The Use of Laser Precipitation Monitor (LPM) of Disdrometer and Weather Radar to Determine the Microphysics Characteristics of Extreme Rainfall in Jakarta. (Jakarta Flood Case Study February 25, 2020)

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Abstract. Heavy rains on February 24, 2020, caused flooding in most parts of Jakarta and its surroundings. The one-day observation of accumulated rainfall from the Laser Precipitation Monitor (LPM) was recorded at 358.6 mm/day at the Kemayoran station on February 25, 2020, at 00.00 UTC (07.00 Jakarta Time). In this study, analysis of the microphysical characteristics of extreme rainfall using LPM installed at Kemayoran meteorology station and weather radar at Cengkareng meteorology station with a spatial radius of 250 km. LPM is used to measure the diameter of the raindrops, the velocity of falling raindrops, LPM reflectivity, and the amount of accumulated rainfall with time resolution per minute and stored in excel data format. While the weather radar is used to measure the reflectivity spatially and temporally in the data volume format (.vol). The method used is, first, to find the relationship between LPM reflectivity and the amount of LPM rainfall with regression analysis. Second, the radar reflectivity is converted into estimated rainfall intensity for the Jakarta area and its surroundings. The results of this study found a relationship between LPM reflectivity (X) and rainfall accumulation LPM (Y) to form a regression relationship with the formula Y = 0.013X with R² = 0.3777. Based on the record of the LPM time series, the peak of rainfall occurred at 18.17 UTC with 1000 raindrops, the maximum fall speed was 10 m/s, and the maximum diameter is 8.5 millimeters. Based on the results of microphysical measurements of LPM, spatial plots, and vertical cross-section radar, it can be concluded that flooding in Jakarta is due to heavy rain from convective clouds.

1. Introduction
Jakarta is the capital city of a large Indonesian capital located northwest of the Indonesian island of Java, which experiences frequent flooding in the downtown area due to heavy rains, which occur mainly during the rainy season from December to February. Therefore, it is very important to study the meteorological conditions associated with heavy rain events and gain a better understanding of the
generation and development mechanisms to ensure the socio-economic security of the big city of Jakarta [1]. Historically, floods caused by heavy rains have occurred in Jakarta since the Dutch East Indies Government in 1619, 1932, and 1933 [2]. In 1996, 2002, 2007, and 2008 there were also major floods caused by extreme rains in Jakarta which resulted in economic and human losses [3]. Aldrian and Susanto (2003) stated that the Jakarta region has a monsoon rain pattern, which has a peak rainy season (December-February) and a dry season (June-August) [4]. The dominant floods that occur in January and February are caused by factors, namely natural factors and artificial factors. Natural factors are factors caused by weather and climate such as La Nina, MJO, Cold Source, Monsoon Asia which have an impact on very heavy rain in the city of Jakarta. While artificial factors are factors caused by urban spatial management that still need to be improved.

Understanding of heavy rain needs to be improved through observing the microphysical characteristics of rain in more detail using a disdrometer. One of the microphysical observations of rain that are still rarely carried out in Indonesia is the observation of the number of raindrops, the speed of falling raindrops, and the diameter of the rainwater. Disdrometer is a tool that can be used to measure rainfall, size, number, and speed of raindrops on the surface [5]. Lam et. al. (2014) Have conducted rain observations using a disdrometer at the Universiti Teknologi Malaysia's (UTM)'s campus in Kuala Lumpur, Malaysia whose results not only offer a better understanding of the microphysical properties of precipitation in heavy rain areas but also provide important useful information for the scientific community regarding remote sensing [6]. Meanwhile, Kalina et. al. (2014) conducted a comparison between Disdrometer and X-Band Mobile radar in Artesia, the USA to study Convective Precipitation microphysics [7]. Microphysical research with disdrometer and radar in Kototabang, West Sumatra (2002) [8] and serpong, Banten (2017) [5] has been conducted by Renggono to observe the vertical structure of rain clouds by detecting the presence of raindrops and the speed of their fall. In early 2020 the BMKG research and development center installed a laser precipitation monitor (LPM) of disdrometer at a meteorological station in Kemayoran. On January 25, 2020, floods occurred again in most areas of Jakarta and its surroundings, this study is intended to see the characteristics of the extreme rain that occurred on February 24, 2020, so that it is expected to provide an overview of the microphysical characteristics of the phenomenon.

2. Methodology

2.1 Data

In this study, using the thies clima LPM of disdrometer installed at the Kemayoran meteorology station with coordinates 106.84 E, -6.16 S and the weather radar EEC (Enterprise Electronics Corporation) at the Cengkareng meteorological station with coordinates 106.65 E, -6.12 S. Rainfall data LPM is measured from February 1, 2020, to February 29, 2020, including rain intensity (mm), the reflectivity of LPM (DBZ), number of raindrops (number of drops), the velocity of raindrops (m/s), and the amount of raindrop diameter (millimeters). The temporal time-series scale of LPM data collection is the minute resolution and stored in excel format (.xlsx) which is available on the LPM server computer at the Kemayoran meteorological station. This study also uses weather radar data from the Cengkareng meteorology station which can cover the spatial area at a radius of 250 km with a grid spatial resolution of 200 meters from 22 to 29 February 2020. The vertical resolution of the radar is 9 layers from a 0.5-degree angle to 10.5. 8 minutes degree angle and temporal time series resolution for PPI (DBZ) parameters in VOL format stored on the radar server computer at the Cengkareng meteorological station.

2.2 Method

The method used in this study is, the minute rainfall data from LPM in excel format is accumulated into daily rainfall by adding up the rain per minute with a total of 1,440 minutes in one day into mm/day from 1 to 29 February 2020 then plotted, in the form of a graph to see the fluctuation of daily rainfall during February 2020 using the R program. Minute rainfall data is plotted for 24 hours (1440 minutes) and compared daily to see the diurnal pattern of the minute rain pattern so that the dominant time of rain and rainfall will be known. The end of the rain in a diurnal pattern. Cengkareng's radar
EEC data on February 22-29, 2020 in the form of vol-format, is first converted to vol-NetCDF using the Enterprise Doppler Graphic Environment (EDGE) software on the radar server computer at the Cengkareng meteorological station. Vol-NetCDF data requires further conversion into NetCDF format so that the raw reflectivity value can be extracted in the PPI scheme in 0.5-degree elevation using the Python Wradlib software [9]. The netCDF data format has advantages in terms of data description, so that other users can clearly describe the data. The three main descriptions in the netCDF data format are variables, dimensions, and global attributes [10]. The acquisition interval for radar reflectivity data at 0.5-degree elevation is every 8 minutes with the cover radius reaching 250 km from the center of the radar. Data of LPM reflectivity and radar reflectivity with intervals every 8 minutes from 00.01 UTC to 24.00 UTC on 24 February the plot to be compared so that the relationship between the two patterns can be seen. LPM reflectivity data and LPM rainfall intensity data during February 2020 were plotted in a scatterplot graph and searched for regression formulas and their correlation values using Excel software. This regression formula will be used to convert the Radar reflectivity into intensity. Rainfall on February 24, 2020, is plotted into a minute time-series graph. Based on the time series plot, the peak rainfall intensity and duration of rain will be known. At the peak of the rain on 24 February 2020, LPM data was extracted for the variable number of grains, grain drop speed, and grain diameter. The peak of rain on 24 February was seen by radar's vertical crosssection from east to west and from north to south so that the vertical characteristics of the clouds that caused the rain peak were known. Also, the spatial reflectivity value of radar is converted into intensity (mm/minute) based on the regression equation of the relationship between LPM flexibility and LPM of rain intensity. So that we get the spatial intensity value with a radar spatial coverage of up to 250 km.

3. Results and Discussion

3.1 Analysis of the accumulated daily rainfall of the LPM of disdrometer in February 2020 and the diurnal cycle of the LPM of Disdrometer

Based on the results of rainfall measurements using the LPM of disdrometer at the Kemayoran meteorological station in Figure 1.A above which is obtained from the accumulated time series on a minute scale from 1 to 29 February 2020, it can be seen that there is a fluctuating amount of daily rain, with almost all days of rain during February 2020 except February 13 and 15 which are days without rain recorded by the disdrometer. The month of February is included in the peak of the rainy season in the city of Jakarta with a monsoonal rain pattern, this is according to the research of Aldrian et. al. [4], based on Syaifullah's (2013) research, the wind profile in February in Jakarta is dominated by the western winds (Indian monsoon) which bring quite a lot of steam from the South China Sea [11]. Heavy rain with a value above 100 mm/day occurred 4 times which were recorded, namely on February 1, 7, 22, and 24. The maximum one-day accumulated rainfall value occurred on February 24,
2020, which was recorded from the LPM measurement recorded at 358.6 mm/day. Based on the results of time series rainfall measurements using the minute scale LPM of disdrometer in Figure 1.B above, it can be seen that the characteristics of diurnal rain in February 2020 are generally minute rain with relatively high intensity and fluctuating generally starting at night at around 15 UTC (22 Jakarta Time) and ends in the morning at around 10 UTC.

3.2 Relationship between LPM Reflectivity and LPM Precipitation

Figure 2 above is a scatter plot of the relationship between LPM reflectivity data on the X-axis and the precipitation intensity on the Y-axis, which is located at the Kemayoran meteorological station on February 22 to 29, 2020 which is a sample of various microphysical conditions from non-rainy conditions, low rain intensity, moderate rain intensity, to heavy rain intensity. There was a significant increase for the LPM rain intensity parameter when the LPM reflectivity was above 40 DBZ. The equation generated from the relationship between LPM reflectivity and LPM rain intensity will be used as a reference to convert radar reflectivity into radar rain intensity estimates so that spatial rain intensity information can be obtained from the Cengkareng radar which covers all Jakarta and its surroundings within a 250 km radius. Based on the picture above, the relationship between LPM reflectivity data and LPM precipitation intensity data shows the correlation value $R^2 = 0.3777$ with the regression equation $Y = 0.013X$.

3.3 Comparison of LPM Reflectivity and Radar Reflectivity

Figure 3 above is a time series graph collected from time to time to illustrate the development of LPM reflectivity data located at the Kemayoran meteorological station and is compared with radar
reflectivity data extracted based on the coordinates of the Kemayoran meteorological station with a data acquisition interval of every 8 minutes at a time. February 24, 2020. Based on Figure 3 above, the LPM reflectivity data shows that the daily reflectivity value has occurred at 00.08 UTC to 05.52 UTC with characteristics that are not continuous or intermittent. Meanwhile, the reflectivity starts to be recorded again at 16.16 UTC to 23.28 o'clock continuously without being interrupted. In terms of installation, the LPM is installed above the ground with a height of 1.2 meters while the radar reflectivity data with a height of 0.5 degrees above the Kemayoran station is measured from the Cengkareng Meteorology Station, based on the comparison between the reflectivity value of LPM and the reflectivity of radar, it can be seen that the reflectivity patterns of both which is almost similar but the reflectivity value of the radar data recording is greater than the reflectivity value of the LPM data. This is consistent with research conducted by Tokai et. al. 2008 [12] there is a bias between the reflectivity measurement from the radar at a higher elevation than the disdrometer data due to the lag between the fall time from observations of radar reflectivity at an elevation of 0.5 degree and the measurement of the disdrometer on the surface as well as the presence of other factors such as wind that causes shifts of raindrops measured by the disdrometer on the surface.

3.4 The peak of LPM rainfall is on February 24, 2020

Flooding has been reported to have occurred on February 25, 2020, in Jakarta and surrounding areas. Based on LPM observation data with a minute-scale time series resolution installed at the Kemayoran meteorological station, it occurred on February 24, starting at 16.32 UTC (23.32 Jakarta Time) and ending on February 25 at 01.44 UTC (08.44 Jakarta Time). Judging from the duration of the rain that occurs is for 10 hours 12 minutes with fluctuating intensity and the rain occurs continuously without a break (see Figure 4 above). The peak rain recorded by the LPM of disdrometer is at 18:17 UTC with an intensity of 4.38 mm/minute (262.87 mm/hour) which is shown by the red circle in Figure 4 above.
3.5 Analysis of the LPM peak rainfall on February 24 2020 at 18.17 UTC

The characteristics of the number of raindrops, the amount of raindrop diameter, and the dropping speed of different raindrops in different seasons indicate that for stratiform type rain, the rainfall intensity is more influenced by the diameter of the raindrops, while for convective type rain, the rainfall intensity is more influenced by the Raindrop size distributions. [13]. Figure 5.ABC is a spectrum graph for measuring the characteristics of rain in the form of the number of granules, the speed of falling raindrops, and the amount of rain diameter at the peak of rainfall that occurs at 18.17 UTC on 24 February 2020, this analysis is based on the previous Figure 5 to see the characteristics of the rain unique with more detail. Rainfall characteristics in an area can be determined from the distribution of raindrops. To obtain the distribution of raindrops, a function that shows the number of raindrops with a certain diameter is used in a space volume unit [5]. Precipitation can be classified into types of convective rain and stratiform rainfall based on rainfall characteristics. Based on Figure 5.A, the rain spectrum graph above shows that the relationship between the diameter of rain and the speed of falling raindrops shows a non-linear relationship. The maximum speed of rain measured from the LPM of the disdrometer reaches 10 m/s and the maximum diameter measured by the LPM of the disdrometer is up to 8.5 millimeters. Based on Figure 5.B above, it can be seen that the amount of raindrops with a diameter of 0.125 mm is the highest number of grains with the number of grains reaching around 1000 raindrops per minute. At the same time, for raindrops with a diameter of 0.75
mm and above 0.75 mm, there was a decrease in the number of raindrops to below 200 raindrops per minute. Based on Figure 5.C above, it can be seen that the speed of falling raindrops with a speed of 1 m/s and 1.8 m/s is the velocity of falling at most with the number of grains reaching around 1000 raindrops per minute. The drop speed of 1 m/s is the maximum number of beads in various sizes of raindrop diameter. Based on the spectrum analysis above, it can be seen that this is a convective type of rain following previous Renggono (2017) research [5].

3.6 Analysis of the radar reflectivity on 24 February 2020 at 18.17 UTC
Figure 6. Radar image of the Cengkareng Meteorological Station (a black point is the location of the Kemayoran meteorological station) at 18.17 UTC on 24 February 2020
A. Radar conversion results from reflectivity to rain intensity per minute (mm/minute)
B. Vertical cross-section of radar reflectivity from north to south
C. Vertical cross-section of radar reflectivity from east to west

Figure 6.A is the rain intensity per minute (mm/minute) from the conversion of radar reflectivity to rain intensity using the regression equation $Y = 0.013X$ (see Figure 2). Based on radar image data obtained from the Cengkareng meteorological station as shown in Figure 6.A. On February 24, 2020, at 18:17 UTC, it was seen that rain covered the entire area of Jakarta with an intensity above 4 mm/minute to 6 mm/minute and the surrounding area with an intensity that varied from 0.1 mm/minute to 4 mm/minute. A black dot in figure 6.A. shows the location of the Kemayoran meteorological station where the LPM is installed, based on a radar image the intensity value at the point location of the Kemayoran meteorological station shows a yellow gradient which means 4 to 5 mm/minute rain intensity, this shows the similarity between the measurement of rain intensity from radar conversion and the results of LPM measurements at the Kemayoran meteorological station.

Based on Figure 6.B, it can be seen that the vertical cross-section of radar reflectivity from north to south at an elevation of 0.5 degrees is measured from the coordinates 6.5 S to coordinates 5.3 S, this indicates that the measured length of the cloud from north to south is 133.6 km. Based on the vertical cross-section, the radar reflectivity from north to south for the point of the Kemayoran meteorological station has a reflectivity value of about 35 to 40 DBZ at an elevation of 0.5 to 12 degrees while the measured reflectivity reaches a maximum height of 19 degrees. Based on Figure 6.C, which shows the vertical cross-section of radar reflectivity from east to west at an elevation of 0.5 degrees measured from coordinates 106.1 E to coordinates 107.1 E, this indicates that the length of the cloud from east to west as measured by radar is 111.3 km long. Vertical cross-section of radar reflectivity from east to west for the point of the Kemayoran meteorological station has a reflectivity value of about 35 to 40 DBZ at an elevation of 0.5 to 12 degrees while the peak of the reflectivity reaches a maximum height of 19 degrees. Based on the characteristics of the cloud as seen from its radius area and peak height based on vertical cross-section, it can be seen that these characteristics are a type of convective cloud.

4. Conclusion

Based on the results of the LPM of disdrometer data processing, it can be concluded that rain occurs for 10 hours 12 minutes with fluctuating intensity and rain occurs continuously without pause. The peak of extreme rain that was recorded by the LPM of disdrometer was at 18.17 UTC with an intensity reaching 4.38 mm/minute (262.87 mm/hour) with the microphysical characteristics of rain, namely with 1000 raindrops, the maximum fall speed is 10 m/s, and the maximum diameter is 8.5 millimeters. Based on the 0.5-degree elevation radar, the length of the cloud from north to south is 133.6 km and the length of the cloud from east to west is 111.3 km with the center point being the Kemayoran meteorological station. Based on the microphysical characteristics of extreme rain, it is caused by a type of convective cloud.

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