

ARM



Uncertainty Analysis of Cloud Properties Retrieved From MICROBASE

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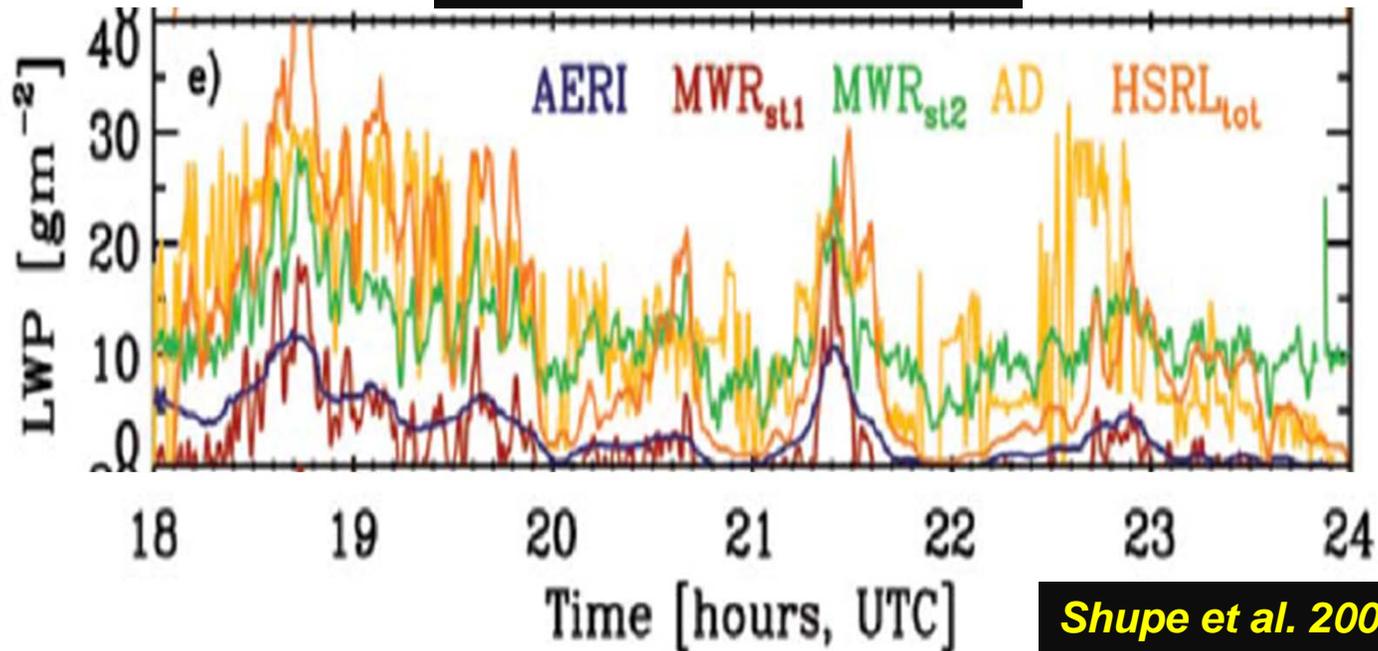


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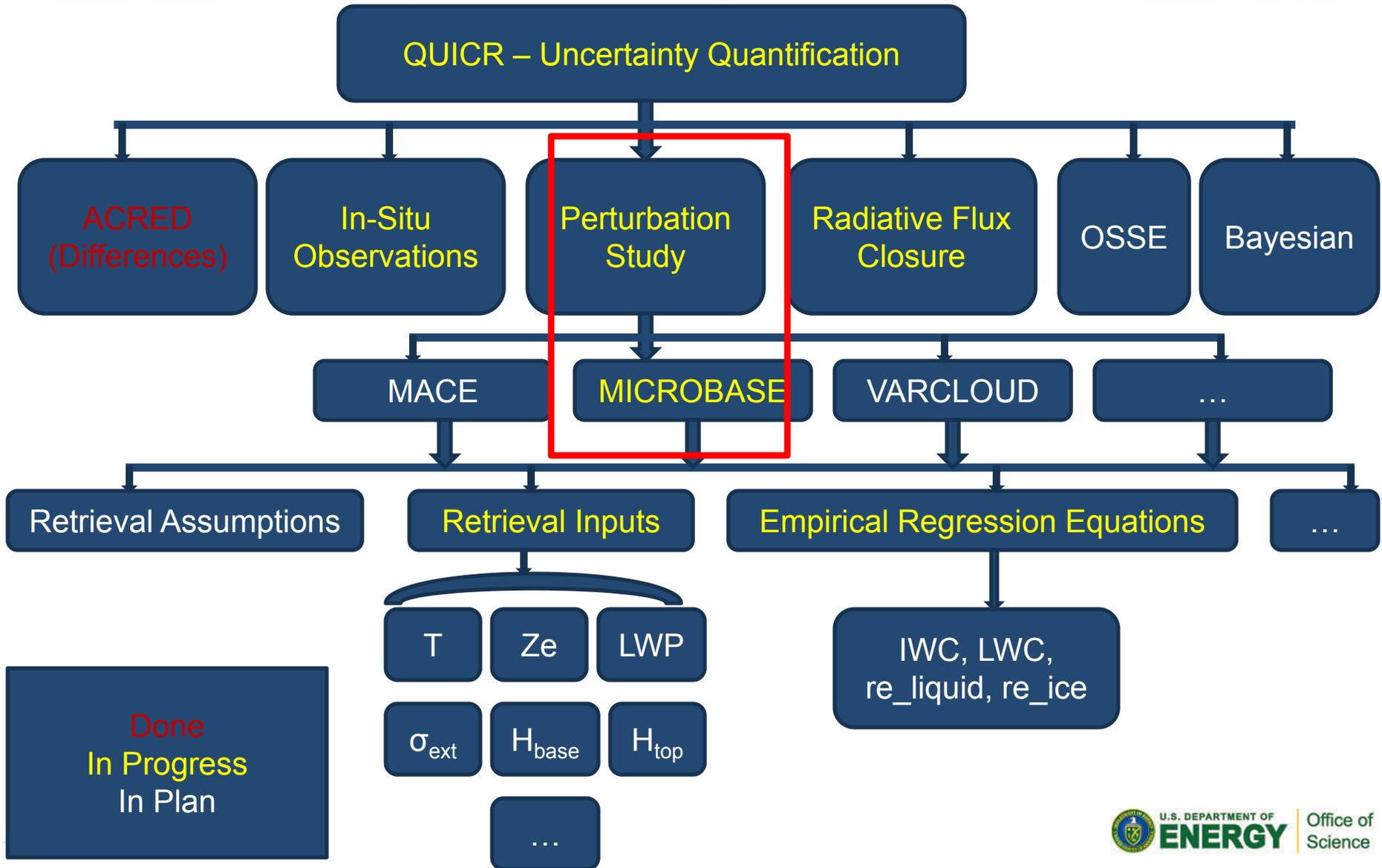
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Large Differences Among Retrievals

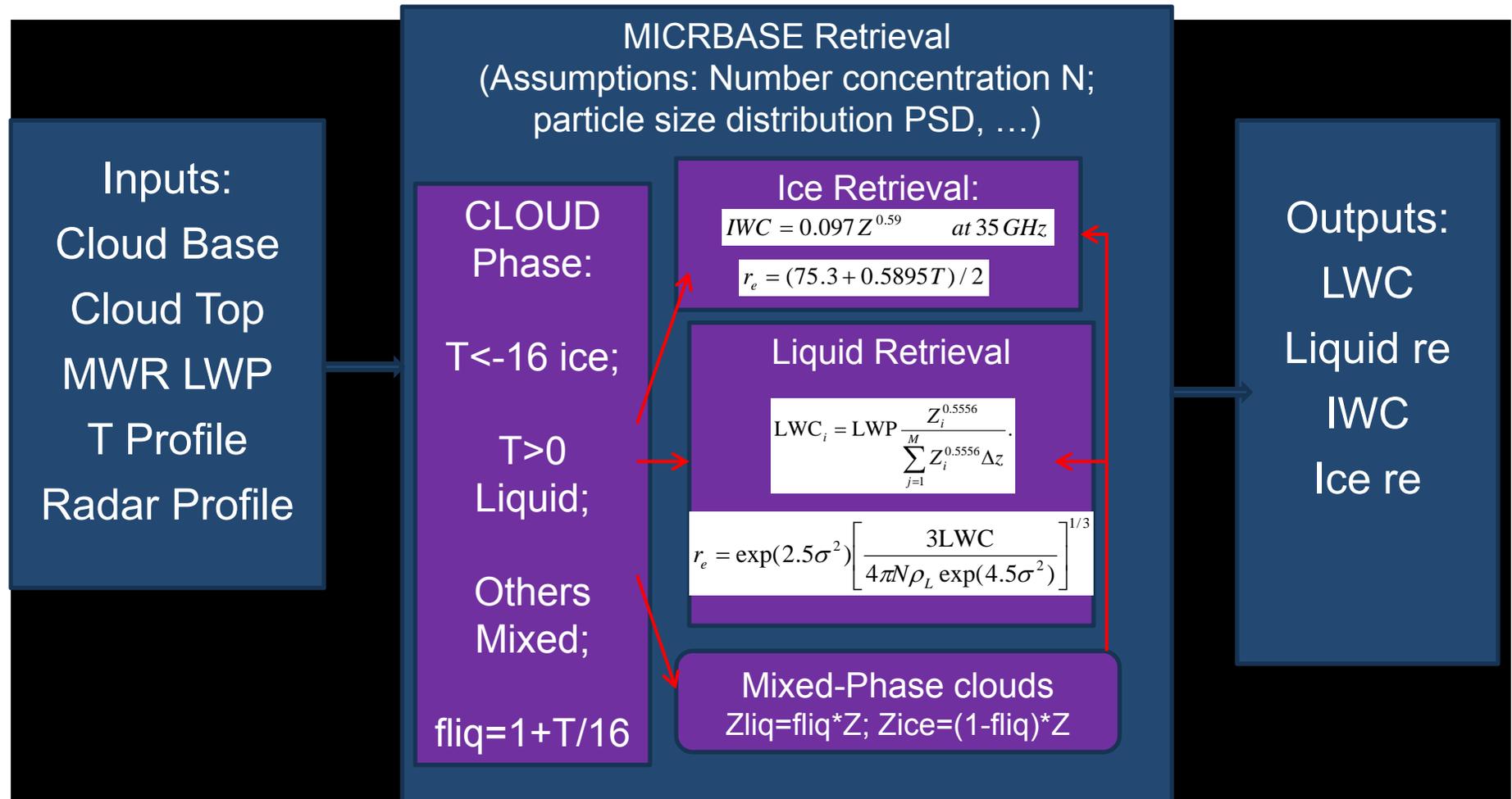
Comstock et al. 2007
Turner et al. 2007
Shupe et al. 2008
Huang et al. 2011
Zhao et al. 2011



Research Activities



Structure of MICROBASE Retrievals



Three Types of Uncertainties

1. Uncertainties from the Input Measurements

- LWC: LWP, Z_e
- Liquid re: LWP, Z_e
- IWC: Z_e
- Ice re: Temperature

2. Uncertainties from the Retrieval Assumptions

- Liquid re: N, sigma Assumption; (Others are in progress)

3. Uncertainties from the Retrieval Empirical Regression Equations

- LWC: $LWC \sim Z_e$
- IWC: $IWC \sim Z_e$
- Ice re: $r_e \sim T$

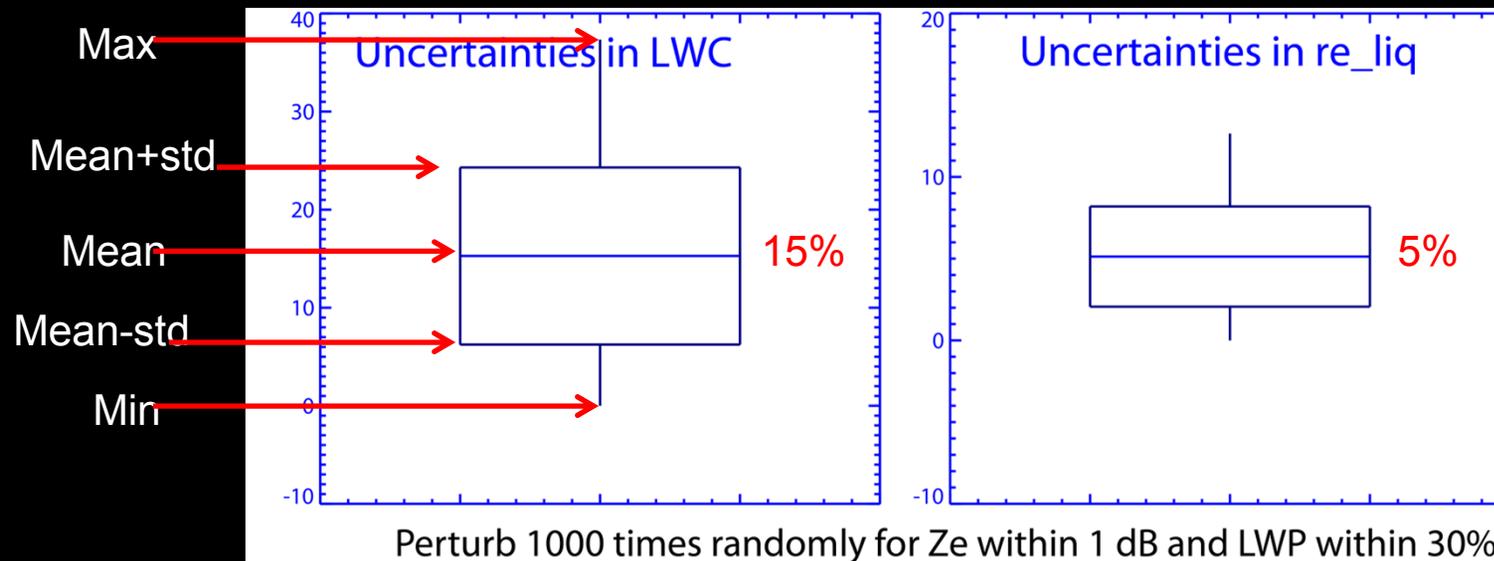
1. Uncertainties from Retrieval Inputs:

Properties	Inputs	Inputs Errors	UQ method	Retrieval Uncertainties
LWC	LWP; Ze	LWP (30%); Ze (1 dB)	Perturbation Method	
Liquid re	LWC	-	$\frac{d\ln re}{d\ln lwc} = 1/3$	
IWC	Ze	0.5 dB	$\frac{d\ln IWC}{d\ln Ze} = 0.59$	Within 7%
Ice re	T	1 K	$\frac{dre}{dT} = 0.295$	For ice re between 10-38 um, uncertainty is 3%-1%

Perturbation method for LWC

Randomly perturb 1000 times to LWP within 30% and Ze within 1dB at the same time without considering the covariance between these two inputs.

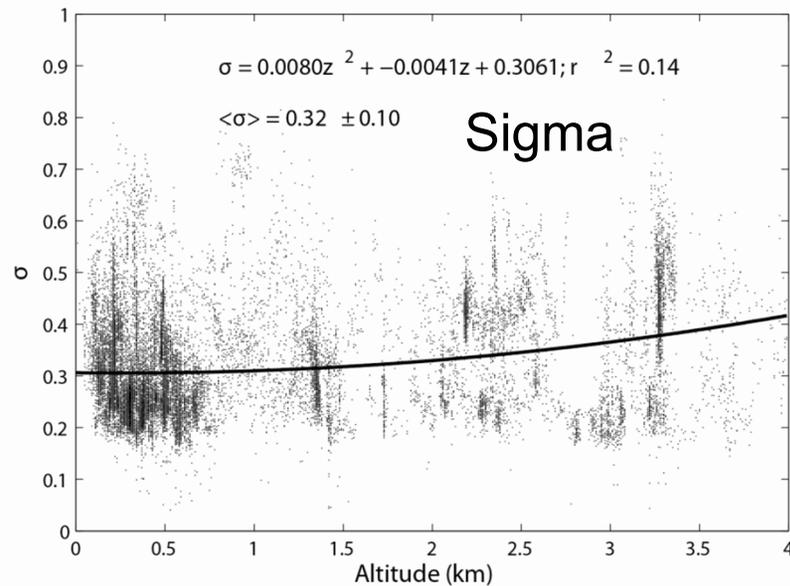
Uncertainties from Retrieval Inputs are generally low



Uncertainties (%)	LWC	Re_liq	IWC	Re_ice
Mean (std)				
From Inputs	15 (10)	5 (3)	Within 7%	1-3%

2. Uncertainties from Assumptions: Liquid r_e – Nd and sigma

MICROBASE has assumed $N=200 \text{ cm}^{-3}$ and $\sigma=0.35$ in the retrieval process. However, N could vary a lot (we examine the range of 50 to 350 cm^{-3} , while it could be broader) and σ could vary between 0.2 and 0.6.



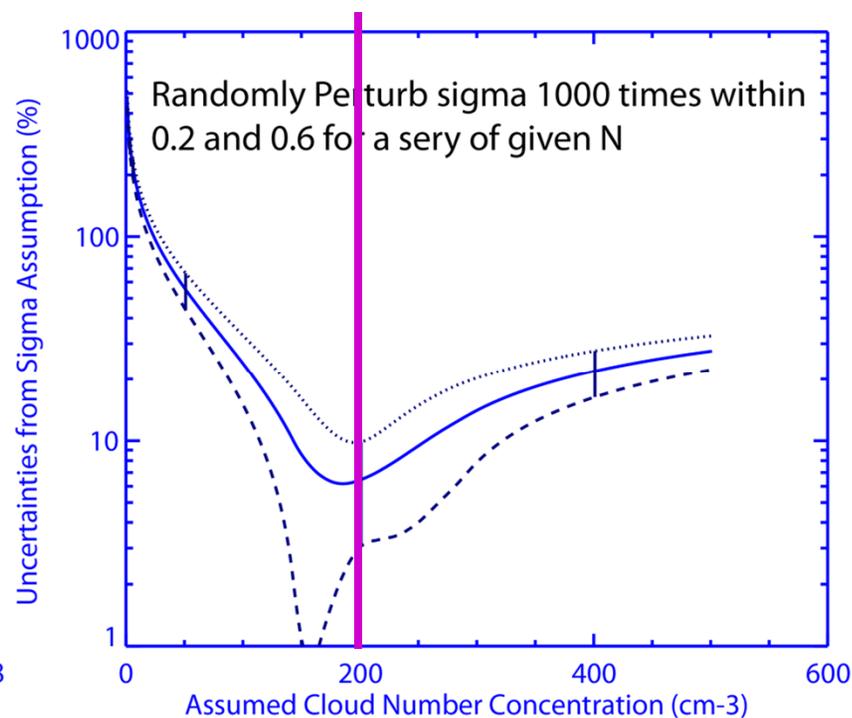
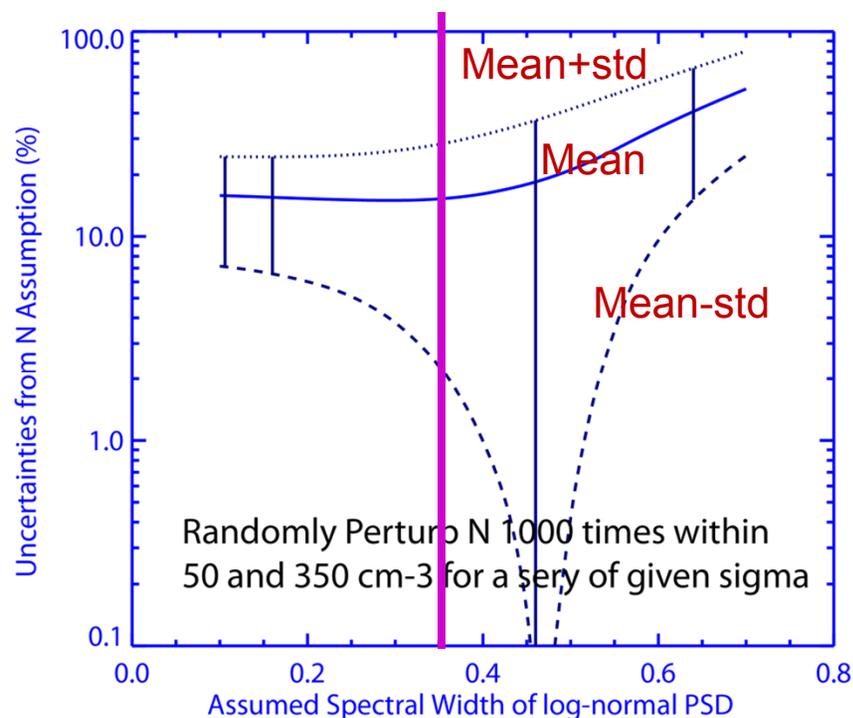
Zhao, 2007 (Phd Thesis)

**Sigma: 0.1-0.7
(Mainly 0.2-0.6)**

Figure 4.17: Measured standard deviation of a log-normal size distribution from UW CV580 aircraft measurements during The First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE) - Arctic Cloud Experiment (ACE) in 1998.

Uncertainties from Assumptions: for Liquid r_e are large

Other assumptions?



Uncertainties (%) Mean (std)

Re_liq

From Assumptions in N (sigma=0.35)

15 (15)

From Assumptions in sigma (N=200)

7 (5)

From Assumptions in both N and sigma

??

3. Uncertainty from Empirical Regressions for Liquid properties

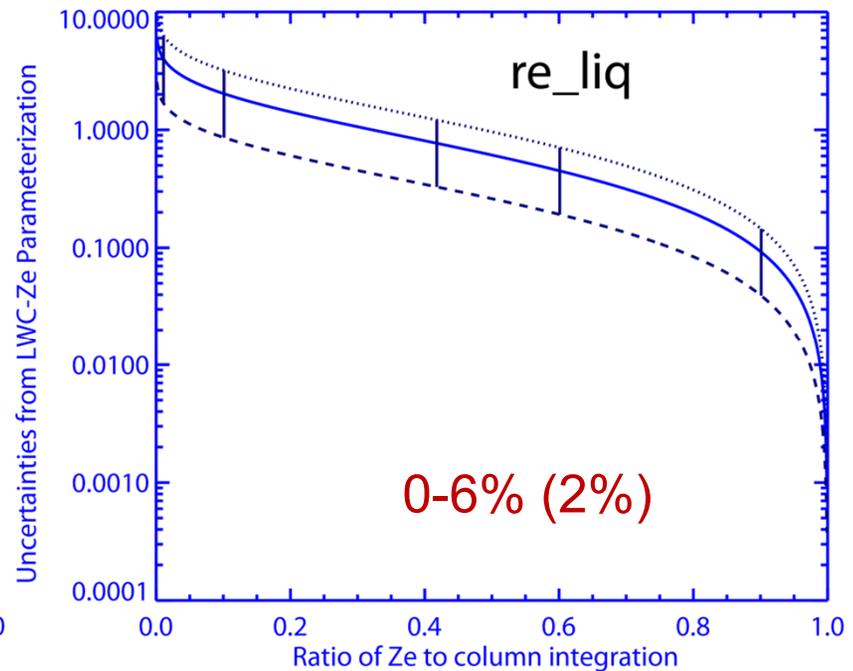
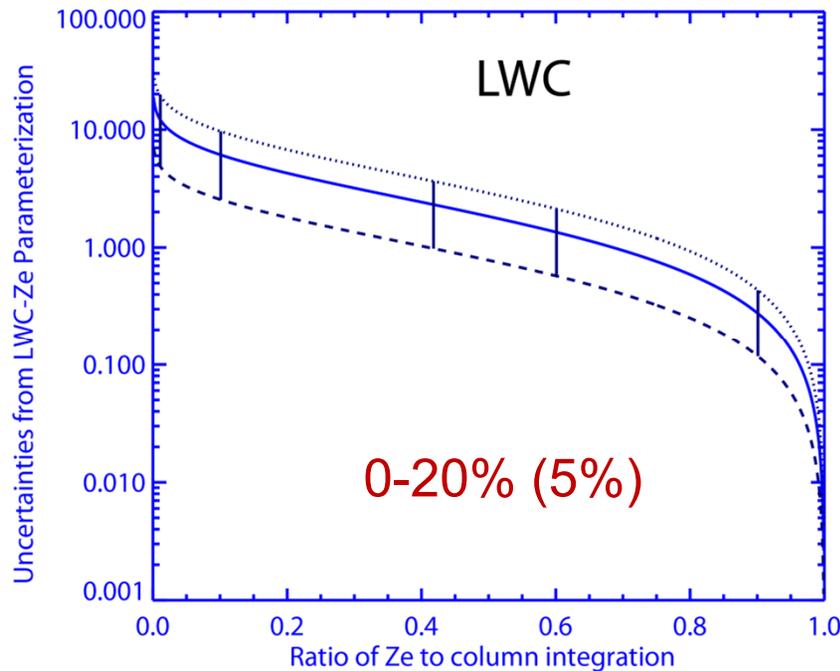
MICROBASE
$$\text{LWC}_i = \text{LWP} \frac{Z_i^{0.5556}}{\sum_{j=1}^M Z_j^{0.5556} \Delta z_j}$$

$$\text{LWC}_i = \text{LWP} \frac{Z_i^b}{\sum_{j=1}^M Z_j^b \Delta z_j}$$

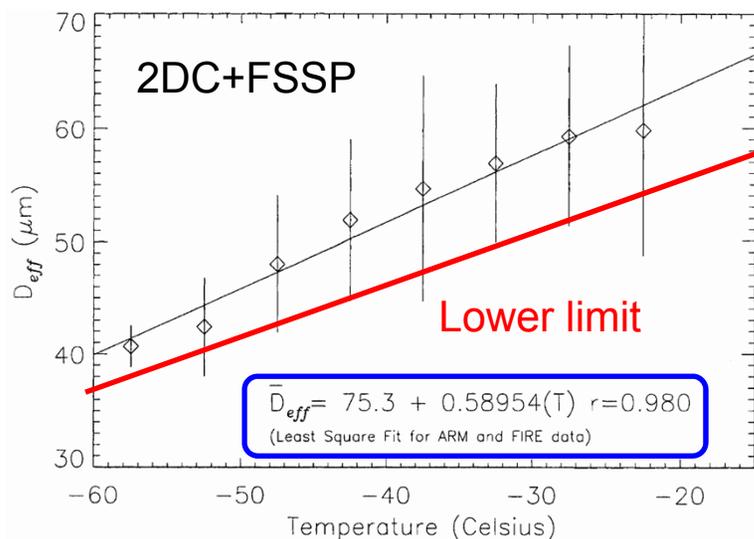
$$\text{LWC}_i = \text{LWP} \frac{Z_i^{0.5}}{\sum_{j=1}^M Z_j^{0.5} \Delta z_j}$$
 MACE

Method

For different ratio of radar reflectivity relative to the column integrated value, we randomly perturb the parameters b between 0.5 and 0.606.

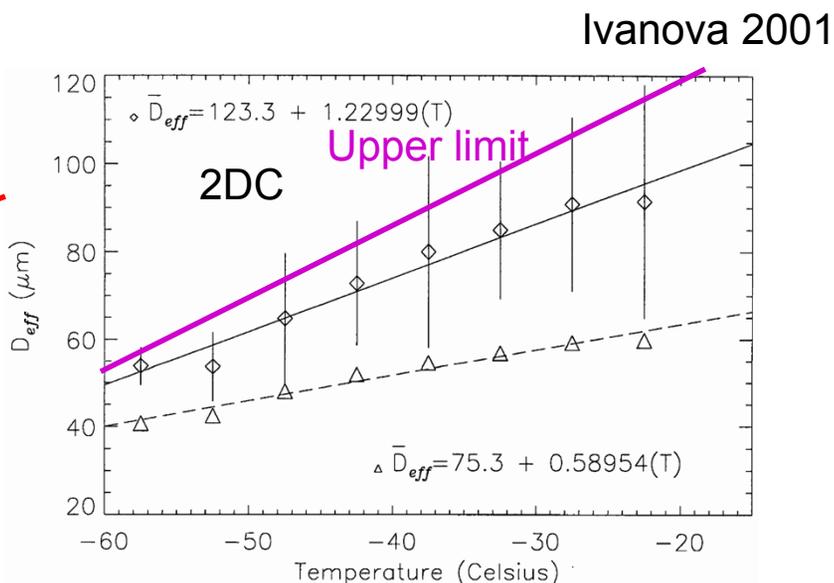


Uncertainty from Empirical Regression for Ice r_e



$$r_e = (64.4 + 0.4622T) / 2$$

$$= 15.1 + 0.2311(T + 73.81)$$



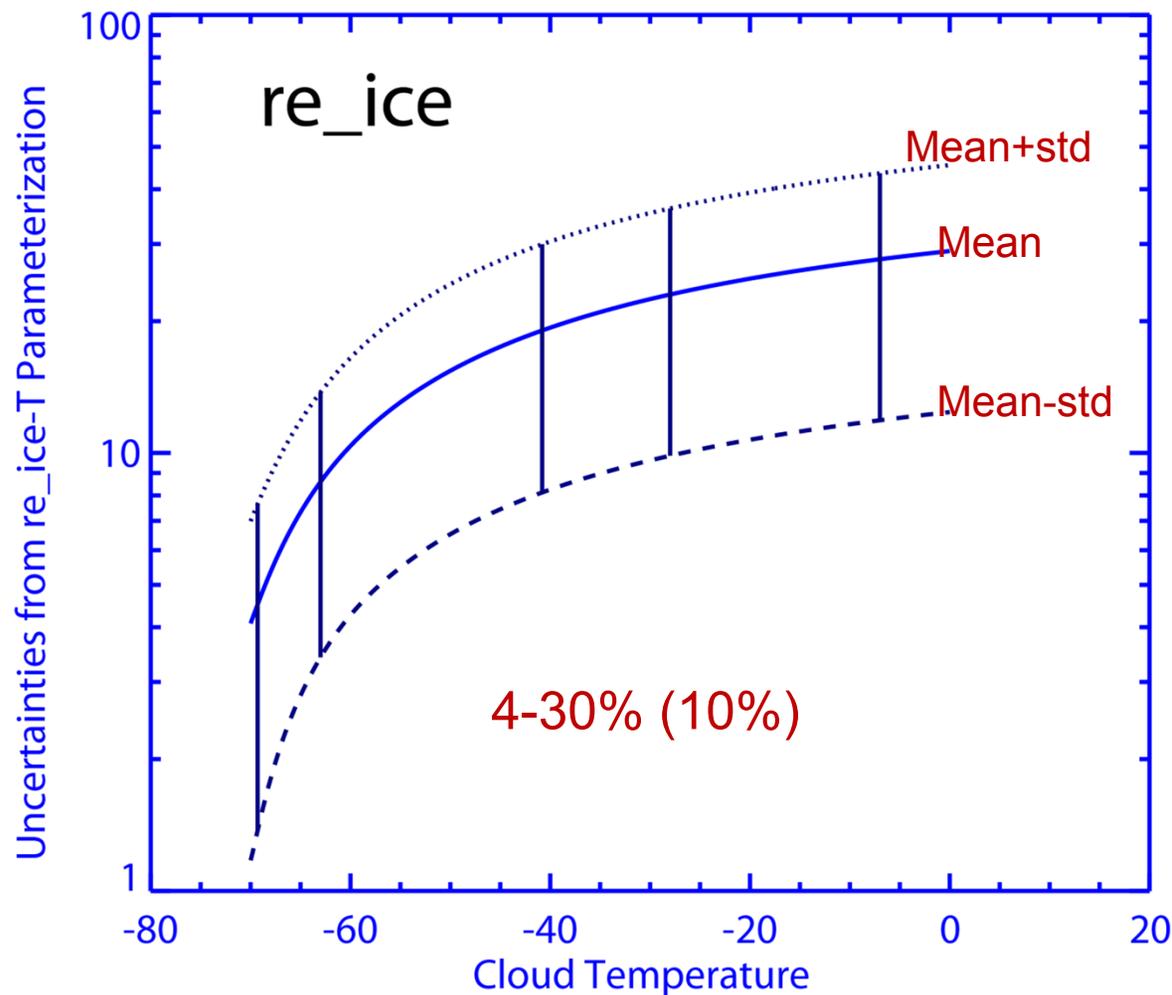
$$r_e = (151.5 + 1.6422T) / 2$$

$$= 15.1 + 0.8211(T + 73.81)$$

Method

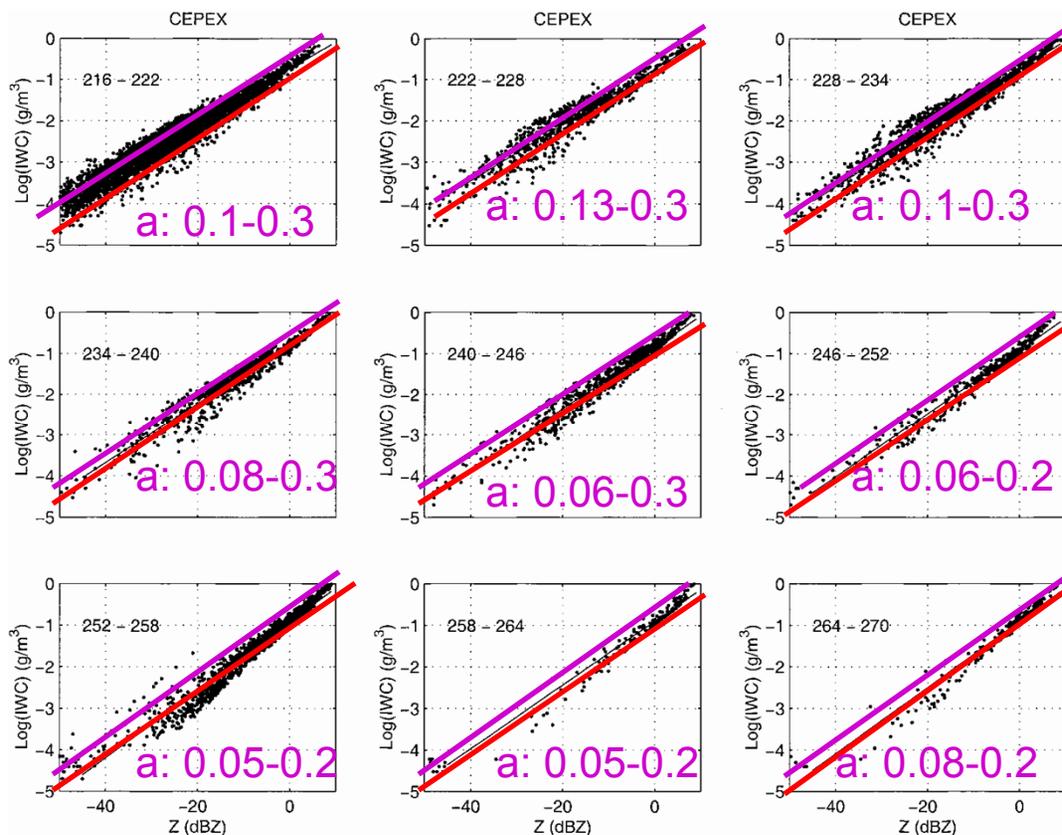
$r_e = a + b(T + c)$: We quantify the retrieval uncertainty from this regression by randomly perturbing b 1000 times within 0.2311-0.8211 and comparing them to MICROBASE;

Uncertainty from Empirical Regression for Ice $r_e \sim 4-30\%$



Uncertainty from Empirical Regression for IWC

Liu and Illingworth 2001



CEPEX: Central Equatorial Pacific Experiment

$$IWC=0.0977Z_e^{0.596}$$

FIRE: FIRST ISCCP Regional Experiment

$$IWC=0.064Z_e^{0.58}$$

MICROBASE

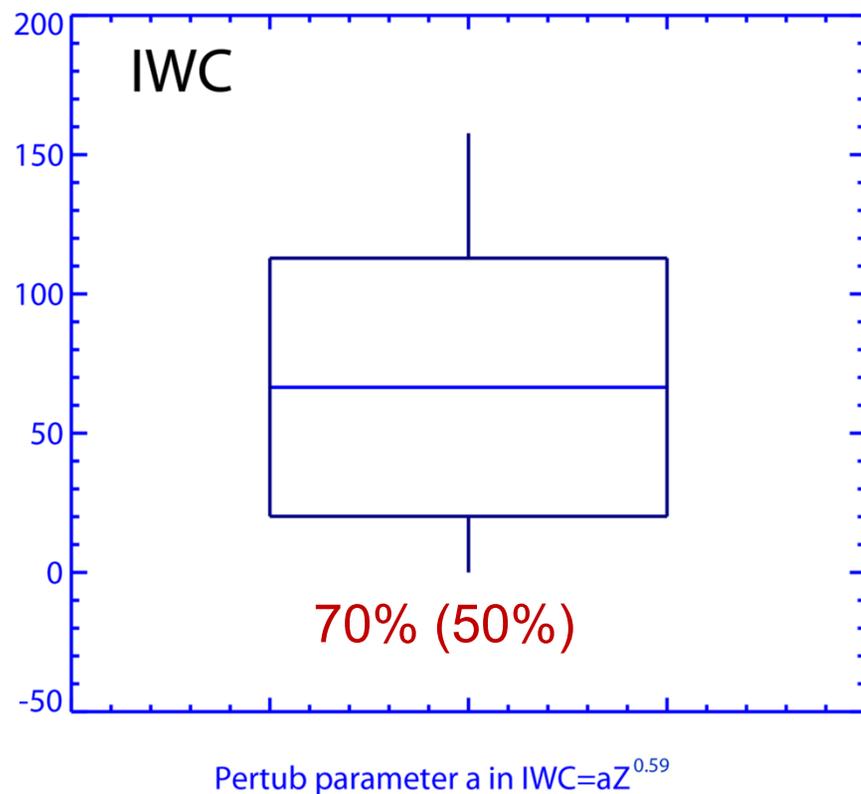
$$IWC=0.097Z_e^{0.59}$$

Method

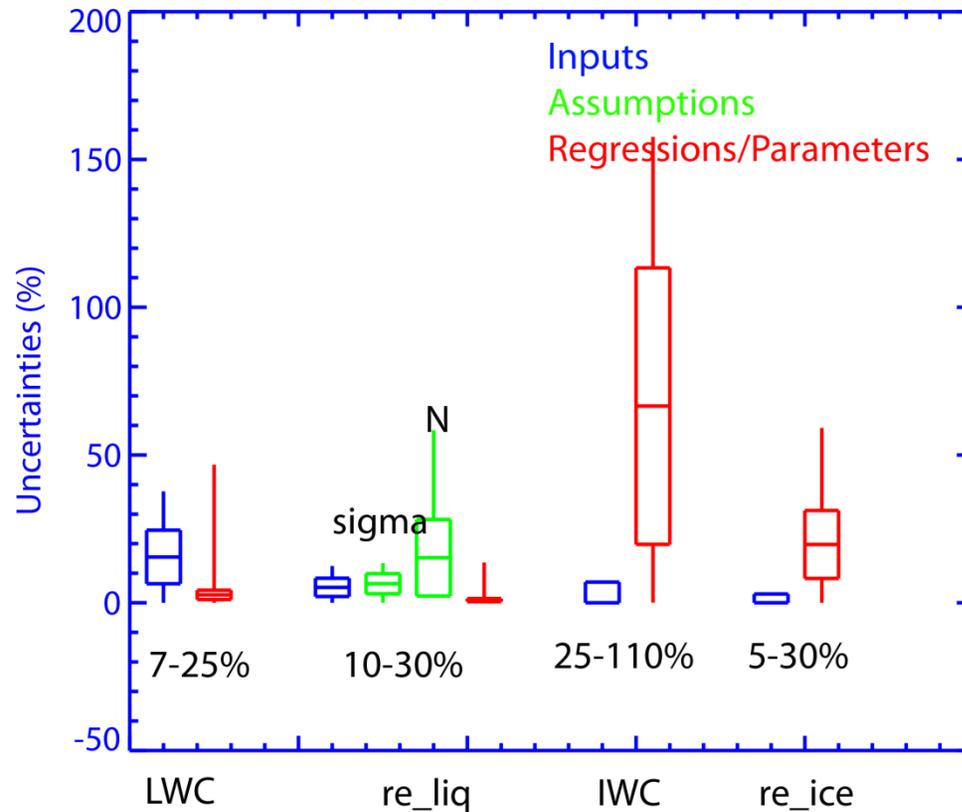
For $IWC=aZ_e^{0.59}$; we randomly perturb parameter a 1000 times within 0.05 – 0.25

Relative uncertainties should be $\text{abs}(a/0.097-1)*100\%$ with a maximum of 160%, not related to Z_e

Uncertainty from Empirical Regression for IWC ~70%



Summary of Retrieval Uncertainties



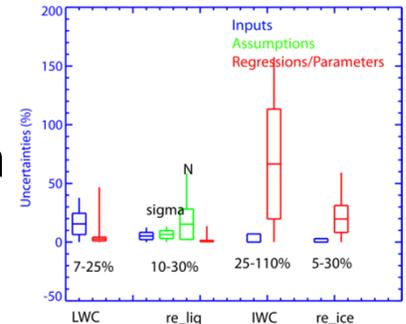
For LWC, uncertainty related to inputs dominates, 7-25%

For re_liq, uncertainty related to assumptions (particularly in N) dominates, 10-30%

For IWC and re_ice, uncertainty related to empirical regressions dominates, which are 20-110% and 5-30%, respectively.

Remaining Issues

- We have randomly perturbed the inputs, assumptions, and regression parameters with a uniform distribution. Further studies with accurate PDFs in assumptions and regression parameters are needed.
- Uncertainties from other assumptions are not considered (like PSD, Ice crystal habits, ...)
- Uncertainties for mixed-phase clouds have not been examined in this study: more information about the accuracy of the Ze partition between liquid and ice is needed.
- Uncertainties from different factors need be combined
- More in-situ measurements are needed to determine accurate empirical regressions for different cloud regimes. Then uncertainties for different cloud regimes could be studied/evaluated.



Thanks and Questions ...