15R.7 ALGORITHM FOR RAIN RATE RETRIEVAL FROM SPECTRAL MOMENTS OF VERTICALLY POINTING DOPPLER RADAR

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1 INTRODUCTION

Most retrieval algorithms for estimating rainfall rate from vertically pointing doppler radar observations operate on a spectrum-by-spectrum basis (e.g. Hauser and Amayenc, 1981, 1983; Sangren et al., 1984; Williams, 2002). In other words, these algorithms estimate the parameters of the rainfall drop size distribution, the magnitude of the vertical wind, and the magnitude of the turbulence-induced spectral broadening (i.e. 4 to 5 parameters in total) for each doppler spectrum separately (e.g. Doviak and Zrnić, 1993). Hence, they generally do not take into account the spatial and temporal correlation structure that is characteristic for these parameters in rainfall.

We propose a rainfall retrieval algorithm which bypasses the need for estimating drop size distribution parameters on a spectrum-by-spectrum basis. Instead, it relies on statistical moments of the Doppler velocity spectrum, which can be obtained from vertically pointing doppler radar observations. The key idea is to relate the rainfall rate to these moments using a regression model.

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basis. It is based on statistical relationships between rain rate and the low-order moments of the doppler spectrum (Sekhon and Srivastava, 1971; Atlas et al., 1973), i.e. the radar reflectivity factor (0th order moment), the mean doppler velocity (1st order moment), and the doppler spectral width (2nd order moment). These relationships are in fact generalizations of the widely used power law radar reflectivity - rain rate relations.

2 RESULTS

- If the raindrop terminal fall velocity-diameter relation follows the power law $v(D) = \alpha D^{\beta}$, then the rain rate estimator for any parameterization of the raindrop size distribution (DSD) follows the general (double power law) form

$$R = c \ Z \ v_D^{-\left(3-\beta\right)/\beta}, \quad (1)$$

where $c$ is a function of $\alpha$ and $\beta$, of the upper diameter truncation limit $D_{\text{max}}$ of the DSD, and of the width of the DSD (or, equivalently, the width of the Doppler velocity spectrum). This is actually a special case of the double-moment normalization of drop size distributions proposed by Lee et al. (2004).

- For an exponential parameterization for the DSD ($\mu = 0$) and for $D_{\text{max}} \to \infty$, $c \approx 1.31$ (see Fig. 1) if $\alpha = 3.78$ and $\beta = 0.67$ (Atlas and Ulbrich, 1977), where $v$ in m s$^{-1}$ and $D$ in mm.

- For a gamma parameterization for the DSD (arbitrary $\mu > -1$) and a given upper diameter truncation limit $AD_{\text{max}}$, the expression for $c$ becomes a rather complicated function of $\alpha$, $\beta$, $AD_{\text{max}}$, and $\mu$, involving multiple incomplete gamma functions (see Fig. 1).

- For a lognormal parameterization for the DSD...
and for $D_{\text{max}} \to \infty$, on the other hand, the rain rate estimator takes the simple explicit (triple power law) form

$$R = d \, Z \, v_D^{-(3-\beta)/\beta} \left(1+CV_D^2\right)^{(3-\beta)/(2\beta^2)},$$

where $d = 6\pi \times 10^{-4} \alpha^{3/\beta} \approx 0.725$, $-(3-\beta)/\beta \approx -3.48$, and $3(3-\beta)/(2\beta^2) \approx 7.79$ (see Fig. 1). For finite values of $D_{\text{max}}$ (assumed to be a fixed multiple of the geometric mean diameter) $d$ tends to increase as a function of the width of the DSD (and consequently as a function of the width of the Doppler spectrum).

- Application of the proposed dual- and triple parameter rainfall retrieval algorithms to optical spectropluviometer (SPO) measurements for three contrasting precipitation events during HIRE’98 (HYDROMET Integrated Radar Experiment 1998) in Marseille, France, reveals that the parameters of the estimators are much more stable than those of the traditional single-parameter reflectivity-based ($Z - R$) estimator (see Figs. 2–10).

- The universality of the parameters of the studied rainfall estimators is currently being investigated using a large dataset of raindrop size distribution measurements collected with different types of disdrometers (impact, optical and video-disdrometers) at the Cabauw Experimental Site for Atmospheric Research (CESAR) in the Netherlands.

- The next step in this investigation will be to apply the developed rainfall retrieval algorithms to measurements from S-band (the Transportable Atmospheric Research Radar TARA from TU Delft) and K-band (METEK Micro Rain Radar) vertically pointing Doppler radar measurements collected at CESAR.
3 CONCLUSIONS

We have derived theoretical relations between rain rate and the doppler spectral moments for several widely used parametric forms of the raindrop size distribution (gamma, lognormal), taking into account diameter truncation effects. We have demonstrated that by taking into account additional information provided by higher order spectral moments, the parameters of the derived statistical relations should become less dependent on the raindrop size distribution and its variability.

Using measured raindrop size spectra, we have demonstrated the validity of the derived theoretical relations in different types of rainfall (convective, stratiform) in different climatic settings (The Netherlands, south of France). We are currently investigating the implications of our approach for the scaling (normalization) of raindrop size distributions and doppler spectra. Finally, we are in the process of assessing the potential of the proposed methodology for practical purposes by investigating its sensitivity to the magnitudes of vertical wind and turbulence-induced spectral broadening.

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REFERENCES

6 October 1998: LTHE Optical Spectro−Pluviometer (corrected)

retrieved rain rate, 0.834 $Z v_D^{-3.48} \text{ mm h}^{-1}$

measured rain rate, $R$ (mm h$^{-1}$)

469 measured DSDs
1:1 line (RMSE = 0.87 mm h$^{-1}$)

6 October 1998: dual−parameter rainfall retrieval ($Z, v_D$)

time, $t$ (UTC)
cumulative rainfall, $R_{\text{cum}}$ (mm)

Figure 9: Results of dual-parameter $R(Z, v_D)$ rainrate retrieval using optical spectropluviometer data collected during HIRE’98 on 6 October 1998.

6 October 1998: LTHE Optical Spectro−Pluviometer (corrected)

retrieved rain rate, 0.759 $Z v_D^{-3.48} (1+CV_D^2)^{1.79} \text{ mm h}^{-1}$

measured rain rate, $R$ (mm h$^{-1}$)

469 measured DSDs
1:1 line (RMSE = 0.73 mm h$^{-1}$)

6 October 1998: triple−parameter rainfall retrieval ($Z, v_D, w_D$)

time, $t$ (UTC)
cumulative rainfall, $R_{\text{cum}}$ (mm)

Figure 10: Results of triple-parameter $R(Z, v_D, w_D)$ rainrate retrieval using optical spectropluviometer data collected during HIRE’98 on 6 October 1998.


