The 7th Indonesia Japan Joint Scientific Symposium (IJJSS 2016)
Chiba, 20-24 November 2016

Hail Detection By A Low Cost Local Weather Radar Operated For Disaster Early Warning System

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Abstract

A local weather radar (LWR) has been developed by modifying X-band marine radar. LWR has been installed and operated to measure presipitation in Bandung area, West Java, Indonesia at 107.586491^0 W and6.894958^0 S. During its observation, LWR has detected hail falling in West Bandung region on March 26, 2016. LWR can observe hail formation and growthprocesses thanks to its 2 minutes of sampling interval. Hail occurence was also confirmed by C-band weather radar installed 120 km away in northwest side of LWR site and black body temperature data of Himawari 8 satellite which analyzed using Auer method. This C-band radar identify hail occurence at 2.43 pm until 3.14 pm (around 31 minutes). Maximum recorded reflectivity data of this hail precipitation is 58.46 dBZ which close to 55.1 dBZ of C-band radar data. This results confirm that LWR is suitable as a low cost solution for disaster early warning system due to precipitation.

Keywords
Keywords : local weather radar, Himawari 8, hail, reflectivity, disaster.

1. Introduction

Deep convective cloud mostly appear in tropical region. This convective cloud can generate severe weathers such as heavy rain, tornado, strong wind and hail. Urban areas are severe weather catastrophe-prone regions due to its dense population and building. Therefore, efforts to predict and monitor severe weather are necessary to avoid huge damage.

Hail, which formed by strong and wide updraft, has diameter until around 5 mm (Barnes,2010). Many methods have been developed to detect hail. Weather Radar is a useful tool to conduct real time observation of hail. Dual polarization weather radar is very effective for distinguishing rain and hail by measuring Z_{DR} - differential reflectivity (Marzano et al., 2007). Single-polarization weather radars can not distinguish among different types of hydrometeors, however many method have been developed in order to distinguish between hail and rain using single polarization (Holleman, 2001). Most single polarization radar is commonly S-Band or C-band system. Recently, there are low-cost short range X-Band systems developed for observing precipitation in urban area (Einfalt T, et al,2004 ; Rollenbeck and Bendix, 2006 ;Van de Beck et al., 2010) and hail storm (Capozzi, V et all, 2016).

In this paper, a preliminary results of using LWR and image processing for hail detection are presented. Hail with rain and strong wind has occured in urban area of Cimahi city, a west region of Bandung in Indonesia, for around 30 minutes (14.45 pm) in March 26, 2016 (http://jabar.tribunnews.com , access May 20th 2016). The hail diameter was up to 2 cm with strong wind damaging trees and bilboard. A local Weather Radar (LWR) developed in 2012 has been utilized to observe the precipitation around the radar site. The LWR is a precipitation radar developed by modifying an X-band marine radar. Signal and image processing system of the X-band radar are modified to analyze rainfall reflectivity data rather than marine target. Hail observation results were verified by comparing them with measurement results of a C-band weather radar located 120 km northwest of the LWR location.

2. Data and Methods

The LWR is a modification results of a marine radar. Data acquisition and digital signal processing are developed for the LWR to extract, overlay, and display precipitation reflectivity (Nugroho and Awaludin, 2013). In order to verify the hail occurence, observation data from Himawari 8 satellite and Indonesia Agency for Meteorology, Climatology, and Geophysics (BMKG) C-Band weather Radar in March 26, 2016 are utilized. The C-Band weather radar has single polarization and its coverage area compared to the LWR area is illustrated in Fig. 1. White dot is the location of the C-Band radar while the yellow pindrop is the LWR location.

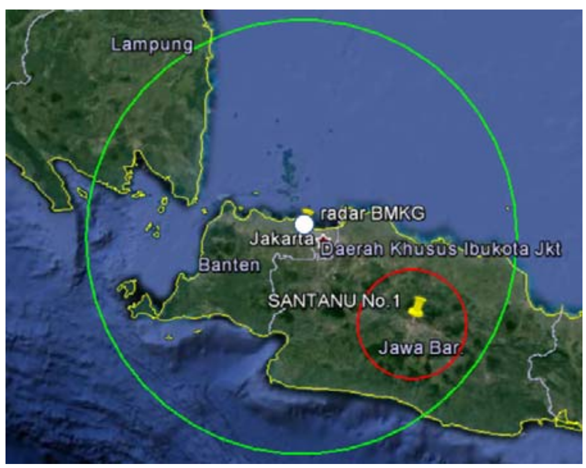


Figure 1. Coverage area of C-Band Radar (green circle) and LWR (red circle).

C-band weather radar with CAPPI method and black body temperature (T_{bb}) data from Himawari satellite were used to identify the hail object. Previous research showed that increase on diameter of scattering particles will increase radar reflectivity significantly. Threshold was used to distinguish between severe rain and hail by employing CAPPI method with 57 dBZ (Mason 1971) and 54 dBZ (Auer,1994) of threshold. Obtained hail properties were compared with LWR observation data. Location and reflectivity value were analyzed to know the LWR performance in detecting hail.

3. Results and Discussions

A method to recognize hail by using combination of radar reflectivity and cloud-top temperature had been proposed in (Auer, 1994). According to this method, threshold of CAPPI reflectivity (Z_{TH}) for hail as a function of cloud-top temperature (T_{top}) is given by equation (1). Optimum threshold for this equation varies between 36 and 53 dBZ for cloud-top temperatures between −11 and −55°C.

$$Z_{TH} = \begin{cases} -0.38.\left(T_{top} - 85.0\right) \; if \; T_{top} \leq \; -11°C \\ 1.33.\left(T_{top} + 38.8\right) \; if \; T_{top} \; > \; -11°C \end{cases} \quad (1)$$

Hail occurence in Cimahi city, west region of Bandung, was investigated using this method. Black body temperature (T_{bb}) data of Himawari 8 satellite was presented as cloud-top temperature data as shown in Fig. 2. This data reveals that cloud with top temperature around -60°C appears during hail occurence which indicates strong convective process. Z_{TH} value of this temperature is 55.1 dBZ.

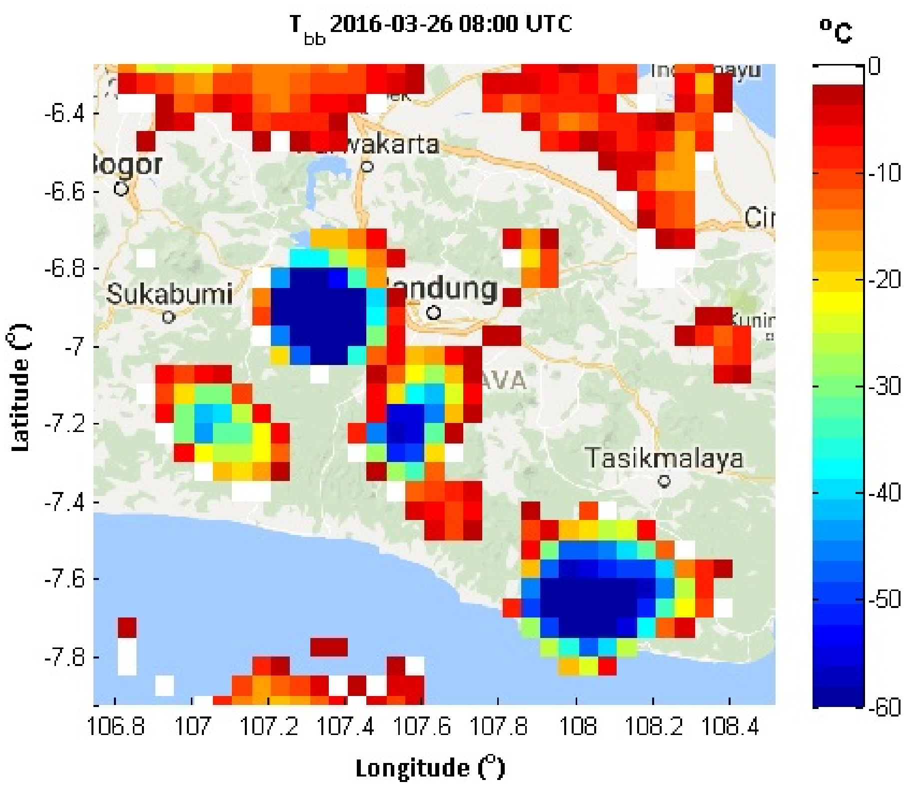


Figure 2. Temperature Black Body (T_{bb}) data of Himawari-8 satellite at 08:00 UTC.

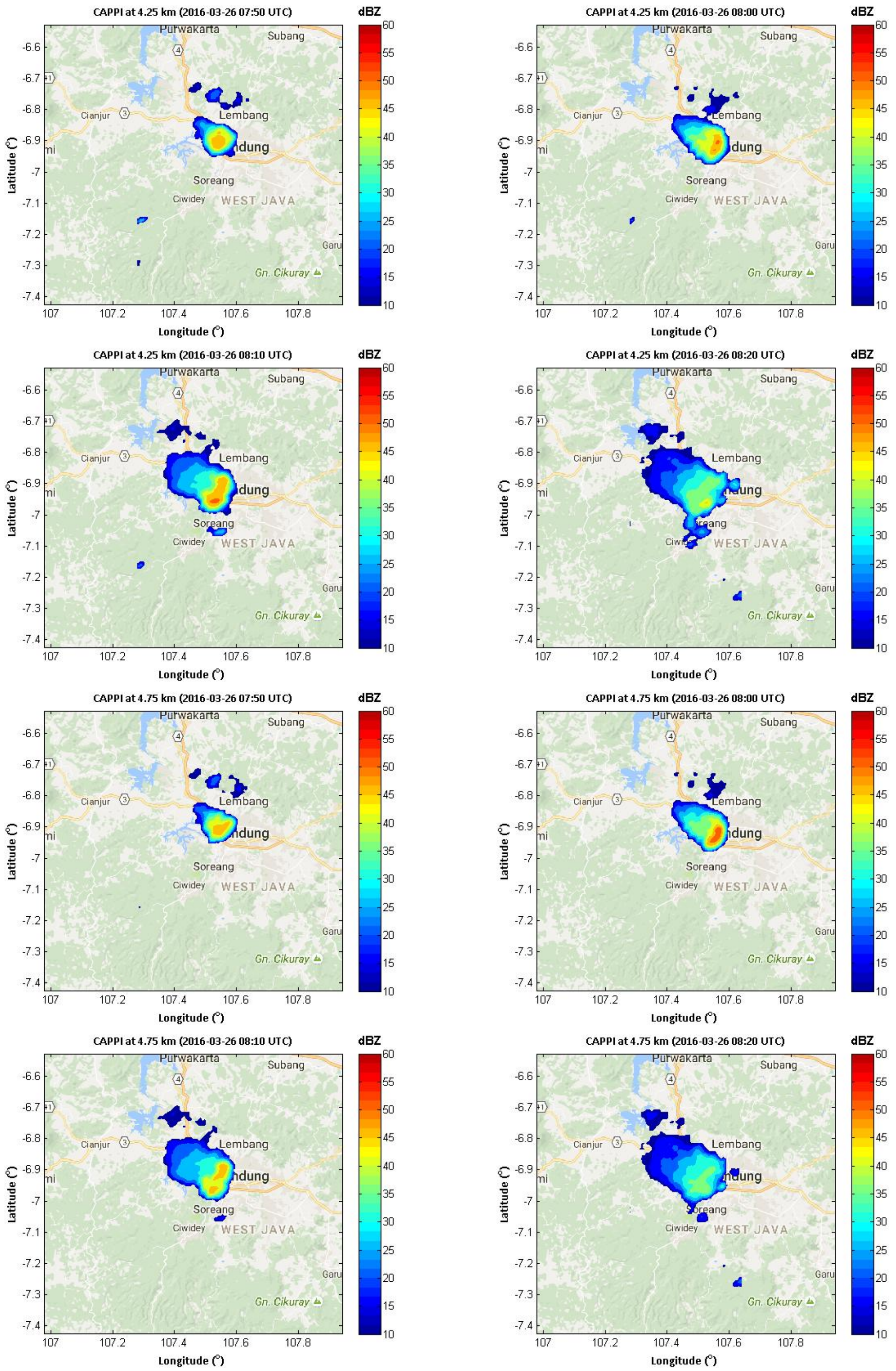
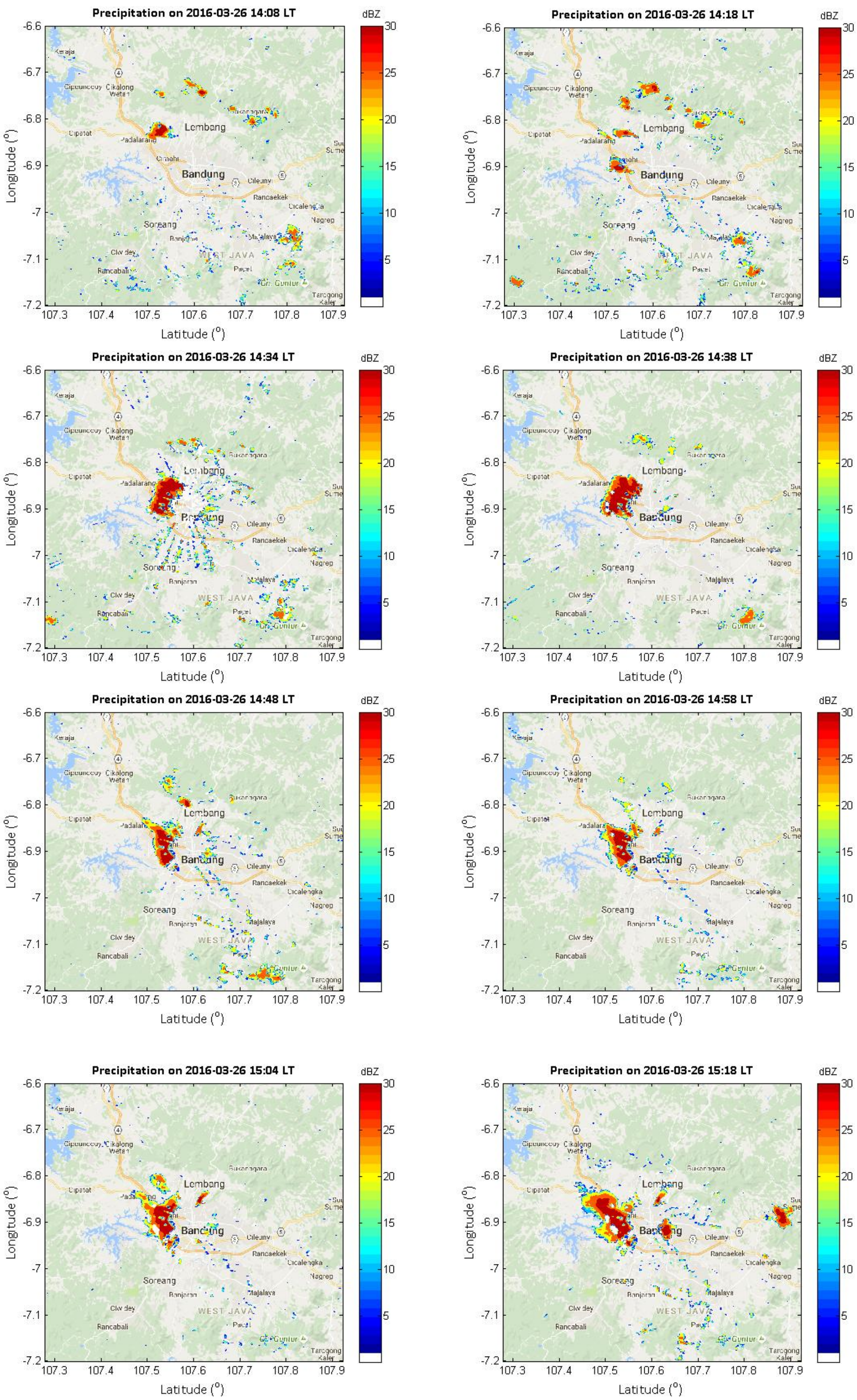


Figure 3. Reflectivity in CAPPI by C-Band weather radar at 4.25 dan 4.75 km.

Observation data by C-band weather radar at constant altitute of 4.25 and 4.75 km were presented to confirm Himawari 8 data. Both radar and satellite data confirm high reflectivity above 50 dBZ at 08:00 UTC but with slightly different location of west Bandung region. Whereas colocation data of both radar and satellite reveals reflectivity threshold of 40.77-46.38 dBZ in that region. Since cloud top temperature in the colocation area is below -30°C, it can be concluded as hail occurence.



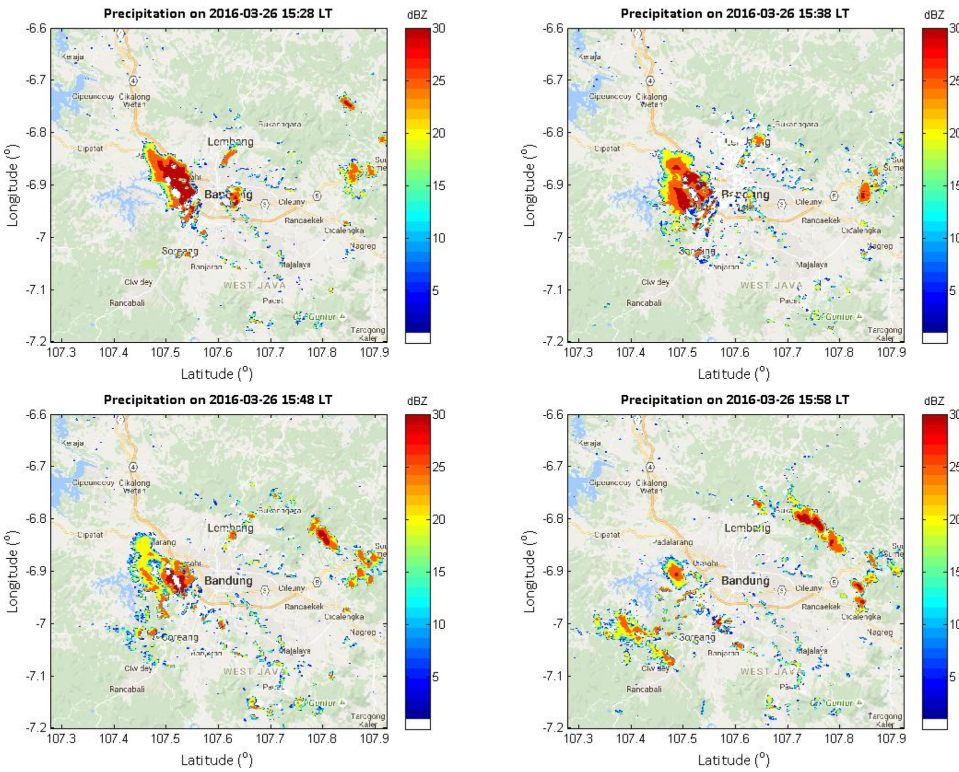


Figure 4. Precipitation evolution from the LWR observation data.

C-Band weather radar data indicated that high reflectivity is detected in west Bandung region. LWR also observed high reflectivity in similar location. Time frame images of both radar showed similar time period of high reflectivity between 07.40 until 08.10 UTC. Thus, according to both radars, hail occured for about 1 hour 40 minutes. However, the shape of the reflectivity area from both radar are different, this is due to different specification of both radar and also scan method. By using time sequential images as outlined in Fig. 4, it can be observed that the growth of the heavy precipitation (including hail) started at 07.18 UTC, continued to grow at 08.04 UTC, and then dispersed at 08.58 UTC.

Observed LWR reflectivity data is much lower than C-band weather radar results for similar target due to its low power and wide beamwidth. In this regard, 4 kW LWR measurement data has been calibrated using 25 kW X-band weather radar (Nugroho, 2015). According to the calibration results, LWR reflectivity which equal to the X-band radar reflectivity is given by

$$dBZ\ LWR = 7.338\ \times \ln(ADC\ count) + 22.71 \tag{2}$$

By using equation (2), calibration result of 30 dBZ reflectivity in LWR data which has 4,8721 of ADC count is 58.46 dBZ, slightly higher then 55.1 dBZ of C-band radar reflectivity. Both radar data confirm hail occurence since minimum reflectivity that confirm hail by radar is 50 dBZ (Auer, 1994).

4. Conclusion

Hail occurence during heavy precipitation in March 26, 2016 has been investigated using developed LWR. Black body temperature (Tbb) data of Himawari 8 satellite and images data of C-band weather radar data are presented to verify hail detection of the

LWR results using Auer method. Both satellite and C-band radar data confirm the hail occurence. LWR observation result is in good agreement with C-band radar data in hail detection by recording LWR maximum reflectivity of 58.46 dBZ compared to 55.1 dBZ of C-band radar data.

Acknowledgements

This research is supported by Center for Atmospheric Science and Technology, Lembaga Penerbangan dan Antariksa Nasional (LAPAN) Indonesia for the LWR project and Indonesia Agency for Meteorology, Climatology, and Geophysics - BMKG for C-Band weather radar data.

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