SPATIOTEMPORAL EVALUATION OF GLOBAL PRECIPITATION MAPPING -GSMAP AT BASIN SCALE IN SAGAMI RIVER, JAPAN

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ABSTRACT

A deep understanding of rainfall is important to make countermeasures against water related damages which is thought to be increasing by climate change. In this study, the latest satellite based precipitation product GPM-GSMaP was evaluated for its cause of error and usage for temporal and spatial characteristics. As a result, GPM-GSMaP was found to underestimate the rainfall with the intensity of 20 [mm/day], and seemed to occur in the following conditions: 1). the precipitation with large temporal change, 2). the precipitation with high spatial concentration. In addition, the calibrated rainfall rate of the rainfall larger than 20 [mm/day] had correlation coefficient of 0.99. This implies that the dataset could be an important input data for hydrological models.

Keywords:GPM-GSMaP, rain gauge, evaluation, accurate, underestimation

1 INTRODUCTION

Precipitation is a key factor in water cycle since it is a precious freshwater resource. However, its distribution and variation have been considerably influenced due to global warming, and human activities. Large variations of precipitation can turn into water problems such as floods and droughts have increased.Therefore it is important to accurately understand spatiotemporal characteristics of precipitation in order to mitigate the damage. Direct ground observation by rain gauge is precise, but the number of stations is very limited especially in developing countries (Romilly et al. 2011).On the other hand, satellite-based precipitation data has many advantages such as quasi-global coverage, readily usage and free of charge. Thus, satellite data is essential for spatiotemporally understanding precipitation.

Satellite precipitation data is estimated by combining Microwave Radiometer (MWR) and Precipitation Radar (PR) (Kachi et al. 2010). MWR estimates two-dimensional rainfall intensity in large width by directly measuring radiation strength of microwave from raindrops. PR estimates three-dimensional rainfall intensity by measuring the active radio wave.

In previous studies, many satellite rainfall products have been evaluated in many areas by comparing with rain gauges. Especially, GSMaP (Global Satellite Mapping of Precipitation) products are becoming popular recently and have been reported by researchers (Fu et al. 2011). The latest version of GSMaP is the Global Precipitation Measurement-GSMaP (GPM-GSMaP), withhourly resolution, at $0.1° \times 0.1°$ lat/lon. GPM started as a successor mission of the Tropical Rainfall Measuring Mission (TRMM) projectto achieve more accurate and frequent precipitation estimation than TRMM(Hou et al. 2014).

The objective of this study is to evaluate the accuracy of GPM-GSMaP spatially and temporally against local rain gauge network data. Then, the identified biases GPM-GSMaP was corrected for its improvement.

Satellite data, once verified, can be useful for improving our understanding of the occurrence of hazardous events, possibly for mitigating their impact on local economics, and for reducing losses (Hong et al. 2007).

2 STUDY AREA

Sagami River is located in Yamanashi and Kanagawa Prefectures in Japan as shown in **Figure1**. The catchment size is 1,680 km^2, and the main stream length is 109 km. The basin outlet is at Sagami River Bay. The annual precipitation is 1,800mm. The main land use type at the upper region and the downstream are forest and urban, respectively. There are 17 rain gauge stations where ground precipitation data can be obtained in the basin.

The basin was selected as target basin mainly because there are adequate rain gauge stations to cover the whole basin. The quality of data can be suitable to be compared against Satellite data.

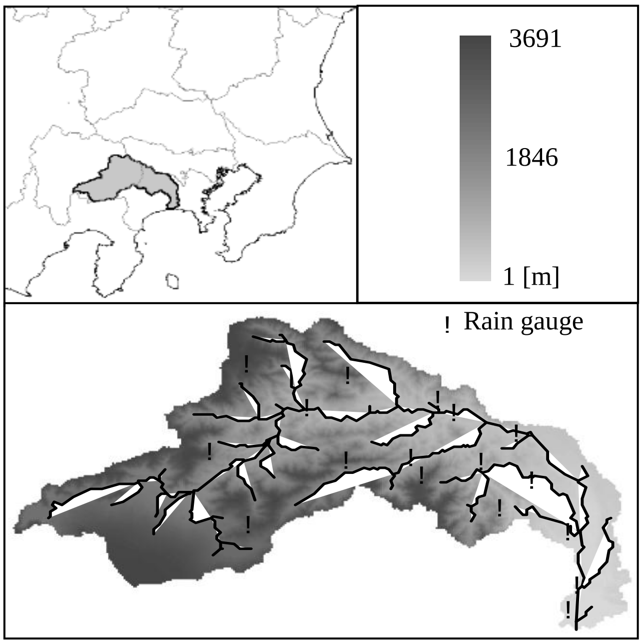


Figure1. Elevation and rain gauge location map of Sagami River Basin

3 METHOD

The target term is from March to October, 2014.

3.1 Data preparation

3.1.1 GPM-GSMaP

Global Precipitation Measurement - Global Satellite Mapping of Precipitation (GPM-GSMaP) was opened to the public in September 2014with a resolution 0.1° × 0.1° lat/lon.In addition, it is combined with NOAA Climate Prediction Center (CPC) global gauge data set. GPM started as an international project, and its core satellite which carries the newest instruments called Dual-frequency Radar (DPR) and GPM Microwave Imager (GMI) was launched in February 2014 (Kubota et al. 2009). In this product, the core satellite and constellation satellites which load microwave radiometers (MWR) are used together for rainfall estimation in order to achieve more accurate, frequent and extensive precipitation data.

3.1.2 Rain Gauge

There are 17 rain gauge stations which observe rainfall directly.Spatial precipitation maps were obtained using an interpolating method which predicts the value of cells at locations that lack rain gauge stations. The method used in this research is Inverse Distance Weighing interpolation (IDW) (Ahrens et al. 2005). It determines cells values using a linear-weighed combination set of rain gauge stations. The weight assigned is a function of the distance of an input point from the output cell location. The greater the distance is, the less influence the cell has on the output value. After the interpolated maps were obtained, the maps were fitted to the resolution of GPM-GSMaP.

3.2 Accuracy Evaluation

3.2.1 Correlation coefficient (R)

R is a measurement of the strength and direction of a linear relationship between variables. In general, the value greater than 0.8 is described as strong correlation, whereas the value less than 0.5 is described as weak correlation. R is defined as equation (1)

$$R = \frac{\sum_i^n (x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_i^n (x_i - \overline{x})^2 (y_i - \overline{y})^2}} \qquad (1)$$

3.2.2 Relative Error (R.E)

Relative error is the value which is absolute error divided by true value. It is calculated as equation(2). The lower the value is, the more accurate GPM-GSMaP is. In this study, true value means rain gauge precipitation since it is observed directly. This indicator is used to analyze temporal and spatial locality.

(2)

where,

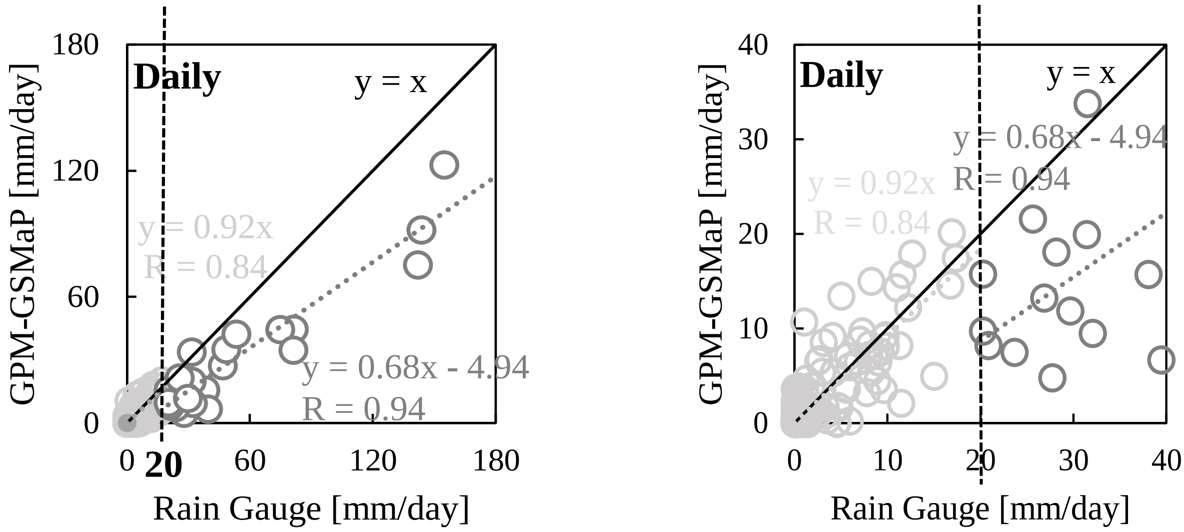
GPM: GPM-GSMaP precipitation

RG: Rain Gauge precipitation

4]RESULTS AND DISCUSSION

4.1 Linear Regression (daily scale)

The linear regression between rain gauge and GPM-GSMaP in daily scale is shown in**Fig 2**.In its precipitation less than 20 [mm/day], the accuracy is high; gradient of the approximated line is 0.92. On the other hand, in case of the events more than or equal to 20 [mm/day], fitting is good but GPM-GSMaP significantly underestimates actual precipitation except for one event and the accuracy is low; the gradient is 0.68. From this figure, the accuracy of GPM-GSMaP is considerably different whether rain gauge precipitation is more than 20 [mm/day] or not. In addition, GPM-GSMaP tends to considerably underestimate heavy precipitation events.



1.1

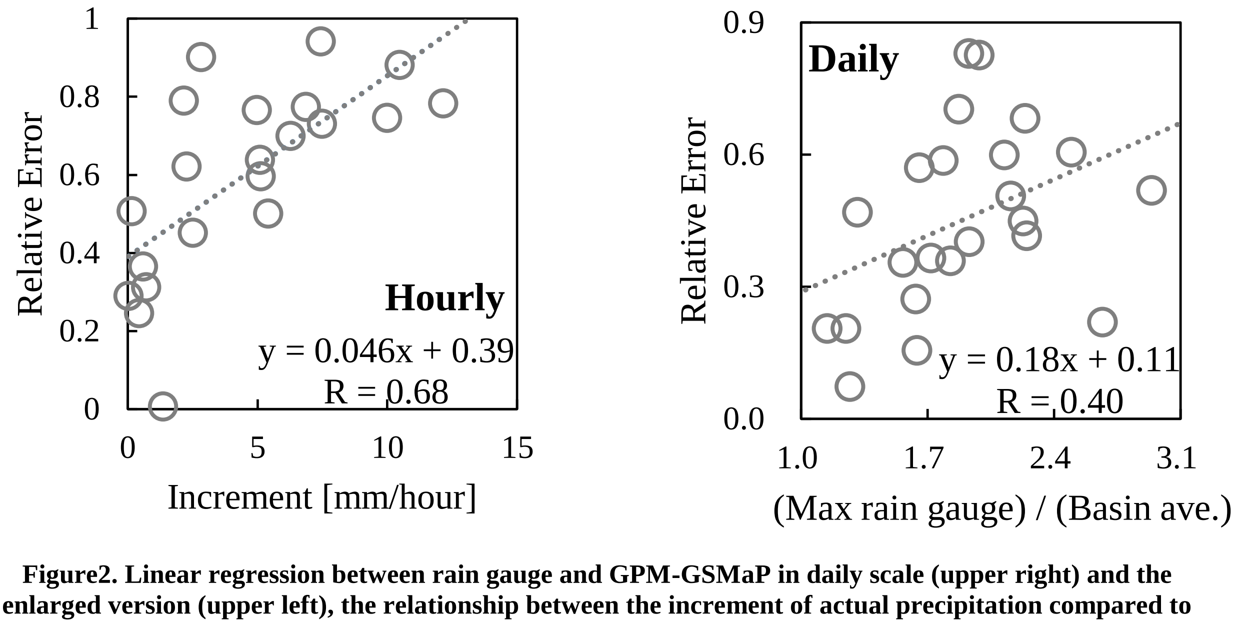


Figure2. Linear regression between rain gauge and GPM-GSMaP in daily scale (upper right) and the enlarged version (upper left), the relationship between the increment of actual precipitation compared to that one hour ago and relative error about the events over 10 [mm/hour] (lower left), and Relationship between max rain gauge precipitation value divided by average precipitation and relative error (lower right).

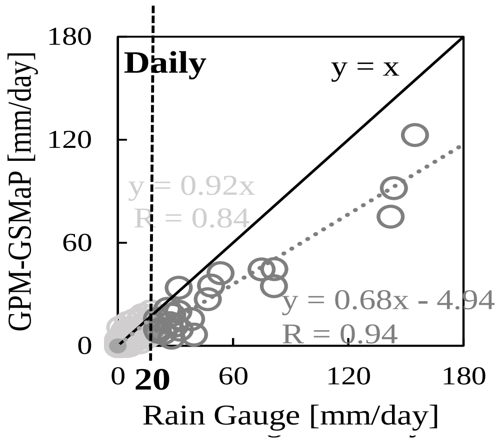


Figure 3. Linear regression between rain gauge and GPM-GSMaP in daily scale

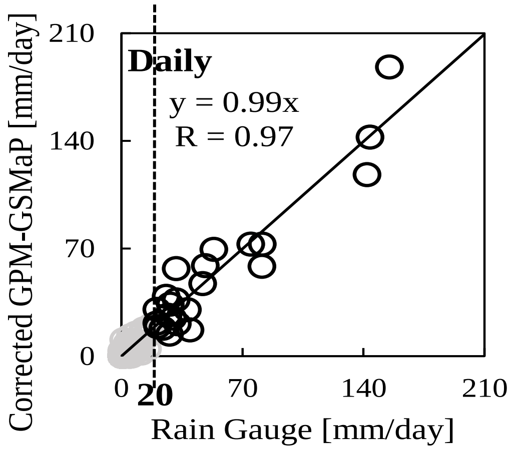


Figure4. Relationship between rain gauge and corrected GPM-GSMaP value applied to the events

4.2 Temporal Analysis

Firstly, the rainfall events over 10 [mm/hour] are focused on in order to identify the reasons of the underestimation seen in daily scale. The relationship between the increment of the actual precipitation compared to that one hour ago and relative error is shown in **Figure2**. From this figure, these two variables show strong positive correlation; R is 0.68. In other words, the larger the increment is, the higher relative error is. Therefore, GPM-GSMaP has a tendency to underestimate suddenly strengthened precipitation.

4.3 Spatial Locality

As for the rainfall events over 20 [mm/day], the relationship between max rain gauge precipitation value divided by average basin precipitation and relative error is shown in **Fig. 2** (lower right). R is 0.40, and it indicates that the two variables have positive correlation. Actually, GPM-GSMaP tends to underestimate precipitation events which have large regional difference.

4.4 Correction Method

As for the actual rainfall events more than or equal to 20 [mm/day] (defined as “heavy precipitation events” here after), the correction of heavy precipitation events is necessary for establishing accurate hydrological model. The approximated line is shown in equation (3) and can be converted to equation (4).

(3)

$$x = 1.47y + 7.28 \quad (4)$$

Value x represents the precipitation of rain gaugeand value y represents that of GPM-GSMaP. We can consider rain gauge precipitation as the control value since it is observed directly. In equation(4), if we put the value of GPM-GSMaP into *y*, we can estimate and determine x as “Corrected GPM-GSMaP” value. As shown in**Figure 3**and**Figure4,**the precise satellite-based rainfall values can be obtained by applying this correction method to heavy precipitation events. R and gradient of the approximated line of this“calibrated satellite-based precipitation product” which corrects heavy rainfall events in equation (4) are 0.97 and 0.99 respectively. It is accurate enough to input the corrected precipitation data into the hydrological model.

5 CONCLUSION

Firstly, as for linear regression in daily scale, GPM-GSMaP tends to underestimate actual rainfall amount observed by rain gauge. In addition, the accuracy of GPM-GSMaP decreases substantially if rain gauge precipitation is over 20 [mm/day].

Secondly, it is a little difficult for GPM-GSMaP to precisely estimate rainfall events which were strengthen suddenly or had large regional difference. Overall it was found out GPM-GSMaP tends to underestimate heavy rainfall events.

Thirdly, "calibrated satellite-based precipitation product" can be obtained by applying the adequate correction equation. Its accuracy is very high; gradient of the approximated line is 0.99 and R is 0.97. By improving the accuracy of heavy rainfall events, GPM-GSMaP can be useful as input data of hydrological model to simulate flood events, and eventually mitigate their potential damages.

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