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THE IMPACT OF POSITIVE IOD AND LA NIÑA ON THE DYNAMICS OF HYDRO-CLIMATOLOGICAL PARAMETERS ON PEATLAND

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ABSTRACT: Peatlands in Indonesia are highly flammable during extremely dry seasons and are prone to flooding during extreme rainy seasons. This incident is related to the dynamics of the hydro-climatological parameters of the peatland. In 2019 the IOD+ phenomenon occurred which caused extreme drought and in 2020 there was a La Niña phenomenon that caused above-average rainfall. This study aims to determine and compare the dynamics of hydro-climatological parameters in the dry season during the 2018 normal climate, when there is IOD+ 2019, and when there is La Niña 2020. The data used are the results of in situ measurements by an integrated measurement system called SESAME and the measurement data of the MODIS satellite. The results of this study show that the rainfall and groundwater level during the IOD+ phenomenon in 2019 was lower than during the normal climate in 2018, while during La Niña in 2020 it was higher than during the normal climate in 2018. This study found a relationship that rainfall affecting groundwater level, and groundwater level affecting the number of hotspots, but their correlation is not significant. It is also found that hotspots can appear when the groundwater level reaches -0.65 m in West Kalimantan and -0.81 m in Central Kalimantan.

Keywords: Dynamics, Hydro-climatological parameters, Peatland, Positive IOD, La Niña.

1. INTRODUCTION

Indonesia has vast tropical peatlands. The peatland area in Indonesia is about 20 million hectares or nearly half of the total tropical peatland area in the world. These peatlands are located in the islands of Papua, Kalimantan, Sumatra, and Sulawesi. Peatlands in Indonesia are highly flammable during extremely dry seasons, so efforts should be made to prevent this recurrence [1-6]. The Indonesian government has done a lot to prevent fires on peatlands. One of them is establishing an integrated measurement station for hydro-climatological parameters, which are thought to be closely related to the occurrence of fires in peatlands. The station is managed by an Indonesian government-owned agency called the Peat and Mangrove Restoration Agency (BRGM). This research has used data from the measurement results of the BRGM station in Kalimantan, especially the rainfall and groundwater level data combined with the hotspot data from NASA's MODIS satellite measurements [7-10].

In 2019 a natural phenomenon called positive Indian Ocean Dipole (IOD+) occurred, which caused minimal rainfall in several regions in Indonesia, including Kalimantan island. This minimal rainfall has resulted in severe drought and fires on ine peatlands. This period is called the extremely dry season, which occurs from July 2019 to December 2019 [7-10]. Meanwhile, in 2020 the opposite phenomenon occurred where there was more rainfall than normal conditions during the dry season [11-12]. This natural phenomenon is known as La Niña. La Niña which occurred in 2020, is classified as La Niña with a moderate level so that the amount of rainfall is not too excessive. It is fascinating to study the dynamics of hydro-climatological parameters on peatlands when these two phenomena occur compared to normal conditions in 2018.

Research on the dynamics of hydro-climatological parameters on peatlands during the 2019 IOD+ phenomenon in South Sumatra has been carried out, but for the La Niña event in 2020, it has not been carried out [13-14]. The research conducted is in different locations, namely in West Kalimantan and Central Kalimantan. The data period used is also longer, namely for 2018, 2019, and 2020. The purpose of this study is to study the dynamics of rainfall, groundwater levels, hotspots, and the relationship between these three parameters on the peatlands in Kalimantan at the time of the IOD+ phenomenon in 2019 and La Niña 2020 and compare them with normal events in 2018. The novelty of this research is that this research was conducted to study the differences in the dynamics of hydro-climatological parameters for 3 different events, namely during normal climate conditions in 2018, when there was an IOD+ phenomenon in

2019, and when there was a La Niña phenomenon in 2020, especially on peatlands in Kalimantan. This research is limited to knowing the impact of climate change on hydro-climatological parameters in the peatlands of West Kalimantan and Central Kalimantan in 2019-2020. The same event may occur in the coming year with different impacts.

This research has tried to answer the following questions: (a) What is the pattern of changes in the hydro-climatological parameter values during 2018, 2019, and 2020?; (b) How is the relationship between rainfall and groundwater level?; (c) How is the relationship between the groundwater level and the number of hotspots? Research on the relationship between rainfall and hotspots has been carried out [13], but the relationship between groundwater levels and hotspots, especially on peatlands in Kalimantan, has never been done.

2. RESEARCH SIGNIFICANCE

Peatlands in Kalimantan are easily burned during the extreme dry season and easily flooded during the extreme rainy season [6]. An extreme dry season has occurred in 2019 due to the IOD+ phenomenon, and an extremely rainy season has occurred in 2020 due to the La Niña phenomenon. Parameters that are directly related to natural disasters on peatlands are rainfall, groundwater level, and hotspots. Research to determine the dynamics of these parameters during the extreme dry season and an extremely rainy season is very important as an effort to mitigate fire and flood disasters on these peatlands. Previous research has been conducted on the dynamics of these parameters in the South Sumatra region for 2019 [16-17]. This research was conducted in the Kalimantan region for three years, 2018, 2019, and 2020. As previously explained, in 2019 there was IOD+ and 2020 La Niña, while in 2018 the climate is normal. It is very interesting to study how the dynamics of these parameters differ over the 3 years.

3. MATERIAL AND METHOD

Data is measured through an in-situ data measurement system in the field, using an equipment system called SESAME. This equipment system consists of several sensors to measure rainfall data and groundwater levels. The data used in this research are hourly rainfall and hourly groundwater levels, obtained from the SESAME website at the following address: https://web.sesame-system.com. SESAME (Sensory Data Transmission Service Assisted by Midori Engineering Laboratory) is an in-situ integrated measurement system of several hydro-climatological parameters on peatlands in Indonesia, including in Kalimantan [16]. SESAME was built on the cooperation between the Indonesian government and the Japanese government. The SESAME equipment system has been installed in Kalimantan since 2018, therefore the data used in this study is data from that year. The Peat and Mangrove Restoration Agency manage SESAME [16-17].

This research data are data from measurement results at 2 SESAME stations in West Kalimantan and Central Kalimantan. The coordinate for the West Kalimantan station is (-0.210, 109.394), and the coordinate for Central Kalimantan is (-2.321, 114.056). The data taken from both stations are hourly in situ rainfall data and hourly in situ groundwater level data. This study has also used hotspot data from NASA's MODIS satellite measurements. Hotspot data is available on the NASA website at the following address: https://firms.modaps.eosdis.nasa.gov. The photo of the SESAME equipment system installed on peatlands is shown in Figure 1.

So that we can answer the questions in the introduction section, we have evaluated the parameter values of rainfall, groundwater level, and hotspots for 3 consecutive years and made a graph of their dynamics. The graph is analyzed how the pattern changes in its value and compares it when there are no natural phenomena in 2018, when there is an IOD+ phenomenon in 2019, and when there is a La Niña phenomenon in 2020 at the two research locations. We have also looked for the relationship between the three parameters to find out how the relationship between the three parameters is formed.

Fig 1. Photo of the SESAME equipment installed on peatlands

4. RESULT AND DISCUSSION

4.1. Dynamics of Rainfall

Table 1 and Table 2 state the total monthly rainfall for 2018, 2019, and 2020 at the two research locations during the dry season from July to September (J-A-S-O). In Table 1 and Table 2, it can be seen that the total rainfall that occurred during the J-A-S-O period was different for 2018, 2019, and 2020. At the West Kalimantan location, there was a total monthly rainfall: 633 mm, 514.5 mm, and 1283 mm for 2018, 2019, and 2020, while for Central Kalimantan, 426.5 mm, 318 mm, and 1200 mm, respectively.

Table 1. Monthly rainfall of West Kalimantan

	West Kalimantan		
	RF 2018 (mm)	RF 2019 (mm)	RF 2020 (mm)
July	31	42	635
August	103.5	113.5	105
September	156	101	209
October	342.5	258	334
Total	633	514.5	1283

Source: https://web.sesame-system.com

The least rainfall occurred in 2019 for the two research locations, wherein 2019, the positive IOD phenomenon occurred [10]. Previous studies show that the IOD+ phenomenon has caused less rainfall in the dry season (2019) than in the typical dry season (2018). The peak of extreme dryness in West Kalimantan occurred in July 2019, while in Central Kalimantan, it occurred in July and September 2019, where the total monthly rainfall was below 50 mm.

Table 2. Monthly rainfall of Central Kalimantan

	Central Kalimantan		
	RF 2018 (mm)	RF 2019 (mm)	RF 2020 (mm)
July	92.5	13	263
August	80	104	237
September	52.5	14	170
October	201.5	187	530
Total	426.5	318	1200

Source: https://web.sesame-system.com

The most rainfall occurred in 2020, wherein 2020 the La Niña phenomenon occurred [11-12]. The La Niña phenomenon has caused more rainfall during the dry season (2020) compared to the normal dry season (2018). The highest rainfall peak in West Kalimantan occurred in July 2020, while in Central Kalimantan, it occurred in October 2020, where the total monthly rainfall was above 500 mm.

a. Dynamics of Groundwater Level

Figure 2 states the average monthly groundwater level for 2018, 2019, and 2020 at the two research locations during the dry season (J-A-S-O). In Figure 2, it can be seen that the average monthly groundwater level (GWL) that occurred during the J-A-S-O period was different for 2018, 2019, and 2020. At the two research sites, the lowest monthly average groundwater level occurred in 2019, while the average groundwater level in 2018 and 2019 did not differ much. These data indicate that the IOD+ phenomenon has a significant impact on the groundwater level, while La Niña does not significantly affect changes in the groundwater level.

It appears that in 2019 the average groundwater level in West Kalimantan was -0.81 m, and in Central Kalimantan, it was even lower at -1.17 m on average. This shows that in the 2019 extreme dry season, peatlands in Central Kalimantan are more flammable than peatlands in West Kalimantan. At the time of La Niña in 2020, the groundwater level was still below -0.40 m, indicating that the high rainfall due to the La Niña phenomenon 2020 did not cause flooding in these two locations.

Laboratory tests have been carried out to determine the characteristics of the peat soil. The test results show that the peat soil is hemic which has a moderate level of weathering. Hemic peat soil has been partly weathered and partly in the form of fibers. Peat soil has a relatively high water holding capacity on a dry weight basis. The maximum water binding capacity for hemic peat is 450–850 % [21].

The 2019 J-A-S-O average groundwater level for Central Kalimantan, which is lower than West Kalimantan, is estimated to be due to the station's position. The Central Kalimantan station is located in the middle of a huge palm plantation, while the West Kalimantan station is not found in the middle of large palm plantations. Palm plantations require much water, therefore water on peatlands is mainly used to irrigate oil palm plantations, which is likely to make the groundwater level drop more sharply during the extreme dry season [21-22].

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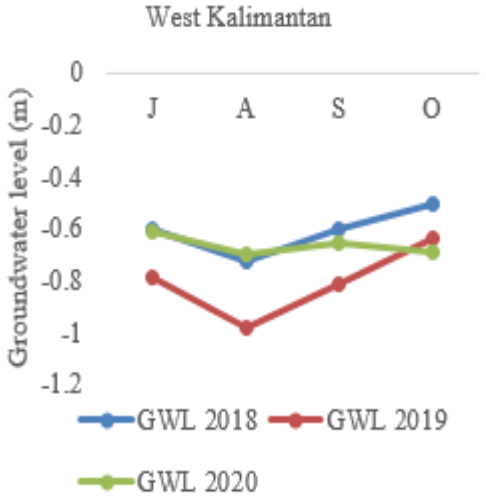

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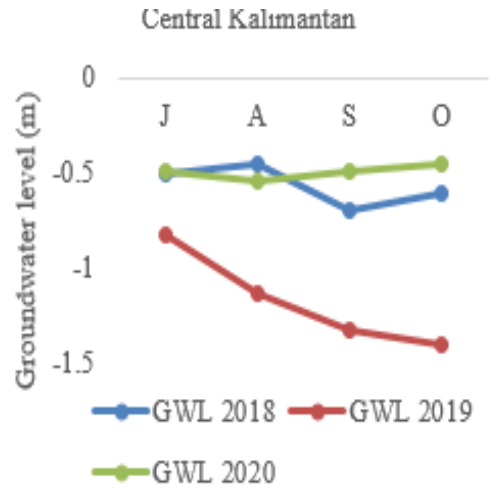


(b)

Fig 2. Graph of total average groundwater level in the dry season 2018, 2019, and 2020 in West Kalimantan (a) and Central Kalimantan (b)

b. Dynamics of Hotspots

Table 3 and Table 4 present the number of hotspots (H) in West Kalimantan and Central Kalimantan that appeared in the dry season of 2018, 2019, and 2020. The highest number of hotspots that emerged was in the location of Central Kalimantan in 2019, where the IOD+ phenomenon occurred that year. Whereas in 2020, there are no hotspots that appear. In Figure 6 (b), for the location of Central Kalimantan, it seems that hotspots always appear. The highest number of hotspots occurred in September 2019, as with many as 195 hotspots.

Table 3. Number of hotspots in West Kalimantan

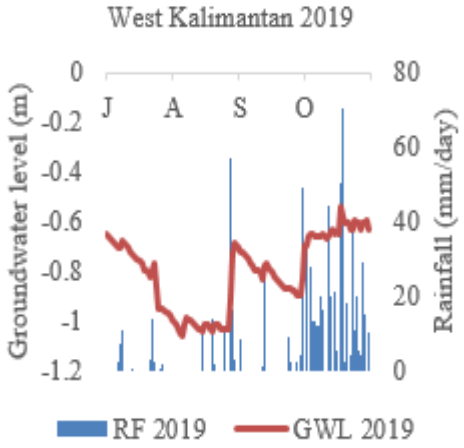
	West Kalimantan		
	H 2018	H 2019	H 2020
July	8	0	0
August	159	39	0
September	0	10	0
October	0	0	0
Average	167	49	0

Source: https://firms.modaps.eosdis.nasa.gov

Table 4. Number of hotspots in Central Kalimantan

	Central Kalimantan		
	H 2018	H 2019	H 2020
July	0	27	0
August	0	51	0
September	6	195	0
October	1	6	0
Average	7	279	0

Source: https://firms.modaps.eosdis.nasa.gov



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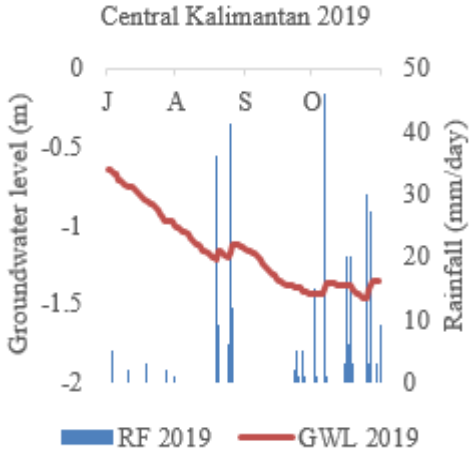


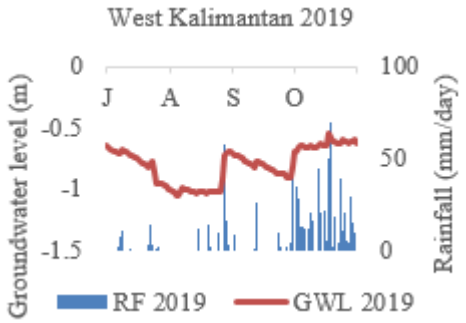
(b)

Fig 3. Time series graph of a relationship between rainfall and groundwater level

4.4. Relationship between Rainfall and Groundwater Level

Figure 3 is a time-series graph showing the relationship between groundwater level and rainfall. In general, there was a significant decline in groundwater and a substantial decrease in rainfall during 2019. In Figure 3 (b) for the location of Central Kalimantan, it can be seen that the groundwater level fell more steeply compared to Figure 3 (a) for the area of West Kalimantan. This happened because, during the 2019 extreme dry season, there was less rainfall in Central Kalimantan compared to West Kalimantan. In general, it appears that the groundwater level is strongly influenced by rainfall, where when there is no rainfall, the groundwater level continues to fall, and vice versa [23-24].

Apart from the rainfall factor, other factors that can cause the groundwater level to fall lower during the extreme dry season, namely the presence of canals on peatlands. Canals made legally or illegally on almost all peatlands in Indonesia are generally used as a means of transportation and for irrigation to plantations around peatlands. The dry canals during the extreme dry season cause water in the peatlands to be sucked in to fill the canals so that the groundwater level in the peatlands drops drastically.



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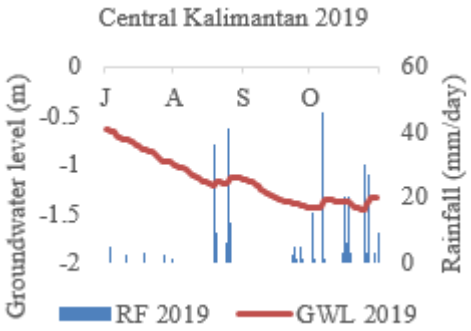
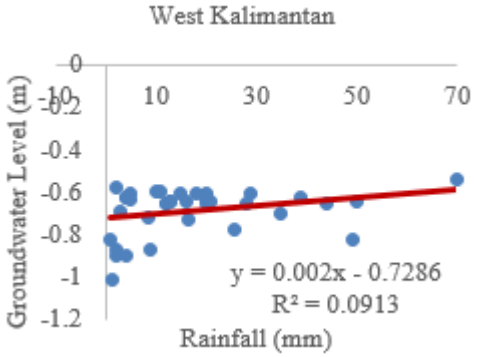


(b)

Fig 3. Time series graph of a relationship between rainfall and groundwater level

Figure 4 (a) and (b) show a graph of the correlation between rainfall and groundwater level during the extreme dry season in 2019. In Figure 4 (a) in West Kalimantan, the trend is that the greater the rainfall, the higher the groundwater level. This indicates that at this location the increase in rainfall still affects the increase in the groundwater level. Statistical tests have been carried out, namely the correlation significance test. The results show that the correlation coefficient value (r) is 0.3. However, the correlation is not significant because the correlation coefficient (r) only has a value of 0.3. In Figure 4 (b) in Central Kalimantan, it can be seen that the greater the rainfall, the lower the groundwater level. This indicates that at this location in the extreme dry season rainfall does not have a significant effect on the increase in groundwater level. Groundwater will tend to fall continuously due to the water it contains being pulled out by the surrounding environment.



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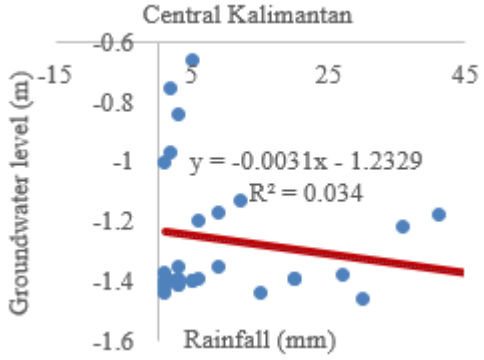


(b)

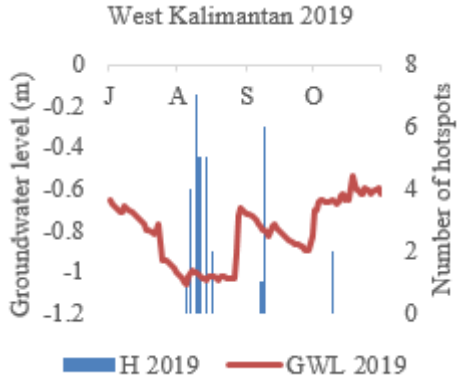
Fig 4. Correlation graph between rainfall and groundwater level

5.6. Relationship between Groundwater Level and Hotspots.

To obtain the relationship between the groundwater level and hotspots, data from 2019 is used because hotspots appeared a lot in 2019. In Figure 5 (b), it seems that there are more hotspots with a lower groundwater level compared to Figure 5 (a). Figure 5 also shows that, in general, it can be

concluded that when the groundwater level is shallow, many hotspots appear and vice versa.

The shallow groundwater level causes the soil on the peat surface to be very dry. The drier the surface soil of a peatland, the more quickly it burns, so the possibility of hotspots appearing is greater [25-26]. Thus, peatlands in Central Kalimantan are more flammable than those in West Kalimantan because the groundwater level is shallow.



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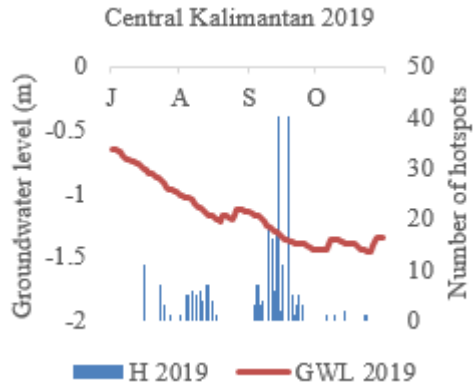


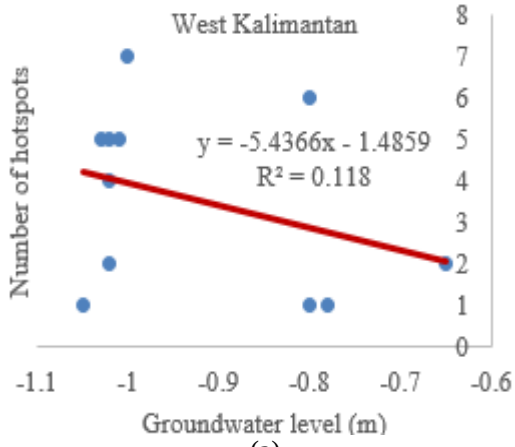
(b)

Fig 5. Time series graph of a relationship between groundwater level and hotspots

Figure 6 (a) and (b) show a graph of the correlation between the groundwater level and the number of hotspots. In Figure 6 (a) at the location of West Kalimantan, it can be seen that there is a trend where the lower the groundwater level, the more hotspots appear. The same thing happened at the location of Central Kalimantan as shown in Figure 6 (b).

At the Central Kalimantan location, the number of hotspots that appear is more than in the West Kalimantan location. This is because the groundwater level in Central Kalimantan is much lower than the groundwater level in Central Kalimantan.

In West Kalimantan, information is also obtained that hotspots can appear when groundwater is at a minimum level of -0.65 m, while in Central Kalimantan it is at a minimum level of -0.81 m. It is necessary to do further research on the minimum groundwater level that must be maintained so that hotspots do not appear, especially on Kalimantan Island.



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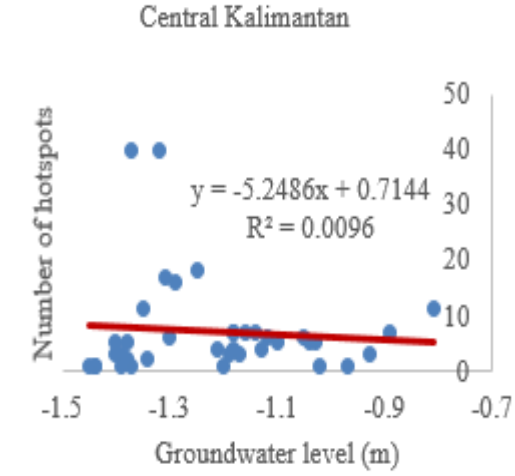

(b)

Fig 6. Correlation graph between groundwater level and hotspots.

5. CONCLUSIONS

This research has produced a novelty about the differences in the dynamics of hydro-climatological parameters on peatlands during the normal climate in 2018 when there was an IOD+ phenomenon in 2019, and when there was a La Niña phenomenon in 2020, specifically for the Central Kalimantan and West Kalimantan regions. The IOD+ phenomenon in the dry season in 2019 caused deficient rainfall on peatlands in West Kalimantan and Central Kalimantan. This scarce rainfall resulted in the groundwater level dropping drastically. Shallow groundwater levels can cause the surface of the peatlands to become very dry, triggering the emergence of hotspots, especially on peatlands around the Central Kalimantan station. The La Niña phenomenon in 2020 caused high rainfall but did

not cause flooding in the peatlands around West Kalimantan and Central Kalimantan stations.

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