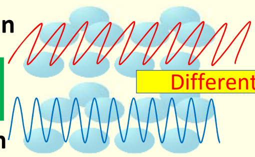
Development of assimilation methods for polarimetric radars at storm scales

Takuya Kawabata[1,2] (*tkawabat@mri-jma.go.jp*), Thomas Schwitalla[2], Hans-Stefan Bauer[2], Ahoro Adachi[1], and Volker Wulfmeyer[2]

1: Meteorological Research Institute, Japan Meteorological Agency

2: Institute of Physics and Meteorology, University of Hohenheim

Why Dual-Polarized Radar?



Intensity: Z_h, Z_v, Z_{DR} (Z_h-Z_v)

Phase: φ_{DP} (φ_h- φ_v), K_{DP} (spatial derivation of ϕ_{DP})

Polarimetric radars provide not only intensity of rain but also information on the shape of rain.

1 Two-moment microphysics

Drop size distribution $\phi(D) = N_0 D^{\mu} e^{-\Lambda D}$

N_0 Intercept, Λ Slope, μ Spectral shape parameters

* Three parameters in the drop size distribution are detected by the two-moment cloud microphysics scheme.

2 Two types of observation operators

Oblateness: $r = 0.9951 + 2.51 \times 10^{-2} D - 3.644 \times 10^{-2} D^2 + 5.303 \times 10^{-3} D^3 - 2.492 \times 10^{-4} D^4$

(Brandes et al. 2005)

Rain water in the model is considered spheroid as the diameter increases.

1) Model variables -> pol. observation

Fitting (indirect scattering calculation) (Zhang et al. 2001)

$$|S_{h,v}(D)| = \alpha_{h,v} D^{\beta_{h,v}}$$

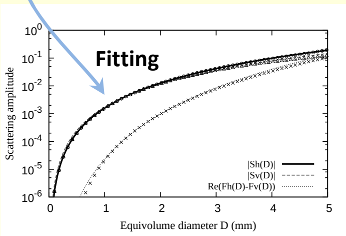
$$Z_{H,V} = \frac{4\lambda^4}{\pi^4 |K_w|^2}\left(\alpha_{h,v}^2 N_0 \Lambda^{-(2\beta_{h,v}+1)} \Gamma(2\beta_{h,v}+1)\right)$$

$$K_{DP} = \frac{180\lambda}{\pi} N_0 \alpha_k \Lambda^{-(\beta_k+1)} \Gamma(\beta_k+1)$$

$$A_H = \alpha_H K_{DP}{}^{\beta_H}$$

$$A_{DP} = \alpha_d K_{DP}{}^{\beta_d}$$

α, β are fitting coefficients.



Scattering amplitude against rainwater size and the fitting functions. Marks represent backscattering amplitudes and the difference between horizontal and vertical polarizations calculated by the T-matrix, and lines are fitted with power-law functions.

2) Pol. Observation -> model variables

Evaluate three converters here.

$$\mathrm{Qr}(Z_h, \mathrm{ZDR}) = c_1 Z_h^{a_1} 10^{0.1 b_1 Z_{DR}}$$

$$\mathrm{Qr}(K_{DP}) = c_2 \left(\frac{K_{DP}}{f}\right)^{b_2}$$

$$\mathrm{Qr}(K_{DP}, Z_{DR}) = c_3 K_{DP}^{a_3} 10^{0.1 b_3 Z_{DR}}$$

$a_{1,3}$, $b_{1,2,3}$, and $c_{1,2,3}$ are the empirical constants.

(Bringi and Chandrasekar 2001)

How to evaluate these? Comparison

True Qr — Model simulated rainwater → FIT Convert → Z_h, Z_{DR}, K_{DP} — Pseudo observation (Z_h, ZDR K_{DP}) → Qr(Z_h, Z_{DR}, K_{DP}) Convert → Qr — Re – converted rainwater

3 Results

Averages and standard deviations in comparison with actual observations

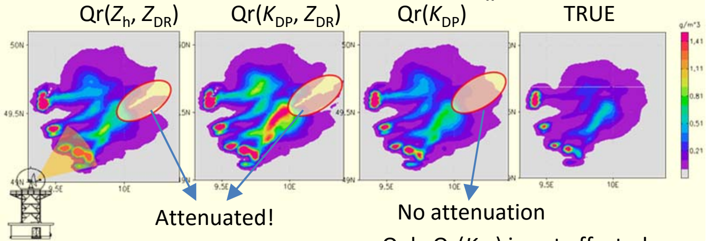
	Z_h (dBZ)		Z_{DR} (dB)		K_{DP} (° km^{-1})	
	AVG	STD	AVG	STD	AVG	STD
OBS	18.99	11.10	0.93	1.05	1.31	1.54
FIT	19.23	10.37	0.55	0.41	0.25	0.18
FIT – OBS	-0.10	14.68	-0.30	0.99	-0.91	1.47

Differ

	Bias	STD
Qr(Z_h,Z_{DR})	0.033	0.07
Qr(K_{DP})	-0.006	0.03
Qr(K_{DP},Z_{DR})	0.044	0.10

Qr(K_{DP}) is the most accurate.

Attenuation effect (Simulated Z_h)

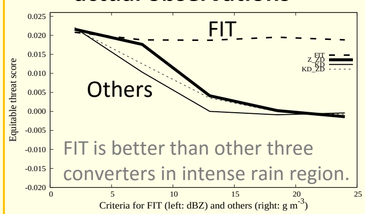


Attenuated!

No attenuation

Only Qr(K_{DP}) is not affected by the attenuation.

Threat scores against actual observations



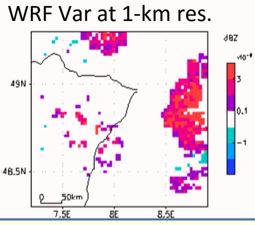
Conclusion

FIT or Qr(K_{DP}) are suitable for DA. Since values of the threat scores are quite low, we need to evaluate which one is better through DA.

4 Data assimilation

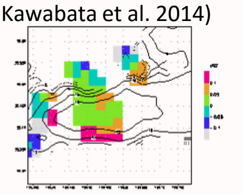
Assimilate Z_h, Z_{DR}, and K_{DP} With FIT.

WRF Var at 1-km res.



Analysis increment (shade) and observation (contour) of Z_h.

NHM-4DVarat 2-km res. (Kawabata et al. 2014)



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[2] Kawabata, T., H. Iwai, H. Seko, Y. Shoji, K. Saito, S. Ishii, and K. Mizutani, 2014b: Impact of Doppler Wind Lidar Assimilation on a Heavy Rainfall Forecast at a Meso-gamma Scale. *Mon. Wea. Rev.*, **142**, 4484–4498

[3] Kawabata, T., H.-S. Bauer, T. Schwitalla, V. Wulfmeyer, and A. Adachi, 2016: Evaluation of Forward Operators for Polarimetric Radars Aiming for Data Assimilation. (under review).

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