Retrieval of raindrop size distributions from a vertically profiling micro-rain radar near Cabauw

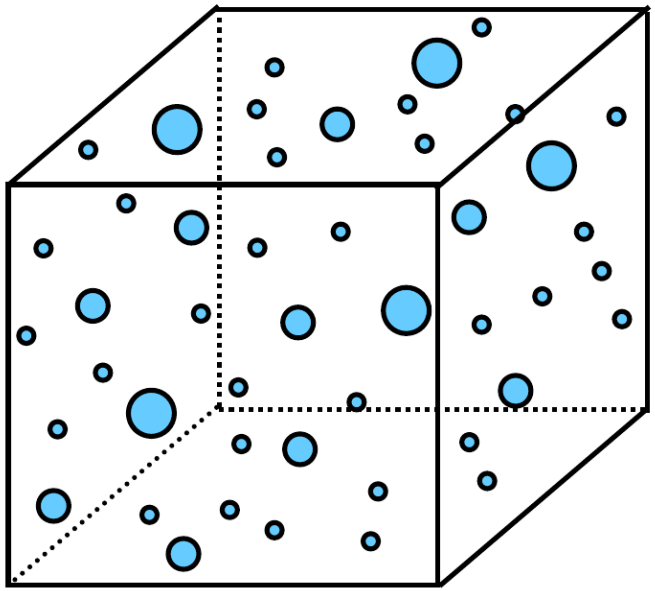
Ruisdael Science Day, 19 June 2019

Ricardo Reinoso Rondinel and Marc Schleiss*

TU Delft

Introduction

What is a raindrop size distribution?



The (rain)drop size distribution (DSD) is a statistical description of:

1. the number of raindrops per m^3
2. their size distribution

DSD is a crucial for understanding:

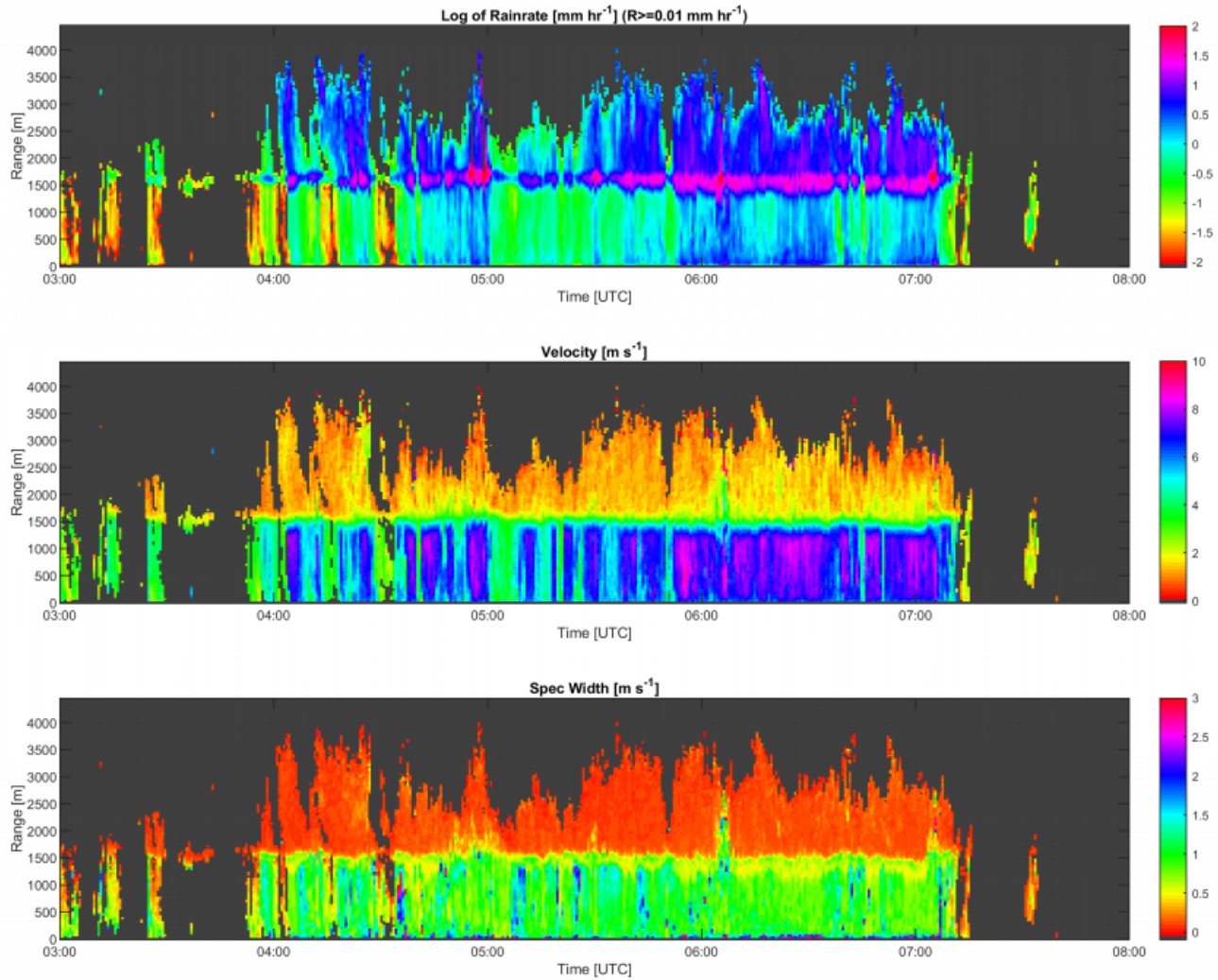
1. microphysics of clouds/rain
2. wet-scavenging of aerosols
3. remote sensing measurements

How are DSDs measured?

- directly on the ground using so-called "disdrometers"
- in the air, using weather radar:
  - Dual-polarization (Zh, Zdr)
  - Doppler spectra

The MRR-Pro (from METEK)

Provides high-resolution (10 s) time-height profiles of rain with 35m range resolution. Measured parameters include reflectivity, rain-rate, vertical velocity and full Doppler spectrum



The 2018-2019 MRR measurement campaign

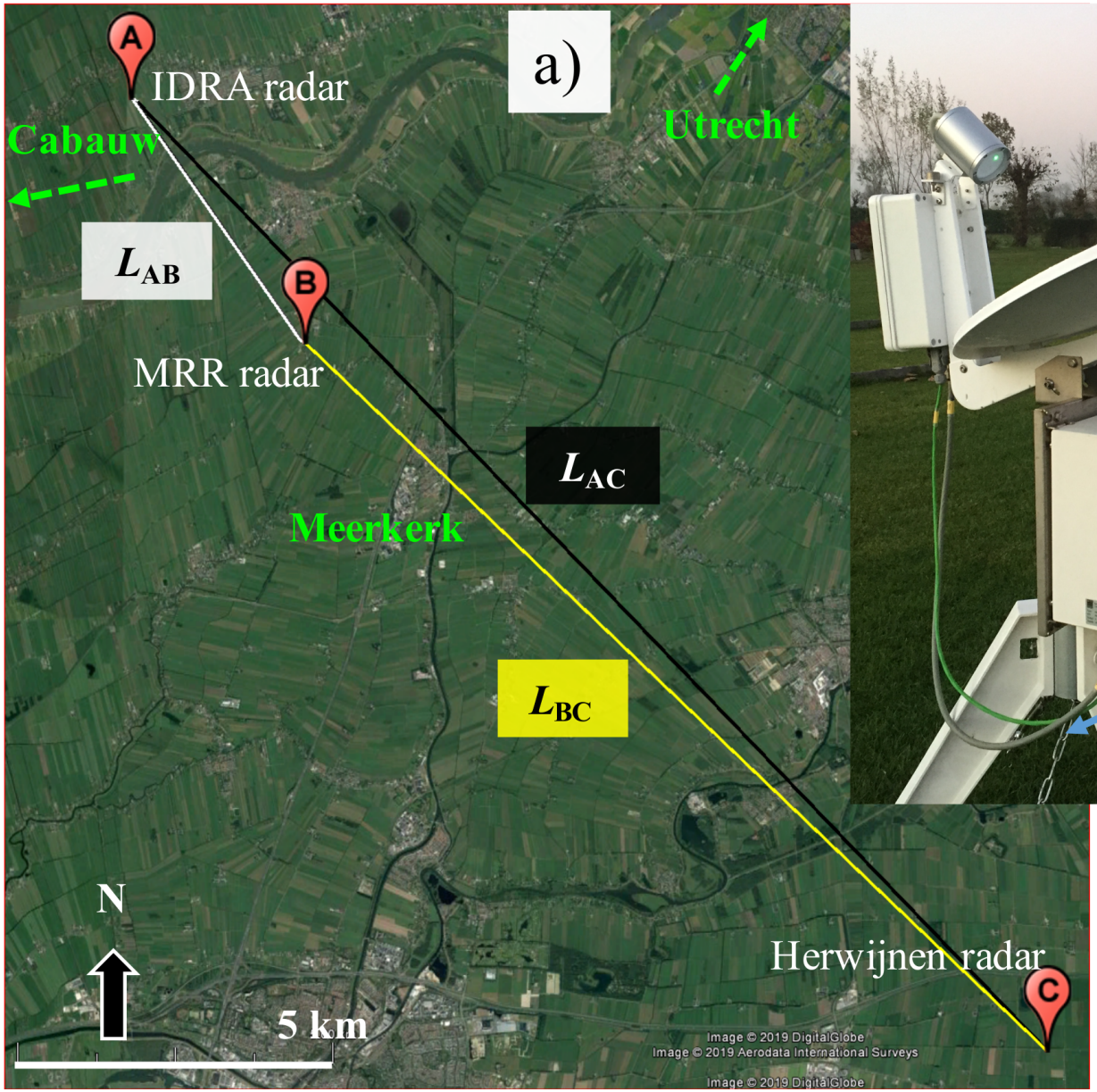
November 2018 to March 2019, camping site "de Victorie" (near Cabauw)

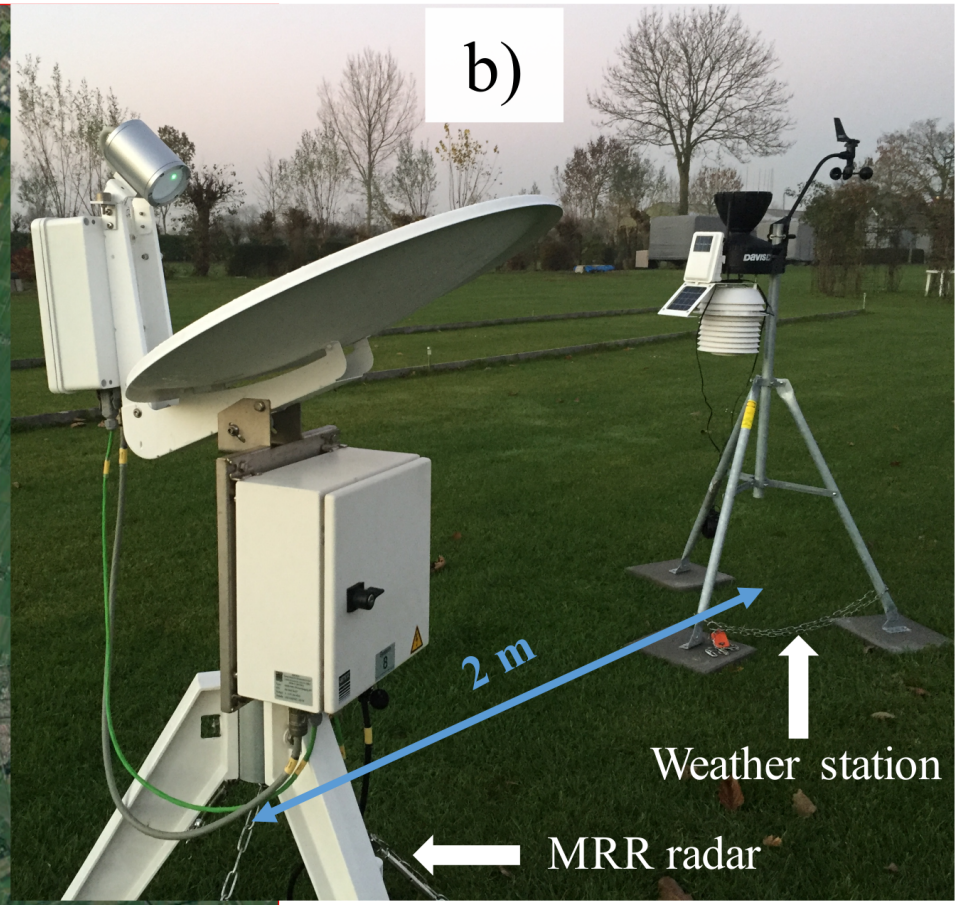
Part 1: July - November 2018

Testing phase at TU Delft

Part 2: Nov 2018 - March 2019

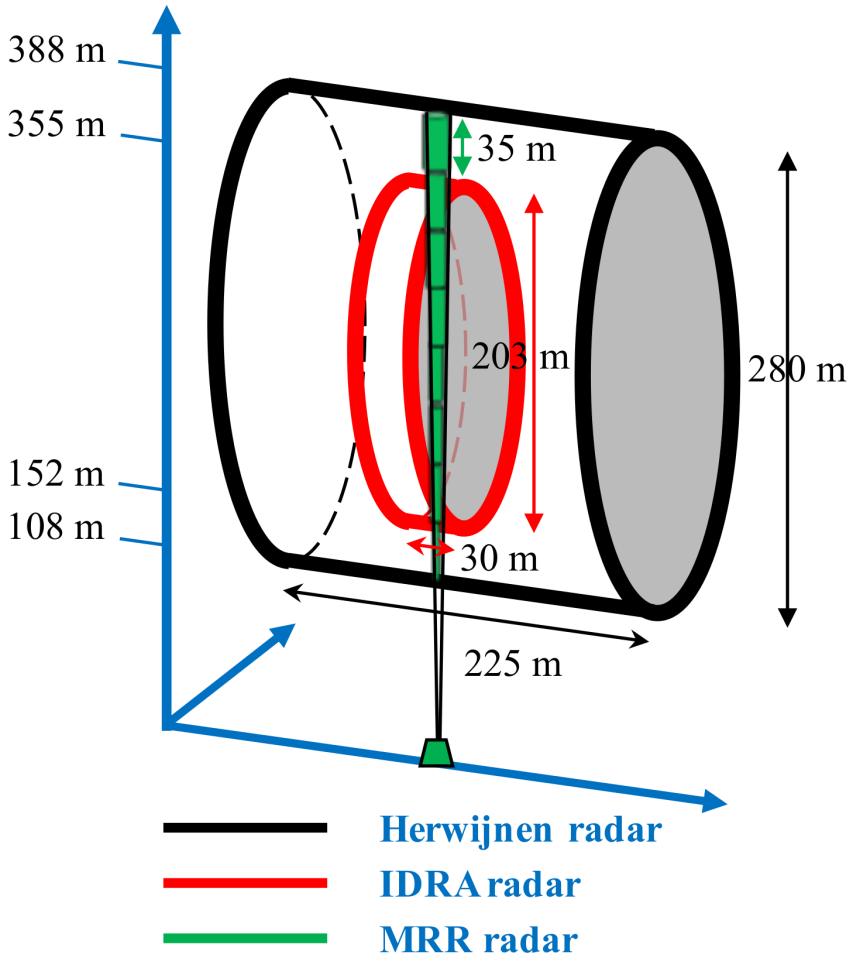
Continuous monitoring phase





L_{AB} = 4.65 km; α_{AB} = 144.84°
L_{BC} = 16.2 km; α_{BC} = 132.97°
L_{AC} = 20.8 km;

Radar Sampling Volumes



Parameter	MRR	IDRA	Herwijnen
Radar type	FMCW	FMCW	Pulsed
Polarization	Single	Full	Dual
Frequency	24.15 GHz	9.475 GHz	5.6 GHz
Range resolution	35 m	30 m	225 m
Max range	4.5 km	15.3 km	187.3 km
Max velocity	12.3 $m\,s^{-1}$	19 $m\,s^{-1}$	24 $m\,s^{-1}$
Velocity resolution	0.1905 $m\,s^{-1}$	0.03 $m\,s^{-1}$	0.189 $m\,s^{-1}$
Revisit time	10 s	1 min	5 min
Beamwidth	2°	1.8°	1°
Height	0 m	213 m	22 m

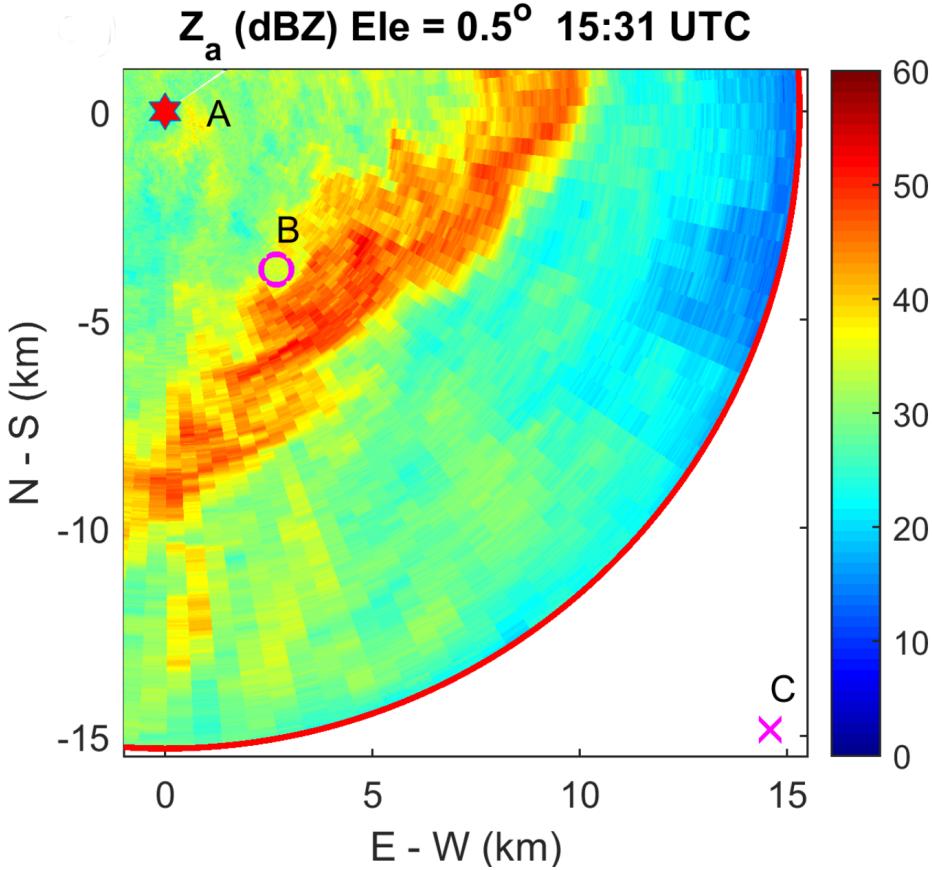
Research questions:

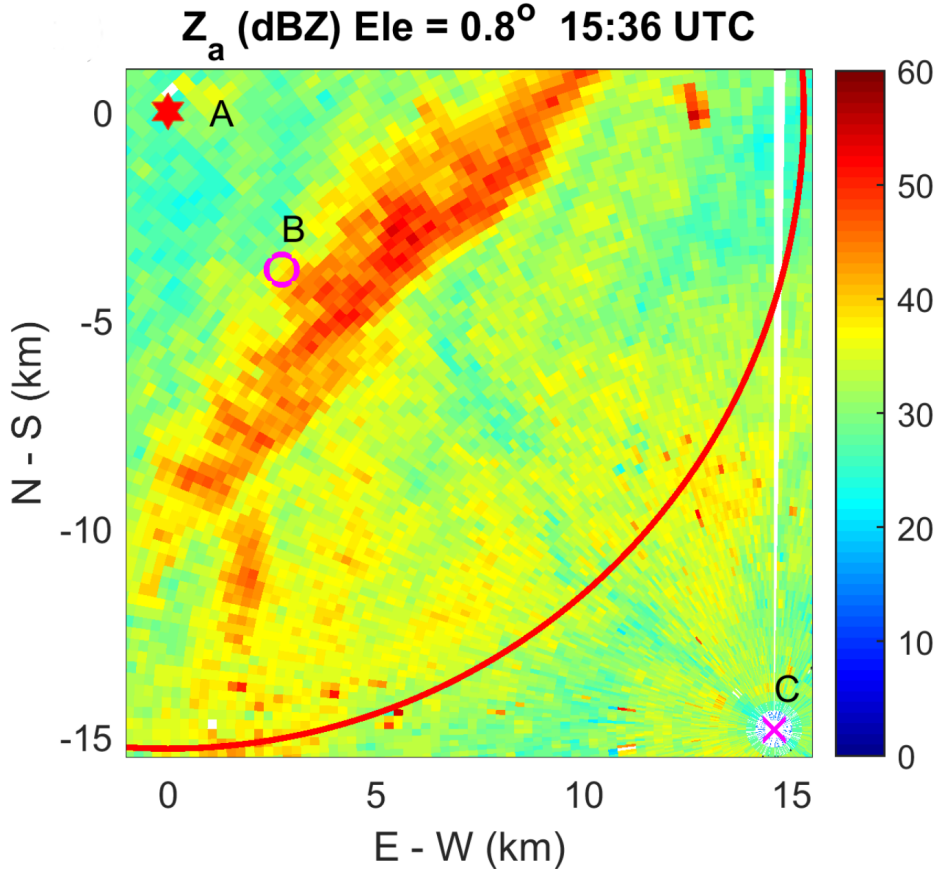
- How well do the 3 radars agree?
- How good are the retrieved DSDs?

Event	Date	Duration (UTC)	Type	Accumulation	R_{max}	W^s_{max}	W^d_{max}	T_{max}
E1	Nov 11	04:00 - 08:00	Heavy	8.8 mm	9.1 mm hr^{-1}	5.3 m s^{-1}	SE	11.2 °
E2	Nov 12	05:00 - 13:00	Moderate	6.7 mm	3.0 mm hr^{-1}	2.7 m s^{-1}	SE	11.5 °
E3	Dec 02	03:00 - 07:00	Moderate	5.6 mm	6.1 mm hr^{-1}	6.2 m s^{-1}	SE	10.3 °
E4	Dec 07	03:00 - 17:00	Heavy	11.8 mm	12.2 mm hr^{-1}	11.1 m s^{-1}	ESE	11.7 °
E5	Dec 08	06:00 - 23:00	Heavy	11.1 mm	9.1 mm hr^{-1}	14.7 m s^{-1}	SSE	10.8 °
E6	Dec 09	04:00 - 23:00	Heavy	7.3 mm	9.1 mm hr^{-1}	12.5 m s^{-1}	S	9.2 °
E7	Dec 21	03:00 - 09:00	Moderate	11.1 mm	6.1 mm hr^{-1}	8.0 m s^{-1}	SE	9.7 °
E8	Dec 22	01:00 - 04:00	Heavy	7.3 mm	12.2 mm hr^{-1}	8.9 m s^{-1}	SSE	9.3 °
E9	Dec 23	09:00 - 23:00	Moderate	10.5 mm	6.1 mm hr^{-1}	5.8 m s^{-1}	WNW	8.1 °
E10	Jan 17	17:00 - 21:00	Moderate	0.5 mm	3.0 mm hr^{-1}	8.0 m s^{-1}	SW	2.1 °
E11	Jan 26	22:00 - 00:00	Moderate	3.5 mm	3.0 mm hr^{-1}	9.4 m s^{-1}	E	6.8 °
E12	Jan 27	01:00 - 13:00	Moderate	6.3 mm	6.1 mm hr^{-1}	8.9 m s^{-1}	SW	7.2 °
E13	Jan 28	00:00 - 10:00	Moderate	3.3 mm	6.1 mm hr^{-1}	11.1 m s^{-1}	WSW	4.8 °
E14	Feb 06	06:00 - 22:00	Moderate	14.0 mm	6.1 mm hr^{-1}	6.7 m s^{-1}	SE	6.7 °
E15	Feb 10	02:00 - 18:00	Moderate	24.9 mm	6.1 mm hr^{-1}	9.8 m s^{-1}	SSE	9.2 °

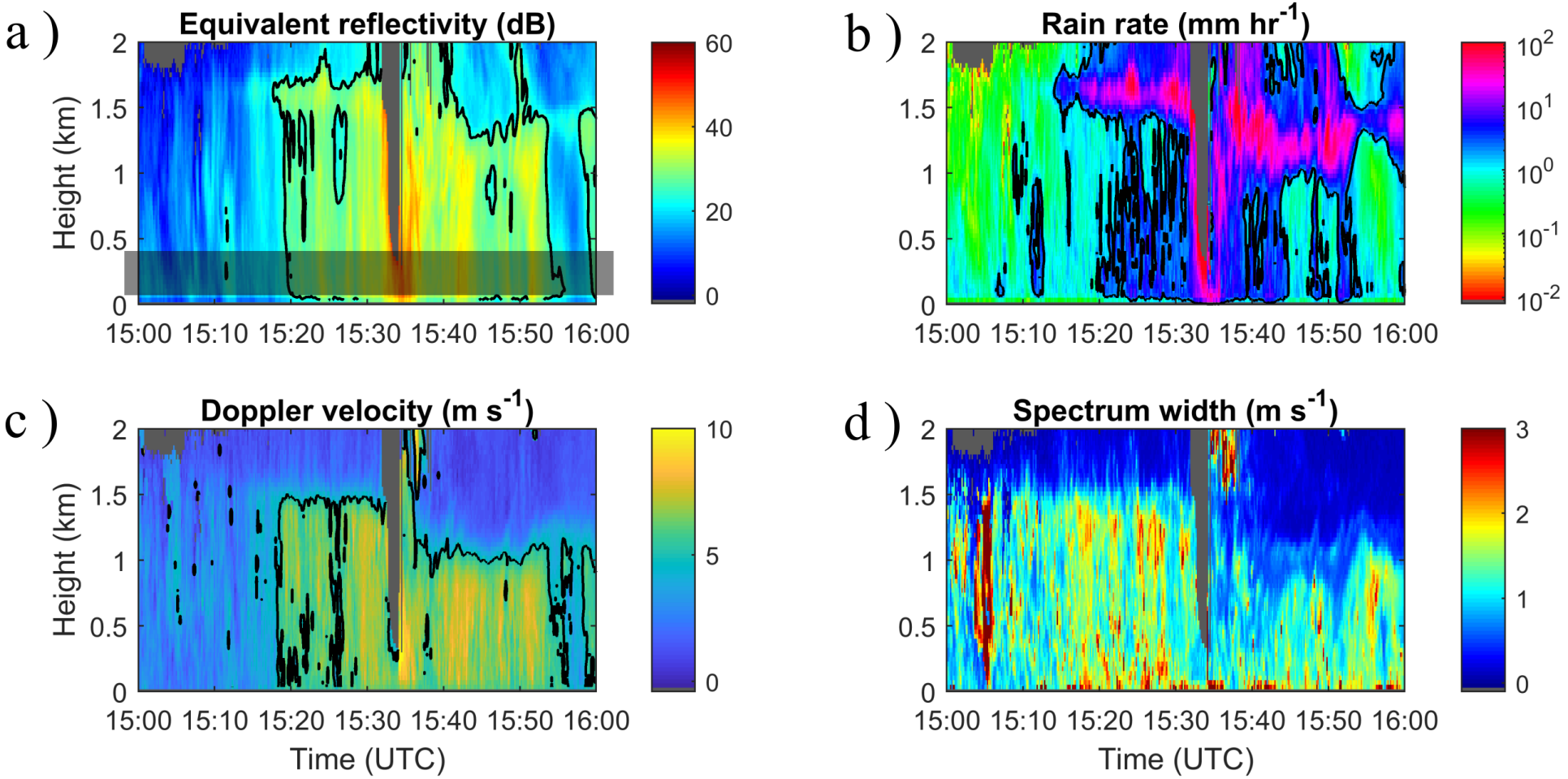
Comparisons between IDRA, Herwijnen & MRR

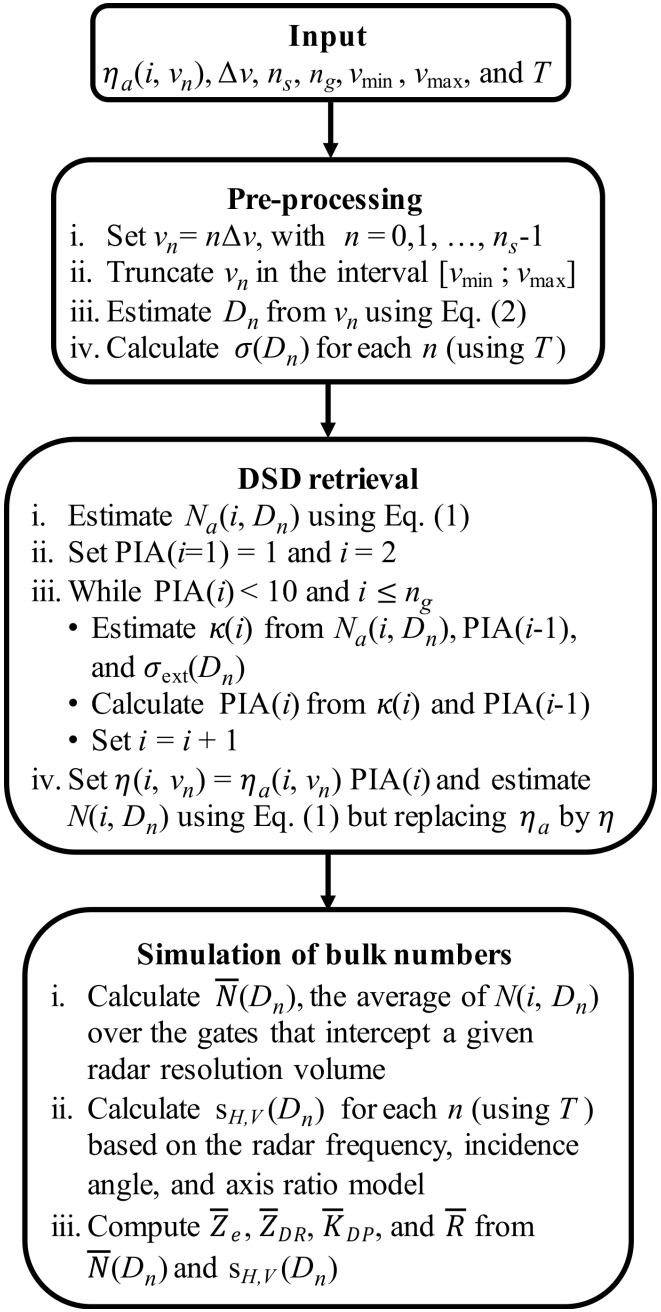
Event 4, Dec 7, 2018





MRR observations Event 4, Dec 7, 2018





DSD Retrieval Algorithm

The DSD is retrieved through the relationship between the Doppler spectra and the fall velocity of raindrops:

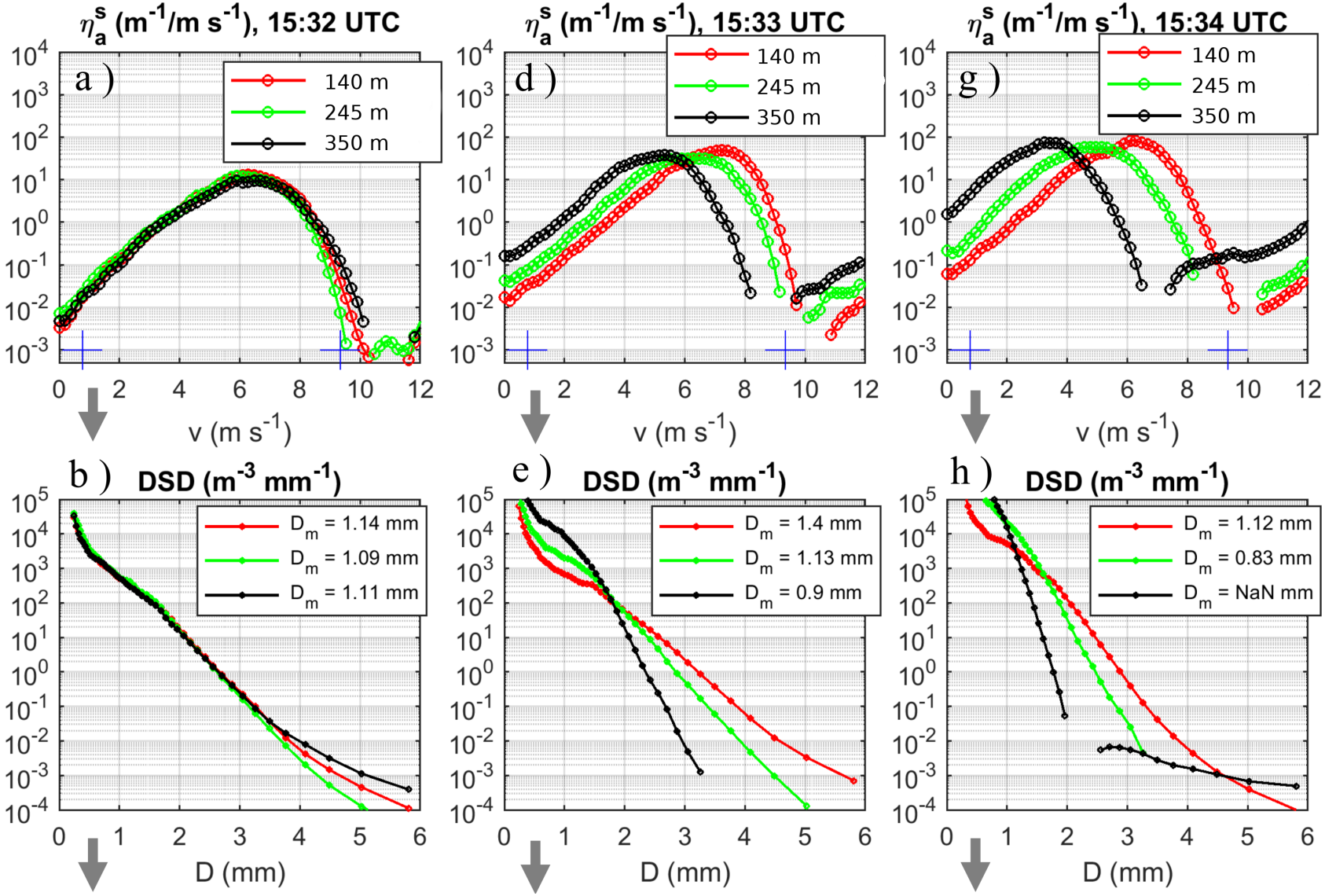
$$N_a(i, D) = \eta_a(i, v) \frac{\partial v}{\partial D} \frac{1}{\sigma_D}$$

with $\frac{\partial v}{\partial D} = 6.18e^{-0.6D}$ (Atlas et al., 1973)
and σ_D = backscattering cross-section of a raindrop of diameter D (at 24.15 GHz)

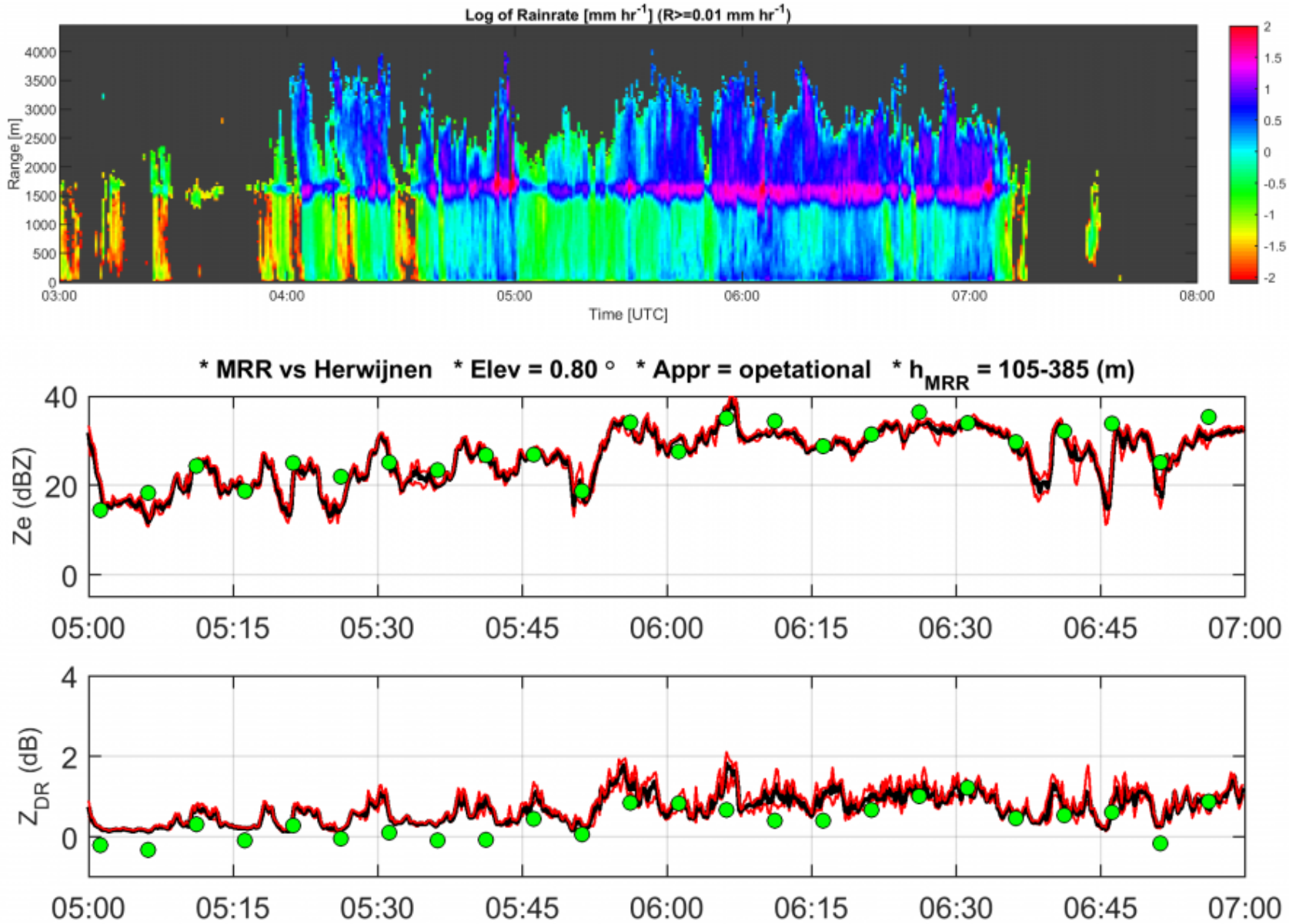
DSDs are corrected for attenuation (iteratively)

Validation is performed by comparing Zh and Zdr from Herwijnen to theoretical values calculated from the DSD

Example of retrieved DSDs (7 Dec 2018)

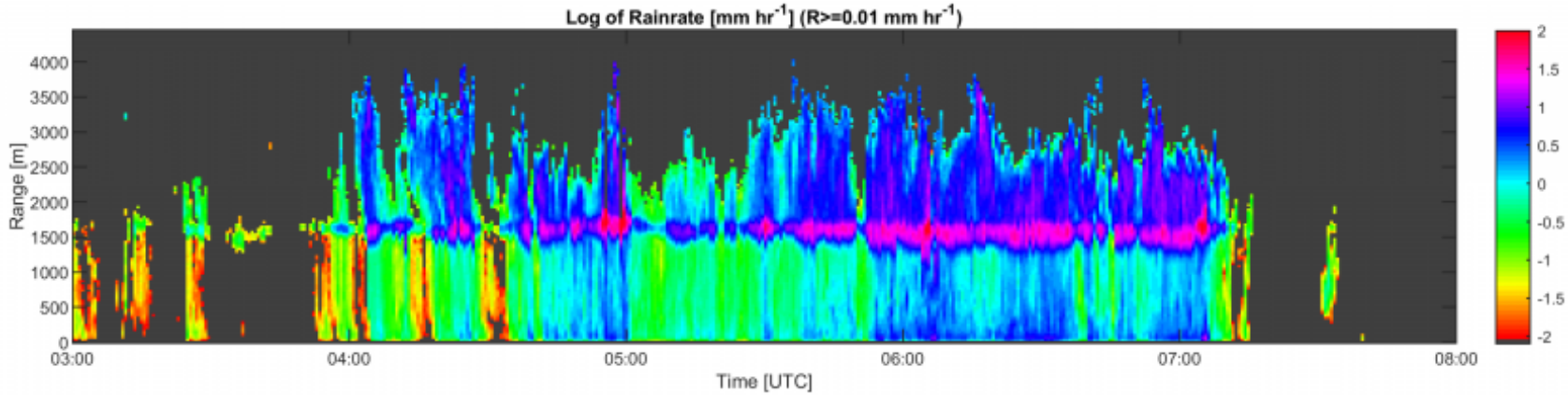


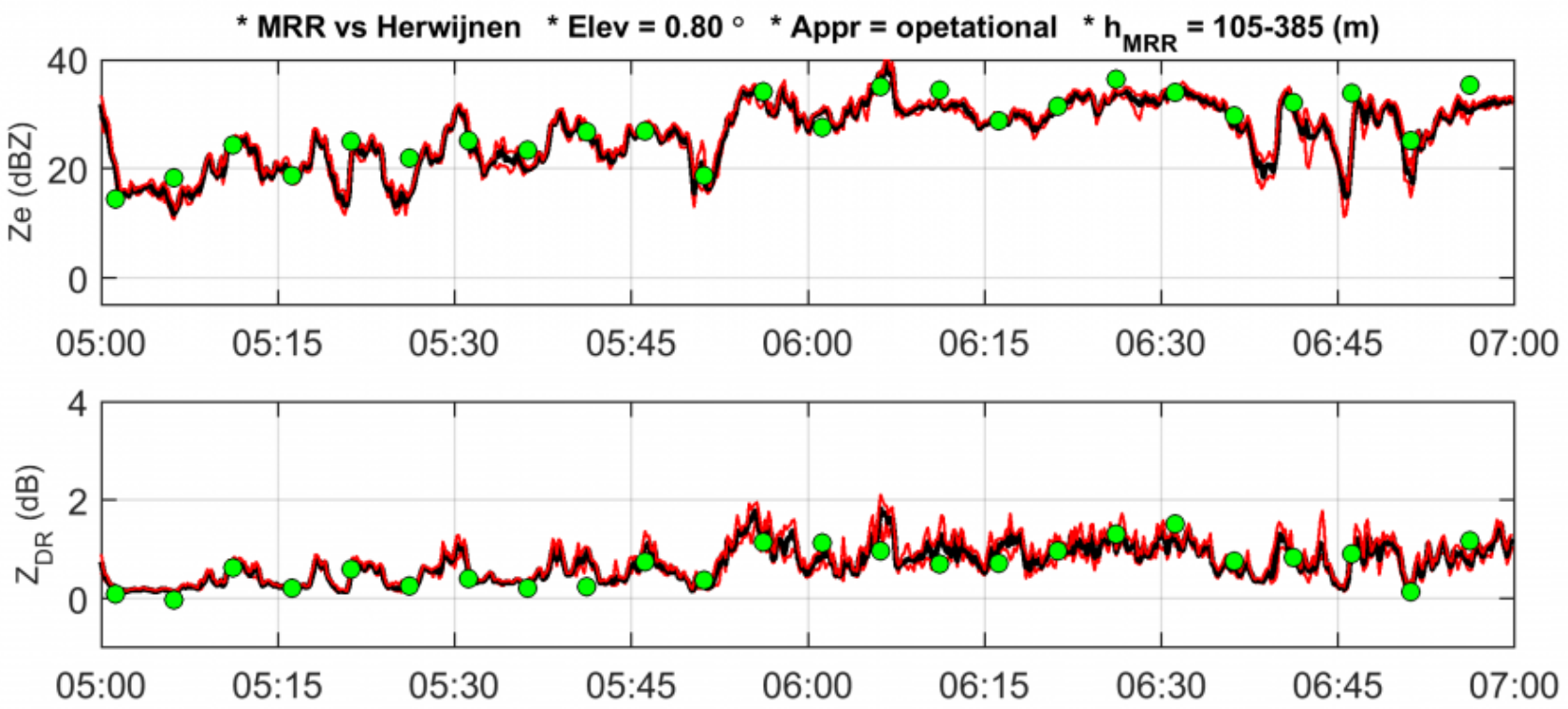
Validation Event 1: 11 Nov 2018



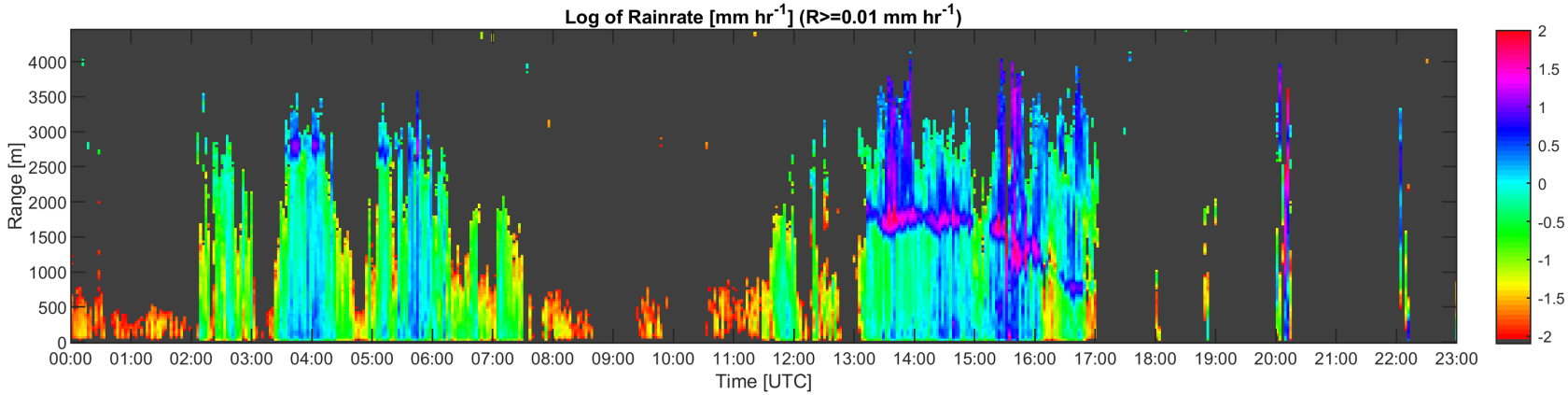
Validation Event 1: 11 Nov 2018

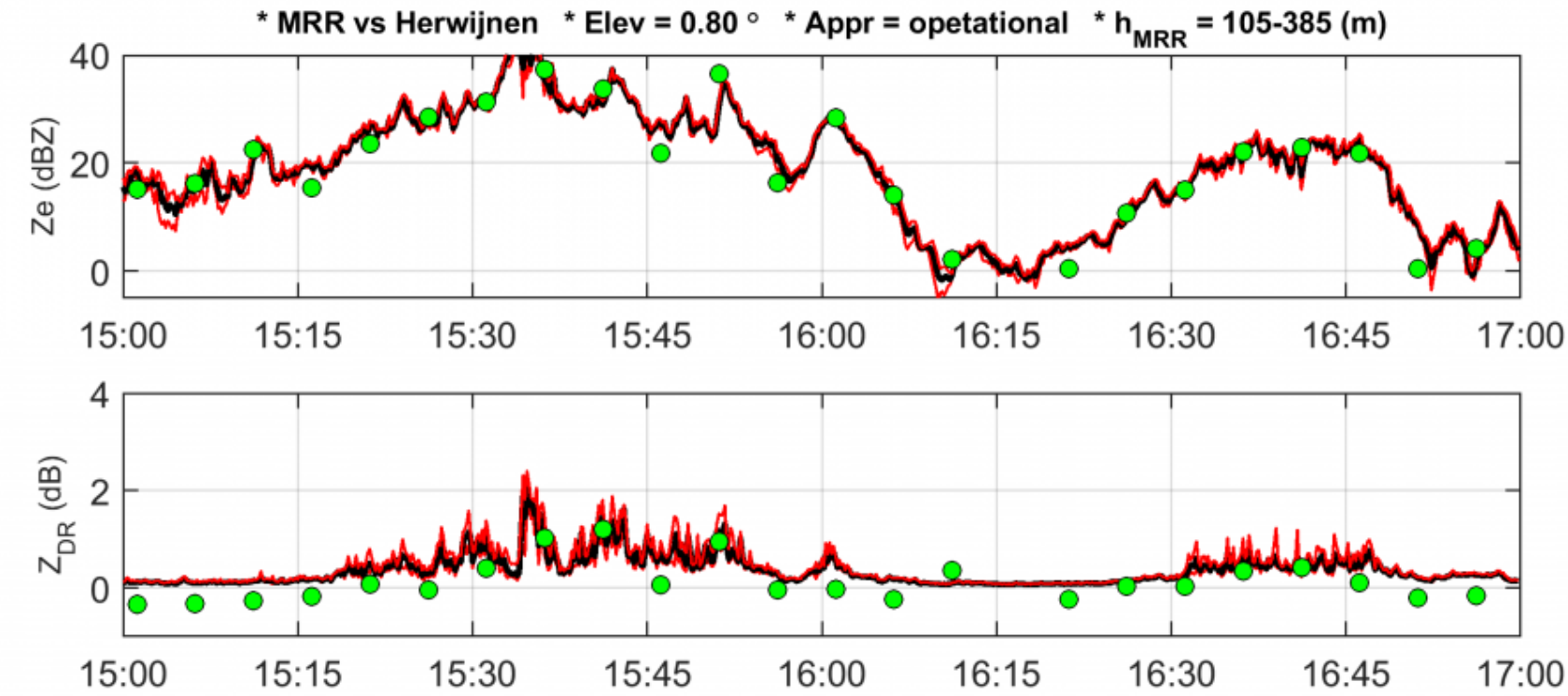
After correction for Zdr offset in Herwijnen radar





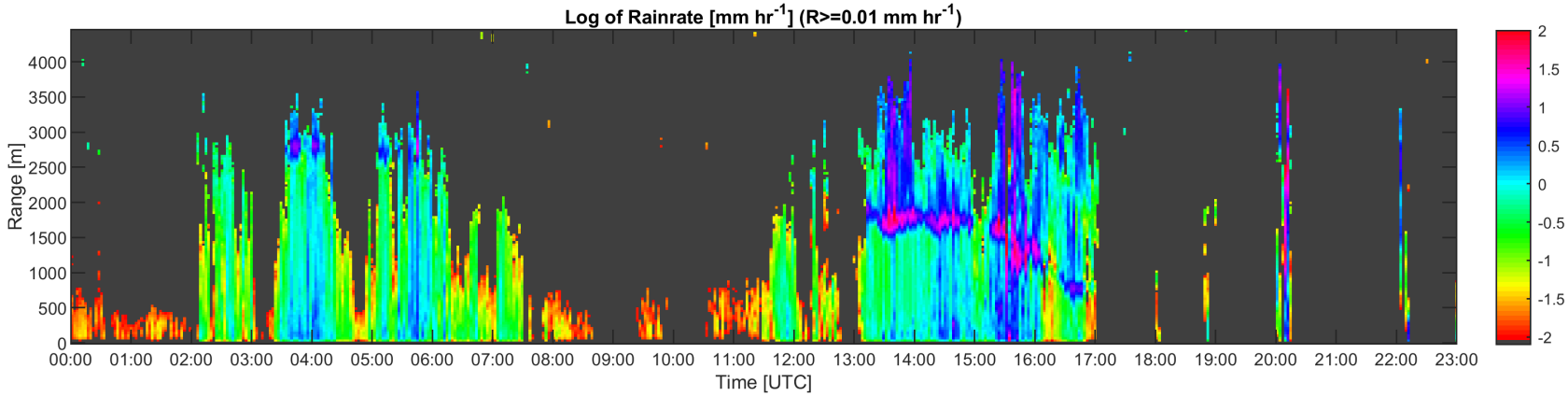
Validation Event 4: Dec 7, 2018

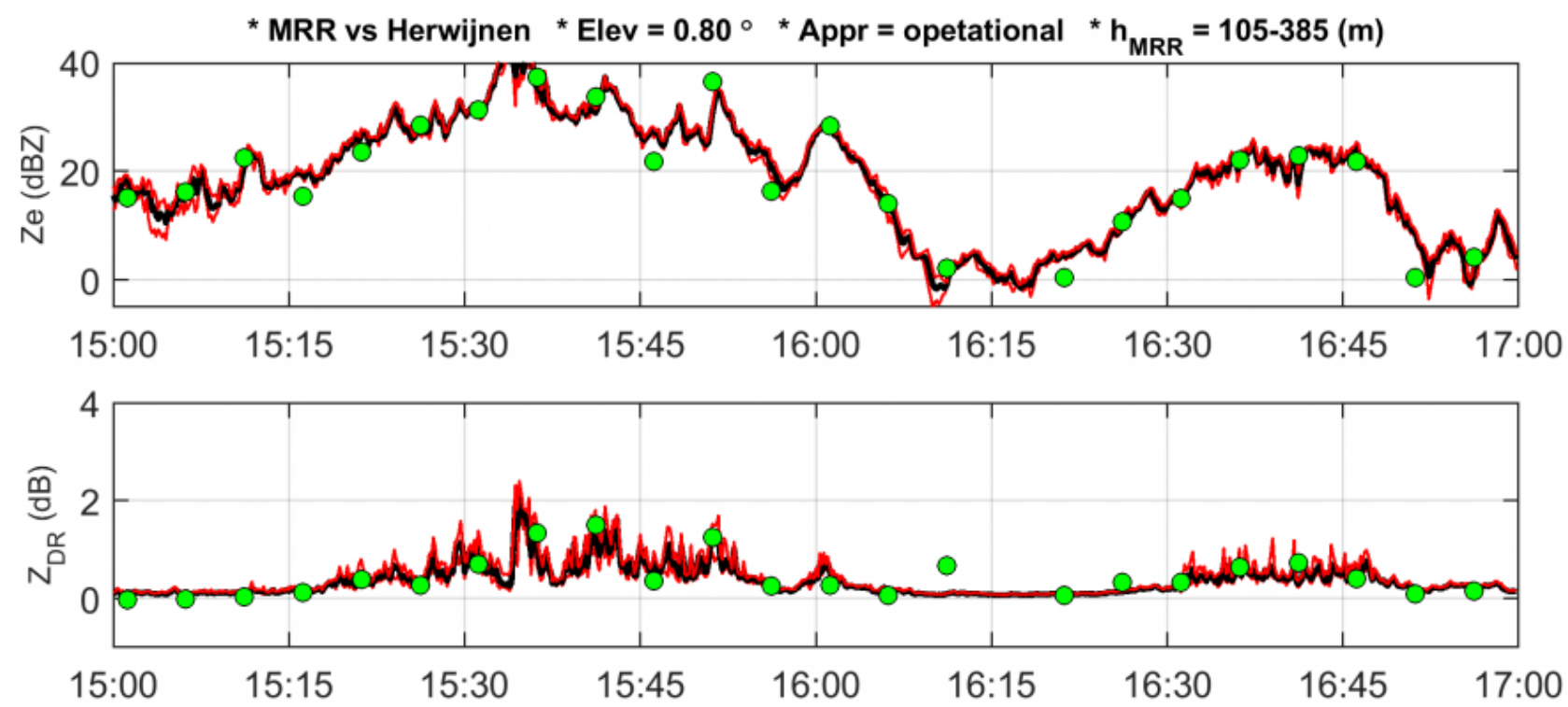




Validation Event 4: Dec 7, 2018

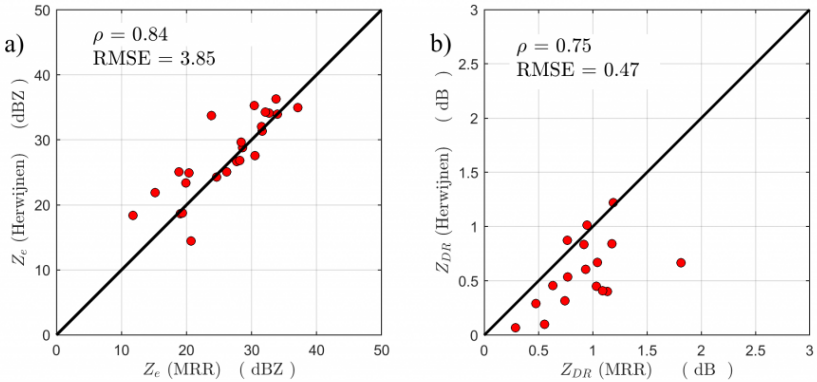
After correction for Zdr offset in Herwijnen radar



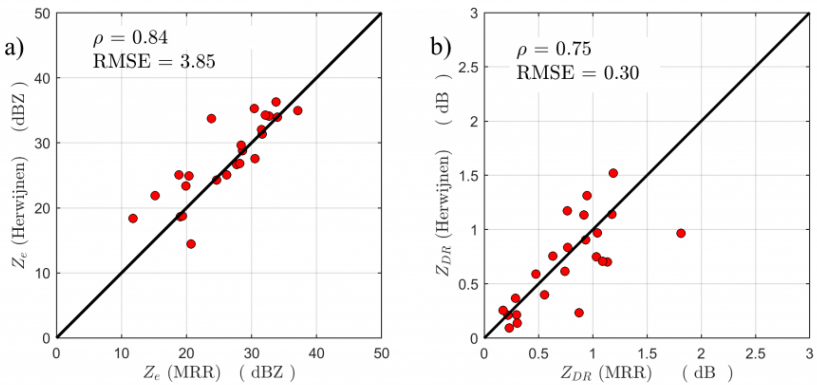


Nov 11

without correction

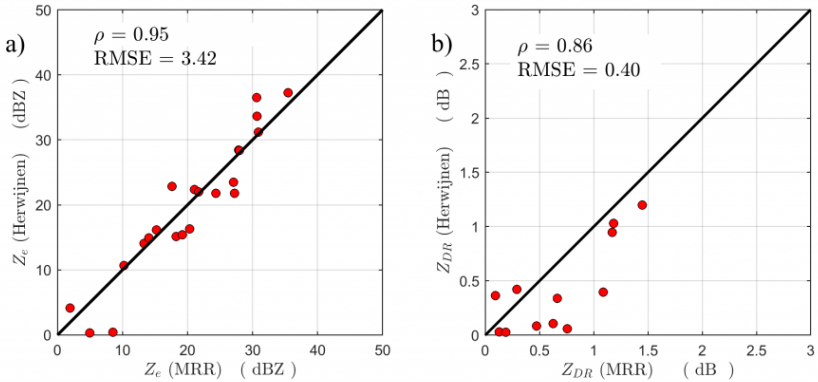


after Zdr correction

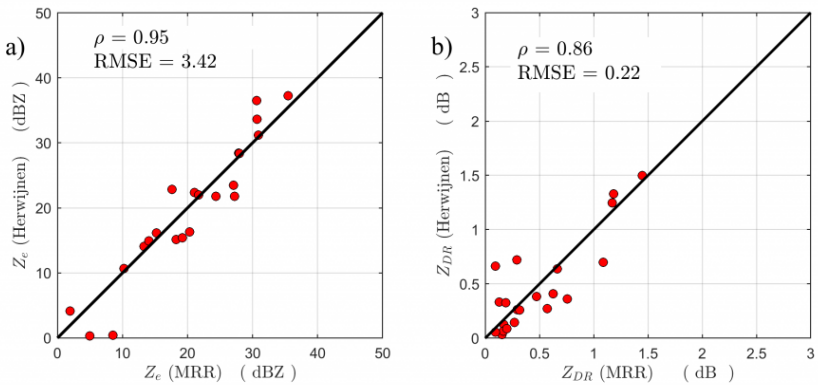


Dec 07

without correction



after Zdr correction



Some future work

- Overall performance over all 15 events (ongoing)
- Comparisons MRR vs IDRA X-band radar (ongoing)
- Best way to detect and handle aliasing during retrievals?
- Sensitivity of retrievals to temperature and cutoff velocity

In the near future: (thanks to Ruisdael)

1. Network of disdrometers for direct in-situ DSD measurements
2. Network of Micro-rain radars (Cabauw & Rotterdam)

Interested in performing joint-experiments within Ruisdael? Contact me!

Marc Schleiss, m.a.schleiss@tudelft.nl