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Features of Monthly Precipitation Data Over Iraq Obtained by TRMM Satellite for Sustainability Purposes

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**ABSTRACT**

To achieve the goals of sustainability, hydrological studies require analysis and modeling of precipitation data, in an accurate and reliable manner. However, measurements of precipitation ought to be more accurate representations of the actual distribution of precipitation. The methods and methods used to gather data on precipitation are numerous. With the advent of satellite products, namely, the Tropical Rainfall Measuring Mission (TRMM) precipitation, which can be used to estimate and analyze precipitation data, hydro-meteorological and climatological applications of satellite precipitation products have recently seen a significant improvement.

In this study, the Iraqi Meteorological and Seismology Organization (IMSO) gathered ground-based rain gauge data at eight sites in Iraq that represent various climatic zones for the years 2010 to 2020 with the goal of validating the TRMM rainfall products. To conduct station-based assessments, statistical performance metrics are used to evaluate the correctness of each IRMM product. The findings indicated that rainfall significantly varied from one season to the next, and this tendency was seen in both sets of data. In most rainy season months, it was discovered that TRMM readings overstate rainfall. The findings show that the run product performed admirably in the country's southern, northern, and western regions, whereas the satellite estimations for the center regions alternated between being overestimated and underestimated. This research offers a preliminary evaluation of the IRMM satellite products' functionality over Iraq. The study’s findings can be helpfully utilized as a reference for rural and arid regions where there are no devices for detecting rain.

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1. INTRODUCTION

A significant part of the hydrological cycle, precipitation takes on many various forms depending on the weather. Moreover, one of the most crucial elements of the planetary energy cycle is precipitation [1],[2].

One of the key inputs for hydrological, meteorological, and climatic models, which are used to forecast various natural disasters including landslides, floods, and droughts, is measurements of precipitation [3],[4]. The reactions of the hydrological and energy cycles are influenced by the geographical distribution, intensity, and duration of the precipitation as well as other factors [5],[6]. As a result, estimations of precipitation with high spatiotemporal precision are always required for diverse applications. The most crucial procedures before carrying out any analysis or creating any hydrologic model are the collection of rainfall data and the quality assurance of precipitation products [7].

Point measurements (i.e., rain gauges), commercial microwave connections, satellite-based sensors, and ground-based weather radar are the methods that are most frequently used to estimate precipitation [3],[8]. Due to its precision when compared to other sensors, rain gauges are thought of as the source of truth for precipitation observations and may offer direct readings of precipitation. Recording rain gauges come in a wide variety of designs. Nevertheless, hydrometeorological organisations often utilise just three types, namely the tipping bucket, the universal weighing type gauge, and the float-type gauge, to measure precipitation. The underestimating of heavy precipitation owing to splashing is just one of several measurement issues that all three gauges face. Other issues include equipment issues, external influences like wind and evaporation of precipitation, and observer mistakes [9].

Gauge measurements also give point values rather than aerial observations, hence they are unable to reflect spatial fluctuations in precipitation. Radar devices employ hydrometeor backscattering of electromagnetic waves to monitor precipitation in an indirect manner (i.e., water drops). Radar's capacity to scan wide regions with a high level of real-time resolution is its key advantage [10]. Radar measurements do, however, also exhibit a variety of error types, including range-dependent systematic errors, mean field systematic errors, random errors, and topographical blockage. Moreover, not all of the earth is covered by radar networks [11].

The use of various satellite sensors to measure the world's precipitation has considerably risen during the past thirty years [2],[11]. The Tropical Rainfall Measuring Mission (TRMM), which began operations in 1997, was the first dedicated satellite used to measure precipitation [12]-[16]. To better understand the distribution of precipitation globally and produce near-real-time precipitation products, the TRMM satellite was designed to measure moderate to heavy rainfall Zhou et al., 2008).

Studies have looked into the reliability of rainfall predictions made using satellite data, such as the Tropical Rainfall Measurement Mission (TRMM) and demonstrated their potential for hydrological applications (e.g., [17],[18]).

According to recent research, employing satellite measurements instead of terrestrial ones significantly improved rainfall intensity detection and measurement (e.g., [19]-[23]. The findings revealed that the TRMM's levels of accuracy varied across various events and geographic areas.

This research is being done to assess the TRMM's ability to accurately predict rainfall across Iraq between October 1, 2010, and May 30, 2020. The findings will provide information on the regional research area's native satellite products' accuracy as well as the efficacy of late goods' enhancements. Moreover, the outcomes will offer direction on whether semi-real-time satellite products with high temporal and geographical resolutions can be adequate for different hydrometeorological applications in the region.

Consumption and thus reducing exhaust gas emissions to the environment, and the second to enhance the engine thermal efficiency by removing the load resulting from the cooling system and finally, to increase the COP of the cooling system.

2. STUDY AREA

This study covers the geographic coordinates provided in Table (1) and includes the Monthly Accumulated Rainfall gathered by the Iraqi Meteorological and Seismology Organization (IMSO) at eight stations (Figure 1) in Iraq that represent various climatic zones.
Features of Monthly Precipitation Data Over Iraq (Alsultani, Riyadh)

Figure 1: Locations of selected stations in Iraq.

Table 1: The geographical parameters for selected stations.

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Station ID</th>
<th>Longitude (°E)</th>
<th>Latitude (°N)</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mosul</td>
<td>ML</td>
<td>43.05</td>
<td>36.25</td>
<td>223</td>
</tr>
<tr>
<td>Sylaymaniyyah</td>
<td>SH</td>
<td>45.48</td>
<td>35.58</td>
<td>853</td>
</tr>
<tr>
<td>Anah</td>
<td>AH</td>
<td>42.00</td>
<td>34.42</td>
<td>150</td>
</tr>
<tr>
<td>Baghdad</td>
<td>BD</td>
<td>44.39</td>
<td>33.33</td>
<td>32</td>
</tr>
<tr>
<td>Rutba</td>
<td>RA</td>
<td>40.42</td>
<td>33.00</td>
<td>615</td>
</tr>
<tr>
<td>Nukhuyb</td>
<td>NB</td>
<td>42.05</td>
<td>32.07</td>
<td>305</td>
</tr>
<tr>
<td>Nasiriyah</td>
<td>NH</td>
<td>46.25</td>
<td>31.00</td>
<td>5</td>
</tr>
<tr>
<td>Basra</td>
<td>BA</td>
<td>47.78</td>
<td>30.50</td>
<td>2</td>
</tr>
</tbody>
</table>

Tropical and subtropical climates in arid and semi-arid areas define these places. In the northern hemisphere, the climate is cold and wet (or snowy) in winter and hot and sunny in summer. The climate is desert in the centre and the south, with moderate winters and extremely scorching summers. In the mountains, it is semi-desert, with comparatively chilly winters. There are a number of rain gauge stations in each of these eight areas.
3. PRECIPITATION DATA SETS

3.1. Ground-Based Precipitation Data Set

As they offer a direct physical record of the precipitation at a specific location, rain gauges are used as references for precipitation data all around the world. Daily rainfall data from each of the eight locations used for this study were gathered using the online database service offered by the Iraqi Meteorological and Seismology Agency (IMSO). The availability of rainfall records for the research period, which runs from October 1, 2010, to May 30, 2020, dictated the data collection (i.e., the rainy season). 128 stations collected a total of 1455 observations. Throughout the research period, there was a minimum of 0.1 mm of rain every day. The stations are relatively closely spaced in the western region (Anah and Rutba), in the southwestern region (Nasiriyah and Basra), where the climate is dry, as well as in the middle region (Baghdad and Nukhuyb), where there is a dense population. This is because the rain gauge network in Iraq is unevenly distributed. Nonetheless, the density of rain gauge stations is rather low in the and northern (Modol and Sylamaniyah) areas.

3.2. Satellite-Based Precipitation Data Set

Estimates of the precipitation observations from the satellite constellation were made using the Tropical Rainfall Measuring Mission (TRMM), a monthly mission. Since the satellite’s launch, this algorithm has been continuously utilised to calculate the quantity of precipitation. Every half-hour, the 3B43 (V6) TRMM algorithm generates estimates of precipitation at a high geographical and temporal precision of 0.1°X 0.1° (longitude X latitude).

4. METHODOLOGY

Many procedures were used in order to analyse the rainfall products. Together with processing and preparation of the TRMM data, the procedure begins with the preparation of the ground measurement data. The last stage involves utilising well used statistical performance metrics to compare the observed satellite data (TRMM data) with the reference data (rain gauge data).

4.1. Ground Measurements And Data Preparation

The coordinates of each station were retrieved, and the rainfall ground measurement data were downloaded from the ISMO website. Each rain gauge station’s elevation (height) was determined using the GEOPLANER website (http://www.geoplaner.com/). Decimal degrees were used to express the coordinates. Each rain gauge station’s coordinates were converted from decimal degrees to Universal Transverse Mercator (UTM) coordinates using the UTM CONVERTER tool (available at http://www.utmconverter.com/). Last but not least, a station ID was assigned to each station, consisting of one number referencing the sequence in the database list and two characters used to identify the region.

4.2. Performance Measures

To assess the degree of connection between the two sets of data, Pearson product moment correlation was utilised. The most popular statistical performance metric, known as Pearson product moment correlation, is chosen with the goal of evaluating the TRMM satellite precipitation products: the Pearson's correlation coefficient [24]. The consistency between satellite estimations and data from rain gauges was described using the Pearson's correlation coefficient. It is often represented by the Greek letter and is defined as the ratio of the covariance of the two variables to the product of their respective standard deviations:

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

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.:

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

Where:

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

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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 $\rho < 0$. $\rho$ 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 $\rho$ indicates the strength of the monotonic relationship between the two variables. $\rho$ of 1 indicates a perfect linear relationship, i.e. $Y = a + bX$.

4.3. Comparison Process

The region-based comparison was done to compare each sub-rainfall region’s detected by the TRMM satellite to that sub-rainfall region’s recorded by rain gauges to see which was more accurate. The idea is to assess the general accuracy of the measures for the eight administrative areas of Iraq over the course of eight months, starting in October and ending in May.

5. RESULTS AND DISCUSSION

In this study, Pearson’s correlation coefficient was used to conduct an analysis for the eight months that correspond to the rainy season for each sub-region of the eight selected stations throughout all of Iraq. Figures 2 to 9 compare the monthly cumulative rainfall for the eight stations using the TRMM and the IMSO, respectively.

In most months of the rainy season, Mosul and Sylaymaniyah, respectively, may see monthly cumulative rainfall of 140–148 mm. Although the patterns of the TRMM and IMSO rainfall readings over time are comparable, it appears that the TRMM data provide an accurate estimation of the quantity of rainfall for the majority of the months. Results of comparisons between Anah and Baghdad stations are shown in Figs. 4 and 5. In most months of the rainy season, the total amount of rainfall may exceed 58 and 60 mm, respectively. This station also shows that TRMM readings typically overestimate rainfall. Figures 4 to 9 show that Basra, Nasiriyah, Rutba, and Nukhuyb stations have accurate rainfall estimates made by TRMM. It is noteworthy that Rutba and Nukhuyb station receives extremely little rainfall each month between the months of October and May—no more than 10 mm. Given that this station is situated in Iraq's desert region, this is to be anticipated. Analysis results reveal that the amount of rainfall over Iraq changes greatly from season to season.

The scatter plots of monthly rainfall measured by IMSO vs TRMM for the eight sites are displayed in Figure 10. Data are obviously strongly linked. The correlation coefficient between TRMM and IMSO measurements for the stations in Mosul, Sylaymaniyah, Anah, Baghdad, Rutba, Nukhuyb, Nasiriyah, and Basra was found to be 0.8924, 0.8985, 0.8533, 0.8419, 0.8810, 0.8850, 0.9180, and 0.9205, respectively, according to a linear regression test of Pearson. Because to the strong connection between IMSO and TRMM monthly rainfall data, it is possible to estimate Iraqi rainfall using TRMM readings for a range of water-related applications. In places without weather stations, TRMM readings can be used to estimate rainfall and make up for missing records.
Figure 2: Comparison between TRMM and IMSO monthly accumulated rainfall for Mosul station.
Figure 3: Comparison between TRMM and IMSO monthly accumulated rainfall for Sylaymaniyah station
Figure 4: Comparison between TRMM and IMSO monthly accumulated rainfall for Anah station.
Figure 5: Comparison between TRMM and IMSO monthly accumulated rainfall for Baghdad station.
Figure 6: Comparison between TRMM and IMSO monthly accumulated rainfall for Rutba station.
Figure 7: Comparison between TRMM and IMSO monthly accumulated rainfall for Nukhuyb station.
Figure 8: Comparison between TRMM and IMSO monthly accumulated rainfall for Nasiriyah station.
Figure 9: Comparison between TRMM and IMSO monthly accumulated rainfall for Basrah station.
Figure 10: Scatter plots of IMSO rainfall versus TRMM rainfall for selected stations.
6. CONCLUSIONS

This study focuses on the validation of the Tropical Rain Measurement Mission (TRMM) level 3 output (3B42) over Iraq for the time frame of October 1, 2010, through April 30, 2020 utilising ground-based rain gauge data as a reference. For eight selected stations representing the north, centre, west, and south of the country, respectively, Mosul and Sylaymaniyah, Anah and Baghdad, Rutba and Nukhuyb, and Nasiriyah and Basra, monthly accumulated rainfall collected by the Iraqi Meteorological and Seismology Organization (IMSO) was compared with TRMM measurements. According to the findings, TRMM rainfall data may be used to estimate rainfall, especially in areas without access to gauge observations. As a result, these measurements are helpful for a variety of water-related applications. Findings also showed that rain is very varied from one place to another.

7. ACKNOWLEDGMENTS

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8. AVAILABILITY OF DATA AND MATERIALS

The data and materials had been included in the manuscript.

REFERENCES


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