3D grid interpolation of raw X-band radar data for analysis of Hiroshima extreme rainfall

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1. INTRODUCTION

In this study, we utilized the multi-parameter X-band radar (MP-X radar) to visualize a localized heavy rainfall event that occurred in Hiroshima in August 2014. Raw MP-X radar data described in polar coordinates was interpolated onto a high spatial and temporal resolution 3D Cartesian-grid rain cloud by using a 3D interpolation scheme. The interpolated 3D grid rain will be used to analyze the structure of the heavy rainfall event and to predict the event beforehand.

2. DATA AND METHODS

The data which we used in our study was provided by the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Chugoku Regional Bureau, and it consists of raw MP-X radar parameters such as (reflectivity, rainfall, wind velocity etc.) from two radars at Ushioyama and Nogaibara located in Hiroshima Prefecture. The analyzed heavy rainfall event occurred on 20th August 2014 early in the morning. Below in our results we focused on 1 hour time period between 2:30 and 3:30 am with a high peak rainfall. Radar scanning mode provided us with a full scan every 5 minutes, thus we chose 5 minute intervals for our interpolation.

To produce a 3D representation of the cloud we devised a 3D interpolation algorithm with modified Cressman weight interpolation shown in Eq. (1), Eq. (2) and Eq. (3), which conserves the quantitative precipitation data set (Maesaka, 2011). Although the MP-X radar provides us with multiple measured parameters, in this study we analyzed only the radar rain cells which are derived from radar reflectivity parameter. Thanks to the scanning mode of MP-X radars, there is a high precision data available both in spatial and temporal resolution, which allows us to produce a detailed 3D display. We have created a 3D grid to encompass the whole coverage area of both radars at Ushioyama and Nogaibara. We set the horizontal resolution of the 3D grid to be 1 km and vertical resolution of 500 m up to 10 km elevation and it changed to 1 km for elevations above 10 km to accelerate the computation process (Yanjiao et al., 2008).

$$w_{h,i} = \frac{1}{1 + C_h \left(\frac{d_i}{R_s}\right)^2} \tag{1}$$

$$w_{v,i} = \frac{1}{1 + C_v \left(\frac{h_i}{H}\right)^2} \tag{2}$$

$$V = \frac{\sum (w_{h,i} \times w_{v,i}) v_i}{\sum (w_{h,i} \times w_{v,i})} \tag{3}$$

where,
$w_{h,i} =$ horizontal weight of radar cell i
$w_{v,i} =$ vertical weight of radar cell i
$C_h =$ 0.5, $C_v =$ 20,
$v_i =$ rainfall of radar cell i
$d_i =$ distance from the radar cell i to grid point (km)
$R_s =$ sampling effective radius (km)
$h_i =$ altitude of radar cell i above the ground level (km)
$H =$ 5000 m, $V =$ areal composite of rain grid

3. RESULTS

In order to validate our results we have extracted a 2D horizontal surface from 3D interpolated volume data at 800 m above sea level which is the lowest height of the 3D grid rain. Then we have compared the 2D horizontal surface with the 2D processed composite surface provided by the MLIT shown in Fig. 1. Agreement between both data sets shown in Fig. 1 was very high. Although the 2D validation at near surface level was successfully completed, a reasonable 3D validation remains difficult because there is no range height indicator (RHI) scan available in this area and for this event.

3D rainfall intensity representation in five minute intervals over a period of one hour capturing the highest rain band flow was successfully accomplished and is shown in Fig. 2. High intensity rain band with over 70 km in length and more than 6.5 km in height was concentrated along the mountain range running from the Hiroshima bay to north of the city. The highest intensity of around 120 mm/hr rainfall was concentrated north of the Hiroshima city where severe landslides haves occurred.

Keywords: MP-X radar, 3D interpolation, Cressman scheme
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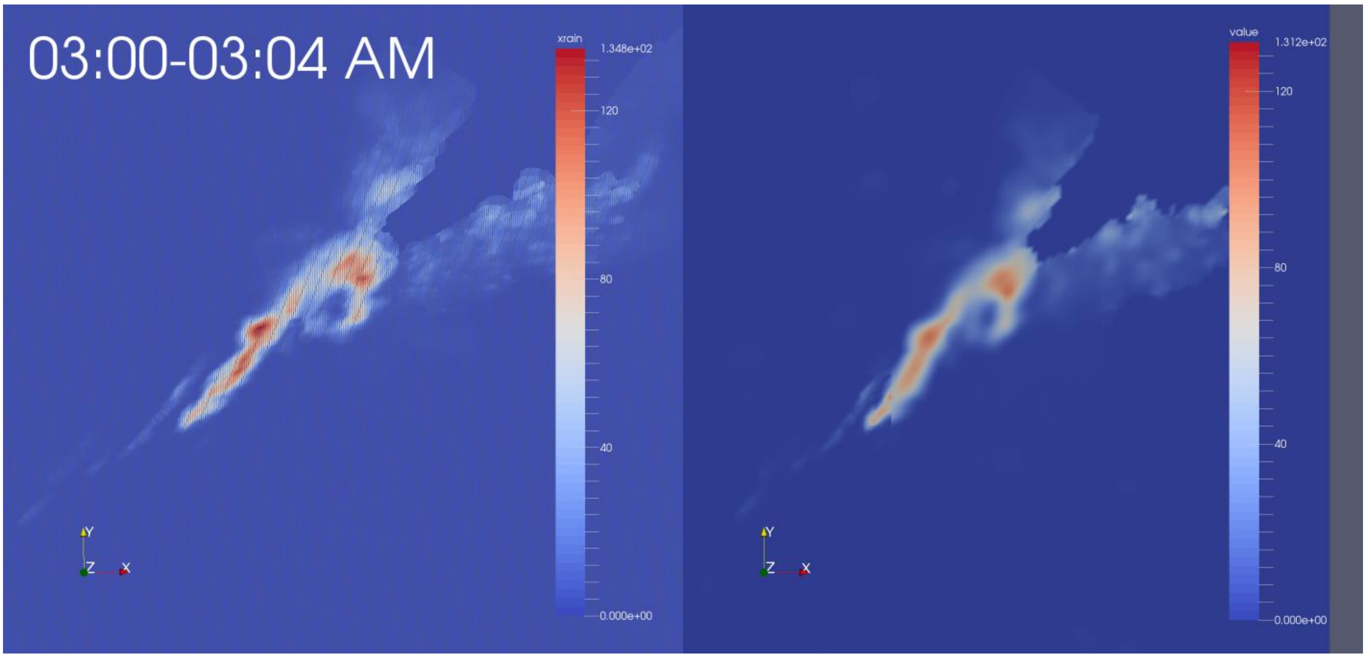

Fig. 1 a) MLIT processed data with resolution 250 m. b) 3D interpolated data with resolution 1 km. 20th August 2014

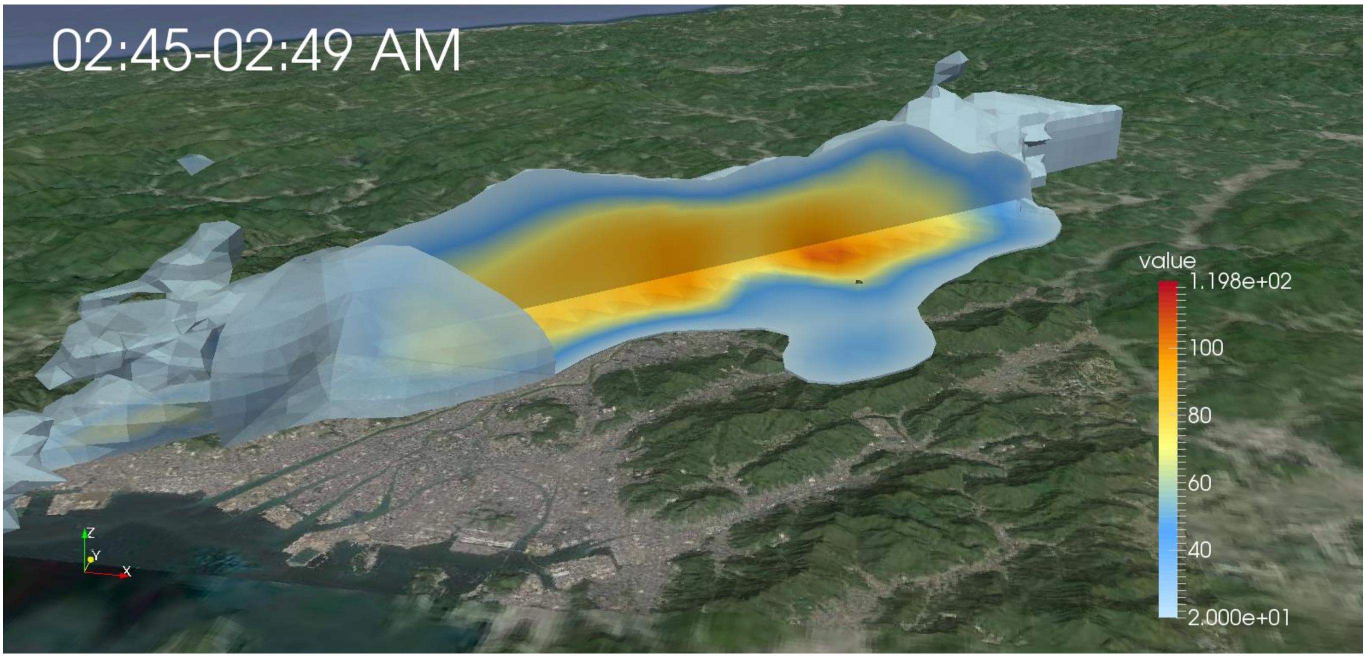

Fig. 2 3D section of the rain cloud on 20th August 2014 in Hiroshima city showing rainfall intensity (mm/hr)

4. CONCLUSIONS

The detailed 3D map of rain cloud was generated in 5-min intervals. The spatiotemporal structure of the 2014 Hiroshima heavy rainfall event was successfully visualized. The processed rain cloud could be used to improve dangerous rainfall event prediction capabilities. We should further focus on analyzing 3D wind velocity which could provide useful information when trying to predict similar events.

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