Geographical and seasonal characteristics of APHRODITE and GSMaP in Lao P.D.R

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Abstract. Water-related hazards account for 90 percent of all natural hazards, and their frequency is generally rising, in association with climate change. To combat climate change, real-time and gridded precipitation data is important, especially where no ground observation is operated. Hence, this study aimed to assess the performances of different gridded precipitation datasets, APHRODITE and GSMaP in geographical and climate terms, in Lao P.D.R. For the elevation factor, precipitation at the time of conversion from over to underestimation of GSMaP was found to be dependent on elevation, as the conversions occur with lower precipitation in higher elevation classes.

1. Introduction
Precipitation is an important component of the hydrological cycle, and its accuracy and reliability can have a significant impact on climate trends analysis and water resource management and meteorological, climatic and hydrological predictions. Recent changes in precipitation patterns due to global warming have been a factor that has increased the importance of accurate and prompt precipitation monitoring, especially by gridded monitoring.

Three main methods are well known for determining precipitation [1]. First, collecting raindrops with ground-based rain gauges, then calculating and predicting precipitation from the collected raindrops. Second, using satellite data. It estimates precipitation from IR (infrared radiometer) data on geostationary earth-orbit satellites or by combining that data with PMW (passive microwave) sensors, usually incorporated on low orbit satellites achieve higher spatial and temporal resolutions. Third, calculate precipitation using a combination of rain gauge data and satellite data.

Precipitation measurement using rain gauges is the most common method, and it is considered highly accurate since it directly acquires precipitation data. However, since only point data is available by ground-based observation, it is necessary to make corrections to the gridded precipitation using Thiessen decomposition or other means when using the data spatially.

Also, it is virtually impossible to cover the entire ground surface with precipitation gauges, so the precipitation measurement's accuracy depends on the density of the precipitation gauges. Besides, it takes a certain amount of time to publish and provide the data. On the other hand, precipitation measurements using satellite data have advantages in that they can cover almost the entire globe and take only a short time to publish and provide data, although algorithms are constantly being improved to make the accuracy higher. As for accuracy, several previous studies have mentioned inaccuracy,
especially in mountainous area. This paper discusses the geographical and seasonal influences on precipitation observations by using ground and satellite observation data in light of these background.

2. Methodology

2.1. Study area

We selected Lao People's Democratic Republic (Lao P.D.R) as our study area. This country is an interior country located on the Indochina peninsula in Southeast Asia and 70-80% of its land area is covered by plateaus and mountains [2]. The geographical map of the study area is shown in Figure 1.

Area from 13.05°N to 23.05°N and 100.05°E to 108.05°E was cut out for the analysis. According to the country assistance policy published by ministry of Japan's foreign affairs, Lao P.D.R is a key location in the Mekong region. This country's security and development are recognized as essential for the Mekong region and ASEAN (south-east Asia) region's security and prosperity. On the other hand, in Lao P.D.R, there has been a lack of ground-based observations, and the need for satellite precipitation analysis is high.

This country is classified as tropical monsoon area, with the rainy season from May to mid-October, when rainfall is high due to the southwest monsoon, and the dry season from mid-October to April, when the atmosphere is dry due to the northeast monsoon [2]. In this analysis, 1 May and 17 October were designated as the start and end of the rainy season, respectively. Rainy season consists of 169 days and the rest of the year was designated as the dry season. Previous study has pointed out the diurnal cycle of rainfall in the Indochina peninsula [3], including the Lao P.D.R, and it shows that there are regional differences in the timing of precipitation beginning. In Lao P.D.R, the eastern part of the Khorat Plateau has both the frequency peak and intensity peak of precipitation from midnight to early morning, when the total precipitation becomes peak [3][4].

![Figure 1. Geological information and three main cities in Lao P.D.R](image-url)
2.2. Precipitation dataset

Satellite data used in this analysis was a product called GSMaP, provided by JAXA as part of the Global Precipitation Measurement (GPM) project, which applies a combination of multiple precipitation-observing satellites to provide 0.1° × 0.1° spatial resolution and 1-hour time resolution. The GSMaP precipitation determination algorithm's key feature is that it utilizes information from the GPM main satellite and the Tropical Precipitation Monitoring Mission (TRMM) precipitation radar, the first space-based precipitation radar in operation between 1997 and 2015.

Data used were in 2014, with the beginning of the day at 0:00 and end of the day at 23:59. In 2014, GSMaP algorithm was modified, after March 2014, it was migrated to a product called GSMaP_MVK. In this analysis, we used data from GSMaP_MVK (Version 6) after March 1, and before that, we used the reanalysis data, called GSMaP_RNL. Although the data's names are different, the same algorithm as GSMaP_MVK (Version 6) was used for this reanalysis data and the difference between these two data is neglectable [5].

Some previous studies about the accuracy of GSMaP have pointed out that a) it tends to be underestimated compared to the rainfall observed by ground-based observation, b) that it is more geographically sensitive, then the accuracy is better on the flat area than on the mountains, and c) that the accuracy may be reduced due to cloud development [6]. It has also been pointed out that precipitation estimated from instantaneous data alone may not be expected to increase with time for phenomena with agile scale changes. There is a tendency to underestimate precipitation, such as geomorphic rainfall associated with local upwelling occurrence due to topography change.

Data sets adopted for the analysis are summarized in Table 1. Asian Precipitation-Highly-Resolved Observational Data Integration Towards Evaluation (APHRODITE) was chosen as the rain gauge data for this analysis. APHRODITE is a product of the project to create high spatial resolution daily precipitation grid data in Asia by collecting daily precipitation data from rain gauge observations. In this analysis, we used data called V1801_R1, which was observed from 1998 to 2015. This data is provided in two spatial resolutions: 0.25°×0.25° grid and 0.50°×0.50° grid; we used the data of 0.25° × 0.25°grid. It should be noted here that a previous study conducted in Indochina peninsula has pointed out that the precipitation of APHRODITE is approximately 33–38% less than the local rain gauge data [7]. For the elevation data, we also used data from APHRODITE (0.05°×0.05°).

Table 1. Data description

| Ground Observational Data | Satellite-Based Data | Elevation Data |
|---------------------------|----------------------|----------------|
| Data Name                 | GSMaP_RNL/GSMaP_MVK(v6) | ELEVATION     |
| Time Coverage             | RNL: 2000/3/1~2014/2/28 MVK(v6): 2014/3/1~ until now |
| Area Coverage             | 60° S – 60° N         | 54.975° E-150.025° E, |
|                           | 15.0° S - 55.0° N     | 20.025° S-60.025° E |
| Unit                      | mm/day                | m             |
| Spatial Resolution        | 0.25° × 0.25°         | 0.05° × 0.05°  |
| Temporal Resolution       | 1 day                 | 1 hour        |

2.3. Data comparison

Prior to the analysis, the spatial resolution of GSMaP, APHRODITE and elevation data were adjusted. The reference resolution was set as 0.1° × 0.1° of the GSMaP and APHRODITE and elevation data grid was adjusted to GSMaP. Specifically, we weighted the mean value and estimated the value from the overlapping grids. The number of grids corresponded to 8,000 grids of 0.1° × 0.1° grid. In practice, 7,170 grids were used in this analysis, excluding missing values such as those overseas.

Since GSMaP and APHRODITE provide hourly and daily precipitation data, respectively, the precipitation of GSMaP was multiplied by 24 for comparison.
About 70-80% of Lao P.D.R is plateau and mountainous area, and the major cities such as Vientiane (160-180m above sea level), Pakse (90-130m above sea level) and Savannakhet (130-180m above sea level) are located in the remaining 20-30% of the flat area. So, we divided the entire grids into three classes corresponding to the elevation: flat area (100m to 200m), plateau area (200m to 600m) and mountainous area (600m to 2000m), to analyze the effects of elevation. The number of grids each elevation class after categorization was 1,688, 2,106, and 2,293, respectively.

3. Result and discussion

There was a clear difference in precipitation between the rainy (R) and dry (D) seasons both in GSMaP and APHRODITE (Figure 2). GSMaP amounts in the flat area were larger than those of APHRODITE but the relationship was reversed in the plateau and mountainous areas.

![Figure 2. Total Precipitation by each product. Green bars are GSMaP values and yellow bars are APHRODITE values. Capital letter of D and R stand for Dry season and Rainy season, respectively. The six bars on the left, middle and right are precipitation on flat area, plateau area, mountainous area, respectively.](image)

![Figure 3. Precipitation amount calculated by subtracting APHRODITE's precipitation from GSMaP's precipitation at each elevation, with 5 days accumulated precipitation amount.](image)
The time series of precipitation differences among the products at each elevation are shown in Figure 3. The difference between products was small during the dry season because there was not much precipitation during that period, but the difference was larger during the rainy season. Interestingly, while the precipitation of GSMaP was slightly overestimated compared to APHRODITE precipitation at the beginning of the rainy season, there was a reversed trend in the middle and the end of the rainy season, where the precipitation of GSMaP was underestimated compared to that of APHRODITE. This trend seemed to be intensified with increasing elevation.

The boxplots provide a more detailed analysis of the estimation trends (Figure 4 a-c). These boxplots can be read that the difference in observational coverage appeared to be small in the middle of the rainy season at flat area and in the beginning and end of the rainy season at plateau area, but the range of precipitation the other combinations was varied. For these varied combinations, the GSMaP seemed to overestimate on flat area, while above 200m altitude (plateau and mountainous area), the opposite tendency can be shown. We created scatter plots for each combination and calculated slope of regression line and coefficient of determination as a next step. Then, we made a scatter plot about intersection point of regression line and the equation of y=x (Figure 5).

Figure 4. Estimation trend in flat area (a); plateau area (b), and; (c) mountainous area. Period-basis precipitation events happen on each grid during the specific period, divided by the number of days in that period. The grids where either GSMaP or APHRODITE has 0 mm/day of precipitation have omitted. Black line within each box means median; bottom and top of each box are 25th and 75th percentiles.
Here we found that in every elevation, the order of coordinate value was same (x_{end}<x_{beginning}<x_{middle}, as well as y coordinate). This indicated that focusing on period, the precipitation at the conversion from overestimation to underestimation of GSMaP increased with the order of end-beginning-middle of rainy season in all elevation class. Besides, focusing on specific elevation, there was a tendency that the conversion happened with less amount of precipitation in mountains area than plateau area, and flat area followed it.

Here we suggest that underestimating GSMaP can be caused by low precipitation in the mountainous areas, compared to the other elevation classes. This is consistent with a previous study mentioned that GSMaP underestimates more in high elevation area than low elevation area[8], and here we also considered the amount of precipitation that caused underestimation.

On the contrary, in flat area, GSMaP was overestimated compared to the APHRODITE until certain amount of precipitation (in this case, 6mm/grid). In the previous study, it has been pointed out that APHRODITE value is about 33-38% less than the rain gauge value itself, and because of this, GSMaP could be a useful product in flat area.

Figure 5. Scatter plot about intersection point of regression line about GSMaP and APHRODITE correlation diagram and y=x line

4. Conclusion
In this analysis, topographical (elevation) and seasonal effects on satellite data (GSMaP) were discussed by comparing with ground-based observations (APHRODITE). About the elevational factor, we found that the precipitation when conversion from overestimate to underestimate of GSMaP happens varies from each elevation and that the precipitation which occurs the conversion increases as the elevation decreases. Which means the conversion can be caused with small amount of precipitation in the mountainous area. On the other hand, in flat area, GSMaP is overestimated compared to the APHRODITE until certain amount of precipitation (in this case, 6mm/grid). That could be a promising result for using GSMaP, given what has been pointed out in the previous study that APHRODITE value is about 33-38% less than the rain gauge value itself. About the periodical factor, we found that the
conversion happened at smallest precipitation in the end of rainy season, then beginning of rainy season, and then middle of the rainy season, in all elevation classes. Unfortunately, we couldn’t identify the factor which causes this trend in this analysis. In this analysis we only used the data in 2014, so further verification with longer data is expected.

Reference

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