ARM Facilities: Opportunities for (Long-Term) Observations of New Particle Formation

BROOKHAVEN NATIONAL LABORATORY

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U.S. DEPARTMENT OF ENERGY | Office of Science

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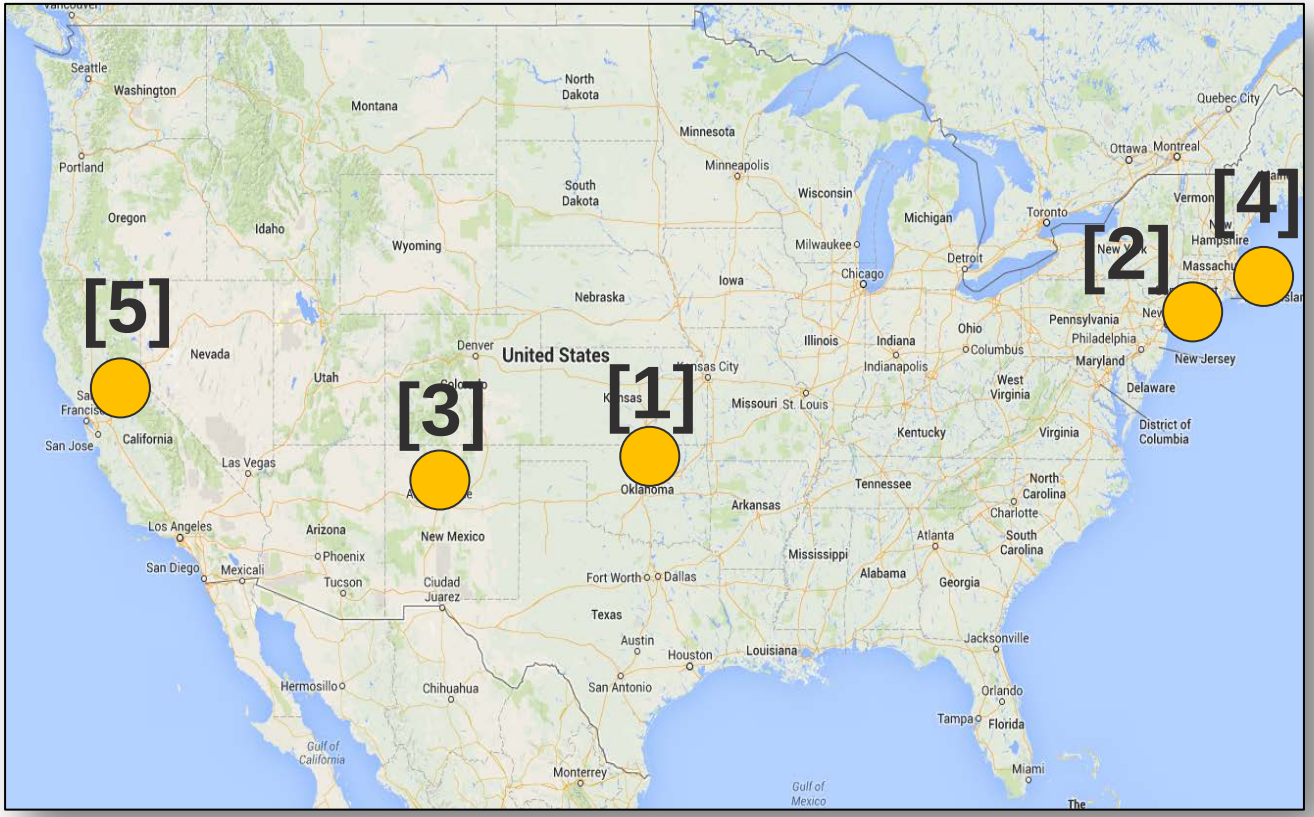
ARM Facilities and Studies: NPF Observational Opportunities



[1] **New Particle Formation Study: 04/2013 – 5/2013**, Fixed - Southern Great Plains (**SGP**)
[2] Aerosol Life Cycle: 06/2011 – 08/2011, Mobile Aerosol Observing System (**MAOS**)
[3] Pajarito Aerosol Coupling to Ecosystems: 12/2011 – 04/2012, **MAOS**
[4] Two-Column Aerosol Project: 07/2012 – 06/2013, **MAOS**, ARM Aerial Facility (**AAF**)
[5] Carbonaceous Aerosol and Radiative Effects Study: 06/2010, **AAF**

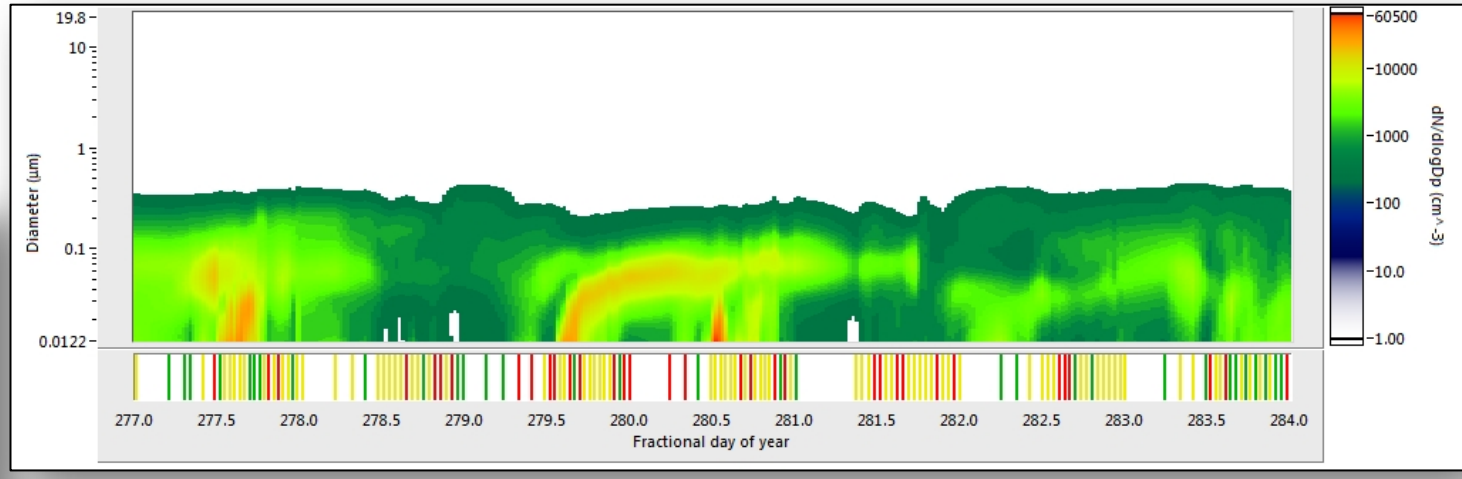
Key Facility Instrumentation and Observables

- Mobile Aerosol Observing System (**MAOS**):
  - **CPCs** (> 3 nm, > 10 nm): total number concentration for aerosol larger than 3 nm and 10 nm
  - Scanning Mobility Particle Spectrometer (**SMPS**): aerosol size distribution (10 – 500 nm)
  - **SO_2** Analyzer: SO_2 concentration
  - Needs – Nano SMPS

- ARM Aerial Facility (**AAF**) G1:
  - **SO_2** Analyzer (**CARES**)
  - **CPCs** (> 3 nm, > 10 nm)
  - Fast Integrated Mobility Spectrometer (**FIMS**): aerosol size distribution (30 – 100 nm range during **CARES**)
  - Needs – fast response 1 nm aerosol spectrometer

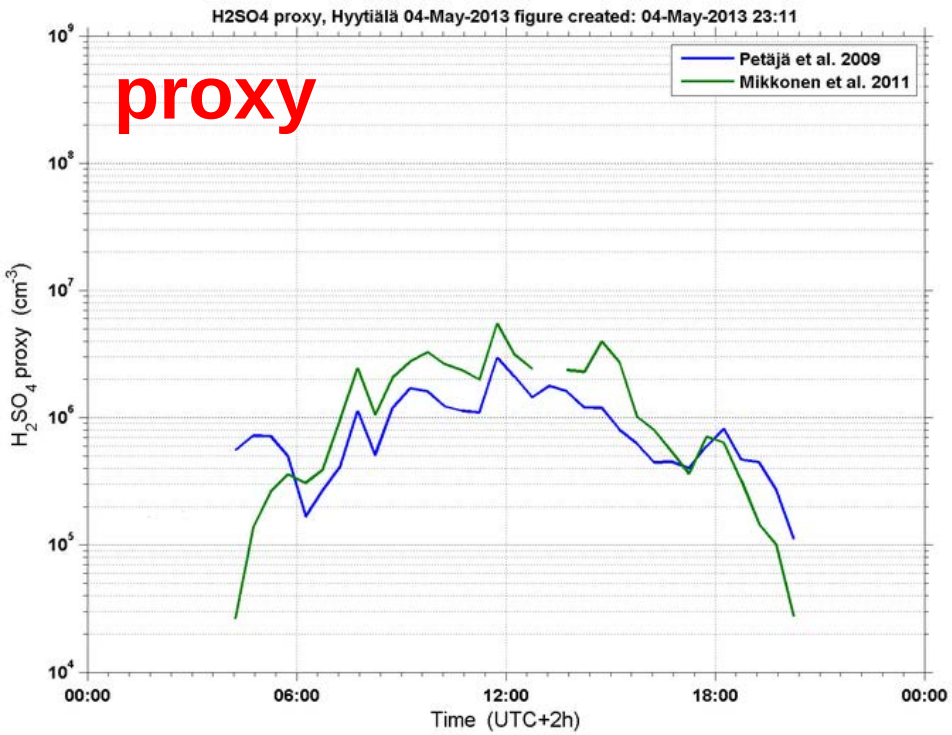
Key Facility Instrumentation and Observables

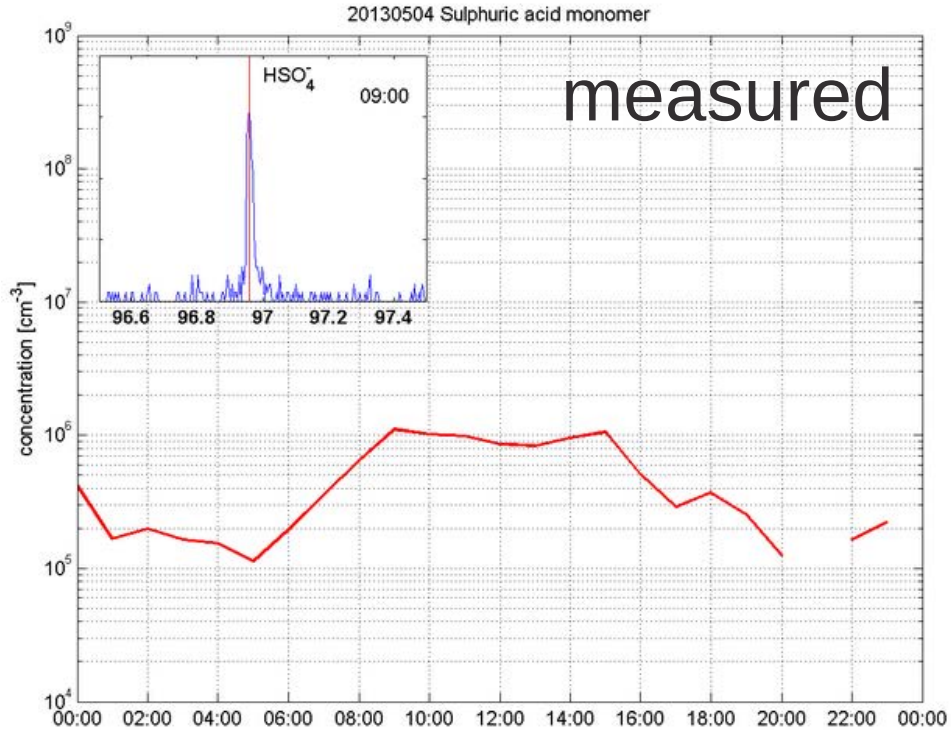
- Southern Great Plains (**SGP**) Central Facility, Lamont, OK:
  - Humidified Tandem Differential Mobility Analyzer (**HTDMA**): hygroscopic growth factors, particle size distribution (10 – 1000 nm)
  - CPC (> 10 nm)
  - Needs – **Nano SMPS** and an **SO_2 analyzer**



TDMA data from SGP: Analysis by John Ortega (NCAR)

SO_2 Analyzer: Previously Inaccessible Measurements and Products at SGP





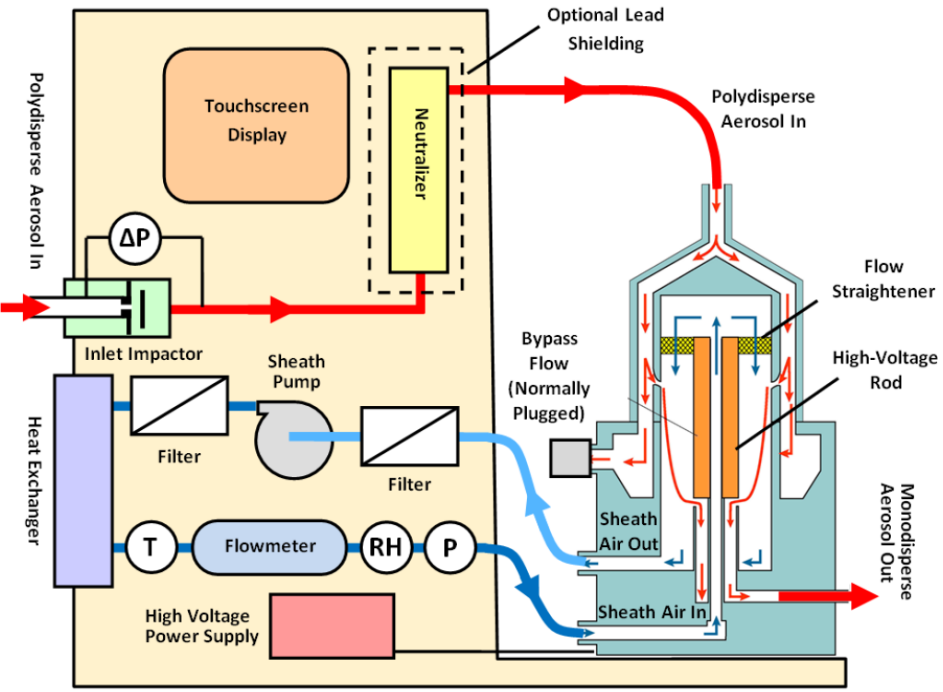
- New measurement deliverables at **SGP**:
  - 1. SO_2 concentration
  - 2. potential **[H_2SO_4] proxy** derived from [SO_2] and UV-B radiation or global radiation measurement

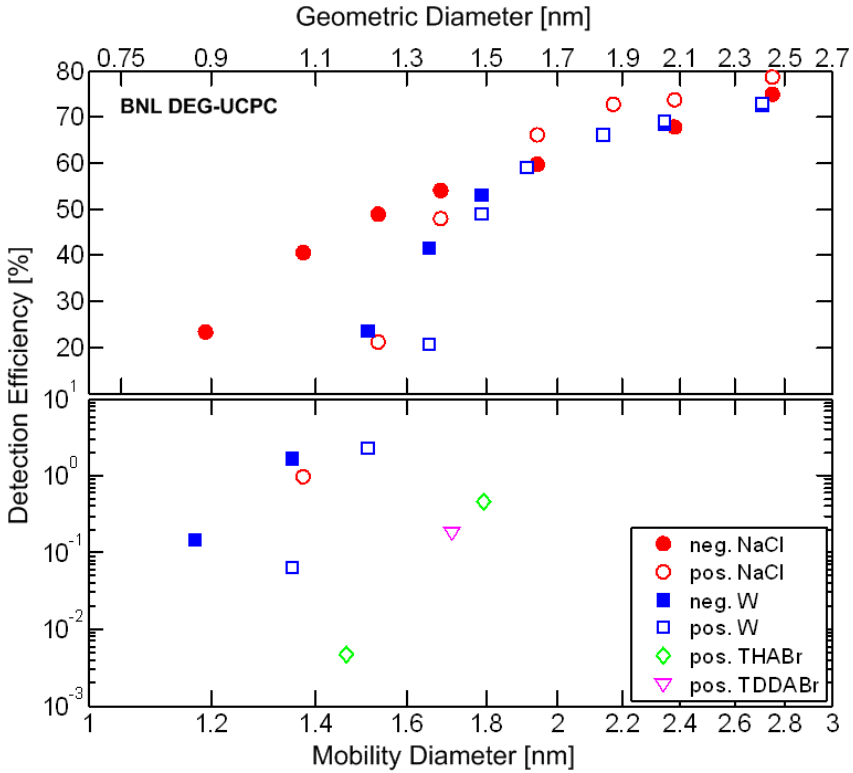
Petäjä, T., *Atmospheric Chemistry and Physics, 9(19), 7435-7448.*

Nano SMPS: Approaching Direct NPF Measurement at SGP

- Proposed **permanent** installation and deployment at SGP
- Extends size distribution measurement from 10 nm down to **2.5 nm**
- Composed of two instruments that have been optimized for detection down to 2.5 nm and below (**with modification**):
  - Mobility Classifier - sizing
  - Particle Detector - counting

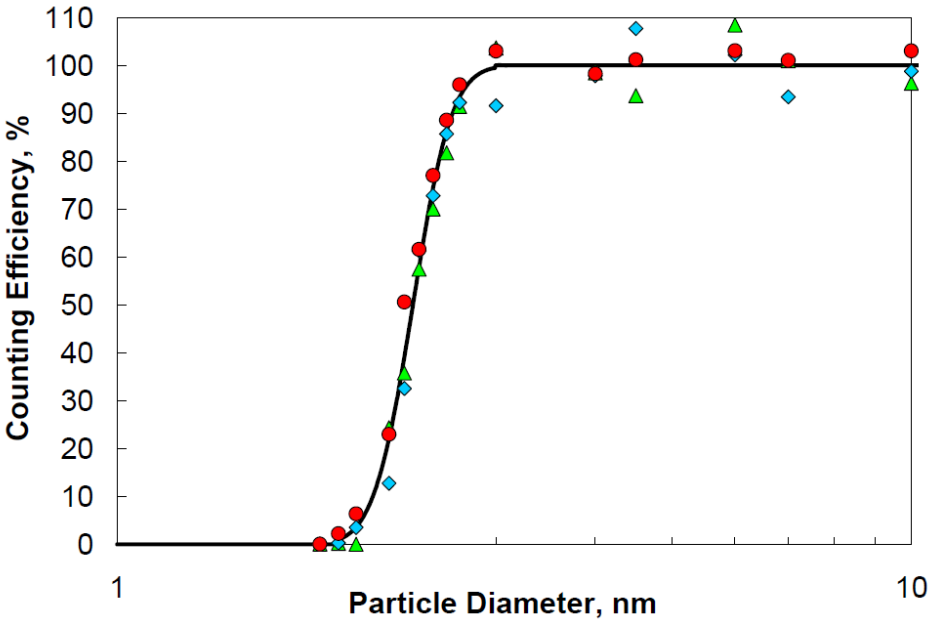
Nano SMPS: Mobility Classifier





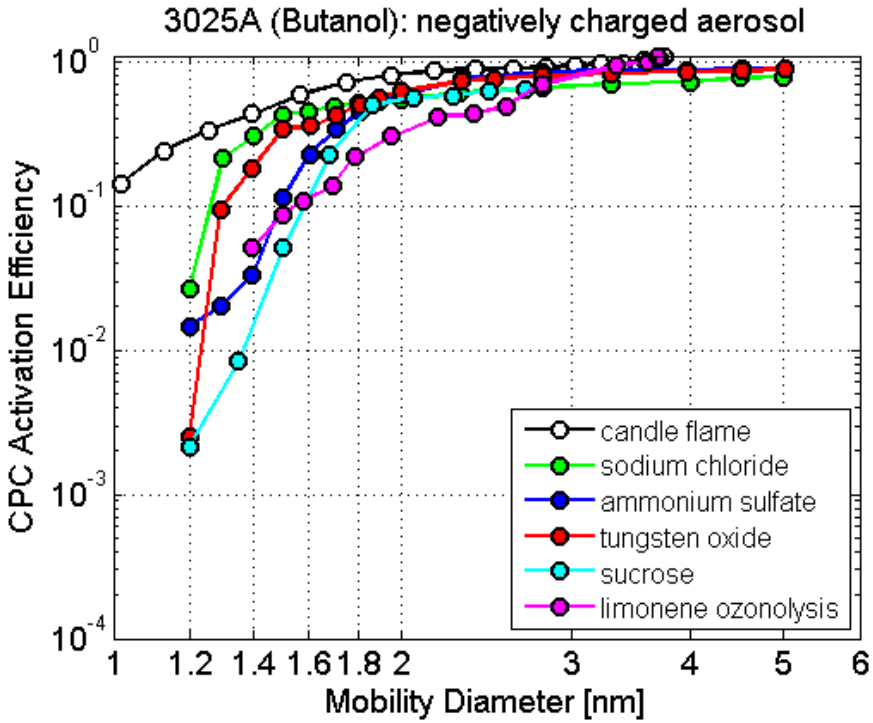
- Key characteristics
  - Dual polarity power supply: exploit higher charging and activation efficiency of negatively charged sub 3 nm particles
  - Higher capacity sheath pump: can achieve mobility diameter classification down to **1.3 nm** at applied voltage of 10V

Nano SMPS: Particle Detector - Standard



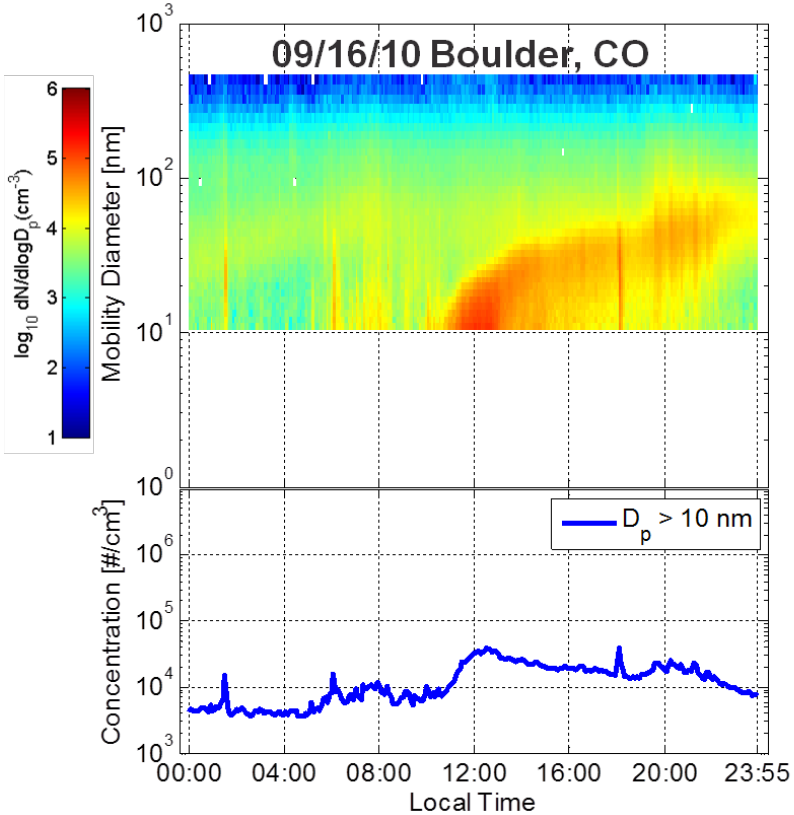
- Key characteristics:
  - Butanol working fluid
  - **50% detection efficiency at 2.5 nm** (sucrose particles)
  - Improved counting statistics
  - Stable, continuous operation

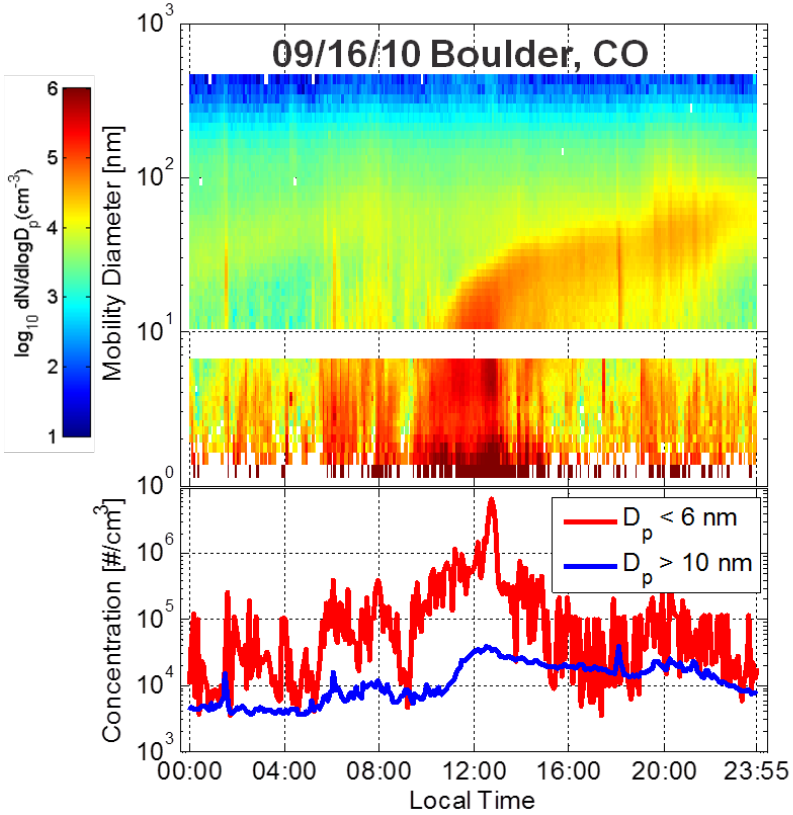
Nano SMPS: Particle Detector - Modified



- Key characteristics:
  - **50% detection efficiency at ~ 1.5 nm**
  - Evidence of reduced composition dependence cf. water CPC
  - Demonstrated stable, continuous operation (recent field campaign)

Nano SMPS: Previously Inaccessible Data Products at SGP





- New measurement deliverables at **SGP**:
  - 1. size distribution from 3 – 10 nm
  - 2. size resolved growth rates down to 3 nm
  - 3. extrapolated nucleation rates
  - 4**. Items 1 – 3, except down to 1 nm (with instrument modification)**

Continuing Work: Opportunities and Challenges

- Measurement:
  - 1 nm aerosol spectrometer on AAF G1 (several mentions of NPF observations during BBOP and CARES)
  - extend lower size limit for SGP Nano-SMPS from 3 nm down to 1 nm

- Analysis
  - [H_2SO_4] proxy from SO_2 measurement
  - Nucleation rates (J) and initial growth rates (GR)
  - Long term data set that correlates J, GR, and [H_2SO_4]

Acknowledgements

- Jim Mather, ARM Climate Research Facility - Technical Director
- Doug Sisterson, ARM Climate Research Facility - Manager
- ARM Data Management Facility
- Instrument mentors:
  - Anne Jefferson
  - Stephen Springston
  - Don Collins

Outline

- 1. ARM resources: SGP CF, MAOS-A (aerosol)/C (chemistry)
- 2. Deployments: MAOSA/C (ALC IOP, PACE IOP, TCAP IOP), with map of locations, duration, etc., PI?
- 3. Current Instruments and Measurements of interest: N3, N10, N10-3, PSD (10 – 500 nm), [SO_2]
- 4. New measurements: Nano-SMPS (down to < 2.5 nm at SGP) – include some new calibration data?, and some model predictions for sizing ability
- 5. Challenges/Needed Measurements: gas-phase (SO_2) at SGP (generation of sulfuric acid proxy)

ARM Facilities and Studies

- Fixed Site: Southern Great Plains (**SGP**) – Central Facility, Lamont, OK
  - New Particle Formation Study (**Smith**): 04/2013 – 5/2013

- Mobile Facility: Mobile Aerosol Observing System (**MAOS**)
  - Aerosol Life Cycle (ALC, **Sedlacek**): 06/2011 – 08/2011
  - Pajarito Aerosol Coupling to Ecosystems (PACE, **Dubey**): 12/2011 – 4/2012
  - Two-Column Aerosol Project (TCAP, **Berg**): 07/2011 – 06/2013

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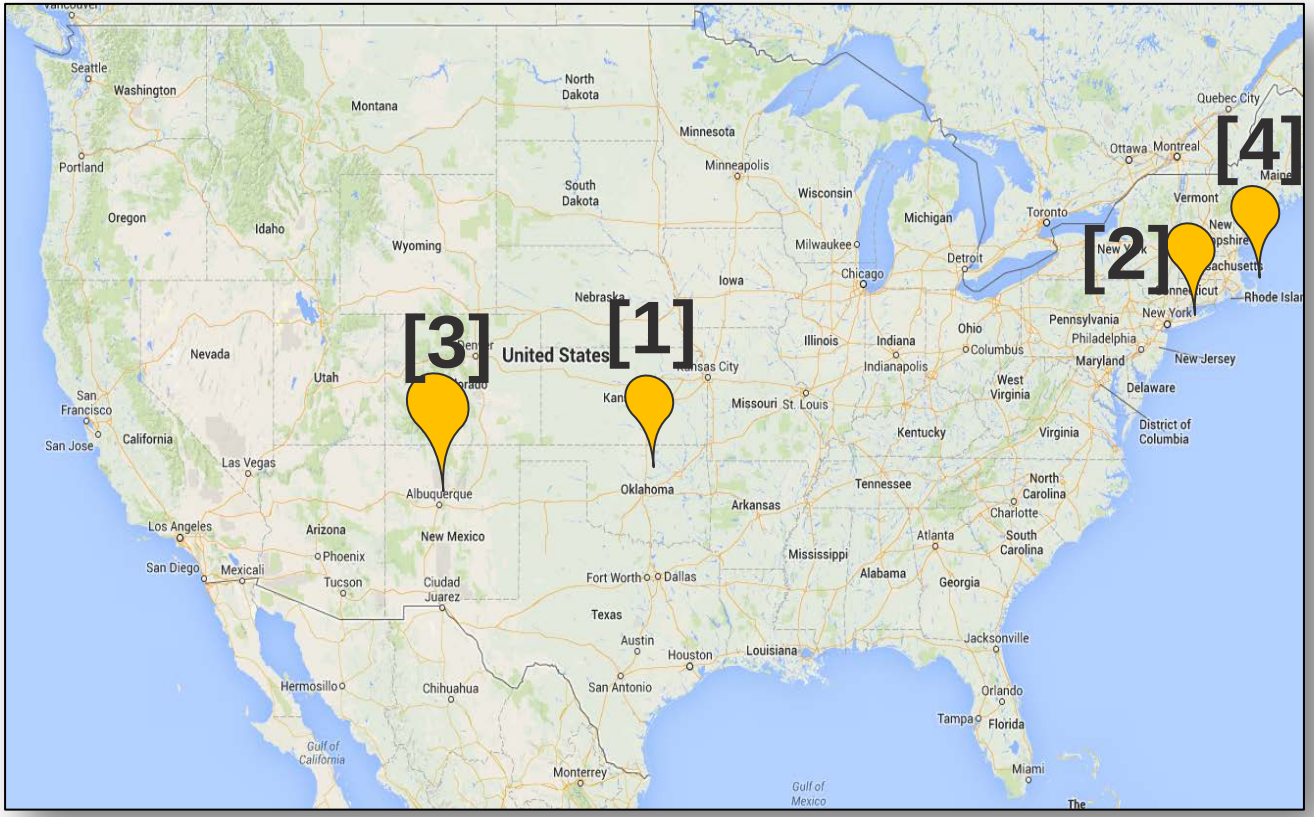

Fixed Site: Southern Great Plains (**SGP**)

[**1**] New Particle Formation Study: 04/2013 – 5/2013

Mobile Aerosol Observing System (**MAOS**)

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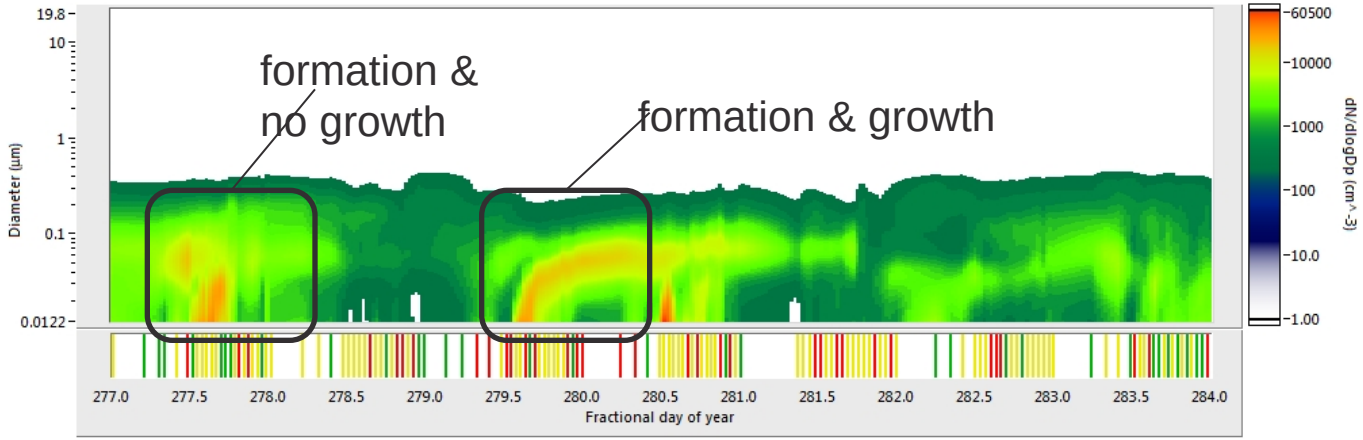
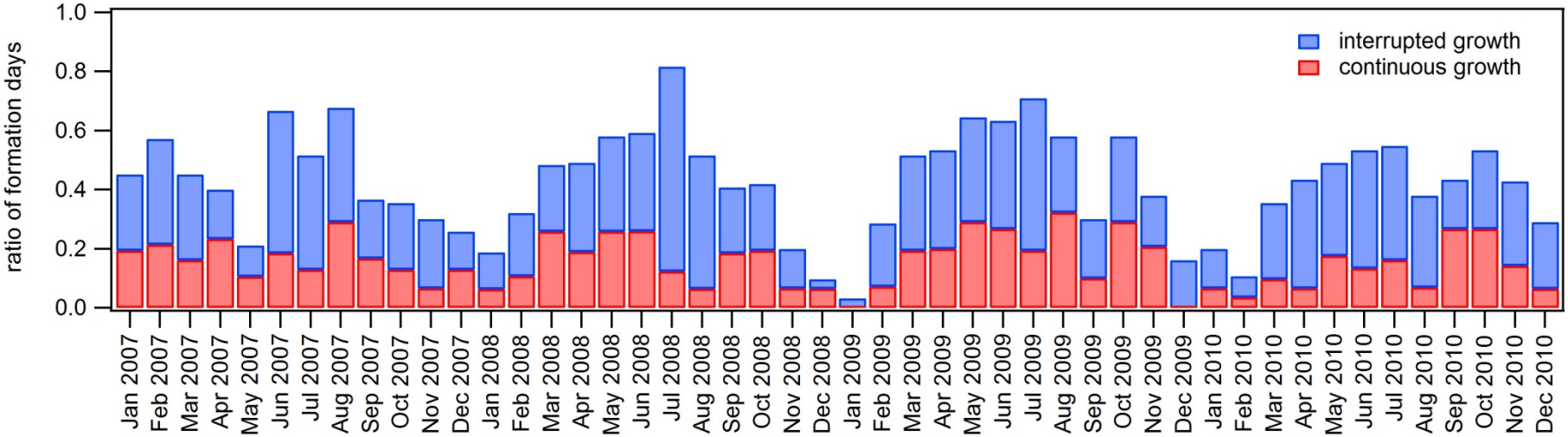
Why Southern Great Plains? Reason 1: Frequent particle formation events





- New particle formation is observed in SGP during over half the summer months
- Classic formation and growth events are more common in May and September (meteorological effect?)

TDMA data from SGP: Analysis by John Ortega (NCAR)

Why Southern Great Plains? Reason 2: ARM infrastructure!

Existing SGP Central Facility Instruments and Support

- hygroscopicity (TDMA)
- PM1 composition (ACSM)
- cloud condensation nuclei (CCNc)
- aerosol optical properties
- remote sensing data (radars, lidars, etc.)
- frequent balloon-borne sounding launches
- Calibration facilities, engineering support, regular gas deliveries, …

SGP NPF: Measurement and modeling opportunities for ALC members

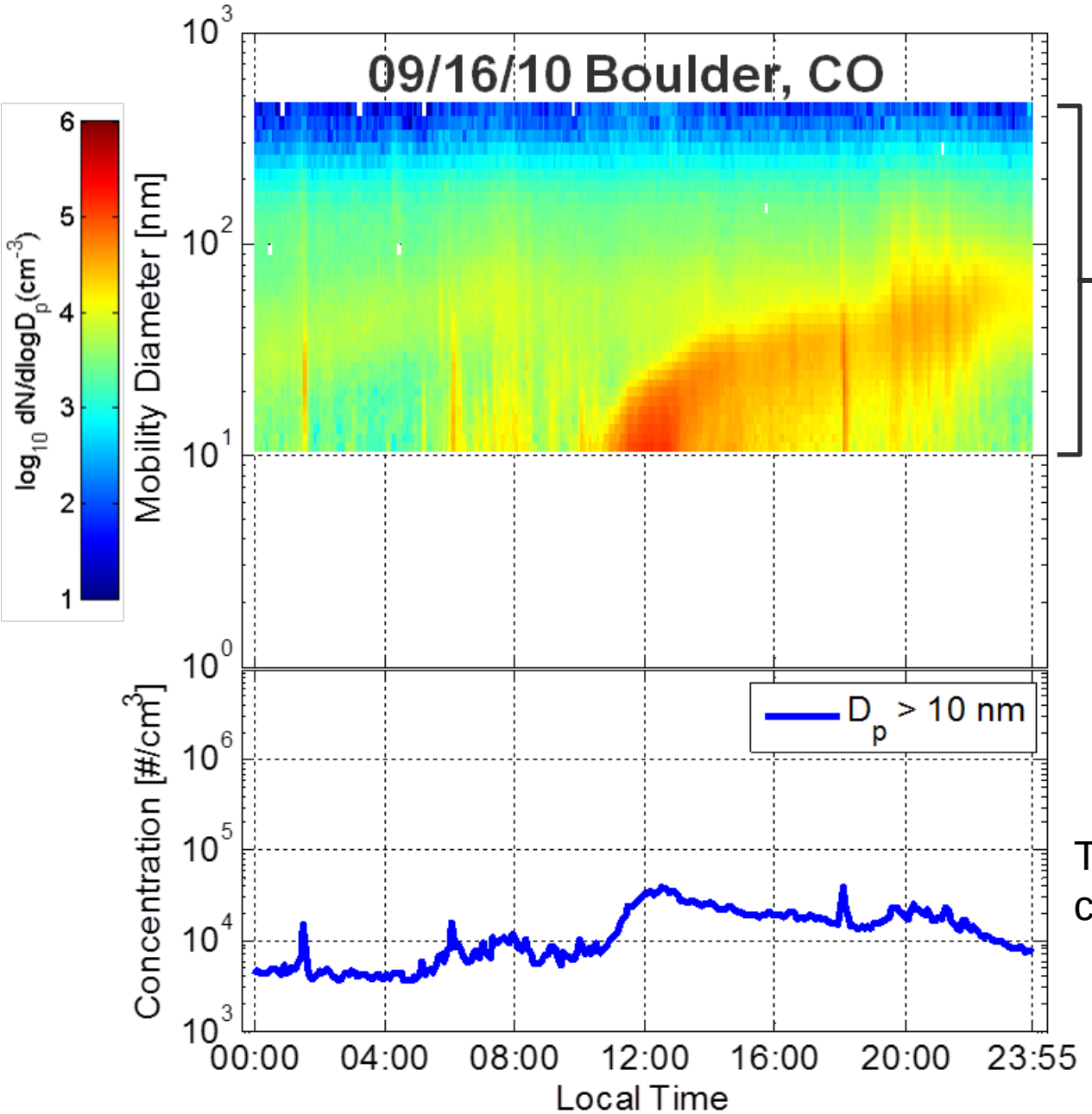
Modeling:

- We need process-scale modeling of aerosol formation and growth through acid/base chemistry
- We need participation of regional scale modelers, making use of aerosol physico-chemical properties, gas precursors, and 3-D-resolved atmospheric properties

Measurements:

- organic acids
- VOCs (PTR-MS)

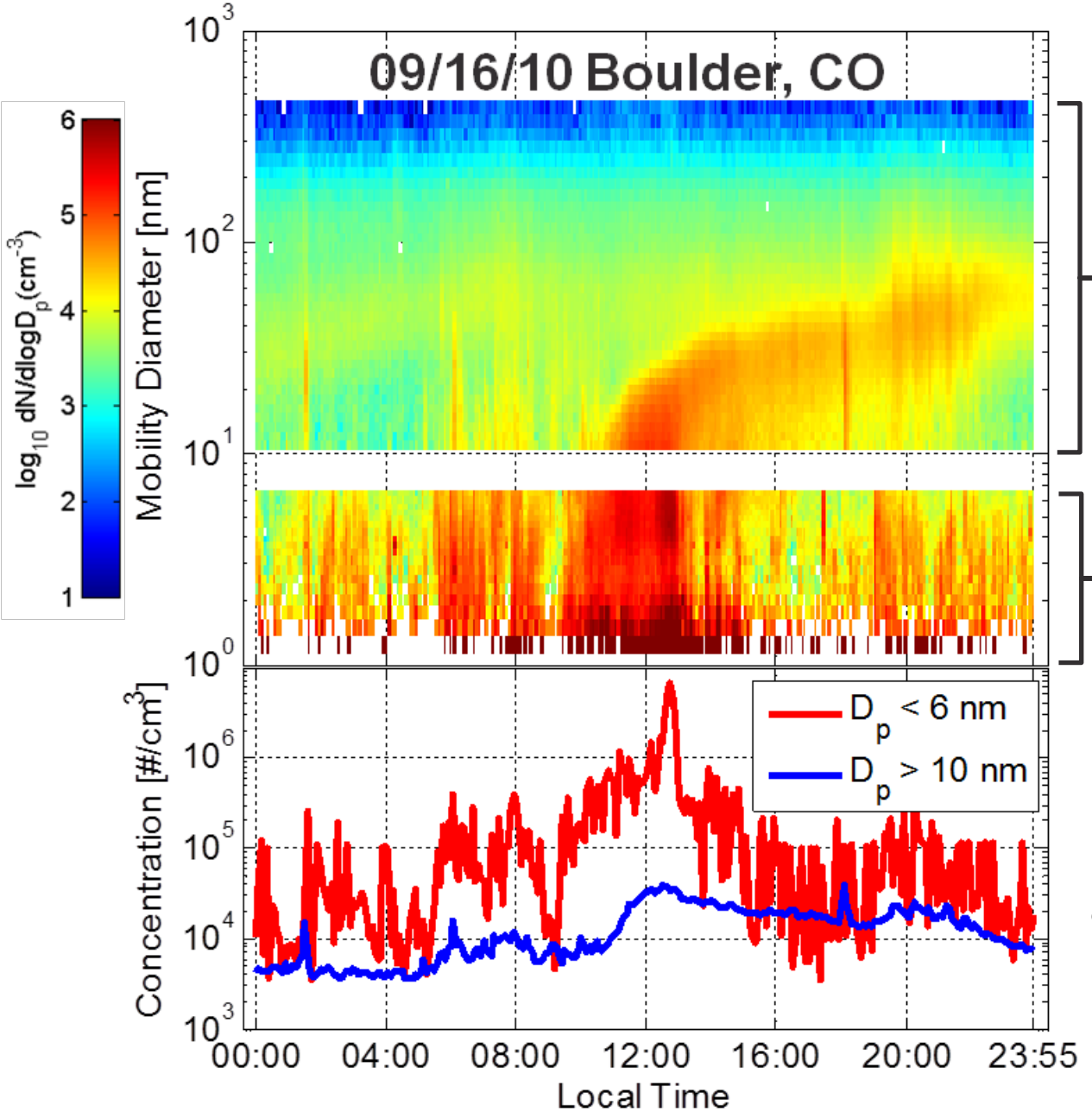
New Instrument Bridges the Cluster Measurement Gap



Conventional aerosol size distribution measurement

Total aerosol number concentration above 10 nm

New Instrument Bridges the Cluster Measurement Gap



Conventional measurement

New measurements down to 1 nm:

1. **Direct cluster formation rates**
2. **Direct initial growth rates**

NPF adds >100X to **pre-existing** aerosol concentration