Icing Remote Sensing Using Radar and Radiometer

J. Vivekanandan, Guifu Zhang, Merritt Deeter, John Williams, Julie Haggerty, Marcia Politovich, and Edward A. Brandes

National Center for Atmospheric Research
Research Applications Program
Boulder, Colorado

AWRP

NCAR

Background

1. Radar: (a) Polarization

   (b) Dual-wavelength

2. Radiometer: (a) Microwave

   (b) Vis and IR.

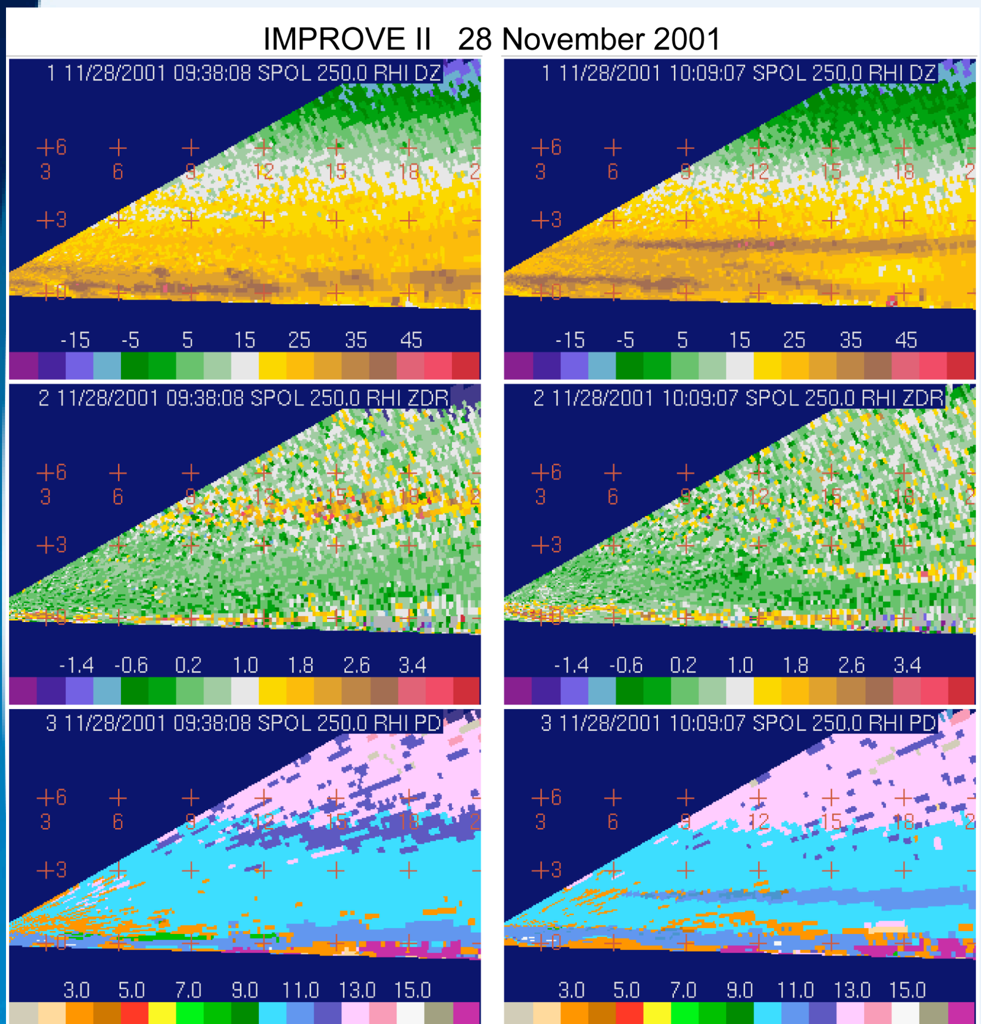
A. Polarization Radar

1. Verify radar-based winter precipitation type classification using in situ aircraft observations.
2. Delineate regions of dominant liquid, ice and mixed-phase regions using dual-polarization and dual-wavelength radar observations.

ISSUES:

1) Weak radar signatures
2) Polarimetric measurements at short ranges contaminated by ground clutter
3) Wide variety of hydrometeor types
4) Precipitation often shallow
5) Smaller terminal velocities
6) Attenuation due to brightband

Particle Typing Using Polarization radar data



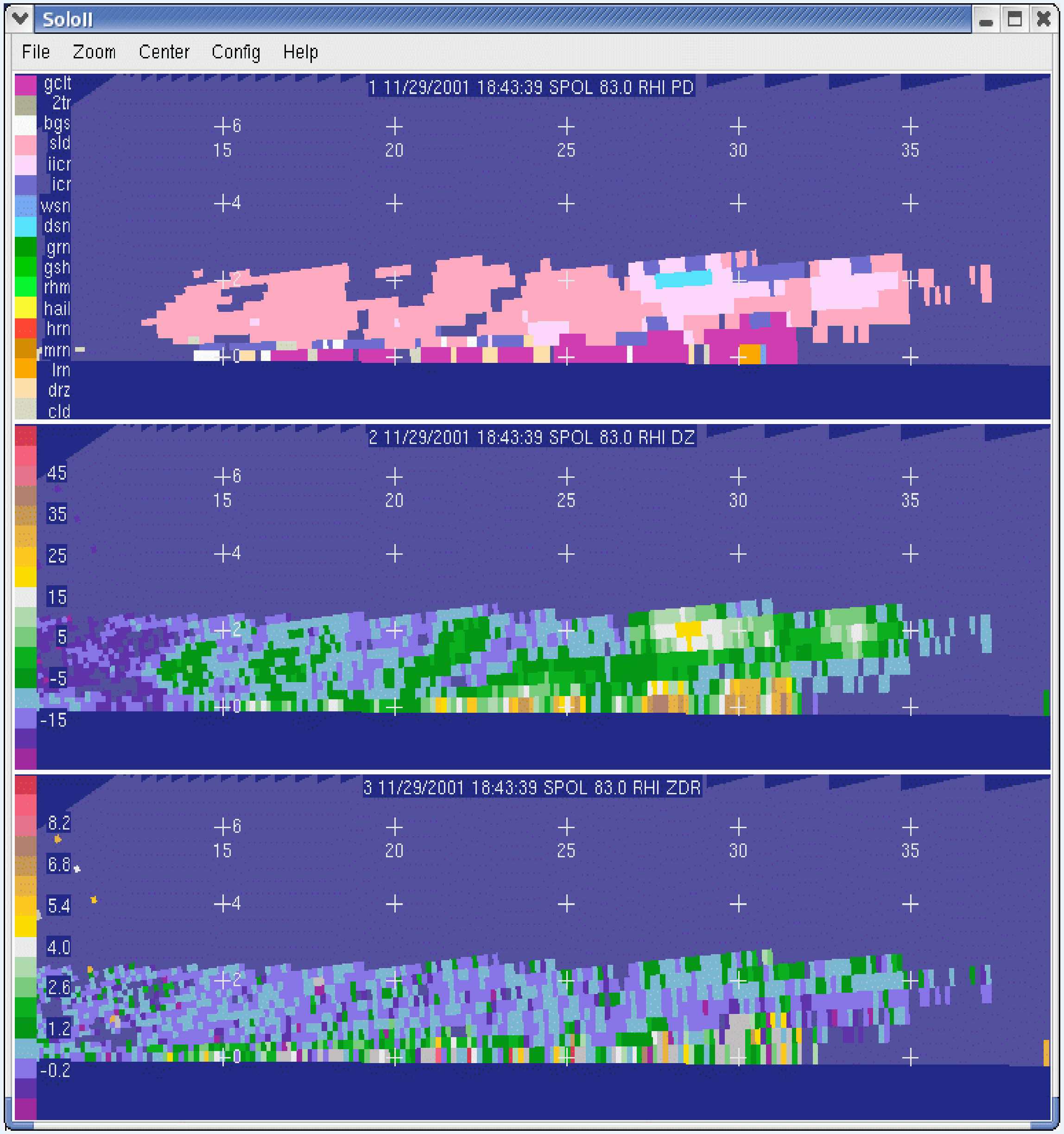
Hydrometeor Designations

1	Cloud Drops	10	Dry Snow
2	Drizzle	11	Wet Snow
3	Light Rain	12	Ice Crystals
4	Moderate Rain	13	Irregular Ice Cystals
5	Heavy Rain	14	Supercooled Liq. Drops
6	Hail	15	Insects
7	Rain/Hail	16	Birds
8	Graupel/Small Hail	17	Ground Clutter
9	Graupel/Rain		

Vertical cross sections through a stratiform rain observed in the Oregon Cascades on 28 November 2001. The panels from 0938 and 1009 UTC show radar reflectivity (top), differential reflectivity (middle), and hydrometeor designations (bottom). Emergence of multiple freezing levels is suggestive of the warm frontal zone passing through the cascades at this time.

AWRP

NCAR

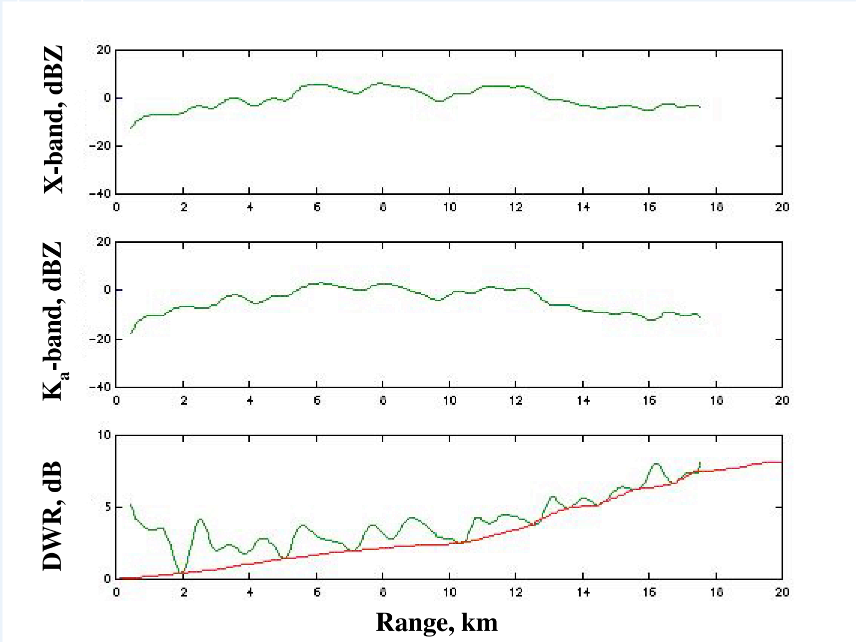

SoloII
File Zoom Center Config Help
1 11/29/2001 18:43:39 SPOL 83.0 RHI PD
gclt
2tr
bgs
sld
iicr
icr
wsn
dsn
grn
gsh
rhm
hail
hrn
mrn
lrn
drz
cld
2 11/29/2001 18:43:39 SPOL 83.0 RHI DZ
45
35
25
15
5
-5
-15
3 11/29/2001 18:43:39 SPOL 83.0 RHI ZDR
8.2
6.8
5.4
4.0
2.6
1.2
-0.2
15
20
25
30
35

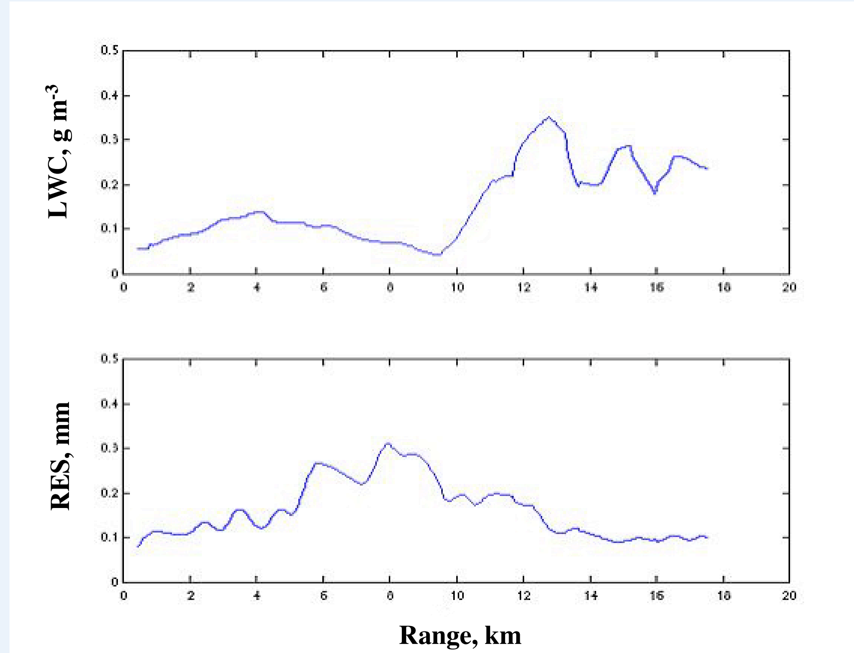
NCAR

B. Dual-wavelength radar

1. Estimate LWP (liquid water path) and LWC (liquid water content) using dual-wavelength radar measurements.

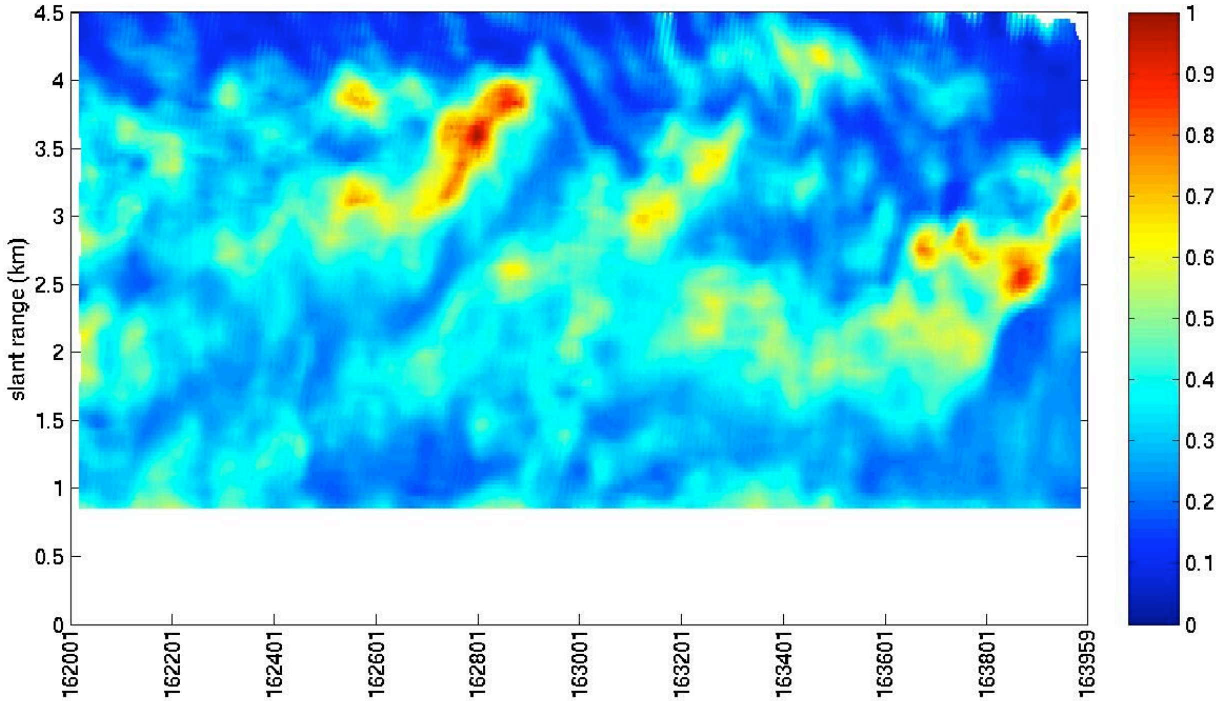
2. In liquid cloud only region, estimate characteristic size of droplets using dual-wavelength reflectivity and absorption measurements.





X- and Ka-band reflectivity, dual wavelength ratio (DWR), along with retrieved LWC and RES along a radial for a stratified cloud with precipitation particle small compared to Ka-band wavelength. Slope of the line joining local minima in the DWR is used for estimating attenuation and LWC. The data were collected in northeastern Colorado on 18 April 1991 between 17:28 and 17:30 GMT along 2830 azimuth and 1.50 elevation.

Solving dual-□ liquid retrieval problems



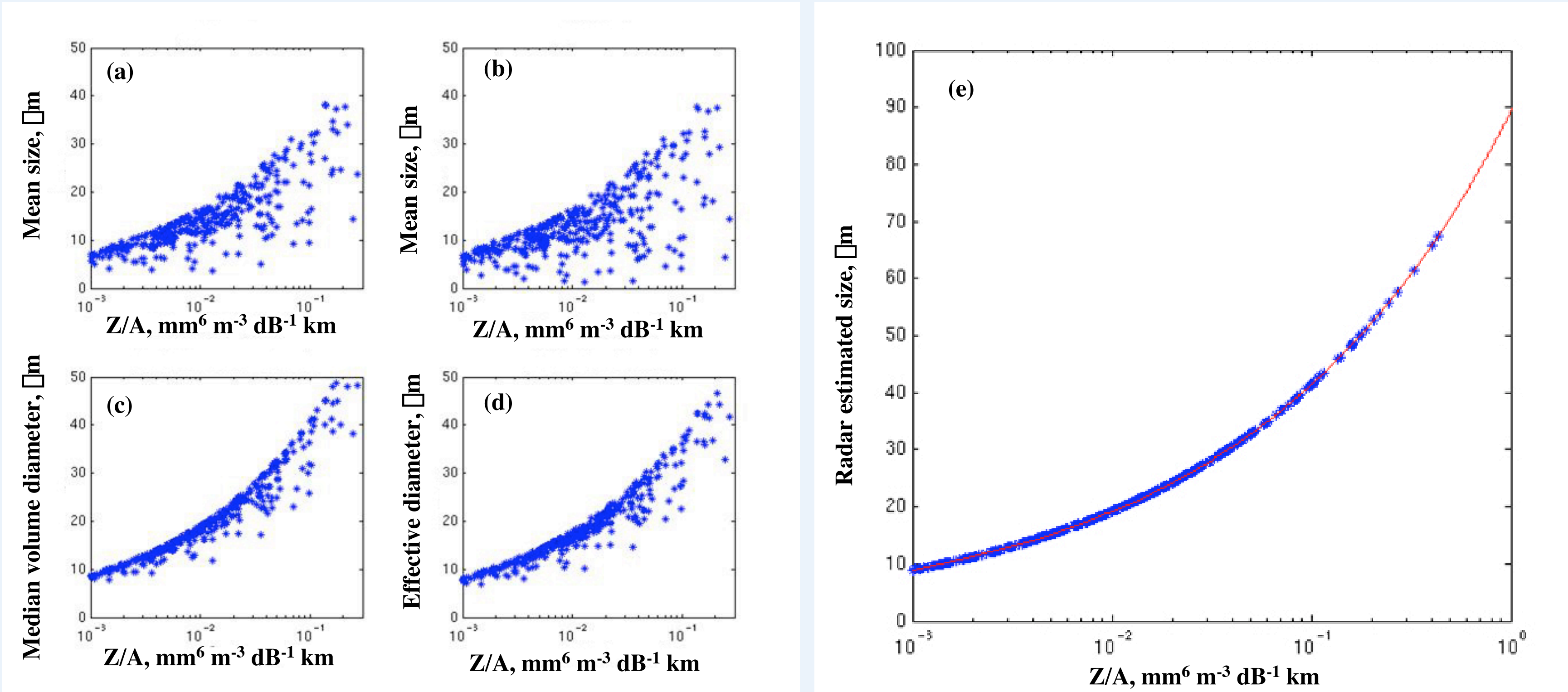
Approaches:

- Dual-□ reflectivities
- Gamma distribution fit
- $Z^{1/2}$ proportional assignment
- Weighted combination

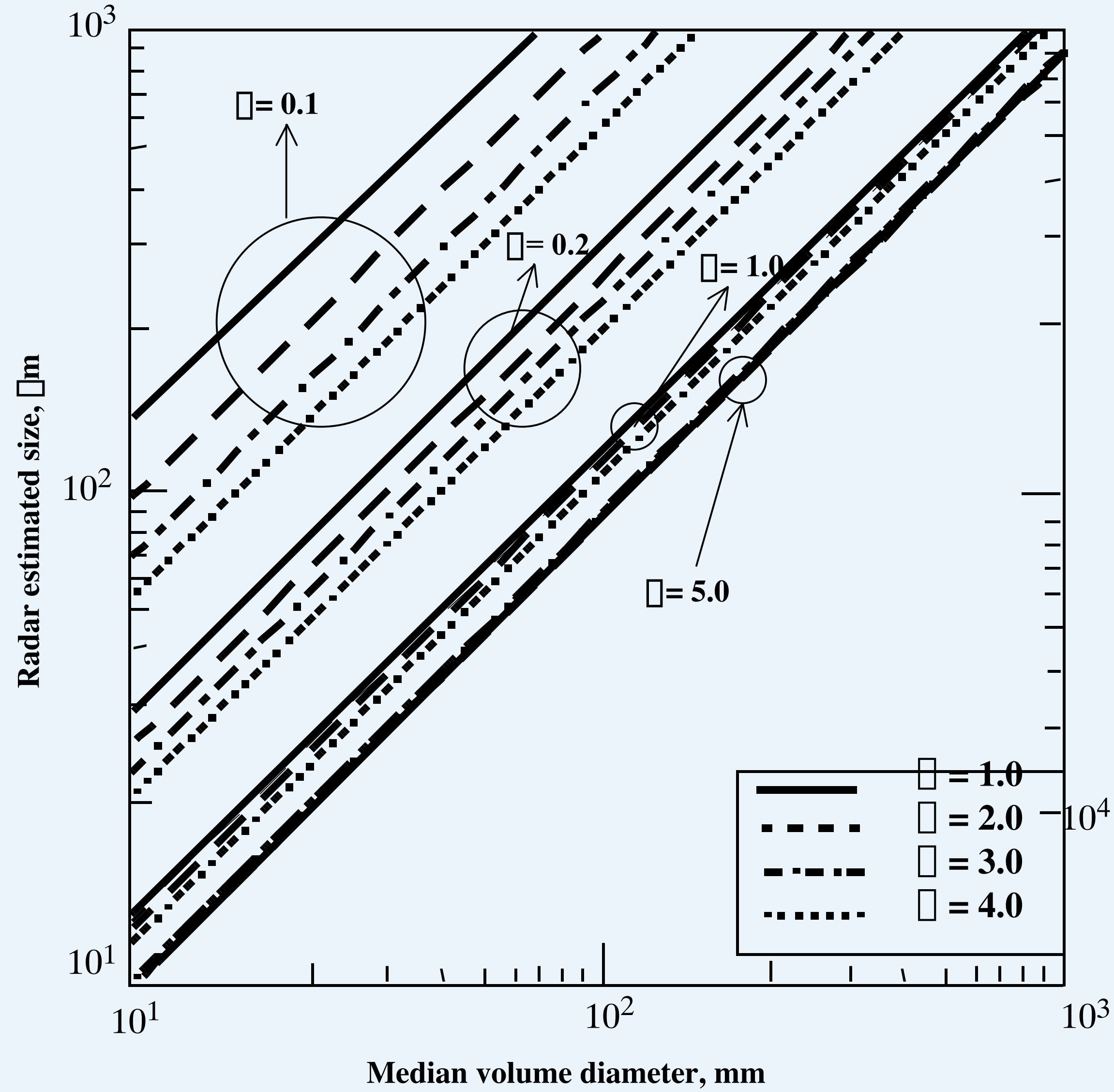
Williams et al., "Evaluation of remote icing detection techniques using X-, Ka-, and W-band radar and microwave radiometer observations," for ARAM conference, Portland OR, May 2000

AWRP

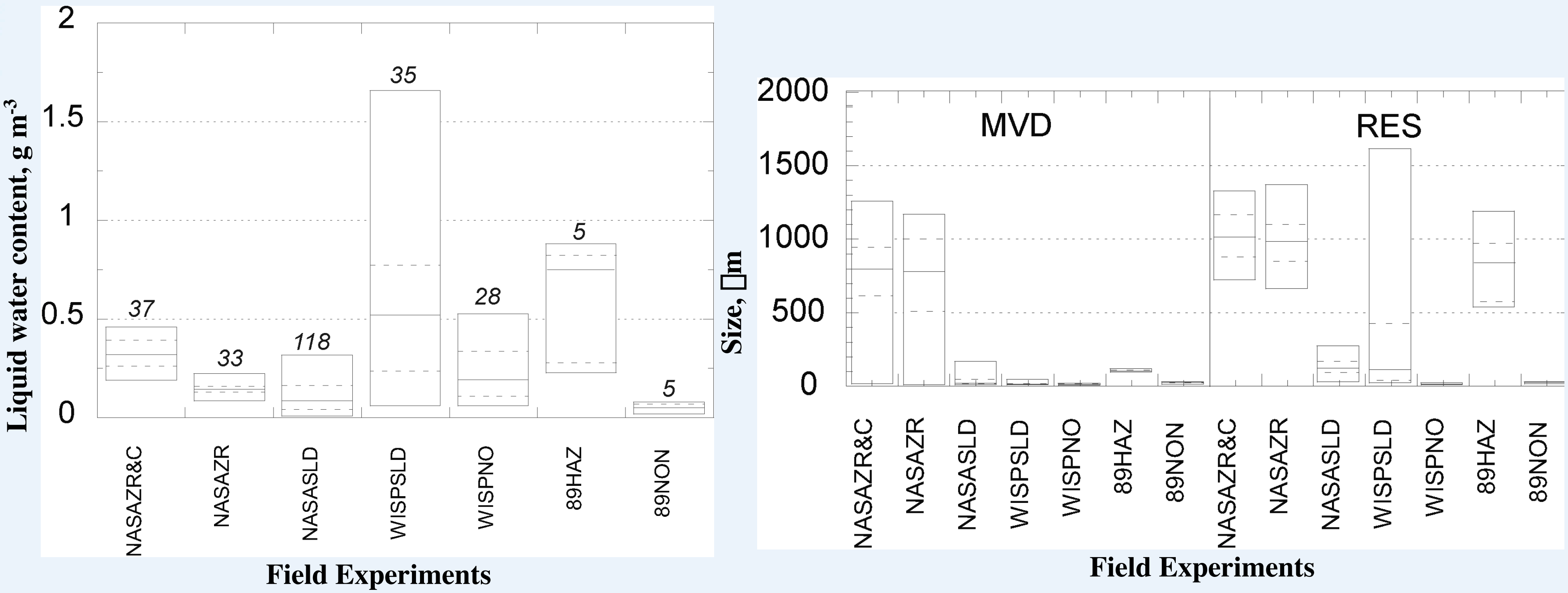
NCAR



Scatter plot between DSD statistic and reflectivity/attenuation (Z/A) ratio: (a) mean diameter, (b) model diameter, (c) median volume diameter (MVD), (d) effective diameter (EFD), and (e) radar estimated size (RES). Note RES verses Z/A is exact due to the definition.



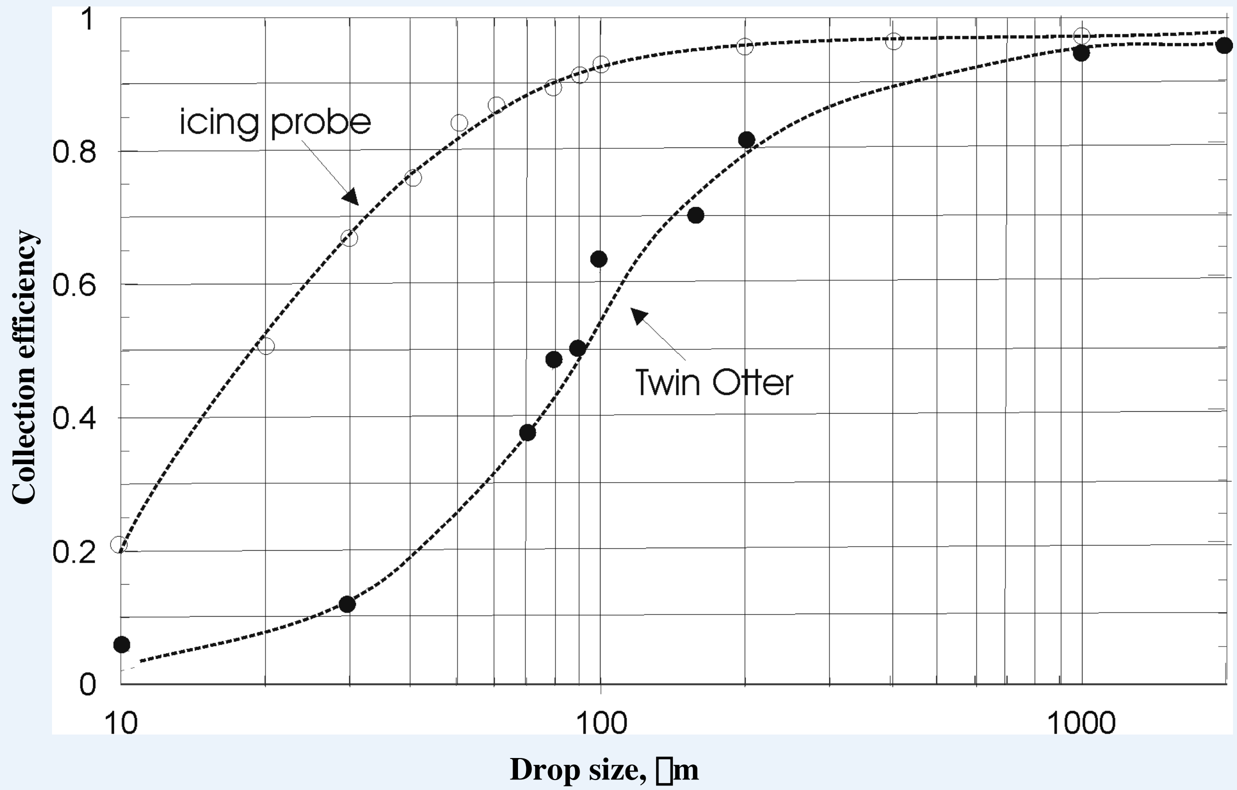
The relation between MVD and RES for various values of and .
a and g are parameters of a modified Gamma size distribution.



Distributions of a) LWC and b) RES and MVD for the data sets described in the text. The top and bottom of each box is the 10th and 90th percentiles of the measurement set; the middle solid line is the median (50th percentile); dashed internal lines are the 25th and 75th percentiles. The numbers of samples are listed at the tops of the boxes. Data sets are described in the text.

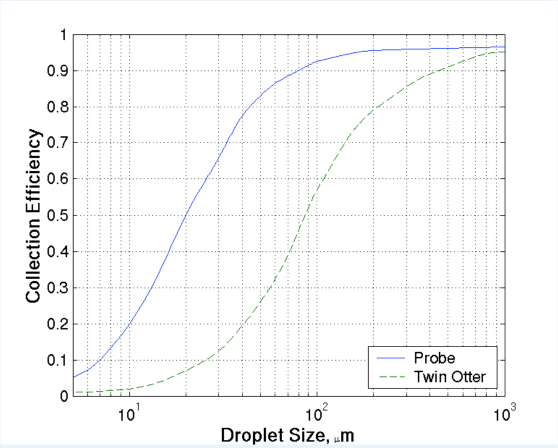
AWRP

NCAR

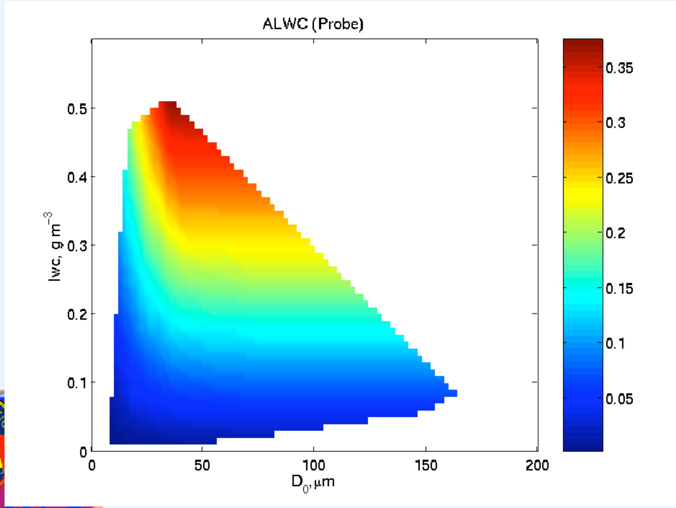


Collection efficiency plotted against droplet size for the Rosemount Ice Detector and the Twin Otter. The Rosemount Ice Detector efficiencies are for an assumed airspeed of 90 m s-1 at 1000 hPa and do not account for any flow effects around the fuselage. Twin Otter efficiencies are from Wright and Potapczuk (1998). Best-fit lines are shown.

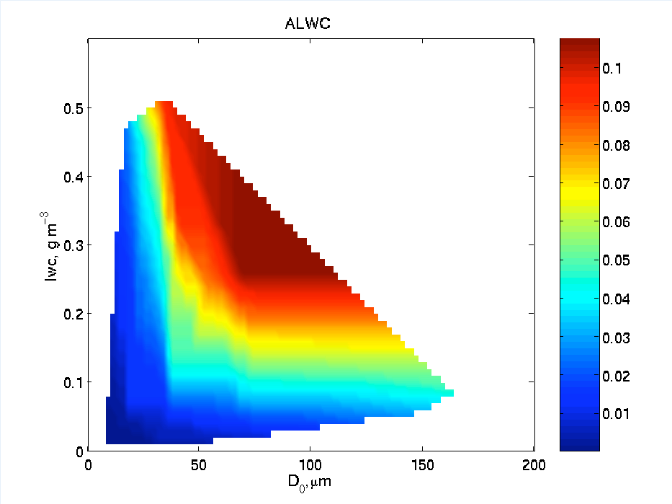
Quantitative definition of icing



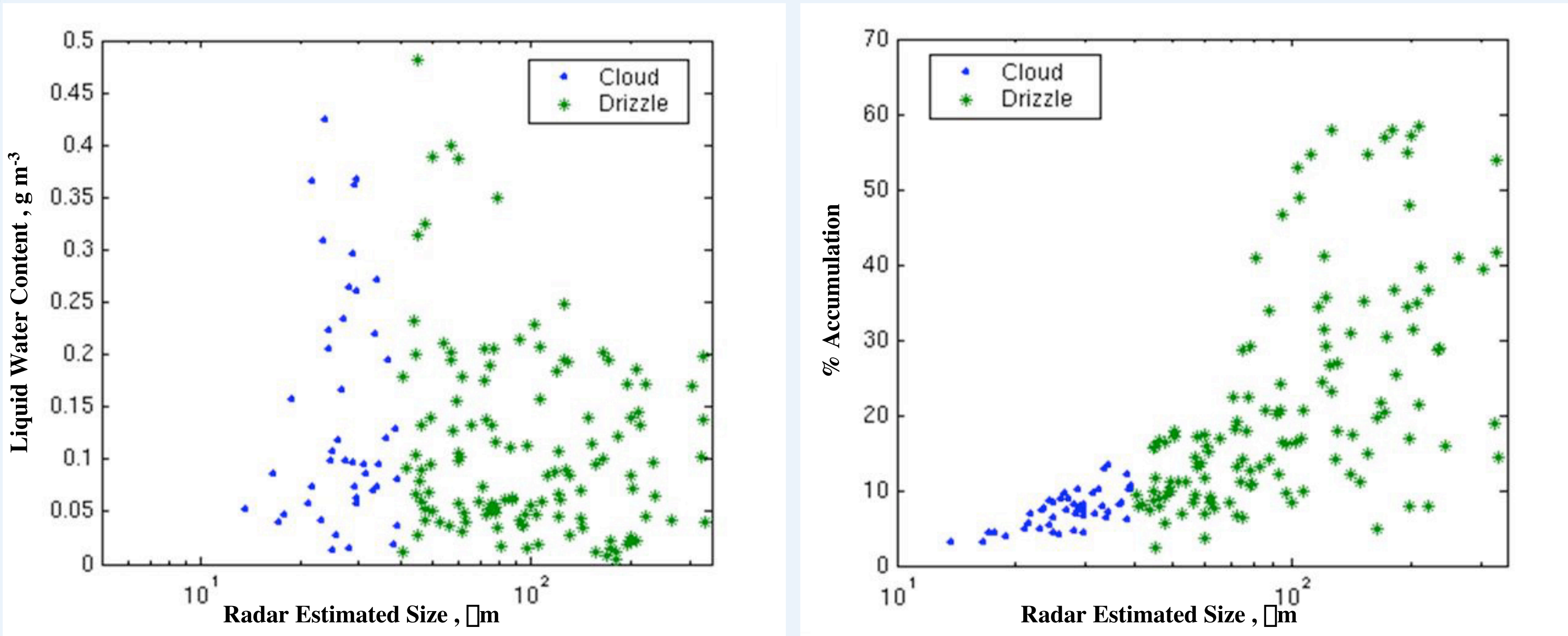
Collection efficiency



(a) Rosemount icing probe



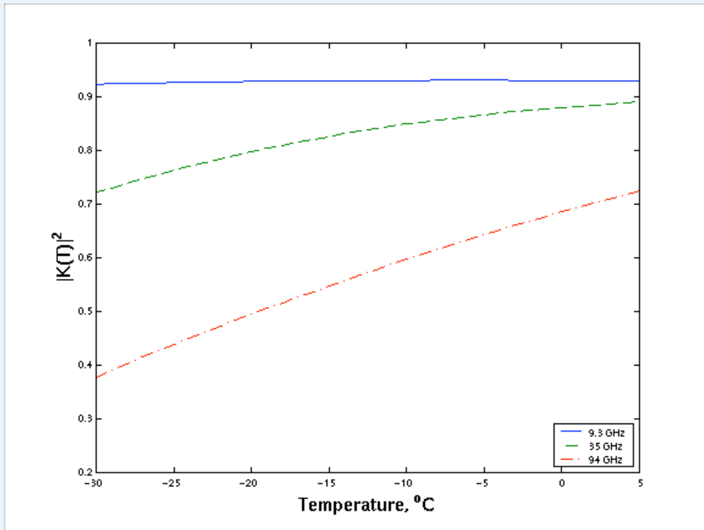
(b) Twin Otter



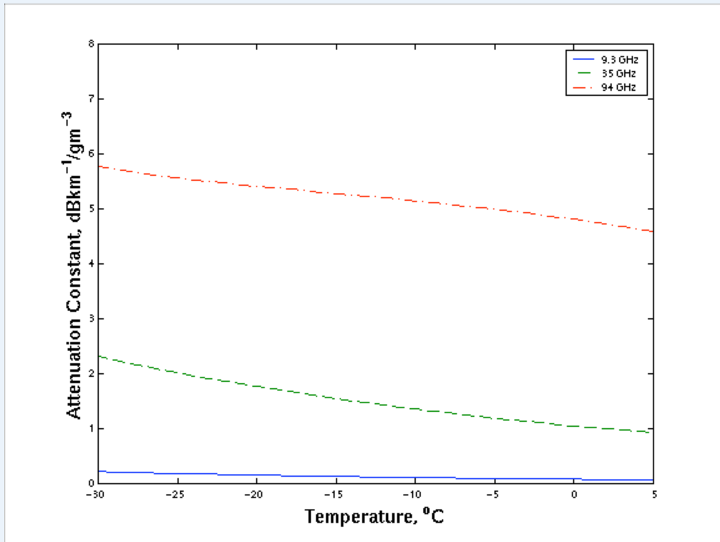
(a) LWC and (b) percentage of accretion plotted versus RES for the data sets described in the text. The Twin Otter collection efficiency shown in Fig. 7 was used for calculating the percentage of accretion.

NCAR

Temperature dependence of radar reflectivity and attenuation



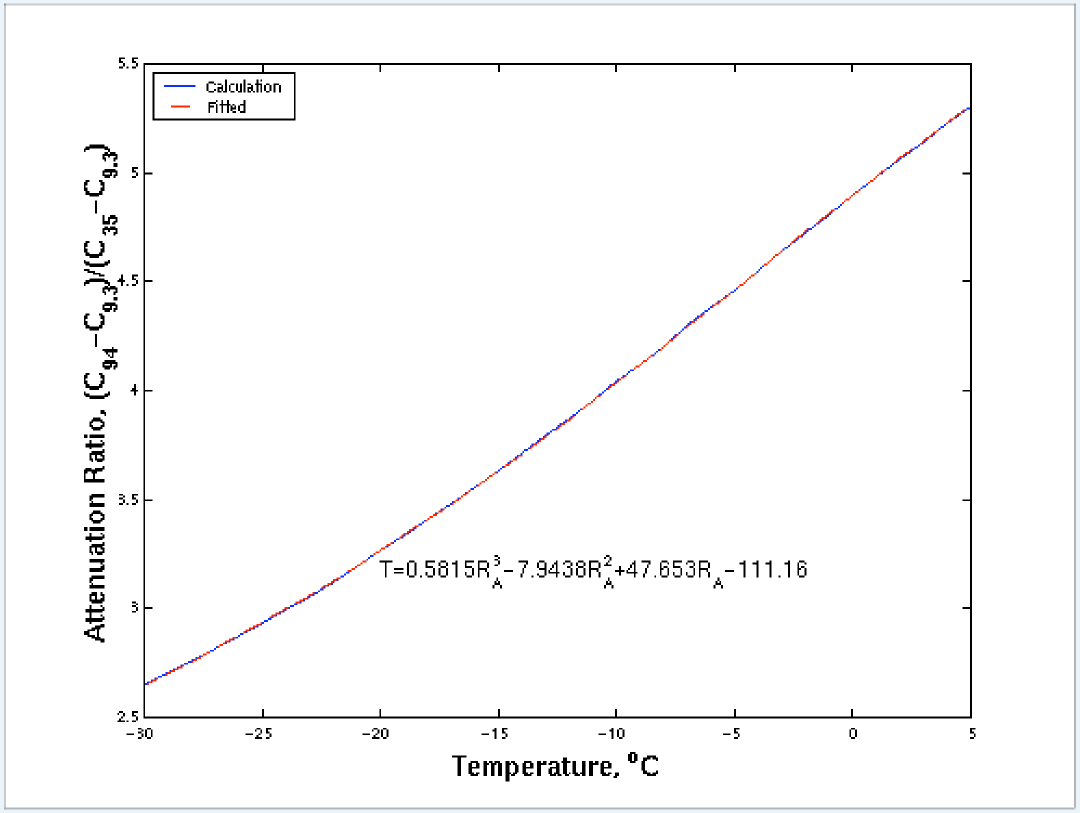
Polarizability



Attenuation coefficient

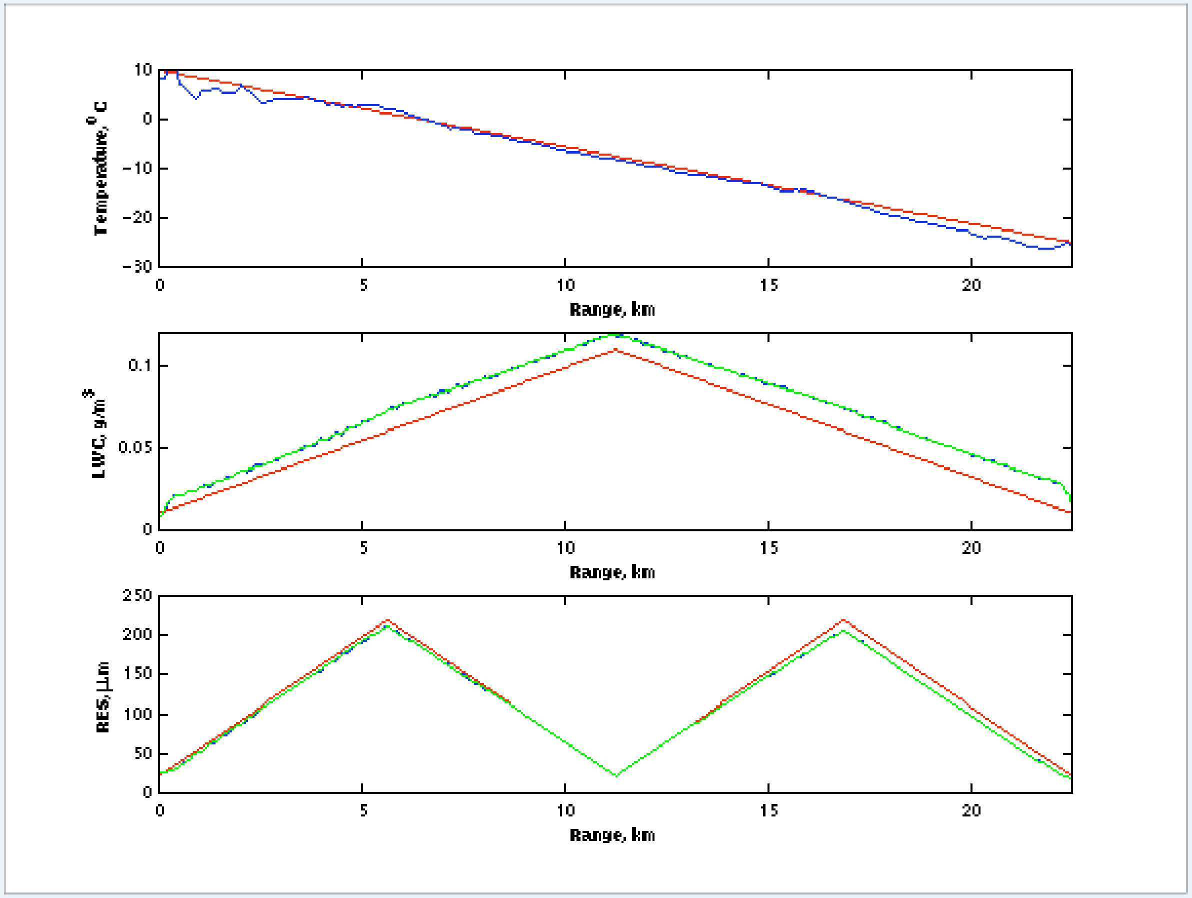
NCAR

Temperature determined from the ratio of attenuation difference



NCAR

An example of temperature retrieval with simulated data



C. Ground-based Radiometer and Satellite

1. Investigate feasibility of retrieving mean radiating temperature of the cloud using ground-based 20, 30 and 90 GHz brightness temperature measurements and TP-WVP-3000 profiles.
2. Test a nonlinear retrieval technique for improved temperature profiling from the TP/WVP-3000 multi-channel radiometer.
3. Use 90 and 150 GHz brightness temperatures to detect mixed phase icing condition.
4. Vis and IR satellite data analysis
5. Detection of mixed phase cloud using AMSU-B

AWRP

NCAR

What we have to work with

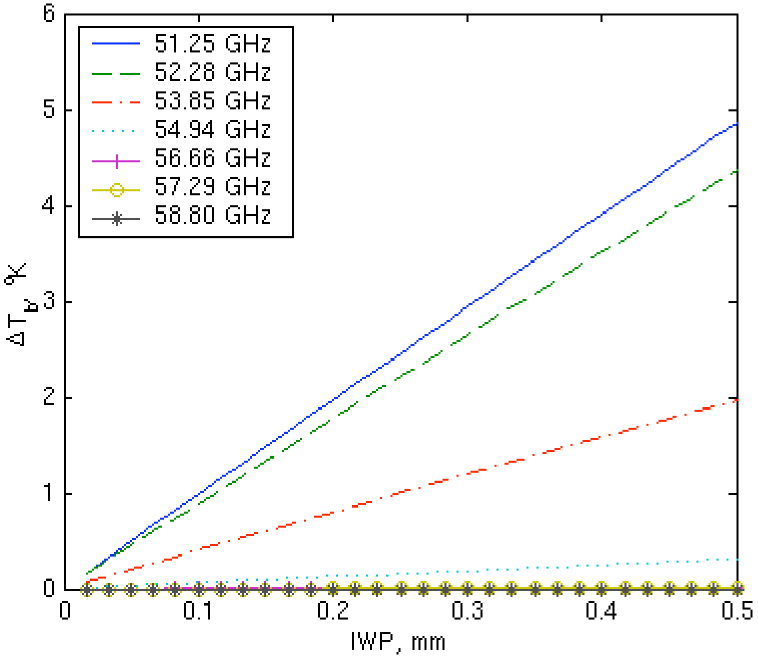
K band	V band
22.235	51.25
23.035	52.28
23.835	53.85
26.235	54.94
30.00	56.66
	57.29
	58.8

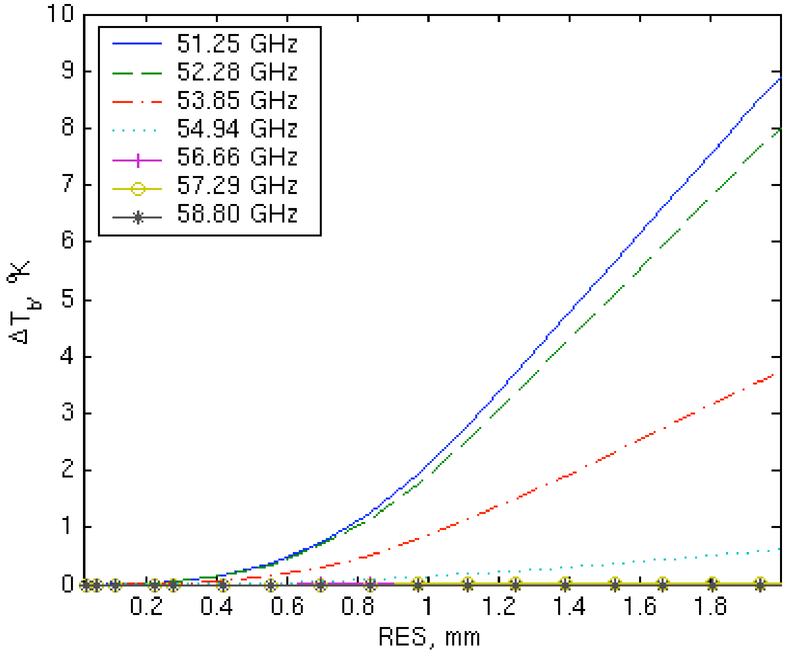
K and V bands are sensitive to O_2, H_2O

Millimeter wave band more affected by Ice scattering

In collaboration with Radiometrics Inc. millimeter wave radiometers at 90 and 150 GHz frequencies were developed to detect scattering and mixed phase icing by large ice and liquid

Bias at V-band

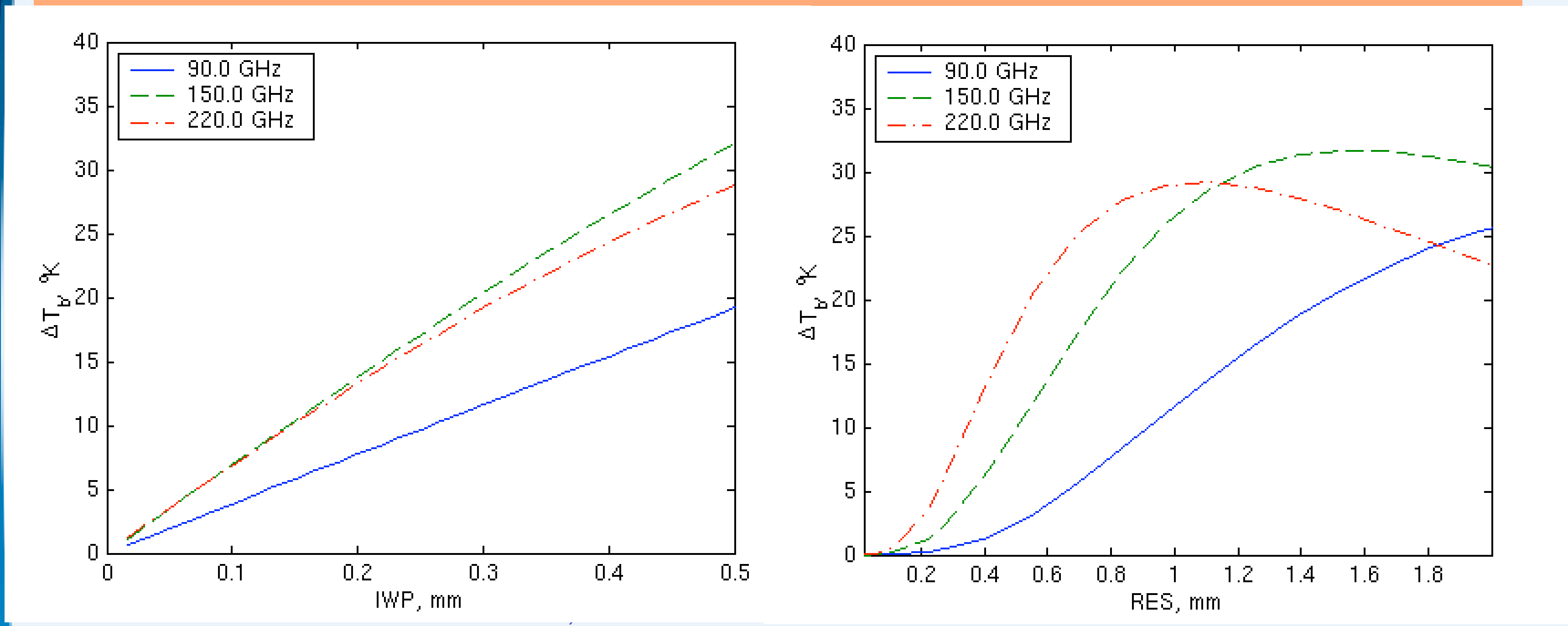




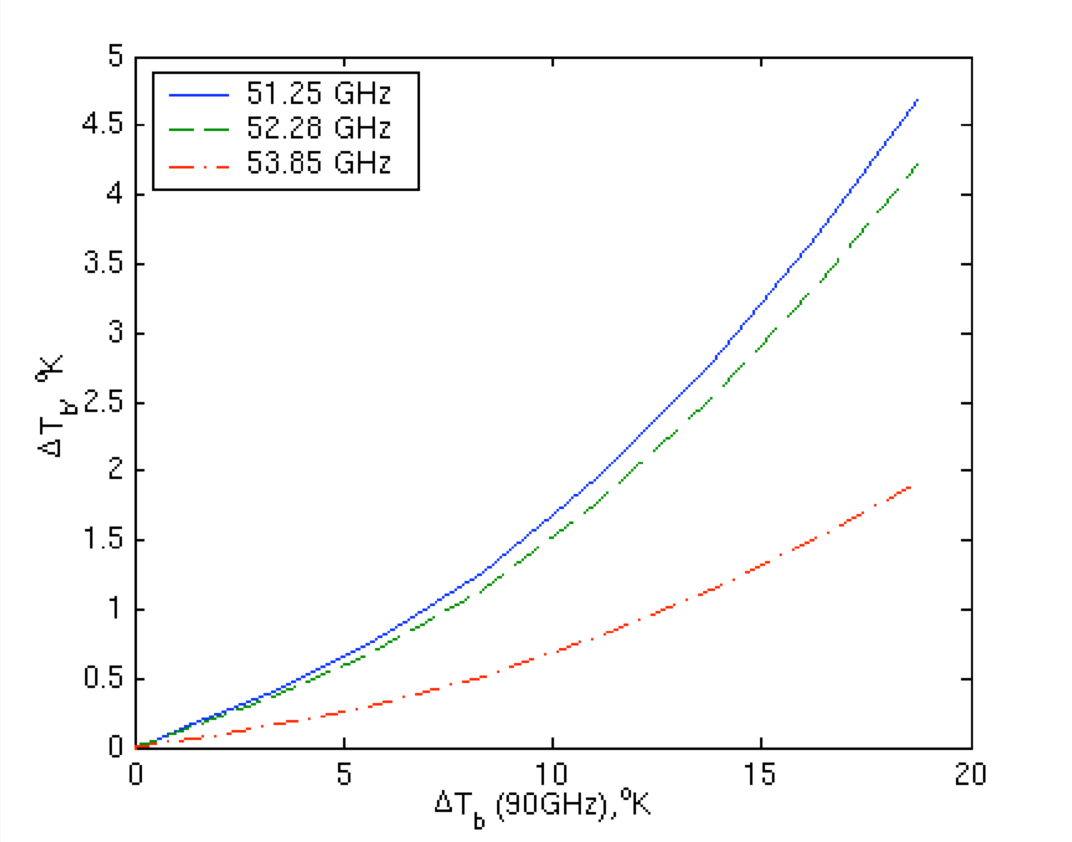
AWRP

NCAR

Bias at Higher Frequencies



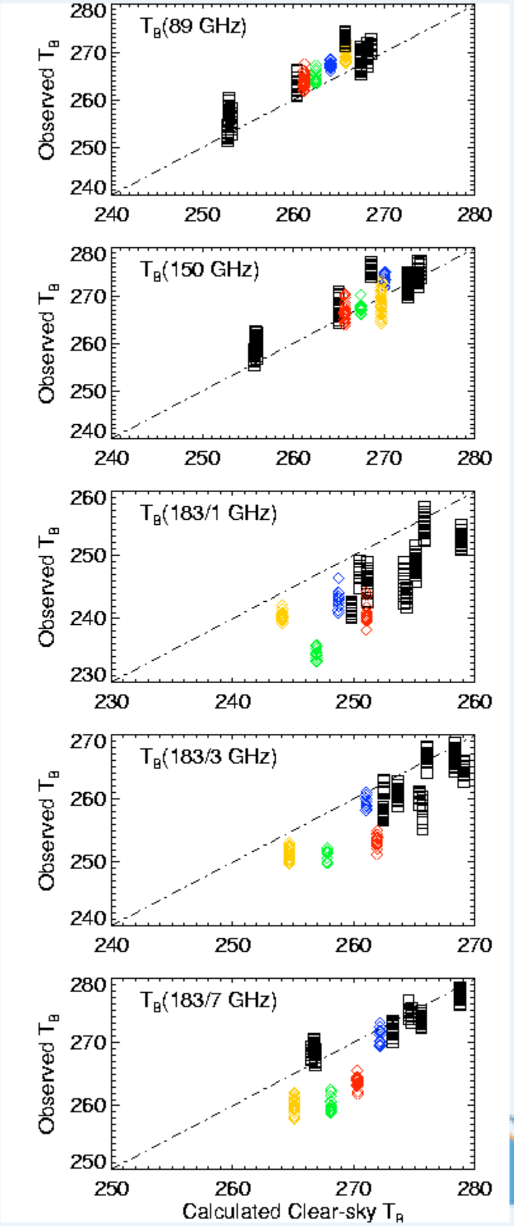
Ratio: Correction Factor



NCAR

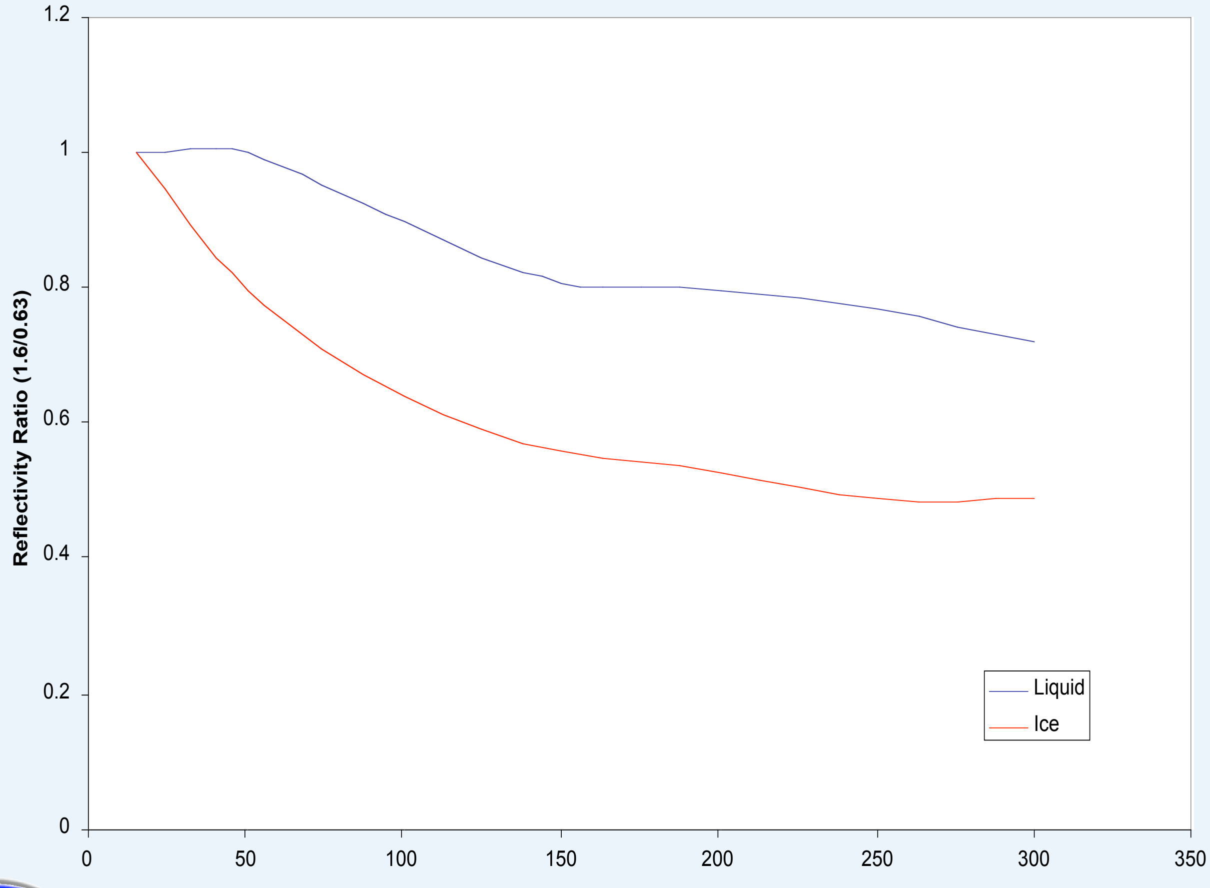
Comparison of observed and model-calculated AMSU-B brightness temperatures at ARM Southern Great Plains site for January 9-11, 2002. Cloudy-sky overpasses on 1/10/02 and 1/11/02 are plotted in color using the 'diamond' symbol. For overpasses on 1/10/02, blue indicates overpass at 0810 UTC, green indicates overpass at 1324 UTC, and orange indicates overpass at 1934 UTC. Observations acquired during the overpass at 0043 UTC on 1/11/02 are plotted in red. All clear-sky overpasses are plotted in black using the 'box' symbol.

Results demonstrate higher sensitivity of AMSU-B water vapor channels (esp. 183/7 GHz) relative to window channels for detecting mixed-phase clouds.



NCAR

Variation of Reflectivity Ratio for Liquid and Ice



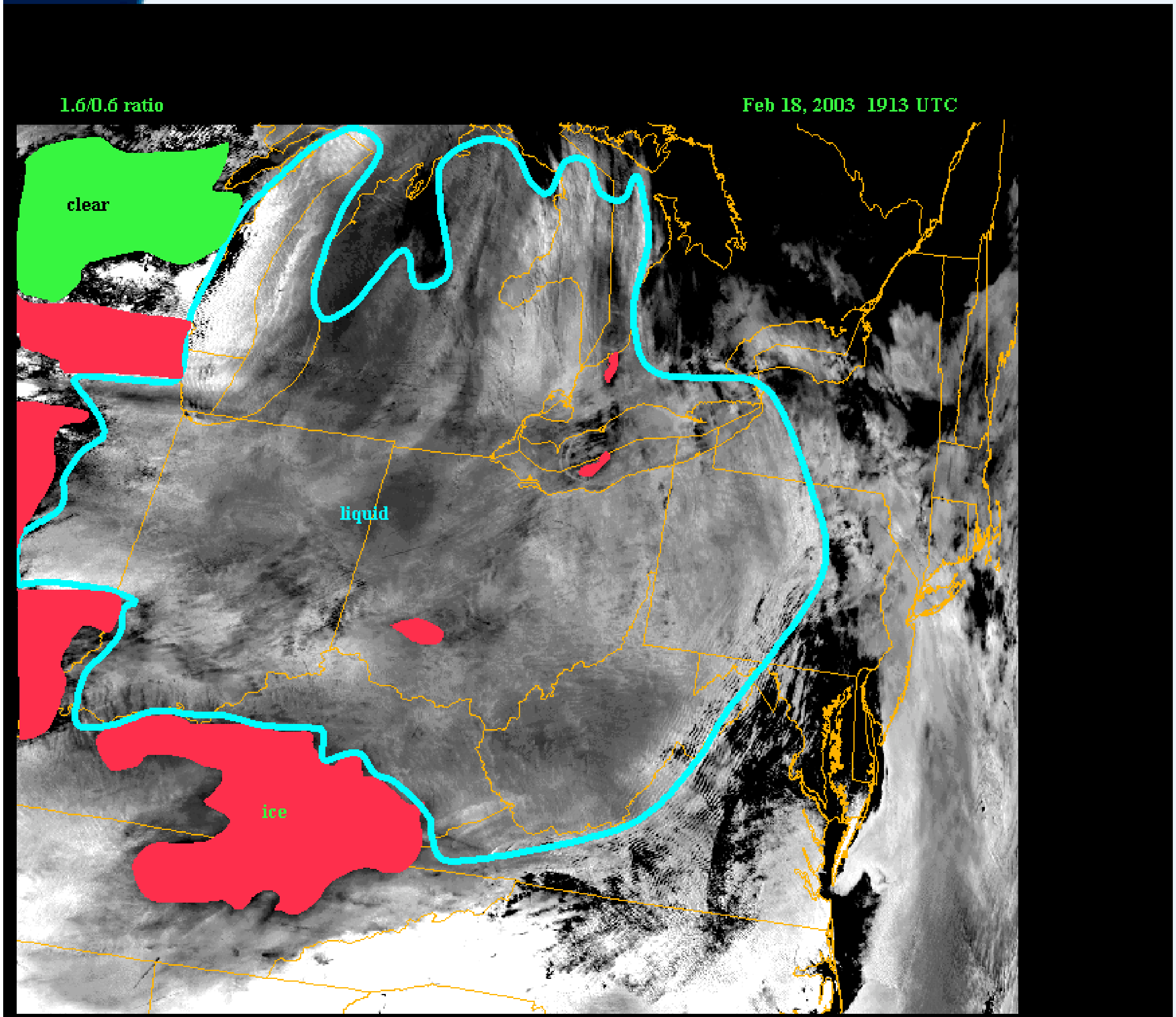
Detection of Supercooled Liquid at Cloud Top Using AVHRR

Use visible and/or infrared channels to identify cloudy areas.

Exploit differences in reflectivity of liquid and ice at 1.62 μm to discern cloud drop phase.

Identify sub-freezing cloud tops with infrared channels.

Sub-zero cloud top temperatures and liquid droplets suggest the presence of supercooled liquid.



Cloud phase classification from AVHRR imagery on Feb 18, 2003. Measurements by the NASA Twin Otter and the GOES cloud phase products confirm the presence of SLD.

NCAR

Summary and Conclusions

- Polarization radar-based icing detection need to be verified using in situ observation
- Quality dual-wavelength data are needed for retrieving LWC and size
- Physically-based algorithm might improve ground-based radiometer performance
- Development of cloud type detection using AMSU-B observation
- Improved icing product using vis and IR measurements

AWRP

NCAR