Water Harvesting Research Vol. 5, No. 1, Spring & Summer 2022, Original Paper p. 67-79
University of Birjand
10.22077/JWHR.2022.5502.1071

A Comparative Analysis of Spatial-Temporal Precipitation Accuracy of TRMM and Synoptic Stations

Massoud Goodarzi*[a], Saeed Elmi[b], Ali Khalkhali[c]

[a]Associate Professor in Soil Conservation and Watershed Management Research Institute (SCWMRI), AREEO, Tehran, Iran.
[b]Master of science in Soil Conservation and Watershed Management Research Institute (SCWMRI), AREEO, Tehran, Iran.
[c]Master of science in Soil Conservation and Watershed Management Research Institute (SCWMRI), AREEO, Tehran, Iran.

*Corresponding Author, E-mail address: m.goodarzi@areeo.ac.ir, mgoodarzi@scwmri.ac.ir

Received: 6 August 2022/ **Revised**: 18 September 2022/ **Accepted**: 20 September 2022

Abstract

The Tropical Rainfall Measurement Mission (TRMM) provides an important rainfall database for hydrological applications in aquatic basins. However, its accuracy and usage have not been sufficiently studied due to the occurrence of network-scale rainfall and water basins. In this study, the accuracy of the prediction of TRMM 3B42 V7 rainfall values in Iran is investigated. For conducting this study, the daily net precipitation values of TRMM 3B42 V7 from an Iranian basin were extracted with a 0.25-degree spatial resolution over the period 01.01.1998 to 31.12.2015. Precipitation data recorded at synoptic stations were also provided during this period. The accuracy of TRMM precipitation is evaluated using the nearest neighbor spatial resolution function. The findings show that not only in terms of temporal coherence but also in magnitude, there was a significant difference between the predicted TRMM rainfall values and the rainfall recorded by the stations. The bias value (BIAS), mean absolute error of magnitude (MAE) and root mean the square of error (RMSE) of the Caspian, Urmia, and Persian Gulf basins were reported much higher than in other regions. The Precipitation indicators of the probability of detection (POD), Fault Alert Ratio (FAR), Mean Critical Success Index (CSI) indicates lower accuracy for TRMM 3B42 V7 in the prediction of rainfall at the grid-scale and catchments of Iran.

Key words: Accuracy Evaluation, Fault Alert Ratio, Precipitation, TRMM.

1. Introduction

Precipitation is the most important hydrological variable that establishes the link between the atmosphere and surface processes. Positive and negative precipitation anomalies cause floods and droughts. Hence, the spatial-temporal variations of this parameter make it a controversial parameter in climate-atmospheric models. Access to good precipitation data is needed to increase understanding of climate and climatic and hydrological systems and to properly predict the human dimension of climate change. Spatial-temporal density precipitation data on the oceans and large portions of land are very narrow. In recent years, there has been a great demand for network data in the areas of agriculture, hydrology, and health. Network data play an important role in validating regional and global climate models. However, for regional analysis, it requires better bases of time and space. So that such bases can detect climatic differences in smaller zones and analyze climatic averages and trends. In the last few years, several daily-scale bases in Europe, South America, North America, and Asia have appeared in spatial resolution of about 50 km (Herrera et al., 2012). It is clear that the lack of access to a regular ground-based rain gauge network impedes the development and use of flood and drought and hydrological warning models (Ghagourian and SanaeiNejad, 2013). In the framework of the African DAms ProjecT (ADAPT), an integrated water resource management study in the Zambezi Basin is currently under development. In view of the sparse gauging network for rainfall monitoring, the observations from spaceborne instrumentation currently produce the only available rainfall data for a large part of the basin (Cohen et al., 2012)

An increasing number of satellite-based rainfall products are now available in near–real time over the Internet to help meet the needs of weather forecasters and climate scientists, as well as a wide range of decision makers, including hydrologists, agriculturalists, emergency managers, and industrialists. Many of these satellite products are so newly developed that a comprehensive evaluation has not yet been undertaken. This article provides potential users of short-interval satellite rainfall estimates with information on the accuracy of such estimates. Since late 2002 the authors have been performing daily validation and intercomparisons of several operational satellite rainfall retrieval algorithms over Australia, the United States, and northwestern Europe. Short-range quantitative precipitation forecasts from four numerical weather prediction (NWP) models are also included for comparison. Synthesis of four years of daily rainfall validation results shows that the satellite-derived estimates of precipitation occurrence, amount, and intensity are most accurate during the warm season and at lower latitudes, where the rainfall is primarily convective in nature. In contrast, the NWP models perform better than the satellite estimates during the cool season when non-convective precipitation is dominant. An optimal rain-monitoring strategy for remote regions might therefore judiciously combine information from both satellite and NWP models (Ebert et al., 2007).

Since it is virtually impossible to capture such information at regional and global scales by terrestrial stations, the use of satellite data can increase our knowledge of climate, including rainfall. Networked precipitation data has many advantages over terrestrial sources, such as the uniform spatial resolution of the Earth, free data availability, and up-to-date data (Kalinga, and Gan 2010). The airborne radar monitors spatial-temporal precipitation, yet the database due to the clouds, rains, vertical reflection, or other obstacles can be faulty (Tardivo and Berti, 2012; Dinku et al., 2002).

The lack of high resolution precipitation data has posed great challenges to the study and management extreme rainfall events. Satellite-based rainfall products with large areal coverage provide a potential alternative source of data where in situ measurements are not available. Fong et al. developed a statistical spatial downscaling scheme based on the relationships between precipitation and related environmental factors such as local topography and pre-storm meteorological conditions (Fang et al., 2013). Besides, precipitation inputs have a significant impact on the performance of a wide range of hydraulics, climates, and atmospheric models (Villarini and Witold, 2008; Turk and Miller, 2005). Therefore, before the practical use of satellite data, it is necessary to compare these data with ground data and to determine their accuracy and correction as far as possible (Tong et al., 2014; Sylla et al., 2013; Prakash et al., 2010). In recent years, many researchers have based their studies on global databases. For example, Su et al. (2008) compared TRMM 3B42 rainfall data with precipitation data from Laplatas catchment stations in South America and found that the correlation coefficient between them was significant on a monthly basis. Almazroui, (2011) calibrated the precipitation of the mentioned product in Saudi Arabia and showed that on a daily and annual basis, the precipitation corresponds to the ground stations. Condom et al., 2011 examines the accuracy of TRMM satellite precipitation data in the Peruvian Mountains and proposes mass and multiplier coefficients to correct satellite data. Comparison of the three satellite precipitation products TMPA 3B42 RT, CMORPH, and PERSIAN with station data in Indonesia showed that, overall, the PERSIAN product has the highest prediction and the CMORPH product contains the lowest prediction of precipitation. TMPA 3B42 has the best performance in this regard.

However, there were differences between this database and the station data that used the oblique correction equation to solve this problem (Vernimmen et al., 2012). They found the differences between this satellite product and the stations in coastal and high-altitude regions to be very significant. Li et al., (2012) while comparing TRMM satellite rainfall with ground station data, evaluate the suitability of the mentioned satellite data for calculating water balance in hydrological models in the Xinjiang Basin. The results indicate the suitability of the data for hydrological modeling at the monthly scale and its disproportionality at the daily scale. Chen et al. (2013) showed that the TRMM 3B V7 precipitation product is in good agreement with the data recorded in the Pacific. Sebastian (Sebastian, et al., 2019) compared TRMM 3B42 product accuracy with data from 185 Chinese hydrometeorological stations. The results showed that this product: 1) shows the spatial-temporal distribution of daily precipitation. 2) Average daily rainfall is observed in areas with low rainfall and medium to high altitude, while average rainfall is negligible in areas with high rainfall and moderate to low altitude. 3) The abundant rainfall strongly reflects the accuracy of satellite products. On the root, between my home and my home, there was a concomitant of the time series and the precipitation values. Their study showed a strong correlation coefficient between the TRMM database and the national database. From the results of the above studies, it can be concluded that by combining data from satellite and station data, a new precipitation product can be obtained that is spatiotemporally more comprehensive than station data. In the present study, the objective is to evaluate the accuracy and performance of the TRMM database in comparison with the precipitation data of synoptic stations in catchments of Iran.

2. Materials and methods

2.1.Study area

Iran covers an area of about 1.648 million square kilometers, between latitude 25 ° North to 40° North and longitude 44° to 64° East. Rainfall incidence and its amount varies with the wetland of the West, where the east and the middle of the rainy season are located (Masoudian, et al., 2014). These features are characterized by a strong precipitation gradient with an average annual precipitation of 250 mm, the major rainfall concentrated in winter.

2.2.Description of data

In this study, the daily rainfall data of 410 synoptic stations, which were fully registered by the IMO between 1.1.1998 to 12.31.2015. The reason for selecting 410 synoptic stations was because these numbers in total had better statistics than other synoptic data. The TRMM satellite is the first satellite to provide users with valuable spatial and temporal resolution information on precipitation and natural disasters (Tian et al., 2009; Scheel et al., 2011; Adler et al., 2001). The satellite was launched on November 27, 1997, in partnership with the NASA and the JAXA. The first mission dedicated to measuring tropical and subtropical rain is through microwave, infrared, and visible sensors, covering 50 degrees south to 50 degrees north (Tian et al., 2009; Scheel et al., 2011; Adler et al., 2001; Liang et al., 2012; Huffman et al., 2010). TRMM Satellite consists of three products in 3-hour (3B42), daily (3B42 derived) and monthly (3B43). In the present research, TRMM 3B42RT V7 product on a daily basis at synoptic stations was evaluated and compared with a spatial resolution of 0.25° x 0.25°. The 3B42V7 product consists of two products: the near-real-time 3B42 V7 RT product and the real-time 3B42 V7 product; the former is produced solely from satellite remote sensing information, the latter with prediction of terrestrial estimates are corrected (Zhonga et al., 2019).

2.3.Validation methodology

The first step was to compare the temporal and spatial resolution of the TRMM 3B52 V7 product and the precipitation data of the 410 stations in the Iranian catchments. First, the daily precipitation data of the TRMM rainfall database were extracted on the Iranian map over the period 1.1.1998 to 12.31.2015. During this period, the measured precipitation values were also obtained on the synoptic stations on the Iranian map. Since the spatial resolution of the mentioned databases is different, in order to evaluate the accuracy of the predicted precipitation values of the TRMM precipitation database, their spatial resolution was first approximated by the nearest neighbor method. In other words, Iran, which lies between latitude 25° and 40° N, and latitude 44° and 64° E, is proportional to the dimensions of the TRMM base in the form of a regular grid with pixels of 0.25° 0.25°, Latitude and latitude. Since the spatial resolution of satellite data is about 27 km, it is necessary to have precise geographical coordinates of the synoptic stations in order to compare the data of the ground stations with the center of the nearest satellite pixel to each station. After ensuring the accuracy of the station coordinates, the coordinates of each synoptic station in Iran were then compared with the TRMM precipitation database coordinates, and the nearest pixel TRMM precipitation database center to each station was selected as the representative pixel of that station. The precipitation data of each ground station were then compared with the representative precipitation data of the stations on the TRMM precipitation database.

2.4.Accuracy metrics

Statistical indices such as R, R^2, BIAS, and MAE, for analyzing the accuracy of TRMM precipitation data compared with the synoptic stations' precipitation data. And the RMSE was used on a monthly basis, as follows:

$$R = \frac{\sum_{i=1}^{n}\left(O_i - \bar{O}\right)\left(P_i - \bar{P}\right)}{\sqrt{\sum_{i=1}^{n}\left(O_i - \bar{O}\right)^2 \sqrt{\sum_{i=1}^{n}\left(P_i - \bar{P}\right)^2}}} \quad (1)$$

$$R^2 = \left[\frac{\sum_{i=1}^{n}\left(O_i - \bar{O}\right)\left(P_i - \bar{P}\right)}{\sum_{i=1}^{n}\left(O_i - \bar{O}\right)^2 \sqrt{\sum_{i=1}^{n}\left(P_i - \bar{P}\right)^2}}\right]^2 \quad (2)$$

$$Bias = \frac{\sum_{i=1}^{n}\left(P_i - O_i\right)}{n} \quad (3)$$

$$MAE = \frac{\sum_{i=1}^{n}\left|P_i - O_i\right|}{n} \quad (4)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left(P_i - O_i\right)^2}{n}} \quad (5)$$

Where P_i represents the amount of precipitation predicted by the satellite and O_i is the amount of precipitation observed at the synoptic stations, n is the number of precipitation data times, $\bar{P}$ is the average amount of precipitation per pixel, and $\bar{O}$ is the average amount of precipitation at the synoptic stations. Positive values of R and negative values of MAE and RMSE indicate high accuracy. Also, negative and positive values of BIAS, respectively, mean low and high evaluation of satellite precipitation data, respectively.

In addition to the TRMM 3B42 V7 satellite product verification for precipitation event, statistical indices such as the POD, FAR, and CSI were used on a monthly basis. POD is the fraction of precipitation events correctly identified by the satellite. FAR indicates a fraction of precipitation events that are not correctly detected by the satellite (Ebert et al., 2007; Wilks, 2011). While the CSI indicates the number of correct prediction of a rainfall event divided by the total number of hits, false alarms (EI Kenawy et al., 2019). The 2×2 probability table of event and no-event precipitation for each precipitation index is shown in Table 1.

$$POD = \frac{a}{a + c} \quad (6)$$

$$FAR = \frac{b}{a + b} \quad (7)$$

$$CSI = \frac{a}{a + b + c} \quad (8)$$

$$Absolute\,error\,(\%) = \frac{(a+b)+(a+c)+(c+d)+(b+d)}{Total} \times 100 \quad (9)$$

Table 1. Probability of precipitation occurrence

Station / Satellite	Gauges Rain	Gauges No-Rain	Total
Satellite Rain	Hits (a)	False alarm (b)	a + b
Satellite No- Rain	Misses (c)	Correct Negative (d)	c + d
Total	a +c	b +d	Total

In the above equations, *a* represents the state of occurrence at the precipitation station, and the satellite indicates the occurrence of precipitation. Furthermore, *b* indicates a condition that did not occur at the precipitation station, but the satellite indicates the precipitation event. c indicates the condition that occurred at the precipitation station, but the satellite does not indicate its occurrence. *d* (Correct Negative) indicates a condition that did not occur at the precipitation station and the satellite did not show it. The best values for POD, FAR, and CSI are one, zero, and one, respectively (Wilks, 2011). Also, in the present study, for the first time, the absolute error of satellite estimation data (Absolute error) was calculated on a daily scale, which has not been done in any previous research. In fact, one of the most important differences of this study from previous studies is the absolute error calculation. The absolute error of satellite estimation data calculates the percentage of satellite success in detecting rainfall events, percentage of satellite error in detecting precipitation event, percentage of satellite error in detecting precipitation event, and the percentage of satellite success in detecting precipitation events on Iranian water basins.

3. Results and discussion

In this study, a comparison of the TRMM precipitation database based on precipitation was performed on Iranian synoptic stations. What is more important than comparison is the use of data from this database with greater confidence. Temporal breach of climatic data is a major obstacle for many studies. Iran is widely distributed in time and space, thus deconstructing the climate parameters is very important.

The findings of this study showed that there is the least coordination between the TRMM precipitation database and station precipitation on a daily scale. At this scale, the predicted values of the TRMM precipitation database are much higher than the predicted precipitation values at the stations (Figure 1-A). The linear coefficient (R^2) between the precipitation of the TRMM precipitation database and the precipitation of stations on a daily scale indicates the different outputs of both databases (Figure 1-B).

In addition, in this study, the performance and performance of the TRMM database were compared with the precipitation data of the synoptic stations. Furthermore, Satellite Success Percentage, Satellite Error Detection, Satellite Error Detection, and Satellite Success Percentage on Iranian Water Basins were calculated. Based on the satellite map of the percentage of success of satellite event detection, the TRMM rainfall database performance in precipitation event detection in the Caspian Sea, Urmia Lake, and the Persian Gulf catchments is higher. On the Caspian high coast, the efficiency and performance of the TRMM base for accurate detection of precipitation is about 20%. Yet, on the high Zagros middle zone, values of them are about 7%. Satellite performance is relatively low in detecting precipitation events on the Central Plateau, Oman Sea, and the Persian Gulf basins. Overall, the satellite's success rate in detecting precipitation events in the watersheds is 1.7%. The TRMM estimated rainfall events on Iran's water basins to be 9.92% lower (see table 2).

An analysis of the satellite error percentage distribution map for precipitation event detection made it clear that the TRMM precipitation database was not able to accurately detect precipitation events in high-lying areas of Iran such as the south-west coasts of Caspian and Zagros. This percentage is less than 10% in the aforementioned areas. However, this percentage is relatively higher in the catchments of the Central Plateau, especially the Oman Sea and the Persian Gulf. Overall, the percentage of satellite error detection in precipitation was 7.31%.

Distribution of satellite error percentage in precipitation event detection showed that the performance of the TRMM rainfall database in event detection and rainfall event in Caspian, Urmia, and northern Persian Gulf catchments was higher and higher than other catchments. On the high costs of the Caspian Sea was 20%. This proportion was relatively lower in the Central Plateau catchment and even in parts of this basin. The percentage of satellite error in detecting precipitation events on Iranian water basins was 1.11%.

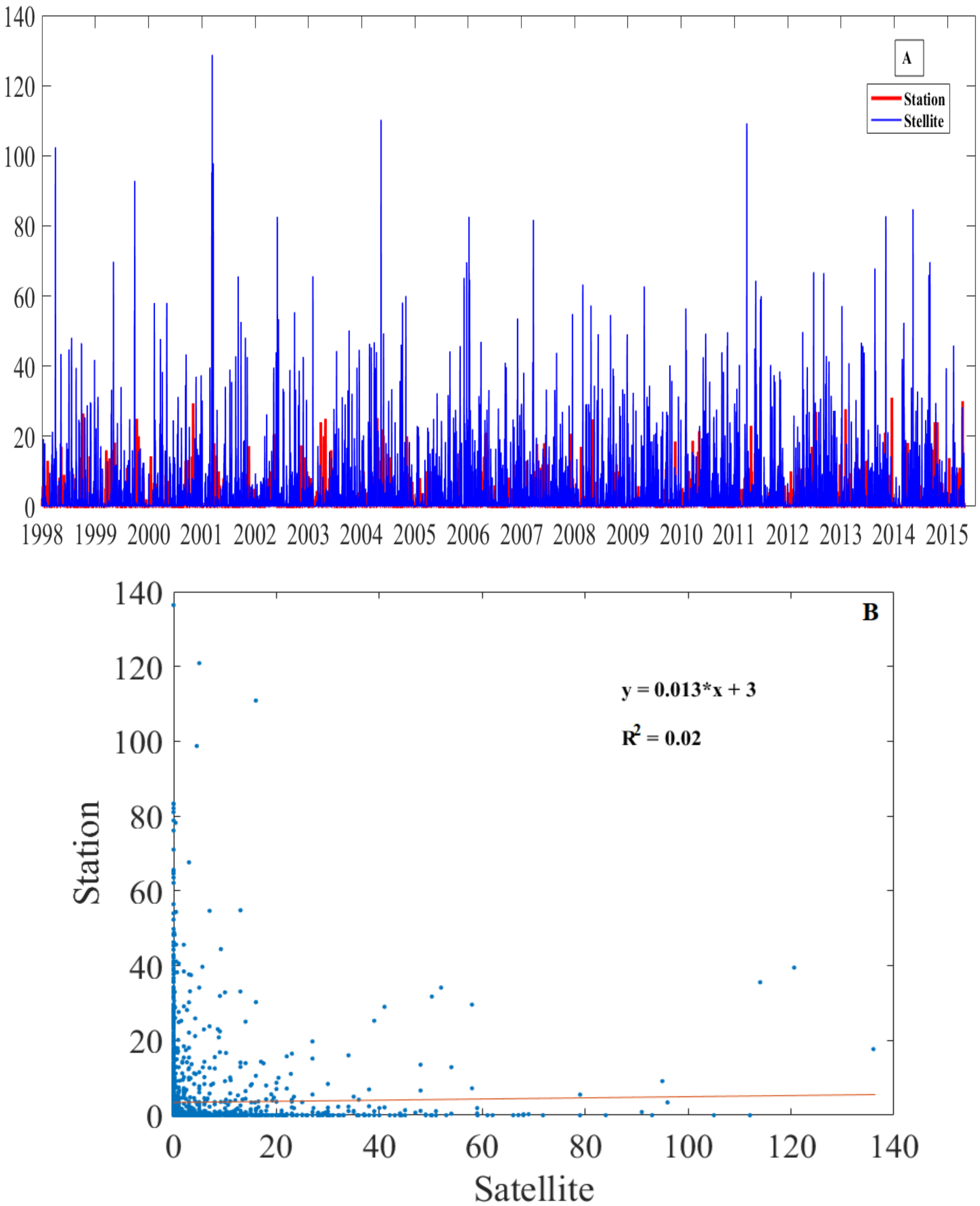
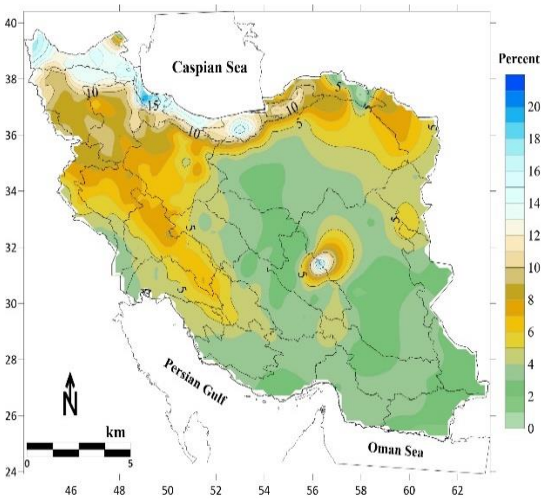
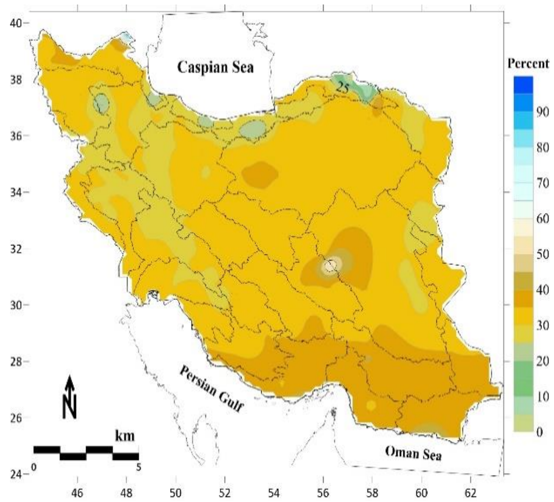


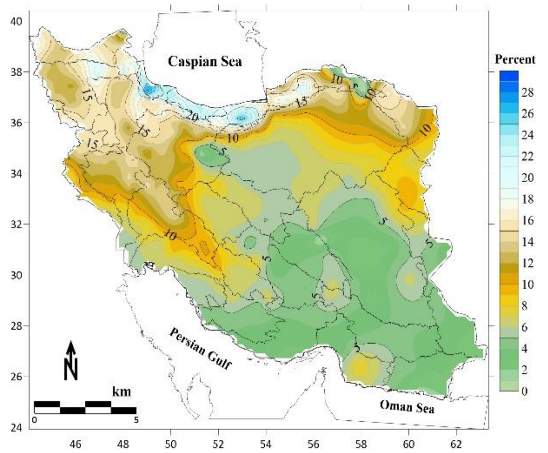
Fig 1. Time series (A), R^2 (B), between TRMM database rainfall data and daily synoptic station precipitation data



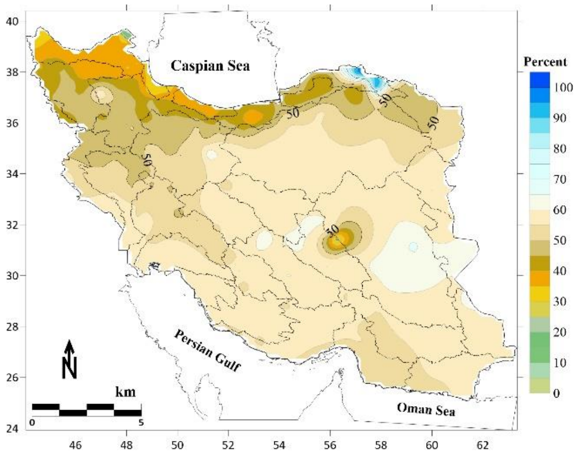
Satellite success rate in detecting precipitation



Satellite error rate of detection no-precipitation



Satellite success rate in detecting precipitation



Satellite error rate of detection no-precipitation

Fig 2. Satellite Absolute Error in Accurately Determining Occurrence and Non-Occurrence of Daily Scale Precipitation on Iran's Watersheds

Table 2. Percentage of the occurrence and non-occurrence of precipitation

Station / Satellite	Gauges Rain	Gauges No-Rain
Satellite Rain	1.7%	7.31%
Satellite No-Rain	1.11%	1.50%

Based on the distribution map of the satellite's percentage of success in accurately detecting rainfall events, it can be said that satellite performance in detecting rainfall events is higher in Caspian and Urmia catchments. Overall, the satellite's success rate in detecting rainfall events in Iran's catchments is 1.5%. Overall, the TRMM database corresponds to the data of the synoptic stations in 2.57% of cases. However, in 8.42% of the cases, the TRMM baseline prediction cannot be trusted.

3.1.Evaluation of TRMM accuracy and precipitation data of monthly synoptic stations

In order to assess the accuracy of the TRMM rainfall estimation in the Iranian catchments in a single unit, the indices used in this study were calculated separately for each month (Figure 4). In order to evaluate the accuracy of the TRMM database precipitation data, the method of comparing the nearest observation station to the representative pixel center of the station on the case study was used; the analysis showed the R^2 between this base and Precipitation is very poor throughout the year, even in January, February, May, June, July, and August. The average values of TRMM rainfall and precipitation were also compared. As the figure shows, there is no co-ordination between the baseline case and the precipitation of the stations during all months and during the period investigated.

The positive and negative values of the TRMM rainfall database are compared with the rainfall data of the station data using the BIAS. The skewed average precipitation calculation for the surveyed base and stations in all months shows significant results. In all months of the Iranian catchments, there is a difference of about 6-4.1 mm between the two bases. Most of the precipitation predictions are observed in the Caspian and Persian Gulf catchments. In these areas, the precipitation from the TRMM base prediction is more than the precipitation estimated by the stations. However, the predicted amount of precipitation in the fertile regions of Iran (southwest coast of Caspian and middle Zagros) is about -0.8 mm. This means that precipitation in these areas is, on average, about 0.8 mm lower than the precipitation of the stations. Therefore, it can be concluded that the estimated rainfall of the TRMM database is lower in the high-rainfall areas than in the stations. This study is consistent with the results of the study by Vernimmen et al. (2012) in Indonesia and Sebastian, et al., (2019) in China. Their research showed that the estimation of the TRMM 3B42 V7 product in the coastal and high-altitude zones is different from other satellites.

MAE was used to identify the average difference between the TRMM database and station precipitation data. Based on the distribution map of this index, the average difference between the estimated TRMM baseline precipitation and the estimated precipitation of the stations in all months on the Iranian water basins was between 0 and 7.5 mm. The maximum estimated rainfall of the base is observed on the southwest coast of the Caspian with an error rate of more than 7.5 mm, which is consistent with the findings of Sebastian, et al., (2019) in China. Only in a small part of southeastern Iran is the estimated error rate zero. RMSE was used to detect the average error between precipitation estimated by the WAC and base stations with higher weight for high errors, making the RMSE mean difference between the estimated rainfall from the TRMM rainfall database and the estimated rainfall from the stations' overall water basins is between 1 and 17 mm. The baseline error of the case study is higher than the rainfall received by the stations on the high-lying areas of Iran (southwest coasts of the Caspian Sea and Zagros).

As Table 3 shows, in general, the R between TRMM bases and station rainfall is very poor across Iranian water basins throughout the year. The BIAS is high at different months of the year. The maximum amount of precipitation in March was 2.613 mm. During the cold months, the highest MAE is observed in the cold months, RMSE and highest in all months. According to the POD, the days of rainfall occurrence in Iran's watersheds are high in the rainy months relative to the low rainfall months, with the likelihood of accurate detection of precipitation occurring in January. The FAR is the same as the POD during the most productive months of the TRMM database. Based on the CSI, the baseline case study performs well in identifying the days of the event and the event of precipitation on the water basins. The satellite also performs well in accurately detecting days of rainfall.

3.2.TRMM monthly precipitation spatial distribution

The spatial distribution of the mean long-term monthly precipitation of the TRMM database over the Iran area is given in Figure 5. The maximum average precipitation in different months of the year in Table 4 indicates that most of the precipitation in Iran occurred in December and March, respectively.

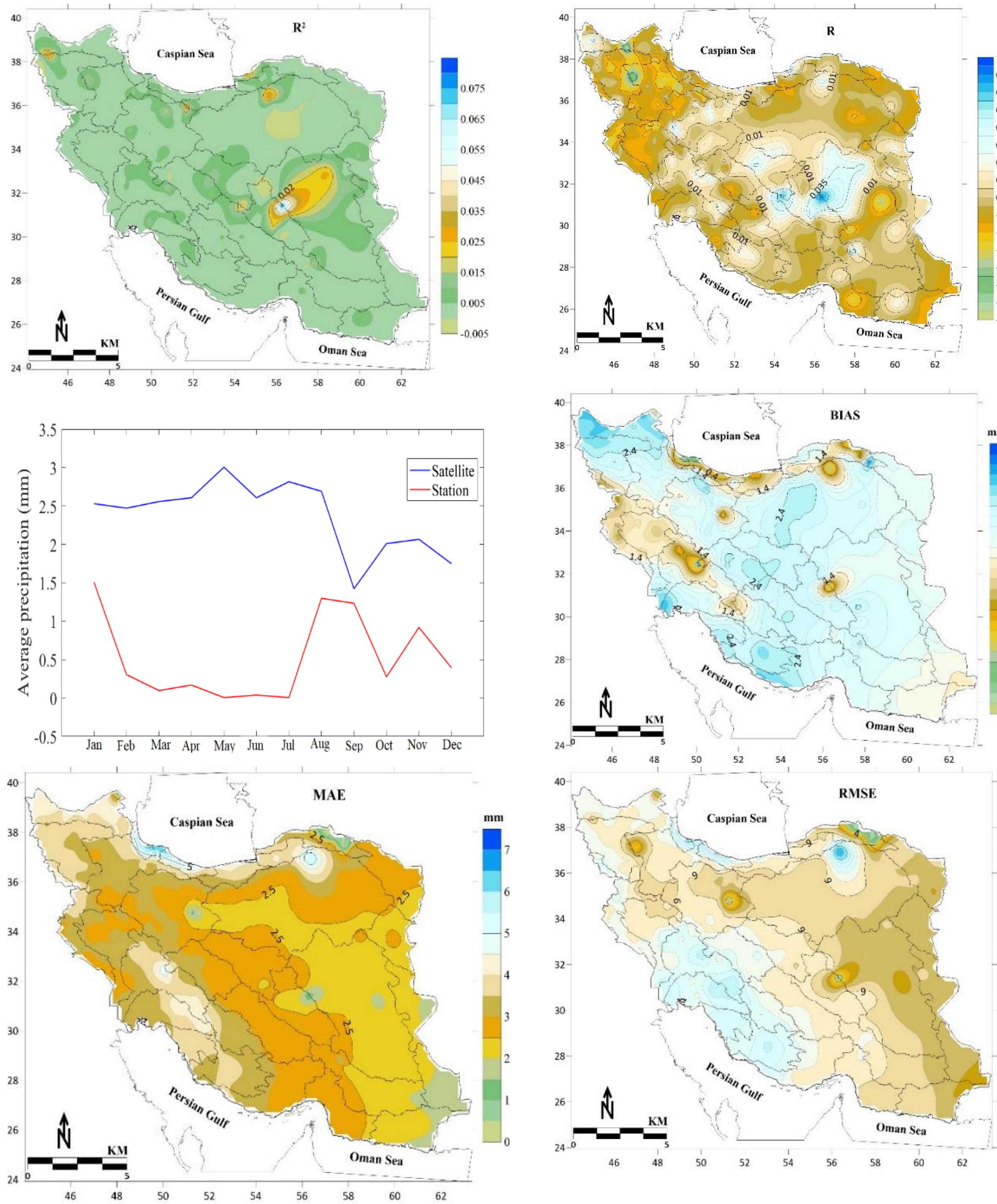


Fig. 3. Map of R, R^2, Rainfall Variation Chart, BIAS, MAE, and RMSE between TRMM monthly rainfall data and station data Monthly scale synoptic.

Table 3. Monthly values of tracer indices based on TRMM precipitation and synoptic stations precipitation

Month	CN (%)	CSI (%)	FAR (%)	POD (%)	RMSE (mm)	MAE (mm)	BIAS (mm)	R^2
Jan.	42	22.5	2.15	3.20	10.97	3.9	1.484	0.5
Feb	45.7	24.2	5.18	6.11	10.238	3.476	2.047	0.4
Mar	44.7	29.3	16	10	10.217	3.051	2.613	0.3
Apr	39.9	32.9	2.16	11	8.596	2.743	2.38	0.1
May	45.7	33.7	6.11	9	8.004	2.397	2.104	0.4
Jun	51	40.9	4.4	7.3	8.225	2.583	2.260	0.4
Jul	55.2	38.5	5.3	8.2	10.099	2.223	2.282	0.5
Aug	60	34.3	4.3	3.2	10.219	3.776	1.254	0.5
Sep	59.2	34.3	6.3	9.2	9.752	3.488	0.839	0.5
Oct	53.5	32.7	1.8	7.5	10.165	3.41	1.287	0.6
Nov	49.6	26.8	9.14	7.8	11.186	3.817	1.195	0.4
Dec	53.5	29.7	2.8	6.8	10.9	3.732	1.546	0.5

Table 4. The average TRMM rainfall in different months of the year.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rain(mm)	142.8	139.64	163.9	127.55	128.97	138.94	124.29	131.53	130.67	145.22	157.14	**164.97**

4. Conclusions

In this study, the TRMM database and measured rainfall at 410 synoptic stations in Iran from 01.01.1998 to 31.12.2015 were compared. The purpose of this study was to evaluate the accuracy of TRMM basin precipitation values in Iran catchments. To achieve this goal, the accuracy of the estimated precipitation values in the daily and monthly time scales of this base was compared with the measured precipitation values of the synoptic stations using the indices analyzed in the study. If there are low errors and high correlation between the TRMM database and measured data, TRMM database information can be used to predict precipitation.

Overall, the results of TRMM basin precipitation assessment on Iran catchments showed that:

1. Correlation between precipitation of TRMM 3B42 V7 and rainfall of synoptic stations with 25.0 to 25.0-degree spatial resolution on a daily and monthly scale in Iran catchments.

2. Evaluation of TRMM 3B42 V7 product in Iranian catchments showed that based on BIAS the precipitation product analyzed in all catchments of Iran was overestimated. At the same time, estimates of bases on the fertile areas of Iran (south-west coast of Caspian and Zagros) are lower.

3. Based on the values of MAE and RMSE, the product analyzed overall catchments of Iran, especially in the high-rainfall areas, was overestimated, indicating a high assessment of the Iranian rainfall by the product. It has a TRMM 3B42 V7.

4. The results showed that TRMM 3B42 V7 precipitation processing efficiency varied depending on the amount of rainfall received by different regions.

5. Estimated precipitation values by TRMM 3B42 V7 are always higher than actual values recorded at synoptic stations located in catchments of Iran.

6. Absolute error analysis of the data showed that in 2.57% of cases, the satellite corresponds to the data of the synoptic stations, and in 8.42% of cases, there is no concordance.

7. Overall, based on the findings of this study, the accuracy of the TRMM 3B42 V7 satellite product is very poor in detecting precipitation on Iranian catchments, and it is not able to accurately detect the amount of rainfall. Therefore, if there is a problem with a shortage of station data, TRMM 3B42 V7 output data cannot be trusted.

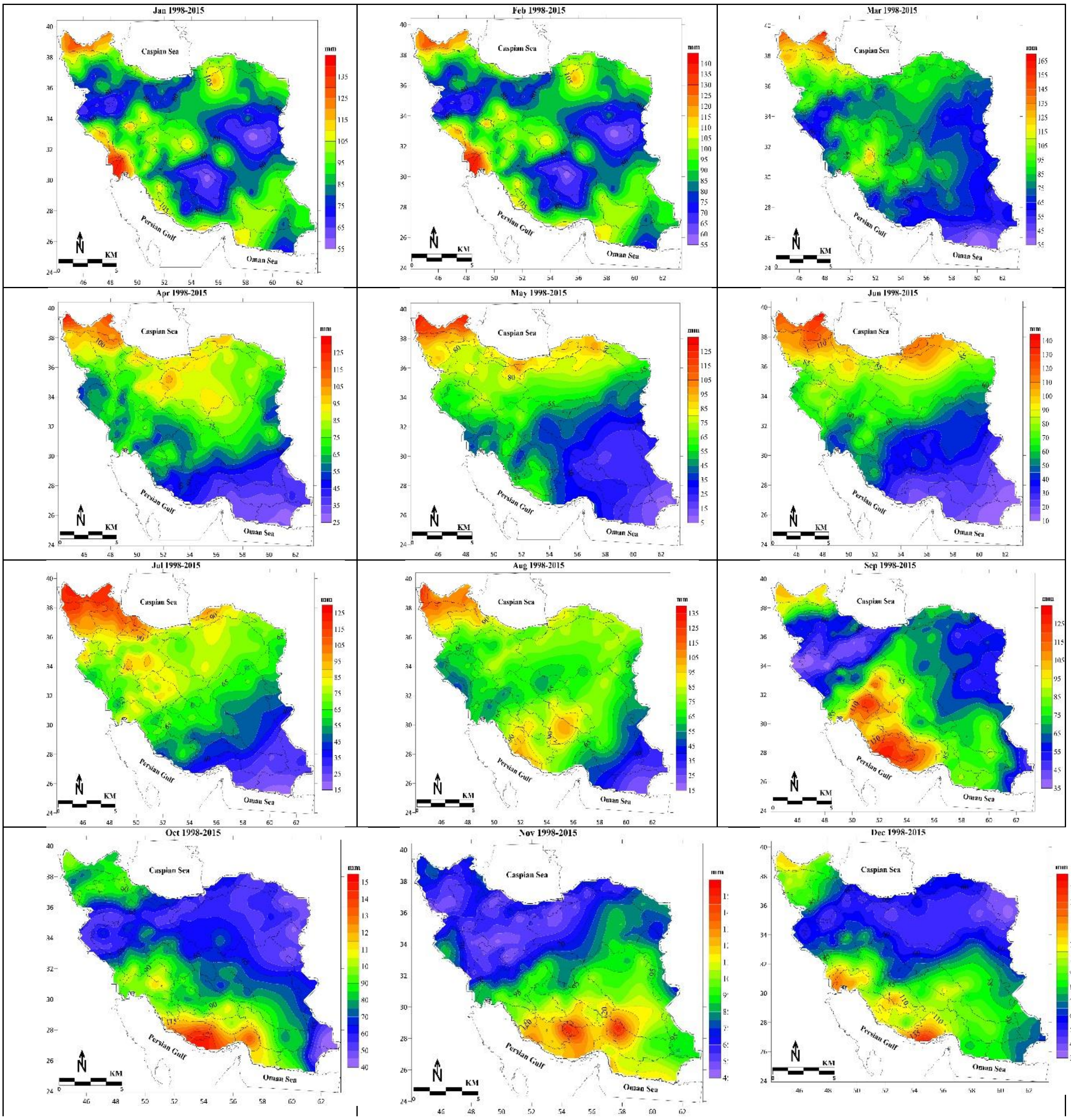


Fig. 4. Spatial Distribution of Average Monthly Precipitation TRMM Data.

5. Acronyms

TRMM	Tropical Rainfall Measurement Mission
POD	Probability of detection
FAR	Fault Alert Ratio
CSI	Critical Success Index
IMO	International Meteorological Organization
R	Correlation
R^2	Coefficient of determination
BIAS	Bias index
MAE	Absolute mean error data
NASA	US National Aeronautics and Space Administration
JAXA	Japanese Space Exploration Agency

6. Acknowledgment

This research is extracted from a part of the results of the project 2-29-29-94114 which was done using the facilities of Soil Conservation and Watershed Management Research Institute and we hereby thank the esteemed officials of the research institute for their support and assistance.

7. Disclosure statement

No potential conflict of interest was reported by the authors

8. References

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