Uncertainties in Raindrop Size Distributions Retrieved from Profiler Observations using Ensemble Statistics

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Motivation

Assimilation of precipitation estimates into numerical models requires information on the error characteristics of the observations which include:

Measurement Error: Uncertainties in directly measured and derived quantities.

Representativeness Error: Variability of observed or derived quantities in space & time.

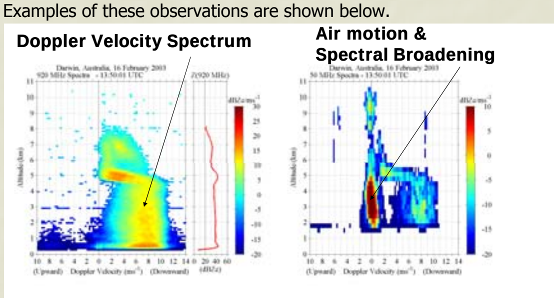
This study estimates the Measurement Error of raindrop size distributions (DSDs) retrieved from vertically pointing Doppler radars by retrieving the DSDs from different numerical models and analyzing the DSD statistics relative to the ensemble mean.

DSD Model Inputs

All of the DSD retrieval models use the same inputs from two profilers operating at 920-MHz and 50-MHz. The profilers provide the following observations:

- **Vertical air motion (50-MHz profiler)**
- **Spectral Broadening (50-MHz profiler)**
- **Radar Doppler velocity spectrum (920-MHz profiler)**

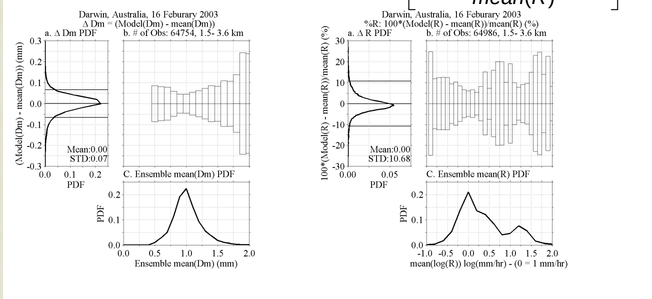
Examples of these observations are shown below.



Statistics Relative to the Ensemble Mean

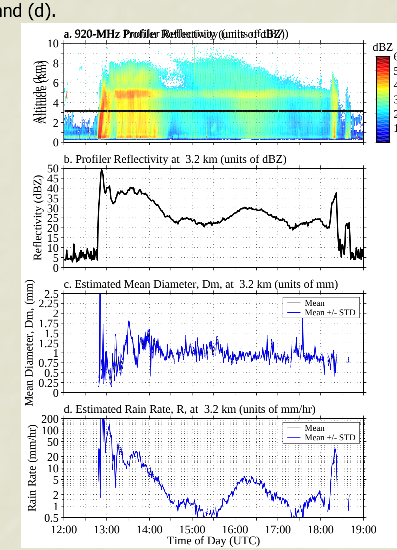
The mean mass-weighted diameter, D_m, and the rain rate, R, are estimated for each DSD model and the ensemble mean is estimated for each resolution volume (each profile (45 second) and range gate (100 meters)). The statistics for each parameter relative to the ensemble mean are shown below.

$$\Delta D_m = Model(D_m) - mean(D_m) \qquad \%R = 100\left[\frac{Model(R) - mean(R)}{mean(R)}\right]$$



D_m & R Statistics at 3.2 km

The top panel shows the 920-MHz profiler reflectivity for the precipitation event that passed over the Darwin, Australia, profiler site on 16 February 2003. Panel (b) shows the reflectivity at 3.2 km. The mean and standard deviation of the ensemble D_m and R are shown for the 3.2 km altitude in panels (c) and (d).



DSD Model Descriptions

The DSD retrieval models assume different functional forms of the DSD and are divided into two numerical classes. The flow diagrams for the two classes are shown to the right and the functional forms of the DSD used in this study include:

Deconvolution Techniques

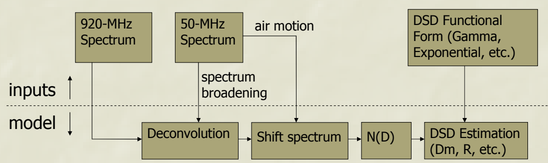
A	Modified Gamma	$N(D)=N_oD^{\mu}\exp[(4+\mu)D/D_m]$	Ulbrich 1983
B	Normalized Gamma	$N(D)=N_o^* F_\mu(D/D_m)$	Testud et al. 2001
C	Log-Normal	$N(D)=N_t\exp[-\ln^2(D/D_m)/(2\ln^2\sigma)]$	Feingold & Levin 1986
D	Discrete Distribution	no mathematical function	

Note-For methods A,B, and C, the cost function was minimized in D^k space with k = 3, 4, 5, and 6 to produce 4 different solutions.

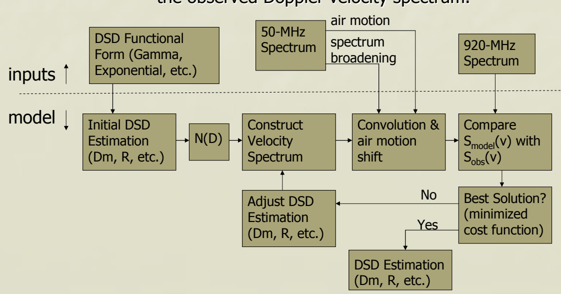
Convolution Techniques

E	Exponential μ=0	$N(D)=N_o\exp[-(4)D/D_m]$	μ=0
F	Modified Gamma, μ=2.5	$N(D)=N_oD^{2.5}\exp[-(6.5)D/D_m]$	μ=2.5
G	Modified Gamma, variable μ	$N(D)=N_oD^{\mu}\exp[-(4+\mu)D/D_m]$	μ=variable

The goal of the **Deconvolution Technique** is to convert the observed Doppler velocity spectrum into a raindrop number concentration and then estimate the rain parameters from this number concentration.



The goal of the **Convolution Technique** is to estimate the raindrop number concentration that best replicates the observed Doppler velocity spectrum.



Concluding Remarks

Given the same inputs from two vertically pointing profiling radars (one radar providing the vertical air motion and spectral broadening estimates and the other providing the radar Doppler velocity spectrum), the raindrop size distribution (DSD) at each range gate is estimated using 16 different retrieval models. The statistics of the different retrieved DSD parameters relative to the ensemble mean provides an estimate of the Measurement Error for the DSD retrievals.

Using the observations from 16 February 2003 at Darwin, Australia, the ensemble statistics indicate:

- **the variation in D_m relative to the ensemble mean has a standard deviation of about 0.1 mm.**
- **the variation in relative rain rate difference has a standard deviation of about 11%.**

These statistics do not provide any information on the absolute error of the profiler retrievals compared with other instruments. Those statistics will be performed in a future study.

References

Feingold, G., and Z. Levin, 1986: The Lognormal Fit to Raindrop Spectra from Frontal Convective Clouds in Israel. J. Appl. Meteor., 25, 1346–1364.

Testud, J., S. Oury, R.A. Black, P. Amayenc, and X. Dou, 2001: The Concept of "Normalized" Distribution to Describe Raindrop Spectra: A Tool for Cloud Physics and Cloud Remote Sensing. J. Appl. Meteor., 40, 1118–1140.

Ulbrich, C.W. 1983: Natural Variations in the Analytical Form of the Raindrop Size Distribution. J. Appl. Meteor., 22, 10, 1764–1775.