# Hydrometeor classification tuned for Austrian C-band polarimetric weather radar data

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## 1. Introduction

Austrian weather radar network was renewed during the past years. The new radars provide polariemtric data which allows for many new applications such as the identification of various types of precipitation.

Since the measurement of the horizontal reflectivity factor $Z_H$ alone is often not sufficient to distinguish between different hydrometeor types, the inclusion of polarimetric measurements provides valuable additional information about the particle size, shape, and falling behaviour as well as the aggregate state of precipitation particles.

In this paper, different types of hydrometeors are classified, based on verified observations. These observed precipitation events are either referenced in METAR of the Austrian airports Vienna and Salzburg or Austrian reports in the European Severe Weather Database (ESWD).

## 2. Data and methodology

Austrian complex orography is covered by 5 dual-pol weather radars (WXR), located on flatlands as well as on the top of Alpine mountains. The considered precipitation events in this paper are limited to the two flatland radars; Rauchenwarth (RAU) and Feldkirchen (FEL); near the airports Vienna and Salzburg (Figure 1).

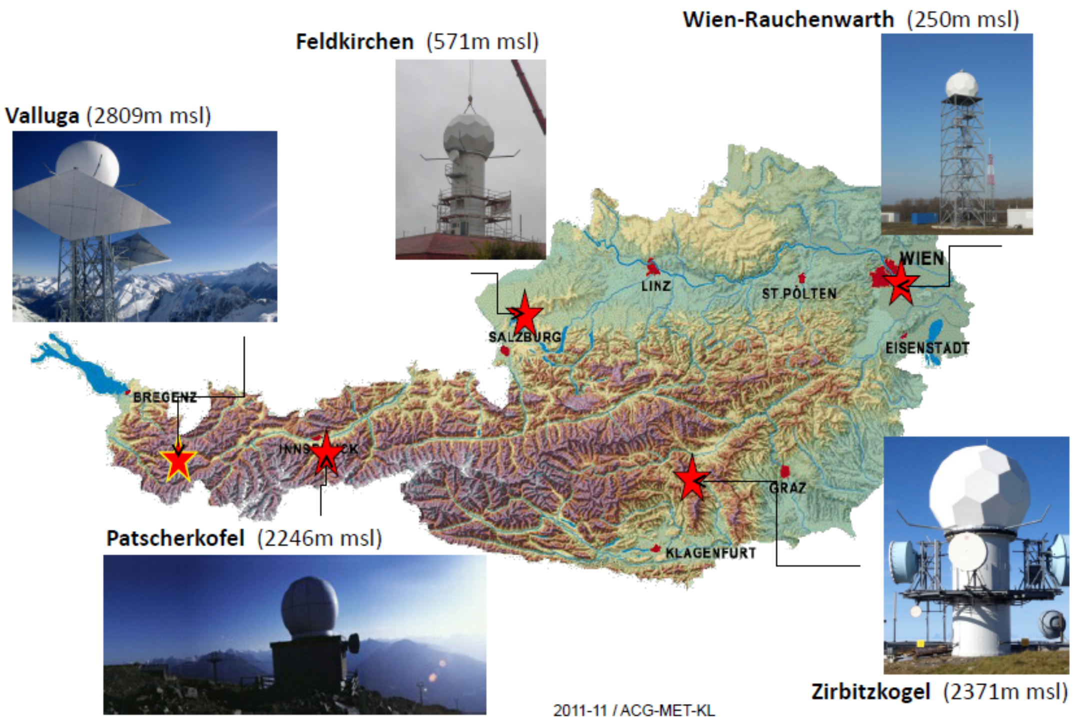


*Figure 1: Austrian weather radar network - [Kaltenboeck (2012a)]*

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First, the locations (range and azimuth) and heights (with respect to the freezing level) of polarimetric measurements, in which the observed precipitation classes are found, have to be determined. Confirmed events and the corresponding weather radar measurements are then linked to each other. Due to the complexity of the Austrian terrain, it is not always possible to use the lowest elevation, thus the lowest possible elevation height can vary.

To define membership-functions for different hydrometeor classes, the used moments in this study are reflectivity $Z_H$, differential reflectivity $Z_{DR}$, the co-polar correlation coefficient $\rho_{HV}$ and the specific differential phase $K_{DP}$.

According to Gourley (2007), the texture (root mean square deviation) of $\phi_{DP}$ is a good parameter to distinguish between non-meteorological and meteorological echoes and thus to eliminate groundclutter.

Since the radar data are generated by measurements with C-band radars, the attenuation along the propagation path can not be neglected anymore. In order to make an accurate estimation of $Z_H$ and the differential reflectivity $Z_{DR}$, a linear attenuation correction scheme has to be applied. The values that have been used are $\alpha$ = 0.08 dB/° for $Z_H$ and $\beta$ = 0.03 dB/° for $Z_{DR}$ [Ventura (2012)].

To obtain the filtered $\phi_{DP}$, which is required for the attenuation correction, a medianfilter is used [Graf (2013)]. The corresponding filter width for C-band-radar is 6 km [Ventura (2012)]. At last, the specific differential phase $K_{DP}$ in °/km is calculated.

With the preprocessed data, trapezoidal membership-functions are created. The trapezoidal functions are described by four parameters $x_1$ to $x_4$ [Park (2009)]. Thereby the parameters $x_1$ and $x_4$ represent the minimum and maximum value of the distribution, whereas $x_2$ and $x_3$ are the 5. and 95. percentiles. The adjusted membership-functions may then be used for classification based on Fuzzy-logical-methods.

## 3. Results

In this work only 8 hydrometeor classes have been taken into account: drizzle, light rain, moderate rain, heavy rain, snow, graupel/rain mixture, dry hail and hail/rain mixture.

Figure 2 shows the distribution of $Z_H$ and $Z_{DR}$ values for different hydrometeor types. Sharp lower boundaries for dry hail and hail/rain mixture occur because $Z_H > 45$ dBZ is used for hydrometeor classification. The resulting membership-functions for the input variables $Z_H$ and $Z_{DR}$ can be seen in figure 3 and 4.

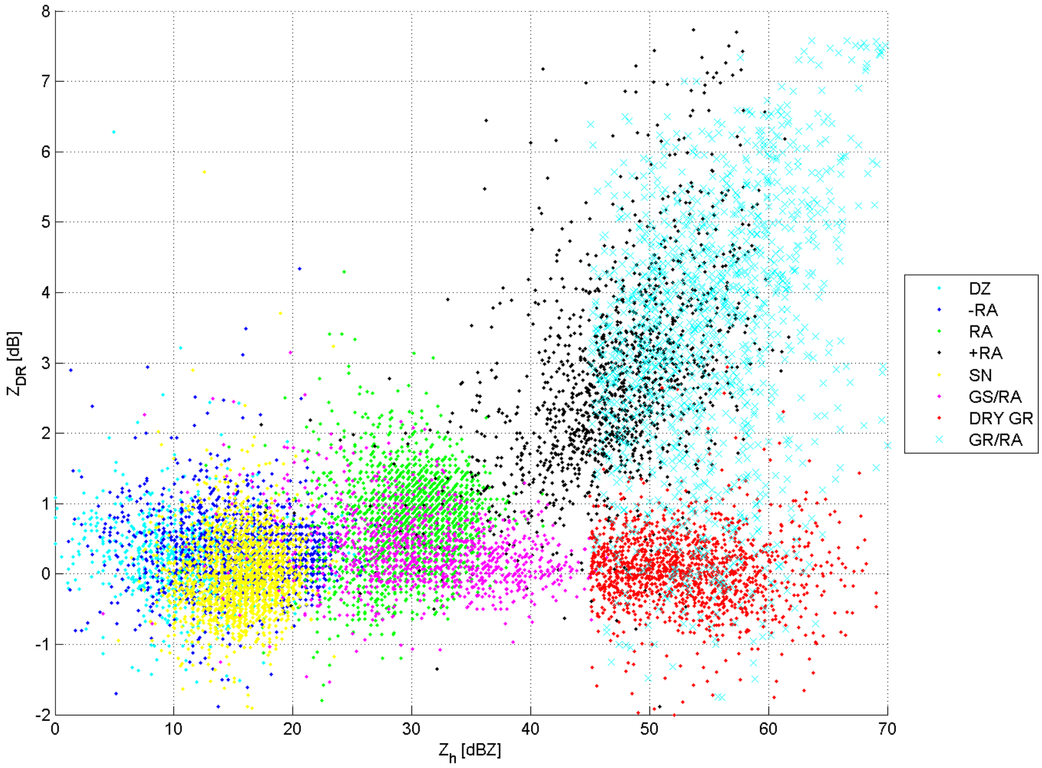


*Figure 2: Scatterplot of $Z_{DR}$ vs. $Z_H$, with different colors for different hydrometeor types. DZ=drizzle, -RA=light rain, RA=moderate rain, +RA=heavy rain, SN=snow, GS/RA=graupel/rain mixture, GR=dry hail and GR/RA=hail/rain mixture.*

For example, the shape of a raindrop affects the radar signal. Due to the oblate shape of falling raindrops, $Z_{DR}$ values vary from near zero dB for small, almost spherical droplets like drizzle to values as large as 5 dB for echos from large water drops. This additional information and the knowledge of the reflectivity $Z_H$ can be used to discriminate between different intensities of rain (figure 3 and 4 a-d).

Snow and ice particles have a lower dielectric constant than liquid water and therefore the hydrometeor type 'dry snow' is associated with small values of $Z_H$. Snow has also low values of $Z_{DR}$, because snowflakes tumble and therefore the polarization effects cancel out (figure 3 and 4 e).

Both, dry hail and hail/rain mixture are characterized by strong reflectivities ($Z_H > 45$ dBZ), but they differ in $Z_{DR}$. Hailstones generally tumble as they fall, therefore the polarization effects average out and for dry hail $Z_{DR}$ is close to zero. In contrast, $Z_{DR}$ values from mixed precipitation start to increase rapidly and can range up to 6 dB (figure 3 and 4 g-h).

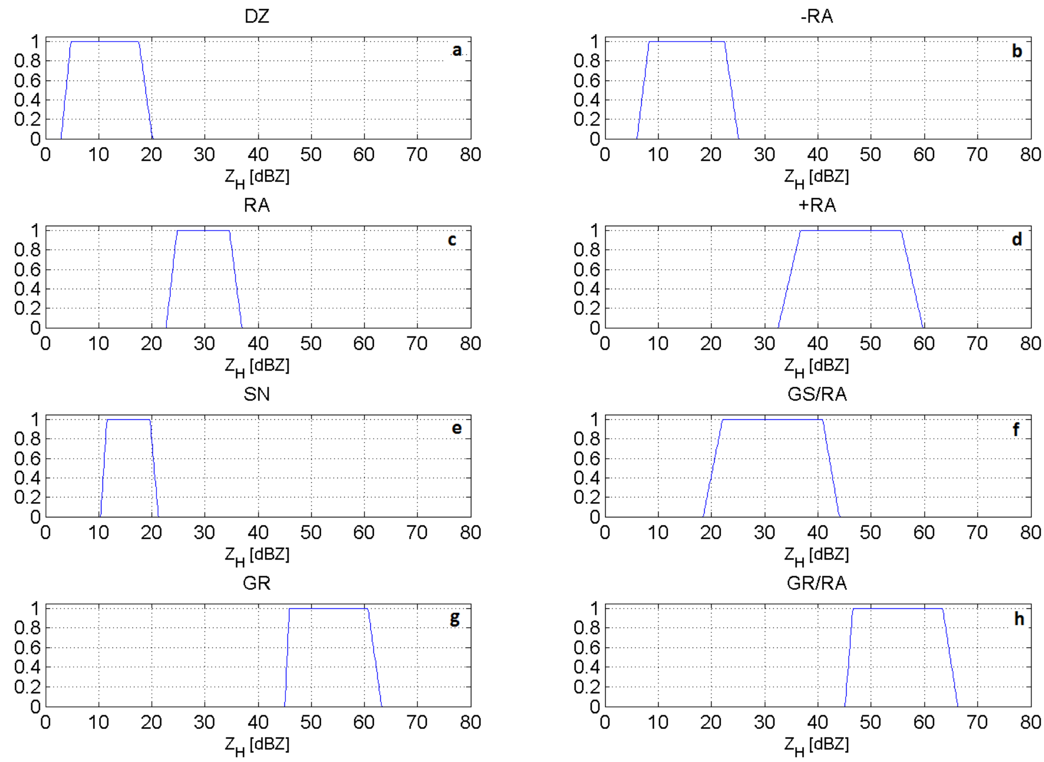


*Figure 3: Membership-functions for the input variable $Z_H$ in dBZ.*

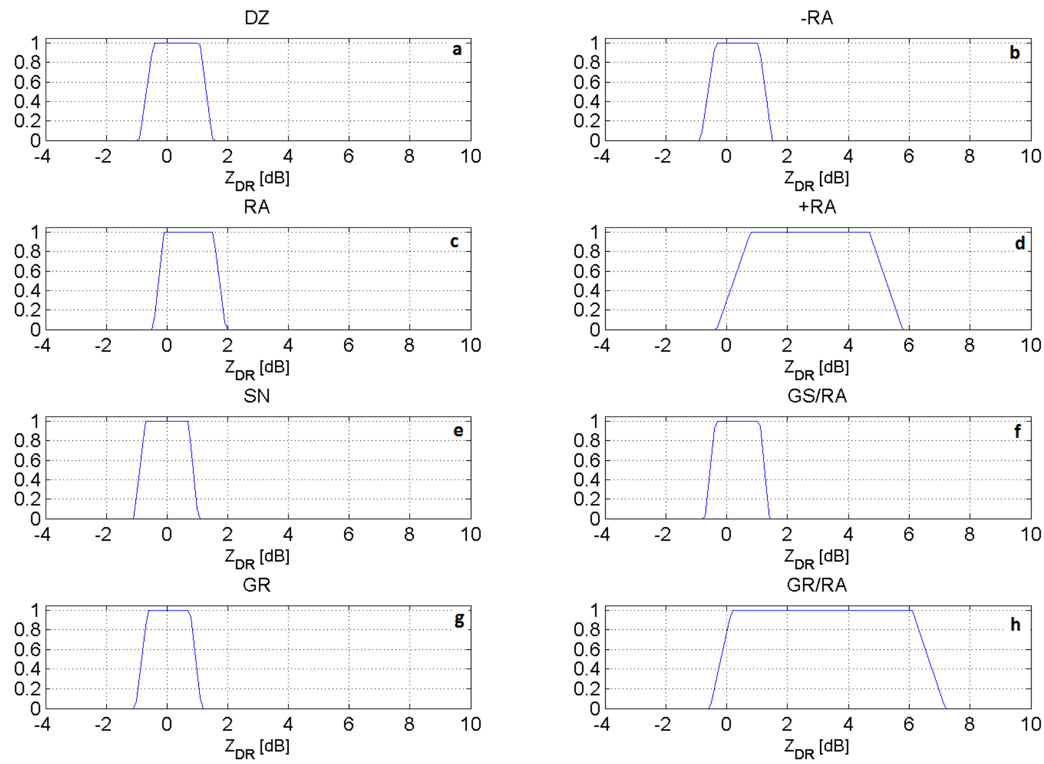


*Figure 4: Membership-functions for the input variable $Z_{DR}$ in dB.*

## 4. Case study - Heavy Rain - May 24, 2014

During the day of May 24, 2014, a severe thunderstorm hit the city of Vienna. The available data were generated by the dual-polarized C-band radar 'Rauchenwarth', located near the Vienna Airport, about 25 km appart. The heavy rain caused local floods, especially in the western half of Vienna. The duration of the event was about one hour. In this time 60 mm of rain were measured [ESWD (2014)].

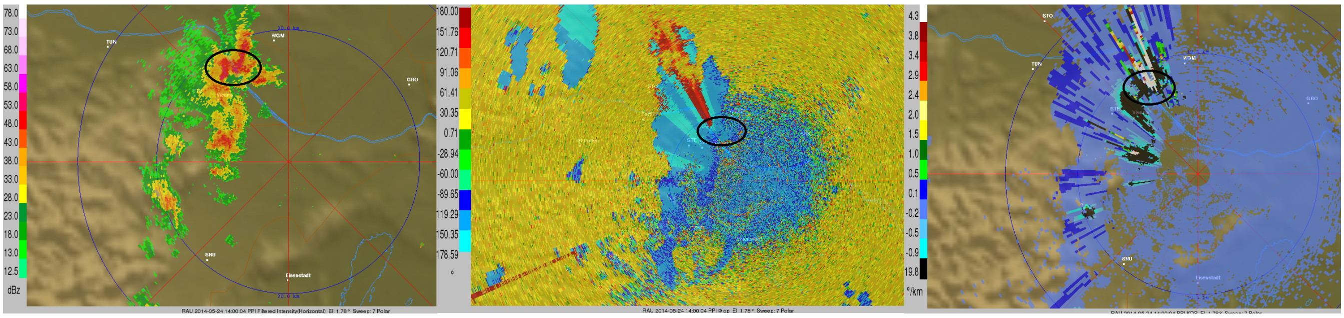

*Figure 5: Heavy rainfall event on May 24, 2014 - 14:00 UTC: PPI at Elevation 1.8° from WXR RAU. The left figure shows $Z_H$, middle figure shows $\phi_{DP}$, the right handed side figure shows $K_{DP}$. Inner ring distance is 30 km.*

To study the range of the polarimetric variables, the used parameters are represented in scatterplots or histogramms. Figure 6 shows $Z_{DR}$, $\rho_{HV}$ and $K_{DP}$ as a function of $Z_H$. Heavy rain is characterized by high values of $Z_H$ accompanied by very high $Z_{DR}$ as well as decreasing values of $\rho_{HV}$. For this heavy rain case the observed values of $Z_H$ vary between 30 and 60 dbZ, $Z_{DR}$ varies from -2 to 7 dB and $\rho_{HV}$ lies within the range of 0.7 to 0.99. In such kinds of storms not only large raindrops are present, the radar volume also contains plenty of small and medium sized drops. Therefore the low $Z_{DR}$ values are due to smaller droplets, negative values of $Z_{DR}$ indicating attenuation. The range of $\rho_{HV}$ is also quite large, the lower values of $\rho_{HV}$ indicate resonance effects of large droplets (figure 6: above and middle).

Since the differential phase $\phi_{DP}$ is immune to attenuation, classification with $K_{DP}$ is more efficient, especial for rain, heavy rain or hail (figure 6: below). In heavy rain $K_{DP}$ varies between 0 and 5°/km. It can also be seen, that the values of $K_{DP}$ increase with increasing $Z_H$.

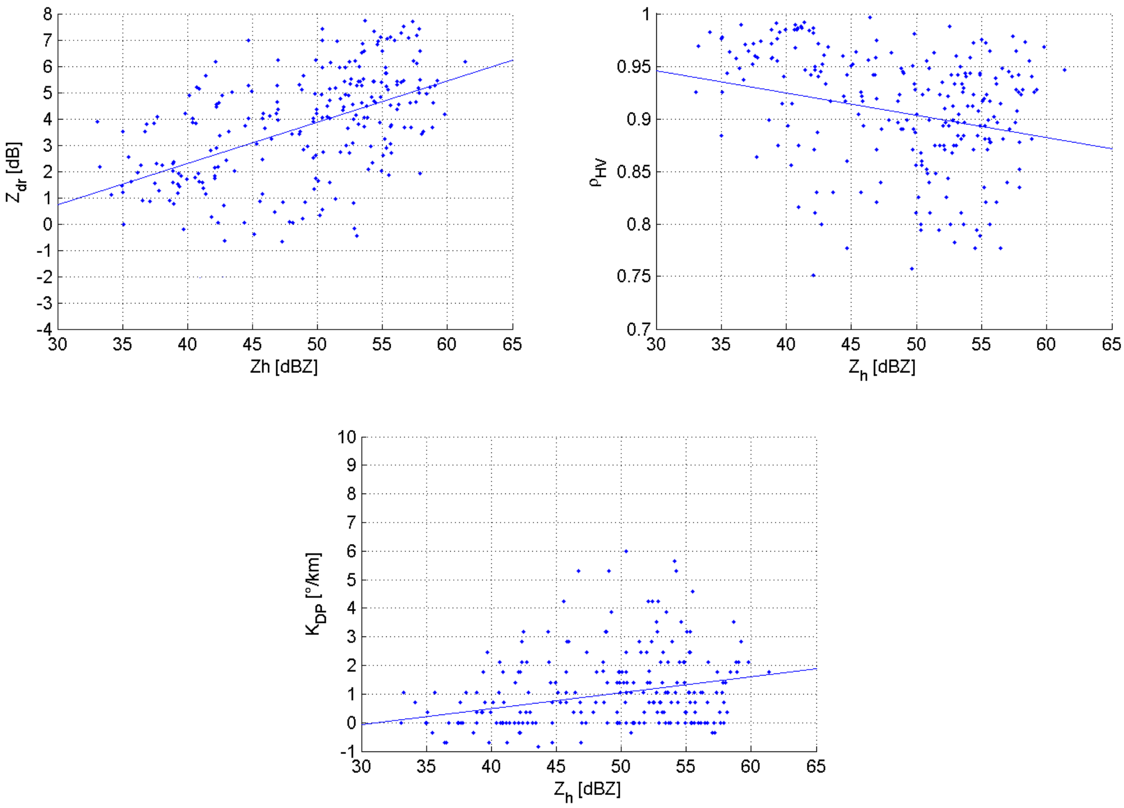


*Figure 6: The values of $Z_{DR}$, $\rho_{HV}$ and $K_{DP}$ as a function of $Z_h$ for the heavy rainfall event on May 24, 2014 in Vienna.*

## 5. Conclusion and outlook

There are differences between the ranges of the polarimetric variables of the observed hydrometeor classes and which one that can be found in the literature [Keenan (2002)].

The consistency ranges from 25 $\%$ (DZ) to slightly more than 90 percent (GR/RA) (figure 7). There are some reasons, why these deviations may occur. For example, in this paper rain is classified into light, moderate and heavy rain, whereas in the literature these rainfall intensities are summarized together in one category. Moreover, the distinction between drizzle and light rain is very difficult, since the values of $Z_H$ and $Z_{DR}$ partly overlap.

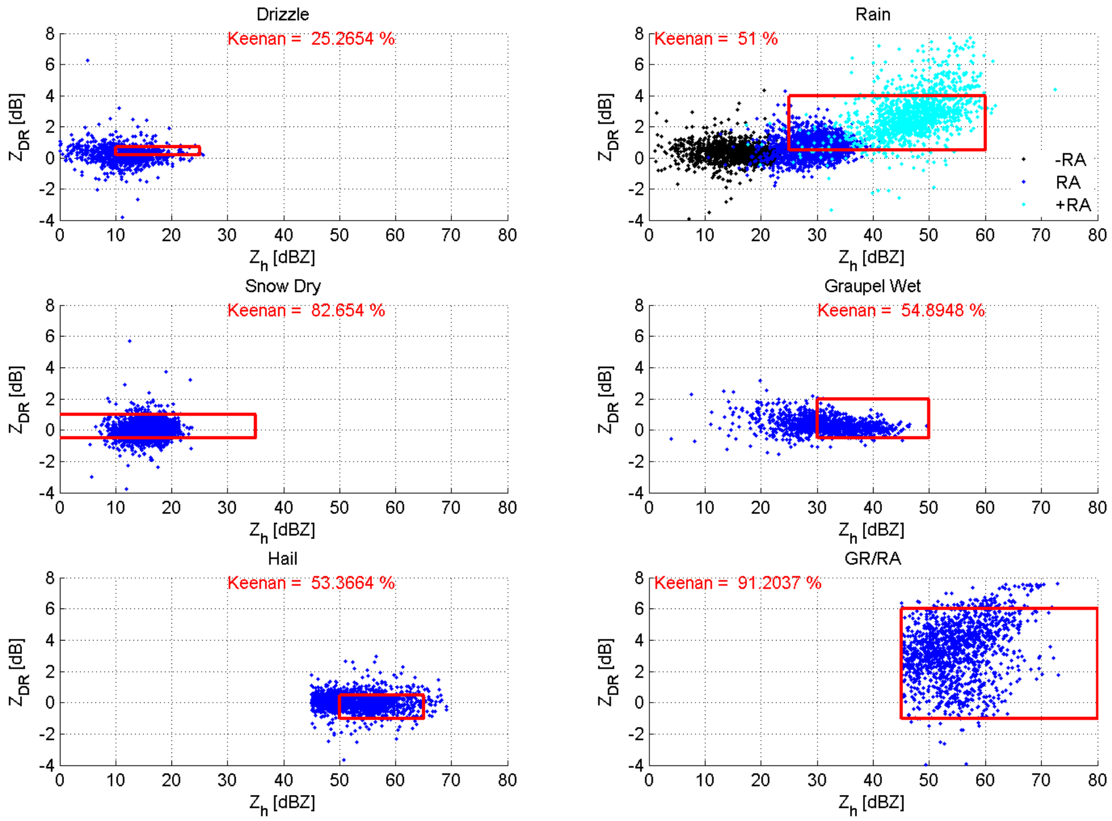


*Figure 7: $Z_{DR}$ as a function of $Z_H$. The red rectangles indicate the range of values from Keenan (2002), the blue points are the measured values.*

For better representation of Austrian precipitation characteristics it is important to adjust these threshold values.

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