Mapping Extreme Rain Conditions in Sumatra by Influence Global Conditions

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Abstract. Determination of the extreme value category with a specific threshold value for a region with diverse climate characteritics may lead to incorrect extreme characterization. This study aims to determine thresholds of extreme rainfall in Sumatra, identify its spatial patterns and occurence in Sumatra and examine the link between extreme weather events to global climate phenomena which are the ENSO and the Dipole Mode. The data used in this study are daily rainfall data from 38 stations in Sumatra and indices of global climate phenomena, the dipole mode index (DMI) and the Southern Oscillation Index (SOI). The method used to determine the threshold for extreme value is with a probability of 95% based on their corresponding distribution, cluster analysis and correlation analysis. The expected result is an extreme value for all parts of Sumatra, the extreme character of all clusters by time and region, as well as its relationship with DMI and SOI. Preliminary results obtained that extreme daily rainfall values ranged from 42.4 to 114.7 mm per day. Extreme daily rainfall for western region of Sumatra has an average value higher and more varied than the eastern region. Extreme daily rainfall over northern region has an average value higher and more varied than the southern region. Clustering analysis of 38 observation stations with ward method gets 5 (five) clusters. At least 20 years long periods of ideal data are needed to find the threshold of extreme rainfall over Sumatra region. Threshold of extreme rainfall with long periods of different data showing different values for each station are sometimes larger or smaller that may be caused by different spread of the data for each station.

1. Introduction

Sumatra Island is geographically an island which is above equatorial region surrounded by ocean. Rainfall in Indonesia in general is influenced by the interaction of land, atmosphere and the oceans around it. The phenomenon of positive anomaly of sea surface temperatures in the Indian Ocean to the west and negative anomalies in sea surface temperatures occurred west of Sumatra, resulting in increased rainfall in Sumatra's west coast region known as the Indian Ocean dipole mode (IOD) [1]. There is a negative IOD in most areas of Sumatra causing increased rainfall. In Indonesia the events of floods and severe droughts are always associated with El Niño-Southern Oscillation (ENSO) [2]. The results of research related to extreme rainfall with cumulative distribution function method for Sumatra conducted by Marpaung et al [3] using rainfall data from TRMM and observations indicate that extreme rainfall events with the number of incidence days of 1 to 2 days per annum dominant place. In 1998 and 1999 it appears to increase in extreme rainfall events for a number of days per year incidence greater than 2 days, especially in the water of the West and East Sumatra. This increase is allegedly due to the influence of global phenomenon La Nina and the Dipole Mode. The threshold value of extreme rainfall for Sumatra is 60 to 130 mm / day. Several studies of extreme rainfall also done abroad including Zhang et al [4] that did a study in the valley of the Yangtze River, China. They analyzed daily rainfall data of 150 stations from the 1960-2002 period in the Yangtze River valley. They use extreme climate index of the highest daily rainfall amount of 5-day and 10-day (R5D and R10D) and the maximum daily rainfall at the 95th percentile (prec95p) and the 99th percentile (prec99p). Frequency of R5D and R10D show a downward trend. The phenomenon is more noticeable on the middle of the Yangtze River valley. Moberg [5] analyzed temperature and precipitation for stations in the Western Europe region. They calculated the daily extreme climate index of the data series in the period 1901-2000. They use criteria of extreme climates percentile of 90, 95 and 98 to calculate the index of extreme temperature and precipitation in Western Europe during the winter and summer. The study showed that in winter a trend is warmed (~ 1.0 °C / 100 years) than summer (~ 0.8 °C). In the winter, total rainfall average in 121 stations in Europe showed a significant trend of increased ~ 12% per 100 years. The trend of daily rainfall in the winter with the calculation of the 90th percentile, 95 and 98 also show the same thing. Other studies calculate extreme values using the median quantile regression that was first introduced by Roger Koenker and Gilbert Basset [6]. Some researchers determine the extreme value distributions that use the Generalized Extreme Value (GEV) developed by Jenkinson [7] to model extreme precipitation. This approach is referred to as block maxima using distribution modeling for maximum data at each time interval called the block. Other researchers use the approach of Peak Over Threshold (POT), which was originally introduced in the field of hydrology to define extreme values. POT method uses a threshold value for defining the precipitation with a value exceeding the threshold as extreme precipitation. POT overall uses observational data in modeling extreme precipitation, this is what distinguishes it from the GEV approach. Extreme rainfall events from time to time in Indonesia are more frequent that often leads to loss of property and loss of life. The extreme value issued by BMKG under regulation KBMKG No: Kep.009 Year 2010 is rainfall intensity of 50 mm/day or 20 mm/hour. The determination of threshold values with the extreme categories that limit values for a region as diverse character of the climate was not able to provide characterization of the extreme right. Therefore, this study aims to determine the threshold of extreme rainfall in Sumatra and group them by similarity.

2. Data and Methods

2.1. Research Locations

Location of the study is the island of Sumatra in the form of 18 points stations in Sumatra and surrounding areas.

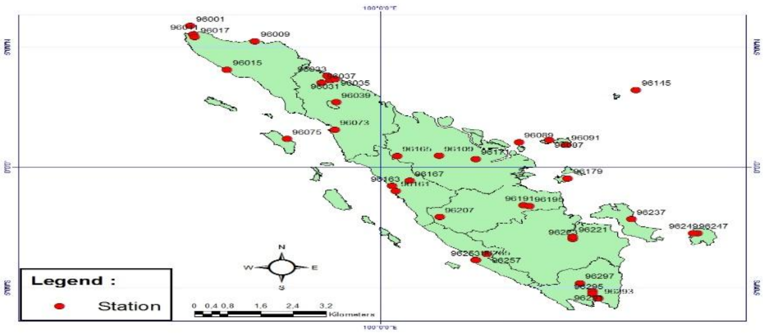

Figure 1. Map of research site.

2.2. Data
The data used in this study are the daily rainfall data of observation stations in the island of Sumatra in the period of 1983-2012.

Table 1. Inventory of daily rainfall stations data in Sumatra Island.

No.	Station Id	Name of station	Station Location	Latitude	Longitude	Mean Sea Level	Period
1	96291	Masgar	Pesawar, Lampung	-5.172	105.18	71	1996-2012
2	96295	Raden Inten II	South Lampung, Lampung	-5.27	105.18	81	1981-2012
3	96293	Maritim Panjang	Bandar Lampung,	-5.47	105.33	1	1998-2012
4	96297	Kota bumi	North Lampung, Lampung	-4.836	104.87	60	1994-2012
5	96253	Fatmawati Airport	Bengkulu City, Bengkulu	-3.88	102.33	16	1981-2012
6	96257	Kepahiyang	Kepahiyang, Bengkulu	-3.63	102.59	517	1985-2012
7	96255	Baai Island	Baai Island, Bengkulu	-3.87	102.32	10	1985-2012
8	96223	Kenten	Palembang, South Sumatra	-3.00	104.70	8	1981-2012
9	96221	Sutan Mahmud Badarudin II	Palembang, South Sumatra	-2.90	104.70	11	1981-2012
10	96237	Depati Amir Airport	Pangkalpinang, Bangka Belitung	-2.17	106.13	33	1981-2012
11	96249	H.A.S Hanandjoedin	Belitung, Bangka Belitung	-2.757	107.75	47	1981-2012
12	96247	Pilang	Belitung, Bangka Belitung	-2.757	107.65	22	1995-2012
13	96191	Sei Durian	Muaro Jambi, Jambi	-1.60	103.49	34	1998-2012

14	96207	Depati Parbo	Kerinci, Jambi	-2.083	101.45	450	1985-2012
15	96195	Sultan Thoha	Sultan Thoha, Jambi	-1.634	103.64	26	1983-2012
16	96171	Japura	Indra Giri Hulu, Riau	00.33	102.32	19	1982-2012
17	96109	Sultan Syarif Kasim	Pekanbaru, Riau	0,324306	101.43	27	1981-2012
18	96087	Hang Nadim	Batam, Riau Islands	1.117	104.12	28	1993-2012
19	96089	Raja Haji Abdullah Airport	Tanjung Balai Karimun, Riau Islands	01.03	103.38	1	1994-2012
20	96091	Kijang Airport	Tanjung Pinang, Riau Islands	0,6375	104.53	18	1983-2012
21	96145	Tarempa Airport	Kepulauan Anambas, Riau Islands	03.20	106.25	2	1991-2012
22	96179	Dabo Airport	Lingga, Riau Islands	-0.48	104.58	29	1991-2012
23	96167	Sicincin	Sicincin, West Sumatra	-0.575	100.71	137	1985-2012
24	96163	Minangkabau International Airport	Padang, West Sumatra	-0.793	100.29	6	1982-2012
25	96165	Silaing Bawah	Padang Panjang, West Sumatra	0,317	100.40	773	1996-2012
26	96161	Teluk Bayur	Kota Padang, West Sumatra	-0.996	100.37	2	1994-2012
27	96031	Sampali	Deli Serdang, West Sumatra	3.617	98.78	25	1980-2012
28	96033	Belawan	Medan, West Sumatra	3.788	98.71	3	1982-2012
29	96035	Kualanamu Airport	Deli Serdang, North Sumatra	3.642	98.89	23	1981-2012

30	96037	Tuntungan	Deli Serdang, North Sumatra	3.501	98.56	86	1991-2012
31	96039	Parapat	Simalungun, North Sumatra	2.694	98.92	1061	1997-2012
32	96073	F.L Tobing Sibolga	Tapanuli Tengah, North Sumatra	01.55	98.88	10	1981-2012
33	96075	Binaka	Gunung Sitoli - Nias, North Sumatra	1.165	97.71	175	1982-2012
34	96001	Cut Bau Maimun Saleh Airport	Sabang, Nanggroe Aceh Darussalam	0,269	95.35	126	1981-2012
35	96009	Malikussaleh Airport	Aceh Utara, Nanggroe Aceh Darussalam	5.228	96.93	28	1983-2012
36	96011	Sultan Iskandar Muda Airport	Aceh Besar, Nanggroe Aceh Darussalam	5.521	95.42	20	1982-2012
37	96015	Tjut Nyak Dien Meulaboh Airport	Nagan Raya, Nanggroe Aceh Darussalam	4.049	96.25	3	1982-2012
38	96017	Indrapuri	Aceh Besar, Nanggroe Aceh Darussalam	05.40	95.46	51	1995-2012

2.3. Method

2.3.1. Cluster analysis
Cluster analysis is part of a multivariate analysis with the purpose to categorize objects based on the characteristics of its observations, where each object in the same group have a level of closeness and similarity between one another [8]. The result of cluster analysis is the formation of groups that have a degree of similarity and heterogeneity of high inter-cluster. Nazaripour and Khosravi [9] classify the intensity of daily rainfall in Zahedan, Iran with Ward cluster analysis method. Techniques within the Ward's method calculate the sum of the squares between the two groups for all variables. Ward's equation is as follows:

$$d\,(r,s) = \frac{n_r n_s d_{rs}^2}{(n_r + n_s)} \quad (1)$$

d (r, s) : distance
drs : distance between *r* and *s*
nr : group-r
ns : group-s

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2.3.2. Analysis of Opportunities

In determining the threshold of extreme rainfall that contains zero millimeters of rainfall, the chances are calculated by the method of distribution of mixture [10], namely:

$$H(x) = q + pP_x(X) \tag{2}$$

where :

H (x) : probability distribution for a mixture of rain recesses value that exceeds x for $x \geq 0$
q : zero chance of rain events
p : probability of rain events greater than zero, $p = 1 - q$
Px (X) : probability of rain events by gamma cumulative distribution opportunities ($x > 0$)

2.3.3. Data Length Determination

The steps in determining the length of the data that is used to find the value extreme are:

1. Find a station that has a data length more than 30 years
2. Divide data into several periods where each period is a multiple of five years
3. Determine the extreme value of each station
4. Create scatter plot graph
5. Determine the value that is closest to the ticket

3. Result and Discussion

3.1. Analysis Cluster

Results of grouping rainfall stations in Sumatra based extreme value with threshold of each month are five clusters (figure 2).

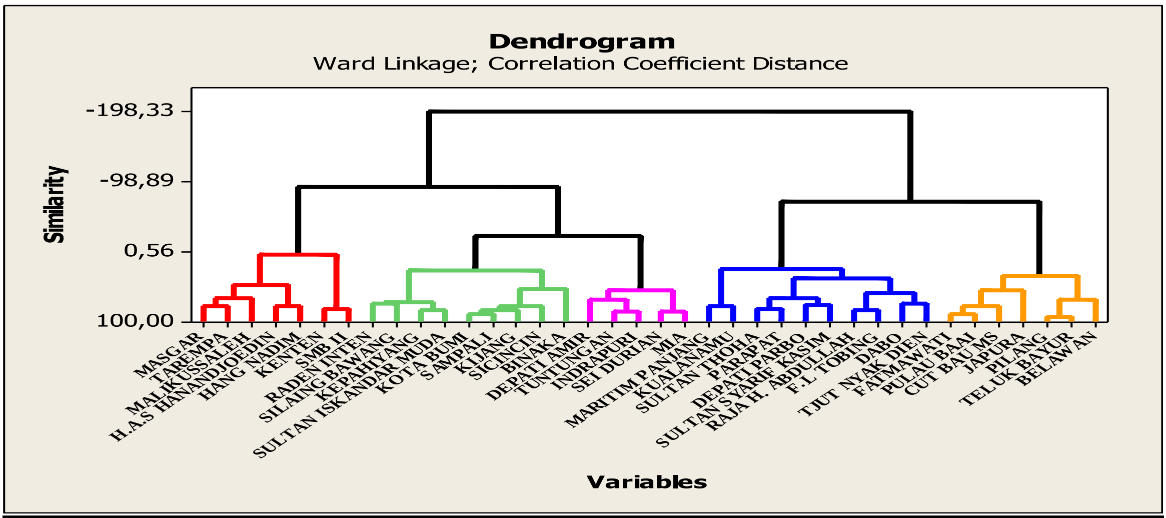

Figure 2. Dendogram of rainfall station groups in Sumatra Island.

Based on the analysis results it is obtained that in cluster 1 there are 7 stations, 9 stations in cluster 2, 10 stations in cluster 3, 7 stations in cluster 4 and 5 stations in cluster 5. Groups of rain stations are shown in table 2.

Table 2. Station groups based on the extreme threshold.

No.	Station Id	Name of station	Cluster	No.	Station Id	Name of station	Cluster
1	96291	Masgar	1	20	96091	Kijang Airport	2
2	96295	Raden Inten II	2	21	96145	Tarempa Airport	1
3	96293	Maritim Panjang	3	22	96179	Dabo Airport	3
4	96297	Kota bumi	2	23	96167	Sicincin	2
5	96253	Fatmawati Airport	4	24	96163	Minangkabau International Airport	5
6	96257	Kepahiyang	2	25	96165	Silaing Bawah	2
7	96255	Baai Island	4	26	96161	Bayur Bay	4
8	96223	Kenten	2	27	96031	Sampali	2
9	96221	Sutan Mahmud Badarudin II	1	28	96033	Belawan	4
10	96237	Depati Amir Airport	5	29	96035	Kualanamu Airport	3
11	96249	H.A.S Hanandjoedin	1	30	96037	Tuntungan	5
12	96247	Pilang	4	31	96039	Parapat	3
13	96191	Sei Durian	5	32	96073	F.L Tobing Sibolga	3
14	96207	Depati Parbo	3	33	96075	Binaka	2
15	96195	Sultan Thoha	3	34	96001	Cut Bau M. Saleh Airport	4
16	96171	Japura	4	35	96009	Malikussaleh Airport	1
17	96109	Sultan Syarif Kasim	3	36	96011	Sultan Iskandar Muda Airport	2
18	96087	Hang Nadim	1	37	96015	Tjut Nyak Dien Airport	3
19	96089	Raja Haji Abdullah Airport	3	38	96017	Indrapuri	5

The pattern of rainfall threshold in cluster 1 shows that the threshold value is the highest rainfall in January. The pattern of rainfall threshold in cluster 2 in figure 4 shows that the threshold value is the highest precipitation in February. The pattern of rainfall threshold in cluster 3 shows that the threshold values are the high rainfall in August in contrast to cluster 1 and cluster 2. The pattern of rainfall threshold in cluster 4 shows that the limit values are high in June and August and the lowest is in April. The pattern of rainfall threshold in cluster 5 shows that the extreme rainfall has two peaks, where the first peak occurs in February and the second peak occurs in August (figure 3).

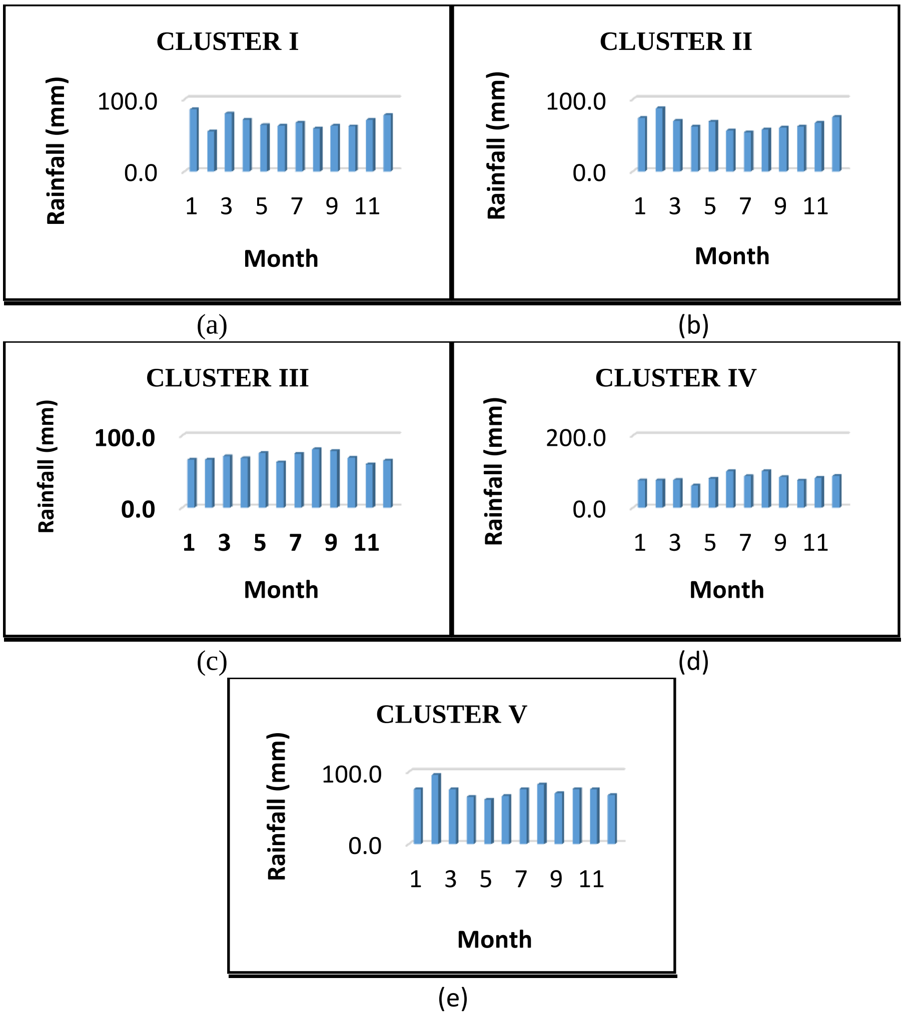

Figure 3. The pattern of extreme monthly rainfall in (a) Cluster I;(b) ClusterII;(c) Cluster III; (d) Cluster IV (e) Cluster V.

3.2. Analysis of Opportunities

Figure 4 shows that the extreme daily rainfall values range from 42.4 to 114.7 mm. Extreme value of daily rainfall in western region of Sumatra has an average value higher and more varied than the eastern region. While the northern region of Sumatra has an extreme value of daily rainfall is higher than in the south.

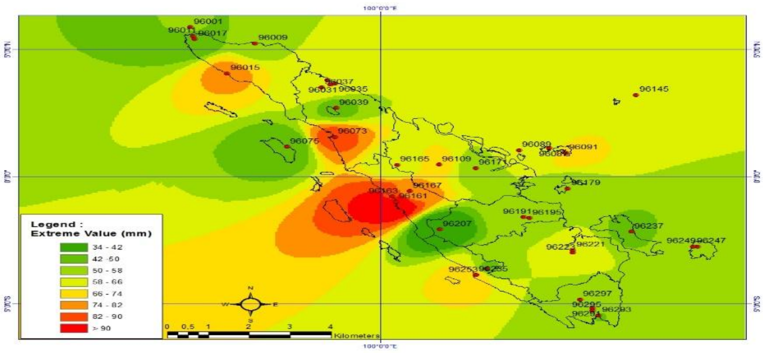

Figure 4. Threshold of extreme rainfall in Sumatra island (1998-2012).

3.3. Analysis of Data Period

Minimum length of data period is very important as a reference in determining the length of data that is ideal for calculating the thresholds of extreme rainfall. Determination of a minimum length of the data period was done by taking a sample of rainfall observation data over 30 years. After sorting the data from 38 stations in Sumatra, seven stations that have long data period for 35 years are Raden Inten II Lampung, Fatmawati Bengkulu, Kenten South Sumatra, Sutan Mahmud Badarudin II South Sumatra, Depati Amir Bangka Belitung, Sampali North Sumatra, Kualanamu North Sumatra.

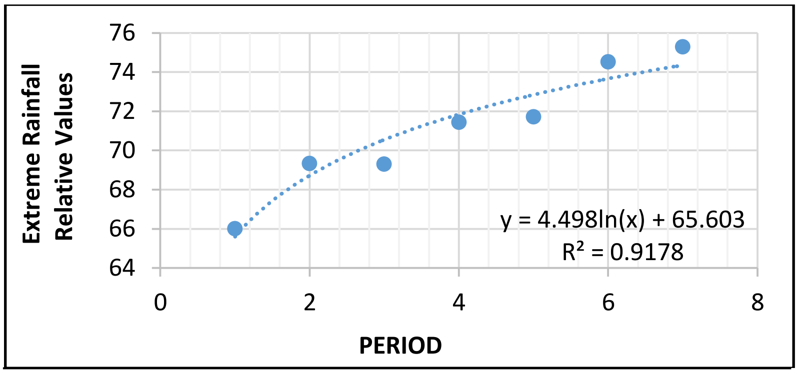

Figure 5. Graph of the average threshold of each period.

Figure 5 shows that the period approaching the intersection line is the 4th period (1978-1997) so that it can be concluded that long periods of minimum rainfall data taken in seeking the minimum threshold require extreme data over 20 years. After sorting, as many 18 stations have data more than 20 years including Raden Inten II, Fatmawati, Kenten, Sutan Mahmud Badarudin II, Depati Amir, HAS Hanandjoedin, Sultan Thoha, Japura, Minangkabau International Airport, Sampali, Belawan, Kualanamu F.L Tobing Sibolga, Binaka, Kijang, Cut Bau Maimun Saleh, Sultan Iskandar Muda and Tjut Nyak Dien Meulaboh.

As many 28 stations have data at least 30 years. These stations include Raden Inten II, Fatmawati, Kepahiyang, Baai Island, Kenten, Sutan Mahmud Badarudin II, Depati Amir, HAS Hanandjoedin, Depati Parbo, Sultan Thoha, Japura, Sultan Syarif Kasim, Hang Nadim, Kijang, Tarempa, Dabo, Sicincin, Minangkabau International Airport, Sampali, Belawan, Kualanamu, Tuntungan, F.L Tobing, Sibolga, Binaka, Cut Bau Maimun Saleh, Malikussaleh, Sultan Iskandar Muda and Tjut Nyak Dien Meulaboh.

Table 3. Calculation of minimum data length using the 7 observation stations.

PeriodTEN		Extreme Values							
		Raden inten	Fatmawati	Kenten	SMB II	Depati amir	Sampali	Kualanamu	Average
Period 1	1978-1982	64,57	77,00	71,52	58,04	59,88	64,37	66,63	66,00
Period 2	1978-1987	70,93	81,92	70,00	65,65	59,77	64,74	72,27	69,33
Period 3	1978-1992	73,28	83,77	71,16	62,21	59,35	66,81	68,52	69,30
Period 4	1978-1997	73,30	98,00	72,00	63,73	59,40	66,15	67,40	71,43
Period 5	1978-2002	73,30	84,00	74,00	75,16	59,11	67,28	69,17	71,72
Period 6	1978-2007	72,33	98,00	75,00	75,80	58,40	71,71	70,38	74,52
Period 7	1978-2012	72,05	96,81	77,00	75,60	58,30	77,00	69,21	75,28

4. Summary and Concluding Remarks

Clustering analysis of 38 observation stations with the ward method results 5 (five) clusters. Each cluster has a different pattern every month. Extreme daily rainfall in the region of Sumatra has a value ranging from 42.4 to 114.7 mm. Extreme daily rainfall over western region of Sumatra has an average value higher and more varied than the eastern region. Extreme daily rainfall over the northern region has an average value higher and more varied than the southern region. Threshold of extreme rainfall with long periods of different data showing different values for each station are sometimes larger or smaller that may be caused by different spread of the data for each station.

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