2016 Conference on Weather Analysis and Forecasting

High-Resolution Spectral Analysis of Precipitation Through Range Imaging with the Chung-Li VHF Radar

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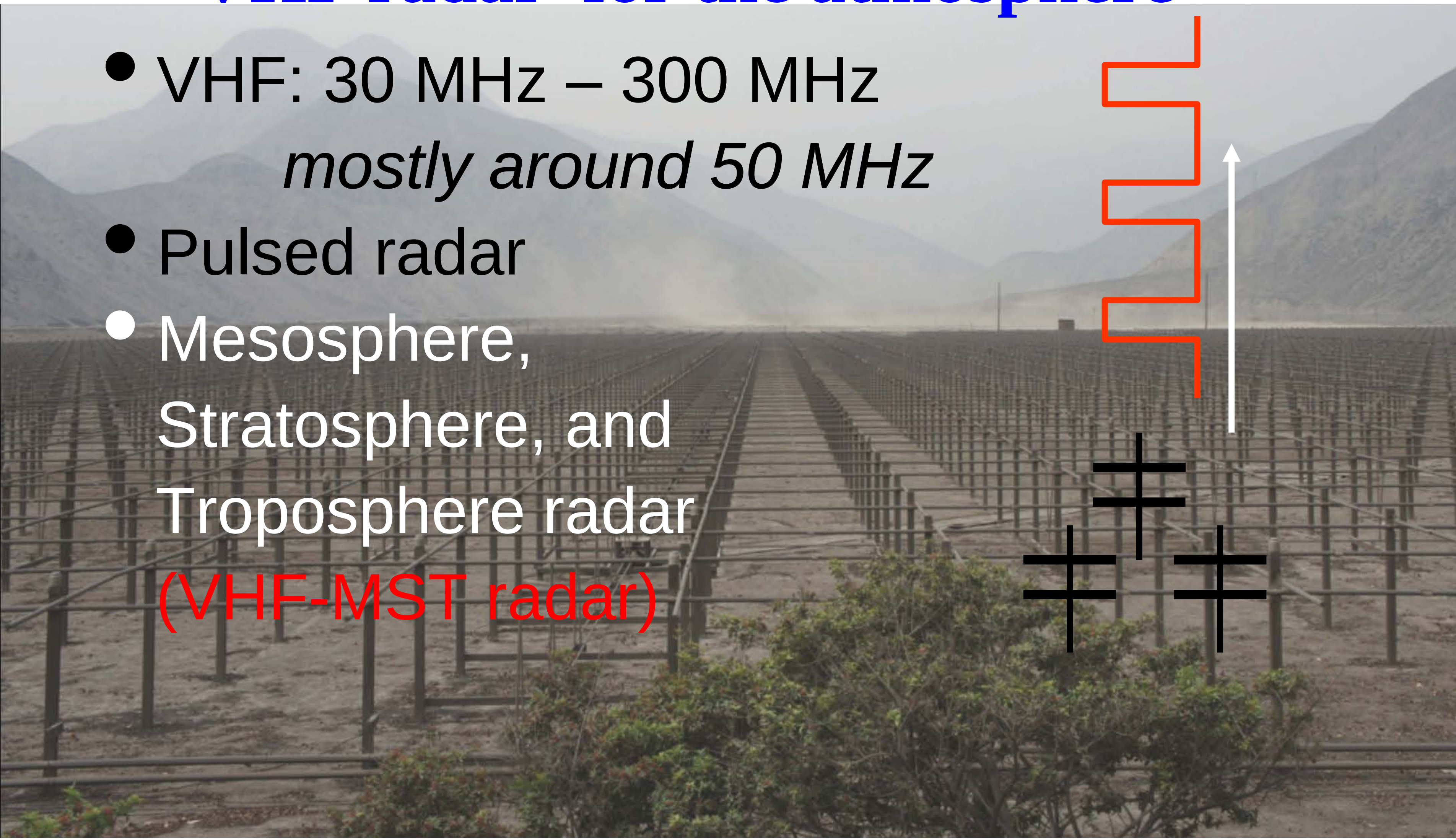
Outline

- Introduction
- Theory
- Experiment
- Analysis and discussion
- Conclusions

Introduction

■ VHF radar for the atmosphere



- VHF: 30 MHz – 300 MHz

  mostly around 50 MHz
- Pulsed radar
- Mesosphere, Stratosphere, and Troposphere radar (VHF-MST radar)

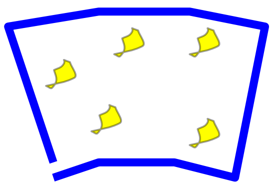
Introduction

■ Finite spatial resolution of radar echoes

- Finite beam width & pulse length

➔ the echoes are scattered/reflected from a finite volume space

➔ the spatial resolution is finite



- To improve the spatial resolution of sampling

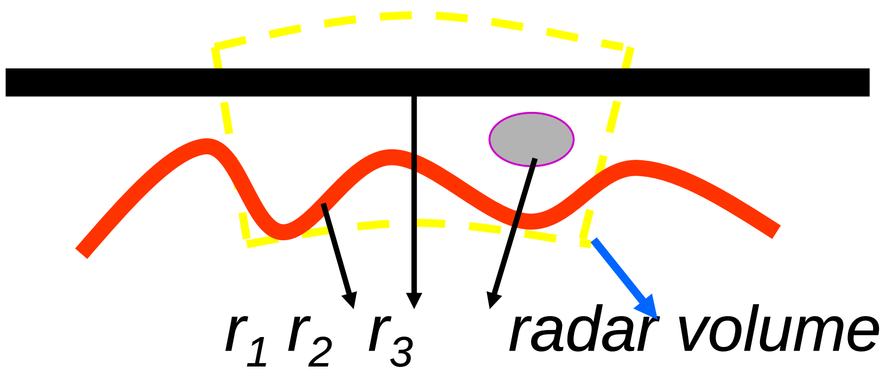
1) shorter pulse length ➔ less power !

2) narrower beam width ➔ larger array size and more money !!

Theory

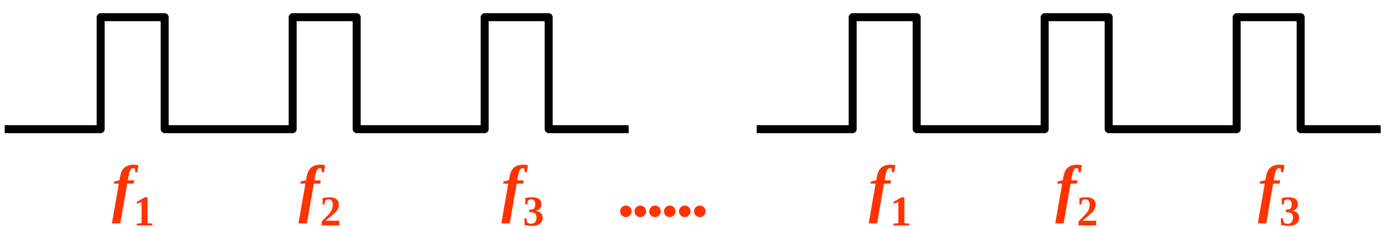
■ Multi-frequency range imaging (RIM)

- *Resolve multiple layers / fine structures in the radar volume*



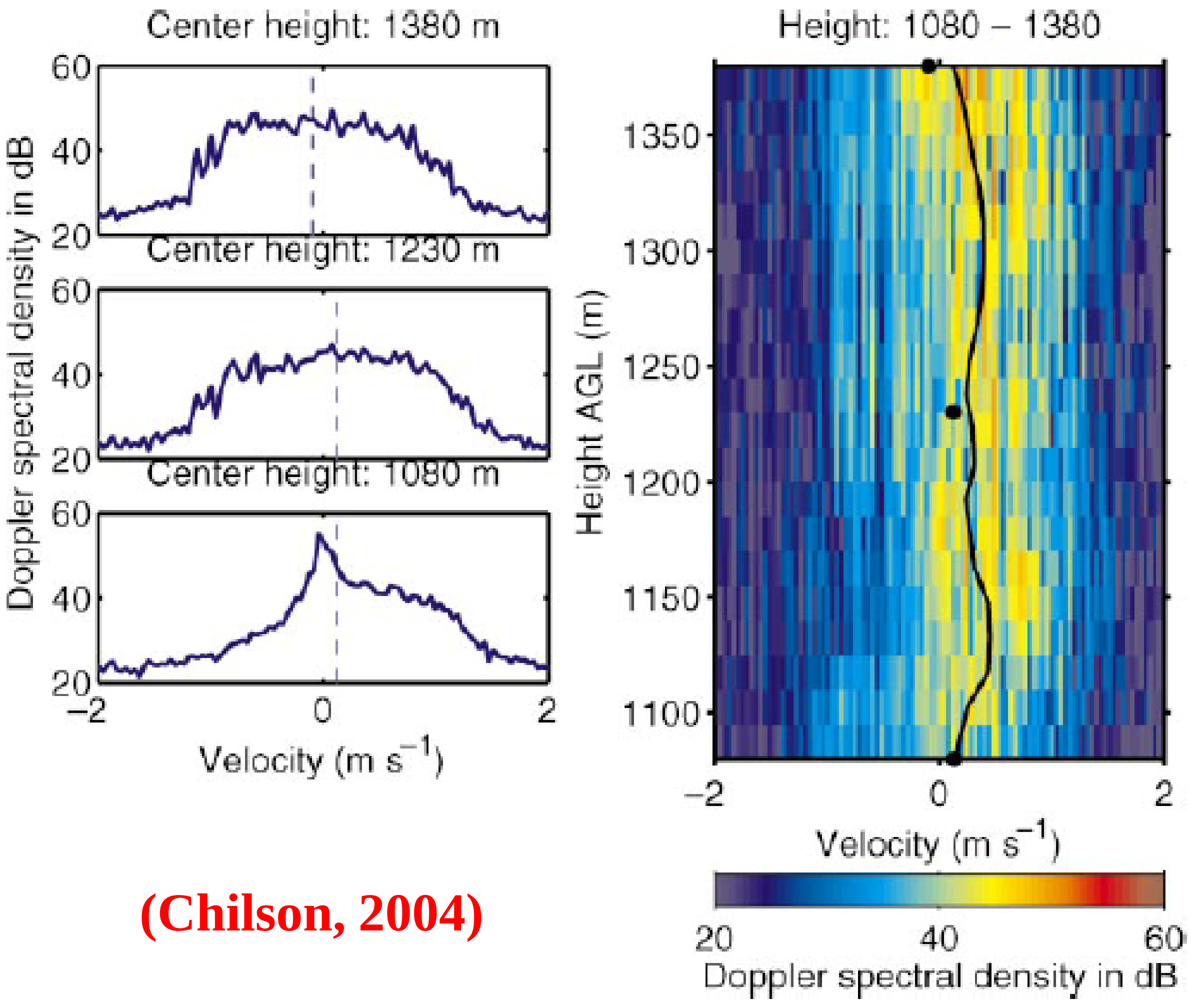
refractive-index layers

- ◆ *Change the carrier frequencies pulse by pulse*



Theory

■ Power spectrum analysis for RIM



(Chilson, 2004)

$$w_{jn} = \frac{V^{-1}e}{e^{+}V^{-1}e}$$

$$e_{jn} = \exp\left(i2k_n r_j\right)$$

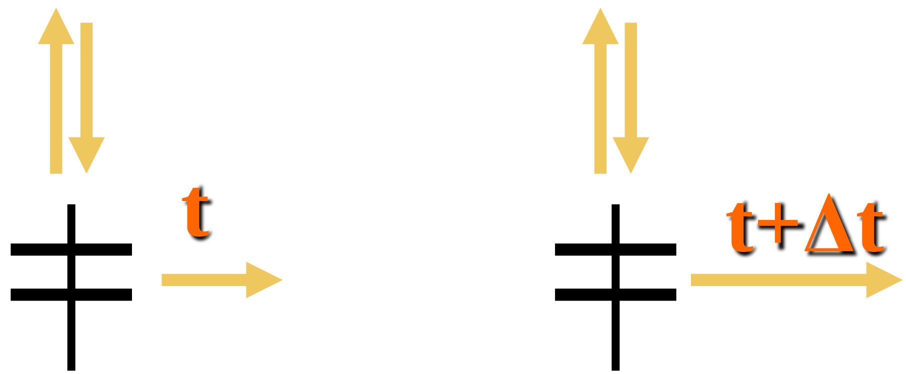
$$\tilde{s}_j(t) = \sum_{n=1}^{N} w_{jn} s_n(t).$$

FFT

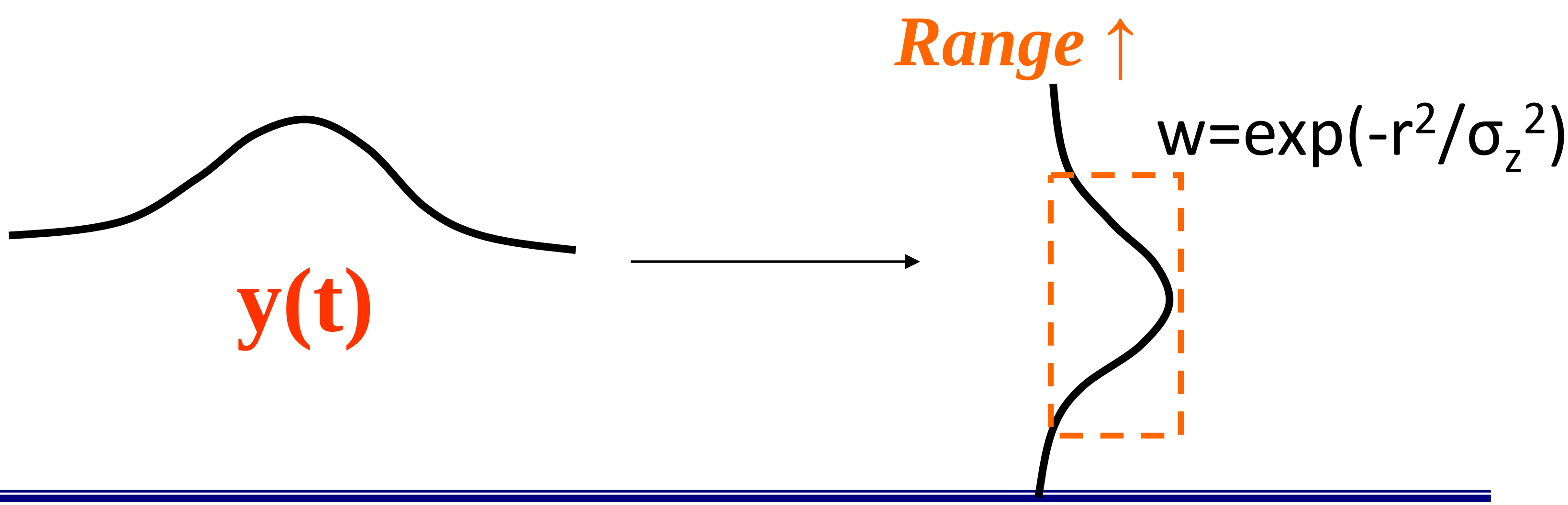
Theory

■ Phase calibration for RIM

(1) Time delay of signal in the radar system



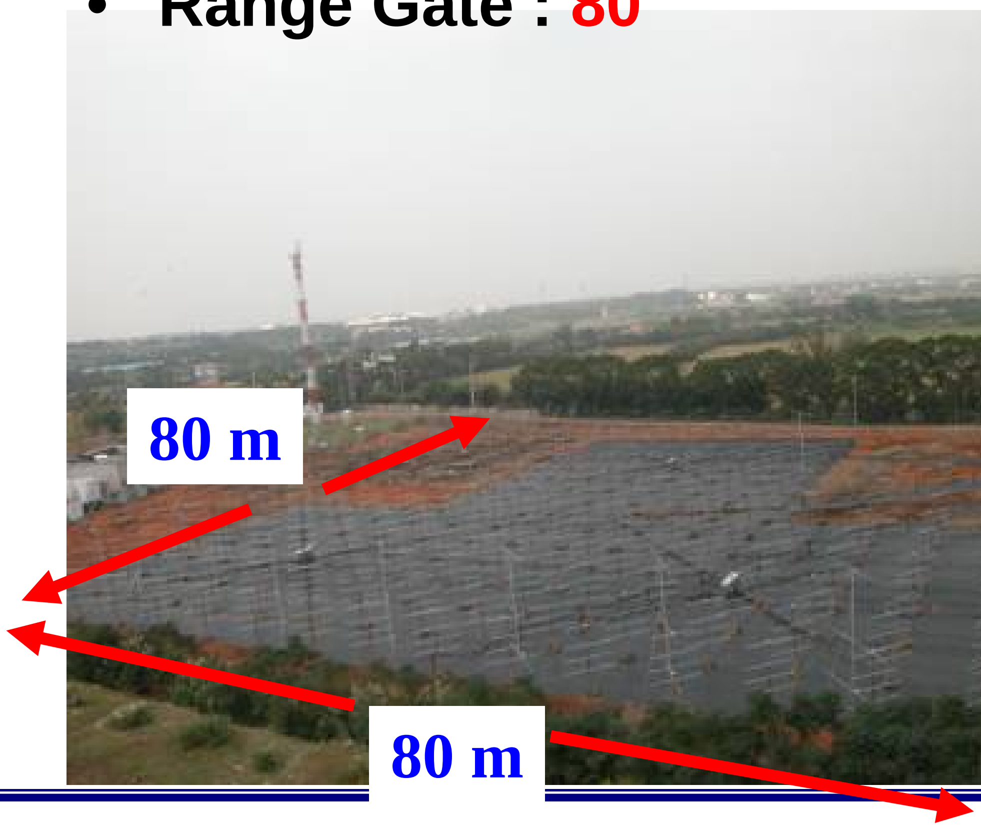
(2) Range-weighting function correction for RIM

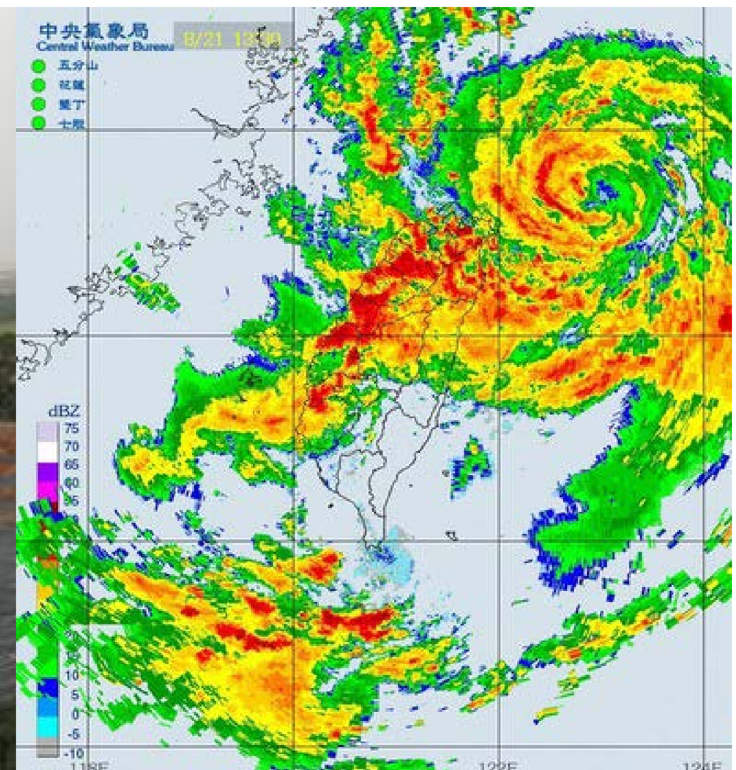


Experiment

■ Chung-Li VHF radar

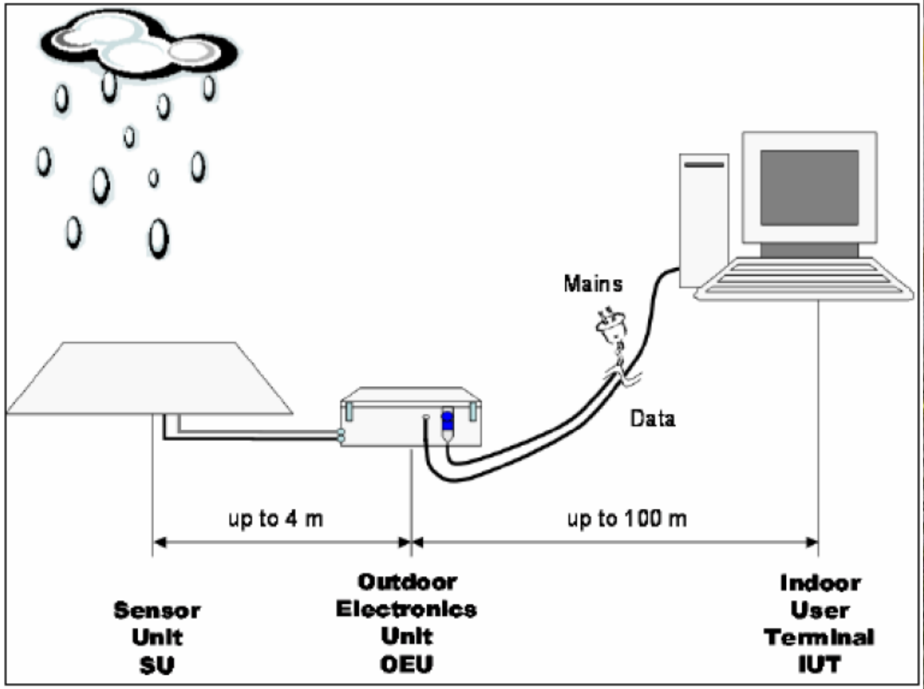
- Date of observation: 2013/08/21 ~ 08/23
- Frequencies:51.5 51.75 52 52.25 52.5(MHz)
- Min Range : 1.5 km
- Range Gate : 80





Experiment

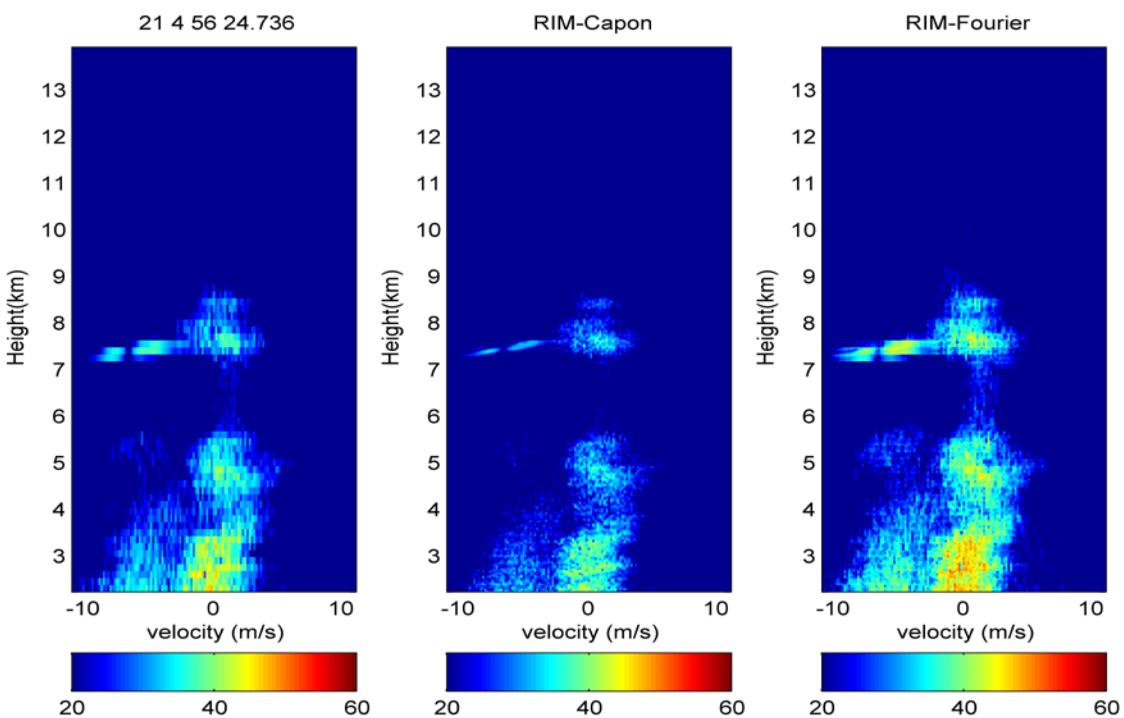
■ Disdrometer



Analysis

■ **Comparison of the spectrum analysis methods for RIM**

Original | Capon | Fourier



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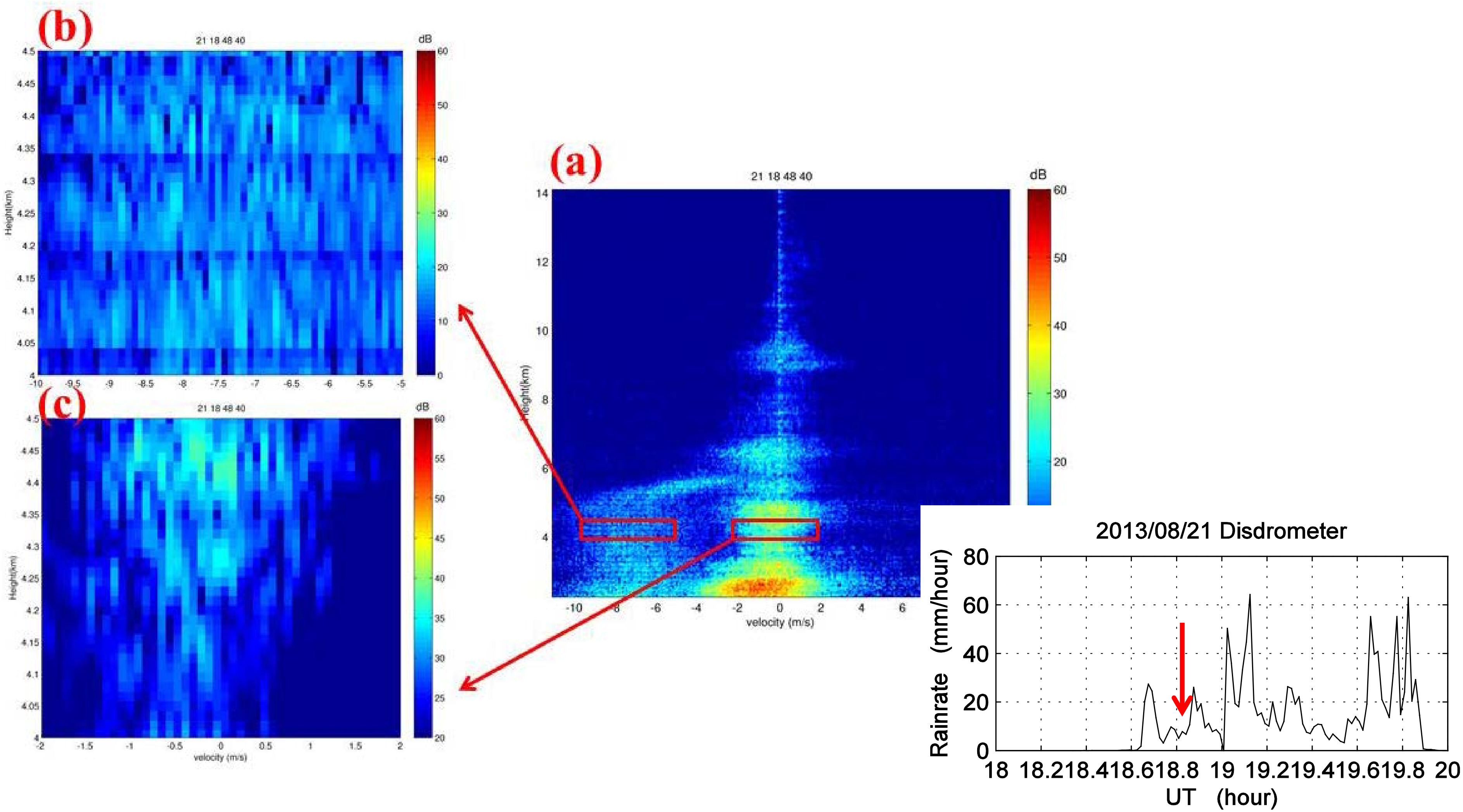
FFT

(Chilson, 2004)

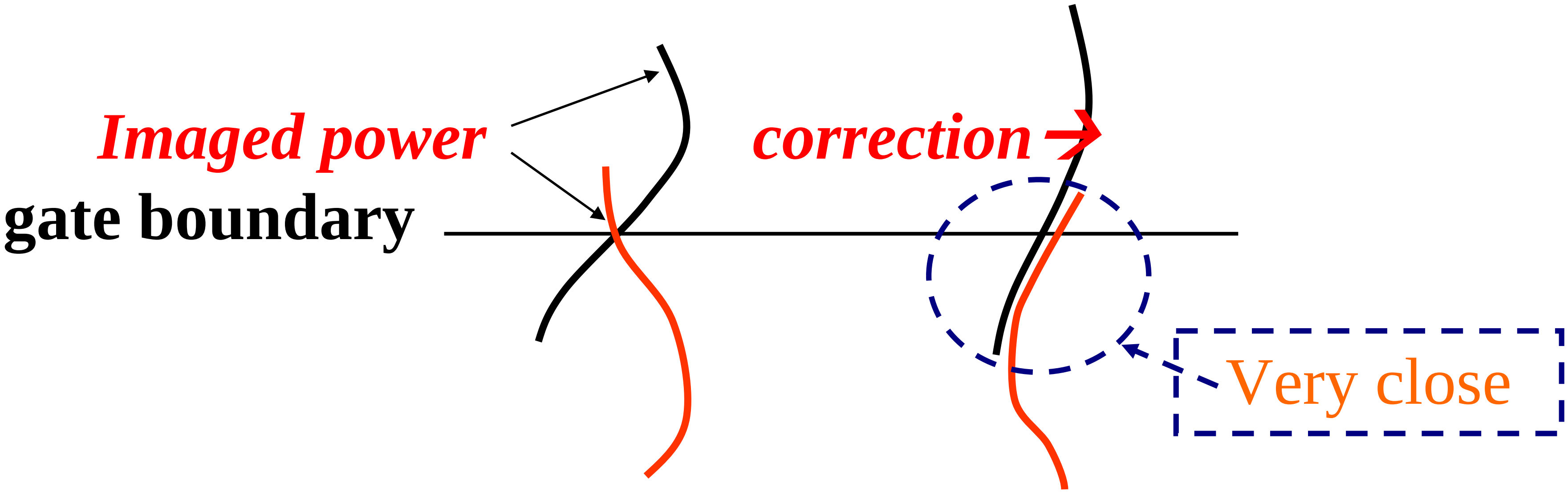
Analysis

■ A new calibration method of precipitation spectrum analysis for RIM



Analysis and discussion

■ A new calibration method for RIM



for $\Phi = 0 : \Delta\Phi : \Phi_{max}$

for $\sigma_z = 0 : \Delta\sigma_z : \sigma_{max}$

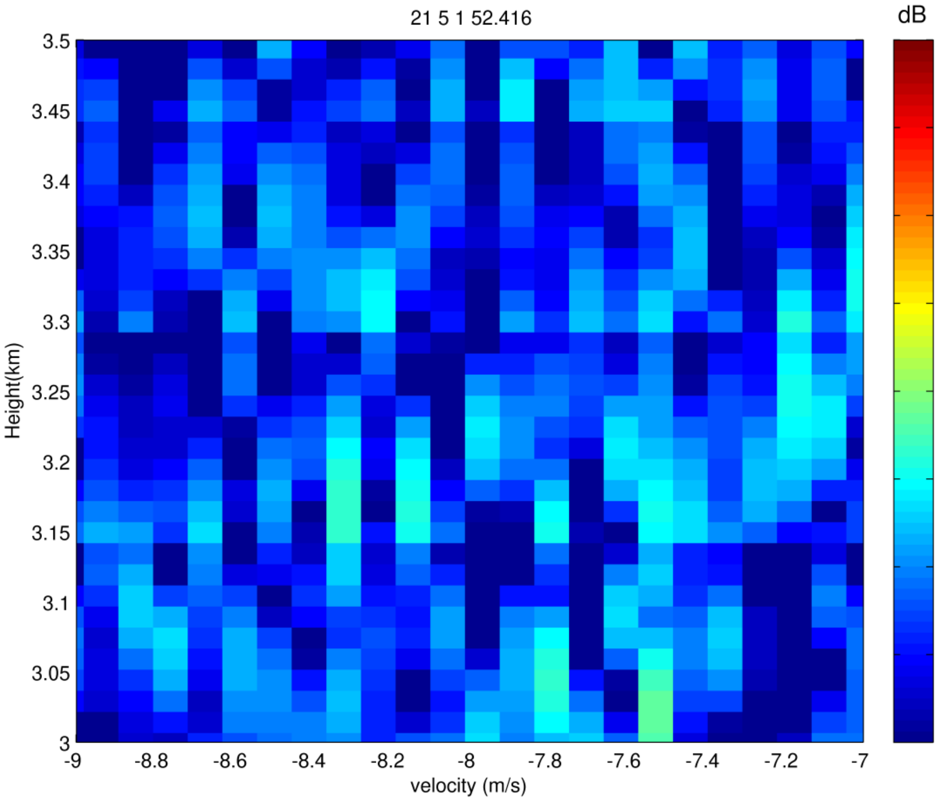
(Chen and Zecha, 2009)

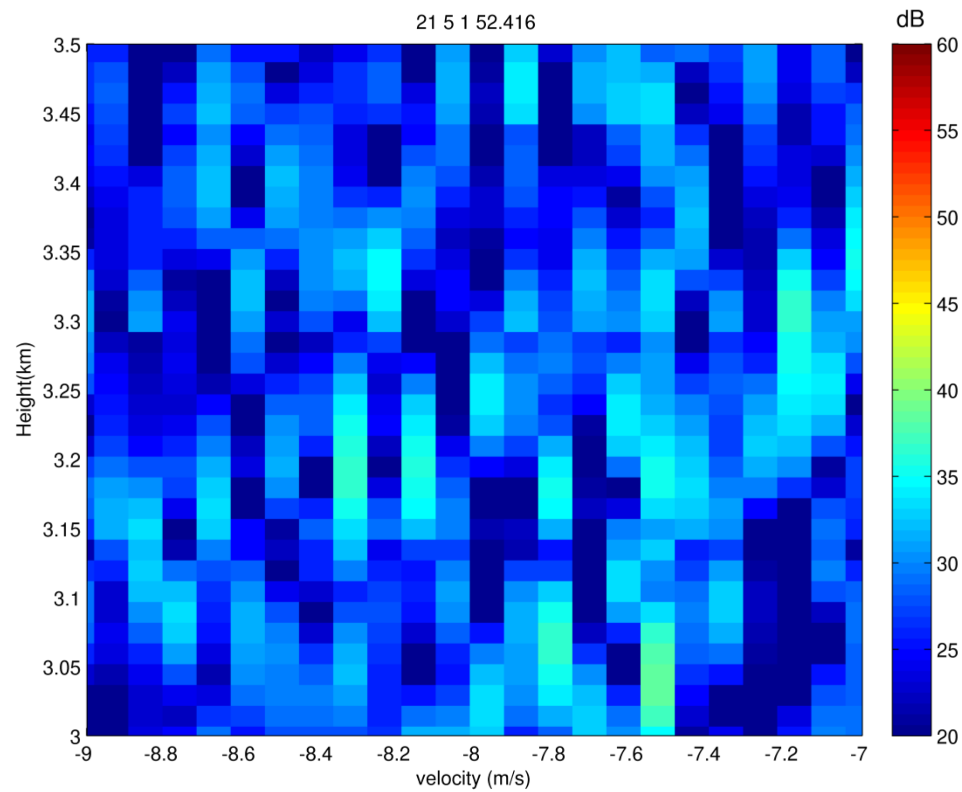
$$error = \sum_{i=1}^{N} \frac{(P_{1i} - P_{2i})^2}{P_{1i}P_{2i}} = \sum_{i=1}^{N} \left(\frac{P_{1i}}{P_{2i}} - 2 + \frac{P_{2i}}{P_{1i}}\right)$$

Analysis and discussion

■ **A new calibration method for RIM**

2013/08/21- 1301LT



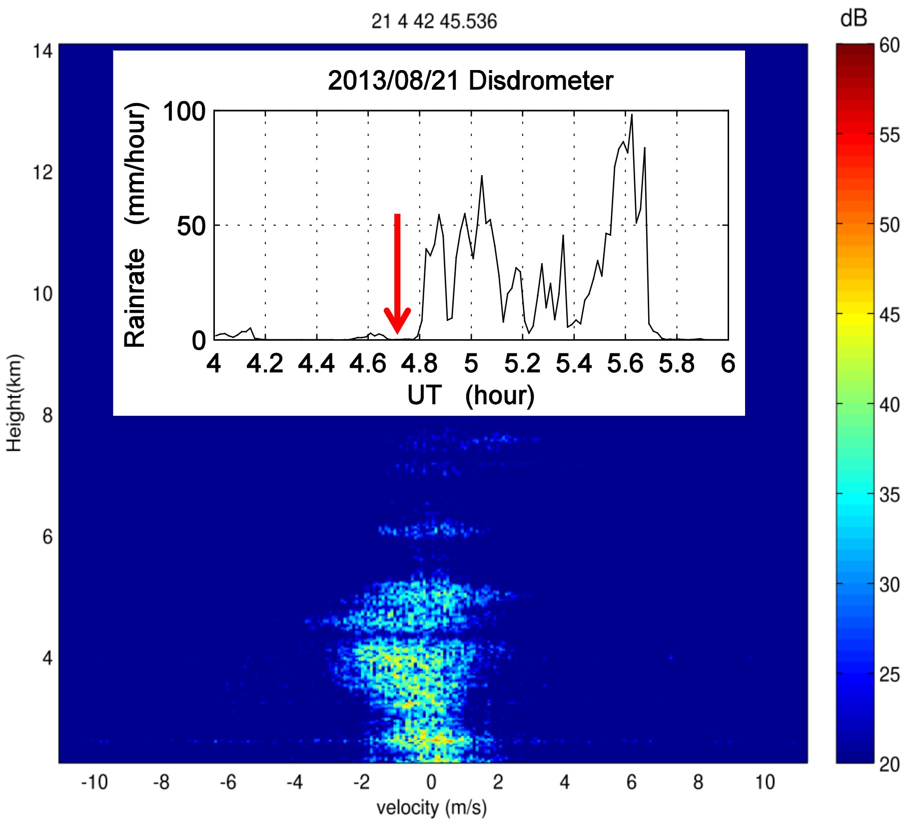


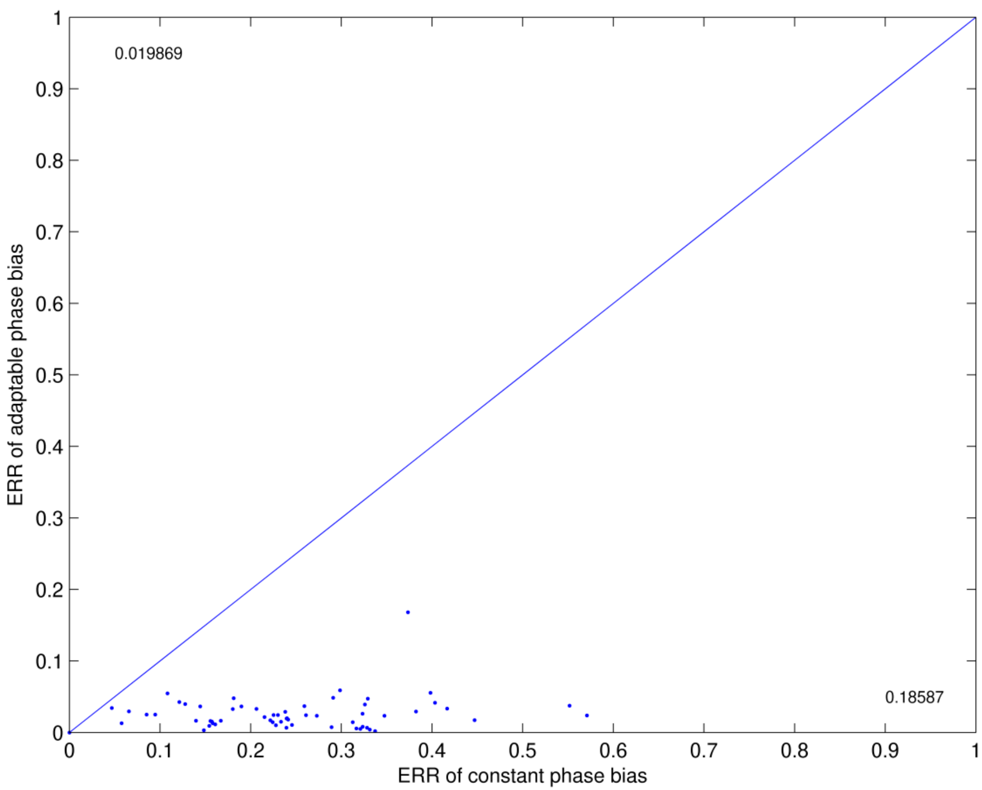
Constant phase bias

Adaptable phase bias

Analysis

■ A new calibration method of precipitation spectrum analysis for RIM

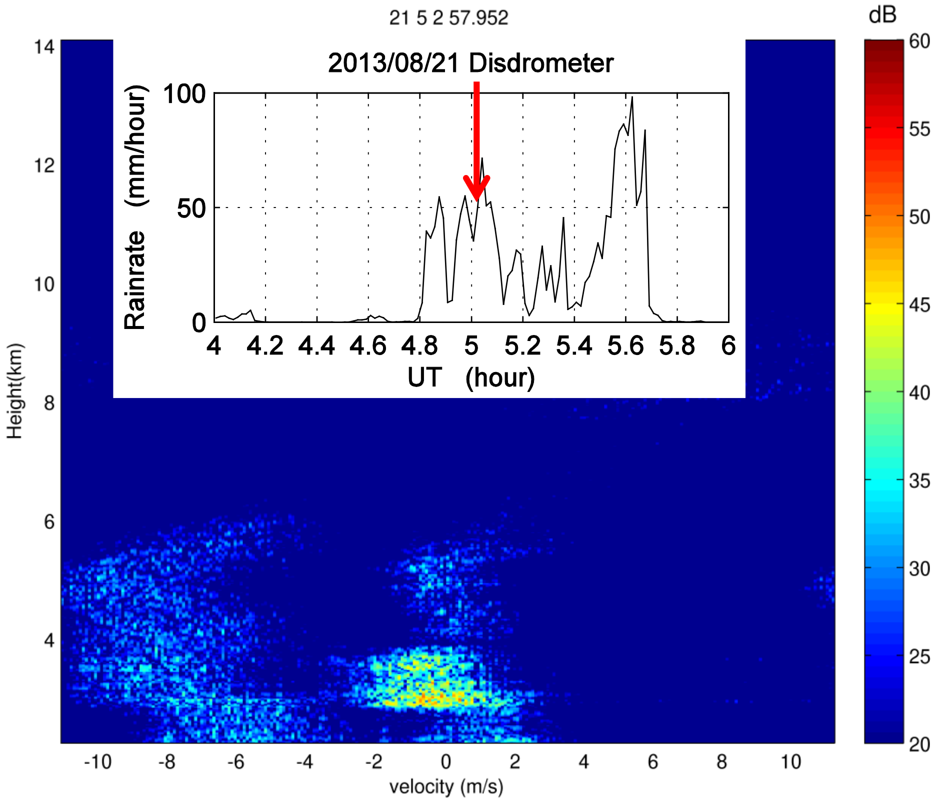


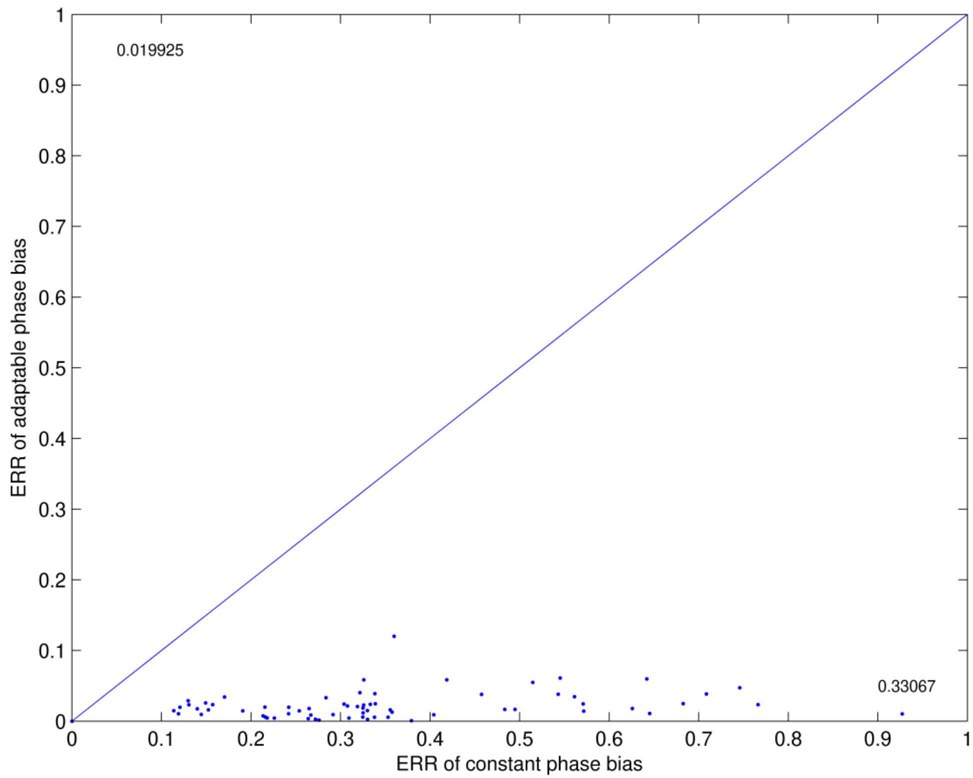


Constant phase bias compare to Adaptable phase bias

Analysis

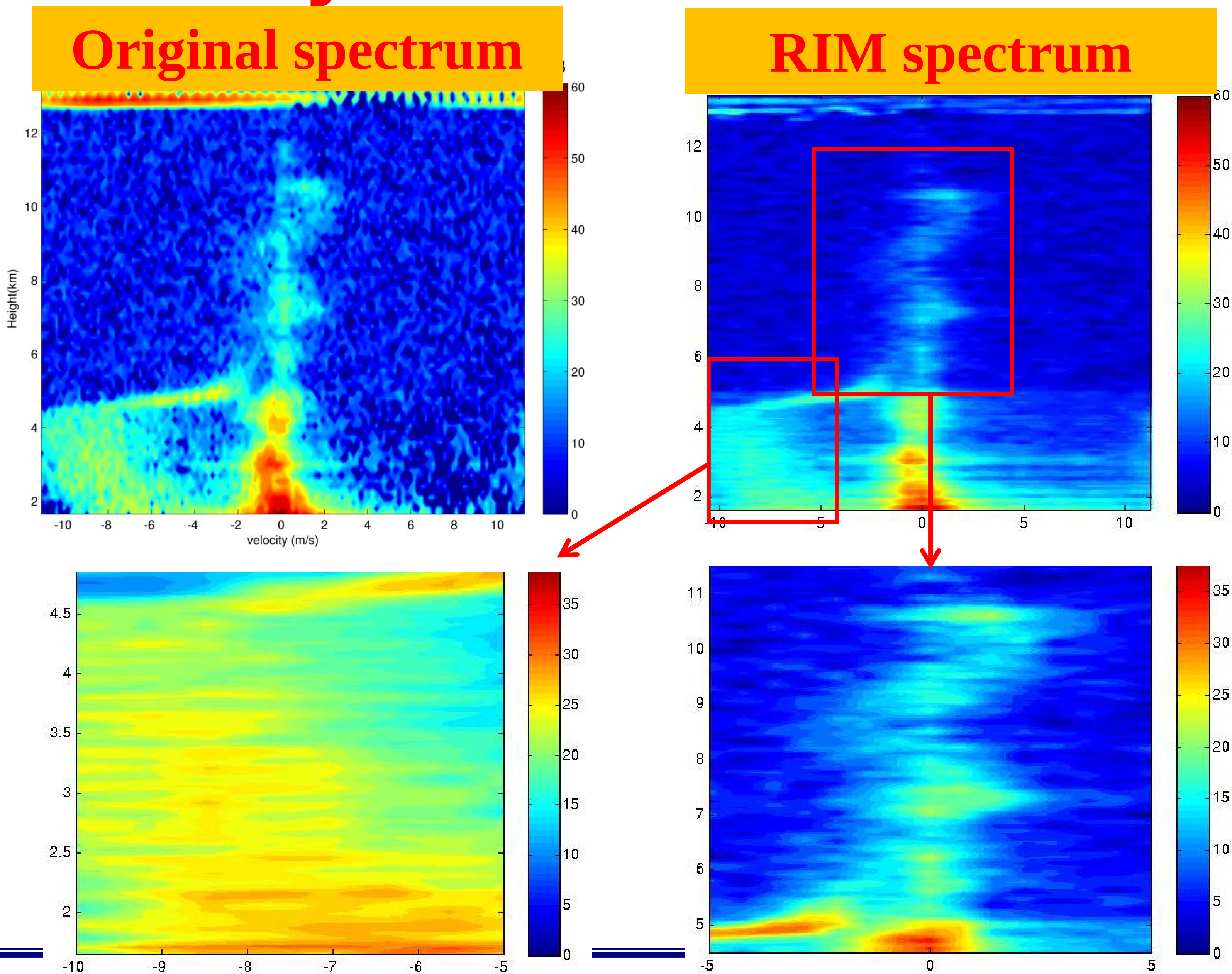
■ A new calibration method of precipitation spectrum analysis for RIM





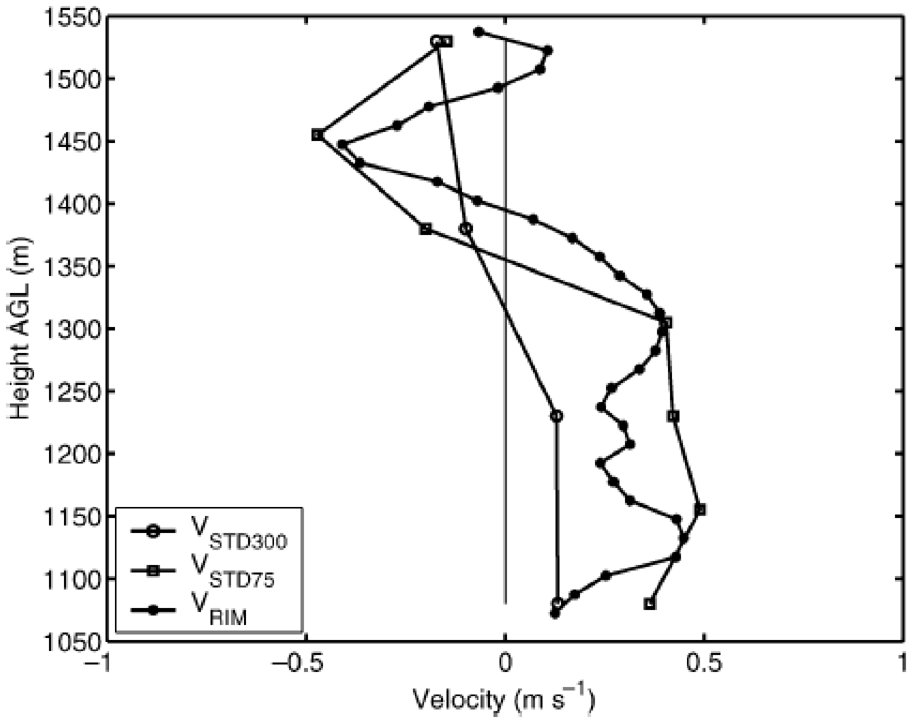
Constant phase bias compare to Adaptable phase bias

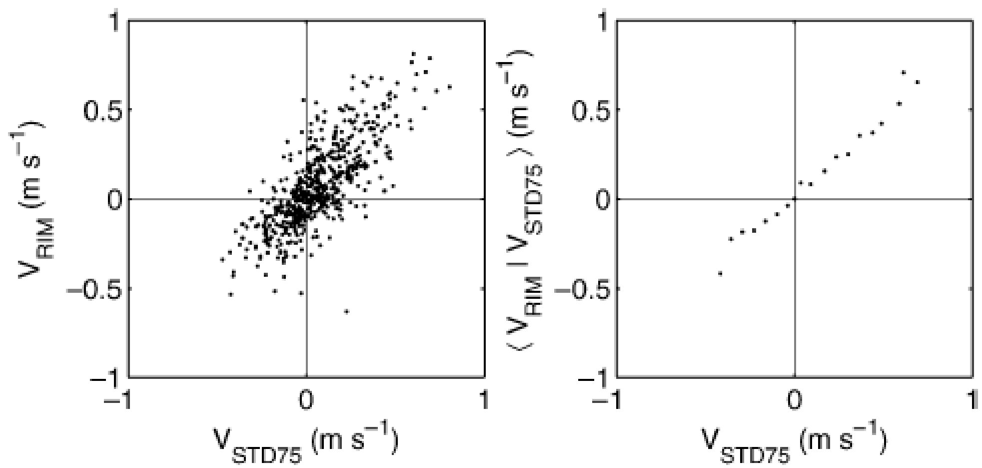
Analysis and discussion



Analysis

■ The validation of precipitation velocity and spectrum width estimates from RIM





$$\langle y|x\rangle = \rho\frac{\sigma_y}{\sigma_x}x. \tag{12}$$

Therefore, the slope $s \equiv \partial\langle y|x\rangle/\partial x$ proves to be simply

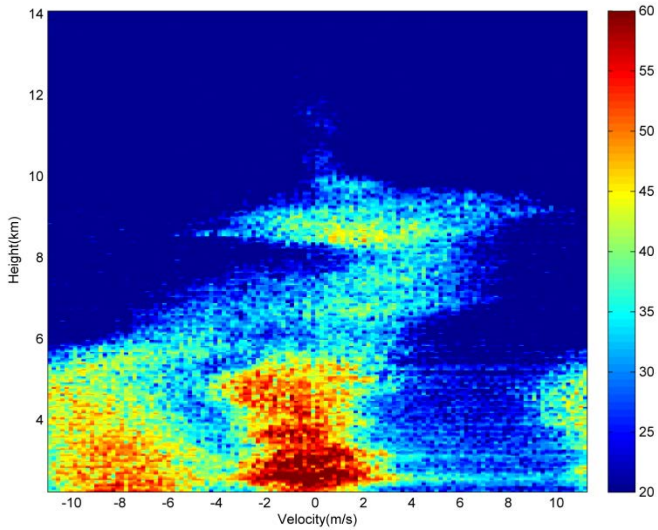
$$s = \rho\frac{\sigma_y}{\sigma_x}. \tag{13}$$

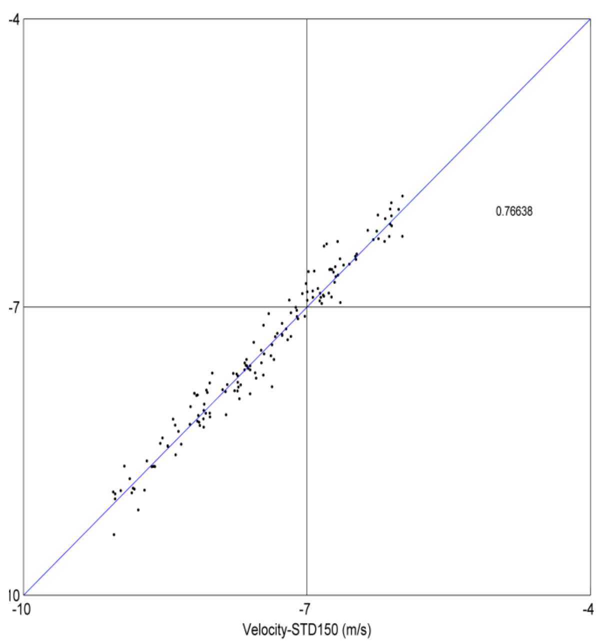
(Chilson, 2004)

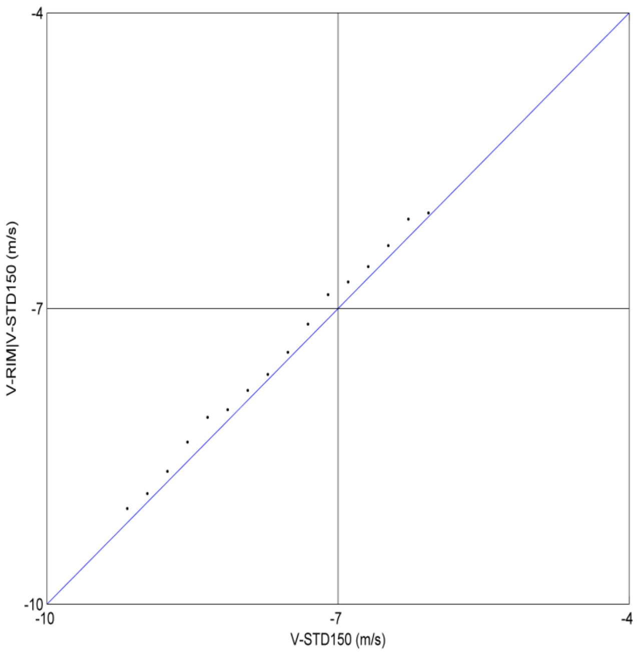
Analysis

■ The validation of precipitation velocity and spectrum width estimates from RIM

Stratiform precipitation





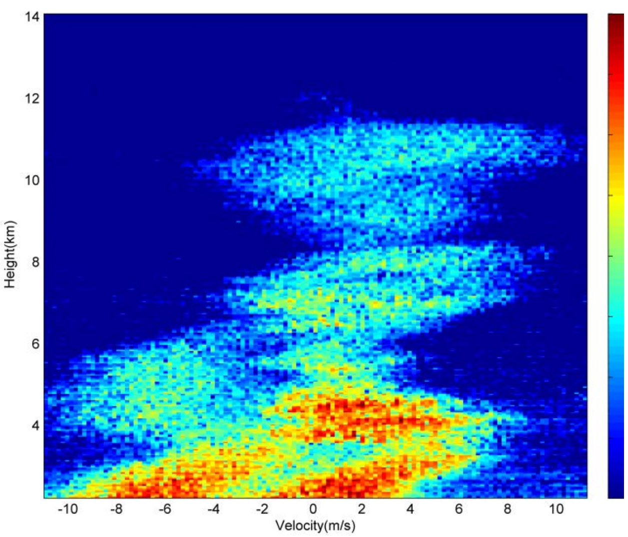


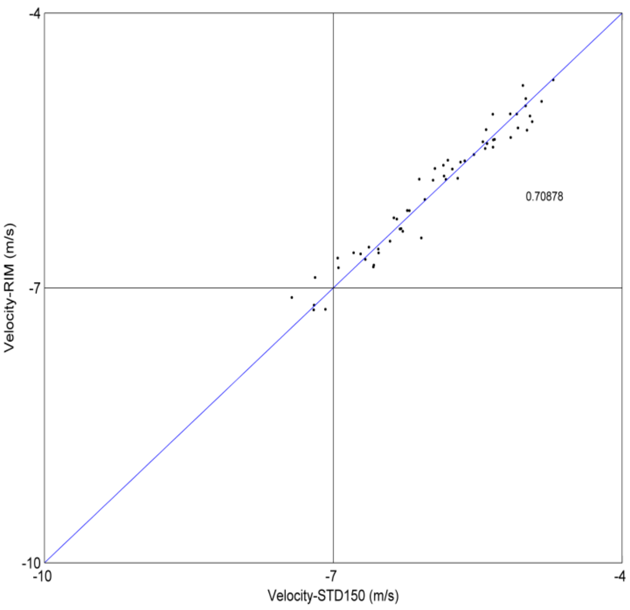
Doppler velocity

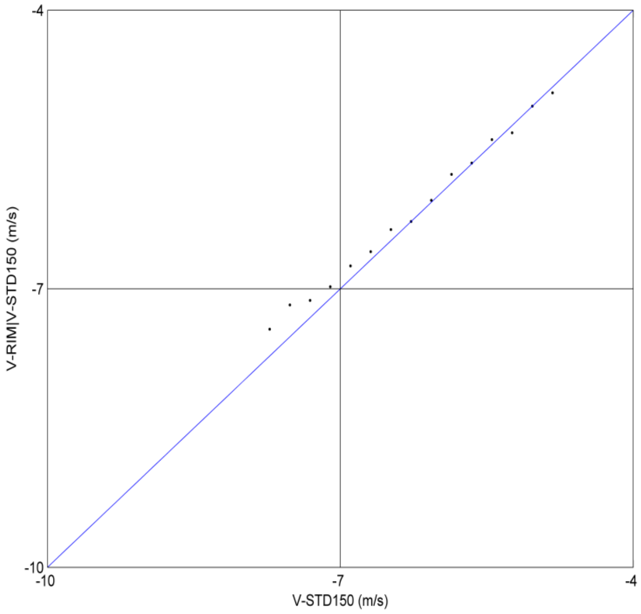
Analysis

■ The validation of precipitation velocity and spectrum width estimates from RIM

Convective precipitation







Doppler velocity

Conclusion

- RIM-Capon performed better in noise suppression than RIM-Fourier, but it also inhibit the precipitation echo power.

- The difference between the two sets of imaged power spectra around the edge of two adjacent range gates can be reduced after a procedure of adaptable phase bias correction.

- In the case of stratiform precipitation, RIM is providing the needed resolution to detect the velocity field; In the case of convective precipitation, RIM performed better when velocity is larger.

Thank you!