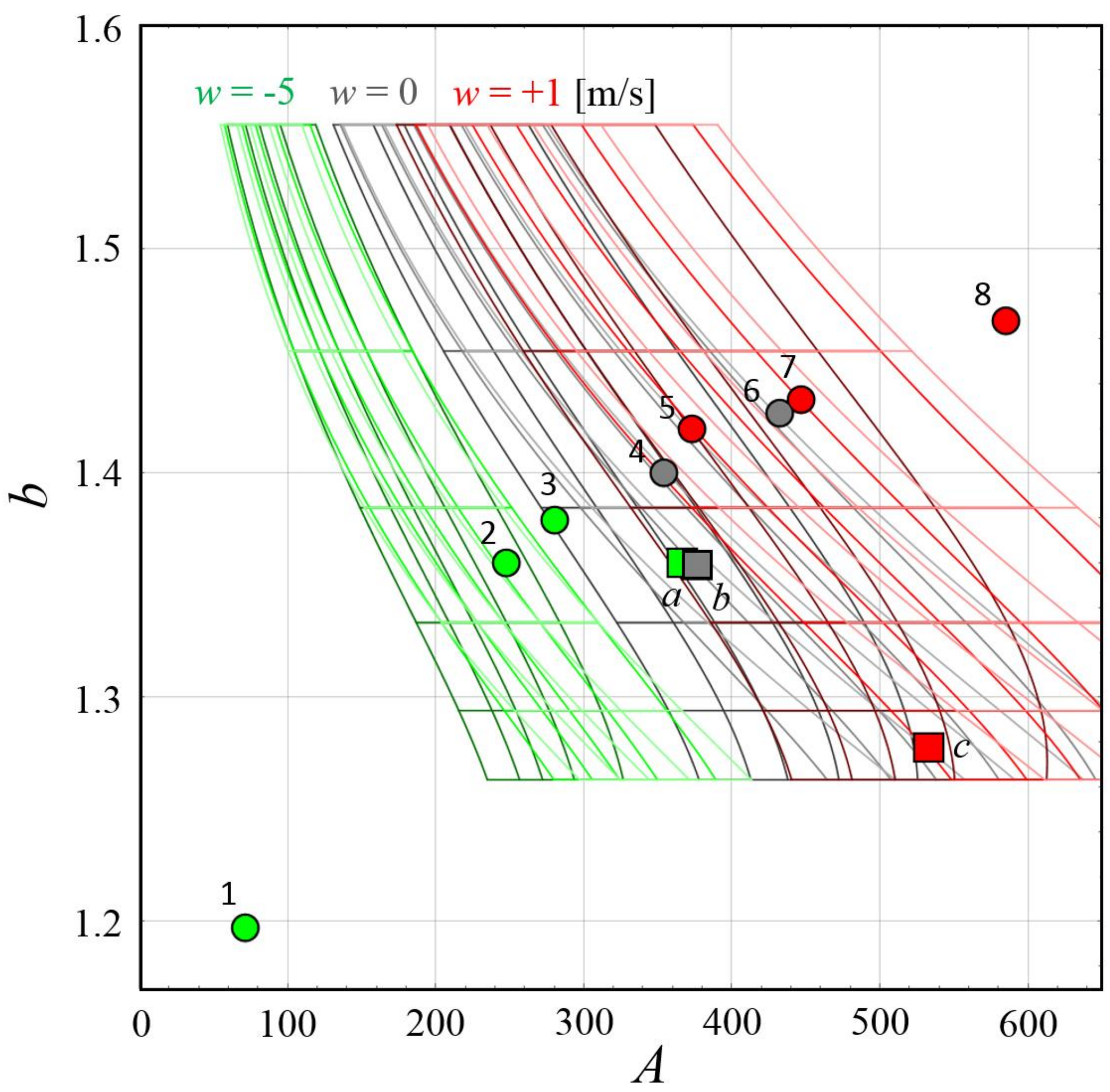
A Possible Explanation for the Z-R Parameter Inconsistency when Comparing Stratiform and Convective Rainfall

John Lane
Easi-ESC, Kennedy Space Center
Florida, USA

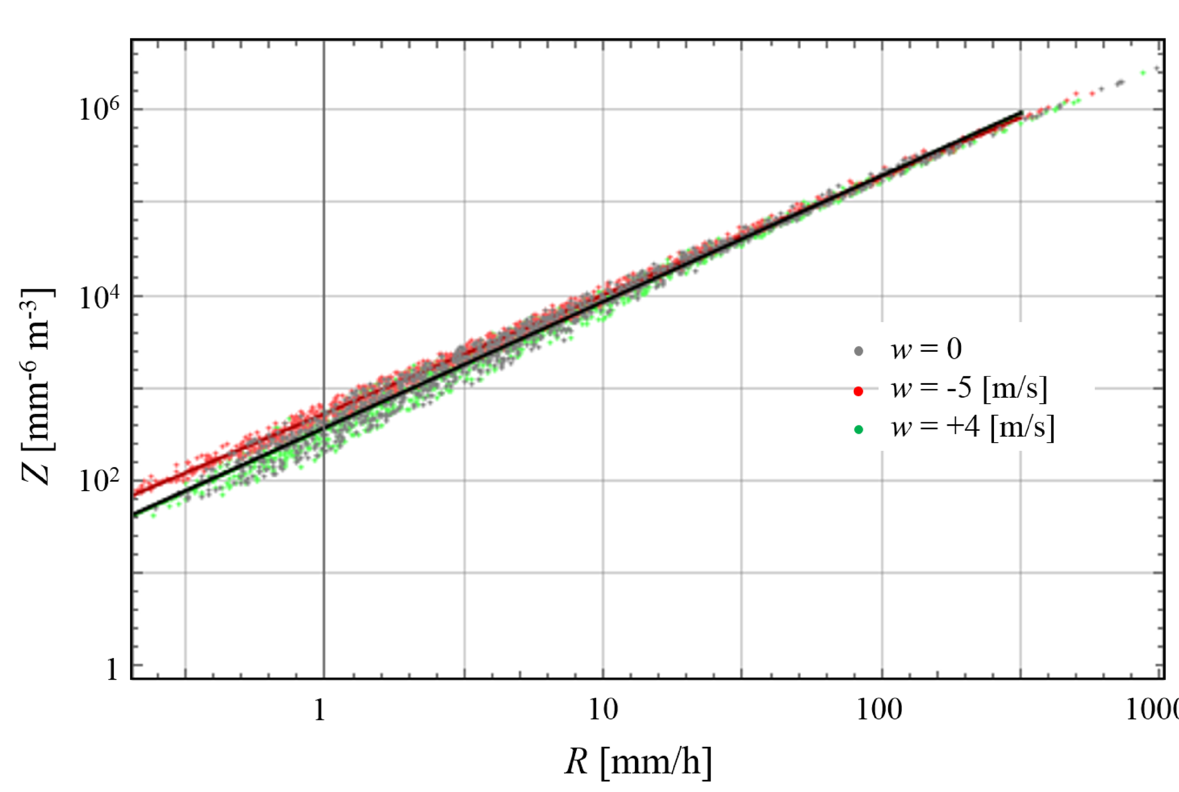
Takis Kasparis
Cyprus University of Technology
Limassol, Cyprus

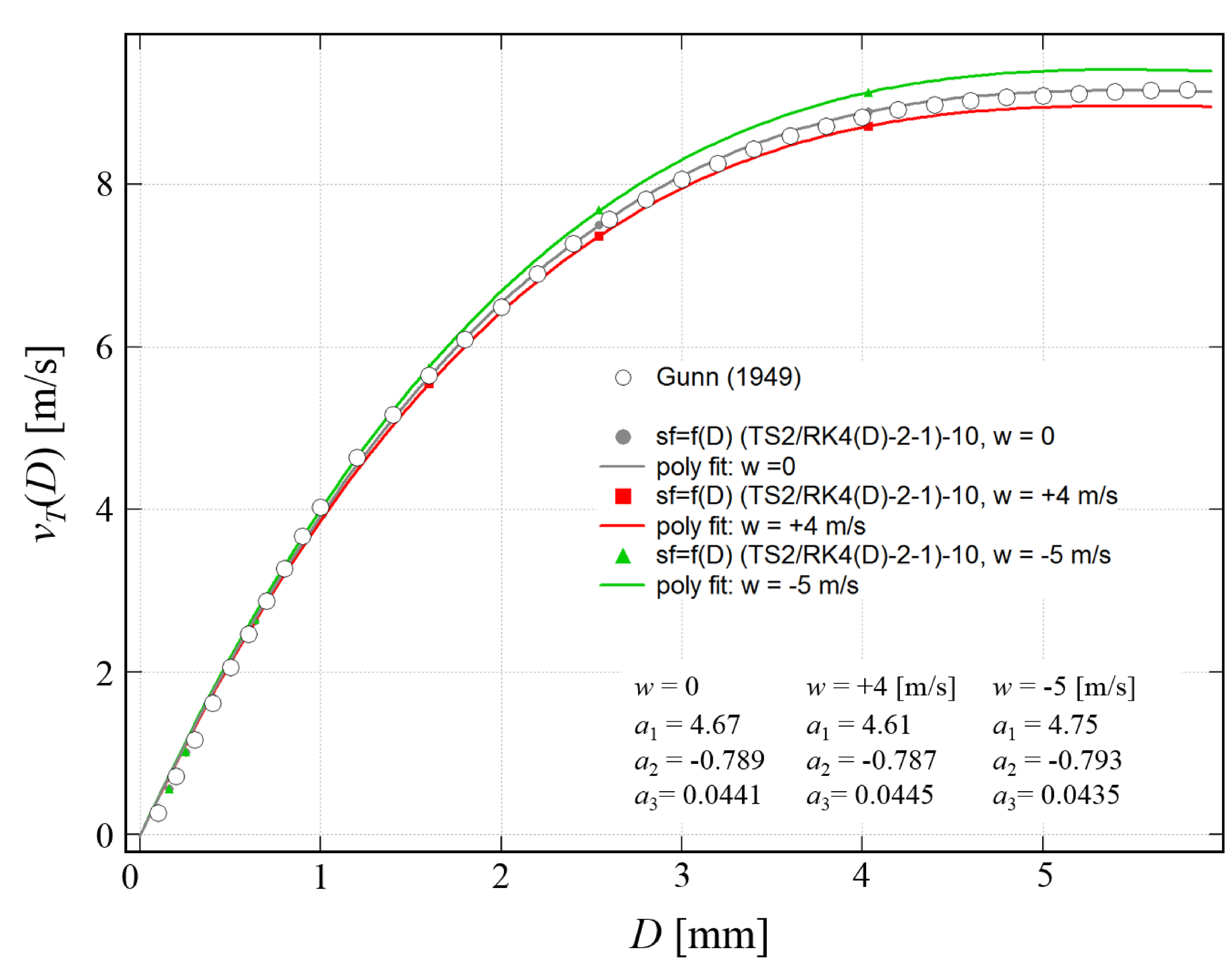
Silas Michaelides
Cyprus University of Technology
Limassol, Cyprus

The well-known Z-R power law $Z = A R^b$ 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, $v(D) = \alpha D^{\beta} - w$, where w is a somewhat artificial constant vertical velocity of the air above the disdrometer. This model predicts three regions of A, corresponding to $w < 0$, $w = 0$, and $w > 0$, which approximately matches observed data.



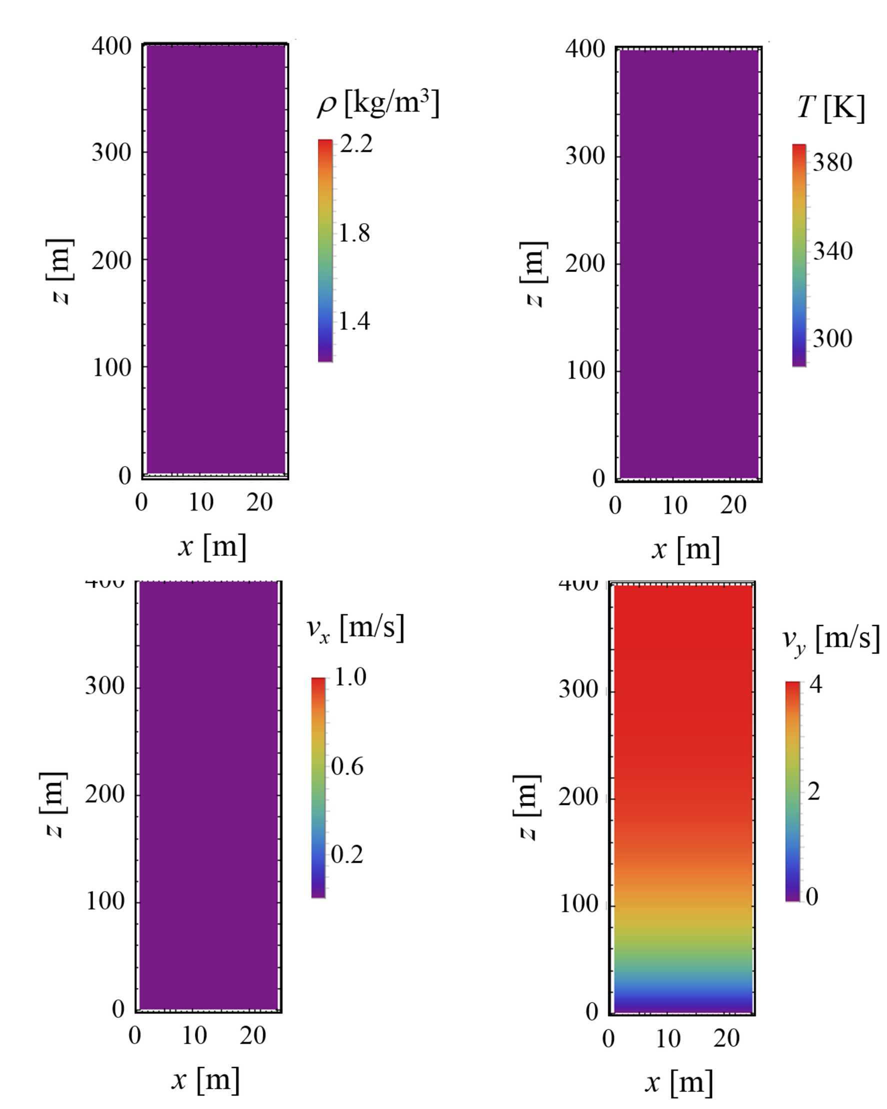
Circles are JWD derived A-b pairs (near Athalassa, Cyprus) from selected 24 hour averages during 2011 - 2014. Gray circles represent stratiform events defined by rainfall rates that did not exceed 10 mm/h at anytime during the 24-hour period. Green and red circles represent convective events defined 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 and 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 $v(D) = \alpha D^{\beta} - w$. For various values of N_0, μ, and Λ, gray lines correspond to $w = 0$, green lines to $w = -4$ [m/s], and red lines to $w = +1$ [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: $w = 0$, $w = -5$ [m/s], and $w = +4$ [m/s]. A-b parameter pairs are then found by performing a Monte Carlo Z-R scatter plot using the three-parameter gamma DSD.

CFD Input to Particle Trajectory Code: air density, air temperature, horizontal air velocity, and vertical air velocity. Below are the inputs for the $w = +4$ case.



Joss Disdrometer Data
Anthalassa, Cyprus,
35.15N, 33.40W

1: Aug 10, 2011 **2**: May 29, 2011 **3**: Apr 17, 2013 **4**: Jan 27, 2012 **5**: Oct 18, 2013 **6**: Sep 23, 2011 **7**: Oct 24, 2012 **8**: May 10, 2013