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Comparison between Iraqi Gauges and TRMM Rainfall Data Over Middle Euphrates Region During Period from 1998 to 2017

Abstract- *The aim of this paper is evaluated and compares between Iraqi gauges in the Middle Euphrates region and TRMM rainfall data during the period from 1998 to 2017. Middle Euphrates Region, whose Area is 26611 km2 was selected as a study area. Two sets of Iraqi data gauges and Tropical Rainfall Measuring Mission (TRMM) average monthly rainfall data were used for analysis. Rainfall data were acquired from two sources, Iraqi Meteorological Organization and Seismology (IMOAS) and Giovanni website to download TRMM v7 0.25-degree data. Data collected from five stations in the study area and these stations are, Dewaniya, Hilla, Karbala, Najaf, and Semawa. Statistical analysis indices such as bias, root mean square error (RMSE), and R-Square were used to comparison between data. Monthly and seasonally comparison approaches have been used to understand the relationships, trends and error propagations between two data sets for five gauges' station. The final results of monthly comparison approach were illustrated that some of the months have good agreements for each to other and other months have medium and weak agreements between two data sets in all five stations which mentioned above. Also, the results of seasonally comparison approach were illustrated that some of the seasons have good agreements for each to other and other seasons have medium and weak agreements between two data sets in all five stations which mentioned above. There are high values of Bias and RMSE between some months and some seasons of two data sets in all stations; this meaning there are high shifting between them.*

Keywords- *Bias, Iraqi gauges, Middle Euphrates Region, Rainfall, and TRMM.*

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1. Introduction

Rainfall is the most important forcing data for hydrological models and the prime necessity of life on Earth [1]. Accurate estimation of rainfall is crucial for crop yield assessment, water resource management and flood and drought monitoring. Excess rainfall causes severe flooding, property and lives loss. The extended absence of rainfall leads to droughts, which can devastate crop yields and limits human consumption [3]. Rainfall is a highly dynamic process, constantly changing in form and intensity as it passes over a given area. Traditionally rainfall is measured using rain gauges, an instrument that accurately measures the actual amount of rain that falls over it [2]. Rain gauge measurements are usually limited by their spatial coverage. A network of weather radars provides good spatial and temporal coverage. However, the problem of inter-radar calibration and blockage by mountains still limit its capability. Remote sensing techniques using space-borne sensors provide an excellent complement to continuous monitoring of rain event both spatially and temporally [3]. These sensors do not measure rain directly, but the reflection of electromagnetic waves from the falling droplets over a volume. The relation between the reflections and the corresponding rain rate must be established, to achieve the corresponding rainfall data [2]. The Tropical Rainfall Measuring Mission (TRMM) is the first space mission dedicated to measuring tropical and subtropical rainfall through microwave and visible/infrared sensors. TRMM is a joint mission between the National Aeronautics and Space Administration (NASA) of the United States and the Japan Aerospace Exploration Agency (JAXA) of Japan. The satellite was launched on November 27, 1997, and is currently continuing to operate. The objectives of TRMM are to measure rainfall and energy (i.e., latent heat of condensation) exchange of tropical and subtropical regions of the world from the space. The Precipitation Radar (PR) is crucial to the TRMM mission because of its ability to see the precipitation field with high resolution in both the

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horizontal and vertical. The PR operates at a frequency of 13.8 GHZ (2.17 cm wavelength, Ku band) [4]. This paper aims to evaluate and compare between five stations of Iraqi gauges in the Middle Euphrates region and TRMM V7 rainfall data during the period from 1998 to 2017 over Middle Euphrates Region.

2. Materials and Methods

I. study area

The study area is the middle Euphrates region of Iraq. It is bounded by the coordinates (from 43° 30' E to 45° 30' E) longitude and (from 31° 0' N to 33° 0' N) latitude in zone 38N according to UTM projected coordinate system. It covers an area of 26611 Km^2 (Figure 1). The climate of the study area is arid to semi-arid with dry hot in summer and cool in winter. Rainfall in the area begins in October and ends in June after which it becomes scarce. Maximum of the monthly average rainfall values is 20 mm in January as shown in Figure 2.

II. Rainfall data

The monthly rainfall data were collected from Iraqi Meteorological Organization and Seismology (IMOAS). Twenty years from 1998 to 2017 of monthly rainfall were obtained from five gauge stations over the study area and these stations are: Dewaniya, Hilla, Karbala, Najaf, and Semawa.On the other hand, The monthly rainfall TRMM 3B43 version 7 data were used in this paper during the period 1998 to 2017.TRMM 0.25 degree data were downloaded from Giovanni as csv, TRMM online visualization and analysis system (TOVAS) of Goddard Earth Sciences, data and information services center (GES DISC), NASA [1]. For this research, area-averaged monthly rainfall data were used.

III. Statistical Indices

To compare rainfall data, the following statistical analysis indices were used: bias, root mean square error (RMSE), and R-Square [5].

$$Bias = \frac{\sum_{i=1}^{N}(Rsi-Roi)}{N}\ mm \quad (1)$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(Rsi-Roi)^2}\ mm \quad (2)$$

$$R = \frac{\sum_{I=1}^{N}(Rsi-AV.Rs)(Roi-AV.Ro)}{\sqrt{\sum_{i=1}^{N}(Rsi-AV.Rs)^2}\ \sqrt{\sum_{i=1}^{N}(Roi-AV.Ro)^2}} \quad (3)$$

Where:
Rsi is the value of TRMM rainfall data
Roi is the value of IMOAS rainfall data
AV.Rs is the average value of TRMM rainfall data
AV. Ro is the average value of IMOAS rainfall data.

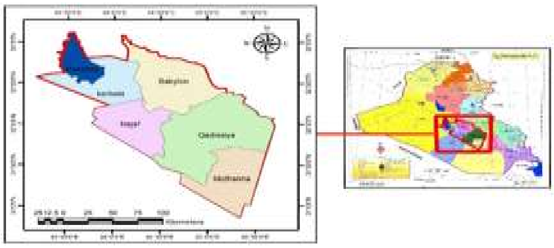

Figure 1: Iraq map with a map represents the study

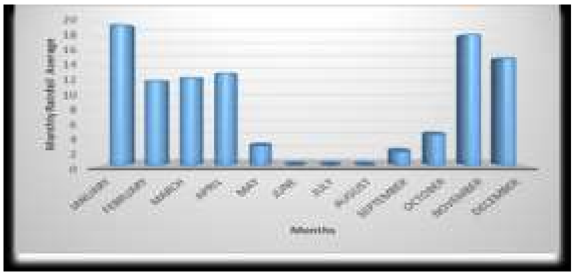

Figure 2: The average of monthly Rainfall (mm) 1998-2017 (IMOAS 2017)

3. Results and Discussion

In this paper, monthly and seasonally comparison approaches have been used to understand the relationships, trends and error propagations between IMOAS and TRMM Rainfall data for five gauge stations. The evaluation results follow:

I. Monthly comparison approach

In this approach, twenty years monthly average of two sets of data were used. These years began from 1998 to 2017. The Tables from 1-5 and Figures from 3-7 summarize the Bias, RMSE, and R-Square between the IMOAS and TRMM rainfall data for stations of the study area.
Table 1 and Figure 3 show statistical results of IMOAS and TRMM rainfall data over Dewaniya station. The correlation between IMOAS and TRMM rainfall data were 0.51, 0.58, 0.87, and 0.51 during April, May, September, and November respectively and the other months correlate less than 0.5. There are good agreements between two sets of data in September and medium agreement in April, May, and November, on the other hand, there is a weak agreement in the other months in this station. Table 2 and Figure 4 show statistical results of IMOAS and TRMM rainfall data over Hilla station. The correlation between IMOAS and TRMM rainfall data were 0.72, 0.63, 0.8, and 0.57 during April, May, September, and October respectively and the other months correlate less than 0.5. There are good agreements between two sets of data in April and September, medium agreement in May and October; on the other hand, there is a weak agreement in the other months in

this station .Table 3 and Figure 5 show statistical results of IMOAS and TRMM rainfall data over Karbala station. The correlation between IMOAS and TRMM rainfall data were 0.52, 0.67, 0.75, 0.56, 0.51, and 0.54 for April, May, September, October, November, and December respectively and the other months correlate less than 0.5. There are good agreements between two sets of data in September, and medium agreement in April, May, October, November, and December, on the other hand, there are a weak agreement in the other months in this station. Table 4 and Figure 6 show statistical results of IMOAS and TRMM rainfall data over Najaf station. The correlation between IMOAS and TRMM rainfall data were 0.61, 0.77, 0.74, and 0.59 during May, September, October and December respectively and the other months correlate less than 0.5. There are good agreements between two sets of data in September and October, medium agreement in May and December; on the other hand, there are weak agreements in the other months in this station.

Table 5 and Figure 7 show statistical results of IMOAS and TRMM rainfall data over Semawa station. The correlation between IMOAS and TRMM rainfall data were 0.82, 0.63, 0.53, 0.72, 1, 0.62, and0.57during February, March, April, May, September, October, and December respectively and the other months correlate less than 0.5. There are high agreements between two sets of data in September, good agreement in February and May and medium agreement in March, April, October, and December, on the other hand, there is a weak agreement in the other months in this station.

The correlation is increased with decreased bias and RMSE between two sets of data. On the other hand, June, July, And August months have zero value in two sets of data in all stations; therefore there are not shifting between two sets of data during these months. Finally, all results were illustrated that some of months have good agreements for each to other and other months have medium and weak agreements between two data sets in all five stations which mentioned above. There are high values of Bias and RMSE between some months of two data sets in all stations; this meaning there are high shifting between them.

Table 1: Statistical results between average monthly rainfall data of IMOAS and TRMM in Dewaniya station 1998 -2017

Month	IMOAS Rain Average mm	TRMM Rain Average mm	Bias mm	RMSE mm	RSQ
Jan.	22.94	26.00	3.06	20.51	0.25
Feb.	11.14	16.43	5.29	15.78	0.18
Mar.	9.26	21.51	12.2	23.38	0.48
Apr.	12.99	13.26	0.28	10.05	0.51
May	2.67	5.95	3.28	5.55	0.58
Sep.	0.00	0.08	0.08	0.15	0.87
Oct.	3.60	8.77	5.17	13.09	0.08
Nov.	18.92	22.96	4.04	17.87	0.51
Dec.	15.29	14.63	-0.6	14.73	0.39

Table 2: Statistical results between average monthly rainfall data of IMOAS and TRMM in Hilla station 1998 -2017

Month	IMOAS Rain Average mm	TRMM Rain Average mm	Bias mm	RMSE mm	RSQ
Jan.	19.73	35.71	15.98	27.5	0.41
Feb.	11.27	19.81	8.54	18.9	0.25
Mar.	10.87	27.80	16.93	36.9	0.43
Apr.	10.80	16.80	6.01	15.1	0.72
May	3.04	7.15	4.12	7.20	0.63
Sep.	0.19	0.36	0.18	0.79	0.80
Oct.	4.40	9.69	5.29	14.8	0.57
Nov.	19.95	26.22	6.27	17.6	0.45
Dec.	18.28	16.71	-1.57	23.9	0.05

Table 3: Statistical results between average monthly rainfall data of IMOAS and TRMM in Karbala station 1998 -2017

Month	IMOAS Rain Average mm	TRMM Rain Average mm	Bias mm	RMSE mm	RSQ
Jan.	15.37	32.49	17.12	28.7	0.45
Feb.	10.03	26.15	16.12	27.8	0.47

Mar.	13.79	30.72	16.94	41.6	0.13
Apr.	8.70	19.60	10.90	20.6	0.52
May	2.65	8.26	5.61	8.82	0.67
Sep.	0.02	0.56	0.54	0.93	0.75
Oct.	3.01	8.90	5.89	14.7	0.56
Nov.	12.87	31.02	18.15	36.2	0.51
Dec.	10.87	25.93	15.06	22.3	0.54

Table 4: Statistical results between average monthly rainfall data of IMOAS and TRMM in Najaf station 1998 -2017

Month	IMOAS Rain Average mm	TRMM Rain Average mm	Bias mm	RMSE mm	RSQ
Jan.	15.66	22.75	7.09	15.7	0.43
Feb.	9.45	14.69	5.25	13.5	0.41
Mar.	7.90	17.06	9.16	18.7	0.31
Apr.	11.13	17.01	5.88	22.6	0.34
May	3.29	5.68	2.40	5.64	0.61
Sep.	0.00	0.13	0.13	0.23	0.77
Oct.	4.56	6.42	1.87	4.07	0.74
Nov.	15.26	21.34	6.08	15.7	0.43
Dec.	12.76	15.33	2.57	8.89	0.59

Table 5: Statistical results between average monthly rainfall data of IMOAS and TRMM in Semawa station 1998 -2017

Month	IMOAS Rain Average mm	TRMM Rain Average mm	Bias mm	RMSE mm	RSQ
Jan.	19.02	25.65	6.63	17.8	0.46
Feb.	13.67	14.01	0.34	2.93	0.82
Mar.	17.43	19.69	2.27	12.5	0.63
Apr.	11.13	14.02	2.89	14.1	0.53
May	4.78	6.95	2.17	12.3	0.72
Sep.	0.05	0.06	0.01	0.02	1.00
Oct.	3.66	6.95	3.30	10.8	0.62
Nov.	16.77	21.04	4.27	27.7	0.43
Dec.	14.52	18.14	3.62	15.8	0.57

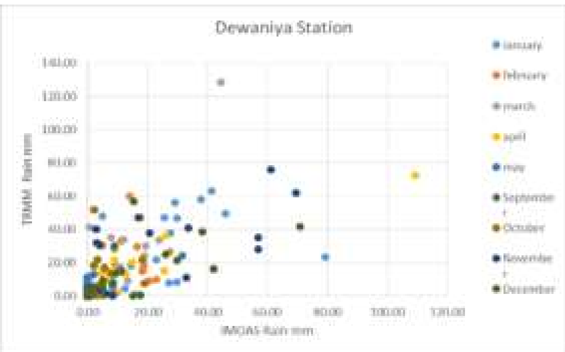

Figure 3: Scatter plot between monthly rainfall data of IMOAS and TRMM in Dewaniya station 1998-2017

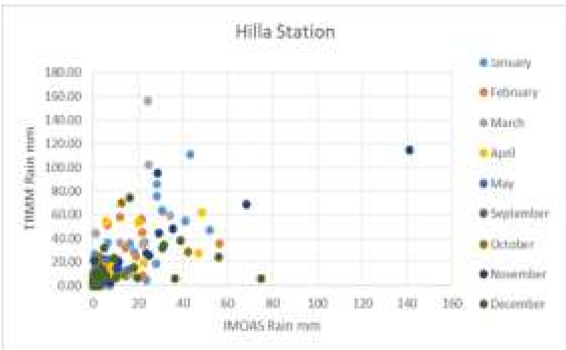

Figure 4: Scatter plot between monthly rainfall data of IMOAS and TRMM in Hilla station 1998-2017

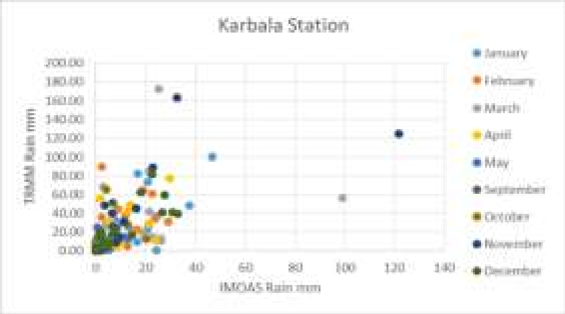

Figure 5: Scatter plot between monthly rainfall data of IMOAS and TRMM in Karbala station 1998-2017

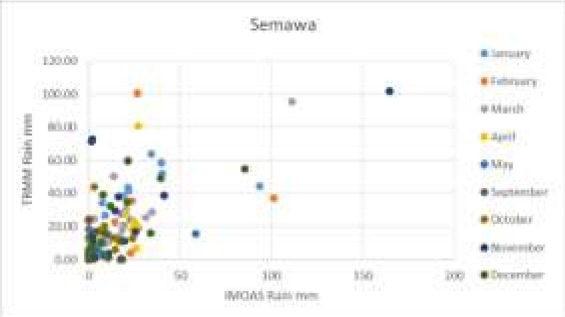

Figure 6: Scatter plot between monthly rainfall data of IMOAS and TRMM in Najaf station 1998-2017

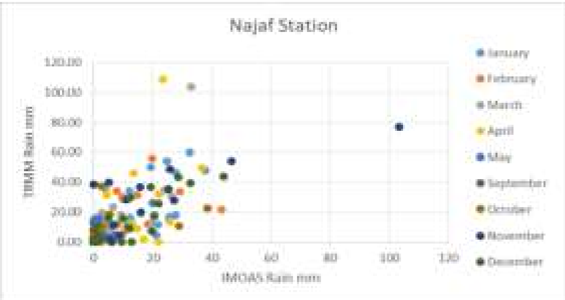

Figure 7: Scatter plot between monthly rainfall data of IMOAS and TRMM in Semawa station 1998-2017

II. Seasonally comparison approach

In this approach, twenty years seasonally average of two sets of data were used from 1998 to 2017. The Tables from 6-10 and Figures from 8-12 summarize the Bias, RMSE, and the correlation between the IMOAS and TRMM rainfall data for stations of the study area. The results of Dewaniya station were illustrated that the correlation between IMOAS and TRMM rainfall data were 0.29, 0.51, and 0.54 for winter, spring and autumn respectively.

There are medium agreements between two sets of data in spring and autumn; on the other hand, there are a weak agreement in winter in this station as shown in Table 6 and Figure 8. The results of Hilla station were illustrated that the correlation between IMOAS and TRMM rainfall data were 0.46, 0.60, and 0.84 for winter, spring and autumn respectively. There are good agreements between two sets of data in autumn and medium agreement in spring, on the other hand, there are a weak agreement in winter in this station as shown in Table 7 and Figure 9. The results of Karbala station were illustrated that the correlation between IMOAS and TRMM rainfall data were 0.59, 0.45, and 0.73 for winter, spring and autumn respectively.

There are good agreements between two sets of data in autumn and medium agreement in winter, on the other hand, there are a weak agreement in spring in this station as shown in Table 8 and Figure 10. The results of Najaf station were illustrated that the correlation between IMOAS and TRMM rainfall data were 0.58, 0.44, and 0.74 for winter, spring and autumn respectively.

There are good agreements between two sets of data in autumn and medium agreement in winter, on the other hand, there are a weak agreement in spring in this station as shown in Table 9 and Figure 11.

The results of Semawa station were illustrated that the correlation between IMOAS and TRMM rainfall data were 0.47, 0.63, and 0.56 for winter, spring and autumn respectively. There are a medium agreement in spring and autumn, on the other hand, there are a weak agreement in winter in this station as shown in Table 10 and Figure 12. On the other hand, the summer season has zero value in two sets of data. Therefore, there are not shifting between two sets of data during this season.

The final results were illustrated that some of the seasons have good agreements for each to other and other seasons have medium and weak agreements between two data sets in all five stations which mentioned above.

Also, there are high values of Bias and RMSE between some seasons of two data sets in all stations; this meaning there are high shifting between them.

Table 6: Statistical results between average monthly rainfall data of IMOAS and TRMM in Dewaniya station 1998 -2017

Season	IMOAS Rain Average mm	TRMM Rain Average mm	Bias mm	RMSE mm	RSQ
Winter	16.45	19.02	2.5	17.1	0.29
Spring	8.30	13.58	5.2	15.0	0.51
Autumn	7.51	10.60	3.10	12.7	0.54

Table 7: Statistical results between average monthly rainfall data of IMOAS and TRMM in Hilla station 1998 -2017

Season	IMOAS Rain Average mm	TRMM Rain Average mm	Bias mm	RMSE mm	RSQ
Winter	16.43	24.08	7.65	23.7	0.46
Spring	8.23	17.25	9.02	23.4	0.60
Autumn	8.18	12.09	3.91	13.3	0.84

Table 8: Statistical results between average monthly rainfall data of IMOAS and TRMM in Karbala station 1998 -2017

Season	IMOAS Rain Average mm	TRMM Rain Average mm	Bias mm	RMSE mm	RSQ
Winter	12.09	28.19	16.1	26.4	0.59
Spring	8.38	19.53	11.1	27.3	0.45
Autumn	5.30	13.49	8.19	22.5	0.73

Table 9: Statistical results between average monthly rainfall data of IMOAS and TRMM in Najaf station 1998 -2017

Season	IMOAS Rain Average mm	TRMM Rain Average mm	Bias mm	RMSE mm	RSQ
Winter	12.62	17.59	4.97	13.0	0.58
Spring	7.44	13.25	5.81	17.2	0.44
Autumn	6.61	9.30	2.69	10.7	0.74

Table 10: Statistical results between average monthly rainfall data of IMOAS and TRMM in Semawa station 1998 -2017

Season	IMOAS Rain Average mm	TRMM Rain Average mm	Bias mm	RMSE mm	RSQ
Winter	15.73	19.27	3.53	19.1	0.47
Spring	11.11	13.55	2.44	13.0	0.63
Autumn	6.83	9.35	2.52	17.1	0.56

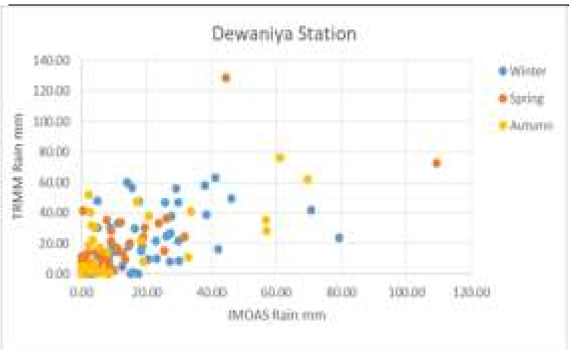

Figure 8: Scatter plot between monthly rainfall data of IMOAS and TRMM in Dewaniya station 1998-2017

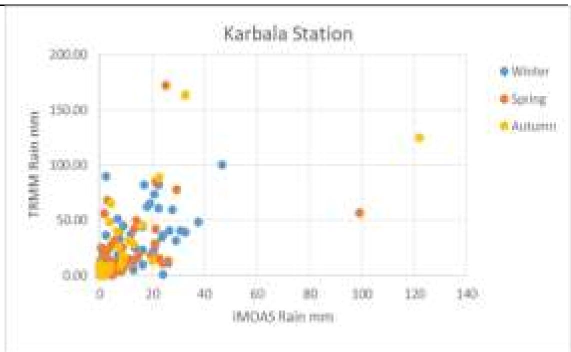

Figure 10: Scatter plot between monthly rainfall data of IMOAS and TRMM in Karbala station 1998-2017

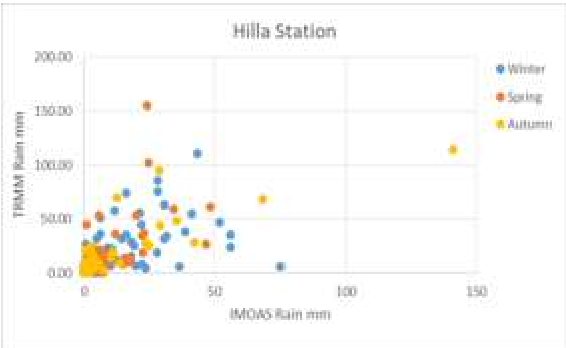

Figure 9: Scatter plot between monthly rainfall data of IMOAS and TRMM in Hilla station 1998-2017

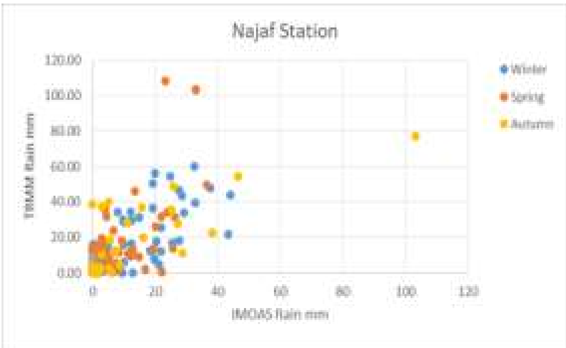

Figure 11: Scatter plot between monthly rainfall data of IMOAS and TRMM in Najaf station 1998-2017

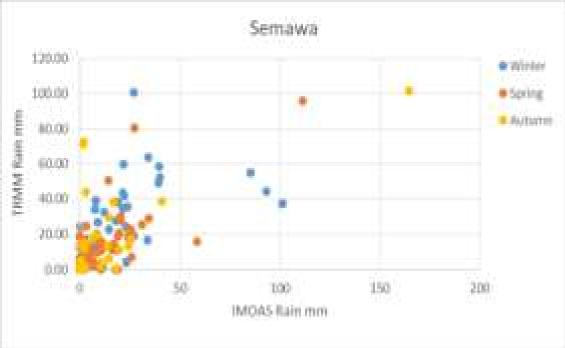

Figure 12: Scatter plot between monthly rainfall data of IMOAS and TRMM in Semawa station 1998-2017

4. Conclusions

In this paper there are three statistical indices were used: bias, root mean square error (RMSE), and R square.it is used to compare between Iraqi gauge rainfall data and TRMM rainfall data. Monthly and seasonally comparison approaches have been used to understand the relationships, trends and error propagations between Iraqi gauges and TRMM Rainfall data for five gauges stations over the Middle Euphrates region.

These stations are Dewaniya, Hilla, Karbala, Najaf, and Semawa. Finally, the results of monthly approach were illustrated that some of months have good agreements for each to other and other months have medium and weak agreements between two data sets in all five stations which mentioned above. June, July, And August months have zero value in two sets of data in all stations; therefore there are not shifting between two sets of data during these months. The correlation is increased with decreased bias and RMSE between two data sets. There are high values of Bias and RMSE between some months of two data sets in all stations; this meaning there are high shifting between them .

The final results of the seasonal approach were illustrated that some of the seasons have good agreements for each to other and other seasons have medium and weak agreements between two data sets in all five stations which mentioned above. The summer season has zero value in two sets of data in all stations; therefore there are not shifting between two sets of data during this season. The correlation is increased with decreased bias and RMSE between two data sets. Also, there are high values of Bias and RMSE between some seasons of two data sets in all stations; this meaning there are high shifting between them.

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