Single particle characterization using SP-AMS with light scattering module in urban environments

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Atmospheric Chemistry and Physics Discussions

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Single particle characterization using the soot particle aerosol mass spectrometer (SP-AMS)

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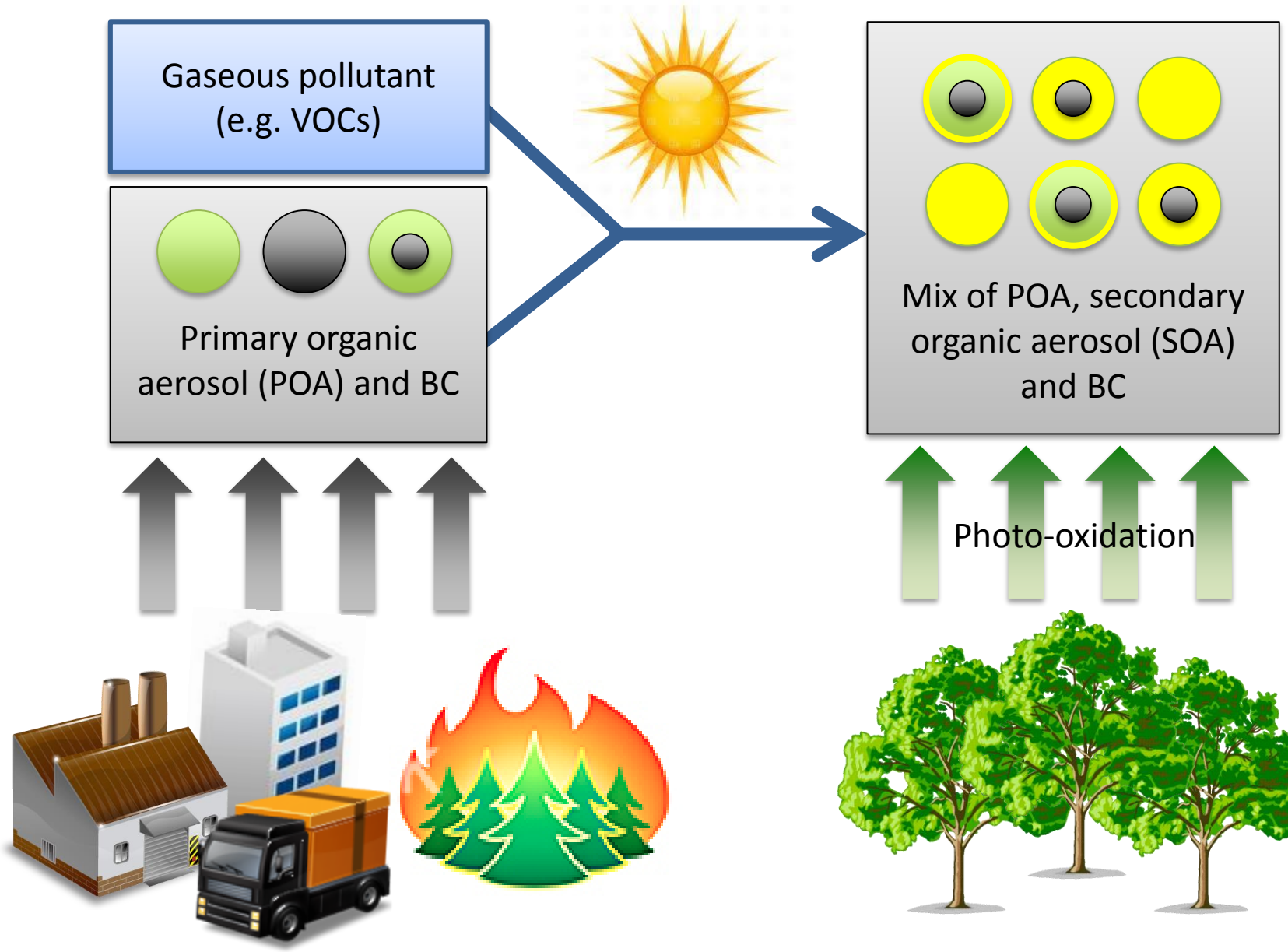
Formation of BC coating



Objectives

- To demonstrate the capability of Aerodyne soot particle aerosol mass spectrometer equipped with a light scattering module (LS-SP-AMS) for detecting single particle mass spectrum of black carbon

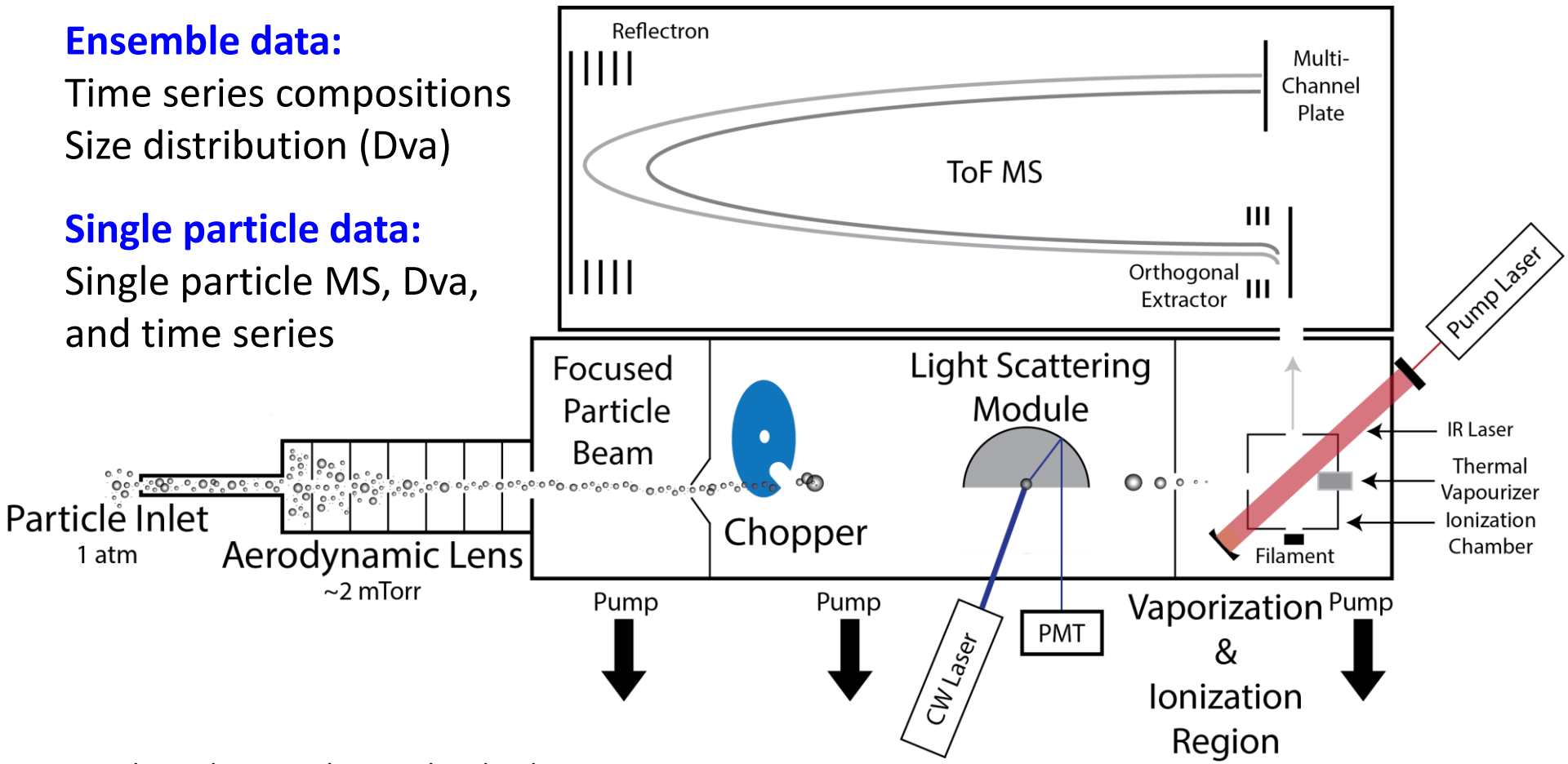
- To understand the sources and mixing state of black carbon and the characteristics of their coating materials in urban environment (downtown Toronto)

Soot particle aerosol mass spectrometer

Location: Toronto (Downtown campus of University of Toronto)
Study Period: 18-22 Sep, 2012 (5 days)

Ensemble data:
Time series compositions
Size distribution (Dva)

Single particle data:
Single particle MS, Dva, and time series

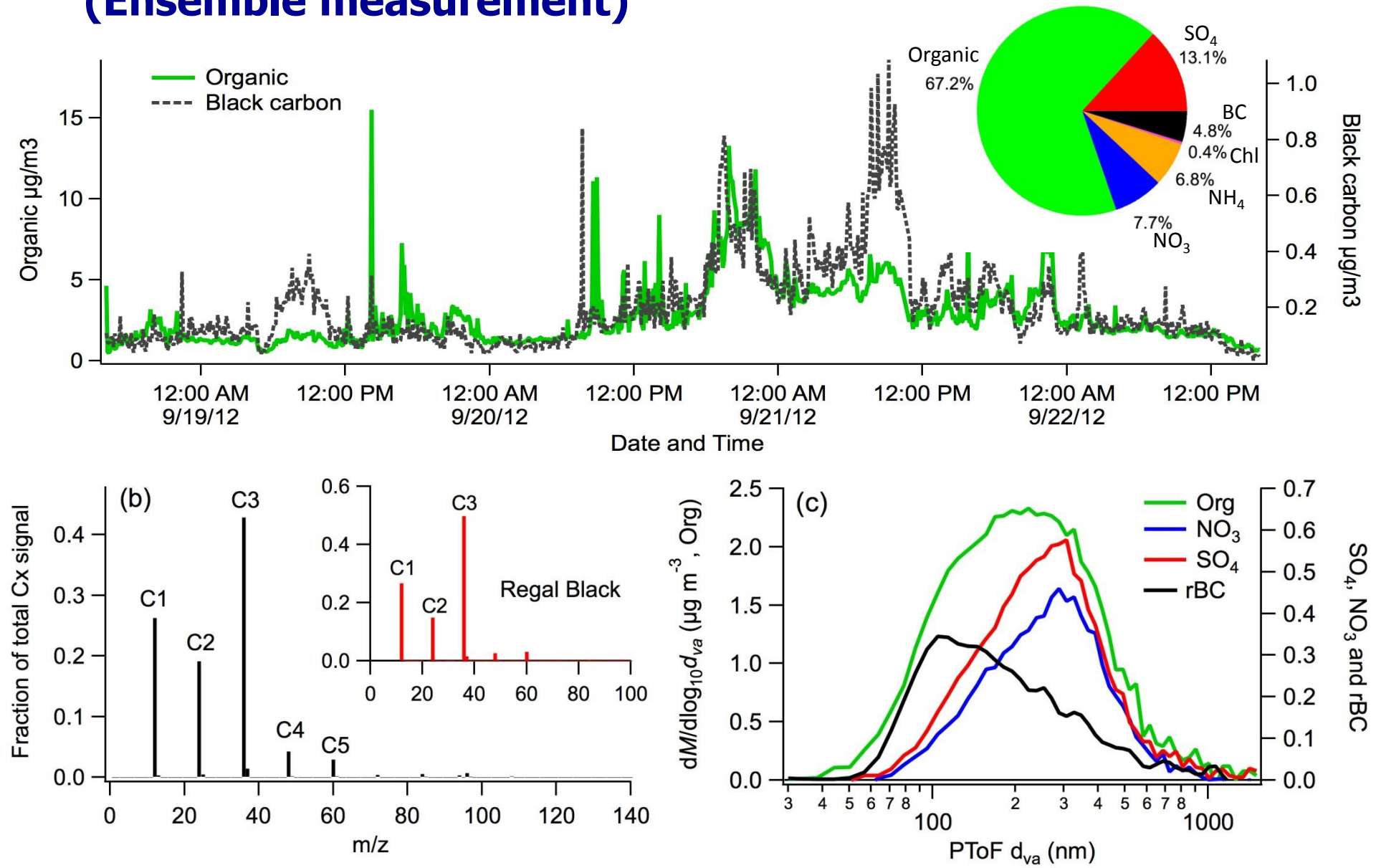


Onasch et. al., Aerosol Sci. and Technol., 2012
Cross et.al., Aerosol Sci. and Technol., 2007

Urban environment - downtown Toronto

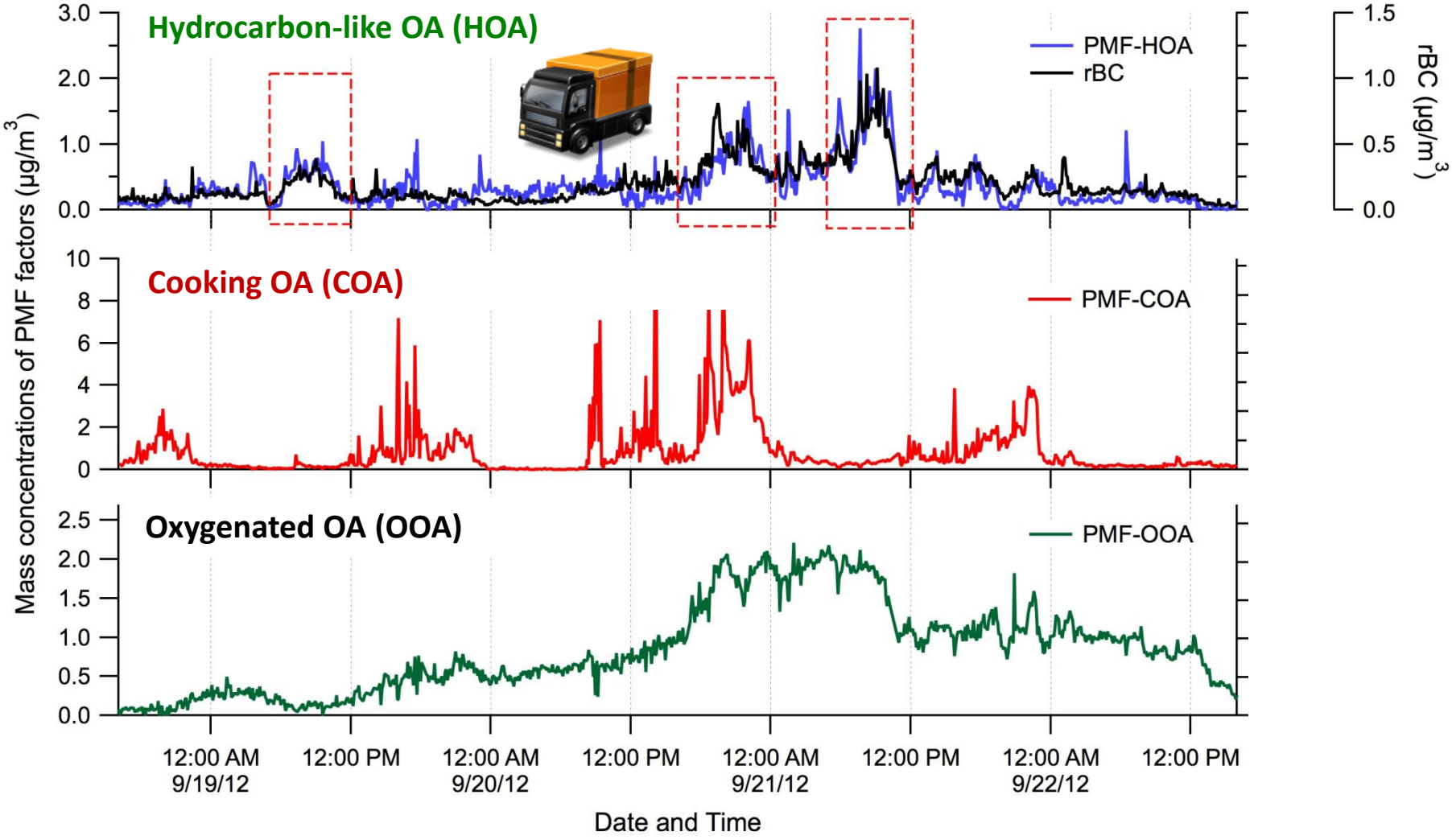
Characteristics of black carbon

(Ensemble measurement)



Sources of black carbon and organic aerosols

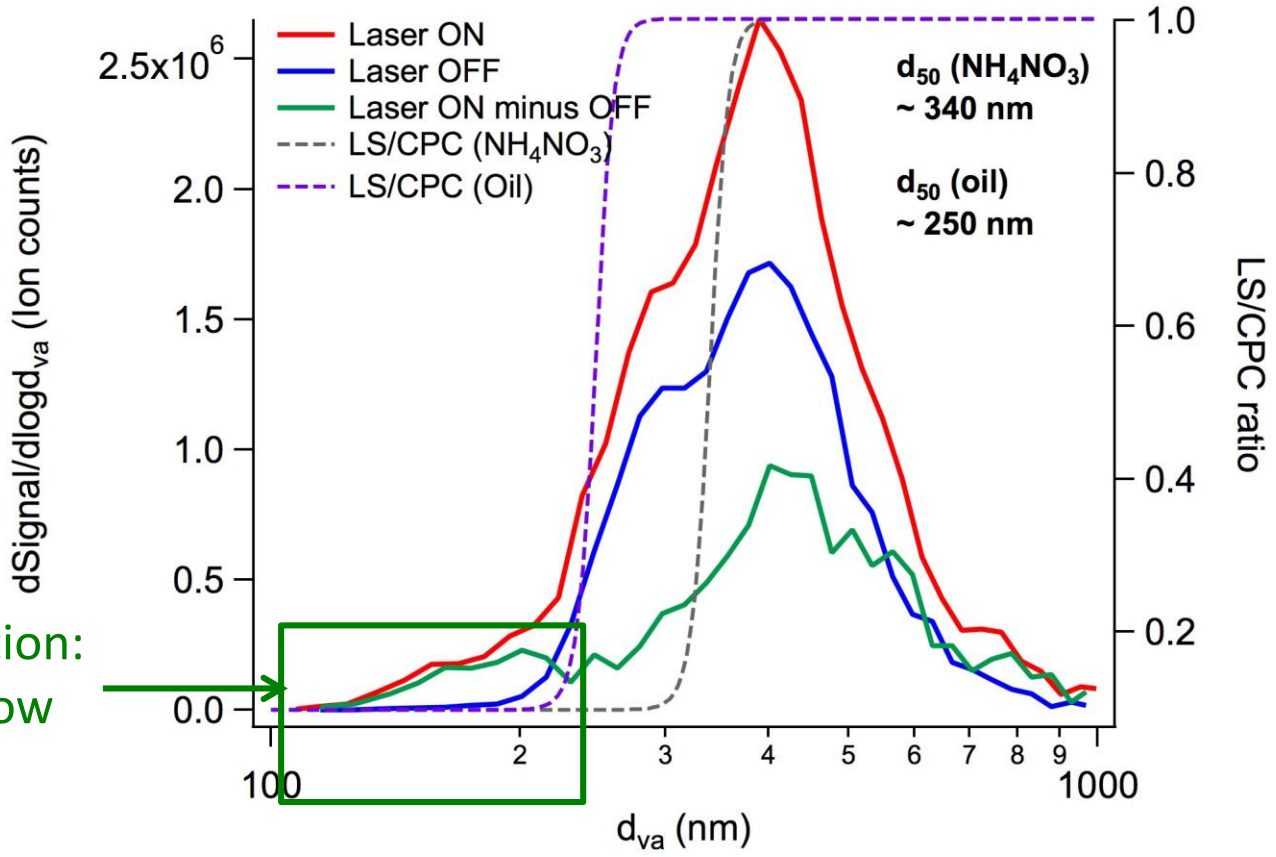
(Positive Matrix Factorization of organics, PMF)



Summary of single particle detection

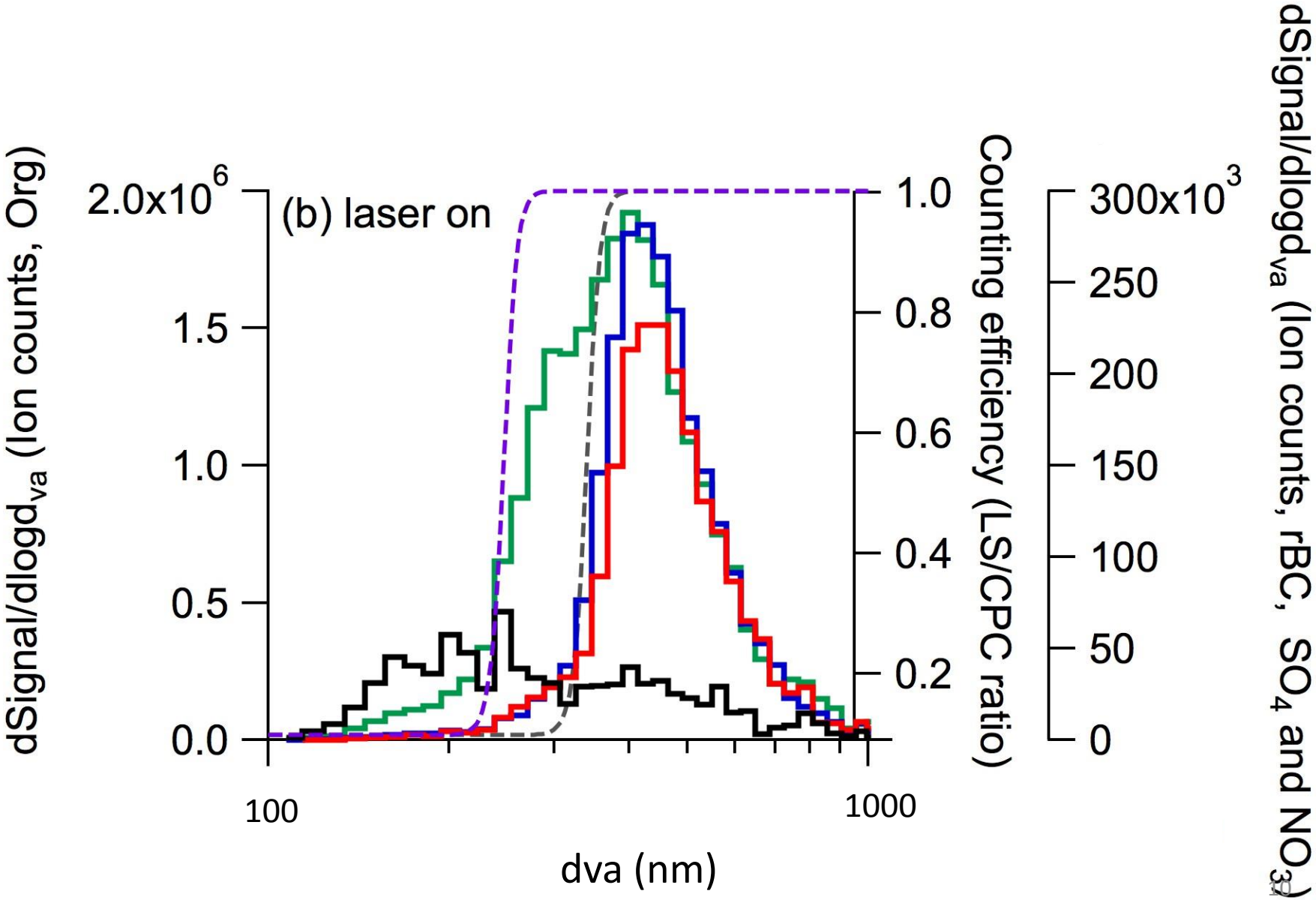
Single particle numbers	35,001

Light scattering laser cutsize for NH_4NO_3
D_m = 250 nm
D_{va} = 340 nm

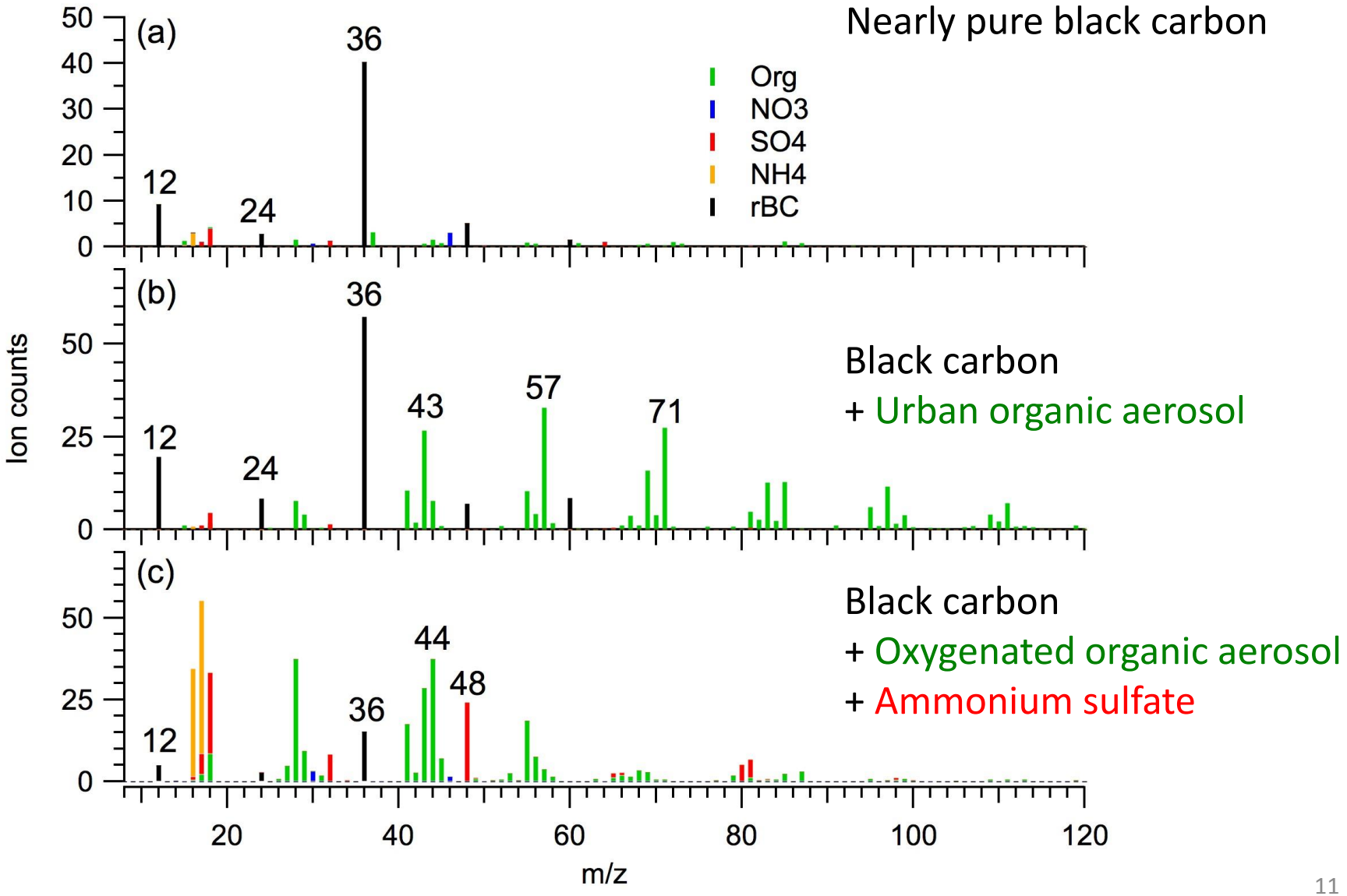


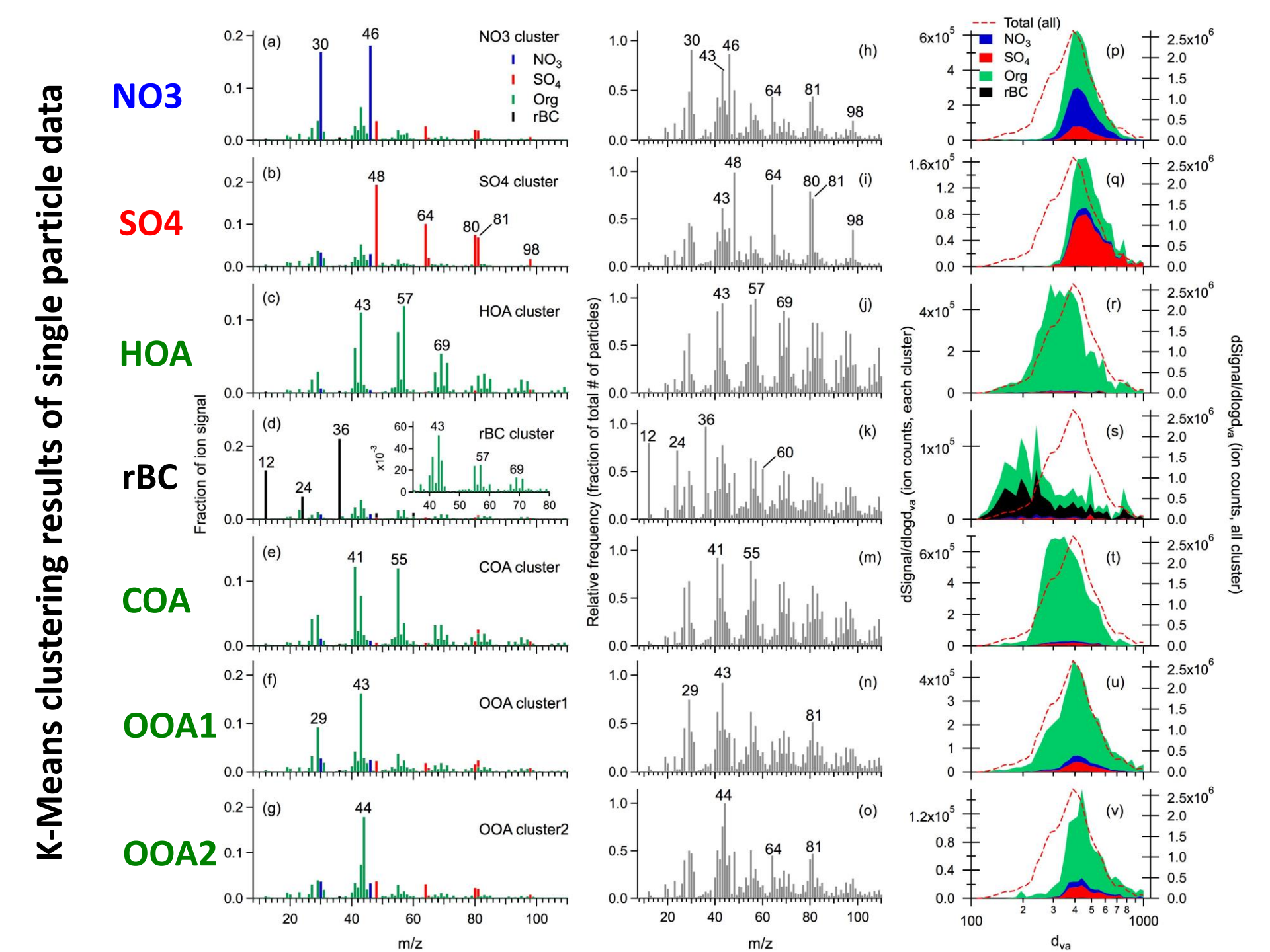
Additional information:
Black carbon with low effective density

Size distribution of major components

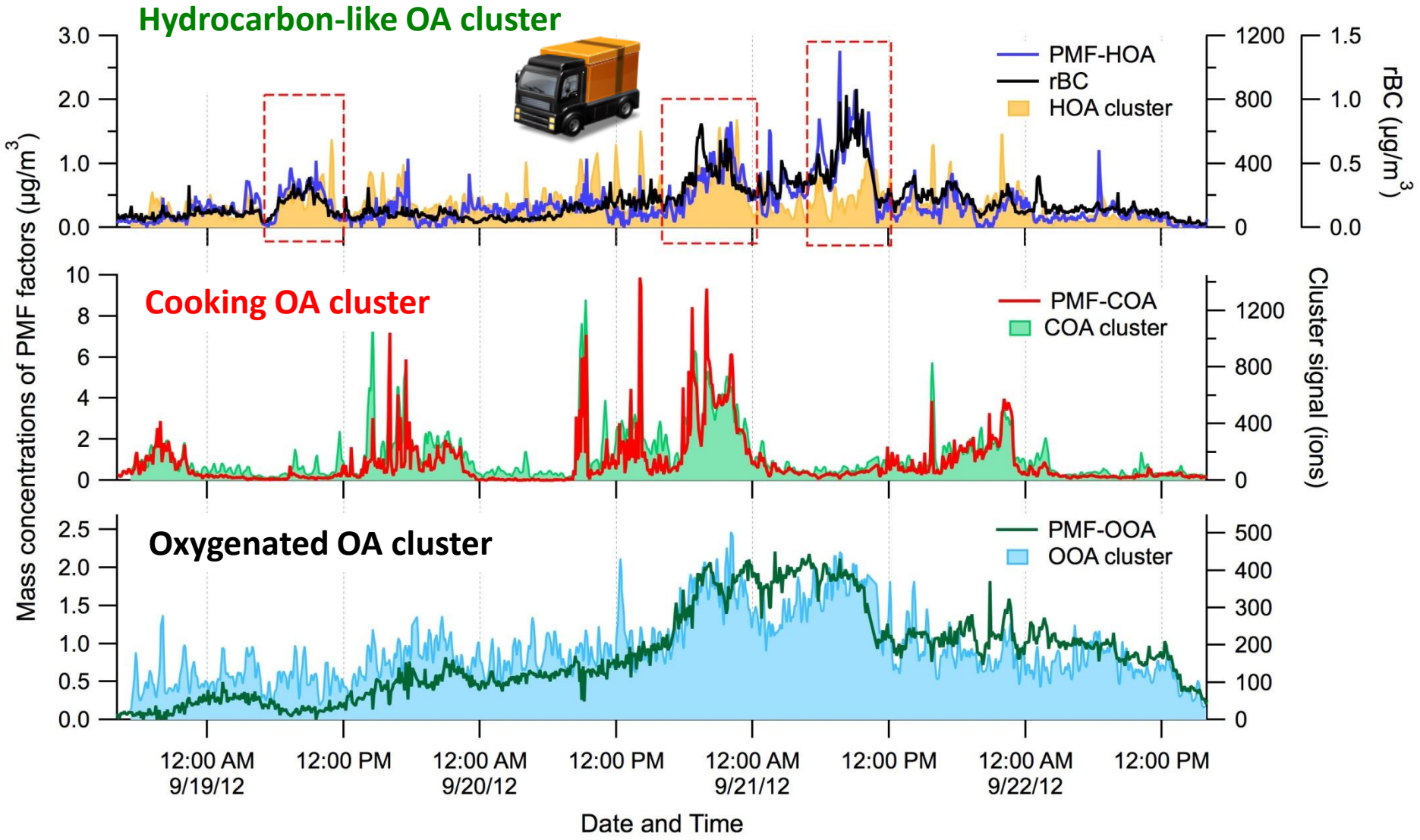


Single particle detection: BC and its coating

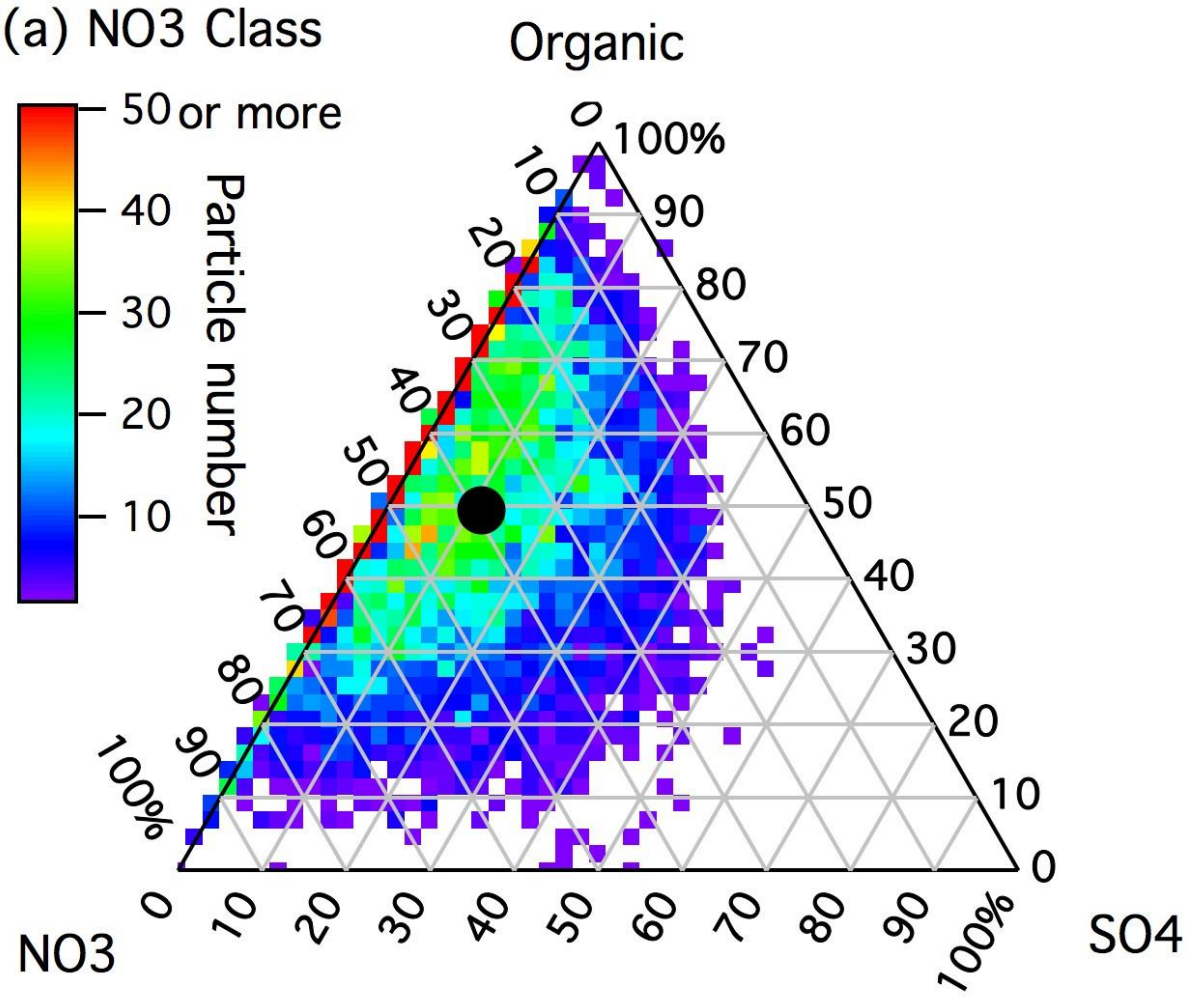


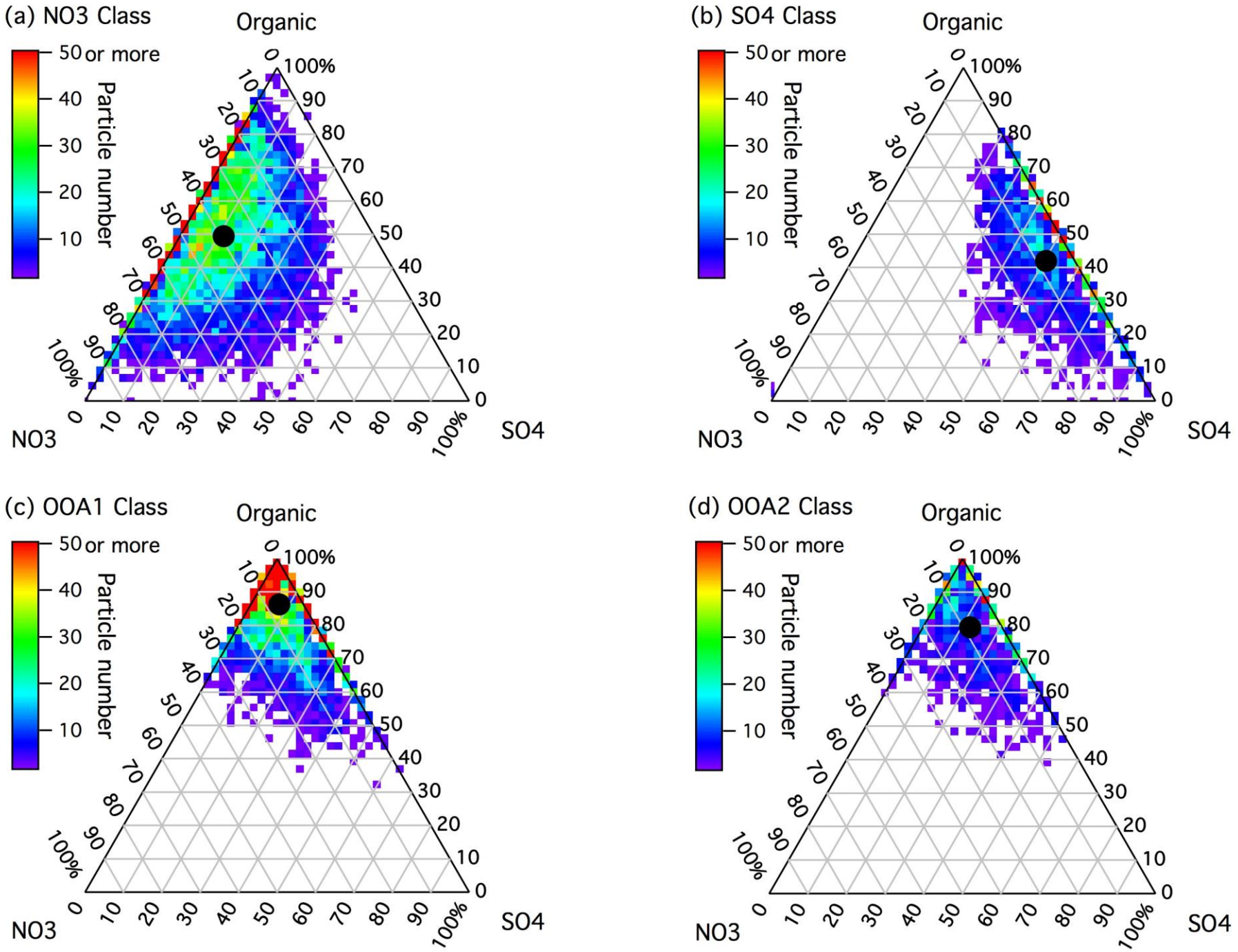

K-Means clustering results of single particle data
NO3
SO4
HOA
rBC
COA
OOA1
OOA2
Fraction of ion signal
Relative frequency (fraction of total # of particles)
dSignal/dlogd$_{va}$ (ion counts, each cluster)
dSignal/dlogd$_{va}$ (ion counts, all cluster)
m/z
d$_{va}$
NO3 cluster
SO4 cluster
HOA cluster
rBC cluster
COA cluster
OOA cluster1
OOA cluster2
Total (all)
NO$_3$
SO$_4$
Org
rBC

Cluster analysis vs. PMF analysis



Mixing state of secondary species

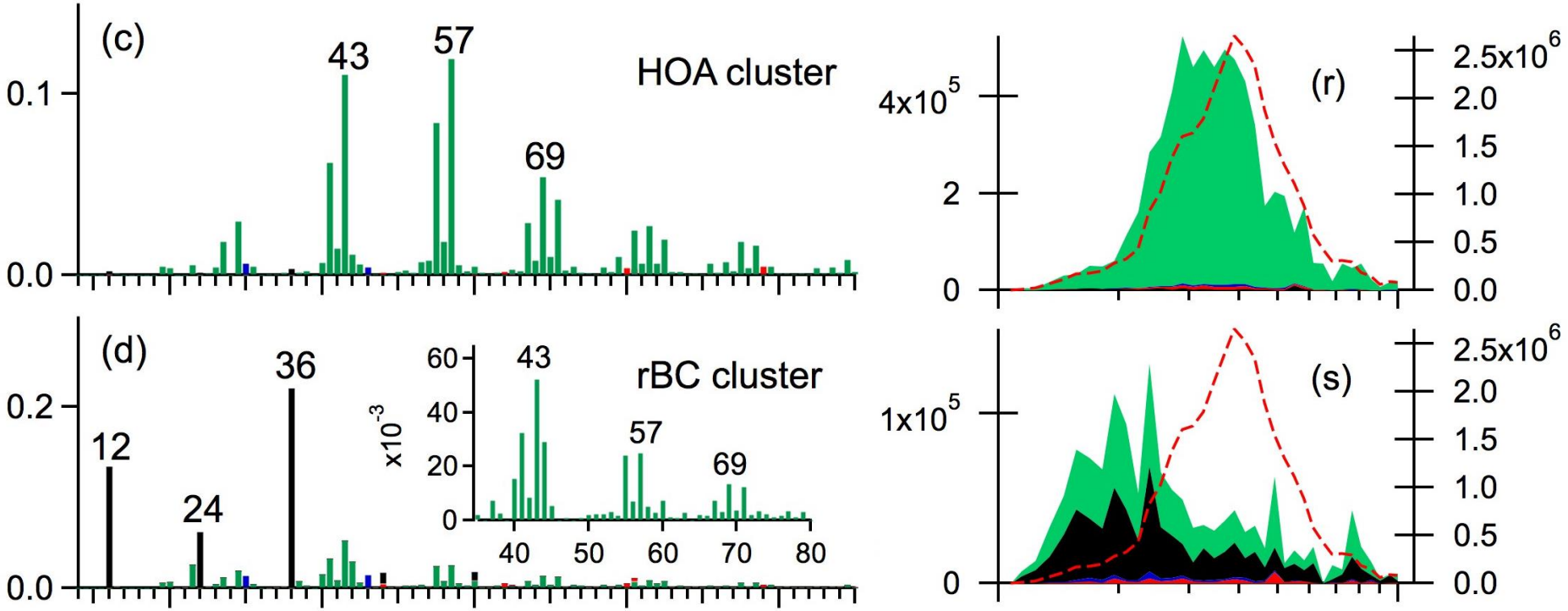



(a) NO3 Class
(b) SO4 Class
(c) OOA1 Class
(d) OOA2 Class
Organic
NO3
SO4
Particle number
50 or more
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100%

Mixing state of black carbon and HOA

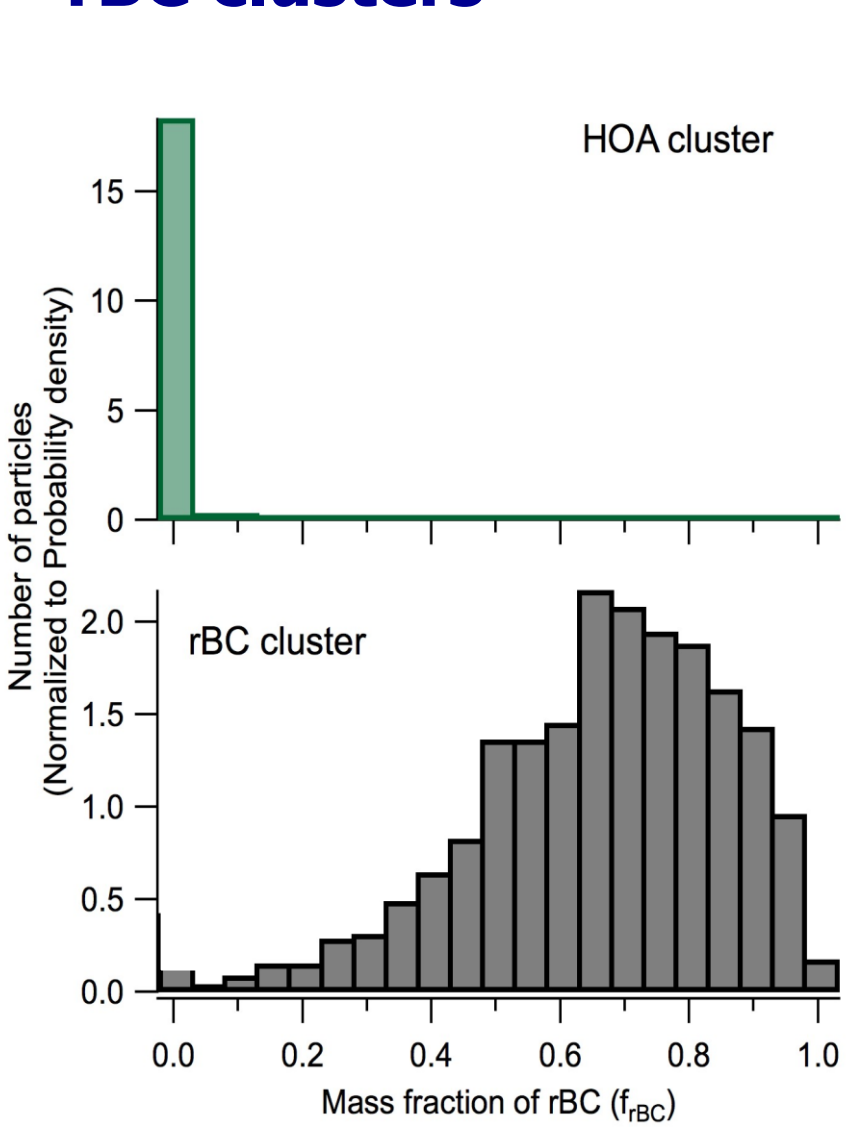
(K-means clustering results)

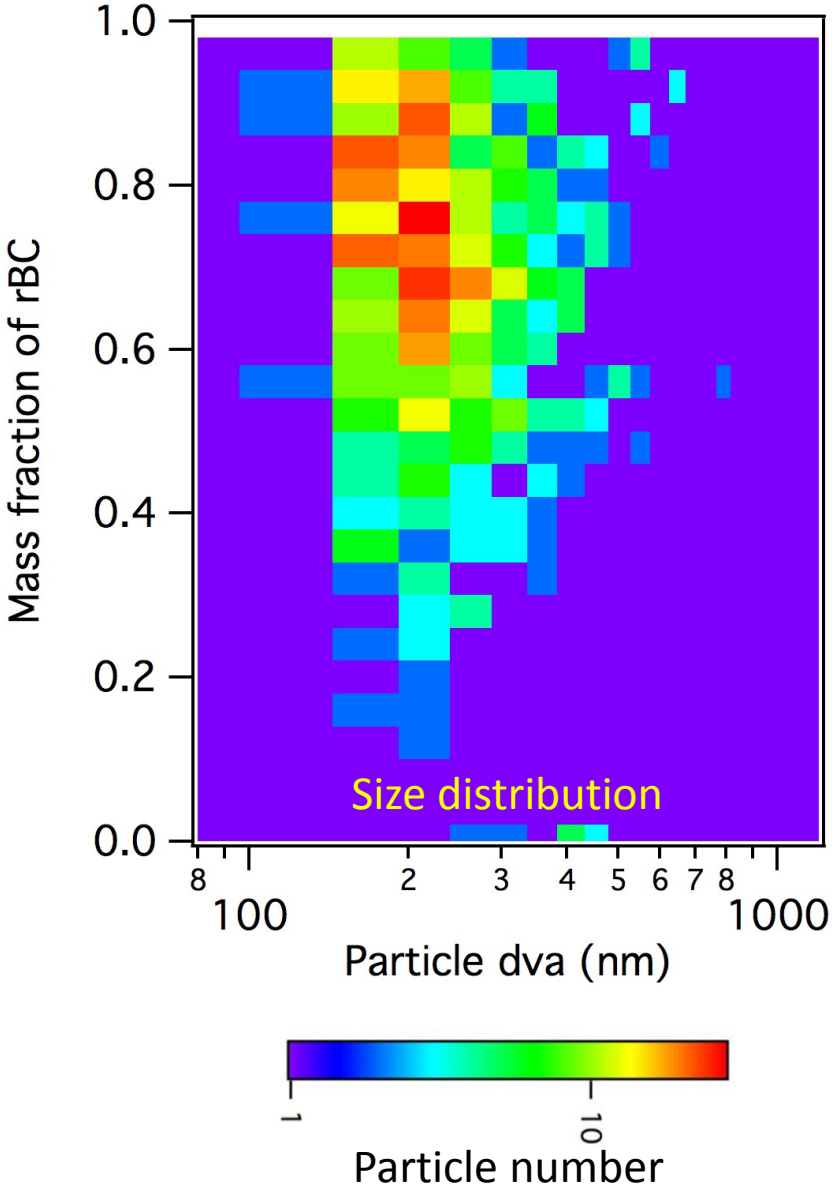
Most HOA are externally mixed with BC



BC are thinly coated with HOA materials (<25 wt%)

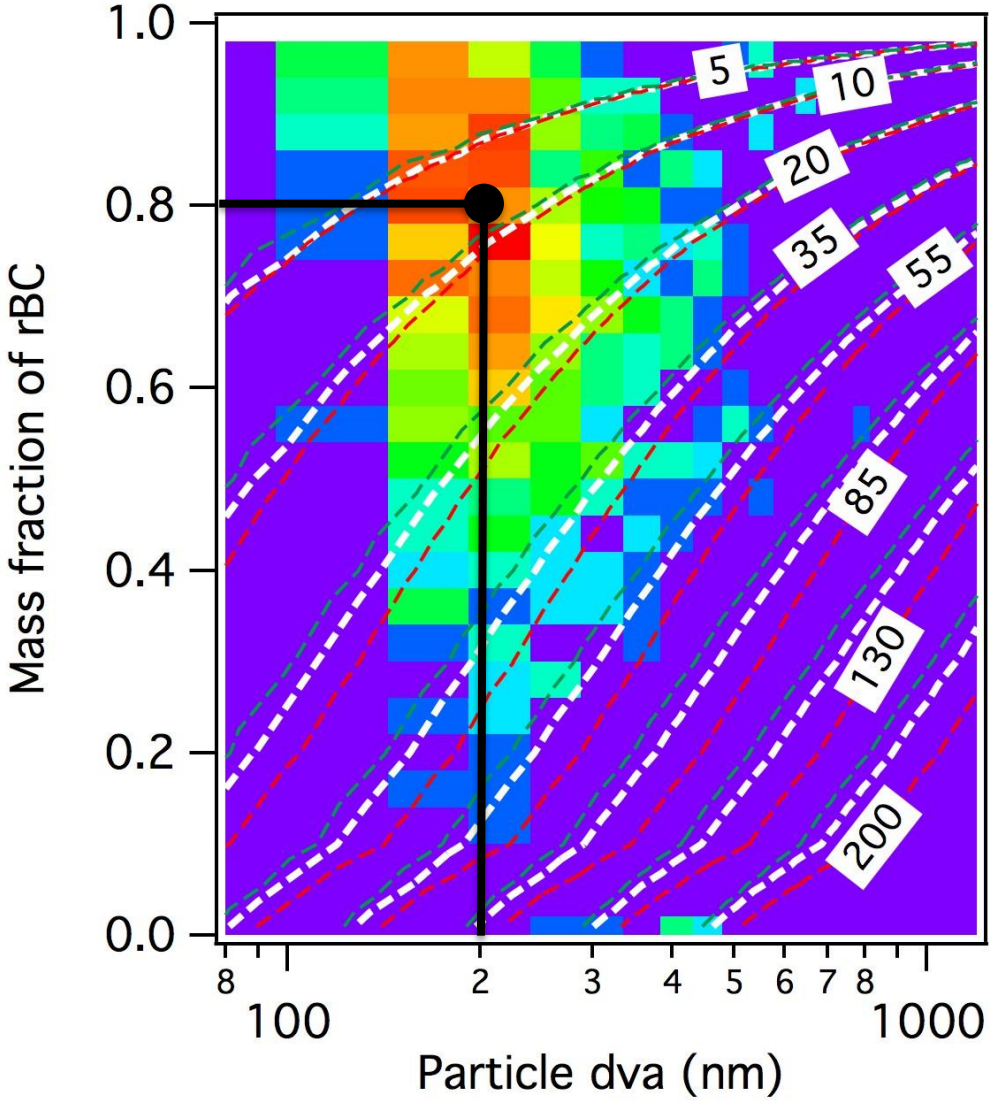
Mass fraction distributions of rBC in HOA- and rBC clusters

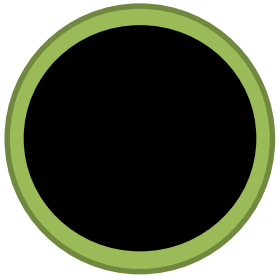




Coating thickness estimation – Core-shell structure

rBC-rich clusters results from both sites

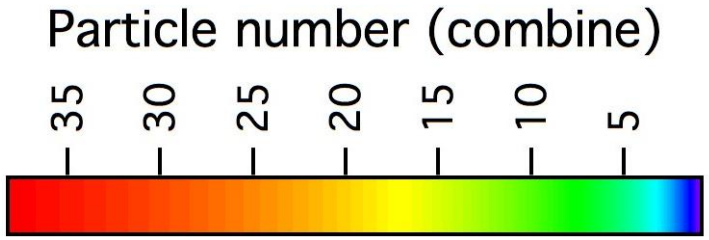




Assumption:

- Spherical shape
- Uniform coating thickness
- HOA density = 0.9 g/cm^3

- **White**: BC eff. density = 0.8 g/cm^3
- **Red**: BC eff. density = 0.3 g/cm^3
- **Green**: BC eff. density = 1.3 g/cm^3



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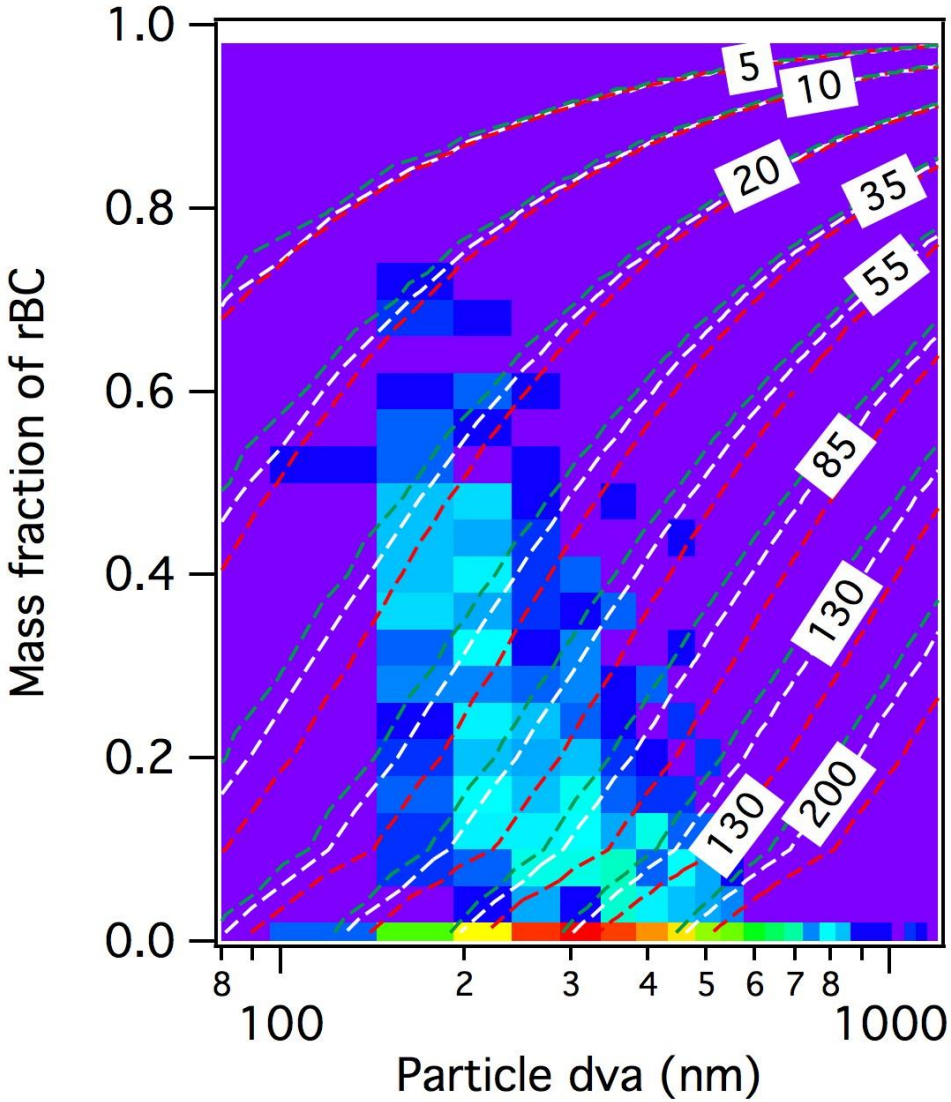

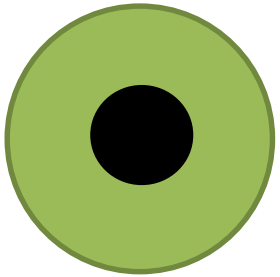

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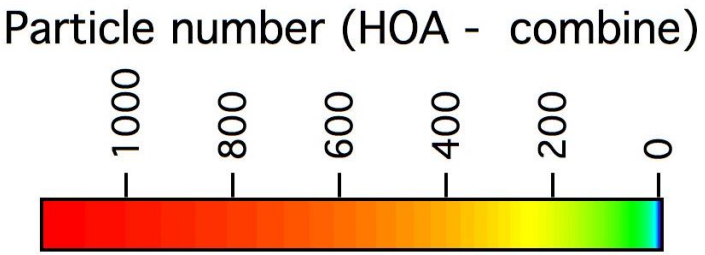
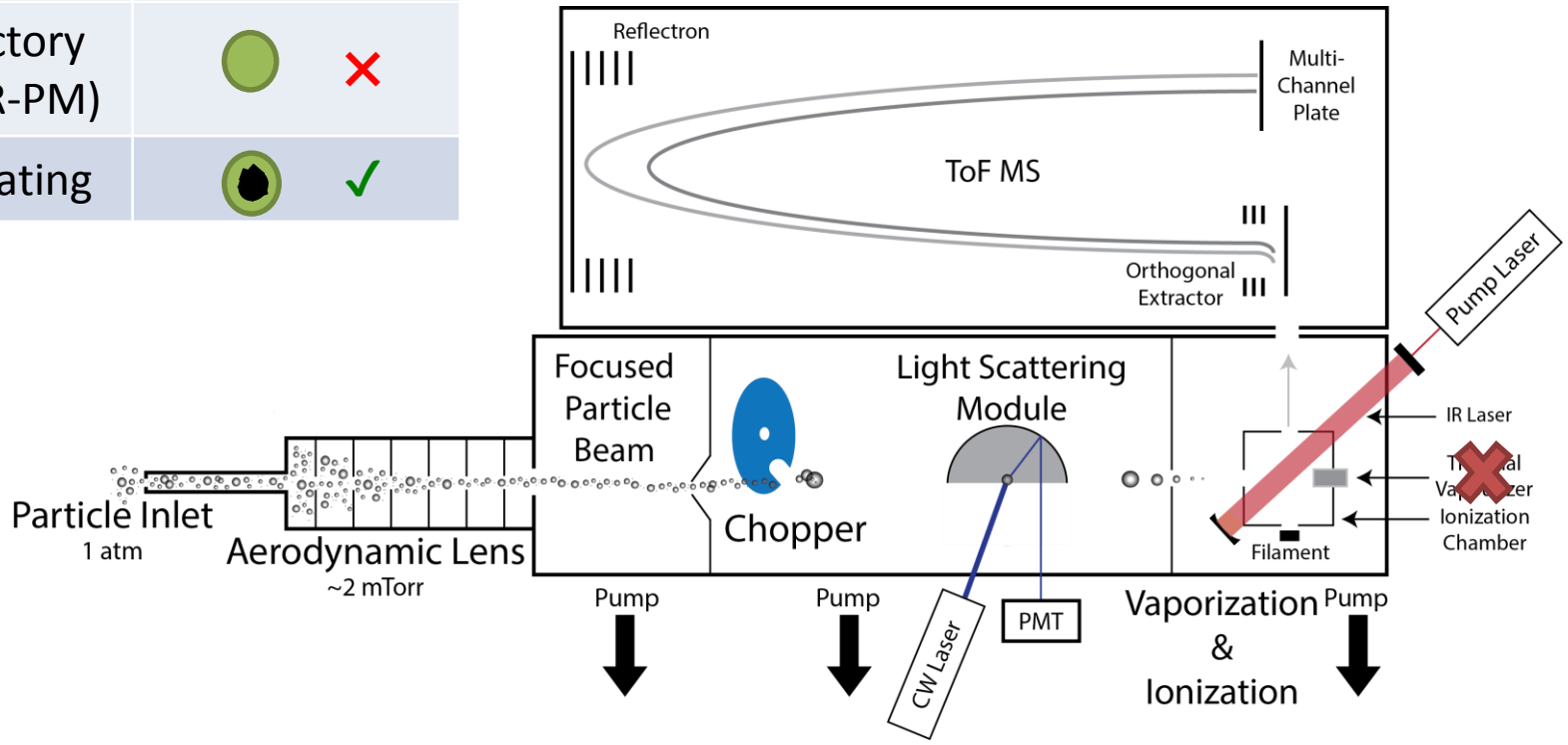


Black carbon in roadside environment

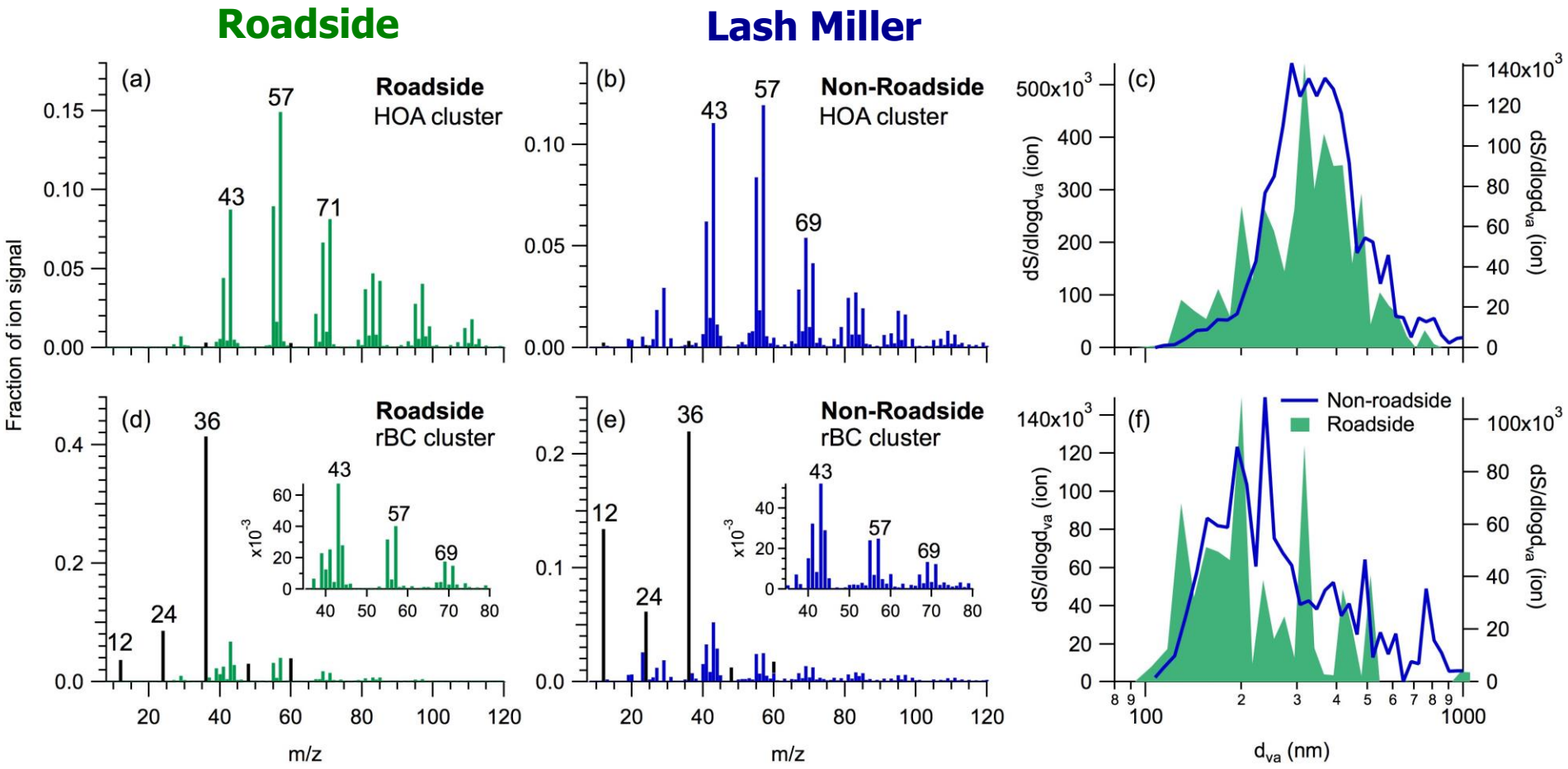
SP-AMS without thermal vaporizer

Detection of black carbon-containing particles only

Particle types	Laser vaporizer
Black carbon (BC)	✓
Non-refractory aerosol (NR-PM)	✗
BC with coating	✓

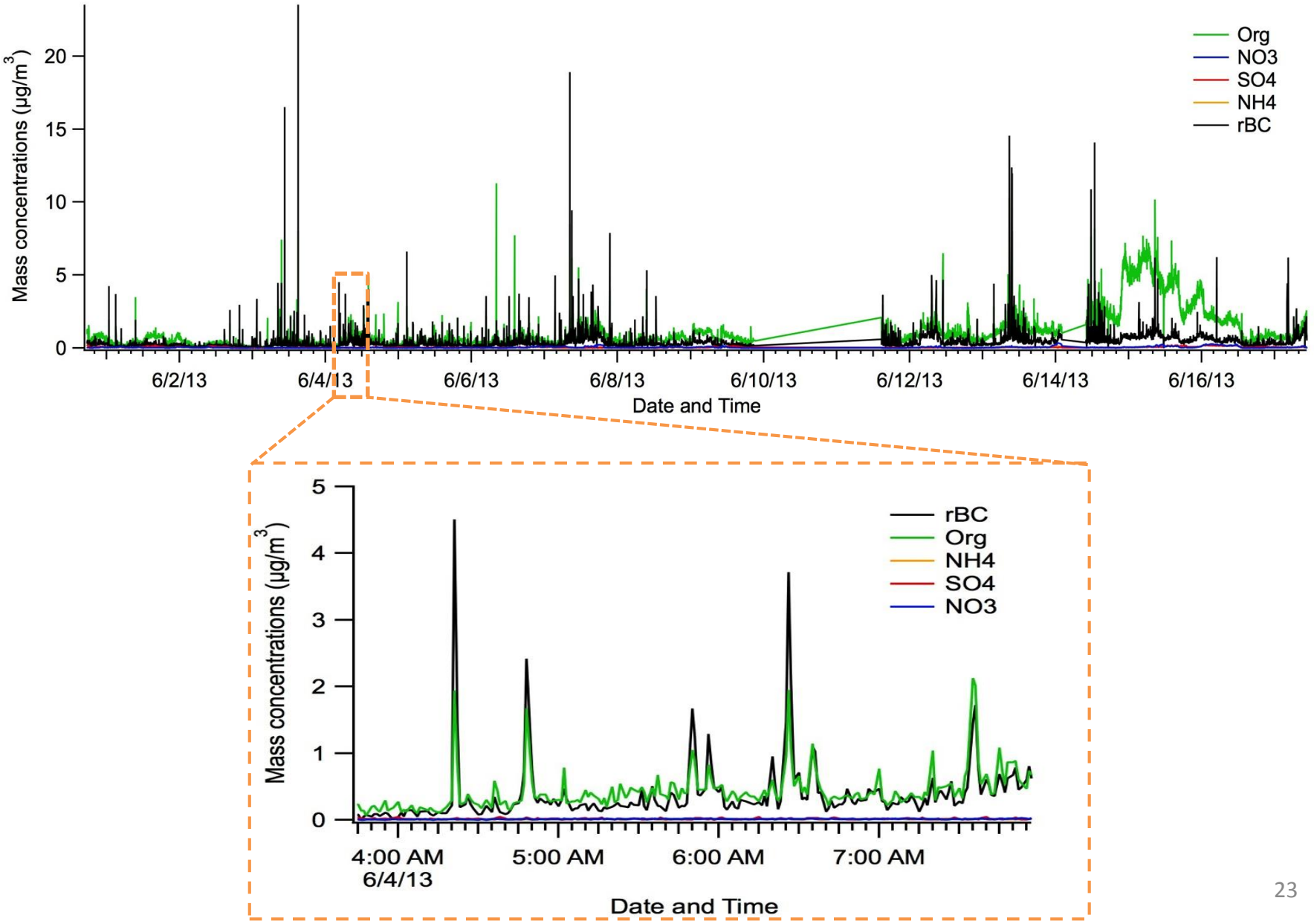


Comparison: Roadside vs. Non-roadside conditions

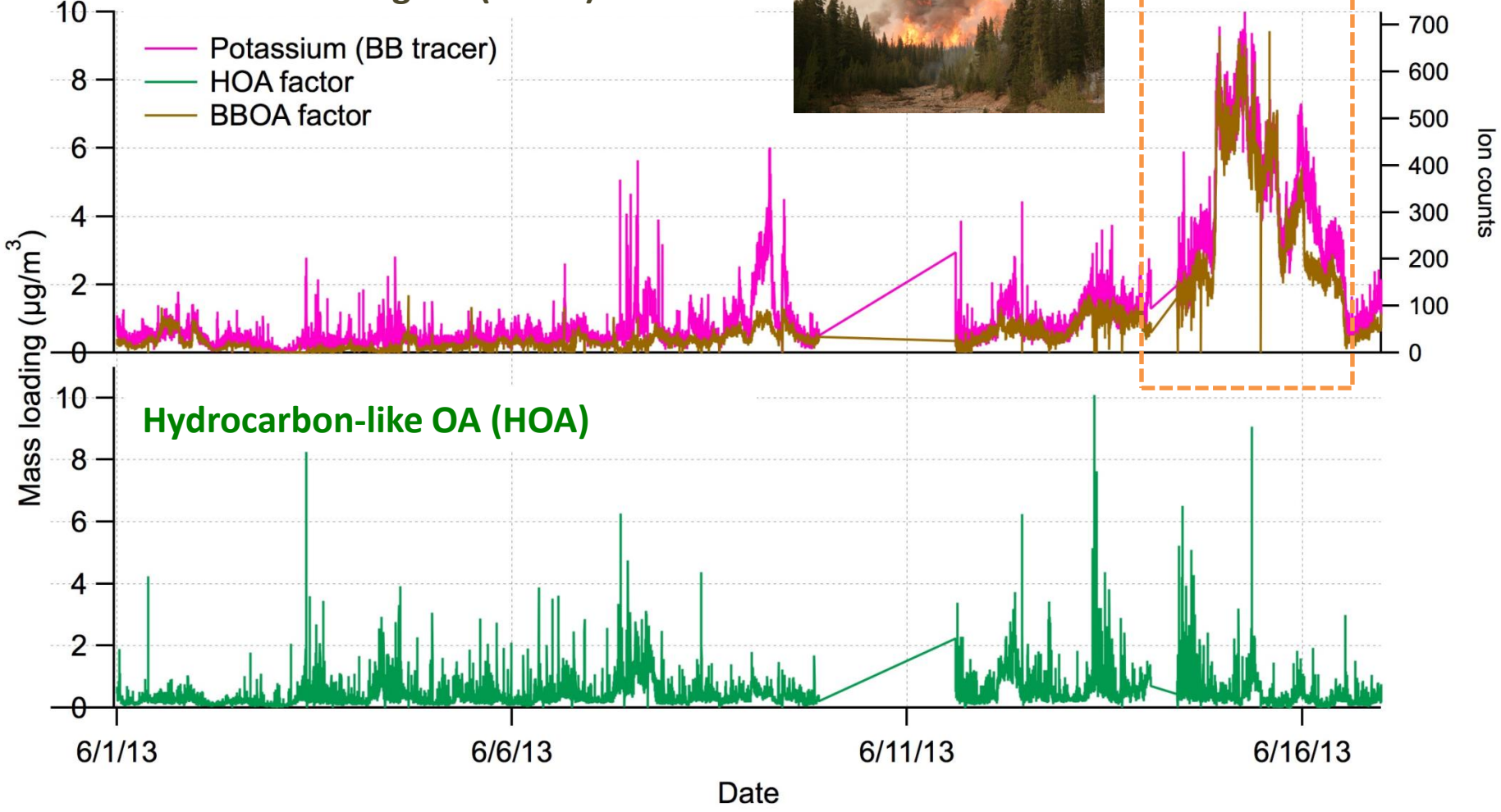


Characteristics of HOA-rich and rBC-rich clusters are similar between the two sites

Fresh rBC emissions from vehicles

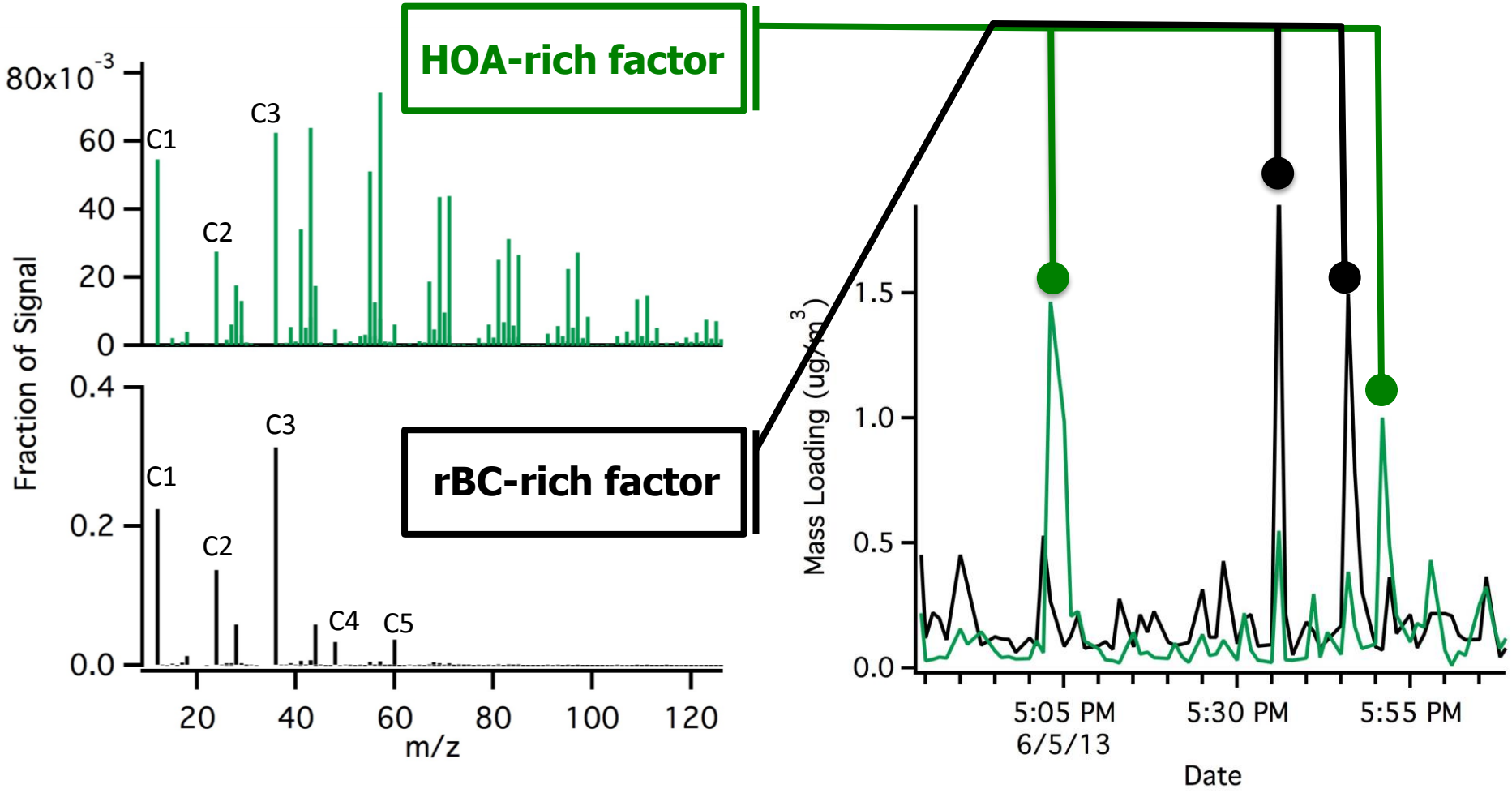


Influence of biomass burning event

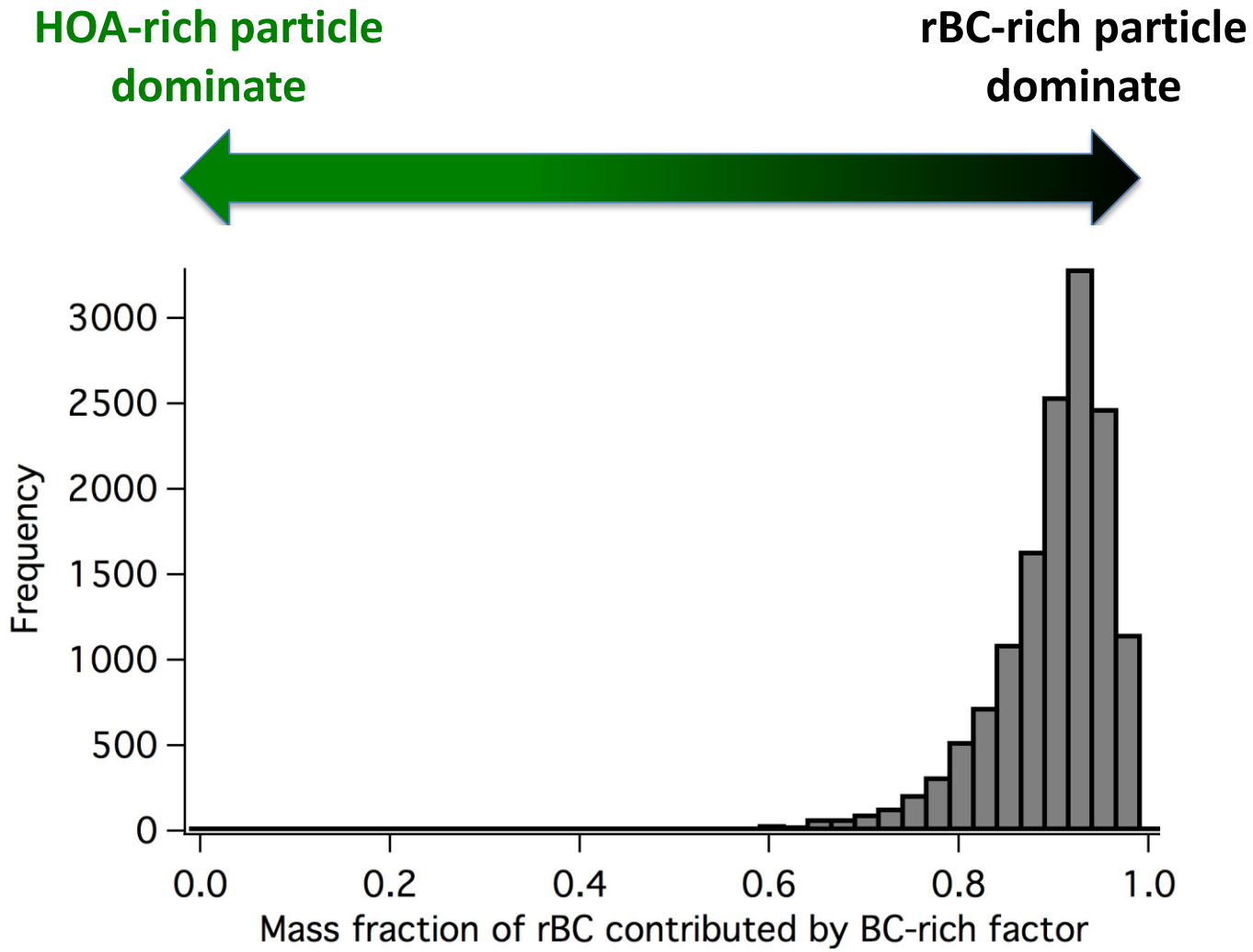


Characteristics of traffic-related emissions

(PMF of organics and rBC - 4 factors solution)



Mass fraction of traffic related-BC contributed by BC-rich factor



Summary

- There are two major types of particles associated with vehicle emissions: 1) HOA-rich and 2) rBC-rich particles

- The core-shell structure model estimates that the rBC-rich particles are thinly coated with HOA materials (e.g., 200 nm dva, 5-10 nm coating thickness).

- With the support of single particle measurements, rBC-rich particles can contribute ~90% of total rBC mass emitted from vehicle at roadside condition of downtown Toronto based on PMF results of ensemble measurements.