評估雙偏極化雷達參數觀測算符於對流尺度資料同化之影響

Evaluate the Impact of Assimilating Radar Data with Different Operator Configuration - **Methods of Scattering Amplitude Calculation**

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Introduction

Data
& Methodology

Result
& Discussion

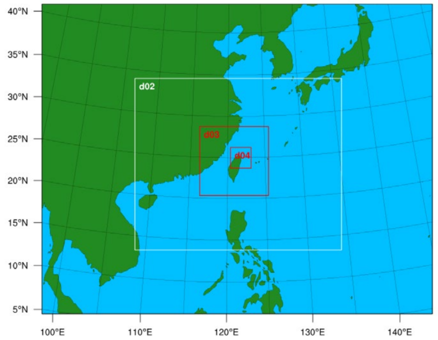
Summary

Introduction

Variables Converting before Assimilation

Retrieve

(Sun and Crook, 1997; Kawabata et al, 2011; Wang et al., 2013; Schwitalla et al., 2014)

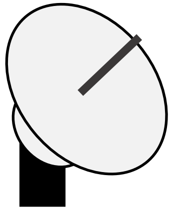


NWP models

Hydrometeors: q, N

State variables: P, T …

Dual-polarization Radar Observation



Vr and Z_H (Traditional)

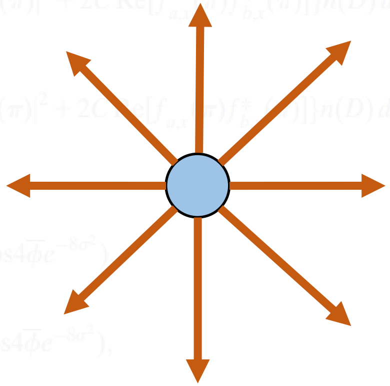
Z_{DR}, K_{DP} and ρ_{hv} (Dual-Pol)

Observation Operator

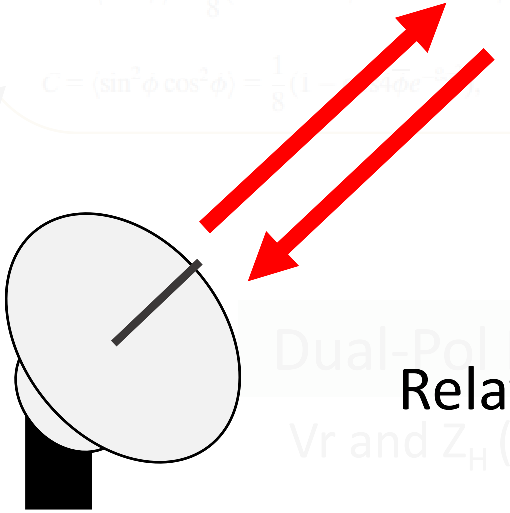
(Jung et al. 2010, 2012; Putnam et al. 2019, 2021; Oue et al. 2020; You et al. 2020; Zhuang et al. 2021)

Scattering amplitude represent the power of scattered electromagnetic wave.

Rayleigh scattering:
particle size < wave length*0.1

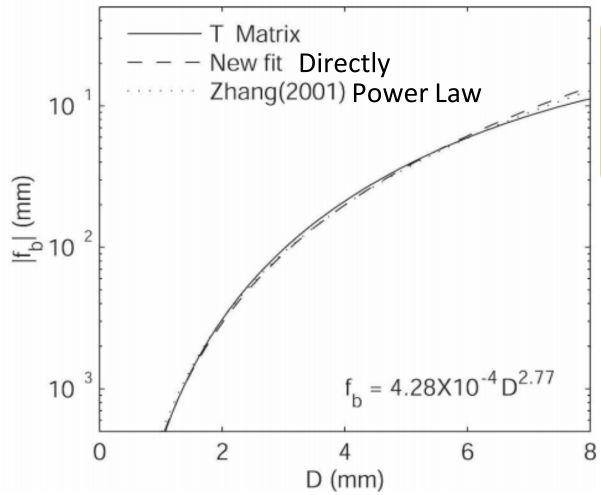


K_{DP}
Related to Forward Scattering



Z_H and Z_{DR}
Related to Back Scattering

Scattering Amplitudes



Directly calculation

Cut into many bins, and use T-matrix method to calculate |f(D)|

Power Law Fitting

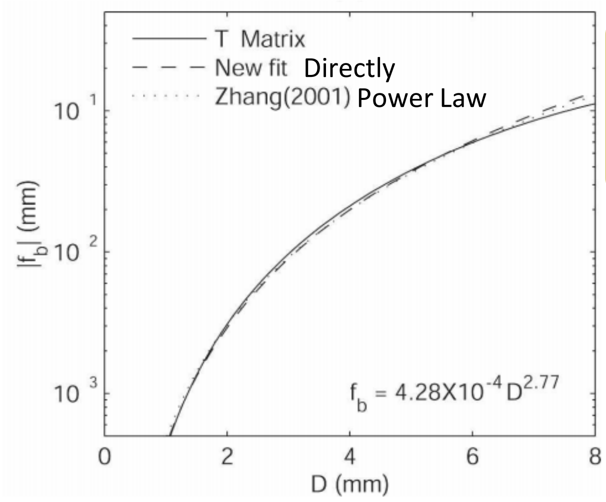
$$|f_a| = \alpha_{xa} D^{\beta_{xa}} \quad (unit : mm)$$

$$|f_b| = \alpha_{xb} D^{\beta_{xb}} \quad (unit : mm)$$

Compare the different methods of raindrop SA calculation.

Then, find out the best way to assimilate Dual-Pol radar data.

Scattering Amplitudes



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Calculation of Scattering Amplitude

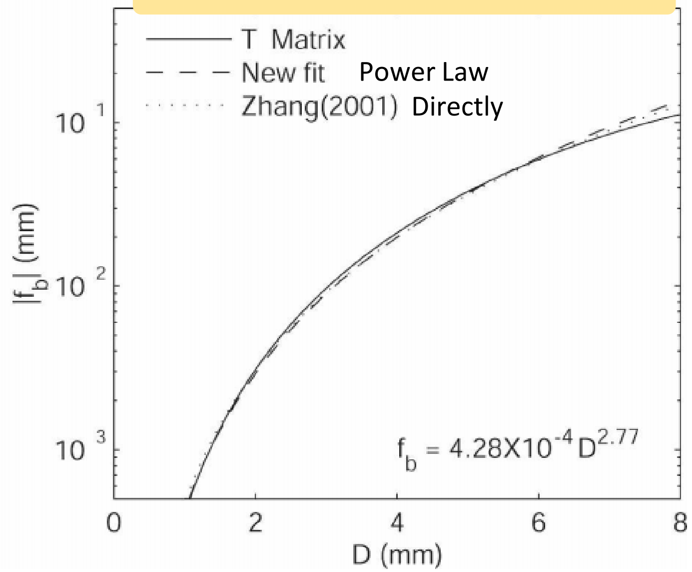
T-matrix Method

$$\mathbf{E}_{inc} = \sum_{n=1}^{\infty} \sum_{m=-n}^{n} \left(a_{mn}\mathbf{M}^1_{mn} + b_{mn}\mathbf{N}^1_{mn}\right)$$

$$\mathbf{E}_{scat} = \sum_{n=1}^{\infty} \sum_{m=-n}^{n} \left(f_{mn}\mathbf{M}^3_{mn} + g_{mn}\mathbf{N}^3_{mn}\right)$$

$$\begin{pmatrix} f_{mn} \\ g_{mn} \end{pmatrix} = T \begin{pmatrix} a_{mn} \\ b_{mn} \end{pmatrix}$$

Scattering Amplitudes



Jung et al.(2008A)

T-matrix: **incident** vs. **scattered** electric field.

Directly Calculation

Jung et al.(2010); Ryzhkov et al. (2011)

Cut into bins

+

λ, T, canting angle, axis ratio…

=

Scattering Amplitude (*f*) at each bins

Power Law Fitting

Jung et al.(2008a) Kawabata et al.(2018)

$$|f_h| = \alpha_{h,x} D_x^{\beta_{h,x}}$$

$$|f_v| = \alpha_{v,x} D_x^{\beta_{v,x}}$$

Fit the relationship between particle diameter (D) and scattering amplitude f(D)

Power Law Fitting (Jung et al., 2008a)

$$|f_h| = \alpha_{h,x} D_x^{\beta_{h,x}}$$

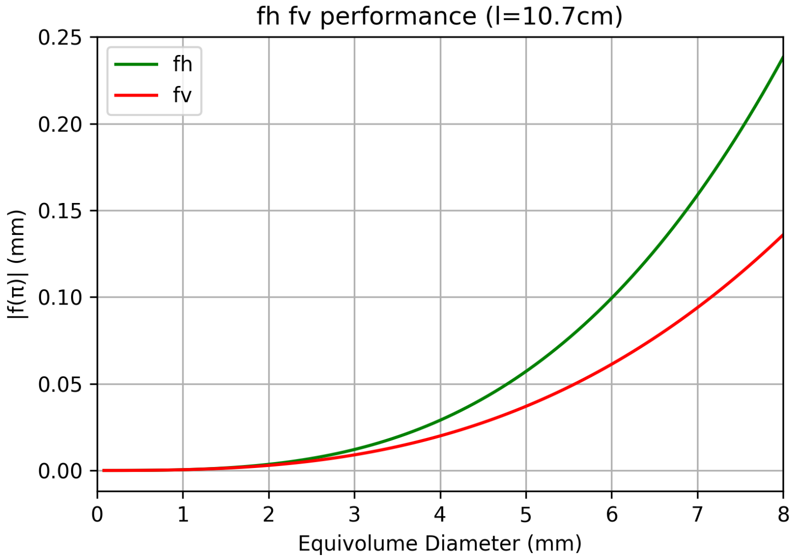
$$|f_v| = \alpha_{v,x} D_x^{\beta_{v,x}}$$

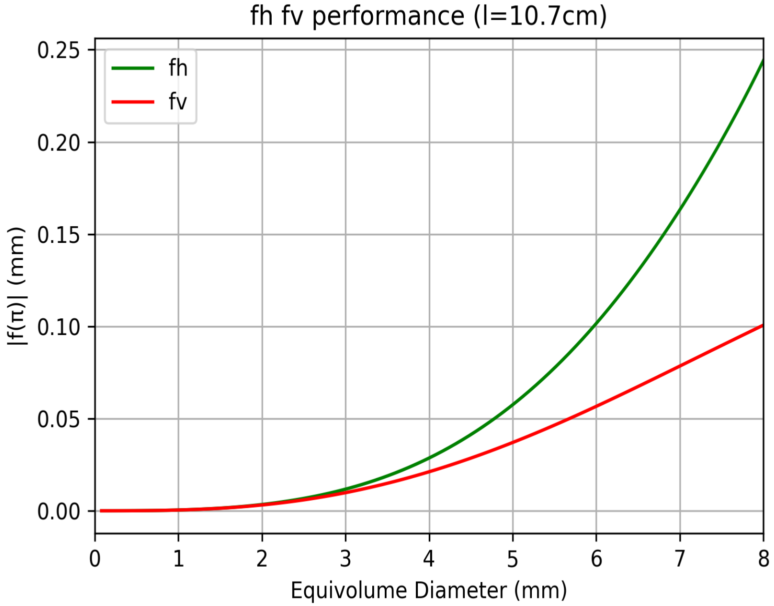
$$\alpha_{h,x} = 4.28 \times 10^{-4}$$

$$\alpha_{v,x} = 4.28 \times 10^{-4}$$

$$\beta_{h,x} = 3.04$$

$$\beta_{v,x} = 2.77$$





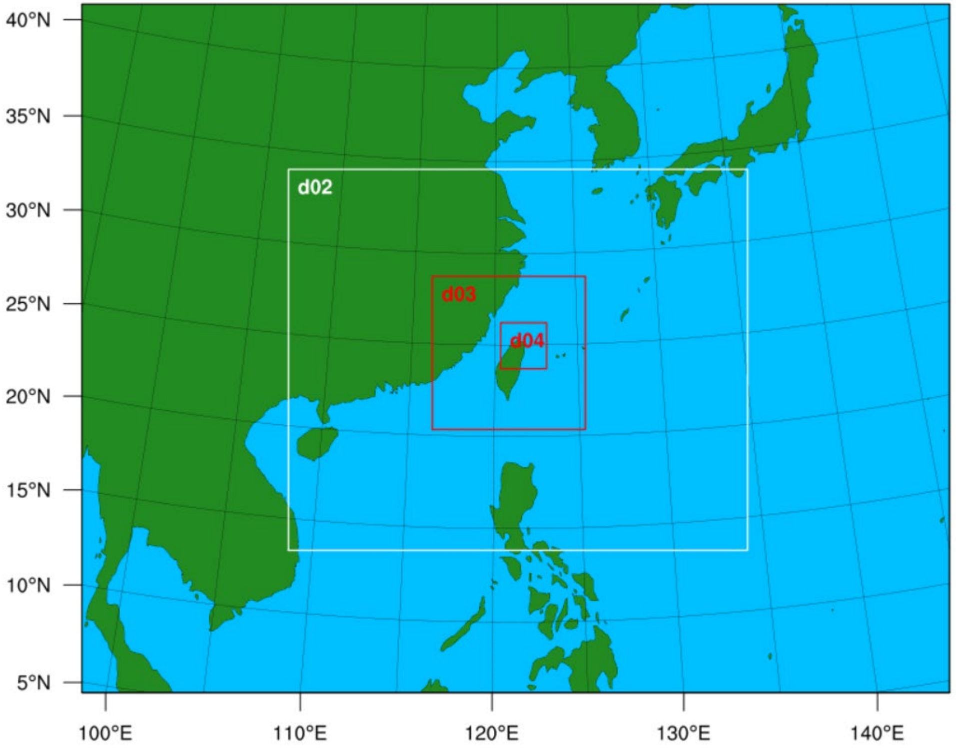
Directly Calculation (Jung et al., 2010)

T-matrix setting	
D_r	0.08 ~ 8mm
bins	100
T	10°C
Degr	0°
λ	10.7 cm
Axis ratio	Bradnes et al.(2003)

Directly calculate the scattering at each bins.

Model configuration

WRF-ARW V4.1.3



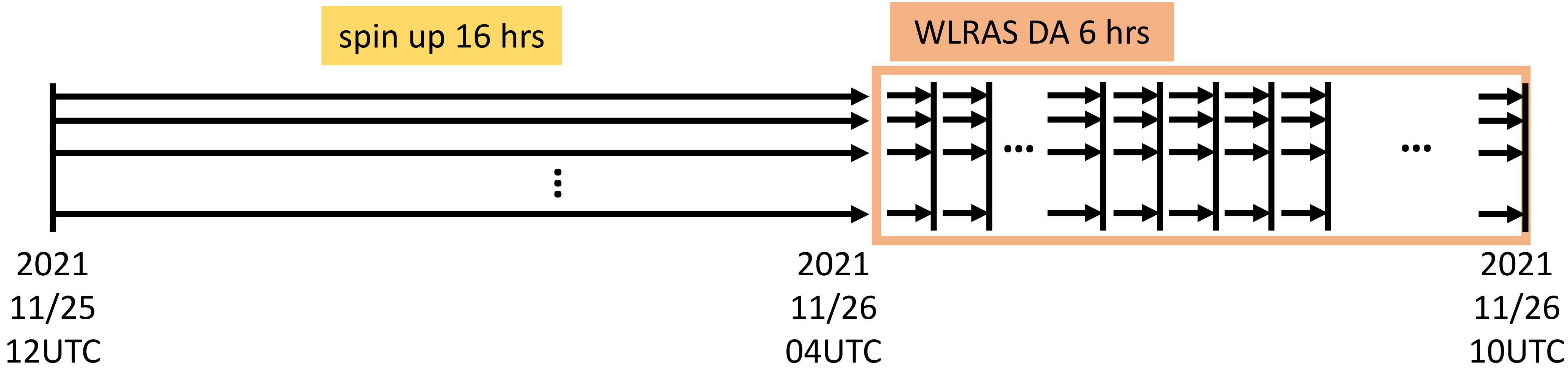
Domain	1	2	3	4
Size	190*151	301*250	301*301	271*271
Resolution	27km	9km	3km	1km

Wintertime Rainfall Case

Start time	2021-11-25-12 UTC
End time	2021-11-26 06 UTC
Initial & Boundary condition	NCEP FNL 0.25°
Vertical levels	52 levels from surface to 10hPa
Members	128
Perturbation method	WRFDA cv3
Nesting	2-way nesting
Physics	mp_physics= WDM6 (Lim and Hong, 2010) ra_lw_physics= RRTM scheme ra_sw_physics= Dudhia scheme bl_pbl_physics= YSU scheme
Damping	W_damping=1 Upper layer: implicit gravity-wave damping layer Vertically propergation sound wave damping (Dudhia 1994)

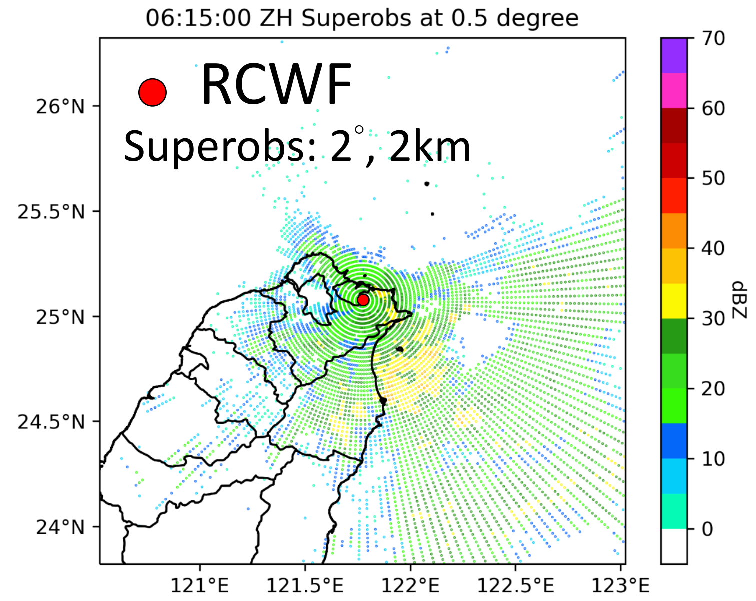
Configuration of Data Assimilation

WRF-LETKF Radar Assimilation System (WLRAS; Tsai et al, 2014)
Period of DA cycle: 15 mins, 25cycles



	Var. name	Assi data	σ_o
Vr	Radial velocity	Full volume (15 elevations)	3(m/s)
Z_H	Reflectivity	$< 3 \times \sigma_o$	5(dBz)
Z_{DR}	Differential Reflectivity	<3 km height $< 3 \times \sigma_o$	0.2(dB)

Update					
Varibles	U, V	W	PH, T,	q_v, q_c, q_i	q_r, q_s, q_g, N_r
Hori. Loc. radius	36 km	12 km	12 km	24 km	12 km
Vert. Loc. radius	4 km				
Inflation	1.08				



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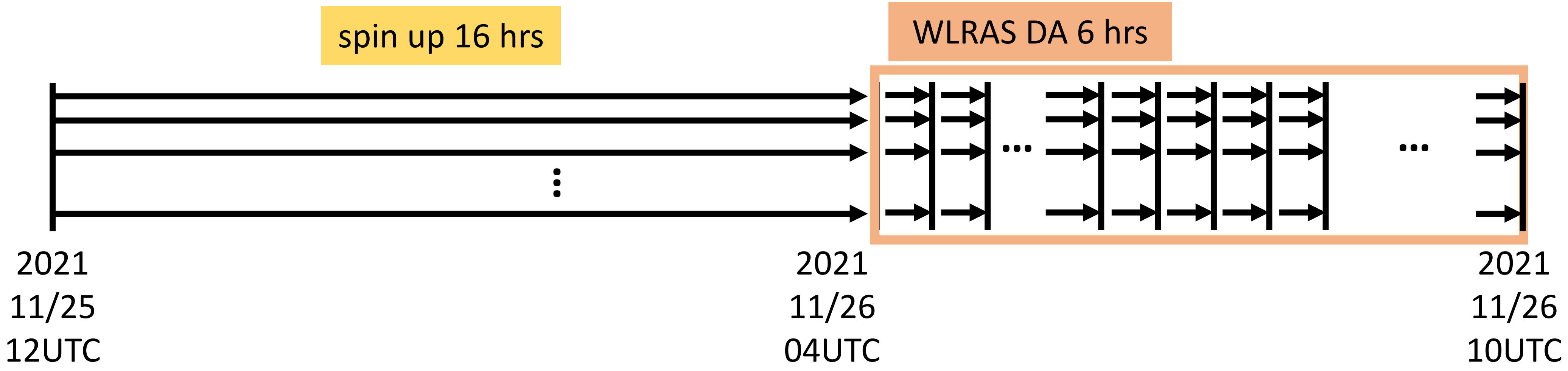
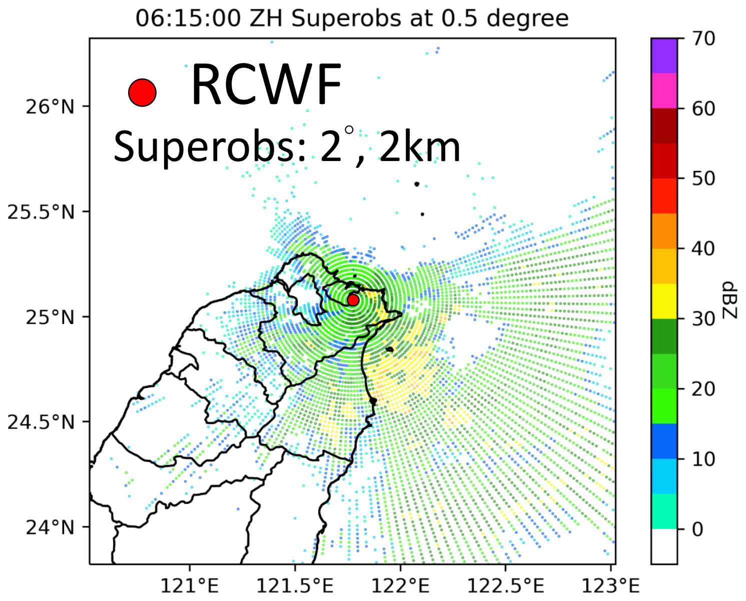


Experiments	Assimilated parameters	DA operator
VrZ	Vr Z_H (traditional)	J08A (Power Law)
VrZZ_POW	Vr Z_H Z_{DR} (dual-pol)	
VrZZ_DIR		J10 (Directly)



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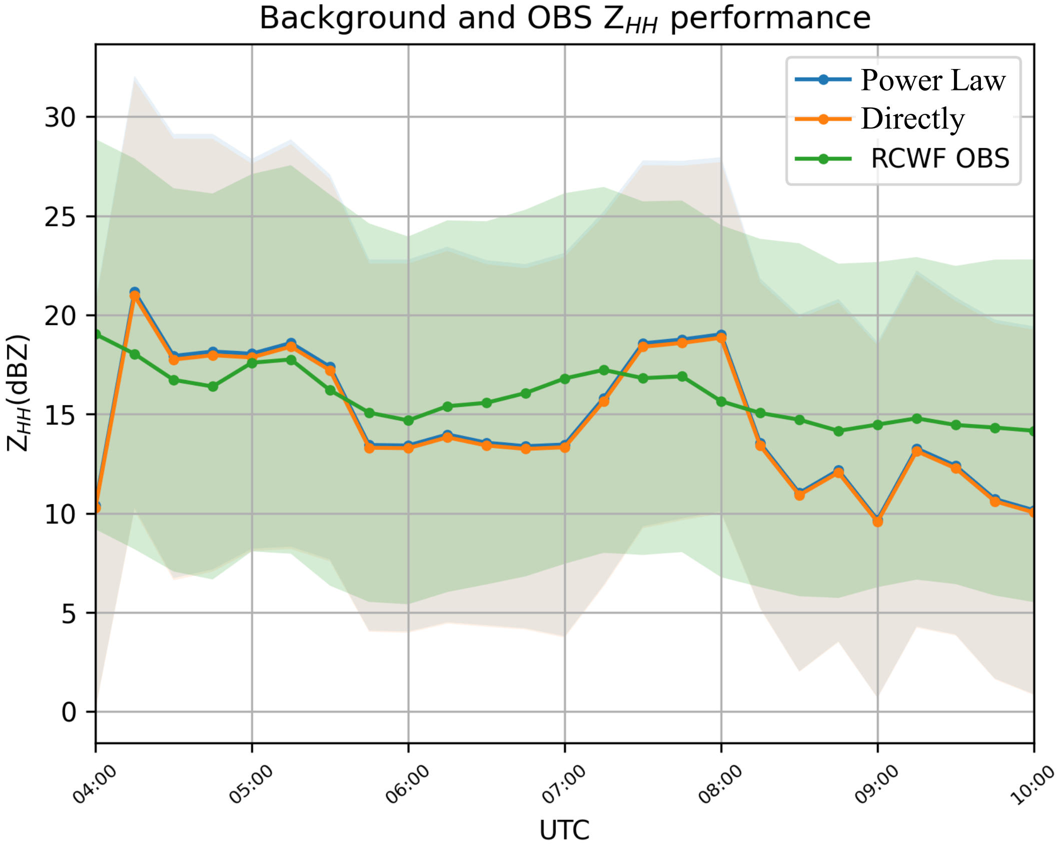
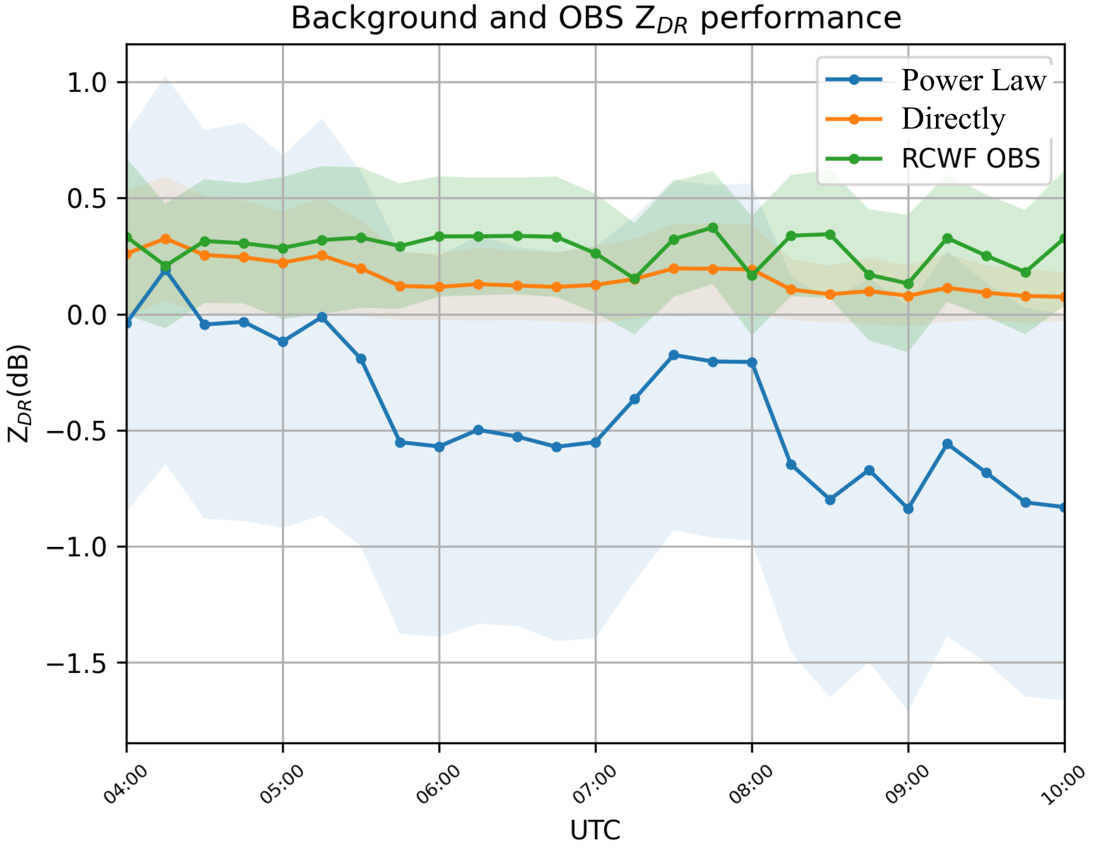
Performance in Background

Background Cycling Performance

Calculated by VrZ





✓ Z_H structure doesn't change a lot.

✓ Z_{DR} gets close to OBS when using 'Directly' operator!

Z_{DR} Bias in Power Law Operator

Jung et al.(2008a):

$$|f_h| = \alpha_{h,x} D_x^{\beta_{h,x}}$$

$$|f_v| = \alpha_{v,x} D_x^{\beta_{v,x}}$$

$$\alpha_{h,rain} = 4.28 \times 10^{-4}$$

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$$\beta_{h,rain} = 3.04$$

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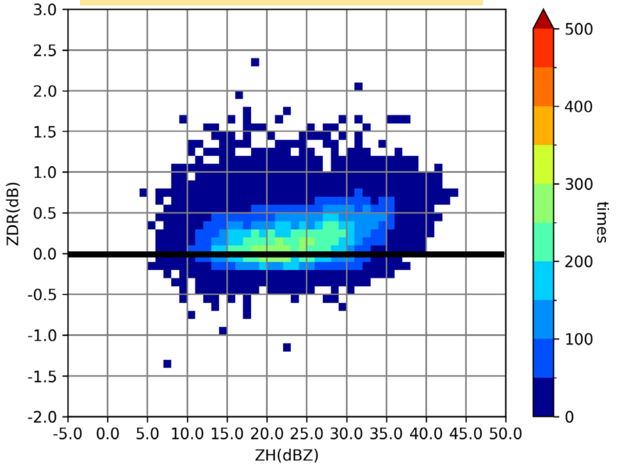
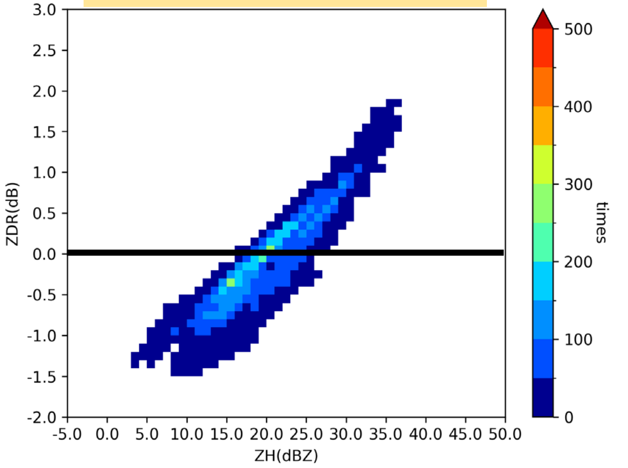
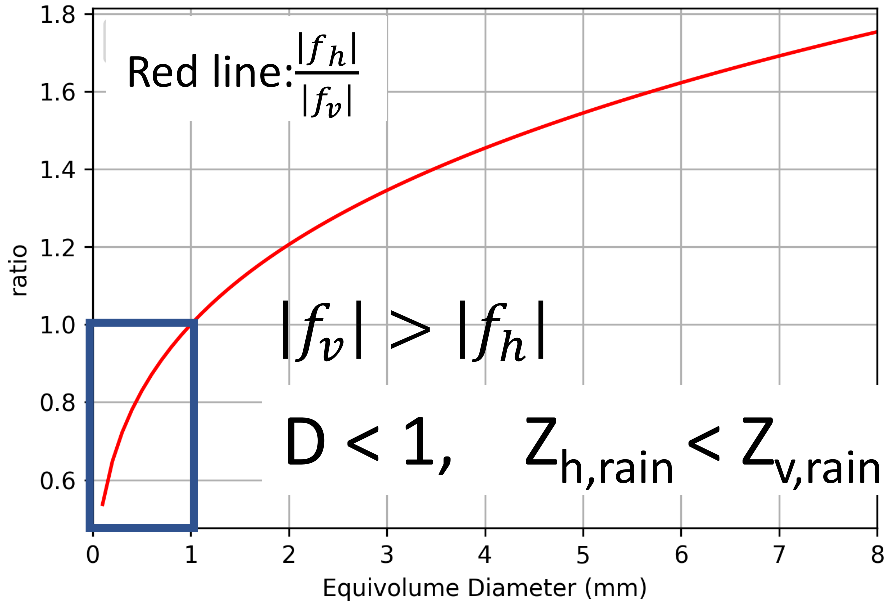
OBS (RCWF)



VrZ (Using J08A)



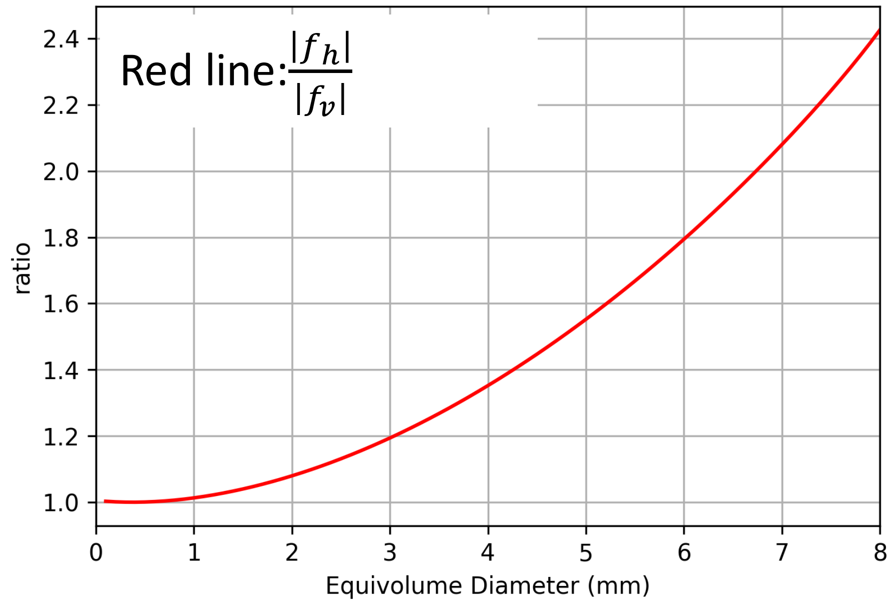
f_h and f_v Ratio by Power Law Fitting (J08A)



$|f_v| > |f_h|$

$D < 1, \quad Z_{h,rain} < Z_{v,rain}, \quad Z_{DR} < 0$

f_h and f_v Ratio by Directly Calculation (J10)



Result
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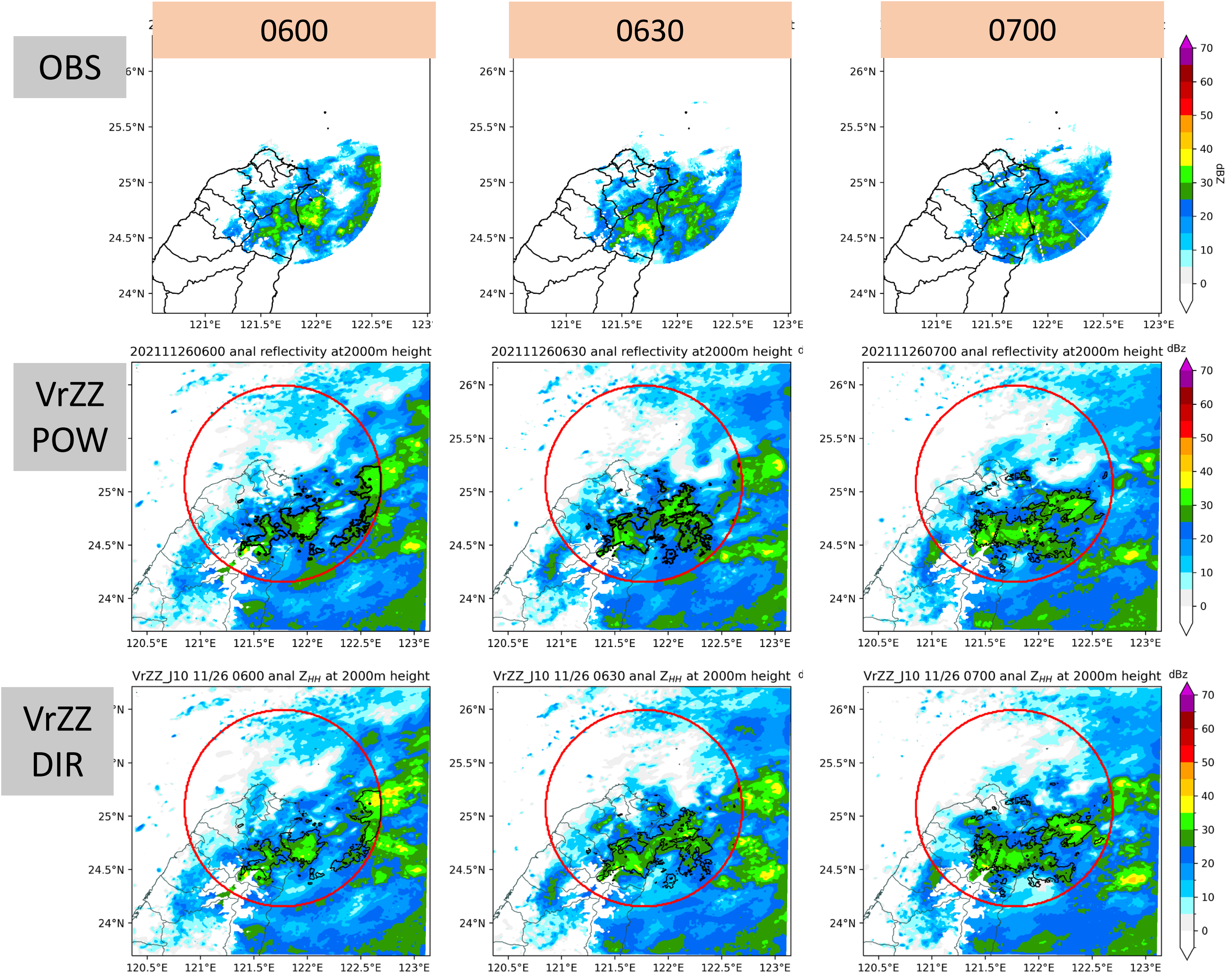
Performance in Analyses

Analyzed Z_H performance

- Both experiments can capture the pattern of the system.



Black contour: Z_HOBS>25dBZ

Result & discussion

Dual-pol radar DA performance in wintertime rainfall case

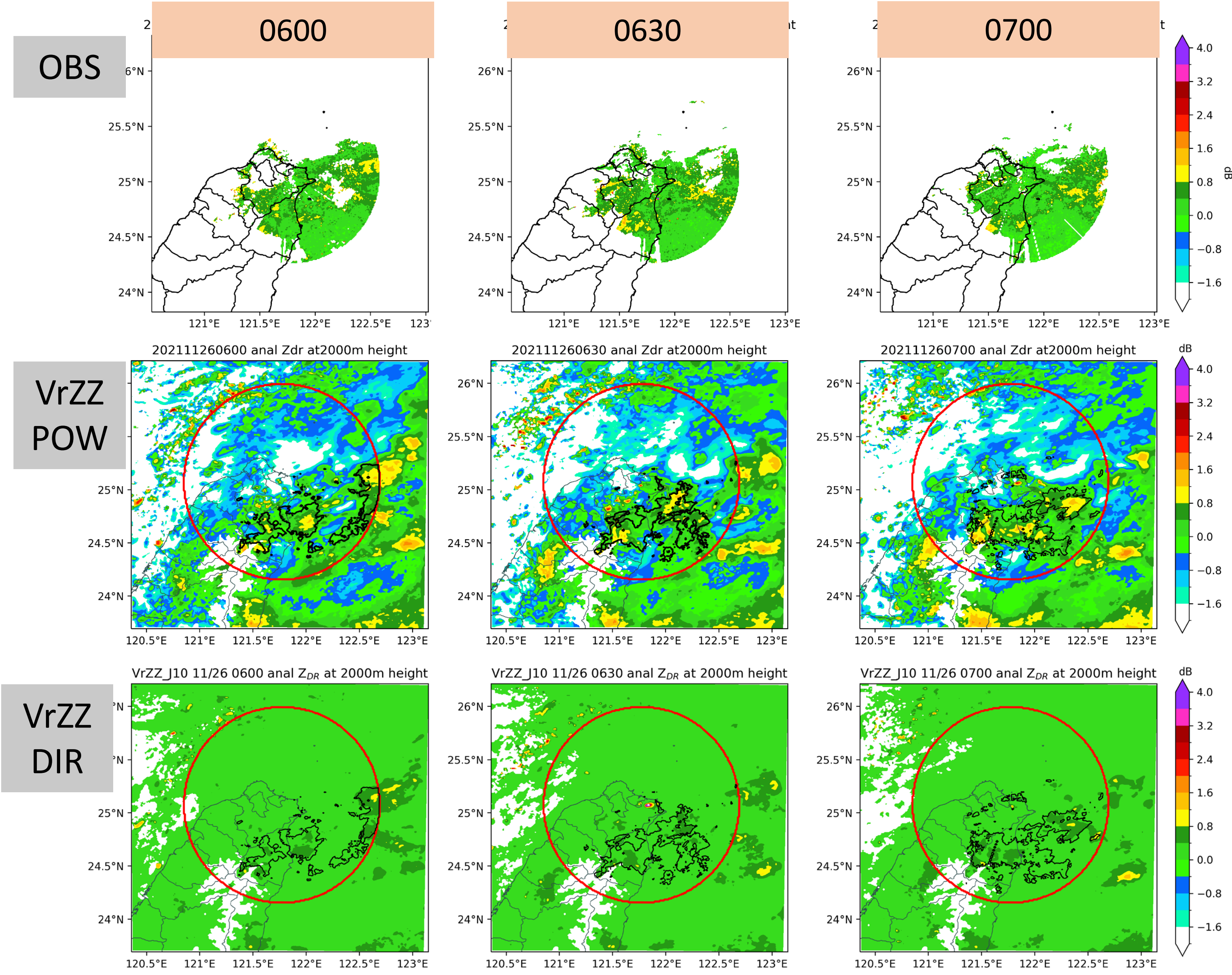
Analyzed Z_H performance

- Both experiments can capture the pattern of the system.

Analyzed Z_{DR} performance

- VrZZ_POW can't describe the uniform Z_{DR} performance

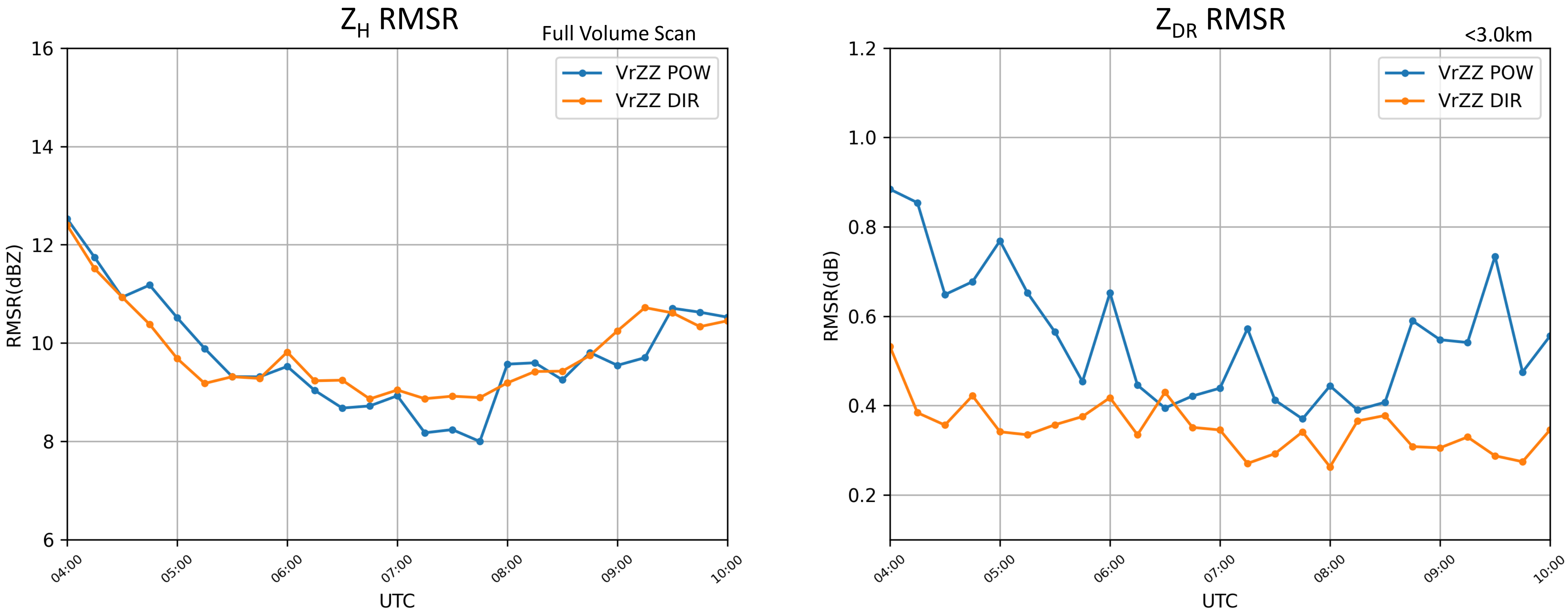
→ Overestimation (underestimation) inside (outside) the system



Black contour: Z_HOBS>25dBZ

Cycling performance --- Root mean square residual

Calculated by **analyses** $\sqrt{\frac{\sum(y^o - H\bar{x}^a)^2}{n}}$



Directly: Z_{DR} closer to OBS.

Result & discussion

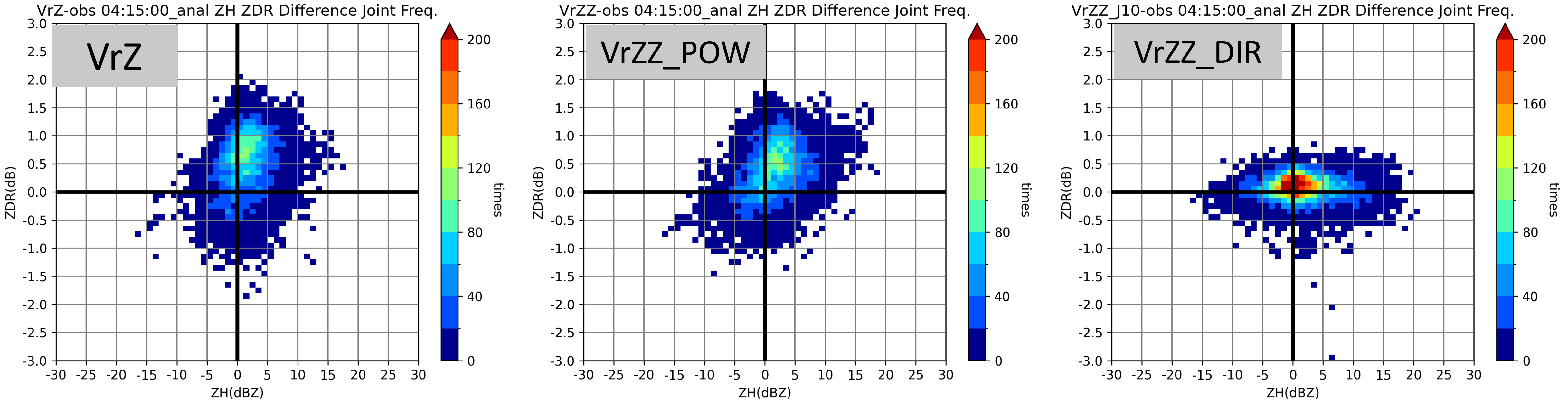
Performance with different DA methods

Z_H – Z_{DR} difference between Exp. and OBS

0415UTC (cycle02)

Calculated by **analyses at OBS points**<3.0km

shaded: Accumulated Times



- X-axis: EXP. Z_H – OBS Z_H
- Y-axis: EXP. Z_{DR} – OBS Z_{DR}
- Assimilating radar data with using J10 (Directly) leads analyses closer to the observation!

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- The calculation of scattering amplitude plays an important role in the operator:
  1. K_{DP} related to Forward-Scattering
  2. Z_H and Z_{DR} related to Back-Scattering
- Power law fitting: Z_{DR} bias when the raindrop diameter smaller than 1.0 mm.
- 'Directly' method: reasonable Z_H and Z_{DR} structure, closer to OBS.
- By all of the results, we suggest that it's better to assimilate dual-pol radar data by using 'directly' method .

Thanks for listing!