A Possible Explanation for the Z-R Parameter Inconsistency when Comparing Stratiform and Convective Rainfall

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The well-known Z-R power law $Z = AR^b$ uses two parameters, $A$ and $b$, in order to relate rainfall rate $R$ to measured weather radar reflectivity $Z$. A common method used by researchers is to compute $Z$ and $R$ from disdrometer data and then extract the A-b parameter pair from a log-linear line fit to a scatter plot of Z-R pairs. Even though it may seem far more truthful to extract the parameter pair from a fit of radar $Z_R$ versus gauge rainfall rate $R_g$, the extreme difference in spatial and temporal sampling volumes between radar and rain gauge creates a slew of problems that can generally only be solved by using rain gauge arrays and long sampling averages. Disdrometer derived A-b parameters are easily obtained and can provide information for the study of stratiform versus convective rainfall. However, an inconsistency appears when comparing averaged A-b pairs from various researchers. Values of $b$ range from 1.26 to 1.51 for both stratiform and convective events. Paradoxically the values of $A$ fall into three groups: 150 to 200 for convective; 200 to 400 for stratiform; and 400 to 500 again for convective. This apparent inconsistency can be explained by computing the A-b pair using the gamma DSD coupled with a modified drop terminal velocity model, $v(D) = \alpha D^{\beta} - \omega$, where $\omega$ is a somewhat artificial constant vertical velocity of the air above the disdrometer. This model predicts three regions of $A$, corresponding to $\omega < 0$, $\omega = 0$, and $\omega > 0$, which approximately matches observed data.

Circles are JWD derived A-b pairs (near Athalassa, Cyprus) from selected 24 hour averages during 2011 - 2014. Gray circles represent stratiform events defined by rainfall rates that did not exceed 10 mm/h at anytime during the 24-hour period. Green and red circles represent convective events defined by rainfall rates greater than or equal to 10 mm/h at anytime during the 24 hour period. Green circles are A-b pairs that fall to the left of the stratiform gray circles, while red circles are pairs that fall to the right. The lines are output from a model simulation using the 3-parameter gamma DSD with drop terminal velocity approximated as $v(D) = \alpha D^{\beta} - \omega$. For various values of $\Delta$, $\mu$, and $\Lambda$, gray lines correspond to $\omega = 0$, green lines to $\omega = -4$ [m/s], and red lines to $\omega = +1$ [m/s]. The squares correspond to the A-b pairs from the particle trajectory simulation in the graph to the right.

Using CFD based single particle trajectory modeling and a vertical wind profile, the terminal velocity can be approximated under any given wind conditions. The resultant terminal velocity function is then approximated by a 3rd order polynomial. Three cases are simulated: $\omega = 0$, $\omega = -5$ [m/s], and $\omega = +4$ [m/s]. A-b parameter pairs are then found by performing a Monte Carlo Z-R scatter plot using the three-parameter gamma DSD.