Using Rain Microstructure Information from 2-D Video Disdrometer for Propagation Predictions at 20 GHz

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Propagation predictions/calculations (in rain) use bulk assumptions:

a) 1-minute drop size distribution (e.g. exponential, gamma, log-normal)
b) mean drop shapes (often assuming oblate spheroids with axis ratio depending on drop diameter)
c) drops have a Gaussian canting angle distribution, given by zero deg mean and 5-10 deg standard deviation.

Q: Are these assumptions valid to predict co and cross-polar effects ?

A: Examine shape/size/orientation of individual hydrometeors and perform 'drop-by-drop' scattering calculations

Contents

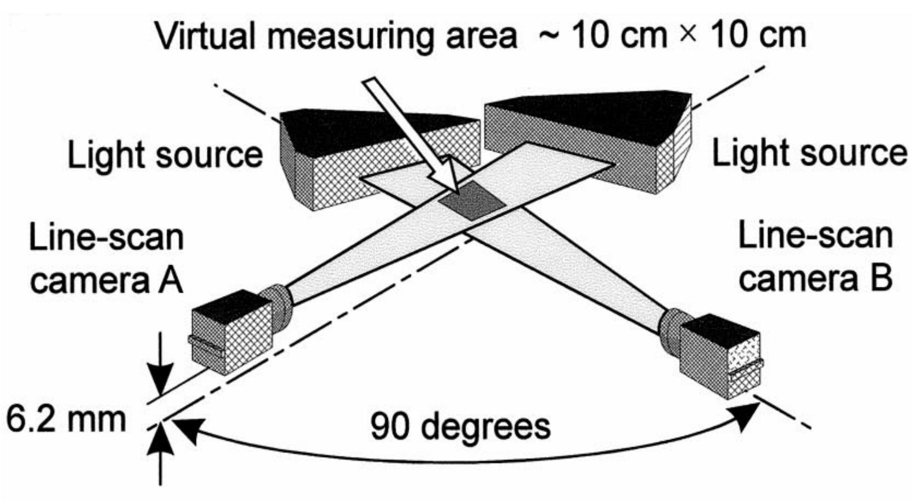
- 2-D video disdrometer : brief description and retrieving shape/size/orientation from the images
- Summary of drop shapes and canting angle distributions
- Scattering calculations for individual hydrometeors and 1-minute ‘integration’ versus assumed bulk properties
- Specific attenuation vs. rainfall rate (cf. Rec. P. 838-3)
- XPD spread
- Comments

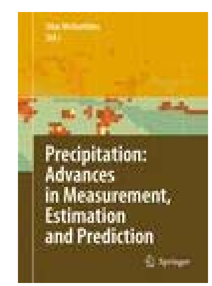
Some of the 2DVD locations

In-depth analysis of data (in terms of rainfall microstructure) has been done in several locations:

Alabama – continental
Toronto – mid-latitude, continental
Okinawa – sub-tropical, oceanic
Sumatra – equatorial
Colorado – High plains

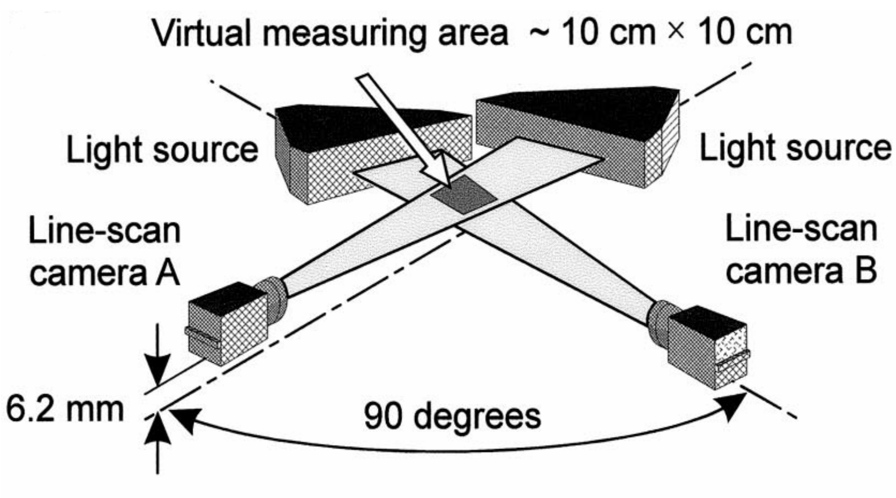
Also data from the controlled artificial rain experiment





Springer 2008
ISBN: 978-3-540-77654-3
Michaelides, Silas C. (Ed.)
540 p. 38 illus., 23 in color., Hardcover

Pixel frequency of 40 MHz



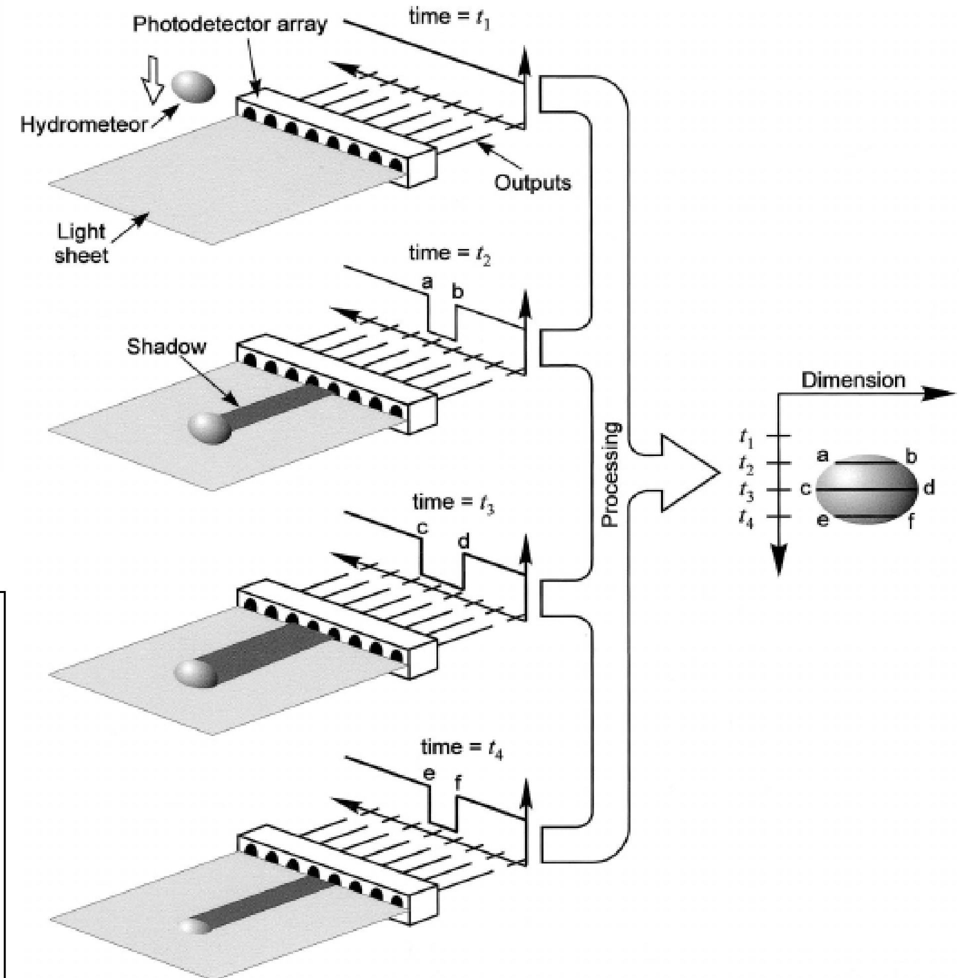


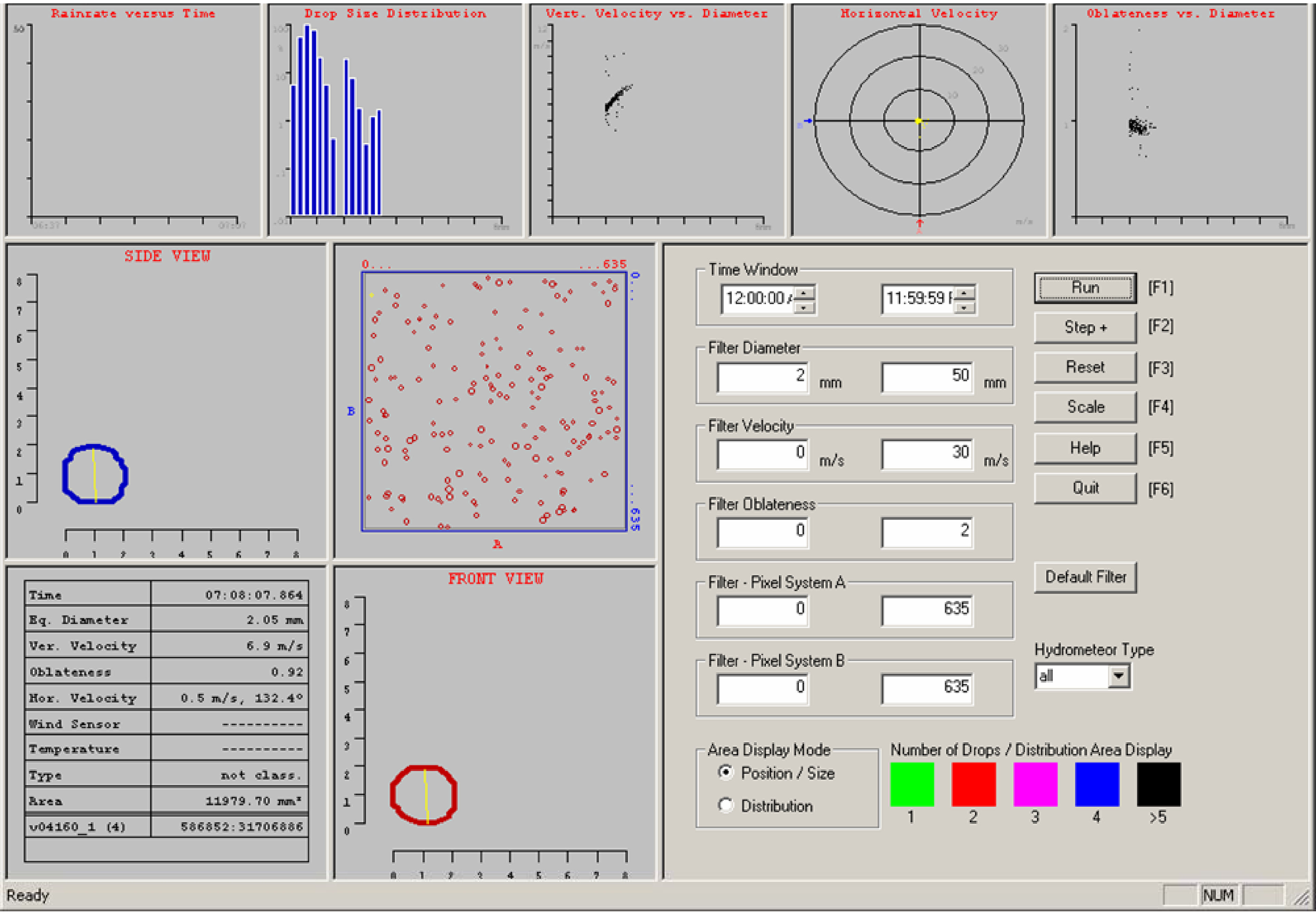
FIG. 4. Reconstructing the shape of a hydrometeor. (left) When pixels are polled at time t_1 (top) the hydrometeor is outside the light sheet and all photodetectors are illuminated. When the pixels are polled at times t_2, t_3, and t_4, the hydrometeor is in the light sheet, and 2, 3, and 2, respectively pixels are dark. (right) Approximate reconstruction of hydrometeor projection.

From Kruger and Krajewski (2002)

<u>Performance Specifications</u>

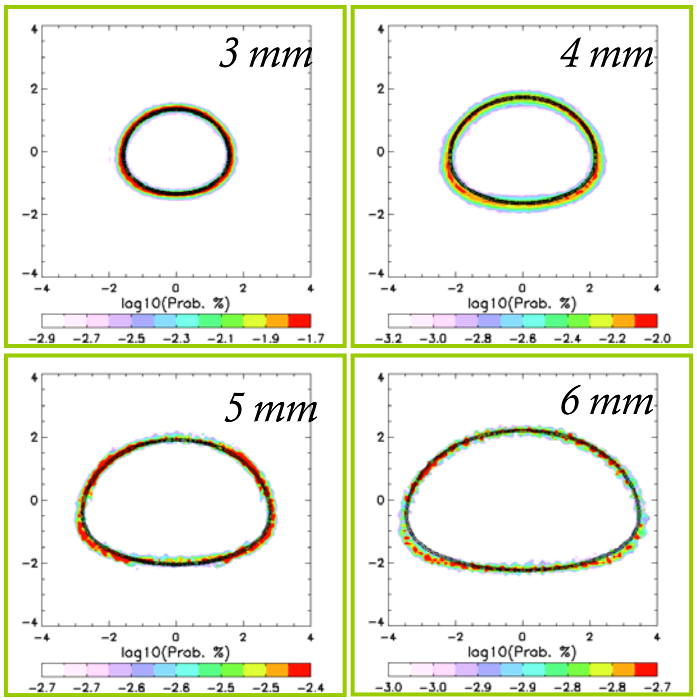
horizontal resolution better than 0.19 mm
vertical resolution better than 0.19 mm (vert. vel. < 10 m/s)
vertical velocity accuracy better than 4% (vert. vel. < 10 m/s)
sampling area approx. 100 x 100 mm²
integration time 15 sec. to 12 hours (for display)
data rate 2- 4MB/mm rain (typ.)
mains voltage 100 - 240 V at 50/60 Hz
power consumption appr. 500 W

2D-Video-Disdrometer : View_Hyd software



Drop shapes / variations

from the artificial rain experiment
(over 115,000 drops)

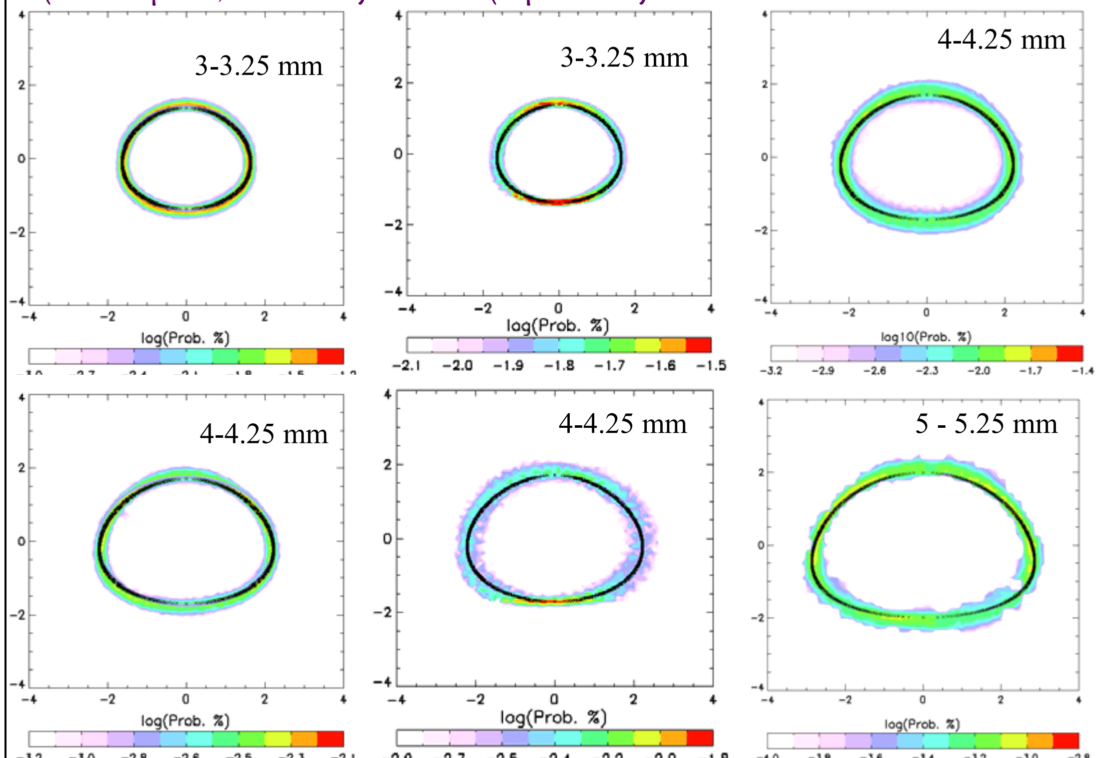


in natural rain

Okinawa
(sub-tropical, maritime)

West Sumatra
(equatorial)

Alabama
(mid latitude, continental)

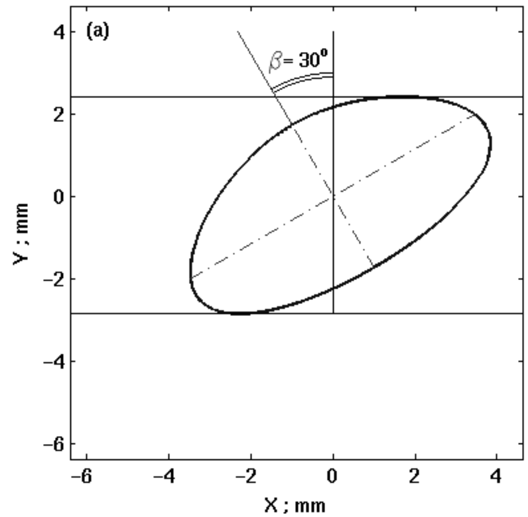


Solid black curves represent the 'most probable' drop shapes from the artificial rain experiment.

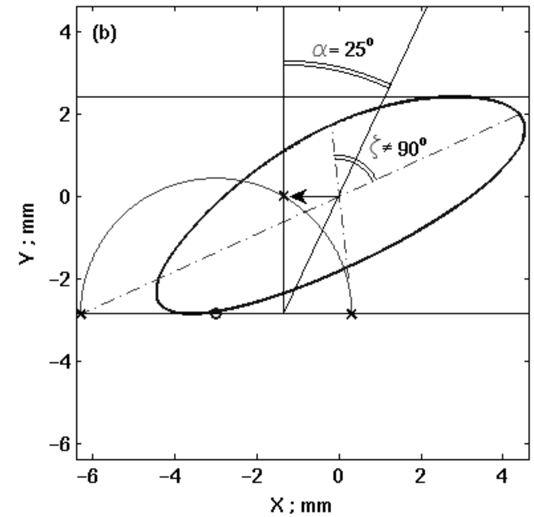
Journal of Atmospheric and Oceanic Technology, 2008

Orientation Angle Distributions of Drops after 80 m fall using a 2D-Video Disdrometer

G.J. Huang, V. N. Bringi, M. Thurai



With intrinsic canting
No horizontal velocity

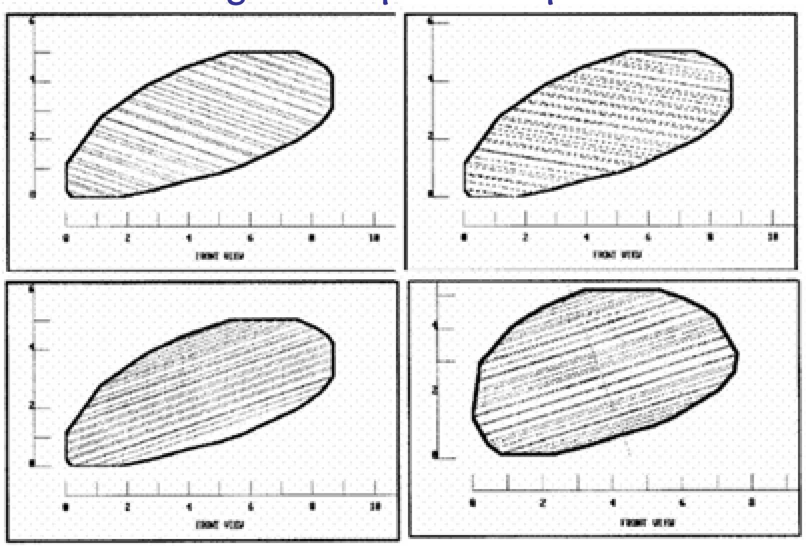


With intrinsic canting
With horizontal velocity

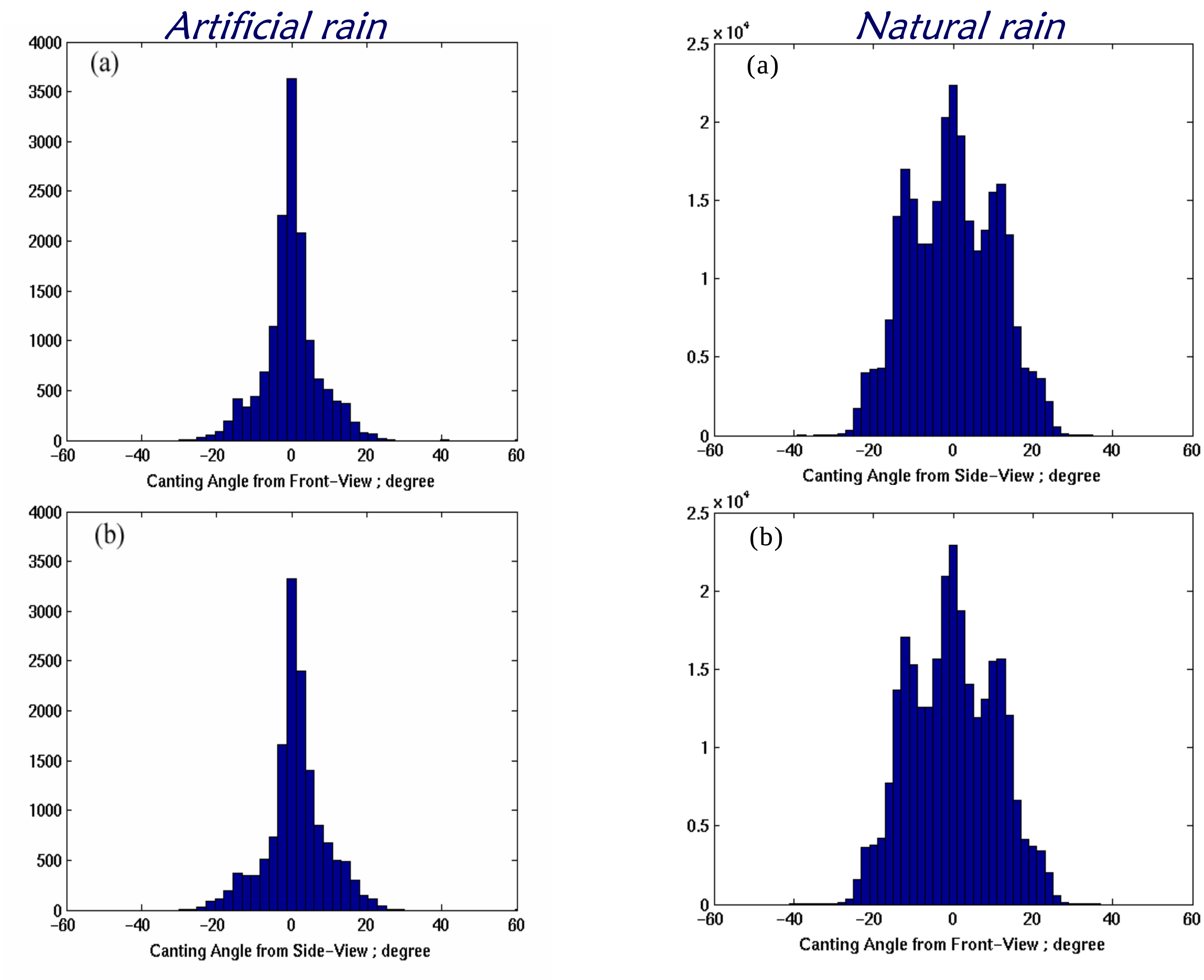
$$x' = x + y\tan\alpha$$

$$y' = y$$

De-skewing algorithm developed by Joanneum Research to recover canting and shape in one plane



Histograms of canting angle from 2 views



T-Matrix Scattering Method

$$\begin{bmatrix} E_h^s \\ E_v^s \end{bmatrix} = \left(\overline{T}\right) \begin{bmatrix} E_h^i \\ E_v^i \end{bmatrix}$$

Incident plane wave

Calculating propagation (fundamental) parameters

- Use T-matrix calculations to derive $\vec{f}_H$ and $\vec{f}_V$ for the n^th drop, based on the individual drop data

$$\gamma_H^{n^{th}\ drop} = -8.686\,\lambda\,10^3\,Im\left(\vec{f}_H\right)\ ;\ dB/km \qquad (1)$$

$$\gamma_V^{n^{th}\ drop} = -8.686\,\lambda\,10^3\,Im\left(\vec{f}_V\right)\ ;\ dB/km \qquad (2)$$

$$\gamma_{hv}^{n^{th}\ drop} = -8.686\,\lambda\,10^3\,Im\left(\vec{f}_H - \vec{f}_V\right)\ ;\ dB/km \qquad (3)$$

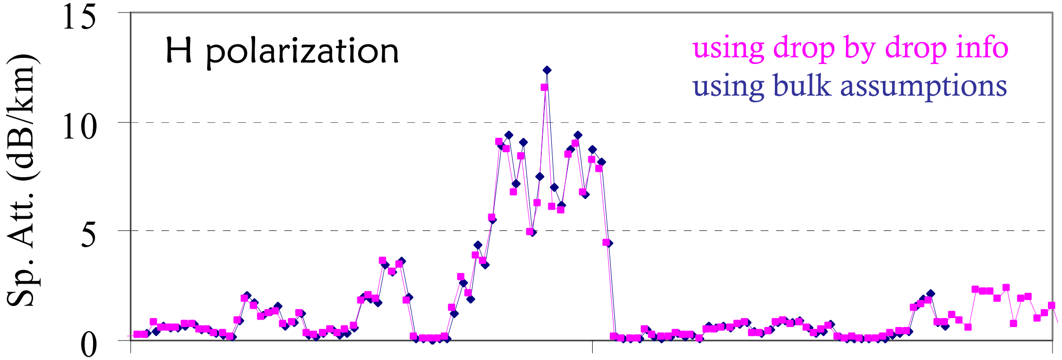
$$K_{DP}^{n^{th}\ drop} = \frac{180}{\pi}\lambda\,10^3\,Re\left(\vec{f}_H - \vec{f}_V\right)\ ;\ deg/km \qquad (4)$$

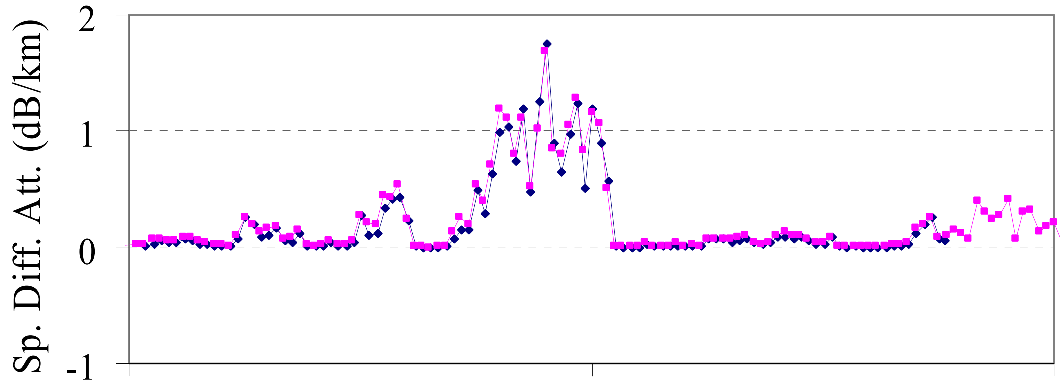
(1)–(2): specific attenuation for H and V

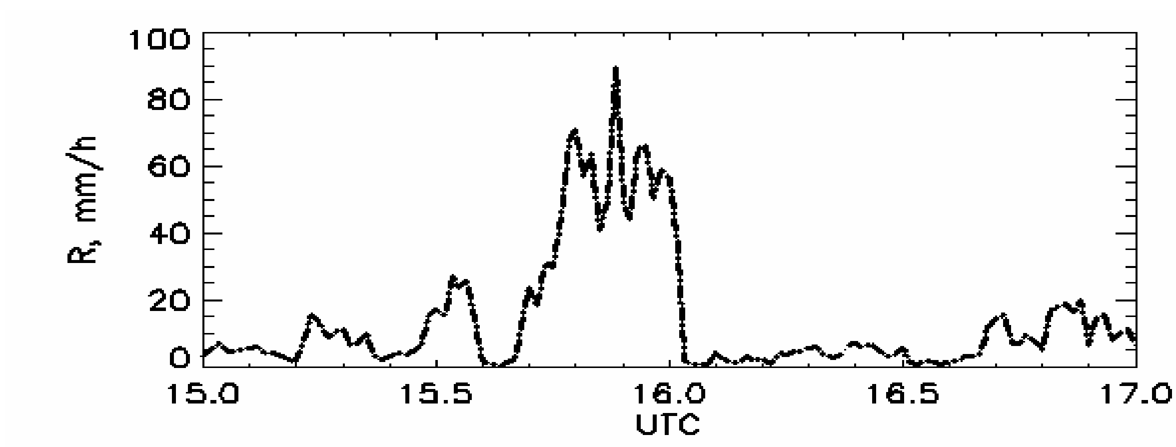
(1)–(4): XPD – CPA variation

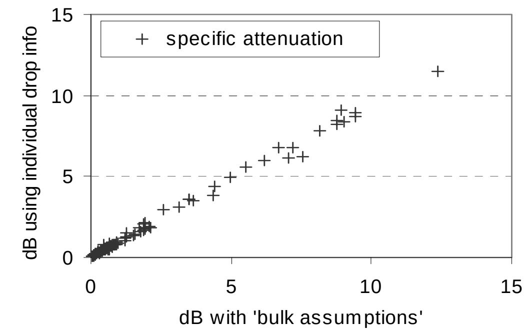
- Integrate individual drop contributions over say 1 minute and normalized with respect to the drop concentration

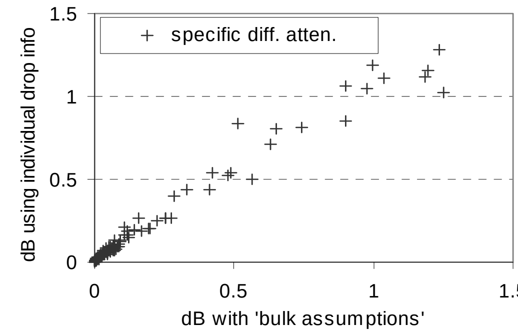
20 GHz calculations for an event





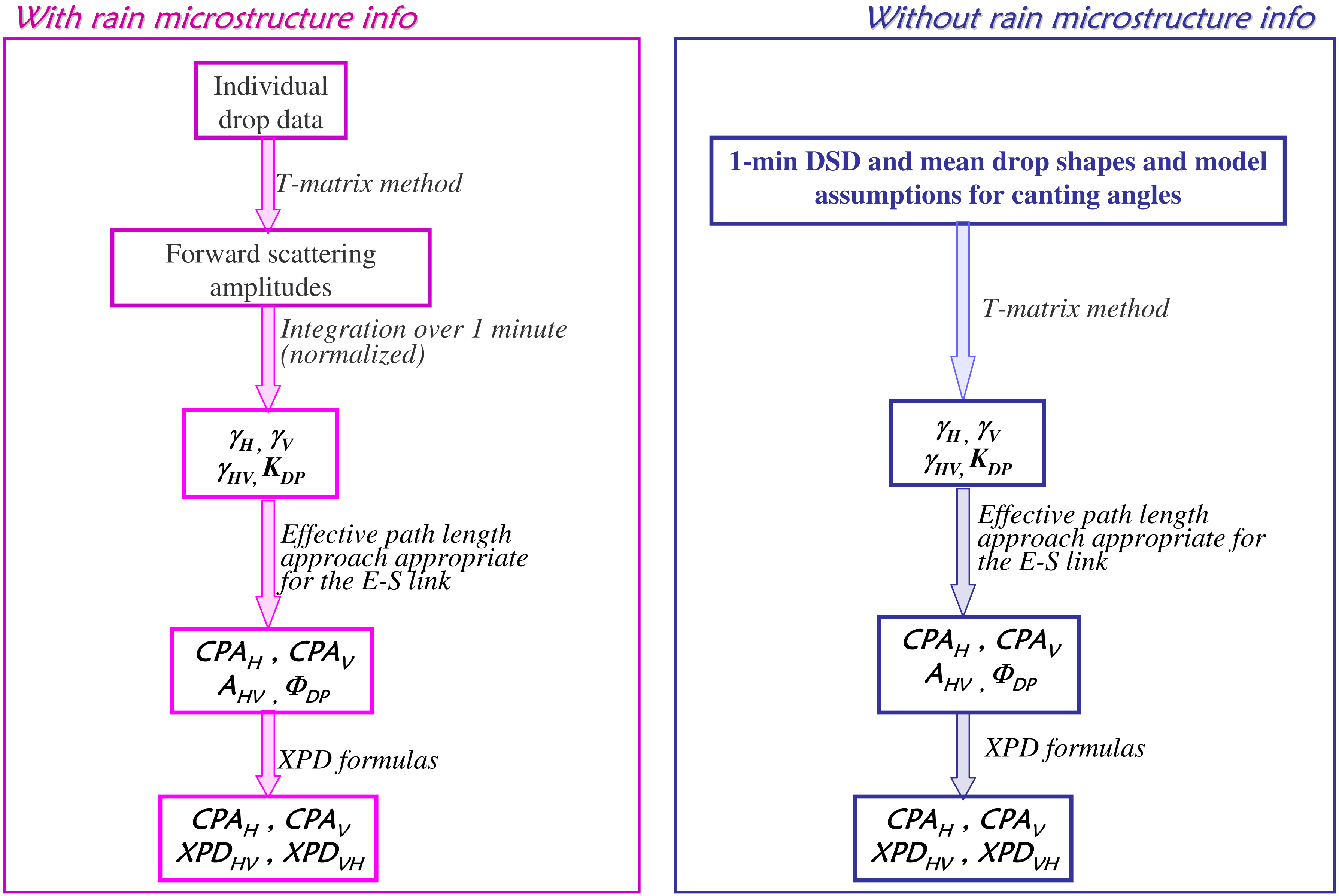






Not significantly different from Calculations using 1-min DSD, mean drop shapes and model based canting angle distributions

XPD – CPA variation

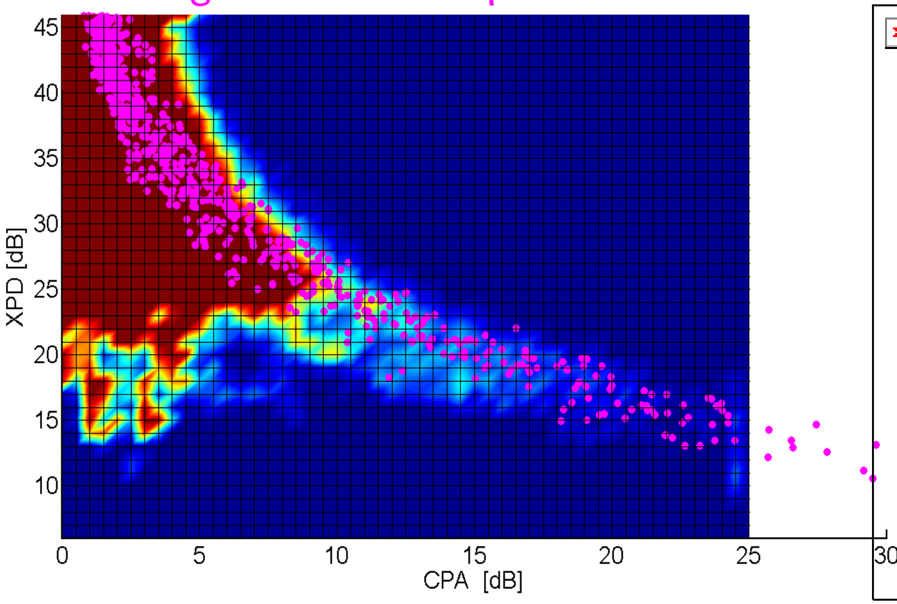


$$XPD = 20\log_{10}\left|\frac{\chi_{rain} + \tan^2(\phi-\delta)}{(\chi_{rain}-1)\tan(\phi-\delta)}\right|; \qquad \chi_{rain} = \exp-\left\{\frac{A_{HV}\ln 10}{20} + j\Phi_{dp}\frac{\pi}{180}\right\}$$

Parameters used for the XPD-CPA calculations for the 20 GHz beacon experiment [Rocha et al. 2005]

Transmit signal:	19.701 GHz from Eutelsat Hotbird-6, H-polarisation, tilt = 23°
Receiver:	1.5 m antenna, elevation = 38° Co-polar and XPD (complex) measurements
Lat and Long:	40° 38N and 8° 39W
Calculated effective path length for point-to-path scaling	3.96 km, assuming the annual mean rain height to be 2.4 km

Using individual drop info



Using 1-min DSD etc …

Both cases show good agreement with the 1-year data, but the drop-by-drop based calculations additionally show the spread in the XPD arising from shape variations (due to drop oscillations) and individual drop canting

Comments

- 2-D video disdrometer can provide pertinent information on individual hydrometeors (shape, size, orientation), needed for scattering calculations.

- (Normalized) individual contributions can be integrated say over 1-min to derive γ_H and γ_V as well as γ_{HV} and K_{DP}

- Specific attenuation calculations show similar results to those using with 1-min DSD and bulk assumptions

- XPD – CPA variation has been computed for a 19.7 GHz beacon experimental scenario; taking rain microstructure into account clearly shows the spread in XPD.