The Regionalization of Indonesian Maritime Continent Rainfall based on Integrated Multi-satellite Retrievals for GPM (IMERG)

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Abstract. The need for adequate rainfall data in all regions of Indonesia cannot be achieved only by relying on ground observation tools. This work aims to evaluate the application of spatial satellite rainfall data in characterizing rainfall associated with climatic conditions over Indonesia. This study applied an Integrated Multi-satellite Retrievals for GPM (IMERG) data using a double correlation method (DCM). The analysis was carried out in the period April 2014 to March 2019. Before regionalization, IMERG V06 data were validated using observed rainfall data from the Agency for Meteorology, Climatology, and Geophysics of the Republic of Indonesia (BMKG). The results showed that 96% of 154 total validation locations have a high correlation score between IMERG and rain gauges ($r = 0.5 – 0.97$). IMERG was also able to identify monthly and annual rainfall patterns in Indonesia. Based on DCM, we obtained four rainfall regions in Indonesia. Region A has the monsoonal characteristic, covers central and south Indonesia from south Sumatra to Nusa Tenggara, south parts of Kalimantan, some areas of Sulawesi, and parts of Papua. Region B has an equatorial pattern (semi-monsoonal), located in the equatorial area of Indonesia and covers the west and east part of Sumatra and the north-central part of Kalimantan. Region C, with an anti-monsoonal pattern, covers Maluku, western-central Papua, and parts of Sulawesi. Region D is influenced by monsoon and cold surge characteristics, located in the north part of Sumatera and a small portion of northern Kalimantan to the South China Sea region. Besides the new region D, this research also showed five other differences between IMERG-based map and gridded rain gauges’ data-based map (2003). The regionalization results based on IMERG reveal that there is a possibility of updating areas with certain rainfall characters in Indonesia related to resolution, density, and updates data sources.

Keywords: IMERG, validation, DCM, regionalization

1. Introduction

Indonesia is a tropical archipelago country located along the Equator, between the continents of Asia and Australia, between the Pacific Ocean and the Indian Ocean. It traversed by the equator, consisting of islands stretching from west to east. The length of Indonesia's coast reaches 95,181 km with a sea area of 5.8 million km², dominating the total area of Indonesia's territory of 7.7 million km² [1]. The ratio of sea area to land area in Indonesian region is around 75% compared to 25%. With such an extensive comparison, Indonesian climate is greatly influenced by the seas within the Indonesian archipelago and around its geopolitical areas [2]. By fact, Indonesia is also called Indonesia Maritime
Continent (IMC) [3,4]. Generally, the climate of Indonesia is very complex due to the geographic position and also because of the interaction between global climate phenomenon and the local environment. In a climatological aspect, rainfall patterns in Indonesia are fascinating for researchers to study. Bayong (1999) [5] divided rainfall in Indonesia into three pattern areas, i.e. monsoonal type, equatorial type, and local type. Using pentad-mean rainfall data from 46 stations period 1961-1990, Hamada et al. (2002) [6] made four distinct dominant rainfall pattern within Indonesia. Hereafter, Aldrian and Susanto (2003) [2] regionalized rainfall region in Indonesia using data grid (2.8125°x2.8125°) based on 100 land stations. They introduced a Double Correlation Method (DCM) and determined three dominant rainfall regions in Indonesia.

Today's technological developments make it possible to learn about the character of rainfall in an area not only with rain gauges but also with weather satellites. The applications of satellite rainfall products are swiftly escalating due to their wide spatial coverage, continuous measurement, free of charge and nearly real-time availability of some products via the internet. The most essential point is the satellite precipitation product could overcome the spatial coverage limitation of point-based ground observations in remote area such as mountainous and oceanic regions [7]. One of the newest generation of weather observatory satellites is Global Precipitation Measurement (GPM). It’s on mission to provide next-generation observations of rain and snow after the Tropical Rainfall Measurement Mission (TRMM) era. The GPM Core Observatory was launched by NASA and the Japan Aerospace Exploration Agency (JAXA) on February 27, 2014. The tool carries a sophisticated instrument that will set a new standard for measuring precipitation from space. The Integrated Multi-satellite Retrievals for GPM (IMERG) products provide better spatial (0.1°) and temporal (30 min) resolutions than the TRMM and Multi-satellite Precipitation Analysis (TMPA) products. Besides, the coverage of the IMERG (60°N–60°S) is also more extensive compared to the TMPA products (50°N–50°S).

The performance of IMERG in depicting precipitation features over various areas have been examined. In the United States, Sungmin and Kirstetter [8] showed that IMERG precipitation estimates could be a reliable alternative to ground-based measurements even at the sub-daily scale, IMERG substantially overestimates normalized amplitude of diurnal precipitation in the central U.S., while it tends to underestimate diurnal variations over the mountain regions. Gaona et al. [9] found that IMERG underestimation bias is small enough to propose it as a reliable source of precipitation data in a mid-latitude country such as the Netherland. In Singapore, IMERG correlated well with gauges measurements monthly but moderately on a daily scale [10]. They also identified that IMERG overestimated moderate precipitation events (1–20 mm/day). Xu et al. [11] highlighted the superiority of GPM to TRMM in the southern Tibetan Plateau region. Also, they recommended that further improvement of the rainfall retrieval algorithm is needed by considering topographical influences for both GPM and TRMM rainfall products. In the India monsoon area, Prakash et al. [12] showed that the IMERG estimates represent the mean monsoon rainfall and its variability more realistically. However, the ability of IMERG to describe rainfall variations over Indonesia maritime continent (i.e., concerning area in this study) has not been evaluated in detail by previous studies; therefore, this topic is very interesting to be discussed in this study. By using high-resolution satellites data rather than ground observation data, this study expected to provide more comprehensive description of rainfall characteristics in Indonesia.

2. Data and Methods

2.1. IMERG data

The Integrated Multi-satellite Retrievals for GPM (IMERG) is an algorithm for combining information from the GPM satellite constellation into an estimate of rainfall over most of the earth's surface [8]. IMERG products are available in several types such as IMERG-E, IMERG-L, and IMERG-F. Those three terms are explained as follows: "Early" multi-satellite product is produced 4 hours after observation time, "Late" multi-satellite product is delivered 12 hours after observation time, and once after the monthly gauge analysis is received "Final" satellite-gauge product is available three months after the observation. IMERG-F or research products are manufactured by The NASA Precipitation Processing System (PPS) when all required additional and high-quality geolocation data is received with
the aim of accuracy, completeness and consistency. The detailed characteristics of IMERG-F [13] used in this study were shown in Table 1 below.

Table 1. IMERG Level 3 Final Run specification used in this research

| Algorithm                  | Integrated Multi-satellite Retrievals for GPM |
|----------------------------|-----------------------------------------------|
| Basic acronym              | IMERG                                         |
| Data sets                  | 3IMERGHH/3IMERGM Final Run multi satellite-gauge combination |
| Spatial grid; Coverage     | 0.1°x0.1° lat/lon; 14°S - 8°N/ 90°E - 142°E     |
| Version                    | 06A                                           |
| Time interval; span        | daily and monthly; April 2014-March 2019       |
| Latency                    | Final 3.5 month after the month's end          |

2.2. Ground rainfall observation data

This study covers region between 14°S to 8°N and 90°E to 142°E (Figure 1). Geographically, the site belongs to Indonesian territorial (coloured map). Rainfall data on 154 locations of rain gauges were obtained from the Agency for Meteorology, Climatology, and Geophysics of the Republic of Indonesia (BMKG) spread across 34 provinces in Indonesia. The monthly data were accumulated from daily observations by standard manual (Observatory) rain gauges. The analysis was carried out in the time span from April 2014 to March 2019. The months that contain missing value were removed and were not used in the validation process.

Figure 1. Research area and observational rain gauge distributions

2.3. Validation

Statistical validations are used for validating IMERG rainfall product in this research are:

Linear Correlation Coefficient ($r$): this analysis was performed to determine the relationship between rainfall from IMERG and in situ data. The cross-correlation analysis can identify how the validity of rainfall data from IMERG. The equation is defined as follows [14]:

$$r = \frac{\sum_{i=1}^{n} (S_i - \bar{S})(G_i - \bar{G})}{(n-1)\sigma_S \sigma_G}$$

(1)
Mean Bias Error (MBE) and Root Mean Square Error (RMSE): both analysis used to find out how much the average error value between the data from IMERG and in-situ data. The equation (Feidas, 2010) used are:

\[
MBE = Bias = \frac{1}{n} \sum_{i=1}^{n} (S_i - G_i) 
\]

\[
RMSE = \left( \frac{1}{n} \sum_{i=1}^{n} (S_i - Bias - G_i)^2 \right)^{1/2}
\]

Where \(S_i\) are the satellite data, \(G_i\) are the ground station data, \(\sigma_S\) and \(\sigma_G\) are their standard deviations (respectively), and \(n\) is the number of data pairs. The correlation coefficient \((r)\) measures the degree of linear association between the satellite data and observed data distributions. The MBE represents the systematic component error by overestimating or underestimating the gauge data by the satellite estimates. The RMSE involves the departures' square from reality and, therefore, is sensitive to extreme values.

Point-by-point analysis and spatial analysis were applied to the monthly data [15]. The point-by-point analysis consisted of a comparison between gauge data coordinates with satellite data corresponding pixel. The average spatial analysis consisted of a spatial average of all rain gauge locations compared to all corresponding pixels of satellite data based on the Indonesia rainfall region. Not all observational data were used for this purpose because several rain gauge locations were located between two areas of rainfall pattern, from 154 rain gauge stations on existing data selected to only 119 stations that match the location criteria and rain patterns. The distribution of validation locations is 94 stations located in parts of Indonesia, which covers the monsoonal types (A), 17 stations located at the Equatorial types (B), and eight stations located at anti-monsoonal types (C). Figure 2 showed the rain gauge station's distribution according to monsoonal type, semi-monsoonal type, and anti-monsoonal type of rainfall.

![Figure 2](image_url)

**Figure 2.** Distribution of rain gauge locations based on three rainfall pattern types in Indonesia. Green colours dots showed monsoonal rainfall type, while blue and red representing equatorial type and anti-monsoonal type respectively.

### 2.4 Double Correlation Method (DCM)

This research applied the same procedure used for rainfall regionalization known as DCM method described in Aldrian and Susanto (2003) [2]. The main differences were; 1. This research used high-resolution IMERG data with 0.1°x0.1° spatial resolution, while previous research used 2.8125°x2.8125° spatial resolution, 2. Our calculation involved all grids in the research area, including land and ocean grids, while the previous result just using land data based grids, 3. This study used only five years period starting from January 2015 to December 2019 (adjust to the acquisition of pure high-resolution data
from GPM core) while previous research’s result examined monthly rainfall data from January 1961 – December 1993 (33 years). There were five steps to apply the DCM method to IMERG data. First, Image raster data preparation. Second, Raster calculator and extractions. Third, Selecting the reference grids, which represents monsoon, equatorial, and anti-monsoon rainfall patterns. Successively selected grids located at Cut Nyak Dien Meteorological-Aceh (96.25°E, 4.05°N), Kupang Climatology Station-NTT (123.65°E, 10.15°S), and Ambon Climatology Station-South Maluku (128.35°E, 3.35°S). Fourth, Reference grids correlated with all existing grids. Grids linked above a particular threshold value were selected to belong to a region. Each region formed was then averaged. Fifth, the mean annual cycles of the resulting areas then were correlated again to all grids. Final parts were the result of these two times correlation. The threshold is \( r^2 \geq 0.67 \), with a 99% confidence level. For several areas not included in the regionalization based on these three reference points, additional reference points were selected, and the same procedure was carried out. So that all areas were known for their rainfall patterns. Regions that have a strong correlation merged into the same place.

3. Results

3.1 Monthly point by point time-series validation

Figure 3 showed the time series of monthly rainfall points between IMERG and rain gauge data based on 154 locations in five-year records. Generally, the relationship between IMERG value with rain gauge is medium to very high (0.41 to 0.96) was indicated by point-by-point analysis. The time series of monthly rainfall showed 128 point gauges have a very high correlation (\( r > 0.7 \)), 20 point gauges with high Correlation (\( r=0.5-0.699 \)), and only six rain gauge locations have medium correlation (\( r = 0.43 – 0.499 \)). It can be boldly stated that 96% of total validation locations show a high compatibility level between IMERG and rainfall observations in the field. The point-by-point error statistical results show RMSE of 154 point gauges varied between 22% – 205%. The majority of validation locations (98 rain gauges) have RMSE less than 50% from their monthly rainfall average. Fifty point gauges have RMSE between 50% - 100%, and only 6 locations have RMSE more than 100% from their monthly rainfall average.

![Figure 3. Monthly point by point correlation between IMERG and rain gauge data period April 2014 to March 2019.](image)

3.2 Monthly rainfall spatially averaged validation on three rainfall regions in Indonesia

The pattern of averaged time-series monthly rainfall from IMERG was quite similar to gauge data in Indonesia’s unique rainfall region showed by Figure 4. Whereas, a statistical validation results can be seen in the table 2. In Monsoonal type (A), the average monthly rainfall from IMERG was 212.09 (mm/month). Meanwhile, the average monthly rainfall from the rain gauge time series was 201.99 (mm/month). The spatially averaged time-series monthly rainfall relationship between IMERG and rain gauge has a very high correlation (\( r=0.99 \)) with RMSE was 8.34%, and the MBE score was 5.08%. In the Semi-monsoonal type (B), the average monthly rainfall from IMERG and rain gauge were 212.09
(mm/month) and 201.99 (mm/month), respectively. The spatially averaged time-series monthly rainfall relationship between the two datasets has a very high correlation ($r=0.99$), and RMSE was 8.34%. The MBE score was 5.08%, indicating overestimation slightly from IMERG data to ground references. In the Anti-monsoonal type (C), the same as other regions, the rainfall pattern was almost identical, although IMERG average rainfall was higher than rain gauge average rainfall. IMERG averaged data was 221.44 mm/month while ground observation rainfall average in Region C was 203.7 mm/month. Statistical scores indicated a very high Correlation ($r = 0.93$) between IMERG data and ground reference data. The score of RMSE and MBE was 19.77% and 9.04%, respectively.

Table 2. Statistical monthly time series validation results between IMERG and rain gauge data, spatially average based on Indonesian Rainfall Pattern

| Type  | Rainfall Average (mm/month) | $r$ | MBE (%) | RMSE (%) |
|-------|---------------------------|----|--------|---------|
| Rain gauge | IMERG                     |    |        |         |
| A     | 201.59                    | 0.99| 5.21%  | 8.60%   |
| B     | 233.58                    | 0.92| 5.99%  | 14.67%  |
| C     | 203.07                    | 0.93| 9.04%  | 19.77%  |

Figure 4. Comparison of monthly rainfall spatially averaged time series from IMERG and rain gauges in Monsoonal type (A), Semi-monsoonal type (B), and Anti-monsoonal type (C) on period April 2014 to March 2019

Figure 5 exhibited the monthly relationship between rainfall measured by IMERG and rain gauge in regions A, B, and C for five years averaged. In region A, The IMERG data suggested a perfect match with the field data giving a very high correlation ($r=0.997$), and the RMSE was 13.0 mm/month (table 3). Statistical mean bias error value (10.55 mm/month) indicates that IMERG data was higher than average rainfall on ground references. This condition dominantly occurred from February to September. In region B, which has two rainfall climax in a year, IMERG followed this double peaks rainfall pattern well (Figure 5). The Correlation was very high ($r=0.976$) and RMSE only 20.69 mm/month (Table 3). Almost the same as region A, monthly mean IMERG data in this region also higher than ground observation (MBE = 14.05 mm/month) but the period of significant gap occurred from December to
March and July to October. The annual pattern of area C from IMERG has produced a similar pattern to the rain gauge rainfall annual data pattern (Figure 5). The Correlation was very high \(r=0.97\), and RMSE was 25.62 mm/month (Table 3). The Mean Bias Error showed a positive score (18.36 mm/month), indicating overestimation from IMERG to ground rainfall observation. The period of significant deviation between these two data occurred from November to April.

**Figure 5.** Comparison of annual pattern of IMERG and rain gauge rainfall data in Monsoonal type (A), Semi-monsoonal type (B), and Anti-monsoonal type (C) averaged on period April 2014 to March 2019

| Type  | \(r\)   | MBE   | RMSE  |
|-------|---------|-------|-------|
| A     | 0.996   | 10.48 | 13.27 |
| B     | 0.976   | 14.05 | 20.69 |
| C     | 0.970   | 18.36 | 25.62 |

### 3.3 Four Dominant Rainfall Regions Within Indonesia

The results from the DCM on 110,000 grids of IMERG data over Indonesia and surrounding area were four climate regions. The processes passed are in the form of determining initial references. The three initial IMERG grids selected were in the Kupang-NTT, Cut Nyak Dien-Northern Sumatra, and Ambon-Maluku. Because some areas were not covered by regionalization which only used three reference points in DCM, then one reference point was added first in Medan (another side of Northern Sumatra). It turns out that this grid point produces a region outside the three areas generated by the three initial reference grids. The remaining areas that were still not incorporated in any part given additional reference points.

Figure 6 indicated, Region A (green area) covers central and south Indonesia from south Sumatra to Nusa Tenggara, south parts of Kalimantan, some areas of Sulawesi, and parts of Papua. Region B (blue area) has an equatorial pattern, located in the equatorial area of Indonesia and covers the west and east part of Sumatra and the north-central part of Kalimantan. Region C (red area) with an anti-monsoonal pattern, covers Maluku, western-central Papua, and parts of Sulawesi. Region D (yellow area) located on the north part of Sumatera and a small portion of northern Kalimantan. With a threshold value \(r^2 \geq 0.67\) and the corresponding confidence level 99% in DCM, the four dominant patterns of Indonesia rainfall regions obtained.
The mean annual rainfall pattern of each region was explained in Figure 7. From the figure, every zone has its different characteristics. Region A has one topper and one valley indicating an exact habitude of the rainy season and dry season. The rise of the rainy season is in January while the lowest amount of rainfall in the dry season is in August. Region B has double peaks. The first period of high rainfall is on October – November and the second peak is on April. It can be seen from the graph that this region has enough rain throughout the year. Region C, which covers the east part of Indonesia, has one rainfall summit in the middle of the year, precisely in June. It looks different from patterns A and B. One might say, and it seems like the opposite of Region A patterns. Region D which mostly located on the South China Sea has the peak of rainfall on October and lowest rainfall in February. The rainfall pattern of this area notched like a combination pattern between regions B and C.
4. Discussion

4.1 Evaluation of IMERG Rainfall products in Indonesia

The distribution of monthly rainfall by satellite data showed high compatibility with ground references almost in all area of validation. The IMERG data was capable of depicting rainfall condition on the local site (point by point) in Indonesia, which has many islands, variations in the topography, and the influence of the seas around Indonesia. However, satellite data showed overestimated condition in monsoonal type (region A), equatorial type (B), and anti-monsoonal type (C). It was evident from the positive bias error, where the MBE were 5.21%, 5.99%, and 9.04%, respectively (Table 2). Based on rainfall monthly time series (figure 4) and annual pattern (Figure 5), IMERG performs a better estimate of rainfall for the rainy season than for the dry season. The estimated rainfall during the rainy season is underestimated, while during the dry season it is overestimated. This similar pattern also previously captured in Singapore [11], and Brazil [16]. IMERG has difficulty to estimate rainfall during the dry season, when the characteristics of rainfall events are generally less intense, lower in volume, and more sparsely spread across the region.

IMERG spatially averaged annual pattern rainfall data indicated the near-perfect capability to figure out the monthly rainfall observed at ground stations (Figure 5). This situation indicates that IMERG product can be used to determine annual climatic characteristics. The relationship of the monthly average rainfall measured by IMERG and rain gauge showed good agreement giving very high correlation score (r=0.97-0.99) and RMSE was less than 25 mm/month. These results indicated that IMERG has a bright future as rainfall data source for remote areas. So that, we can find out the potential for water reserves from rainfall in these areas.

4.2 Indonesian Rainfall Regions based on IMERG and its comparison with the previous result

The results of rainfall pattern regionalization in study area yielded four dominant rainfall regions in Indonesia including Region A, Region B, Region C, and Region D. Region A is the classical part mostly located at the south of the equator. This region is highly affected by a monsoonal wind conditions, composed of Australian monsoon or southeast monsoon (in April – September) and the Asian monsoon or northwest monsoon (in October-March). A large number of moistures during the Asian monsoon produce heavy rainfall in the wet season period [2,17]. Region B is the equatorial type of precipitation where the sun passes through the equator area twice a year (in March and September). The peaks of rainfall occur one month later than the movement of the sun through this region. Those two peaks (occurred in April and November) are semi-monsoonal type influenced by northward and southward propagation of the Inter-Tropical Convergence Zone (ITCZ). Tanaka (1981) [18] and Davidson et al. (1984) [19] described in detail the ITCZ movement in this region in boreal winter. Besides, the westerly wind over the Indian Ocean also carries water vapour toward the Maritime Continent, especially in spring and autumn [20, 21].

Region C has a reversed pattern characteristic with the monsoonal region A. Therefore; this region is called Anti-monsoonal region. In this area, rainfall has a peak in June. By paying attention to the distribution of Region C area that reaches the Western Pacific Ocean, there is a possibility that the annual rainfall pattern in this region is associated with the warm pool in that part of the ocean. This condition reinforced by the presence of Indonesian Through Flow (ITF) which moves from the Western Pacific Ocean to the Indian Ocean across small islands in the eastern part of Indonesia. During the dry season in region A (MJJAS) the sun position is in the Northern Hemisphere. The ITF carries warmer water from the warm pool to the Maluku Sea [22]. This warmer sea surface temperature (SST) enhances the convective zone [2].

Consequently, the climax of rainfall in June obtained. Another possible reason is the mountainous topography of the islands in this region. The condition can trigger orographic rain from the direction of the wind. Therefore, the area facing the wind direction will get rain while the opposite situation occurs in the area behind the mountains. Region D is the new rainfall region which obtains from this research. Region D mostly located at northern hemisphere in the west side of the research area. This region has high rainfall starting from June to December and a low amount of rain February – March. The pattern is associated with monsoon because it has one peak and one valley (but because it has dry difference period then region A, therefore, we call it monsoon type II). The low amount of rainfall in February and
March is unique. There is solid evidence of the possibility of cold surface current arriving from the north out of the South China Sea during January–March [23, 24] which reduces the amount of precipitation.

Several differences were shown by the overlaid regionalization map with the consequence of previous regionalization [2] see figure 8. First, in northern Sumatra, there is a new region obtain from this research that identified as a region D (monsoonal type II). This result consistent with the study by Hamada et al. (2002) [6] which also categorized this area as a monsoon region. Second, from the IMERG based regionalization can be seen that there is the semi-monsoonal pattern on the coast of South Sumatra area facing the Indian Ocean. The Bukit Barisan mountains border this narrow area. Third, a difference lies in South Sulawesi Province. From the IMERG based map can be recognized that there is a small area with Anti-monsoonal type rainfall in the middle-east part of South Sulawesi, which could not see in the result of the previous study. Fourth, we got to the Maluku region wherein the previous study categorized as Anti-monsoonal type. By using IMERG, this area has a variety of rain patterns. On Seram Island (Maluku), there is a monsoon type area which located behind the anti-monsoonal type bordered by mountains. Fifth, a wider anti–monsoonal area was identified in Western Papua which is directly adjacent to the Jayawijaya Mountains which has a semi-monsoonal rainfall pattern. The sixth, variability of rainfall patterns in North Sulawesi are more pronounced with data processing based on IMERG than before. There is three rainfall type on North Sulawesi. Monsoonal type on the northern side, anti – monsoonal type on the southern part, and equatorial type on the central mountainous region. There are some more detail differences that can be revealed from the comparison between IMERG based regionalization then gridded rain gauge base. Indeed, the result from IMERG was more detailed because of the 28 times higher spatial resolution then gridded rain gauges, and it includes measurements of rainfall on the ocean area. Thus, regionalization based on IMERG data successfully carried out with the result of four rainfall regions within Indonesia.

5. Conclusion
The IMERG V06 accurately represented the rainfall condition in Indonesia. It identified the monthly time series and monthly mean pattern correctly. However, several issues should be addressed. The distribution of monthly rainfall by IMERG data showed an overestimated than the gauge data in the three rainfall regions in Indonesia. The overestimated condition tends to occur on the dry season period. Nevertheless, IMERG spatially averaged annual rainfall data indicated the near-perfect capability to figure out the annual characteristic of ground observed rainfall.
The results of Indonesian rainfall regionalization using DCM based on IMERG obtained four rainfall region pattern in Indonesia. Region A has the monsoonal characteristic, covers south and central Indonesia from south Sumatra to Nusa Tenggara, parts of Kalimantan, parts of Sulawesi, and parts of Papua. Region B has an equatorial pattern (semi-monsoonal), located in the equatorial area of Indonesia and covers the west and east part of Sumatra and the north-central part of Kalimantan. Region C with anti-monsoonal pattern covers Maluku, western-central Papua and parts of Sulawesi (close to the western Pacific region). Region D, with a combination of monsoonal and cold surge characteristic, is located on the north part of Sumatera and a small portion of northern Kalimantan to South China Sea region.

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