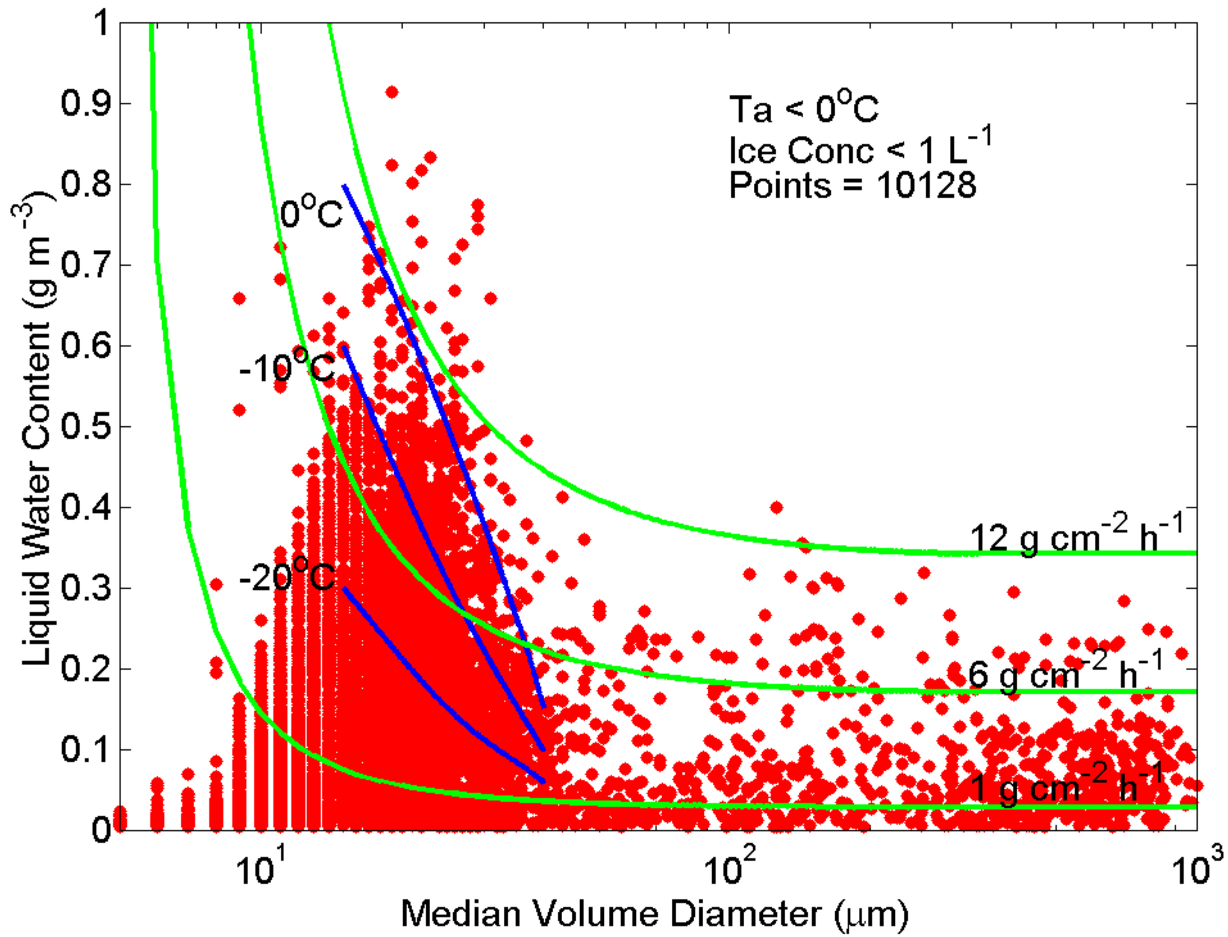
Subsets of the SLD Data

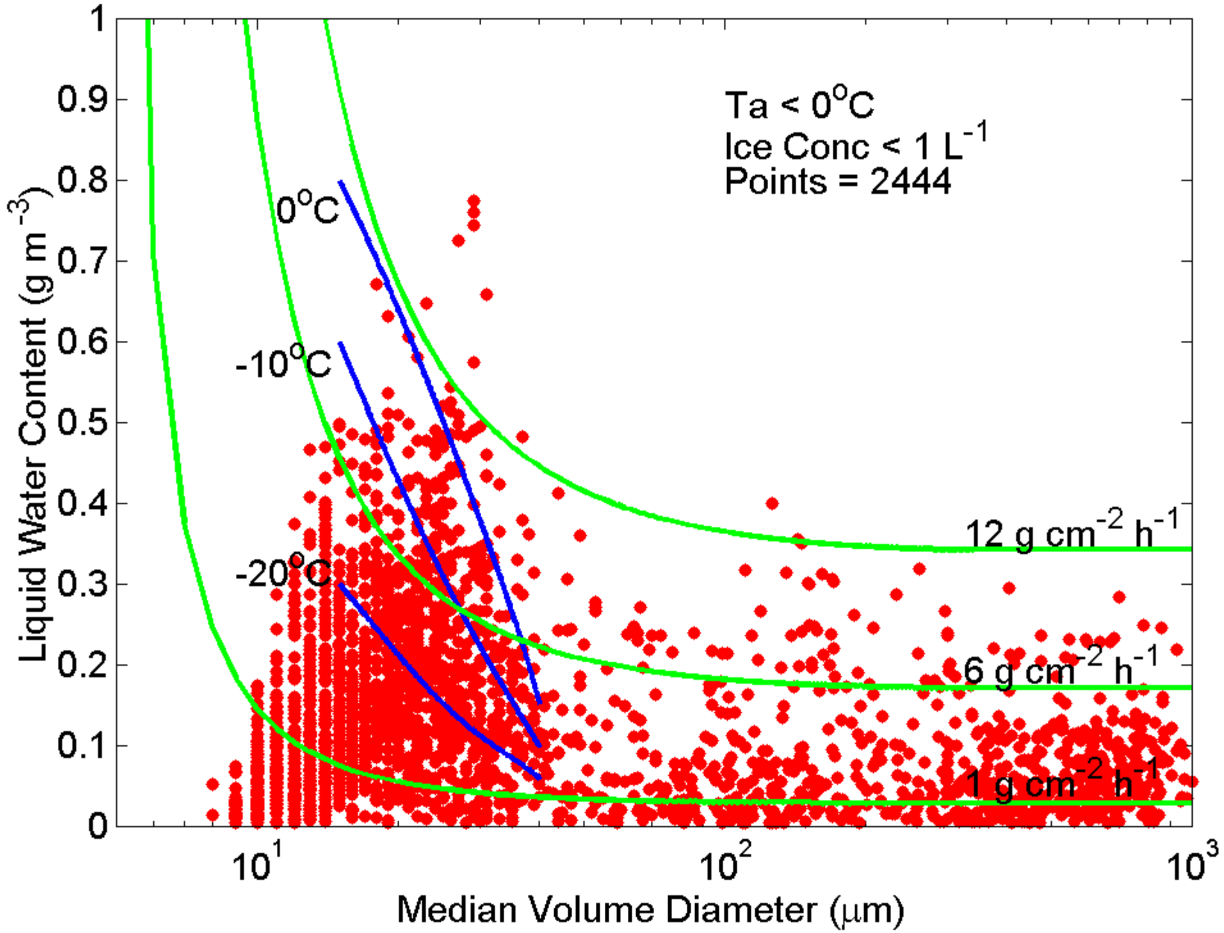
Environment	MVD	Dmax	Points
Freezing Drizzle	< 40 μm	100-500 μm	1469
Freezing Drizzle	> 40 μm	100-500 μm	335
Freezing Rain	< 40 μm	> 500 μm	193
Freezing Rain	> 40 μm	> 500 μm	447

Icing Data Points



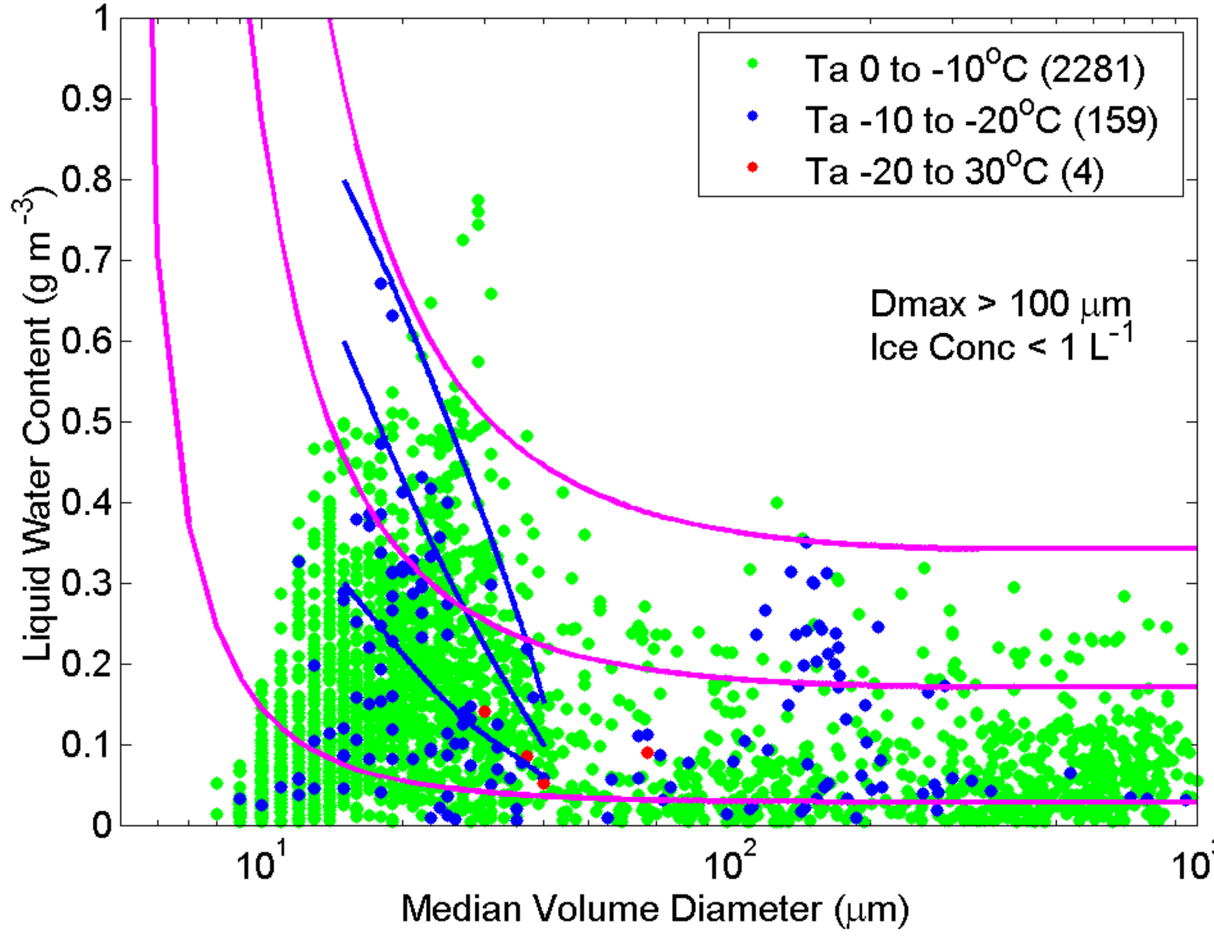
3-km Data

SLD Data Points



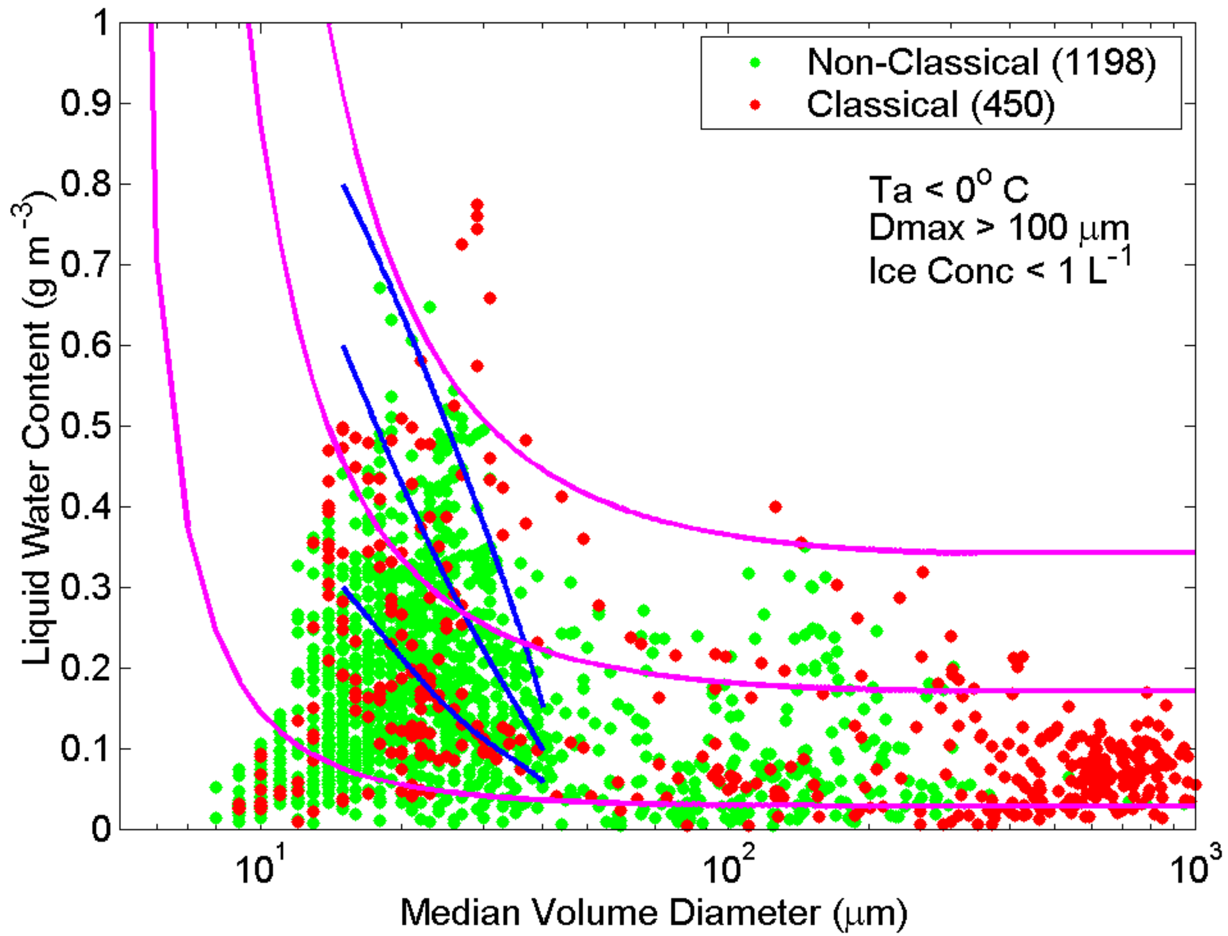
3-km Data

SLD - Temperature



3-km Data

SLD – Formation Mechanism



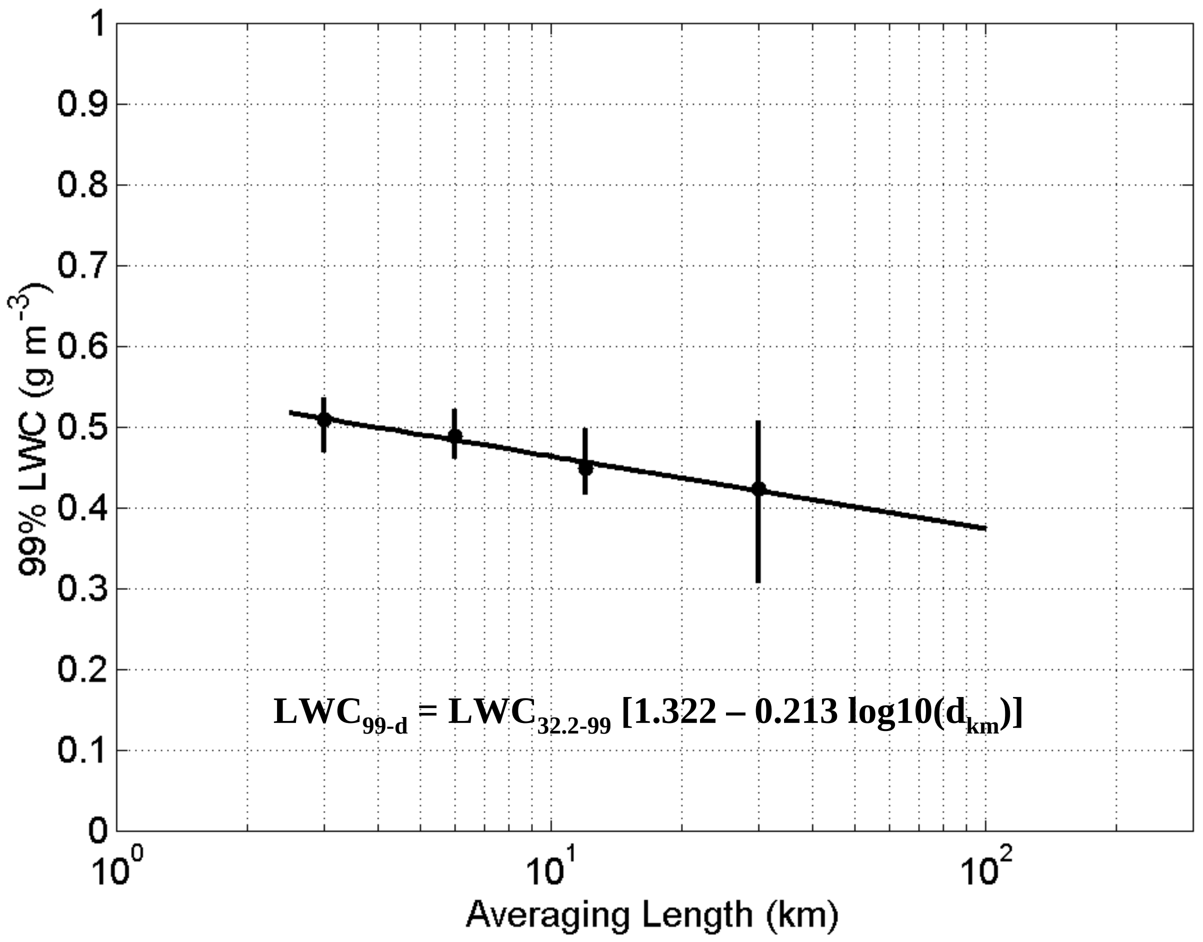
3-km Data

SLD Scale Factor

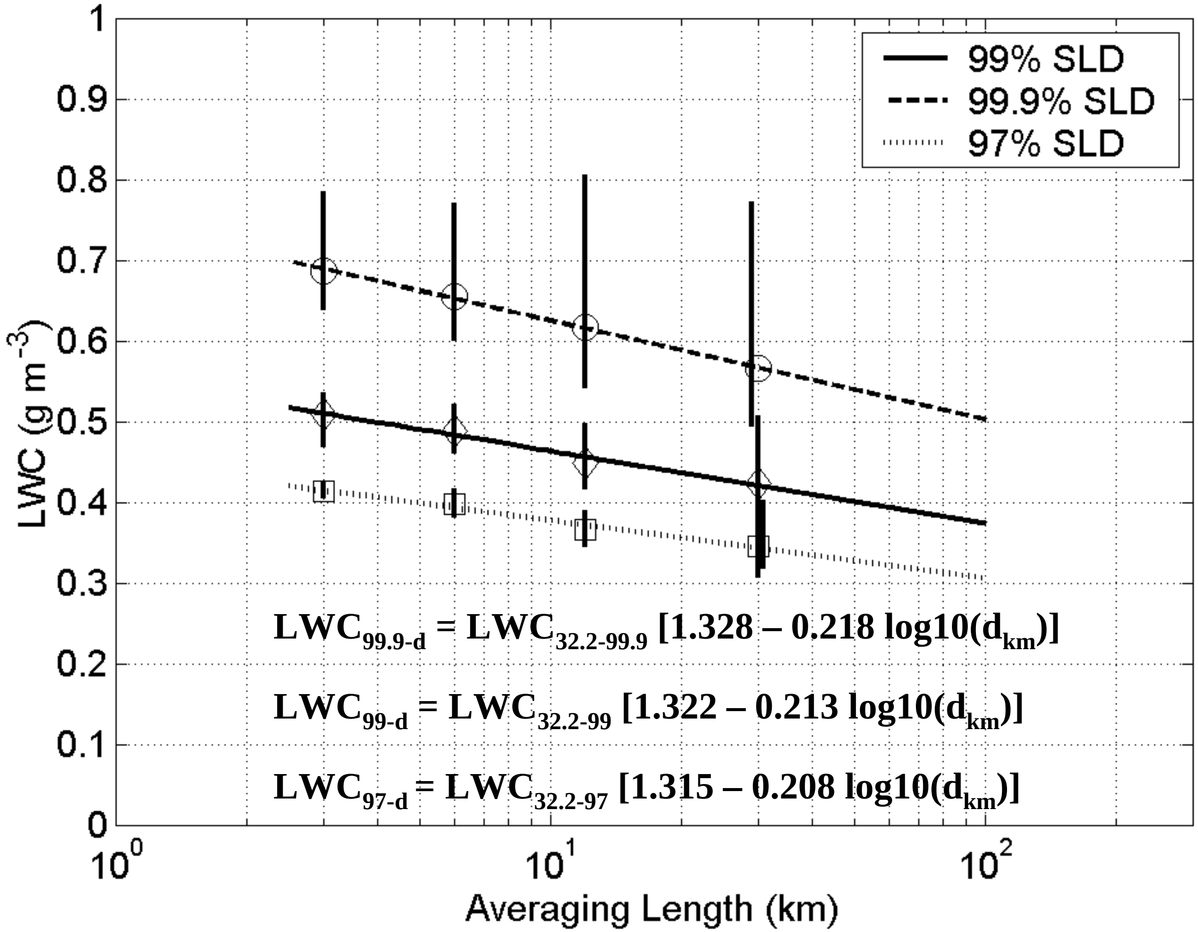
Sample Size of SLD Conditions for Scale Factor Analysis

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

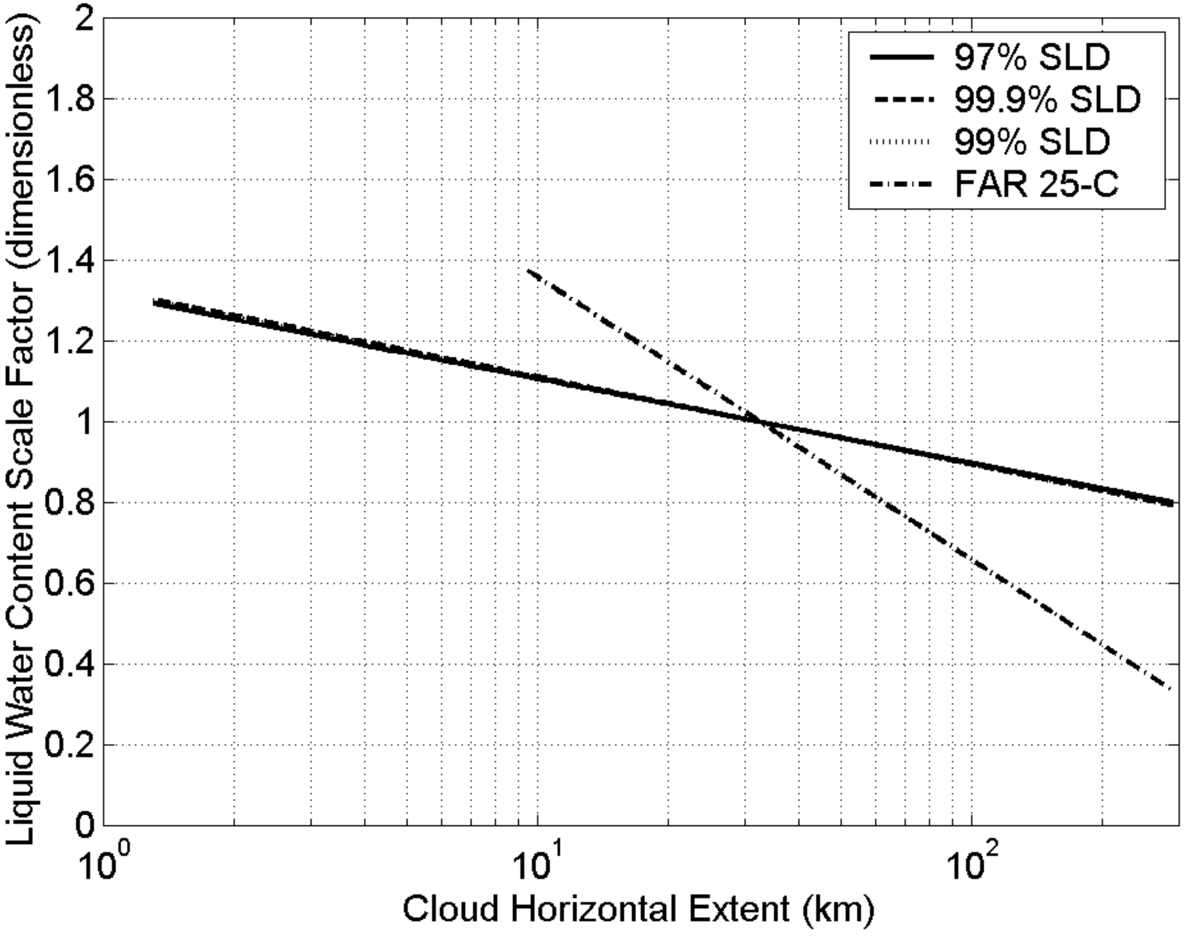
99% SLD LWC Scale Factor



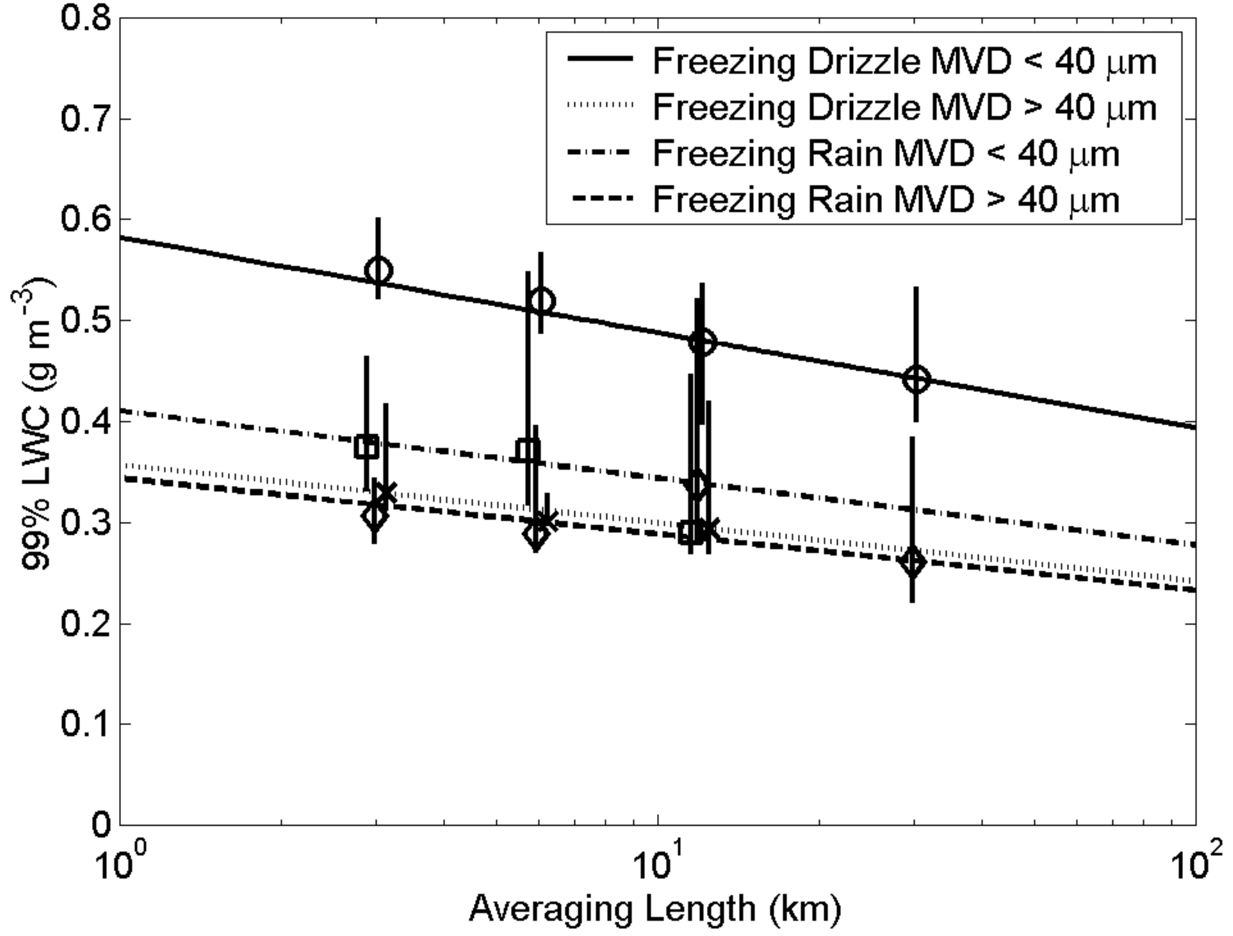
97 to 99.9% SLD LWC Scale Factors



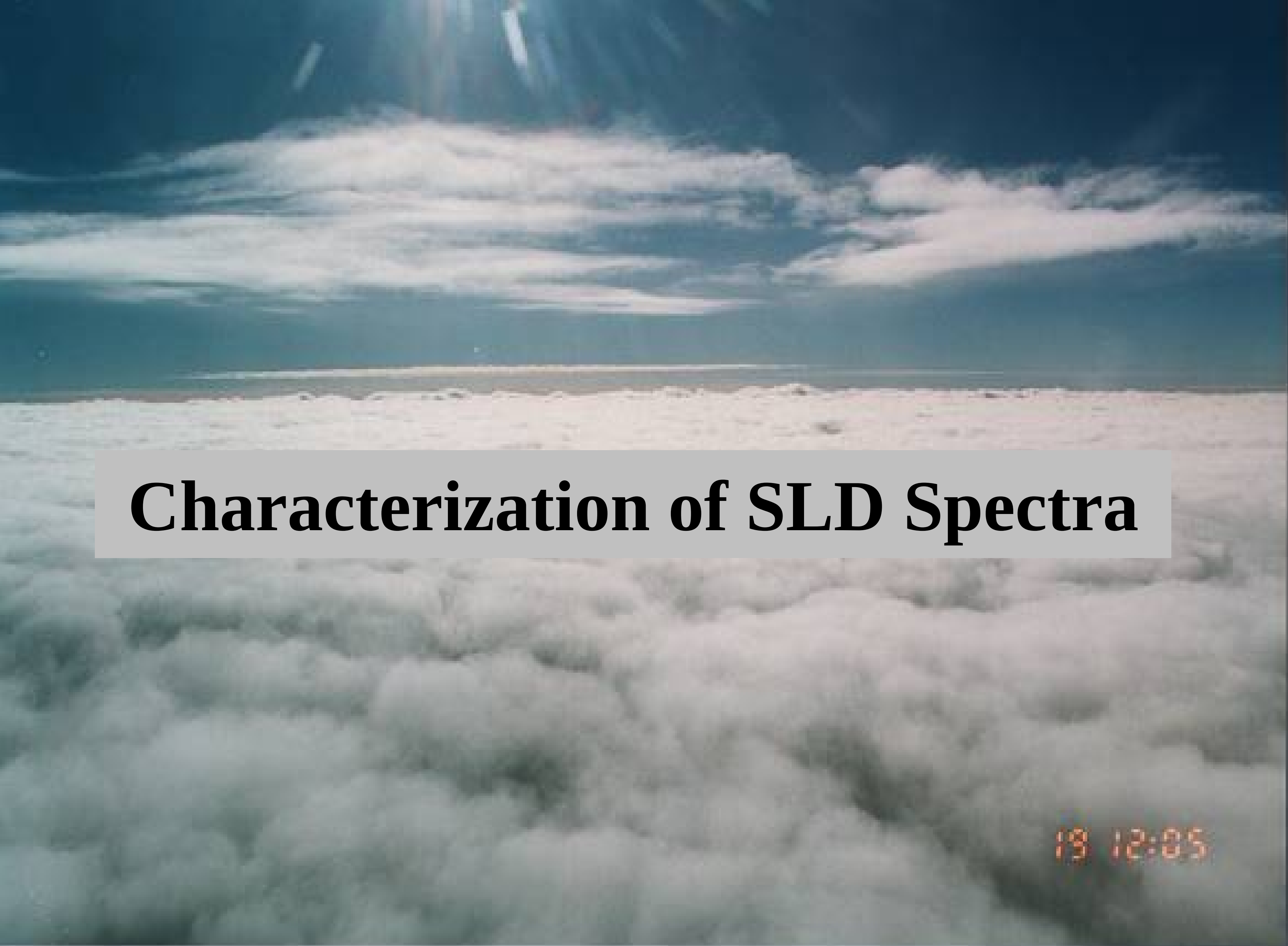
SLD LWC Scale Factor



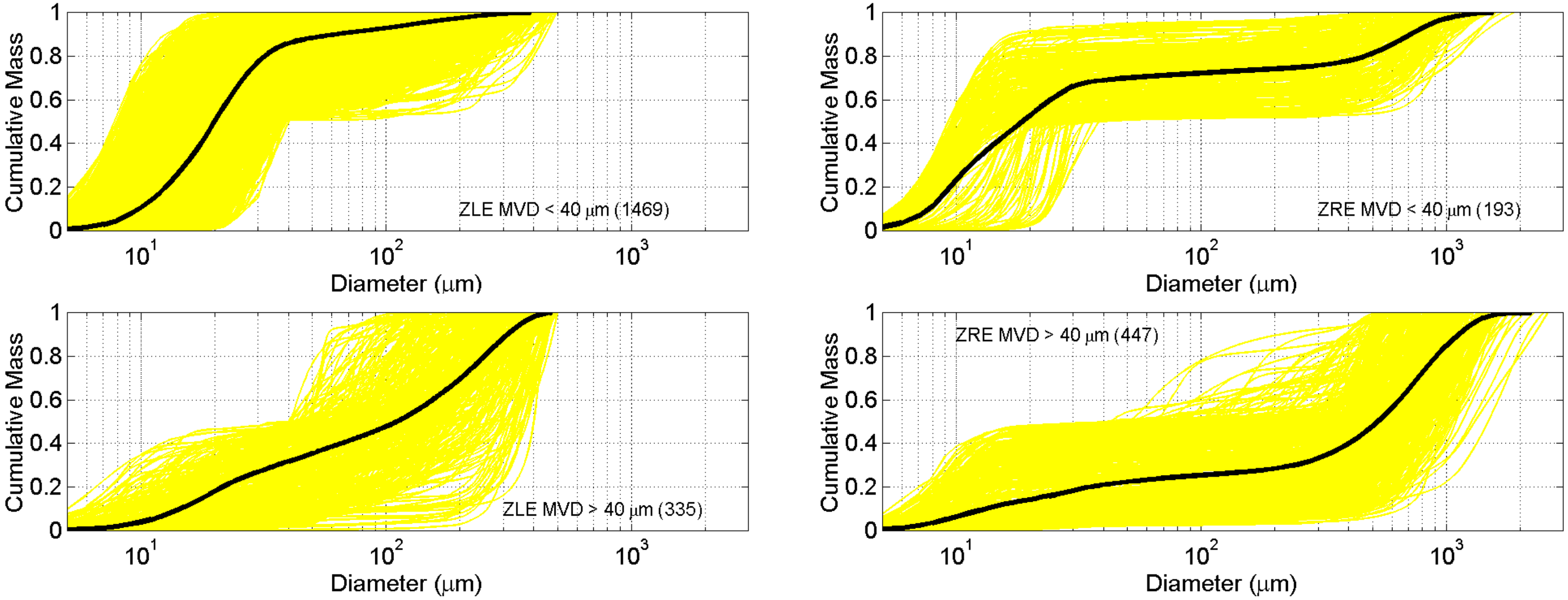
SLD Subsets LWC Scale Factor



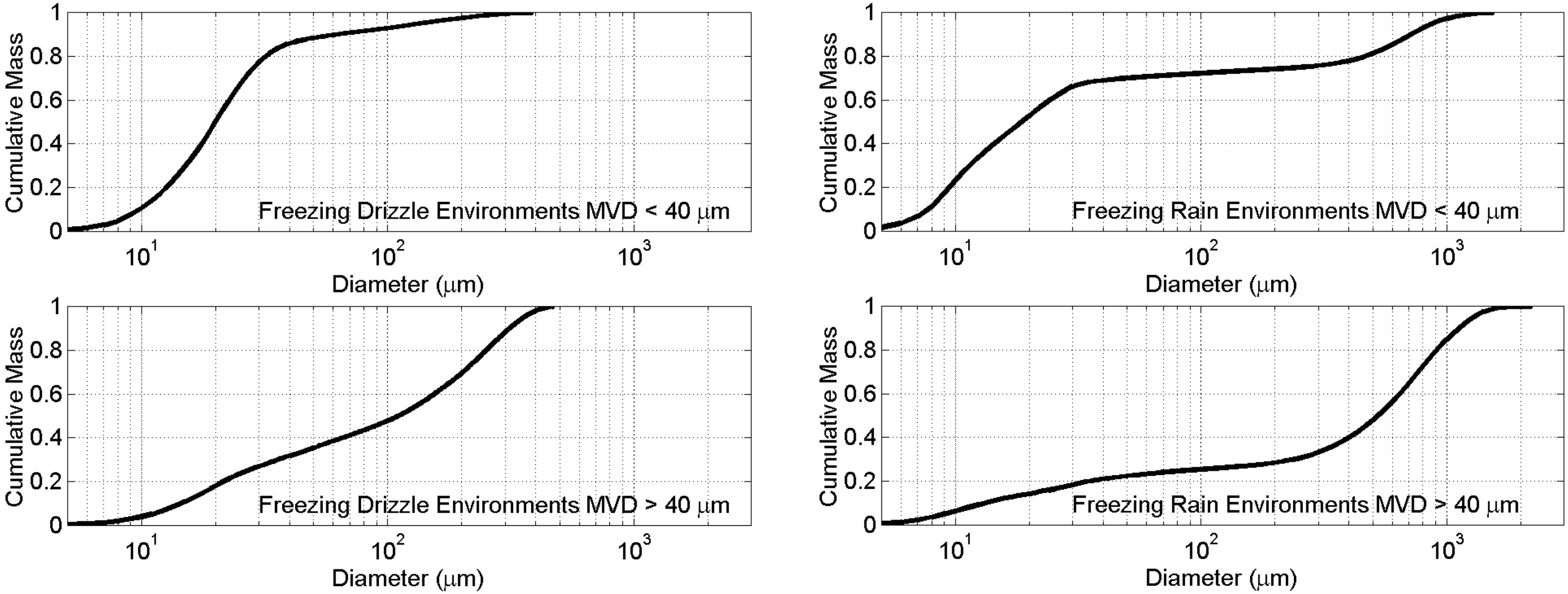
Characterization of SLD Spectra



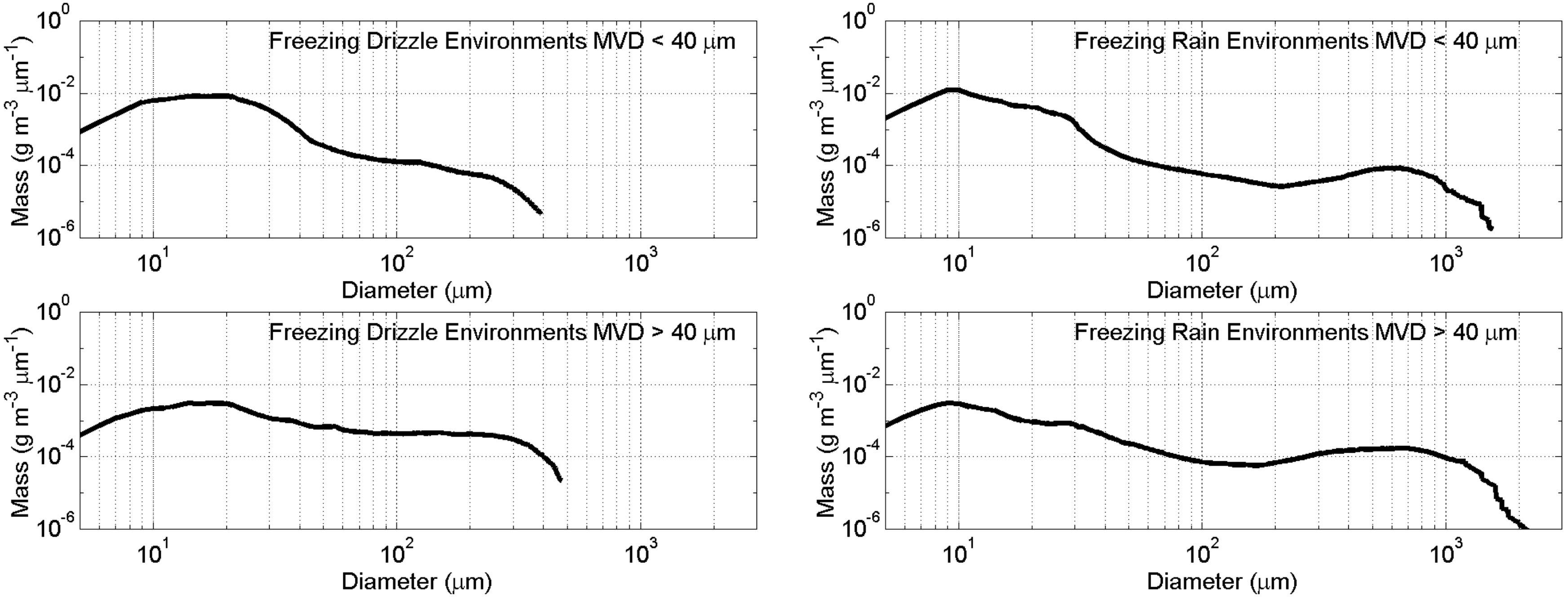
SLD Cumulative Mass Spectra



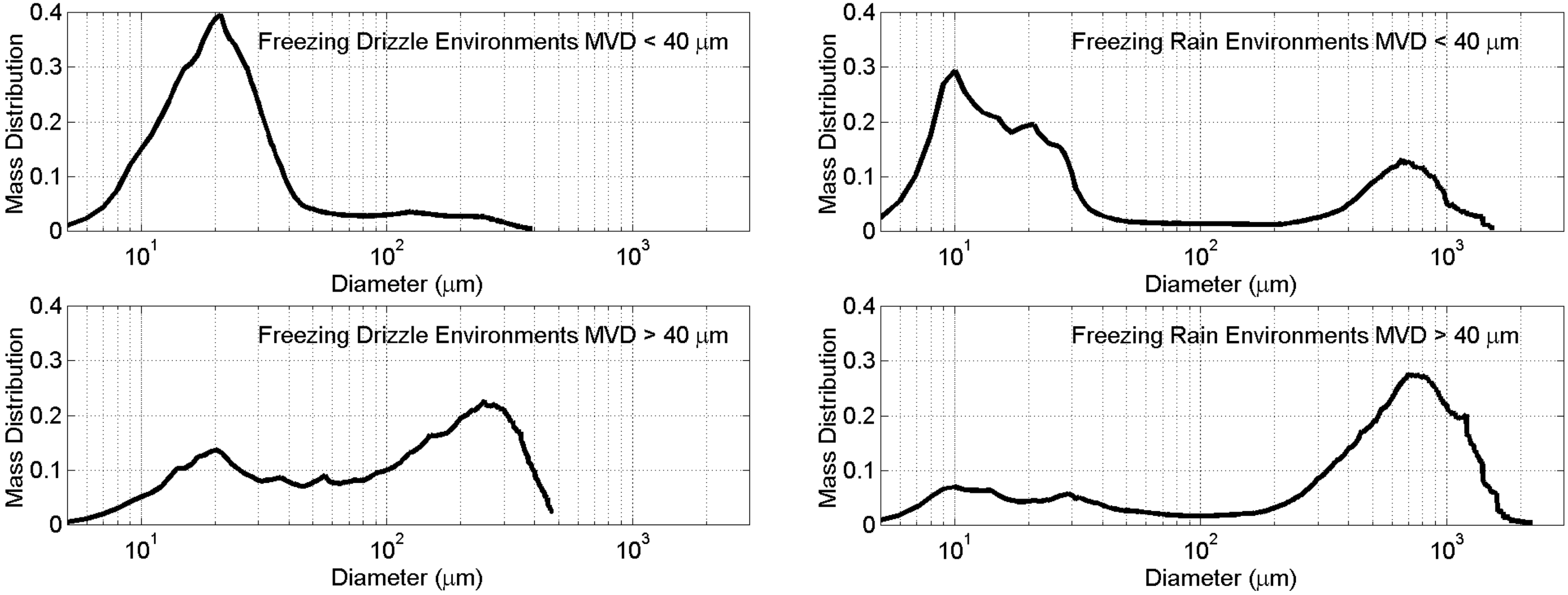
SLD Cumulative Mass Spectra



SLD Mass Spectra

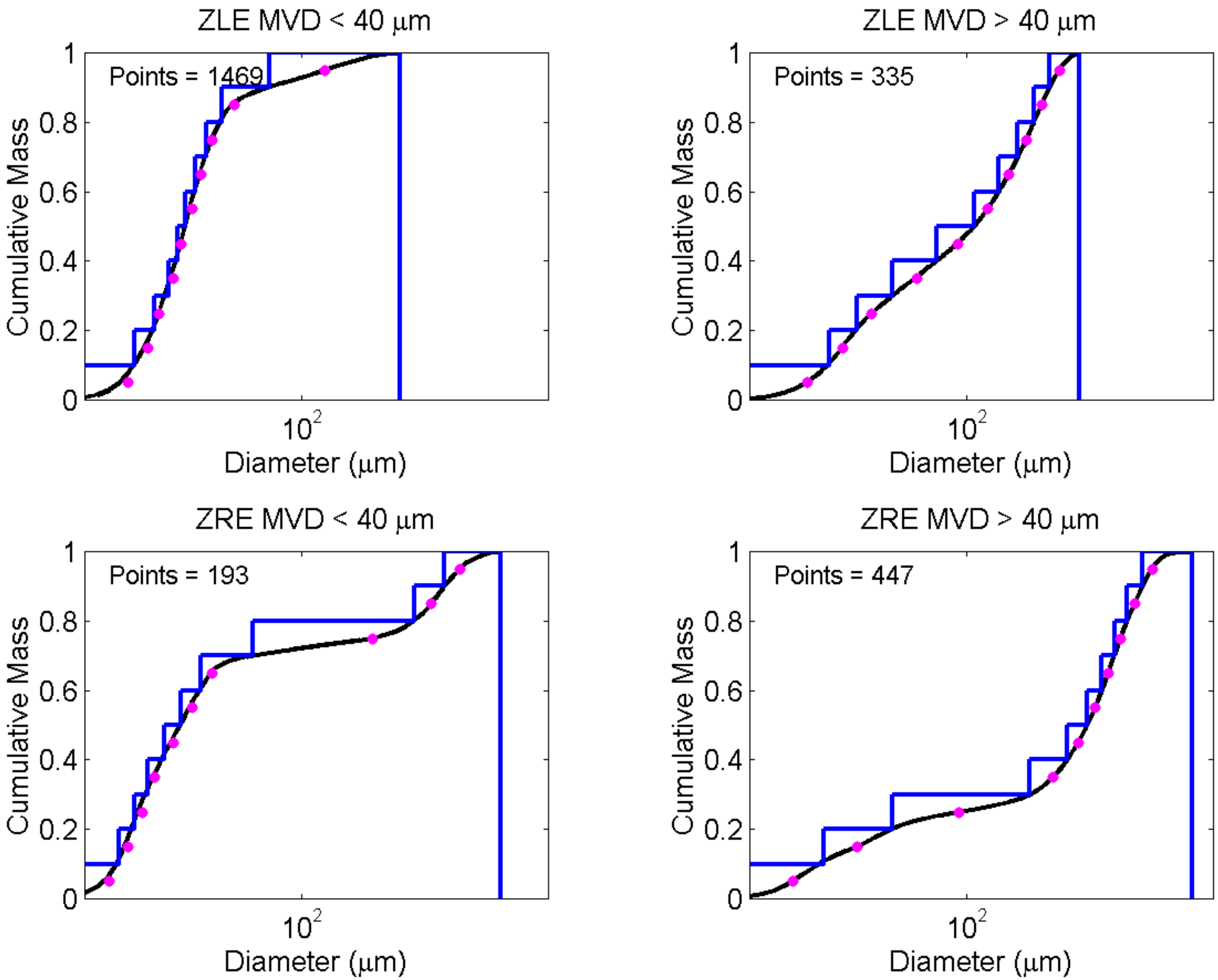


SLD Spectra



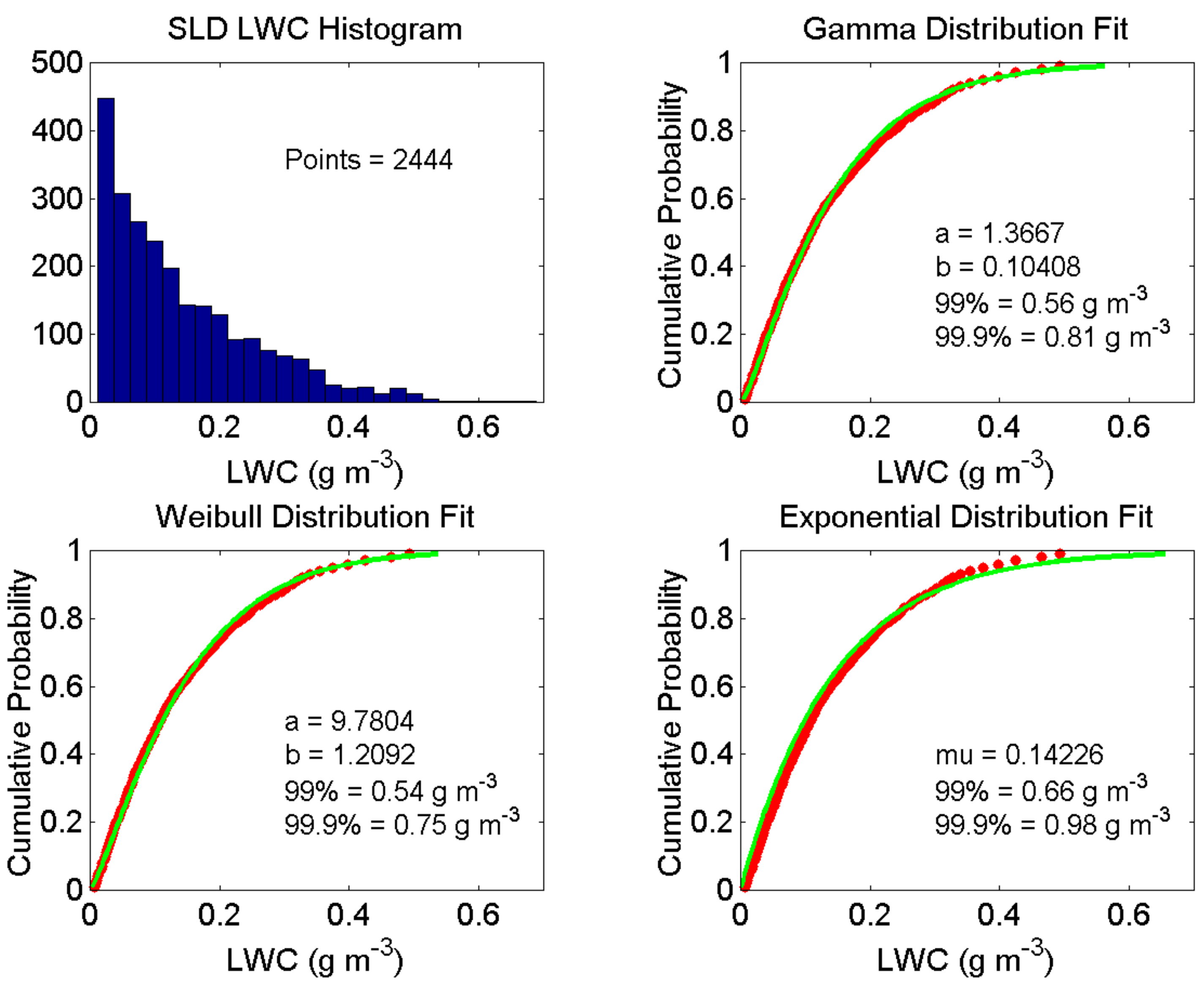
Mass Distribution = $\Delta LWC_b / \log(D_{b2}/D_{b1})$

SLD Cumulative Mass Bins



Estimation of Extreme SLD LWC Values

Fitting SLD LWC Distributions



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

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

μ = location parameter

Ψ = scale parameter

ξ = shape parameter

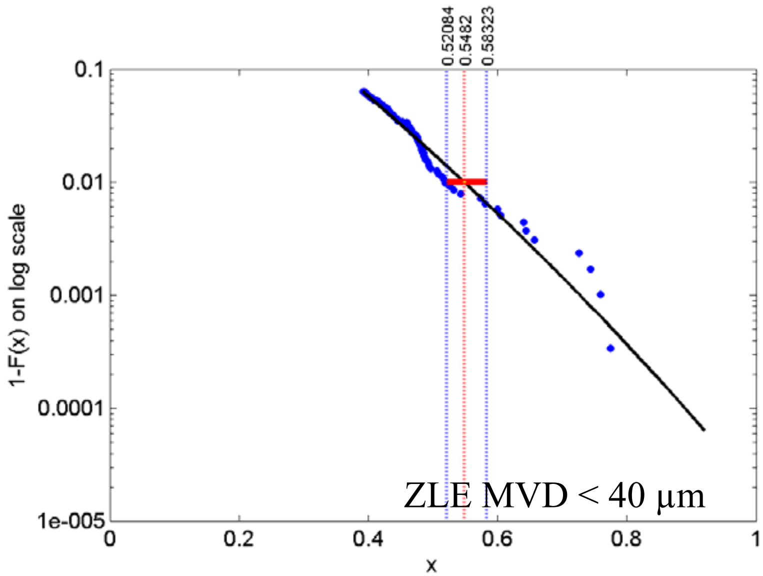
- $\xi > 0$ Fréchet family $P \sim \exp[-x^{-\alpha}]$ $\alpha = 1/\xi$ (long tail)
- $\xi < 0$ Weibull family $P \sim \exp[-(-x^{\alpha})]$ $\alpha = -1/\xi$ (short tail)
- $\xi = 0$ Gumbel family $P \sim \exp[-e^{-x}]$ (medium tail)

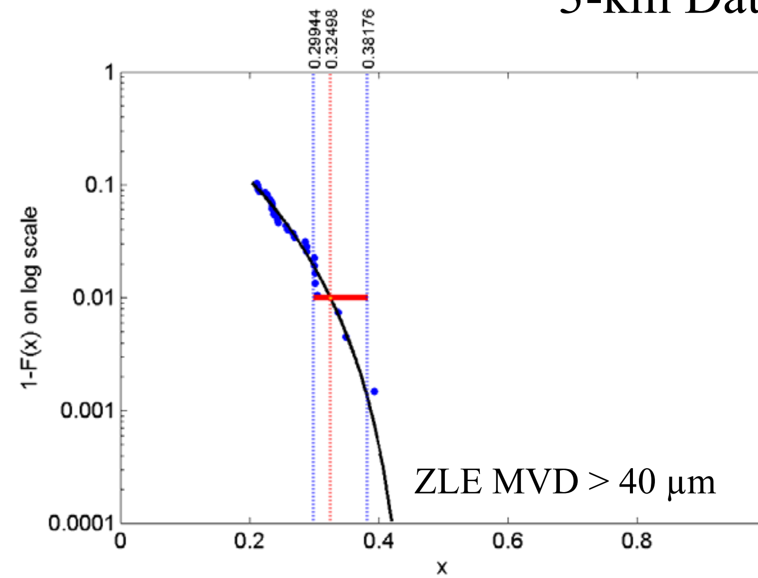
- Use the technique of threshold selection to fit the tail of the distribution to a Generalized Pareto Distribution of the form:

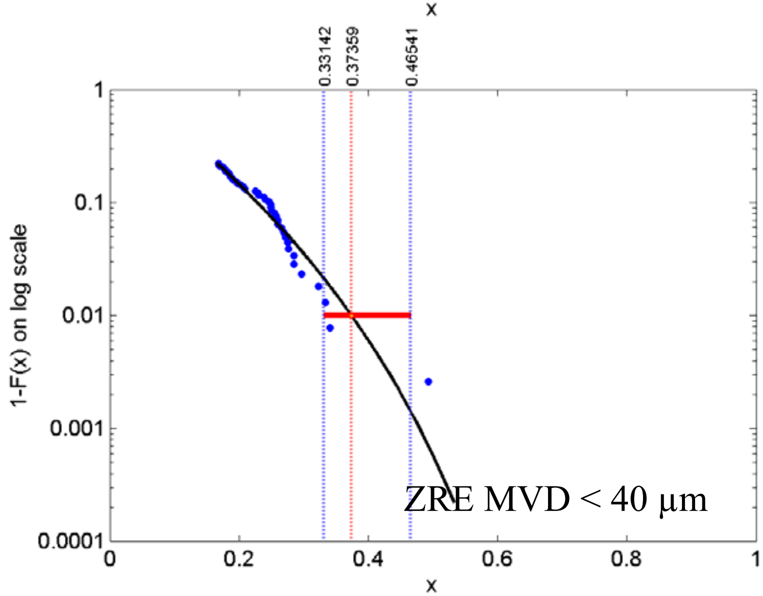
$$G = 1+\xi(\frac{x-\mu}{\psi})^{-1/\xi}$$

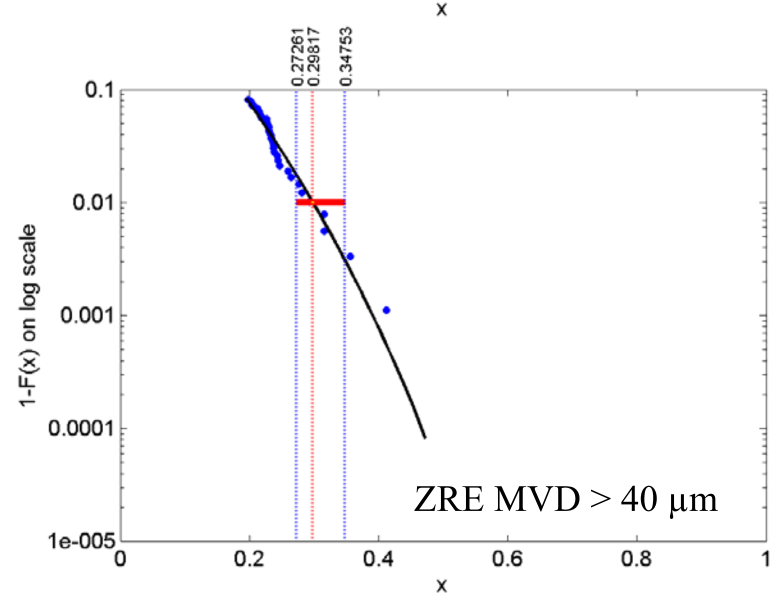
99% SLD LWC Estimates

3-km Data



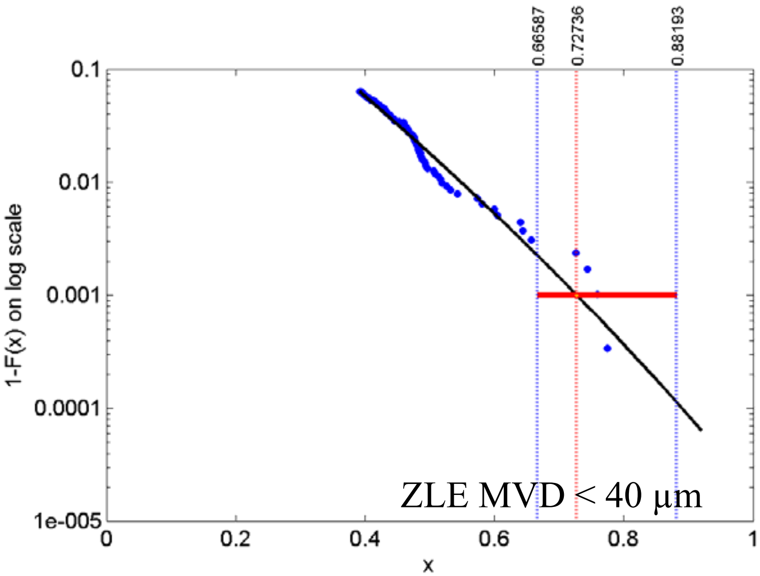


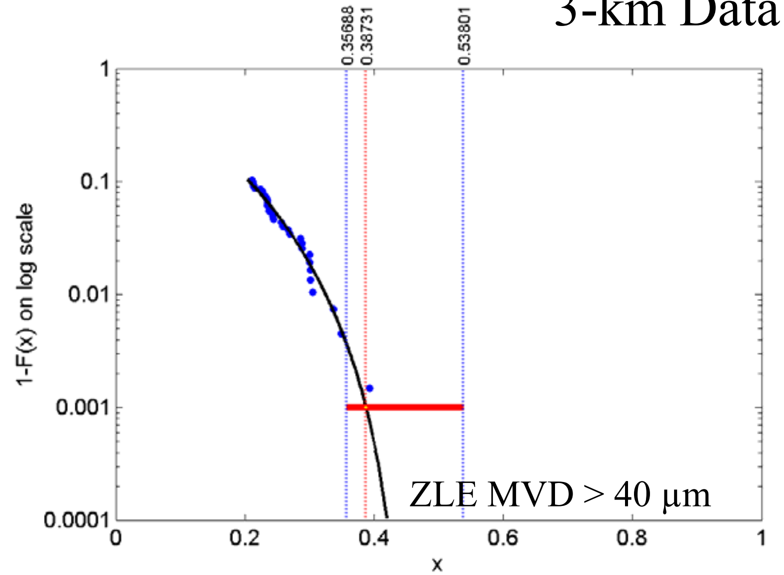


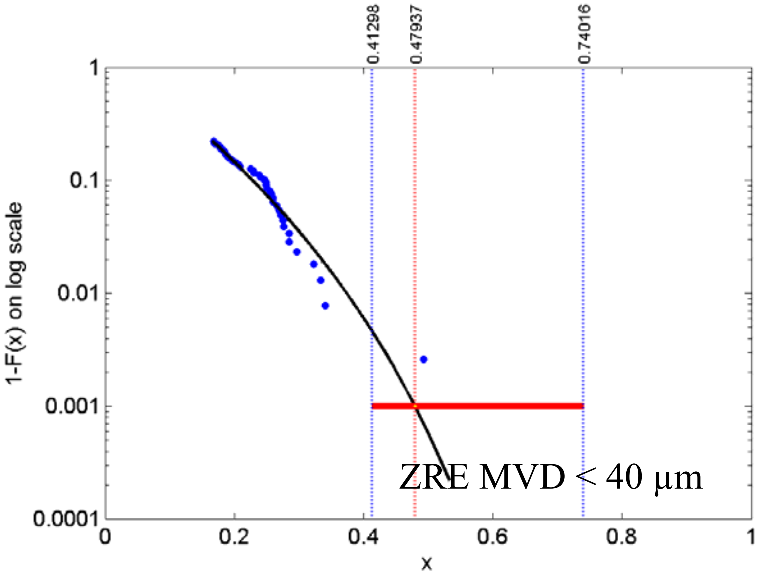


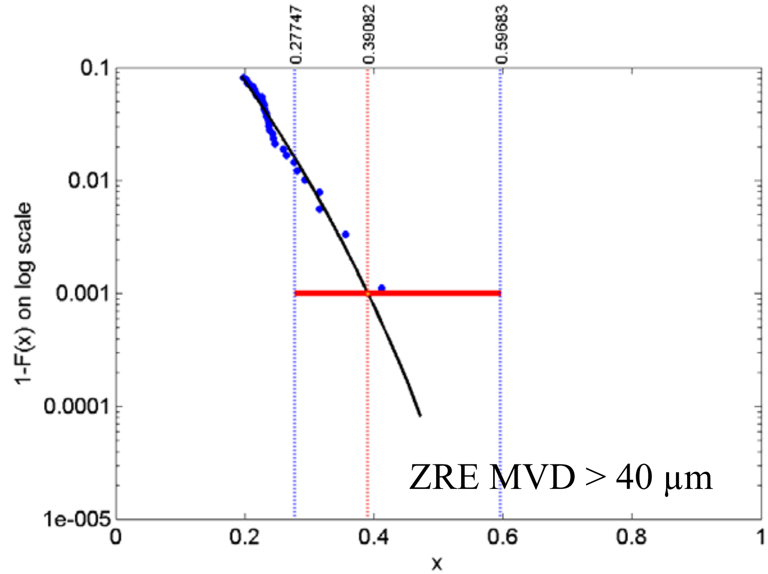
99.9% SLD LWC Estimates

3-km Data







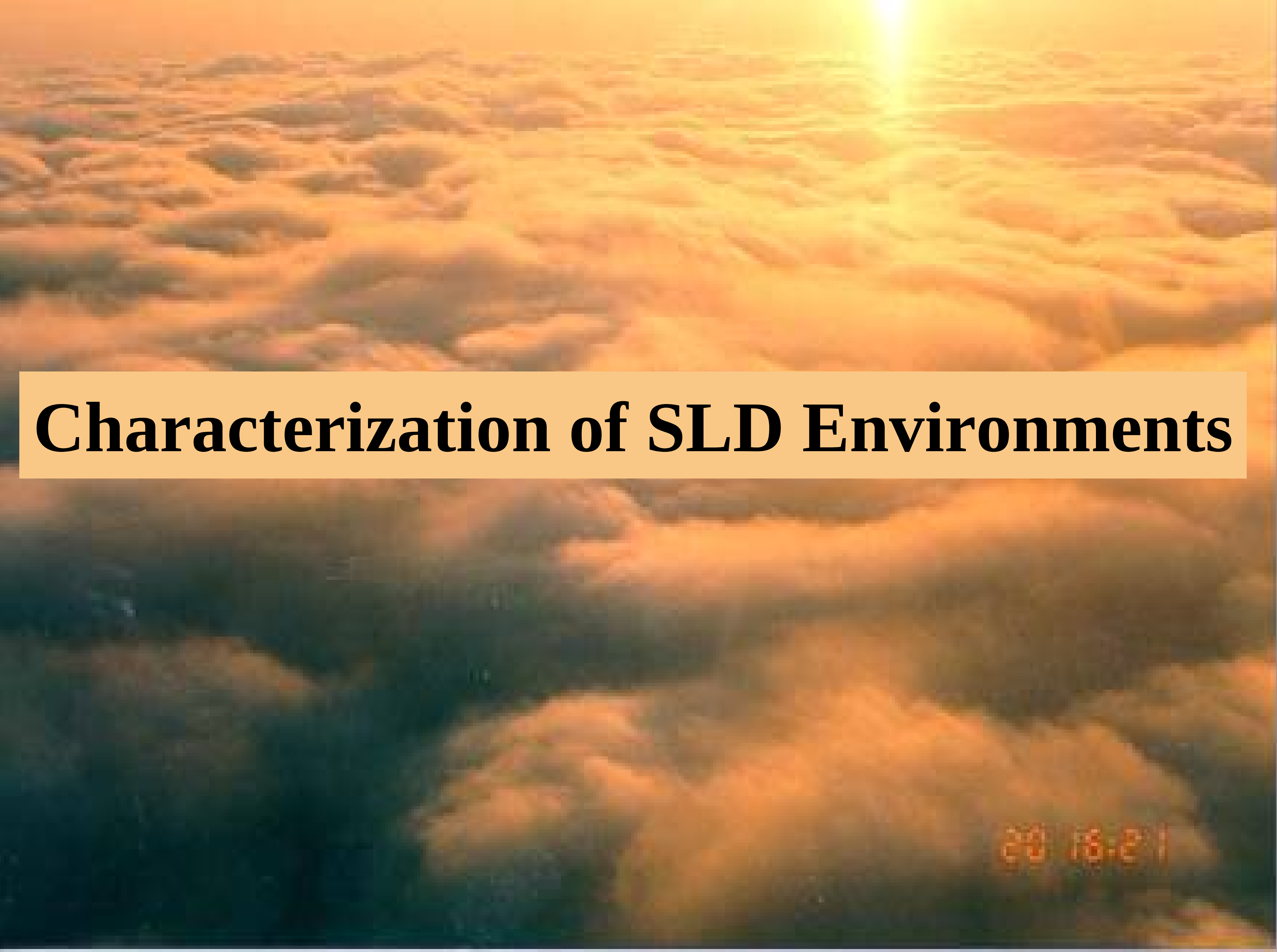


99% and 99.9% LWC Values

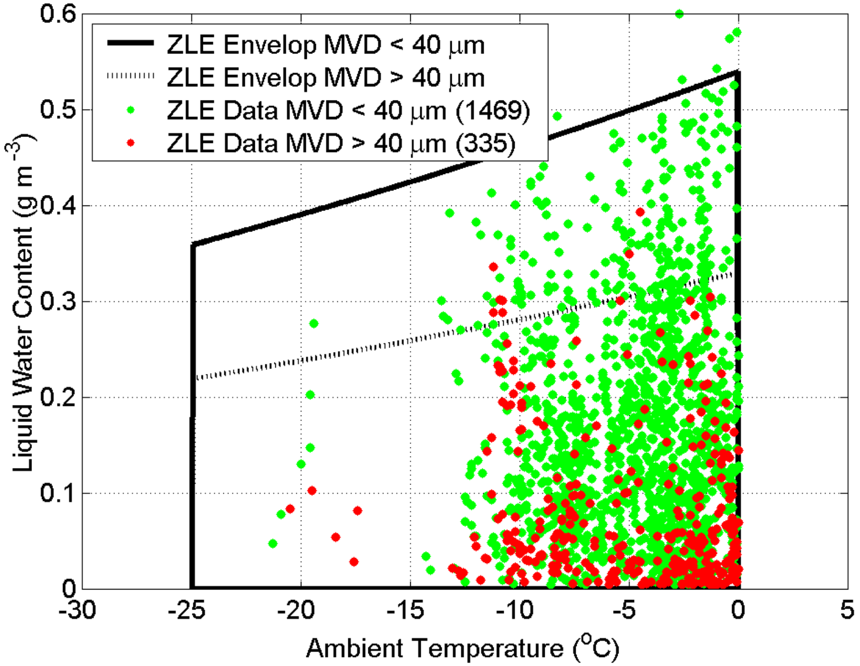
Environment	MVD	Dmax	99.0% LWC	99.9% LWC
Freezing Drizzle	< 40 μm	100-500 μm	0.44 g m^{-3}	0.58 g m^{-3}
Freezing Drizzle	> 40 μm	100-500 μm	0.27 g m^{-3}	0.31 g m^{-3}
Freezing Rain	< 40 μm	> 500 μm	0.31 g m^{-3}	0.37 g m^{-3}
Freezing Rain	> 40 μm	> 500 μm	0.26 g m^{-3}	0.33 g m^{-3}

17.6 n mi / 32.2 km

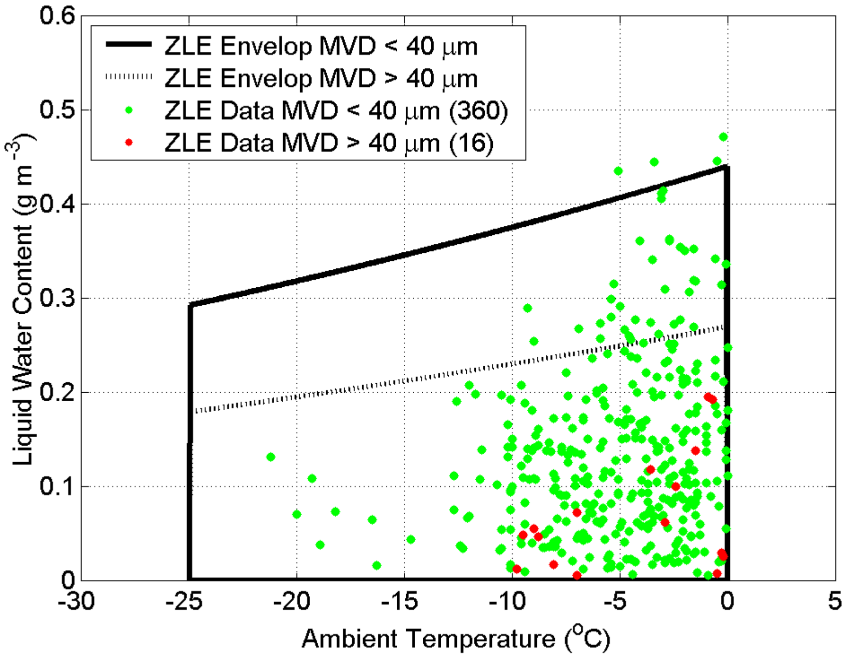
Characterization of SLD Environments



ZLE LWC – Temperature Envelopes

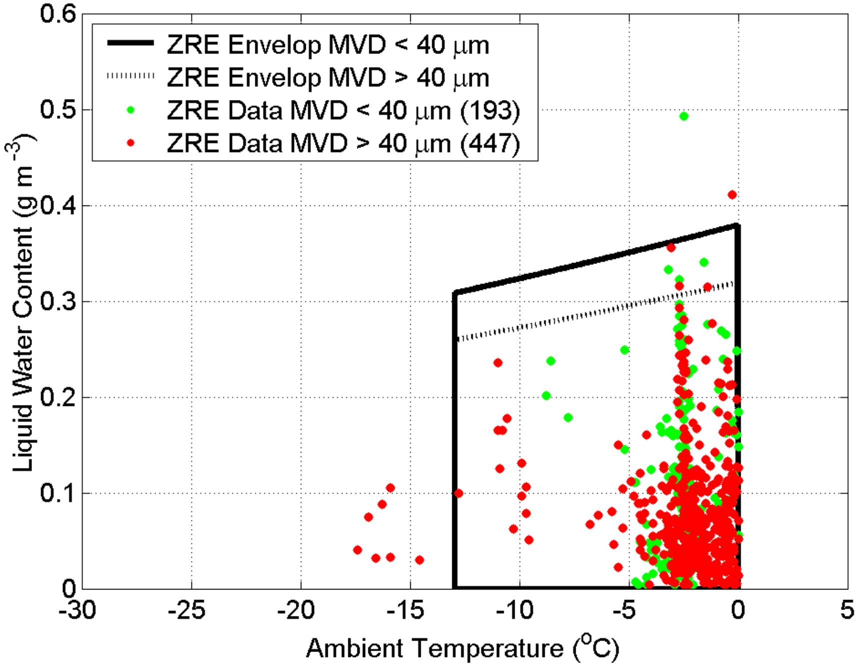


3-km Data

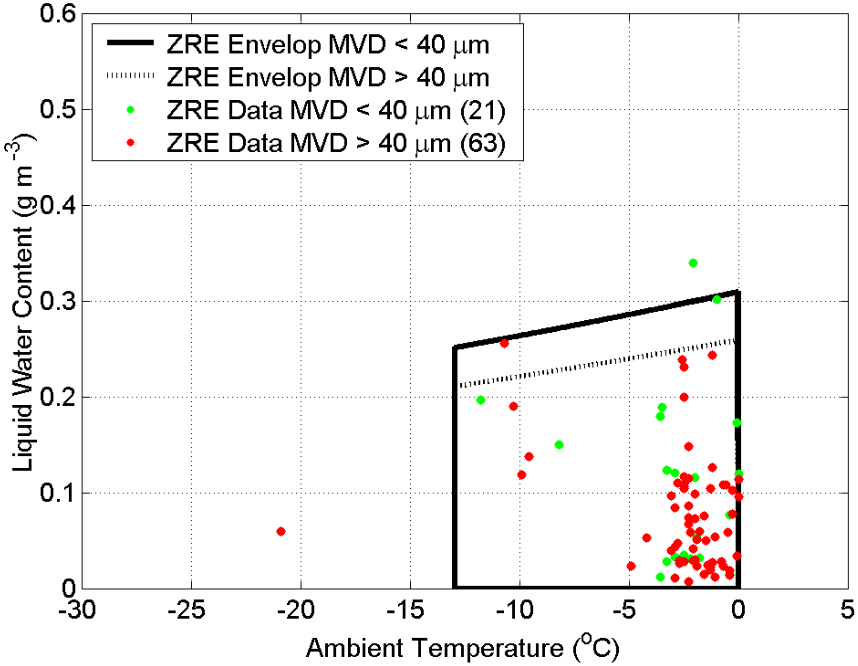


30-km Data

ZRE LWC – Temperature Envelopes

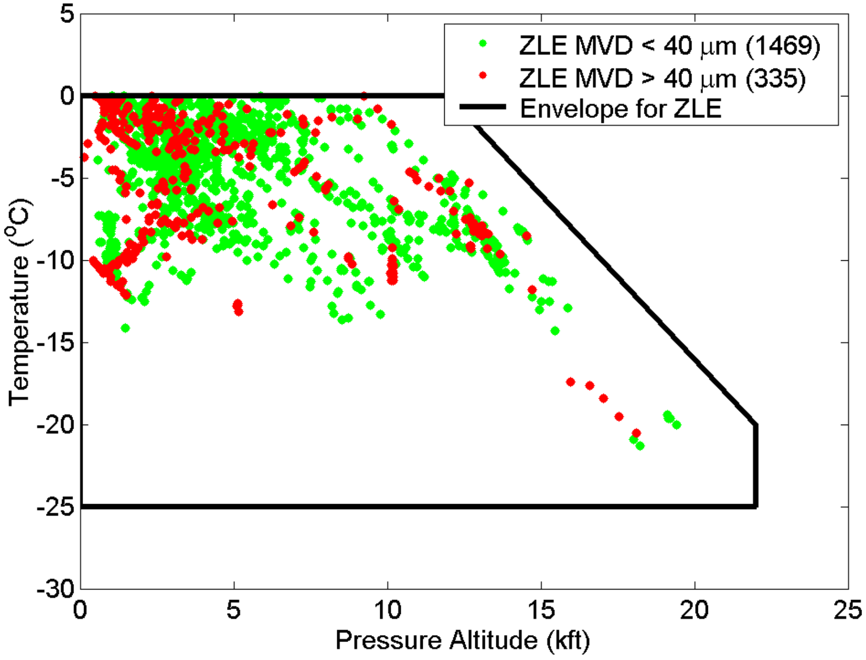


3-km Data

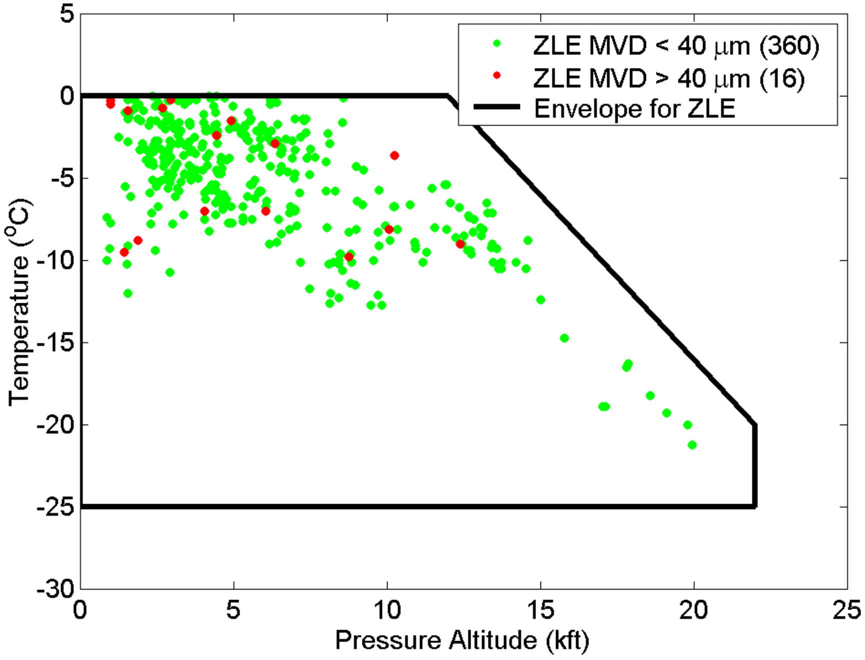


30-km Data

ZLE Temperature – Altitude Envelopes

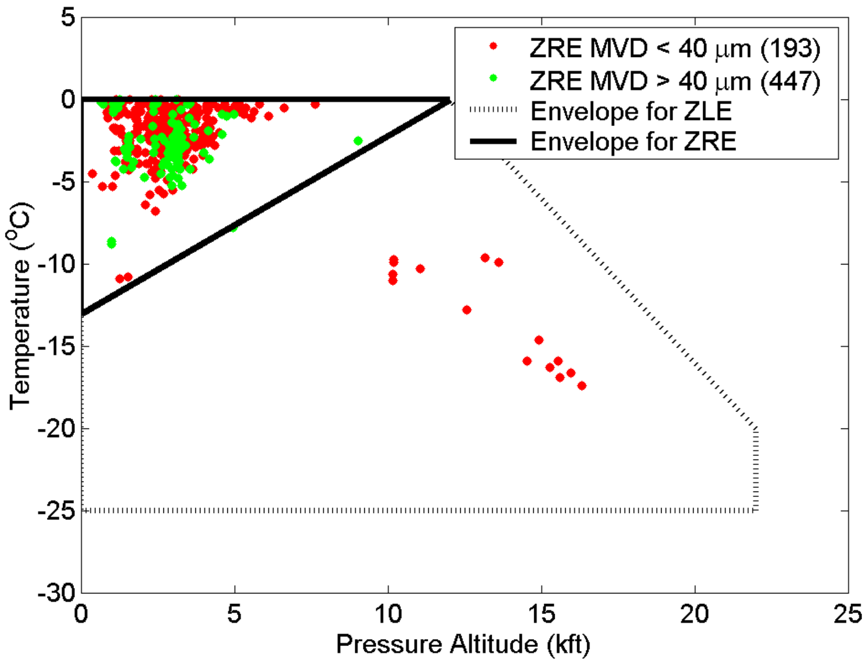


3-km Data

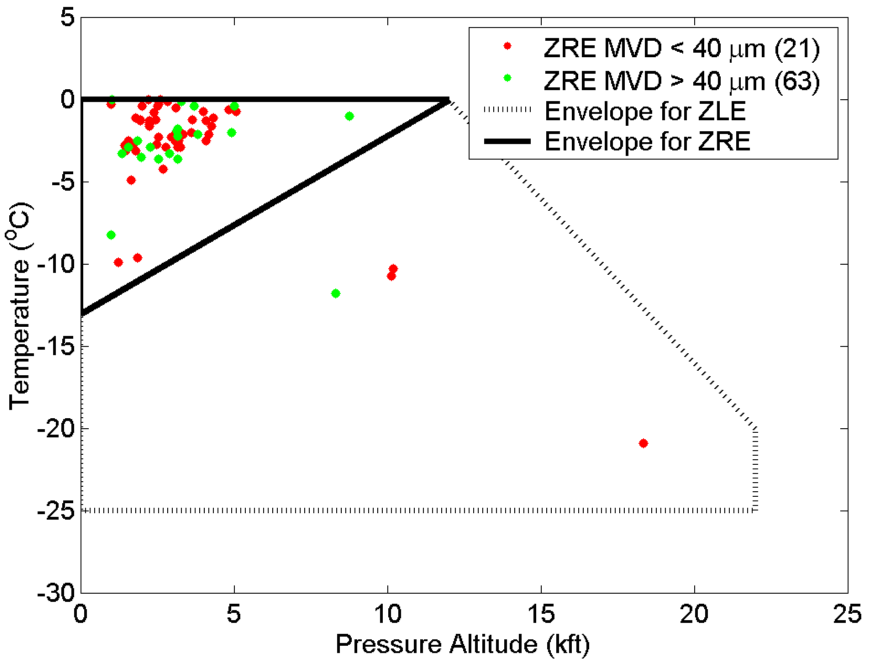


30-km Data

ZRE Temperature – Altitude Envelopes

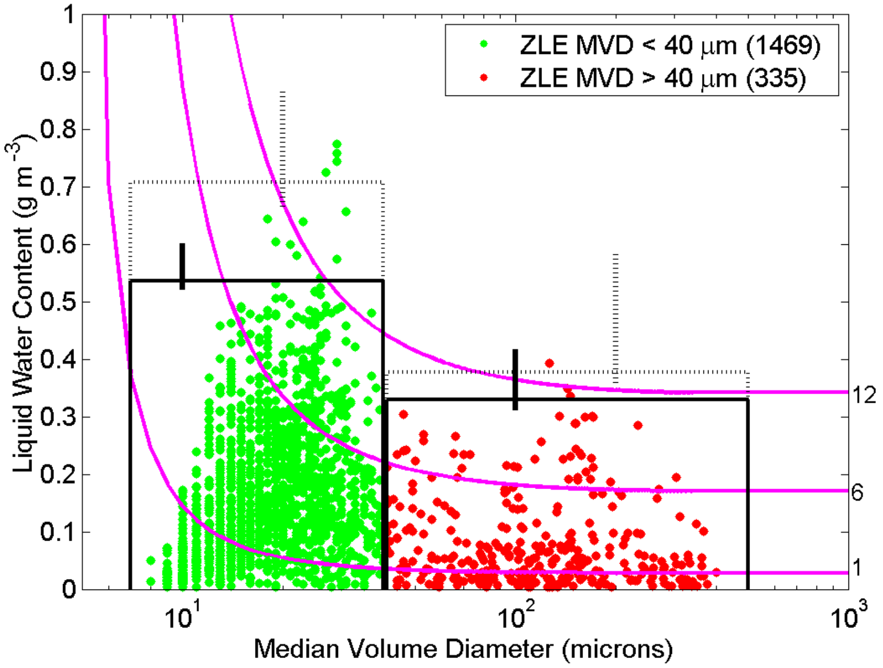


3-km Data

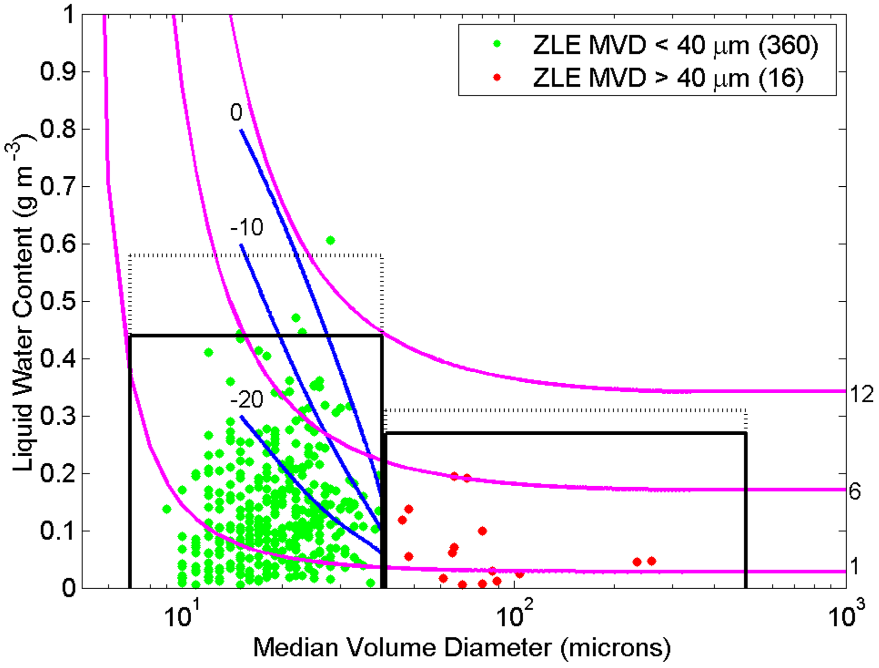


30-km Data

ZLE LWC – MVD Envelopes

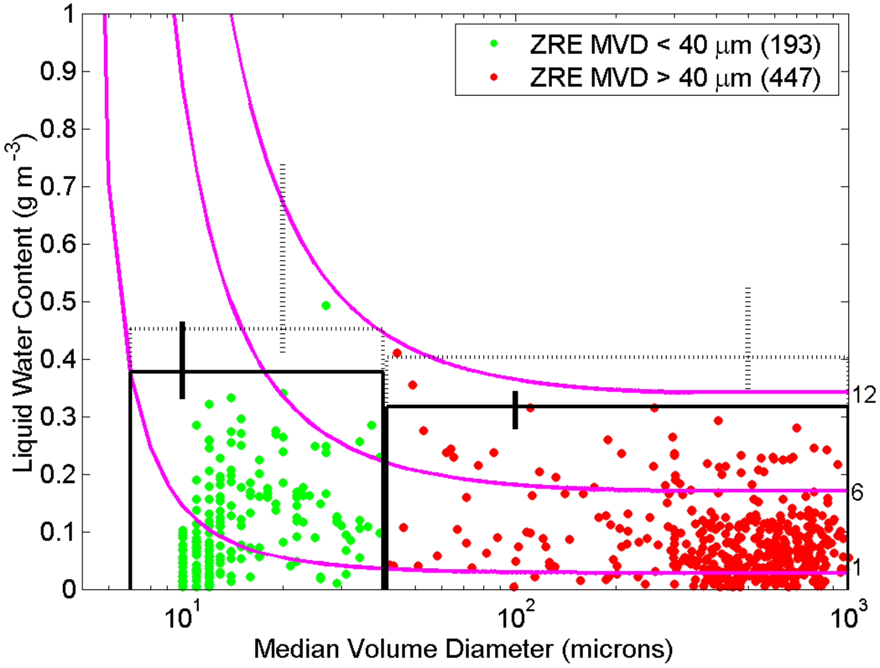


3-km Data

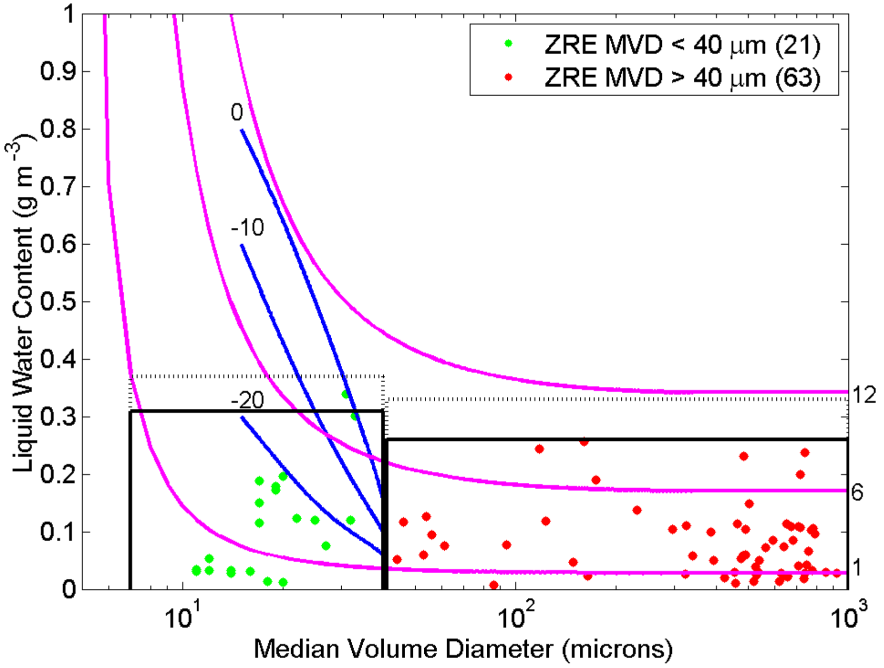


30-km Data

ZRE LWC – MVD Envelopes



3-km Data



30-km Data

Conclusions

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.