TEMPORAL COMPARISON OF GSMAP RAINFALL DATA: CASE STUDY IN WADI AL-KHOUD, SULTANTE OF OMAN

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ABSTRACT

This The Wadi Al-Kloud area is constantly exposed to floods due to the lack of sufficient stations to predict the intensity of the flood, which causes a danger to the infrastructure and the lives of people. This research studied the difference between the ground stations in the area and the satellite stations. The adjusted GSMaP estimates were blended with the rain gauge dataset, to evaluate the Global Satellite Precipitation Mapping Product (GSMaP) using rain gauges over 20 years (2001–2021). And we found that the satellite stations are more accurate than the ground stations and to provide data to correctly predict the intensity of floods the study was done daily, monthly, and annually. The coefficient correlation (R) results were, respectively, as follows; daily = 0.590, monthly = 0.742 and annually = 0.747.

Keywords: Flood, Wadi Al koud, stations, GSMaP.

1 INTRODUCTION

Precipitation is essential to sustaining life on Earth and is an indispensable part of the Earth's dynamic cycle and climate system[1].To enable efficient response and management of water-related natural disasters, their intensity, frequency, and duration must be measured more comprehensively and accurately.

The ground-based rain gauge is the traditional direct method of precipitation measurement and is also the most widely used and accurate method for precipitation monitoring but it also has certain limitations[2]. Rain gauges become insufficient for field measurement, so they cannot provide accurate data on precipitation in a particular area.

The poor assessment of accuracy in gridded precipitation analyzes lies in areas that are not well observed, especially in the spatial variability of precipitation, which is quite challenging as areas with complex topography in Oman.In addition, a rain gauge is not economical when it is necessary to increase estimates over an area and is also susceptible to instrument errors and sample biases.

Satellite observations contribute to providing complete data in areas with little data and are characterized by high spatial and temporal accuracy that complement the monitoring operations of ground rain gauge[3], [4].

Data poor regions need a product such as Global Satellite Precipitation Mapping (GSMaP) that provides information on the amount and distribution of precipitation for an area. GSMaP data are passive microwave radiometers and infrared radiometers mixed with hourly precipitation products[5]. GSMaP dataset consists of a standard product, a re-analysis product, real-time product, and a near-real-time product[1].

This study was usesGSMaP (Near-real-time) to monitor extremism over Wadi Al-Khoud, Oman. The beginning of using the GSMaP_NRT product is from 2002. GSMaP_NRT data gives accuracy required because it consists of high-resolution data with temporal (hourly and daily) and spatial resolution of (0.1) in a wide precipitation scale[6]. It is not expensive to measure precipitation. Moreover, they are readily available. However, there are major biases. This can be avoided by reducing biases by blending precipitation data with GSMaP data to make the estimates more reliable.

The accuracy of satellite precipitation products has been validated in disaster-prone regions such as East Asia and the Western Pacific. However, precipitation data from satellites needs a lot of studies to ensure their quality, so that satellite data become certified in each study area. GSMaP_NRT product has not been validated in Wadi Al-Khoudh region, Oman, although it is applied in many areas Such as Australia.

In this paper, we tried to evaluate the accuracy of the data set to estimate the accuracy of the GSMaP_NRT (satellite-based) product in Wadi Al-Khoud, Oman, by comparing the GSMaP_NRT data with the observed measurement data, which is the purpose of this research.

2 MATERIALS AND METHODS

2.1 Study Area

Our study area is Wadi Al-Khoud basin which is in sultanate of Oman in Muscat Governorate. Figure 1 shows a map of the basin used in this research, as well as a depiction of its topography. There is various type of topography and Wadi Samael and Wadi Al-Khoud separate the Al-Hajar mountain range into two parts: the eastern Al-Hajar mountain range, and the western Al-Hajar mountain range[7], [8]. It is a mountain range that covers a large part of northern Al Batinah in Oman. It extends from RasMusandam to Ras Al Hadd in the eastern region of Oman[9]. The Hajar Mountains extend in the form of a great arc from the northeast of the Sultanate of Oman to its southwest. Wadi Al-koud Basin is located in the northern part of Oman and at the -western north- part of Muscat, the capital of Oman at long: (57° 58′ W & 58° 02 E ′) and Lat: (24° 00′ N & 23° 00 S ′)[10]. It is classified as one of the estuaries for several wadis such as WadiBid bid, Samail and Fanja. The watershed area of wadiAlkoud basin is 1874.84 Km2 and the length is 93 km. The most important characteristic of the Al-Khoud region is its abundance of water, and the Al-Khoud region is characterized by its desert climate, as the temperatures in this region rise significantly in the summer, and the winter season is characterized by its warm temperature, and the rain falls in this region in small proportions. The Wadi Al-Khoud Basin has many uses as major water sources, such as agricultural and domestic uses.

2.2 Rain Gauge in Wadi Al-koud

Fig.2 The distribution of rain gauges over the Wadi Al-koud is depicted as black dots, where six ground stations are located in the vicinity of the valley. Precipitation information from Bid bid gauge station was used to validate the GAMaP_NRT estimate. Rain gauge information was taken from the Ministry of Regional Municipalities and Water Resources for Oman. It includes time scales of different precipitation (daily, monthly, annual) over eight years (2014-2021).

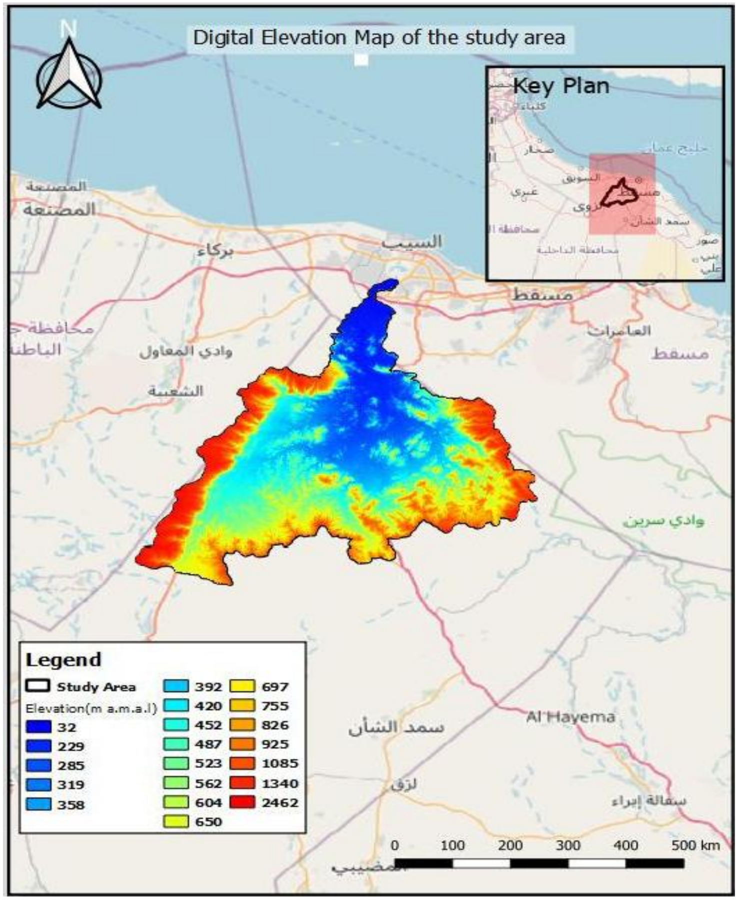

Figure 1. Map of study area showing elevation

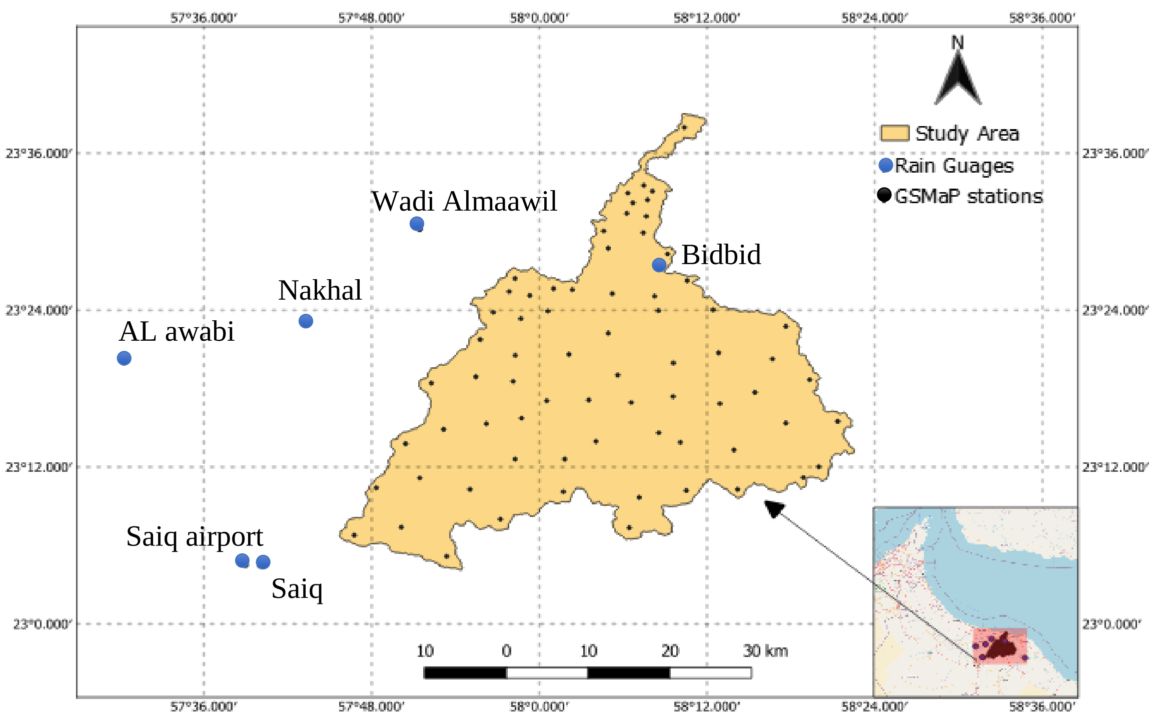

Figure 2. In-situ Rain gauges distribution and Observation points by GSMaP_NRT

2.3 Datasets

The GSMaP_NRT product was used in this study to develop modified products by means of a satellite dataset, from the Japan Aerospace Exploration Agency (JAXA)[11]. There are several sources of data used in this study. In Table 1 information about the dataset is presented.

Table 1. Information on datasets used in this study area.

Datasets	Organization	Details	Resolution
GSMaP_NRT	JAXA	Present rain rates by displaying cloud motion. Rain gauge calibrated by comparing daily data to CPC Unified Analysis over the previous 30 days. (Complexity-free algorithm compared to standard GSMaP).	0.1◦ × 0.1◦, 1 h
Rain gauge data	Stations	Record of rainfall data from bidbid in wilayatsamail	The number of stations adjacent to the study area is about 7 (the closest to the basin was used “bidbid”), daily.

Identification of the systematic biases of satellite estimates helps to understand the results generated in this study. Satellite estimates vary in performance and can decrease in terrain with the potential for underestimating precipitation at higher elevations[12]. In addition to reducing very low and very high precipitation rates, precipitation rates from low (warm) cloudscaused a weak signal and difficulty in detecting it from satellites.

Reanalysis data has been shown to exaggerate the frequency and volume of low totals while underestimating high totals. By comparing the rain gauge data with the GSMaP_NRT data set, the quality was verified and used to obtain the most accurate data.

2.4 Methodology

The rainfall observed in this study comes from one station in Bidbid province, DIDBID (Gauge 1) as shown in Fig. 2. The coordinate of these rain gauges is 23.46 latitude and 58.17 longitude. Precipitation data is recorded daily from June 9, 2014, to Dec 19, 2021, in the event of a flood by the Ministry of Regional Municipal and Water Resources. Recorded precipitation data is collected daily at each rain gauge. GSMaP_NRT precipitation data with 0.1o grid resolution have a fixed shape and each file records a 1-hour observation result. The same days are chosen as the estimation period. Figure 3 shows a visualization of these steps.

Furthermore, the same coordinates of the observed data are selected for recording from the GSMaP data. Since the stations cover less area than the BIDBID region, the IDW method in QGIS is used here to record the spatial distribution of daily precipitation in the study area. This method is used for observed data and GSMaP_NRT data to perform spatial comparison.

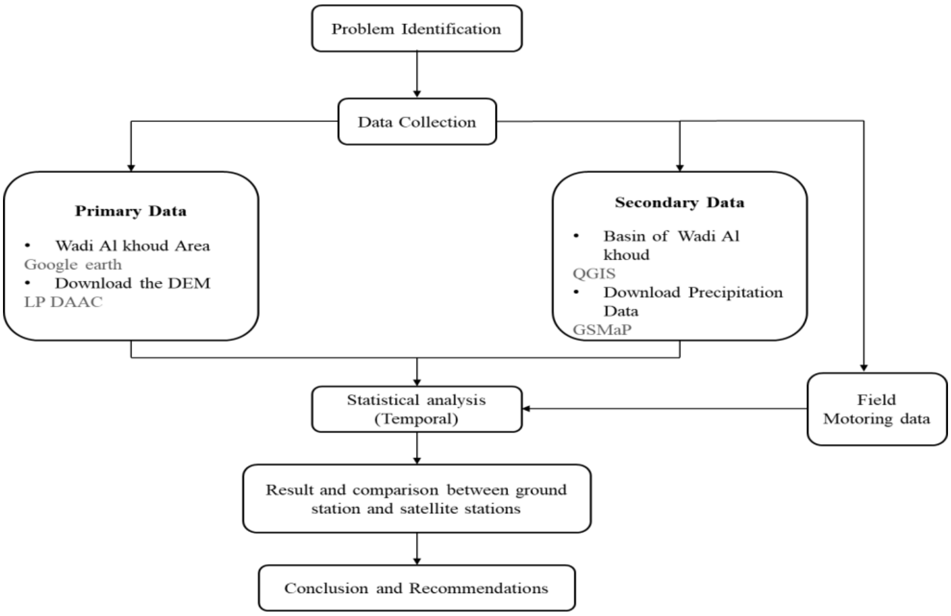

Figure 3. The flowchart of this paper

The GSMaP data should compared with the data observed in the region and with the daily precipitation of each station to demonstrate the reliability of the GSMaP_NRT data from several aspects. According to the given station names and their lat- itude and longitude, it is necessary to find the neighboring grid from the GSMaP observation files and collect the grid data according to time in each file to calculate the daily precipitation from the GSMaP satellite. Qualitative and quantitative assessment were carried out as fol- lows. The qualitative method consists of measuring the correspondence between the value of the estimates and the observations. To quantify the correspondence value, the following five statistical indices were used[6],[13], [14] the relative bias (B), the mean error (E), the Nash Sutcliffe (CNS), the root mean square error (RMSE), the coefficient correlation (R). These indices are given by the following equations.

$$r = \frac{\sum_{i=1}^{N}(G_i-\bar{G})(P_i-\bar{P})}{\sqrt{\sum_{i=1}^{N}(G_i-\bar{G})^2}\sqrt{\sum_{i=1}^{N}(P_i-\bar{P})^2}} \qquad (1)$$

$$RMSE\ (\%) = \frac{\sqrt{\frac{\sum_{i=1}^{N}(G_i-P_i)^2}{N}}}{\frac{\sum_{i=1}^{N}P_i}{N}} \times 100 \qquad (2)$$

$$BIAS\ (\%) = \frac{\sum_{i=1}^{N}(G_i-P_i)}{\sum_{i=1}^{N}P_i} \times 100 \qquad (3)$$

$$E = \frac{1}{N}\sum_{i=1}^{N}(G_i - P_i) \qquad (4)$$

$$C_{NS} = 1 - \frac{\sum_{i=1}^{N}(G_i-P_i)^2}{\sum_{i=1}^{N}(P_i-\bar{P})^2} \times 100 \qquad (5)$$

Where, N is the total number of the rain gauge data or GSMaP data; Gi is the satellite estimates and Pi is the rain gauge observation values.

The other validation statistic is the quantitative method that evaluates the GSMaP precipitation detection capacity, a 2x2 contingency table of events yes / no with rain / without rain is also used as shown in Table 2, "Hit" (a) represents correctly estimated rain events, "false alarms" (b) represent when rain has been estimated but has not occurred, "missing" (c) represents when rain was not estimated but did occur, and "correct negatives" (d) represent correctly estimated rainless events. The POD (Probability of Detection), which measures the proportion of correctly diagnosed observed events. The False Alarm Ration (FAR), which indicates the proportion of diagnosed events that were found incorrect.The Heidke Skill Score (HSS), which shows the Precipitation Detection Accuracy measures satellite estimates relative to random number matches. The CSI (Critical Success Index), which indicates the value of warnings, is calculated as follows to assess the precision of the GSMaP_NRT precipitation data[2], [15].

$$POD = \frac{a}{a+c} \tag{6}$$

$$FAR = \frac{b}{a+b} \tag{7}$$

$$CSI = \frac{a}{a+b+c} \tag{8}$$

$$HSS = \frac{2(ad-bc)}{(a+c)(c+d)+(a+b)(b+d)} \tag{9}$$

Table 2.Contingency table of yes or no events/with rain or no rain

		GSMaP_NRT	
		Yes	**No**
	Yes	a	c
Observed Data	**NO**	b	d

3 RESULTS

Figure 4 shows the precipitation rates for each of the GSMaP_NRT data and the observed datamonthly and annually in the study area. In comparison, we note that the precipitation data are close, but not completely similar. The GSMaP_NRT data is slightly different with the observed data, as it is slightly smaller and sometimes slightly larger. It is also illustration that the GSMaP_NRT product overestimated rainfall in the wet season.Figure 5 shows the relationship between satellite precipitation (mm) and observed precipitation(mm), which is a linear relationship.The correlation coefficient is 0.747, 0.742, and 0.590 for the year, month, and day, respectively.

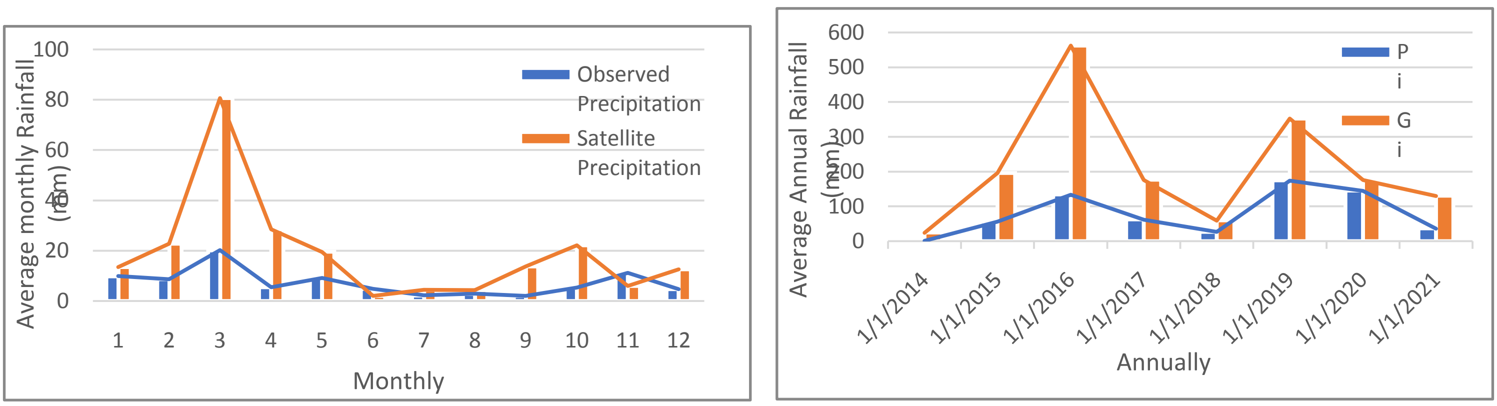

Figure 1. The comparison between two data sets.

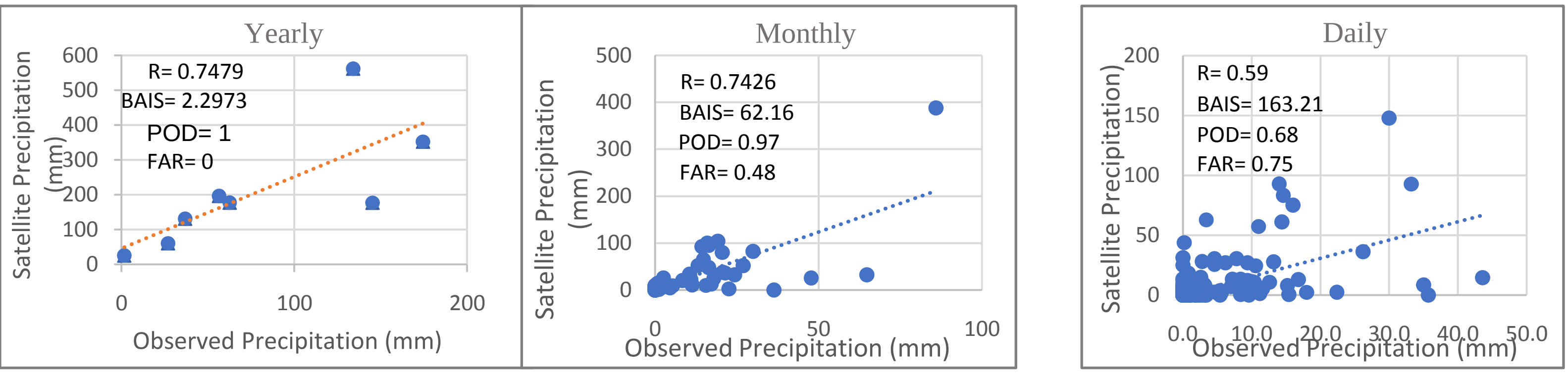

Figure 5. The correlativity between the two rainfall data sets.

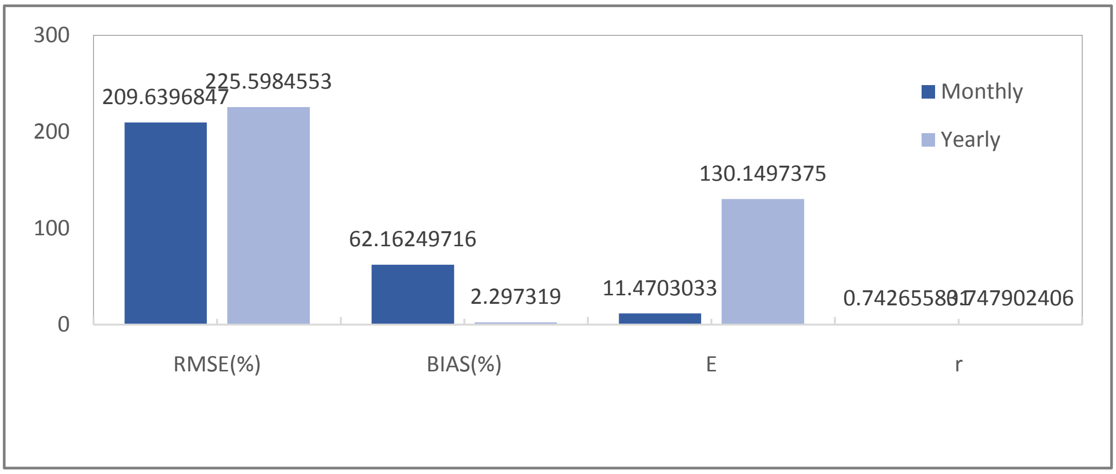

Figure 6. Figure 1 Qualitative validation using gauge data. Root-mean squard-error (RMSE), Mean bias (MB) and mean absolute error (E)-all are in mm/say-The coefficient correlation (R)-Unitless.

GSMaP_NRT products were validated by temporal behavior and seasonal statistics in Wadi Al-Kloud. Figure 6 Comparison results of GSMaP_NRT satellite precipitation estimates with the station's precipitation for each year, month, and day.

With a comparison of the total precipitation data between the GSMaP_NRT data and the observation data during the study period (in 2020), the performance in it was somewhat similar, reaching 145.2 mm for the rain data and 176.5211 mm for the GSMaP and indicating the compatibility of the data from the rain gauge (r =0.747902406) and the bias value 2.297319 in yearly. Also, it was Contrast value (130.15 and 225.6) The greater the difference between them, the greater the variance in errors. The CN index determined the consistency of GSMaP_NRT to measure the amount of precipitation and it was CN% =-8 %. The good correlation coefficient indicates the qualified correlation between the observed precipitation data and the GSMaP data at the regional scale.

The PODs for GSMaP_NRT were almost 100% in yearly, and the FAR% was zero. In addition to the HSS stats of 0%, this shows how good GSMAP_NRT can detect rain. The CSI value is 1, which confirms that the GSMaP_NRT algorithm is of good quality for calibrating the data in the study area.

CONCLUSION

In this study, the GSMaP_NRT product was evaluated using a rain gauge on different time scales (daily, monthly, and yearly). Over a period of 8 years (2014 -2021) in Al Khoudh region, Sultanate of Oman. We conclude through temporal comparison that satellite data that has been correlated with observational data significantly reduces the effect of errors and biases. This research shows that the GSMaP near-real time product is able to correctly predict the day and hour of rain. The GSMaP_NRT data is reliable and has higher accuracy with a correlation factor of 0.7479. Accurate rainfall estimates based on satellites are able to simulate flash floods more accurately. The GSMaP product can improve the flood simulation performance of the hydrologic model by correcting the hourly multiplier bias of the GSMaP data product.

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