Current status of GSMaP_Gauge

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Introduction

Precipitation is one of the most important parameters on the earth system, and the global distribution of precipitation and its change are essential data for modeling the water cycle, maintaining the ecosystem environment, agricultural production, improvements of the weather forecast precision, flood warning and so on. In the GPM (Global Precipitation Measurement) project, the integrated products of high resolution mapping of precipitation from microwave measurements from constellation satellite and infrared radiometers from geo-stationary orbit are developed and supplied to the public. However, sometimes such high resolution product as GSMaP_MVK underestimates the surface precipitation and causes large error for hydrological modeling. In this presentation, global gauge data set are combined with GSMaP_MVK. Methodology of a new combined algorithm (GSMaP_Gauge) is described and then evaluated from the local radar rain gauge data sets.

GSMaP Gauge Methodology

$$a_{n+1} = a_n + w \quad (1)$$
$$x = \alpha a_n + v \quad (2)$$
$$\sum_{n=1}^{24} a_n = R \quad (3)$$
$$w \approx N(\mu_w, \sigma_w^{\,2}) \quad v \approx N(\mu_v, \sigma_v^{\,2})$$

R: Rain rate from CPC global gauge data sets

n: Time (hour), *a*: Rain rate from GSMaP_Gauge

x: Rain rate from GSMaP_MVK

v, *w*: Noise

(1)The rain rate at the time of n+1 at a certain pixel is assumed to be same as that at 1 hour before. But, in reality the rain rate usually increases or decreases with time and such an error is expressed here at w_n. The distribution of the w_n in the system model is shown in Figure 1. The distribution is calculated from the radar rain gauge network data in Japan, and Figure 1 indicates that the rain rate change in one hour is normally distributed with the standard deviation of 1.14 mm/h.

(2) the rain rate in the GSMaP MVK assumed to be linearly correlated with the rain rate in the GSMaP Gauge. This assumption is actually reasonable. Figure 2 presents a scatter plot between GSMaP MVK versus CPC data on a monthly basis with the 0.5 degree resolution for 2014 JJA from -60 to 60 latitude over land and indicates that the rain rate in GSMaP MVK is linearly correlated with global gauge measurement, showing that the system assumption in the GSMaP Gauge product is statistically correct assuming the CPC data is a truth.

(3)The output from the CPC data is expressed here as *R* which needs to be equal to the sum of the rainfall rate for 24 hours. The spatial resolution of the GSMaP_Gauge is 0.1 degree, while the CPC data has the 0.5 degree resolution. In order to downscale the spatial resolution to the GSMaP system from the CPC data, a simple spatial interpolation method is applied to the original CPC data, and then the above optimal solution is calculated at each 0.1 degree pixel. CPC data are 0.5 degree and 24 hour accumulate rain rate, the optimal solution occasionally persists weak rain pixels in a CPC grid. Thus the GSMaP Gauge algorithm remove rain in no cloud region. No cloud region is retrieved from Geo-IR data.

Cost function

$$L(a) = -\ln\left[\Pr(\boldsymbol{x}, \boldsymbol{a}) \times exp\left\{\frac{\lambda}{2}\left(\sum_{n=1}^{24} a_n - R\right)^2\right\}\right]$$

$$= \ln\left[\Pr(a_1)\prod_{m=1}^{24}\Pr(am|a_{m-1})\prod_{n=1}^{24}\Pr(xn|an) \times exp\left\{\frac{\lambda}{2}\left(\sum_{n=1}^{24} a_n - R\right)^2\right\}\right]$$

GSMaP Gauge Methodology

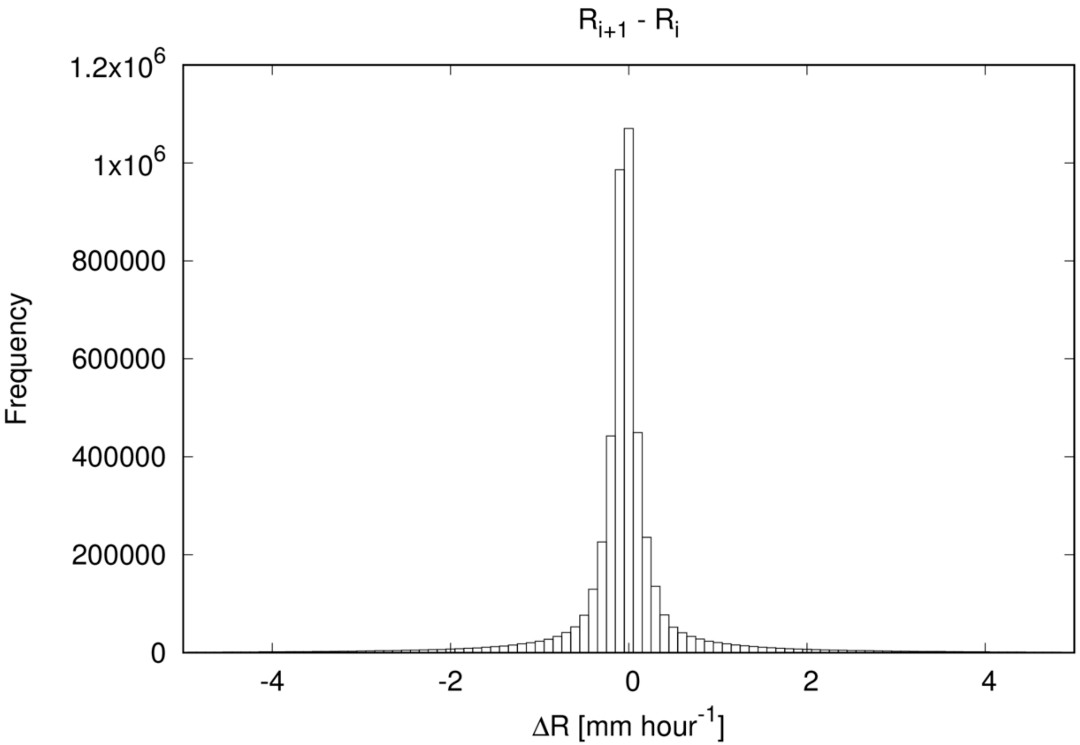


Figure 1 Histogram of the rain rate change in one hour. The data is obtained by analyzing the radar rain gauge network over Japan.

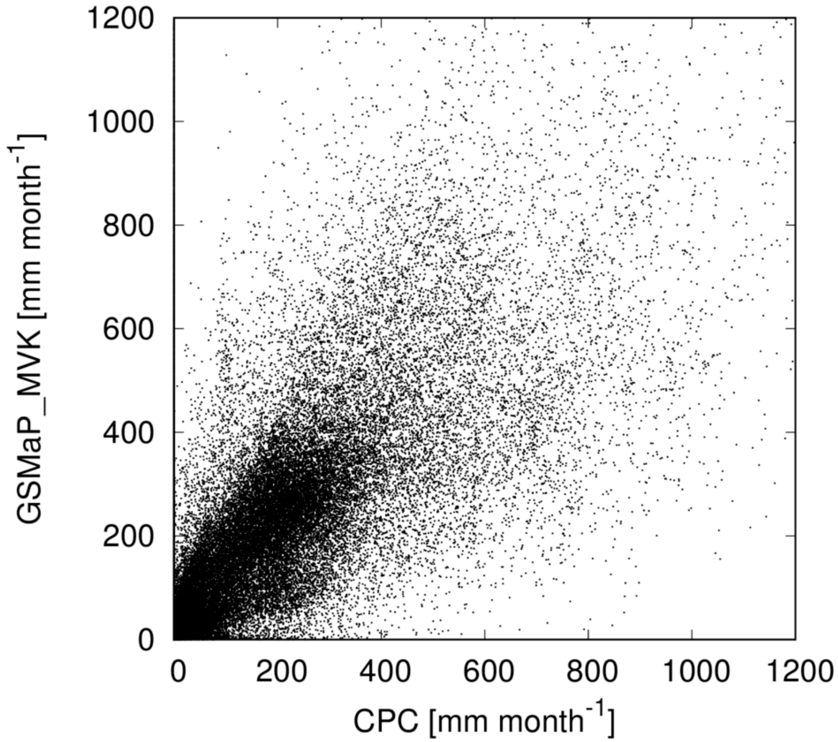
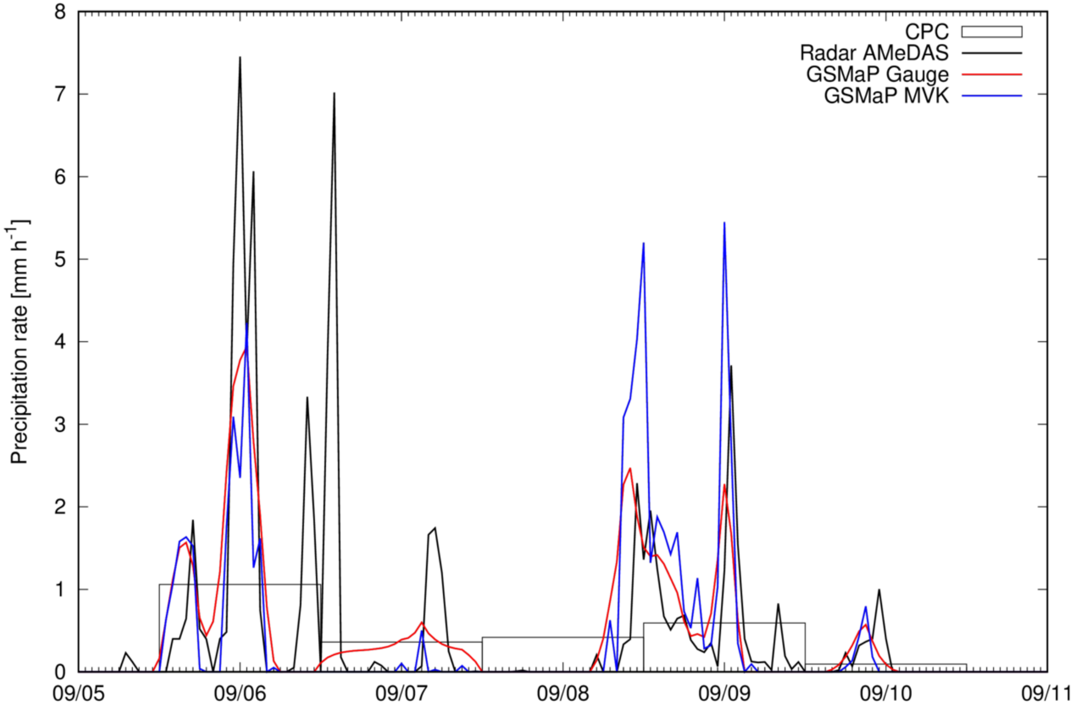
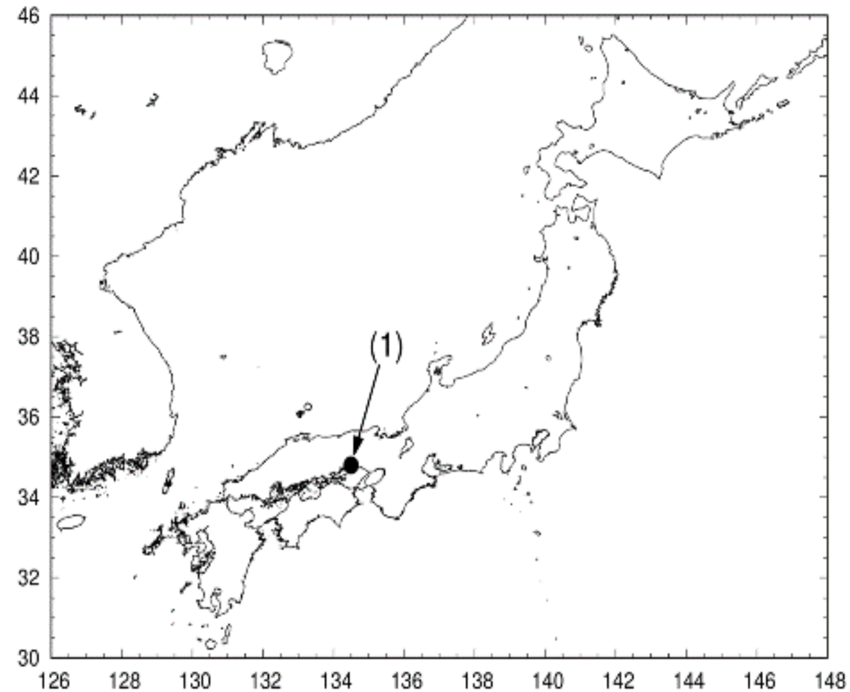


Figure 2 Scatter plot of rain rate from the CPC and the GSMaP_MVK data. This comparison is on a monthly basis with the 0.5 degree resolution for 2014 JJA from -60 to 60 latitudes.

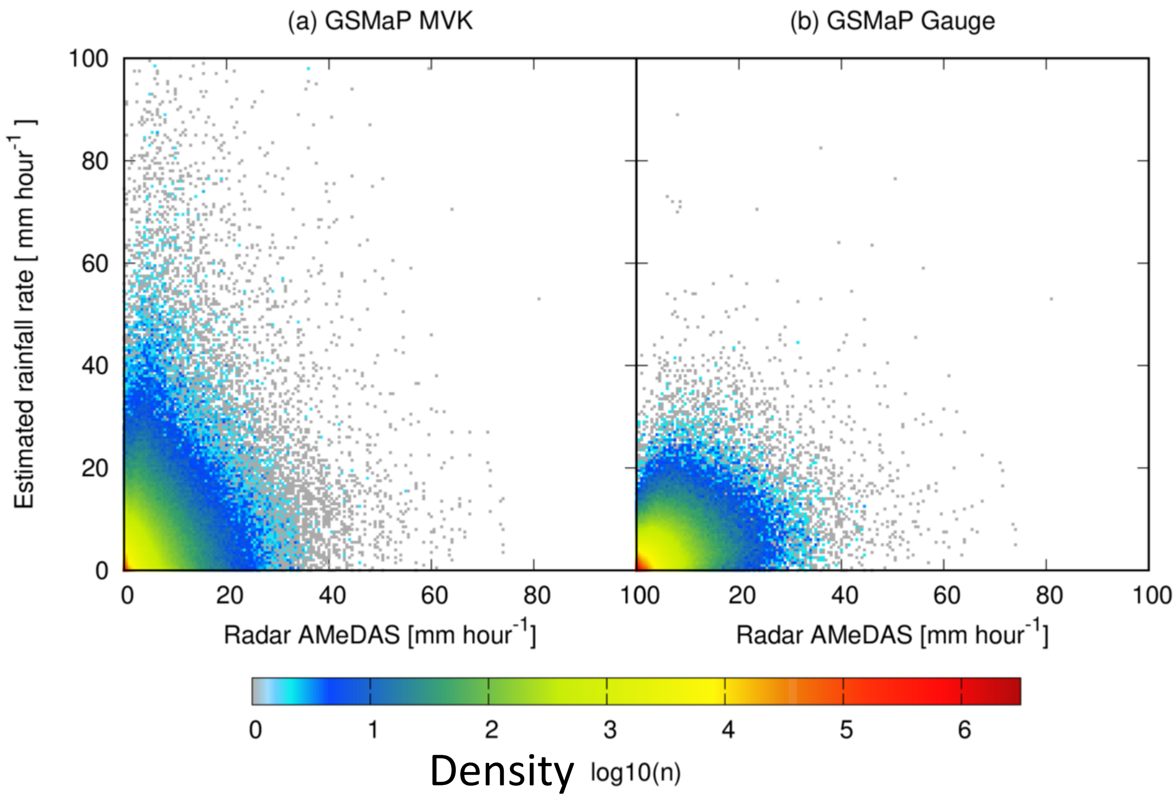
One example of the time series of precipitation estimates





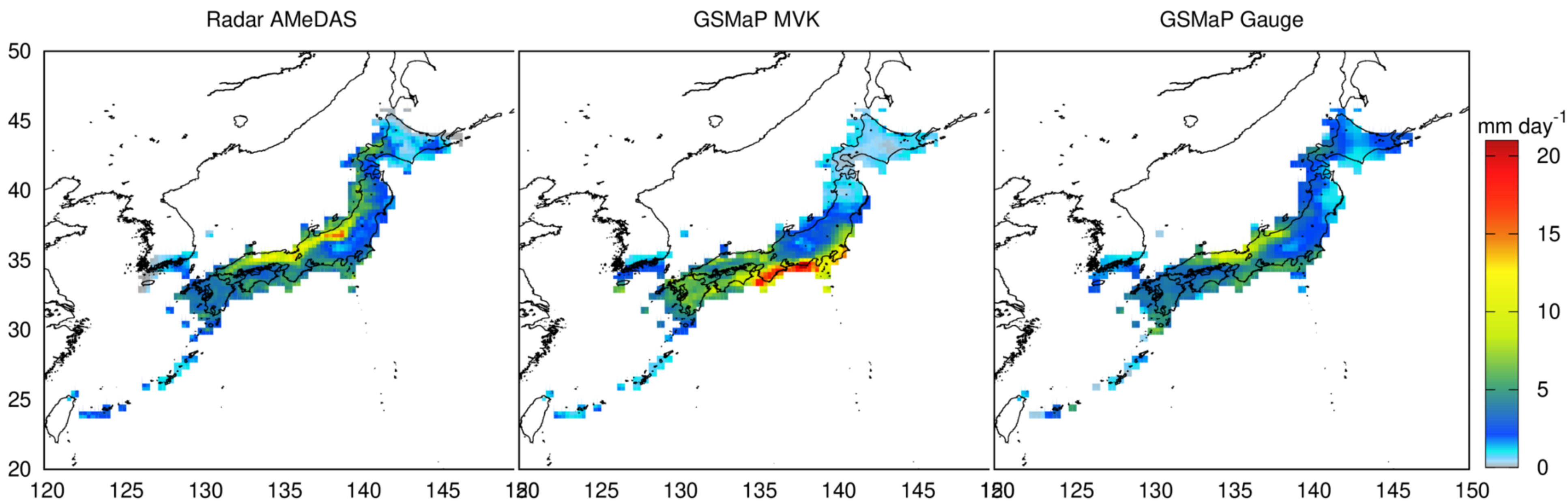
As one example of the comparison, the above figure shows a time series of the hourly precipitation estimates from GSMaP_Gauge, GSMaP_MVK, RadarAMeDAS, and CPC data at that location with 0.1 degree resolution. In this evaluation, RadarAMeDAS data is averaged in every 0.1 degree to fit the resolution of the GSMaP data sets. From 09/08 to 09/10, RadarAMeDAS detects a few peaks of precipitation, while GSMaP_MVK tends to overestimate these precipitation rates. To the contrary, the GSMaP_Gauge product successfully reduces the overestimation seen in the satellite only GSMaP_MVK. On the other hand, from 09/06 to 09/07, GSMaP_Gauge totally misses the peak of the rain rate in RadarAMeDAS. Probably, this is because GSMaP_MVK also fails to detect this peak and CPC data also does not show any signal during whole day.

Scattergram of Hourly Precipitation



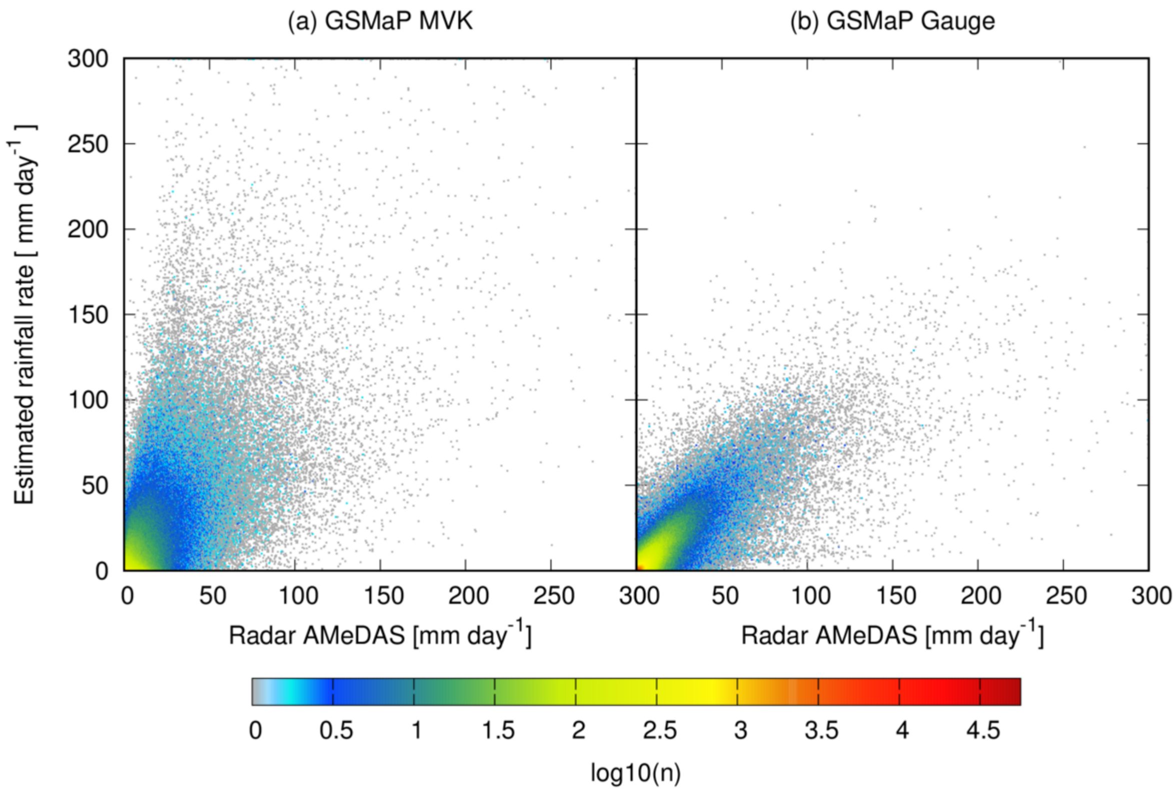
In this study, Japan islands are selected, because we have a well calibrated nationwide radar network data (RadarAMeDAS) with less than 1 hour and 10 km resolution over that area. In this comparison each data was regridded to 0.25x0.25 degree grid. It is clear that the new GSMaP_Gauge data is better correlated with Radar AMeDAS data than satellite only product (GSMaP_MVK).

Mean daily rainfall rate (January 2015)



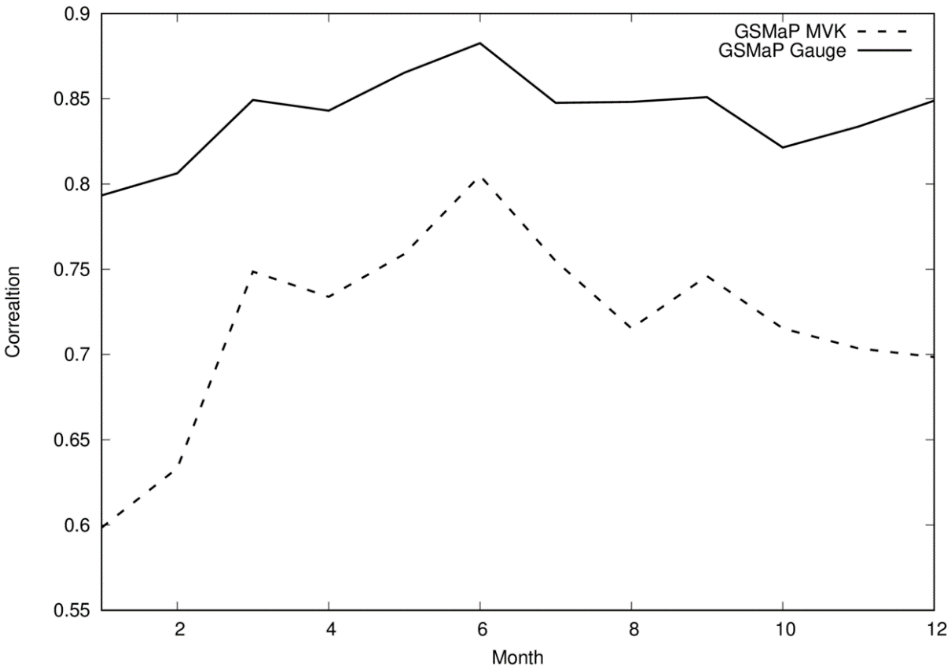
GSMaP_MVK misses heavy precipitation along the coast facing the sea of Japan, and also strongly overestimate along the pacific coast. To the contrary, precipitation pattern in the GSMaP_Gauge product is more similar to that in the Radar AMeDAS product.

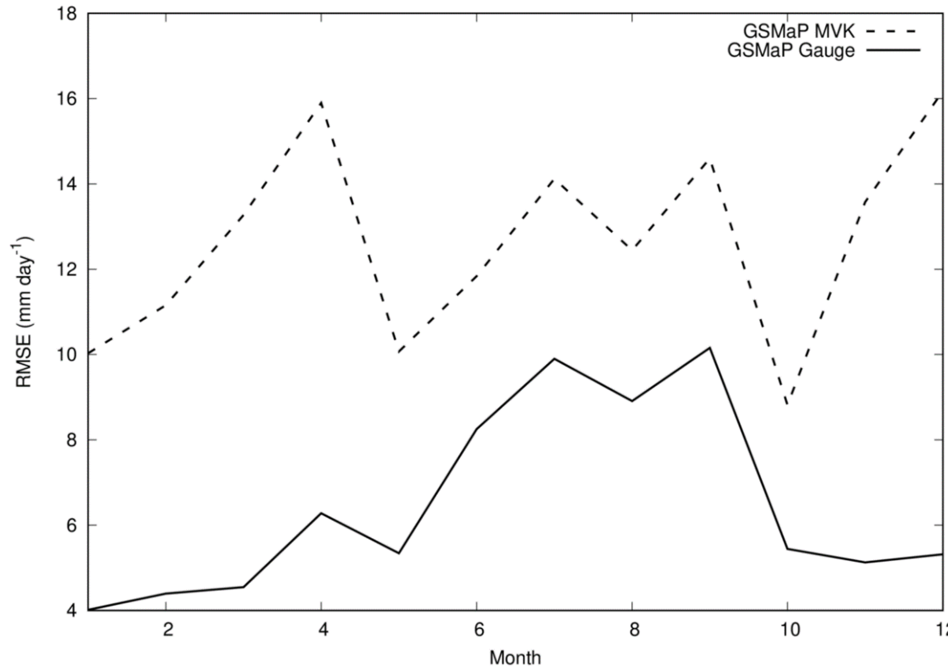
Scatter gram of Daily precipitation



In daily scale comparison, clearly GSMaP_Gauge estiamtion is more linearly correlated with Radar AMeDAS estimates.

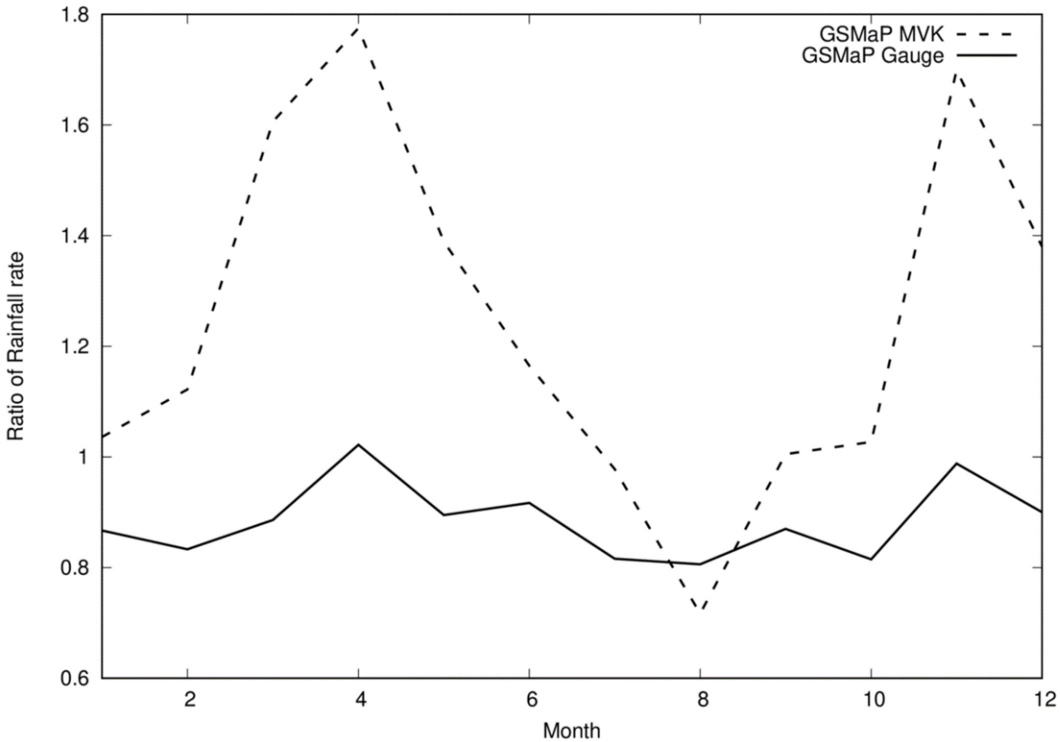
Correlation coefficient and RMSE



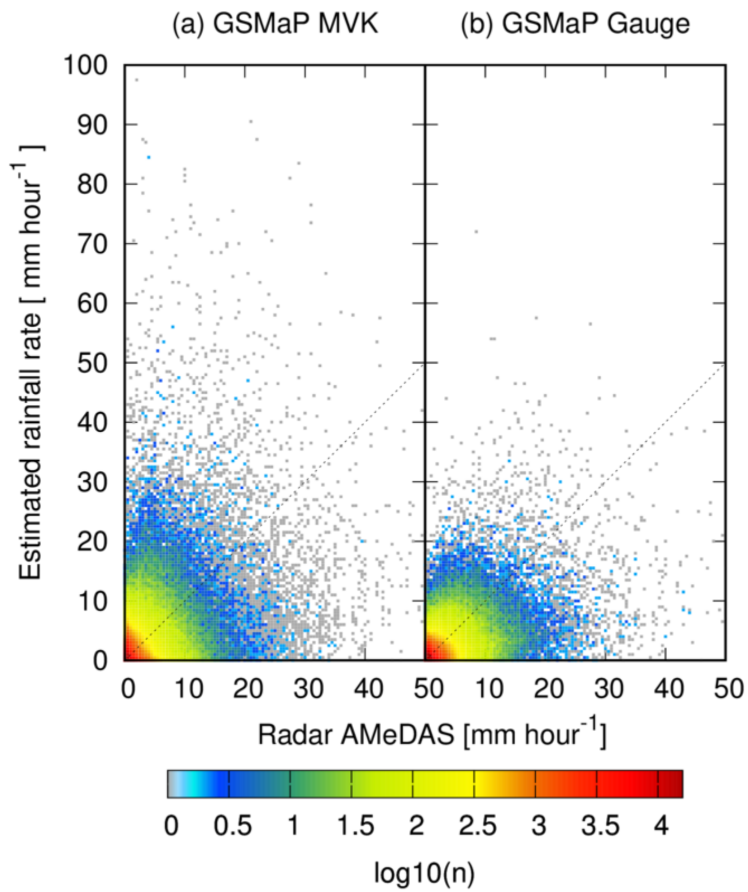


- Correlation and RMSE on daily scale averaged for one month.
- GSMaP Gauge improves both the correlation and root mean square error (RMSE).

Precipitation Amount



Hourly precipitation
September



Left panel shows the ratio of the total rain amount from GSMaP products(GSMaP_Gauge and GSMaP_MVK) and from Radar AMeDAS over Japan, indicating that the GSMaP_Gauge estimates precipitation more accurately(close to 1) and stably in terms of total precipitation amount.

Statistical parameters

	POD	FAR	FB	CSI	HSS
GSMaP MVK	0.434	0.107	0.486	0.412	0.197
GSMaP Gauge	0.601	0.116	0.680	0.557	0.299

Probability of Detection (POD), Critical Success Index (CSI), Frequency bias (FB) and Heidke Skill Score (HSS) are also improved. On the other hand, False Alarm Ratio (FAR) is a little bit decreased.

Summary

- The algorithm for the gauge adjusted GSMaP (GSMaP Gauge) is described. Satellite only products like GSMaP_MVK are pointed to sometimes underestimate the precipitation fields particularly in extremely heavy rainfall case or overestimate weak precipitation case. In order to mitigate the problem, one of the best ways is to use the global gauge data analysis and adjust the precipitation fields of the satellite product to fit the gauge data. The algorithm uses the optimal estimation scheme and the solution is calculated by maximizing the probability density function defined in the system model of the GSMaP_Gauge product.
- Initial assessment showed that the GSMaP_Gauge succeeded in reproducing the rain rate missed in the GSMaP_MVK based on the CPC global gauge analysis. Daily comparison with ground radar and gauge measurement showed that the GSMaP_Gauge has the least root mean square error among the any other GSMaP products with less than 3.4 mm/day. Hourly scale comparison, however, showed that sometimes the GSMaP_Gauge missing the peak of the rain rate.