W-band Moments and Rain Rate

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Steiner et al. (2004) give relationships for a gamma distribution of rain drops and radar moments in the Rayleigh approximation:

 (1)

Three moments of interest are the reflectivity, *Z*, the rain rate, *R*, and the Doppler velocity, *WR*,

 (2a)

 (2b)

 (2c)

Here *R* is in mm/h, *D* is in mm, and the sedimentation velocity of a drop, *V(D)*, is approximated by



With *V0*=3.78.

The variables *ZR* and *VR* and measurable by radar. We can use (2a) to eliminate *N0* from (2b)

 (3a)

 (3b)

and we can use (2c) to eliminate Λ from (2b).

 (4)

Thus we can derive an equation for rain rate in terms of radar observables,

 (5)

We can also use (3a) and (4) to eliminate Λ and derive an expression to compute *N0* from radar observables

 (6)

In principle (5) and (6) can be used to estimate rain rate and the rain drop concentration parameter at radar wavelengths where the Rayleigh approximation is valid. However, at W-band this is not the case. So, we need a way to correct W-band reflectivity, *ZWB*, and Doppler velocity, *VWB*, to get the equivalent Rayleigh values. To do this, we have used figures 1 and 7 from Tian et al. (2007) to abstract the following approximations for μ=0

 (7a)

 (7b)

Where .

We have applied these formulae to the CALWATER2 mean values shown if Figs. 7 and 8.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | | | | | | | |
| <*Rnc*> | *dBZWB* | *VWB* | *ΔV* | Δ*dBZ* | *dBZR* | *VR* | *R* | *10e3\*N0* | *D0* |
| mm/h |  | m/s | m/s |  |  | m/s | mm/h | mm-1m-3 | mm |
| 0.4 | 5 | 3.4 | 1.1 | 4 | 8.5 | 4.5 | 0.05 | 1.1 | 0.7 |
| 1.0 | 11 | 3.7 | 1.6 | 6 | 17 | 5.3 | 0.2 | 1.4 | 0.9 |
| 2.1 | 16 | 3.9 | 2.0 | 8 | 24 | 5.9 | 0.7 | 2.4 | 1.0 |
| 4.1 | 19 | 4.1 | 2.5 | 10.5 | 29.5 | 6.6 | 1.8 | 2.9 | 1.2 |
| 7.7 | 22 | 4.3 | 2.9 | 13.5 | 35.5 | 7.2 | 4.8 | 4.0 | 1.4 |

One thing to note is the lower values of R obtained in lighter precipitation. Perhaps this means the NRCS method is overestimating R in many cases? Could be absorption by clouds. The conversion of W-band Doppler and dBZ depends on μ and there is also the ‘double value’ problem. Also, (5) and (7a) suggest extreme sensitivity of R on Vw (7th power!!). One amusing thing, a fit of Λ from (4) against *Rnc* is very close to Marshall-Palmer.