Severe Hail Detection: Hydrometeor Classification for Polarimetric C-band Radars Using Fuzzy-Logic and T-matrix Scattering Simulations

TR32 Conference
06. April 2018

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Polarimetric Radars

Courtesy of Iris Beer
Polarimetric Radar

- Horizontal and vertical polarized EM-wave
- Backscattered signal depending on shape of hydrometeor
Polarimetric Moments

- Differential Reflectivity \((Z_{DR})\)
- Specific Differential Phase \((K_{DP})\)
- Correlation Coefficient \((\rho_{hv})\)
Hydrometeor Classification
Principle of Fuzzy-Logic

Source: G. Zhang (Lecture slides)
Existing Work

- Operational and working algorithms:
  - Hydrometeor Classification Algorithm (HCA) of Park et al. (2009)
  - Hail Size Discrimination Algorithm of Ortega et al. (2016)
HCA Performance

S band

C band
HCA Performance

S band

C band
Backscattering Simulation

Courtesy of Iris Beer
Backscattering Simulation

- Simulating backscattering of a double layered spheroid using T-matrix simulation
  - Dielectric const.: Cole-Cole (1941) equations
  - Model tested and aligned with other literature (e.g. Depue et al. (2007))
Backscattering Simulation

- Wet hail
  - Axis ratio: 0.75
  - Density: 0.93 g/cm\(^3\) (Icecore)
  - Thickness of water-coat: 0.1mm
  - Simulation steps: 0.1mm
  - Std. canting-angle: 7°
  - C-band
  - Temperature: 0°C

Strong Resonance Effects possible
Backscattering Simulation

- *e.g.* small, melting hail
  - Medium, inner: ice (solid), outer: water
  - Dielectric const. at 20°C, 0°C and -10°C
  - Axis-ratio as in Ryzhkov *et al.* (2013)
  - Particle Diameter: 1mm-25mm, 1mm steps
  - Canting angle 0° mean, std.: 7°, 20° and 45°
Backscattering Simulation

- Parameters for small, melting hail
Backscattering Simulation

- Limits of the approach:
  - Empirical values more suitable for ice crystals and biological scatter
  - Irregular shapes (e.g. spiky hailstones) not considered
  - Each variation is equally considered
  - No mixed hydrometeor volumes, yet
Next steps

Fuzzy-Logic Parameters

- Aggregation & Hydrometeor Classification

Evaluation and testing with national C-band radar network & European Severe Weather Database
Summary

- Fuzzy-Logic approach suitable
Summary

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- New Parameters for C-band
  HCA mandatory
Summary

- Fuzzy-Logic approach suitable
- New Parameters for C-band
- HCA mandatory
- Backscattering simulations can provide parameters
Sources

**Literature**


**Pictures**

- Cover: Iris Beer
Take Home Notes

- Fuzzy-Logic approach suitable
- New Parameters for C-band HCA mandatory
- Backscattering simulations can provide parameters

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Appendix
Backscattering Simulation

- High variance of backscattering phaseshift depending on diameter
- For dry hail, variance is even larger
Depue et al (2007) vs. Dual-layer Model

25 deg cant cases:
- spongy: 40% water in ice
- 0.5 mm water coat
- wet: solid ice core
- 0.5 mm water coat
- 25 deg cant dry

75 deg cant cases:
- spongy
- wet
- dry

Differential Reflectivity (dB)

Equal Volume Particle Diameter (mm)
Axis-ratio small, melting hail

As in Ryzhkov et al. (2013)
Current State

- Fine tuning required