IMPORTANCE OF AEROSOLS IN THE INITIATION OF ICE IN CLOUDS

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MAIN OBJECTIVE

Indicate different parameterizations for heterogeneous ice nucleation that can be used to study aerosol cold-cloud interactions.

These parameterizations can/are used in some large scale or cloud models

Compare the different heterogeneous ice nucleation parameterizations, using a parcel model

Case study from Ice in Cloud Experiment – Layer (ICE-L), linking measured aerosol concentration to ice crystal concentration.

THE PARCEL MODEL

Based on an Lagrangian parcel model, originally developed by Feingold and Heymsfield (1992).

Droplet growth by condensation (collision and coalescence ignored)

Ice crystal growth by deposition.

ONLY STUDY PRIMARY INITIATION OF ICE (homogeneous and heterogeneous nucleation only).

- heterogeneous nucleation: ice initiation by an insoluble aerosol acting as ice nuclei (IN).
- homogeneous nucleation : ice initiation in pure liquid droplets.

Treatment of water activity with a single parameter (κ) (Petters and Kreidenweis, (2007)) is implemented. Allows for a simple treatment of internally and externally mixed aerosols.

HETEROGENEOUS ICE NUCLEATION PARAMETERIZATIONS

1) **Based on laboratory studies**:

   Diehl and Wurzler (2004) [DW04].

   Ice nuclei (IN) types included: SOOT from kerosene; MINERAL PARTICLES (kaolinite, montmorillonite and illite); BIOLOGICAL PARTICLES (pollen, leaf litter and bacteria).

2) **Based on theory:**

   Khvorostyanov and Curry (2004) [KC04].

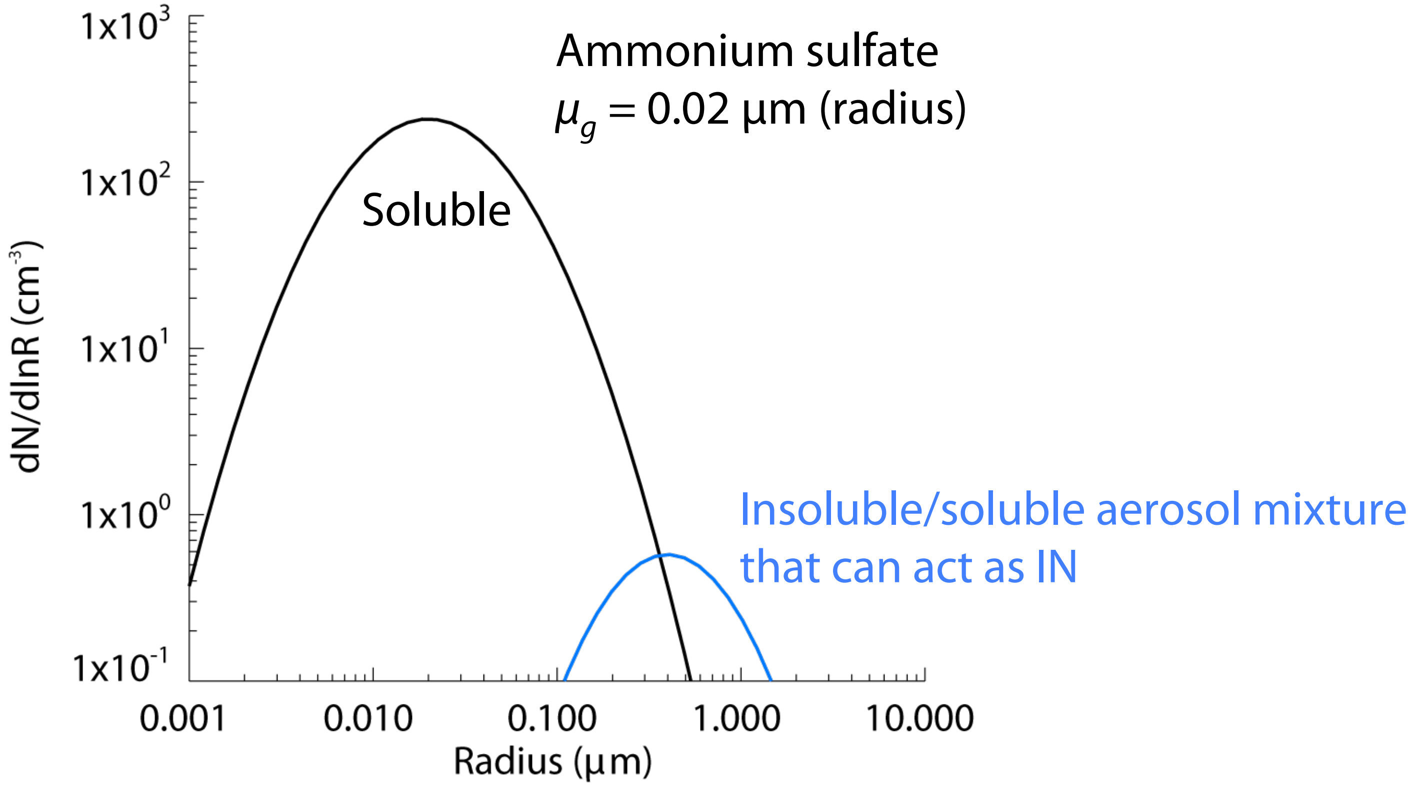
   Different types of ice nuclei (IN) can be accounted for by varying surface properties (contact angle, number of active sites and misfit strain).

3) **Based on field work, constrained by laboratory studies**:

   Phillips, DeMott and Andronache (2008) [PDA08].

   IN types included: DUST, BLACK CARBON AND ORGANICS.

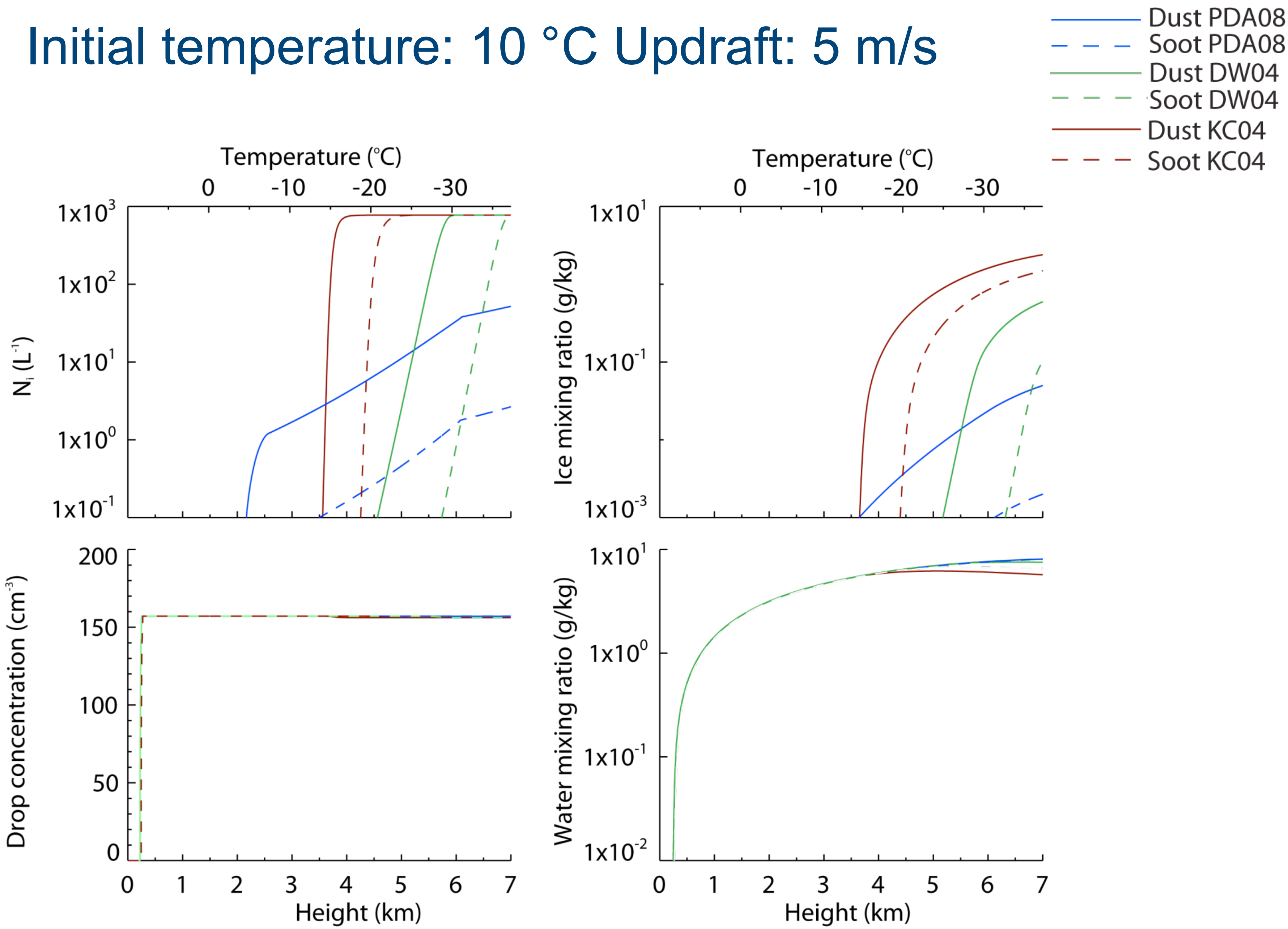
SIZE DISTRIBUTION ASSUMED FOR COMPARING HETEROGENEOUS ICE NUCLEATION PARAMETERIZATIONS



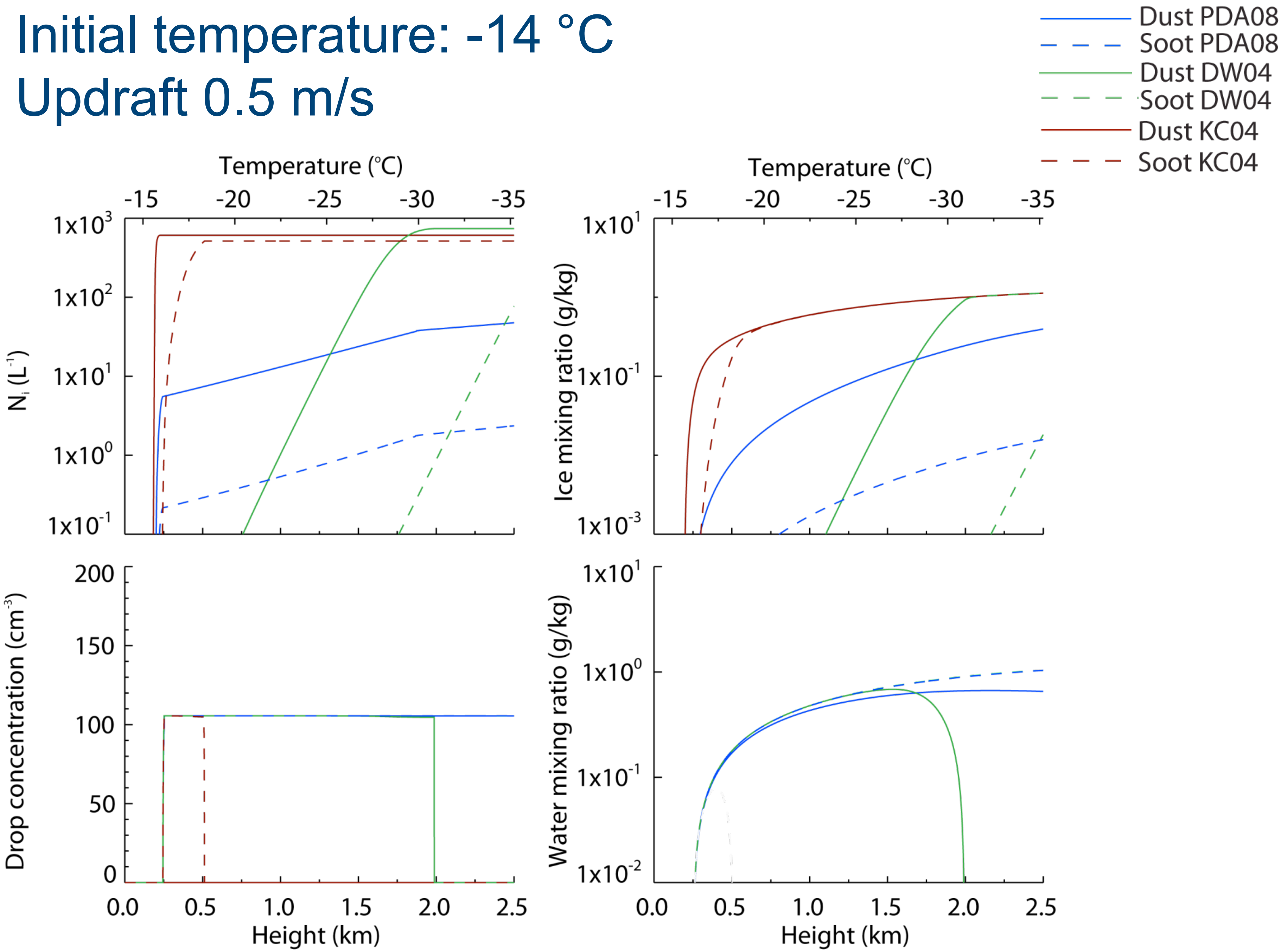
Ammonium sulfate and insoluble 50/50 % mass fraction
(immersion or condensation freezing)

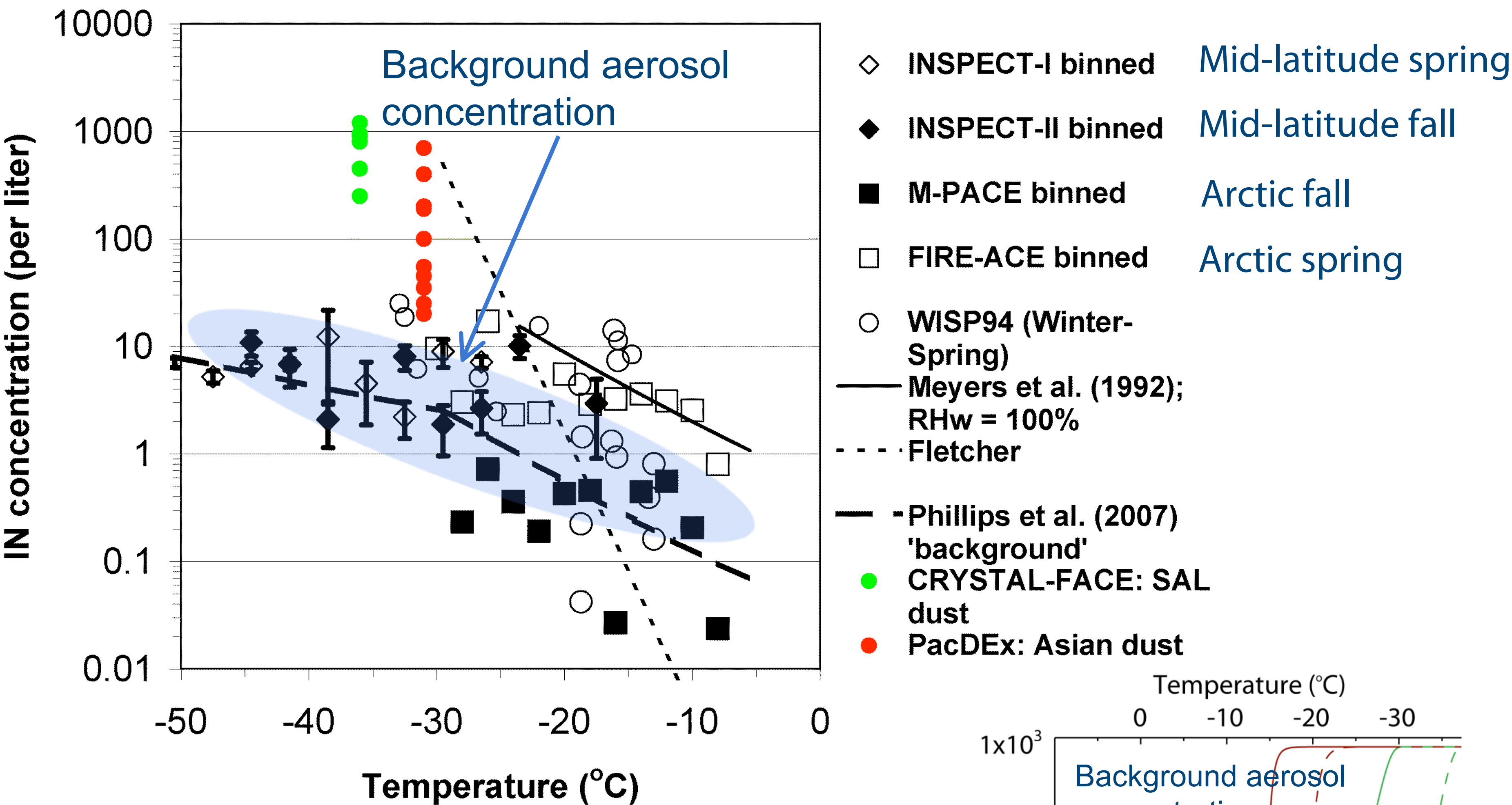
μ_g = 0.4 μm (radius), N = 1 cm^{-3}

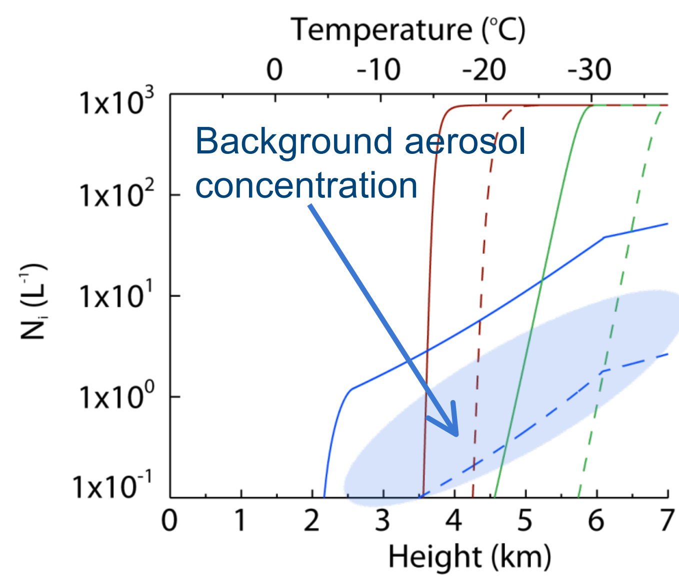
Initial temperature: 10 °C Updraft: 5 m/s



Initial temperature: -14 °C
Updraft 0.5 m/s







IN measurements with
Continuous Flow Diffusion Chamber
(CFDC)

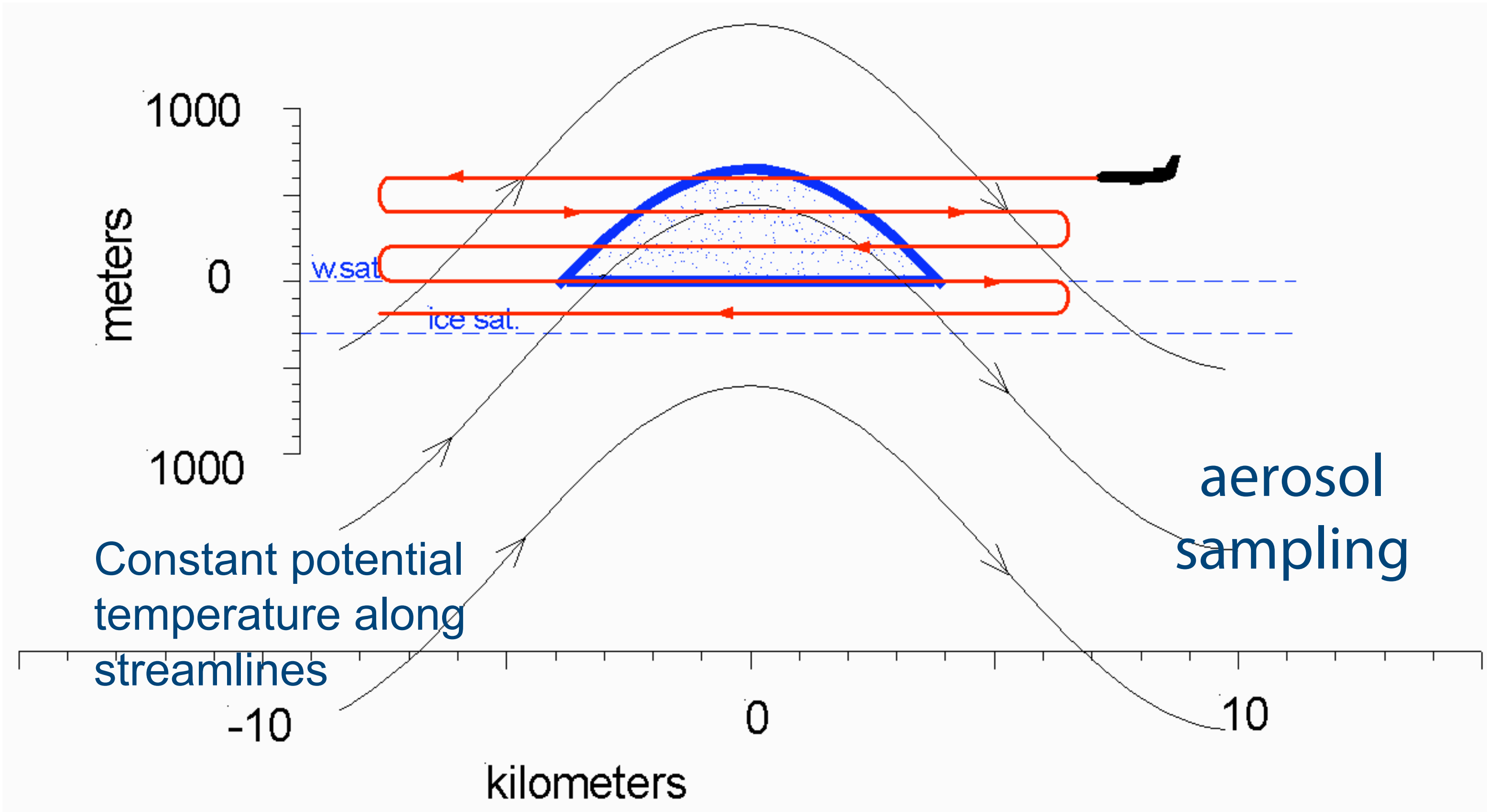
ICE-L (Ice in Clouds Experiment – Layer clouds)

Colorado and Wyoming
November – December 2007

Goal was to conduct measurements in clouds where only primary heterogeneous nucleation occurs, or can be separated (in time and space) from secondary processes.

Measurements mainly in layer clouds, especially lenticular wave clouds.

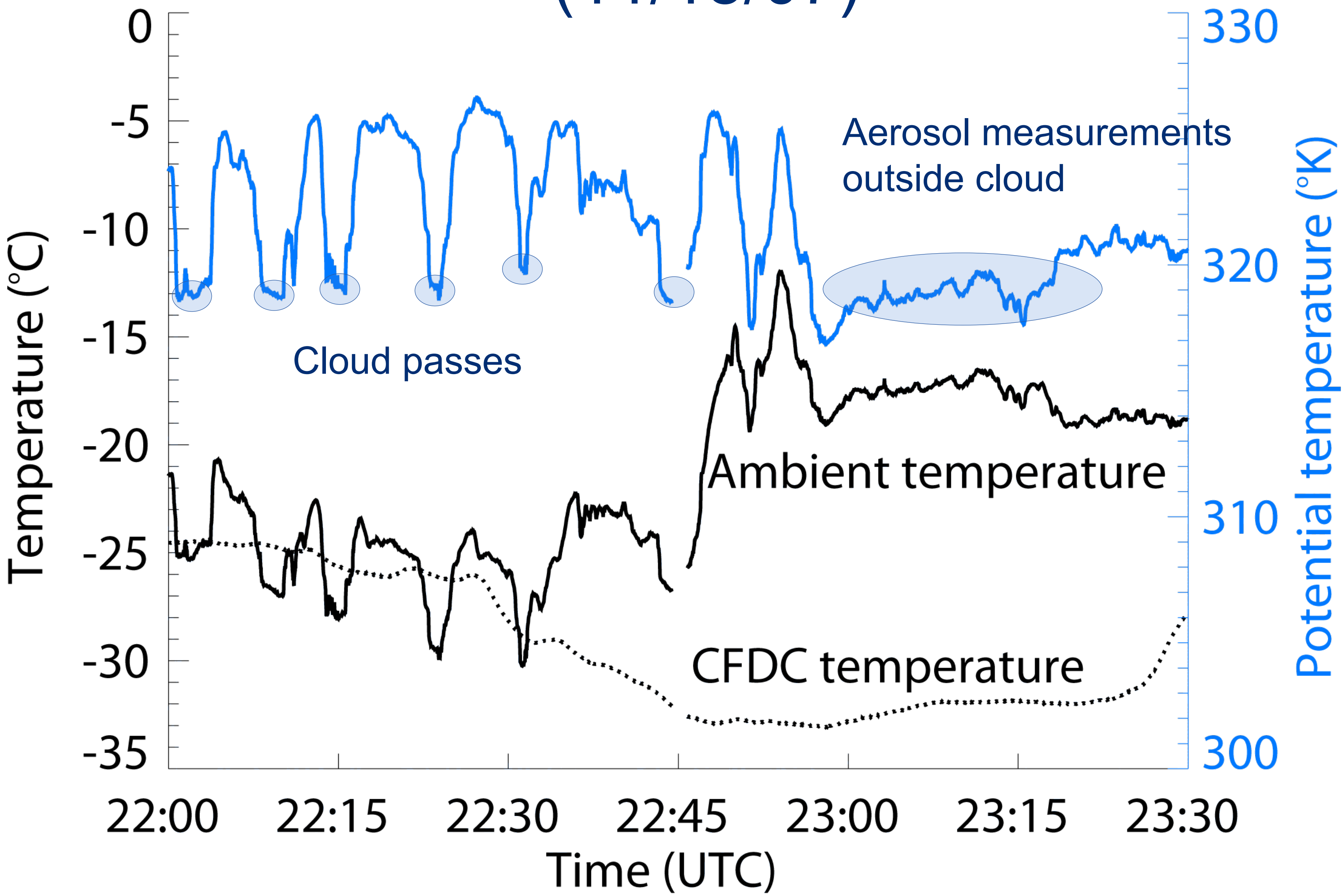
Rogers and DeMott (2002)



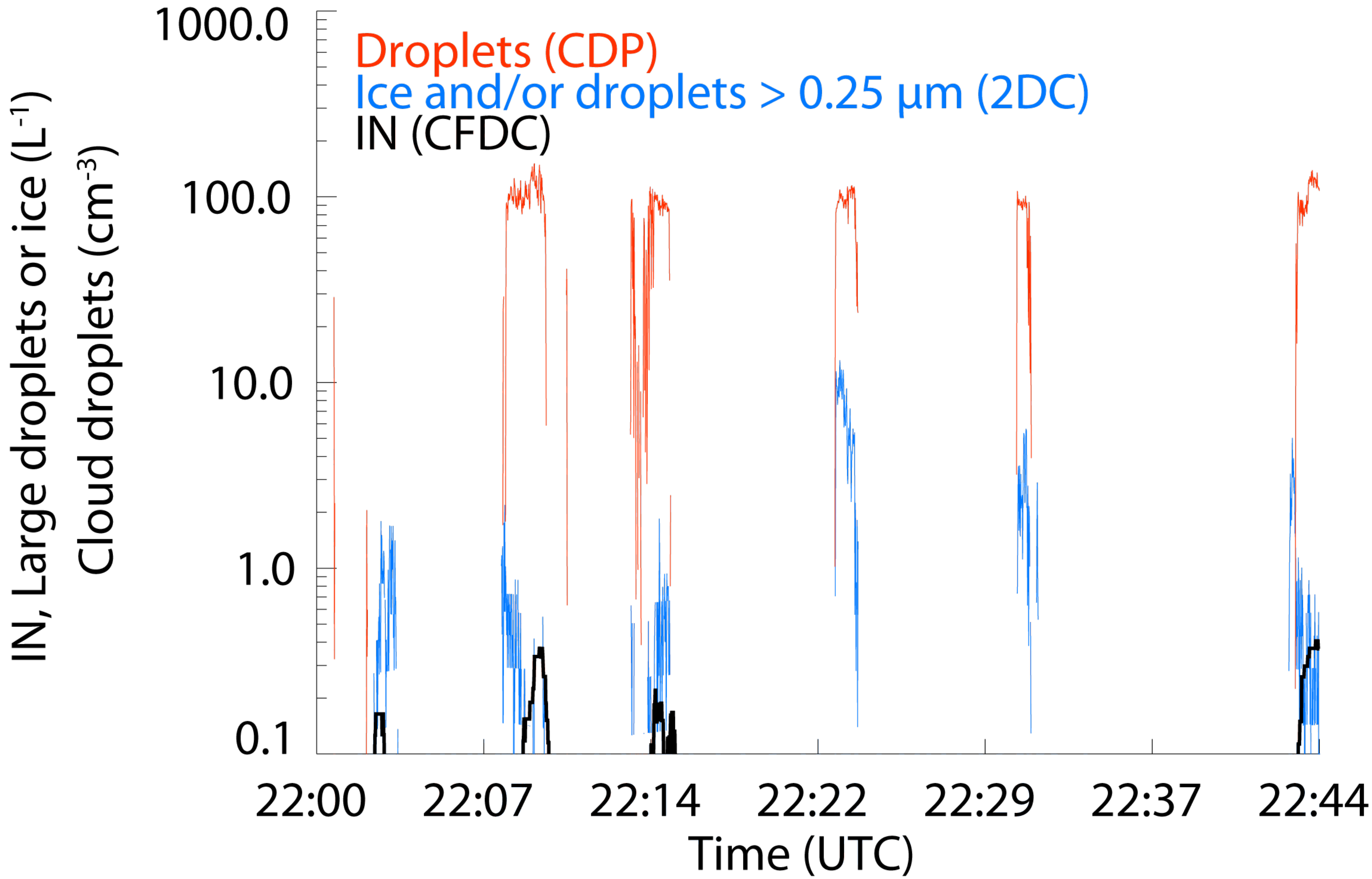
In an idealized setting, air parcels will spend only a few hundred seconds in a layer cloud and mixing and precipitation is not expected.

Wave clouds are ideal for parcel model studies.

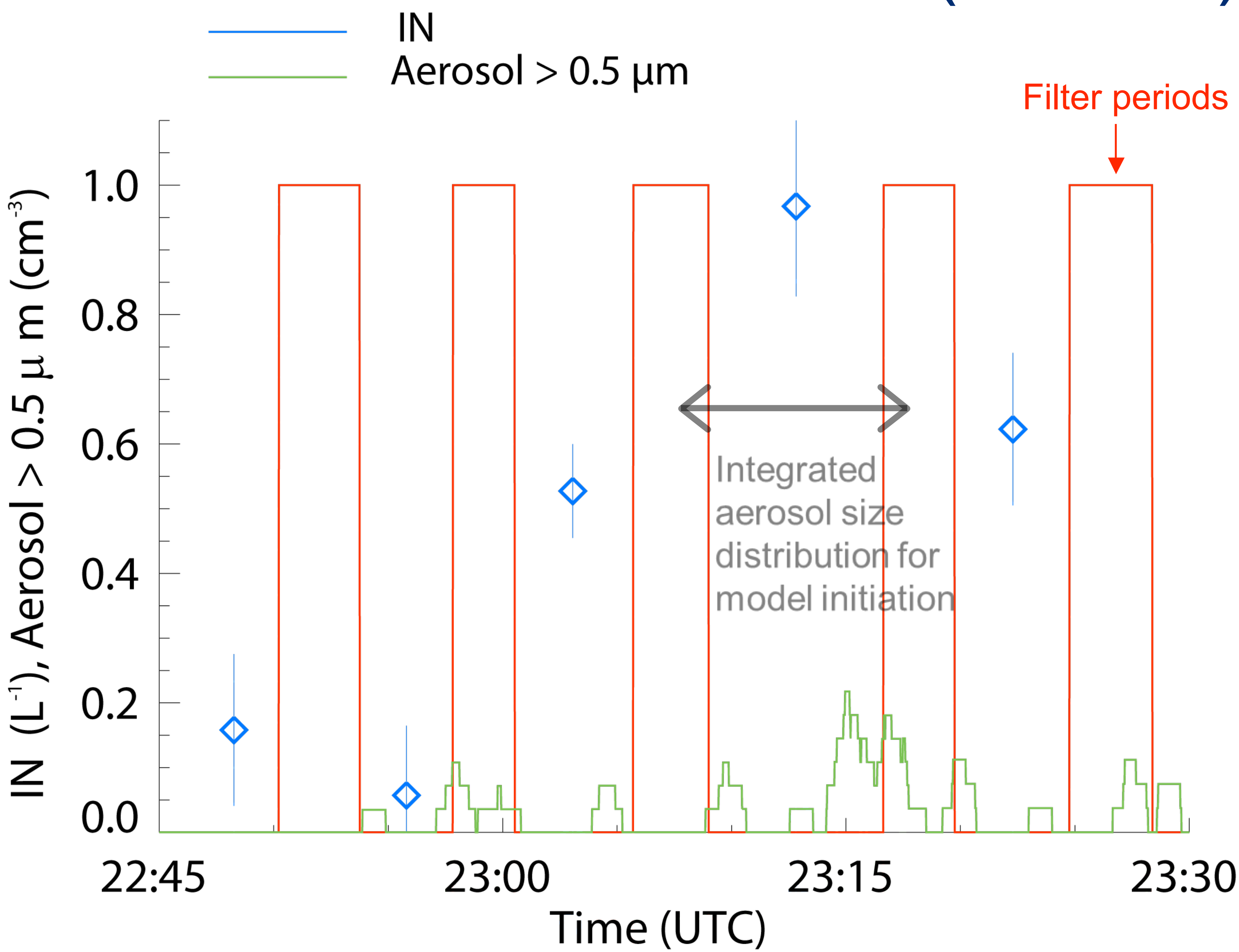
Thermodynamics in wave cloud
(11/18/07)



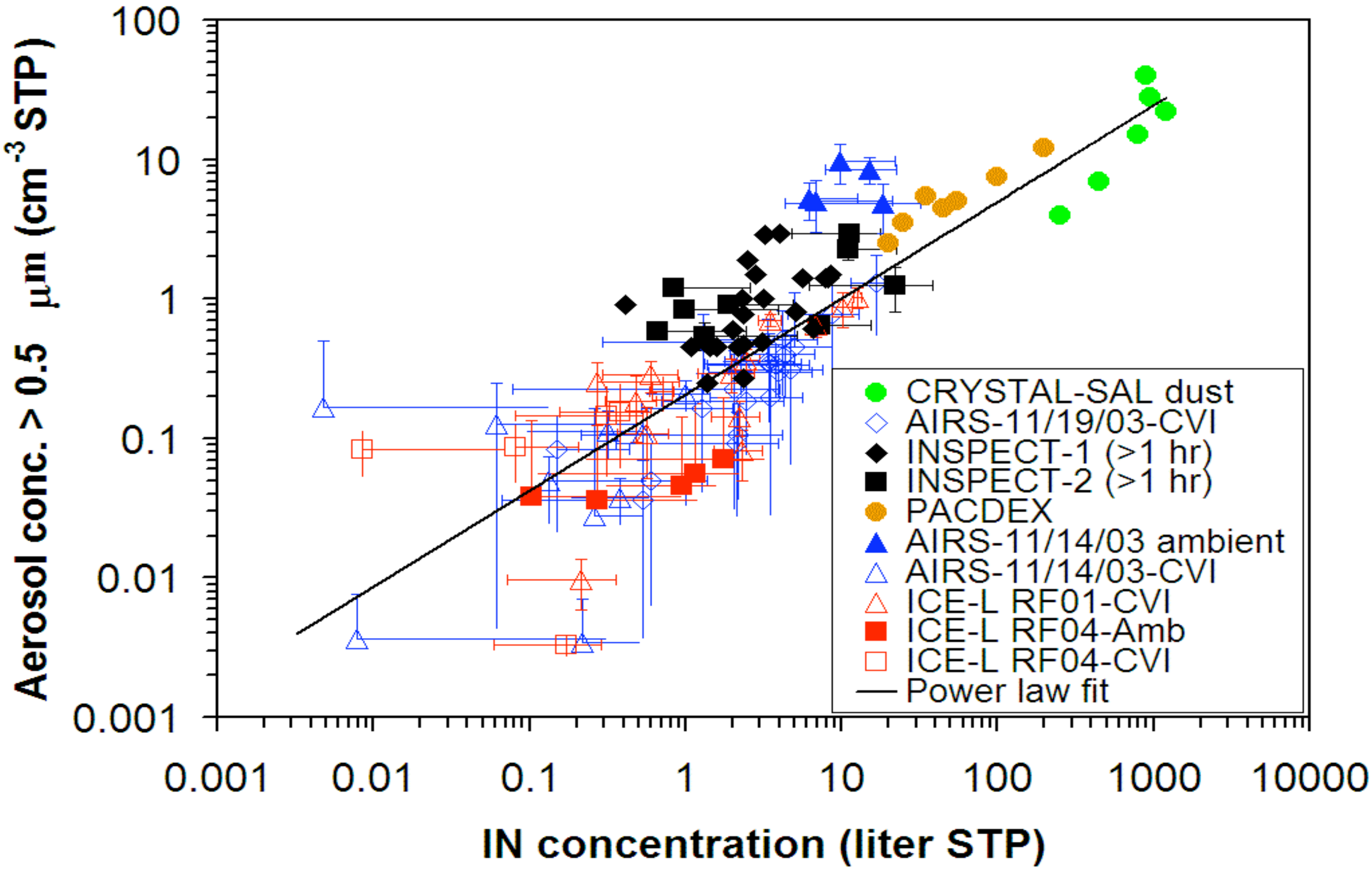
IN measured from collected cloud particle residual nuclei



IN from air outside cloud (same θ)



Measured IN relation to large aerosol concentrations



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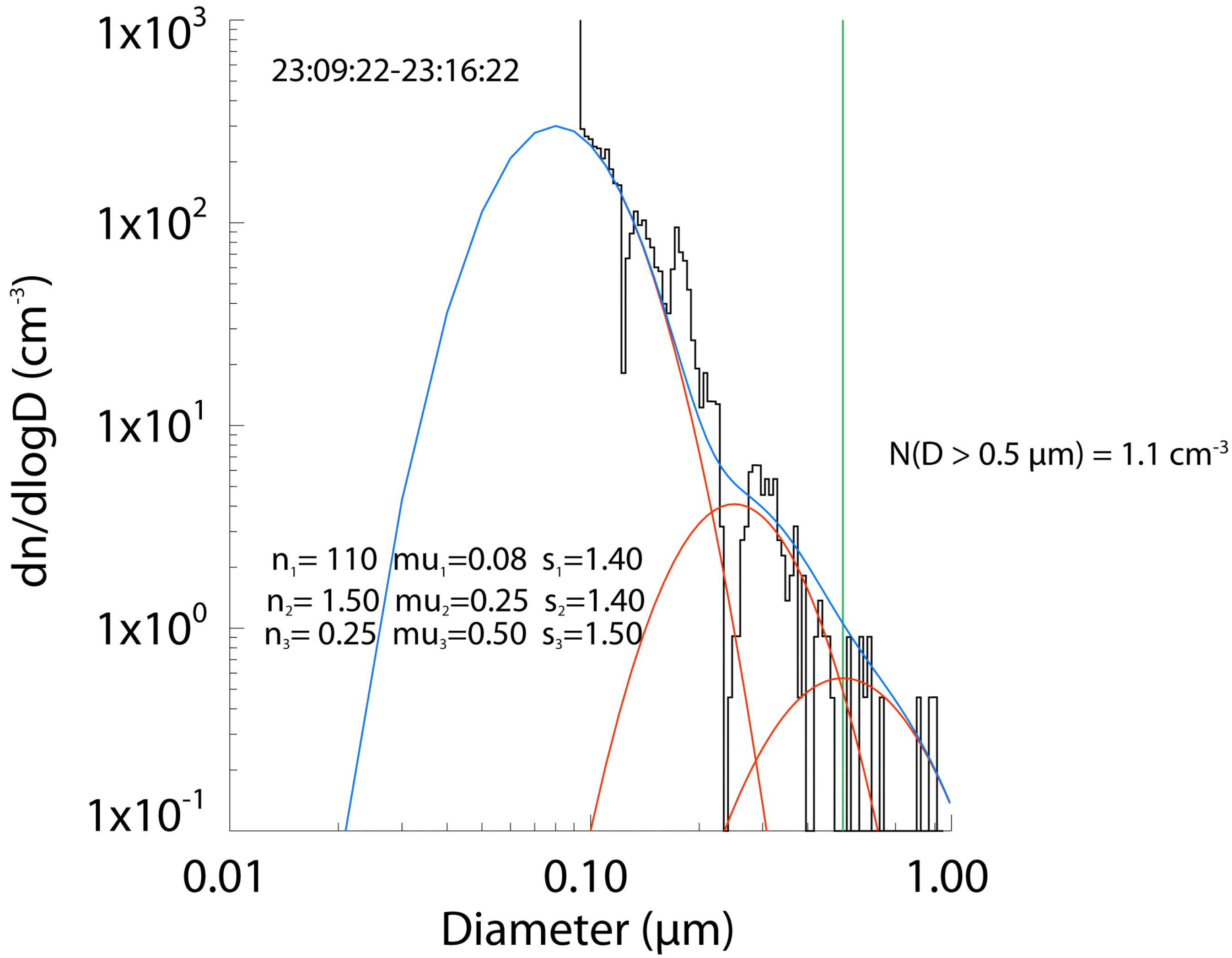
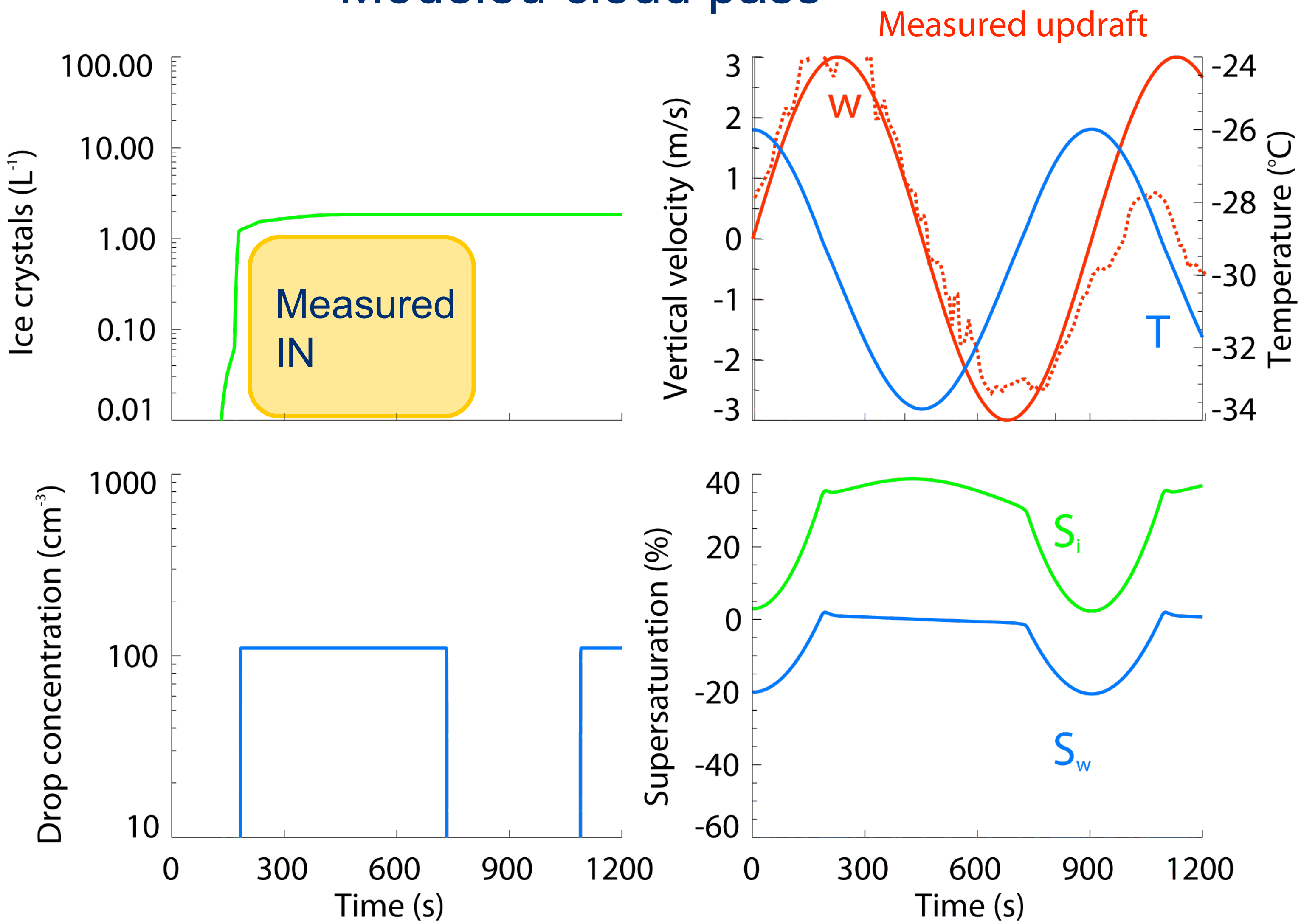
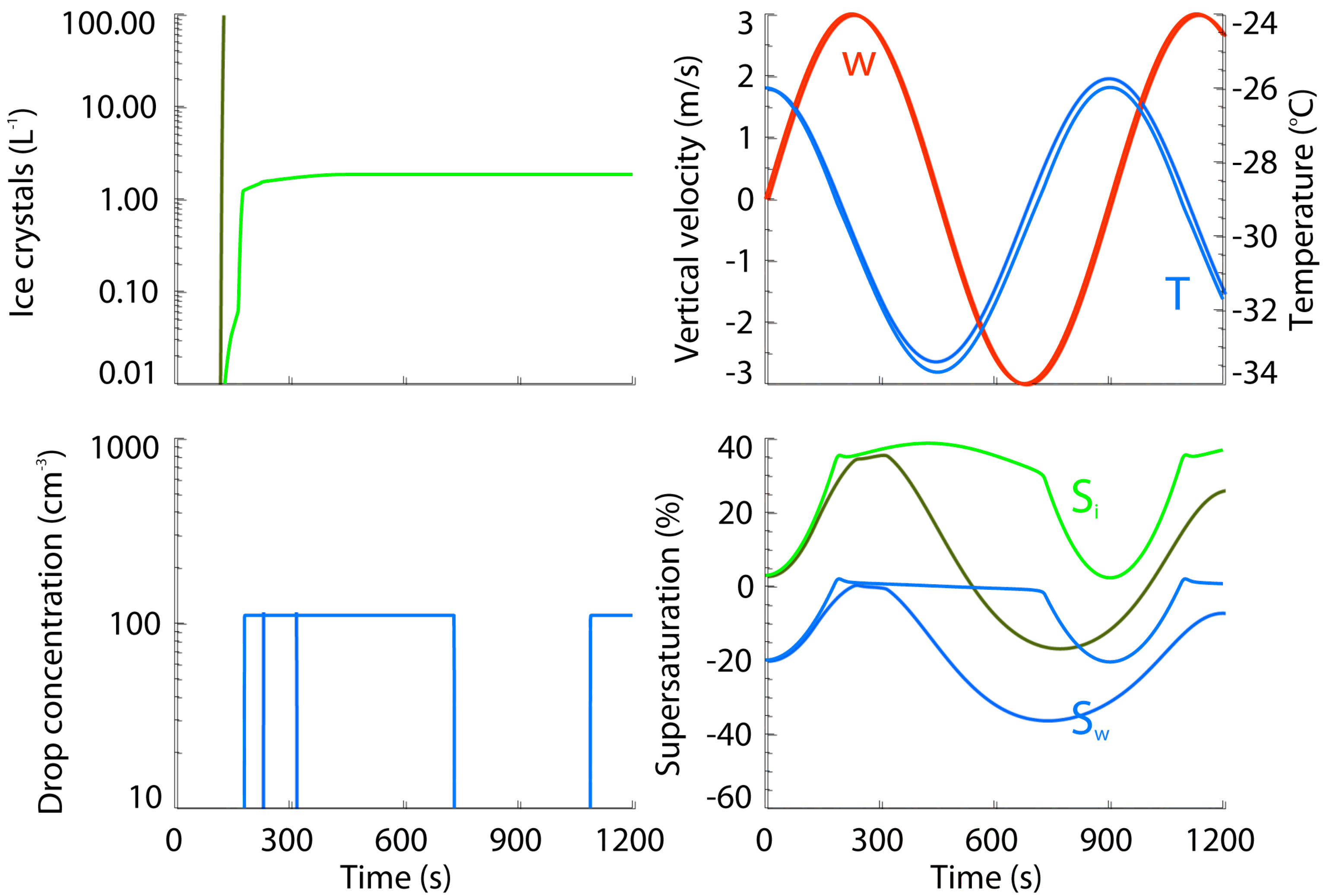
Fitted size distribution from measurements outside cloud



Modeled cloud pass



High dust loading



Existing heterogeneous ice nucleation parameterizations vary greatly between each other in predicted ice crystal concentrations.

Aerosol composition and concentration important factor in ice nucleation.

Concentration of IN seem to be proportional to concentration of large insoluble aerosol.

Lifetime of some cloud systems are very dependent on IN concentration.

Long term goal is to include an aerosol “hook” for heterogeneous ice nucleation into large scale and cloud resolving models.