# COMPARISON OF TWO *X*-BAND POLARIMETRIC DROP SIZE DISTRIBUTION RETRIEVALS: EVALUATION AND APPLICATIONS


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## Motivation:

Ground validation of satellite rain retrievals and cloud resolving model parameterizations.
Physical validation of radar/radiometric measurements and cloud model simulations of stratiform and convective precipitation.
Support flash flood prediction for small scale basins and urban catchments.

## What do we need:

*Accurate evaluation of rain rates at high spatial and temporal resolution and of the hydrometeors' size distribution and phase.*

## Our research questions:

**How accurate *X*-Band Dual-Polarization Radar Rainfall Observations can be in estimating rainfall drop size distribution (DSD) parameters at high resolution?**

## Systems Overview:

### XPOL:

- 9.3 GHz H/V simultaneous transmission at 50 (25/25) kW peak power;
- 0.9 deg beam width; variable pulse length (60-400 m);
- 200 km max range with ~400m resolution, 500 gates and 940 Hz PRF;
- 0.2-dB noise STD in $Z_H$ and $Z_{DR}$ and 1-degree noise STD in $\Phi_{DP}$ and 1-dB ZH and 0.3-dB ZDR calibration;
- -110 dBm minimum detectable signal.

### MP-X:

- 9.375 GHz at 50 (25/25) kW peak power;
- Horizontal and Vertical Polarization;
- 1.3 deg beam width; pulse length 0.5μs;
- 80 km observation range;
- 2.3 dB Noise Figure;
- -110 dBm minimum detectable signal.

## Algorithm Formulation:

$$N(D) = N_0 D^{\mu} \exp(-\Lambda D) \quad \text{where} \quad \Lambda D_0 \cong 3.67 + \mu$$

**Gamma distribution model (Ulbrich, 1983):**

$$N(D) = N_w f(\mu) \left(\frac{D}{D_0}\right)^{\mu} \exp\left[-(3.67+\mu)\frac{D}{D_0}\right]$$

*The gamma raindrop size distribution governing parameters can be normalized in order to be considering more physically (Willis, 1984; Testud et al. 2001).*

**Note:** *Each data point is 3-min-averaged spectra to which a gamma DSD is fitted. There are totally 2725 3-min samples*

### DSD parameter retrieval:

**Once *X*-band data has been corrected for attenuation (Anagnostou et al. 2004; 2006, Matrosov et al. 2002; 2005, Park et al. 2005) it is possible to proceed with the estimation of the three governing parameters (*Nw*, $D_0$ and $\mu$) that control the gamma drop size distribution:**

**(a) Constrained Algorithm (Brandes et al. 2003, 2004):**
**This method assumes a polynomial axis ratio relation:**

$$r = 0.9951 + 0.0251\,D - 0.03644\,D^2 + 0.00503\,D^3 - 0.00025\,D^4$$

$$D_0 = a + bZ_{DR} + cZ_{DR}^2 + dZ_{DR}^3$$

$$LWC = AZ_H \cdot 10^{\left(BZ_{DR} + CZ_{DR}^2 + DZ_{DR}^3 + EZ_{DR}^4\right)}$$

$$\Lambda(mm^{-1}) = \gamma + \beta\mu + \alpha\mu^2$$

**(b) *β(beta)*-method Algorithm (Gorgucci et al. 2000, 2001 & Bringi et al. 2001):**

**This method presented here is based on treating the raindrop shape (or raindrop axis ratio) as a variable:** $r = 1.03 - \beta D$

**Estimate the $\beta$ parameter from the polarimetric data set ($Z_H$, $Z_{DR}$, and $K_{DP}$) using the algorithm described by Gorgucci et al. (2000) assuming Rayleigh scattering (Bringi et al. 2002). The next relations are using the $\beta$-method for polarimetric measurements exceed the thresholds of 0.2 (°km-1) for $K_{DP}$, and 35.0 (dBZ) and 0.2 (dB) for $Z_H$ and $Z_{DR}$, respectively:**

$$\beta = 0.9425\left(\frac{K_{DP}}{Z_H}\right)^{0.2624}\left(\zeta_{DR} - 1\right)^{0.377}$$

$$D_0 = 0.627\,Z_H^{0.057}\,\zeta_{DR}^{\left(0.03\beta^{-1.22}\right)} \qquad \log_{10} N_w = 2.97\,Z_H^{0.07}\,\zeta_{DR}^{\left(-0.03\beta^{-1.26}\right)}$$

**For $K_{DP} < 0.2$ (°km$^{-1}$) and $Z_H < 35$ dBZ and $Z_{DR} \geq 0.2$ dB:**

$$D_0 = 1.38 Z_{DR}^{0.34} \qquad N_w = \frac{18.87\,Z_H}{D_0^{7.692}}$$

**and $Z_H < 35$ dBZ and $Z_{DR} < 0.2$ dB:**

$$D_0 = 1.465\left(\frac{Z_H}{N_w}\right)^{0.13} = \gamma Z_H^{0.13} \qquad \gamma = 1.38\left(\frac{Z_{DR}}{Z_H^{0.25}}\right)^{0.34} \qquad N_w = \left(\frac{1.465}{\gamma}\right)^{7.692}$$

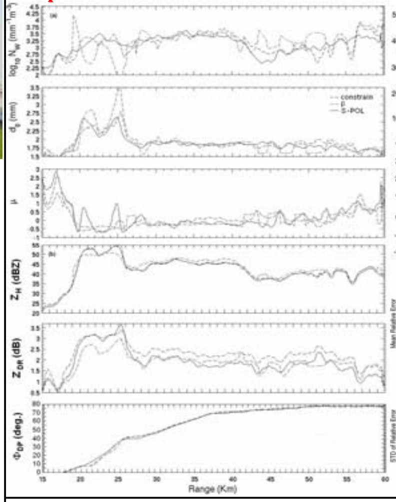
## XPOL experiment in IHOP: May – June 2002:

✓Targeting: evaluation of attenuation correction accuracy, and its sensitivity to axial ratio model and measurement noise; and evaluation of DSD parameter retrieval;

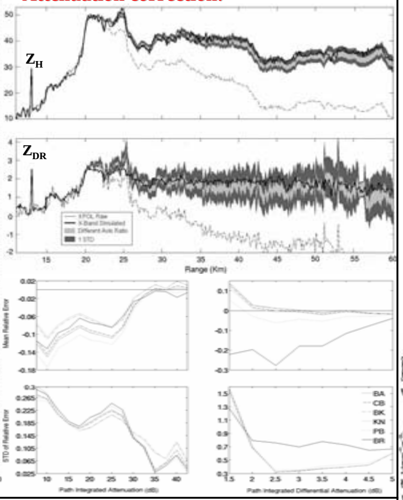
✓Strategy: Coincident and closely matched S-POL and X-POL multi-level PPI and RHI scans;

✓Data: Three major summer storm cases (MCS) with significant convective and stratiform rain regimes;

### Sample Plots:

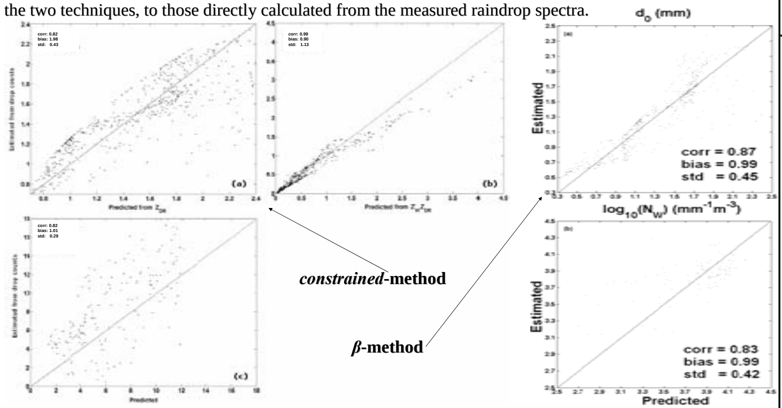



### Attenuation correction:

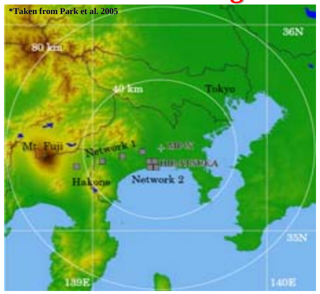


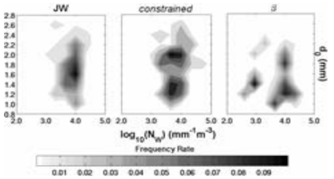

## Algorithm Evaluation From Measured DSD Spectra

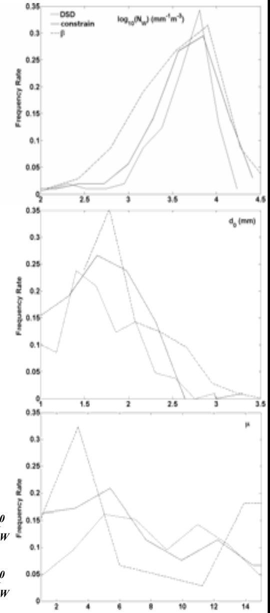
For the evaluation of the relations, disdrometer data from the Typhoon case in Japan are used. We compare the technique-retrieved DSD parameters, i.e., parameters retrieved from the simulated radar parameters using the two techniques, to those directly calculated from the measured raindrop spectra.



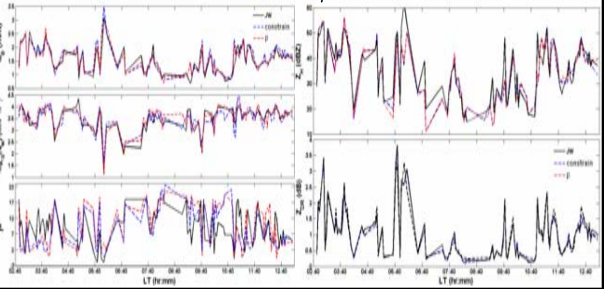

## MP-X Radar 09 August 2003:




| JW-*constrain* | Correlation | Bias | STD | |
|---|---|---|---|---|
| | 0.88 | 1.0317 | 0.454 | $D_0$ |
| | 0.78 | 0.9936 | 0.469 | $N_W$ |
| | 0.57 | 1.6531 | 5.454 | $\mu$ |
| JW-*β* | 0.67 | 0.945 | 0.565 | $D_0$ |
| | 0.56 | 0.98 | 0.598 | $N_W$ |
| | 0.46 | 0.64 | 6.012 | $\mu$ |




## Conclusions and on-going research:

✓We examined two well documented DSD retrieval algorithms that has been tested using observations from *S* and *C*–band frequencies; We reproduced the algorithm for *X*-band frequencies and we compared with unattenuated frequencies and in-suite JW disdrometers.

✓ From the analysis we concluded that the *β*–method is more noise and unstable in low and moderate rainfall because it introduces the $K_{DP}$; On the other hand the *constrained*-method avoids the use of simulated DSDs and the errors associated with $K_{DP}$.

✓ Additional studies are required to verify both algorithms on heavy and moderate rainfall compared to disdrometer measurements as well as the stability of *μ-Λ* relation. In addition, it is required to investigate the rainfall error propagates from each method versus unattenuated polarimetric radar frequencies and in-suite raingauges. This research would benefits to the effort underway by CASA investigators on developing integrated weather and flood forecasting systems to advance flood warning accuracy, resolution and lead-time.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