Preliminary Analysis of Uncertainties in Current Boundary Layer Clouds Retrievals over ARM Sites

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Overview

- Cloud Retrieval Ensemble Data (CRED)
- Retrieval Techniques

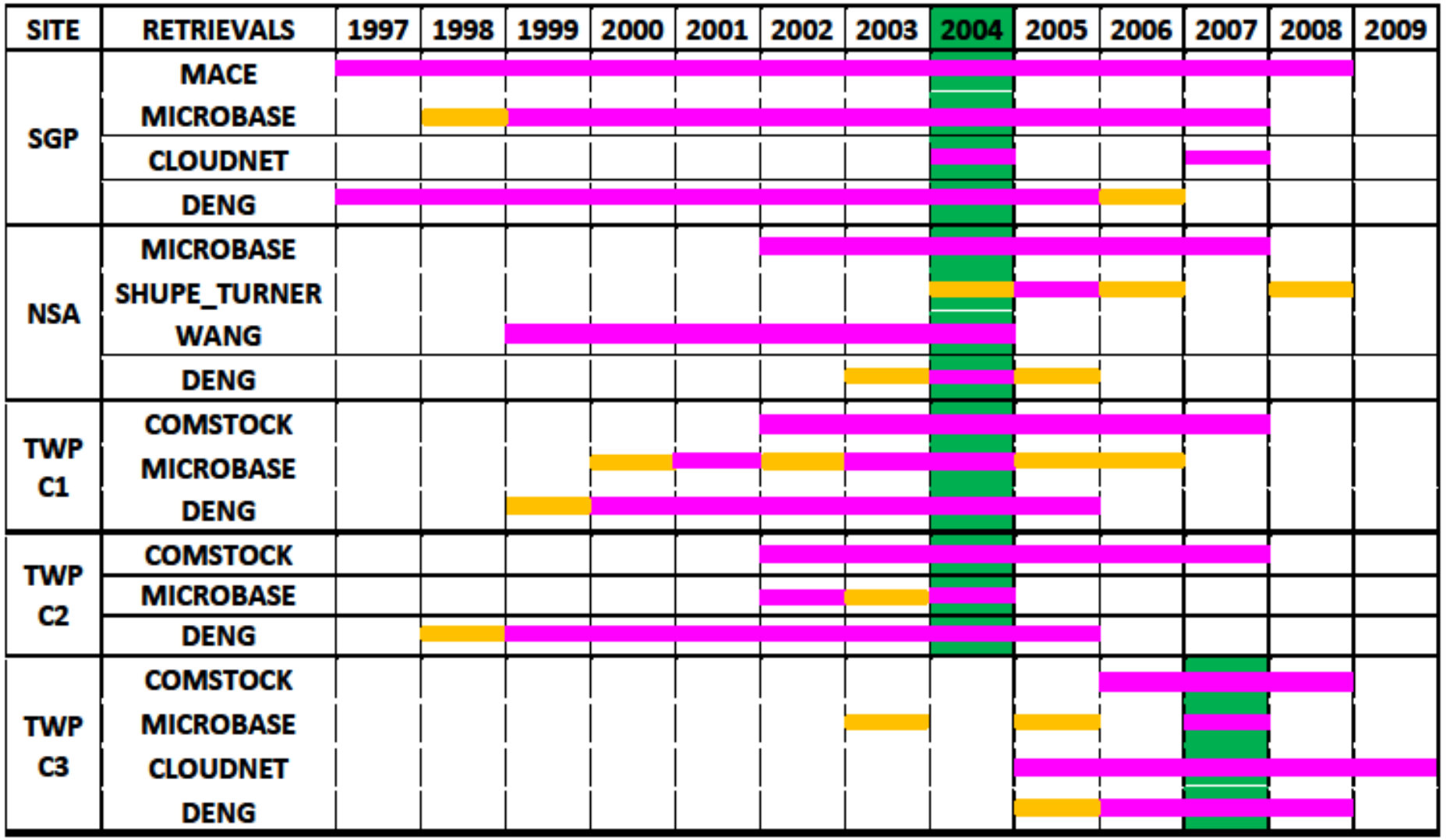
  - Boundary Layer Clouds Retrieval

  - Uncertainty related Technique issues
- Boundary Cloud Properties and Uncertainties

  - SGP

  - NSA
- Summary

1. Data: Cloud Retrieval Ensemble Data (CRED) over ARM Sites



Note that Purple bar means whole year, yellow bar means partial year.

2. Retrieval Techniques – Boundary Clouds (H<2 km)

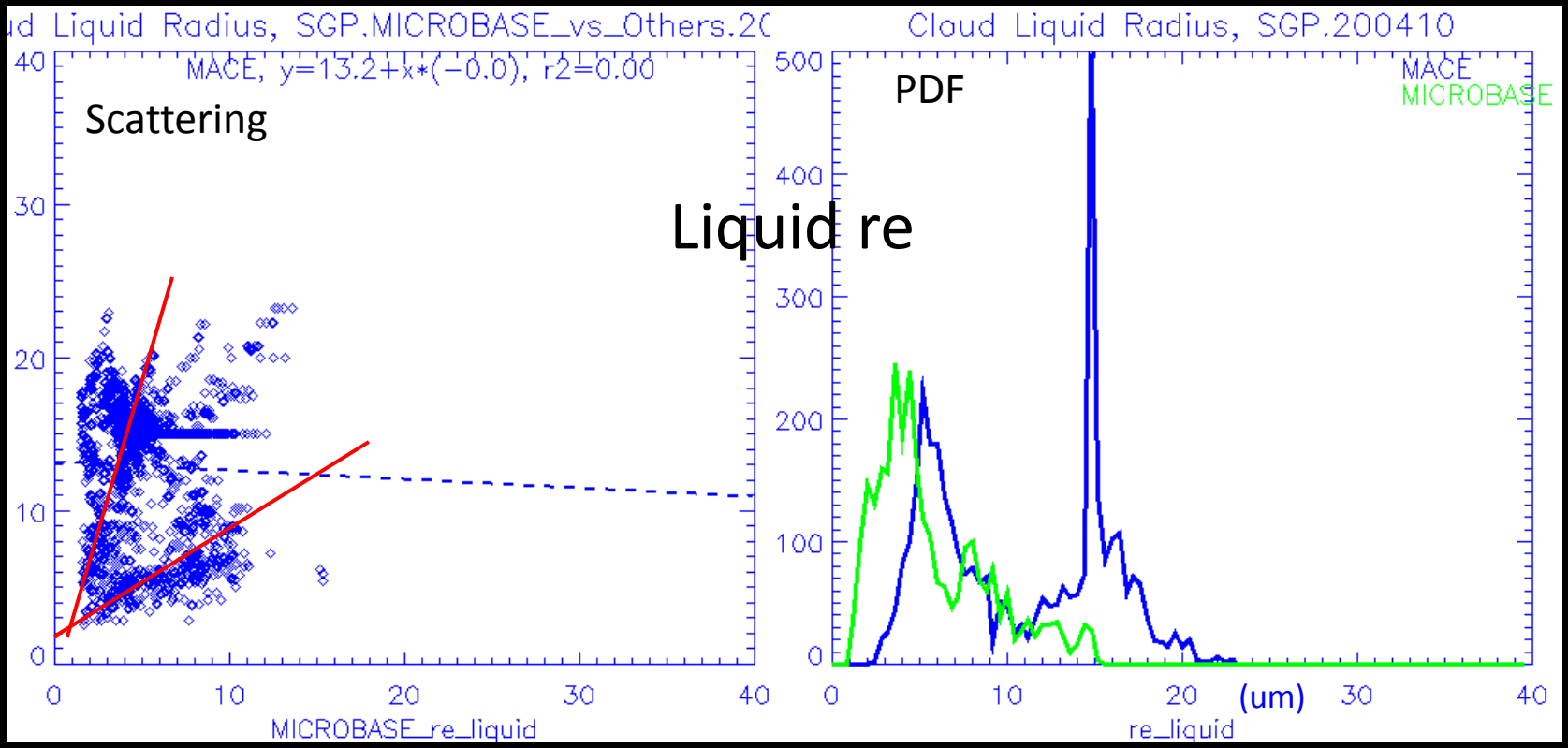
Method	Include Refs	Clouds	PSD	Measure	Comments
MACE	Mace1998	Thin Stratus	Modified Gamma (α=1)	Z, R	Iteration method to converge ε using DISORT; Sensitive to ΔH and T
	CCM3 (Kiehl1998)	All clouds	-	T, P	Diagnostic Parameterization; limited sizes ranges (L: 5-30 um; I: 10-30 um)
	Dong1998	boundary layer stratus	log-normal (σ=0.35)	MWR, T, R	Regression parameterization; Thin: D97; thick: big uncertainty;
	Dong&Mace2001	boundary layer stratus	Log-normal	MWR, Z	LWC(h) ~ F(Z, LWP) (F98); Re(h) ~ F(Z, re_m) or $Re(h)=ae^{0.0394dBZ(h)}$; re_m from D98;
	Frisch1998	stratus	-	MWR, Z	Regression method LWC(h) ~ F(Z, LWP) ; Assuming $\langle r^6\rangle \sim \langle r^3\rangle^2$
MICROBASE (JENSEN)	Liao&Sassen1994 - LWC; Frisch1995 - re	Liquid	Log-normal (σ=0.35)	Z, MWR	Regression Method: $Z=3.6LWC^{1.8}/N$; re~F(LWC, N); (Z-LWC) vapor/droplet competition restricts large sizes;
	Liu&Illingworth2000 - iwc; Ivanova2001- re	Ice	Exponential	Z, T	Empirical/regression relationships : $IWC=0.097Z^{0.59}$ g m^{-3} ; re=(75.3+0.5895T)/2
	see above	Mixed	above	Above	Liquid_Z=(1-T/16)*Z; Ice Z=(T/16)*Z; above
CLOUDNET (HOGAN)	Provide by Ewan O'Connor	Liquid part (LWC)	-	T, P, MWR	Adiabatic profiler with MWR scaling Sensitive to cloud boundaries.
	Hogan2006	Ice Part (IWC)	-	T, P, Z, MWR	Regression Empirical Equation
SHUPE_TURNER	Frisch1995	Liquid only clouds	Log-normal (σ=0.30)	MWR, Z	Adjust N to match MWR LWP $Z=2^6Nr_0^6\exp(18\sigma_x^2)$ $q_l=0.30\rho_w Z^{1/2}N^{1/2}$
	Turner2005	Liquid (thin Mixed)	-	R	optimal Iteration estimate (LBLRTM and DISORT)
	Shupe2005	Ice clouds	exponential	Ze	Tuned regression approach
WANG	Wang2004	Liquid (thin Mixed)	-	MWR, R	Iteration optimal estimation (DISORT); Ice habit is hexagonal.
	Wang&Sassen2002; Wang2004	Ice (Mixed) or Ice only	Modified Gamma	Z, σ	Parameterization of lidar-radar method

Uncertainty Related Technique Issues

- Theory Basis
  - Equations, Parameters; (Z-r, V-r, M-r)
  - Radiation Closure
- Input Data/Data Process
  - Cloud Boundaries/detections
  - Liquid Water Path from MWR
  - Cloud Classifications/Categories
- Assumptions
  - Particle Habit
  - Particle Size Distribution (PSD)
  - Vertical/Horizontal Distribution

3.1 SGP Boundary Layer Clouds – Liquid re

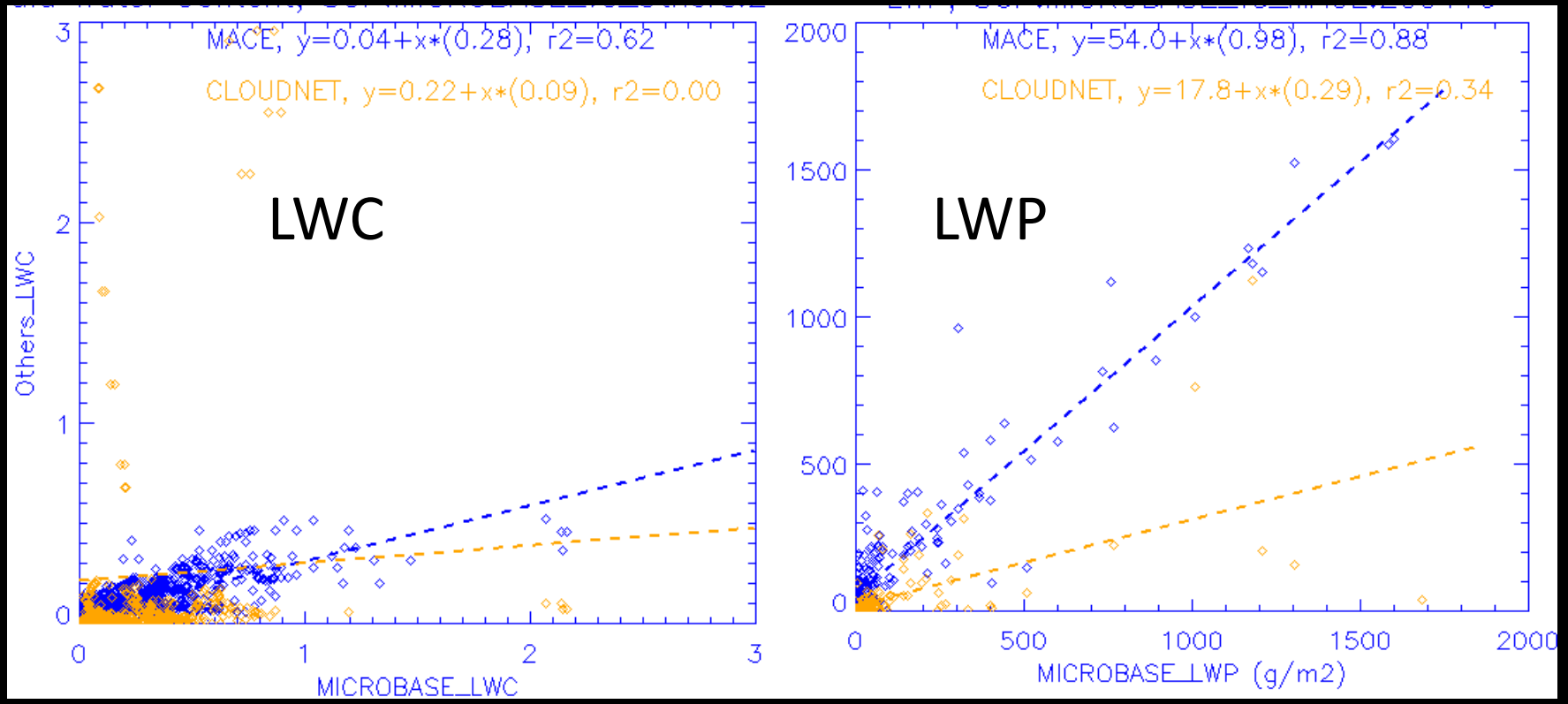
200410



- MICROBASE (Water/vapor competition) < MACE (6th relationship Z-r)
- Difference in LWC/LWP (MICROBASE: $Z \sim LWC^{1.8}/N$; $re \sim N^{-1/3}$)

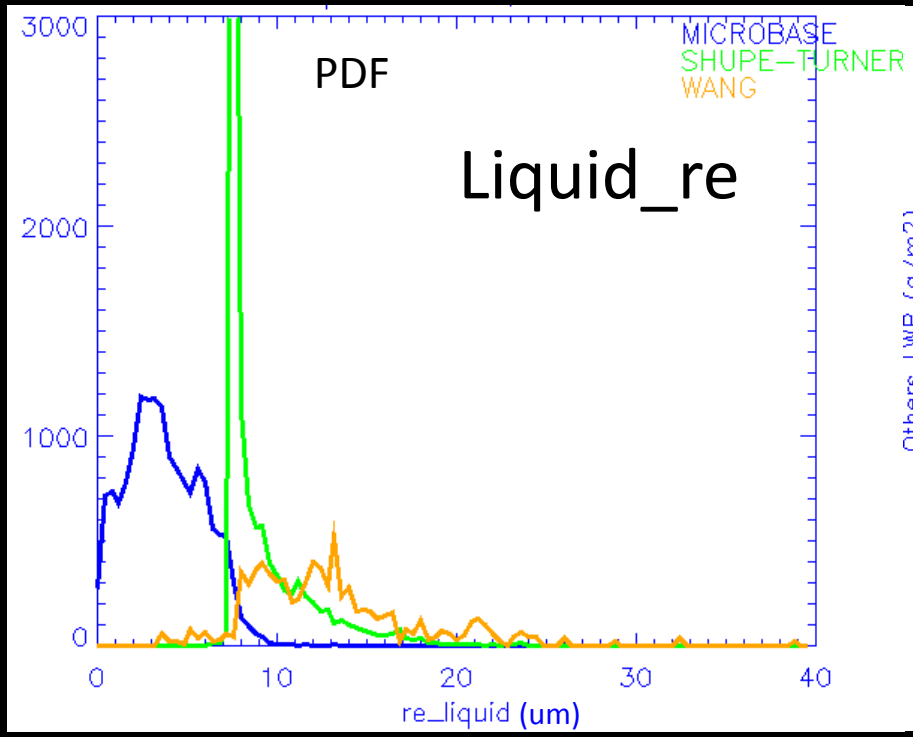
SGP Boundary Layer Clouds - LWC

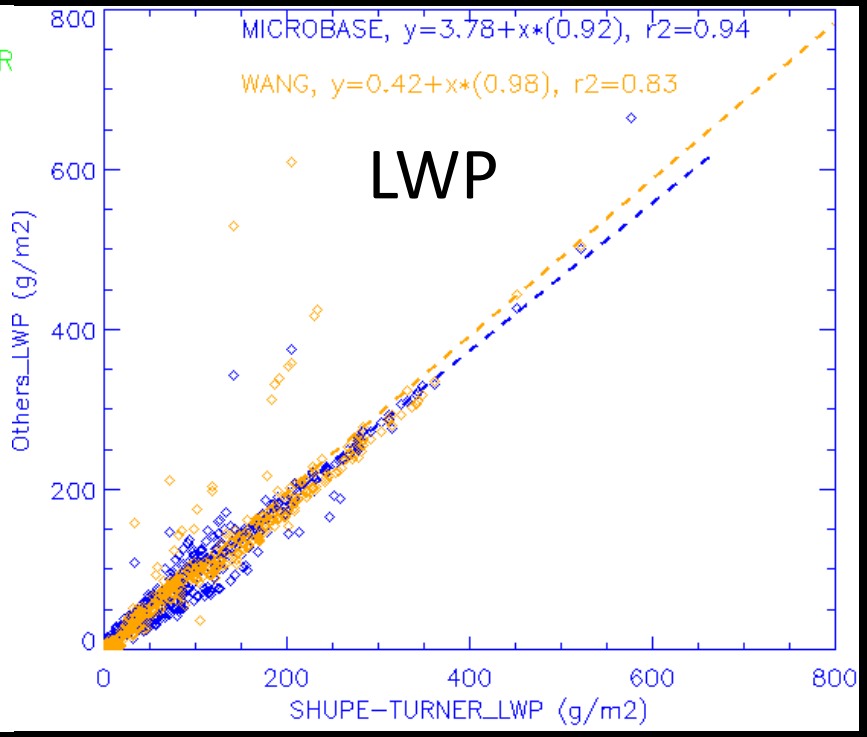
200410



- Method difference?
- Cloud detection/Cloud boundaries?
- LWP constrain? (Different Data Version or Process?)

3.2 NSA Boundary Layer Clouds -liquid part

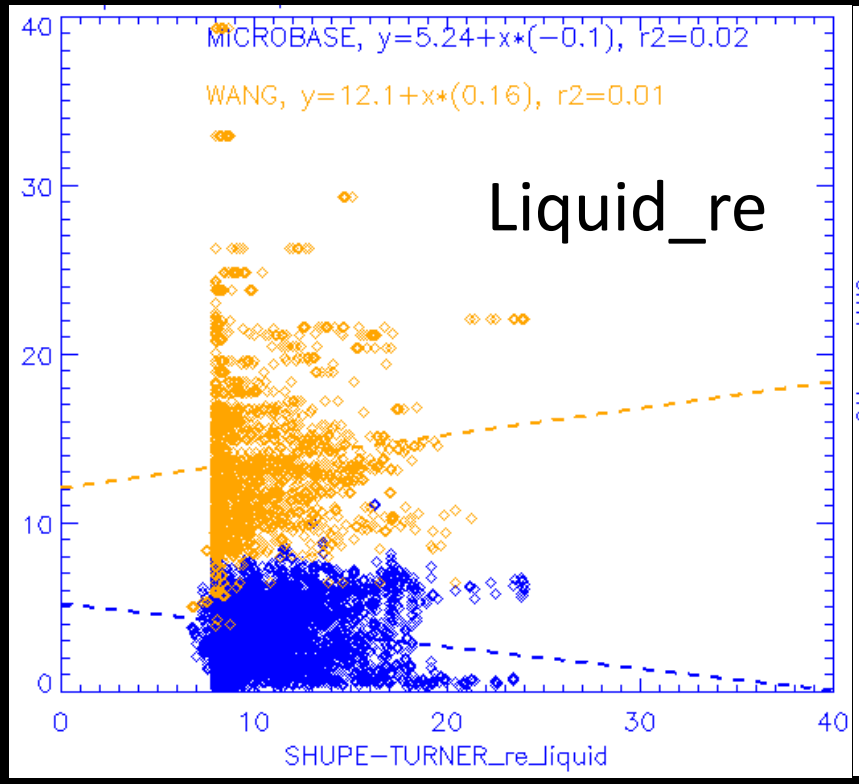


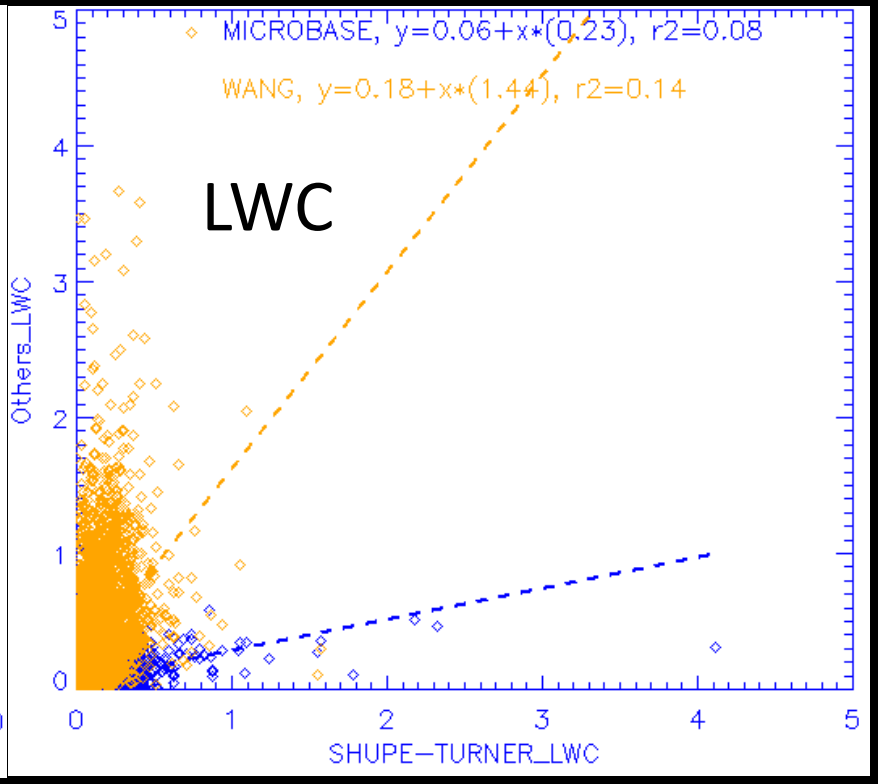


M-PACE Period: 2004.10

- re difference:
  - MICROBASE: Water/vapor competition mechanism
  - LWP difference (NO) (LWP Constrain!!)

NSA Boundary Layer Clouds -liquid part



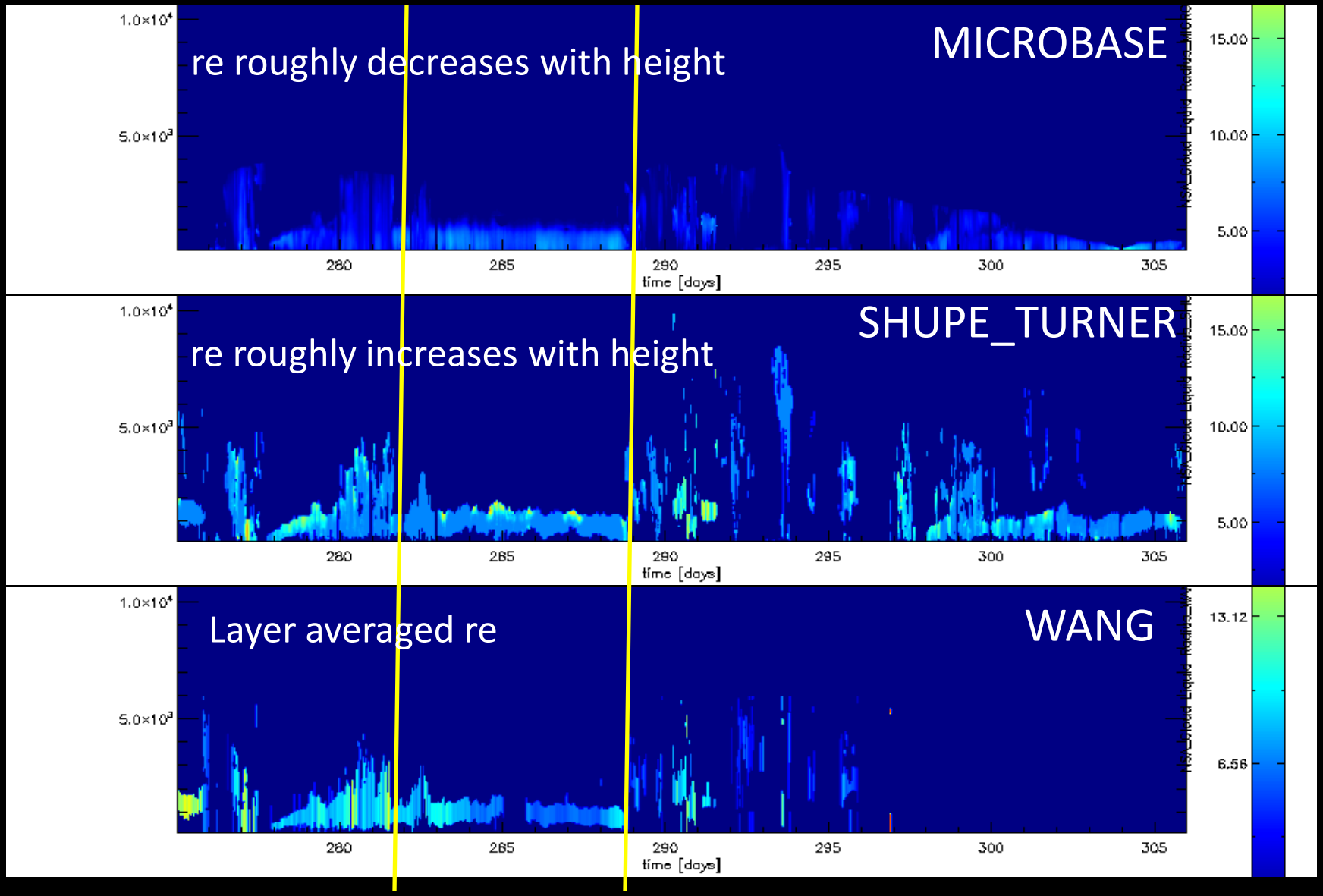


Big scattering (no correlation) (even LWP similar)?

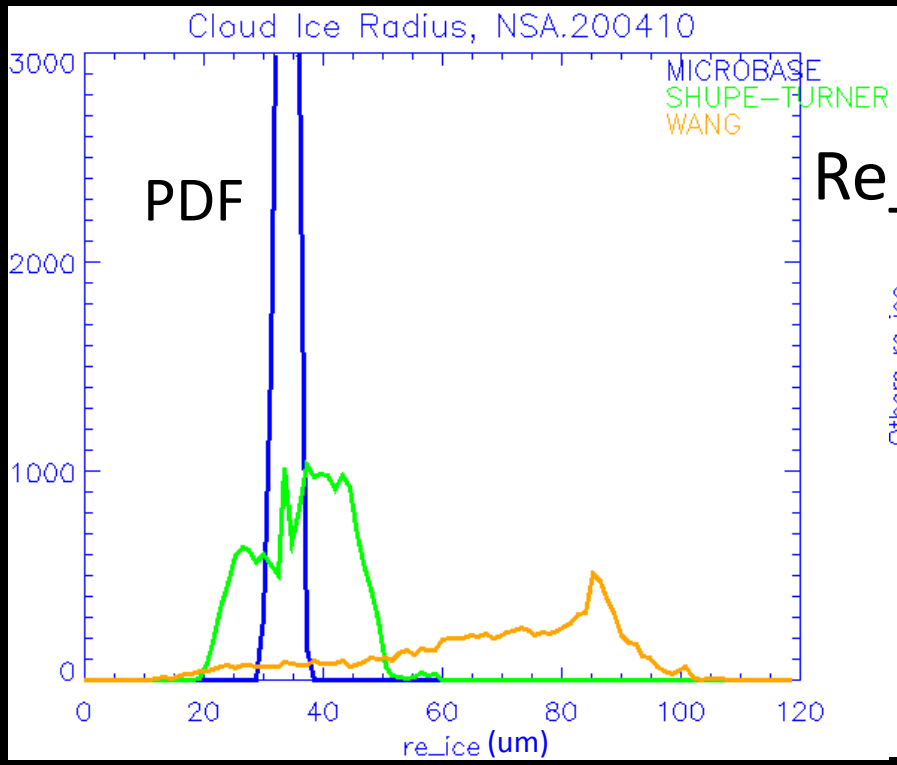
- Method difference (γ, WV, T, etc.): vertical distribution

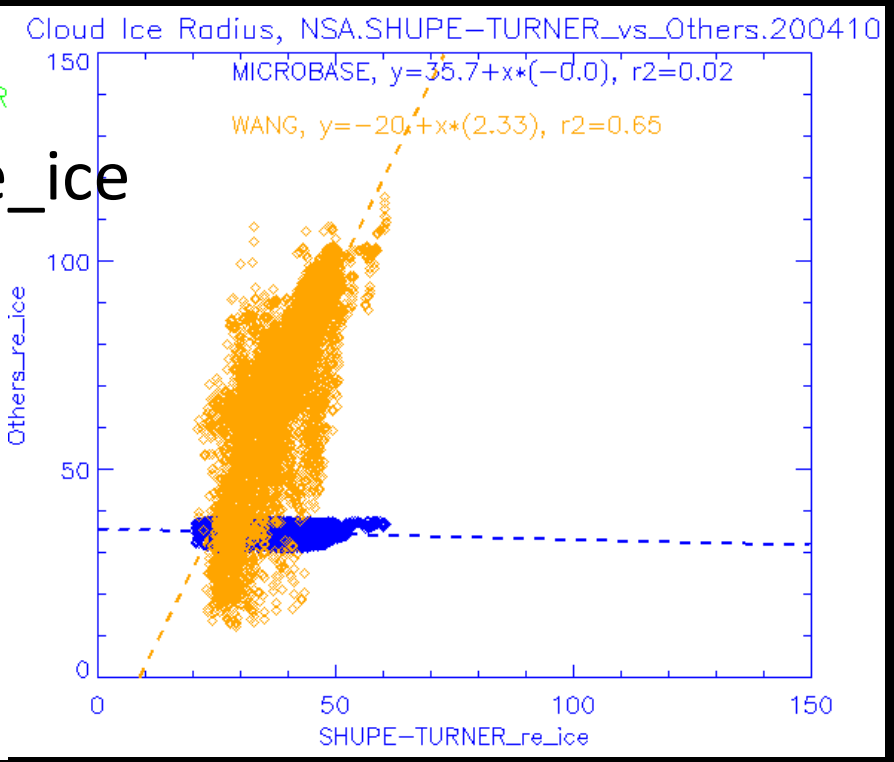
NSA Site re_liquid Different Vertical Pattern

2008.10



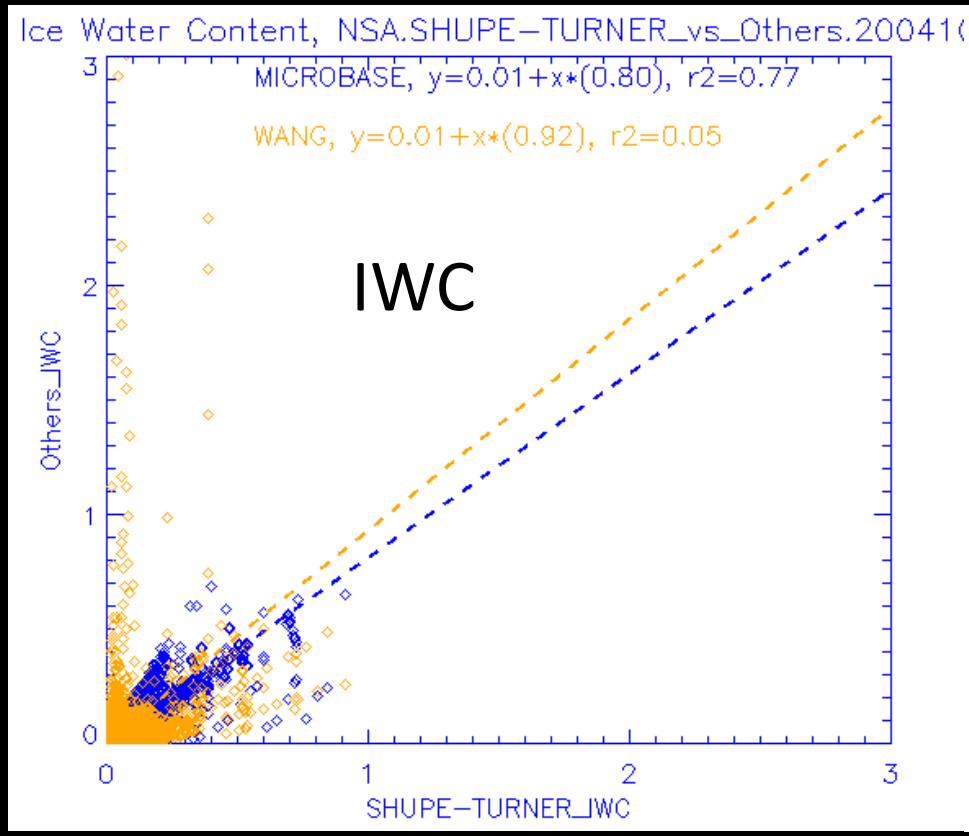
NSA Boundary Layer Clouds – Ice Part

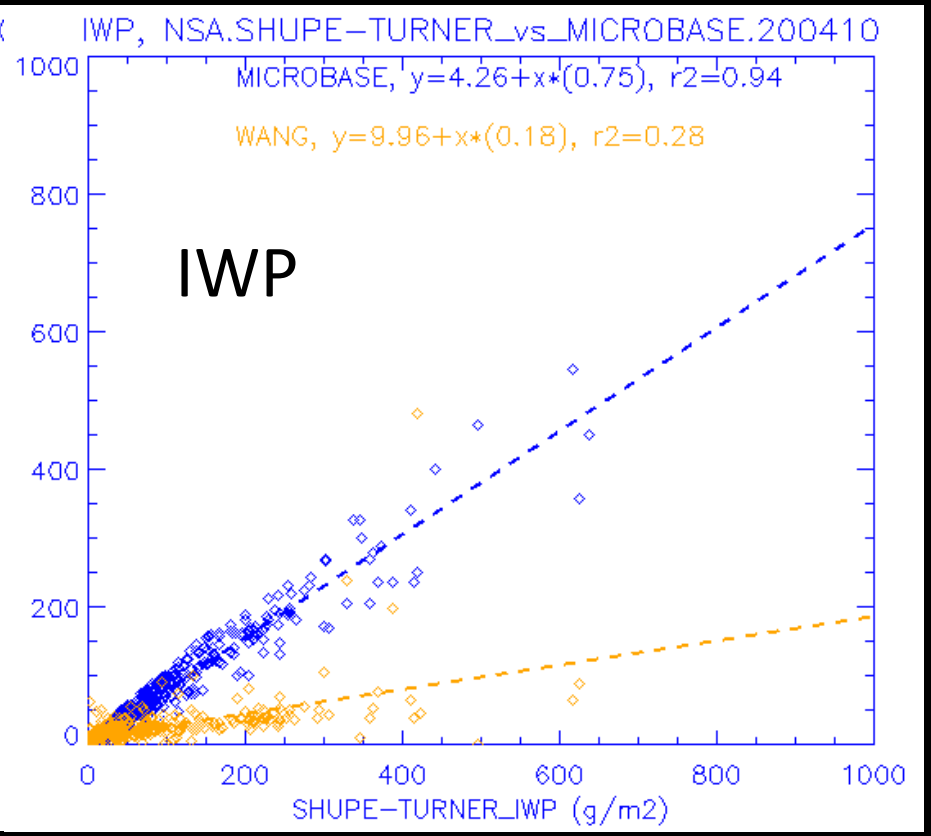




- Different Parameterization!
  - MICROBASE: T-based
  - SHUPE_TURNER: Tuned regression with exponential PSD
  - WANG: Parameterization of Z-σ with modified Gamma PSD
- PSD difference! re (exponential) < re (gamma)

NSA Boundary Layer Clouds – Ice Part





Parameterization!

- SHUPE_TURNER: $IWC=a(time)Z_e^{0.63}$
- MICROBASE: $IWC=0.097Z^{0.59}$
- WANG: $IWC \sim F(\sigma, Z_e)$, $D_{ge} \sim F(\sigma, Z_e)$;

4. Results Summary

Theory Understanding for discrepancies in Boundary cloud properties from 5 methods:

1. Principle (like Z and R); e.g. MICROBASE and MACE (liquid re)
2. Basic equations/parameterization; e.g. empirical regression between MICROBASE and SHUPE_TURNER (Ice re)
3. PSD; e.g. exponential (SHUPE_TURNER) vs gamma (WANG) (Ice re)
4. Vertical Distribution; e.g. NSA site (liquid re, lwc)
5. Input Measurements (like Cloud Detection/boundary, time resolution); e.g. CLOUDNET and MACE (LWP);
6. Others (not discussed here); e.g. ice particle habit, ice density.

5. What These Results Suggest? (Future)

- Discrepancies in different retrievals can, at least partly, be explained from their methods, assumptions and inputs;
- Worthwhile to figure out/understand likely tendency/biases of every method for easy use (Much longer period statistics)
- Using same inputs and assumptions (like cloud H and LWP), an Inter-comparison study might help understand performance of current inversion techs and bring insights to best estimates.
- Necessary for uniform evaluation of uncertainties/biases
- With uncertainties, all retrievals will provide a suggestable range; and could be combined together.

Thank you!