Proceedings of ERAD 2006

Comparison of X-band multi-parameter radar rainfall estimates with conventional radar rainfall estimates adjusted with raingauge network data

Masayuki Maki[1], Ken-ichi Maruyama[1,2], Koyuru Iwanami[1], Ryohei Misumi[1] and Takeshi Maesaka[1]

[1] National Research Institute for Earth Science and Disaster Prevention, Tsukuba (Japan).

[2] Kanazawa University, Kanazawa (Japan).

1 Introduction

Specific differential phase (K_{DP}) measured by multi-parameter radar is a key parameter for accurate rainfall estimations. Recent studies show that K_{DP} has several advantages compared to reflectivity measured by conventional radar: it is immune to factors such as natural variations of rain drop size distribution, rainfall attenuation, radar hardware calibration error, and partial beam blockage by mountain, etc. One of advantages of X-band wavelength compared to C-band and S-band wavelengths is its high sensitivity for K_{DP} measurements. Thus, it is expected that K_{DP} measured at X-band can be used to detect weak rainfall while K_{DP} measured at S-band is applicable to only severe rainfall. The National Research Institute for Earth Science and Disaster Prevention (NIED) carried out rainfall measurements with the X-band multi-parameter radar (MP-X) at Ebina, Kanagawa, Japan to validate its applicability for operational use.

The present paper shows results of comparisons of MP-X rainfall estimates with conventional radar rainfall estimates adjusted with surface raingauge network data which is produced by Automated Data Acquisition System (AMeDAS) operated by Japan Meteorological Agency (JMA).

2 Data

2.1 MP-X radar observations

The NIED multi-parameter radar system was developed in 2000 to study precipitation processes (Iwanami et al 2001). The system, which consists of an X-band radar and a Ka/W band radar, was designed to be transportable; both radars were mounted on two 4-ton trucks. Basic and application studies, such as scattering simulations, microphysical parameter retrievals, artificial snowfall control experiments, and volcanic ash detections, were conducted in the years 2000, 2001, and 2002. In 2003, the X-band wavelength radar system, named MP-X, was dismounted from its truck and set up on top of a 4-story building in Ebina, Kanagawa Prefecture Japan so that it could observe rainfall continuously. Since that time, radar observations have been carried out every year during the warmer months (from June to the end of October) so as to improve and validate the polarimetric rain rate algorithms (Maki et al. 2005a, b; Park et al. 2005), which are necessary to develop systems that warn of heavy rainfall disasters such as urban flooding and landslides. The radar observation area is shown in Fig. 1.

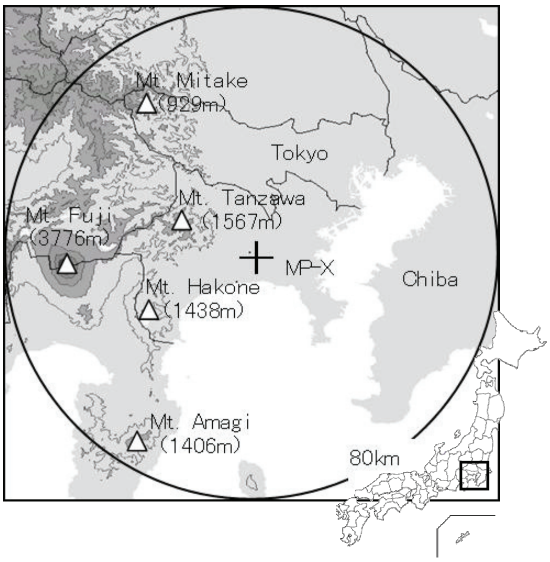

Fig. 1. Radar observation area and topography.

Two types of topography (mountainous and flat metropolitan) are to be found within the radar observation area; mountainous areas are located to the west of the radar site, while the flat metropolitan areas, which include Tokyo

Correspondence to: Masayuki Maki.
maki@bosai.go.jp

and Yokohama, are located to its east. This feature enables the concurrent investigation of rainfall distribution over different topographies. Over 20 million people live in the radar observation area.

2.2 MP-X radar rain data

Rainfall rate was calculated by the composite method presented in Park et al (2005).

$$R = 7.07 \times 10^{-3} Z_{H}^{0.819} \quad \text{for } K_{DP} \le 0.3°\text{km}^{-1} \qquad (1a)$$

$$R = 19.6 K_{DP}^{0.823} \quad \text{for } K_{DP} > 0.3°\text{km}^{-1} \qquad (1b)$$

Where, R, Z_H, and K_{DP} are rain rate (mmh^{-1}), reflectivity (mm^6m^{-3}), and specific differential phase ($°\text{km}^{-1}$), respectively. A threshold of 0.3 $°\text{km}^{-1}$ for K_{DP} is an estimated standard deviation of K_{DP}. The coefficient and exponent used in (1a) are assumed to be those of the stratiform rain type.

MP-X radar observations in 2004 and 2005 focused on obtaining high resolution rainfall data, which is useful for developing urban flooding and landslides warning systems. PPI scans, with two elevation angles (2.1° and 4.4°) every one minute, were employed to obtain rainfall distribution data with high temporal resolutions. PPI scan data, at an angle of 4.4°, were used to calculate rainfall amounts behind mountain areas where PPI scans at an angle of 2.1° could not obtain data due to blockage of the beam by the mountains. The subject mountains are Mt. Oyama (1246m, not shown in Fig. 1), located about 15 km WNW of the radar site, and Mt. Fuji (3776m), located about 60km west of the radar site. The radar data was sent to NIED electronically and calculated rainfall distributions were shown on the NIED website 'Landslide Disaster Prediction Support System (LAPSUS)' (Fukuzono 2004). The LAPSUS website can display 1-, 3-, 6-, 9-, 12-, and 24-hour rainfall accumulation patterns over a 500m resolution grid. The website also has the function of visualizing time changes for rainfall rates and rain accumulation at requested points in the radar observation area.

2.3 Radar-AMeDAS precipitation data

Radar-AMeDAS (hereafter R/A) precipitation data is radar rainfall information adjusted by raingauge data (Makihara 1996; Makihara et al. 1996); radar reflectivity from the twenty C-band radar network is adjusted by rain data from about 1,300 weather stations, which network is called the 'Automated Meteorological Data Acquisition System' (AMeDAS). R/A precipitation data, which is used by JMA to issue heavy rainfall warnings and advisories, is 2.5km spatial resolution, 1-hour precipitation data that is updated every 30 minutes.

3 Comparison of MP-X with Radar-AMeDAS

3.1 Rainfall in mountainous areas

The results of two case studies are shown in this paper. One is of rainfall enhanced by mountainous topography. The second is of a fast moving rain cell over a flat topology. Both

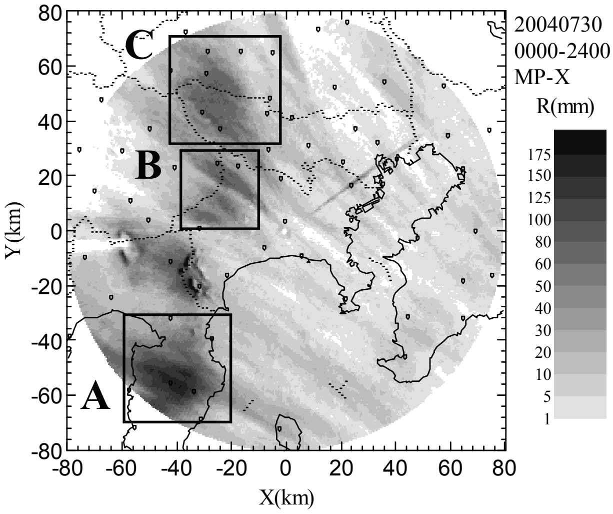

Fig. 2. Distributions of a 24-hour rainfall amount, from 0000 LST 30 June to 0000 LST 31 June, 2004, obtained by MP-X measurements.

cases were observed when typhoon T0410, moving in a westerly direction, arrived at an off-shore location approximately 800km south of the MP-X radar site. Figure 2 shows the distribution of the 24-hour rainfall amount as obtained by MP-X measurements. One minute and 500m resolution rain rate data were used to calculate the MP-X rainfall accumulation. The enhanced rainfall pattern in the mountainous area can be clearly seen in Fig. 2. Streaks of rainfall over the ocean, from 5mm to 20mm, which are the trajectories of strong convective echo cells, can be also seen clearly in the MP-X rainfall data.

Figure 2 demonstrates that MP-X radar provides high resolution rainfall data which are necessary for forecasting urban flooding and landslides. To examine the accuracy of MP-X rainfall information, we compared them with R/A rainfall information that is used by JMA to issue warnings of heavy rainfall. Three different areas, shown as rectangles in Fig. 2, were examined. The result for the area A is shown in Fig. 3. A rainfall amount of more than 160mm during a 24 hour period was observed in the Mt. Amagi area. The rainfall pattern of the MP-X observations is very similar to that of R/A, except for some detailed patterns which could only be detected by MP-X. On the other hand, large differences can be seen in areas B and C. In the Mt. Tanzawa area, a rainfall concentration pattern of 60mm to 100mm, which was detected by MP-X (Fig. 4a), was not observed in the R/A rainfall data (Fig. 4b). A similar tendency can be seen in the Mt. Mitake area (Figure not shown). The discrepancy between MP-X and R/A rainfall data in the Mt. Tanzawa and Mt. Mitake areas is due to the fact that there was limited raingauge data available for the R/A analysis.

3.2 Fast moving convective cells over a flat area

Figure 5 shows a comparison of MP-X and R/A data as observed when back-building type convective cells moved over a flat city area. A concentrated rainfall band pattern of about 3km in width and about 40km in length was detected

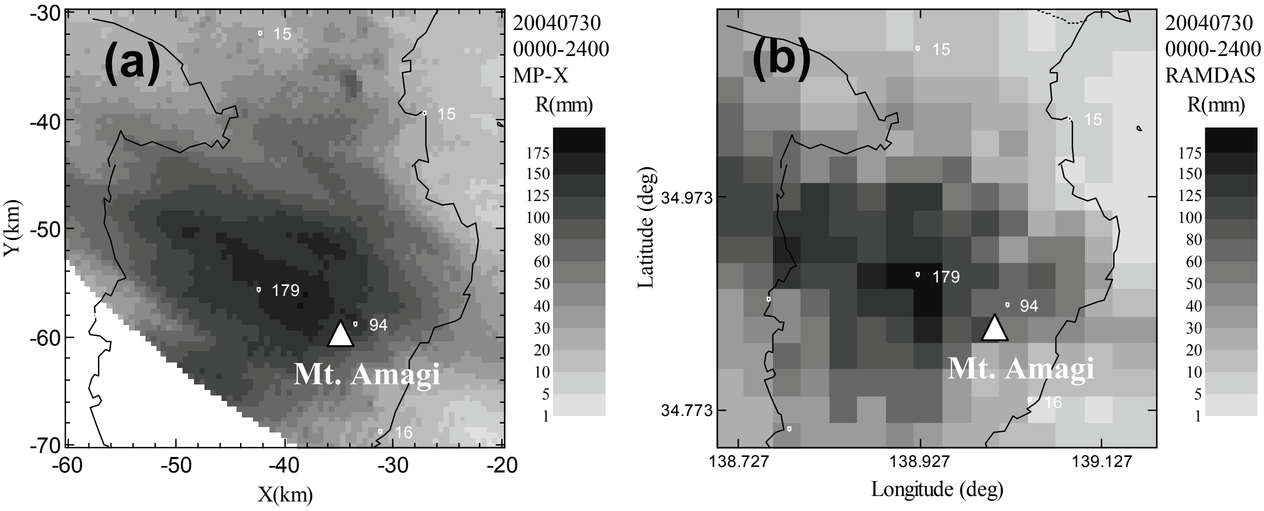

Fig. 3. Comparisons of rainfall distributions by (a) MP-X and (b) Radar-AMeDAS in the area A (Mt. Amagi area). Locations of AMeDAS gauges are shown by small dots with accumulated rainfall amount (mm). 0000-2400 LCT, July 30, 2004.

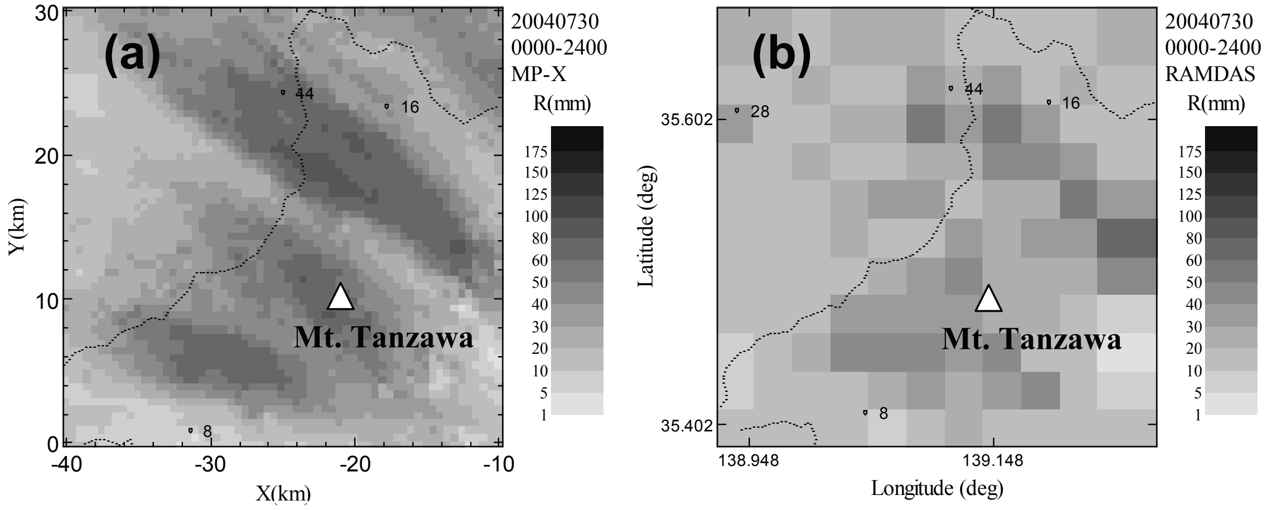

Fig. 4. Same as Fig. 3, except for the area B (Mt. Tanzawa area).

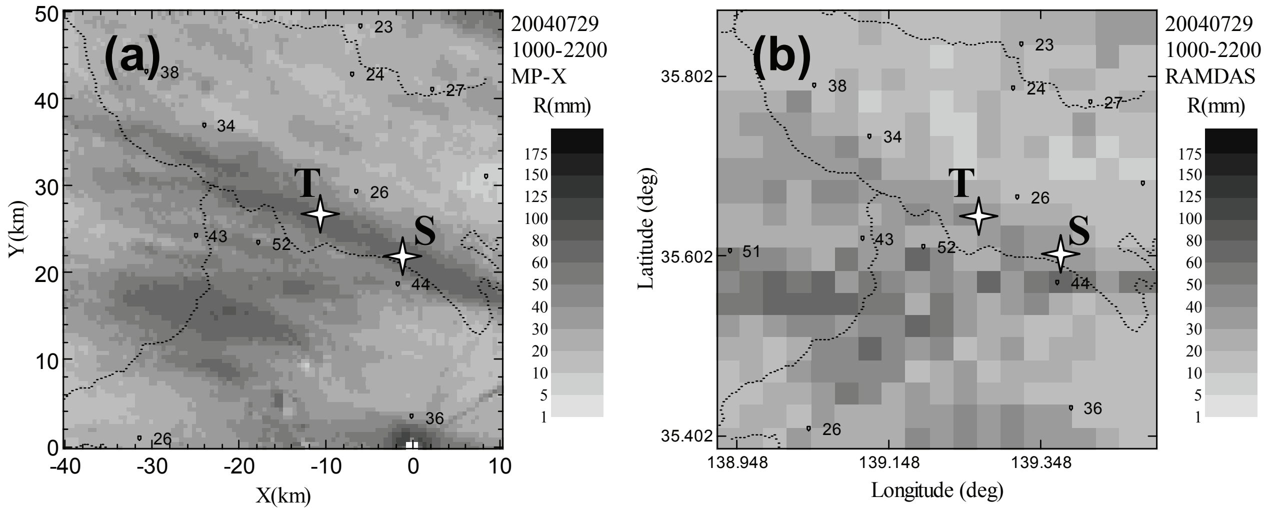

Fig. 5. Comparisons of rainfall distributions by (a) MP-X and (b) Radar-AMeDAS for fast moving convective cells over a flat area. 1000-2200 LCT, July 29, 2004. Non-AMeDAS raingauges, which are used to validate MP-X rain estimation, are located at points shown by stars and letters T and S.

by MP-X while it is not clear in R/A analysis data. This rain band, which has a maximum 12-h rainfall value of about 70mm, was produced partly by trajectories of fast moving convective rain cells, and partly due to a back building mechanism. The average speed of movement of convective cells was estimated to be about 50kmh^{-1}. This example suggests that even the relatively dense AMeDAS raingauge network in flat areas sometimes overlooks strong, small scale convective rain cells. This may affect R/A analysis.

MP-X rainfall data in the second case (Fig. 5) was compared with non-AMeDAS raingauge data to validate its accuracy. Figure 6 shows the comparisons of time change of 10-min rainfall at two locations where heavy rainfalls were observed in a rainfall band. There are good agreements between MP-X data and raingauge data, which confirm the accuracy of MP-X measurements.

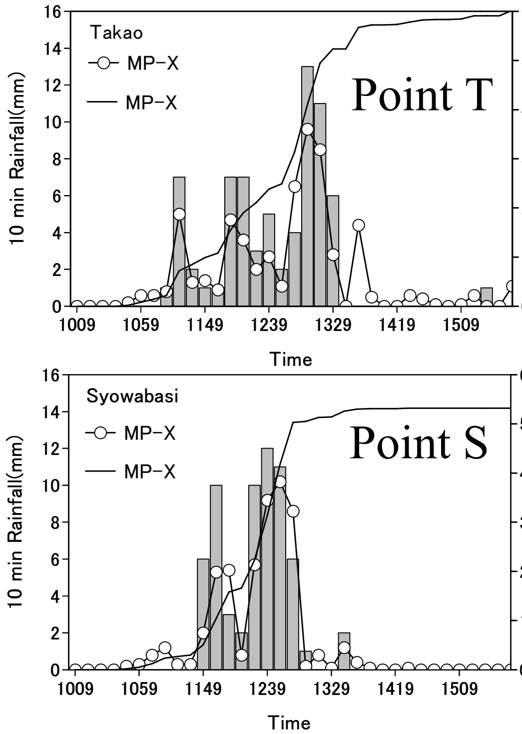

Fig .6. Comparison of MP-X rainfall (shown by lines) and gauge data (shown by bars) at points T and S in Fig. 5.

4 Conclusions

Bringi and Chandra (2001) mentioned in their book that rainfall estimation by radar can be viewed from two different aspects; physically based algorithms and engineering solutions. The fundamental difference between these methods is the absence or presence of feedback from raingauges. Estimation of rainfall by MP-X radar is a typical example of the physically based approaches. The method uses Z_H and K_{DP} radar parameters without any adjustment with raingauges. On the other hand, the JMA Radar-AMeDAS (R/A) analysis is a typical example of the engineering approaches.

By analyzing two rainfall cases, we found that the accuracy of MP-X rainfall estimates is better than that of Radar-AMeDAS (R/A). The results of the two case studies, the mountain enhanced rainfall case and the fast moving rain cell case, show the superiority of MP-X over R/A: First, the accuracy of MP-X radar is higher than that of R/A over mountainous areas, where the number of available raingauges is limited in the R/A estimates. Second, the temporal and space resolution of MP-X radar data is better than R/A data: MP-X radar has a 1-minute time resolution and a 500m space resolution.

Accuracy of engineering approach largely depends on available number of raingauges. JMA appended to their AMeDAS system about 5,000 non-AMeDAS raingauges, which belong to the River Bureau, the Road Bureau, and to local authorities. This dense raingauge network is expected to improve the accuracy and spatial resolutions of R/A precipitation data. However, there exists a great imbalance between non-AMeDAS and AMeDAS data. The distribution of non-AMeDAS raingauges is not necessary uniform, and is limited to one-hour rainfall data being obtained every hour or every half-hour. These imbalances may also make the reliability of R/A analysis imbalanced. Further studies are necessary to confirm this approach.

Acknowledgements: The authors would like to acknowledge the Tokyo, Kanagawa, and Sizuoka local governments for providing raingauge data used in the research The Daito Dengyo Co. is also appreciated for providing space for the MP-X radar.

References

Bringi, V. N., and V. Chandrasekar, 2001: *Polarimetric Doppler Weather Radar: Principles and Applications*. Cambridge Univ. Press, 636 pp.

Fukuzono, T., H. Moriwaki, T. Inokuchi, M.Maki, K. Iwanami, R. Misumi, S. Takami, and T. Shikoku, 2004: Landslide disaster prediction support system based on web GIS, Proc. *International Symposium on GeoInformatics for Spatial-Infrastructure Development in Earth and Allied Sciences*, 118-121.

Iwanami, K., R. Misumi, M. Maki, T. Wakayama, K. Hata and S. Watanabe, 2001:Development of a multiparameter radar system on mobile platform, *Preprints, 30th Conf. on Radar Meteorology*, 104-106.

Maki, M., K. Iwanami, R. Misumi, S.-G. Park, H. Moriwaki, K. Maruyama, I. Watabe, D.-I. Lee, M. Jang, H.-K. Kim, V.N. Bringi, and H. Uyeda, 2005a: Semi-operational rainfall observations with X-band multi-parameter radar, Atmos. Sci. Letters, **6**, 12-18.

—, S.-G. Park and V.N. Bringi, 2005b: Effect of Natural Variations in Rain Drop Size Distributions on Rain Rate Estimators of 3 cm Wavelength Polarimetric Radar, *J. Meteor. Soc. Japan*, **83**, 871-893.

Makihara, Y., 1996: A method for improving radar estimates of precipitation by comparing data from radars and raingauges. *J. Meteor. Soc. Japan*, **74**, 459-480.

—, N. Uekiyo, A. Tabata, and Y. Abe, 1996: Accuracy of radar-AMeDAS precipitation. *IEICE Trans. Trans. Commun.*, **E79-B**, 751-762.

Park, S.-G., M. Maki, K. Iwanami, V.N. Bringi, and V. Chandrasekar, 2005: Correction of radar reflectivity and differential reflectivity for rain attenuation at X-band wavelength. Part II: Evaluation and application., *J. Atmos. Oceanic Technol.*, **22**, 1633-1655.