Analysis of Polarimetric Signatures from the ARM MMCR Ka band radar: Calibration of the precip mode and a new model for raindrop shape

ASR Atmospheric System Research

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Introduction

The analysis considers Ka band CDR signatures at zenith in rain, and leads to important findings for both mm-wave radar engineering and physics of rain processes:

1) detect receiver saturation – and recover main channel reflectivity in saturation conditions

2) calibrate the precipitation mode with respect to the general mode

3) Ka band is sensitive to non-axisymmetric drop oscillations and detects distinct rain streaks indicating the presence of larger drops.

4) The observed depolarization cannot be explained by the current spheroidal model for raindrops

5) An ellipsoidal model for rain is proposed

6) Potential for CDR-based rain-rate estimation and potential for break-up onset detection

Modeling depolarization from raindrops at zenith: spheroids

Gamma DSD: $N(D) = N_0 D^{\mu} \exp[-\Lambda D]$

$\Lambda = 0.0365\,\mu^2 + 0.735\,\mu + 1.935$

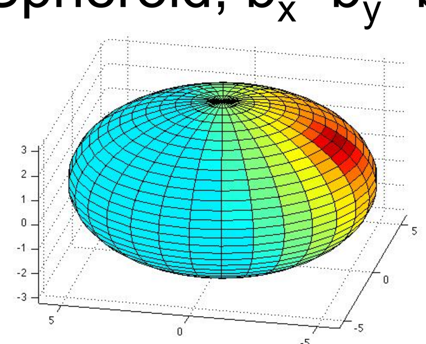
Red: N_0 = 80 000 $cm^{-1}\,m^{-3}$

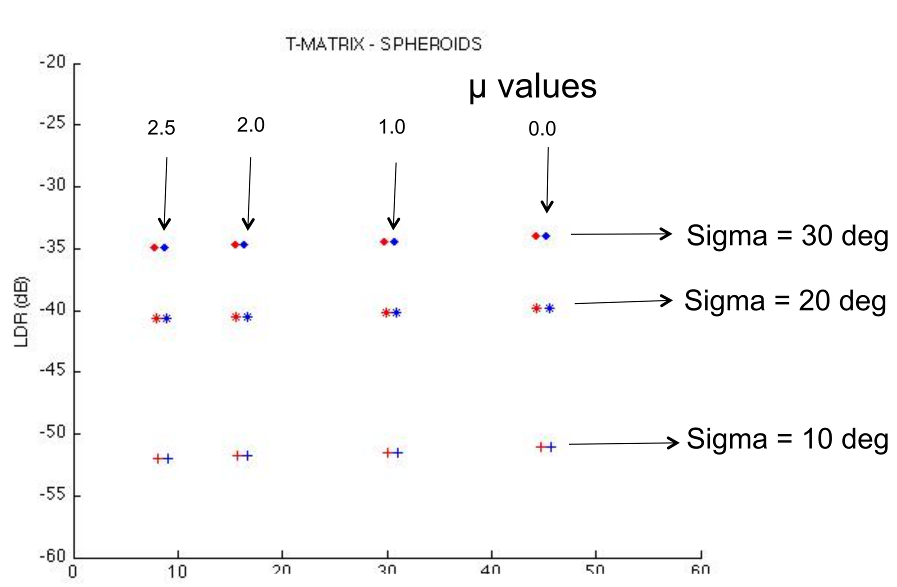
Blue: N_0 = 100 000 $cm^{-1}\,m^{-3}$

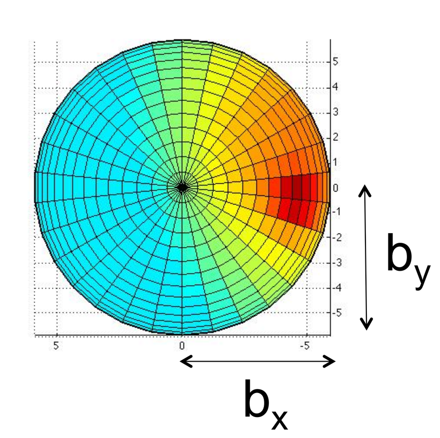
μ = 2.5 – 2.0 – 1.0 – 0.0

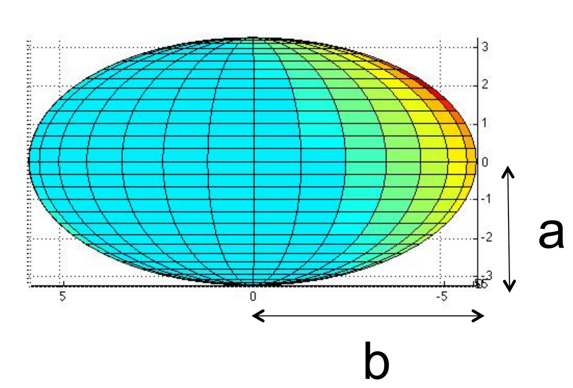
Sigma= 10˚ - 20˚ - 30˚

Spheroid, $b_x=b_y=b$

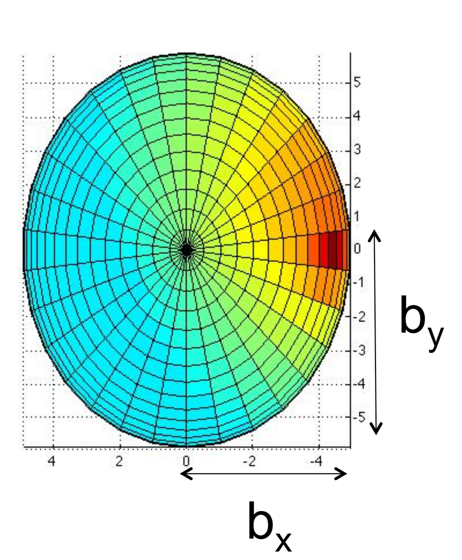


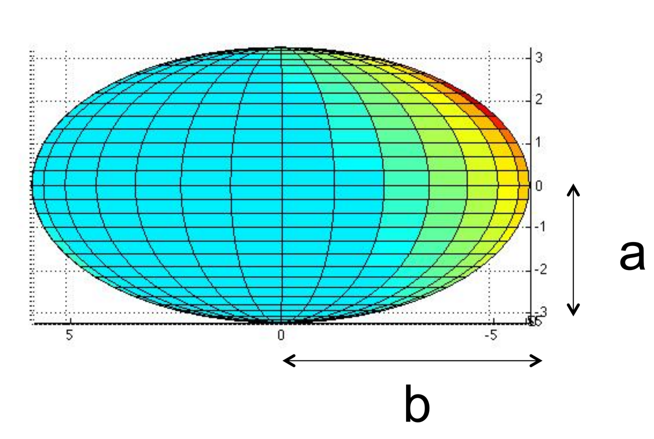


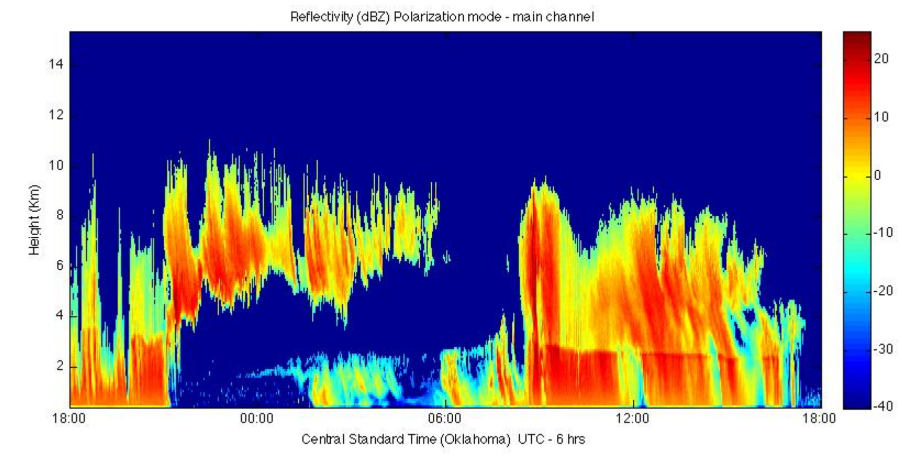




The experimentally observed depolarization cannot be explained with the spheroidal model for raindrop shape.
Non axisymmetric oscillations may be accounted for with an <u>Ellipsoidal model</u>, with $b_x \neq b_y$



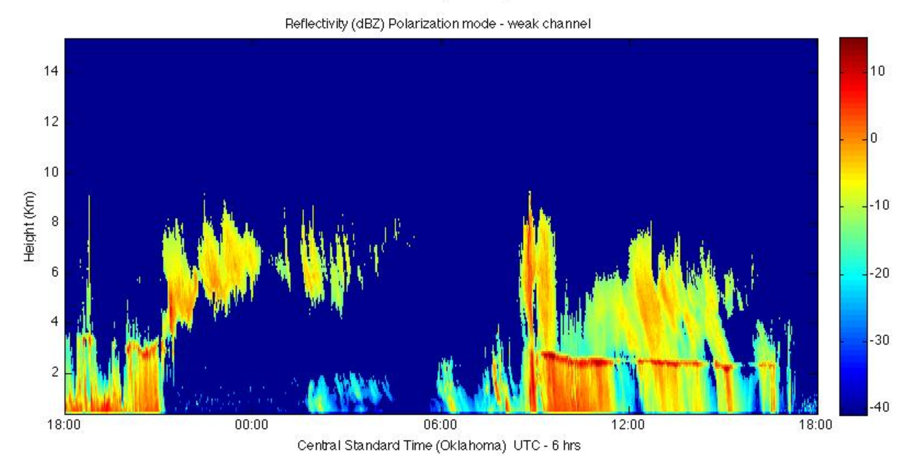




Main channel Z:

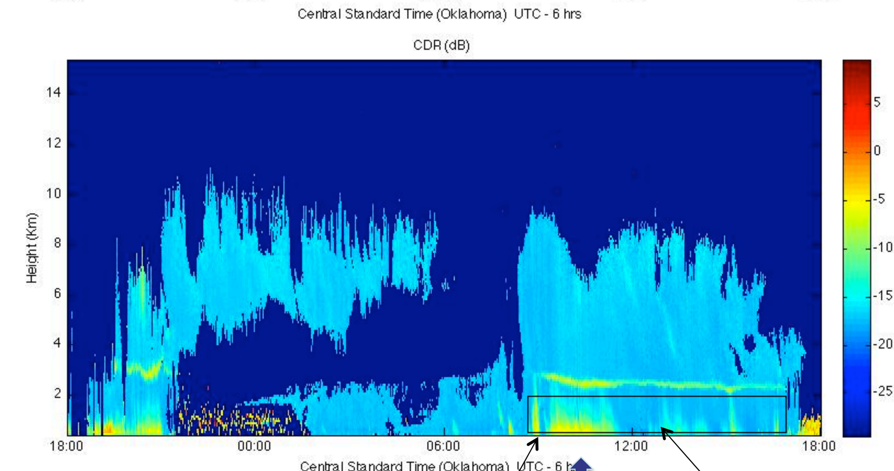
3 channel (General mode)

or 5 channel (Polarization)



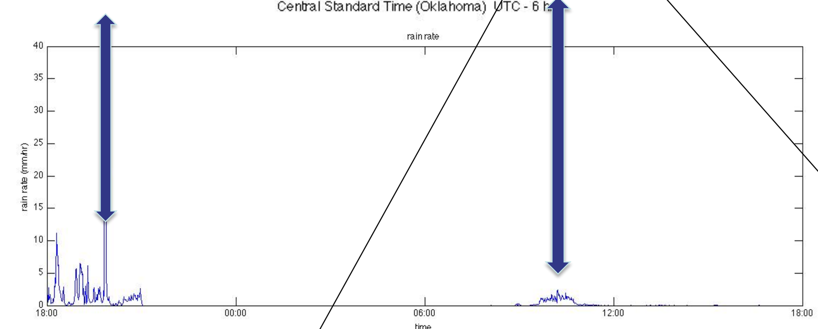
Weak channel Z:

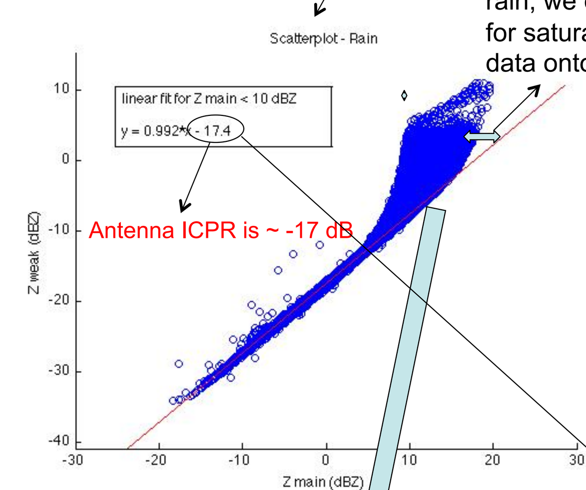
6 channel (Polarization)



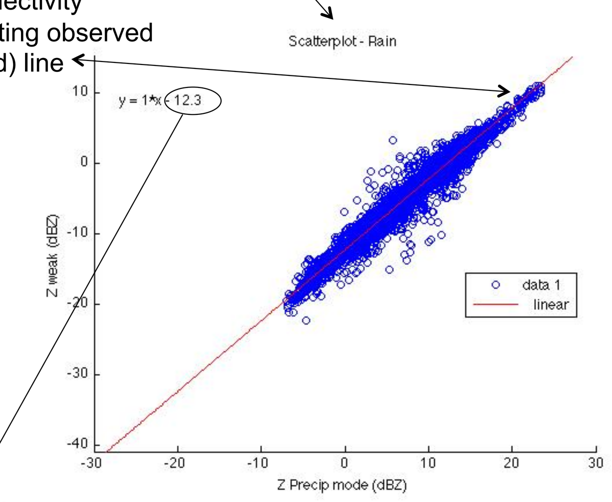
Standard CDR:

5 main channel
6 weak channel



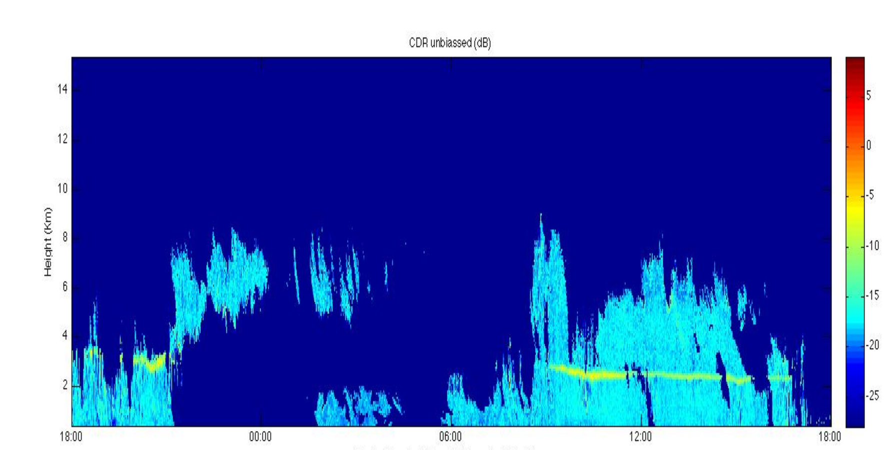


Under the assumption of spherical rain, we can correct reflectivity for saturation by projecting observed data onto the ICPR (red) line



Hockey-stick shape indicates saturation

this difference:
17.4 -12.3 = 5.1 dB
is the mismatch due to the attenuator for the precipitation mode

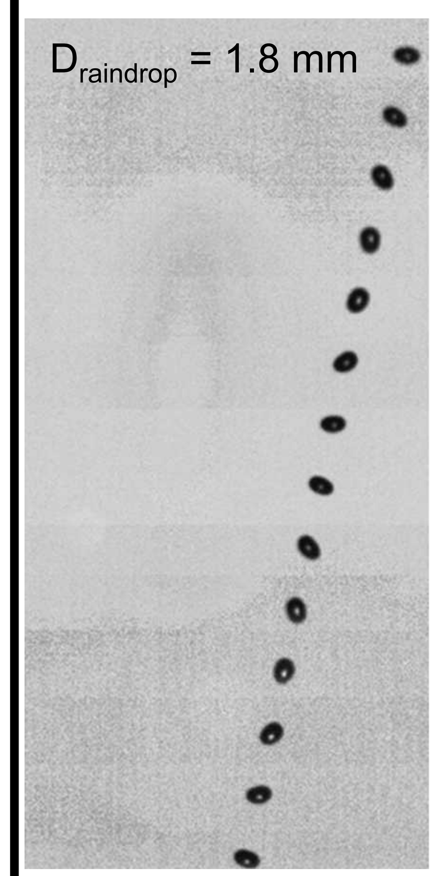


CDR unbiassed:

4 main channel
6 weak channel

- We can detect receiver saturation
- Under the assumption of spherical (spheroidal) raindrops, we can quantify saturation, and reconstruct main channel reflectivity by means of a projection onto the ICPR line.
- We can calibrate the precipitation mode with respect to the general mode
- By using mode 4 and mode 6 we can build an unbiassed CDR field, which, besides insect detection, is the <u>most reliable indicator of the melting band</u>
- Engineering recommendations for the design of the future MMCR/KAZR line of radars: circular pol tx, truly dual-pol (cross-pol coherence available) with precipitation mode, high cx-pol isolation.

How good is the spheroidal model for raindrops?



Non-axisymmetric oscillations of raindrops do cause depolarization even at zenith/nadir

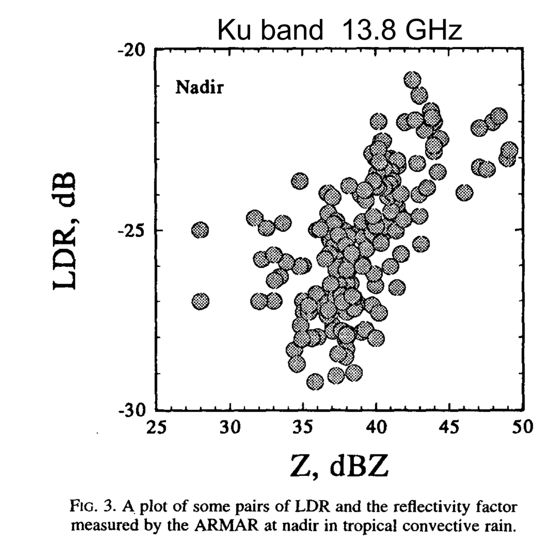
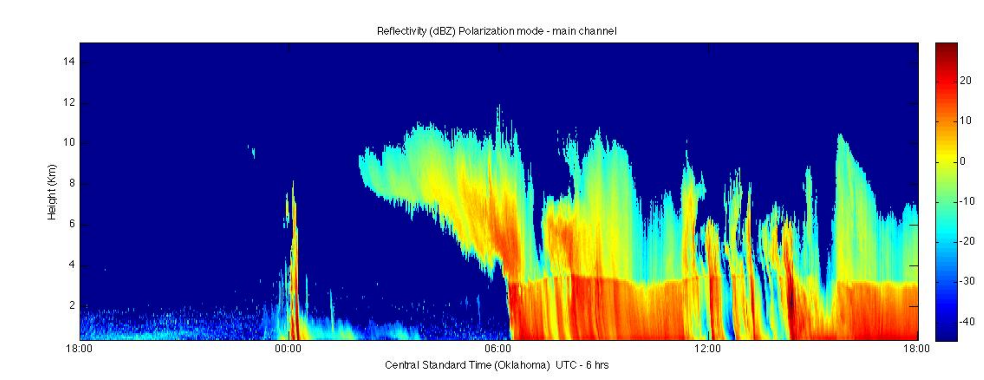


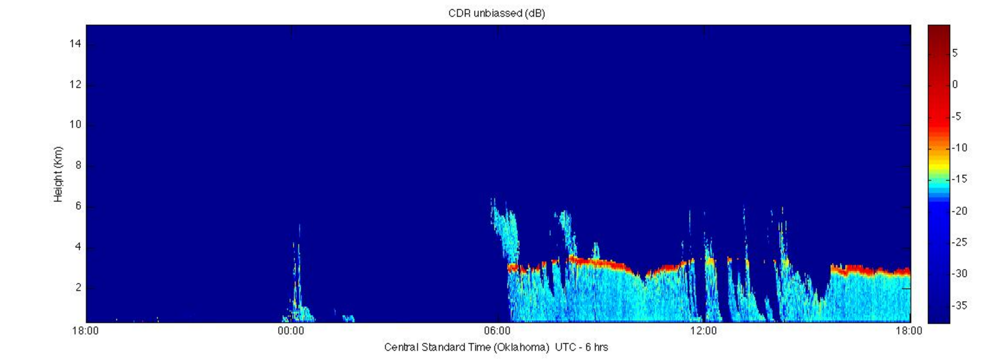
FIG. 3. A plot of some pairs of LDR and the reflectivity factor measured by the ARMAR at nadir in tropical convective rain.

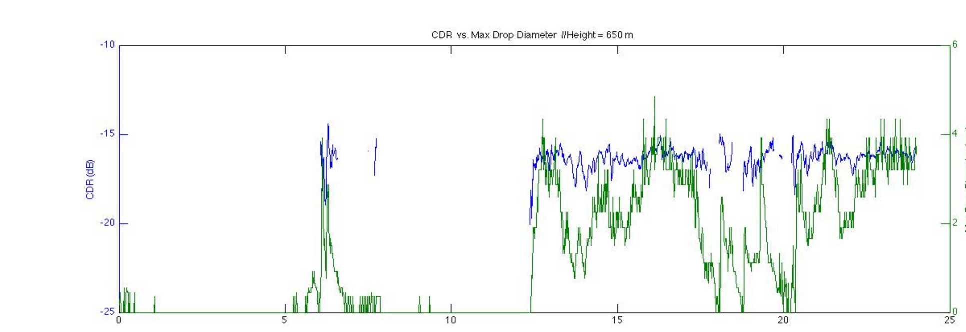
Jameson, A. R., S. L. Durden, 1996: A Possible Origin of Linear Depolarization Observed at Vertical Incidence in Rain. *J. Appl. Meteor.*, **35**, 271–277

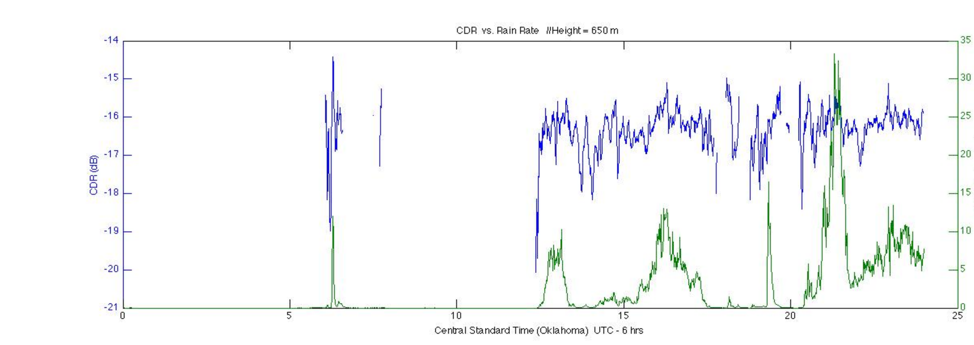
Testik, F. Y., A. P. Barros, L. F. Bliven, 2006: Field Observations of Multimode Raindrop Oscillations by High-Speed Imaging. *J. Atmos. Sci.*, **63**, 2663–2668.

Depolarization from rain

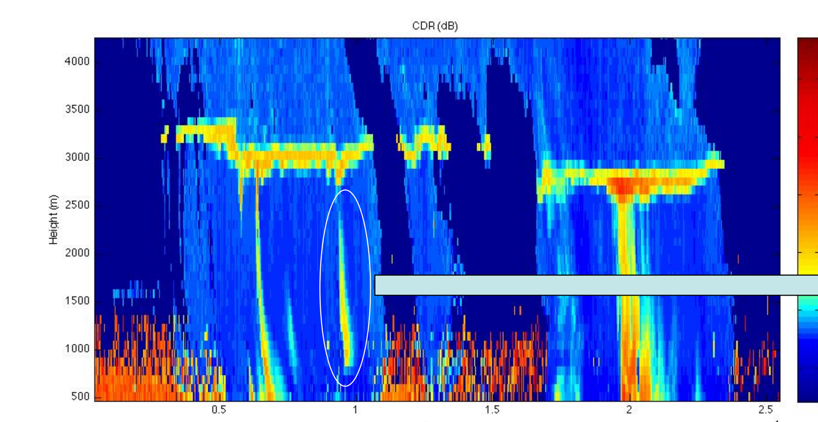








Depolarization from rain is tenuously observed also with the MMCR (ICPR ~ -17 dB) where CDR correlates with rain rate and maximum drop diameter. Low dynamic range though (2 dB), and better ICPR is required for quantitative analysis.



Chances are that some depolarization signatures can not be ascribed to saturation only….
Larger oscillating drops?
Increased break-up rate?

References

1. Galletti, M.; Huang, D.; Kollias, P., "Zenith/Nadir Pointing mm-Wave Radars: Linear or Circular Polarization?," *Geoscience and Remote Sensing, IEEE Transactions on*, Early Access.
2. Galletti, Huang, Kollias, Giangrande, "Towards a CDR-based Rain Rate Estimation Algorithm for zenith-pointing cloud Radars at Ka band" *Proceedings of ERAD 2012, 24-29 June 2012, Toulouse, France.*