Meteorological Applications of Dual-polarization Radar

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Weather Radar Research

Motivation

1. Single-polarization Doppler radar does not distinguish between different hydrometeor types

Dual-polarization radar promises unique classification capability

2. Data quality issues with conventional radar can be overwhelming and difficult to address

Polarimetry provides very efficient ways to improve data quality

3. The accuracy of rainfall measurements with standard Doppler radars is restricted

Polarimetric radar offers significant improvement in the accuracy of rain estimation

4. Inadequate microphysical parametrization of existing numerical mesoscale models limits their prognostic ability

The performance of numerical models can be improved via better parametrization justified by polarimetric measurements and microphysical retrievals

Classification capability of polarimetric radar

Polarimetric radar is efficient for

1. Discrimination between rain and hail

2. Discrimination between rain and snow of different types

3. Detection of freezing rain / icing

4. Localization of convective updrafts

4. Identification of ground clutter / anomalous propagation

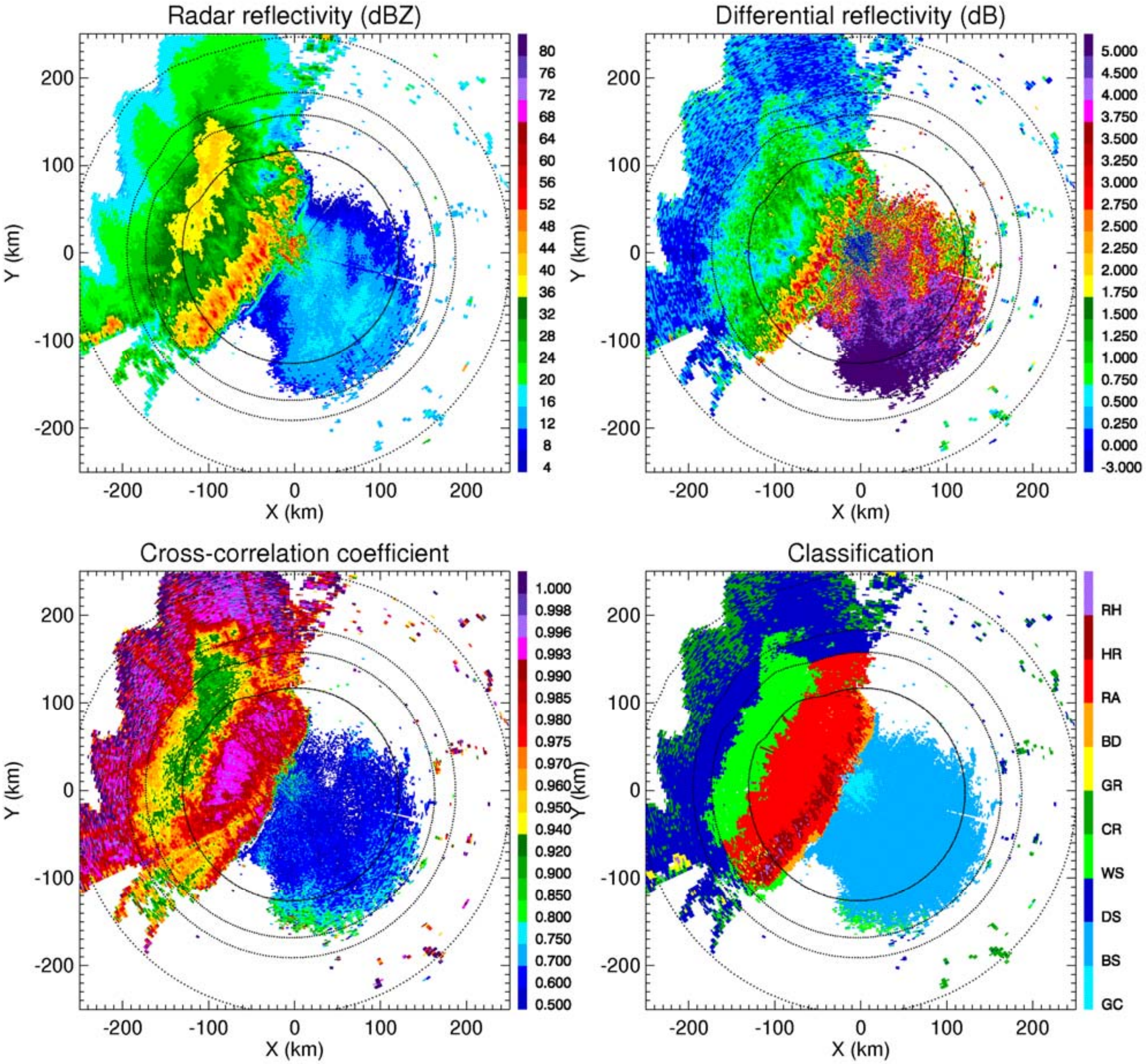
5. Identification of insects and birds

6. Tornado detection (tornadic debris)

7. Detection of military chaff

8. Detection of fires

Example of HCA PPI product for MCS on 05/13/2005



RH – rain / hail

HR – heavy rain

RA – rain

BD – "big drops"

GR – graupel

CR – crystals

WS – wet snow

DS – dry snow

BS – bio scatterers

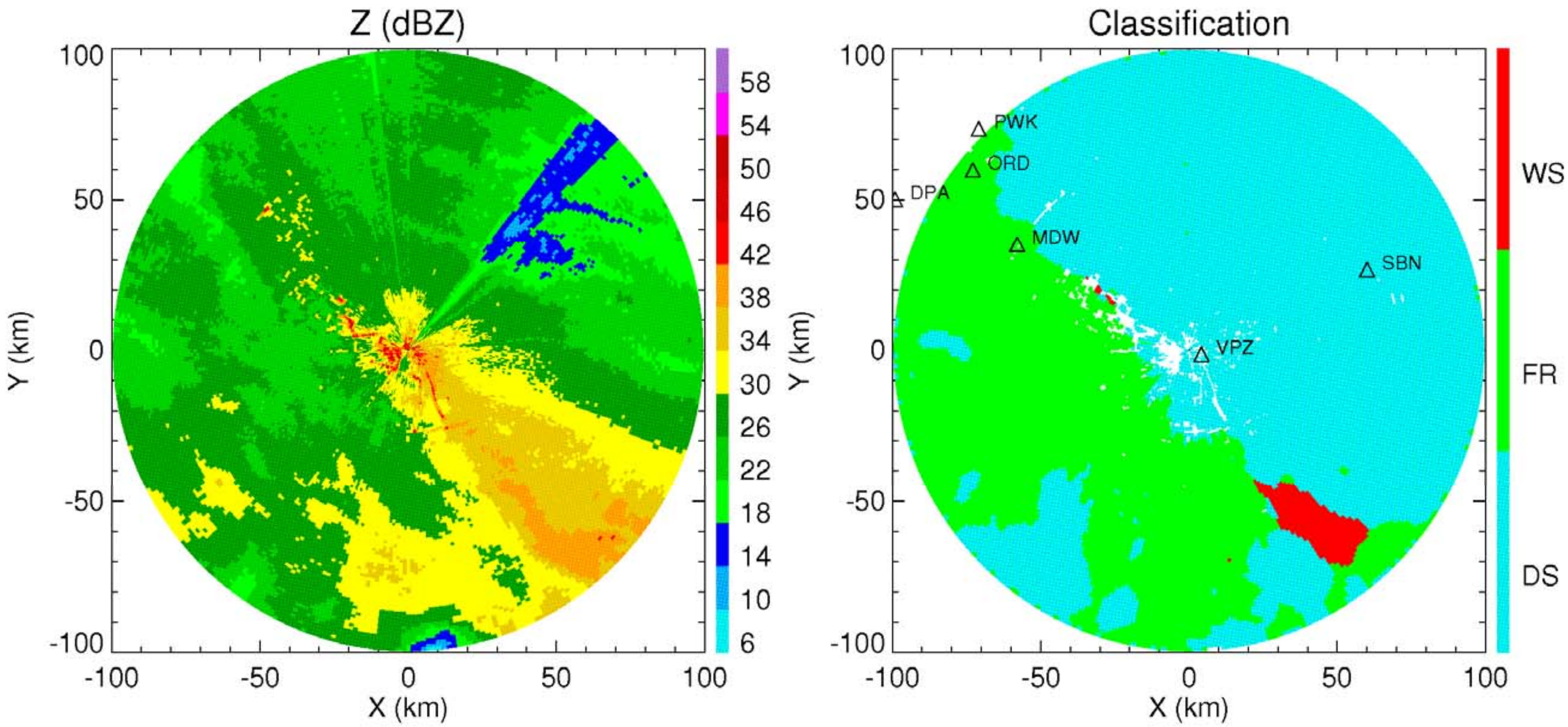
GC – ground clutter / AP

Three fields of different radar variables complement each other providing independent information

Classification of hydrometeor types improves the accuracy of precipitation estimation

Example of HCA product for winter storm on 12/01/2008

Experimental version of HCA for cold season. Freezing rain detection

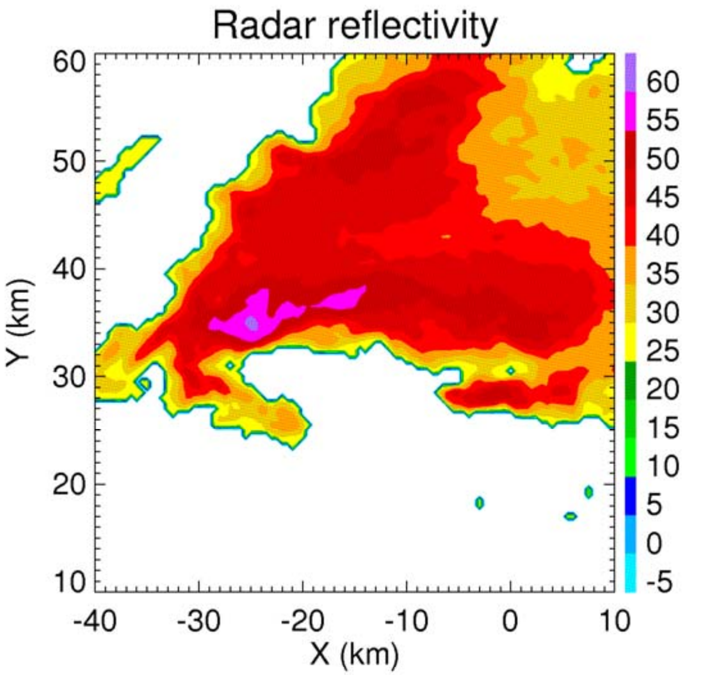


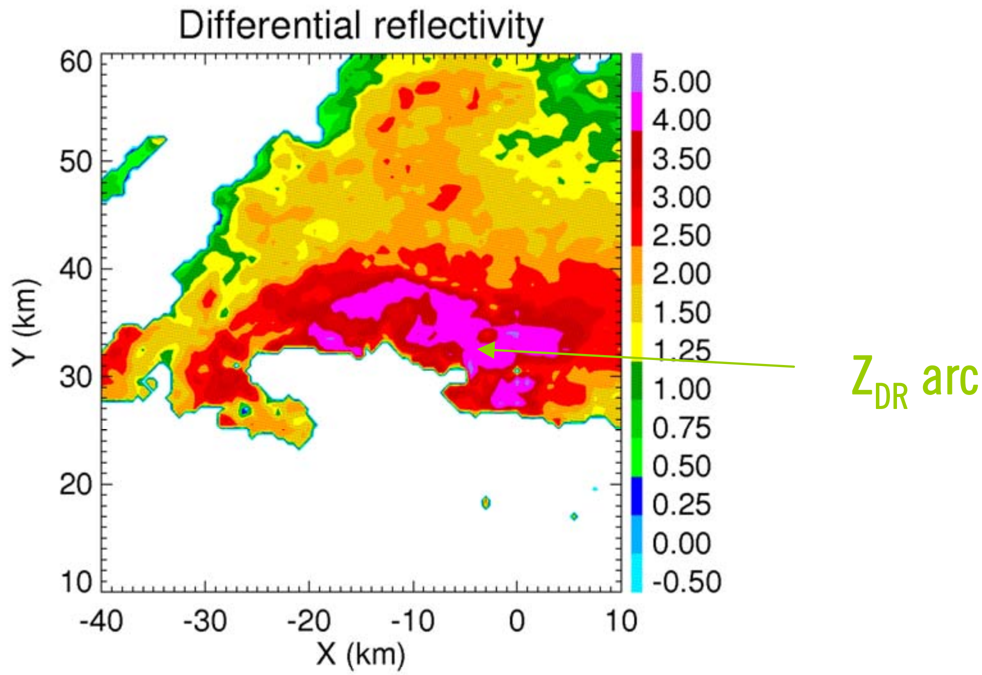
Precipitation classification at the surface

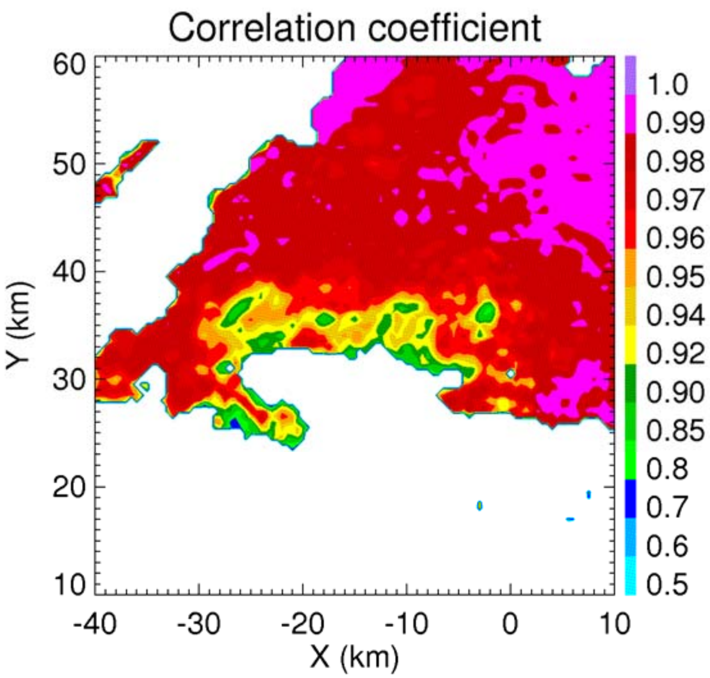
WS – wet snow, FR – freezing rain, DS – dry snow

This version of HCA implies combined use of the radar and thermodynamic data

Polarimetric tornado detection





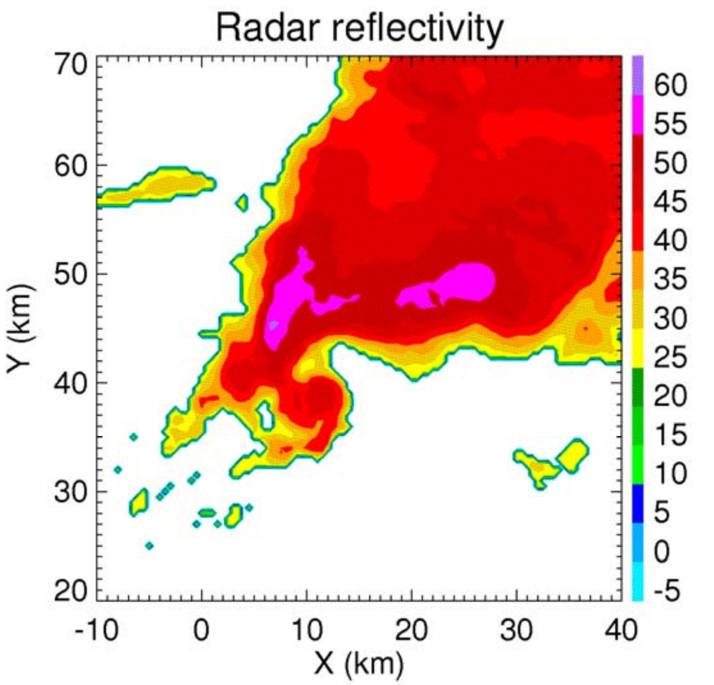


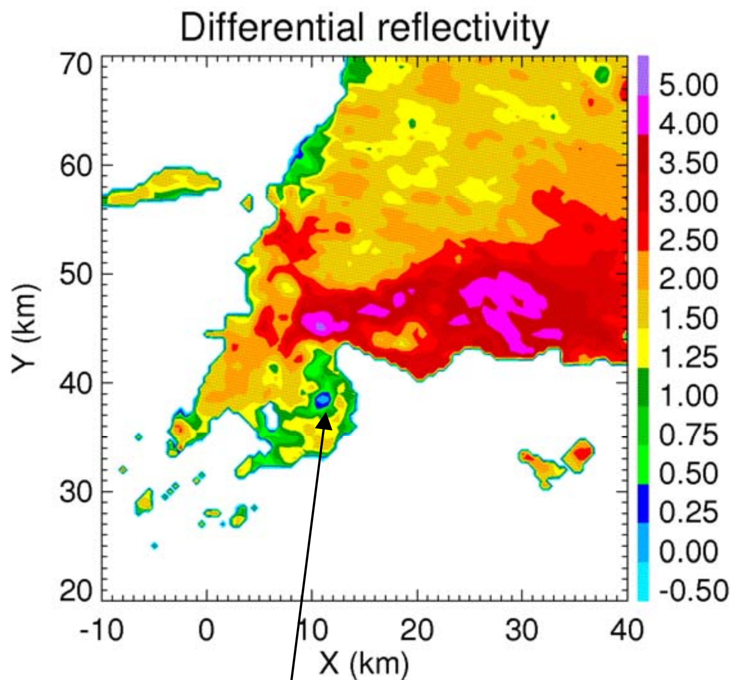
05/10/2003 030532 UTC

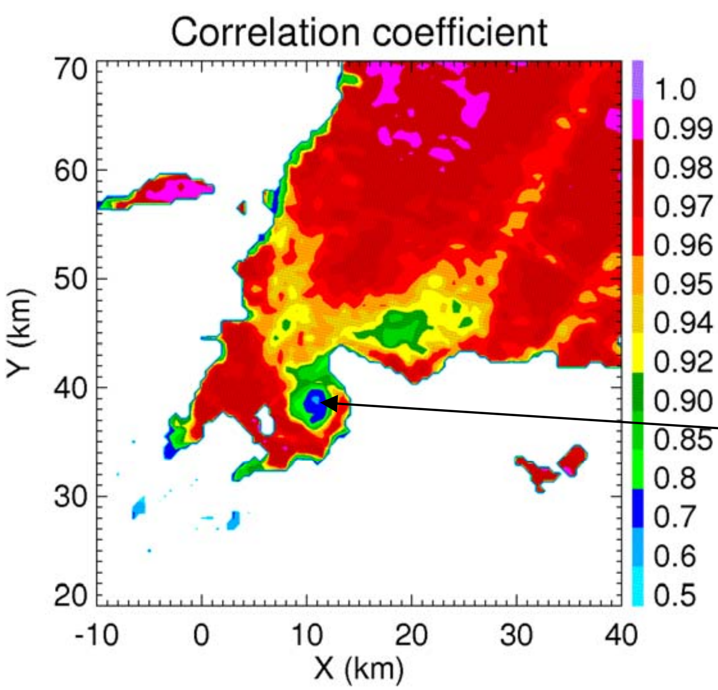
Hook and mesocyclone are present but there is no tornado on the ground at this time

Z_{DR} arc indicates high level of storm-relative helicity

Polarimetric tornado detection







Tornadic debris signature

05/10/2003 035203 UTC

Tornado is on the ground!

Polarimetric method is the only way to detect tornado in real time (not after the fact), especially in the dark or when tornado is wrapped in rain and is not visually observable

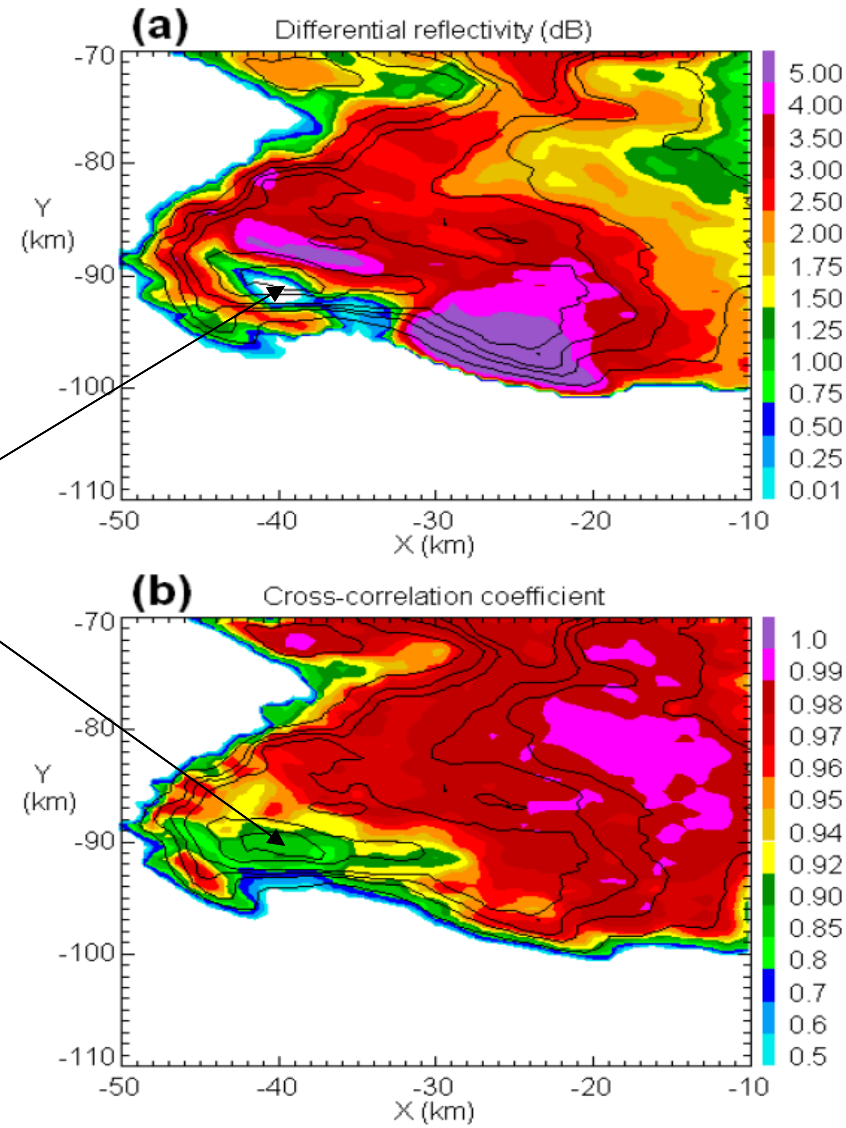
Polarimetric hail detection

At S band, large hail is characterized by high Z, low Z_{DR}, and low ρ_{hv}

Conventional method provides probability of hail in a storm, whereas polarimetric algorithm determines location of hail within the storm

Hail detection statistics from JPOLE:
conventional method
POD=88%, FAR=39%,CSI=0.56
polarimetric method
POD=100%, FAR=11%,CSI=0.89

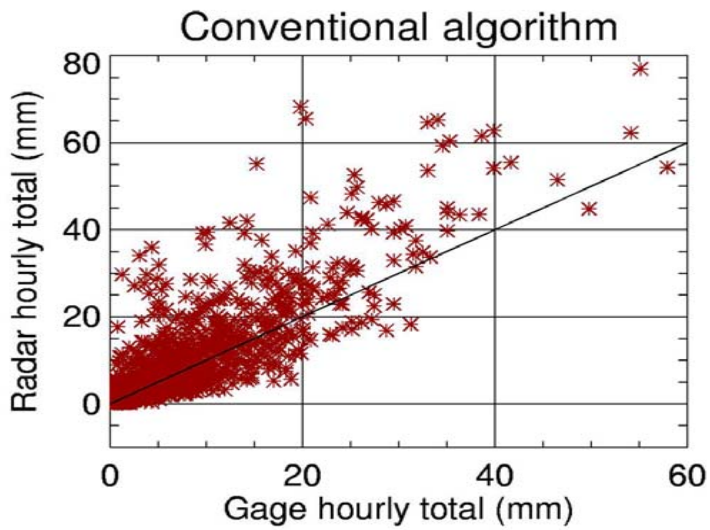
Hail

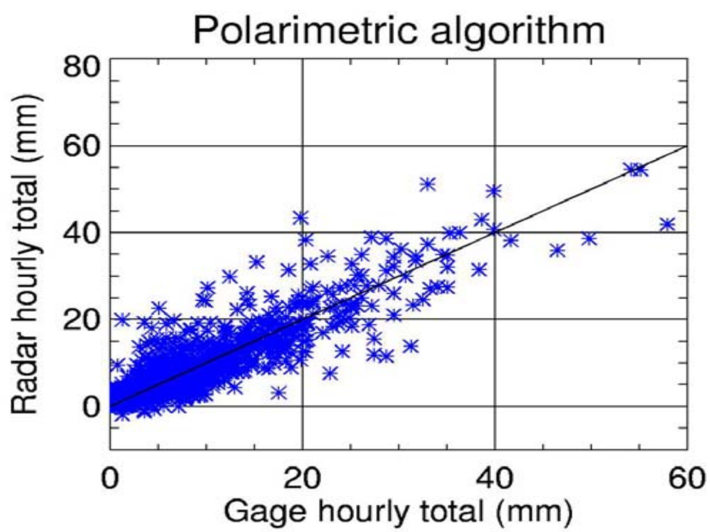


Overlaid are contours of Z

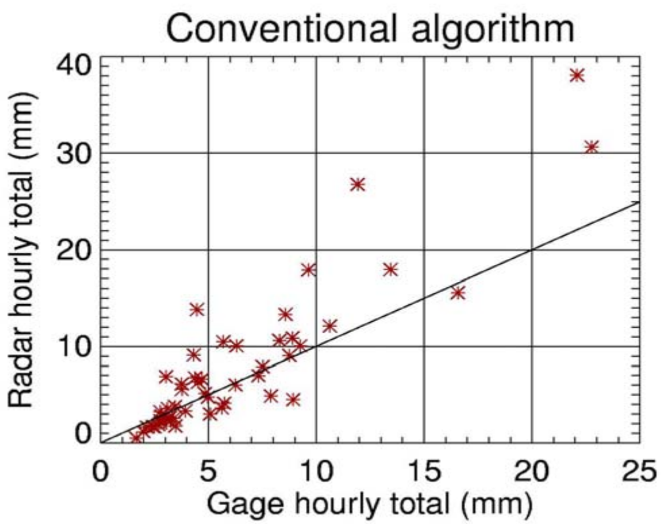
Polarimetric rainfall estimation during JPOLE

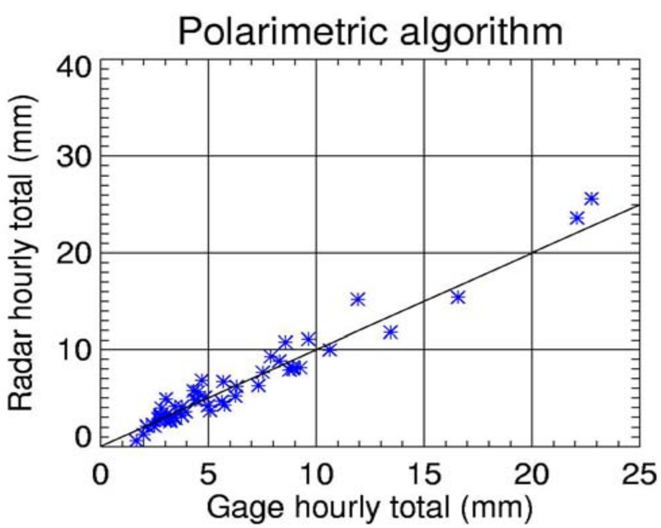
Point Estimates





Areal Estimates

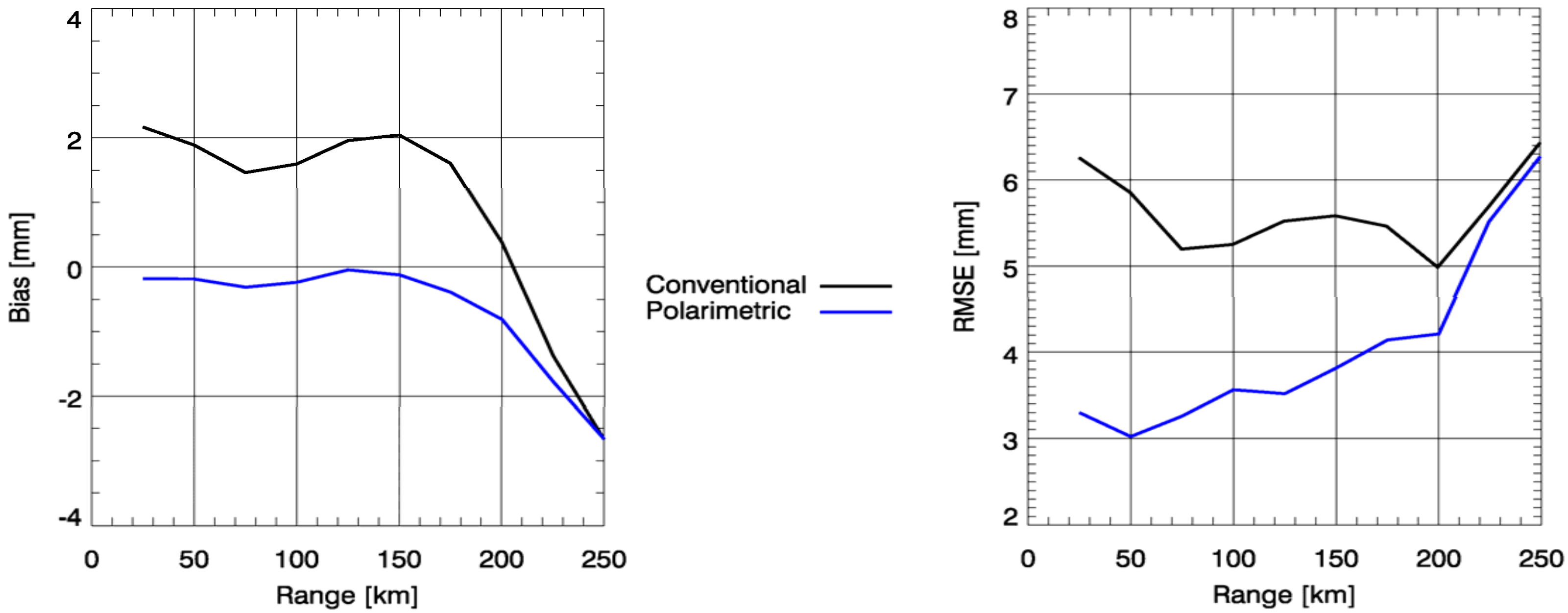




Polarimetric rainfall estimation

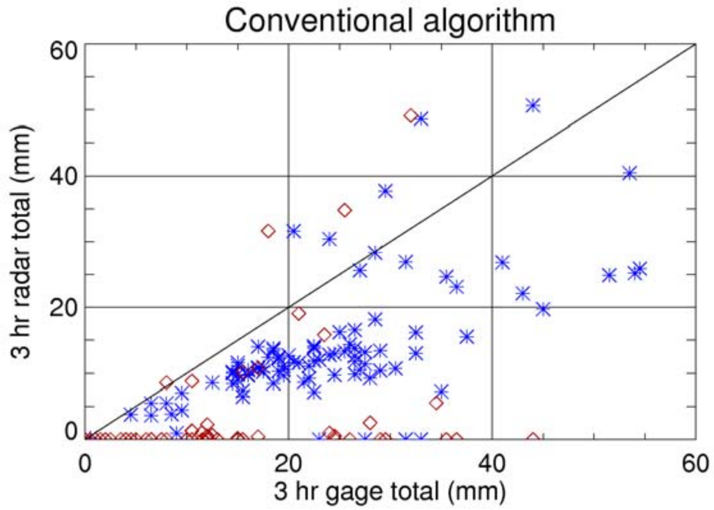
Mean bias and rms error of the conventional and polarimetric hourly rain estimates as functions of range

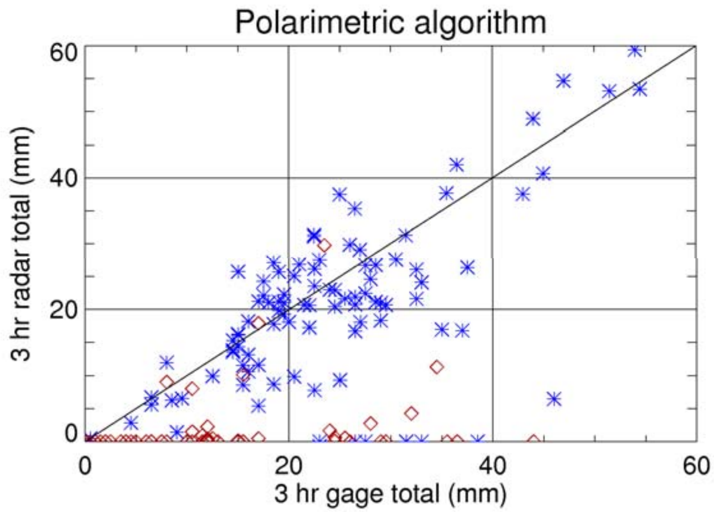
43 events, 179 hours of observations



- **Polarimetric classification of radar echo at longer distances improves the accuracy of rainfall estimation**
- **Reduction of the bias and rms error of hourly rainfall estimates up to 200 km from the radar**
- **At close distances, the rms error is reduced by roughly a factor of 2**

Tropical rain. Complex terrain



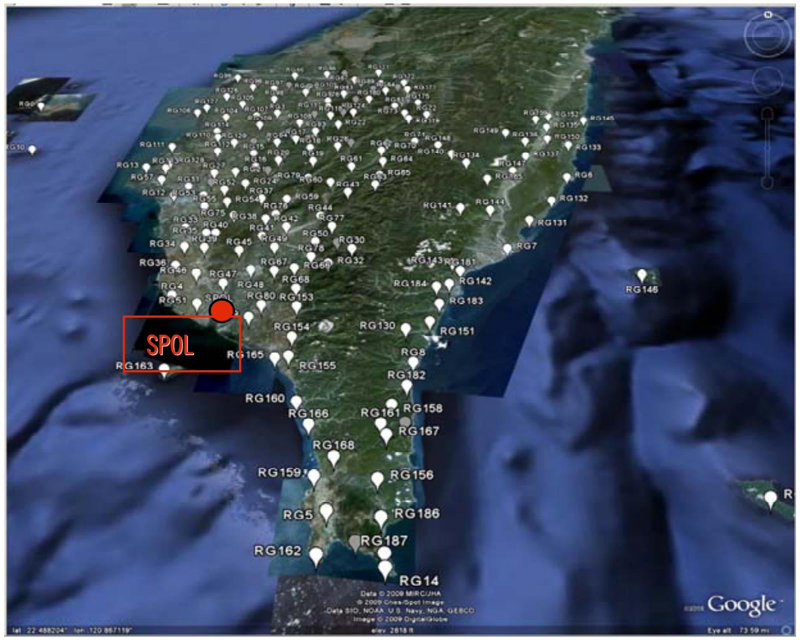


Radar data are from the base elevation (0.5°)

Asterisks – blockage is less than 50%

Diamonds – blockage is more than 50%

Taiwan. 2008/06/14



- Partial beam blockage is mitigated
- Polarimetric rainfall algorithm originally developed using Oklahoma dataset works efficiently in a very different climate and terrain environment

Future directions

- Estimation of hail size from polarimetric measurements
- Hydrometeor classification for winter transitional weather (freezing rain and icing)
- Polarimetric measurements of snow
- Development of polarimetric methods for hydrometeor classification and rainfall estimation at shorter radar wavelengths (C and X bands)
- Improvement in microphysical parametrization of numerical models using explicit microphysical modeling and polarimetric data
- Assimilation of polarimetric data into numerical models

Summary

✓ Polarimetry will revolutionize the whole area of operational applications of weather radars via

- unique capability to identify the source of radar echoes

- dramatic improvement in the accuracy of precipitation estimation

- assimilation of polarimetric radar data into numerical weather prediction models

✓ NSSL is recognized as a world leader in development of polarimetric technology and methodology and their transfer to operational field