Micro-Rain-Radar
MRR-2 and MRR-PRO
a Tutorial

METEK  Oct. 2017
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   a. What is a Micro Rain Radar?
   b. Comparison radar with in-situ rain sensors
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      iii. MRR and in-situ sensor
   c. Why do we need drop size distributions?
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   b. Dynamic Z-R-relation
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Characteristic features of a Micro Rain Radar

- Compact (< 1 m³)
- Low transmit power (< 50 mW)
- Easy to install and to operate (No health or safety issues.)
- Fixed beam, vertically pointing (Range < depth of troposphere is sufficient).
- High frequency (This provides necessary sensitivity for particle detection.)
- Significant rain attenuation (Acceptable due to short range.)

- Retrieves dropsize distributions from Doppler spectra.
The Micro-Rain-Radar retrieves drop size distributions in a column over the radar.

Large drops fall faster than small drops
Rain rate versus cumulated rain fall

A radar measures rain rate $R(t)$. Cumulative rainfall $C(t)$ is obtained by integration

\[ C(t) = \int_{t-\Delta t/2}^{t+\Delta t/2} R(t')dt' \]

A rain gauge measures cumulative rainfall $C(t)$. Rain rate is obtained by differentiation

\[ R(t) = \frac{\partial C(t)}{\partial t} \approx \frac{C(t + \Delta t/2) - C(t - \Delta t/2)}{\Delta t} \]
Integration Time, Distrometter and Rain Gauge

Example with rainrate = 1 mm/h

A distrometer detects 1 to 2 drops per second.
Uncertainty (standard deviation) of 10% requires at least 100 drops $\Rightarrow \Delta t > 1$ min

A rain gauge (tipping bucket or weighing) provides $C$ in steps of 0.1 mm.
For a quantization error of 10% we need 10 steps corresponding to 1 h collection time.
This is much longer than the typical duration of rain events.

These figures become a bit better at higher rain rates. But the main contribution to total annual rain fall at moderate zones is typically caused by low rain rates.
Scanning weather radar and in-situ sensor

Even if we ignore for the moment the basic uncertainty of the relation between radar reflectivity factor and the rain rate, the comparability between in-situ sensors and scanning radar measurements is hampered by the notorious inhomogeneity and instationarity of precipitation fields.

Due to the radar scan scheme only a small fraction of the total time is available for comparisons. Even at the time of closest approach of the radar beam the typical distance between rain gauge and radar volume amounts several hundred meters.

Therefore, it is not surprising that comparisons of in-situ with radar measurements are only useful for very long integration times (weeks, months, or year depending on rain occurrence).
MRR and in-situ sensor

The fixed beam and small distance of lowest range gate allows continuous and efficient comparison.

Since the MRR rain rate retrieval is based on the drop size distribution, the comparison with rain gauge data is not compromised by uncertain drop size distributions.

More explanation on the following three slides.
Retrieval of Drop Size Distributions

A fundamental uncertainty of Radar QPE (Quantitative Precipitation Estimation) is caused by the variable drop size distribution. Although the situation has been improved with the introduction of polarimetric methods, there is still a need for reference and verification. The knowledge of the actual DSD opens an efficient way for weather radar calibration without relying on shaky, non-linear $Z_R$-relations but only on scattering theory (with comparably very small uncertainties).

A unique capability of the MRR is that the DSD can be retrieved simultaneously with the weather radar in the weather radar scattering volume.
Suggested set up for Weather Radar Calibration

(More explanations on following slide.)

\[ R_M(h) = \int N_M(D, h) D^3 v(D) dD \]

\[ R_M(h) = M \cdot RR(h) \]

\[ M = \sum_t R_M(h \approx 0) / \sum_t R_G \]

\[ N(D, h) = N(D, h)_M / M \]

\[ Z(h_W) = \int N(D, h_W) D^6 dD \]

\[ W = Z(h_W) / Z_W(h_W) \]
We wish to estimate the instantaneous calibration error $W$ of the weather radar, which includes effects like wave guide loss, TR-switch loss, receiver gain, transmit power, radom loss, path attenuation, $Z$–$R$-relation. Particularly the last 3 contributions are highly variable in time and can be accounted for only by a fast calibration procedure.

$Z_{W}(h_i) = W \cdot Z(h_i)$ is the reflectivity factor, measured by the weather radar at the intersection volume at height $h_i$.

$N_{M}(D, h) = M \cdot N(D, h)$ is the drop size distribution, measured by the MRR as function of height including $h_i$. $M$ is the calibration error of the MRR. Note that this error does not affect the shape of $N(D)$ but is a common factor. Therefore the rain rate retrieved with the MRR is related to the true rain rate by the same constant factor: $R_{M}(h) = M \cdot R(h)$. Thus $M$ can be estimated from comparing the cumulated rainfall of the in-situ sensor with the integrated rain rate, retrieved at a low range gate $h_l$: $M = \sum_{t} R_{M}(h_t)/C(t)$. Using $M$ a ground-validated drop size distribution can be calculated:

$N(D, h) = N(D, h)_M/M$ which allows to determine the radar reflectivity factor in the intersection volume: $Z(h_i) = \int N(D, h_i) D^6 \, dD$. From this follows the instantaneous radar calibration

$$W = Z(h_W)/Z_{W}(h_W)$$
Updating the Z-R-relation

An alternative way to support QPE by radar is the update of parameters of the Z-R-relation by simultaneous MRR-retrievals of rain rate $R_M$ and $Z$.

Experimental set up for updating Z-R-relations during LAUNCH experiment 2005 at DWD Observatory Lindenberg.

The data at MRR site A were used for retrieving updated Z-R-relations. The update intervals were controlled by the observed short-term correlation coefficient between $R_M$ and $R_Z$ with $R_Z = aZ^b$. The updated parameters were used for the rain retrievals by the scanning weather radar at MRR site A and B.

Results are on the next slide.
$Z = aR^b$
with $a = 250$ and $b = 1.4$

$$\langle a \rangle = \left\langle \frac{Z_M}{R_M^b} \right\rangle$$

Only $a$ was updated while $b$ was kept constant.

Transfer of updated $\langle a \rangle$ from site A to site B at 6 km distance.

Conclusion: The uncertainty was not only locally improved but also at 6 km distance.
MRR-PRO Overhanging Precipitation

rainfall rate dB re 1 mm/h, 2017-10-04
MRR2 Decending Melting Layer

Radar reflectivity $Z$ with overlay of profiles of Doppler Velocity $w$

Location: METEK/Elmshorn/Germany
Super fine structure of Melting Layer MRR-PRO

Turbulence at top of melting layer

Back to content
Annual mean profiles of Doppler Spectra above and below melting layer

The height axis of each profile was shifted by the actual height of the melting layer.

In this example rain rates between 0.2 and 2.0 mm/h were selected.

The spectral peak is shifted to smaller velocities, while the drops fall to the ground.

The velocity profile corresponds to the expected density effect according to Foote and duToit (2 black lines corresponding to two drop sizes).

Foote and duToit, 1969
Present Weather classification

- Shape parameters of Doppler spectra and their height dependence was exploited for creating a feature vector.
- A Bayes decision rule was developed based on training data sets provided by a human observer.
Performance Test  
Source: METEK Technical Note Oct. 2002

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<th>mixed</th>
<th>solid</th>
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<th>3</th>
<th>4</th>
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<td>Still to be tested</td>
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Correlation between WMO code (ww) observations and decision rule output in percent. The green fields represent coincidence.
Snow Observations

In case of snowfall a conversion of Doppler spectra into drop size distributions is not possible because the fall velocity of snow flakes is only weakly size dependent.

Doppler spectra from snow are narrow and their width is often controlled by turbulence.

For quantitative estimation of snow-precipitation rates $S$ empirical $Z(S)$-relations can be employed. They are subject to similar or even larger uncertainty than $Z(R)$-relations. $Z(S)$- relations of the form $Z = aS^b$ have been published for various snow habits. E.g., Matrosov (2007), and Kulie and Bennartz (2009) with $a$ from 19 to 56 and $b$ from 1.1 to 1.74.
COPS, Achern, 2007

Suggestion: Retrieval of $Z(S)$- relations from MRR profiles assuming constant mass flux above and below the melting layer.
Narrow spectra centered at 1.8 m/s with some undulation (probably due to turbulence).
\[ \text{Spectral reflectivity [m}^{-1}\text{]} \]

Broader spectra with larger variability at the high-velocity end.

Turbulence would affect the upper and lower ends in the same way.

\[ \rightarrow \text{Drop size variability is detectable} \]
COPS, Achern, 2007

Melting height – 300 m, vertical

... 300 m below the ML

Broader spectra with larger variability at the high-velocity end. Turbulence would affect the upper and lower ends in the same way. 

→ Drop size variability

The lower edge is shifted to higher velocities, because the snow flakes are completely melted. The diameter of drops falling with less than 1 m/s is less than 0.3 mm with very small scattering cross section.
COPS, Achern, 2007

For snow observations the zero velocity center should be shifted from the left end to some finite fraction of the Nyquist interval (See next two slides).

... 300 m above the ML, with more turbulence.

Aliased frequencies due to upward motion.
10s profile of power spectra (MRR-PRO)

- **Height m**
  - 0
  - 500
  - 1000
  - 1500
  - 2000
  - 2500
  - 3000
  - 3500
  - 4000
  - 4500

- **Doppler velocity m/s**
  - 0
  - 2
  - 4
  - 6
  - 8
  - 10
  - 11
  - 12

- **dB re unit spectral power**
  - 0
  - 10
  - 20
  - 30
  - 40
  - 50
  - 60

**Upward motion**
Upward motion

Shift of zero velocity from the left margin to 15% of the Nyquist interval.

Notch filter for suppressing ground clutter.
Further recommended reading about snow observations:


Browser for viewing MRR snow measurements
http://www.ssec.wisc.edu/lake_effect/mqt/
Volcano Monitoring
Radar-Monitoring at Merapi volcano, 2001-2005


Vöge, M., M. Hort, R. Seyfried, Monitoring Volcano Eruptions and Lava Domes with Doppler Radar, Eos, Vol. 86, No. 51, 2005

DEM courtesy of C. Gerstenecker
Flow mapping L. Schwarzkopf
Explosive event

Time series of 1s power spectra

Vöge and Hort (2009)
Turrialba, Costa Rica

Time Resolution: 1 s
Range Resolution: 200 m
Velocity Range: ±48 m/s

Crater often hidden in fog.
Event 26 Sep. 2017

Turrialba, Costa Rica

Time series of 1s power spectra at 4 range gates

Time series of total power at 4 range gates

Courtesy: A. Geoffrey
Siting Examples
Wind exposed (FINO2)
Forest clearing
Railway Station

Backyard
FMCW Operation Principle
FMCW Operation Principle

Echo from resting point target

Frequency deviation from carrier

Propagation time $\tau = 2r/c$

Sweep time $T$

Amplitude

The beat signal is processed.

Frequency difference $f = B\tau/T$
If the point target is moving, a Doppler shift occurs.

Now the observed beat frequency consists of two contributions

\[ f = 2 \frac{B}{T_c} r + 2 \frac{v}{\lambda} \]
The range-velocity ambiguity must be resolved.

There are many techniques described in the literature, but most of them are restricted to single or few point targets in the radar beam.

(Typical application: Automotive anti-collision radar)

In case of precipitation the radar beam is filled with a large number of randomly distributed scattering particles.

We are aware of only one technique applicable for this scenario, which was proposed by D. Barrick, 1973 for oceanographic applications.
The result of the Fourier analysis of one sweep is a line spectrum, with \( N \) lines that represent the signals from \( N \) range gates, each centered at the frequency \( f_N = N / T \) corresponding to the range \( r_N = N \delta r \).

We show as an example a spectrum of \( N = 6 \) lines.

Each spectral line is a complex number consisting of amplitude and phase, as depicted on the left.

Due to the random positions of the scattering particles, the amplitude and phase is random.

So, one single DFT (Digital Fourier Transform) does not provide useful information.

Consider the noise-like signal of one sweep.
Now we consider a series of $M$ sweeps.
From $M$ spectra, each with $N$ lines, a $M \times N$-matrix with $M$ columns and $N$ lines can be constructed.

Each line represents one range gate.

Systematic phase shifts between columns are caused by a mean motion of the scattering particles.

We can interpret line $N$ as the time series of echo from range gate $N$. 

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FMCW Operation Principle
From one series of $M$ sweeps one realization of Doppler spectra with $M$ lines is derived. For stable results repeated Doppler spectra must be averaged.
As for any Doppler radar, there are fundamental restrictions.

The range-velocity trade-off is different from a pulsed radar.

<table>
<thead>
<tr>
<th>Remark</th>
<th>FMCW</th>
<th>Pulsed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nyquist velocity</td>
<td>$T_s$ sweep repetition</td>
<td>$v_N = 2\lambda/T_s$</td>
</tr>
<tr>
<td></td>
<td>$T_p$ pulse repetition</td>
<td></td>
</tr>
<tr>
<td>Range-velocity trade-off</td>
<td>$r_m$ maximum range</td>
<td>$r_m \ll \frac{1}{4} \frac{c\lambda}{v_N}$</td>
</tr>
<tr>
<td>Example</td>
<td>$\lambda = 1.25$ cm</td>
<td>$r_m \ll 47$ km</td>
</tr>
<tr>
<td></td>
<td>$v_N = 20$ m/s</td>
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</table>

The FMCW restriction of $r_m$ is acceptable for vertically pointing beam (depth of troposphere $\ll 47$ km).
Main specifications MRR2 – MRR-PRO

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Relation</th>
<th>MRR2</th>
<th>MRR-PRO</th>
</tr>
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<tbody>
<tr>
<td>Range resolution</td>
<td>δr</td>
<td>&gt; 10 m</td>
<td>&gt; 10 m</td>
<td></td>
</tr>
<tr>
<td>Wave length</td>
<td>λ</td>
<td>0.01238 m</td>
<td>0.01238 m</td>
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<tr>
<td>Sampling frequency</td>
<td>f_s</td>
<td>125 kHz</td>
<td>500 kHz</td>
<td></td>
</tr>
<tr>
<td>Number of range gates</td>
<td>N</td>
<td>32</td>
<td>32--256</td>
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<tr>
<td>Number of lines per spectrum</td>
<td>M</td>
<td>64</td>
<td>16–256</td>
<td></td>
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<tr>
<td>Acquisition time for one set of spectra</td>
<td>τ</td>
<td>32.8 ms +150 ms dead time</td>
<td>2.048 -- 131.1 ms No dead time</td>
<td></td>
</tr>
<tr>
<td>Velocity resolution</td>
<td>δv</td>
<td>0.188 m/s</td>
<td>0.047 – 6.016 m/s</td>
<td></td>
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<tr>
<td>Nyquist Velocity Range</td>
<td>v_{ny}</td>
<td>0-12.3 m/s</td>
<td>12.3 – 96.3 m/s</td>
<td>Center is fixed Center can be shifted</td>
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<tr>
<td>Duty Cycle (Net-sampling time in one averaging interval)</td>
<td></td>
<td>&lt; 20%</td>
<td>100%</td>
<td></td>
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<tr>
<td>Min. detectable radar reflectivity</td>
<td></td>
<td>-2 dBZ</td>
<td>-8 dBZ</td>
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</table>
Signal Processing MRR-2

Raw spectra

f(n) → SNR → MASK → V=SNR^MASK

Intermediate products

Radar equation, Gunn & Kinzer, Mie theory, ...

F(n) → V=True
N(n) → V=True
PIA → V=True
Z → V=True
z → V=True
RR → V=True
LWC → V=True
W → V=True

Final products

F(n) → V=True
N(n) → V=True
PIA → V=True
Z → V=True
z → V=True
RR → V=True
LWC → V=True
W → V=True

V is a signal quality flag based on the SNR of raw spectra and a spatial continuity criterion of the rain rate. Only selected products are filtered.
Signal Processing MRR-PRO

\[ V = \text{SNR}^\text{MASK} \]

\( V \) is a signal quality flag based on the instantaneous SNR and a spatial/temporal continuity criterion of SNR of the raw spectra. All products except of SNR are filtered.

Radar equation, Gunn & Kinzer, Mie theory, ...

Final products
- \( F(n) \) or \( f(n) \)
- \( N(n) \)
- \( PIA \)
- \( Z_a \)
- \( Z \)
- \( Ze_a \)
- \( Ze \)
- \( RR \)
- \( LWC \)
- \( VEL \)
- \( WIDTH \)
- \( SNR \)
Comparison MRR-PRO versus MRR-2

MRR-2

- Indoor
  - Junction Box
  - Mains
  - Windows PC
  - All products
  - Front end, raw spectra
  - RS422 and power supply
  - Data and Control

MRR-PRO

- Antenna heating (optional)
- Front end, raw spectra and all products, local data storage
- Low noise power supply, power management
- Mains cable
- LAN cable
The MRR-PRO concept facilitates stand alone installations and autonomous operation.

The example on the left shows solar powered system for volcano monitoring.

Local storage of full data set and streaming of compressed alerts every second via mobile communications network.

Turrialba, Costa Rica

Courtesy: A. Geoffrey
Data Storage, Communication interfaces

MRR-PRO
- System configuration, Operation control
- Internal SD card 32 GB for data storage (NETCDF or ASCII)
- Data Streaming (Only ASCII)

MRR-2
- Raw Spectra Streaming (ASCII)

LAN
- GUI (Windows)
- Web-based user interface
- SSH

RS 422
- JuBo

RS 232
- Windows PC

Comparison MRR-PRO versus MRR-2
FAQs MRR-PRO

What is the difference between $Z_e$ and $Z$?

Can the MRR measure snow fall?

What is the use of $Z$ in case of no rain?

Why is the noise level increasing with increasing height? (Only MRR2)

What is the physical meaning of the Doppler velocity $W$?

Why do we see negative drop numbers?

What is the meaning of diameter tables in the data sets?

What is the smallest drop size?

Why reach profiles of $Z_a$ and $Z_{eq}$ sometimes higher than profiles of other variables?
What is the difference between $Z_e$ and $Z$?

The radar reflectivity factor is defined as

$$Z = \sum N(D_i)D_i^6$$

whith $D_i = \text{drop diameter}$ and $N(D_i) = \text{drop size distribution}$.

If the radar wavelength $\lambda$ is much longer than $D_i$ (= valid range of Rayleigh approximation) the volume reflectivity $\eta$ (= backscatter cross section per volume) is related to $Z$ by

$$Z = \eta \frac{\lambda^4}{\pi^5 |K_w|^2}$$

where $|K_w|^2 \cong 1$ depends on the dielectric constant of water. $\eta$ can be derived directly from the received echo power using the radar equation.

If $\lambda$ is not much smaller than $D_i$ the relation between $Z$ and $\eta$ does not hold, and thus $Z$ cannot be inferred from the received echo power. For many purposes it is nevertheless useful to convert $\eta$ using the above relation. The result is referred to as “equivalent radar reflectivity factor” $Z_e$.

$Z_e$ approaches $Z$ for $\lambda/D_i \gg 1$.

Although this condition is not fulfilled for the MRR, the radar reflectivity factor $Z$ can be determined by MRR because the drop size distribution is known.

For comparison with weather radar (with longer wave lengths than MRR wave length) $Z$ is the preferable variable.
Can the MRR measure snow fall?

The MRR standard signal processing software is adapted to the liquid phase of precipitation. It is optimized for deriving drop size distributions and corresponding integrals as for example liquid water content, rain rate or mean Doppler velocity.

In case of snow (or graupel, hail) the standard signal processing does not provide physically meaningful results, because the relations of scattering cross section versus mass and fall velocity are very different for ice crystals than for water droplets. Moreover, certain frequency intervals of the raw spectra are discarded in order to achieve stable results (see e.g. Peters et al., 2005). Particularly in case of snow the main spectral power can be concentrated in the discarded frequency range resulting in seemingly low radar sensitivity.

Maahn and Kollias (2012) have developed a special algorithm for snow detection, which is available on the web mrr_snow. The input needed for initialization is the raw spectrum as provided by the MRR. This algorithm provides reflectivity and higher spectral moments of snow echoes with enhanced sensitivity and has been checked by the authors against simultaneous measurements with a more sensitive cloud radar.
What is the use of $Z$ in case of no rain?

Ideally there should be no signal in case of no rain, and $Z$ (represented on a logarithmic scale) should be $-\infty$. In reality there remain stochastic noise fluctuations. Therefore, there is some probability, that signal is detected in case of pure noise. The frequency of occurrence of such detections divided by the number of samples is the so called false alarm rate. It is about $10^{-4}$ for the MRR-PRO. If this number is significantly exceeded, this is an indication that there is some interference causing a non-white spectrum.
Why is the noise level increasing with increasing height? (Only MRR2)

A given reflectivity leads to an echo signal which is weaker the farther the scattering volume is. Therefore, a reflectivity-calibrated output needs a gain, which increases with increasing distance of the scattering volume. Thermal and electronic noise, which is present at the input of the receiver is therefore increasingly amplified for increasing measuring ranges.
What is the physical meaning of the Doppler velocity $w$?

Definition:

$w$ is the first moment of the noise-corrected power spectrum.

Equivalent:

$w$ is the reflectivity weighted mean fall velocity.

Other weighted mean velocities (for example mass-weighted) can be calculated by post-processing on the basis of the drop size distributions.

It is assumed that $w$ is always downward directed (positive sign). Upward velocities ($w_{\text{up}}$) will be aliased to $w = w_{\text{up}} + w_{\text{nyquist}}$ with $w_{\text{nyquist}} = 12.08 \text{ m/s}$.

$w$ is always calculated, even, if there is no significant signal present. In the latter case $w$ has no physical meaning but it is helpful for diagnostic purposes in case of malfunction of the MRR.

The condition $RR = 0.00$ can be used for masking non-physical values of $w$ at heights with PIA $< 10 \text{ dB}$. A masking algorithm of $w$ working at all ranges (including PIA $\geq 10 \text{ dB}$ ) can be based on a (height dependent) threshold $z_t$ of $z$, which has been defined on the basis of mean values of $z$ ($= Z$) in precipitation-free conditions.
Why do we see negative drop numbers?

The raw spectral power is a superposition of signal due to radar echoes and of noise background. The noise background would result in a permanent non-zero drop size distribution and consequently in non-zero values of liquid water content and rain rate — even in precipitation free conditions. In order to avoid this bias, the noise background is estimated and removed. The noise estimation is based on the so called Hildebrandt-Sekhon method. Assuming white noise it provides one mean value for describing the noise background, which is subtracted from the power spectrum. Ideally the noise-corrected spectral power (ncsp) would be zero, if there is no signal. Due to stochastic fluctuations of the actual spectral noise some ncsp-values are positive and some are negative. In case of a symmetric stochastic distribution the probability of both signs should be 0.5. Due to finite number effects the actual estimate of the noise background is slightly biased and in addition, the stochastic power distribution is not quite symmetric in reality. Therefore the implementation of the method for the MRR provides a slight preference of positive ncsp-values. The negative sign is now kept for the calculation of negative spectral drop numbers in order to avoid bias in integral products as radar reflectivity, liquid water content and rain rate.

Consequently one would expect occasional occurrence of negative signs also for these integral parameters. This is not the case due to the following reasons:

1. The reflectivity is given on a logarithmic scale, which can only represent positive numbers. Values with negative sign are replaced by blanks.
2. Rain rates which do not meet certain criteria (threshold of signal to noise ratio, coherence in adjacent range gates) are replaced by exact zero. (The same is true for the corresponding liquid water content).
3. Only positive velocities are calculated.
What is the meaning of diameter tables in the data sets?

The tables provide the center diameters corresponding to spectral velocities. While the spectral velocities are equidistant the diameters are not equidistant, due to the non-linear relation between fall velocity and diameter.

The height dependence of density in the (standard) atmosphere leads to a height-dependent fall velocity of drops of a given size. Therefore, the center diameter corresponding to a given spectral velocity is height dependent.
What is the smallest drop size?

The MRR does not observe the signal of single drops but the superposition of signals from many drops in the scattering volume. Therefore, the lower size threshold, which can be observed, depends on the actual number density of the corresponding size class. This is not a constant but depends on the actual rain event.

In case of MRR only drops with a fall velocity (in still air) of more than or equal to 0.75 m/s are included in the analysis. This corresponds (in still air) to a minimum diameter of 0.245 mm at ground level.
Why reach profiles of $Z_a$ and $Z_{ea}$ sometimes higher than profiles of other variables?

Most variables are corrected for path integrated attenuation (PIA). If PIA exceeds 10 dB, those variables (including PIA itself) are no longer considered trustworthy and the results are replaced by blanks.

In addition to the attenuation-corrected reflectivity $Z$, $Z_e$ also non-corrected versions $Z_a$ and $Z_{ea}$ are issued, which show relative reflectivity structures also at ranges, where the absolute reflectivity cannot be determined due to excessive attenuation.

The Doppler velocity $W$ and spectral width WIDTH are not biased by attenuation and are therefore issued for all heights with detected signal.

(MRR2: Note, that $w$ is issued, even, if there is no detected signal.)