



*Division of Atmospheric Sciences*

*Science*

*Environment*

*Solutions*



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**Storm Peak  
Laboratory**

***Unique, high elevation, mountain-top atmospheric research facility readily accessible under all weather conditions!!!***



# Storm Peak Laboratory

Located on Steamboat Springs Ski Resort

Elevation: 3.2 km (10,530 ft)  
~690 mb

In cloud ~25% of time

Mixed Phase Clouds

Free Tropospheric Air

Year-Round Access

9 Person Bunkhouse

Full Kitchen, NOW Running Water!

Facility Instruments



**Unique, high elevation, mountain-top atmospheric research facility readily accessible under all weather conditions!!!**

# STORM PEAK LABORATORY

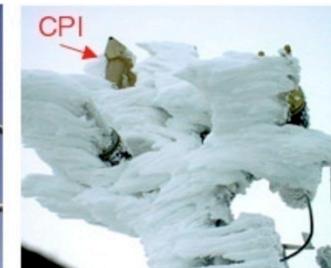
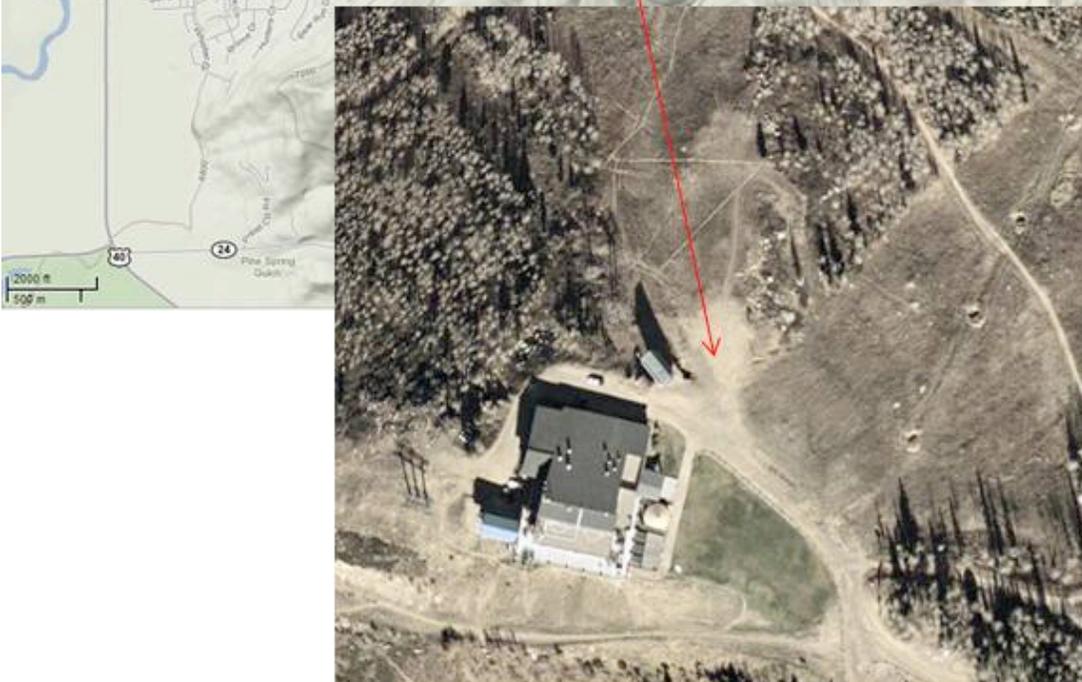
## MISSION STATEMENT:

*To ensure that Storm Peak Laboratory will continue to integrate climate research and education by advancing discovery and understanding within the field of aerosol, pollution, and cloud interactions.*



# Storm Peak Lab **Cloud Property** **Validation** Experiment

AMF2 Deployment October 2010 - April 2011





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### **STORM-VEX THREE OBJECTIVES**

#### *1. Unique opportunity for cloud property retrievals.*

- ❖ Type of clouds from stable liquid phase boundary layer clouds to mixed phase clouds to heavily precipitating snow.
- ❖ Full Doppler spectra from the scanning cloud radar combined with other measurements correlated with continuous in situ data will facilitate development of new algorithms and statistically significant validation of the algorithm results.

#### *2. Unique challenge and opportunity for modeling groups.*

- ❖ Collected in a region of complex terrain.

#### *3. Study role of aerosol in cloud and precipitation processes.*

- ❖ Aerosol data set collected at SPL allows for investigation of role of natural and anthropogenic aerosol in cloud and precipitation processes.



# Mid-Mountain: Thunderhead



Instrument	Measurement
Scanning W-Band Cloud Radar	In-cloud velocity, backscatter
Micro Pulse Lidar	Aerosol, cloud backscatter, Cloud base (532 nm)
High Spectral Res. Lidar	Cld, aerosol optical depth, backscatter
Atmos Emitted Radiance Interferometer	Atmospheric radiance, Temperature
Microwave Radiometer	Integrated atmos. Water vapor
Multi-Filter Rot Shadowband Radiometer	Optical depth, downwelling irradiance. At 6 wavelengths
Long's Radiometry	
Infra Red Sfc Temperature	Infra-red surface skin Temp





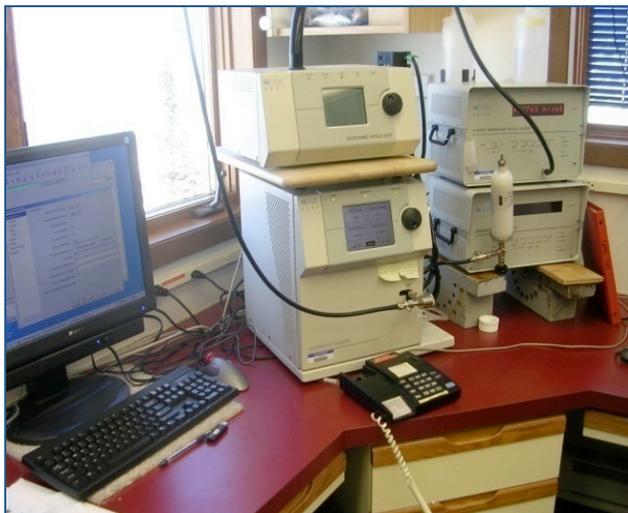
# Valley Floor Site:

## Yampa Valley Medical Center

Instrument	Measurement
Radar Wind Profiler	Winds, back scatter
Ceilometer	Cloud base
Skyrad	Broadband SW, infrared, UV downwel. irradiance
Gndrad	Broadband SW, infrared upwelling irradiance
Total Sky Imager	Cloud fraction
Balloone-borne Sounding Sys.	Wind, Temp, RH atmos. Profile
Surface Fluxes	Heat, Mom., Water Vapor, CO2 sfc fluxes
Surface Met	10 m Winds, Temp, RH, Precip
Infra Red Sfc Temperature	Sfc Skin Temp



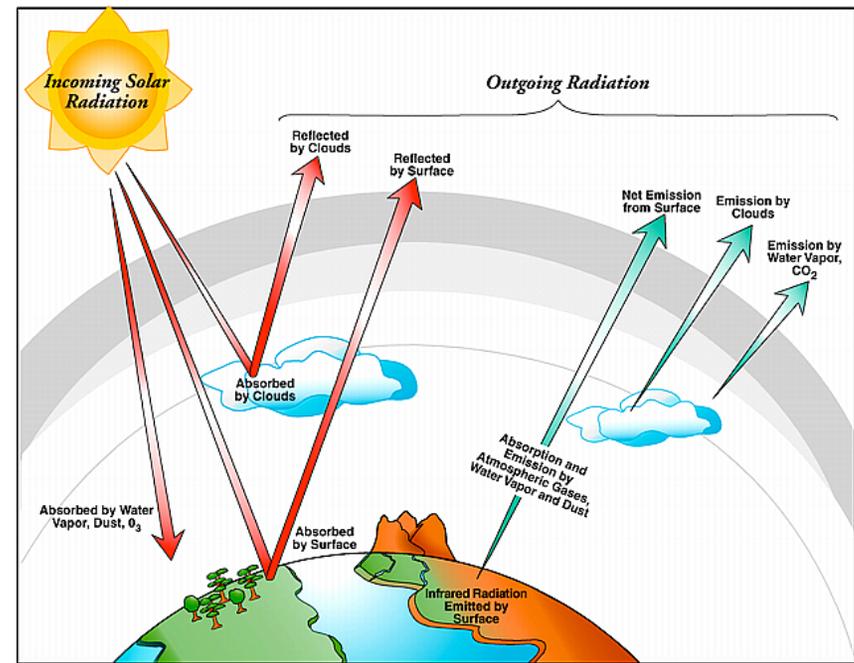
# SPL Current Equipment



- **Aerosol Concentration**
  - Including Ultra-Fine
- **Aerosol size distributions**
  - TSI SMPS and APS
- **DMT Cloud Condensation Nuclei (CCN)**
- **Multi-Filter Shadow-band Radiometer**
- **Cloud droplet size distributions**
  - DMT SPP-100 forward scattering spectrometer
  - modified PMS-2DP precipitation probe
- **CO<sub>2</sub> Measurement - Britt Stevens, NCAR**
- **O<sub>3</sub> Measurement**
- **Pyranometer**
- **Cold Room- Cloud Sieves**
- **Meteorological Station – 7 on Mountain**

# Motivation for Studying Aerosols at SPL

- impact climate through direct and indirect forcing
- degrade air quality and visibility
- have detrimental effects on human health.



*With SPL, questions regarding aerosol mechanisms can be studied and understood.*

*-Why all the OOA?*

*-What triggers nucleation events?*

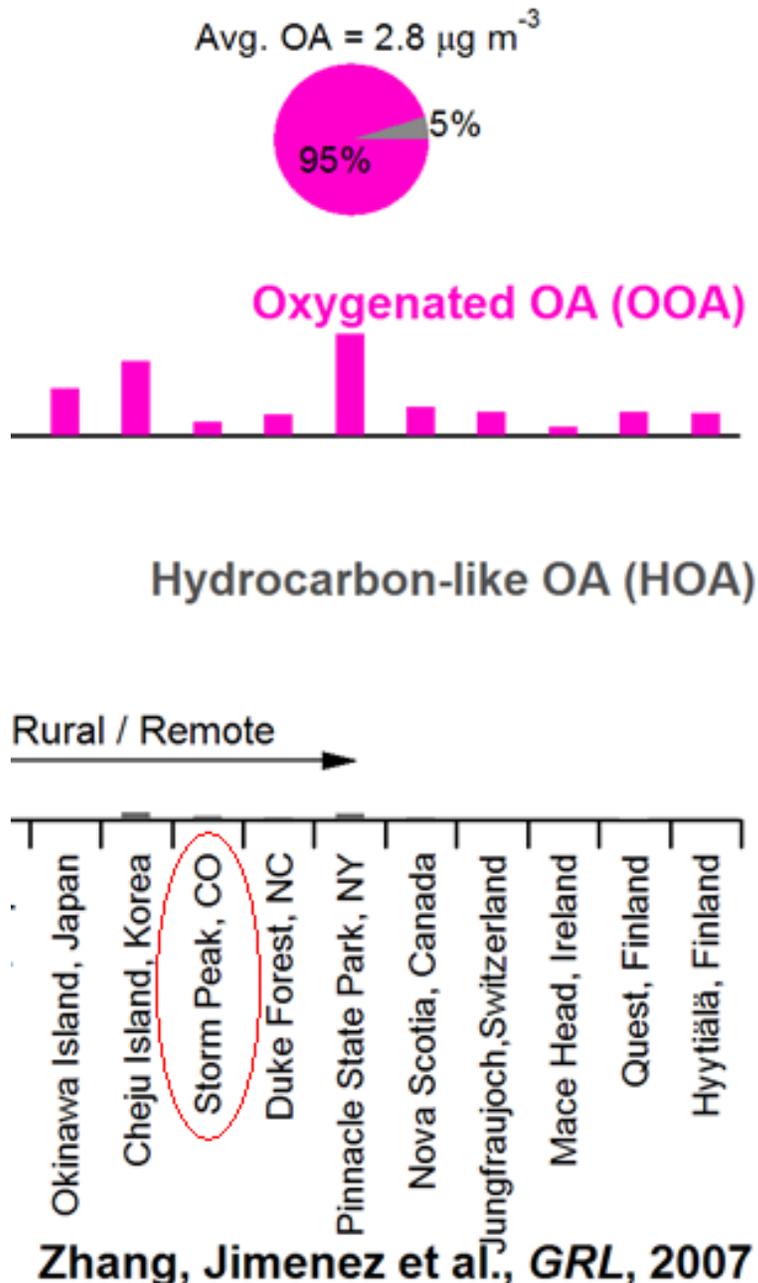
*-Why are nucleation events so frequent at SPL?*

*-Importance of bioaerosols*

*-Understanding the hygroscopicity of OA*

*-Alter cloud microphysics and reduce snowfall through riming inhibition*

# Previous Result OC at SPL



Water extracts of PM<sub>2.5</sub>  
Polar Organic Compounds  
January 9<sup>th</sup> -14<sup>th</sup> 2007

Most abundant compounds:

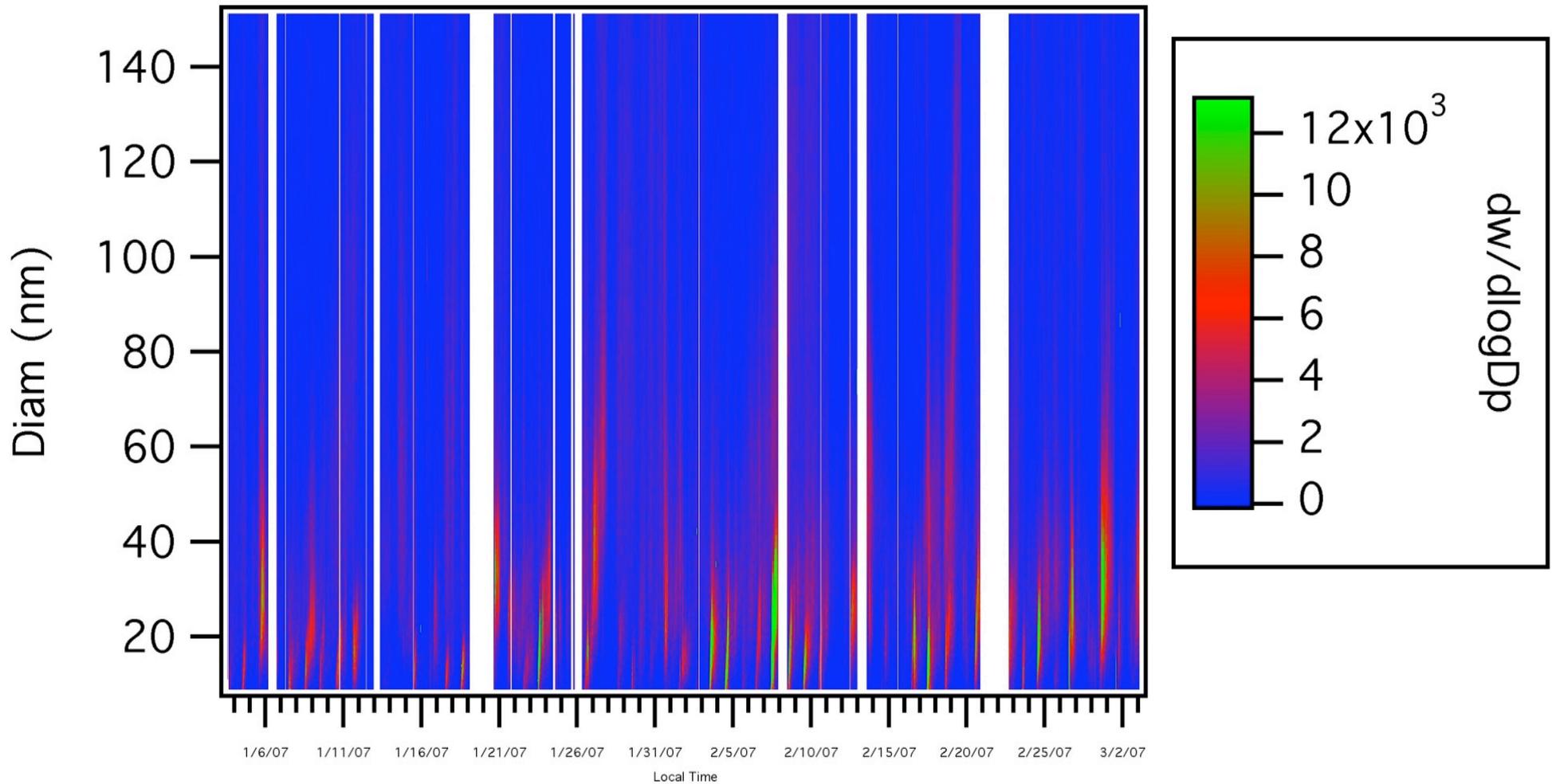
- Levoglucosan ( $9-72 \text{ ngm}^{-3}$ )
- Palmitic acid ( $10-40 \text{ ngm}^{-3}$ )
- Succinic acid ( $18-27 \text{ ngm}^{-3}$ ).

Cloud water from 2002 revealed a similar compound abundance trend.

*Samy et al., submitted Atmospheric Environ. 2009*

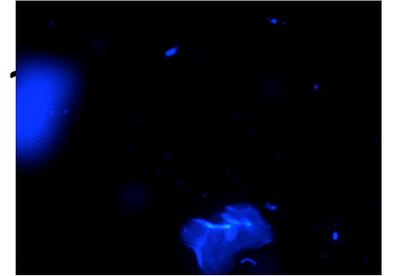


Aerosol Formation at SPL observed 77% of total days including “in cloud” scenarios



# How much of the Organic Aerosol is bioaerosol?

Wiedinmyer et al., 2009; Atmos. Env.



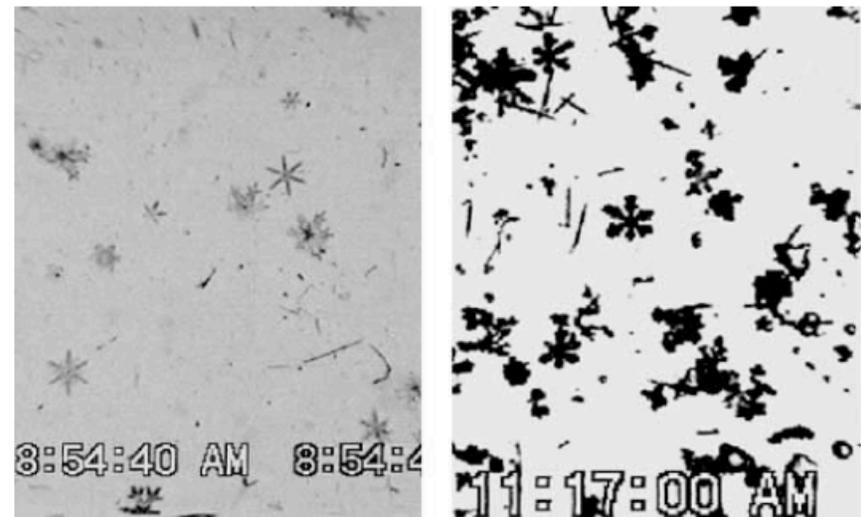
- Method
  - DAPI with epifluorescence microscopy for count
  - Assume average diameter of 1  $\mu\text{m}$
  - Exclude pollen – using DNA results (greater than 10  $\mu\text{m}$ )
  - Empirical fit used to estimate mass of the biological particles; Loferer-Krö̈ßbacher et al., 1998
  - Assume 50% of mass is carbon; Bauer et al., 2002; 2008
  - Compare to OC measurement
- Results
  - Average 40% of OC is biogenic; Although highly **Uncertain**
  - Suggests significance and calls for further studies

# Cloud and Aerosol Interactions at SPL

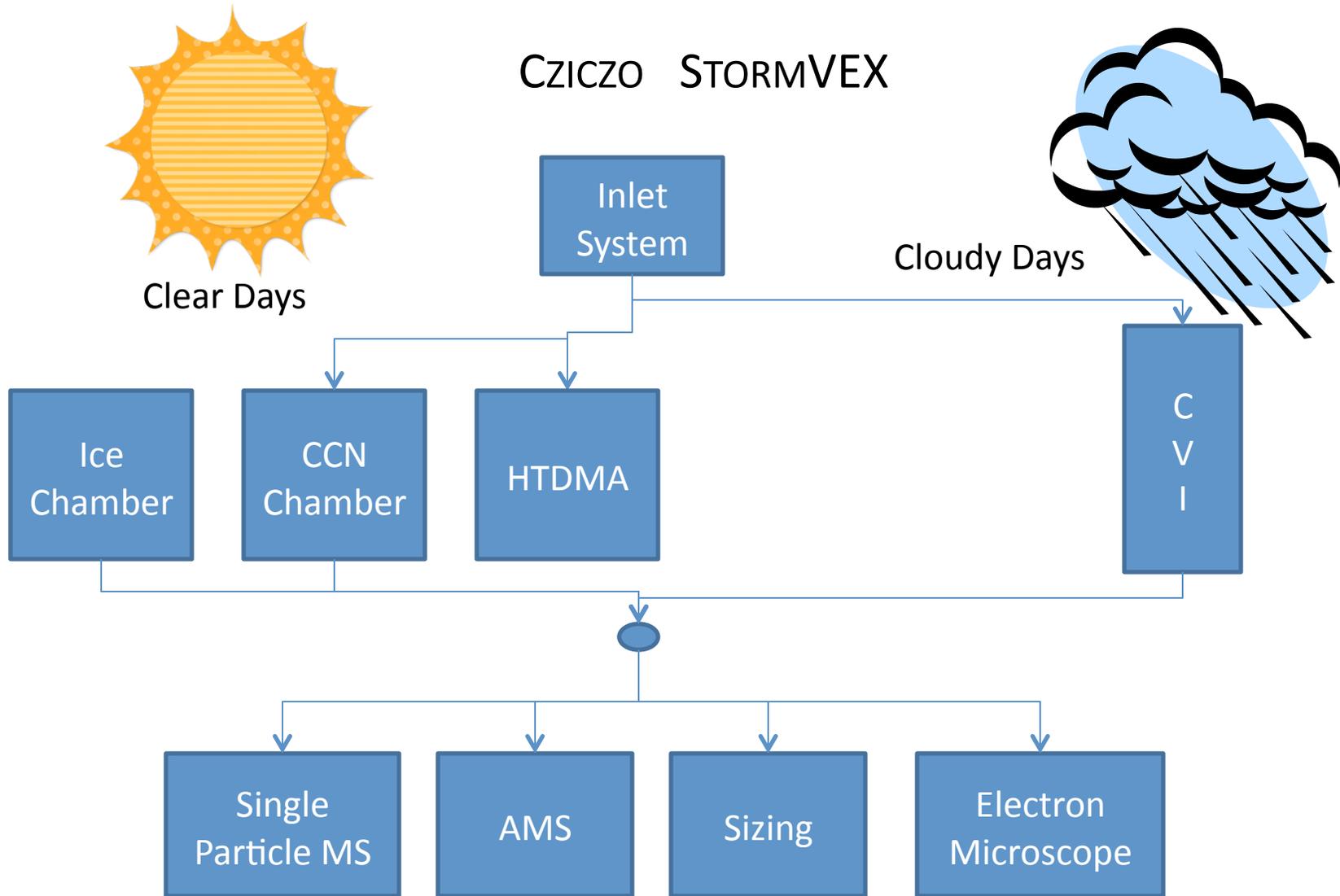
- Investigate the second indirect aerosol effect
- Less accumulated snow water equivalent (SWE) will precipitate to the surface due to the reduction of ice particle growth by riming when anthropogenic aerosol is present
- Sulfate concentration for unrimed case was  $\sim 9$  times higher than found in the rimed case

Citation: Borys, R.D., D. H. Lowenthal, S. A. Cohn, and W. O. J. Brown, 2003

ISPA 2010 –  
PI: Doug Lowenthal & Bill Cotton



**Figure 5.** Video images of snow particles on Feb. 15 (left) and Feb. 19 (right).



- What are the ice nuclei? Ice residue?
- What are the CCN? Drop residue?
- How are these inter-related? Anthropogenic influence?

# STORMVEx Aerosol Request

- High Volume Filter Samples and Analysis
  - Importance of bioaerosols; Coarse Mode
- Aerosol Size Distribution
- Hygroscopic Growth - HTDMA and CCN
- Real Time Chemistry – AMS, Single Particle
- Aerosol Optical Properties
  - Bsp: Nephelometer
  - Bap:PASS, PSAP, SP2
  - Bex: Cavity Ringdown



Thank you for your attention  
You are invited to see the Lab !

<http://stormpeak.dri.edu>

**Contact me with any questions or comments.**

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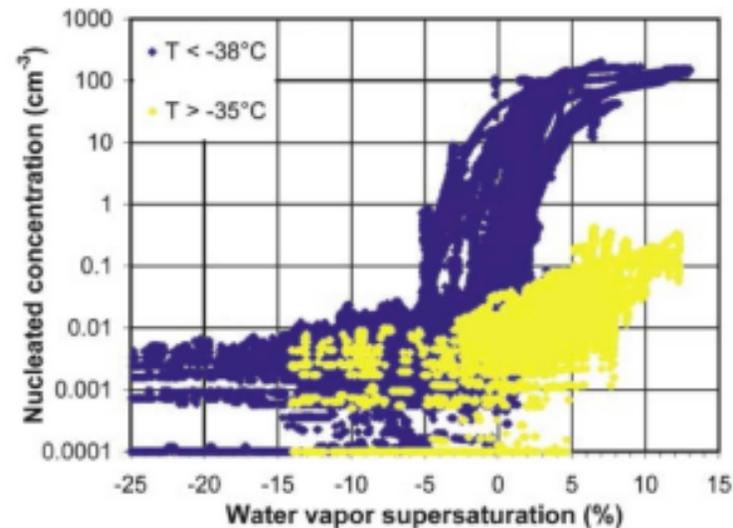
# QUESTIONS?



# Ice Nuclei

## Field Measurements: Aerosol Properties

- Counter-Flow Diffusion Chamber (CFDC) shows modes [DeMott et al., PNAS, 2003]



- and heterogeneous mode strongly enriched in solid components

