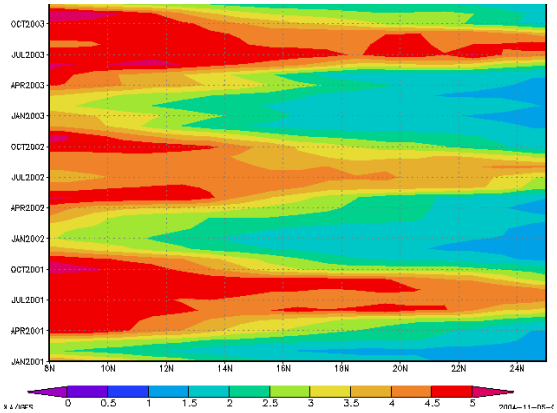
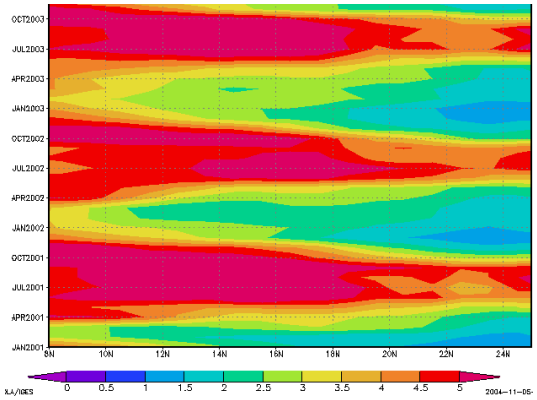


Fig. 2 Time Latitude Plot of TPW and Rainfall from MODIS and TRMM from 2001-2003

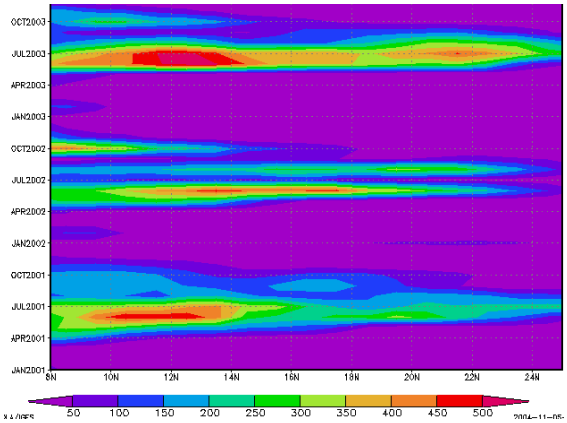
MODIS-TPW (cm) (Avg. Lon. 70-75)



MODIS-TPW (cm) (Avg. Lon. 82-88)



TRMM-Rainfall (mm) (Avg. Lon. 70-75)



TRMM-Rainfall (mm) (Avg. Lon. 82-88)