Contribution of Nucleation Events to Ultrafine Particle Exposures

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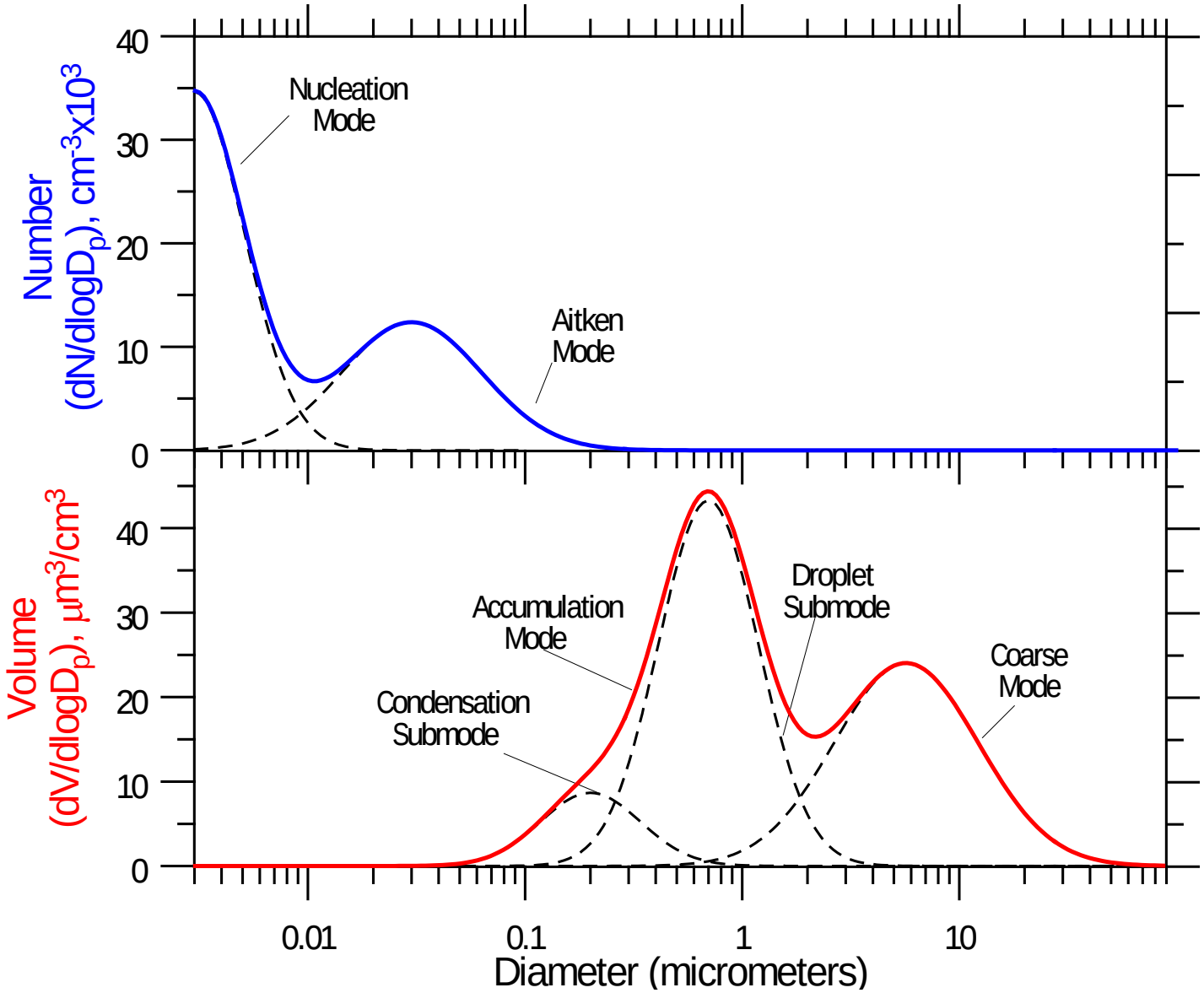
Atmospheric Aerosol Size Distribution



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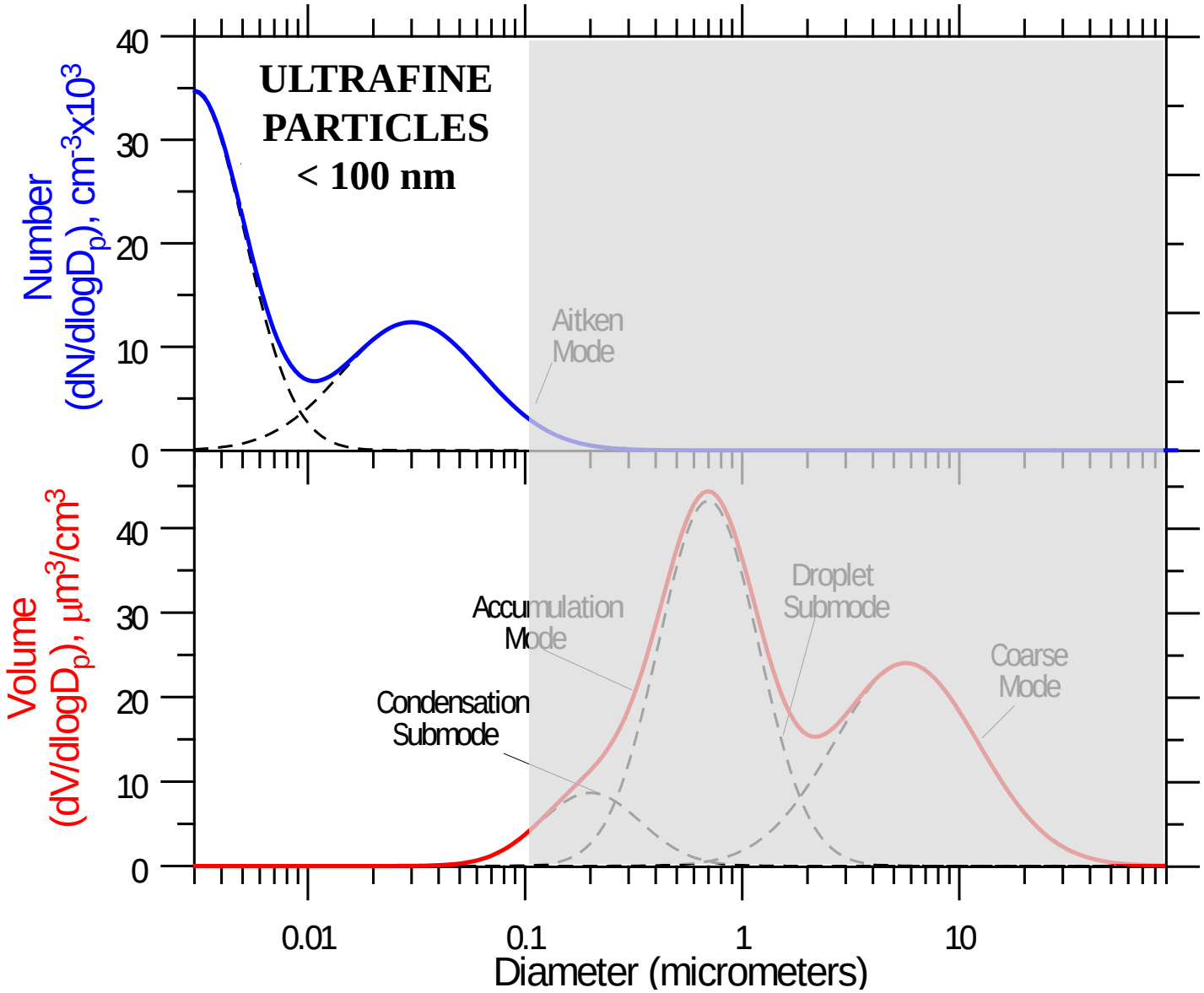
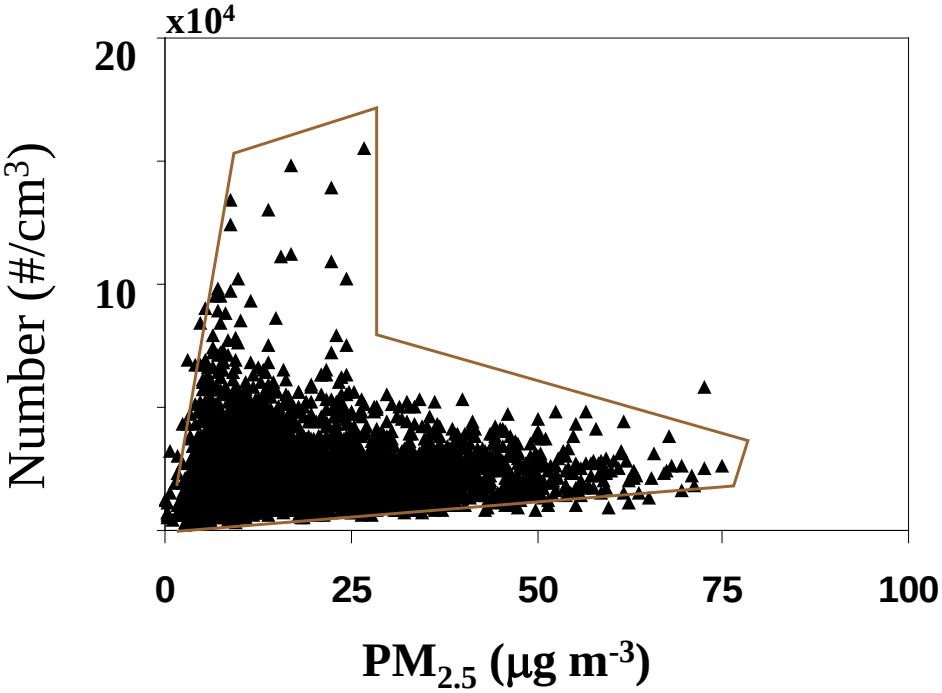
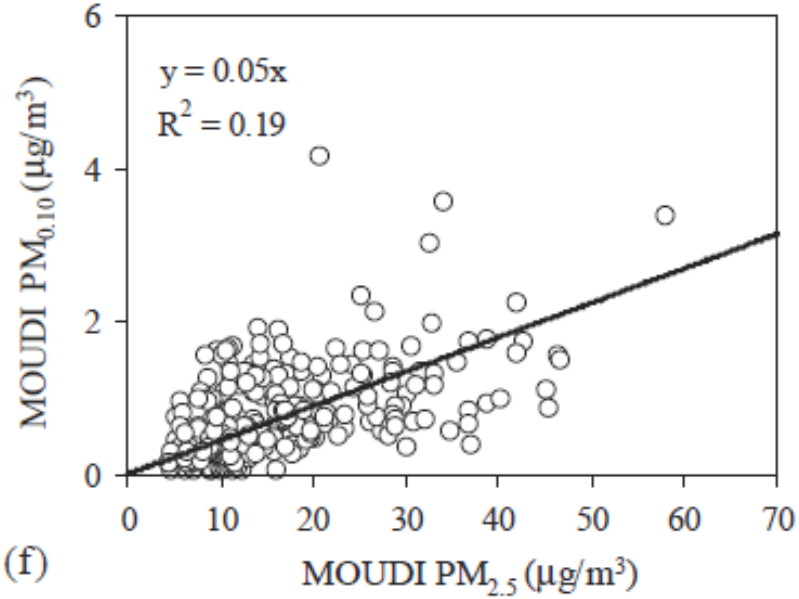


Ultrafine versus $PM_{2.5}$





Stanier et al. AST 2004; Cabada et al. AE 2004

Sources of ultrafine particles

Primary

Gasoline

On-road Diesel

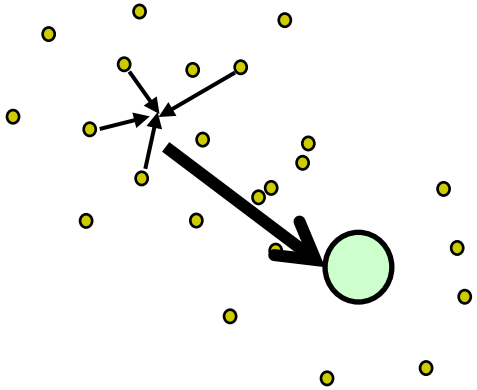
Non-road Diesel

Biomass Combustion

Cooking

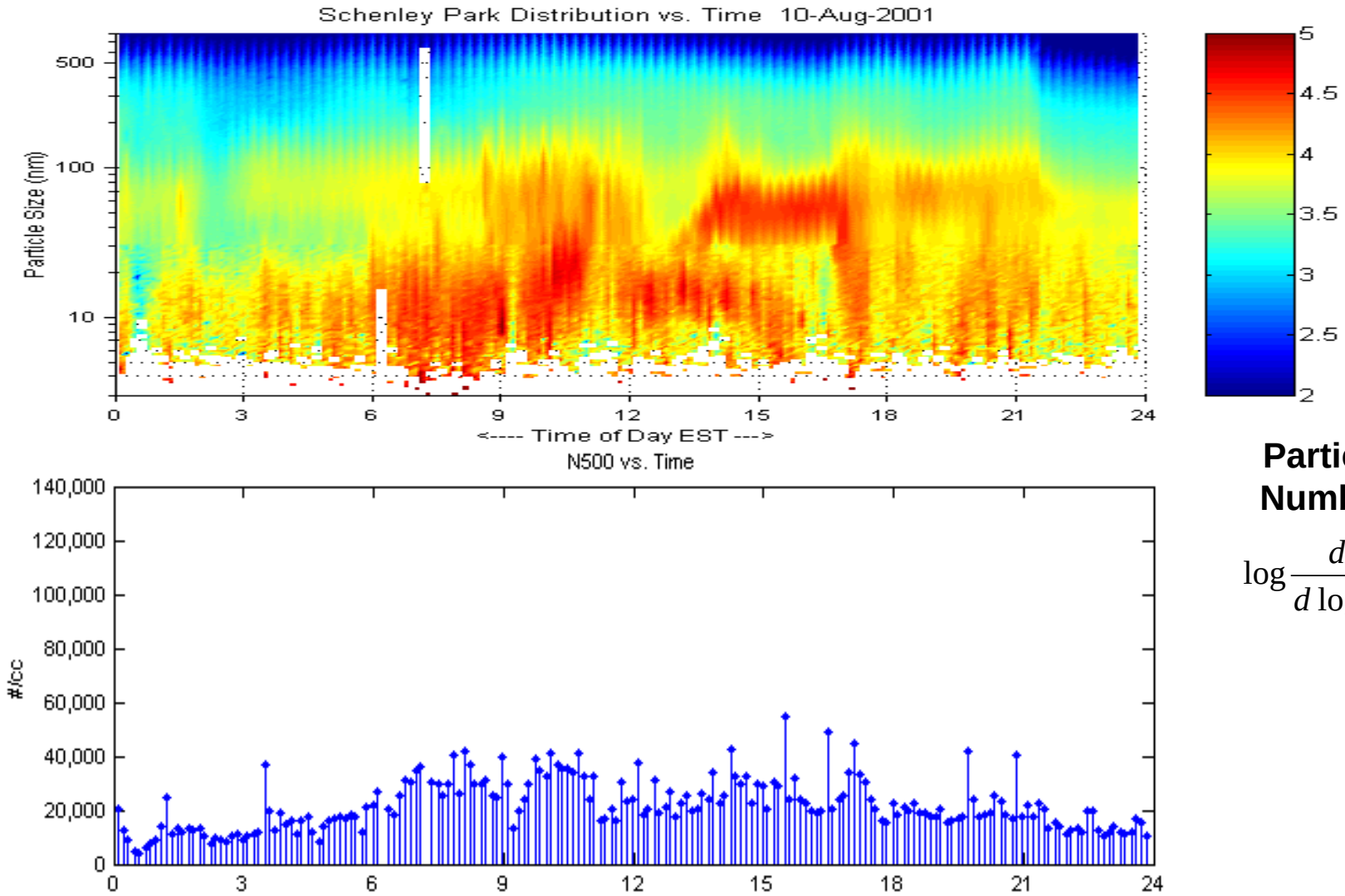
Industrial Emissions

Secondary -- Nucleation



- Binary (H_2SO_4 + Water)
- Ternary (H_2SO_4 + NH_3 + Water)
- Ternary (H_2SO_4 + Org + Water)
- Ion Induced

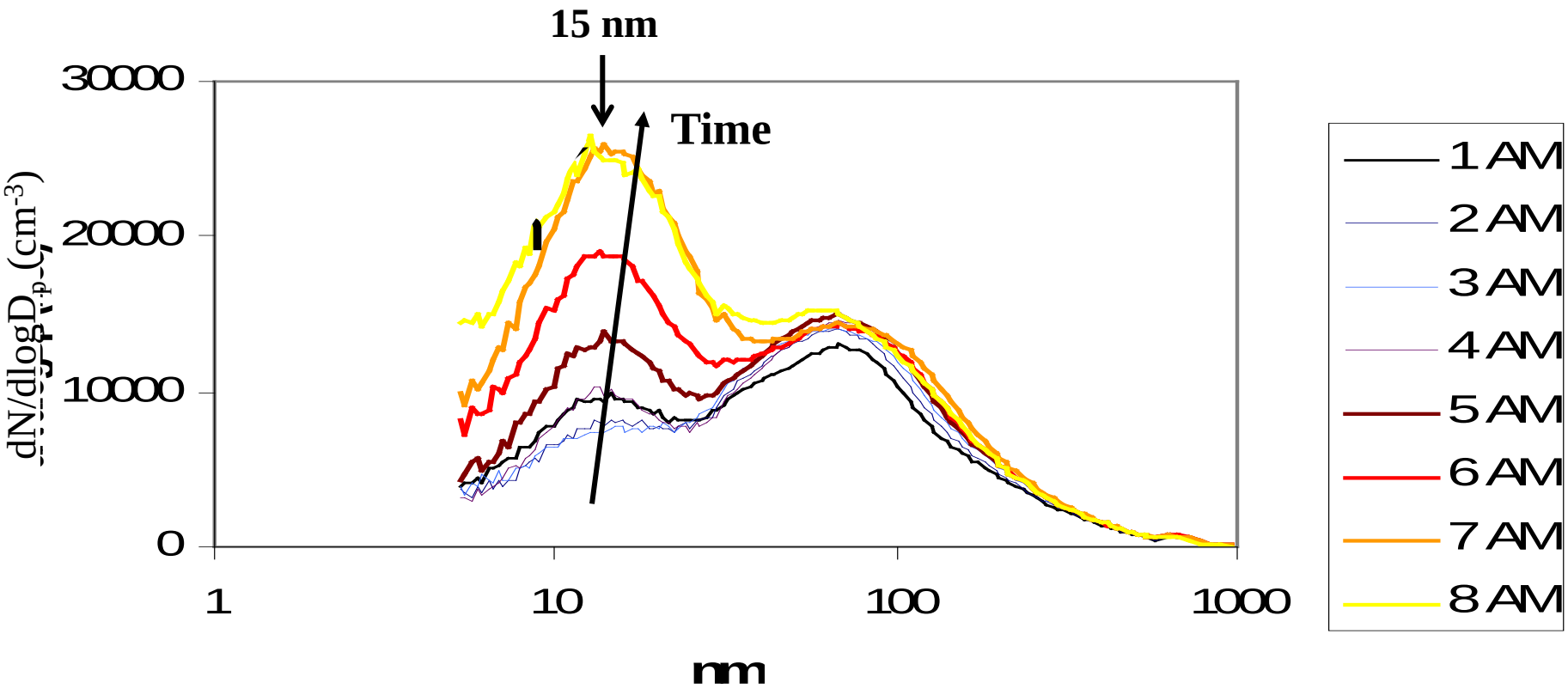
Typical Urban PM Size Distribution



Particle Number

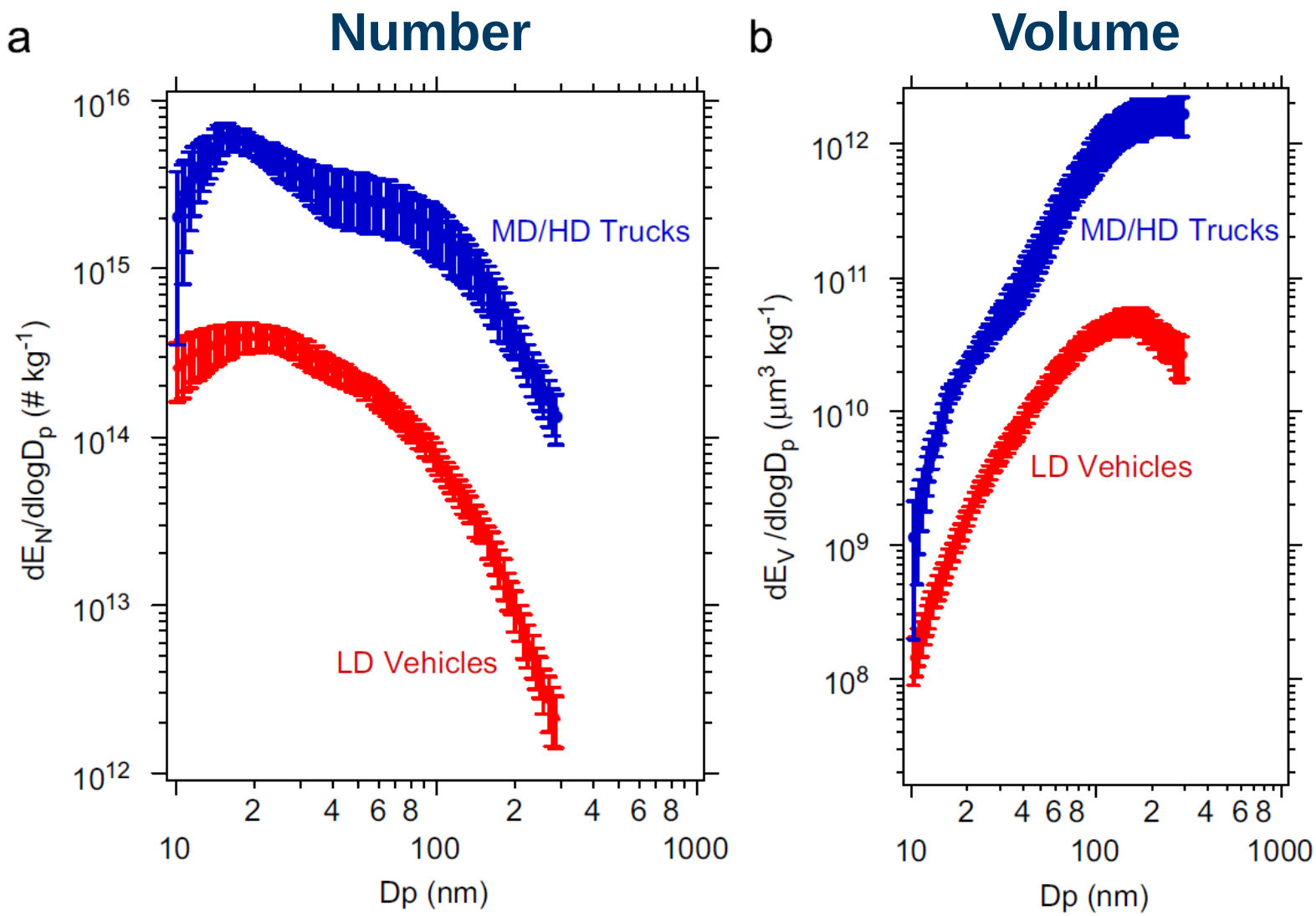
$$\log \frac{dN}{d \log D_p}$$

Ultrafine PM from Traffic



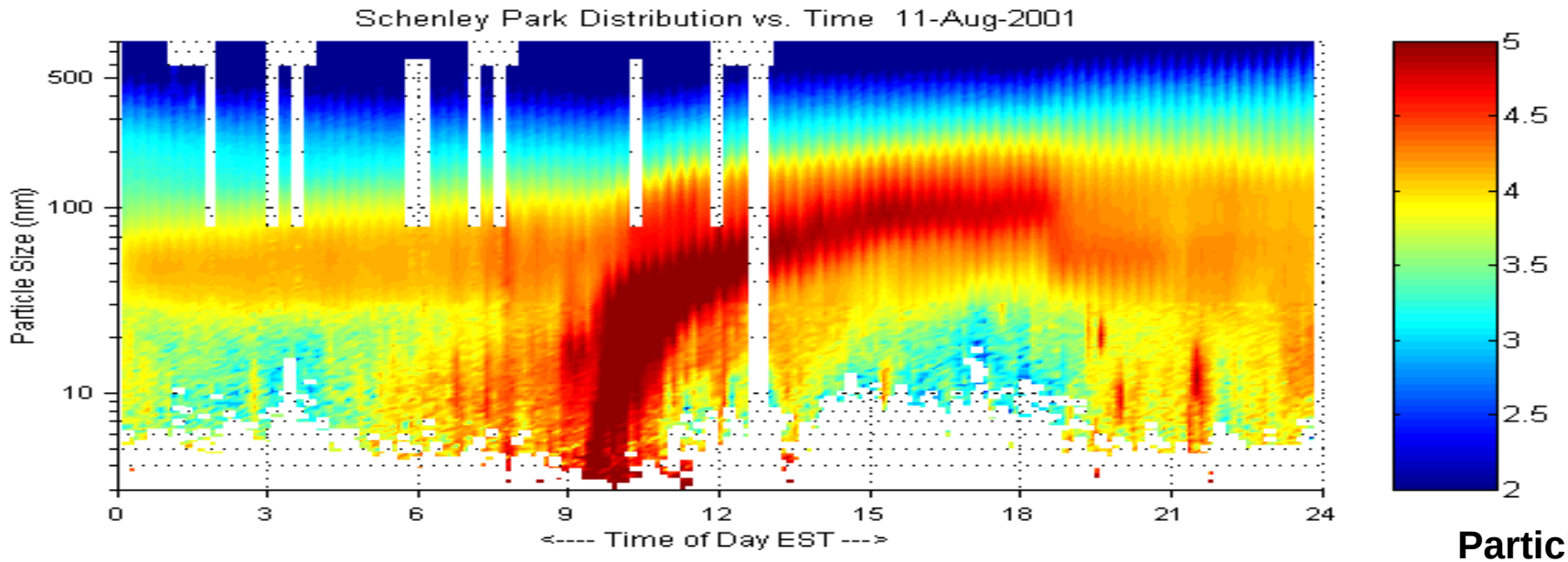
Urban background site in Pittsburgh

Vehicle Emissions



Ban-Weiss et al. (2010)

Nucleation and Growth



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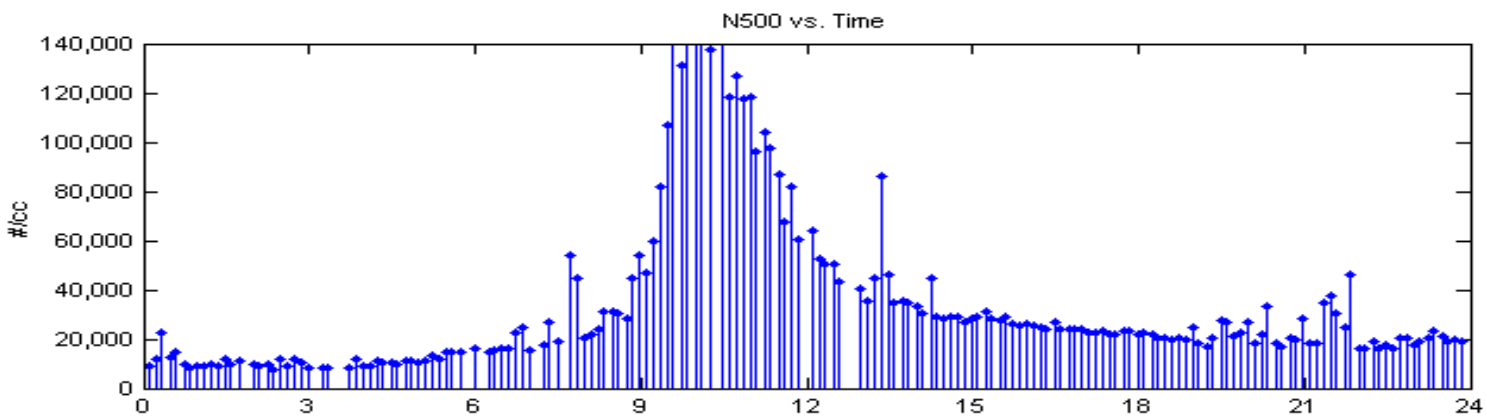
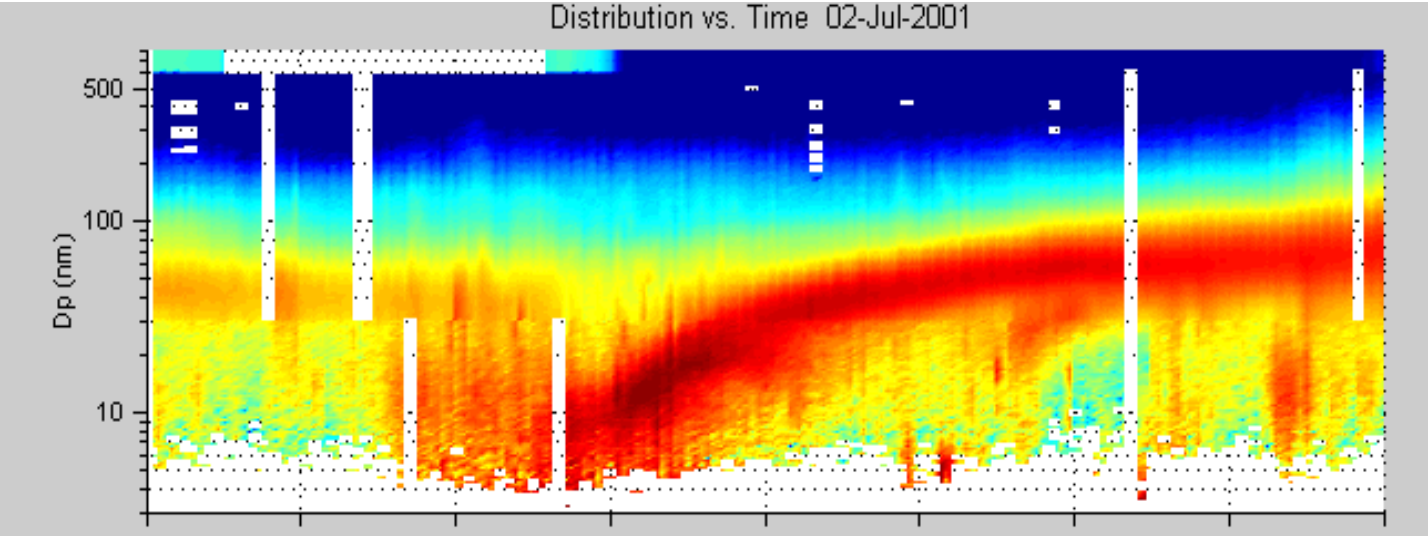


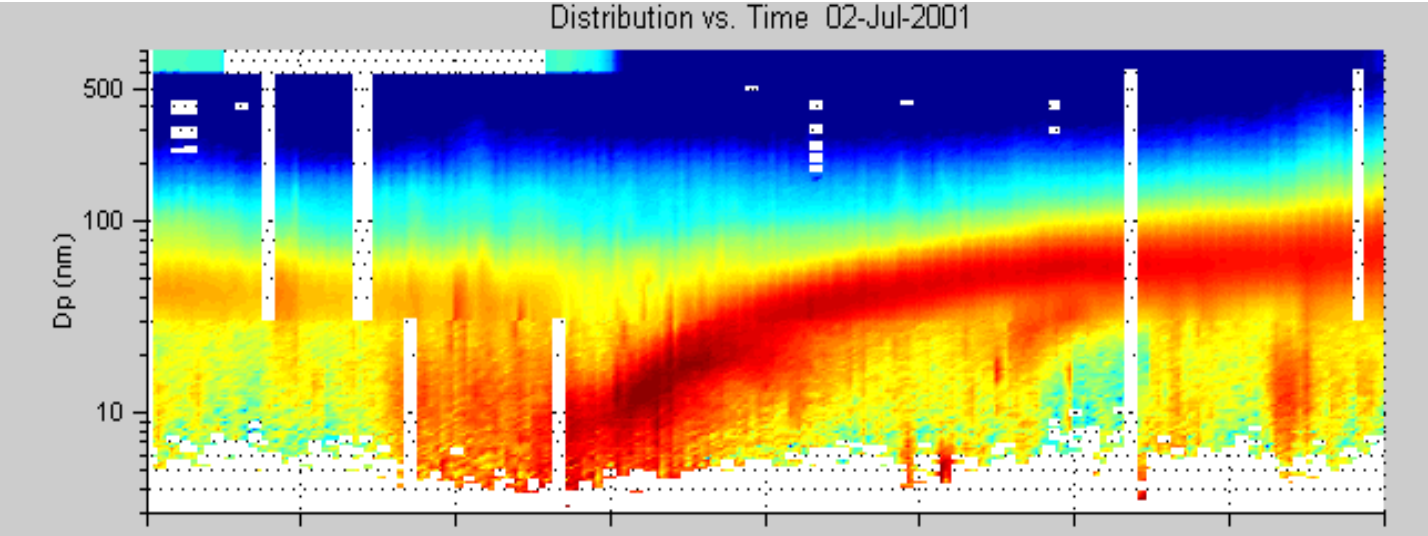
Regional Nucleation

Pittsburgh

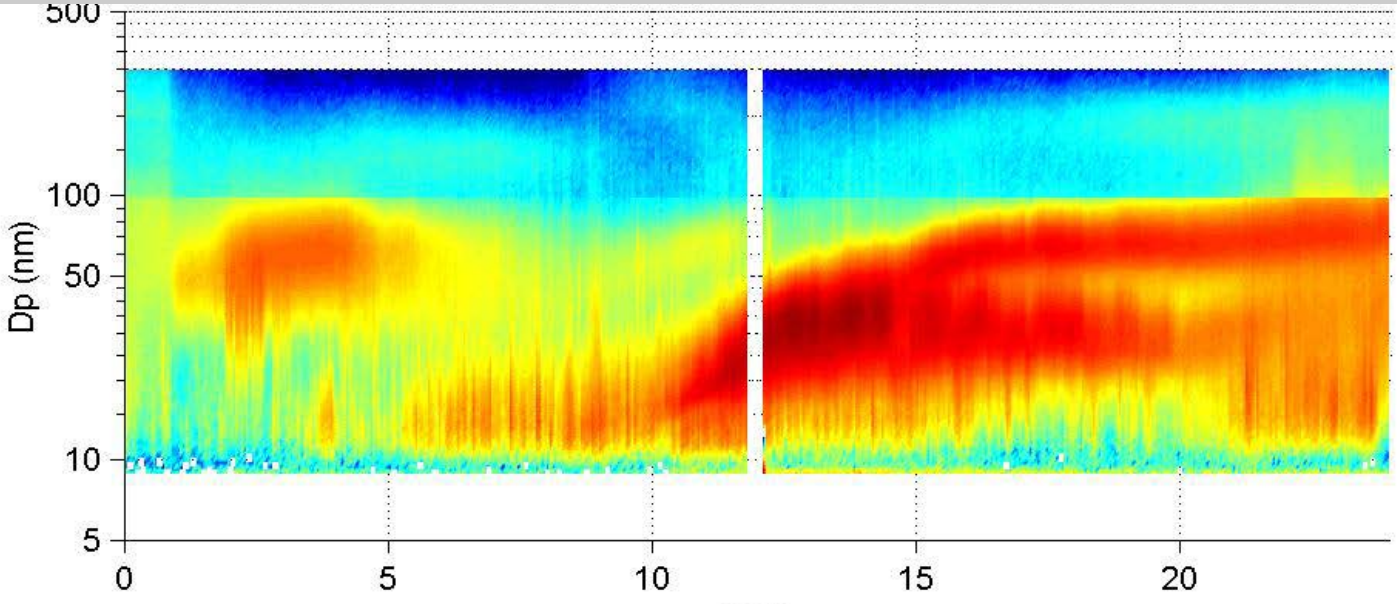


Regional Nucleation : Pittsburgh & Philadelphia (250 mi apart)

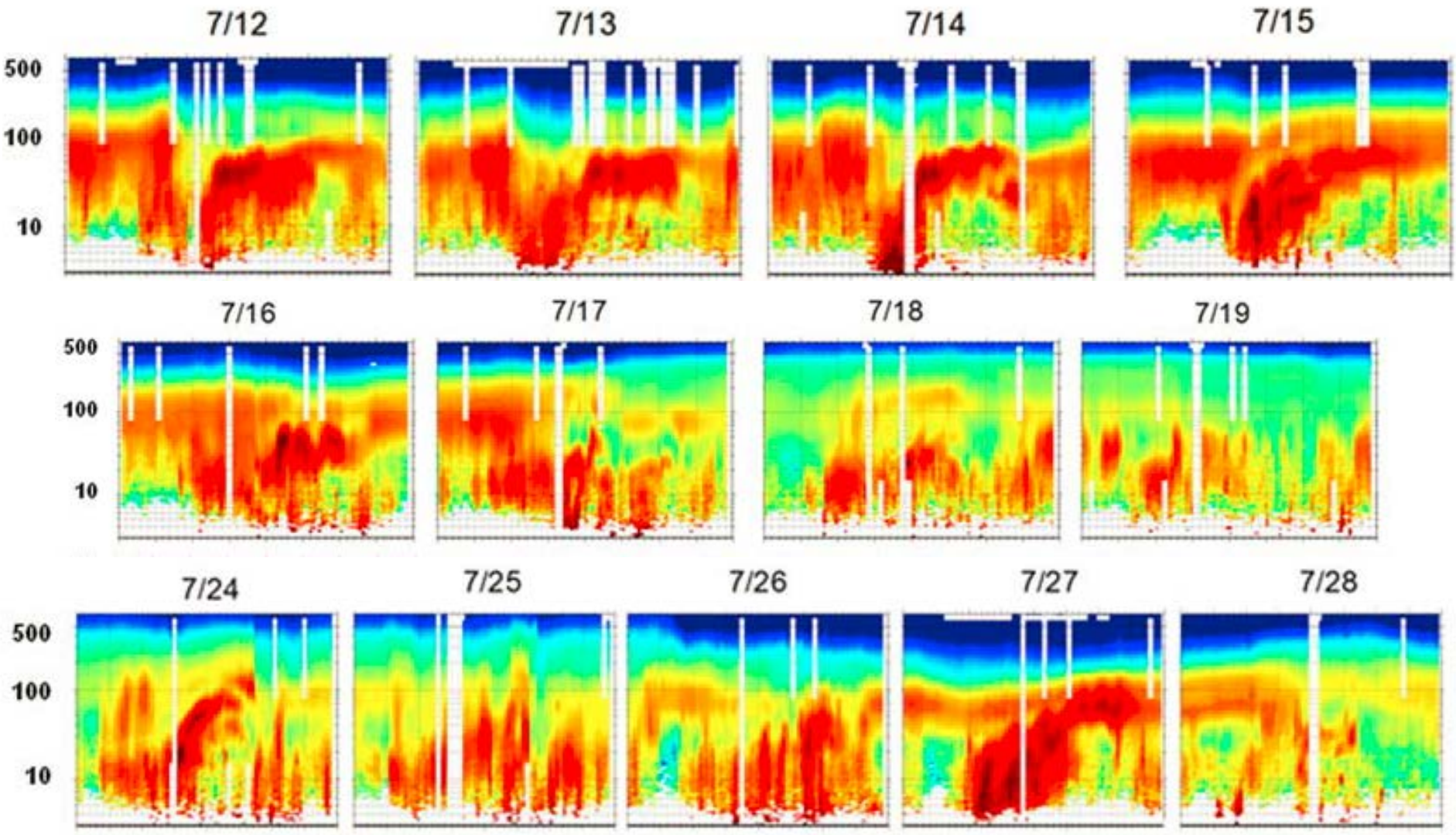
Pittsburgh



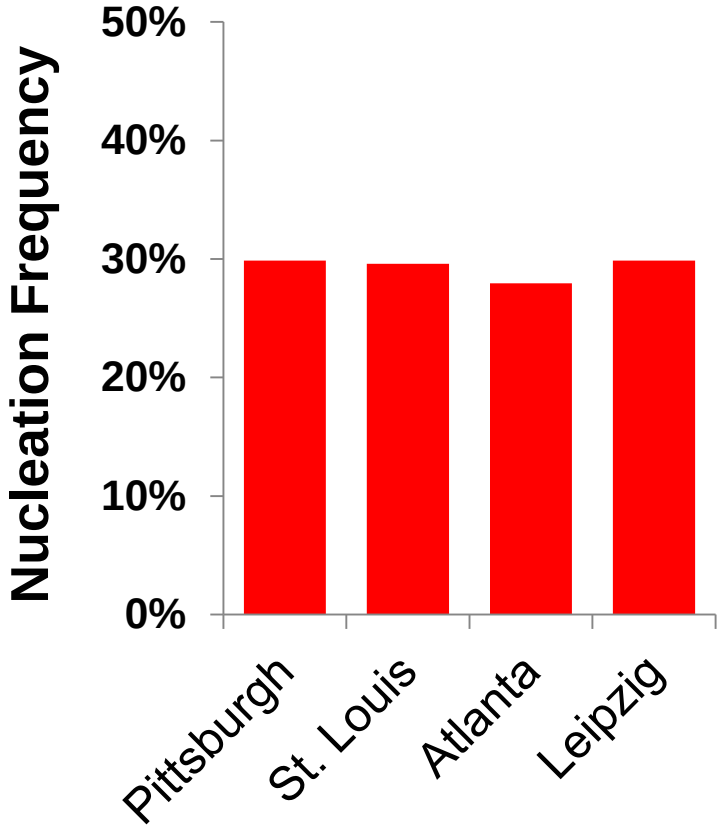
Philadelphia



Nucleation happens a lot

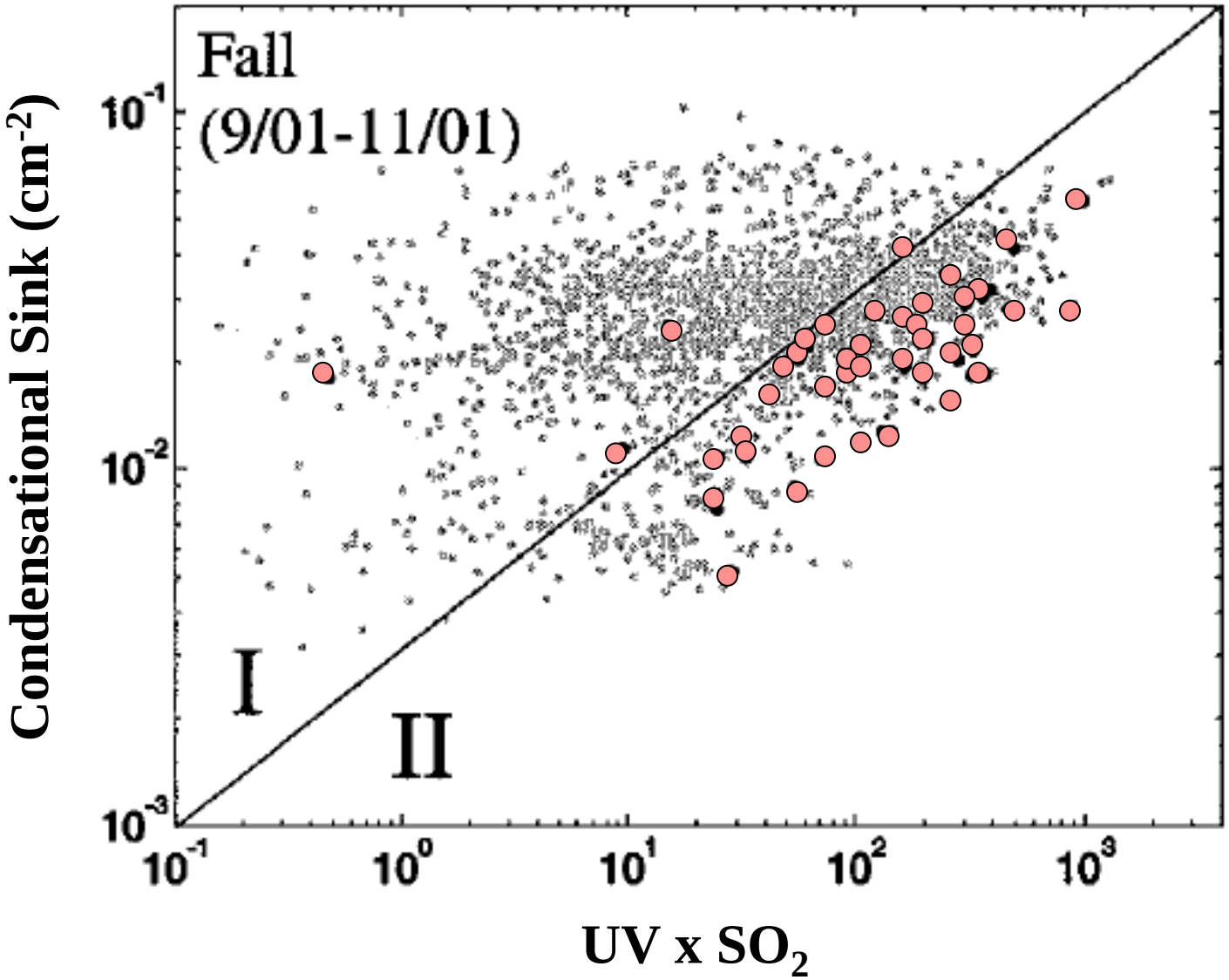


30% of time

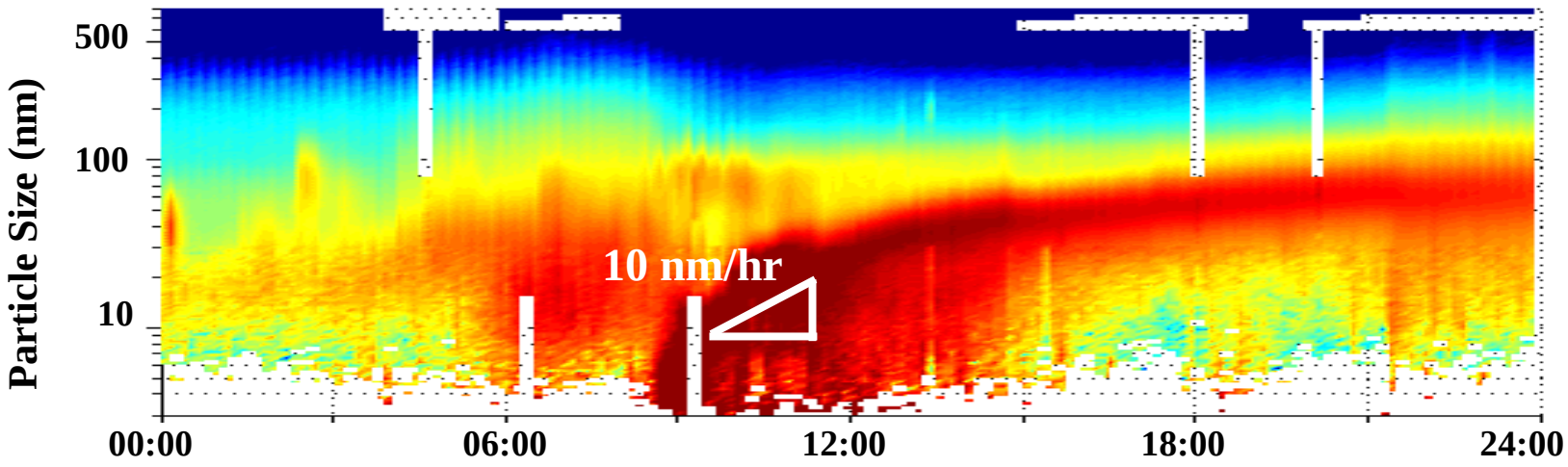


Westervelt et al. ACP 2013; Ma and Birmili Sci Tot Env 2015

Drivers – Photochemistry and lower background



Particle Growth Rate



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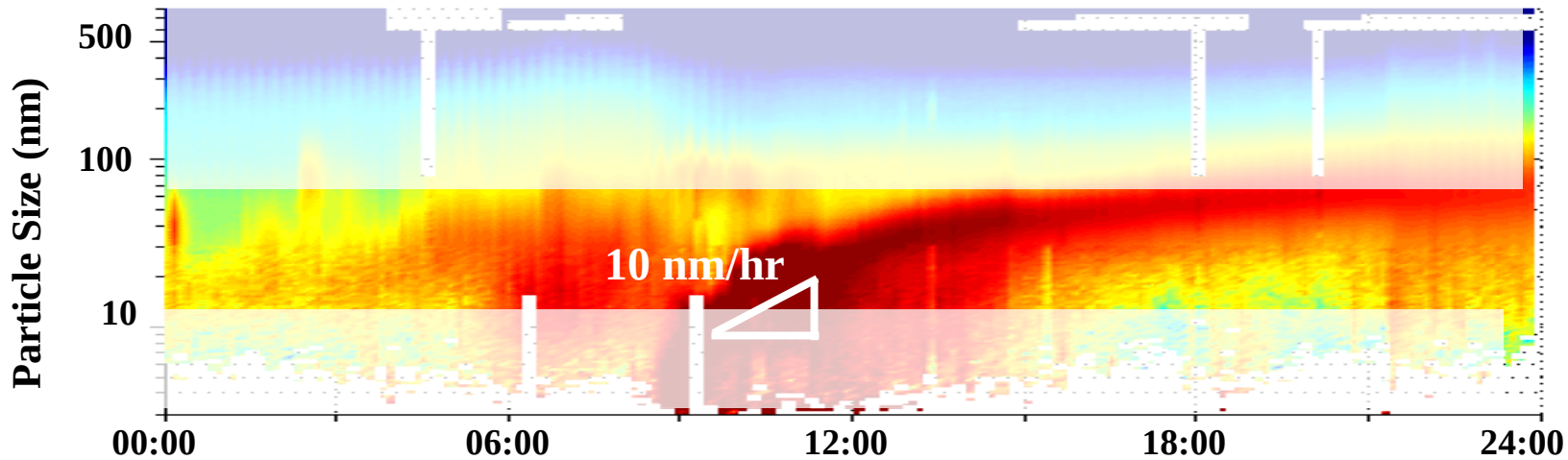
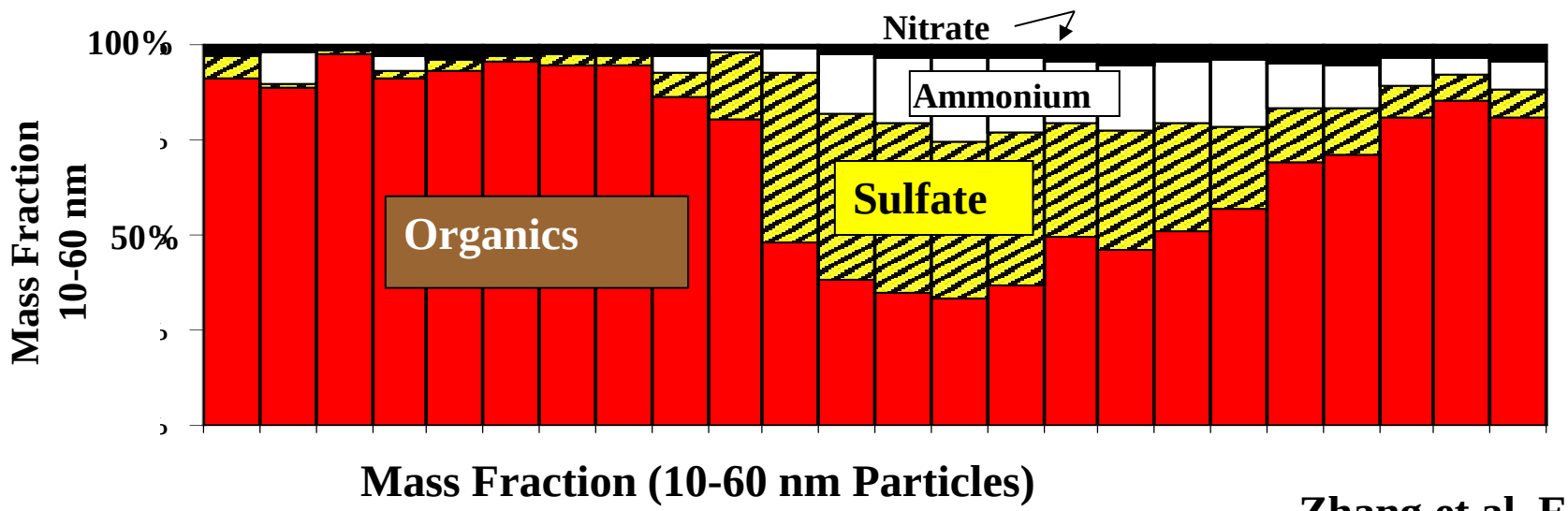
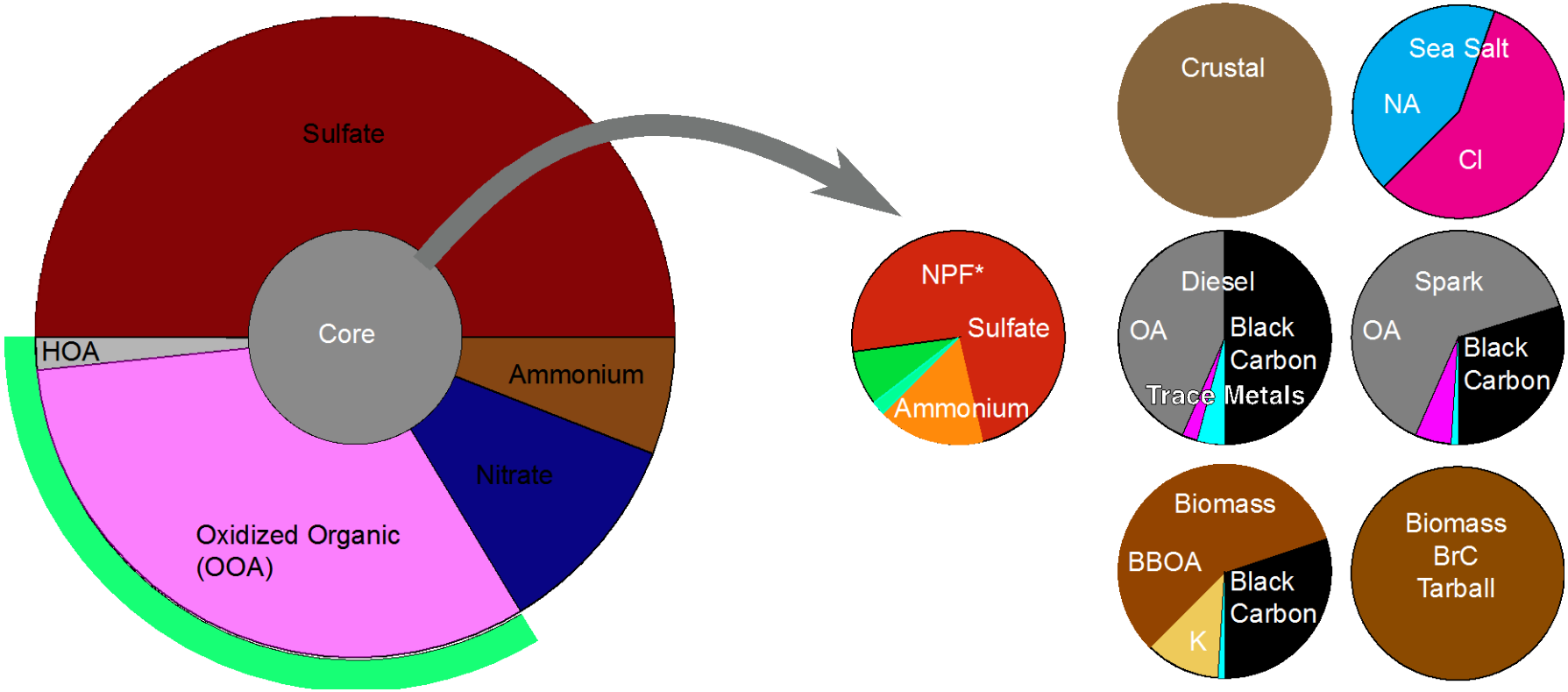




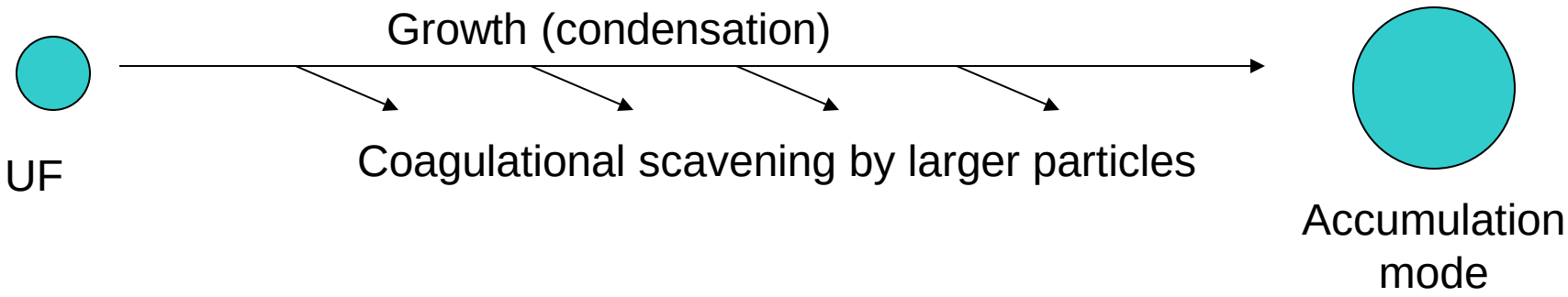
Zhang et al. EST 2004

Ultrafine as core for accumulation mode



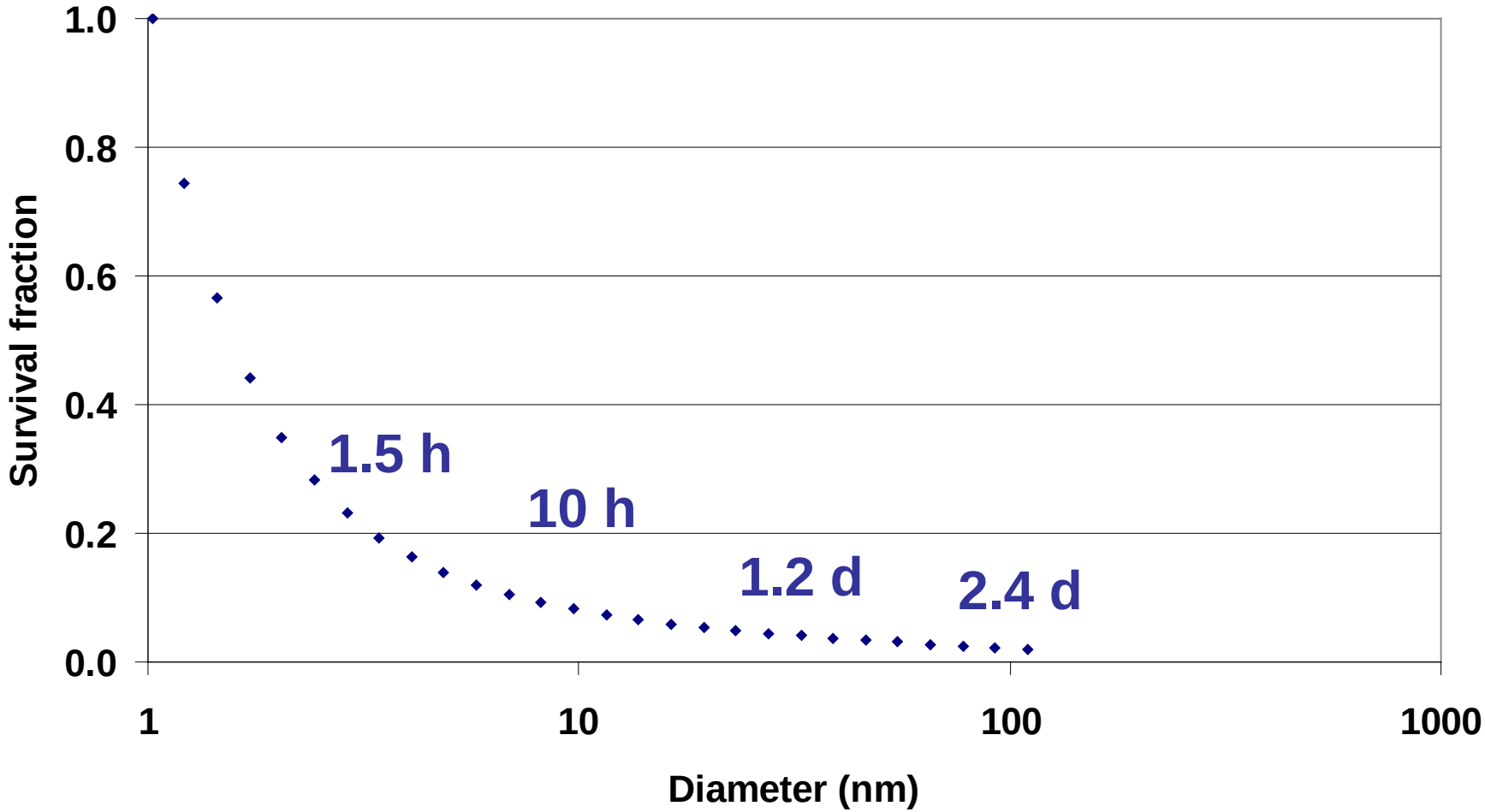
- Small, source-specific core of *primary* PM (<100 nm; ~10% of mass)
- Thick coating of *secondary* PM that condensed over several days (200-300 nm; ~90% mass)

Survival Probability



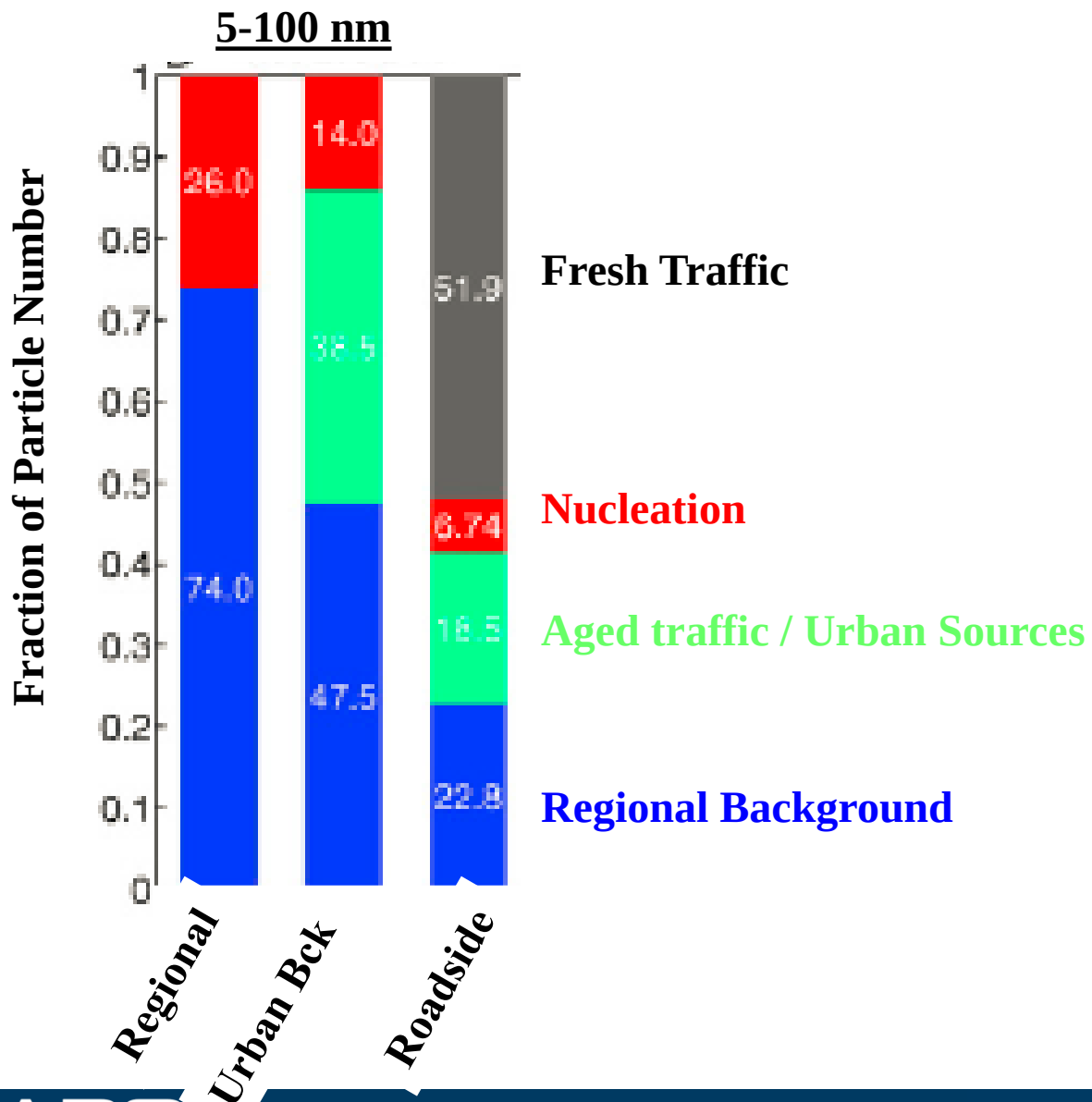
- Competition between
  - Condensational growth (sulfuric acid / organics)
  - Coagulational scavenging
- Small nuclei suffer compared to primary particles
  - Takes longer to grow
  - More diffusive → higher collision probability

Survival and Growth



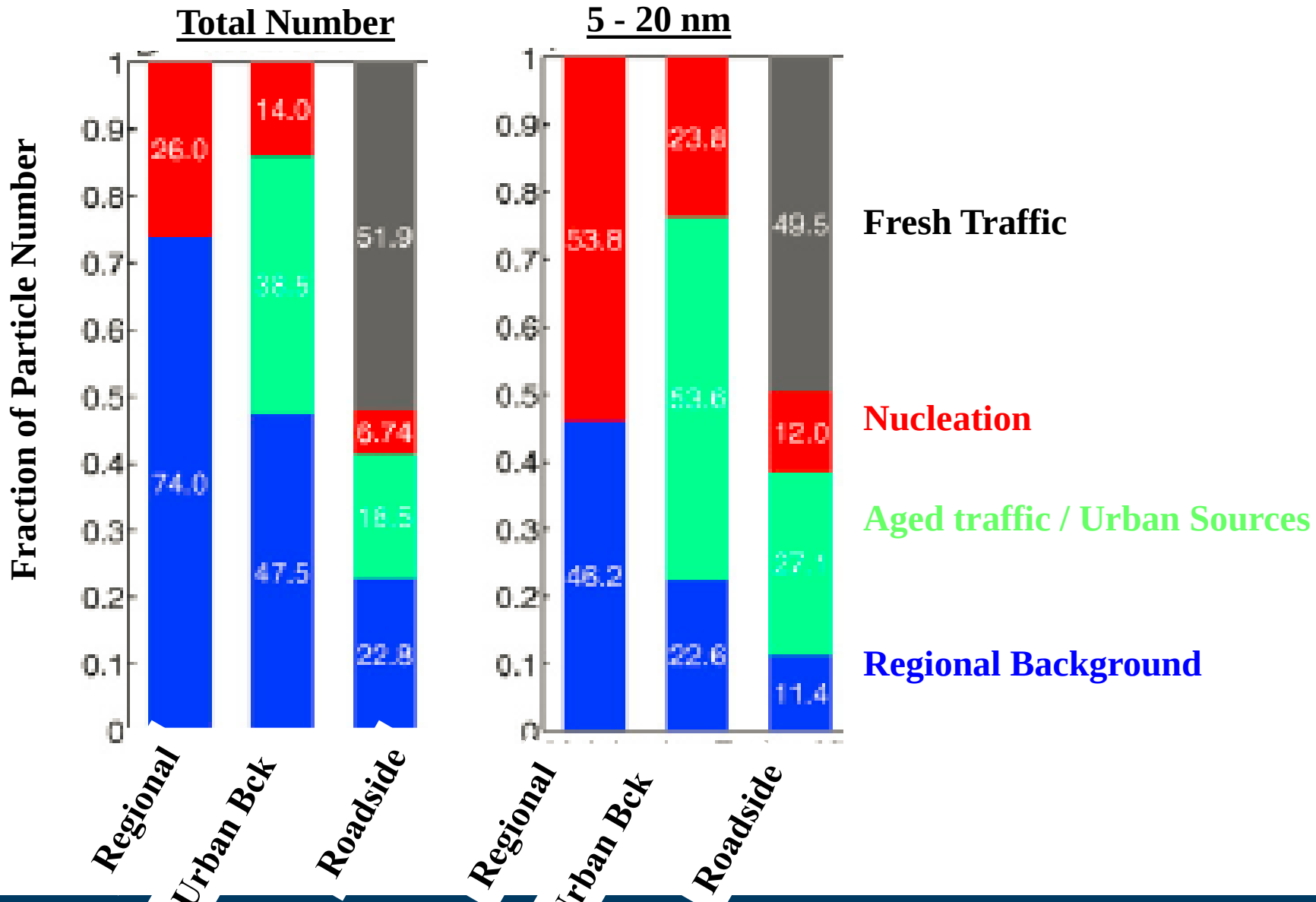
- Survival: 2% (1 nm to 100 nm); 45% (30 nm to 100 nm)
- Size resolution matters in modeling CCN formation

Ultrafine Exposure in Leibnitz



Ma and Birmili Sci Tot Env 2015

Ultrafine Exposure in Leibnitz



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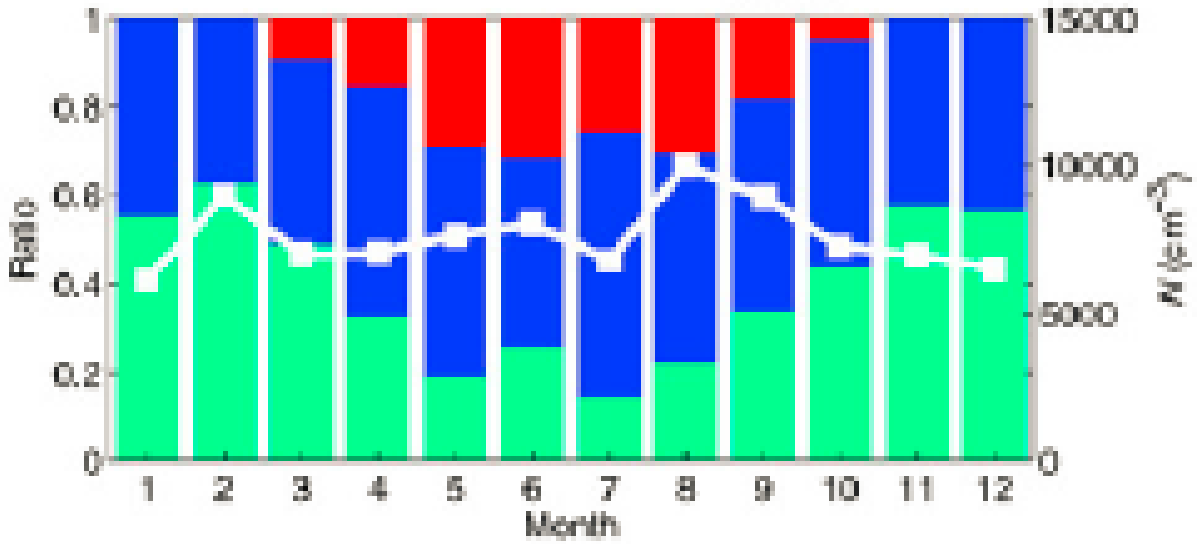
More nucleation in summer

Urban background site



Nucleation

Aged traffic / Urban Sources

Regional Background

Ma and Birmili Sci Tot Env 2015

Conclusions

- Nucleation important source of source of ultrafine at urban sites
  - ~ 15-30% of exposure at urban background sites
- Nucleation has distinctive temporal and seasonal patterns
- Ultrafine particles rapidly change size (condensation)
- Ultrafine particles are rapidly lost (coagulation)
- Both processes occur on timescale of ~hours
- Both processes challenge ability to apply linear statistical models (factors) to explain ultrafine concentrations, size, variability

Acknowledgments

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