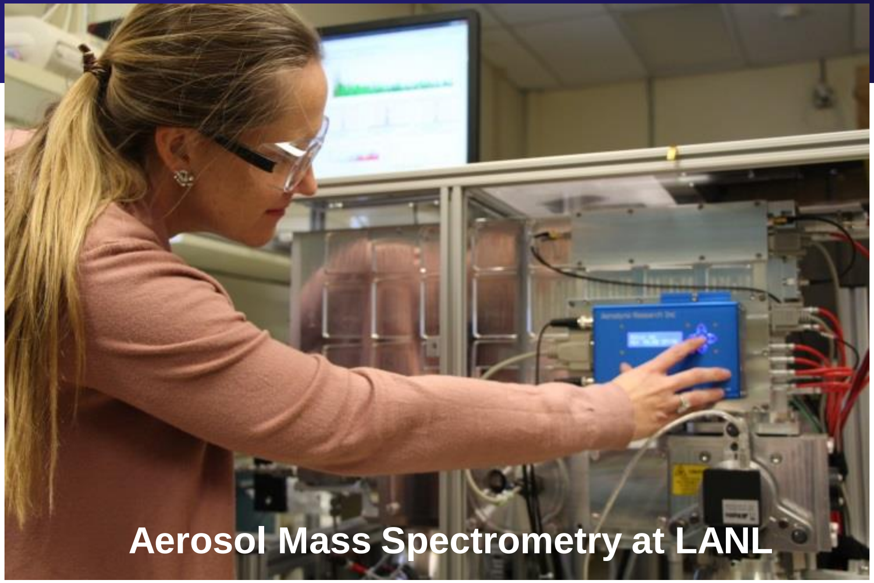
Wildfire Aerosol and Trace Gas Emissions:
Results from the field and laboratory burning experiments


New Mexico Wildfire : Las Conchas, NM


Aerosol Mass Spectrometry at LANL

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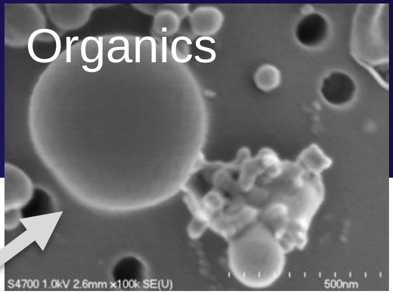
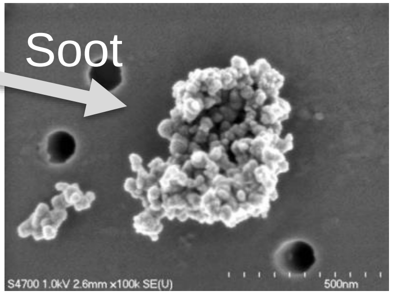
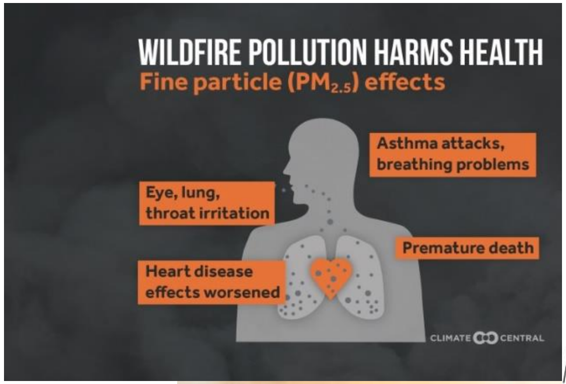
Wildfire Aerosol and Human Health

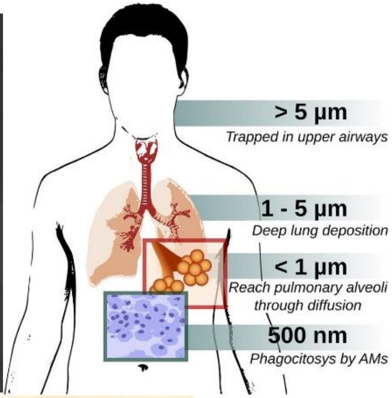
- **Largest source of Carbon to the Atmosphere**
  - Particles: Black Carbon (soot) and Organic carbon
  - Gases: CO, CO_2
  - Local, regional and long-range transport
  - Expected to increase in the future (increased drought and extreme events)
- **Health Impacts and Toxicity**
  - WHO proposed annual $PM_{2.5}$<10 µg m^{-3}
  - Black Carbon a.k.a. "soot"
  - Polycyclic Aromatic Hydrocarbons (PAH's) and Nitro-PAH's
  - Heavy metals
- **Urban/wildfire interface**
  - Emissions change with time, environmental conditions, atmospheric transport, etc.
  - More unknowns, including man-made toxics in urban fuels





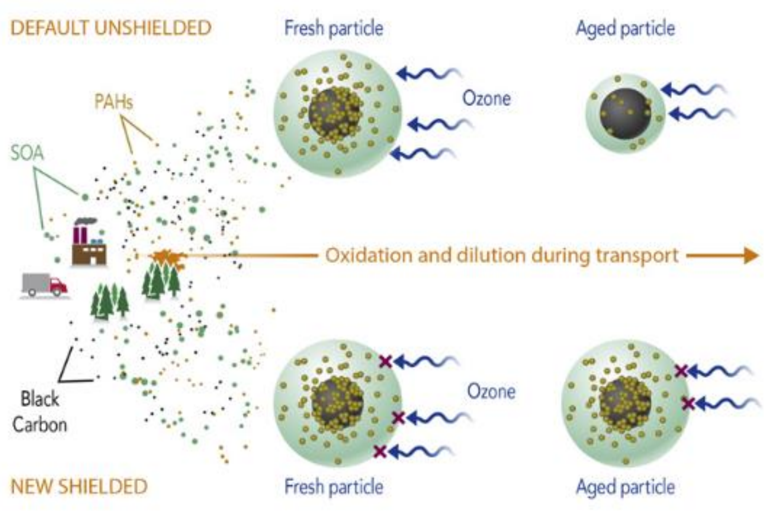
China, Mazzoleni, Gorkowski, Aiken, Dubey, ***Nature Communications****, 2013.*



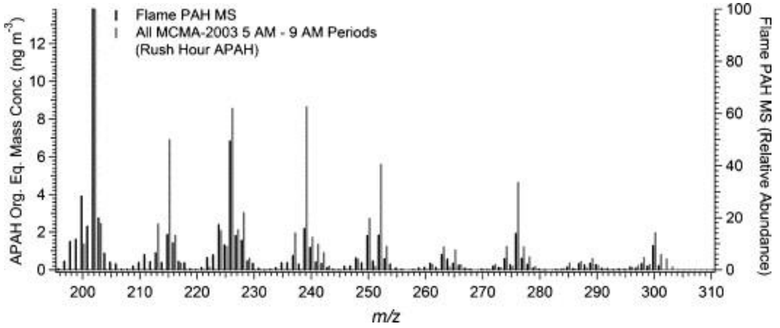


Wildfire Aerosol

- **Aerosols are dynamic in nature**
  - Direct emissions and those formed in the atmosphere
  - Refractory species (e.g. soot) mainly removed through water uptake
  - Semi-volatile species can partition between the gas and particle phases
  - Measurement-driven evidence for long range transport of air toxics
- **Polycyclic Aromatic Hydrocarbons**
  - Detected in urban locations influenced by wildfire emissions, e.g. Mexico City
  - Known carcinogens formed from combustion
- **Direct measurements are needed to unravel transport and toxicity**



Shrivastava et al., PNAS, 2017.

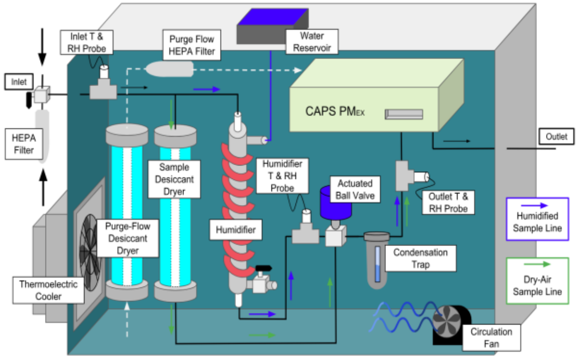


Dzepina et al., International Journal of Mass Spec., 2007.

Center for Aerosol Forensics and Experiments (CAFÉ)

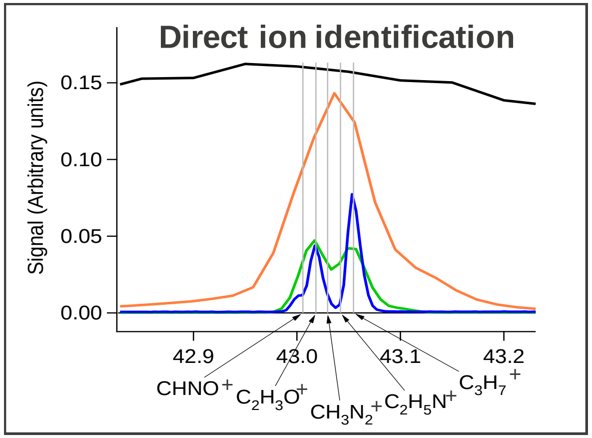
- **Specialize in ambient measurements and lab experiments**
  - Online aerosol and trace gas measurements
    - Limits bias from sampling on a filter
    - Offers high time resolution and high particle statistics
  - ~$2 Million in online aerosol instrumentation: sizing, chemical composition, water uptake, optical properties
    - Single particle information: soot, number concentration, sizing
    - Bulk submicron analysis: light absorption and scattering

Humidified Extinction and Scattering



Soot Particle Aerosol Mass Spectrometer

2 modes: Soot and non-Soot containing chemistry

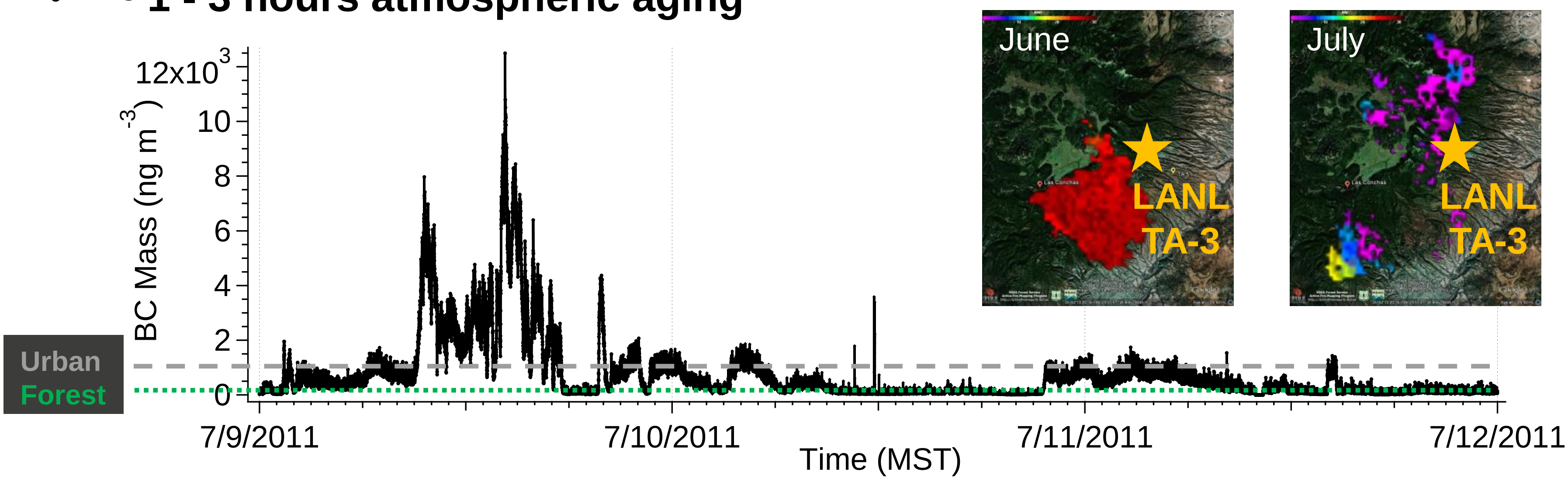


Near Source Wildfire Soot

- **Las Conchas, NM Wildfire**
  - 2nd Largest NM Fire (largest at the time)
  - ~157K acres burned, started ~10 miles W of LANL
  - ~10% of the particles contain BC
- **Soot mass concentrations > 10 μg m^{-3}**
  - After Containment (during, est. 10x ~100 μg m^{-3})
  - ~10x Urban Pollution (Liu, Aiken et al., *Nature C.*, 2015)
  - ~200x “clean” Forest (Ortega… Aiken et al., ACP, 2014)
- **~ 1 - 3 hours atmospheric aging**

Image from the International Space Station (ISS)

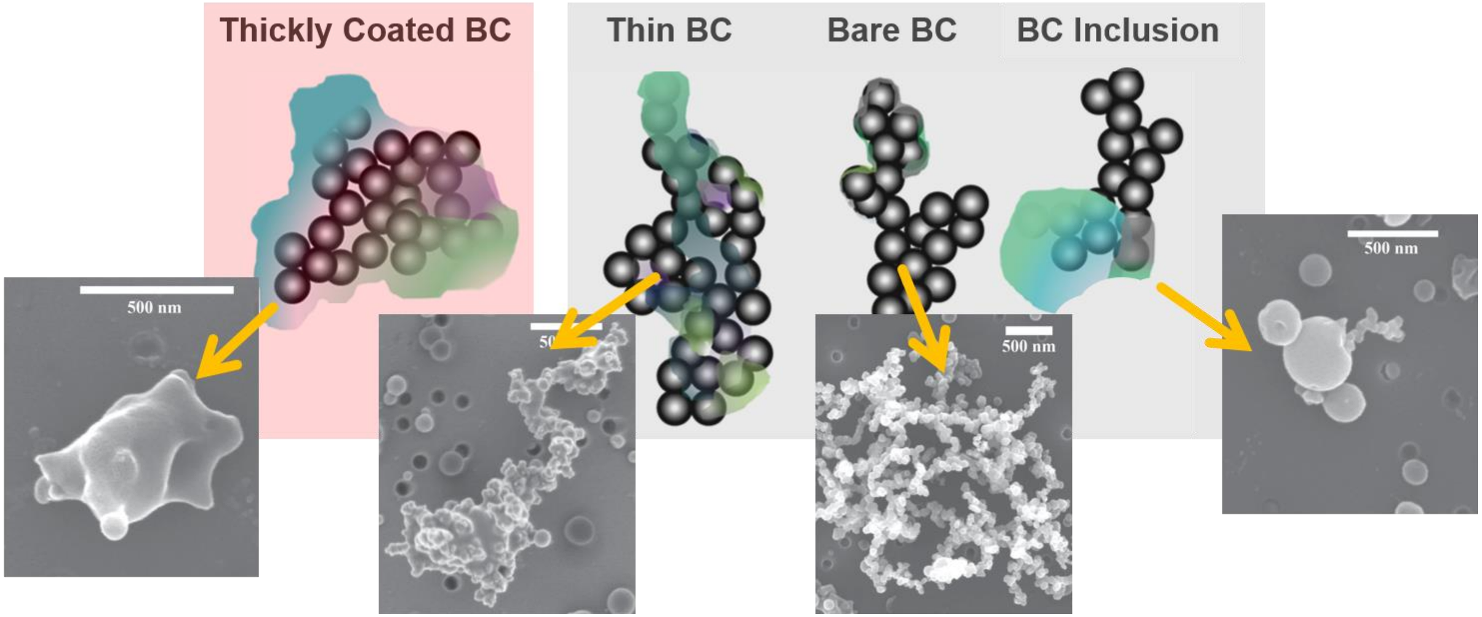
USDS MODIS Fire Burn Scars



Wildfire Soot Morphology and Internal Mixing State

- **4 Types of BC from SEM Images during Las Conchas Wildfire**

  China et al., Nature Communications, 2013
- **Large range in size will impact humans differently (throat versus lung)**



What is the chemistry of the non-soot organic coatings?

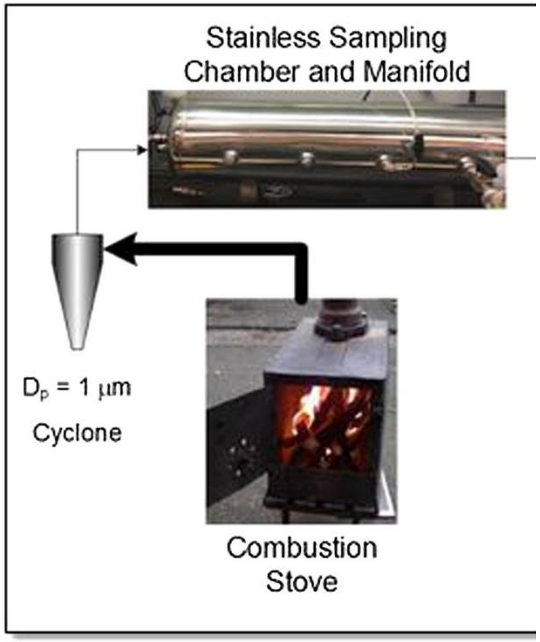
Is it different than the particles without soot?

Do size, chemistry and morphology affect toxicity?

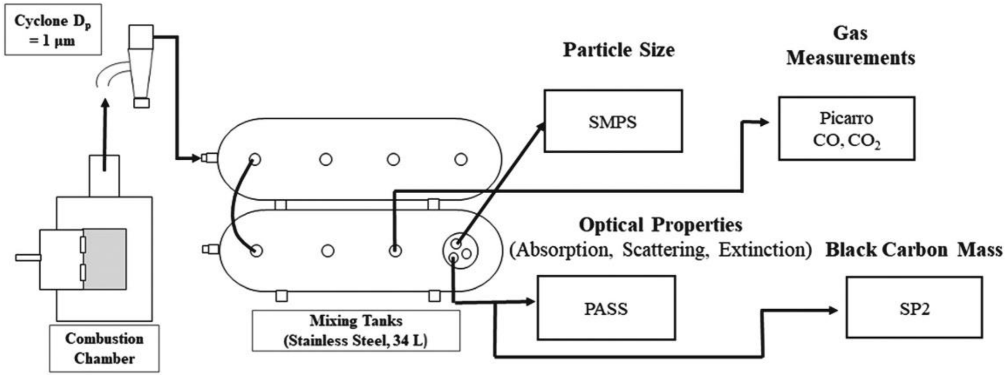
How do health impacts differ for near source versus aged aerosol?

LANL Biomass Burning Experiments

- **Lab studies with dilution to bridge the gap between fresh emissions and atmospherically aged wildfire aerosol**
  - Single-source fuels (< 2 g) burned in a combustion stove
  - Filtered for particles below PM_1
  - Dilution and mixing chambers to homogenize small-scale effects
  - ~20 SW US fuel types sampled by plant structure (sticks, leaves, needles, branches)



Gomez et al., Journal of Geophysical Research, 2018.



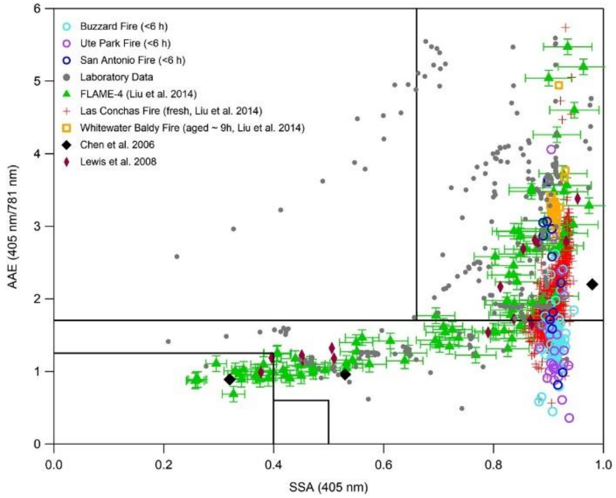
Romonosky et al., Journal of Geophysical Research, 2019.

Laboratory Burn and Wildfire Aerosol Optical Properties

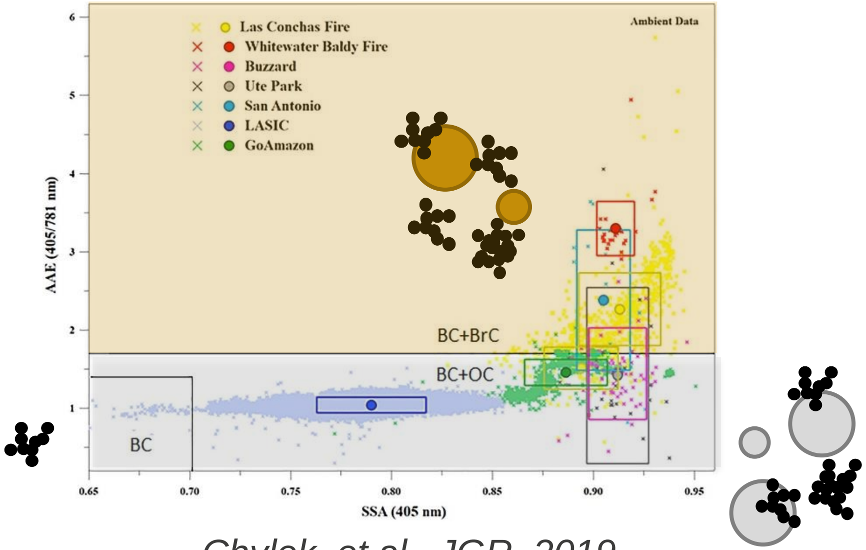
- **Two optical regimes in the lab and field**
  - **Soot-dominated** and **soot and other absorbing organics**
  - Near source wildfires: Mixed absorption species
  - Long range transport wildfires: Soot-dominated

- **Are the optical differences due to source or transport?**

- **What does this mean for wildfire aerosol chemistry and toxicity?**



Romonosky, et al., JGR, 2018.



Chylek, et al., JGR, 2019.

Conclusions

- **Soot Particle Aerosol Mass Spectrometry**
  - Real-time *in situ* measurement of soot and organics, including chemical changes (oxygen-content) in real time
- **Wildfire aerosol is a complex mixture of different carbonaceous species**
  - Local, regional and long-range transport wildfires sampled
  - Particles age in the atmosphere
  - Oxygen content increases with age and hydrocarbon content decreases
- **Laboratory single-source fuel burning experiments at LANL**
  - 20 different species and burning conditions
  - Physical, chemical and optical properties
  - Soot dominates flaming combustion and organics during smoldering conditions

Future Work

- Sample single-source urban and CA fuel sources in the lab
- Characterize soot and non-soot containing aerosol chemistry
- Identify PAH and other aerosol toxics, e.g. metals
- Incorporate new procedures for metals analysis from raw fuels and soot

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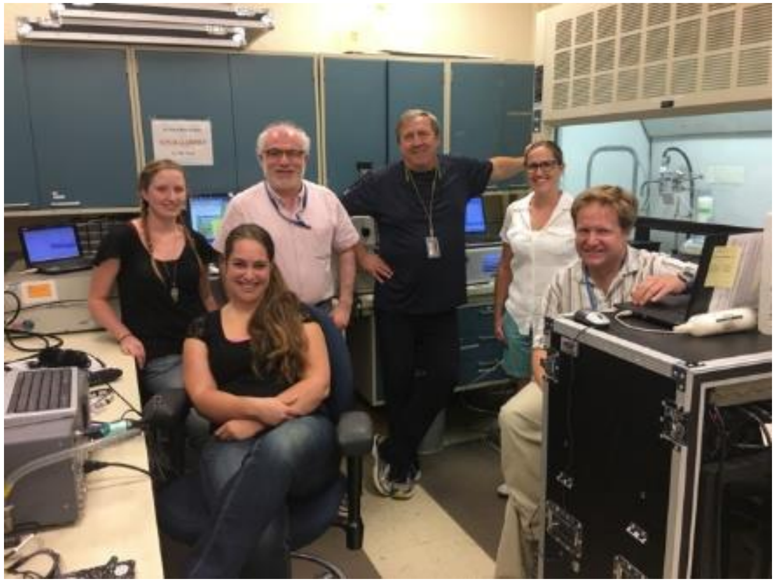

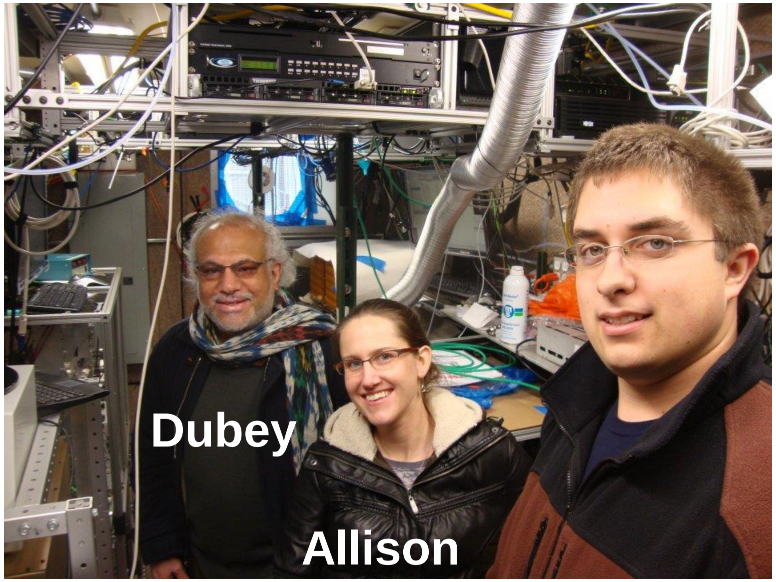

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NNSA National Nuclear Security Administration

U.S. DEPARTMENT OF ENERGY

ASR Atmospheric System Research

ARM

LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT