Preliminary result of characteristic of convective cloud development observed by x-band meteorological radar in Bandung basin

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Abstract. The initial, mature, and dissipation stage changes in a convective cloud development have a short period of time so that the development stage analysis is needed by using data that has a high temporal resolution. The data that used are product CAPPI-V and CAPPI-Z from X-Band meteorological radar and also BBWS Citarum rainfall data from 13 stations that scattered in the area of Bandung basin. The selection of rainfall days is done to take the areas that have a strong convective system, and the result is that Sapan area has higher rainfall than 12 other stations on April 27th, 2017. The precipitation is caused by convective clouds. The initial stage of convective clouds begins with the existence of convergence phenomena in the afternoon and at 10 minutes before the rainfall event. It is also when there are maximum rainfall events on April 27th, 2017 which can indicate the formation of convective clouds. After the formation, the development stage occurs when there is an increase in reflectivity values on the radar and then convective cloud size starts to grow. When convective cloud size is dissipating, there is an identification of a decrease in reflectivity of the previous value in the evening. There is a new convective initiation next to the cloud that is in the dissipation stage and then joins to develops in a short time for about 30 minutes.

Keywords : convective, cloud, rainfall, reflectivity.

1. Introduction
Convective activity can generate the convective clouds that have the potential to cause rainfall event with clear diurnal intensity [1]. Mountainous area has complex topography that can influence diurnal intensity of convective activity in them that caused by valley winds [2]. Fovell and Tan [3] divide the stage of convective cells based on the presence of convective activity: cell formation, cell strengthening, and dissipation. Leary and Houze [4] also divided the convective cloud development stage which consists of the formation stage, strengthening convection, mature stage, and dissipation. Then Anggoro and Pramujo [5] statistically quantified the stage of convective cloud development in Bogor, Indonesia.
and found that convective clouds had a longer time to develop at the mature stage of 80 minutes. Nishiwaki et al. [6] analyze convective cloud structures that develop in mountainous areas in the North Kanto, Japan using X-Band meteorological radar. Jackson et al. [7] also apply the same radar instrument to see the evolution of convective clouds in southwestern England. Identification using radar X-band is an option because X-Band radar measurements provide more detailed information on the structure of precipitation in it [8].

One of the triggers of a strong convective system producing convective clouds is convergence. This convergence was analyzed statistically by the model simulation by [9] because the link between convergence and convection was not good enough in global model, with the result that it will produce a lot of bias. On the other hand, convective clouds are small-scale phenomena then it is difficult to be simulated or even predicted the development of the convective cloud model [10]. Therefore, the main purpose of this study is to determine the characteristic of convective cloud development using X-band radar observation is needed to provide the detailed information in the observed area so that it can develop the reliability of numerical weather prediction. The preliminary result of characteristic of convective cloud development stage is from the initial, mature, and dissipating in the Bandung basin in April 2017. The data used and the methodology followed for the radar data product processing are explained in the following section.

2. Data and Methods
The stages of the development of convective clouds studied in this research are in the Bandung basin area in April 2017 with coordinates 7.93°S-6.13°S and 106.86°E-108.66°E as in figure 1. However, before analyzing the stages, the selection of rainfall days will be conducted in this research. The type of rainfall that chosen is convective rainfall type, because the localized convergence occurs and resulting the large vertical velocities in convective rainfall type [11]. From the 13 rainfall stations that owned by BBWS Citarum that scattered in Bandung basin (figure 1), rainfall data will be taken which shows that rain occurred in all stations in the range of April 2017. Then the data will be percentage and we will take the dates that have the highest percentage of rainfall event in all stations. These rainfall data have 10 minutes temporal resolution. Data can be downloaded via http://bbwscitarum.com. After obtaining this date, it is necessary to validate whether this rainfall event is due to convective cloud.

![Figure 1. Radar coverage area (a) and distribution of rainfall stations in Bandung basin (b).](image)

The next step is to identify the stage of convective cloud development using radar, after the convective clouds, which produce rainfall are identified. Identification of convergence and convective clouds will be examined using X-Band radar products in the form of Constant Altitude Plan Position
Indicator (CAPPI). CAPPI is a horizontal cut of a PPI volume scan at multiple elevation angles. The number of angles depends on the range and height of the CAPPI that want to produce [12]. In this study, 20 elevations from the range 0°-45° in radar PPI scanning will be used. The CAPPI radar is from the observational campaign that held by National Institute of Aeronautics and Space, Indonesia in April 2017. The center point of the X-Band radar is in Majalaya, with coordinate 7.035°S and 107.769°E. Then to identify the convergence, we use CAPPI-V that can show the radial velocity value on the radar. This CAPPI-V product has an image format with the extension. V, therefore the color definition of each pixel in this product will be done. The CAPPI-V pixel color definition according to [13] is:

\[
\text{Velocity (ms}^{-1}\text{)} = 14,346^+ \left(\frac{14,346-(14,346)}{255}\right)\text{pixel value}
\]

(1)

The threshold of radial velocity is +14,346 ms\(^{-1}\) and -14,346 ms\(^{-1}\). If there is a pixel value of CAPPI-V that exceeds that threshold, then that value will not be defined. If the radial velocity value has an opposite value in which a positive value means away from the radar and a negative value means approaching the radar, then in an area where there is an opposite value converge, it indicates the occurrence of convergence. Convergence occurs when two opposing radial velocity values meet each other. CAPPI-V height for convergence identification is 2 km and 3 km, because at height of 1 km, the mountains will block the signal that captured by the X-Band meteorological radar. This obstacle is called ground clutter. The next step is identifying the convective cloud using reflectivity in CAPPI-Z which can show the reflectivity of the radar. CAPPI-Z pixel color definition is:

\[
\text{Reflectivity (dBZ)} = 32^+ \left(\frac{95.5-(32)}{255}\right)\text{pixel value}
\]

(2)

Clutter at height of 1 km can be removed in CAPPI Z (reflectivity) by using the Gabella clutter filter [14] module in the [15], so analysis at height of 1 km can be solved for radar reflectivity parameters without being blocked by clutter that identified on the radar. The removal of ground clutter at the height of 1 km has a threshold of \(t_r_1 = 9, n_p = 10\), and \(t_r_2 = 2.9\). Nishiwaki et al. [6] define the convective echo as a radar that has a reflectivity of more than 8 dBZ with an area of about 3.75 km. If there is a convective echo with a reflectivity of more than 17 dBZ, then the reflectivity is defined as a convective cell. This convective cell on the mature stage that have 37 dBZ reflectivity can be detected by their movements and can result a rainfall to form [16]. Convective initiation is defined by echo that have a reflectivity of 35 dBZ by [17].

Convective cloud development and dissipation stage will be monitored by defining the grid area based on that maximum reflectivity. After the grid area has been determined, the next step is averaging the area of the grid so that it produces one value at one height and one time. Then to average the next height at the same time, the grid area at that level refers to the initial height. There will be 11 values of reflectivity in one grid area. When time increases and reflectivity moves, it is necessary to redefine the area by looking back at the maximum reflectivity value and determining the grid area again. The results of the levelling reflectivity coverage area will be obtained in the form of time series analysis, namely time height. This information can be used to analyse when the cloud develops and dissipates at that time.

3. Result and discussion

3.1. Rainfall days selection based on stations data
The selection of rainfall days during April was taken from 12.00 - 18.00 LT, because the convective cloud was formed at 12.00 and weakened after 18.00 local time. It turns out that there are rainfall events every day in the study area in April 2017. Therefore, a filtering is needed using a percentage analysis of rainfall events to find out on what date the rainfall occurred with a large area. This percentage analysis will take the maximum value, with the result that the rain producing convective clouds in the entire station coverage.
From the bar diagram in figure 2 shows that 13 BBWS Citarum rainfall stations that scattered in the Bandung basin recorded that on April 22 and 27 there was rainfall event. From these two dates, on April 27th at the Sapan station recorded high rainfall values than the 12 other stations (table 1). This difference can be associated as a powerful meteorological phenomenon in the Sapan area, for example convergence, or an intense updraft that forms convective clouds in it. Rainfall on April 27th tends to predominantly move from South to North when viewed from the start time of the station that recording the rainfall events.

![Figure 2. Bar plot of the percentage of rainfall events in April 2017 in 13 stations in Bandung basin](image)

Table 1. Rainfall data (mm) from 13 stations that scattered in Bandung basin on 27th April 2017

| Station        | Rainfall value (mm) |
|----------------|---------------------|
| Ancolmekar     | 22.5                |
| Cicalengka     | 6                   |
| Cidurian       | 32                  |
| Pasir Jambu    | 9.5                 |
| Dago Pakar     | 2.5                 |
| Dayeuh Kolot  | 1                   |
| Hantap         | 3.5                 |
| Jatiroke       | 8                   |
| Kertasari      | 37                  |
| Lembang        | 1                   |
| Paseh          | 6                   |
| Rancaekek      | 22.5                |
| Sapan          | 58                  |

3.2 Analysis of convergence phenomena
The first convergence on April 27th exists at 12.30 LT (figure 3). Rainfall event in the Sapan area occurred at 13.30 LT. Before rainfall occurs (13.20 LT), there is a convergence around Sapan when viewed from the radial speed on the radar both at 2 km and 3 km (figure 4a and 4d). But when there is maximum rainfall (13.40 LT), there is a convergence that decreases speed detected on the radar.
Different things occur at the height of 3 km, where at this height convergence occurs only during the rain event. The radial velocity value is not greater than 2 km height when it rains.

![Figure 3. Spatial plot radial velocity of CAPPI-V at height 2 km at 12.30 LT](image)

Figure 3. Spatial plot radial velocity of CAPPI-V at height 2 km at 12.30 LT

![Figure 4. Spatial plot radial velocity of CAPPI-V at height 2 km (a,b,c) and 3 km (d,e,f)](image)

Figure 4. Spatial plot radial velocity of CAPPI-V at height 2 km (a,b,c) and 3 km (d,e,f)

3.3. **Development and dissipation stage of convective clouds analysis**

By monitoring the reflectivity movements, the analysis can be carried out using a time height plot as in figure 5 to see the development and dissipation process of the convective cloud. The time height is done
by averaging the grids around the maximum reflectivity and follows the movement of the cloud, therefore it will produce the mean reflectivity of cloud. When it is related to the rainfall value recorded at the Sapan station, the developing convective cloud does not cause rainfall. This means that radar does not directly measure rain droplets, because the captured reflectivity is not necessarily immediately identified by the occurrence of rainfall. The increase in rainfall value at 13.30 LT was followed by a decrease at the mean value of radar reflectivity at the height of 5 km, then continued to decline until it reached a value of 16 dBZ in the event of maximum rainfall in the first peak (13.40 LT). However, there was a condition where at 13.50 LT, there was a significant decrease in rainfall for about 8 mm from the previous rainfall peak, then the rainfall increased again until it reached the second peak (14.10 LT) and decreased until 14.40 LT.

Figure 5. Mean reflectivity time height (a) and time series (b) plot of CAPPI-Z at 27th April at Sapan station

There is no difference at the mean reflectivity at 13.40 - 13.50 LT at the height of 1 - 7 km, although the process of decreasing reflectivity still occurs at 8 km height. But there was an increase in reflectivity at 14.00 LT at the height of 1-3 km, even though at that time the detected rainfall had increased. When rainfall reaches the second peak at 14.10 LT, the reflectivity decreases, and the height of the cloud begins to decrease. From the description above, the increase in rainfall value after experiencing a previous decrease is also supported by the identification of decreased reflectivity.

When analyzed with vertical cross section of reflectivity, the convection is initiated on the plain at 12.30 LT. At this time, there is a strong reflectivity of up to 40 dBZ at 3 km height and there are also other convective cells that have a value more than 20 dBZ. This reflectivity increased at 12.40 LT. The reflectivity, which originally had a value of 40 dBZ is strengthened to have a value of 48 dBZ. Strong reflectivity is detected in two places, at 1 and 3 km height. Increasing of the reflectivity value and identification of this wider area can be associated as convective cloud growth. This is consistent with the statement that if the higher reflectivity value identified on the meteorological radar, there is an indication of convective clouds which will potentially produce rainfall [18].
Figure 6. Vertical cross section plot of CAPPI-Z radar reflectivity. The position longitude that used from this v-cut is 107.64E – 107.81E

The convective cloud then continues to grow to a height of 11 km and has a large area, followed by a reflectivity value of about 30 dBZ, which increases to a height of 10 km (figure 6c). But at 13.30 LT, there was a significant decrease in reflectivity at low altitude (2-4 km), although a reflectivity of 27 dBZ was still detected up to a height of 10 km. This decrease in reflectivity is supported by the occurrence of rainfall event at that time in the Sapan area. This shows that the convective clouds identified are included in the vertical cloud type and cause rain (small cumulonimbus cloud). High reflectivity values are found at an altitude of 1 km, which indicates that the reflectivity is moving down. Then when maximum rain occurs at the first peak (figure 6e), the decrease in reflectivity is quite clearly identified, it can be seen that the reflectivity that previously had a value of 27 dBZ at 10 km height is dropped significantly to a height of 5 km. There is still a high reflectivity value of 40 dBZ at an altitude of 1 km, which indicates that rain is still occurring in this area and clouds enter the dissipation stage.
When the rain event reaches the second peak, a new reflectivity is identified to the west of the convective cloud that is being dissipated. It is indicated that there is convective cloud regeneration at this time. This phenomenon is likely the same that explained by [19] about the regeneration of diurnal cycle of convective cloud formation. Here, the cloud begins to develop followed by an increase in reflectivity but within a period of 30 minutes, shorter than the previous convective cloud. This makes convective clouds have a fairly short development time because rainfall event is still recorded when the second convective cloud grows, therefore the clouds enter the dissipation stage more quickly. The stage of dissipation in clouds causes a significant decrease in reflectivity until the convective echo is not identified is occurred at 14.50 LT.

The previous vertical analysis can be simplified in schematic illustration as shown in figure 7. In the initial stage, there is a high reflectivity value which is included as convective cells (figure 7a), then the convective cell strengthens, so that the reflectivity increases so that the size of the cloud enlarges to mature stage (figure 7b). When the rain occurs, a decrease in reflectivity occurs which indicates that the cloud has been dissipated (figure 7c). However, when it entered the stage of dissipation a new convective cloud initiation is placed next to the cloud which is in the dissipation stage and then joins and develops in a short time (figure 7e). The dissipation stage ends when no reflectivity is identified in the area, which indicates that the cloud is no longer exist.

4. Conclusion
The characteristic of cloud convective development like initial, mature, and dissipation stage in the Bandung basin can be identified using X-Band meteorological radar. It has an initial stage which can identify the existence of convergence phenomena at 12.20 LT and at 10 minutes before the rainfall event (13.20 LT) also when there are maximum rainfall events (13.40 LT and 14.10 LT) on April 27th, 2017 which can indicate the formation of convective clouds. After the formation, the development stage occurs when there is an increase in reflectivity values on the radar and then convective cloud size starts to grow at 12.30-13.30 LT, and when there is a rainfall event, the convective cloud size is dissipating, and there is an identification of a decrease in reflectivity of the previous value at 14.10-17.30 LT, therefore it is entered the dissipation stage. Convective cloud initiation occurs next to the cloud which is in the dissipation stage and then joins and develops in a short time.

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