Change in rainfall per-decades over Java Island, Indonesia

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Abstract. The frequency of hydro-meteorological disasters (climate and weather-related) in Indonesia has continued to increase in the last ten years. Java Island is the region with the highest disaster occurrence in Indonesia. The CMAP (the CPC Merged Analysis of Precipitation) rainfall data for the long time period 1981-2016 was used in this study. While the in situ data was used for verification of CMAP data. The rainfall is one of the main parameters that affects the climate in Indonesia. A study using this long-term data has been done to investigate the changes of rainfall occurring in Java Island per-decade. The results showed that the annual rainfall pattern appears to be almost the same during the all periods (period I, II, III and IV), but the intensity of the annual rainfall changes significantly. While the real changes are also seen in seasonal rainfall patterns and their intensity on Java Island. These changes indicate that the average rainfall in period IV is higher than period I, II and III. Likewise, the early of the dry/rainy season and the length of the season appear to be shifting in six locations from seven locations of case studies conducted. The CMAP data is quite well as alternative data in climate-related research because it has a good verification of in situ data.

1. Introduction

According to the report of Intergovernmental Panel on Climate Change (IPCC), since 1901 the global temperature has risen reaching 0.89°C, especially for the Southeast Asia region, the temperature rise is of about 0.4-1°C [1]. It estimated temperature rises in the Southeast Asia region which will spread throughout the land evenly for the medium term (2046-2065) is 1.5-2°C and for the long-term (2081-2100) of 2-4°C. Rainfall is the amount of rain that falls in a place during a particular period. This rainfall is measured in millimeters (mm). Rainfall is expected to increase in some countries including Indonesia and Papua New Guinea [1]. The IPCC notes that the ongoing climate change phenomenon is the impact of human actions and not natural disasters.

The IPCC report also points out that the global climate has changed and has the impacts to the change of rainfall pattern [2], in this case including Indonesia. Other researchers [3], stated that air temperatures in Indonesia have increased by 0.3°C since 1900 and occurred throughout the season. Meanwhile, weather and seasonal changes are marked by an increase in rainfall in a region, whereas in other regions rainfall decreases by 2-3% [3]. A study of the effects of global warming on rainfall conditions in Java and Bali used several GCM models and downscaling statistical models in two emission scenarios, SRESB1 and SRESA2 [4]. The analysis shows that the total rainfall of the transition period (Apr-Jun) is expected to increase 10% from the current rainfall season average, but for the rainy season (Jul-Sep) will decrease between 10-25% [4]. Other studies in the tropics of
Indonesia [5] using multimodel ensembles of global warming simulations show that in the southern part of the equatorial line in South Sumatra, Java and throughout eastern Indonesia, there is a decrease in rainfall trend in the JJA period. Conversely, in northern equatorial lines, including northern, western and central Sumatra, and northern Kalimantan, the analysis shows an upward trend in rainfall. Climate change in Indonesia has had an impact on water availability, such as the results of research [6] which shows a decrease in annual rainfall in southern Java Island period 1931-1960 and 1968-1998 which reached 1000 mm.

Rainfall has a strong influence on the quality of human life in this case related to the availability of water resources for consumption and agricultural needs. If the rainfall takes place with high intensity, in a short time it will cause disaster. The National Agency for Disaster Management (BNPB) report [7] mentions that disaster trends in Indonesia are increasing year by year. The disaster of 2016 was the highest record in the last ten years, where there was a 35% increase compared to 2015. During 2016 there were 2,342 disasters, of which 92% was hydro-meteorological disasters dominated by floods, landslides and *puting beliung*. Increased hydro-meteorological disasters are generally caused by high rainfall in these areas. It appears that one of the impacts of climate change in Indonesia is the change in rainfall pattern which results in the increased risk and magnitude of hydro-meteorological disaster.

Therefore, this research was conducted to evaluate the change of rainfall for long periods, and an extensive coverage is necessary. This paper discusses how the change of rainfall per decade happened in Java Island. BNPB documented that the highest hydrometeorology disaster in Indonesia occurred in Java Island. The rationale for this decade-long rainfall change study refers to the definition of Climate change proposed by IPCC [8] that refers to the average variation in climatic conditions of a place or to its statistically significant variability for long periods of time (usually decades or more).

Application of multi-decade rainfall data, among others, is CMAP data to detect changes in rainfall in the long period that have been done. [9] The results obtained indicate a shift in the characteristics of significant tropical rainfall identified by the trend of increasing the frequency of heavy rain and light rain and trend of decline of moderate rain events in the tropics during 1979-2003.

2. Data and Methods

In Indonesia, the limited number of observation stations and the availability of in situ data are often a constraint for spatial studies related climate change that require data in long periods and broad coverage. So in this study, rainfall data from the CMAP were used as alternative data. The CMAP data were obtained by a combination technique of 5 satellite-based (infrared and microwave) estimates and observations of rain gauge. This data was comparable (but not to be equated) with the same joint analysis by the Global Precipitation Climatology Project (GPCP) as described [10]. The details of the dataset component and the methods used to combine the data can be determined from previous studies [11, 12]. The CMAP data where spatial and temporal resolutions 0.1 x 0.1 degrees latitude / longitude and an hourly respectively used in this study. The data period used 1981-2016 (36 years). While for some case studies, the in situ rainfall data was used as verification of CMAP rainfall data.

Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity [2].

The first stage in the research method is data collection and data extraction for the research domain that includes Java Island with a geographical boundary of 5.5-9.0S; 105-115E. The second stage is the process of grouping data into four periods based on the decade (10 years), i.e. period I (1981-1990), II (1991-2000), III (2001-2010), IV (2011-2016). The grouping used referring to the IPCC climate change is defined by changes in conditions occurring at least in ten years period (decades) [2]. However, in period IV it is only six years since the last update was available. In this study, period IV data is still processed to find out the current conditions. The third stage is to conduct spatial data
processing to obtain annual and seasonal average rainfall per decade for each of these periods. The simple statistical method used in this study is to do the average data on each pixel available for each period and every season. It is necessary to note that the period 1981-1990 was set as the initial period as a baseline to determine changes in rainfall patterns that occurred.

Furthermore, for some areas as case studies, data processing time series should be performed. It is a way to verify CMAP data on in situ rainfall data. The final stage of this research is analyzing and interpreting the results of data processing obtained. The Grid Analysis and Display System (GrADS) is software used to processing spatial data and visualization the result. While for processing temporal data and visualization the result we used Microsoft Excel 2007.

3. Results and Discussions
Based on spatial data processing, the results of the average of annual and seasonal rainfall pattern per-period, and the pattern of changes each period to the baseline period (period I) in Java Island were obtained. Based on data time series for seven locations as a case study, changes at the beginning of the rainy season/dry season and changes in the length of the rainy season/dry season were obtained. Besides, the verification results of CMAP data on in situ were also gained.

The pattern of annual rainfall distribution in Java for the four periods seems to have similarities where maximum rainfall always occurs in the central part of Java, but it is apparent that there was a change of rainfall intensity in each period over the baseline period (period I). The pattern of annual rainfall indicates the characteristics of period I showing the maximum rainfall (2200-2400 mm) occurred and dominated by the Central Java region and the pattern appears to progress to the east and west of the smaller rainfall. The characteristics of annual rainfall is minimum (1600-800 mm) every period where the pattern always occurs in the area of East Java. In the period II, there was a tendency of decreasing annual rainfall over the period I, while the period III and period IV, there was a significant increase in rainfall to the period I in which the maximum annual precipitation was in the range of 2600-2800 mm in Central Java (Figure 1).

In general, the annual rainfall variation in the period I was 1600-2200 mm, while in the period IV looked higher, that was 1600-2800 mm. The results of this study support the previous study [1,3], which used data from TRMM during 1998-2012 and indicated that there was less annual precipitation trend in Java. The results of this study are also in line with previous studies [1,3], using data from TRMM during 1998-2012 and showing that the results of annual rainfall trends indicate an increasing trend toward the east of Java Island.

![Figure 1. The distribution of average annual rainfall (mm) per-decade in Java Island.](image-url)
Associated with the changing rainfall shows in the period II, there was a decrease in annual rainfall from the period I that reached 300-450 mm in parts of Central Java and Yogyakarta. In the period III and period IV, there was an increase in annual rainfall from the period I in Java where the highest of more than 450 mm occurred in parts of West Java (Figure 2). The high rainfall in the period III and IV had an impact on the increasing frequency of hydro-meteorological disaster occurrences as reported by BNPB [7].

![Figure 2. Changes in annual rainfall (mm) per-decade in Java island.](image)

The average of rainfall data distribution for the rainy season (DJF) in period I varied between 750-800 mm in Serang and maximum between 950-1000 mm in Central Java and Yogyakarta. In general, there is a pattern of rainfall increase for each period that it appears in period IV is the highest of the three periods indicated by rainfall variations ranging from 750 to 1050 mm. The maximum rainfall pattern ranges from 1000 to 1050 mm and extended mainly to the areas of West Java and Central Java (Figure 3).

![Figure 3. The distribution of the average rainfall (mm) for the rainy season (DJF).](image)

For the average of the rainy season in the period II in West Java, there was an increase in rainfall reaching 100 mm, whereas in some areas of Central Java and East Java, rainfall tended to decrease up to 150 mm. However, in the period III and IV, there was an increase in rainfall that reached more than 150 mm from the period I, especially in West Java (Figure 4).
Figure 4. Changes in the average of rainfall (mm) per-decade for the rainy season (DJF).

The distribution of the average rainfall data processing for the dry season (JJA) shows the intensity of rainfall pattern in the period IV which is the highest of the three periods. The average rainfall of the dry season generally ranged from 200-400 mm except in East Java which was lower than 100-200 mm (Figure 5). The results of previous research [13] also showed an interesting point during the period of study of 1998-2012, there was a tendency of rainfall characteristic above normal also happened during the period of dry season (in June and July) covering wide area in some areas in West Java, Central Java, and East Java.

Figure 5. Same as Figure 3. but for the dry season (JJA).

The average change of rainfall during the dry season in the period II and III show the rainfall in the whole island of Java was lower (more than 75 mm) than the period I, especially in Central Java and East Java. But, during dry season in the period IV, there was an increase in rainfall that occurred almost in the entire island of Java with a maximum of more than 75 mm compared to the period I which occurred in the southern coast of West Java. A slight decrease in rainfall (25 mm) from the period I was only visible in some areas of East Java (Figure 6).
Figure 7 shows the results of data processing of the average change of rainfall per decade for the transition I from the rainy season to the dry season (MAM) (left) and the transition II from the dry season to the rainy season (SON) (right). It can be seen from Figure 7 (left) during MAM's transition period I that rainfall in Java Island tends to be lower than period I, while for period II and III, rainfall in Java Island tends to be higher (> 75 mm) from period I. Changes in the mean rainfall for the period II, III and IV were the areas of Java Island in the western part which tended to be higher than the period I where the maximum occurred in parts of West Java (> 75 mm) and vice versa for the eastern part of Java which tended to be lower than the period I as shown in Figure 7 (right).

Understanding the Earth's climate and how the process of formation of the water cycle regional/global and reaction to climate disruption will depend on several factors such as atmospheric moisture transport, clouds, rainfall, evaporation, transpiration, latent heat, runoff and large-scale circulation variation [14,15].

In this research, the time series data processing for seven case study locations were done to Jakarta, Bandung, Semarang, Cilacap, Yogyakarta, Surabaya, and Banyuwangi. The position of case study is
shown in Table 1. Data processing time series were conducted to determine the early changes of rainy season drought and the average change of the length of the rainy/dry season which takes place every period. If the rainfall is consecutive less or equal to 150 mm/month, it is the early determination of the dry season. If the rainfall is more than 150 mm/month, it is the beginning of the rainy season. This limitation is also related to the water requirement for rice plants which is 150 mm/month as Oldeman proposed in the study [16].

**Table 1.** The seven locations for the case study.

| No. | Location/ Name of Station | No. Station | LAT (S) | LON (E) | H (m) |
|-----|---------------------------|-------------|---------|---------|-------|
| 1   | Jakarta/ Stamet Halim PK   | 1000 6      | 6.27    | 106.88  | 26    |
| 2   | Bandung/ Geofisika Bandung| 90019       | 7.10    | 107.63  | 791   |
| 3   | Semarang/ Semarang Klimat  | 11037       | 7.13    | 110.38  | 3     |
| 4   | Cilacap/ Cilacap           | 11031       | 7.73    | 108.02  | 8     |
| 5   | Yogyakarta/ Adi Sucipto    | 13047       | 7.78    | 110.43  | 122   |
| 6   | Surabaya/ Stamar Perak     | 120 67      | 7.22    | 112.73  | 7     |
| 7   | Banyuwangi Banyuwangi      | 12077       | 8.22    | 114.38  | 6     |

The average monthly rainfall per decade for the seven case study sites is shows in Table 2 generally indicates that there was a change or shift in the early dry and wet seasons. Likewise, the length of the rainy season and the dry season also changed. The exception to the location of Semarang shows that the early season pattern has not changed for each period (I, II, III and IV). The same length of the dry season / rainy season is six months with the dry season (rainfall <= 150mm) always occurs in June-November and rainy season (rainfall> 150 mm) always occurs in December-May.

For the other six case study sites, there was one month shift ahead/backward during the dry/rainy season for some periods as can be seen in Table 2. The exceptions to Cilacap location during in the period I, II and III, the average dry season occurred for four months (July-October) and rainy season for eight months (November-June). In the period IV, however, there was a shift in the early dry season which averages two months and became shorter (September-October), while the start of the rainy season remained longer but the rainy season was longer for ten months (November-August).

**Table 2.** Changes in the early and the length of the rainy and dry season.

| No. | Location/ Period | Period | Count of Month R<= 150 mm | Period | Count of Month R > 150 mm |
|-----|------------------|--------|--------------------------|--------|--------------------------|
| 1.  | Jakarta/I        | Jul-Nov| 5                         | Dec-Jun| 7                        |
|     | Jakarta/II       | Jun-Nov| 6                         | Dec-May| 6                        |
|     | Jakarta/III      | Jun-Nov| 6                         | Dec-May| 6                        |
|     | Jakarta/IV       | Jun-Nov| 6                         | Dec-May| 6                        |
| 2.  | Bandung/I        | Jul-Nov| 5                         | Dec-Jul| 7                        |
|     | Bandung/II       | Jun-Oct| 5                         | Nov-May| 7                        |
|     | Bandung/III      | Jul-Oct| 4                         | Nov-Jul| 8                        |
|     | Bandung/IV       | Jul-Nov| 5                         | Dec-Jul| 7                        |
Table 2. Changes in the early and the length of the rainy and dry season.

| No. | Location/ Period | Period       | Count of Month R<= 150 mm | Period       | Count of Month R > 150 mm |
|-----|------------------|--------------|---------------------------|--------------|---------------------------|
| 3.  | Semarang/I       | Jun-Nov      | 6                         | Dec-May      | 6                         |
|     | Semarang/II      | Jun-Nov      | 6                         | Dec-May      | 6                         |
|     | Semarang/III     | Jun-Nov      | 6                         | Dec-May      | 6                         |
|     | Semarang/IV      | Jun-Nov      | 6                         | Dec-May      | 6                         |
| 4.  | Cilacap/I        | Jul-Oct      | 4                         | Nov-Jun      | 8                         |
|     | Cilacap/II       | Jul-Oct      | 4                         | Nov-Jun      | 8                         |
|     | Cilacap/III      | Jul-Oct      | 4                         | Nov-Jun      | 8                         |
|     | Cilacap/IV       | Sep-Oct      | 2                         | Nov-Aug      | 10                        |
| 5.  | Yogyakarta/I     | Jun-Nov      | 6                         | Dec-May      | 6                         |
|     | Yogyakarta/II    | Jun-Nov      | 6                         | Dec-May      | 6                         |
|     | Yogyakarta/III   | Jun-Nov      | 6                         | Dec-May      | 6                         |
|     | Yogyakarta/IV    | Jul-Nov      | 5                         | Dec-Jun      | 7                         |
| 6.  | Surabaya/I       | Jun-Nov      | 6                         | Dec-May      | 6                         |
|     | Surabaya/II      | Jun-Nov      | 6                         | Dec-May      | 6                         |
|     | Surabaya/III     | Jun-Dec      | 7                         | Jan-May      | 5                         |
|     | Surabaya/IV      | Jun-Dec      | 8                         | Jan-May      | 6                         |
| 7.  | Banyuwangi/I     | May-Nov      | 7                         | Dec-Apr      | 5                         |
|     | Banyuwangi/II    | Jun-Nov      | 6                         | Dec-May      | 6                         |
|     | Banyuwangi/III   | Jun-Nov      | 6                         | Dec-May      | 6                         |
|     | Banyuwangi/IV    | Jun-Nov      | 6                         | Dec-May      | 6                         |

Note: Period I=1981-1990, Period II=1991-2000, Period III=2001-2010, Period IV=2011-2016

Previous study [4] revealed an early shift of the dry and rainy seasons in Java since the 1916-1990 and 1991-2003 periods. They predicted that some parts of Indonesia, especially the areas located in the south of the equator, may experience longer dry season and shorter rainy season but with higher bulk. Moreover, the climate is also likely to be more volatile, with more frequent erratic rainfall. Studies [2,17] also discovered that global warming was expected to affect extreme climatic events such as droughts, floods, and other extreme events.

In situ rainfall data obtained from BMKG [18] was used to verify the monthly rainfall from CMAP data. The results showed that there was a similar pattern of rainfall as well as similar rainfall values. The difference in some locations is only between 0-50 mm with CMAP data coverage range which is higher than in situ data. It is indicated by the average monthly rainfall graph of each decade in all case study sites (Figure 8). For example, for Bandung, the rainfall range of CMAP data was between 0-400 mm while in situ data ranged from 0-350 mm. Similarly, for Banyuwangi rainfall CMAP data ranged from 0-350 mm but observation data ranged from 0-250 mm. This difference is most likely to occur because satellite sensors in CMAP estimate the "average rainfall area (area), " while the rain gauge measures the "point" of rainfall. The direct comparison of "area" and "point" will be very different due...
to the size of the deposition cell itself [19, 20]. Furthermore, passive microwave radiometers highly underestimate rainfalls generated by this warm process. Merging the microwave estimations with infrared and adjusting it with surface estimation could reduce the underestimation (such as the CMAP, GPCP and merged TRMM products). So in general, the biases to rain-gauges are still large [21].

Figure 8. Comparison of the decade monthly average rainfall from CMAP (left) and in situ (right) for case study locations Jakarta, Bandung, Semarang, Cilacap, Surabaya and Banyuwangi.

Generally, the result shows that in Java Island there was an increase in rainfall. It is indicated by one example of the observation area of Cilacap (Figure 9). The rainfall bias against its mean value during this research period in Cilacap had a positive trend with the regression equation \( y = 1.1149x - 27.315 \). The similarity of CMAP and in situ rainfall patterns and values is described earlier so that the use of CMAP data as alternative data in this study illustrates that the trend of increasing rainfall in Java has occurred significantly in the last two periods.

Figure 9. The rainfall bias in Cilacap area.
4. Conclusion
Climate depends on complex relationships that occur between conditions on land, ocean, and atmosphere. Likewise, climate change is a complex problem. The rainfall is one of the main parameters that affects the climate in Indonesia. Research on changes in rainfall per decade is one of several parameters that indicate climate change on Java Island. In general, for four periods of research, the rainfall annual pattern was still similar, but there was a significant change in rainfall intensity. While on the seasonal pattern, the pattern and intensity of rainfall in Java Island experienced a real change. The period IV is the highest increase in rainfall in Java Island out of the other periods. Changes in rainfall pattern that occur on the island of Java appear to have influenced the pattern of the early and the length of the seasons. In seven locations case studies conducted, it was found that five locations (Jakarta, Bandung, Yogyakarta, Surabaya and Banyuwangi) had experienced a shift the early and the length of the season which generally was more ahead/backward one month. Cilacap shows the early of dry season was late 2 months so that it added to the length of the rainy season in the period IV. While in the location of Semarang, the beginning and length of the dry season/rainy season that remained the same for the four periods. The rainfall verification of CMAP data showed a similarity of pattern and value near the data of in situ. Therefore, this CMAP data looks very well to be used as an alternative in climate-related studies spatially and temporally. The changes of the pattern and intensity of rainfall have occurred in Java Island affecting on the change of season pattern which resulted in an increase in the frequency and magnitude of the risk of hydro-meteorological disasters. However, the environmental analysis of rainfall changes in Java Island for more comprehensive paper analysis is still a challenge. It will be presented in the other future papers as a continuation of this research.

5. References
[1] Intergovernmental Panel of Climate Change (IPCC), Working Group I Contribution to the 5th Assessment Report of the IPCC, (2013)
[2] Intergovernmental Panel of Climate Change (IPCC), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, 976, (2007)
[3] Hulme, M. and N. Sheard, Climate Change Scenarios for Indonesia, Climatic Research Unit, Norwich, UK, 6, (1999)
[4] Naylor, R.L., D.S. Battisti, D.J. Vimont, W.P. Falcon, and M.B. Burke, Assessing risks of climate variability and climate change for Indonesian rice agriculture, Proc. of the National Academy of Science 114, 7752-7757, (2007)
[5] Neelin, J.D., M. Munnich, H. Su, J.E. Meyerson, ann C.E. Holloway, Tropical Drying Trends in Global Warming Models and Observations, PNAS 103, 6110-6115, (2006)
[6] Pawitan, H., Hidrologi DAS Ciliwung dan Andilnya Terhadap Banjir di Jakarta. Lokakarya Pendekatan DAS dalam Menanggulangi Banjir Jakarta, Lembaga Penelitian IPB-Andersen Consult. Jakarta, (2002)
[7] National Agency for Disaster Management (BNPB), http://www.bnpb.go.id (accessed on October, 2016)
[8] Intergovernmental Panel of Climate Change (IPCC), Climate Change 2007: Synthesis Report. a Report of the IPCC, (2007)
[9] Lau K. M. and H. T. Wu, Detecting Trends In Tropical Rainfall Characteristics During 1979-2003, Sci. and Systems Appl. Inc., Lanham, Maryland, (2005)
[10] Huffman, G. J. and co-authors, The Global Precipitation Climatology Project (GPCP) combined data set. Bull. Amer. Meteor. Soc., 78, 5-20, (1997)
[11] Xie, P. and P. A. Arkin, Analysis of global monthly precipitation using gauge observations, satellite estimates, and numerical model predictions, J. Climate, 9, 840-858, (1996)
[12] Xie, P. and P. A. Arkin, *Global precipitation: A 17- year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs*, Bull. Amer. Meteor. Soc., 78, 2539-2558, (1997)

[13] Avia, L.Q., *Analisis Sifat Hujan Periode 15 tahun Terakhir Berbasis Data Satelit TRMM di Pulau Jawa*, Pros. Nasional Simp. Fisika Nasional XXVII, Universitas Udayana, Bali, Indonesia, ISSN : 1411-4771, 77-83, (2015)

[14] Chen, T.C., J. Pfendtner, and S.P. Weng, *Aspect of hydrological cycle of ocean atmosphere system*, J. Phys. Oceanogr., 24, 1827-1833, (1994)

[15] Chang, F.C. and E.A. Smith, *Hydrological and dynamical characteristics of summertime droughts over US Great Plains*, J. Climate, 14, 2296-2316, (2001)

[16] Hidayati, R., *Masalah Perubahan Iklim di Indonesia Beberapa Contoh Kasus*, Program Pasca Sarjana / S-3, Institut Pertanian Bogor, (2001)

[17] Salinger, M.J., *Increasing climate variability and change: reducing the vulnerability*. Climate Change 70, 1-3, (2005)

[18] Meteorological, Climatological, and Geophysical Agency (BMKG), http://bmkg.go.id (accessed on Maret, 2017)

[19] Liu, C., and E. J. Zipser, *Differences between the Surface Precipitation Estimates from the TRMM Precipitation Radar and Passive Microwave Radiometer Version 7 Products*. J. Hydrometeorol., 15, 2157-2175, (2014)

[20] Henderson, D. S., C. D. Kummerow, D. A. Marks, and W. Berg, *A Regime-Based Evaluation of TRMM Oceanic Precipitation Biases*, J. Atmos. Ocean. Tech., 34. 10.1175/JTECH-D-16-0244.1., (2017)

[21] Sekaranom, A.B., and H. Masunaga. *Comparison of TRMM-Derived Rainfall Products for General and Extreme Rains over the Maritime Continent*. Journal of Applied Meteorology and Climatology 56,7, 1867-1881, (2017)

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