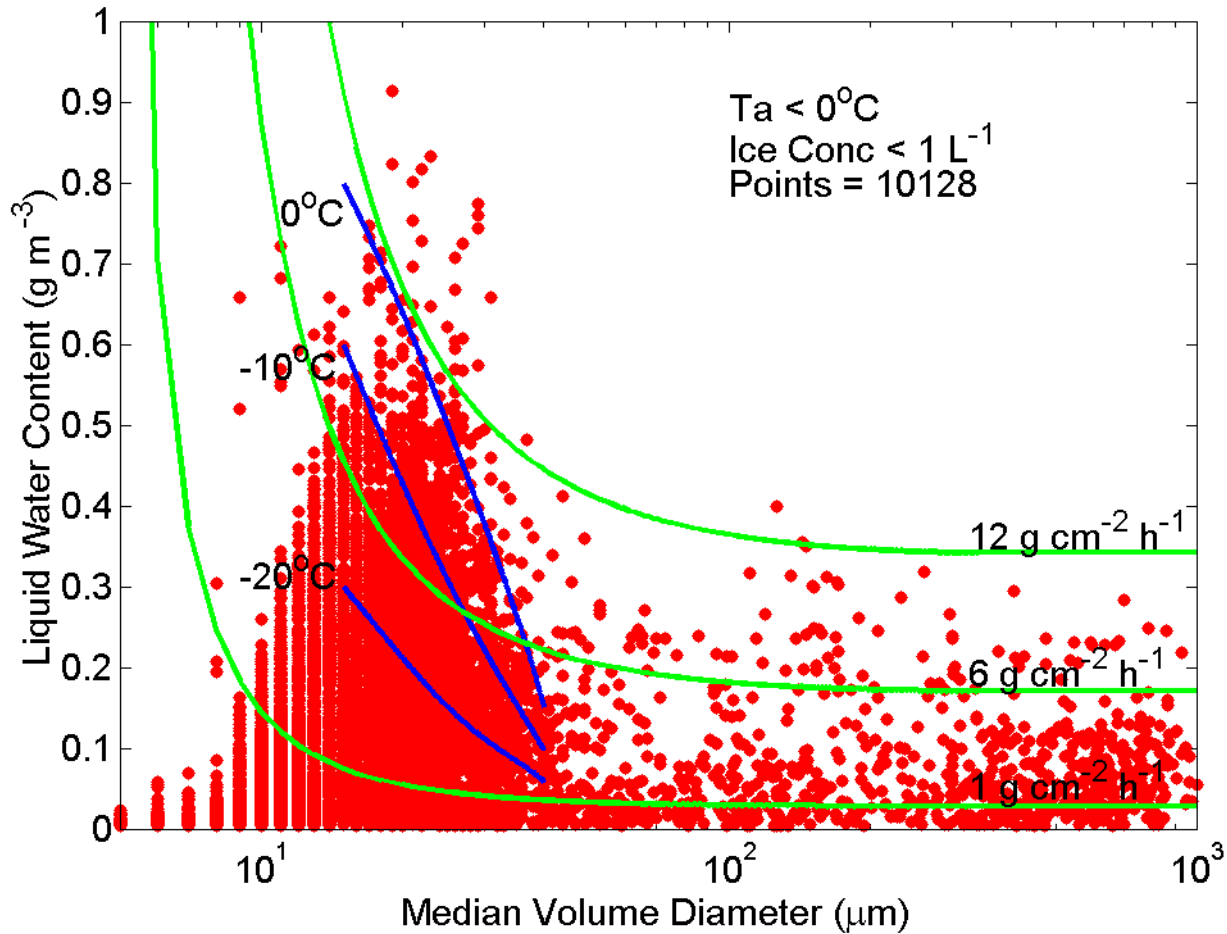


Subsets of the SLD Data

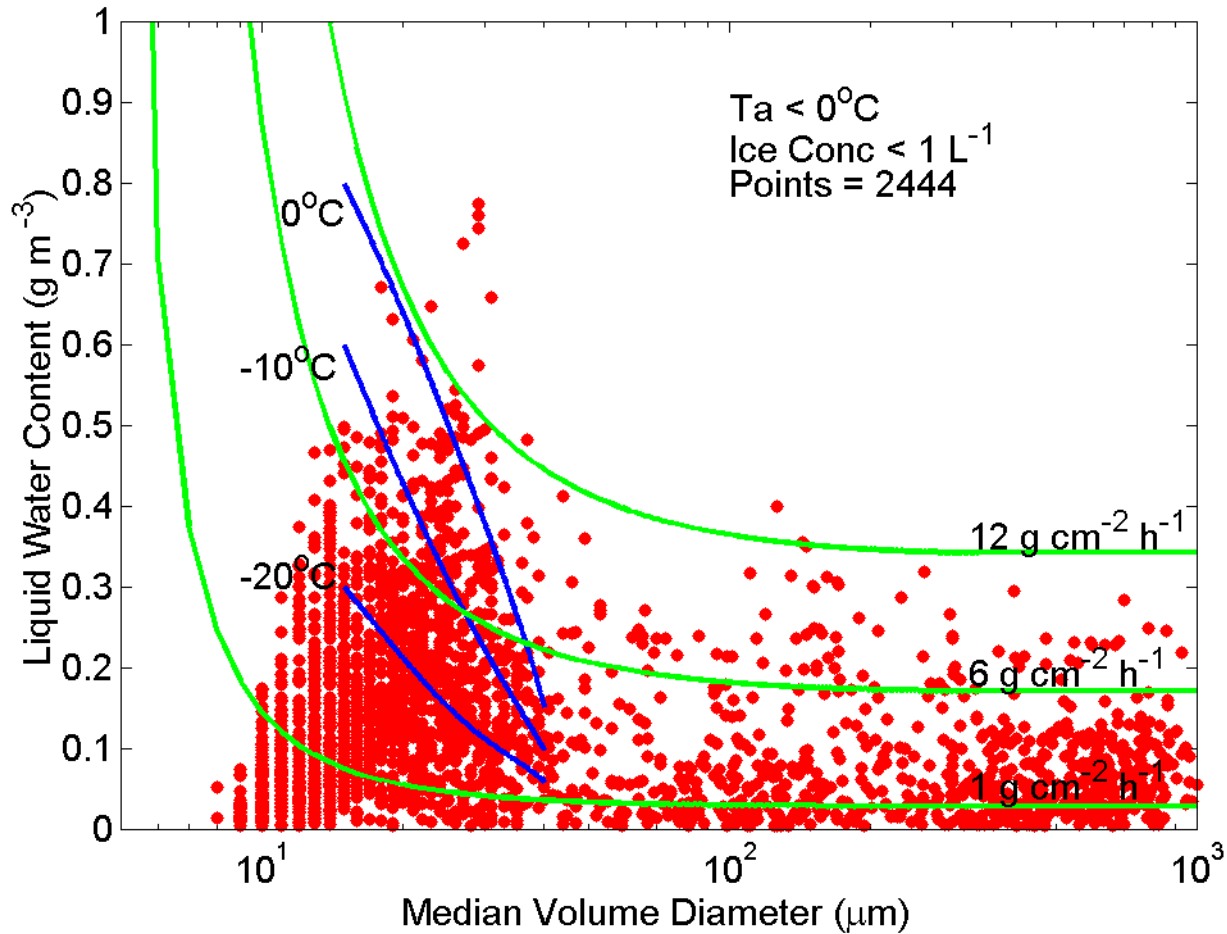
Environment	MVD	Dmax	Points
Freezing Drizzle	$< 40 \mu\text{m}$	100-500 μm	1469
Freezing Drizzle	$> 40 \mu\text{m}$	100-500 μm	335
Freezing Rain	$< 40 \mu\text{m}$	$> 500 \mu\text{m}$	193
Freezing Rain	$> 40 \mu\text{m}$	$> 500 \mu\text{m}$	447

Icing Data Points



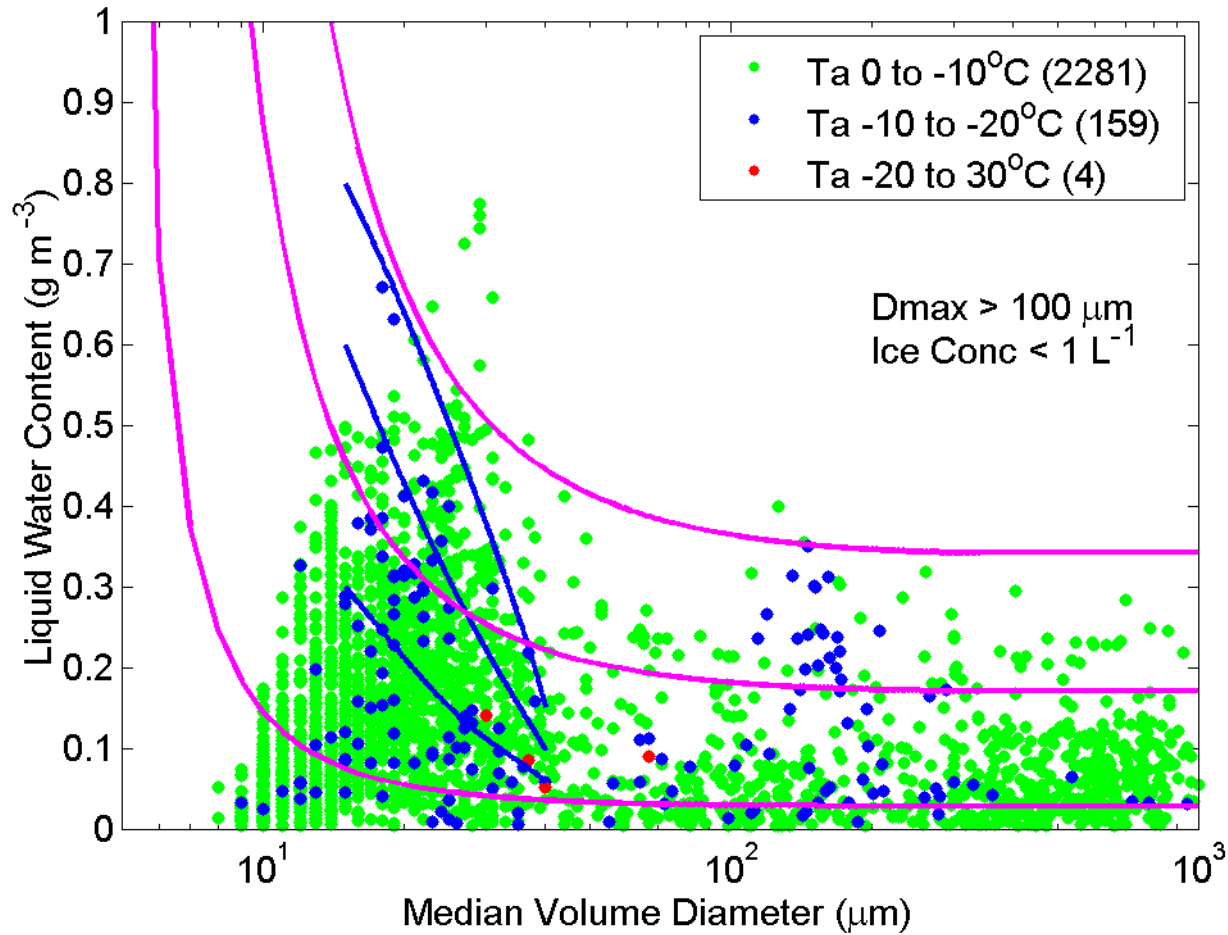
3-km Data

SLD Data Points



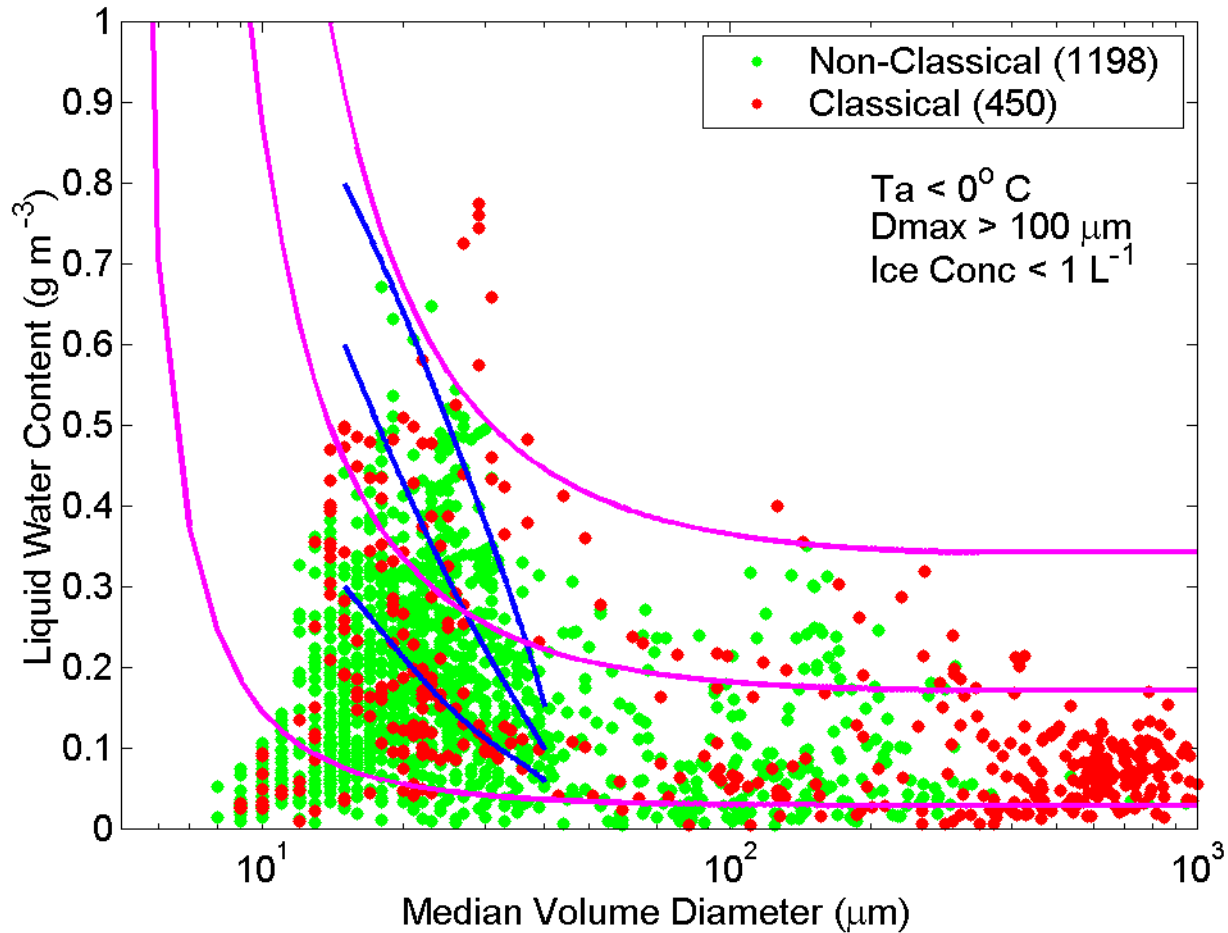
3-km Data

SLD - Temperature



3-km Data

SLD – Formation Mechanism



3-km Data

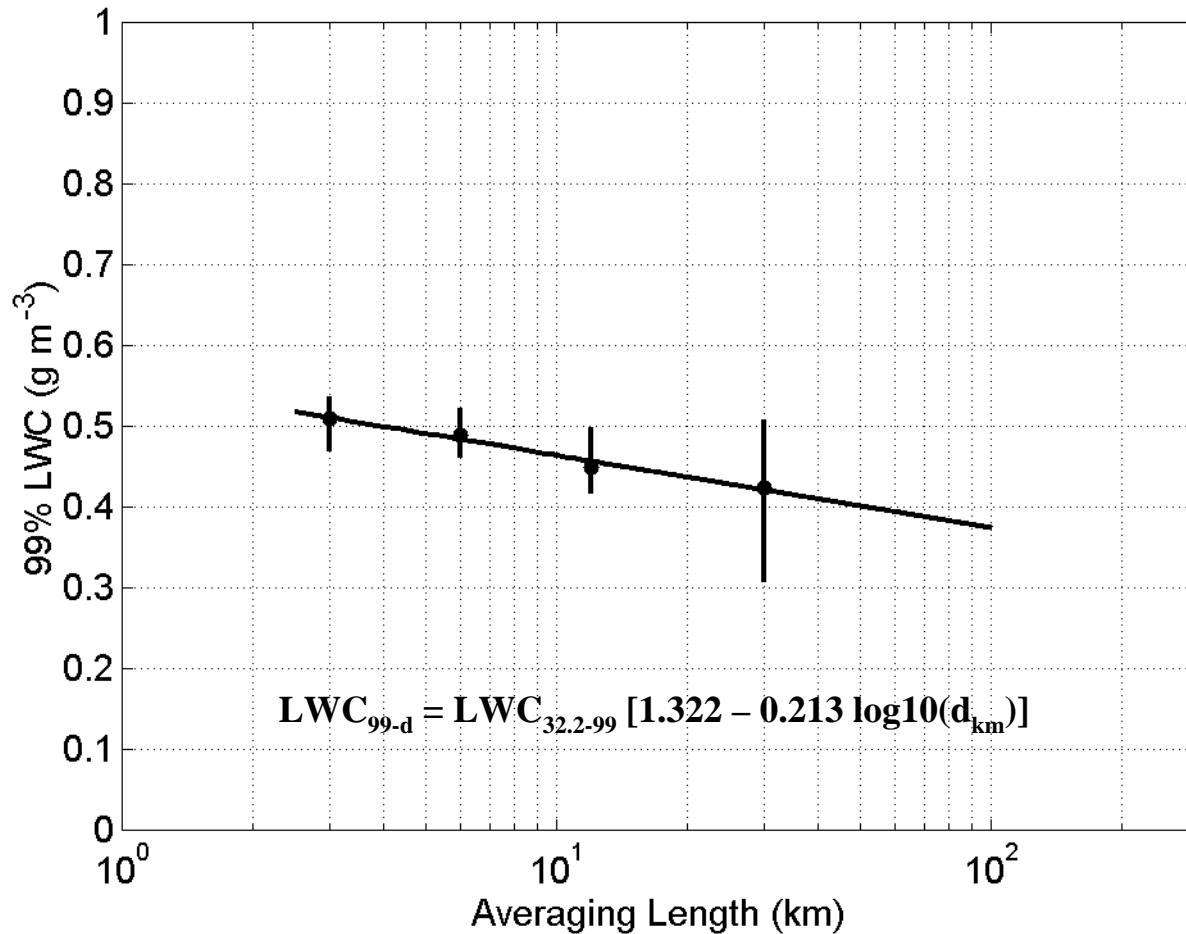
SLD Scale Factor

11/19/59

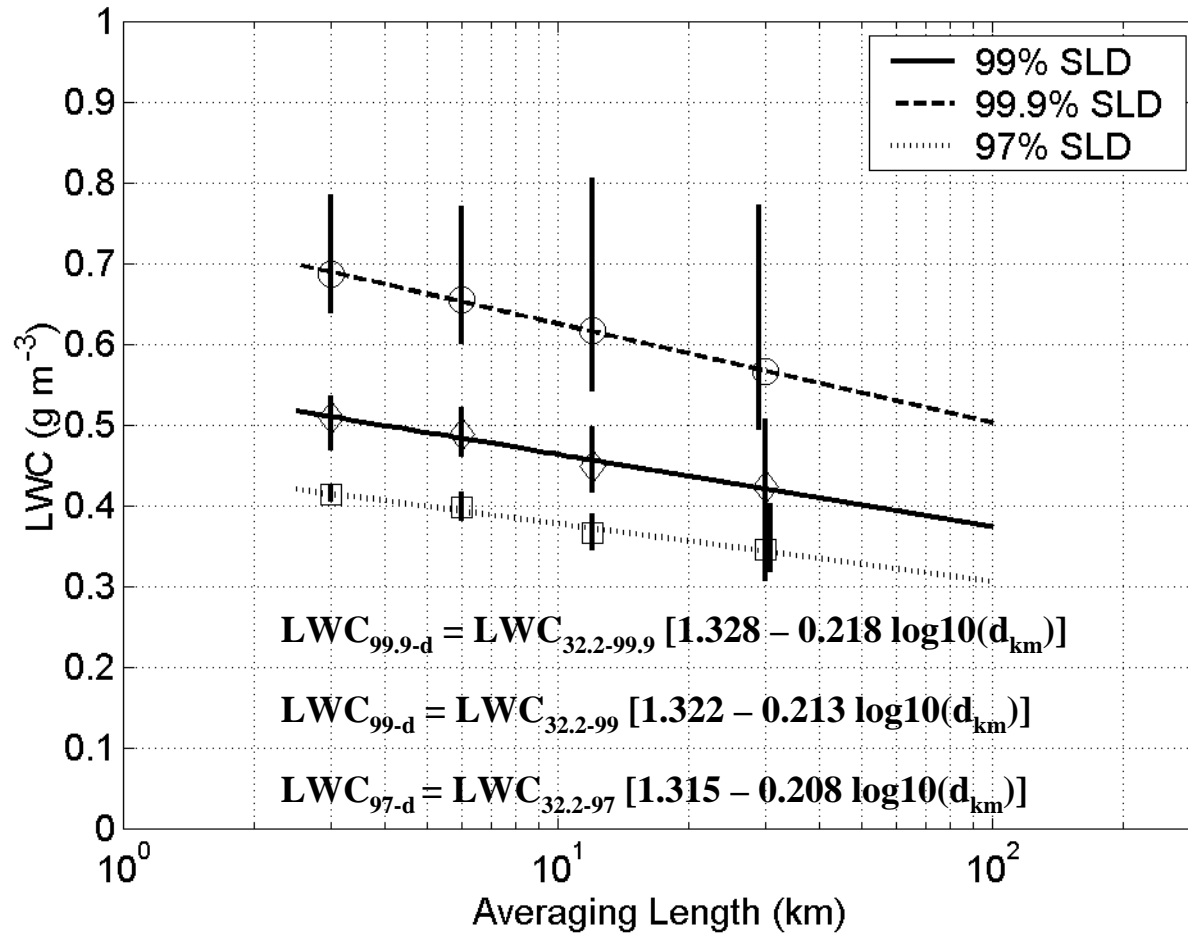
Sample Size of SLD Conditions for Scale Factor Analysis

Averaging interval	Length scale	Number of data points
30-s	3 km	2444
60-s	6 km	1431
120-s	12 km	850
300-s	30 km	460

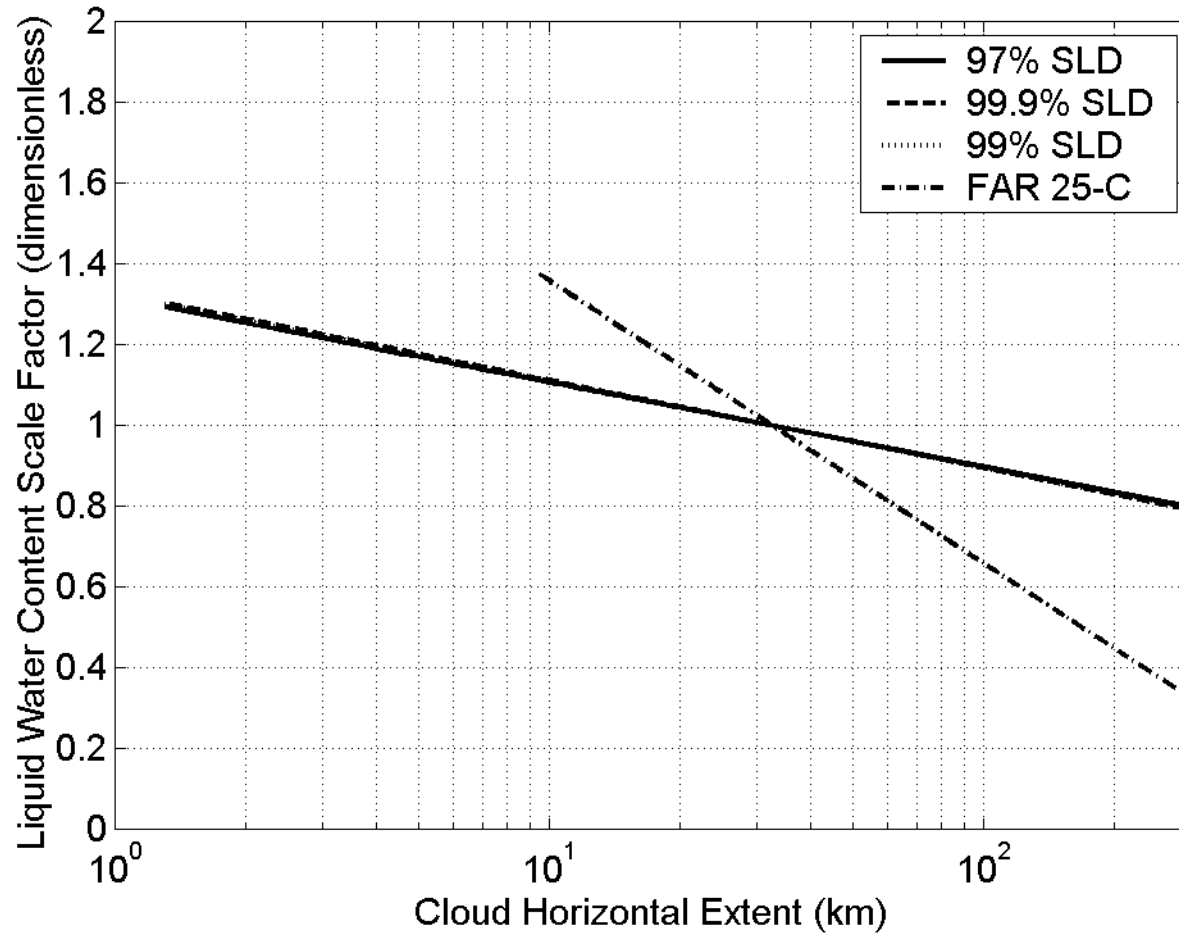
99% SLD LWC Scale Factor



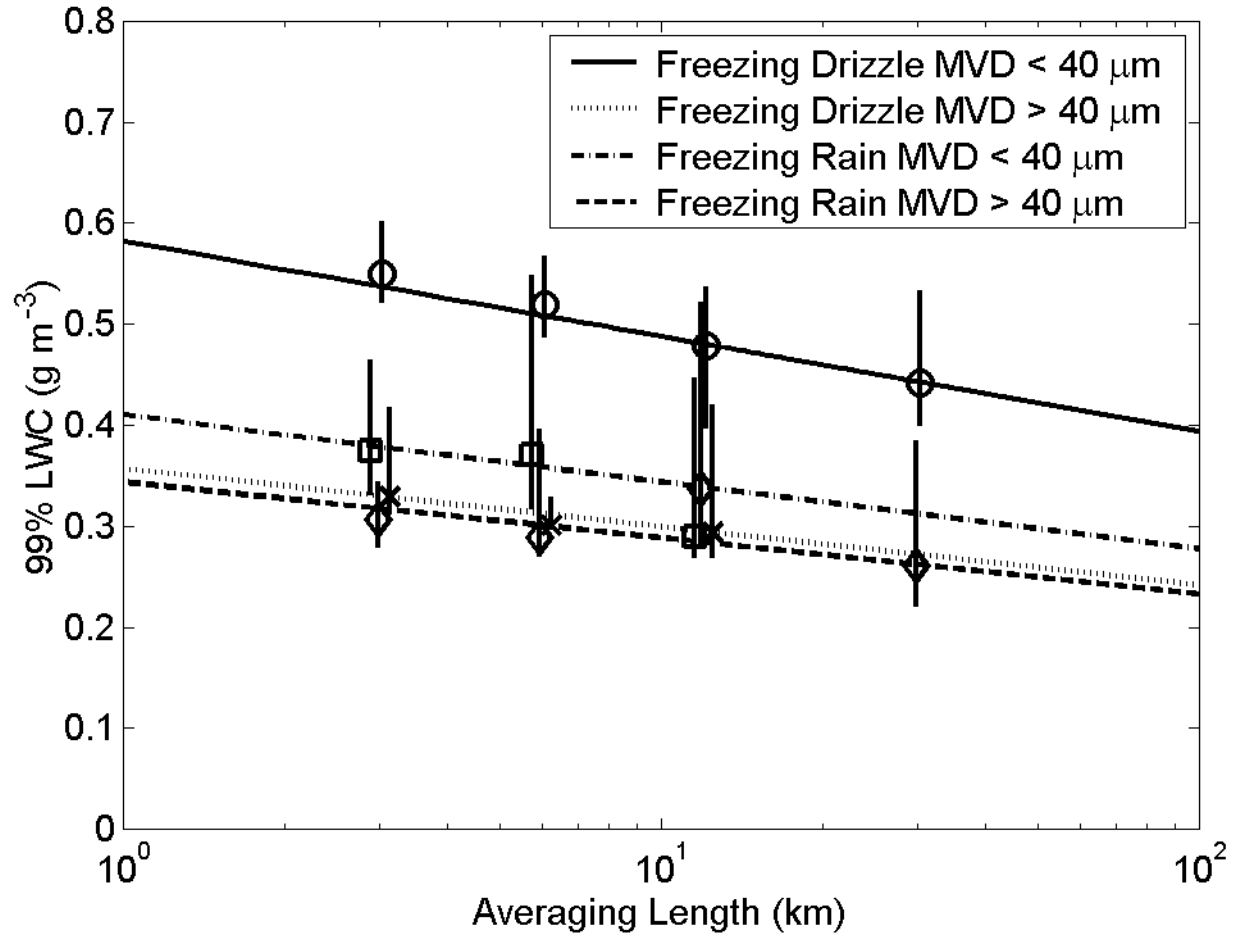
97 to 99.9% SLD LWC Scale Factors



SLD LWC Scale Factor



SLD Subsets LWC Scale Factor

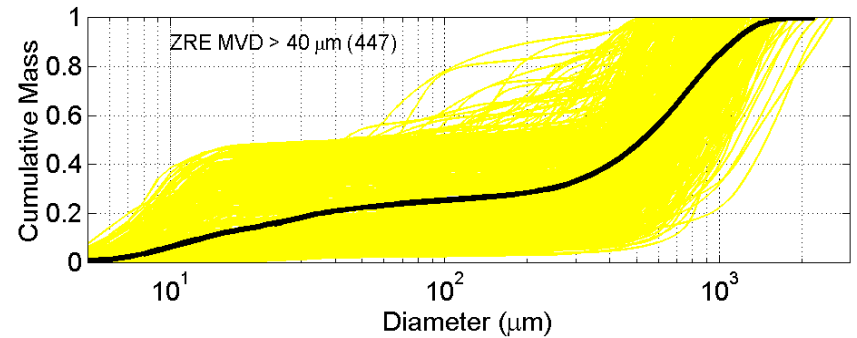
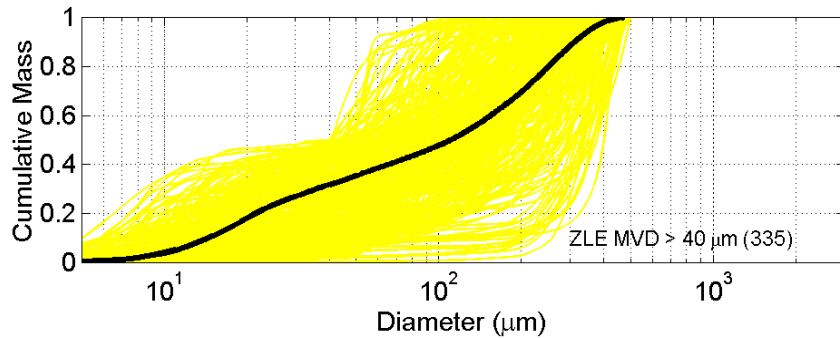
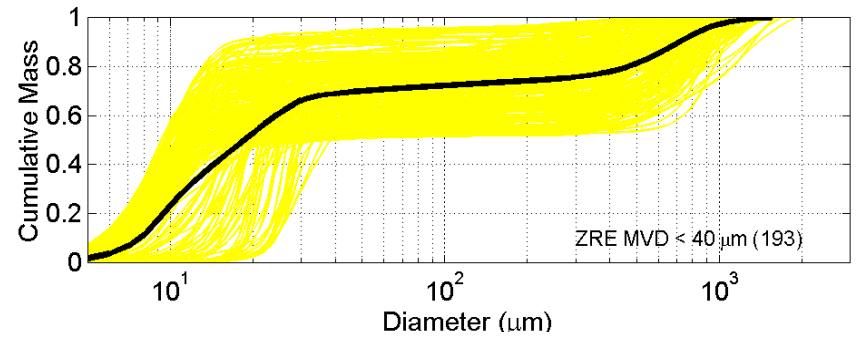
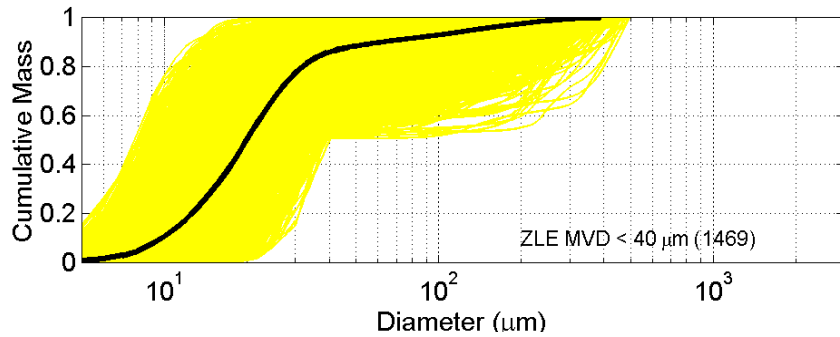


An aerial photograph showing a vast, flat, white landscape, likely a salt flat or a snow-covered plain, extending to a distant horizon. The sky is a deep blue with scattered, light-colored clouds. The overall scene is bright and expansive.

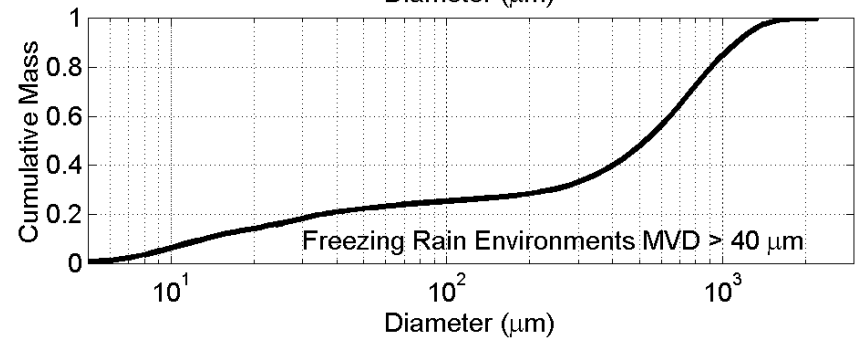
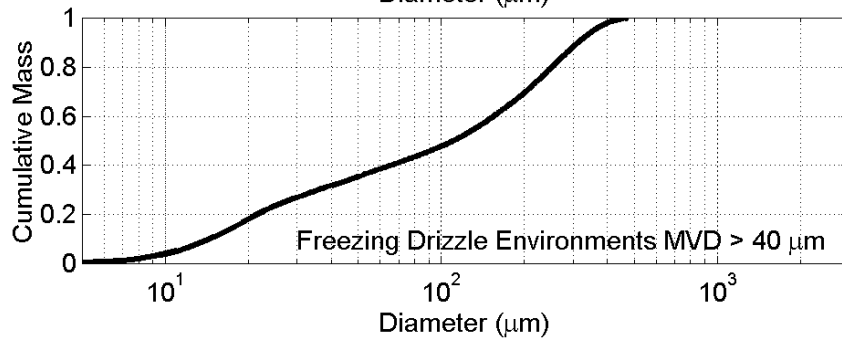
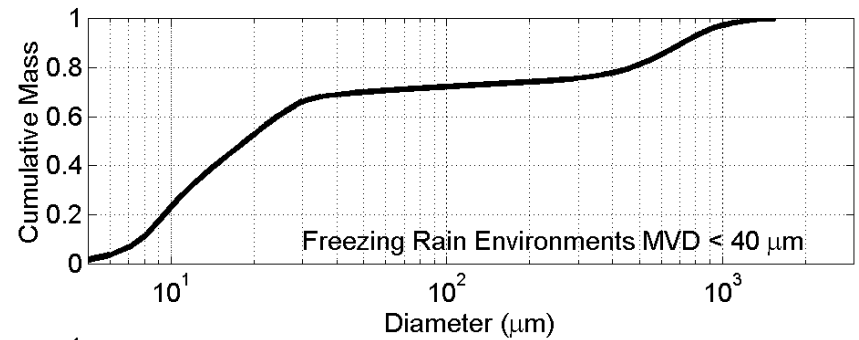
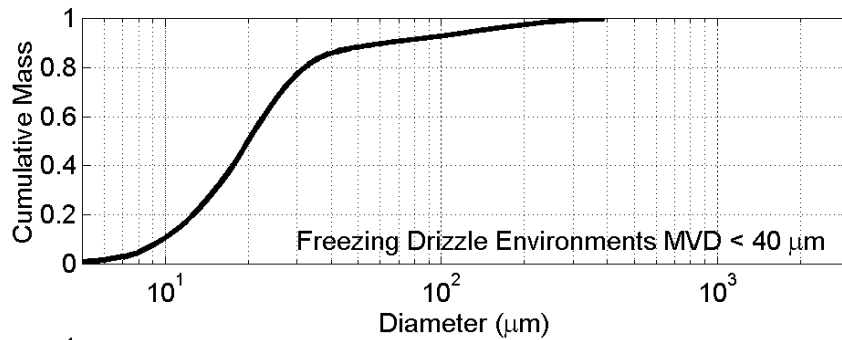
Characterization of SLD Spectra

19 12:05

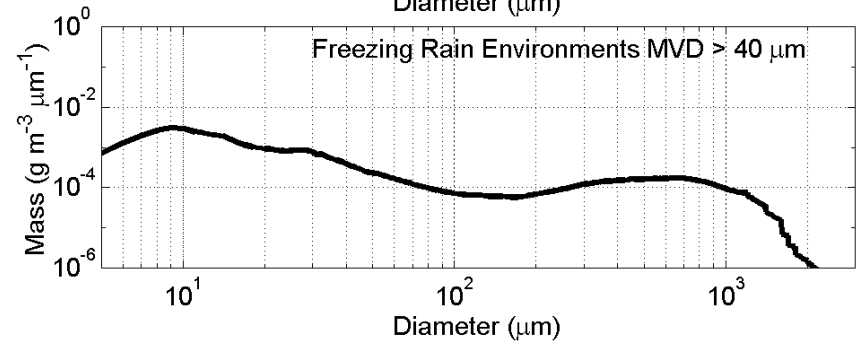
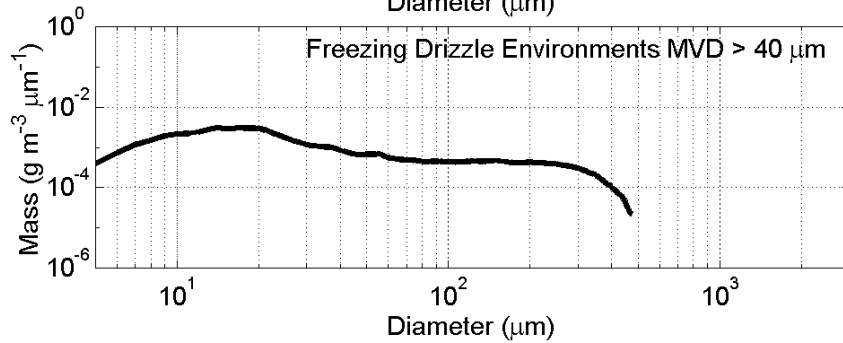
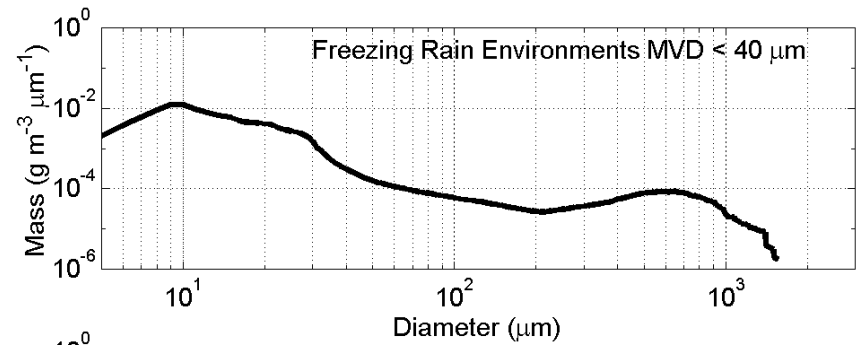
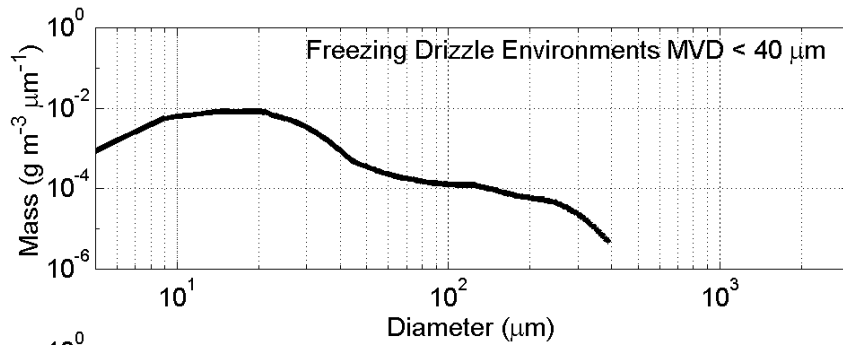
SLD Cumulative Mass Spectra



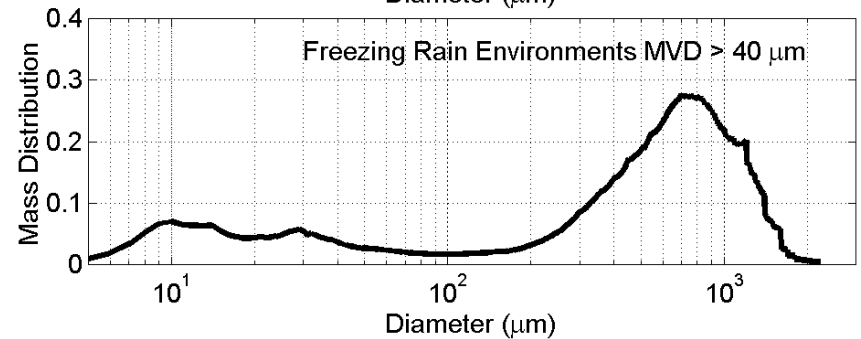
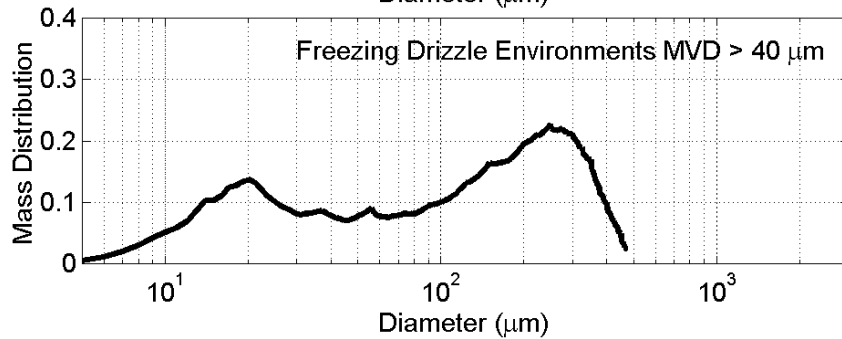
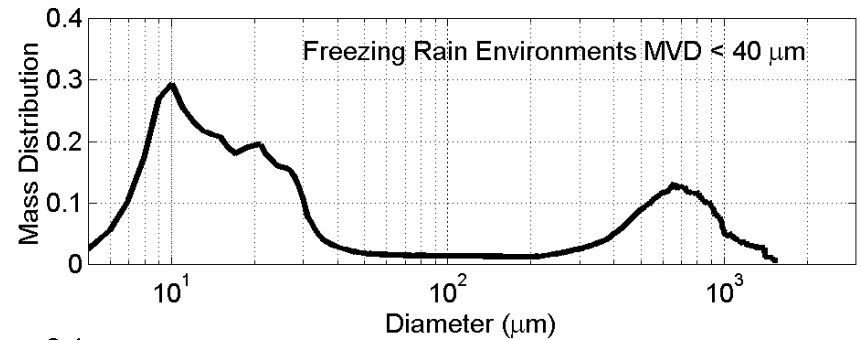
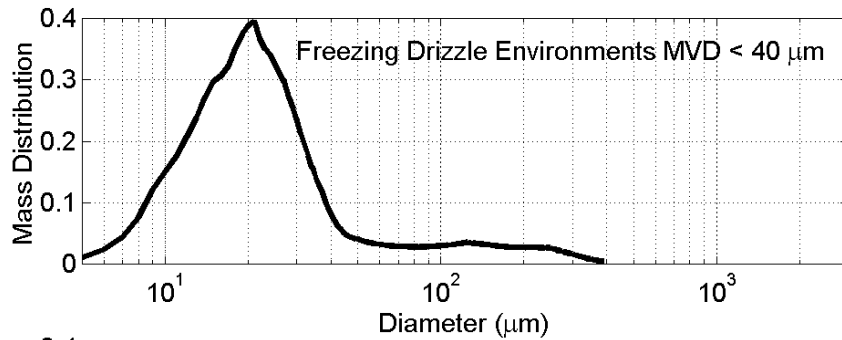
SLD Cumulative Mass Spectra



SLD Mass Spectra

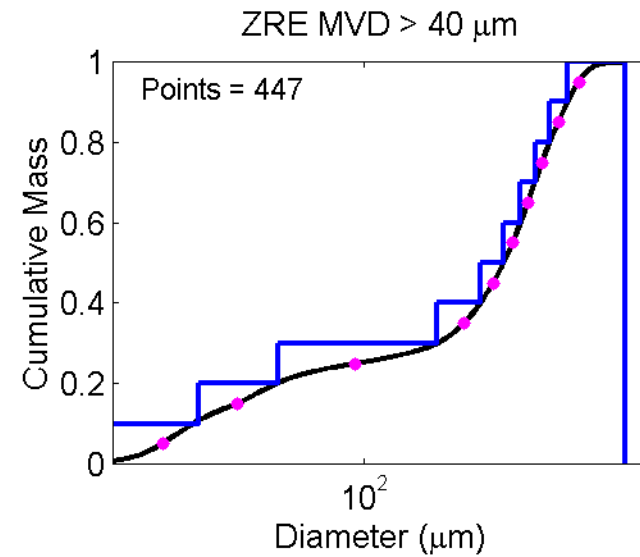
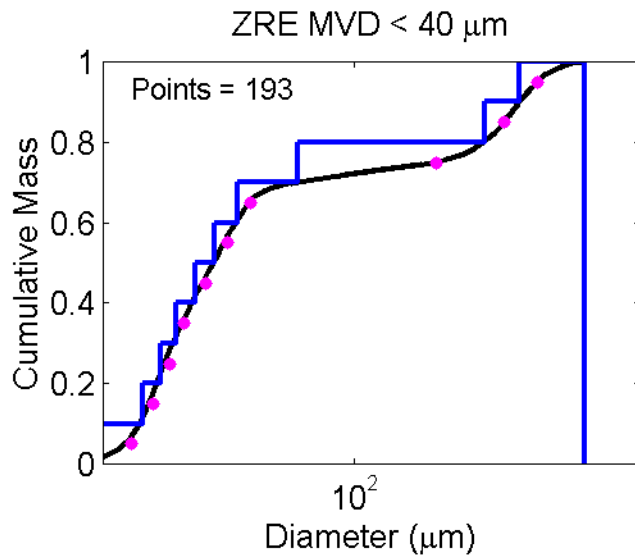
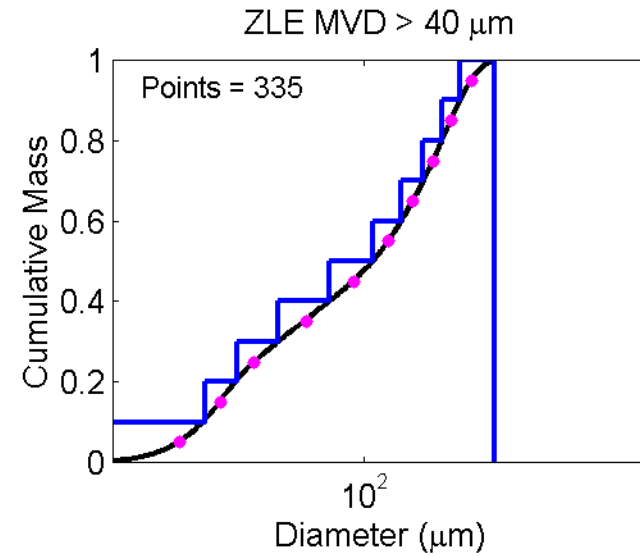
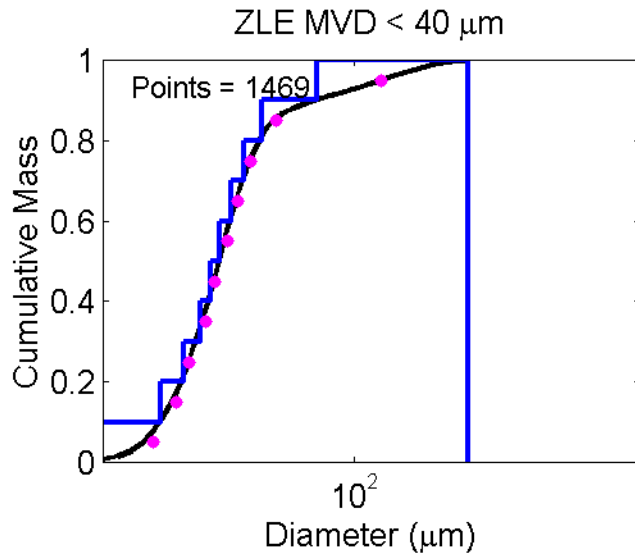


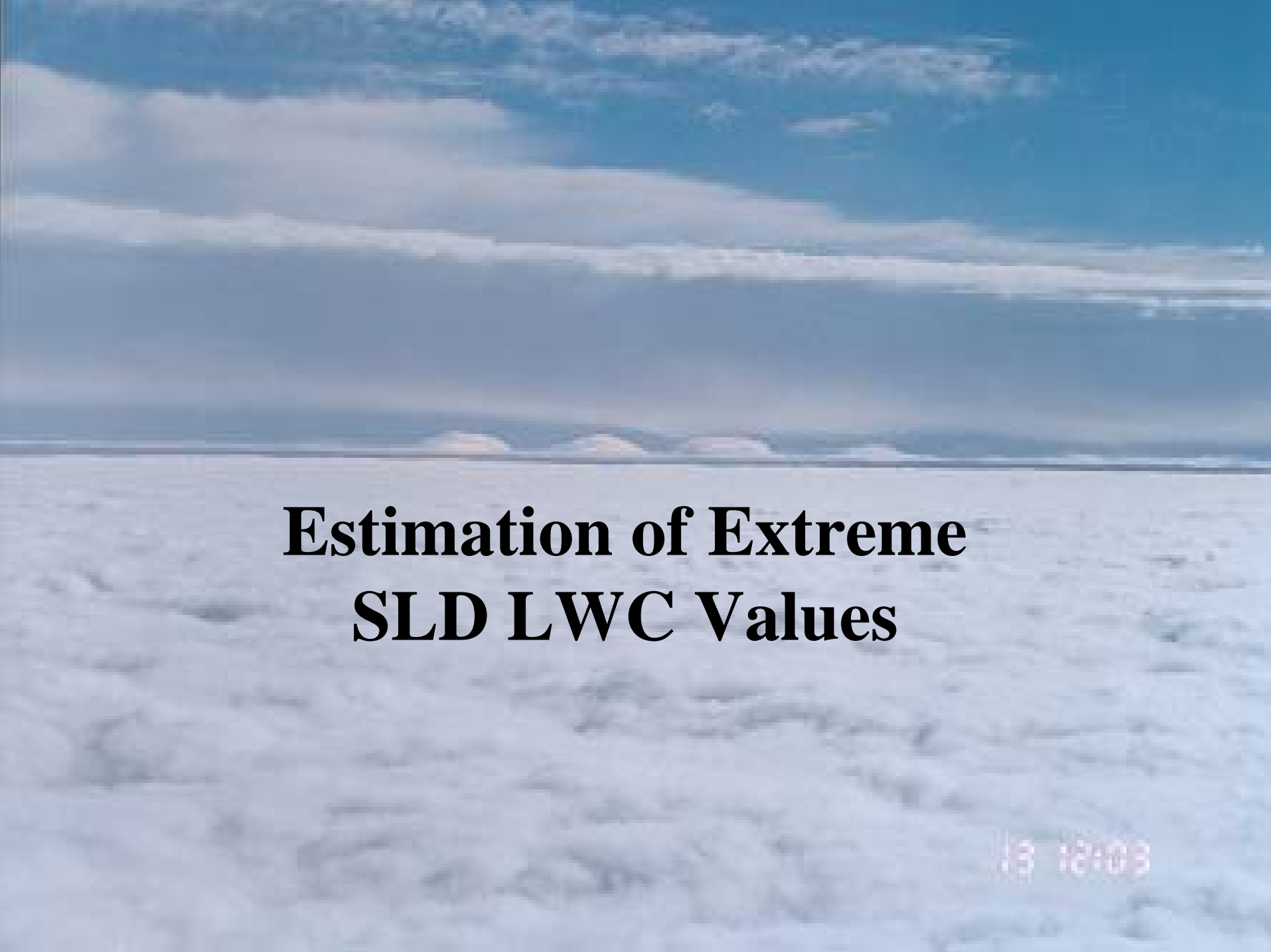
SLD Spectra



$$\text{Mass Distribution} = \Delta\text{LWC}_b / \log(D_{b2}/D_{b1})$$

SLD Cumulative Mass Bins



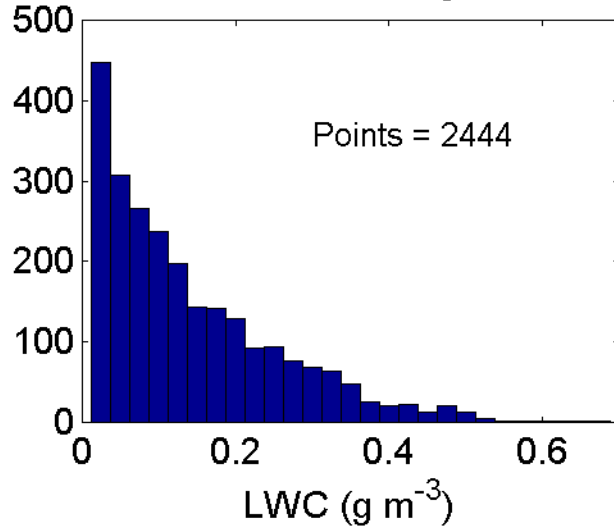
An aerial photograph of a vast, flat, light-colored landscape, possibly a salt flat or a dry lake bed, under a blue sky with scattered clouds. The horizon is visible in the distance.

Estimation of Extreme SLD LWC Values

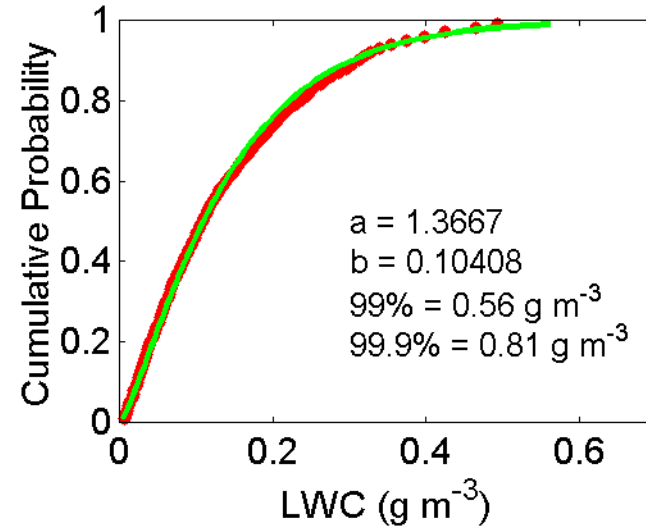
18 18:03

Fitting SLD LWC Distributions

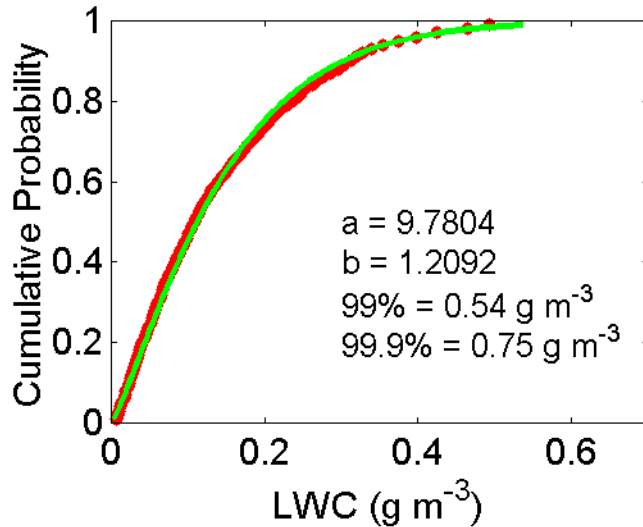
SLD LWC Histogram



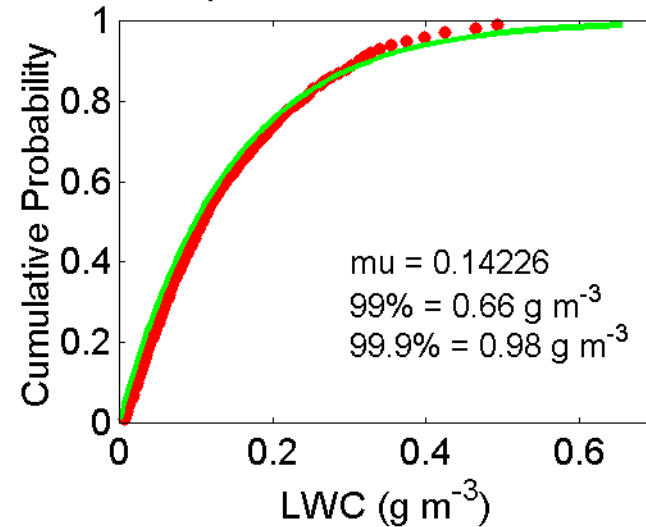
Gamma Distribution Fit



Weibull Distribution Fit



Exponential Distribution Fit



Extreme Value Analysis

- Three types theorem: there are only three types of distribution which can arise as limiting distributions of extremes in random samples.
- Generalized Extreme Value Distribution

$$P = \exp\left[-\left(1 + \xi\left(\frac{x - \mu}{\psi}\right)^{-1/\xi}\right)\right]$$

μ = location parameter

Ψ = scale parameter

ξ = shape parameter

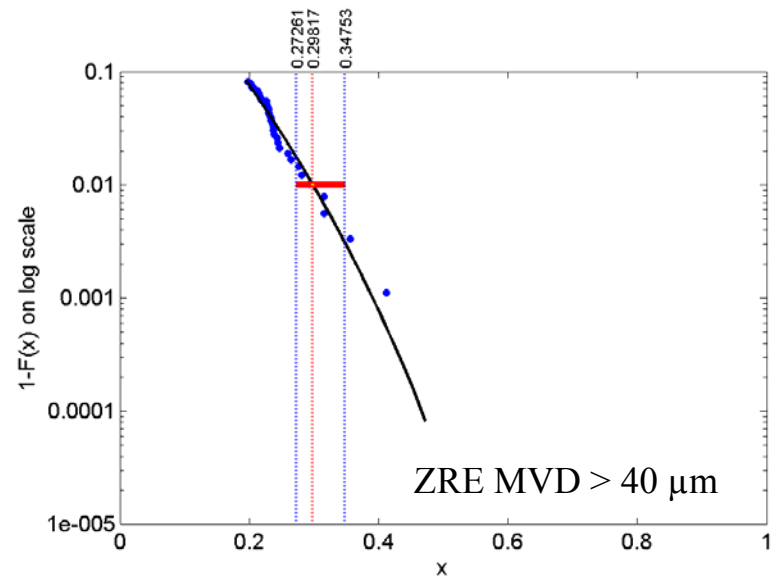
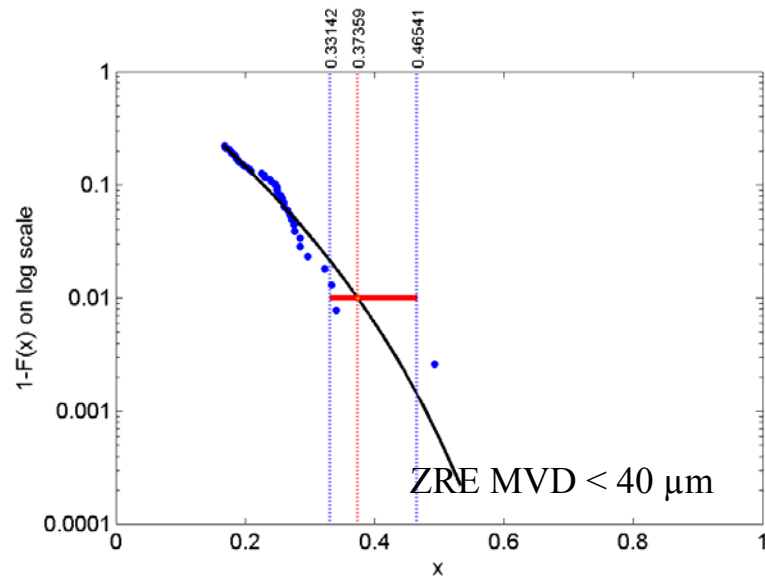
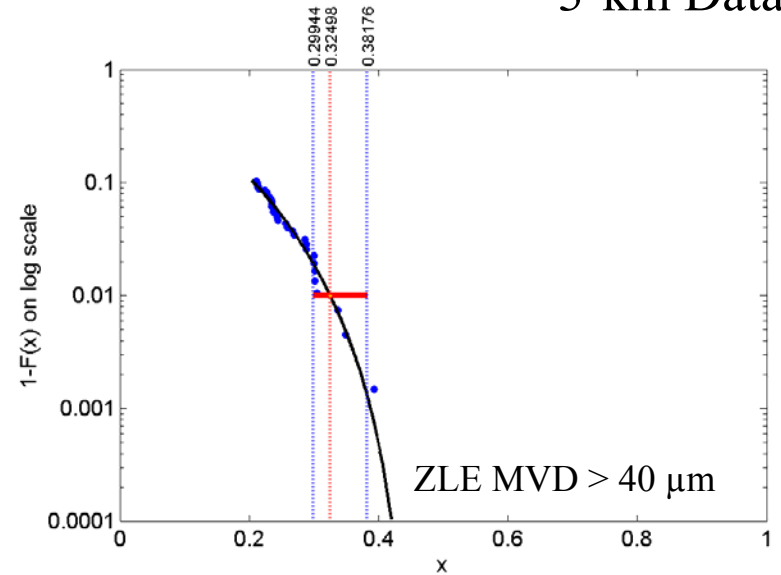
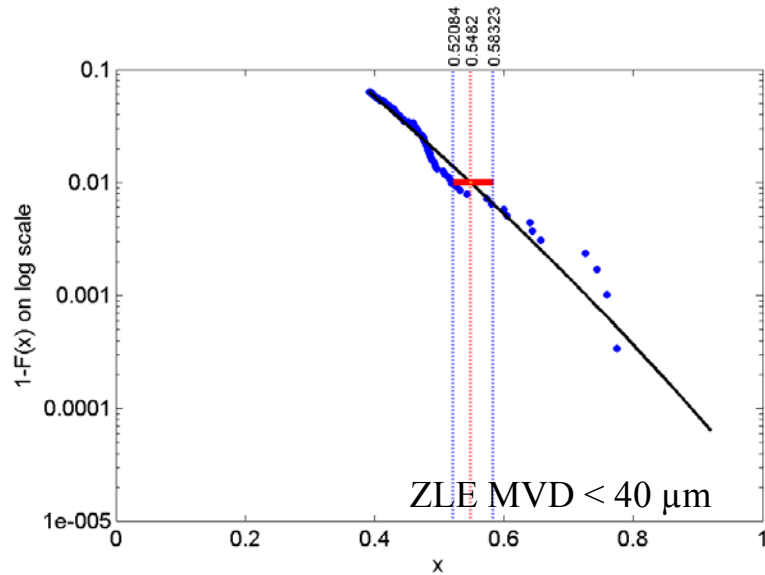
- $\xi > 0$ Fréchet family $P \sim \exp[-x^{-\alpha}]$ $\alpha = 1/\xi$ (long tail)
- $\xi < 0$ Weibull family $P \sim \exp[-(-x^\alpha)]$ $\alpha = -1/\xi$ (short tail)
- $\xi = 0$ Gumbel family $P \sim \exp[-e^{-x}]$ (medium tail)

- Use the technique of threshold selection to fit the tail of the distribution to a Generalized Pareto Distribution of the form:

$$G = 1 + \xi\left(\frac{x - \mu}{\psi}\right)^{-1/\xi}$$

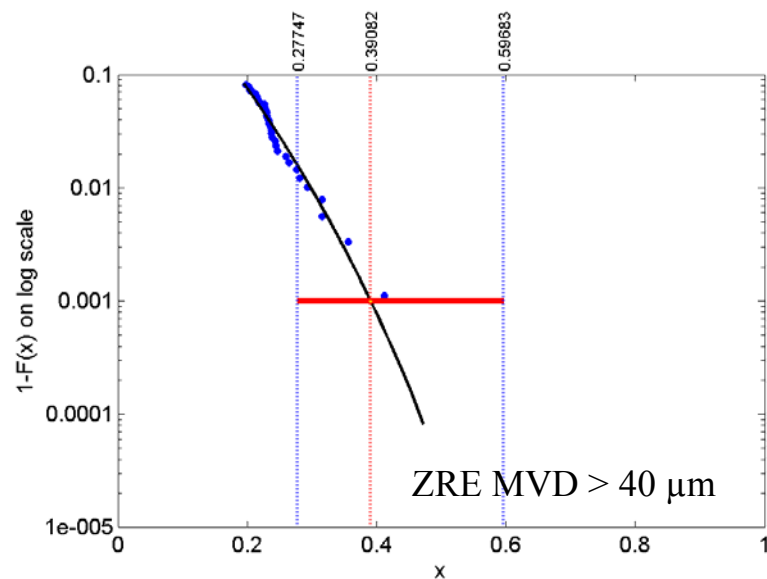
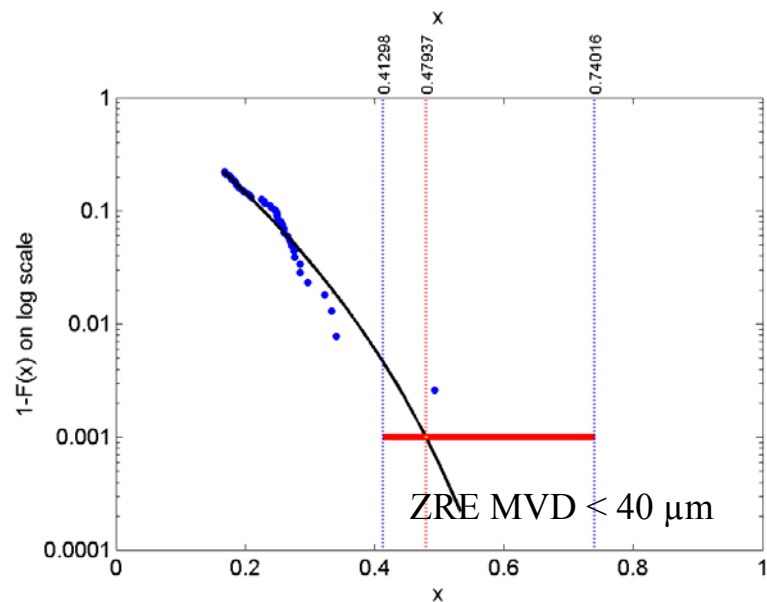
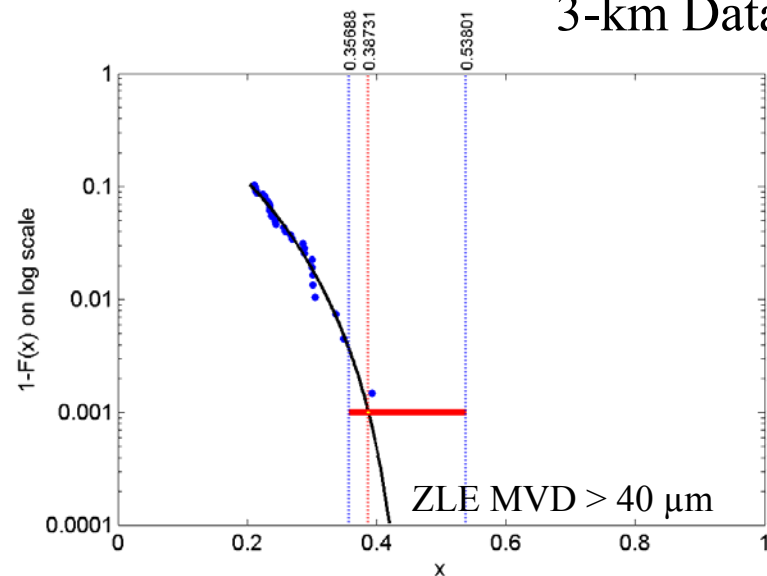
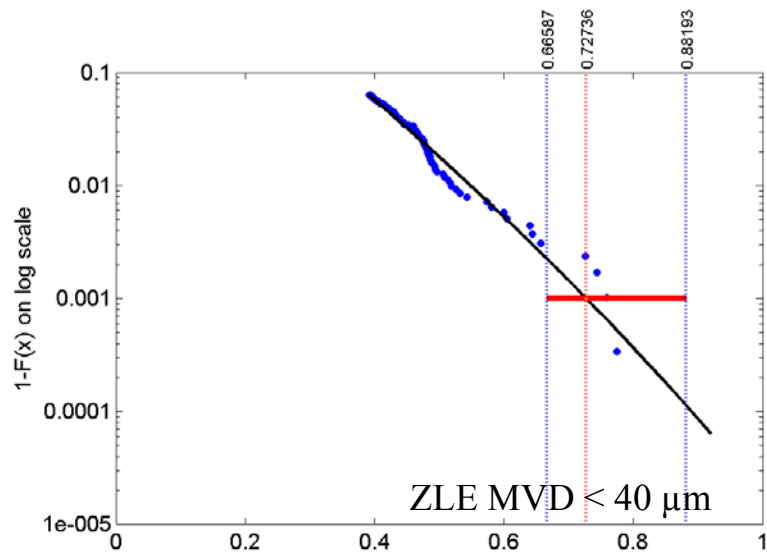
99% SLD LWC Estimates

3-km Data



99.9% SLD LWC Estimates

3-km Data



99% and 99.9% LWC Values

Environment	MVD	Dmax	99.0% LWC	99.9% LWC
Freezing Drizzle	< 40 μm	100-500 μm	0.44 g m^{-3}	0.58 g m^{-3}
Freezing Drizzle	> 40 μm	100-500 μm	0.27 g m^{-3}	0.31 g m^{-3}
Freezing Rain	< 40 μm	> 500 μm	0.31 g m^{-3}	0.37 g m^{-3}
Freezing Rain	> 40 μm	> 500 μm	0.26 g m^{-3}	0.33 g m^{-3}

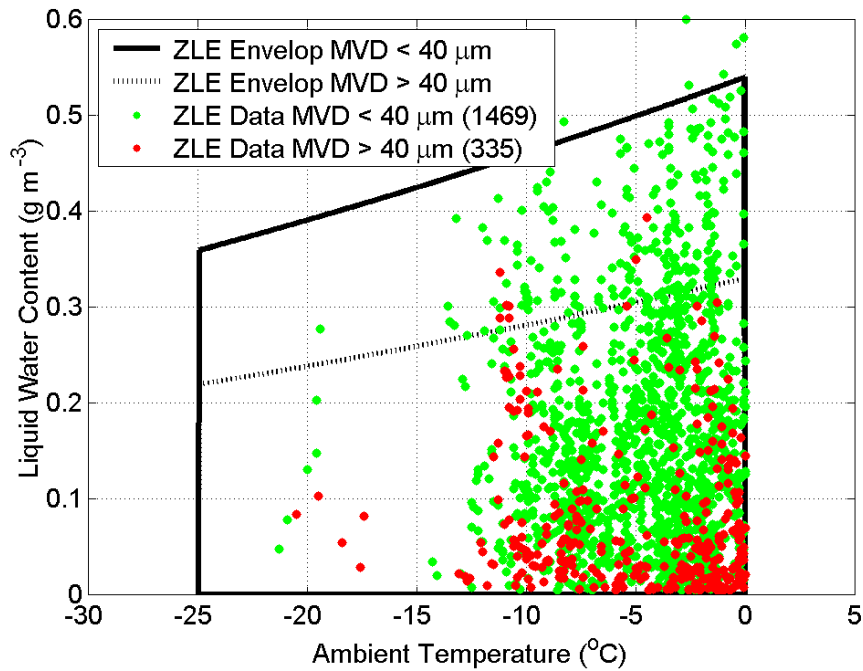
17.6 n mi / 32.2 km

An aerial photograph of a vast, flat, orange-brown landscape, likely a salt flat or a desert. The terrain is covered in a dense, textured layer of material, possibly salt or sand, with a bright sun visible in the upper right corner, creating a strong glare and casting long, soft shadows. The overall color palette is dominated by warm, earthy tones.

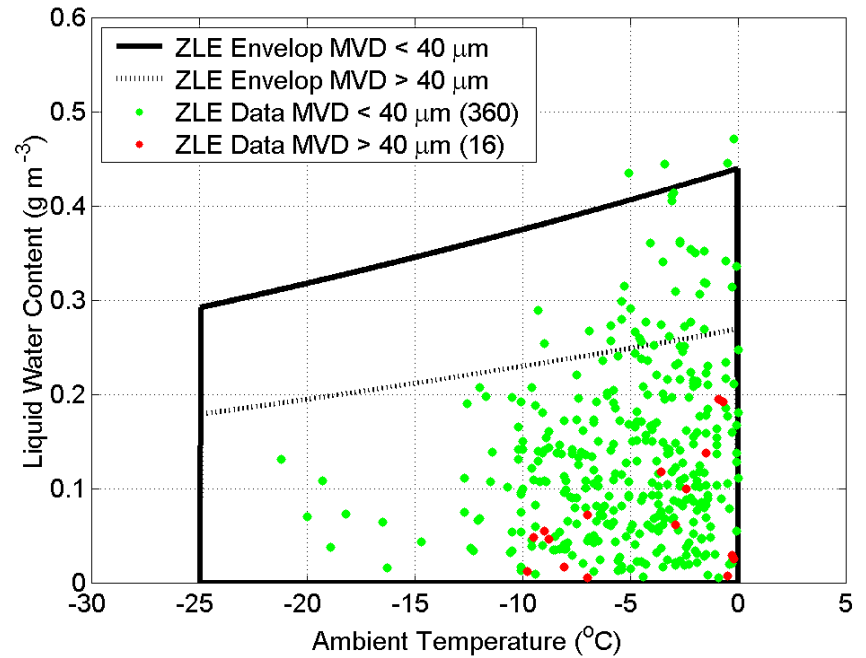
Characterization of SLD Environments

2018.8.1

ZLE LWC – Temperature Envelopes

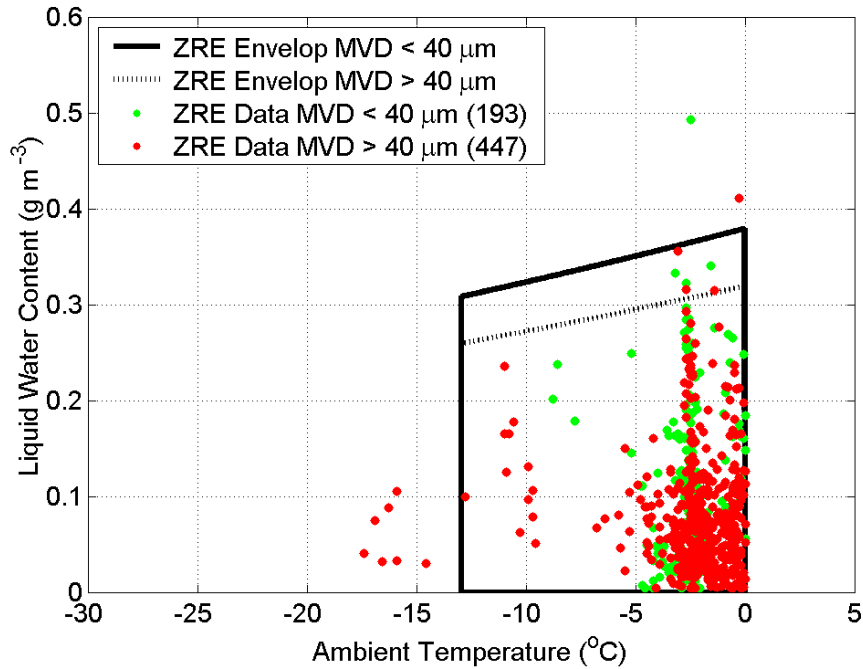


3-km Data

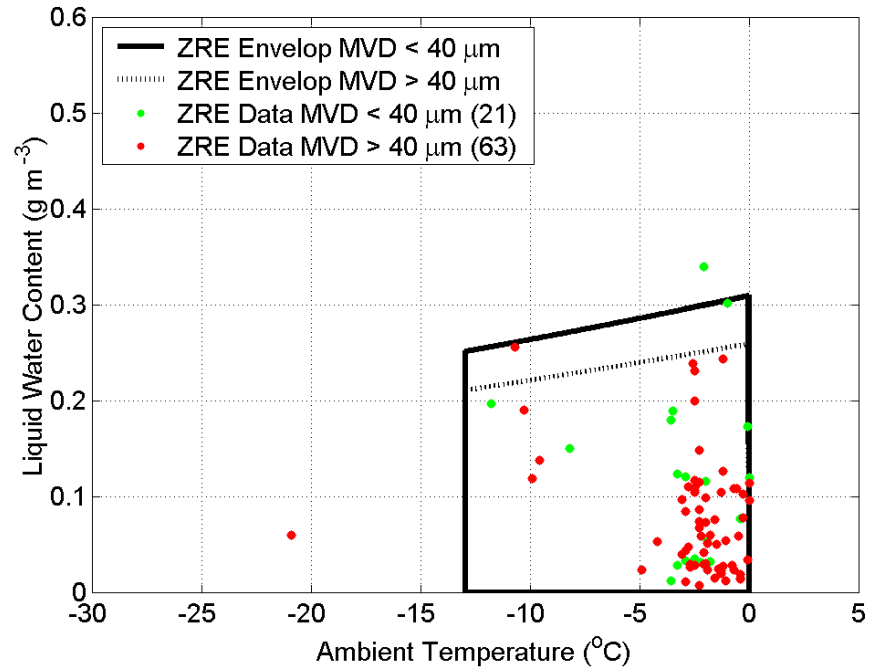


30-km Data

ZRE LWC – Temperature Envelopes

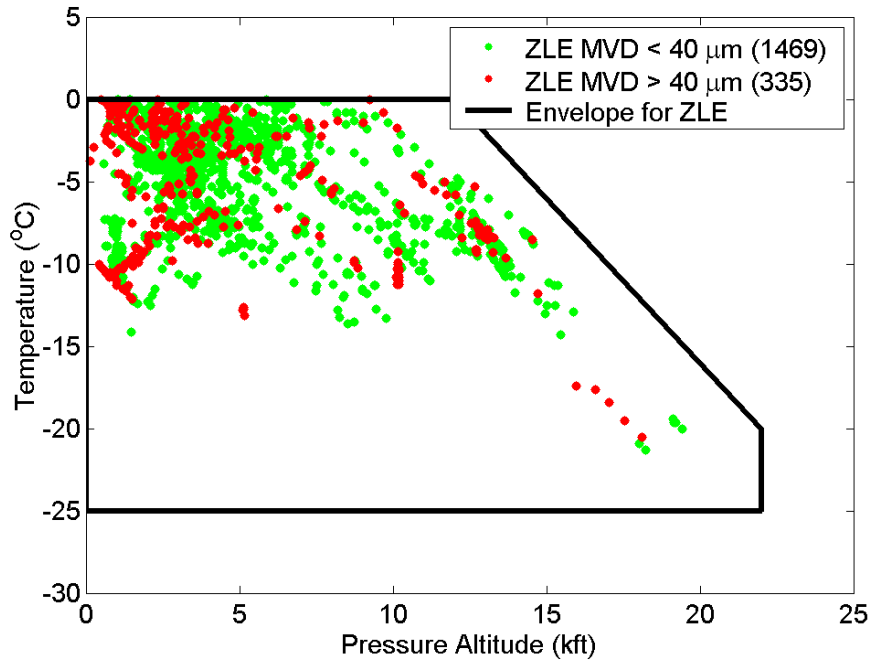


3-km Data

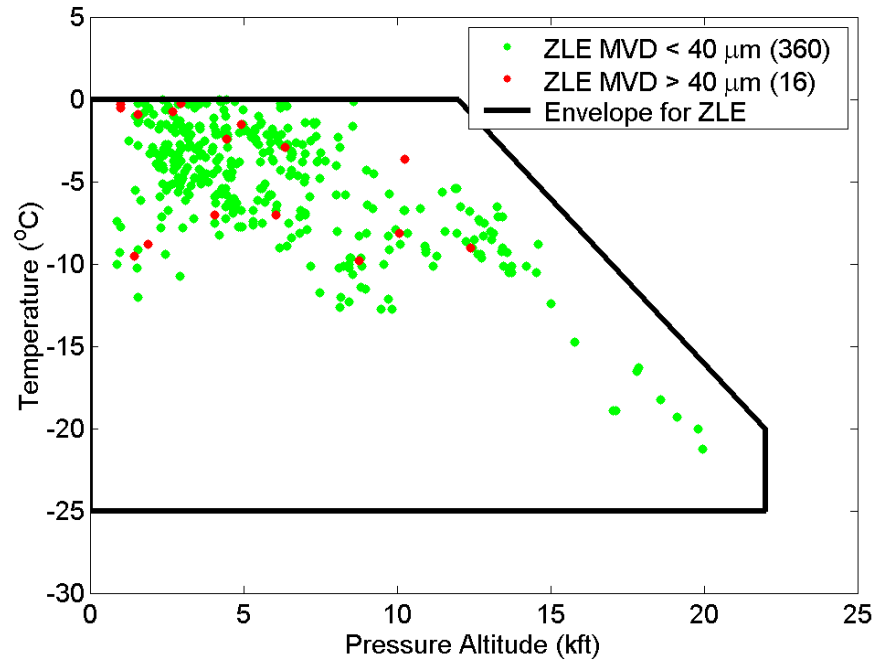


30-km Data

ZLE Temperature – Altitude Envelopes

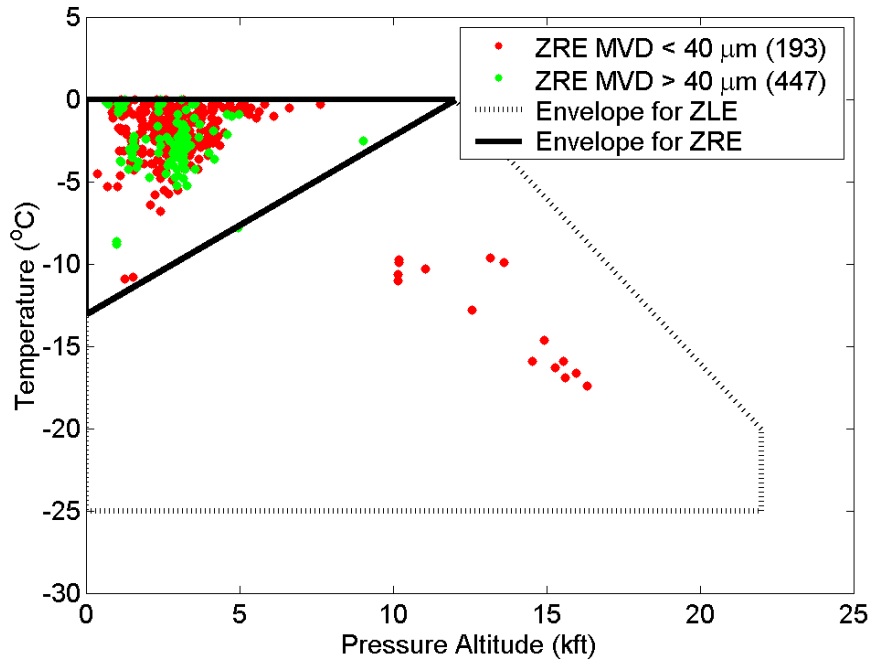


3-km Data

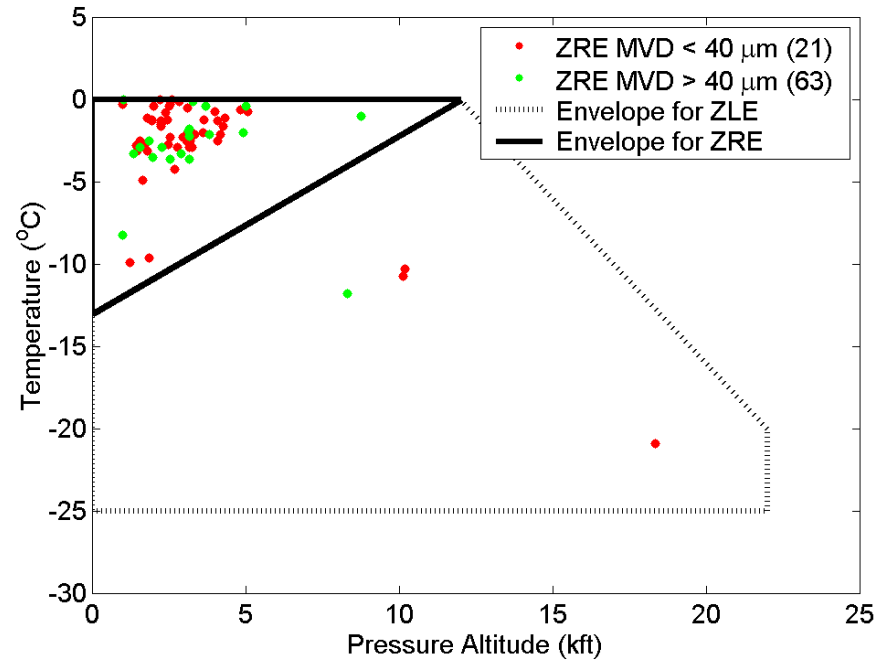


30-km Data

ZRE Temperature – Altitude Envelopes

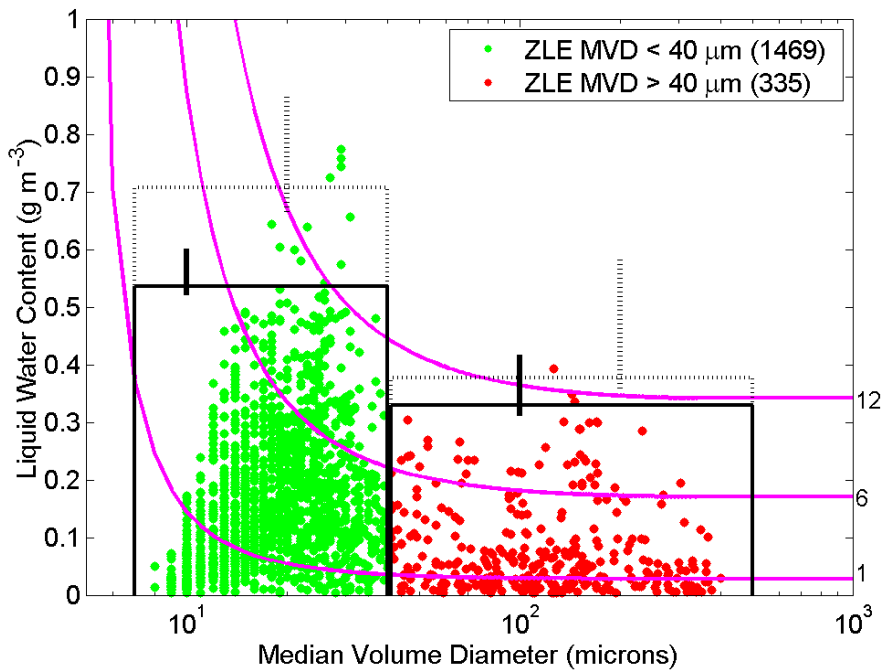


3-km Data

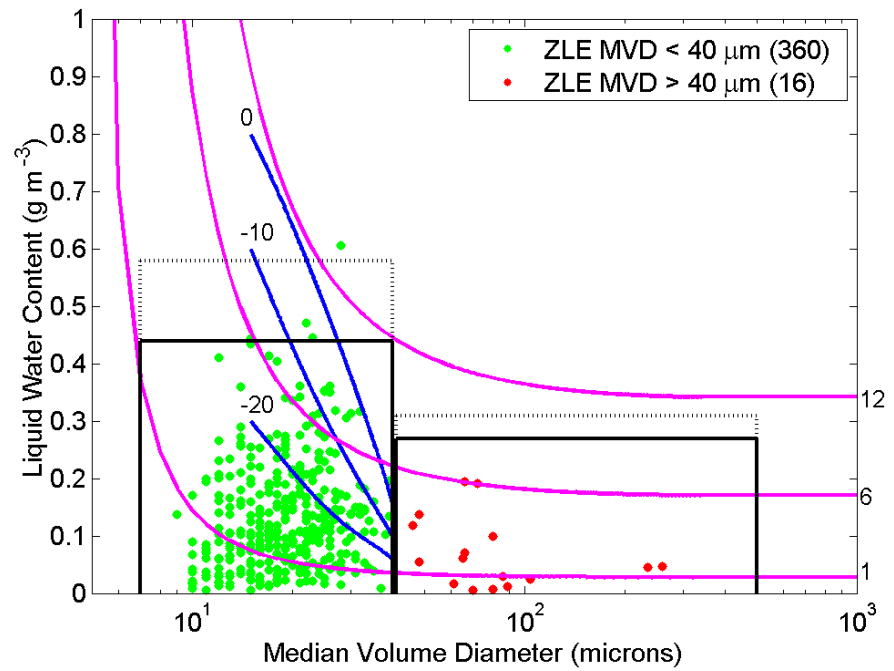


30-km Data

ZLE LWC – MVD Envelopes

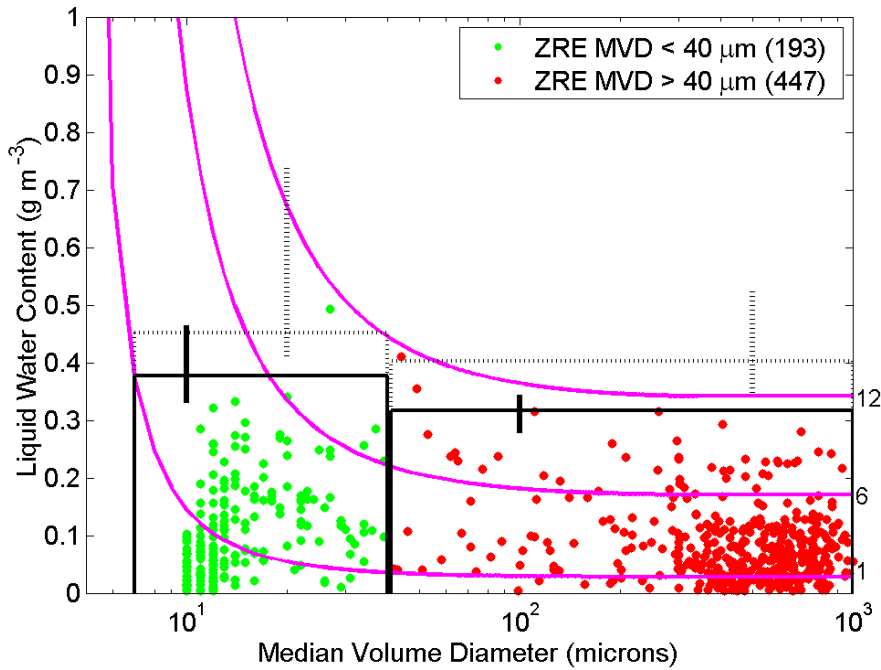


3-km Data

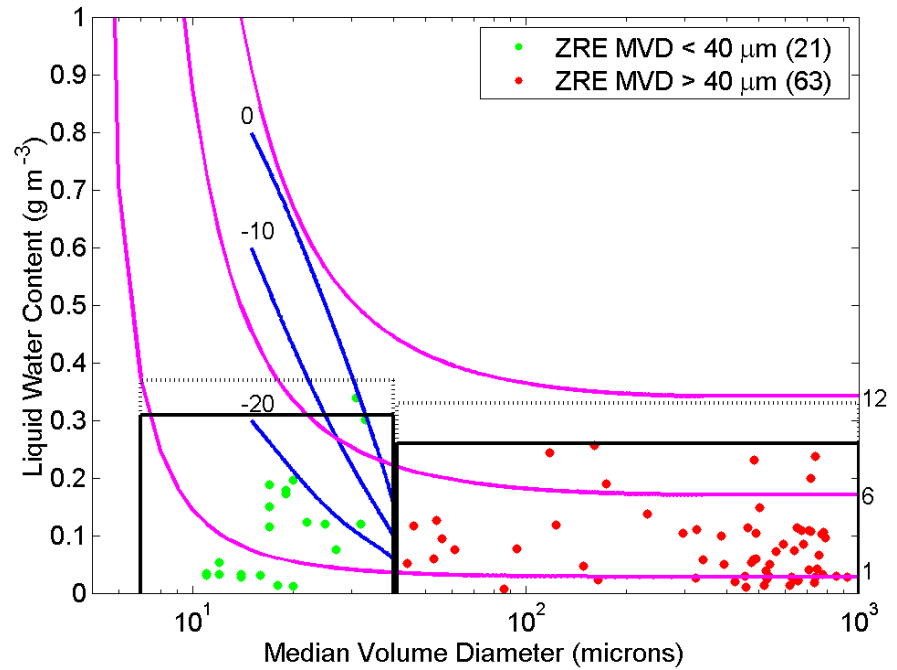


30-km Data

ZRE LWC – MVD Envelopes



3-km Data



30-km Data

Conclusions

2:17:19

Conclusions

- SLD observations were collected with instrumented research aircraft in 134 flights in 6 field experiments.
- Four SLD environments were analyzed as a function of MVD and maximum drop size.
- The data were analyzed in a manner consistent with Appendix C to determine:
 - A distance scale factor for SLD conditions
 - Characteristic SLD spectra
 - 99% SLD LWC values
 - Ranges of temperature, altitude and LWC
- This analysis is currently being considered by the IPHWG for application to SLD certification.

References (Available on Request)

Cober, S.G., G.A. Isaac, A.V. Korolev, and J.W. Strapp, 2001: Assessing cloud-phase conditions. *J. Appl. Meteor.*, **40**, 1967-1983.

Cober, S.G., G.A. Isaac, and J.W. Strapp, 2001: Characterizations of aircraft icing environments that include supercooled large drops. *J. Appl. Meteor.*, **40**, 1984-2002.

Cober, S.G., T.P. Ratvasky, and G.A. Isaac, 2002: Assessment of aircraft icing conditions observed during AIRS. *AIAA 40th Aerospace Sci. Meeting and Exhibit*, Reno Nevada, 14-17 January 2002, AIAA 2002-0674.

Shah, A.D., M.W. Patnoe, and E.L. Berg, 2000: Engineering analysis of the atmospheric icing environments including large droplet conditions. *Society of Automotive Engineers*, 2000-01-2115.

Cober, S.G., G.A. Isaac, A.D. Shah, and R. Jeck, 2003: Defining characteristic cloud drop spectra from in-situ measurements. *AIAA 41st Aerospace Sci. Meeting and Exhibit*, Reno Nevada, 6-10 January 2003, AIAA 2003-0561.

Cober, S.G., and G.A. Isaac, 2006: Estimating maximum aircraft icing environments using a large data base of in-situ observations. *AIAA 40th Aerospace Sci. Meeting and Exhibit*, Reno Nevada, 9-12 January 2006, AIAA 2006-0266.