Characterization of Coarse PM Using Passive Samplers

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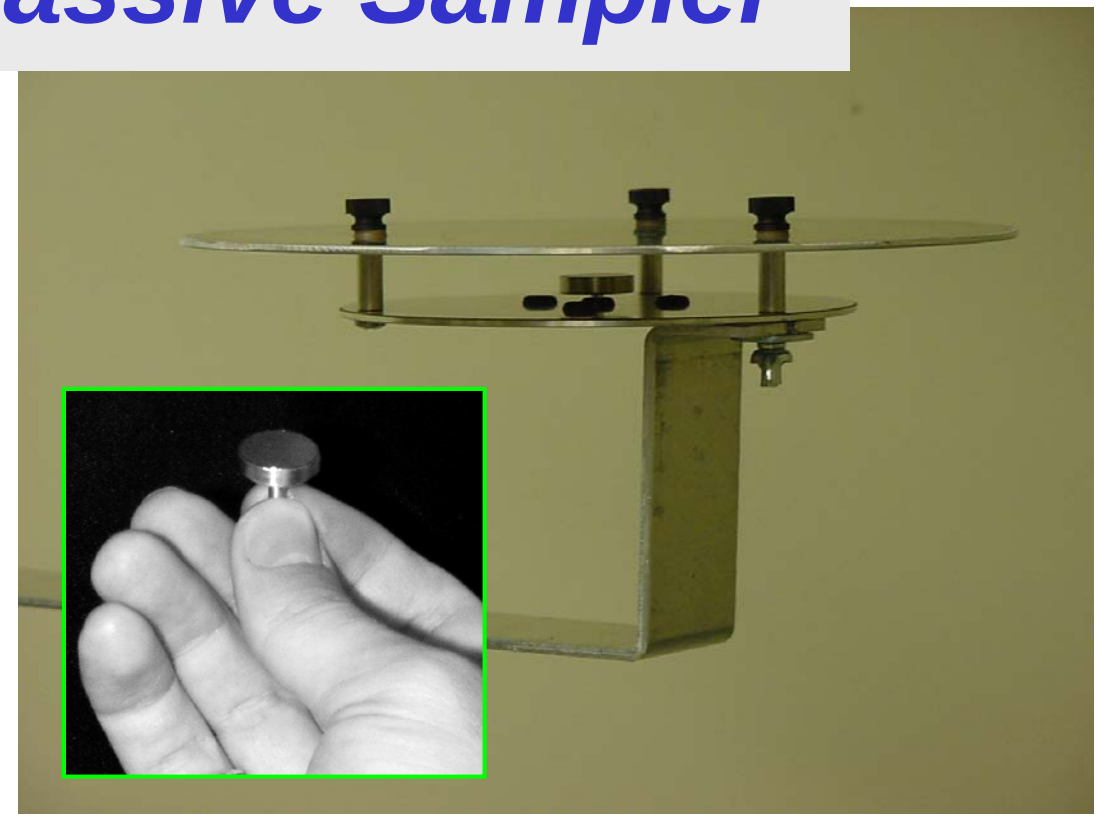
UNC Passive Sampler

- Consists of a standard SEM stub with a mesh cap
- Small, unobtrusive (size and weight of a nickel)
- Easy to use
- Inexpensive and reusable
- No power required



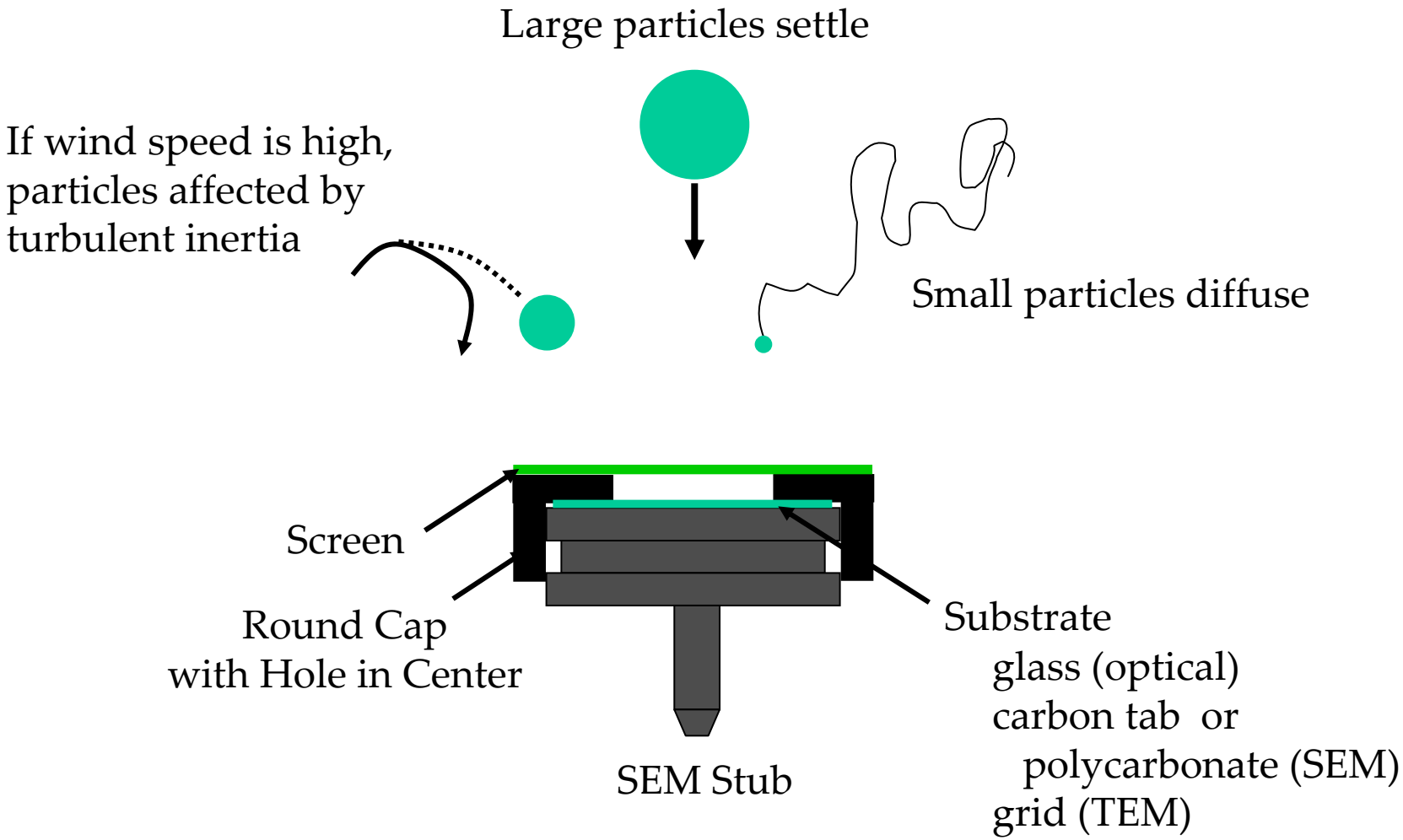
Wagner, J. and D. Leith. *Aerosol Science and Technology*. **2001**, 34(2), 186-192.

Wagner, J. and D. Leith. *Aerosol Science and Technology*. **2001**, 34(2), 193-201.

Wagner, J. and D. Leith. *Journal of Aerosol Science*. **2001**, 32, 33-48.

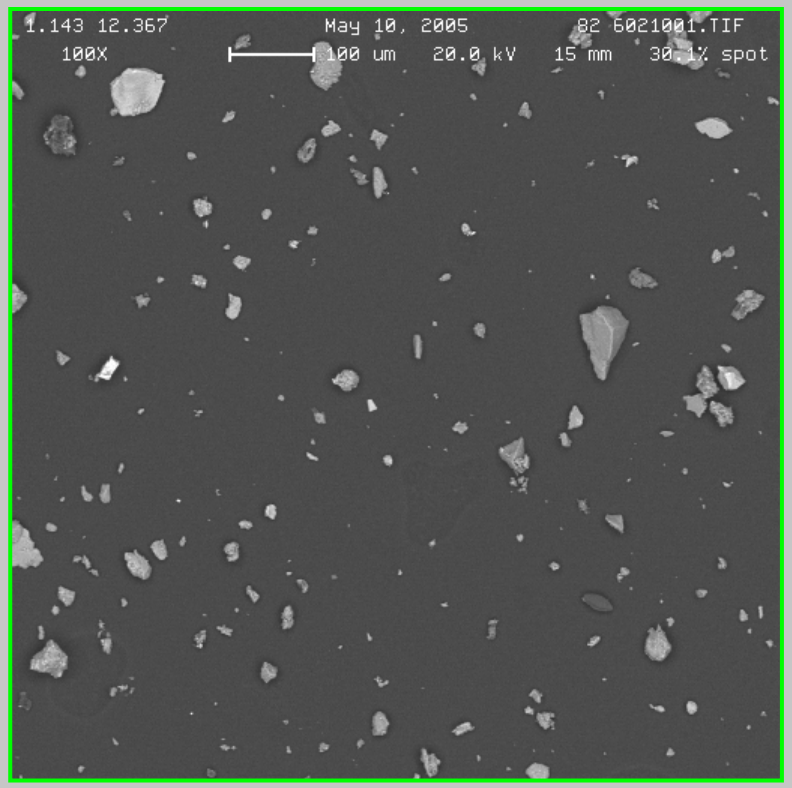
Ott, D. and T. Peters. *Aerosol Science and Technology.* **2008,** 42(4), 299-309.

How it Works

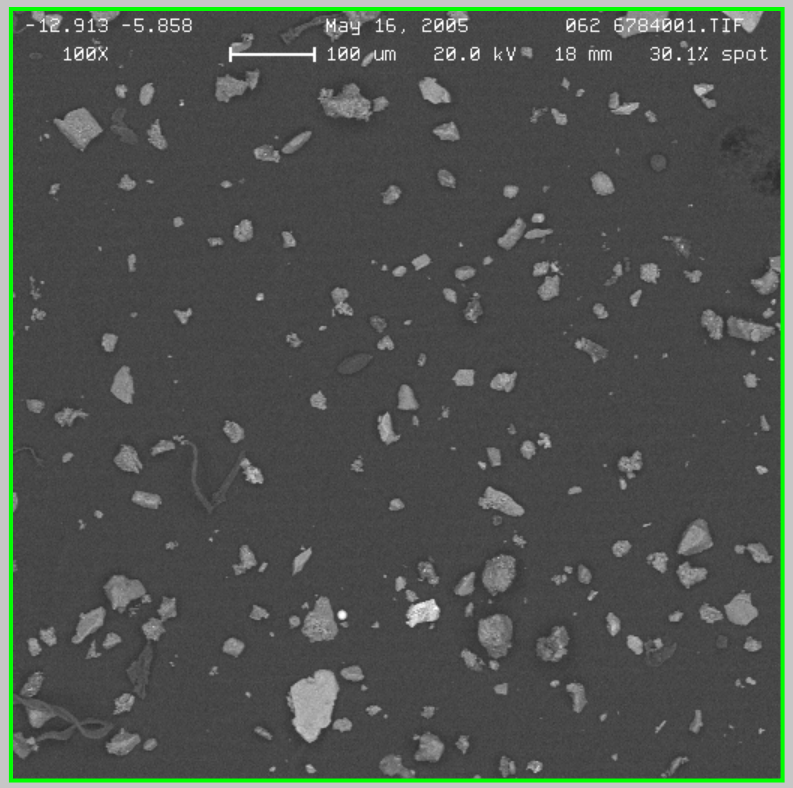

Large particles settle
If wind speed is high, particles affected by turbulent inertia
Small particles diffuse
Screen
Round Cap with Hole in Center
SEM Stub
Substrate
glass (optical)
carbon tab or
polycarbonate (SEM)
grid (TEM)

Particle Loading on Passive Sampler

Phoenix 7-day exposure, 100x magnification



Week 1



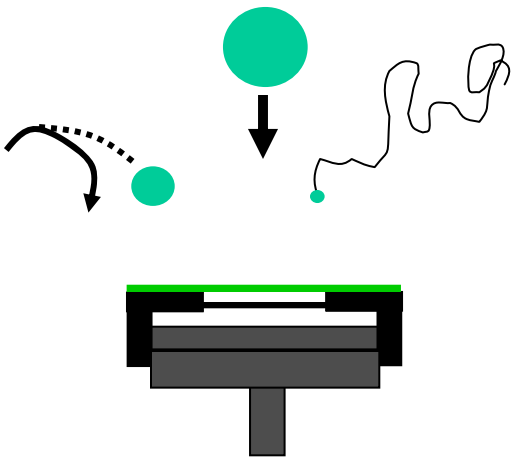
Week 2

How it Measures

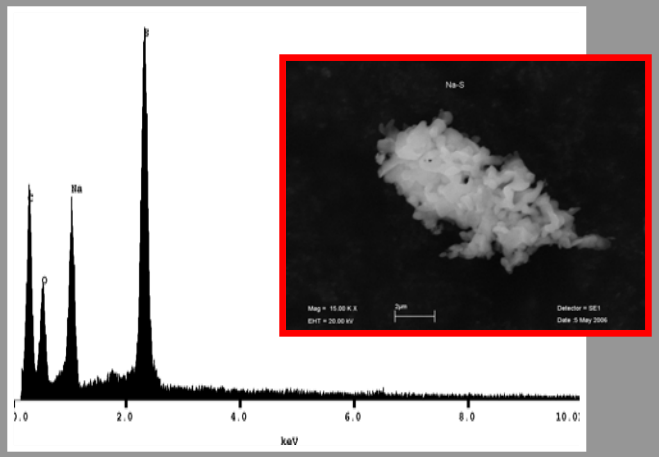
Ambient $PM_{10\text{-}2.5}$ Concentration = $\dfrac{\text{Flux to Sampler}}{\text{Deposition Velocity}}$

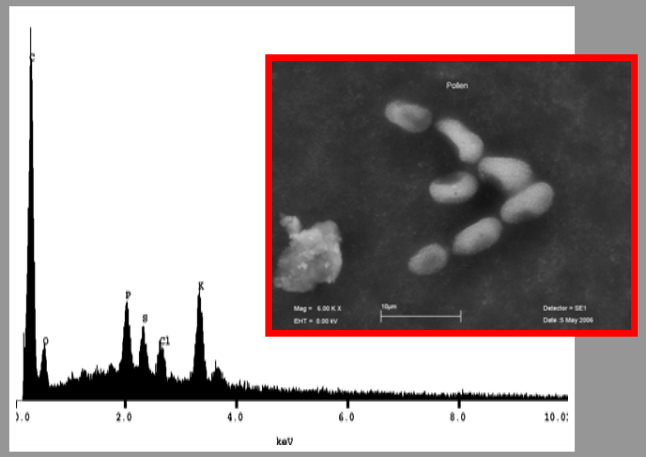
Determined by Computer-Controlled SEM or optical microscopy

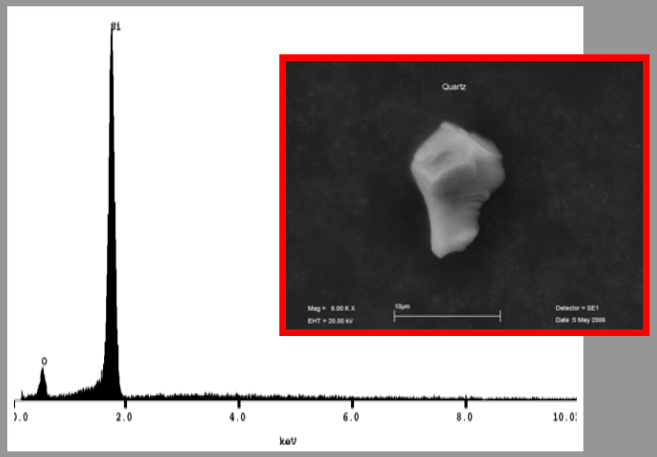
Calculated as function of particle size using theory checked in wind tunnel

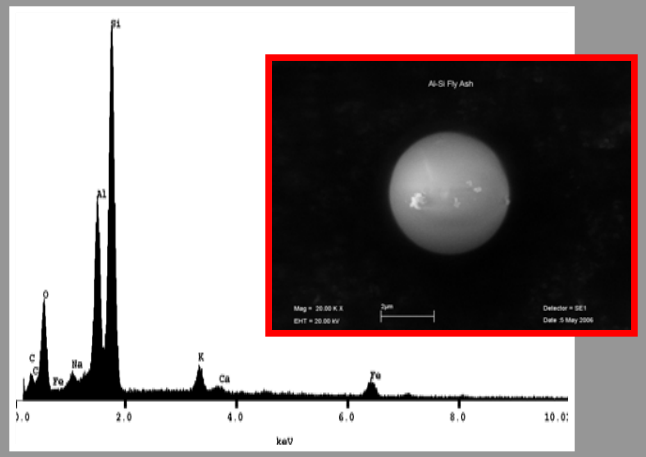


CCSEM with X-ray microanalysis provides size, composition, and morphology of individual particles









Potential Applications

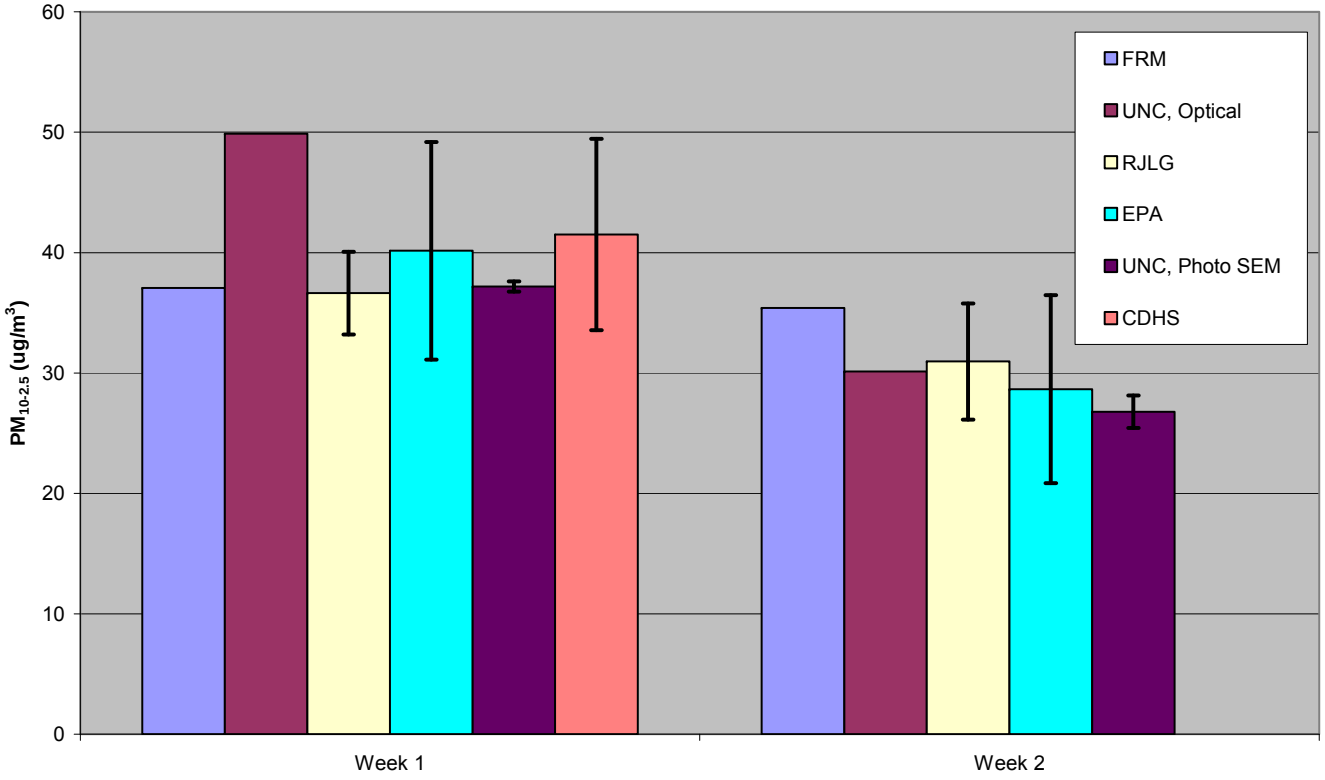
- Evaluate spatial/temporal variability of $PM_{10-2.5}$ mass and composition
  - Source apportionment
  - Nuisance dusts
- Assess personal and workplace exposures for relating to adverse chronic health effects

Field Evaluations

- Phoenix (2005)
- Iowa City (2006, optical samplers)[1]
- Birmingham (2005, 2006, 2008)
- St. Louis (2006, 2007)
- Delhi, India (2007,2008)
- Cleveland (2008, 2009, 2010)

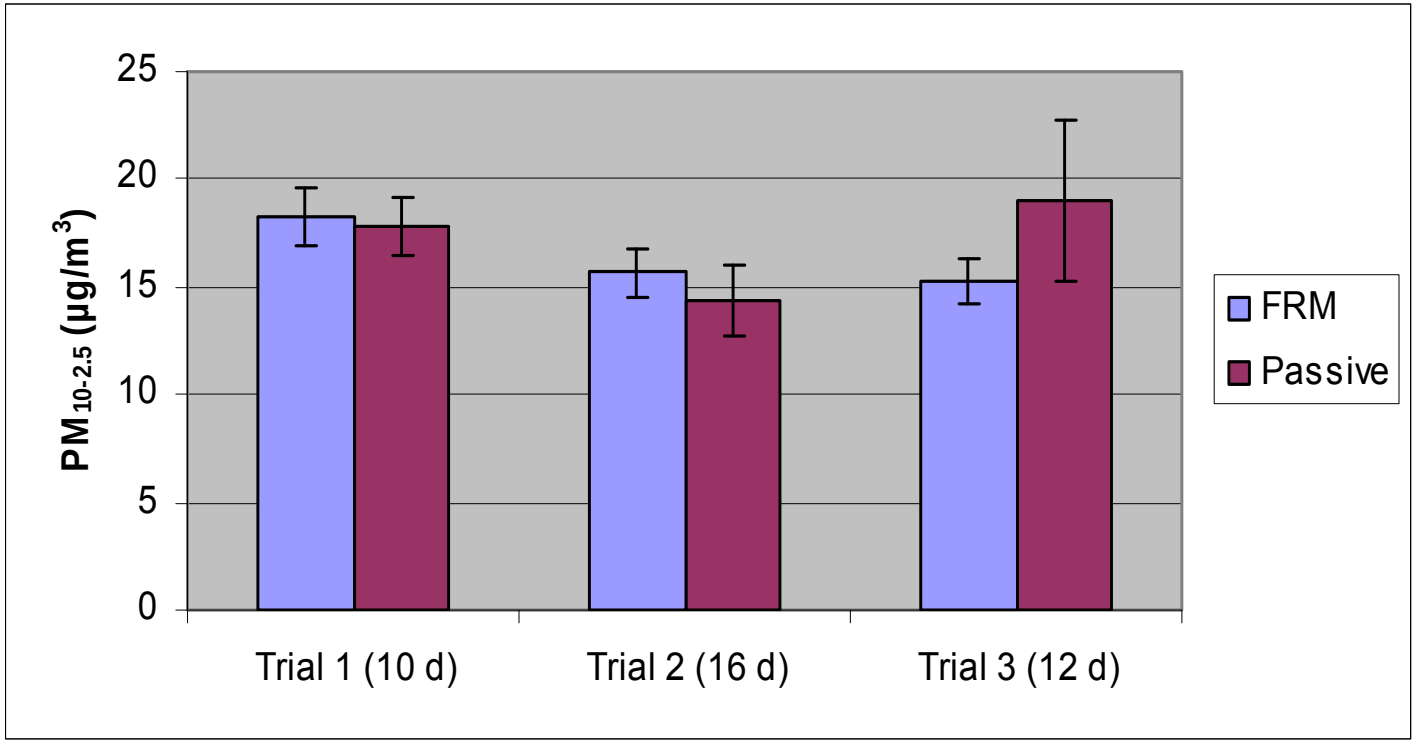
[1]Ott, D., N. Kumar and T. Peters. *Atmospheric Environment.* **2008**, 42 746-756.

$PM_{10-2.5}$ Accuracy and Precision Phoenix, 2005



UNC optical: optical microscopy, Univ. North Carolina
UNC photo SEM: SEM images + Image J, Univ. North Carolina
CDHS: CCSEM, California Dept. of Public Health
RJLG: CCSEM, RJ Lee Group, Inc.

$PM_{10-2.5}$ Accuracy and Precision Birmingham, 2008



Passive sample precision = Std. Dev. of 2 co-located passive samples

Cleveland Scoping Study
August 12 - September 2, 2008

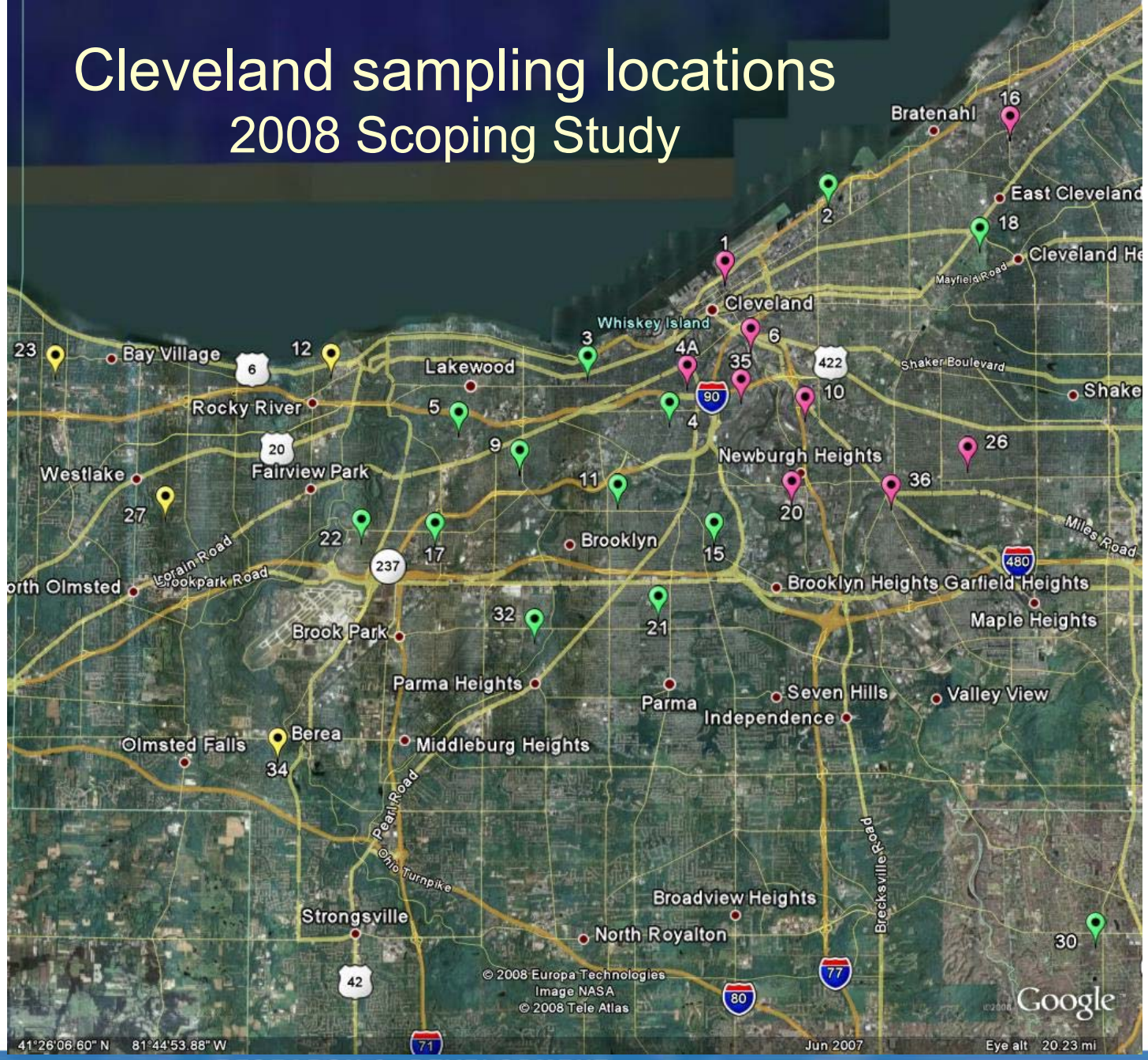
- Objective: Assess the spatial variability of $PM_{10-2.5}$ mass and composition in Cleveland using a network of passive samplers

Cleveland Field Sampling

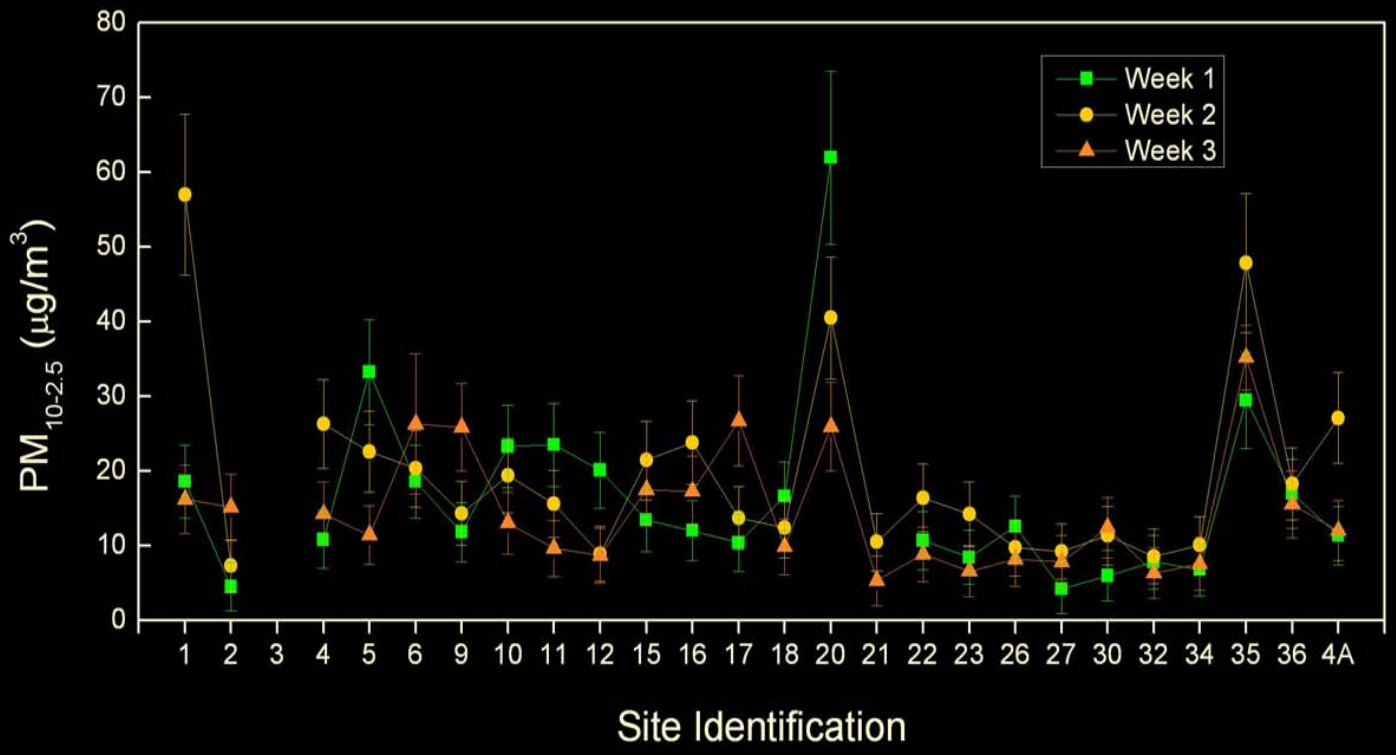
- 26 sampling sites selected to maximize the variability observed in preliminary surface PM_{10} concentrations
- Samplers deployed for 7-day intervals over 3 consecutive weeks
- At each site, two passive samplers (one for optical and one for CCSEM analysis) co-located within a protective shelter
- Results from CCSEM analysis are presented

Cleveland sampling locations
2008 Scoping Study

Sites selection maximizes the variability observed in preliminary surface PM_{10} estimates

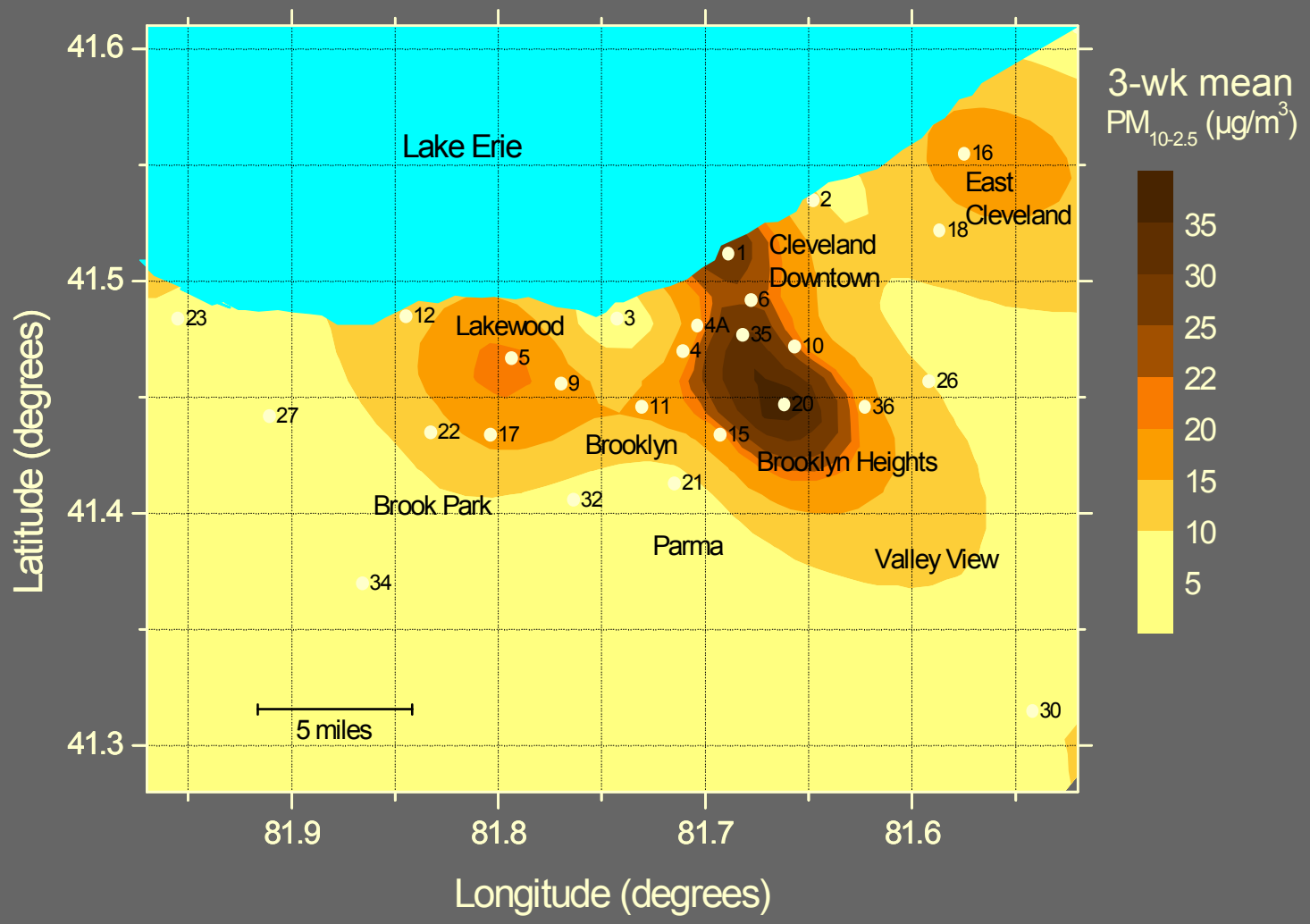


Weekly $PM_{10-2.5}$ by Site



(samplers from site 3 went missing.)

Spatial variability of $PM_{10-2.5}$ measured over 3-week study period



Spatial Variability: Mass

- Distinct pattern with highest concentrations centered on the industrial valley
- 1-week average $PM_{10-2.5}$ across sites
  - Low: 4 (± 3) μg/m^3
  - High: 62 (±12) μg/m^3

Data Quality Results

- Overall precision = 17% (field + analytical)
- CCSEM reproducibility = 4% (repeat analyses of 12 randomly-selected samples)
- Blanks ~ 5 ± 3 $\mu g/m^3$ (10 field blanks)
- Recovery = 96% (86 valid of 90 deployed samples)
- FRM $PM_{10-2.5}$ measurements were not available to determine passive sampling bias

Data Quality Results

- Avg. passive sampling precision = 17% (field sampling variability plus CCSEM precision)
- CCSEM analytical reproducibility = 4% based on repeat analyses of 12 randomly-selected samples
- FRM $PM_{10-2.5}$ measurements were not available to determine passive sampling bias
- Avg. Blank ~ 5 ± 3 μg/m^3 based on analysis of ten blanks
- Only 4 of 90 samples collected were invalidated due to damage or loss

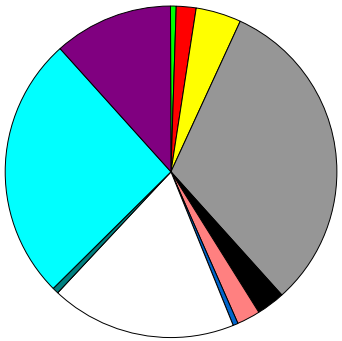
Spatial Variability: Composition

- X-ray microanalysis provides particle elemental composition
- Particles classified into 9 particle types using chemistry-based rules
- Number of particles analyzed ranged from 560 to 801
- Preliminary results shown in comparison across 3 sites for week 3

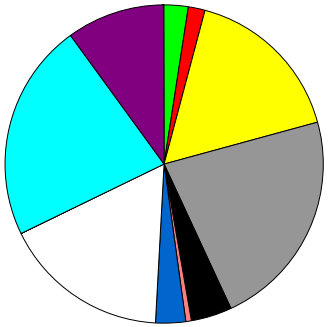
Inter-site Composition Variability

$PM_{10-2.5}$ mass fraction by particle type, Week 3

Site 30
12.5 µg/m^3

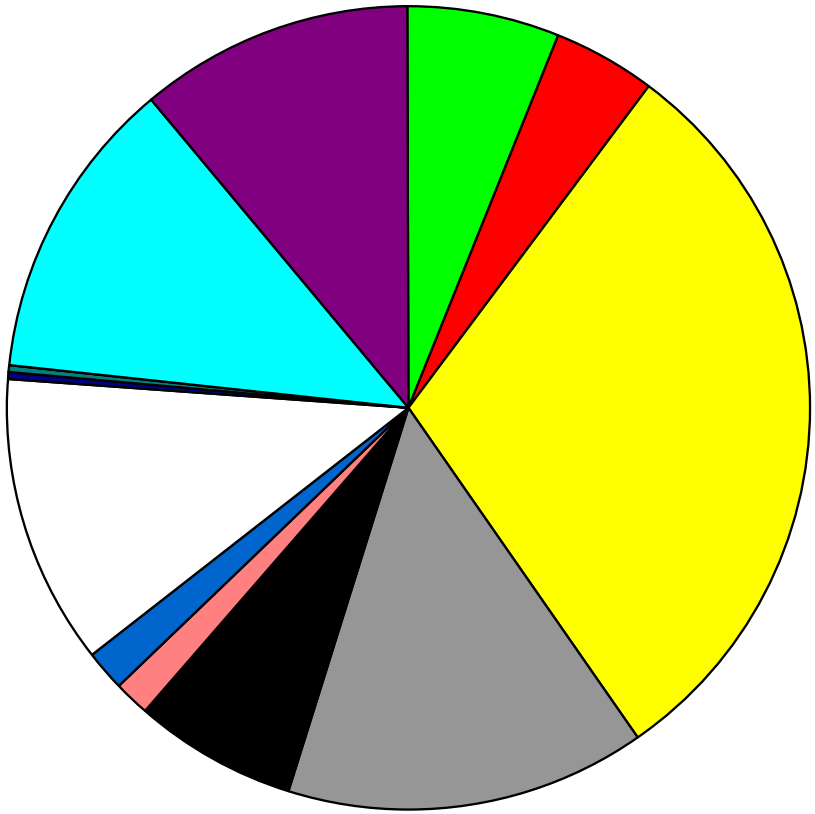


Site 4A
12.0 µg/m^3

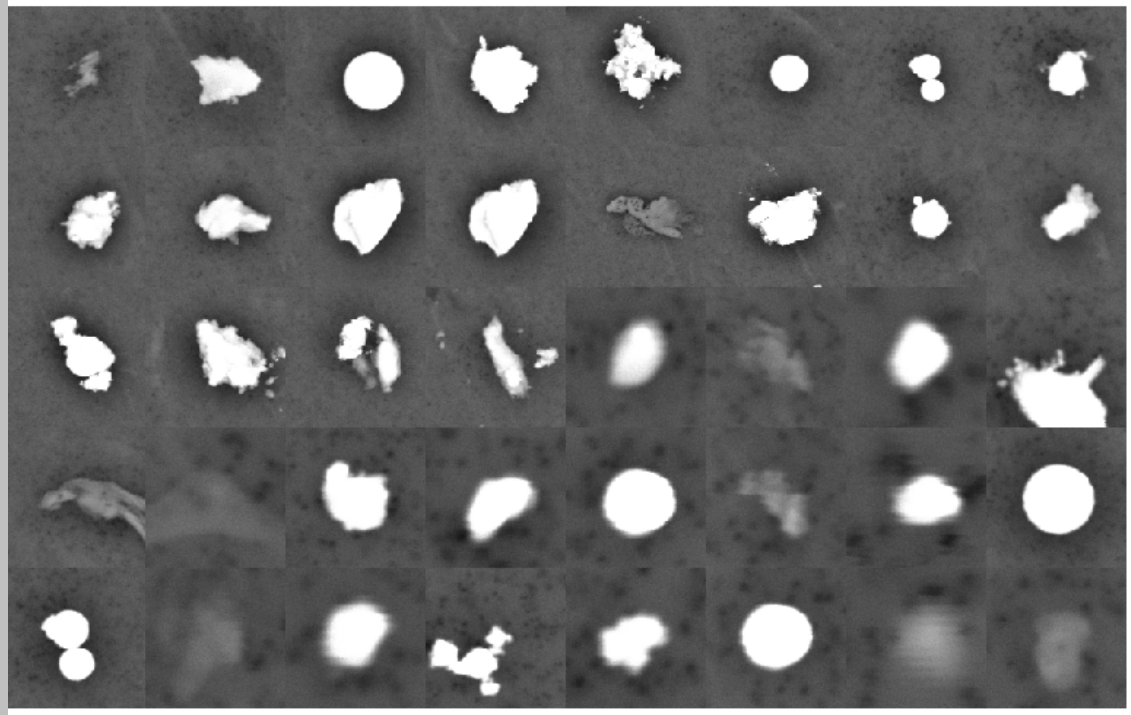


- Al-rich
- Ca/S-rich
- Ca-rich
- C-rich
- Fe oxide
- Fe-rich
- metal-rich
- Misc.
- NaCl
- Na-rich
- pollen
- Si/Al-rich
- Si-rich

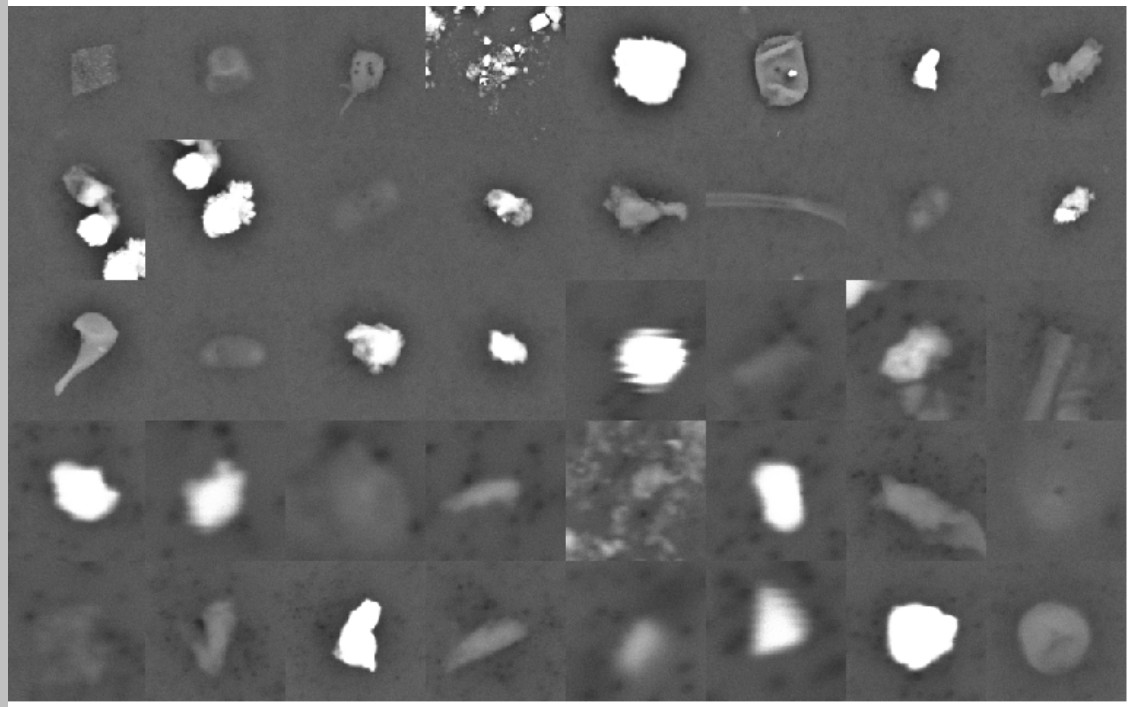
Site 6 (GT Craig)
30.2 µg/m^3



Random subset of low-resolution CCSEM images from Site 6, week 3. Images show mix of dull gray (carbon-rich and/or plant material) and brighter particles (minerals & metal-rich). Bright iron-oxide spheres reflect steel processing activities.



Random subset of CCSEM images from Site 30, week 3. Carbon-rich particles dominate.



Implications

- Central site monitoring of $PM_{10-2.5}$ is unlikely to reflect true exposure given the observed spatial variability
- Passive sampling can help identify local PM sources
- An inexpensive network of passive samplers provides information typically unavailable with conventional $PM_{10-2.5}$ instruments.

Limitations

- Currently only 1 commercial lab (RJ Lee Group) provides CCSEM analysis of passive samplers
- Concentrations are not available in real-time
- Long exposure periods (1 week or more) are typically required for ambient monitoring
- Software tools to manage and interpret the large CCSEM data sets are still in development
- $PM_{2.5}$ underestimated; further evaluation of accuracy/precision required

Future Plans

- Analyze composition variability across all Scoping Study sites
- Process samples from Cleveland Summer '09 Intensive
- Winter '10 Cleveland Intensive
- Extend method to $PM_{2.5}$ and ultrafines?

Acknowledgements

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- Jeff Wagner, California Department of Public Health
- Jerray Battle, North Carolina Central University

Although this work was reviewed by EPA and approved for presentation, it may not necessarily reflect official Agency policy.