Aerosol Measurements: sampling, size distributions, and CCN profiles

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Objectives

- Aerosol samplers
  - BASE – Blunt-body aerosol sampler (Clarkson)
  - Hi-CAS –High-speed cross-flow aerosol sampler (Clarkson)
  - SMAI – Sub-micron aerosol inlet (NCAR, Al Schanot)

- Aerosol size distribution measurements
  - DMT UHSAS (tentative)
    - Optical sizing, 60-1000 nm; 1Hz
  - High-flow Dual-channel Differential Mobility Analyzer (HD-DMA);
    - Electrical-Mobility sizing, 1.6-1000 nm (During ICE-T: 10-100 nm); 0.1 Hz

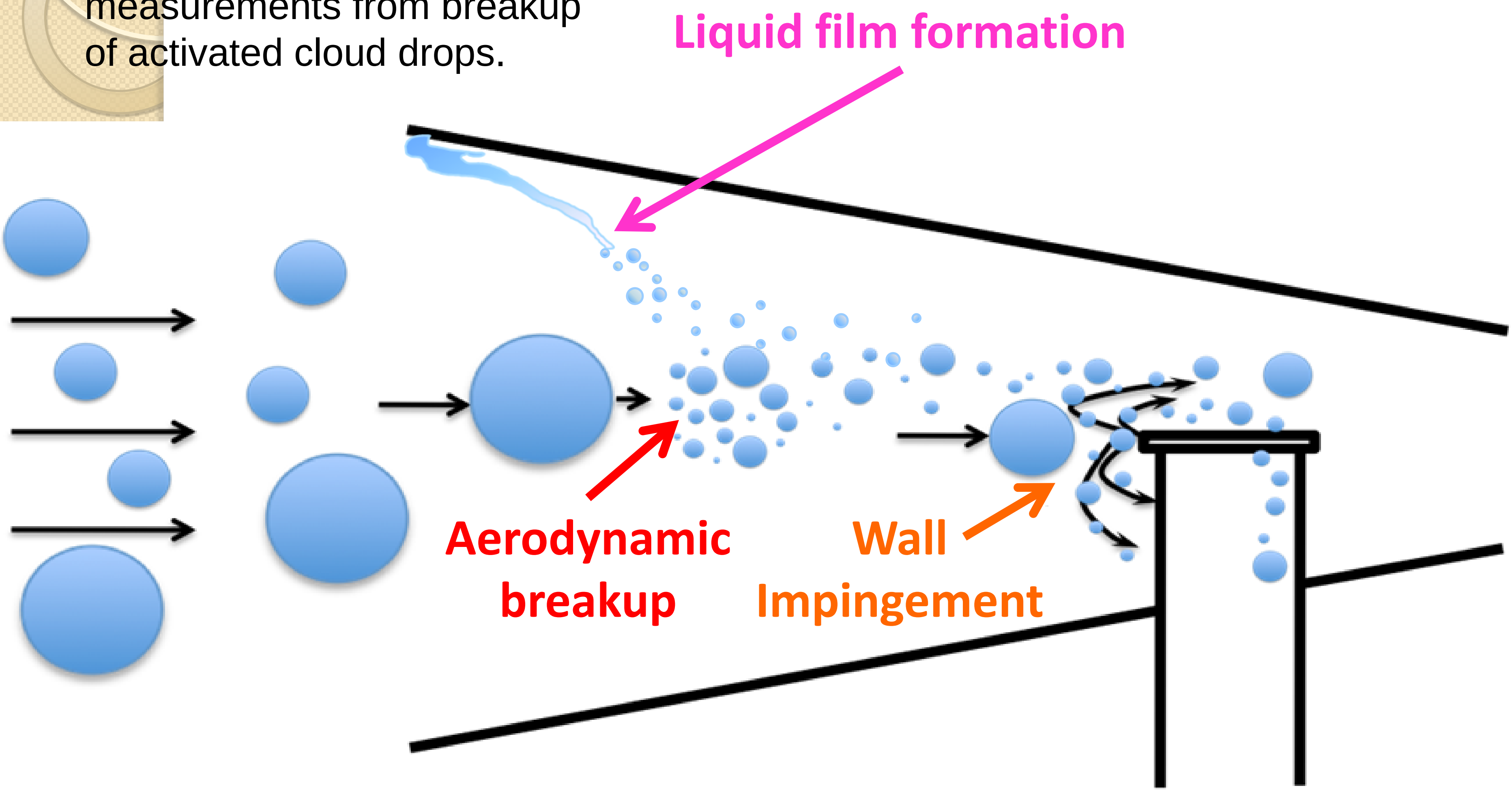
- Size-classified CCN measurements
  - Scanning CCN counter (Athanasios Nenes' instrument)

Relevance to ICE-T

- Accurate aerosol sampling inside and outside cloud systems
- Aerosol size distributions:
  - One of the mission critical measurements.
  - Measurements in the size range of 10-1000 nm will provide a complete picture of the aerosol population at high temporal resolution
  - Measurements of interstitial aerosol size distributions will provide critical data on aerosol population acting as CCN
- Size-classified CCN measurements:
  - Will provide information about the mixing state of the aerosol population
  - Will help determine the possible role of mid-level entrainment in feeding CCN and IN into maritime convective clouds.

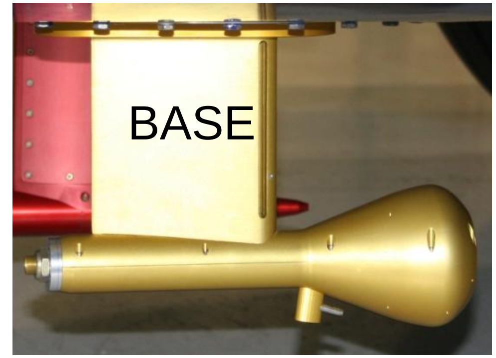
Introduction: Sampling artifacts

• Enhancements to aerosol measurements from breakup of activated cloud drops.

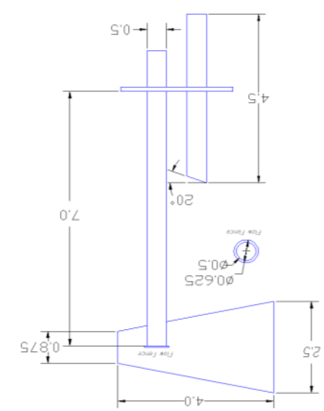


Aerosol samplers

- Intercompare CN measurements from different samplers
- Determine their relative performance in sampling artifact-free interstitial aerosol sampling
- Data from different inlets will permit development/validation of droplet-splatter models

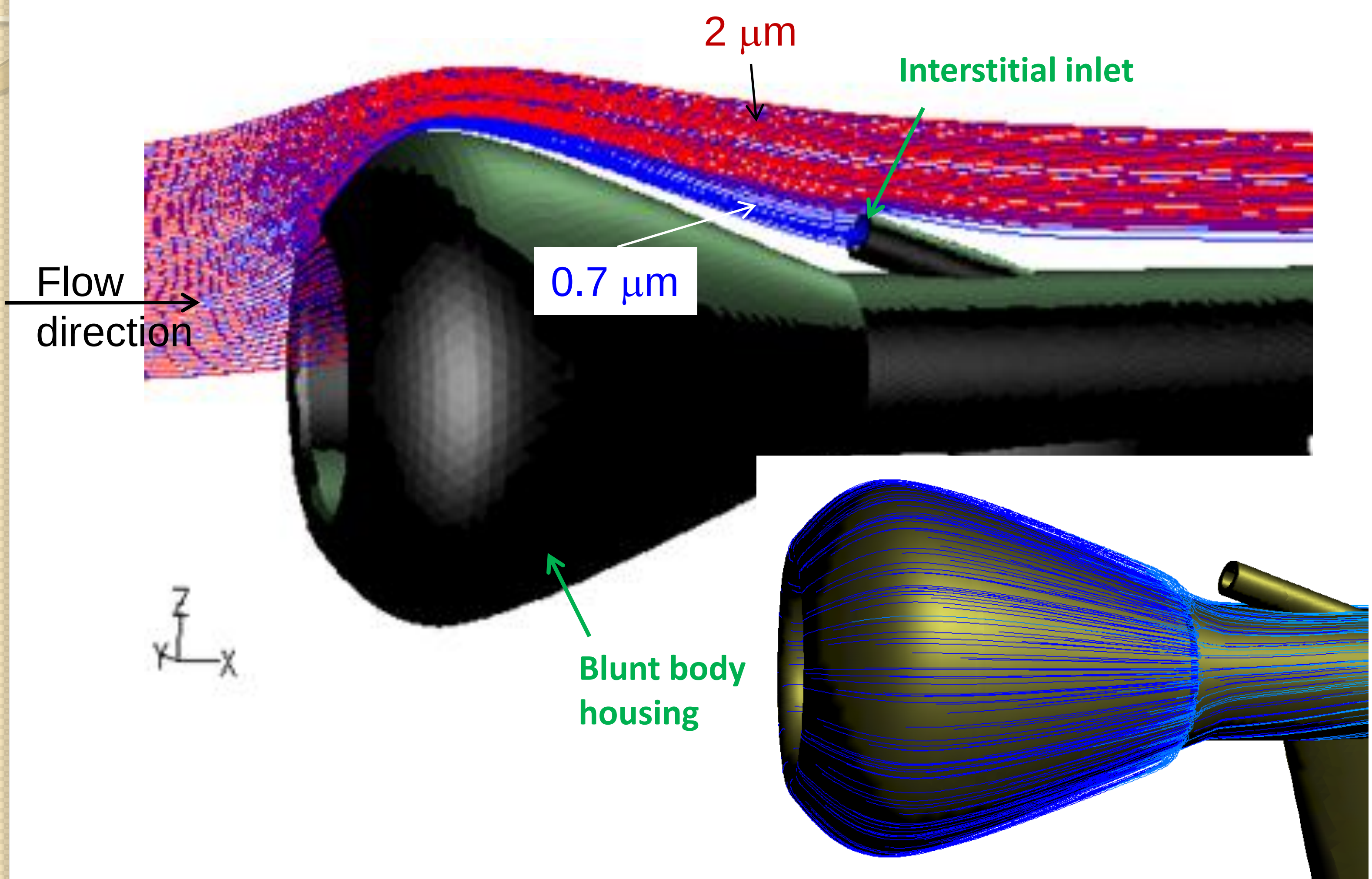


Flow direction

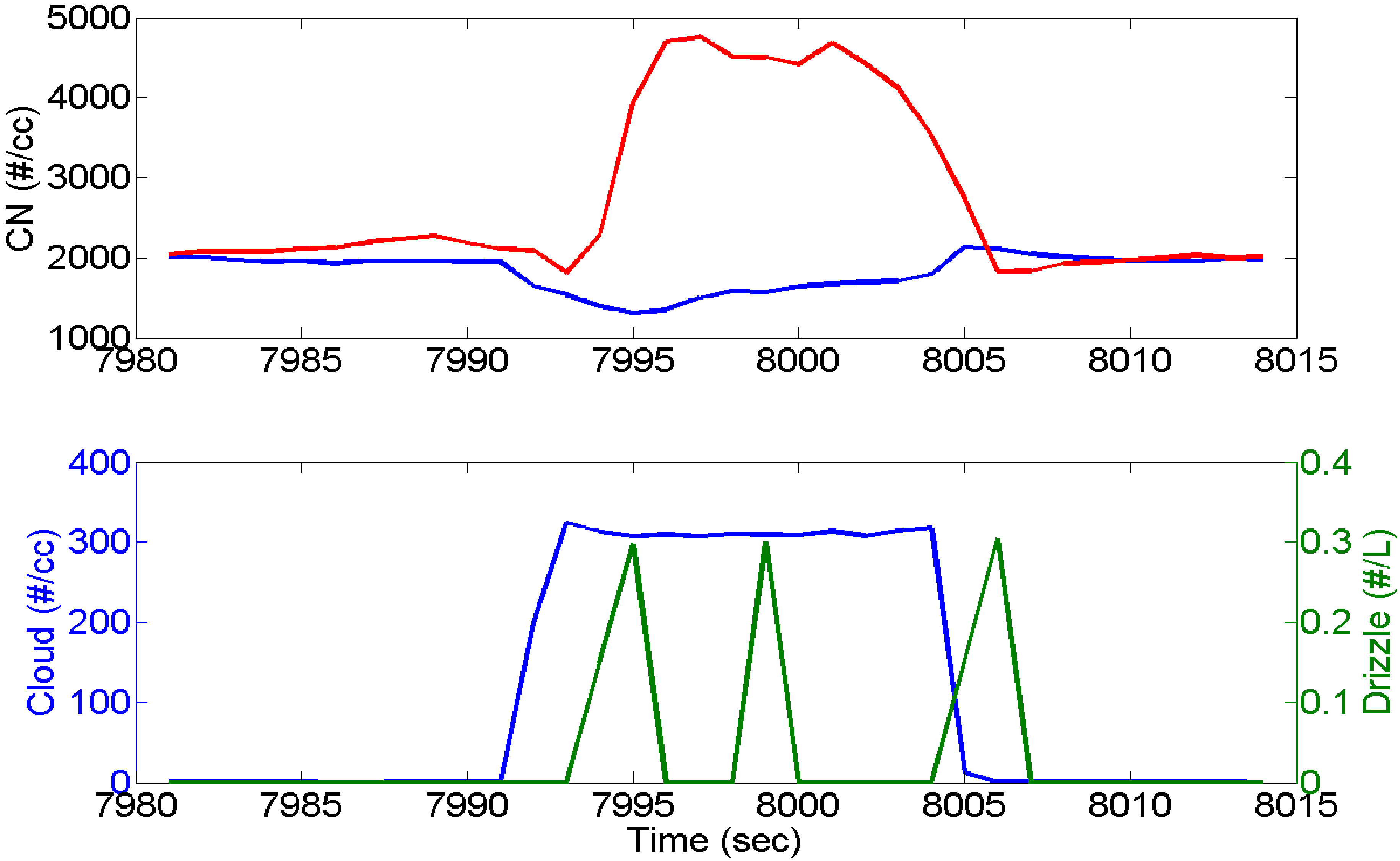


BASE – CFD results

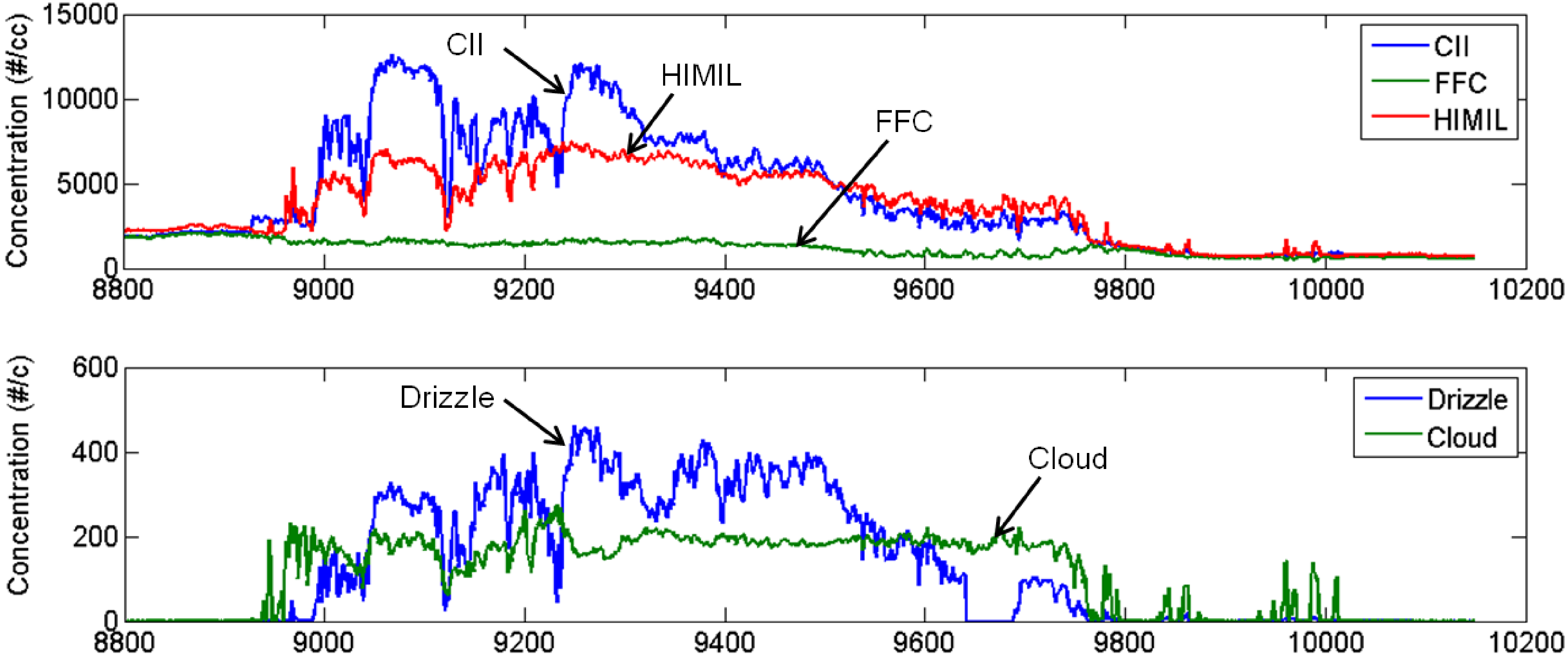
Particle trajectories



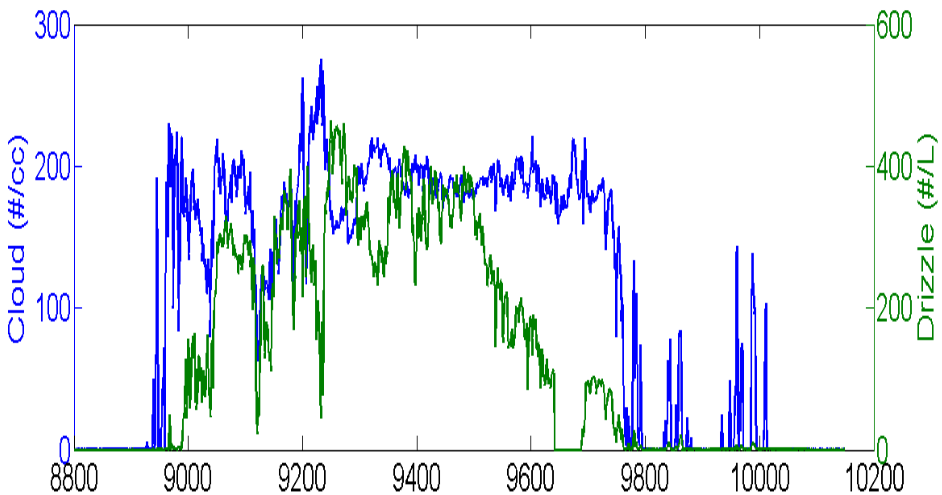
Flight tests – preliminary results (PLOWS)

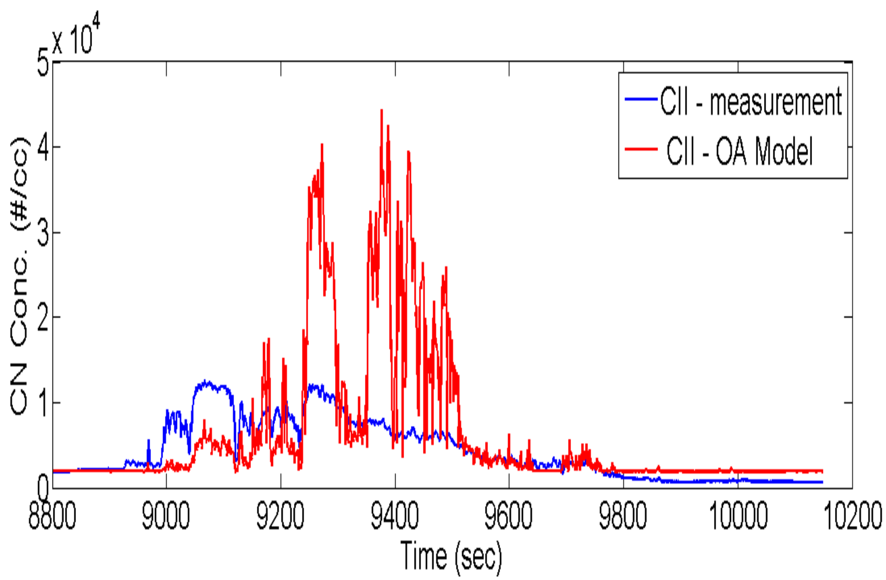


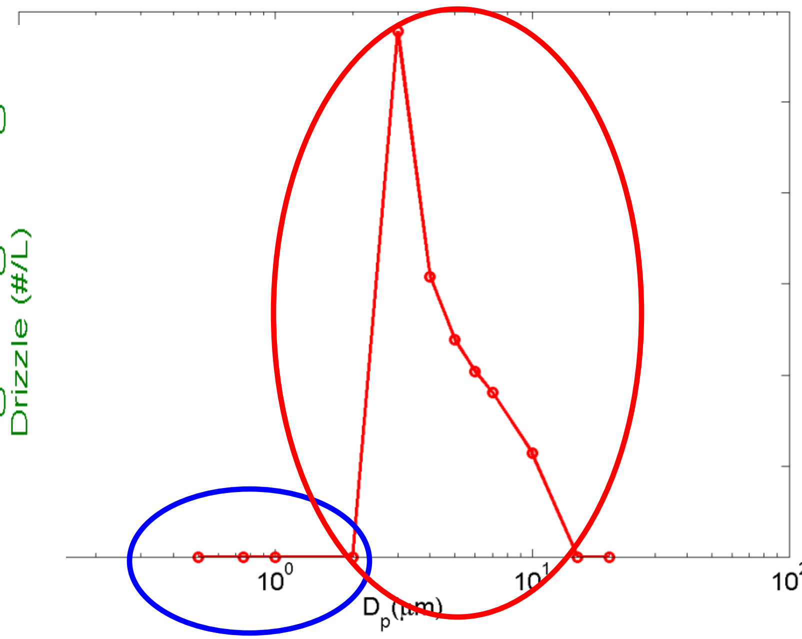
Flight tests – preliminary results



Splash Modeling



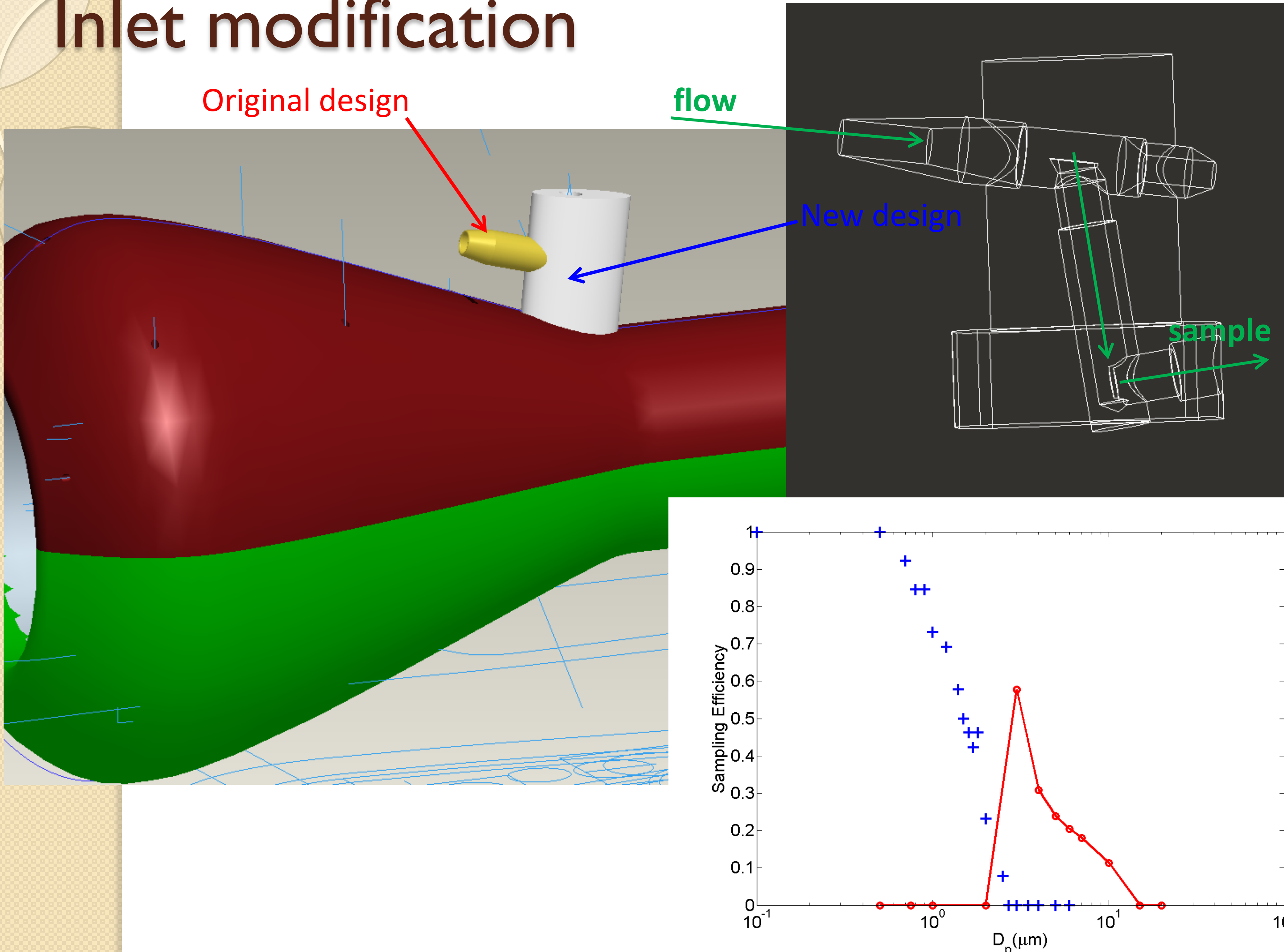




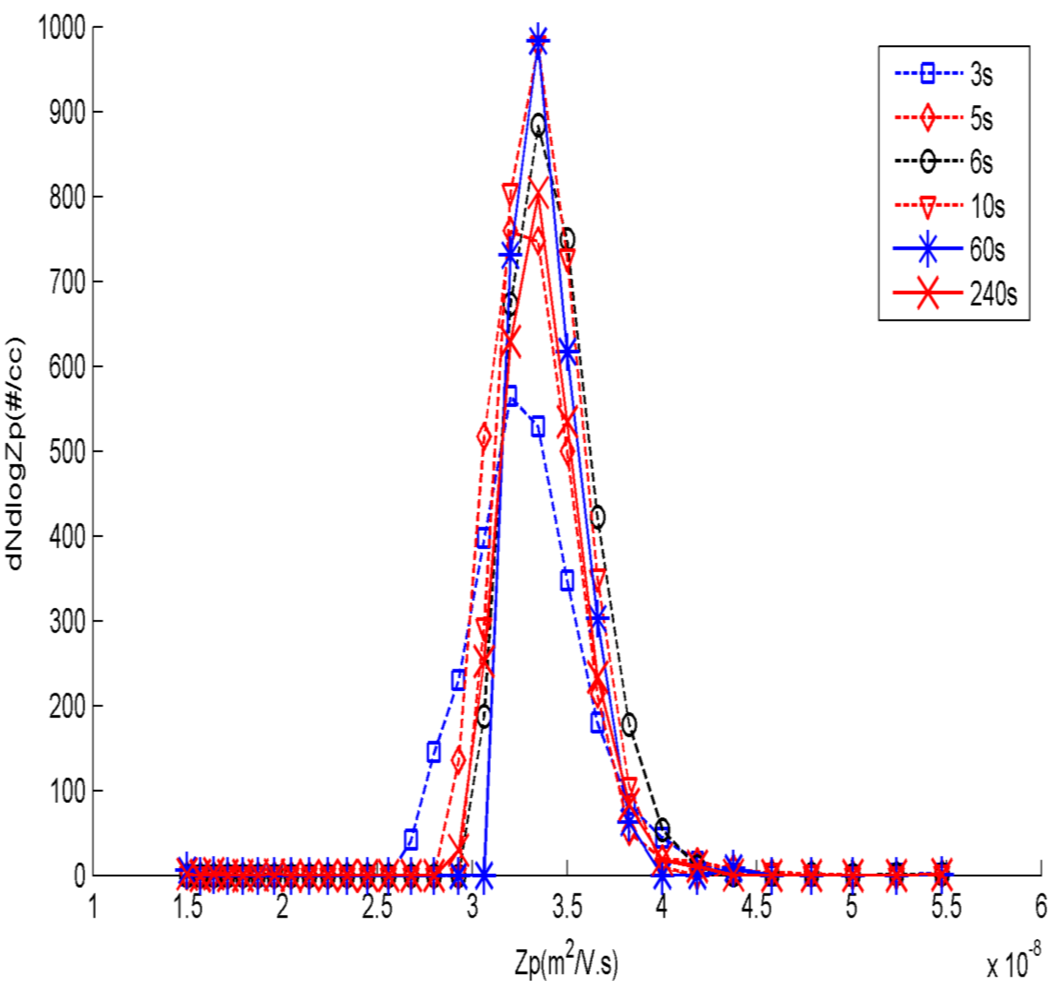
The initial design eliminated splatter particles from cloud droplets of size smaller than 30 – 50 µm

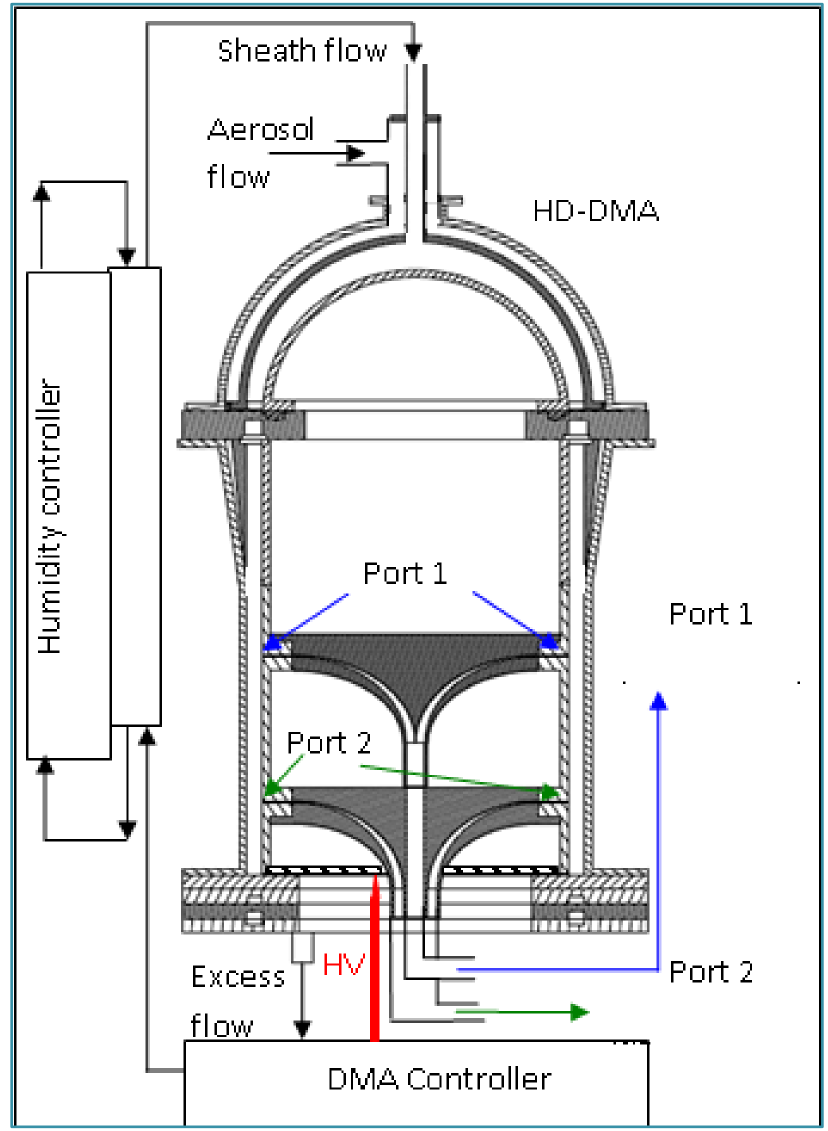
In the presence of drizzle, rain, and ice particles, larger splash/splatter generated particles make it to the interstitial inlet location

Inlet modification

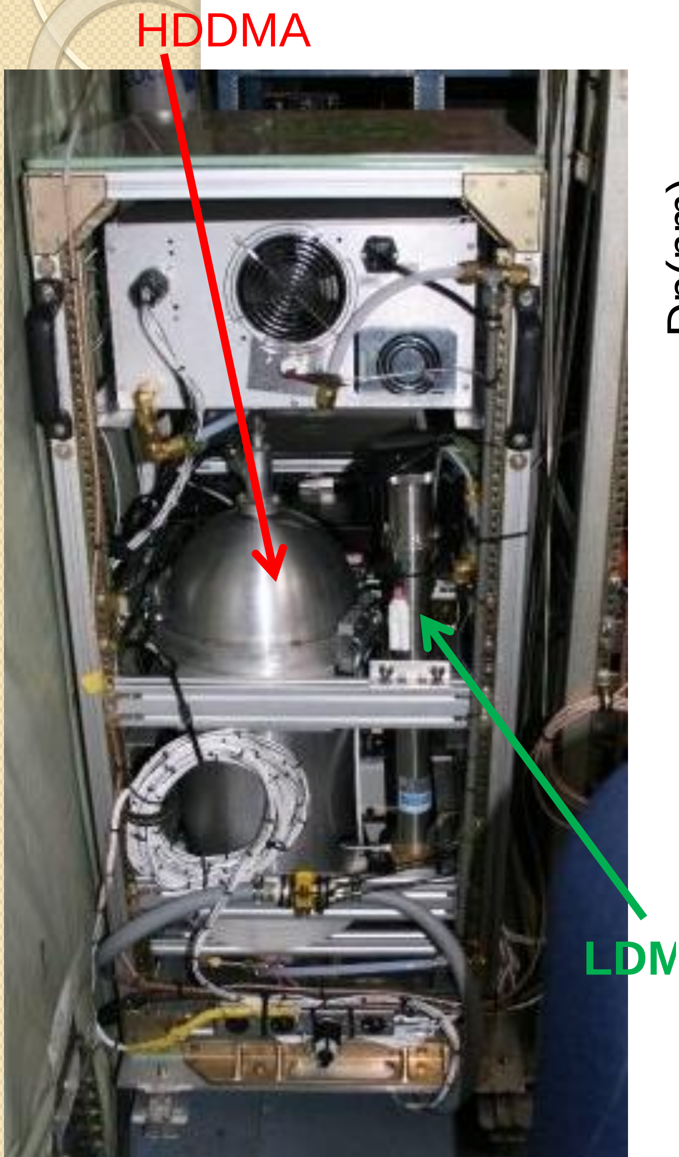


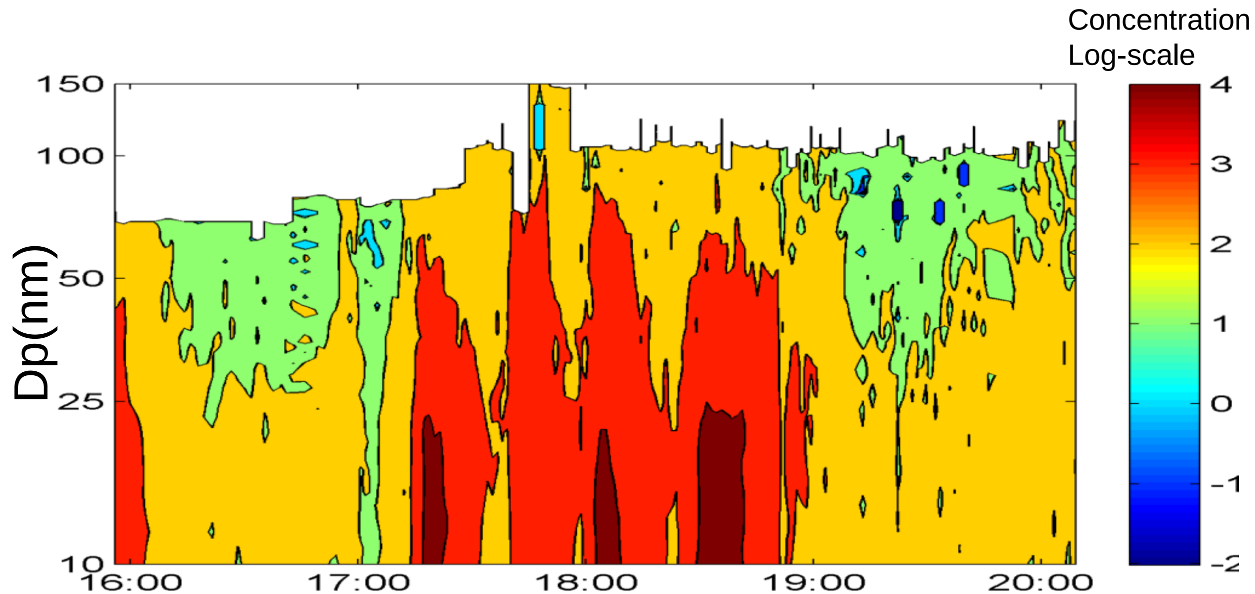
HD-DMA
Fast scanning operation (Dubey and Dhaniyala, 2008)

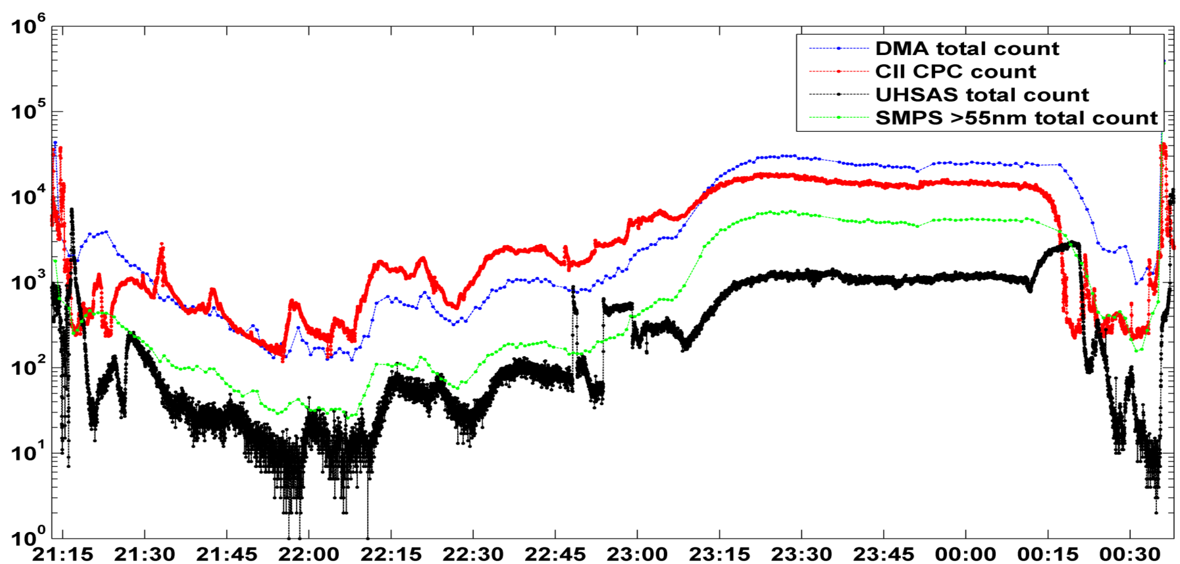




Aircraft based measurement





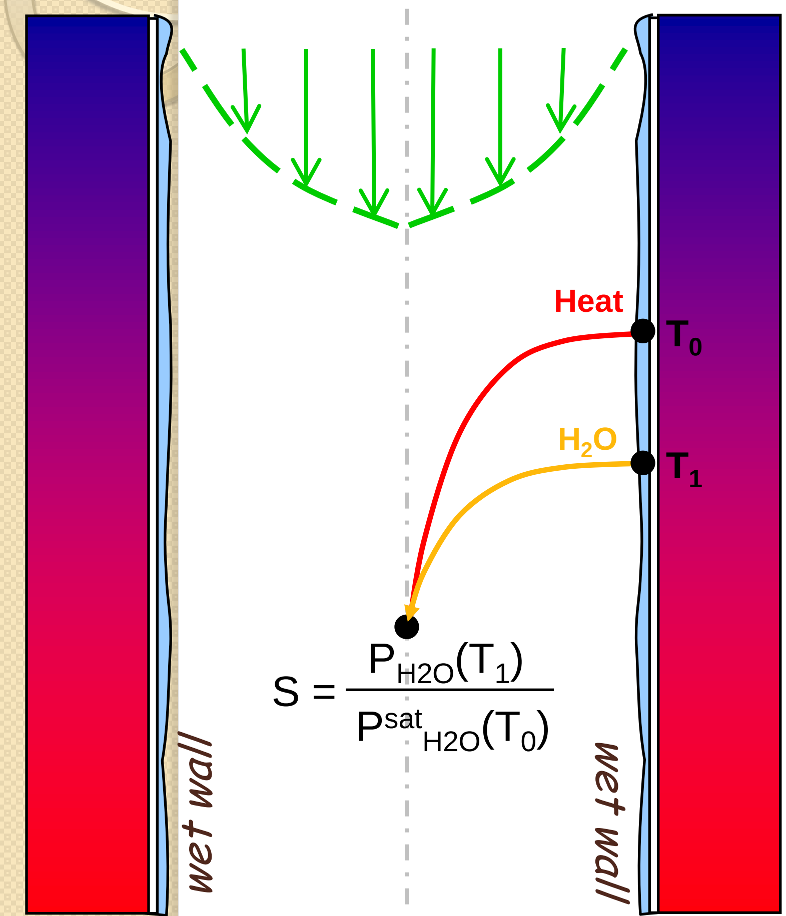


Size-classified CCN

- Scanning flow CCN instrument
  - Range of super-saturations possible in 30 s.
  - Super-saturation profiles of particles in the size range of 50-100 nm will be obtained in different representative air masses

- Size classified particles from the HD-DMA sampled into the Georgia Tech CCN instrument
  - Two possible operational strategies:
    - Size-classified CCN fraction at one supersaturation
      - Possible in ~ 30 seconds
    - CCN fraction at different supersaturations, for selected diameters
      - ~ 2 minutes

The Streamwise Thermal-Gradient Cloud Condensation Nuclei Counter

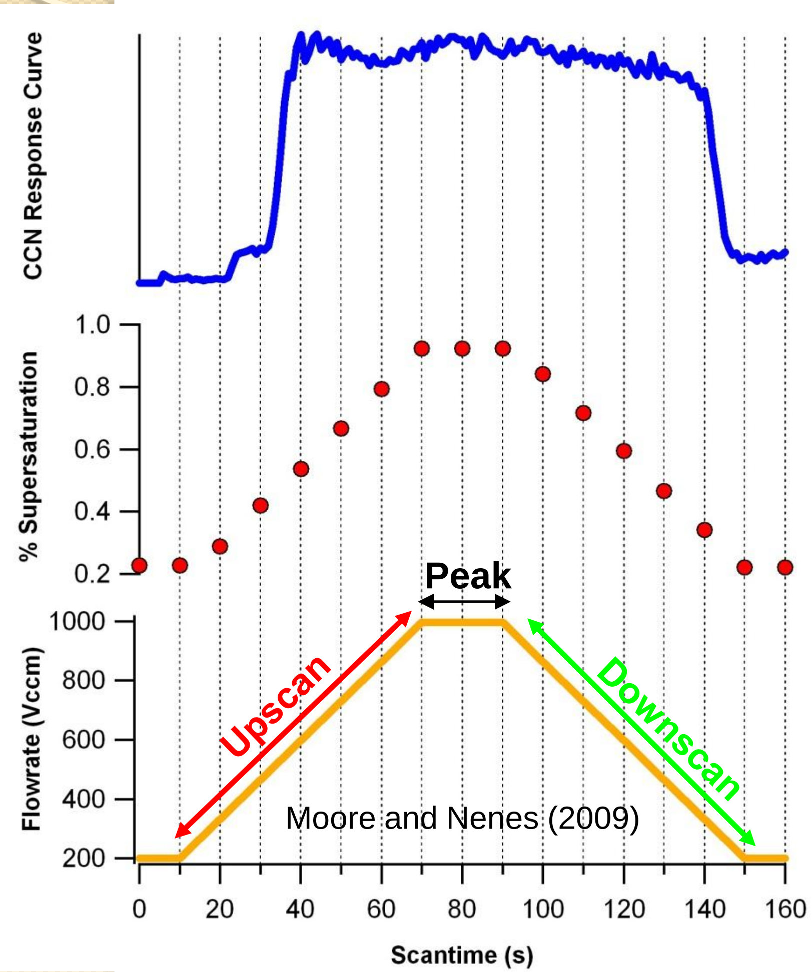


- Metal cylinder with wetted walls
- Streamwise Temperature Gradient
- Water diffuses faster than heat
- Supersaturation, S, generated at the centerline = *f* (Flowrate, Pressure, and Temp. Gradient)

Roberts and Nenes (2005)

Scanning Flow CCN Analysis (SFCA)

Moore and Nenes (2009)



Operation:

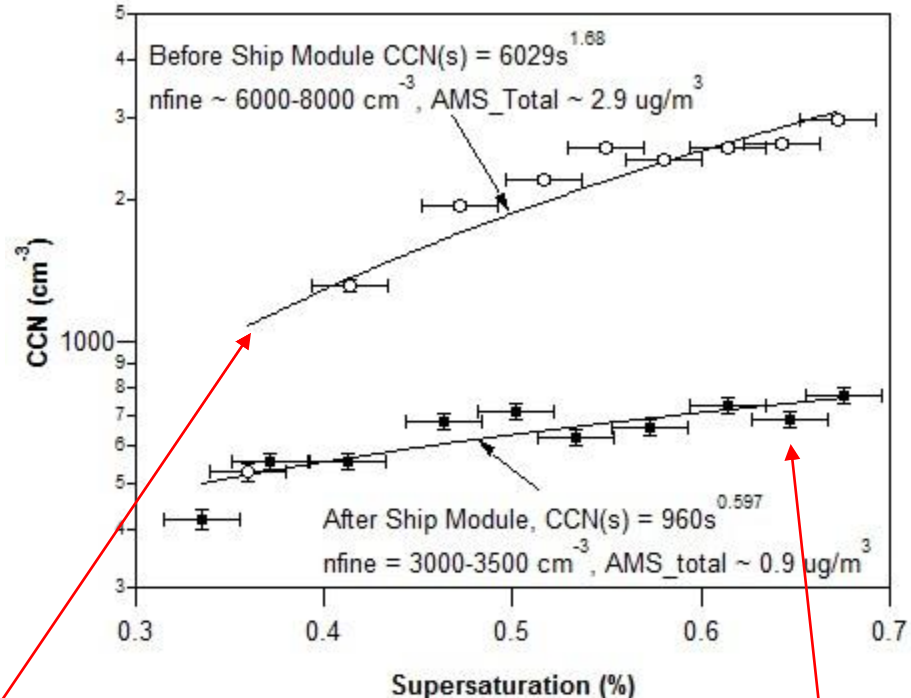
- Flowrate is linearly ramped over user-specified upscan, peak, and downscan time intervals
- Temp. gradient, Press. = const.
- Can be combined with a DMA to select a single particle size and/or a CPC to measure CN

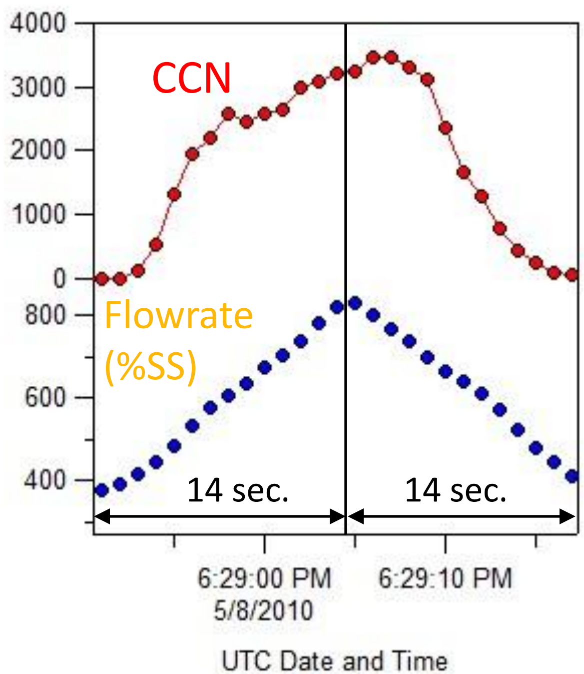
Analysis/Results:

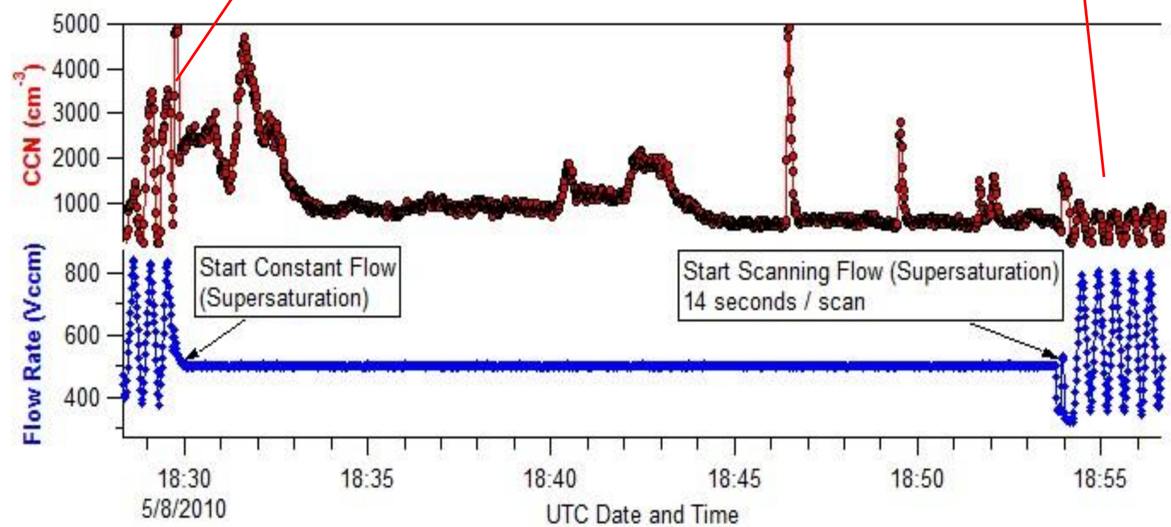
- CCN response curves similar to those obtained by stepping supersaturation
- Complete CCN spectrum in less than 30 seconds! (versus ~ hr.)

SFCA Deployment: Calnex (2010) “Ship module”

- Scanning %SS over 14-sec. intervals (typically ~0.25-0.65% SS) on NOAA WB-P3 airborne platform
- Able to switch between scanning and constant flow modes to track very small (ship) plumes
- Contact info: Athanasios Nenes (nenes@eas.gatech.edu)







Acknowledgments

- Al Schanot, NCAR
- Andy Heymsfield, NCAR
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High-flow Dual Channel DMA (HD-DMA)

- Inner radii : 10 cms
- Outer radii : 11.02 cms
- Length (port 1) : 5cms
- Length (port 2) : 22.5cms
- Particle size : 2nm-2000nm
- Sample flow : 1-20lpm

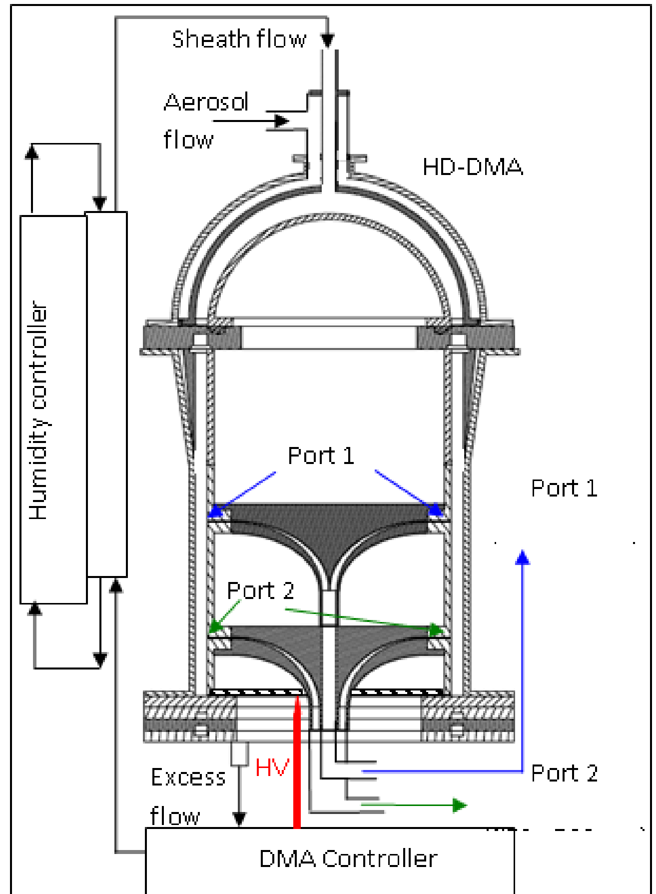
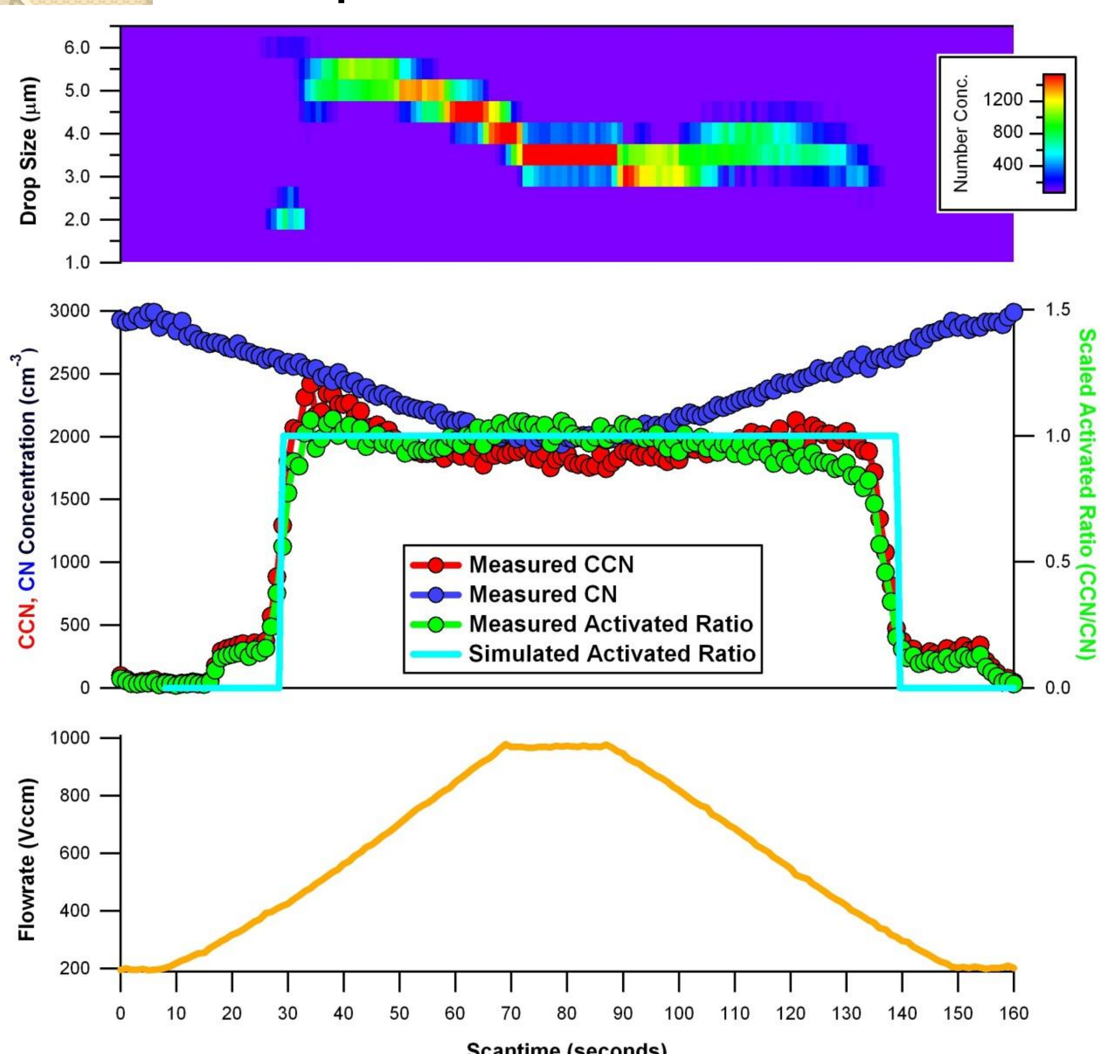


Figure 2: Schematic diagram of the HD-DMA

Experimental Data: Monodisperse AS Aerosol

60-Second Ramps



- **50 nm ammonium sulfate particles selected by DMA**
- **Upscan: t_{scan} ~ 28s**
  Downscan: t_{scan} ~ 136s
  (Green Curve)
- **Excellent agreement between simulated and measured activated ratios!**
- **Outlet droplet sizes plateau and then decrease with decreasing residence time (flowrate), increase with increasing residence time**

Moore and Nenes (2009)

Sample DMA data PLOWS rf06