# Comparisons of Monthly Rainfall Data with Satellite Estimates of TRMM 3B42 over Iraq

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***Abstract-*** Estimation of rainfall by satellite technology is one of valuable data production. These data need to be verified for more consistent with observed data. Tropical Rainfall Measuring Mission (TRMM) precipitation products have been extensively validated at ground sites around the world. This research is a first attempt for evaluating TRMM measurements of monthly rainfall over Iraq. Accumulated monthly rainfall collected by the Iraqi Meteorological and Seismology Organization (IMSO) at four stations, representing different climate zones, in Iraq for the period 2000-2010 were compared with TRMM measurements. Results showed that rain highly varies from one season to another and such behavior is observed in both sets of data. It was found that TRMM measurements overestimate rainfall in most months of the rainy season. The results indicated that there is a high correlation between TRMM and IMSO measurements suggesting that TRMM measurements may be used to estimate rainfall over Iraq. This could be a very useful specially for rural and deserts areas where no instruments are available for measuring rain.

***Index Terms***- Rainfall, TRMM, Pearson's correlation, Iraq

## I. Introduction

In arid and semi-arid areas, such as Iraq, rainfall storms exhibit strong spatial and temporal variability. Iraq suffer from limited surface rainfall monitoring stations and lack of weather radars. Alternative monitoring methods, such as those based on remote-sensing satellite techniques, can be a significant source of data collection this country. The use of satellite precipitation data from various satellite sensors, missions, and algorithms (e.g., Tropical Rainfall Measuring Mission (TRMM), Special Sensor Microwave Imager (SSM/I), Climate Prediction Center Morphing Algorithm (CMORPH)) in scientific investigations has been on the rise due to the general paucity or unavailability of adequate rain gauge data for the majority of the Earth's surface and their higher degree of accuracy due to algorithm development [1]. The aim of this research is to assess the TRMM rainfall measurements in estimating rainfall over Iraq. There are a number of efforts to compare and validate TRMM rainfall products with other rainfall measurements different Asian countries. the TRMM rainfall is calibrated with rain-gauge data from; India [2], Thailand [1], Bangladesh [3], and Nepal [4]. Habib and Nasrollahi (2009) [5] used the TRMM Multi Sensor Precipitation Product(TMPA-3B42) across several arid and semi-arid areas over the western coast of Saudi Arabia, the Sinai Peninsula in Egypt, and Yemen. They found that there are considerable discrepancies between the gauge measurements and the TMPA estimates at the daily scale. Uddin et al., (2008) [6] used a bilinear weighted interpolation technique to generate site-specific precipitation data on a local scale from TRMM measurements and compared it with ground observation in Kuwait. Javanmard et al., (2010) [7] compared high-resolution gridded precipitation data measured with satellite rainfall estimates of TRMM 3B42 over Iran. Their results showed that TRMM measurements underestimate mean annual precipitation by less than 1 mm/day. Almazroui, (2011) [8] assessed the accuracy of TRMM in estimating rainfall over Saudi Arabia and suggested that the TRMM value should be multiplied by 0.93 plus 0.04. TRMM data may be used in a variety of water-related applications in Saudi Arabia. Kheimi and Gutub, (2015) [9] assessed several satellite products against ground observation over the Saudi Arabia region to find out which product best describes accessible in near-real time.

## II. Materials and method

Monthly accumulated rainfall collected by the Iraqi Meteorological and Seismology Organization (IMSO) at four stations, representing different climate zones, in Iraq were used in this work. Table I gives the geographical coordinates of these stations.

Table I: The geographical parameters for selected stations

| Station | Longitude ($^o$E) | Latitude ($^o$N) | Elevation (m) |
|---|---|---|---|
| Mosul | 43.15 | 36.32 | 223 |
| Baghdad | 33.23 | 44.23 | 34 |
| Rutba | 33.03 | 40.28 | 615 |

| | | | |
|---|---|---|---|
| Basra | 30.57 | 47.78 | 2 |

The TRMM is a joint US–Japan satellite mission for monitoring tropical and subtropical precipitation. The TRMM was successfully launched on 27th November, 1997 from Tanegashima Space Center in Japan [10]. The TRMM includes a number of precipitation-related instruments, such as a precipitation radar, a visible and infrared sensor (VIRS), and a SSM/I-like TRMM microwave imager (TMI). The purpose of the3B42 class of algorithm is to produce TRMM-adjusted merged-infrared (IR) precipitation. The monthly TRMM 3B43(V6) accumulated rainfall (0.25°×0.25°) product acquired from TRMM Online Visualization and Analysis System (TOVAS) was used. Rainfall data obtained from the TRMM near the closest point to a station's location was used for comparisons. The period of the study extended from January 2000 to December 2010 [11].

There are many different types of correlation coefficients that reflect somewhat different aspects of a monotone association and are interpreted differently in statistical analysis. In this work Pearson product moment correlation was used to evaluate the correlation between the two sets of data. The Pearson’s correlation coefficient is a common measure of association between two continuous variables. It is defined as the ratio of the covariance of the two variables to the product of their respective standard deviations, commonly denoted by the Greek letter ρ [12]:

$$\rho = \frac{\mathrm{cov}(x, y)}{\sigma_x \sigma_y} \qquad (1)$$

The sample correlation coefficient, r, can be obtaining by plugging-in the sample covariance and the sample standard deviations into the previous formula, i.e.:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} \qquad (2)$$

where:

$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$ and . $\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}$.

The Pearson’s correlation coefficient ranges from -1 to +1. A positive monotonic association (two variables tend to increase or decrease simultaneously) results in $\rho > 0$, and negative monotonic association (one variable tends to increase when the other decreases) results in $\rho < 0$. ρ of 0 corresponds to the absence of the monotonic association, or absence of any association in the case of bivariate normal data. However, for bivariate distributions other than bivariate normal distribution, the Pearson’s correlation can be zero for dependent variables. For example, it can be ‘0’ for the variables with non-monotonic relationship, e.g. $Y = X^2$ , ($x \in (-1, 1)$). The absolute value of ρ indicates the strength of the monotonic relationship between the two variables. ρ of 1 indicates a perfect linear relationship, i.e. Y = a+bX.

## III. RESULTS AND DISCUSSION

The rain season in Iraq start on October and ends on May. Therefore, analysis was carried out for the eight months representing the rain season. Figures 1 to 4 show the comparisons between TRMM and IMSO monthly accumulated rainfall for the four stations respectively. The Mosul station which is located in the northern part on the country receives relatively higher rainfall than the other three station. Figure 1 shows that monthly accumulated rainfall may reach 140 mm during most months of the rainy season. The trends of TRMM and IMSO rainfall measurements over years are comparable but it seems that TRMM measurements overestimate the amount of rainfall during most months. Figure 2 gives the results of comparisons for Baghdad station. Accumulated monthly rainfall may reach more that 60 mm over most months of the rainy season. This station also indicates that TRMM measurements overestimate rainfall during most months. The overestimation of rainfall by TRMM is obvious for Rutba and Basra stations as seen in Figures 3 and 4. It is notable that the monthly amount of rainfall for Rutba station is relatively low during the months, no more than 10 mm October and May. This is expected since this station is located in the desert part of Iraq. The results of analysis show that rainfall over Iraq varies considerably from season to season. Figure 5. shows the scatter plots of IMSO monthly rainfall versus TRMM measurements for the four stations. It is clear that data are highly correlated. Linear regression test of Pearson showed that the correlation coefficient between TRMM and IMSO measurements for Mosul, Baghdad, Rutba, and Basra stations were found to be 0.8924, 0.8419, 0.8850, and 0.9205 respectively. This high correlation between IMSO and TRMM monthly rainfall measurements suggest that TRMM measurements may be used to estimate rainfall over Iraq for a variety of water-related applications. TRMM measurements can be used to compensate missing records and to estimate rainfall over areas where no weather stations exist.

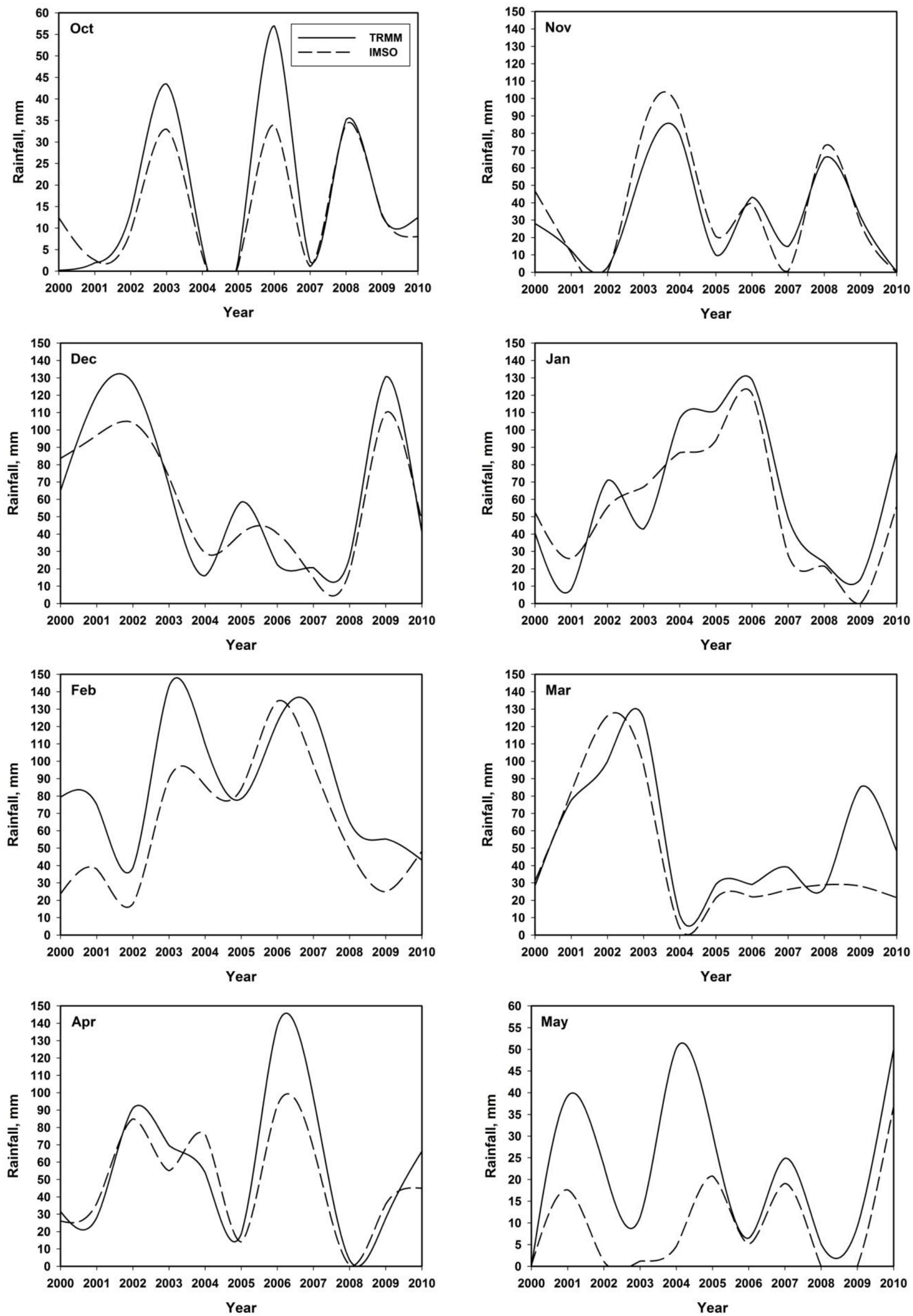


Figure 1: Comparison between TRMM and IMSO monthly accumulated rainfall for Mosul station.

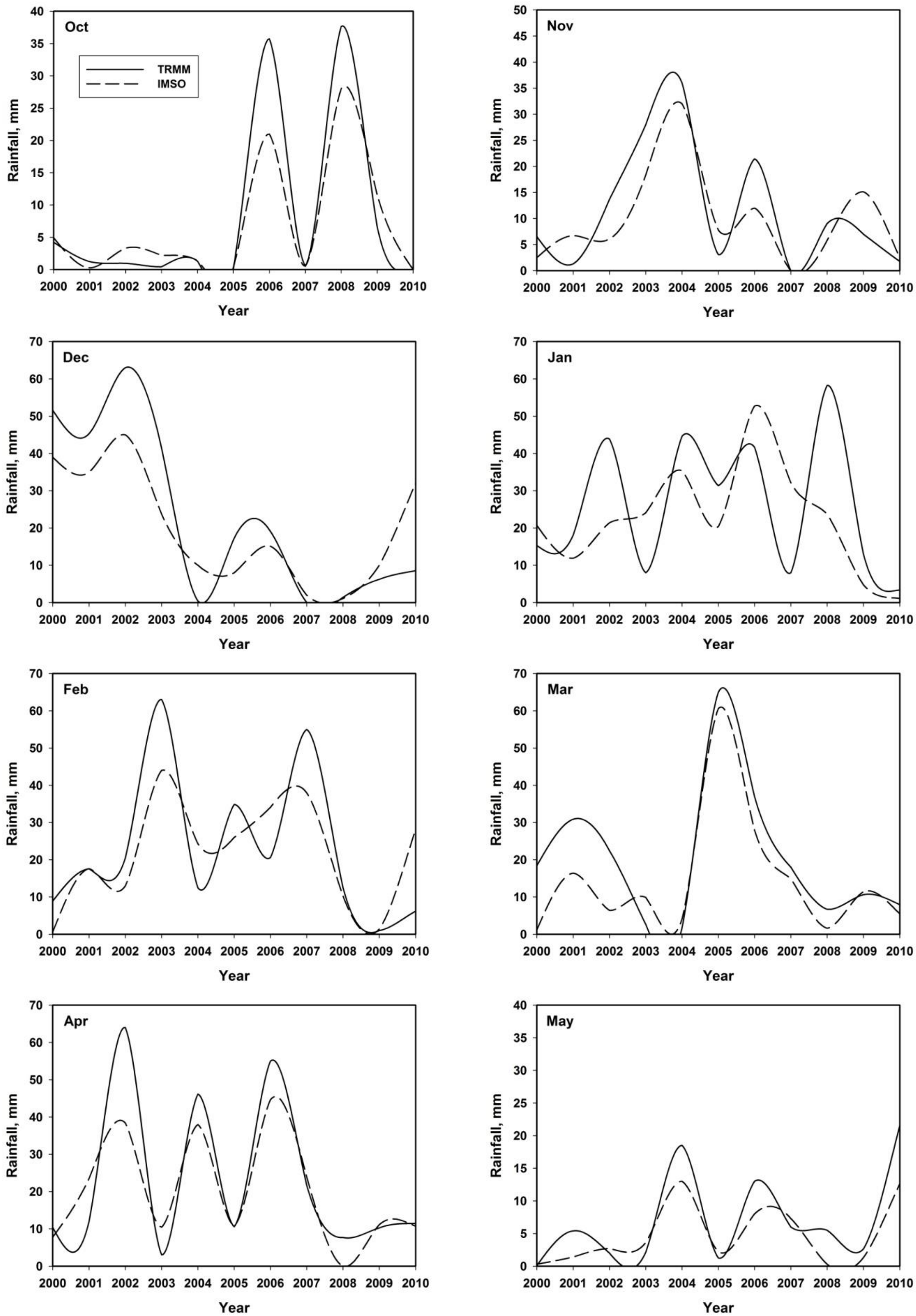


Figure 2: Comparison between TRMM and IMSO monthly accumulated rainfall for Baghdad station.

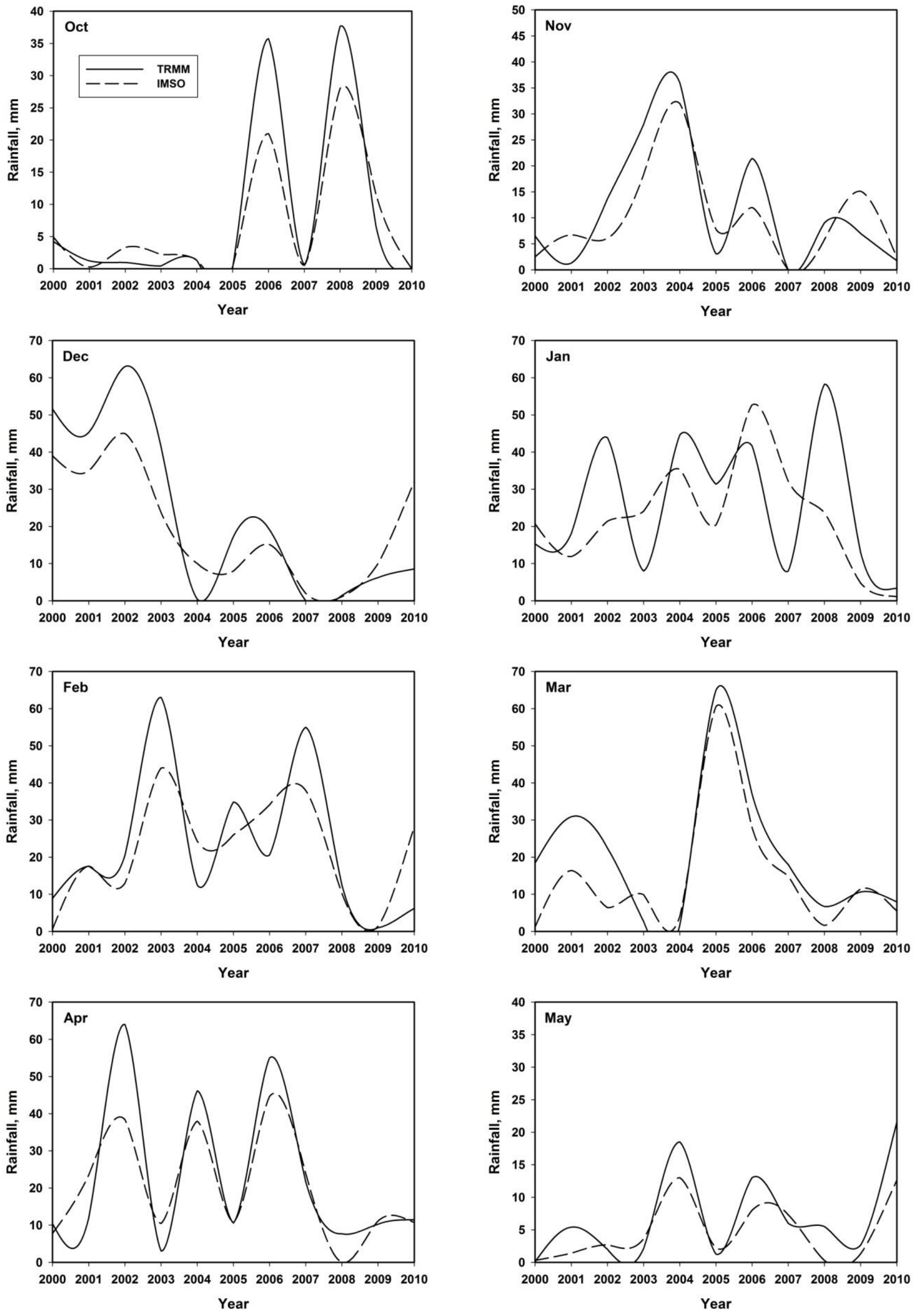


Figure 3: Comparison between TRMM and IMSO monthly accumulated rainfall for Rutba station.

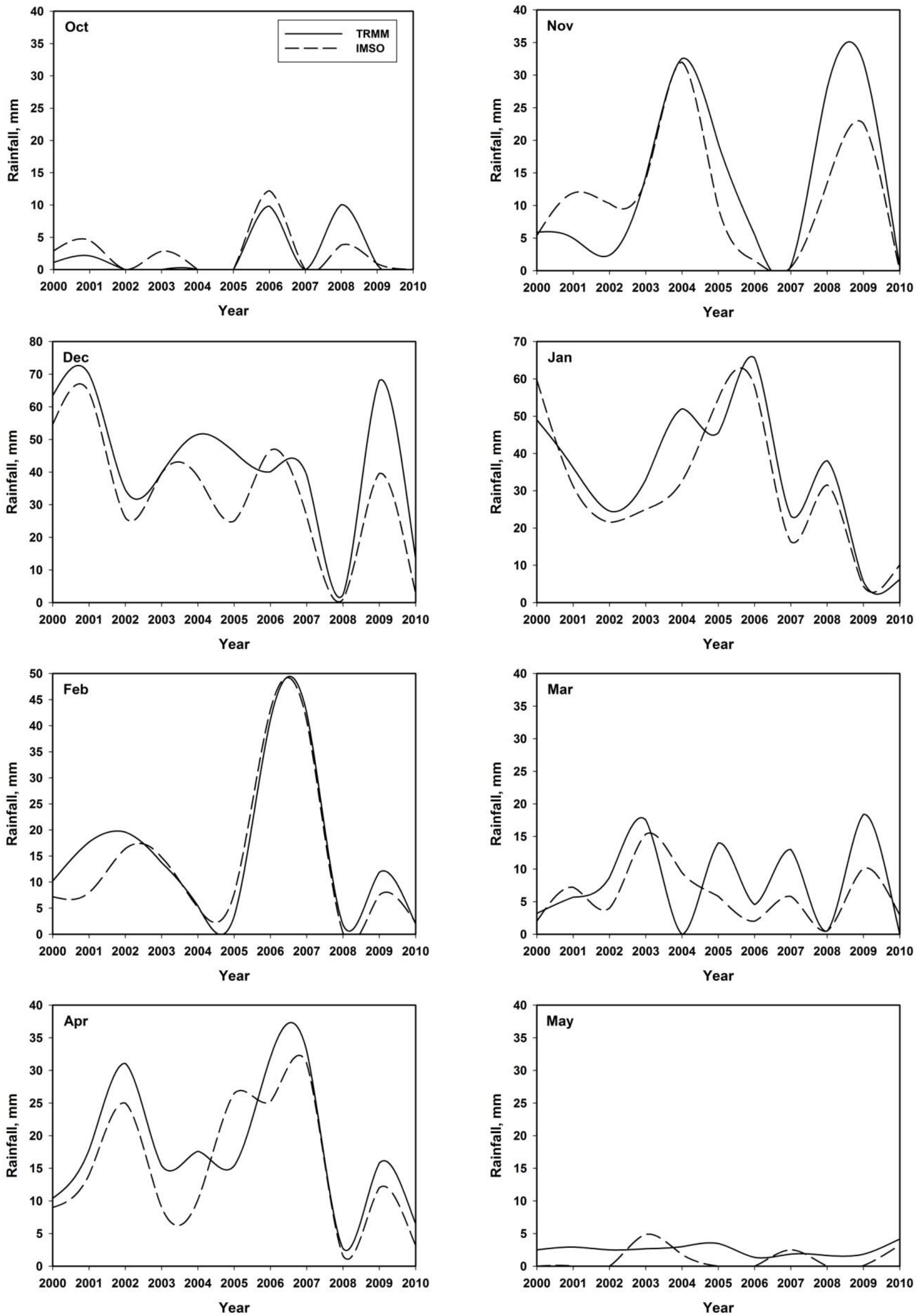


Figure 4: Comparison between TRMM and IMSO monthly accumulated rainfall for Basra station.

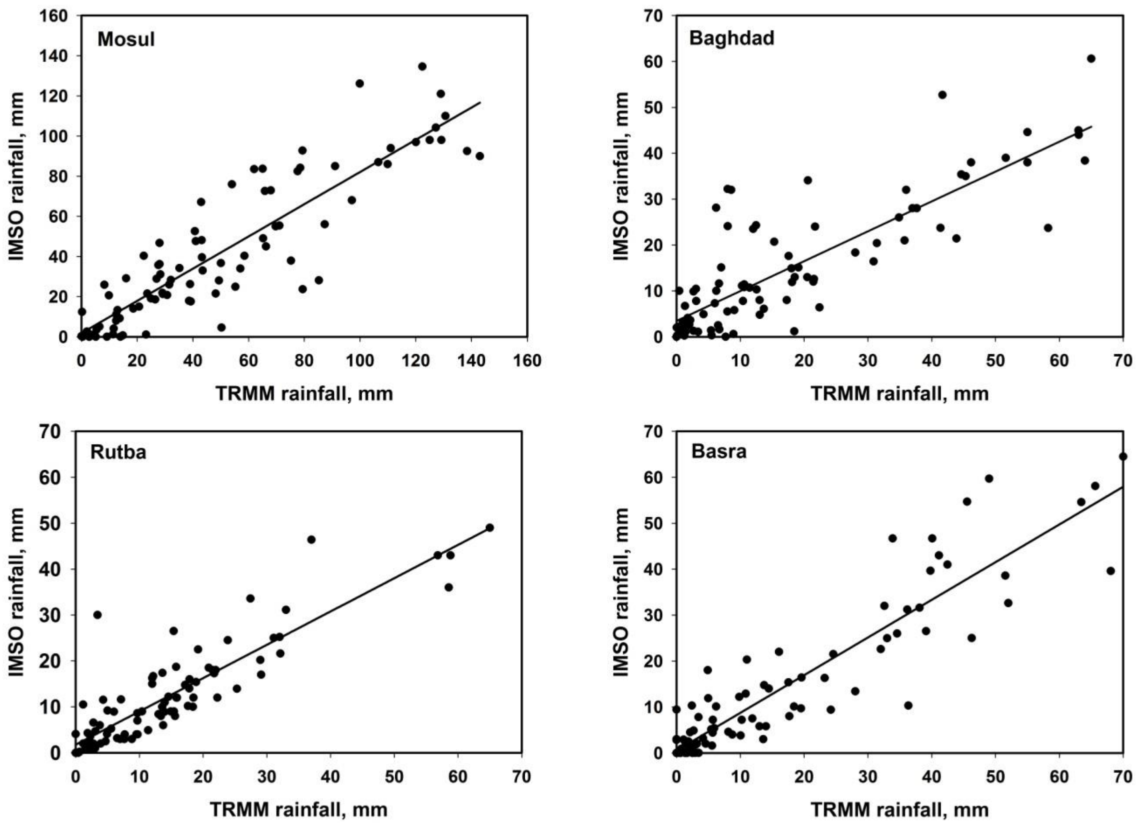


Figure 5: Scatter plots of IMSO rainfall versus TRMM rainfall for selected stations.

## IV. Conclusion

This research is an attempt to evaluate satellite rainfall estimates of Tropical Rain Measurement Mission level 3 output (3B42) (TRMM 3B42) over Iraq ($28^o$ –$38^o$ N, $38^o$ –$50^o$ E). Monthly accumulated rainfall collected by the Iraqi Meteorological and Seismology Organization were compared with TRMM measurements for four selected stations representing north, center, west, and south regions of the country. Results suggest that TRMM rainfall measurements may be useful in estimating rainfall particularly in regions where no gauge observations available and therefore such measurements are useful for many water related applications. Results also indicated that rain is highly variable from one rainy season to another.

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