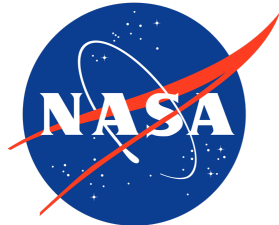


Current status of Developing Polarimetric Airborne Weather Radar for Detecting HIWC as an Aviation Hazard

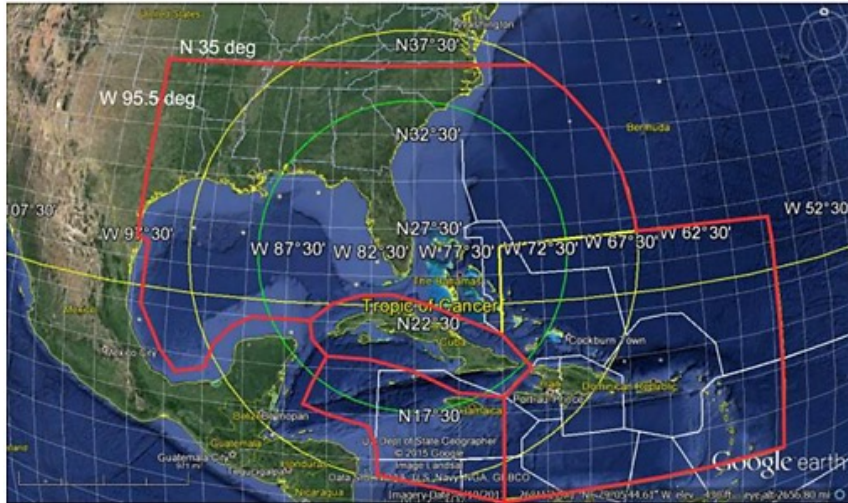
**Yan (Rockee) Zhang, Yunish Shrestha, Jakob Fusselman,
Greg McFarquhar, Alexander Ryzhkov,
William Blake, Joel Martin, and Steven Harrah**



Introduction and Motivation

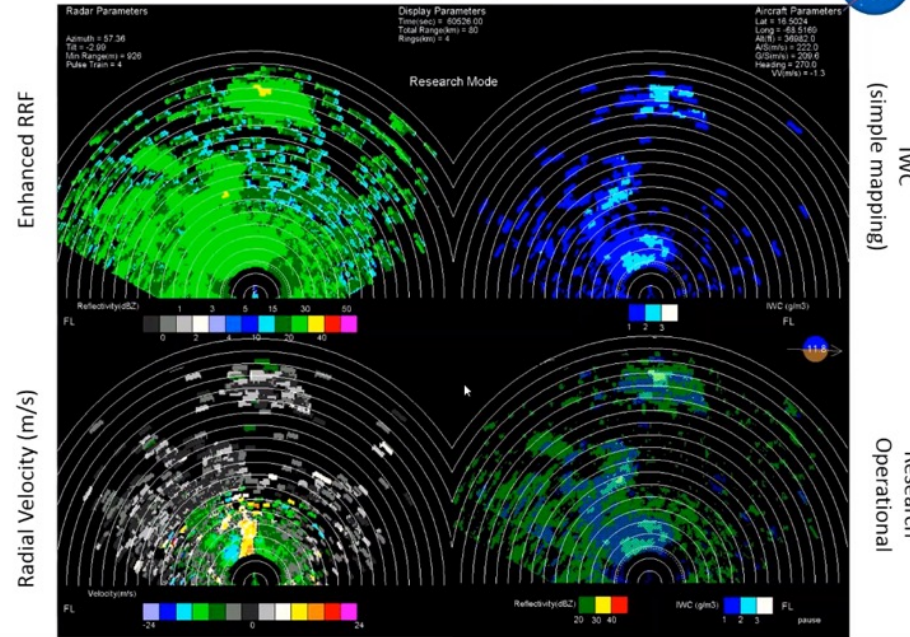
- **High Ice Water Content (HIWC) and its impact on the jet engine operations**
- **Previous and ongoing flight campaigns – NASA LaRC, FAA, Europe, NRC (in-situ probe and onboard radar)**
- **How to use airborne radar to detect HIWC – and Industry Standards**
- **Polarimetric Radar Operating at X-band, or PARADOX – aiming to be the first polarimetric airborne radar for forward-looking detection and monitoring of HIWC**
- **For aviation operation rather than scientific measurement**
- **Setting the Monte-Carlo target simulation for realistic airborne polarimetric radar observations**

2015 NASA DC-8 Flight Campaigns



National Aeronautics and Space Administration

Swerling Display Concept

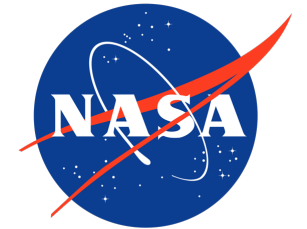


Measured to -50 deg C
Temperature range

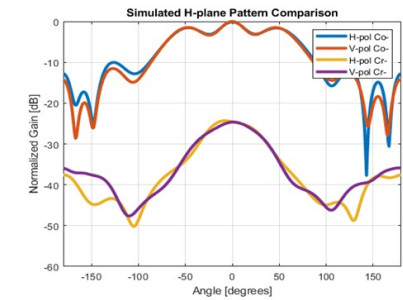
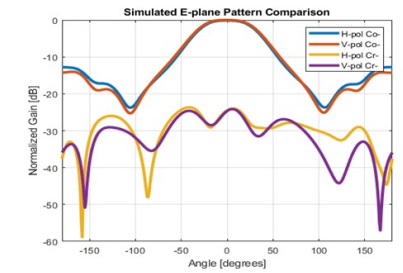
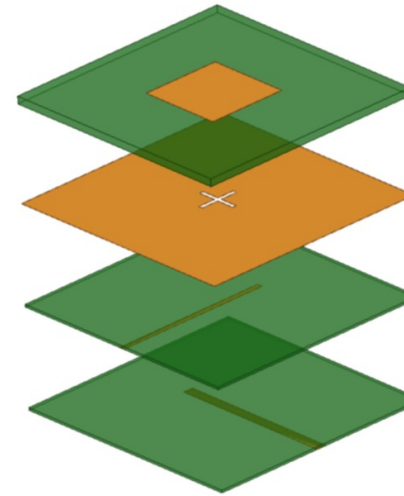
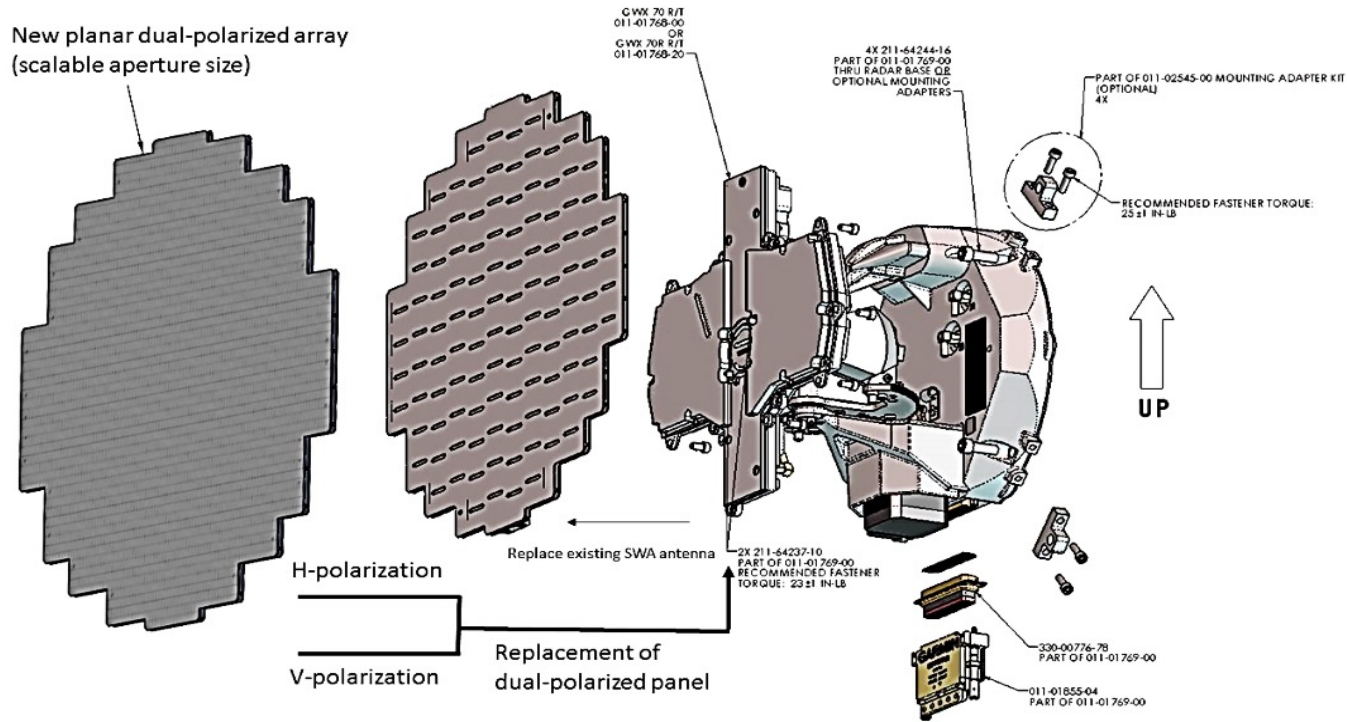
First forward-looking
WX Radar data collection

Using single-polarized,
Honeywell RDR4000
Radar in tests

**Flight path of DC-8 with radar and measured IWC
from IsoKinetic Probe for August 2015**



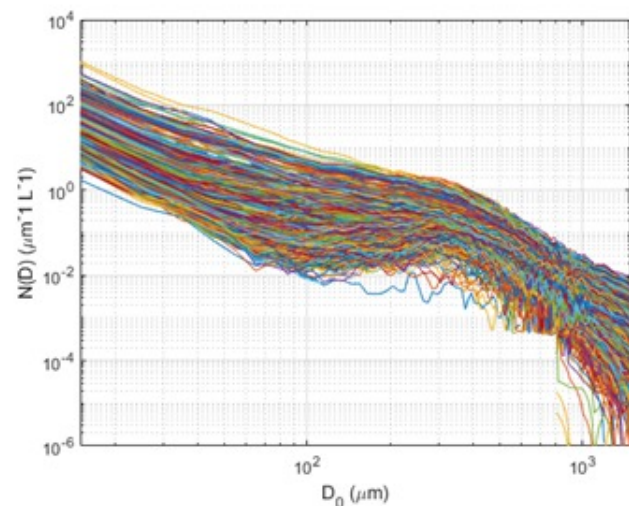
Hardware Development and Progress



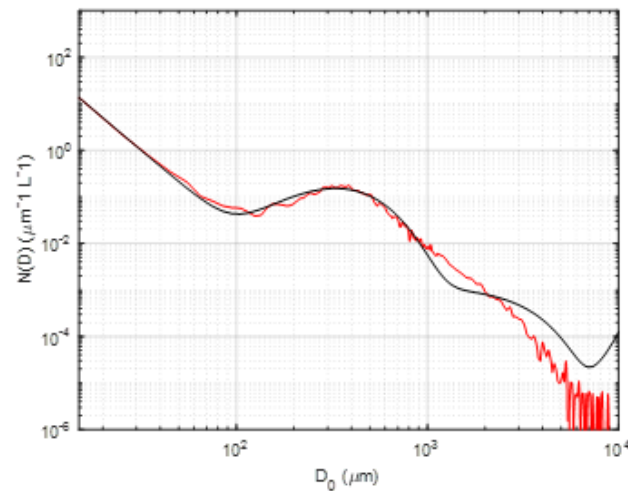
(a)

(b)

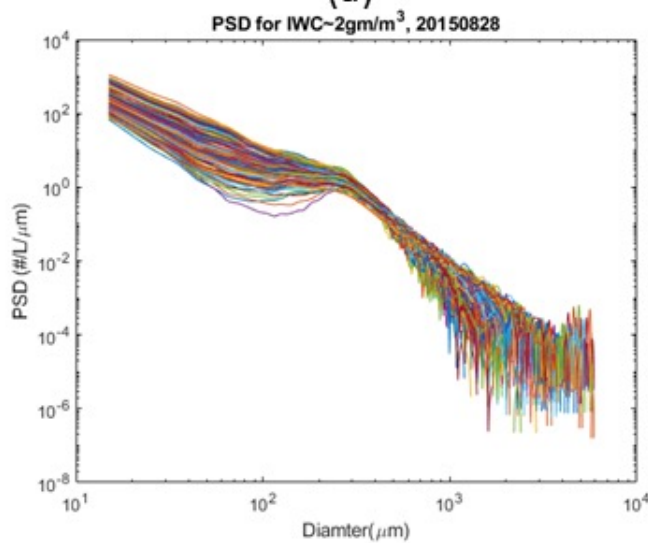
Particle Size Distribution (PSD) and Density-Size Relation



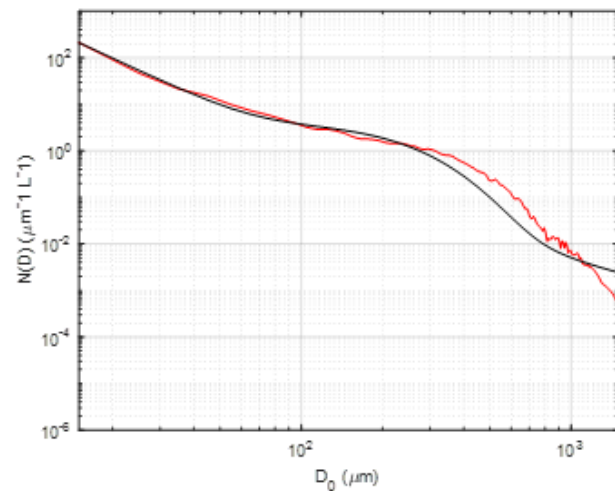
(a)



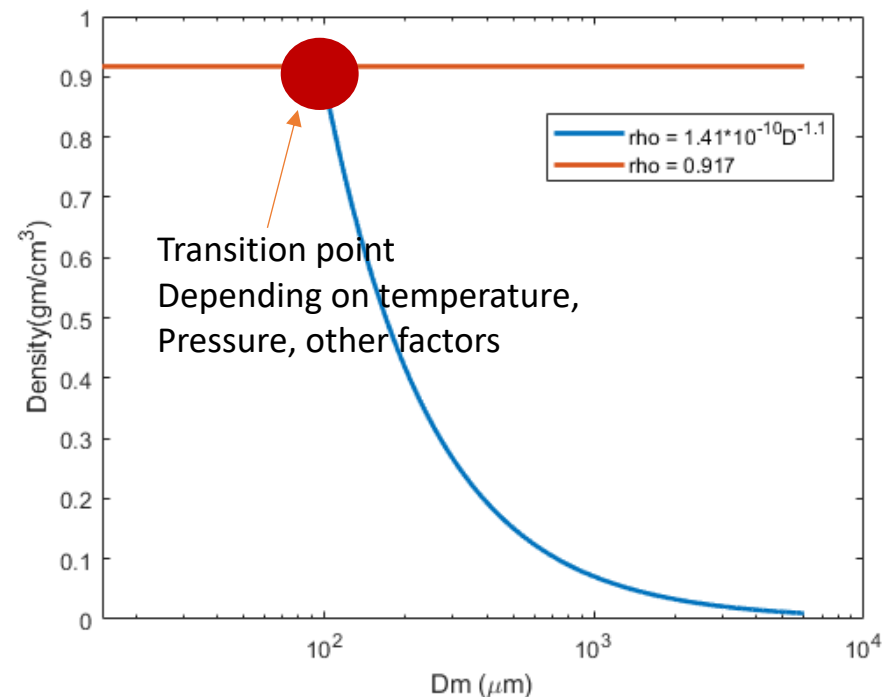
(a)



(b)



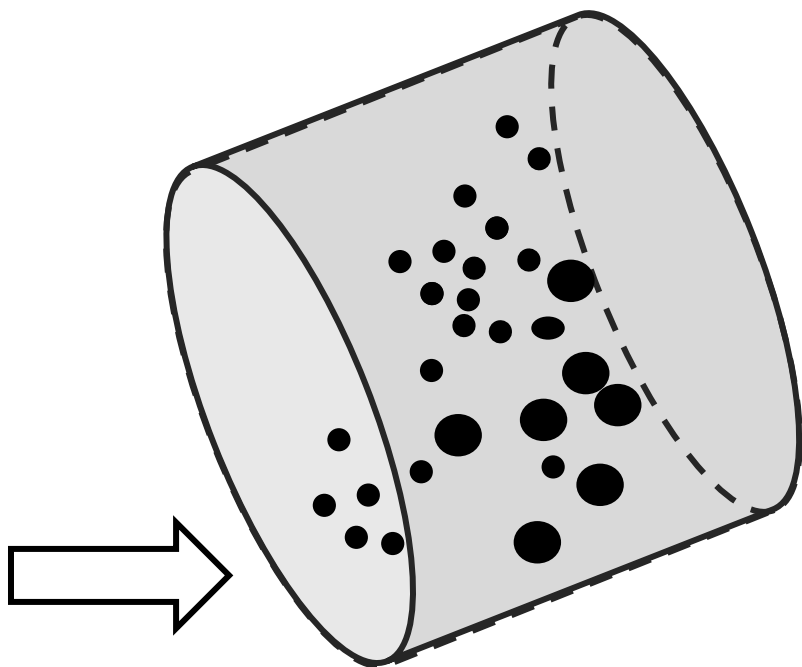
(b)



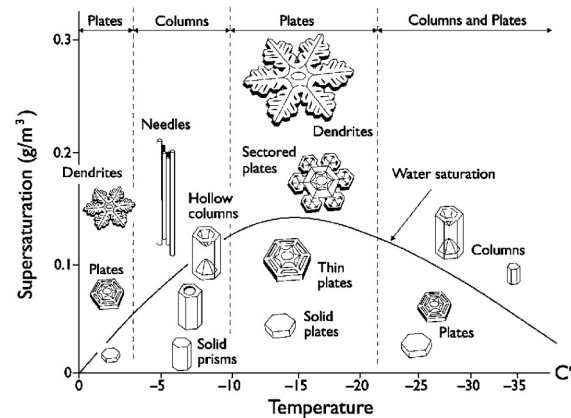
A hybrid constant ice density and BF-95 model provides the best results so far. It needs to be tuned based on environment temperature.

Particles within a Single Radar Cell

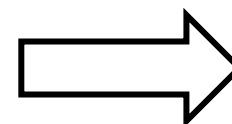
Radar Resolution Volume



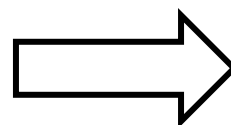
Ice particle “scatterers” are generated
 According to HIWC PSD and total concentration measured
 from unit volume (usually 1 m^3 or 1 liter)
 Assuming uniform volume filling
 (same microphysics applied to entire volume)



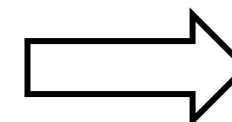
morphology



Equal-Volume spheroid assumption

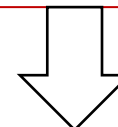


Computing
 “RCS samples” of the
 target each pulse



Airborne
 radar simulator
 Run by
 Radar manufacturers

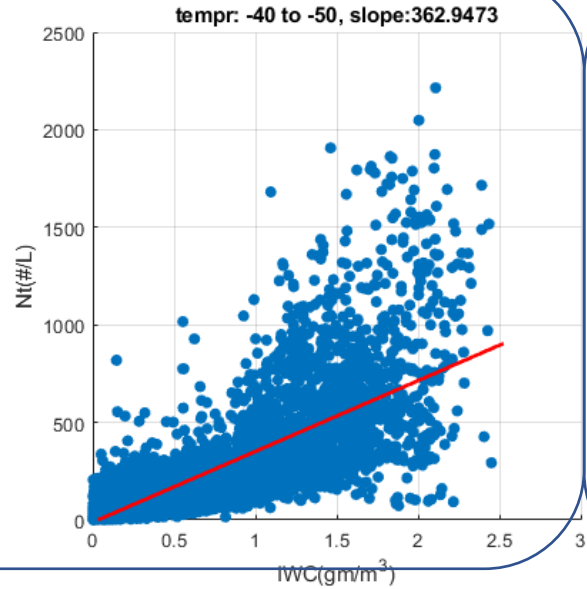
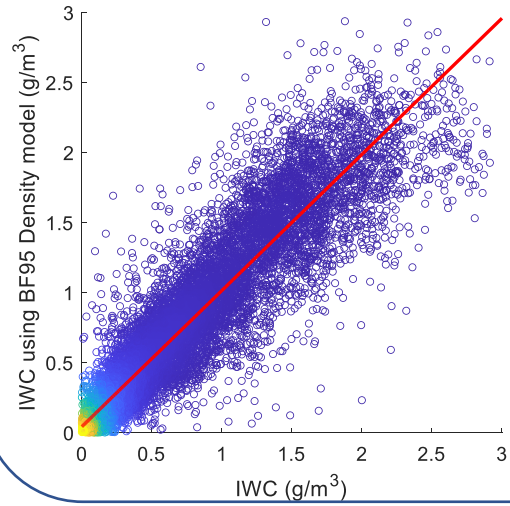
The key for current NASA research is Z (dBZ) changes from pulse to pulse according to the microphysical model/probe data, and result into a target statistical fluctuation model.



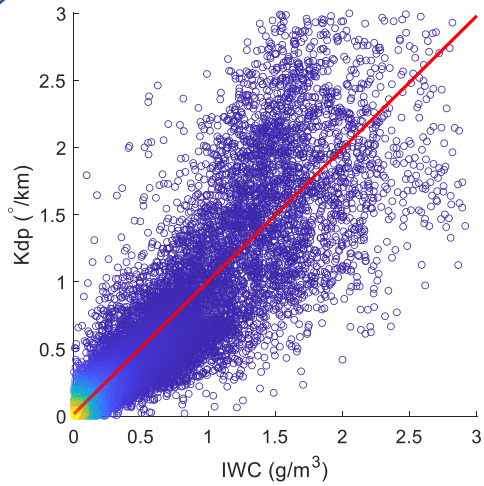
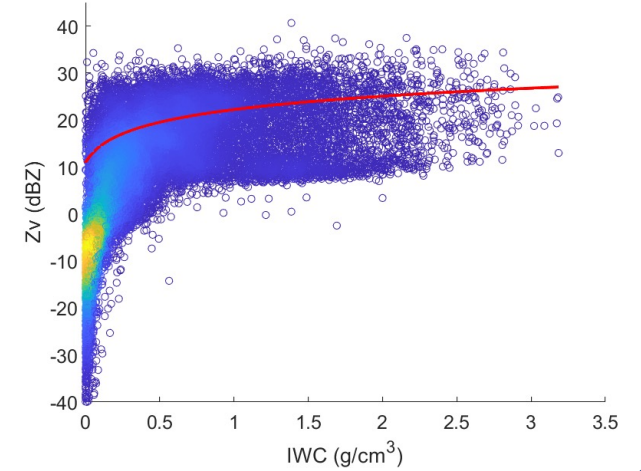
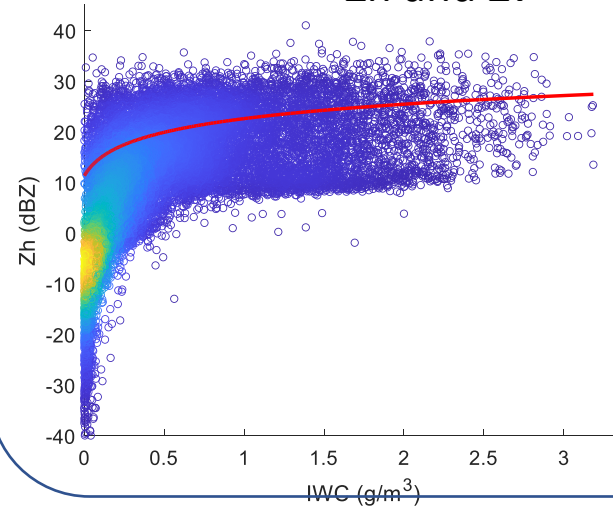
The key for R&D in IART/OU is to be able to use polarimetric radar measurements To estimate or retrieve IWCs for aviation industry usage.

Monte-Carlo Simulation Output and Initial Validations

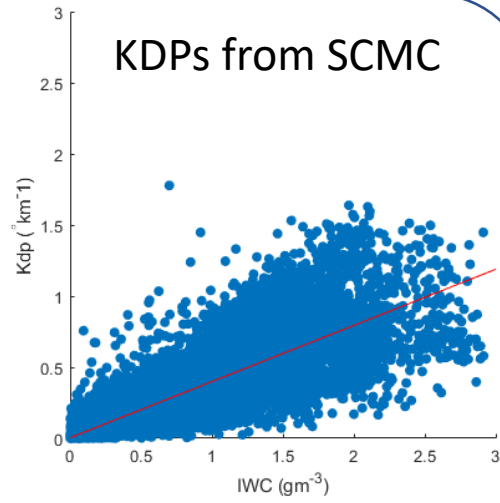
M-D relation validation



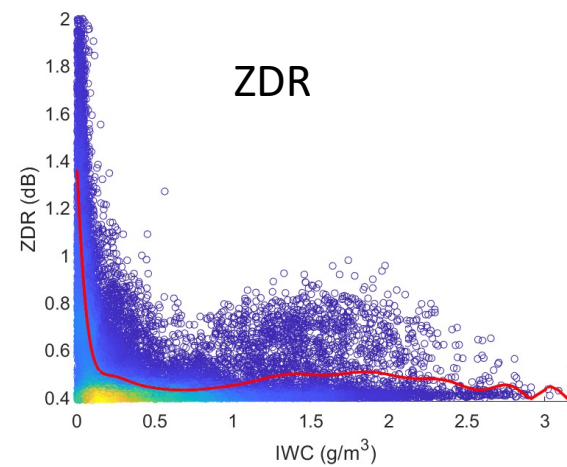
Zh and Zv



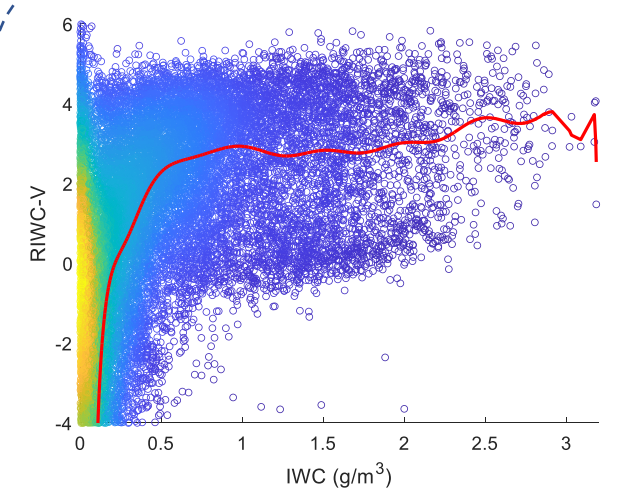
9.41 GHz



3 GHz

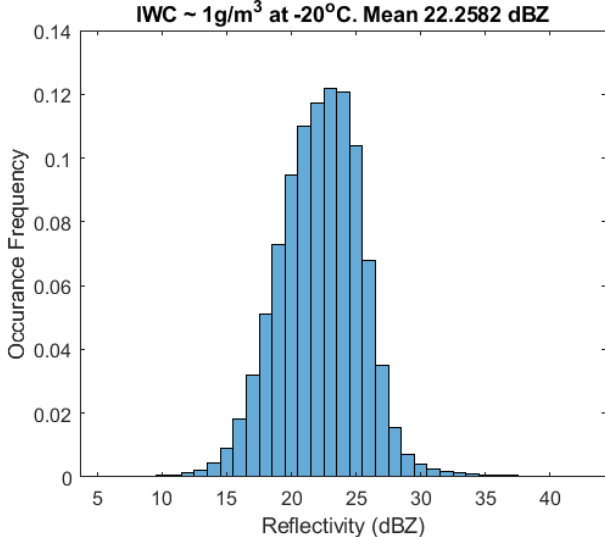
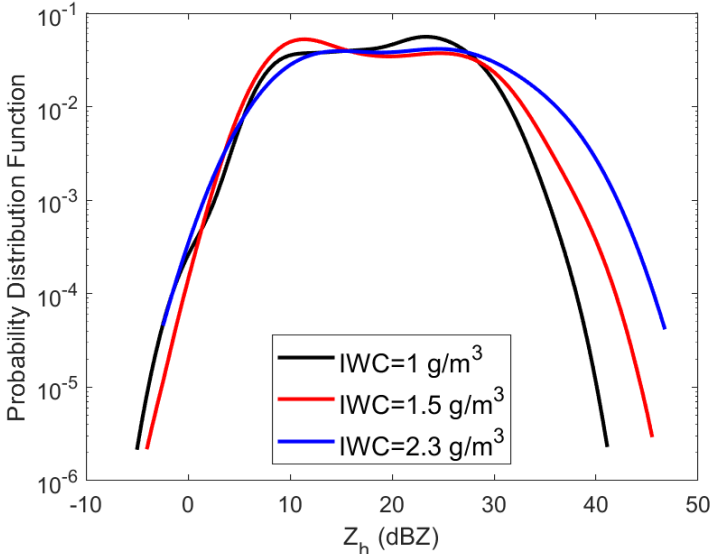


ZDR



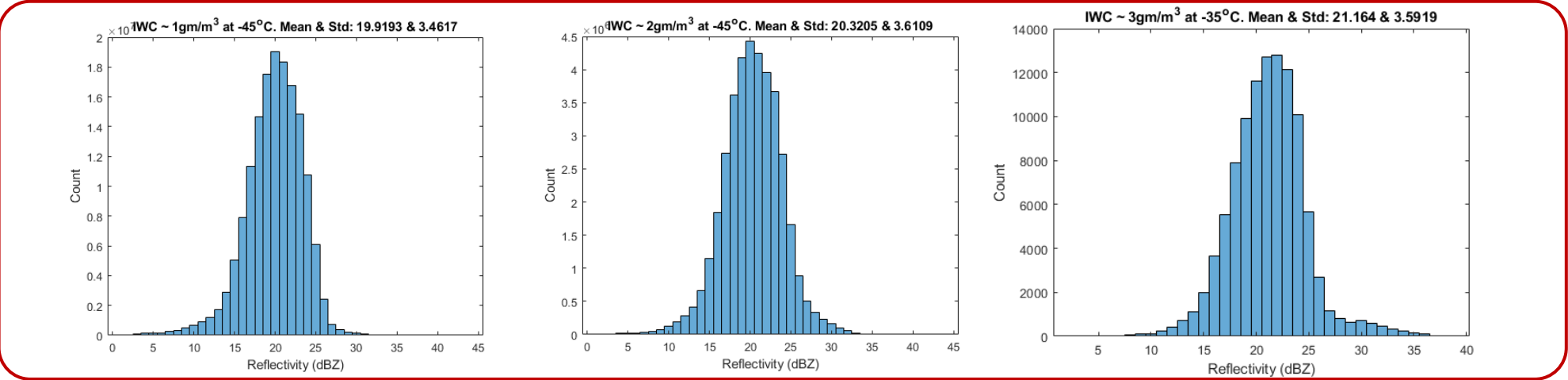
NASA-RTCA focus

Correlations Between Radar and In-situ Measurements



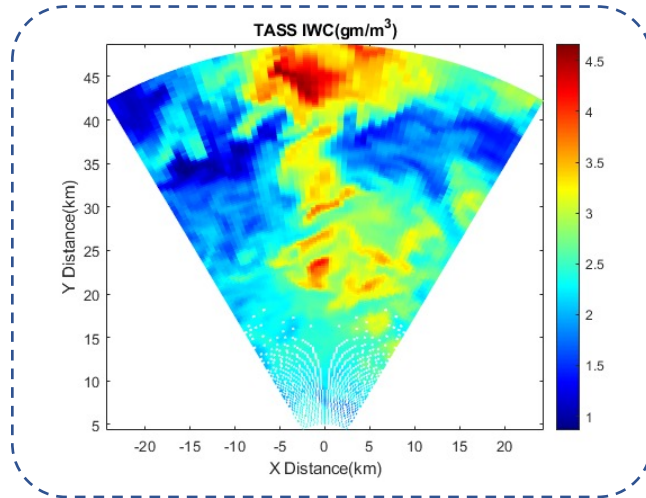
Impact of temperature
 Correlation criteria
 Location matching criteria

Radar Measurements verified
 correct range of RRF values
 and general trend of IWC-Z
 relationship qualitatively.

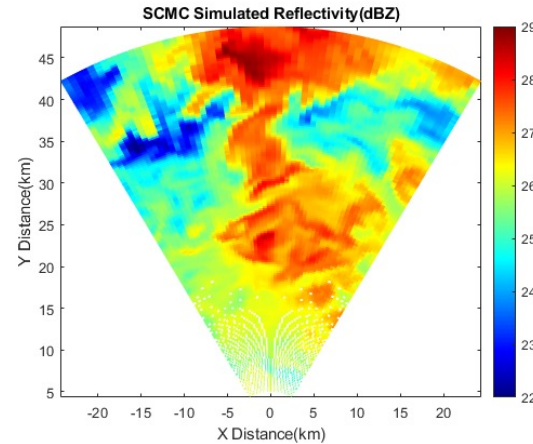


Simulations of Complete Airborne Radar Scans

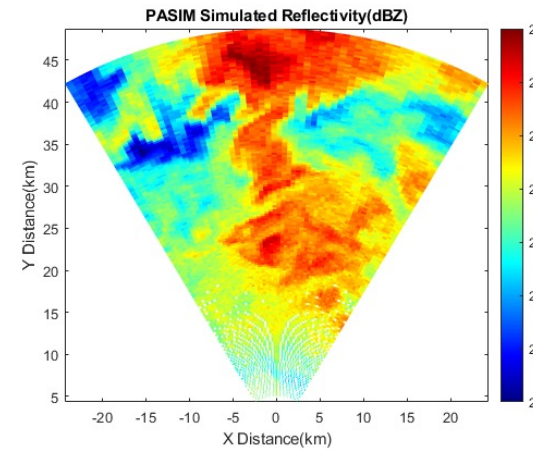
TASS NWP field



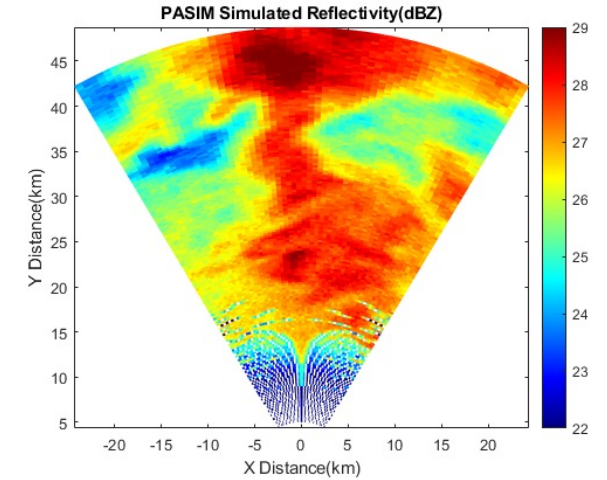
From IWC to Z one snapshot



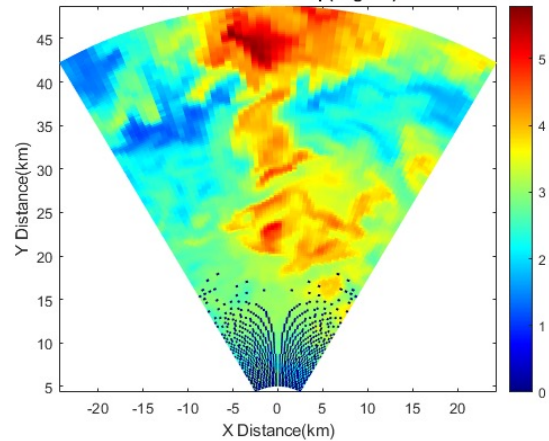
Z-1 deg BW
End-end system simulation



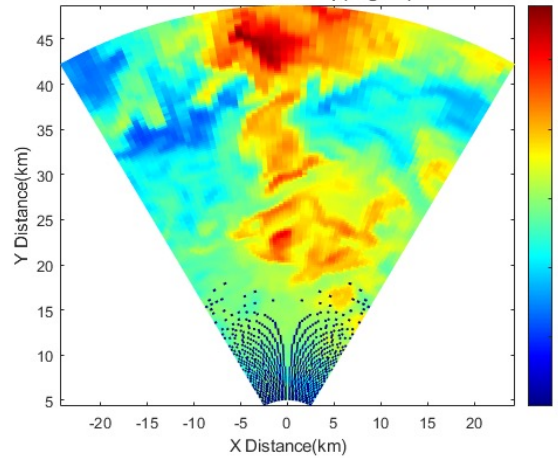
Z-3 deg BW
End-end system simulation



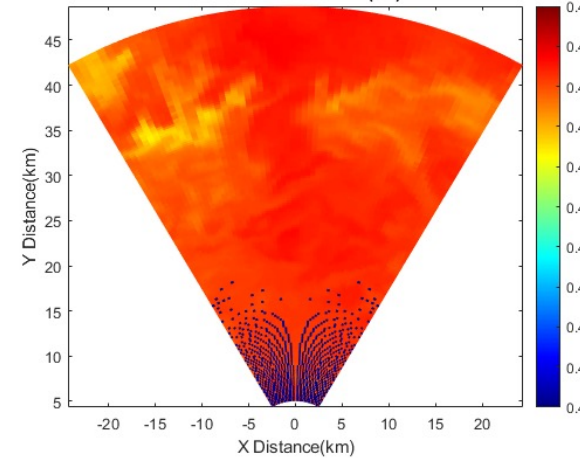
SCMC Simulated Kdp (deg/km)



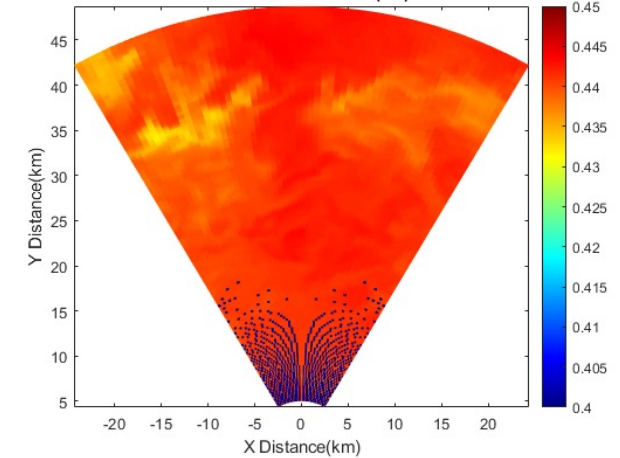
PASIM Simulated Kdp (deg/km)



SCMC Simulated ZDR (dB)



PASIM Simulated ZDR (dB)



From IWC to KDP
one snapshot

From IWC to KDP
End-end system

From IWC to ZDR
one snapshot

From IWC to ZDR
End-end system

Summary and Conclusion

- (1) RIWC is indeed a physically meaningful “derived” radar variable and has a physically meaningful connection with IWC.**
- (2) Usage of RIWC for IWC estimation, however, needs to be careful and needs further studied together with other feature variables, including using new end-end airborne radar simulations.**
- (3) Although we have yet to compare fully quantitatively between SCMC simulated and measured radar reflectivity, we achieved reasonable qualitative verifications.**
- (4) It will be challenging to discriminate HIWC hazard using Z as the only feature variable.**
- (5) The most promising indicator of HIWC seems to be the dual-polarized radar variable Kdp , a polarimetric radar sensing solution maybe still important for long-term development.**