Comparisons between a cloud droplet parameterization, a detailed microphysical parcel model and observations

Nicole Shantz
(University of Toronto)

Knut von Salzen, Richard Leaitch,
Jon Abbatt, Rachel Chang

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Model Comparison

Comparisons between 2 models:

- Detailed microphysical adiabatic cloud parcel model (hereafter called “Parcel model”) (Shantz et al., 2003, Leaitch et al., 1986)
- Cloud droplet parameterization including Piecewise Lognormal Approximation (PLA: von Salzen 2006) (hereafter called “PLA model”)

Comparisons between Parcel and PLA model

- Output from both models that will be compared in this presentation:
  - Initial dry particle size distributions
  - Cloud liquid water content
  - Number of droplets
  - Supersaturation profiles

Also compare with observations

Why these comparisons are important

- Comparisons have been made between the detailed microphysical parcel model and observations with reasonable agreement
- The PLA model will be used as a cloud droplet parameterization in Global Climate Models
- Comparisons between Parcel and PLA model will help to:
  - Determine what values for certain variables should be used
  - Give confidence in the parameterization

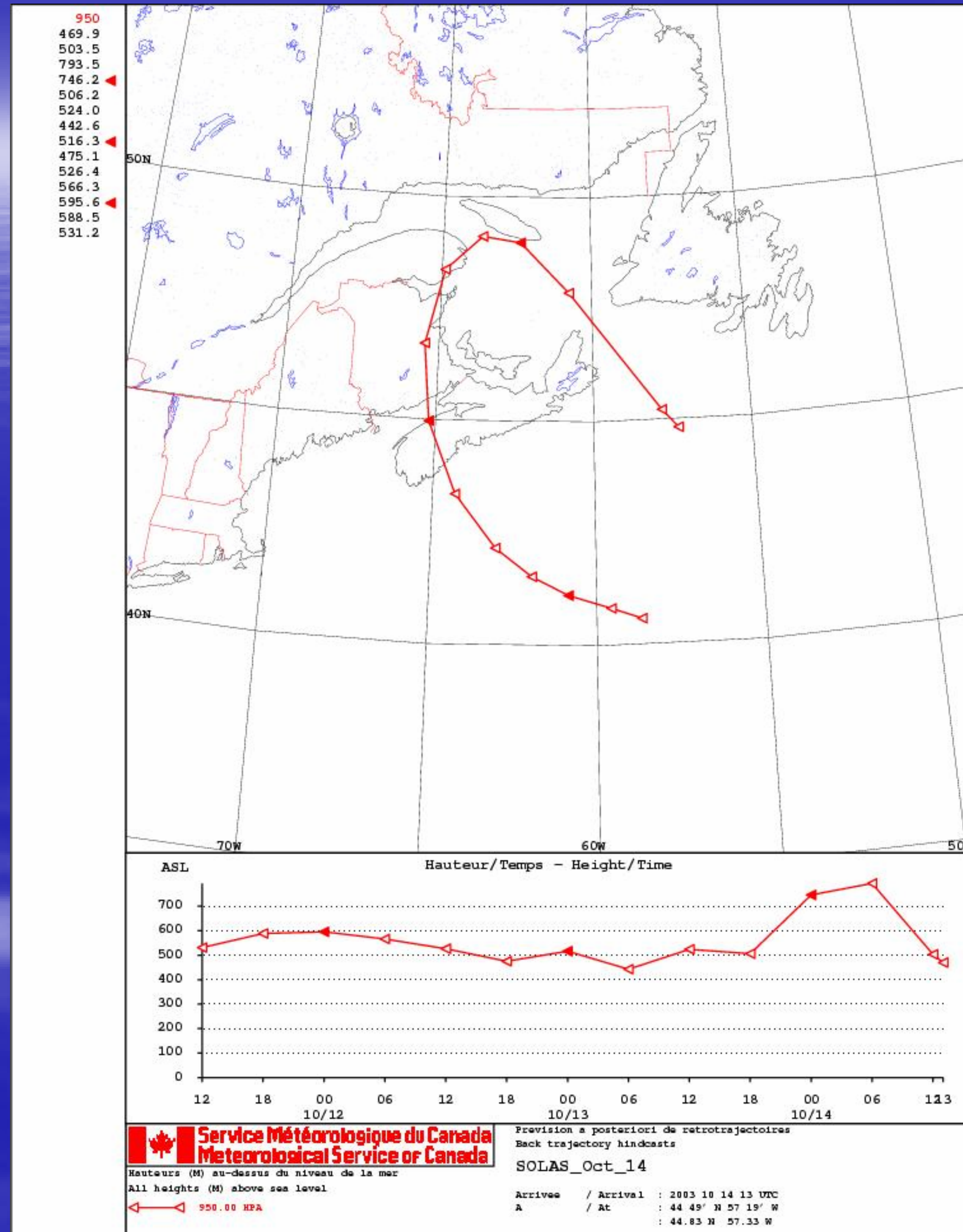
SOLAS 2003

- Canadian Surface Ocean and Lower Atmosphere Study (SOLAS)
- Flights over the Atlantic Ocean a few hundred kilometers east of Nova Scotia
- Flight 2 case studied here was on October 14th, 2003 at 12:00-13:00

Leaitch et al., in preparation, 2007.

Flight 2 from SOLAS 2003

- Trajectory analysis indicates that three days prior, the air had been over the Atlantic Ocean.
- However, it subsequently crossed over parts of eastern Canada before reaching the sampling area.
- Thus, the aerosol sampled during flight 2 had some more recent continental influence.

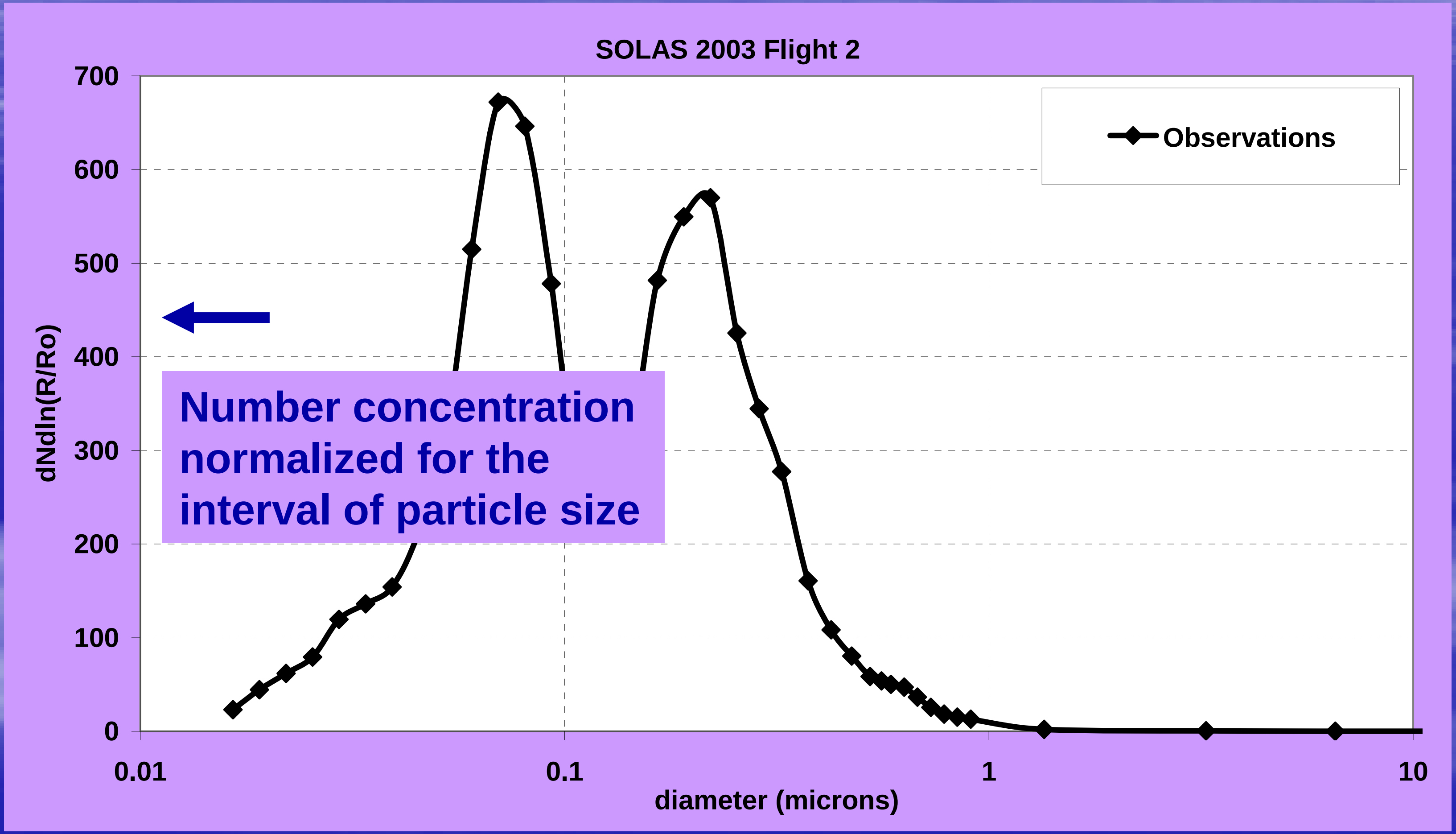


Leaitch et al., in preparation, 2007.

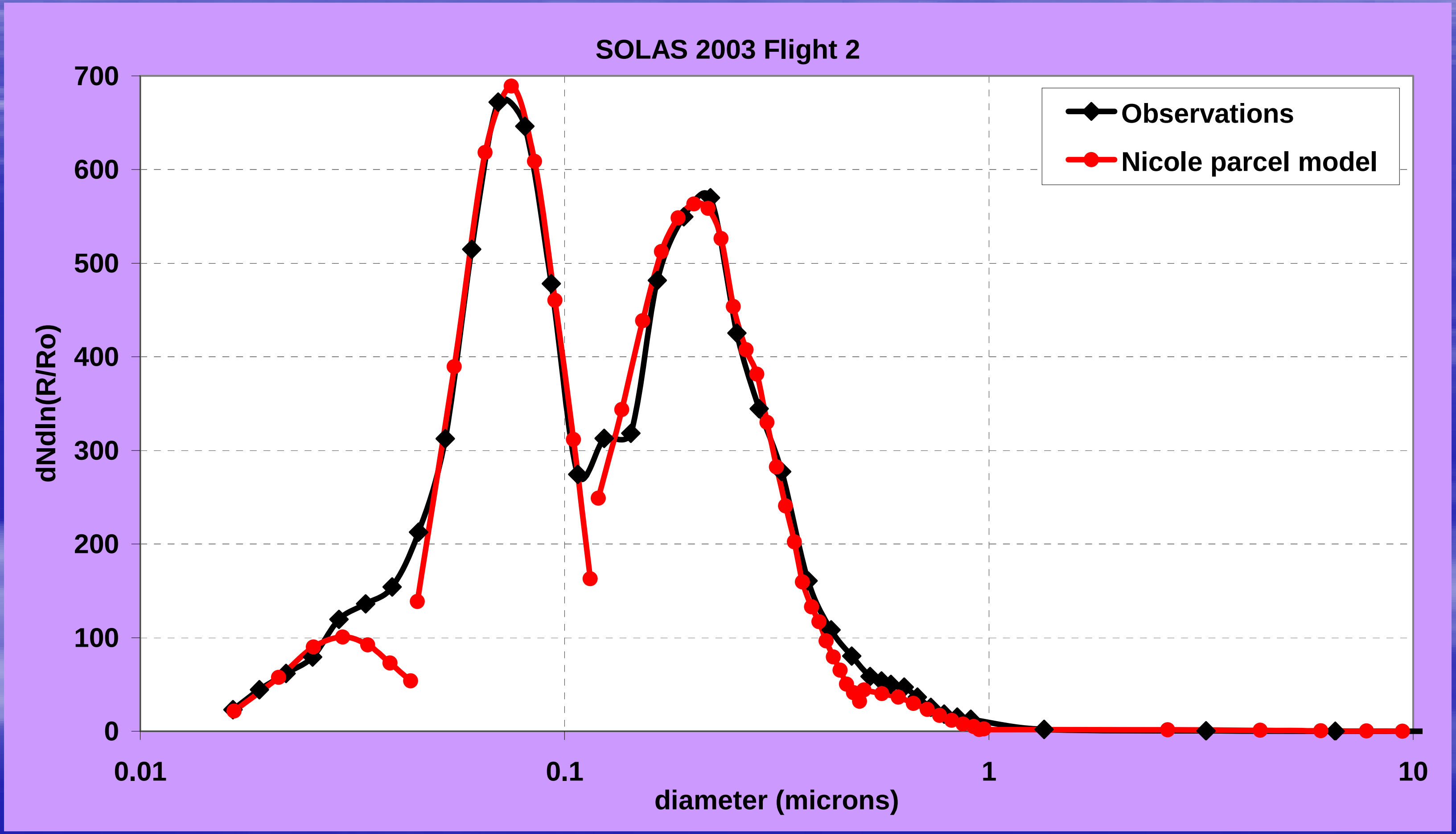
Dry Particle Size Distributions

First, I had to make sure both models were starting with the same dry particle size distribution

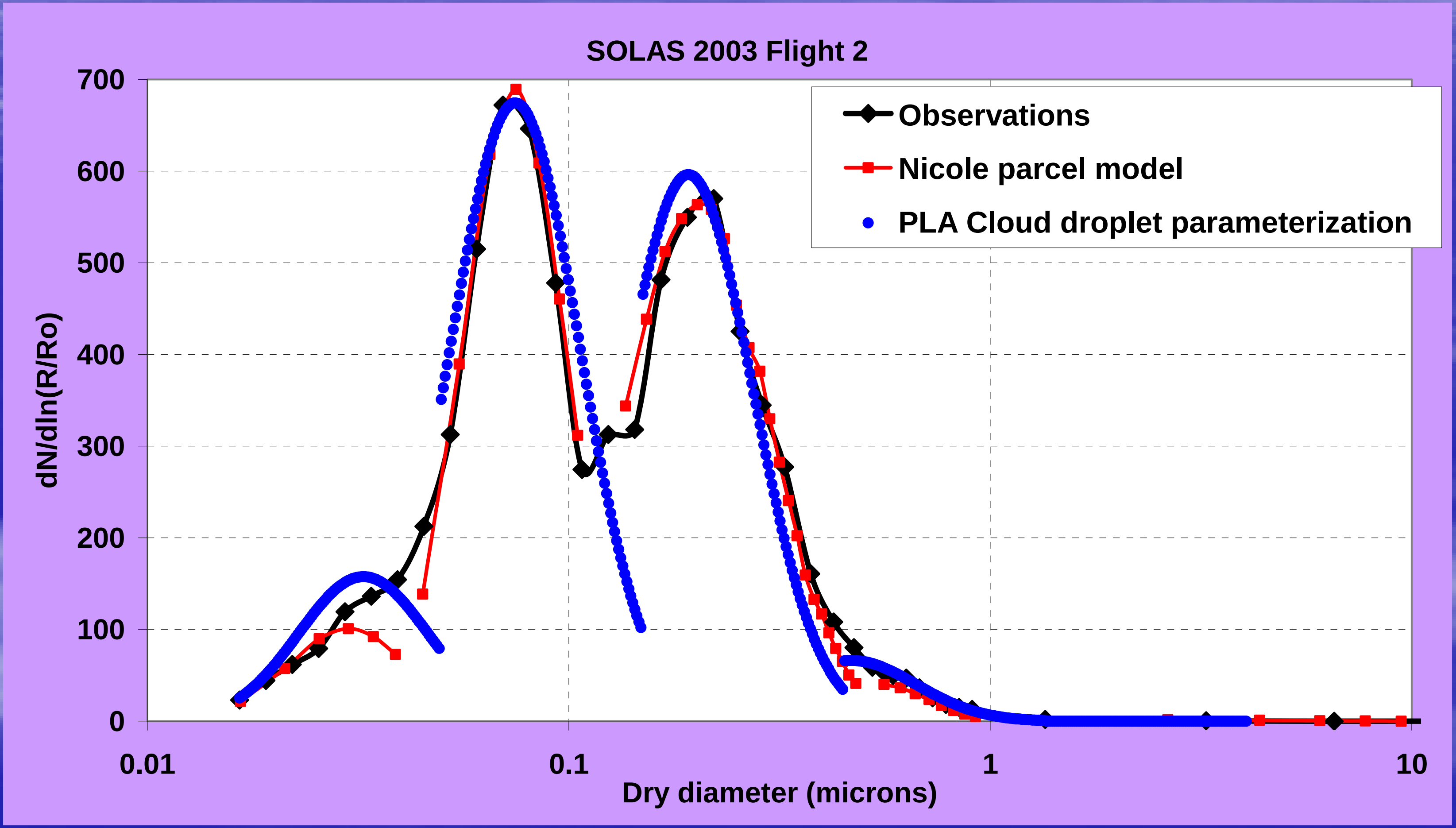
Observed Size Distribution



Parcel Model Lognormal Distribution



Size Distribution Comparison

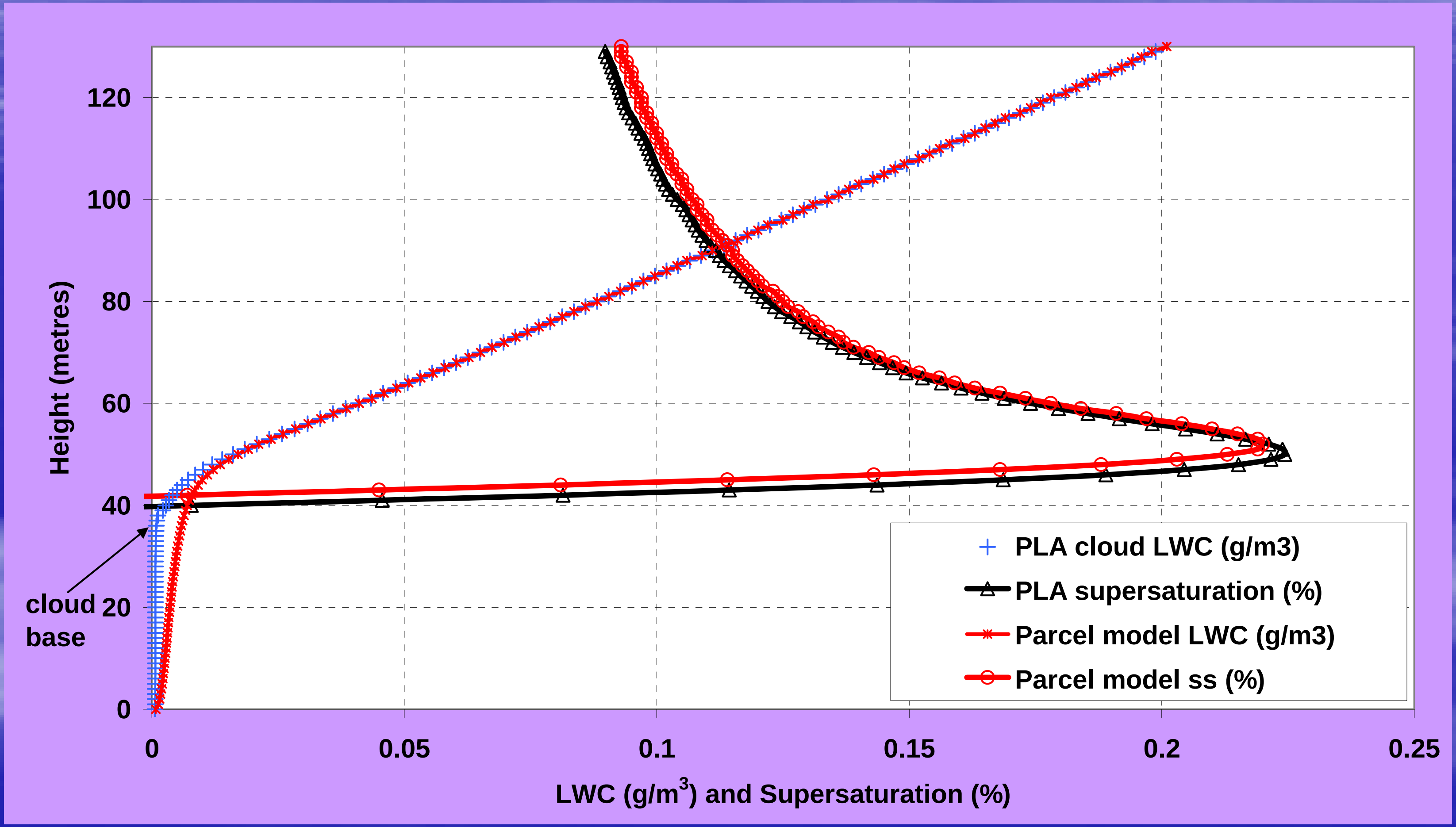


Comparison of supersaturation profiles between models

Initial tests to compare

- Started with a hypothetical situation assuming pure sulphuric acid particles in all modes
- Set parcel model and PLA model to the same initial conditions (the temperature and pressure were based on observations):
  - Starting height=0. m
  - Initial TEMP= 285.66 Kelvin
  - Initial PRES= 965 mbars
  - Initial supersaturation= -0.02 (fraction) or RH=98%
  - Initial height interval DZ=1. m
  - Initial time interval DT=1. s
    - ∴ updraft velocity = DZ/DT = 1 m/s = 100 cm/s

Cloud liquid water content (LWC) and supersaturation (ss) with altitude



Updraft velocity = 100 cm/s

Next, I compared the # of droplets

	Parcel model	PLA model
Height	130 m	129.0 m
Number concentration of droplets (N_d)	680.8 /cc	653.05 /cc
Number concentration of particles (N_a)	1045.9 /cc	1058.1 /cc
% activated	65.09 %	61.72 %

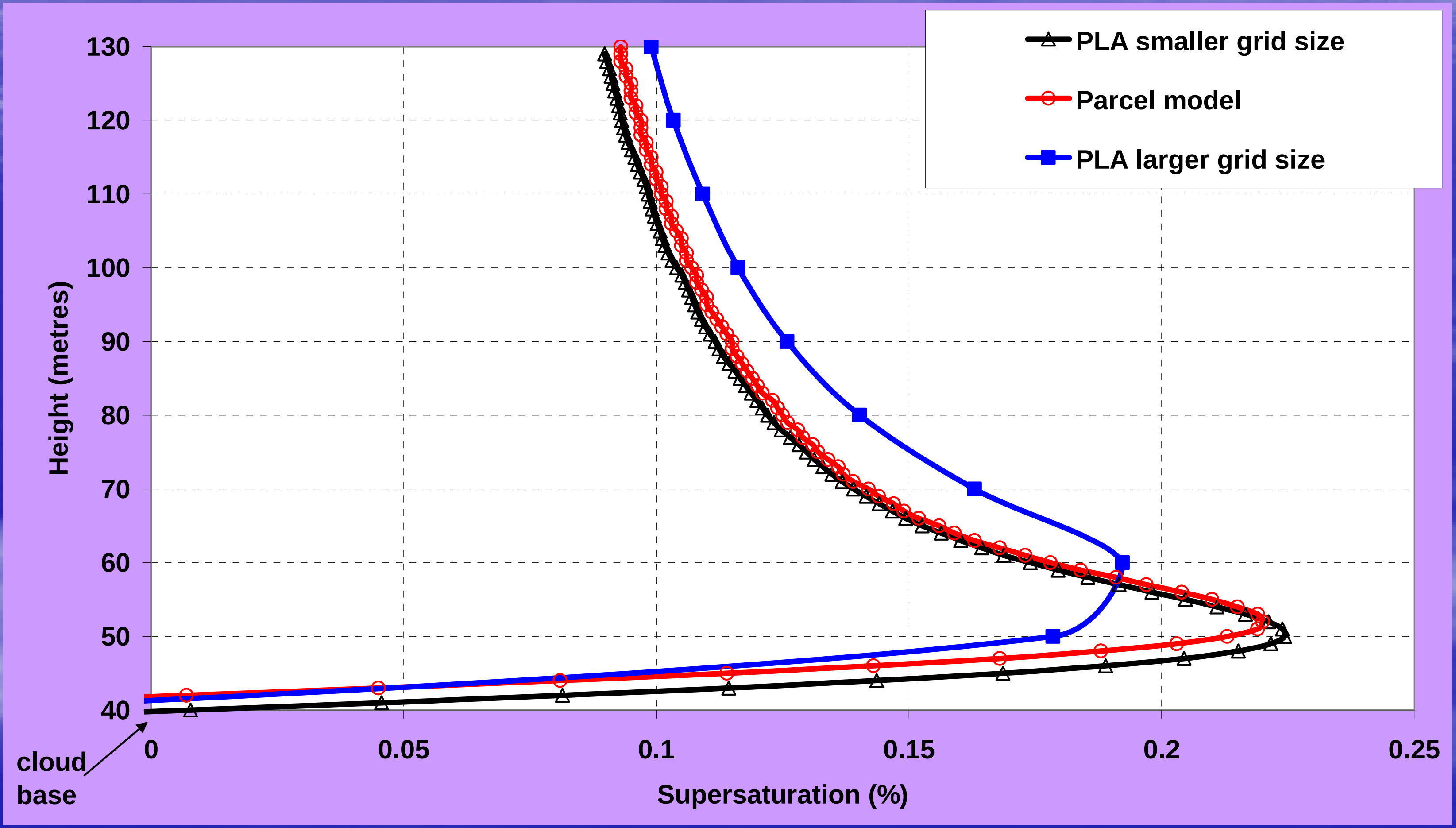
Start changing initial conditions

- The initial conditions were originally:
  - – Initial height interval DZ=1. m
  - – Initial time interval DT=1. s

  (for updraft velocity = DZ/DT = 1 m/s = 100 cm/s)
- This is not normally what would be used in a GCM so I tested for larger grid spaces:
  - – Initial height interval DZ=10. m
  - – Initial time interval DT=10. s

  (for updraft velocity = DZ/DT = 1 m/s still)

Larger grid spacing



The cloud LWC was unchanged so did not plot it here.

Now with larger grid spacing

	Parcel model	PLA model DZ=1 m	PLA model DZ=10 m
Height	130 m	129.0 m	130.0 m
N_d	680.8 /cc	653.05 /cc	598.93 /cc
N_a	1045.9 /cc	1058.1 /cc	1058.1 /cc
% activated	65.09 %	61.72 %	56.6 %

Comparison to a more realistic scenario based on measurements

So far, it has been assumed the aerosol was made up of 100% sulphuric acid. The observations show there is organics present.

How are the organics handled in these models?

Organics in the Models

PARCEL MODEL

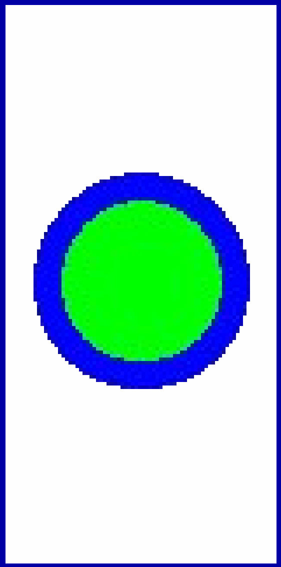
- Assumes organics have the molecular weight, density & surface tension properties of adipic acid
- Assumed the ionic dissociation factor is ν=1
- Assumed the osmotic coefficient is Φ=1
- Sensitivity tests to changing the solubility

  soluble=200g/L

  slightly soluble=5g/L

  insoluble=0.01g/L

How Parcel Model Deals with Solubility



Model assumes the particles are somewhat deliquesced (adds a small amount of water to particle)

As droplets grow by water condensation, some of the soluble material in the particle dissolves, depending on solubility

Droplets continue to grow, dissolves more. This continues until either the entire particle is dissolved or the model run ends.

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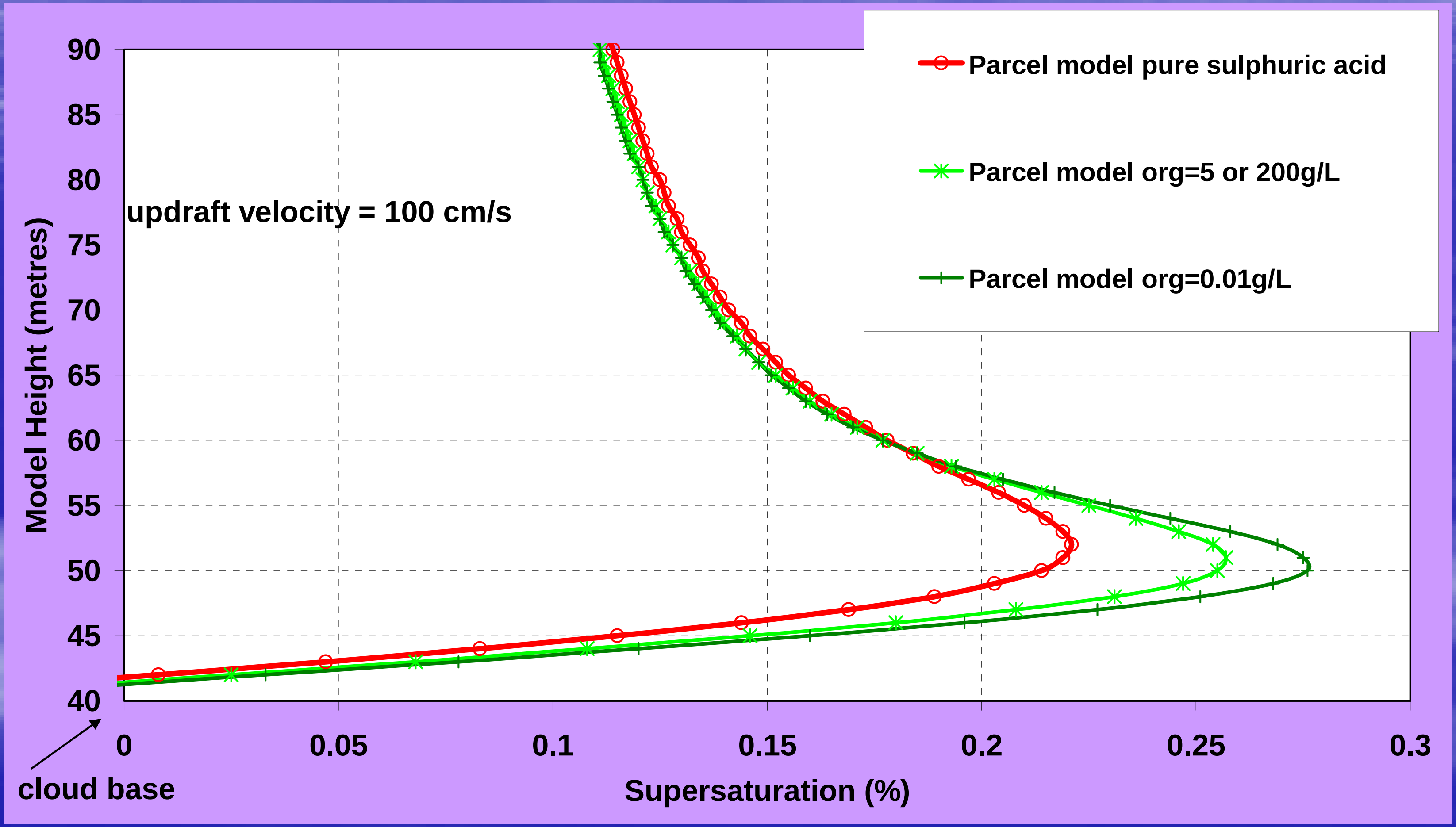
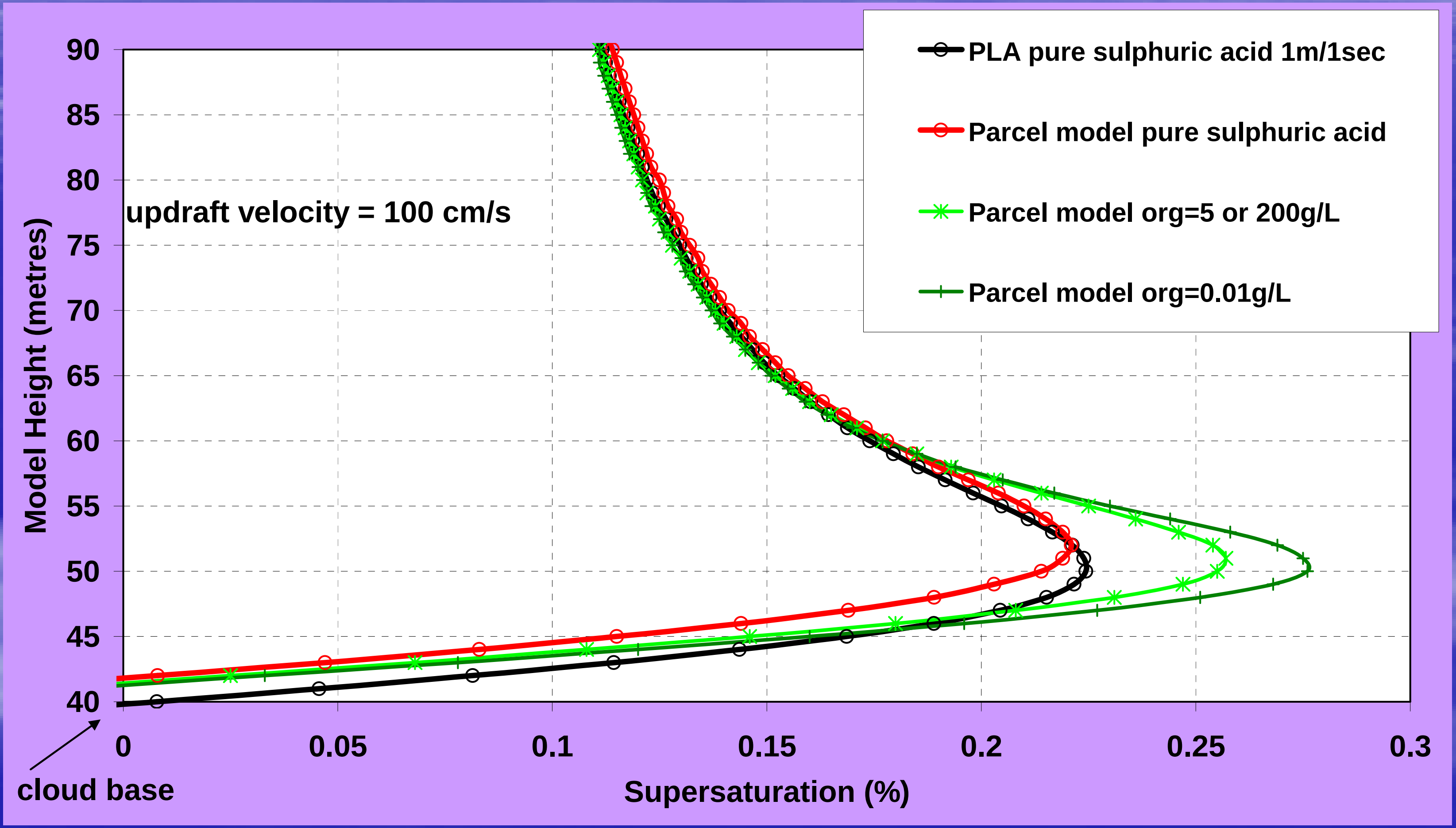
PLA MODEL

- Assign the organics any molecular weight and density in the input file (chose adipic acid for comparison with parcel model)
- The ionic dissociation factor can also be assigned any value.
  - If ν=0, the organic is assumed to be insoluble (ie. it doesn't dissociate)
  - Non-integer values are allowed, showing partial dissociation

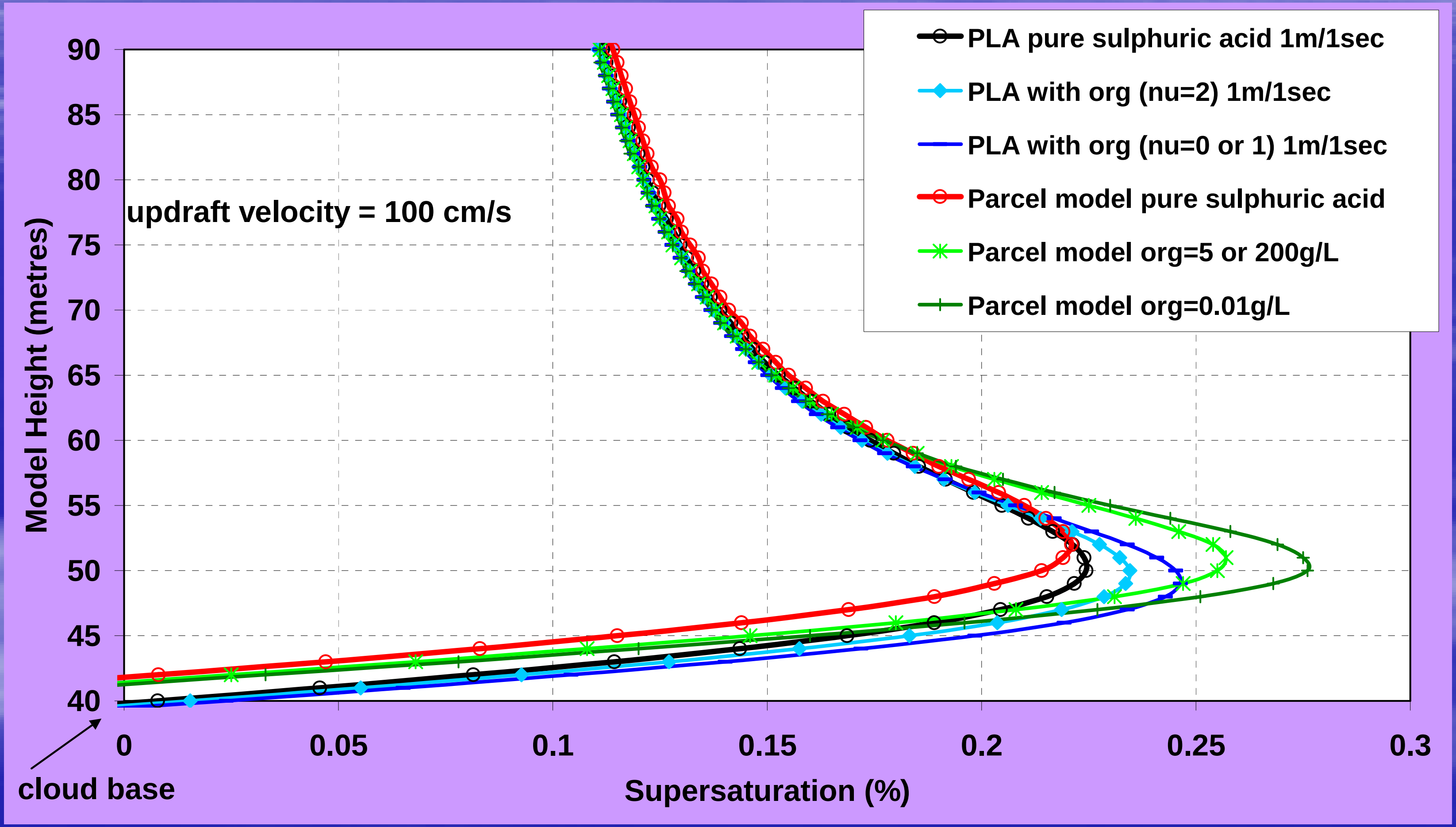
Supersaturation Profiles



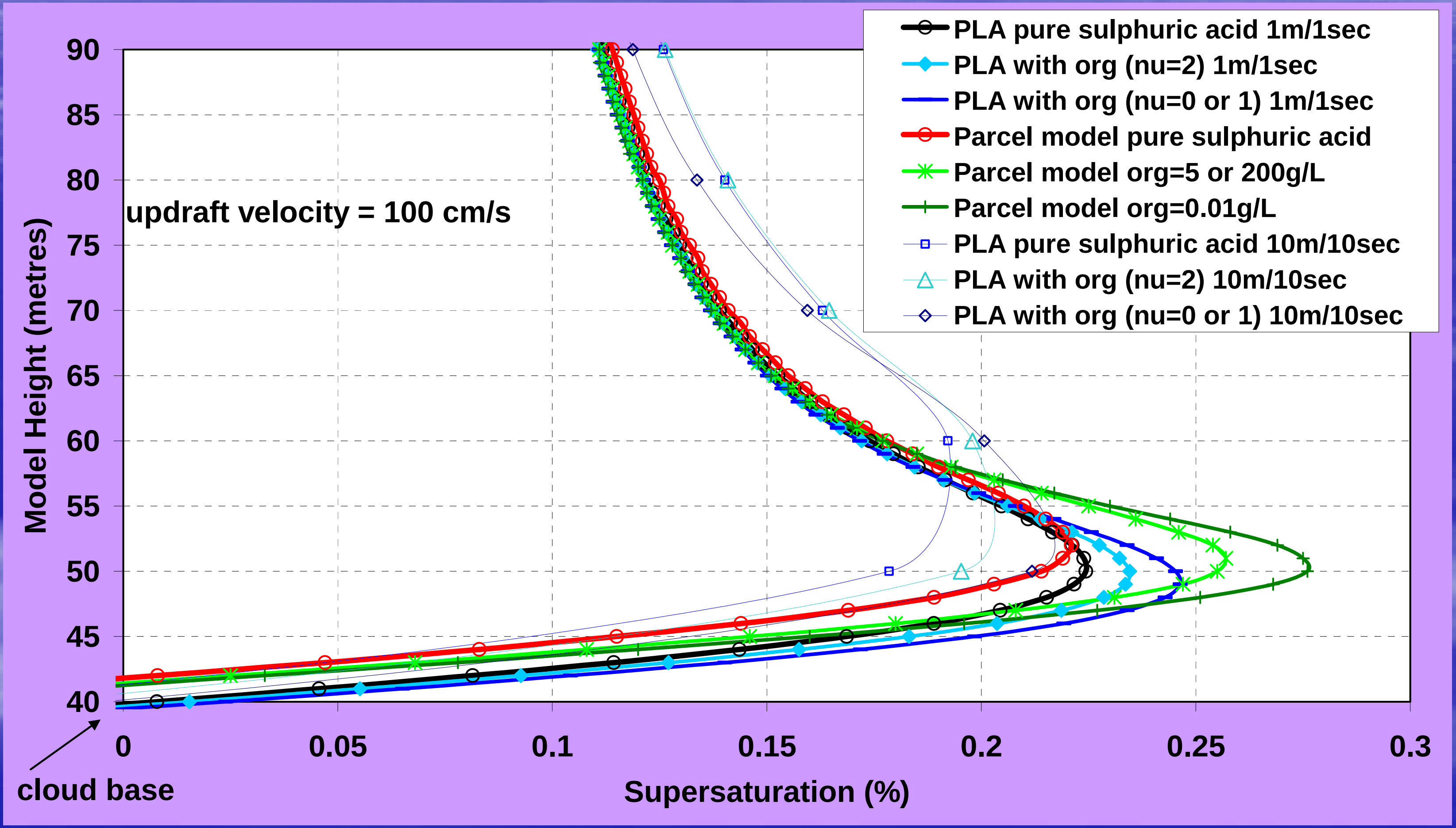
Supersaturation Profiles



Supersaturation Profiles

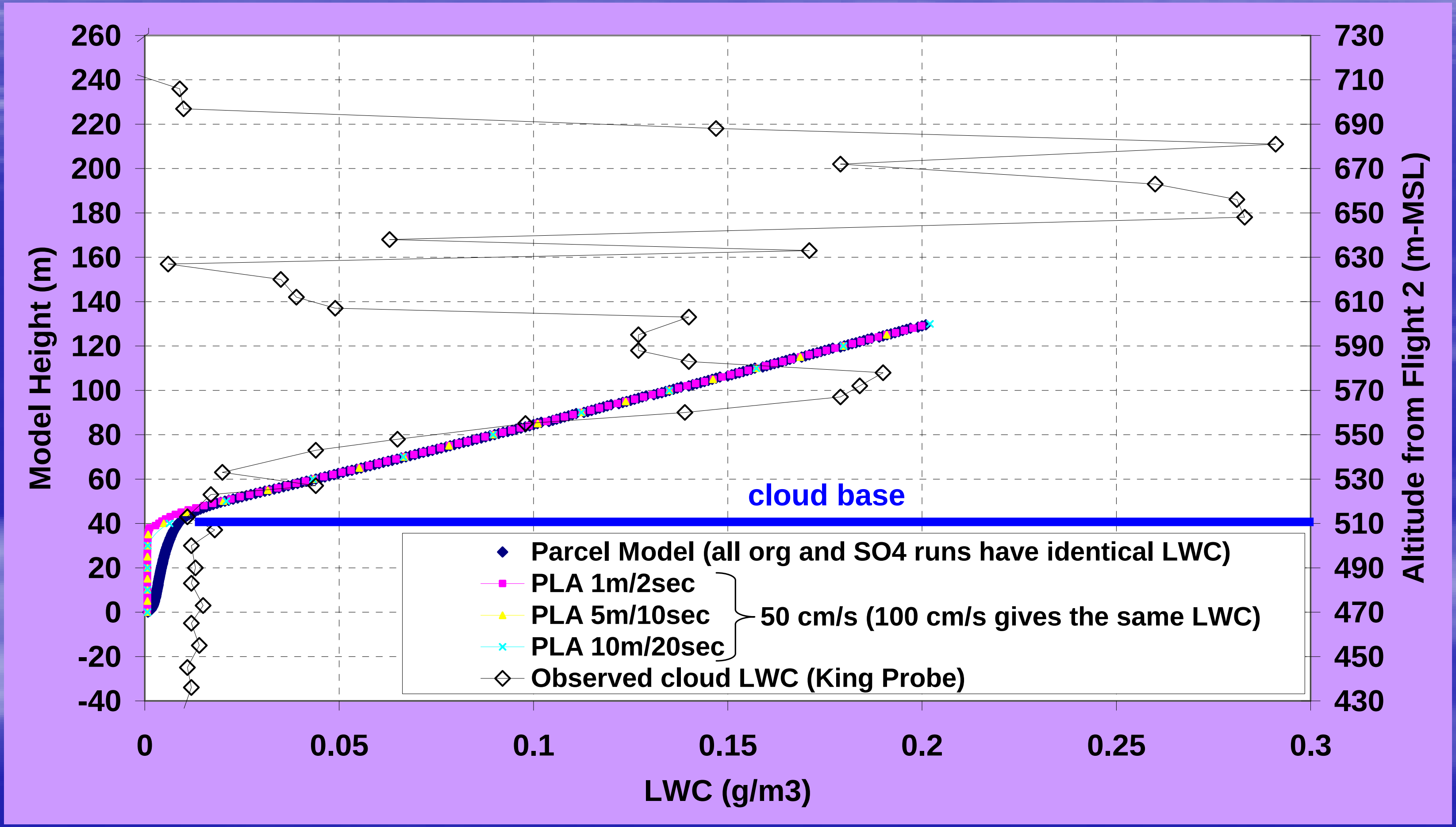


Supersaturation Profiles



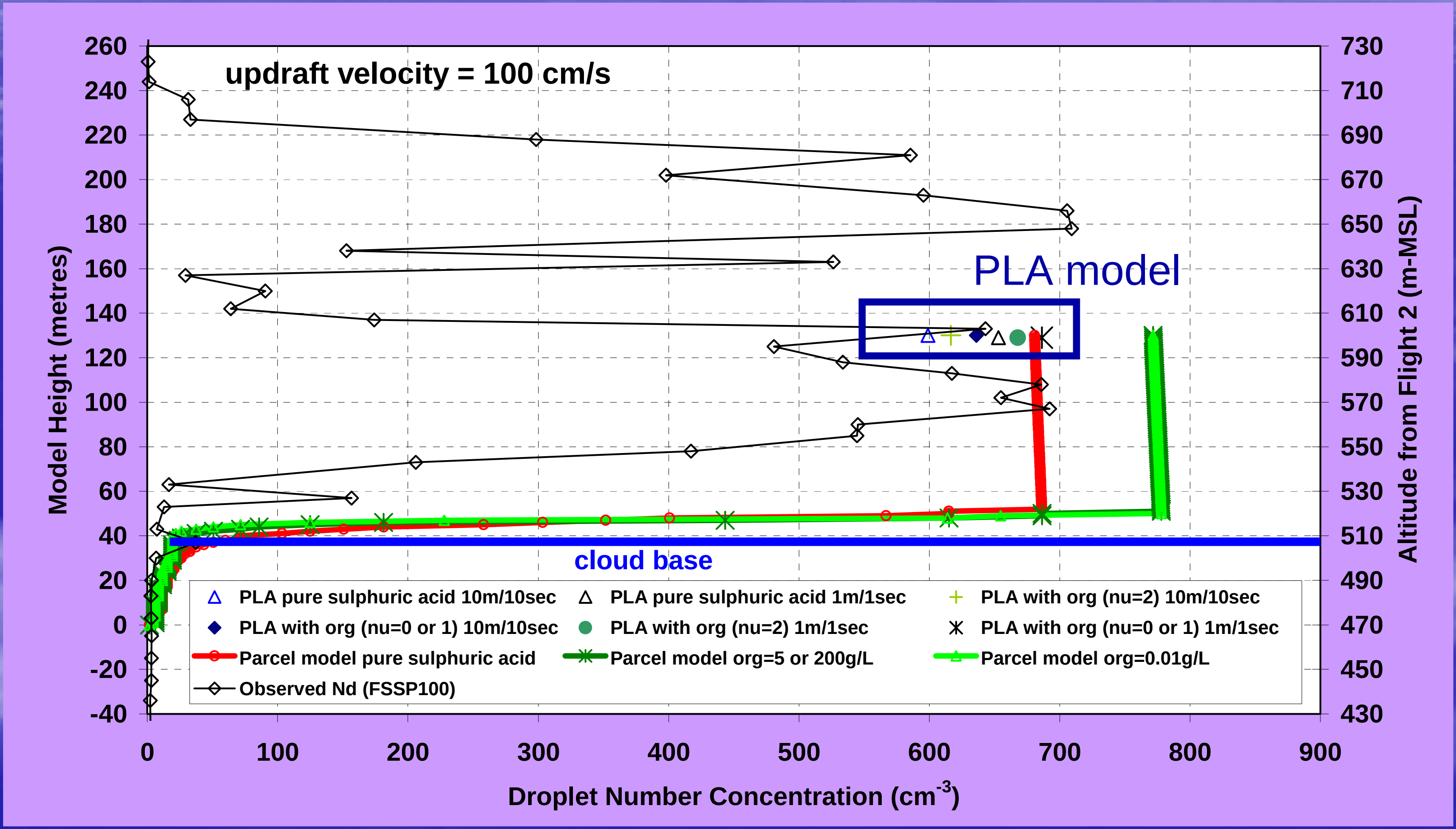
Comparisons with Observations

LWC Profiles (ie. Finally, comparisons with observations)



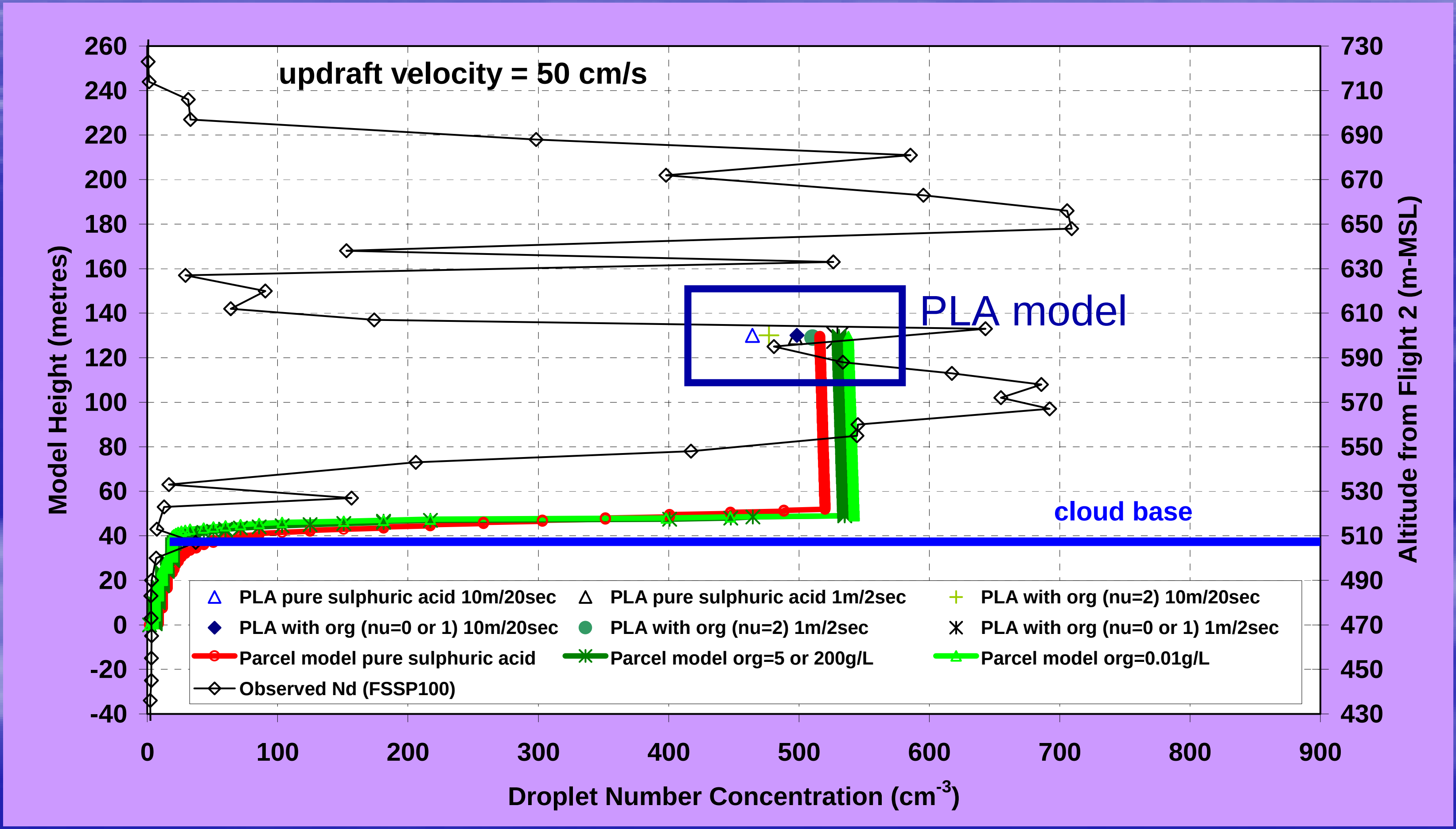
Victoria

Cloud Droplet Number Profiles



Victoria

Cloud Droplet Number Profiles



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N_d for 50 cm/s (Observed N_d in the range of 510-760 cm^{-3})

Parcel Model		PLA Model		
Composition	N_d	Composition	Dz/Dt= 1/2	Dz/Dt= 10/20
Pure H_2SO_4	516	Pure H_2SO_4	497	464
5 or 200 g/L org	531	ν=2	510	477
0.01 g/L org	538	ν=1 or 0	530	498

N_d for 100 cm/s (Observed N_d in the range of 510-760 cm^{-3})

Parcel Model		PLA Model		
Composition	N_d	Composition	Dz/Dt= 1/1	Dz/Dt= 10/10
Pure H_2SO_4	681	Pure H_2SO_4	653	599
5 or 200 g/L org	772	ν=2	668	616
0.01 g/L org	772	ν=1 or 0	686	636

Last topic: Kappa (κ)

Petters and Kreidenweis introduced the idea in 2007 ACP paper

Atmos. Chem. Phys., 7, 1961–1971, 2007
www.atmos-chem-phys.net/7/1961/2007/

Atmospheric Chemistry and Physics

A single parameter representation of hygroscopic growth and cloud condensation nucleus activity

M. D. Petters and S. M. Kreidenweis

Department of Atmospheric Science, Colorado State University, USA

Received: 16 August 2006 – Published in Atmos. Chem. Phys. Discuss.: 5 September 2006
Revised: 20 February 2007 – Accepted: 2 April 2007 – Published: 18 April 2007

What is kappa (κ)?

- κ is:
  - a way to describe the relationship between dry particle diameter and CCN activity
  - a way to describe water uptake below and above saturation in a single parameter
  - a way to simplify the chemical details needed in a model such as osmotic coefficient, number of ions dissociated into, molecular weight etc. (this information is not always available: especially for many organic species or complex multicomponent aerosols with unknown composition)
- κ could potentially be determined for different air masses or air sources, such as biomass burning
- κ may simplify input required for GCM's

Parcel & PLA models now include κ code, also

- Initial tests are promising
- More work is needed
- We hope to determine κ values for different air masses and conditions from the Egbert 2007 study and test these κ's with the models

Conclusions

- Size distribution comparisons: good!
- Pure sulphuric acid supersaturation profiles: good!
- Cases including organics in the mixture:
  - The supersaturation profile for the insoluble case was a little bit different for Parcel model and PLA
  - PLA showed slightly lower droplet number concentration than Parcel model
- Simulated N_d were within the range of N_d observed during SOLAS
- Changing the grid size in the PLA model decreases N_d and changes the supersaturation profile

Future Work

- Comparisons between these models and other observations will continue
- Comparisons between these models and Nenes cloud parameterization have begun
- Kappa (κ): more work to be done

Thanks!