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Application of C-band Doppler Weather Radar (CDR) for Detecting Volcanic Ash Dispersion of Sinabung Eruption 19 February 2018

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Abstract. The weather radar is generally employed to forecast the potential of hydrometeorological hazard. In the present paper, we focus on the application of C-band Doppler Weather Radar (CDR) to identify February 19th, 2018 Sinabung volcanic eruption and its dispersion by using a direct product in the form of CMAX (Column Max) retrieved from reflectivity factor (dBz). The distribution of reflectivity factor varies from the center of the eruption to the farther location indicating the dispersion of material size erupted by the Sinabung. Lapili which is larger material size with 48dBz tends to locate in the nearby volcanic area. The medium size of the material like coarse volcanic ash with 33 dBz of reflectivity was floating in the air and carried away by the wind. Meanwhile fine volcanic ash with 10 dBz of reflectivity flies a great distance along with the wind.

1. Introduction

Indonesia is surrounded by active tectonics where many volcanoes are located leading to among countries most at risk of the threats of volcanic eruption [1]. Volcanoes are observed intensively by PVMBG (Indonesian Center for Volcanology and Geological Hazard Mitigation) by deploying volcano monitoring station. In addition, BMKG (Indonesian Agency for Meteorology, Climatology, and Geophysics) is assigned to monitor hydrometeorological hazard by performing the weather radar. Since 2016, as many as 40 weather radars had been installed throughout Indonesia [2].

Weather radar play a major role in providing services associated with weather forecasts, especially short-term weather (near real-time), for aviation services during take-off and landing at the airport, besides it can be utilized to provide early warning to the occurrence of extreme weather such as torrential rain, typhoons, strong winds, and wind shear as well as for analyzing other extreme weather events [2]. Physically, the weather radar works by recording electromagnetic waves reflected by the material, both water and volcanic ash [3]. Therefore, weather radar can be employed to monitor the dispersal of the volcanic ash of volcanic eruption as part of disaster mitigation.

Sumatra island located at the boundary margin tectonics have subduction and strike-slip faults known as the Great Sumatra Fault [4][5]. The active faults not only create high seismic [6] but also geologically produce high volcanic hazard zones. For instance, the second largest mountain in North Sumatra, Mount Sinabung is known for never erupting since 1600. But suddenly, Sinabung awake in last 2010. A total of 12 thousand residents must be evacuated to the safe area for three consecutive days from 27 to 29 August 2010 as smoke and lava were released from the mountain. Following no record of eruption since 1600, Sinabung is categorized into volcano type B. As it starts to be active again, Sinabung turns into volcano type A leading its status to raise to be “alert” (*Awas*) [7].
On 19 February 2018 Mount Sinabung returned a relatively large eruption by producing dark gray plume with a high volume of ash that rose to about 16.8 km (55,000 ft). Visibility in five surrounding districts was poor and reduced to only about 5 m. Some residents outside of the evacuation zone were self-evacuated [8]. Since a number of active volcanoes type A are also found in Aceh Province, it then draws TDMRC to study the 19 February 2018 Sinabung volcano eruption as a lesson learned of the volcanic disaster mitigation. A team of TDMRC Unsyiah was involved in the Volcano Eruption Impact Assessment on 22-26 February 2018. The team conducted interviews and field samplings. Raw weather radar data during eruption days are available at BMKG Region I Medan which is is the closest weather radar to Mount Sinabung with a distance of 49.69 km. Based on these data, the present paper discusses the effectiveness of weather radar application on the detection of the dispersal of Sinabung volcanic ash [9].

(a) The Sinabung Volcano in closer view

(b) The Sinabung eruption

Figure 1. (a) A closer view of Sinabung from red zone during volcanic eruption impact assessment trip 22-26 February 2018[9] (b) Dark cloud eruption arouse 5000 m height followed by pyroclastic flow, 19 February 2018, at 08.58 local time [10]

2. Method

The weather radar is developed after World War II with the first application in the military field. It is used to mitigate hydrometeorological hazard by observing the precipitation, i.e., rainfall and snow. The range of observation may reach several hundred kilometers depending on the power of emission of the microwaves spectral and the transmitting antenna. The types of weather radar based on the number of antennas are divided into 2 types, e.g., MonoStatic Radar, i.e., Radar where transmitter and receiver are installed in one antenna while another type of Radar is Bistatic Radar where two antennas,e.g., transmitter and receiver are installed separately. At the beginning of the development weather radar in 1960, Non-Doppler Radar is used to detect energy reflectivity from the object only. The next development of radar also includes velocity detection based on Dopler principles (figure 2).

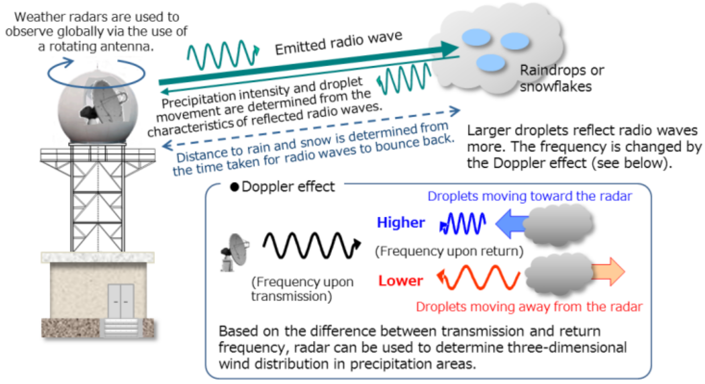
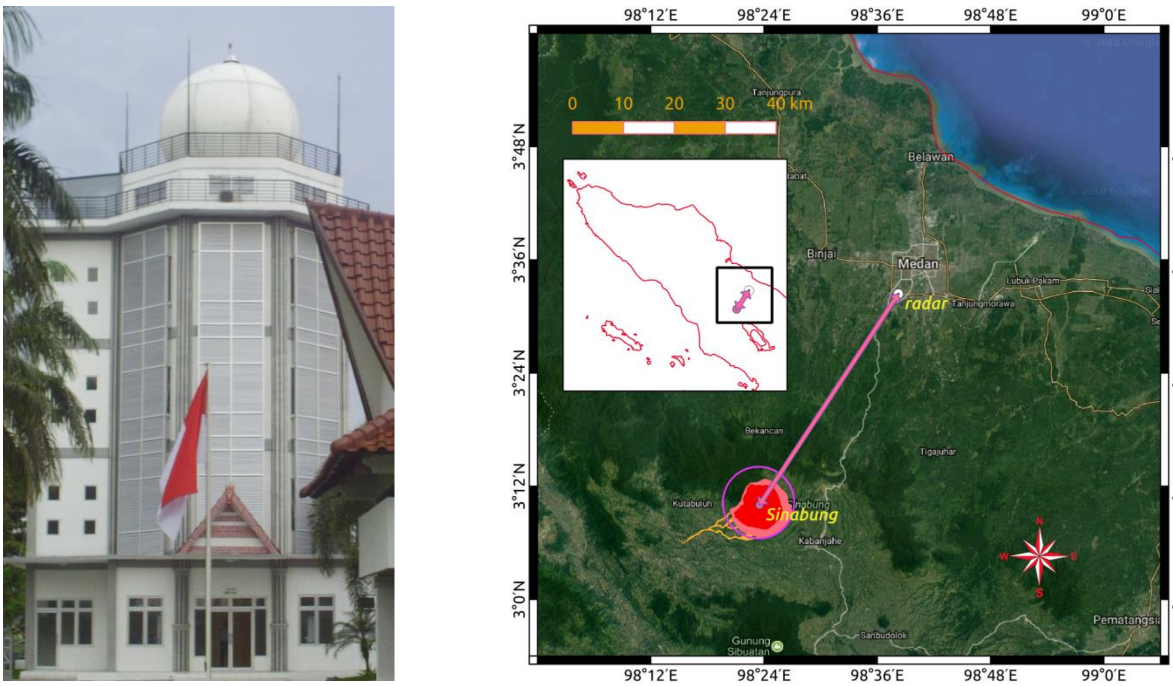


Figure 2.
Cartoons from the Doppler weather radar, the distance to the location of the rain is calculated from the travel time of the electromagnetic wave from the transmitter until it returns to the sensor. Whereas precipitation intensity is calculated from the amplitude of the reflected wave (the strength of echo)
https://www.jma.go.jp/jma/en/Activities/radar/radar.html

In the present paper, we utilize radar for detecting volcanic ash dispersion with a case study of Sinabung Eruption February 19th, 2018. We use C-band Doppler Weather Radar (CDR) from BMKG office in Medan. Figure 3a showed the tower of weather radar at BMKG office. The weather radar observation data were obtained during the field trip Volcano Eruption Impact Assessment[9]. In figure 3b, it is shown the map where weather radar was stationed. Mount Sinabung was located 49.69 km from the station that still includes in the coverage area of the weather radar that may reach 200km.



(a) Weather radar in Medan (b) Radar location and Sinabung Volcano.

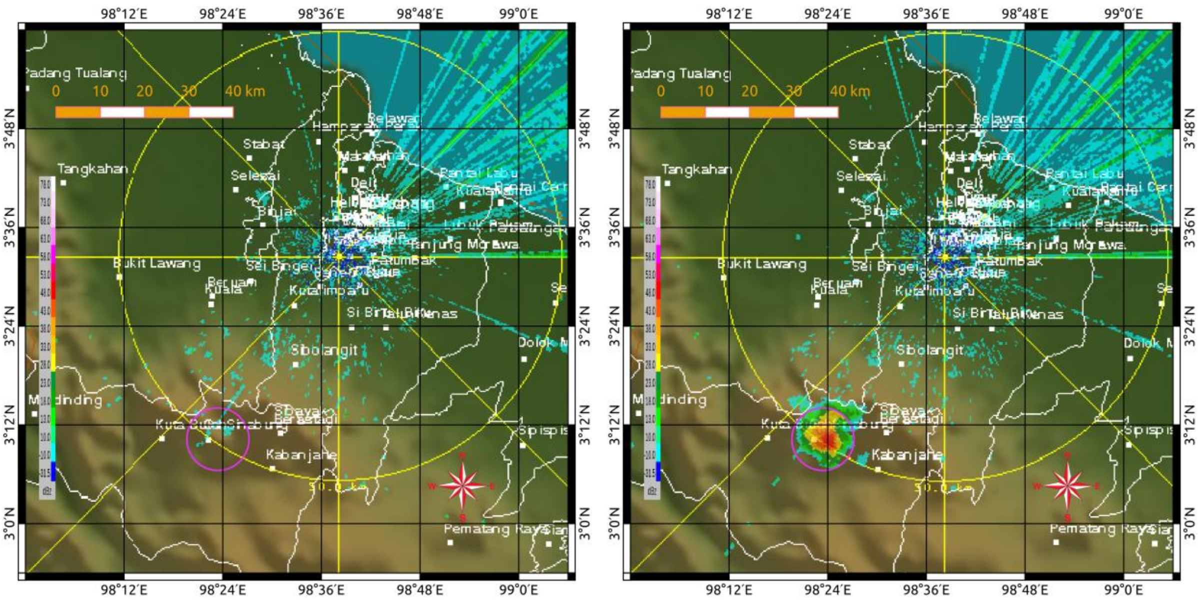
Figure 3. (a) Weather station is called radar site Medan, located at 3.5398N, 98.6371W with 30 meters above sea level. The BMKG tower was built on December 2009 with 23 meter in height and working on CBAND frequency 1.6 GHz with 1^0 beam width and pulse width 0.8 μs. The radar was made by EEC with the TX Magnetron transmitter type with 250 kW power and Rx Stallo receiver. The lowest radar radiation angle is 0.9 and the highest is 19.5 [11]. (b) The location map of the Weather Radar and Sinabung Volcano is 49.69 km. The map is overlaid with KRB I circle (Volcanic Hazard Zone I) of Volcano Sinabung [12].

Single-polarization Doppler radars can measure horizontally-polarized power echo and Doppler frequency shift can determine ash content and radial velocity. The appearance of volcanic clouds just occurred in a short time from a few minutes to several hours after the eruption, so the initial intensity information when the eruption occurs will be very important to save. Weather radar that has detection capability that is far hundreds of kilometers will be very safe from the danger of pyroclastic which can damage equipment. High spatial resolution within a few hundred kilometers is an advantage of weather radar located on land. Radar that can work 24 hours a day can provide immediate information on the volume of volcanic dust clouds, mass quantities, and eruption height so that it becomes one of the important tools in the mitigation of volcanic disasters [13].

3. Results and Discussion

The data obtained is stored in the volumetric (*.vol) format by the radar system. Then the data is processed using EDGE™ Radar Analysis software to display the CMAX (Column Max) product from the reflectivity factor (dBz). this product will display the maximum value of reflectivity factor in a location from vertical scanning or also known as volume scanning. To facilitate the reading of this product CMAX reflectivity factor is zoomed over focus areas and overlaid with other information in the form of scales, wind directions, and volcanic hazard-prone zones with the help of QGIS [14] software as shown in figure 4.

According to Sinabung Volcano Observation Station PVMBG (Center for Volcanology and Geological Hazards) [10], the erupting started at 08.53 WIB (local time). Three minutes before the event the weather radar did not show any significant reflectivity factor at KRB I, see figure 4a.

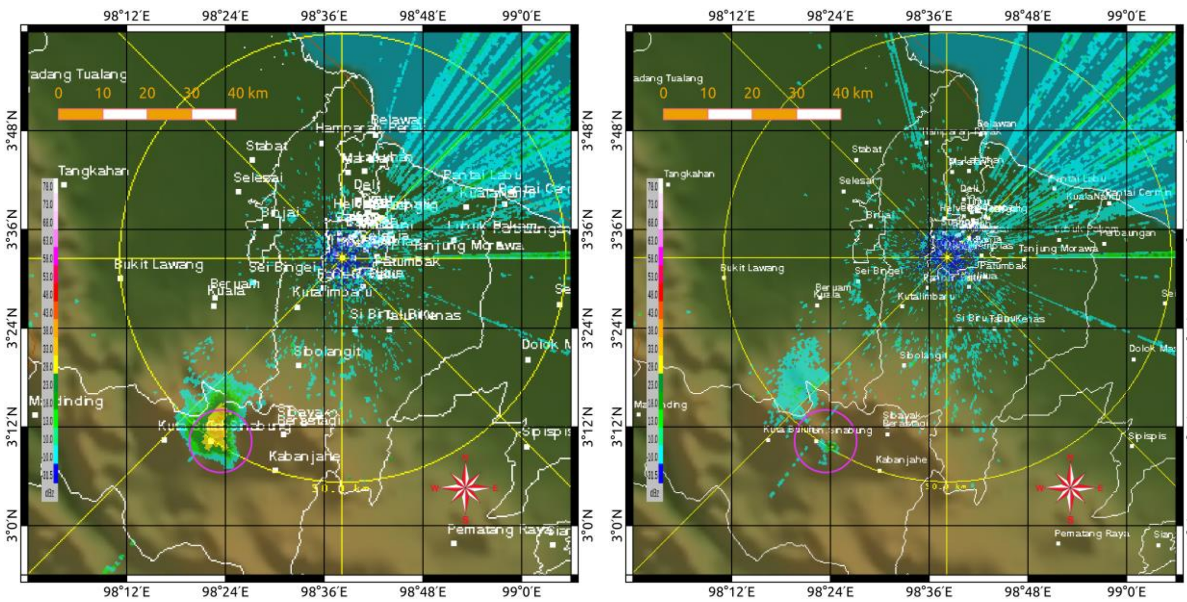


(a) before eruption: 08:50:06 WIB (local time) (b) durring erupting 09:00:06 WIB

Figure 4. CMAX (Column Max) of horizontally-polarized radar reflectivity factor (dBZ), measured by C-band Doppler weather radar Medan site(a) before eruption (b) during eruption

At 09:00 three minutes after the eruption, 48dBz reflectivity factor emerged as shown in figure 4b. This high reflectivity factor rises due to a massive eruption mass concentration such as volcanic bombs (size

> 64mm) and lapilli (2mm< size <64mm). The high reflectivity factor concentration moves Southeastward because the crater is located slightly to the Southeast from the top of the mountain. The midpoint of the KRB I line is at the top of Sinabung Volcano. As a reference the midpoint of the circle of KRB I is at the top of Sinabung Volcano. At 9:10 a.m. 17 minutes after the eruption, the reflectivity factor dropped to a maximum of 33 dBz, see figure 5a. This happens because particles with large masses (volcanic bombs) including lapilli have fallen down by the gravitational force, while coarse and fine volcanic ash is still in the air. At 09:40 47 minutes after the eruption, reflectivity factor falls to 10dBz and moved 15km to the North, except in the crater area where a concentration point show at 28 dBz as shown in figure 5b. This indicating that all rough volcanic ash has fallen down and could not transport to far. Whereas fine volcanic ash remained in the air and could travel far away by the wind. As a result of field observations during the Volcano Eruption Impact Assessment, we were able to find the volcanic ash dust up to Kotacane and Lhoksemawe [9].



(a) after erupting 09:10:07 WIB (b) 47 minute after erupting 09:40:05

Figure 5. CMAX faktor reflectivity (dBz) after no eruption anymore and lapilli particle fell down dan ash transport by wind (a) 17 minute after eruption (b) 47 minute after eruption

4. Conclusions

Weather radar BMKG region I the C-band Doppler Weather Radar (CDR) field works well and records data during the eruption of Sinabung volcano on February 19, 2018. Observations show that CMAX distribution pattern for volcano eruption can be clearly distinguished from the pattern the distribution produced by clouds or precipitation. Volcano eruption pattern begins suddenly as a high reflectivity factor appears in the middle and then spreads around it with a lower value as increasing distance.

In this article, we only discuss CMAX products from horizontal max projection of reflectivity factors. Actually, EGDE^{TM} has many direct products and derivative products obtained from the weather radar need to be investigated for science and volcanic disaster mitigation processes.

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