On Improved Z-R Relation Derived from Czech Distrometer Data

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Abstract— Radar measurement are irreplaceable in understanding precipitation processes and have a very wide range of utilisation. Meteorological S, C and X band radars are often used for rainfall intensity measurements.

The \( R - z \) or \( z - R \) relationship is very important for estimating the intensity of precipitation \( R \) from measurements by a weather radar, which on its principle measures the radar reflectivity \( \eta \) with the help of the radar equation for meteorology:

\[
\eta = \int_0^\infty \sigma(D) \cdot N(D) dD \ [\text{mm}^2 \cdot \text{m}^{-1}]
\]

where \( N(D) \) is the drop size distribution (DSD), \( D \) is equivolumetric rain drop diameter, \( \sigma(D) \) is radar cross section of one rain drop.

Since the radar reflectivity \( \eta \) is frequency dependent, it is recalculated to radar reflectivity factor \( z \ [\text{mm}^6\text{m}^{-3}] \). In practice its decibel form \( Z = 10 \log(z) \) in dBZ is used. To illustrate, a rainfall intensity of \( R = 1 \text{ mm/h} \) corresponds to approximately \( Z = 24 \text{ dBZ} \). It applies:

\[
Z = \int_0^\infty D^6 \cdot N(D) \cdot dD \ [\text{mm}^6\text{m}^{-3}],
\]

\[
R = \frac{3.6}{10^3} \cdot \pi \cdot \int_0^\infty D^3 \cdot v(D) \cdot N(D) \cdot dD, \ [\text{mm/h}]
\]

where \( v(D) \) is the terminal rain drop falling velocity, \( N(D) \) is the drop size distribution.

IAP Prague has several years of measurements of \( N(D) \) droplet spectra corresponding to one-minute averaging. So every minute corresponds to one function \( N(D) \), if it rained. Using the formulas for the radar reflectivity factor \( Z \) calculation from the droplet spectrum \( N(D) \) on the one hand and the precipitation intensity \( R \) on the other hand, we obtain a large number of corresponding pairs \( R - z \). The measurement of droplet spectra by the distrometer actually simulates both the radar reflectivity measurement and the rain gauge measurement using Equations (1) and (2).

Simple approximation relations of the form are used to calculate \( R \) and \( z \) in the next form:

\[
z = a \cdot R^b
\]

Coefficients \( a \) and \( b \) are tabled values for different geographical regions. For Europe \( a = 200, b = 1.6 \) were derived for precipitation from stratiform clouds in mid-latitudes. In our study coefficients \( a \) and \( b \) are found using the Czech distrometer data. Their accuracy is checked by both the correlation coefficient and the RMSE.

And in addition: Based on the knowledge of the spectra, we categorize precipitation into convective and stratiform classes with the help of several criteria. For both of these precipitation classes, we found more accurate \( R - z \) approximations, as we will show through RMSE as well as through correlation.

This helps to make meteorological radar rain rate derivation more accurate.