Poster ID : 275

Calibration of System bias in Z_H and Z_{DR} of S-band Dual-Polarization Radar

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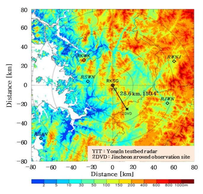
INTRODUCTION

- Polarization capability of weather radar contributes to improvement of radar data quality control, advanced quantitative precipitation estimation (QPE), and development of hydrometeor classification. However, radar measurements suffered from the mis-calibration of radar system, this error leads to significant uncertainty in radar-based QPE as well as hydrometeor classification.
- In this study, we analyzed long-term variability of calibration bias in Z_H and Z_{DR} measurements from S-band dual-polarization radar to product stable and accurate system bias of radar.
- Two Z_H biases were derived based on the self-consistency principle between Z_H and specific differential phase (K_{DP}) and the direct comparison with simulated Z_H from two-dimensional video disdrometer (2DVD), respectively. Z_{DR} biases were calculated by using three approaches based on empirical relationship between Z_H and Z_{DR}, vertical pointing measurements, and direct comparison with simulated Z_{DR} from 2DVD.

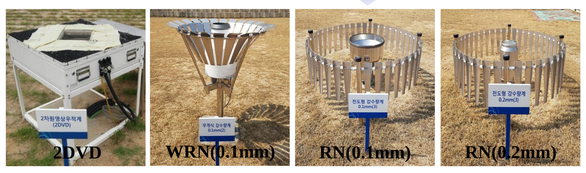
DATA

❖Data

- **Yong-in S-band TESTBED Radar (YIT)**
  - Variable : *Z, V, SW, Z_{DR}, Φ_{DP}, K_{DP}, ρ_{hv}*
  - Antenna height : 473.03 m
  - Obs. Interval / Range : 10 (or 5) min / 240 km
  - Elevation angles : 0.2°~9.69° (11 elevations)
  - Vertical pointing measurement (30 min, 90°)
- **Jincheon ground observation site**
  - ~ 28 km from YIT



Instruments	Abbreviation	Unit
2-Dimenstional Video Disdrometer	2DVD	1
Weighing raingauge (0.1mm)	WRN01	2
Tipping bucket raingauge (0.1mm)	RN01	3
Tipping bucket raingauge (0.2mm)	RN02	3



- **Period : 2015. 5 ~ 2016. 10 rainfall cases (19 cases)**
  - 2DVD measurements with a rainfall difference of less than 20 % are used

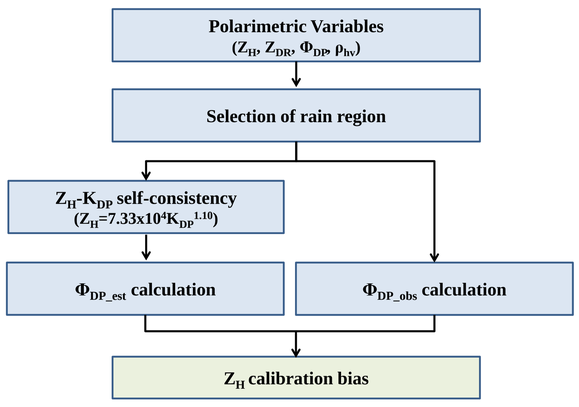
Date	Obs. Time [KST]	Rainfall [mm]		Rainfall difference [%]	Date	Obs. Time [KST]	Rainfall [mm]		Rainfall difference [%]
		2DVD	Avg_RN01				2DVD	Avg_RN01	
`15.05.11	1200-2400	12.0	13.4	10.7	`16.05.03	0000-2400	23.6	26.2	9.8
`15.06.26	0000-1400	31.0	37.4	17.0	`16.05.10	0000-2400	16.9	18.3	7.7
`15.07.12	0000-2400	24.0	26.9	10.6	`16.05.24	0000-1600	15.8	17.7	10.4
`15.07.23	1000-2400	44.2	46.4	4.8	`16.07.01	0500-2400	65.0	78.5	17.26
`15.10.27	0000-1200	15.3	18.2	15.7	`16.09.17	0000-1400	25.7	30.4	15.3
`15.11.13	0000-2400	24.2	27.9	13.3	`16.10.05	0000-1400	10.6	12.2	13.6
`16.04.07	0000-1100	15.7	18.2	14.0	`16.10.07	1200-2400	11.6	13.7	14.9
`16.04.13	0000-1200	15.1	17.1	11.5	`16.10.08	0000-1200	9.81	11.4	14.2
`16.04.16	1100-2400	17.9	20.4	12.4	`16.10.25	0000-1100	28.1	32.5	13.66
`16.05.02	1700-2400	12.8	14.2	9.6					

METHODOLOGY

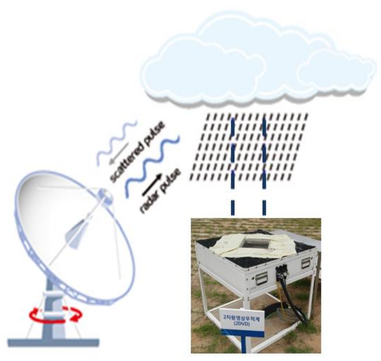
❖Calibration bias algorithms

- **Absolute calibration of Z_H**
  - Z_H can be calibrated by using 1) self-consistency of polarization radar, and 2) 2DVD measurements

	Method	Description
Z_H bias	① Z_H-K_{DP} self-consistency (Z_H=7.33x10^4$K_{DP}^{1.10}$)	Self-consistency constraint between Z_H and K_{DP} (Goddard et al. 1994)
	② 2DVD	Direct comparison with simulated Z_H from 2DVD measurements



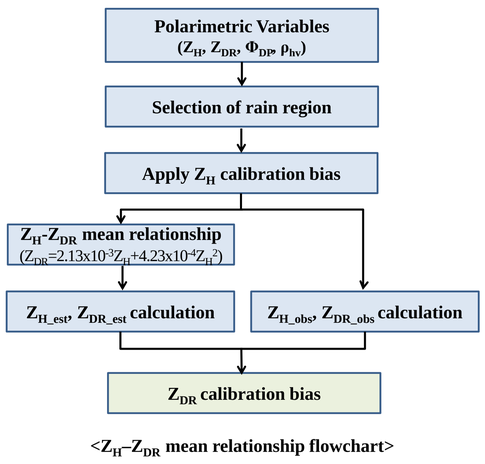
<Z_H-K_{DP} self-consistency flowchart>



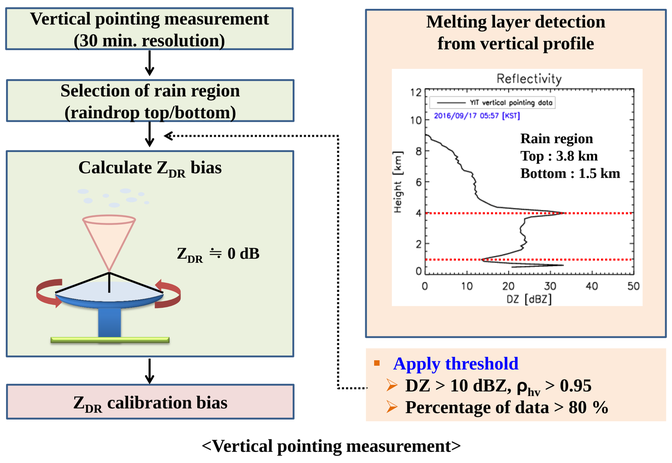
<Comparison of observed Z_H with simulated Z_H from the 2DVD>

- **Calculation of System Bias in Z_{DR}**
  - Z_{DR} calibration biases are calculated by three methods :

	Method	Description
Z_{DR} bias	① Z_H-Z_{DR} mean relationship (Z_{DR}=2.13x10^{-3}Z_H+4.23x10^{-4}Z_H^2)	The average Z_H-Z_{DR} relationship is compared with radar measured Z_H and Z_{DR}
	② vertical pointing	Vertical pointing measurements (Gorgucci et al. 1999)
	③ 2DVD	Direct comparison with simulated Z_{DR} from 2DVD measurement



<Z_H–Z_{DR} mean relationship flowchart>



<Vertical pointing measurement>

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- Goddard, J. W., J. Tan, and M. Thurai.: Technique for calibration of meteorological radar using differential phase. Electon. Lett., 30, 166-167, 1994.
- Gorgucci, E., G. Scarchilli, and V. Chandrasekar.: A procedure to calibrate multiparameter weather radar using properties of the rain medium. IEEE Trans. Geosc. Remote Sens., 37, 269-276, 1999.

ACKNOWLEDGMENTS

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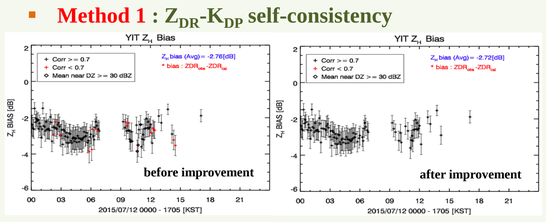
RESULTS

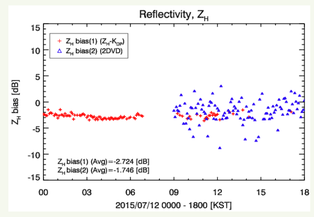
❖Cases 1 : 12 July 2015

- Hourly rain rate < 5 mm hr^{-1}, Total rainfall Acc. : 26.9 mm (RN01_Avg)

❖ Z_H calibration bias

- **Method 1 : Z_{DR}-K_{DP} self-consistency**



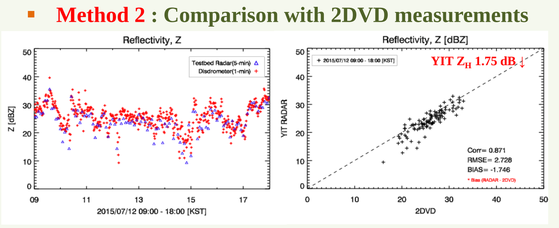


- Corr. < 0.7 remove
- Mean Area DZ ≥ 30 dBZ remove (attenuation effect)

<Time series of the Z_H bias according to calibration methods>

Calibration methods	Z_H Calibration bias [dB]	difference [dB]
Method 1	-2.72	0.97
Method 2	-1.75	

- **Method 2 : Comparison with 2DVD measurements**

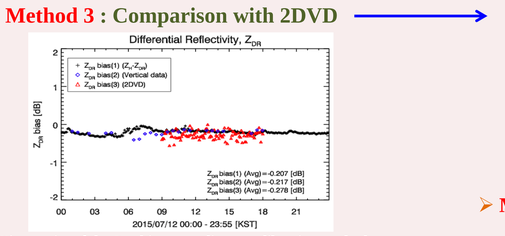


<Time series and scatter plot of the Z_H obtained by 2DVD and YIT radar>

- **Method 1** : Z_H biases are stable, however the number of bias is small even though it is raining
- **Method 2** : Z_H biases are affected by the precipitation system that passes over the 2DVD
  => variation of bias is larger than method 1

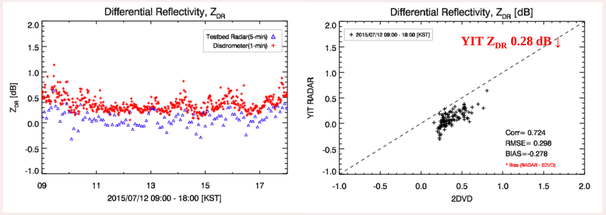
❖ Z_{DR} calibration bias

- **Method 1 : Z_H-Z_{DR} mean relationship**
- **Method 2 : Vertical pointing measurements**
- **Method 3 : Comparison with 2DVD**



<Z_{DR} bias time series according to calibration methods>

Calibration methods	Z_{DR} Calibration bias [dB]
Method 1	-0.21
Method 2	-0.22
Method 3	-0.28



<Z_{DR} bias time series and scatter plot of the Z_{DR} obtained by 2DVD and YIT radar>

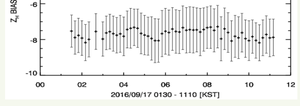
- **Method 1** : using the Z_{DR} data of the 10 ~ 20 dBZ section with small microphysical change
  ⇒ Z_{DR} biases value are stable and many data are used for the calculation
- **Method 2** : a stable Z_{DR} biases are calculated at the time of the precipitation passes over the radar site
- **Method 3** : variation of bias is larger than other methods

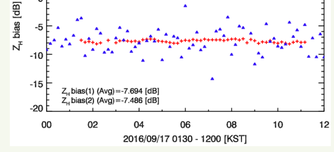
❖Cases 2 : 25 October 2016

- Hourly rain rate < 5 mm hr^{-1}, Total rainfall Acc. : 26.9 mm (RN01_Avg)

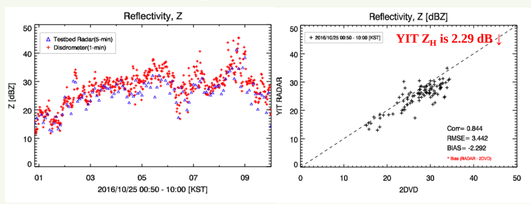
❖ Z_H calibration bias

- **Method 1 : Z_{DR}-K_{DP} self-consistency**



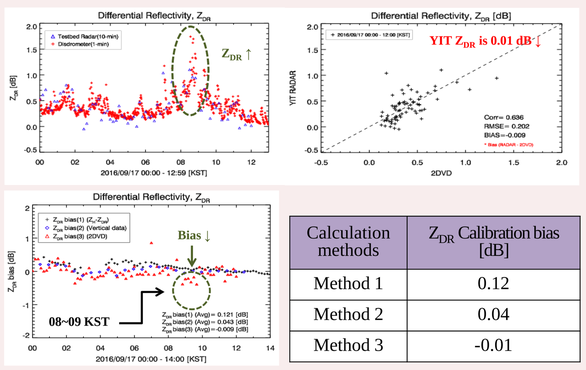


- **Method 2 : Comparison with 2DVD measurements**

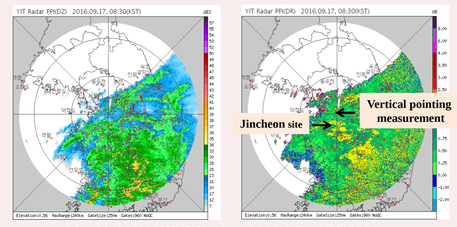


Calibration methods	Z_H Calibration bias [dB]	difference [dB]
Method 1	-7.69	0.20
Method 2	-7.49	

❖ Z_{DR} calibration bias



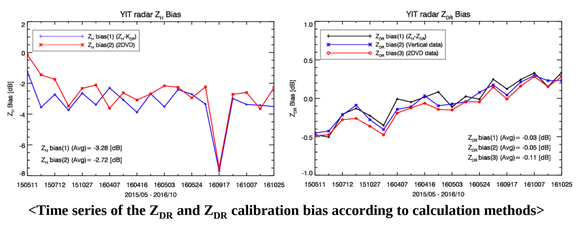
Calculation methods	Z_{DR} Calibration bias [dB]
Method 1	0.12
Method 2	0.04
Method 3	-0.01



< 17 Sep 2016 0830 KST (left) DZ and (right) Z_{DR} 0.56° PPI>

➢ **Method 3** : Z_{DR} bias calculated from the 2DVD also fluctuated around 08~09 KST, when the Z_{DR} greatly fluctuated
⇒ Biases depending on the precipitation system in the observed space

❖Result : May 2015 ~ October 2016 (19 rainfall cases)



<Time series of the Z_{DR} and Z_{DR} calibration bias according to calculation methods>

	Calibration method		Z_H bias (Avg)	Difference
Z_H calibration bias	Z_H-K_{DP}	Method 1	-3.28 dB	0.56 dB
	2DVD	Method 2	-2.72 dB	
Z_{DR} calibration bias	Z_H-Z_{DR}	Method 1	-0.03 dB	0.06~0.08 dB (method 3 standard)
	Vertical pointing	Method 2	-0.05 dB	
	2DVD	Method 3	-0.11 dB	

- Temporal trend of Z_H and Z_{DR} biases are well matched with each other
- However, the standard deviation of both Z_H and Z_{DR} biases obtained from 2DVD measurements were relatively larger than other methods
  ⇒ due to DSD variability in vertical, drop sorting, under–sampling problem of 2DVD
- Stability monitoring of radar system is possible through analysis of calibration bias

SUMMARY

- In this study, we examined calibration bias of Z_H and Z_{DR} according to different calibration methods during the period from May 2015 to October 2016.
- As a result, Z_H mean bias : -3.28 ~ -2.72 dB, Z_{DR} mean bias : -0.03 ~ -0.11 dB

➢ **Z_H calibration bias**
- **Z_H-K_{DP} self-consistency** : this method is stable, however the number of data used for calculation differed according to rainfall cases.
- **2DVD** : Z_H calibration bias is affected by the precipitation system that passes over the 2DVD, and shows more variability compared to Z_H-K_{DP} self-consistency method.

➢ **Z_{DR} calibration bias**
- **Z_H-Z_{DR} relationship** method shows the smallest bias value compared to other methods because it uses the data of the microphysically stable section (Z_H : 10 ~ 20 dBZ)
- **Vertical pointing measurement** : there is a limitation that the 1)Z_{DR} bias can be calculated only when the rainfall system passes over the radar site, 2)depending on the selection of rain regime under the melting layer. However, this method yields a stable bias during the precipitation passes over the radar site.