C3-34

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Studies on Mean Areal Rain Rate using Dual-Polarization X-Band Radar over a Small River Basin, Japan

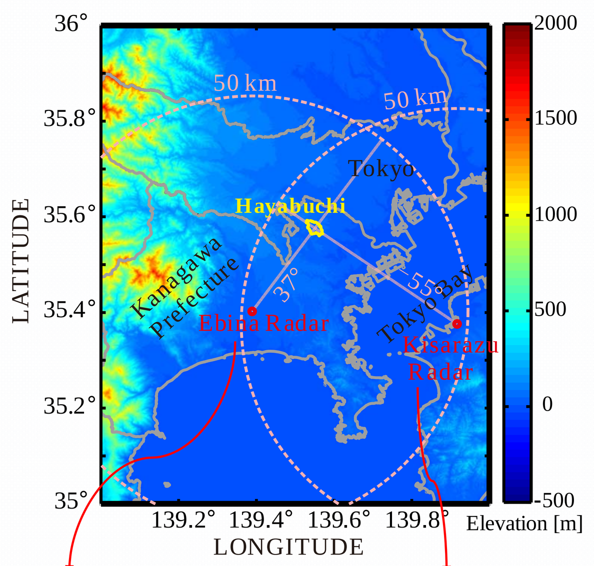
Kohin Hirano(hirano@bosai.go.jp, *National Research Institute for Earth Science and Disaster Prevention, JAPAN*), Masayuki Maki , Takeshi Maesaka, Koyuru Iwanami

Background

- Since National Research Institute for Earth Science and Disaster Prevention (NIED) deployed the first dual-polarization X-band radar around the Tokyo metropolitan area in 2000, a widespread use of **dual-polarization X-band radars** has gained significant momentum in Japan.
- Rainfall estimators using **polarimetric parameters** from X-band radar have been proved to be in the best **harmony with rain gauge measurements** without any corrections from surface observations.
- Most of the common used **hydrological models** still rely on **rain gauges** and are usually based on the assumption of uniform rainfall over the catchment.
- What is the **best rainfall estimating method** in the catchment areas for X-band radars? Can radar derived rainfall **take the place of traditional gauges** be used in hydrological models?

Objective

- Estimate the **areal rainfall rate** using dual-polarization X-band radar and compare the derived results against a **high density rain gauge network** of 30 rain gauges within the area of 20 km² around a very small river basin in Japan.



Experiment Area

- **Hayabuchi** river basin
  - Flow along Yokoama city
  - Merge into Tsurumi river and flow into Tokyo Bay
  - Length : about 13.7 km
  - Max. width: about 20 m
  - Many water parks along the Hayabuchi river
  - Typical city river prone to flash flood
- **Rain gauges**
  - 12 rain gauges in the Hayabuchi river basin, 18 outside
  - 11 rain gauges between 36 – 38 azimuth angles of Ebina Radar

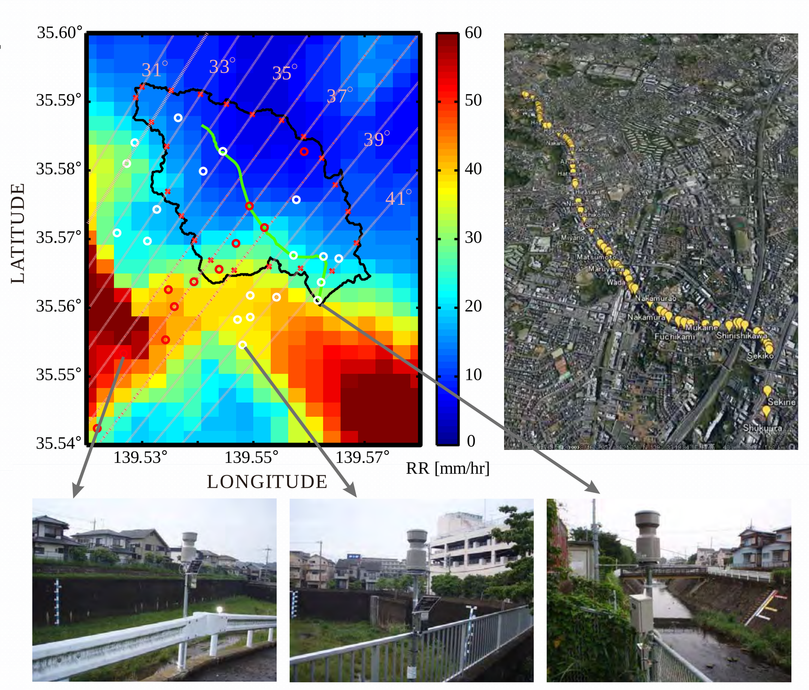
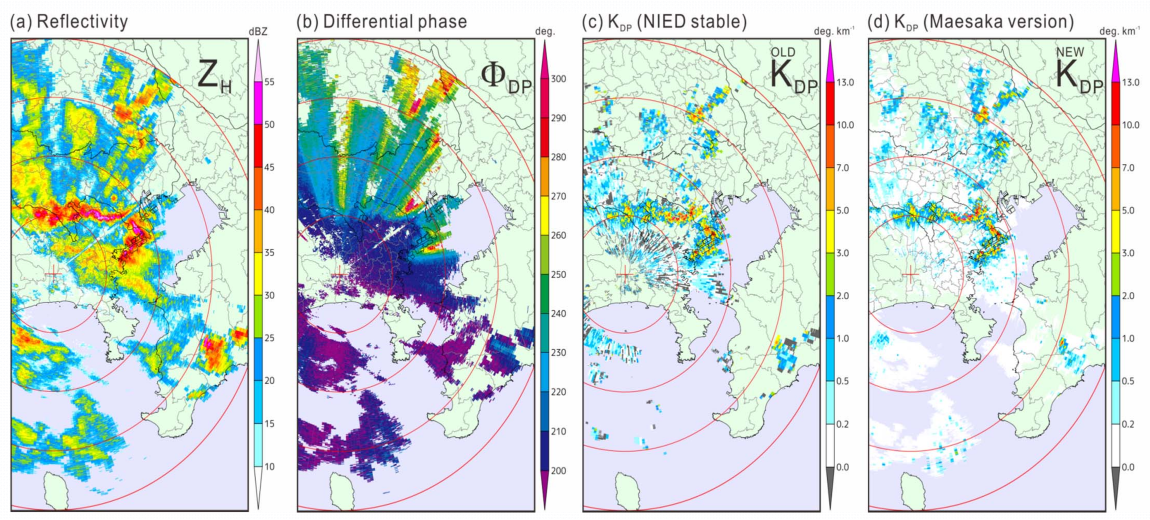


Figure1. Location of experiment area , rain gauges, and radars used in this study

Figure2. PPI images of Ebina Radar
* Volume scan covers 12 elevations within 5 minutes.
*K_{DP} (NIED stable) is estimated using the iterative filter and local linear regression.



Areal Rain-Rate Estimators

(1) Z-R method

$$AR = \int a{Z_i}^b\, dA_i \quad \begin{cases} stratiform\ rain \rightarrow a = 3.96\times10^{-2}, b = 0.551 \\ convective\ rain \rightarrow a = 4.26\times10^{-2}, b = 0.644 \end{cases}$$

(2) K_{DP}-R method

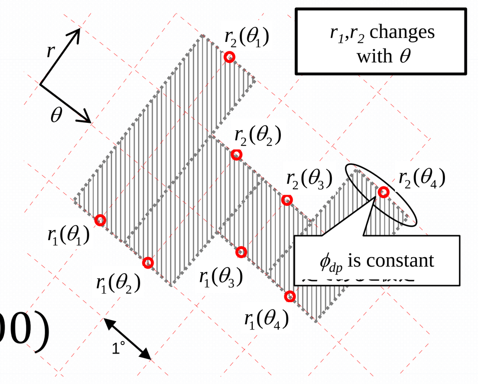
$$AR = \int a|(K_{DP})_i|^b \times sign((K_{DP})_i)\, dA_i$$

$with\ a = 18.9, b = 0.856,\qquad (maki\ et\ al, 2005)$

(3) ϕ_{DP}-AR-Ryzhkov method

$$AR = \frac{a}{2}({r_2}^2 - {r_1}^2) \times \int_{\theta_1}^{\theta_2}\left[\frac{\phi_{DP}(r_2,\theta) - \phi_{DP}(r_1,\theta)}{2(r_2 - r_1)}\right]^b d\theta$$

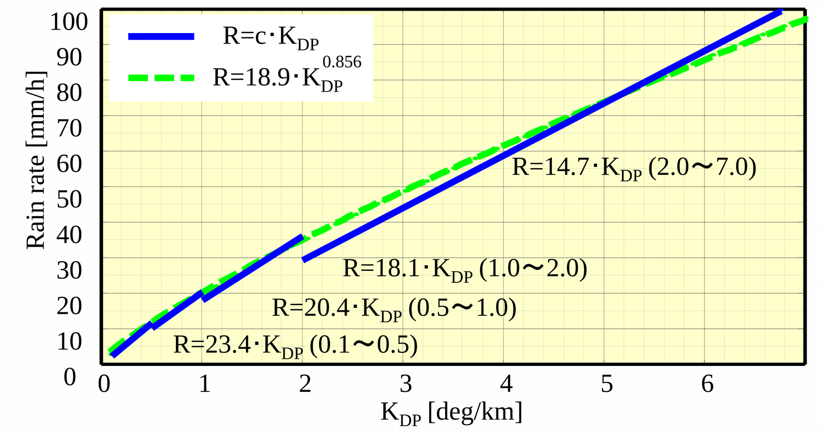
$R = a{K_{DP}}^b, K_{DP}$ is constant for given θ. $(Ryzhkov\ et\ al, 2000)$



(4) ϕ_{DP}-AR-Bringi method $(Bringi\ et\ al, 2001)$

$$AR = \frac{c}{2}\int_{\theta_1}^{\theta_2}\left\{[r_2\phi_{DP}(r_2,\theta) - r_1\phi_{DP}(r_1,\theta)] - \int_{r_1}^{r_2}\phi_{DP}(r,\theta)\,dr\right\} d\theta$$

$R = cK_{DP}$, assuming a linear relation between R and K_{DP}



(5) Composite ϕ_{DP}-AR method (ϕ_{DP}-AR-NIED)

ϕ_{DP}−AR−Ryzhkov (but $R = \alpha K_{DP} + \beta$) at where $10\log_{10} Z > 40$, otherwise **ϕ_{DP}−AR−Bringi** method

(6) MK_{DP}−R method (assuming monotone increasing ϕ_{DP} below melting layer)

$$AR = \int a{K_{DP}}_i^b\, dA_i,\quad {k_i}^2 = 2(K_{DP})_i\Delta r,\quad \phi_i = \sum_{j=0}^{i-1}{k_j}^2,\quad J = J_{obs} + J'_{obs} + J'_{lpf}$$

$((\phi_{DP})_i - \phi_{near})$ mean square errors

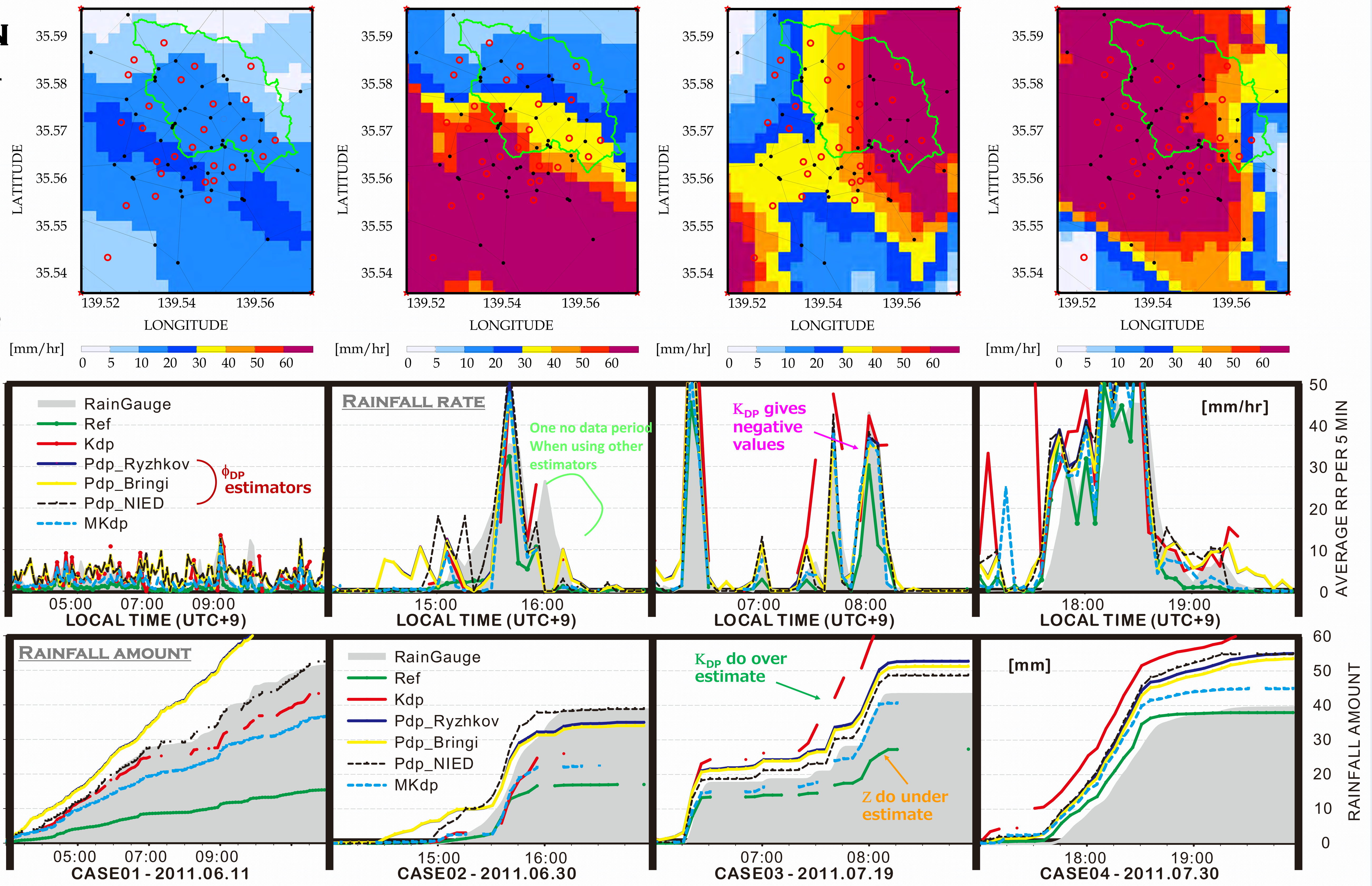
$$J_{lpf} = \frac{1}{N+1}C_{lpf}\sum_{i=0}^{N}\left(\frac{\partial^2 k_i}{\partial r^2}\right)^2,\quad J_{obs} = \frac{1}{N}\sum_{i=1}^{N}(\phi_i - \psi_i)^2, J'_{obs} = \frac{1}{N}\sum_{i=1}^{N-1}(\phi'_i - \psi'_i)^2$$

Results Verification

- **Case studies** were carried out for the verification of 6 areal rainfall rate estimators
- 4 rainfall events occurred in 2011 summer season, which included **1 stratiform** rainfall (CASE01) and **3 convective** rainfalls (CASE02 - 04)
- Radar ray-based verification, and basin-based verification are conducted respectively
- **Basin-based verification result** is shown in this poster
- Areal rainfall rate for rain gauges was obtained by applying **Thiessen algorism**
- Results are noise in the case of stratiform case compared with convective cases
- Only **ϕ_{DP} estimators** produced **time-continuous results**, missing data occurs while using other parameters

Figures on the right

- Upper panels : distributions of rain rate at a sample time for each case
- Middle panels : basin averaged areal rainfall rates with respect to time for each case
- Bottom panels : basin-based rainfall amounts with respect to time for each case



Conclusion and Future Work

- Mean areal rain-rate **estimators using differential propagation phase shift** return the best harmony to Thiessen (gauge) – derived rainfall rates.
- Mean areal rain-rate estimators using **reflectivity tends to underestimate** rainfall rate, while **classic K_{DP} gives negative values** because the differential propagation phase is contaminated by noise sometimes .
- Although **MK_{DP}** (estimated using variational method) avoids the negative K_{DP} values, the **computation cost** is heavy.
- Introduce mean areal rain-rate estimators into hydrological models to forecast real time flash flood is our future work.