

## Constant Raindrop Fall Speed Profiles Derived from Doppler Radar Data Analyses for Steady Nonconvective Precipitation

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### ABSTRACT

For nonconvective, steady light rain with rain rates  $< 5 \text{ mm h}^{-1}$  the mean Doppler velocity of raindrop spectra was found to be constant below the melting band, when the drop-free fall speed was adjusted for pressure. The Doppler radar-weighted raindrop diameters varied from case to case from 1.5 to 2.5 mm while rain rates changed from 1.2 to 2.9  $\text{mm h}^{-1}$ . Significant changes of advected velocity moments were observed over periods of 4 min.

These findings were corroborated by three independent systems: a Doppler radar for establishing vertical air speed and mean terminal drop speeds [using extended Velocity Azimuth Display (EVAD) analyses], a Joss–Waldvogel disdrometer at the ground, and a Particle Measuring System (PMS) 2-DP probe flown on an aircraft. These measurements were supported by data from upper-air soundings. The reason why inferred raindrop spectra do not change with height is the negligible interaction rate between raindrops at low rain rates. At low rain rates, numerical box models of drop collisions strongly support this interpretation. It was found that increasing characteristic drop diameters are correlated with increasing rain rates.

### 1. Introduction

The variation in raindrop size distributions (RSDs) with space and time can provide important insights into rain evolution. For applications in meteorology and hydrology it is desirable to know the RSDs since they determine the radar reflectivity factor. The Marshall–Palmer (1948) distribution is such an attempt to link rain rate to radar reflectivity. The problem is that the

rain rate is measured on the ground, whereas radar reflectivities are measured aloft. The use of Doppler radar, however, allows the measurement of the vertical speed distribution of the scatterers (raindrops), which can be related to the strongly diameter-dependent raindrop fall speeds. Some Doppler radar methods, which have been developed to infer RSDs remotely, will be discussed below. In this study radar signatures of RSD variations in the vertical are analyzed. Comparisons are also made with results obtained by numerical modeling of raindrop evolution by collisions and breakup.

By pointing a Doppler radar straight up, horizontal motion components disappear and radial speeds now consist of the sum of particle terminal speed,  $V_T$ , and vertical air speed,  $w_a$ . Under Rayleigh scattering, the normalized signal power density  $S_n$  at a frequency corresponding to  $(w_a - V_T)$  is related to the particle diameter  $D$ , the number concentration per diameter interval,  $N(D)$ , and the radar reflectivity factor  $Z$  (e.g., Doviak and Zrnić 1984):

$$S_n(w_a - V_T) dV_T = D^6 N(D) dD Z^{-1}. \quad (1)$$

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