RAINFALL VARIABILITY OVER BANGKA BELITUNG ISLAND
BASED ON VALIDATED TRMM PRODUCT

VARIABILITAS CURAH HUJAN DI KEPULAUAN BANGKA BELITUNG
BERDASARKAN DATA TRMM TERVALIDASI

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ABSTRACT

The rainfall variability over Bangka Belitung Island Province is investigated using validated TMPA 3B42RT satellite rainfall data. For 10 years average (2001 - 2010), we find that the validation process could improve the performance of TMPA series at dasarian scale by increasing correlation coefficient from 0.82 to 0.9. In general, the area receives considerably high annual rainfall ranging from 1800 to 3000 mm. The northern part of Bangka District is identified as driest area while the central part of West Bangka District and northern part of South Bangka District is detected as the wettest area. Compared to past rainfall atlas, recent annual rainfall pattern displays possible significant change both in intensity and spatial distribution. Wet season is observed starting from the end of October till May while dry season is detected starting from the early of June till mid of October. There are double peaks of monthly rainfall i.e. April and December over all climate zone of the Province. The findings prove that rainfall patterns are very much affected by interrelation of ITCZ movement and monsoon.

Keywords: TMPA, rainfall variability, Bangka Belitung

ABSTRAK


Kata kunci: TMPA, variabilitas hujan, Bangka Belitung

1. Introduction

The region of Indonesia is an interesting topic for climate research because of its role in atmospheric circulation. Rainfall over the region has been studied by many researchers starting from the colonial era such as Boerema [1] who analyzed monthly rainfall of thousands gauge across the region to create climate sub-division. To avoid the effect of unequal length of the months, he reduced original monthly value into months of 30 days. He found that rainfall in the region is controlled by three factors i.e. the equatorial double rainy seasons, the monsoons and local influence referring to gradient of elevation and unequal local heating. Regionalization of rainfall over Indonesia was then studied in modern era as well using different method [2].

Since Indonesia region covers very large area with thousand islands and various elevation, the rainfall
over the regions is totally not homogeneous and therefore is unique. It is well known that rainfall variability in Indonesia, both in space and time is influenced by external large scale phenomena such as El Nino–Southern Oscillation (ENSO), monsoon [3] and interconnection of those factors [4]. The impact of ENSO is mainly identified in southern monsoonal region and is more spatially coherent during transitional and dry season.

Chang et al. [5] have researched the annual cycle of rainfall over Southeast Asia, including Indonesia. Based on monthly mean rainfall recorded by met stations, he noticed that the stations north of 10°N experience a wet season during July and October and those located in south of 5°S have their wet season during January and April. Those studies of Indonesian rainfall variability were mostly based on observational network data which is unfortunately too sparse. Consequently, rainfall patterns at local scale could not be recognized well. Rainfall estimates based on remote sensing technology such as TRMM product, on the other hand offers advantages in term of continuous measuring and spatial coverage.

There have been several researches maximizing the superior of TRMM product to study Indonesia rainfall. Chang et al. [5] used TRMM data to identify the monsoon regime and found that part of Indonesia lying in south of equator, including Bangka-Belitung Province, is classified as boreal winter monsoon regime. Vermimmen et al. [6] utilized TRMM product to monitor drought over the country. The publications of study focusing on comparison of TRMM product against ground stations in Indonesia confirmed that TRMM product is quite well in monthly scale [7,8]. To reduce the bias, Vermimmen et al. [6] introduced an equation of power function developed using monthly observation versus monthly aggregated TRMM data.

Extending those efforts, the present study aims to explore the benefit of TRMM product at finer scale, 10-day rainfall total in capturing the spatio-temporal variability of rainfall over a local scale, Bangka-Belitung Island, Indonesia. Over the domain area, monthly and annual rainfall atlas has been created using rain gauge data within period of 1911 – 1940 [9] and 1971 – 2000 [10]. Unfortunately, no rain gauge is

well operated afterward due to lack of maintenance. The new set of rain gauges just has been installed in the end of 2011. The result of the present study is therefore, expected to be an update of those publications. The structure of this paper is organized as follows: Section 2 details the study area, the data and methods which were applied in this study. The results and discussion is documented in Section 3 and the last, Section 4 reports the concluding remarks.

2. Methods

Study Area and Data. The Province of Bangka Belitung Island is lying between 104°20’ – 109°30’ East Longitude and 0°50’ – 4°10’ South Latitude, with its total area of 81,725.14 km² [11] as depicted by Figure 1. Bordered by Bangka Strait in the west, Karimata Strait in the east, the South China Sea in the north, and the Java Sea in the south, this province is totally surrounded by waters. The major characteristic of its main islands (Bangka and Belitung) is plane area with scattered valley and hilly.

The data used in this study were acquired using the GES-DISC Interactive Online Visualization And aNalysis Infrastructure (Giovanni) as part of the NASA’s Goddard Earth Sciences (GES) Data and Information Services Center (DISC). We select the TRMM Multi-satellite Precipitation Analysis 3B42 Real Time product at daily scale (TMPA 3B42RT, TMPA hereafter) with 0.25° X 0.25° spatial resolution within period 2001 – 2010 (10 years). Detail description of TRMM satellite and TMPA version could be found in Huffman et al. [12].

This daily estimates rainfall data were aggregated then in to 10-day total (dasarian hereafter, BMKG terminology). There are three dasarian values per month starting with dasarian I for day 1 – day 10, dasarian II for day 11 – day 20 and dasarian III for next day up to last day of the month. Terminology of dasarian I, II and III is actually intended to indicate the early, mid and the end of interested month, respectively. Thus, we have 36 dasarian values per annum. These TMPA data at dasarian scale were validated then against surface observation data collected from three BMKG stations.
Since the TMPA data represent spatial average (one grid cell for 772 km² near equator) [6], it is actually more comparable when we have more rain stations which are proportionally distributed in one TMPA grid cell. Unfortunately, no rain gauges data available in the last decade so that we used BMKG station data only for current study (see Table 1). It is not ideal for validation process in tropic area where local rain storm is dominant. However, the relatively flat study area encourages us to be confident in running this technique. No missing value was found from the surface observation series.

TMPA Validation Technique
The performance of TMPA with regard to observation data was checked by calculating its bias (root mean square error, RMSE) and its correlation coefficient ($r$) at dasarian scale for whole series. In Pangkalpinang, the TMPA data was checked against data from Pangkalpinang Met Station only while in Tanjungpandan, the TMPA data was compared against average of Tanjungpandan Met Station and Tanjungpandan Geo Station (see Table 1). In general, result of performance test shows that using both areas together promises better performance than using individual area (Table 2), which is represented by low error and high correlation. Figure 2 depicts a plot of TMPA compared to observation data for all two validation areas together. We therefore select the average of both two validation areas as a series to produce an equation which is able to improve performance of TMPA series, similar to study by Vernimmen et al. [6]. Among other models that have been applied using “curve fitting technique”, we found that $4^\text{th}$ degree polynomial model could optimally increase the accuracy of TMPA estimate as expressed in Eq. (1).

Table 2. The performance of TMPA presented for each validation area and all two validation areas together.

<table>
<thead>
<tr>
<th>Test</th>
<th>Pangkalpinang</th>
<th>Tanjungpandan</th>
<th>Together</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE (mm/10-day)</td>
<td>54.16</td>
<td>59.32</td>
<td>44.91</td>
</tr>
<tr>
<td>$r$</td>
<td>0.53</td>
<td>0.63</td>
<td>0.69</td>
</tr>
</tbody>
</table>
Figure 2. Performance of TMPA compared to station data averaged for two validation areas together, at dasarian scale for period 2001 - 2010. Jan1-01 refers to first dasarian of January 2001.

\[ P^* = (a * P^1) + (b * P^1) + (c * P^1) + (d * P^1) + e \]  

(1)

Where,

\[ P^* \] = Validated TMPA  
\[ P \] = TMPA  
\[ a = 1.67E-08 \]  
\[ b = 1.32E-05 \]  
\[ c = -0.00845 \]  
\[ d = 1.67 \]  
\[ e = 0 \]

In the below Table and Figure, we demonstrate the ability of established equation in reducing error. For both validation areas together, the root mean square error of 10-day rainfall total over whole series is reduced from 44.91 to 39.14 mm and the correlation is improved from 0.69 to 0.72 (Table 3). Averaged over 10 years (2001 – 2010) to capture the climatology of dasarian rainfall, the validated TMPA data for both validation areas together show good agreement compared to observational data with RMSE of 17.7 mm/10-day and correlation coefficient of 0.9, improved from 0.82 for not validated TMPA (see Figure 3).

Table 3. The performance of validated TMPA which was calculated using established equation as expressed in Eq. (1).

<table>
<thead>
<tr>
<th>Test</th>
<th>Pangkalpinang</th>
<th>Tanjungpandan</th>
<th>Together</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE (mm/10-day)</td>
<td>47.64</td>
<td>52.92</td>
<td>39.14</td>
</tr>
<tr>
<td>( r )</td>
<td>0.55</td>
<td>0.65</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Figure 3. Average validated TMPA at dasarian scale over 2001 – 2010 for two validation areas together, compared to station data and not-validated TMPA.
Rainfall Analysis Method. We perform spatial rainfall variability analysis by mapping annual and monthly rainfall after applying the established equation for all grid cells included in the analysis (see Figure 1). The characteristic of monsoon, in term of its onset and withdrawal, was analyzed as well by mapping rainfall at dasarian scale for October-November (onset) and May-June (withdrawal). To get more detail variability at district level, the original grid cell size was smoothed in to 0.0625° X 0.0625° (around 48 km² per grid cell) in mapping process.

Temporal variability of rainfall was analyzed by plotting annual cycle of rainfall per climate region at monthly scale. For this purpose, we used publication of Indonesia climate zone which was updated recently by BMKG. There are four climate subdivisions over the province, which is quite similar to work by Boerema [1]. The Bangka Island is divided by three zones i.e. west coast, north-west and east coast of the island with climate zone number of 52, 53 and 54 respectively, while Belitung Island is classified as single climate zone regarding its rainfall homogeneity [13].

We adopt our official definition of season and its onset in this study. At monthly scale, wet and dry season is defined based on 150 mm rainfall threshold. Wet season (dry season) is a series of months with rainfall at least (less than) 150 mm. Monsoon onset on the other hand, is defined using finer resolution, dasarian scale (10-day total). Onset (withdrawal) is defined as the first dasarian receiving more than or equals to (less than) 50 mm which is followed by sequence of at least two similar dasarian. Consequently, the information of monsoon onset is not truly a fix date, yet just about the early, mid or end of the month. Thus we will get total of at least 150 mm rainfall during the first three dasarian calculated from monsoon onset.

3. Results and Discussion

Annual Rainfall. Based on distribution of annual rainfall, the driest area over the province is observed in the northern part of Bangka District that receives rainfall around 1800 mm per year. The wettest area, in contrast is observed in the central part of West Bangka District and northern part of South Bangka District with annual rainfall reaches 3000 mm (Figure 4). In Belitung Island, the rainfall is observed relatively similar for the island entirely, around 2200 – 2400 mm/year. In general, the gradient of annual rainfall over the province tends to be NE – SW oriented, where the minimum rainfall is observed in the northeast and the maximum rainfall is recorded in the southwest.

Compared to two previous publications of rainfall atlas [9,10], this pattern is relatively different. Using rainfall series of proportionally distributed 27 gauges over the area within period of 1911 – 1940, it is known from first publication that annual rainfall over Bangka Belitung Island ranges from 2000 – 3500 mm/year where the northern part of Bangka District, northern part of West Bangka District and northwestern part of Belitung District are identified as the wettest area with annual rainfall more than 3000 mm/year. In the newest rainfall atlas which was created using 10 gauges within period of 1971 – 2000, it is observed that annual rainfall varies from 2250 – 3250 mm per year.

Figure 4. Spatial distribution of annual rainfall based on validated TMPA with names of district indicated in the white boxes.
The area with annual rainfall more than 3000 mm/year is only detected in the central part of Belitung District. Unfortunately, the distribution of limited gauges in the newest atlas is not spatially proportional. The first publication is therefore considered more comparable with recent study because of its good distribution of rain gauges. Assuming that effect of unequal length of data period is reduced by averaging process, this finding brings the idea of changing of rainfall pattern. The maximum annual rainfall is reduced from 3500 mm to 3000 mm and the northern part of Bangka District which is identified as wettest area in the past (1911 – 1940), is observed as dry area in the recent study.

**Monthly Rainfall.** The evolution of monthly mean rainfall is shown in Figure 5. In general, December is the wettest month in which every place gets more than 200 mm rainfall, while July-August-September are months with the minimum monthly rainfall, less than 150 mm. Rainfall is observed decreasing over whole province in February. The northern part of Bangka District and eastern part of East Belitung District is noticed as driest area for this month. The increased dryness of monsoon is found as a cause for February rainfall reduction [1].

During March and April, rainfall is recorded increasing again as the effect of crossing the sun over equator in March [5] which is manifested by the southward and northward movement of the inter-tropical convergence zone (ITCZ). Even for central part of West Bangka and northern part of South Bangka, maximum monthly rainfall is found in April. Spatial pattern of rainfall in May is quite similar with that of January, ranging from 150 – 300 mm per month. In June and October, monthly rainfall is observed uniformly across the province with rainfall varies from 150 – 200 mm.

Referring to BMKG definition of wet and dry season where 150 mm rainfall is selected as a threshold at monthly scale, we can roughly define that wet season over the province occurs during October – May, whereas dry season takes place during June – September. Thus September – October and May-June are months where season potentially changes.

**Monsoon onset and withdrawal.** To get more detail spatial information of monsoon onset and withdrawal, we mapped as well, rainfall at dasarian scale over the area of interest. As shown in Figure 6, in dasarian I and II of October, the province receives rainfall less than 50 mm confirming that it still experiences dry season. In dasarian III of October and dasarian I of November, rainfall is observed more than 50 mm for all areas. In the next two dasarian of November, rainfall over the study area is recorded more than 75 mm. This pattern informs us that the monsoon onset over the province, where wet season starts to take place is dasarian III or the end of October.

![Figure 5. Spatio-temporal characteristics of monthly rainfall based on validated TMPA. Number in the right-top of each map symbolizes month, 1 for January.](image-url)
On the other hand, we noticed that the province totally faces dry season starting in dasarian I of June. As depicted in Figure 7, our map starts with rainfall falling in dasarian I of May, in which total rainfall in 10 days is more than 75 mm. In the next two dasarian, total rainfall drops but still more than 50 mm per 10 days. In the early month of June, almost all areas get rainfall less than 50 mm, followed by dasarian II with minor increasing and dasarian III with much more drier rainfall. This clarifies that first dasarian of June is time of monsoon withdrawal.

Temporal Variation. The analysis of annual cycle per climate region exhibits major feature which are the double peak of rainfall over all regions, April and December and the relatively high rainfall during dry season, more than 100 mm/month (see Figure 8). The first peak is obviously affected by crossing the sun over equator (March). Surprisingly, the second peak is not appear in October – November suggesting the missing influence of next crossing the sun over equator (September).

In region 52, monthly rainfall for March, April and May is actually relatively close with minor gap. The first maximum monthly rainfall (April) is quite similar with the second one (December), around 300 mm/month. Region 53 is characterized by sharp peak of April rainfall compared to March and May. Similar with region 52, the rainfall total of April is quite similar also with that of December. In region 54, rainfall in the second peak is much higher than the first peak, 300 mm in December compared to 200 mm in April. During March, April and May, rainfall curve is relatively flat, similar with region 52. In Belitung, the annual cycle graph is very specific. The Island receives more than 200 mm rainfall per month throughout the year except February and September with rainfall considerably drier, around 150 mm/month. Monthly rainfall in April (first peak) is slightly lower than monthly rainfall in December (second peak).

In general, the annual cycle of monthly rainfall over all climate regions explains changing of rainfall intensity in January. In the past, rainfall in April was always lower than that of January [1]. Compared to this study, while the intensity of April rainfall is actually considerably stable, around 200 - 300 mm, the intensity of January rainfall is detected decreasing from 300 – 400 mm to 200 – 250 mm.

These results also inform more detail characteristic than what Aldrian and Susanto [2] found. They identified Bangka Island as southern monsoonal region with single peak and classified Belitung Island as semi-monsoonal region with double peak but the second peak is in October-November, closely related to ITCZ movement. In the present study, we observed obviously that all regions have two peaks. We found also that the province entirely receive second maximum monthly rainfall in December which does not associate to ITCZ movement. The intense Asian wet monsoon could be potential cause of receiving the second peak in December.
4. Conclusion

The performance of TMPA 3B42RT rainfall estimate is considered adequate after validated against observational data using established equation, 4th degree polynomial. Realizing lack of ground observation network, we then explore more the potential use of validated TMPA series to capture major feature of rainfall over Bangka Belitung Island, in space and time. The analysis of annual rainfall successfully identified the driest area in the province i.e. the northern part of Bangka District and the wettest area i.e. the central part of West Bangka District and northern part of South Bangka District.

Compared to past rainfall atlas, the annual rainfall is expected changing both in its intensity and its distribution. The main characteristic of monthly rainfall is the reduced rainfall in February across the province followed by higher rainfall in March, April and May. The detail analysis for each climate zone revealed clear double peak of monthly rainfall confirming work by Boerema [1]. The second peak is in December, suggesting the interrelation between impact of crossing the sun over equator manifested by ITCZ movement and the intense Asian winter monsoon.

References


