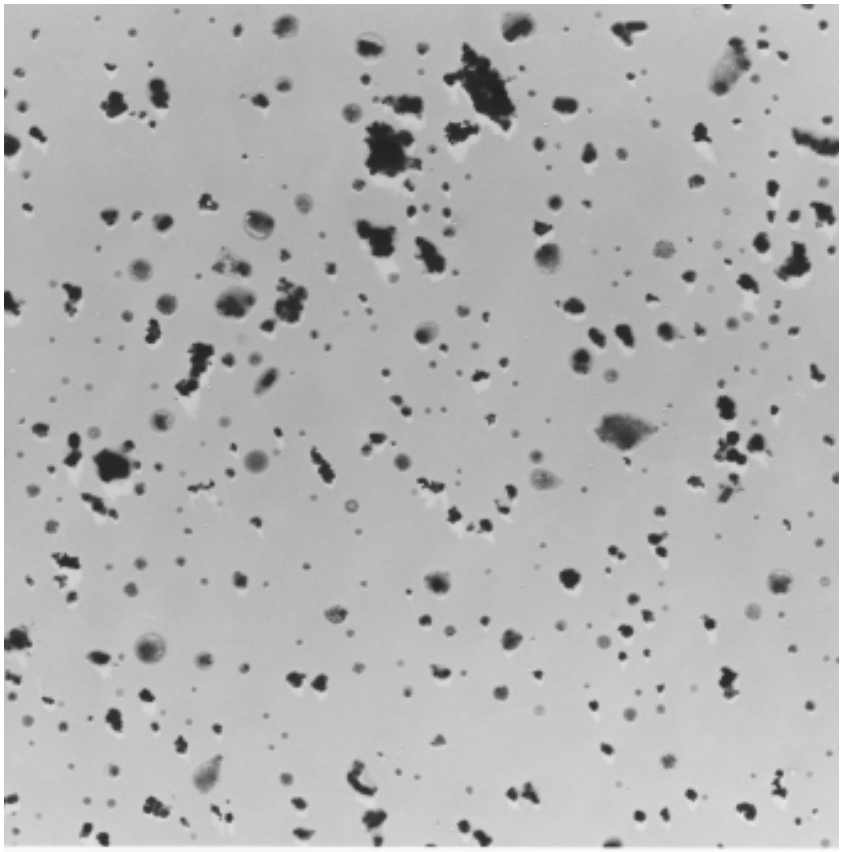
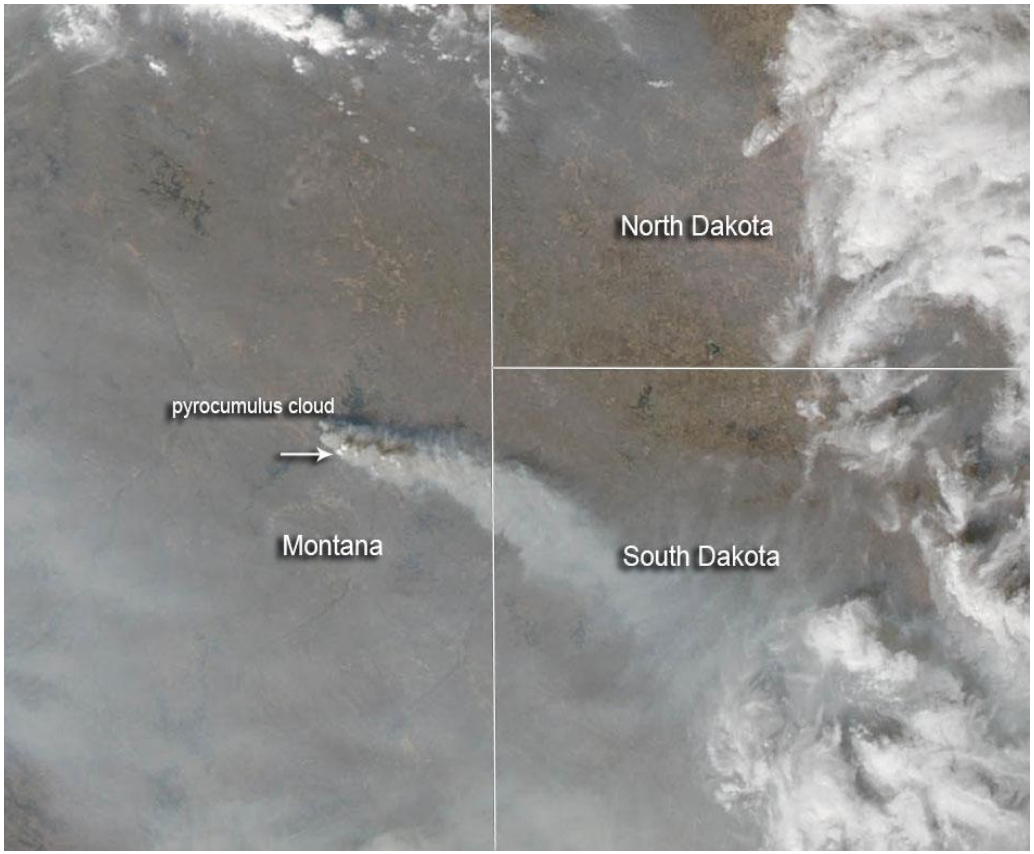
Atmospheric Aerosols and Cloud Condensation Nuclei

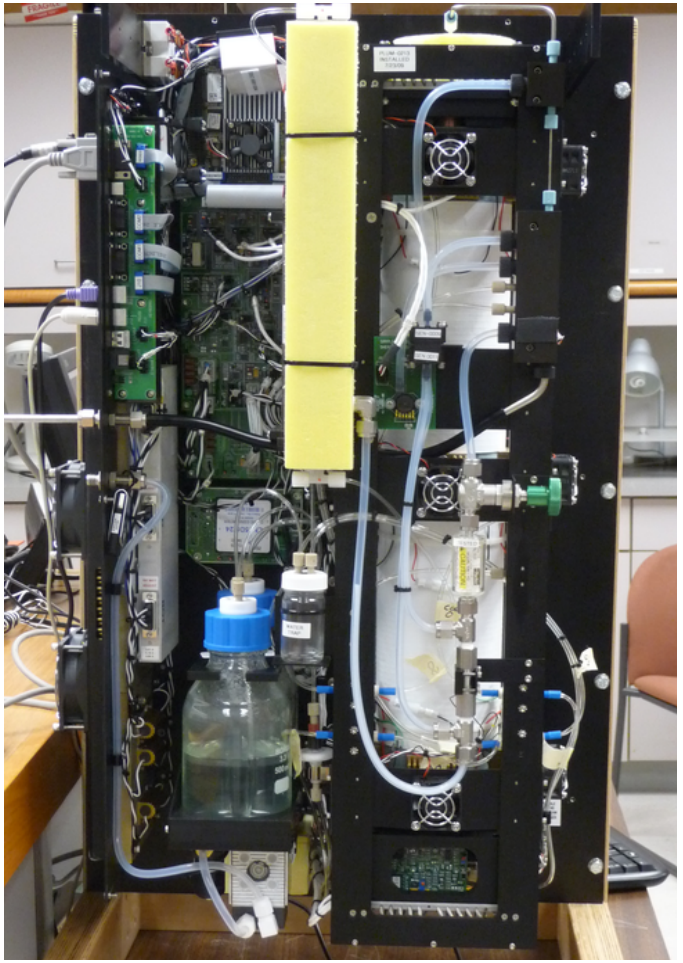




September 19, 2012

Aerosol Importance

- Scatter and Absorb Radiation
- Media for Chemical Reactions
- Serve as Cloud Condensation Nuclei CCN)



Objectives

- Provide an introduction to atmospheric aerosols.
- Explain how Cloud Condensation Nuclei (CCN) are a subset of atmospheric aerosols.
- Illustrate how CCN are measured.
- Show how CCN concentration vary in the atmosphere.

Definitions

Aerosols

- Suspended Solid or Liquid Matter
- Small Settling Velocity

Atmospheric Aerosols

- Suspended material in the Earth's atmosphere that have residence times of days, to a few weeks.
- Atmospheric Aerosols are sometimes referred to as “particles”.

Clouds in the Atmosphere

Clouds are made up of water droplets and/or ice crystals, much larger than typical aerosols (0.01-10 μm).

Clouds are technically aerosols but have unique properties and are typically considered separately.

East Grand Forks: 17 July 2011

Citation Flight: 14 July 2011

Atmospheric Aerosol Size Range

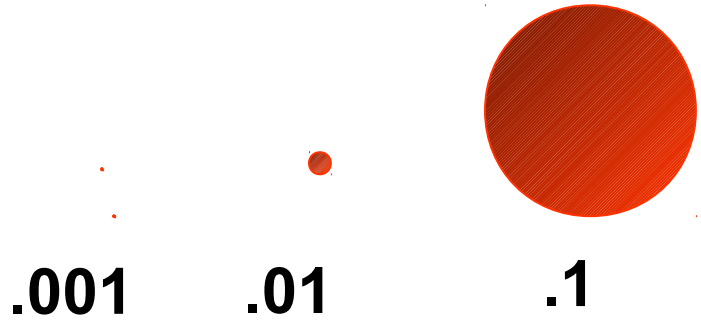
10^{-9}m to 10^{-5} m

.001 µm to 10 µm

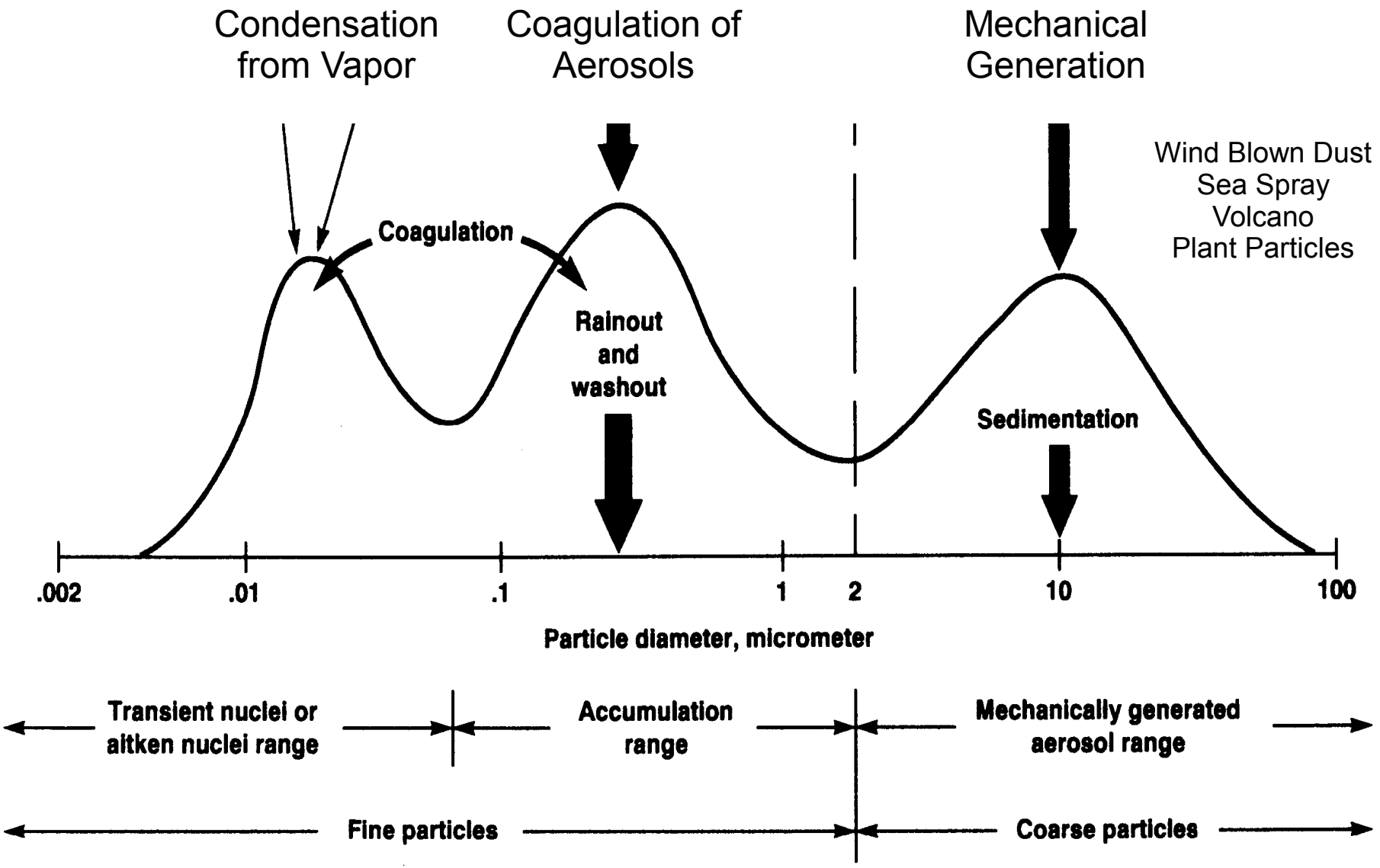
1 nm to 10,000 nm

Wavelength of Visible Light?

Size of a human hair?



Major Aerosol Modes

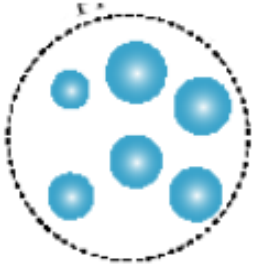


Courtesy of Singh: Figure 5.4

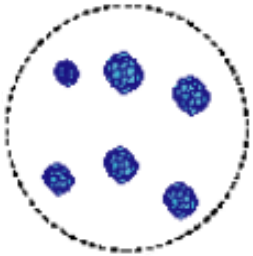
Uptake of Water by Aerosols

Deliquescence

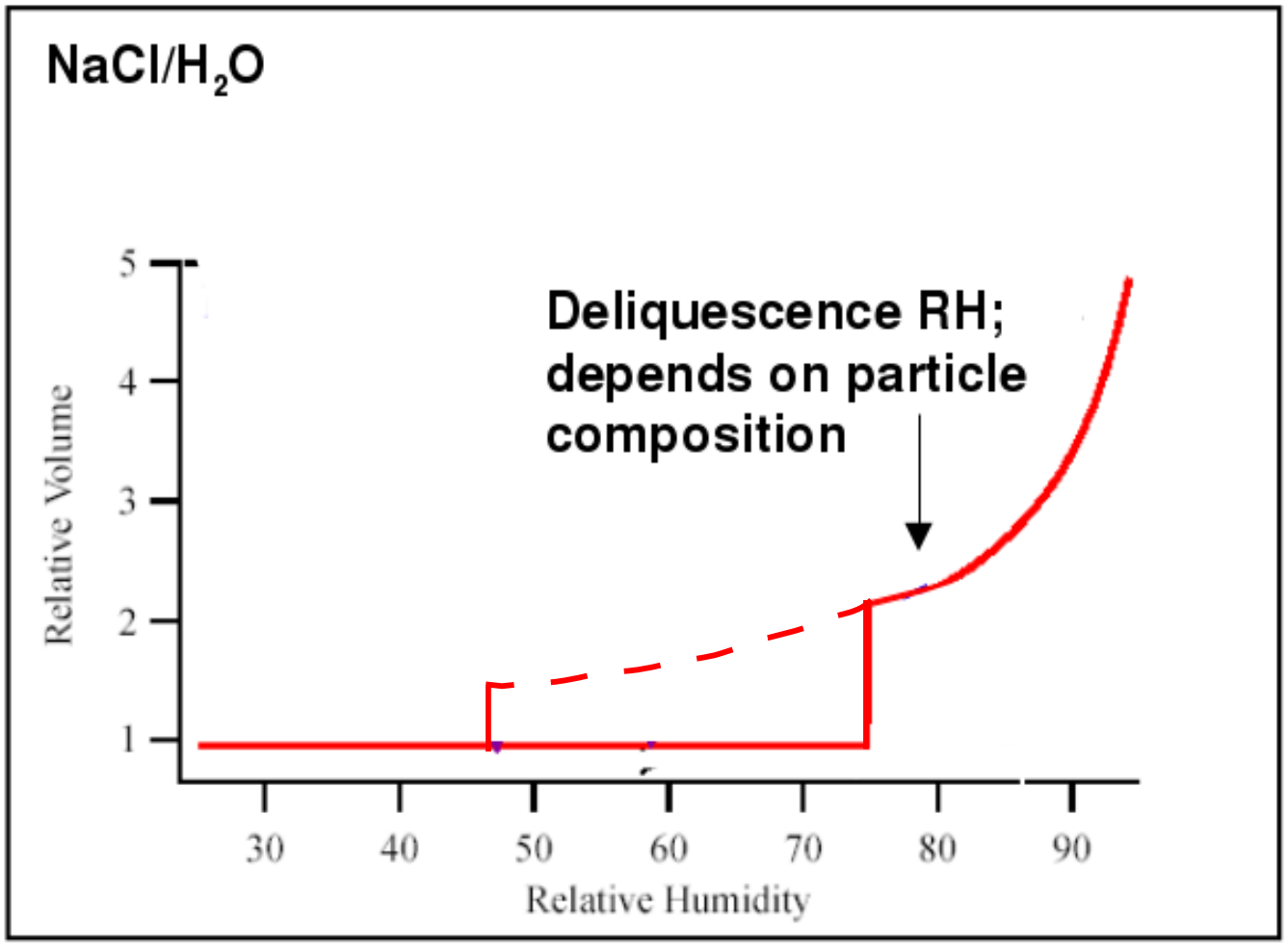
Aqueous Particles



Crystalline Particles

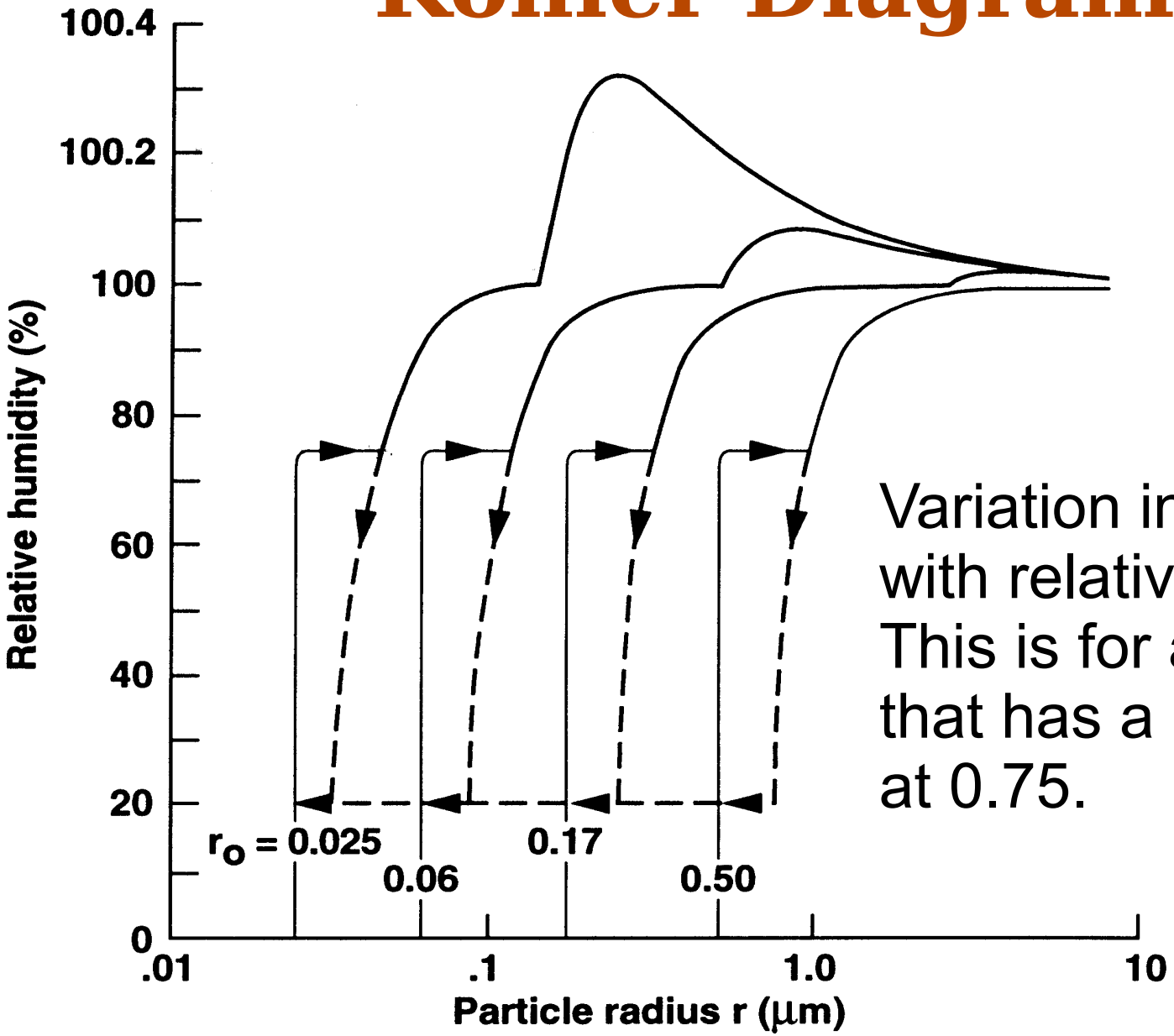


Efflorescence



Courtesy of Daniel J. Jacob

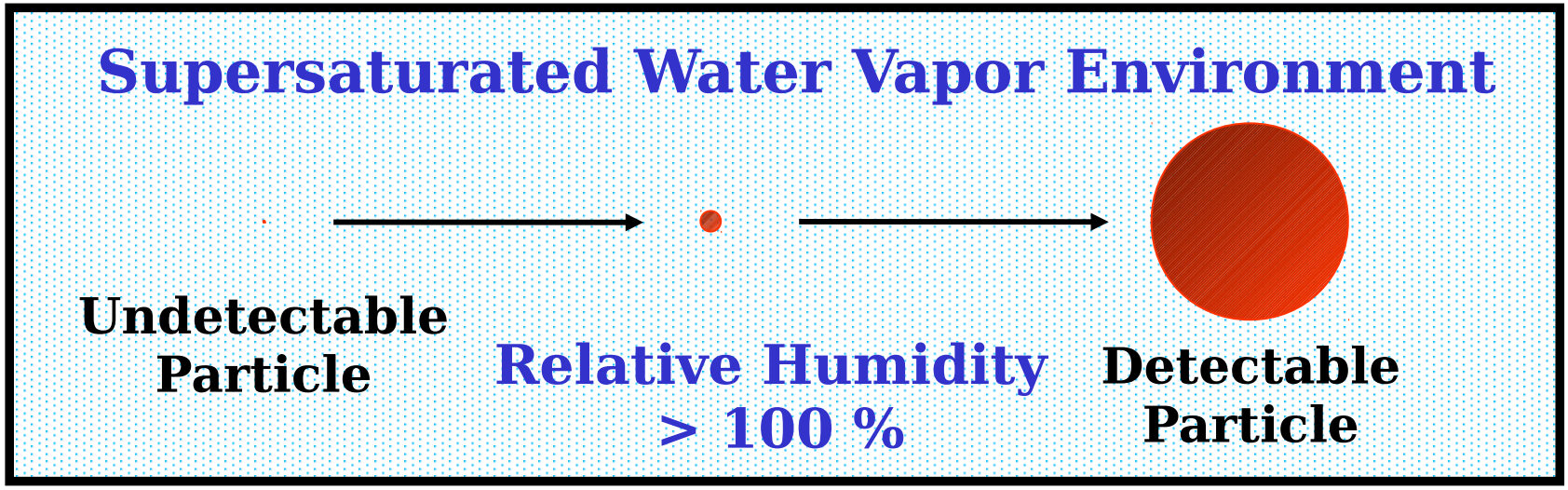
Kohler Diagram

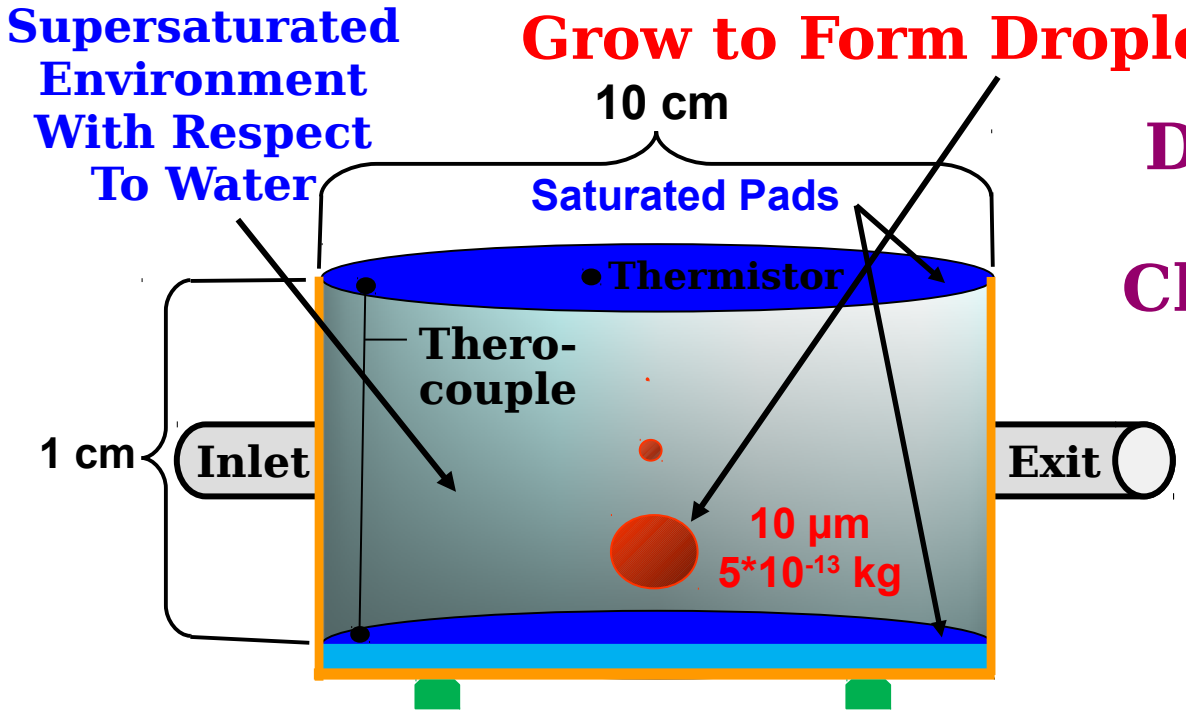


Variation in particle size with relative humidity. This is for a salt (NaCl) that has a deliquescing at 0.75.

Courtesy of Singh: Figure 5.1

Grow Aerosols to Detectable Size





Diffusion Chamber for Cloud Condensation Nuclei Counter

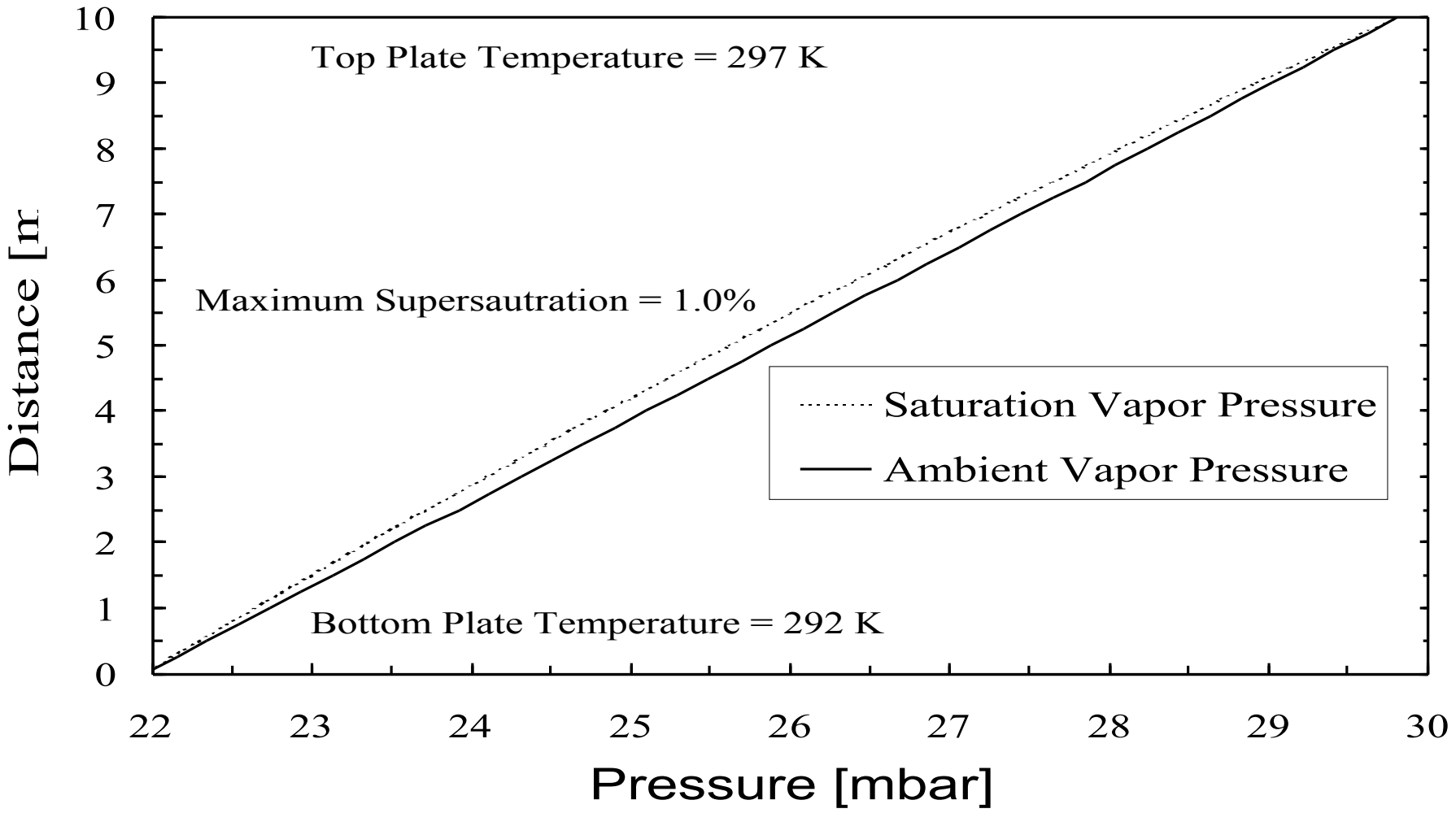
Determines the number of particles in air that cloud droplets form on.

Vapor Pressure

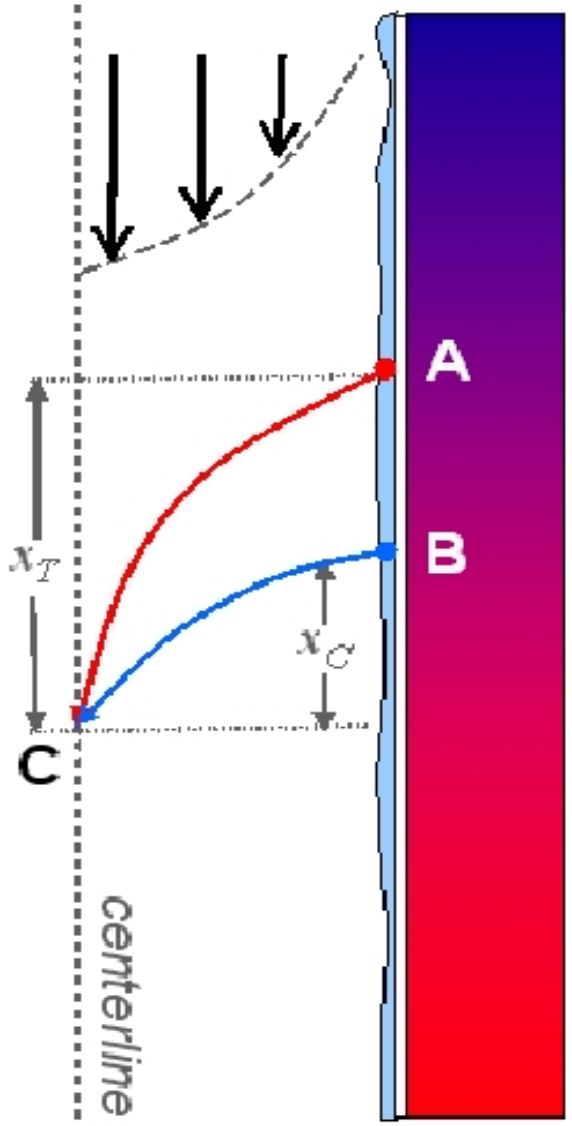
Ambient vapor pressure is linear from top to bottom.

Saturation vapor pressure is a curve from top to bottom.

A supersaturation exists between top and bottom.



Vertical Thermal Diffusion Chamber



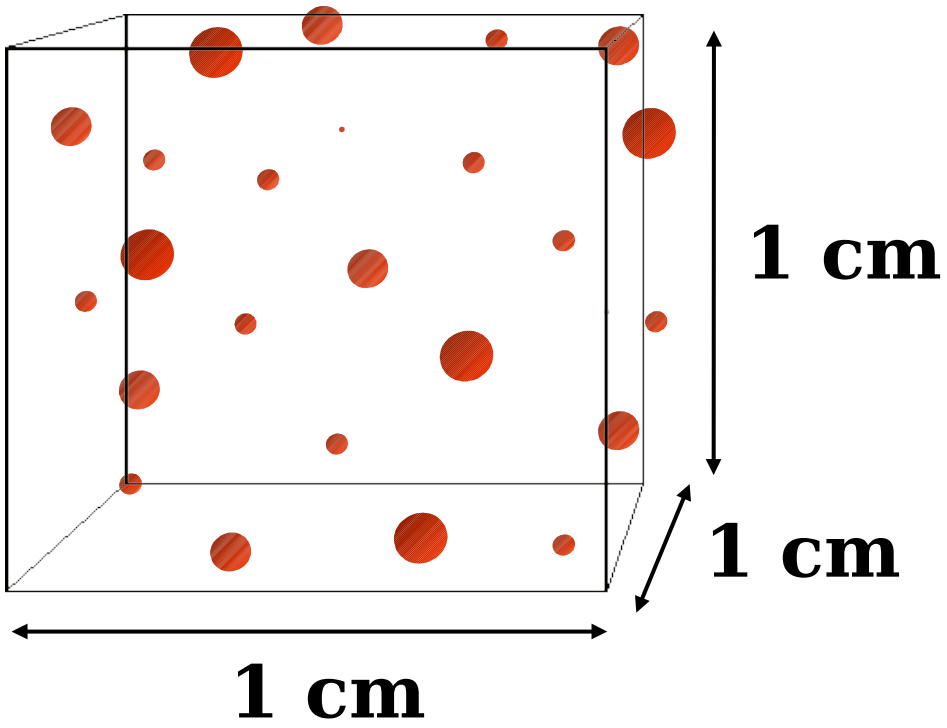
Water vapor diffuses from the chamber walls inward more quickly than heat.

The unit operates at a single supersaturation, because the temperature and water vapor gradient along the wetted walls are approximately constant along the wall.

The centerline supersaturation depends on the temperature difference between the top and bottom of the column, the flow rate and the absolute pressure in the column.

Aerosol Number Concentration

Number of Aerosols per unit Volume



24 particles / 1 cm^3 = 24 cm^{-3}

How does concentration change with heigh?

UWyo CCN Counter Measurements

Location	Time of Year	CCN Concentration
Wyoming, USA	Winter	146 ± 20 #/cm^{-3}
Wyoming, USA	Summer	445 ± 157 #/cm^{-3}
New Zealand	Summer	964 ± 17 #/cm^{-3}
Bamako, Mali	09/08/07	367 ± 247 #/cm^{-3}

Cloud Condensation Nuclei (CCN) concentrations at 0.6% ambient supersaturation measured by the University of Wyoming CCN counter in the lower troposphere at various locations.

Source: Delene, D. J. and T. Deshler, Vertical profiles of cloud condensation nuclei above Wyoming, Journal of Geophysical Research - Atmospheres , 106, 12579-12588, 2001.

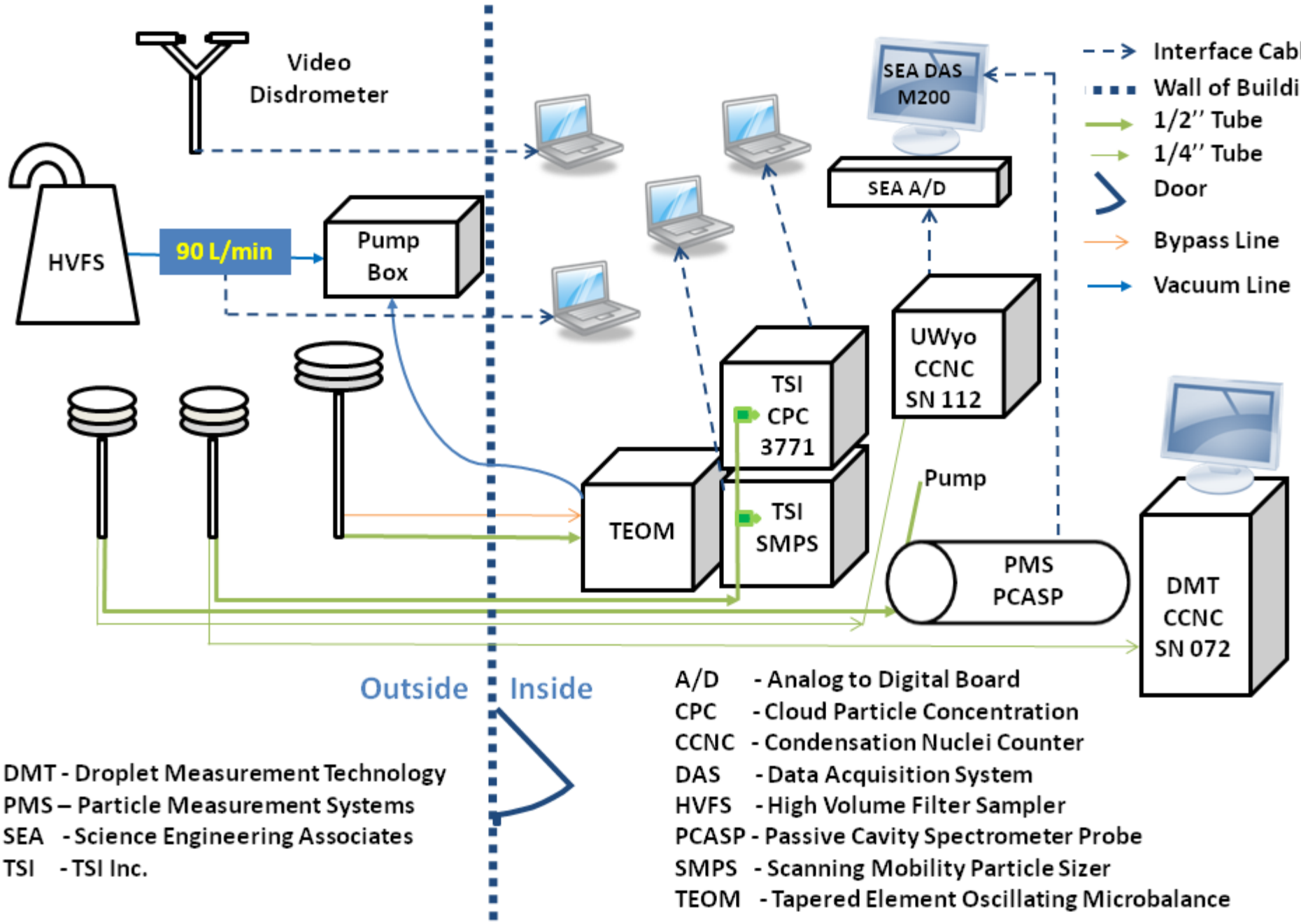
CCN Measurements

Location	CCN Concentration
Australian Cost	120 #/cm^{-3}
North Atlantic Ocean	145-370 #/cm^{-3}
High Planes, Montana	290 #/cm^{-3}
Australia, Africa, USA	600 #/cm^{-3}
High Planes, Montana	2000 #/cm^{-3}
Buffalo, New York	3500 #/cm^{-3}
Texas, USA	3000-5000 #/cm^{-3}

Cloud Condensation Nuclei (CCN) concentrations at 1% Supersaturation measured at various locations.

Source: Pruppacher, H. R., and J. D. Klett, Microphysics of Clouds and Precipitation, pp. 287-289, Kluwer Acad. Norwell, Mass., 1997.

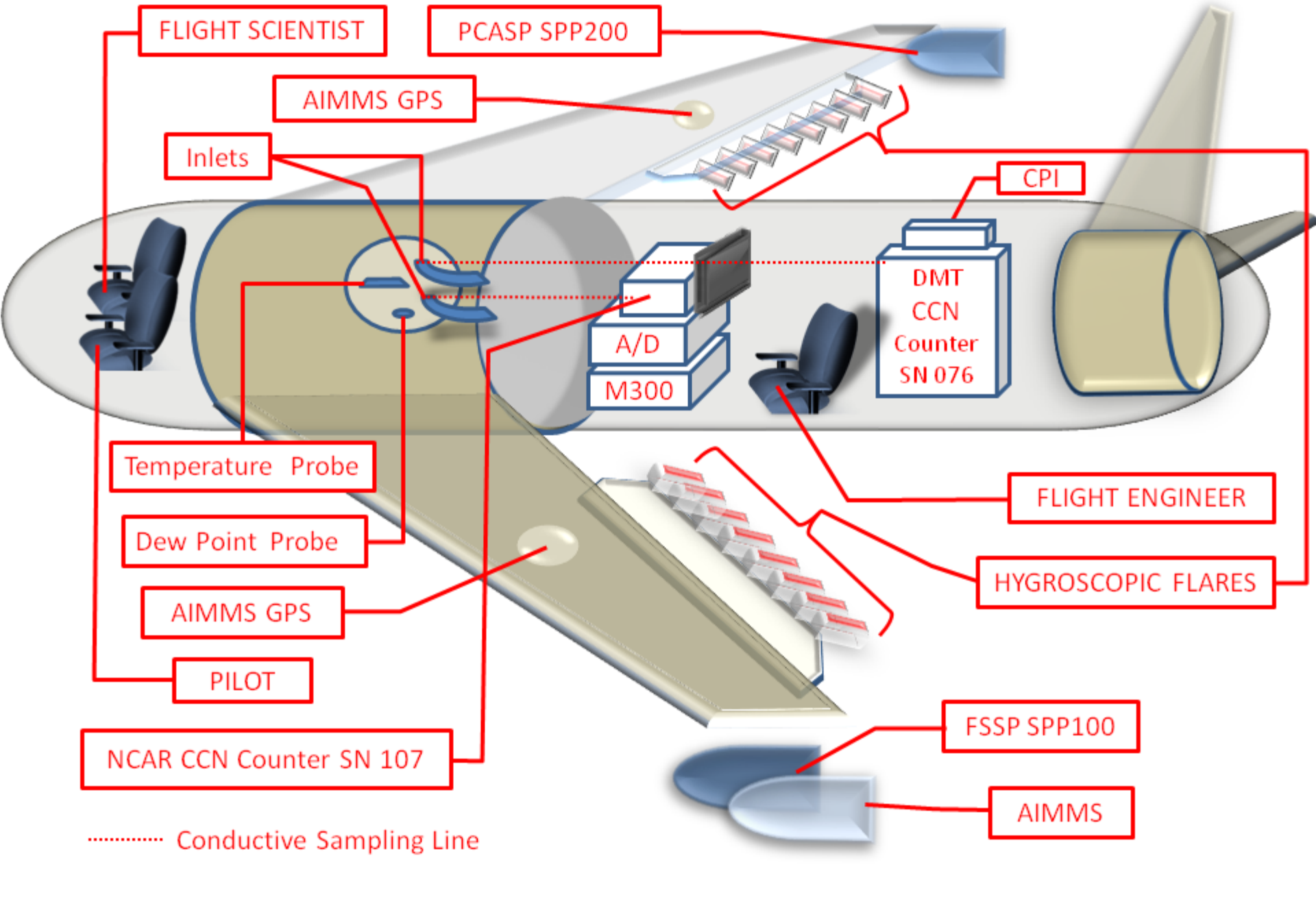
POLCAST4 Surface Measurements: Clifford Hall 601



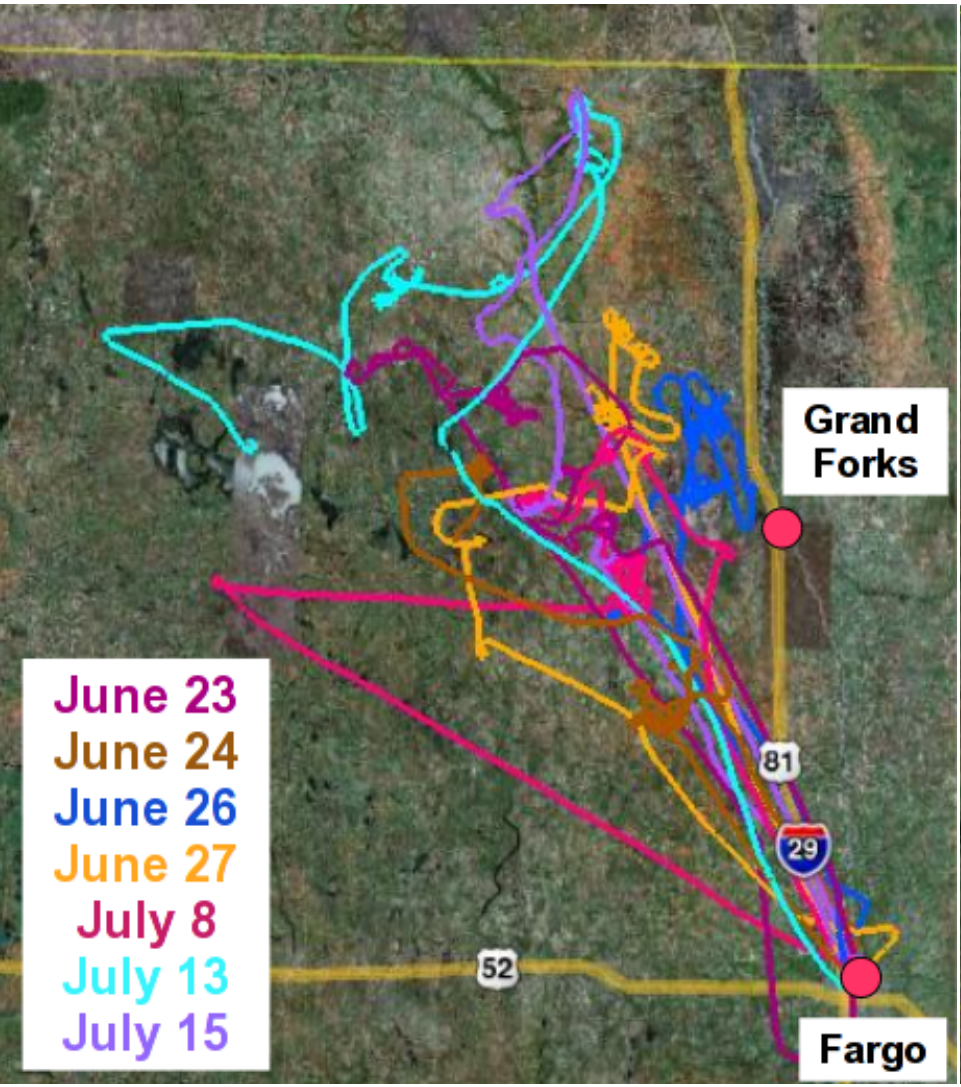
DMT - Droplet Measurement Technology
PMS – Particle Measurement Systems
SEA - Science Engineering Associates
TSI - TSI Inc.

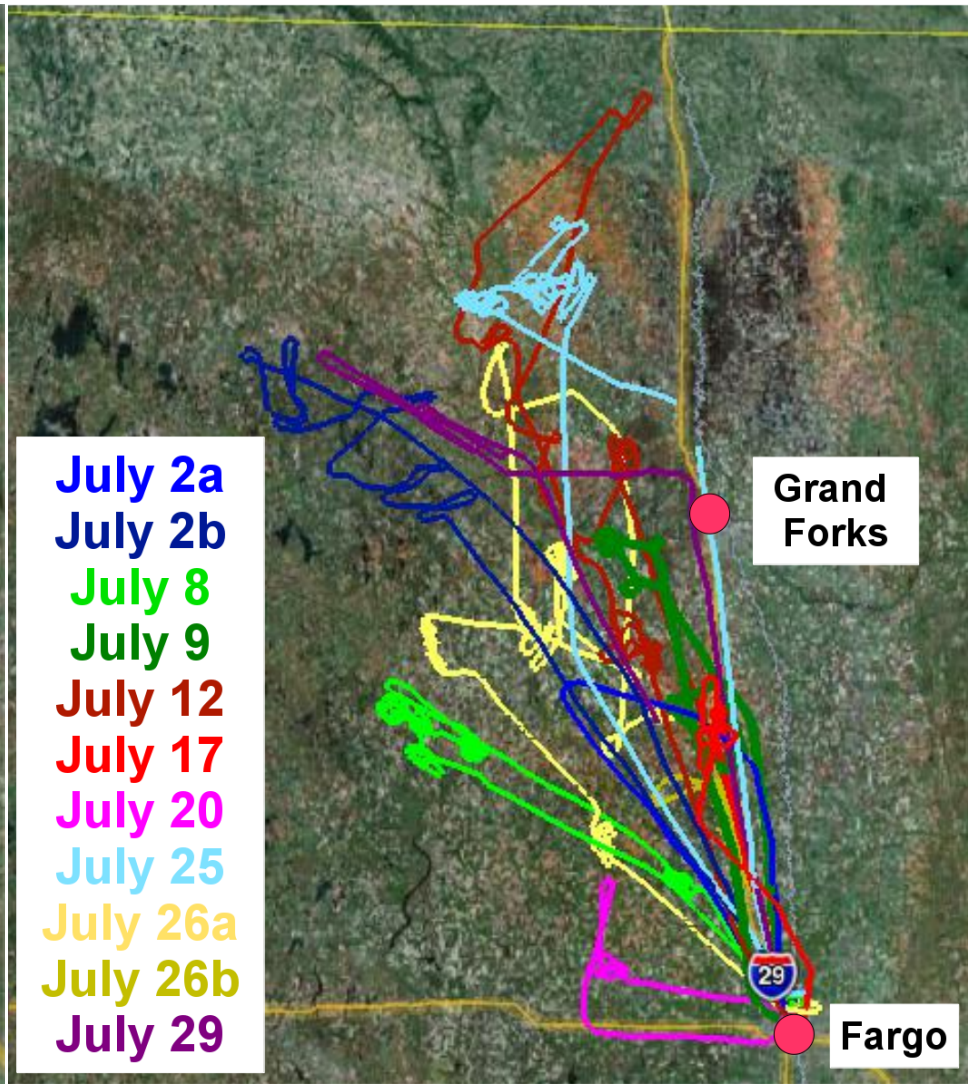
A/D - Analog to Digital Board
CPC - Cloud Particle Concentration
CCNC - Condensation Nuclei Counter
DAS - Data Acquisition System
HVFS - High Volume Filter Sampler
PCASP - Passive Cavity Spectrometer Probe
SMPS - Scanning Mobility Particle Sizer
TEOM - Tapered Element Oscillating Microbalance

POLCAST4 CESSNA340 N98585 INSTRUMENT CONFIGURATION



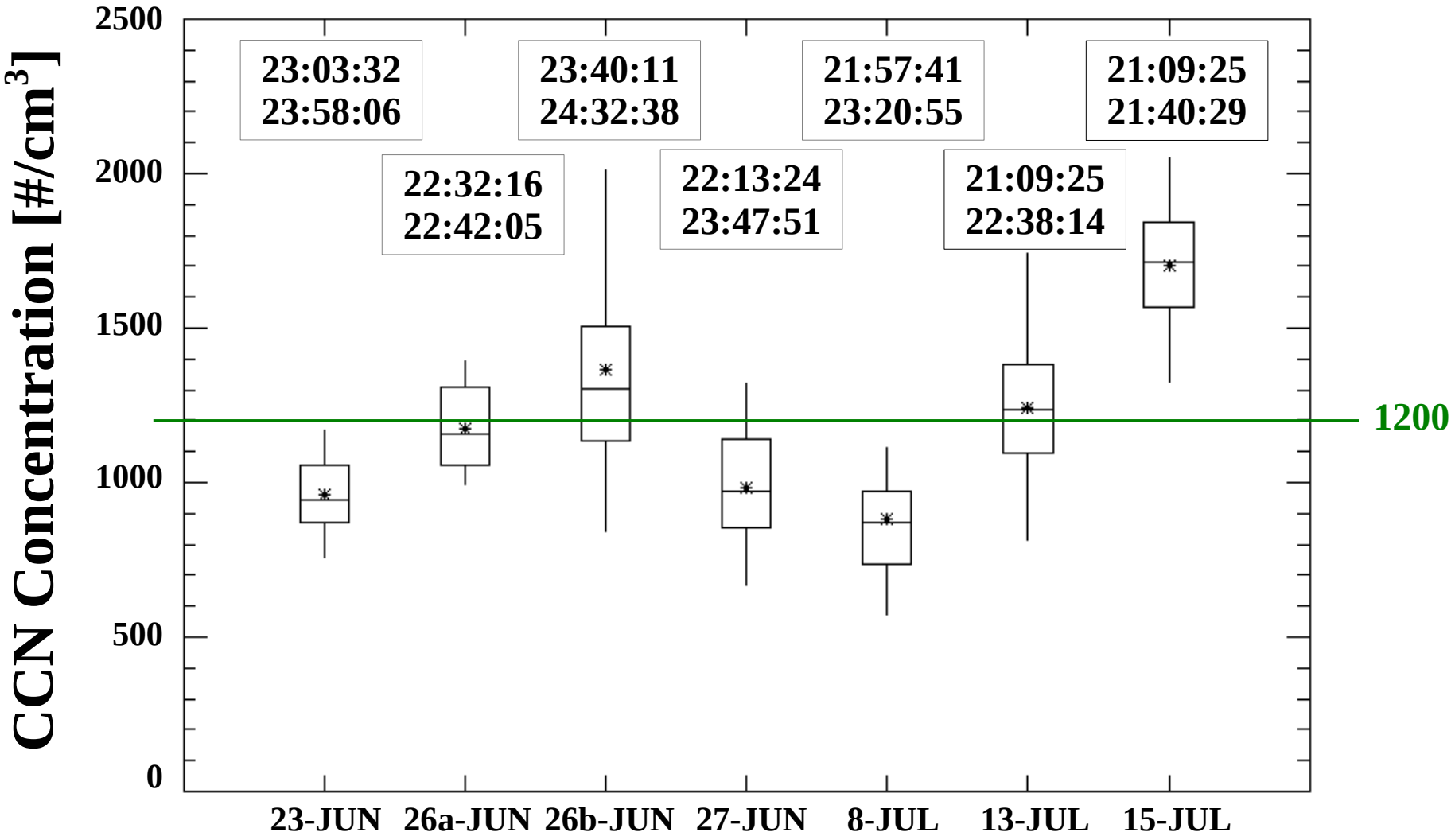
Cessna 340 Flight Tracks





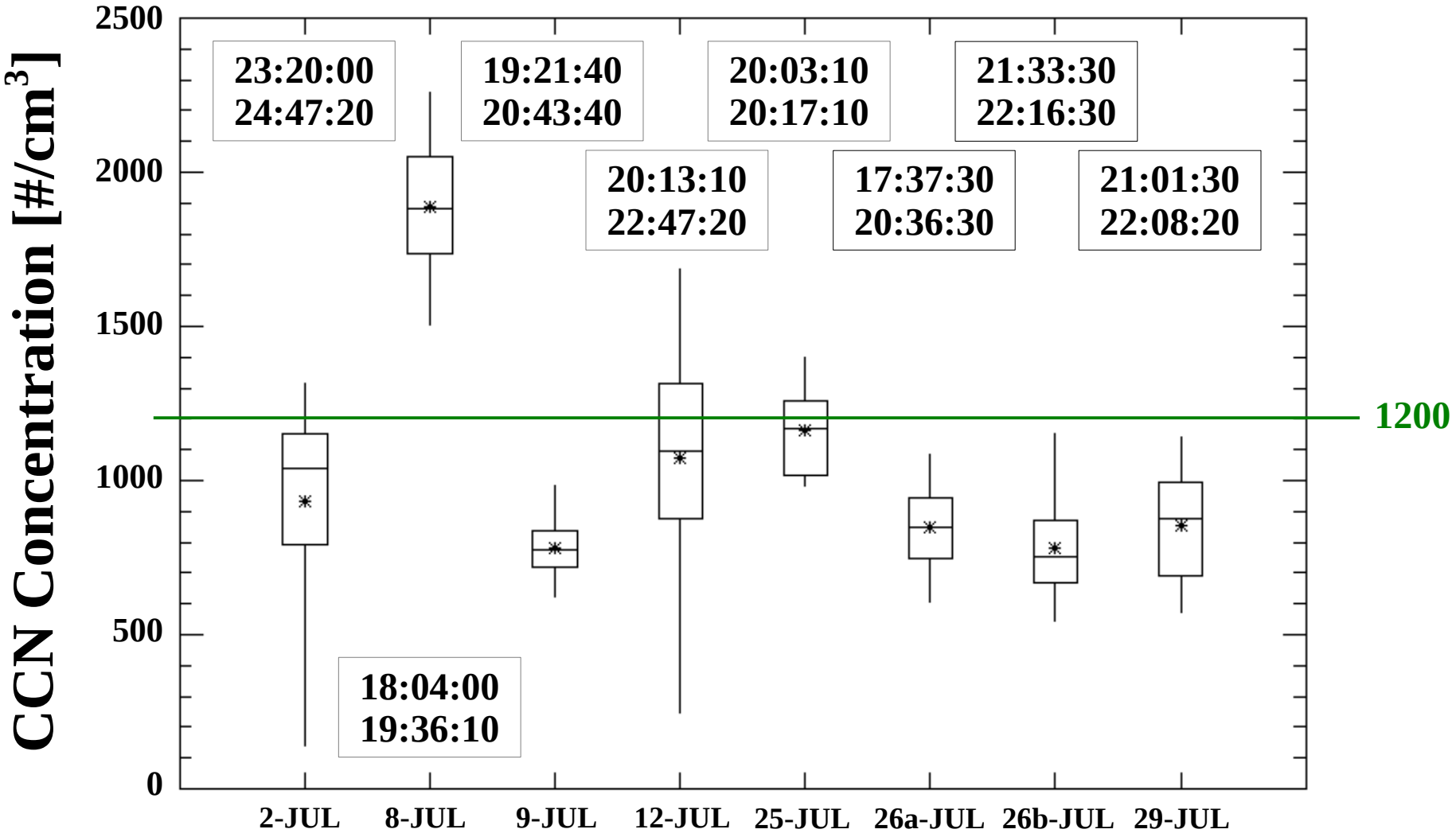
Aircraft flight paths during the 2010 POLCAST3 (left) and 2012 POLCAST 4 (right) field project.

Cloud Base: 2010



Statistical distributions near cloud base of 30 s 1 % supersaturation (Uwyo CCNC theoretical value) Cloud Condensation Nuclei (CCN) adjusted to standard temperature and pressure during the 2010 POLCAST3 field project. The solid circle is the mean value, the horizontal line is the 50th percentile, the top of the box is the 75th percentile, the bottom is the 25th percentile, and the top and bottom of the whiskers are the 95th and 5th percentiles, respectively.

Cloud Base: 2012



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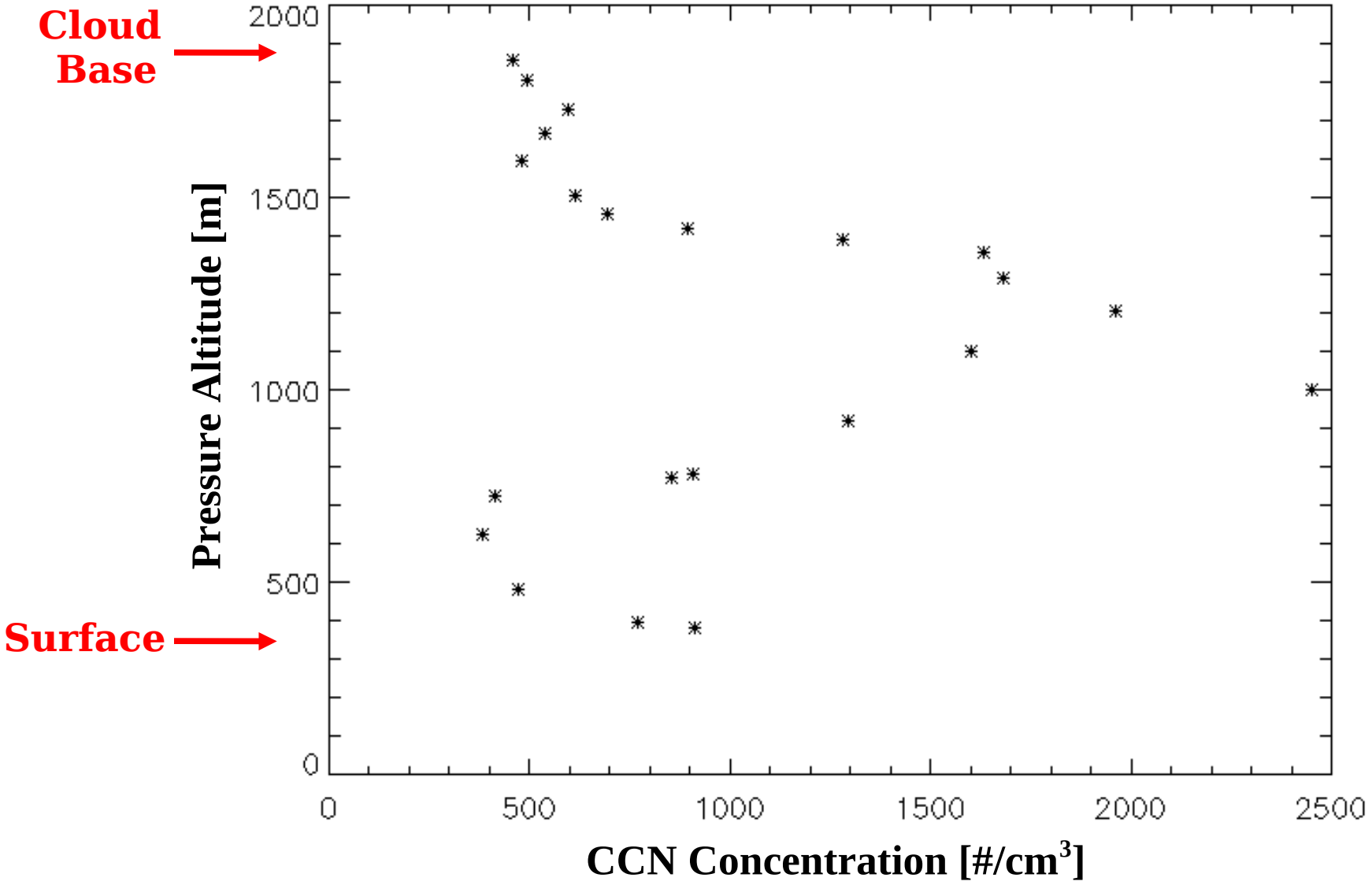
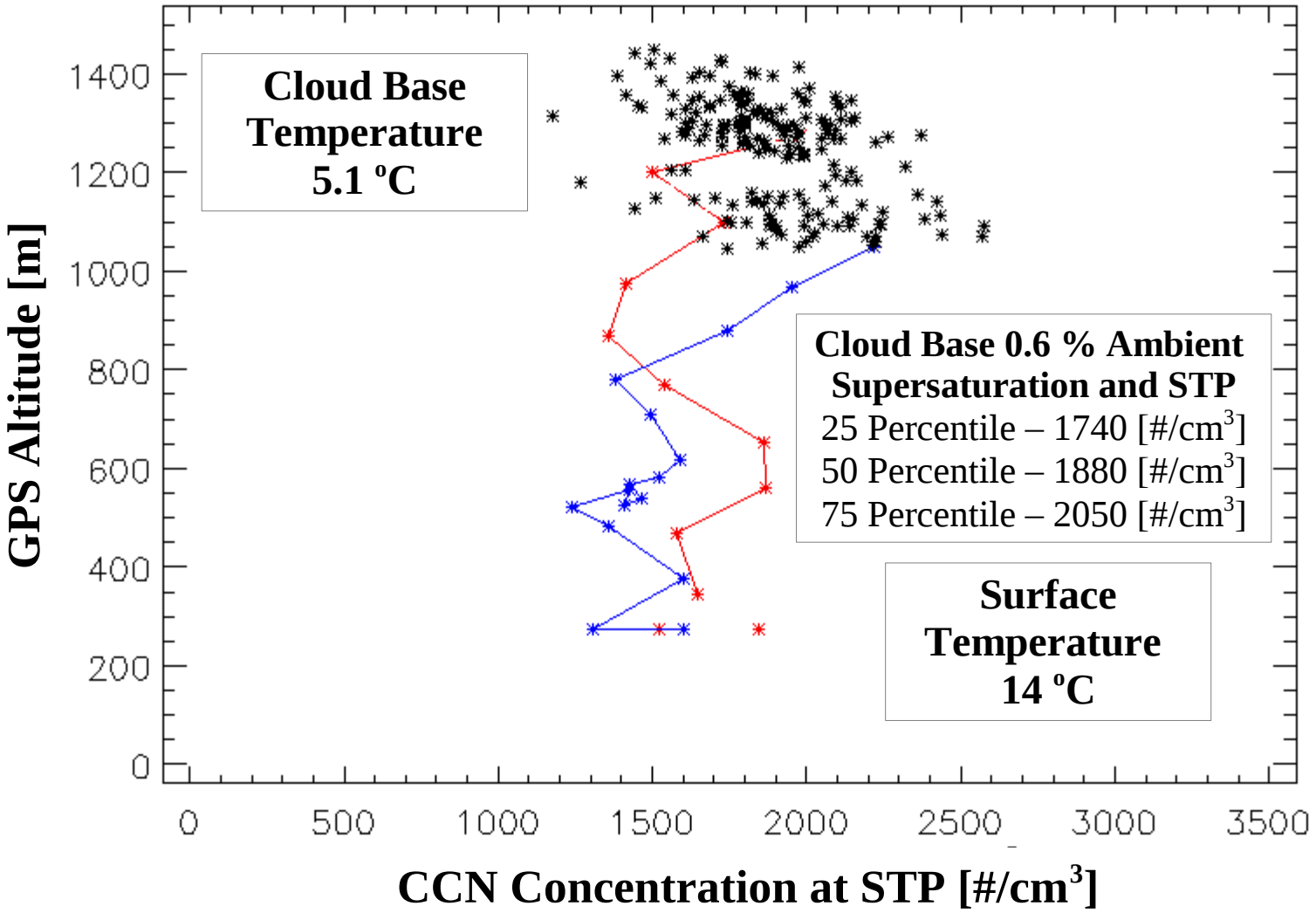


Cloud Condensation Nuclei (CCN) concentrations versus Pressure Altitude measured during decent into Bamako on the September 17, 2007 flight.

July 8, 2012



University of Wyoming cloud condensation nuclei (CCN) counter measurements (0.6 % ambient supersaturation) adjusted to standard pressure and temperature (STP) on aircraft ascent (red, 17:40:00-17:45:00 UTC), during cloud base sampling (black stars, 18:04:00-19:36:10) and during descent (blue, 19:36:20-19:56:40).

Conclusions

Cloud Condensation Nuclei are a very important but difficult measurement.

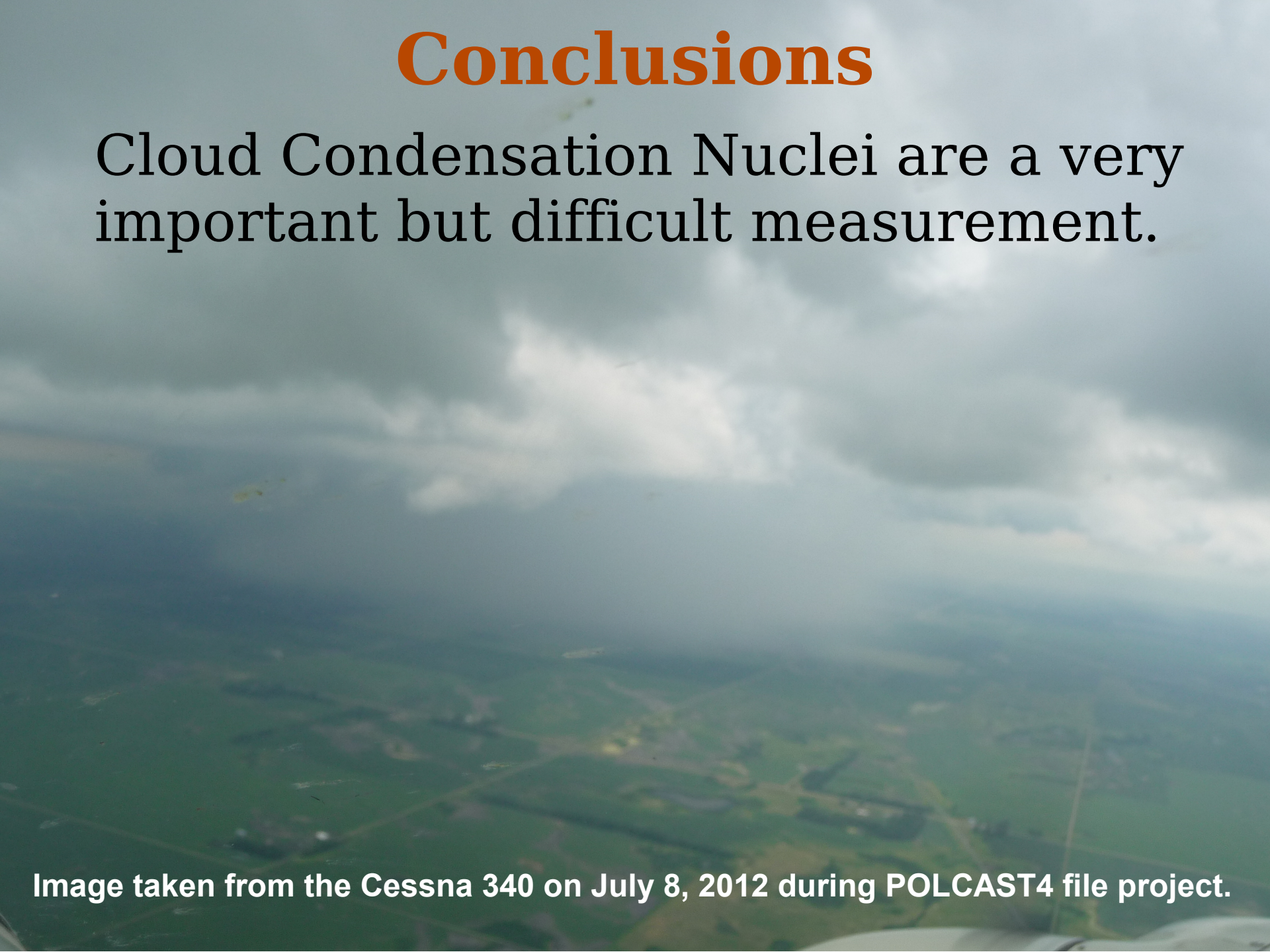
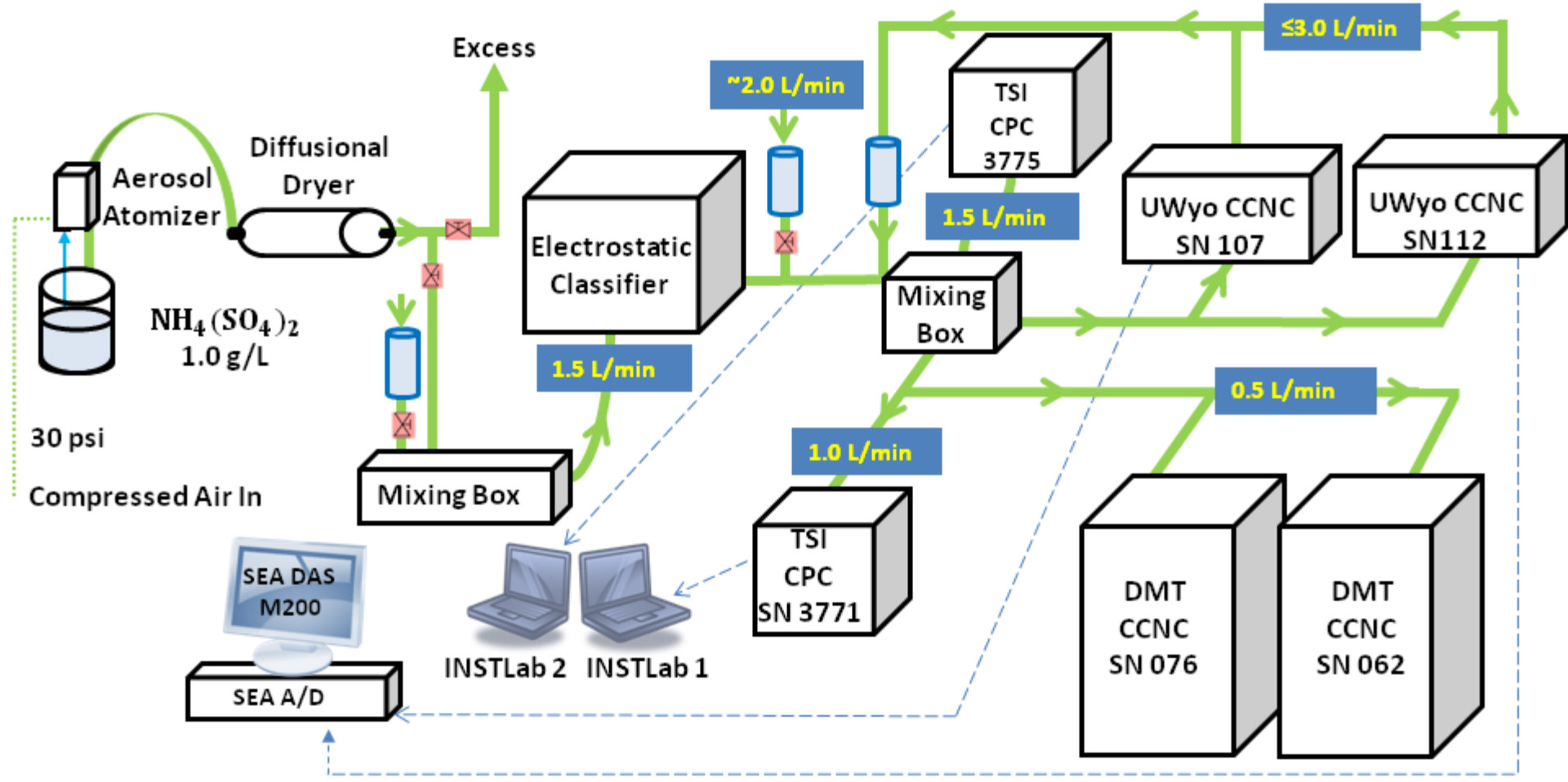


Image taken from the Cessna 340 on July 8, 2012 during POLCAST4 file project.

POLCAST4 Lab: Cloud Condensation Nuclei Performance Check



Interface

Valve

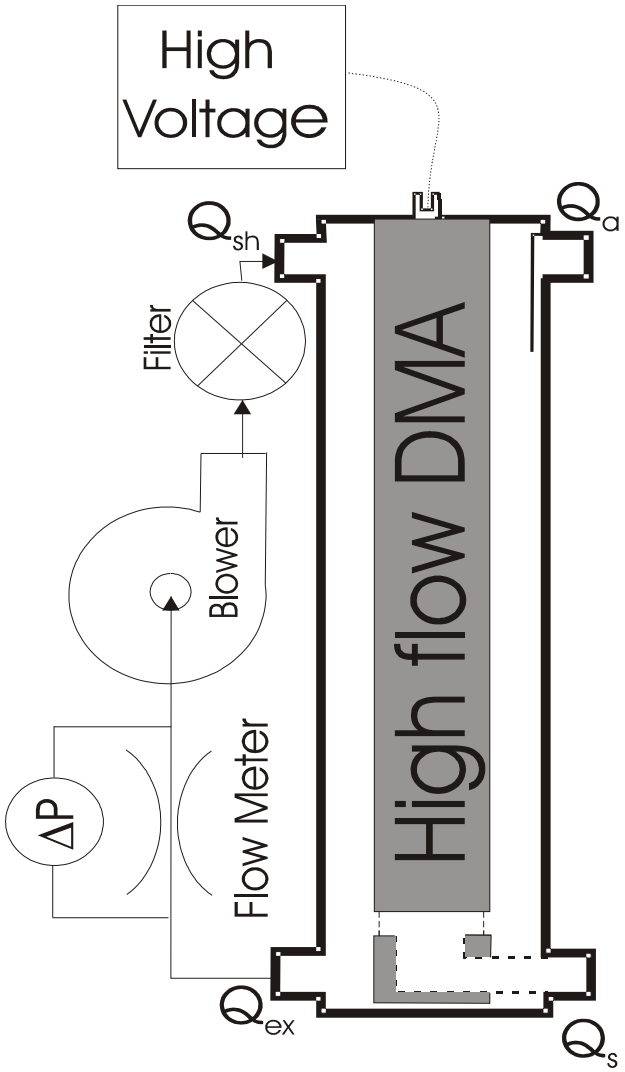
Filter

Direction of Air Flow

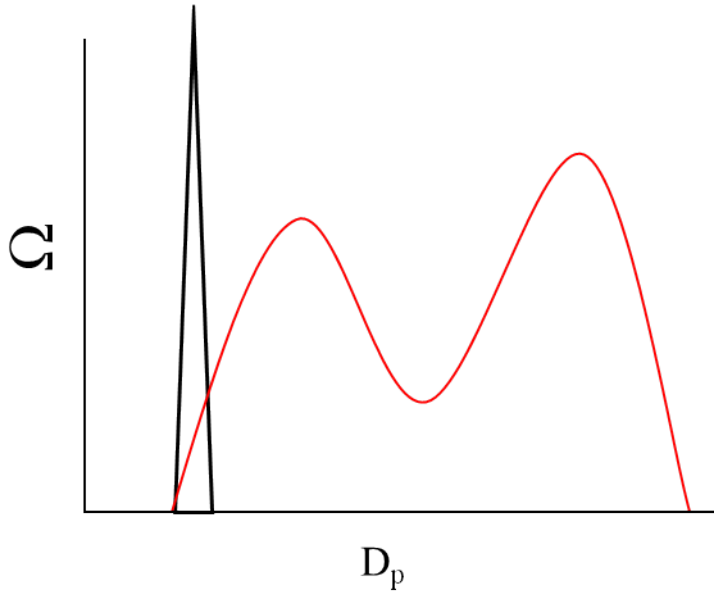
Direction of Water Flow

DMT CCNC - Droplet Measurement Technology Cloud Condensation Nuclei Counter
SEA A/D - Science Engineering Associates Analog to Digital Board
SEA DAS - Science Engineering Associates Data Acquisition System
TSI CPC - TSI Inc. Cloud Particle Concentration
Uwyo CCNC - University of Wyoming Cloud Condensation Nuclei Counter

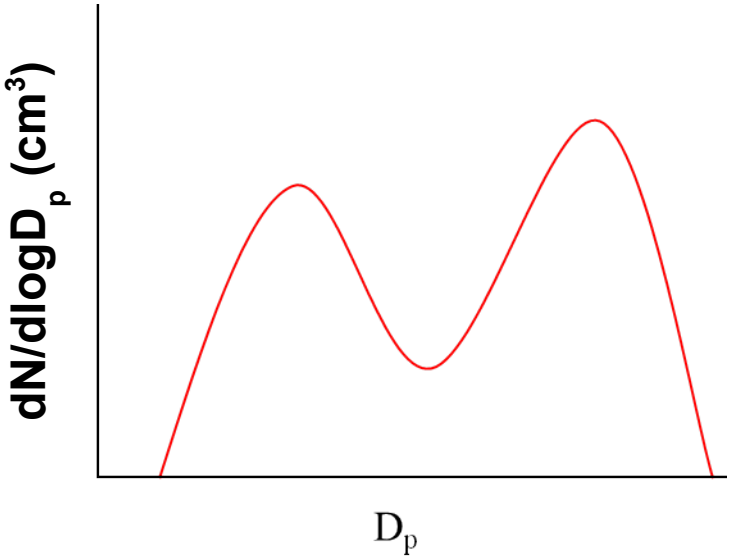
Differential Mobility Analyzer



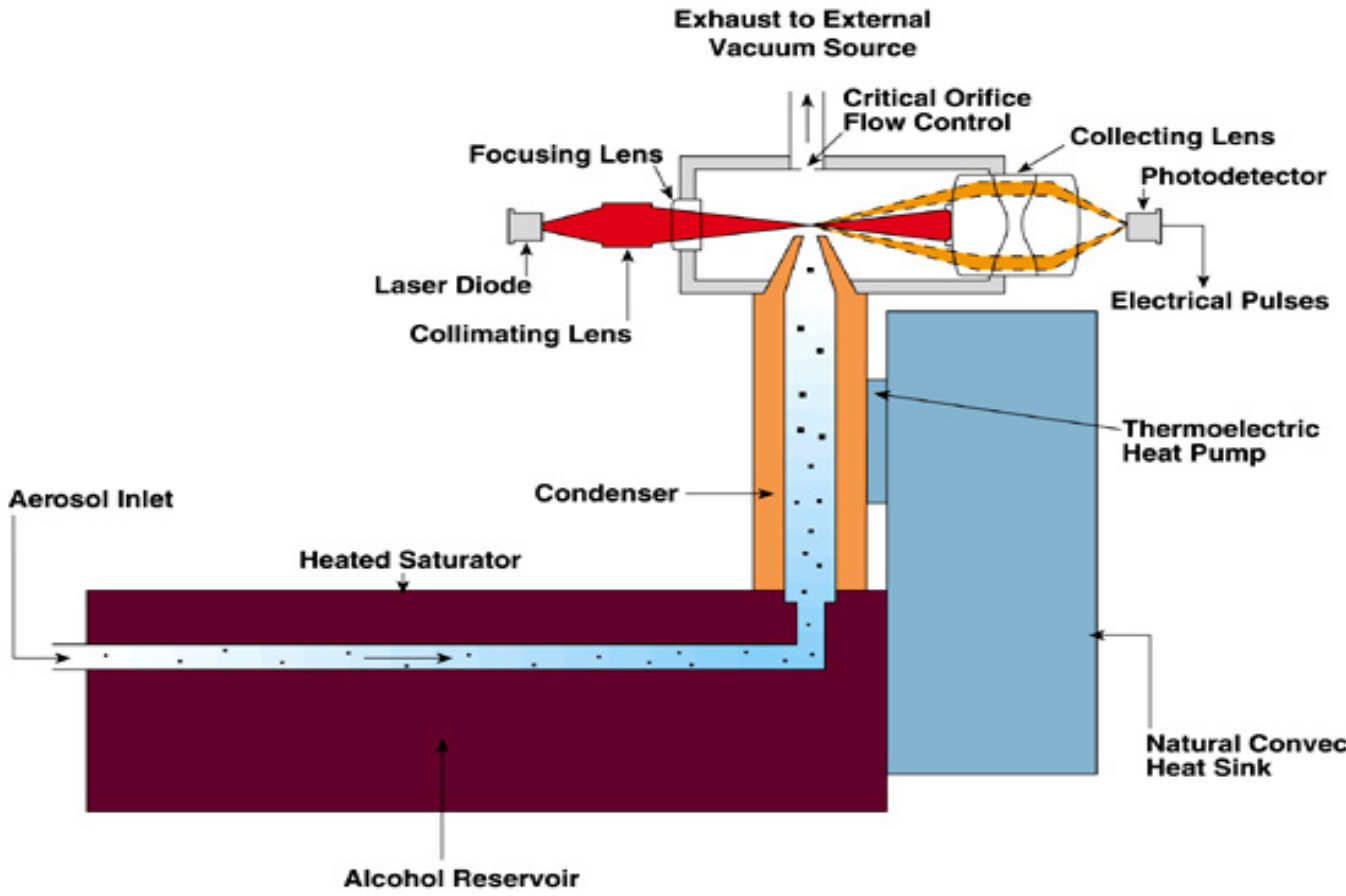
Polydisperse Aerosol In



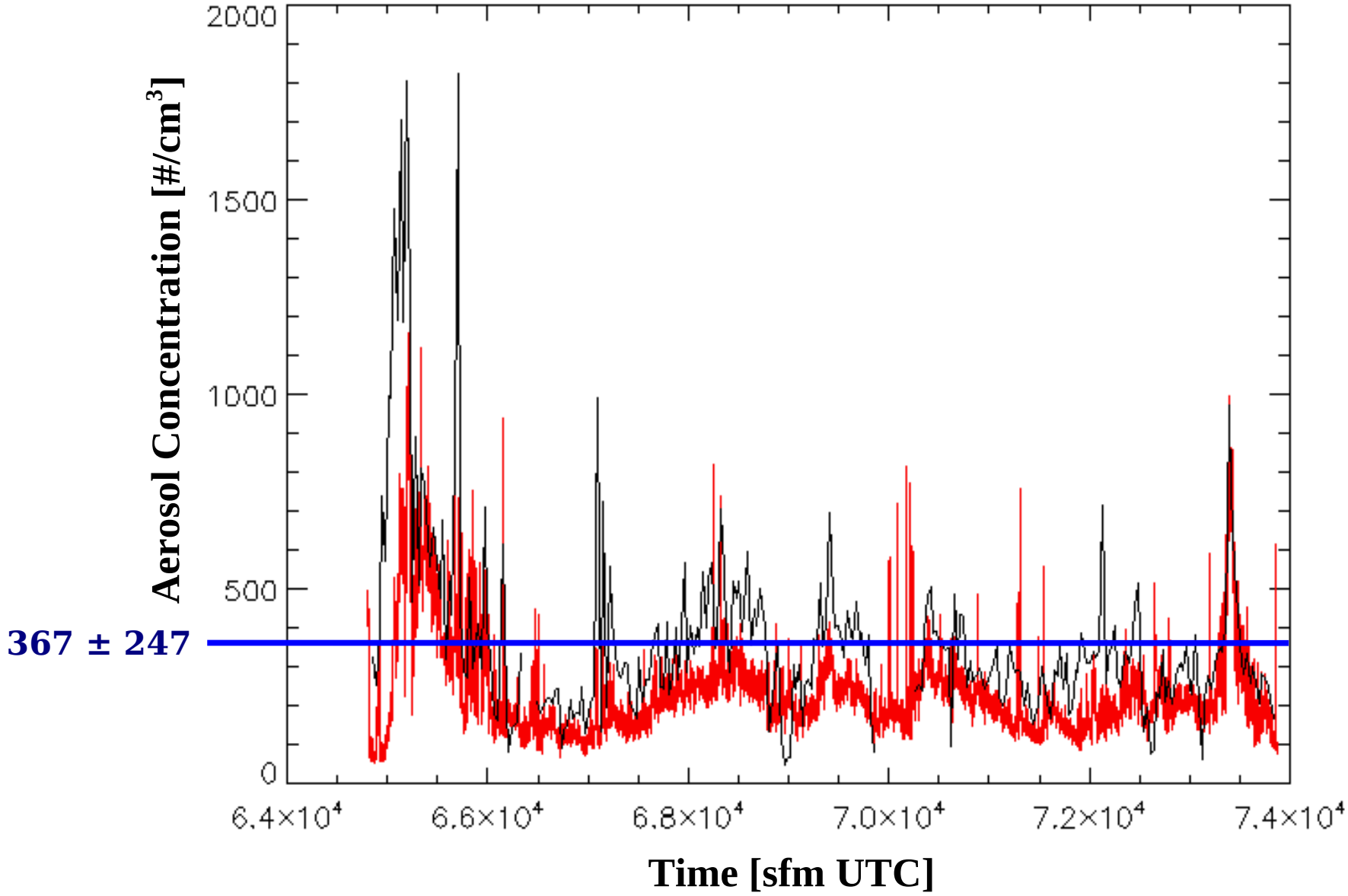
Monodisperse Aerosol Out



Condensation Nucleus Counter

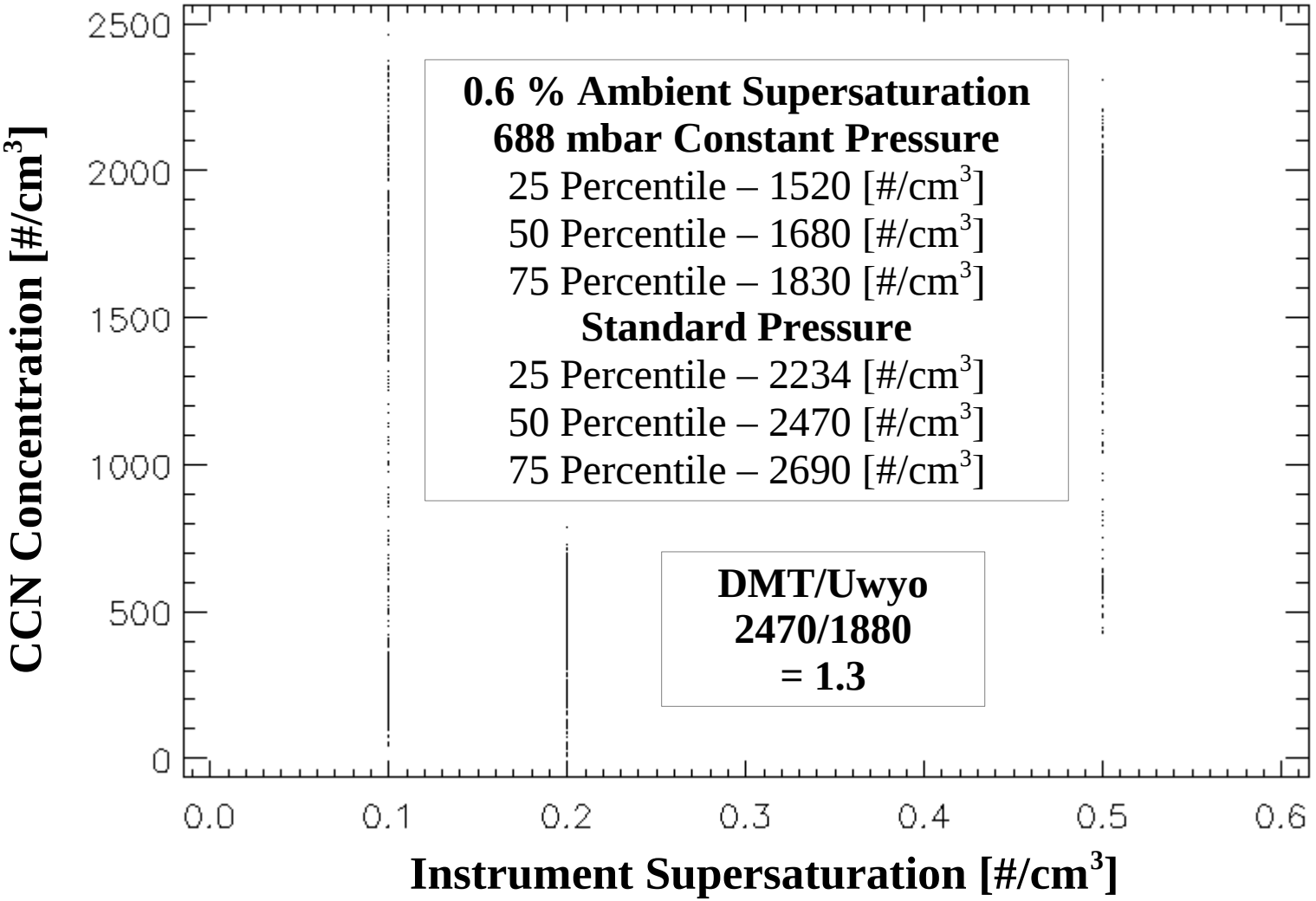


Alcohol vapor condenses onto particles which create droplets large enough to be detected one at a time by an optical particle counter. Upon entering the instrument, the air sample passes through a saturation block where alcohol evaporates saturating the flow. The air sample next enters a condenser tube which cools the air sample. Cooling of the air sample creates a supersaturated environment and the alcohol condenses onto particles, regardless of particle composition.



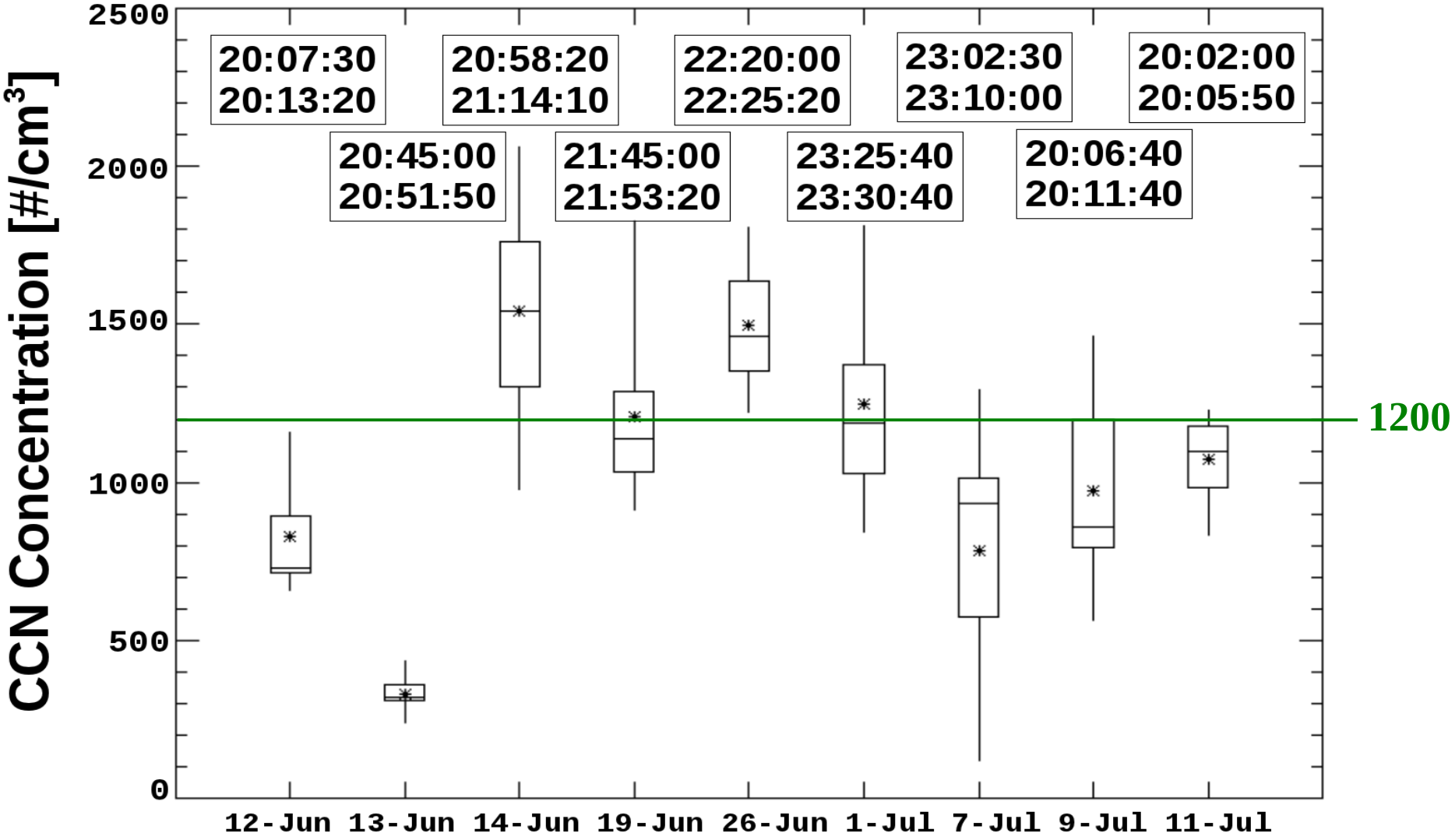
Cloud Condensation Nuclei (CCN) concentrations (black line) and Optical Particle Counter (OPC) concentrations measured East of Bamako on September 8, 2007 just below and above cloud base.

July 8, 2012



Droplet Measurement Technologies (DMT) cloud condensation nuclei (CCN) counter measurements during cloud base sampling (65,700-67,780 sfm UTC).

Cloud Base: 2008



Statistical distributions near cloud base of 30 s 1 % supersaturation (UWyo CCNC theoretical value) Cloud Condensation Nuclei (CCN) adjusted to standard temperature and pressure during the 2008 POLCAST2 field project. The solid circle is the mean value, the horizontal line is the 50th percentile, the top of the box is the 75th percentile, the bottom is the 25th percentile, and the top and bottom of the whiskers are the 95th and 5th percentiles, respectively.