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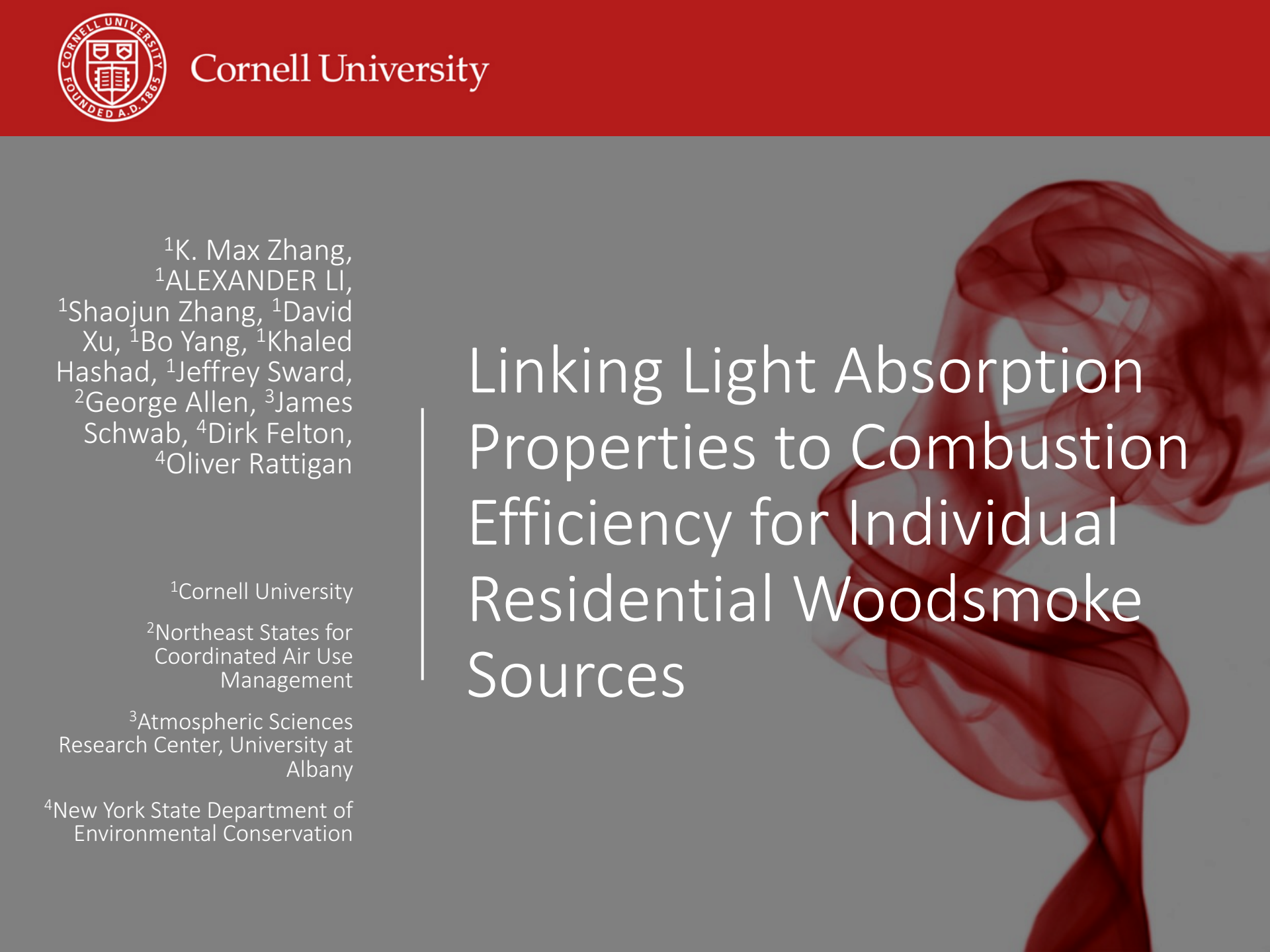
Linking Light Absorption Properties to Combustion Efficiency for Individual Residential Woodsmoke Sources

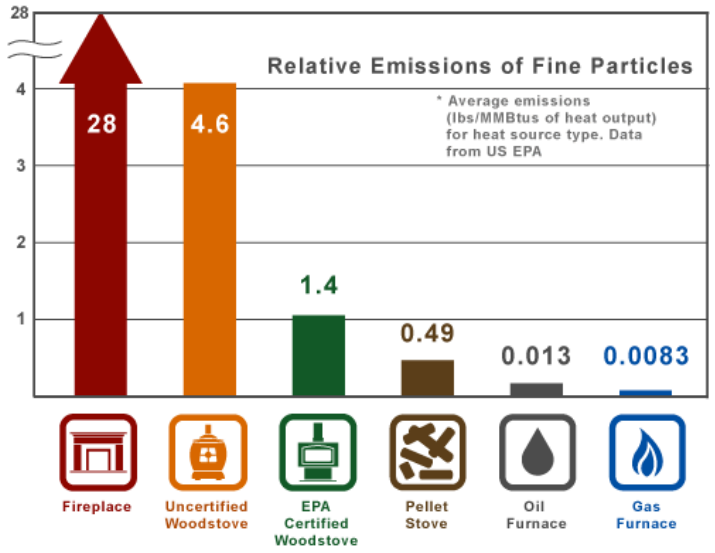


Woodsmoke from residential wood combustion

- Worldwide air pollution problem
- Local air pollution issue
  - Worst in densely populated areas
- Challenge: heterogeneous combustion
  - Real world emissions differ from lab tests
- No convenient monitoring method

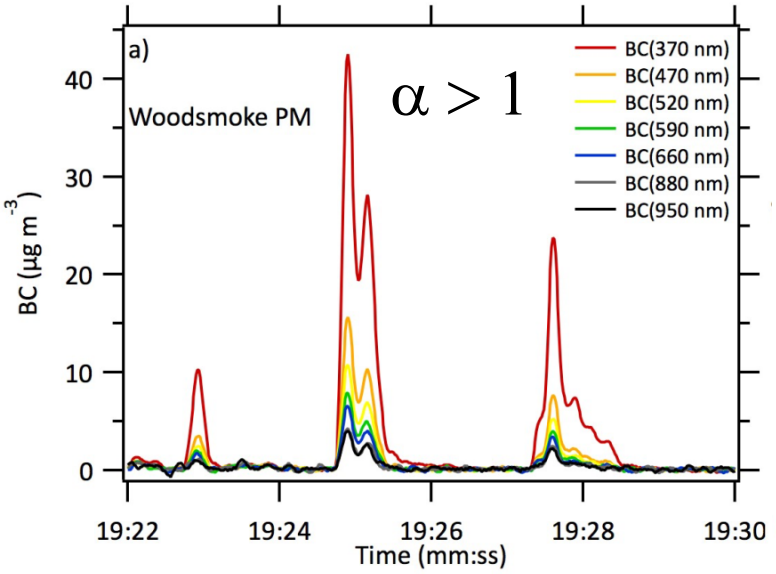
Contribution to $PM_{2.5}$ emissions

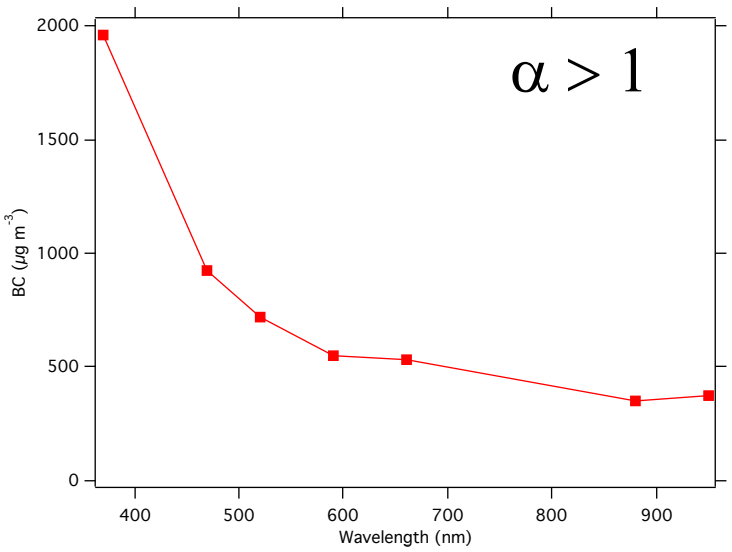
	US	UK
Woodsmoke	14%	35%
Vehicle	5%	13%



Aerosol light-absorption properties

- Woodsmoke contains mostly **Brown Carbon (BrC),**
  - absorb more light at the low visible and near-UV wavelengths
- **Absorption Angstrom exponents (AAE, or α)**
  - power law exponent
  - approximates the change in measured absorption as wavelength changes
- α is commonly used optical property
  - atmospheric warming
  - source apportionment

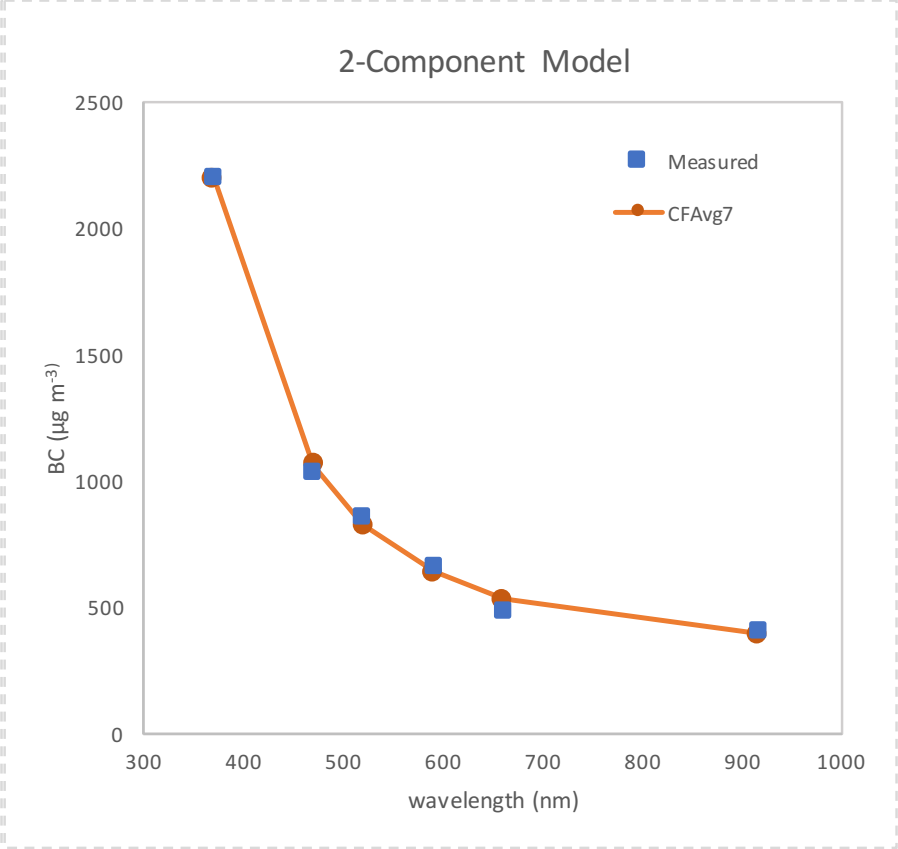




Deriving α_{BrC}

- Two-component (BC and BrC) model:
  - Also used in Chen et al. (2015) and Ran et al. (2016)
  - $B(\lambda) = [BC] + [BrC]\ \lambda^{-\alpha_{BrC}}$
  - Use multiple wavelengths

- Tested different curve fitting parameters
  - including 370nm
  - averaging 880nm and 950nm
- Chosen fitting method
  - fit all 7 wavelengths
  - average 880nm and 950nm



Project Overview

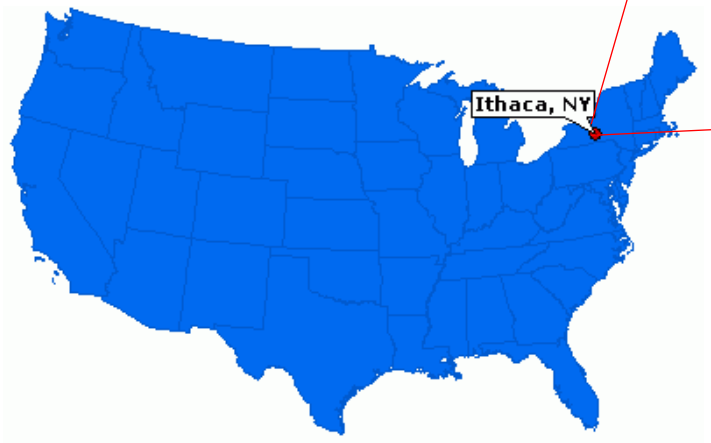
- Understand local air quality impact of residential wood combustion **(RWC)**
  - Identified a large number of sources
  - Real time measurements
- Explored the linkage between optical properties and combustion efficiency

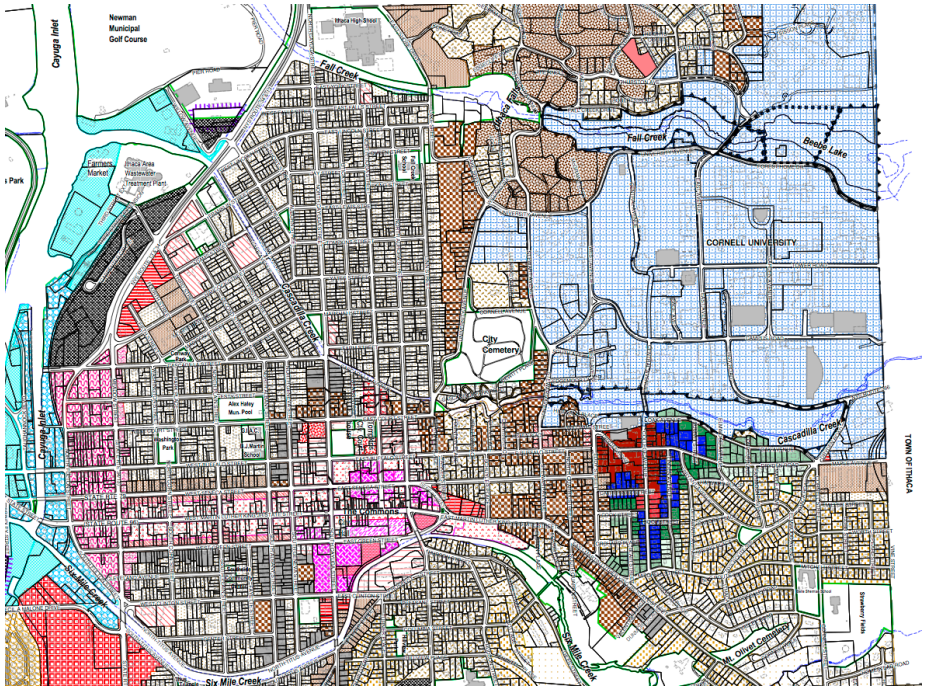
Highlights

First to report real-time, source-specific measurements

Large collection of RWC sources

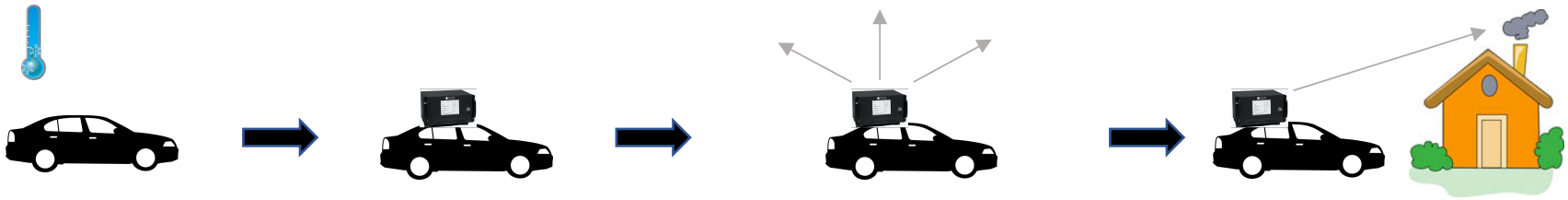
City of Ithaca, NY





Integrated plume sampling

- Cold, low-wind speed winter nights in Ithaca
  - No other emission sources
  - High ground-level impact expected
- A hybrid electric vehicle instrumented with:
  - Aethalometer (AE-33) - light absorption at 7 wavelengths
  - pDR-1500 - $PM_{2.5}$
  - Vaisala GMP343 - CO_2
  - GPS
- **Mobile** monitoring: Search for woodsmoke plumes
- **Stationary** monitoring: Stay by the source until ample plumes have been measured



Data Processing Software

Peak Identification

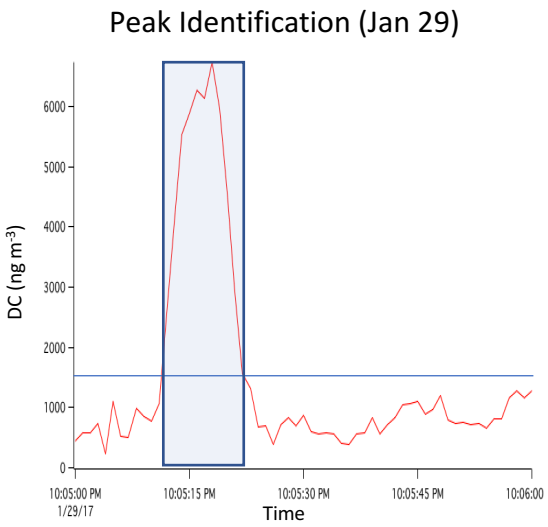
- Identifies woodsmoke plumes
- Searches for elevated DC

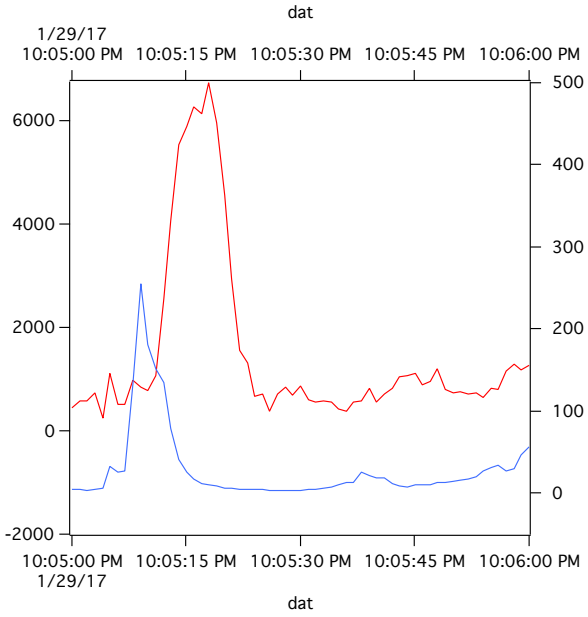
Data Alignment

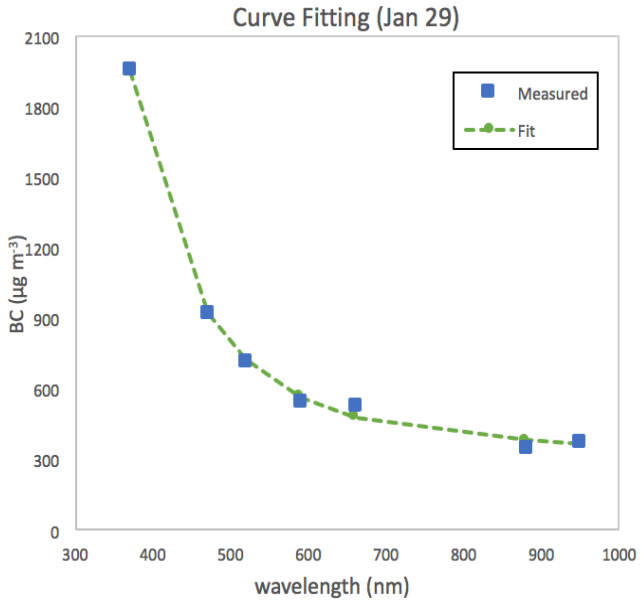
- Fixes instrumental time delay differences
- Align DC and PM2.5

Data Analysis

- Average data over identified peaks
- Find α_{BrC}, average $PM_{2.5}$

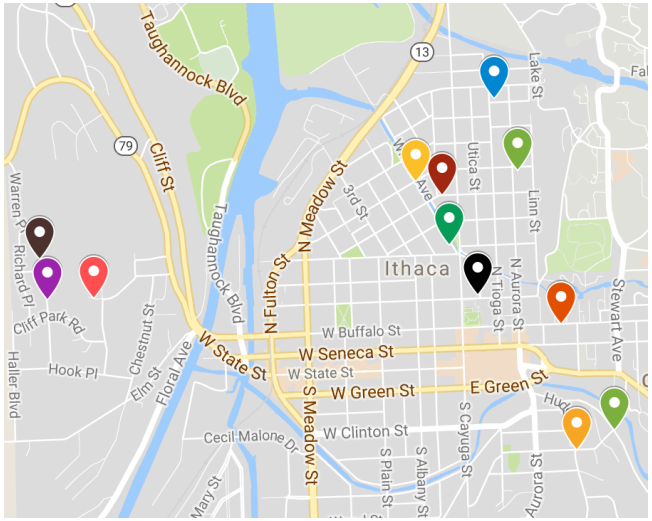




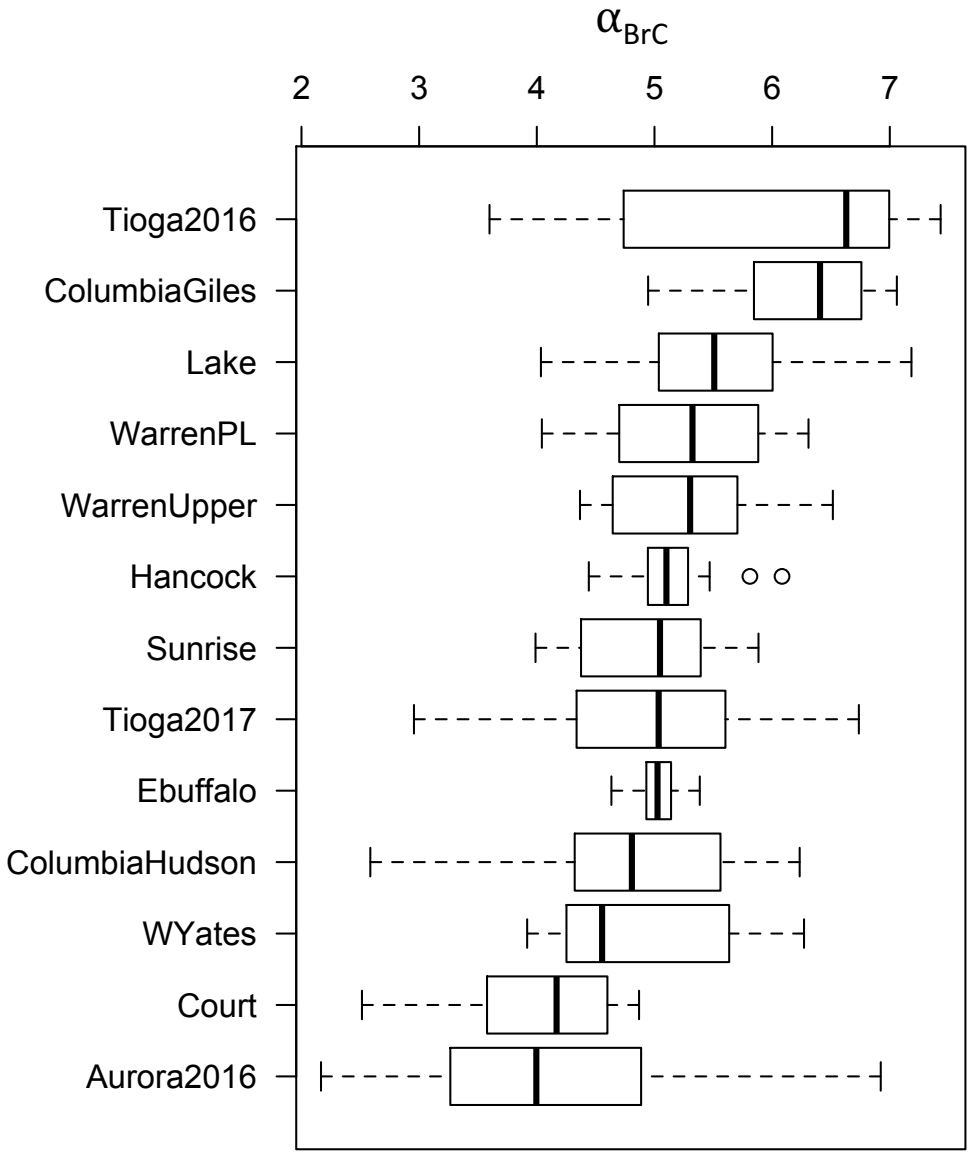


α_{BrC} by Individual Sources

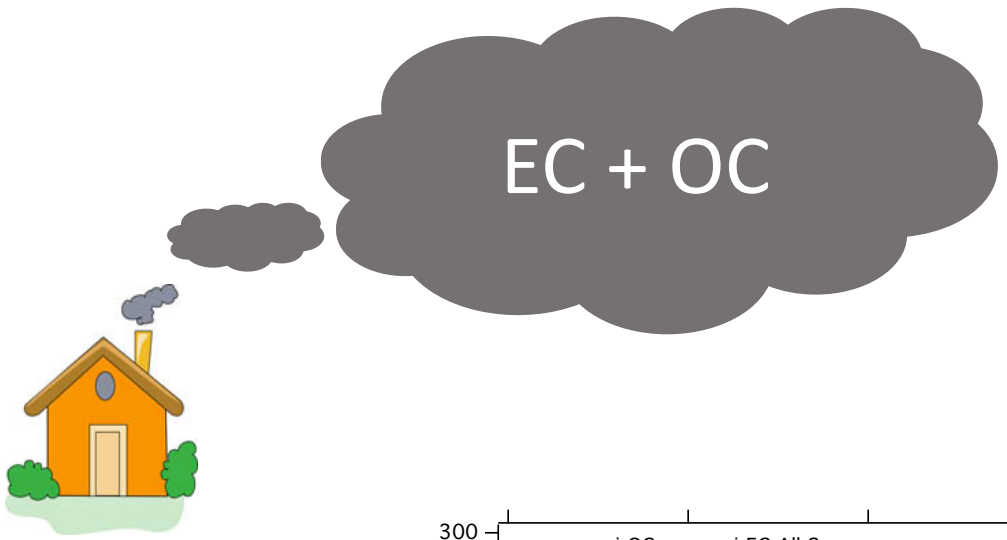
- α_{BrC} is in a range
- Medians between 4 and 6
- Not a constant



Woodsmoke source locations

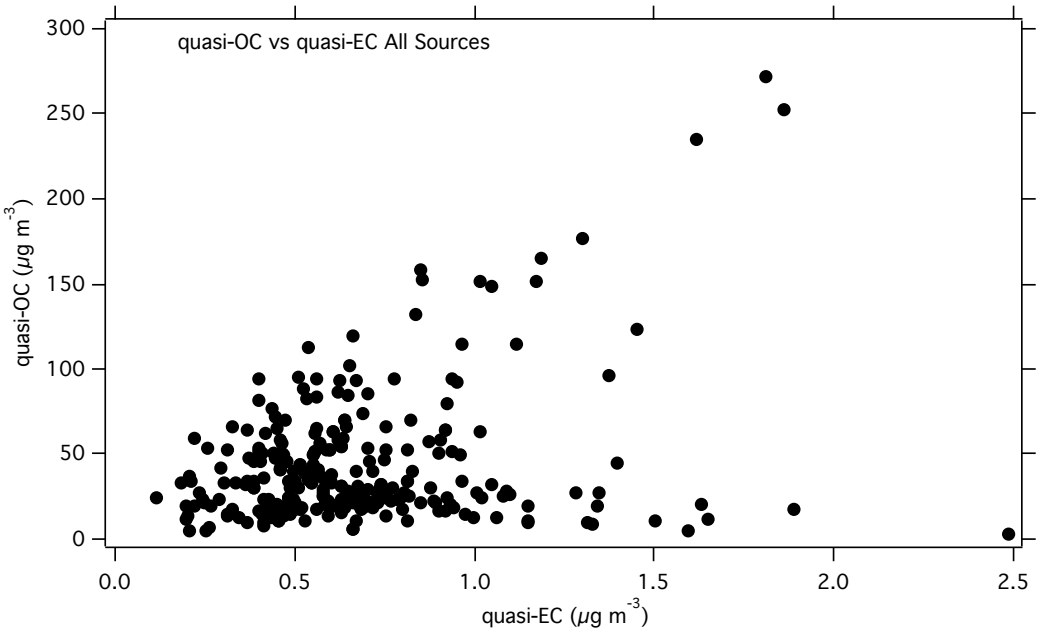


quasi-OC vs quasi-EC



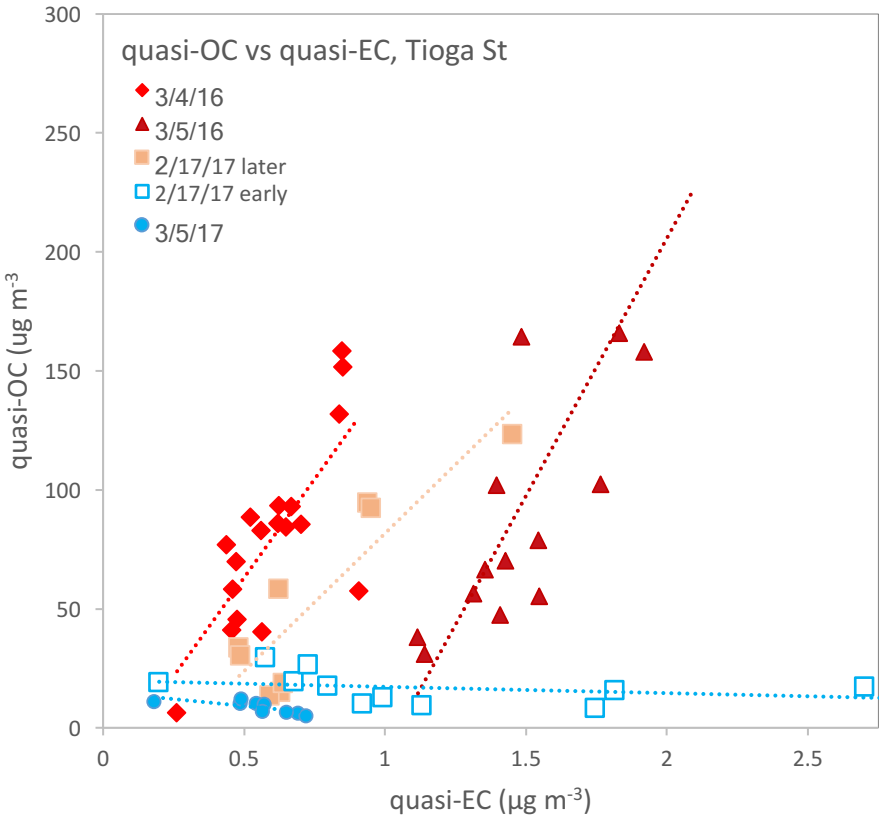
quasi-EC = BC(880)

quasi-OC = $PM_{2.5}$ – quasi-EC



Results: Intervention at Tioga St

- Homeowner used improperly seasoned wood in 2016
- We helped Tioga St's homeowner improve burning practice in 2017



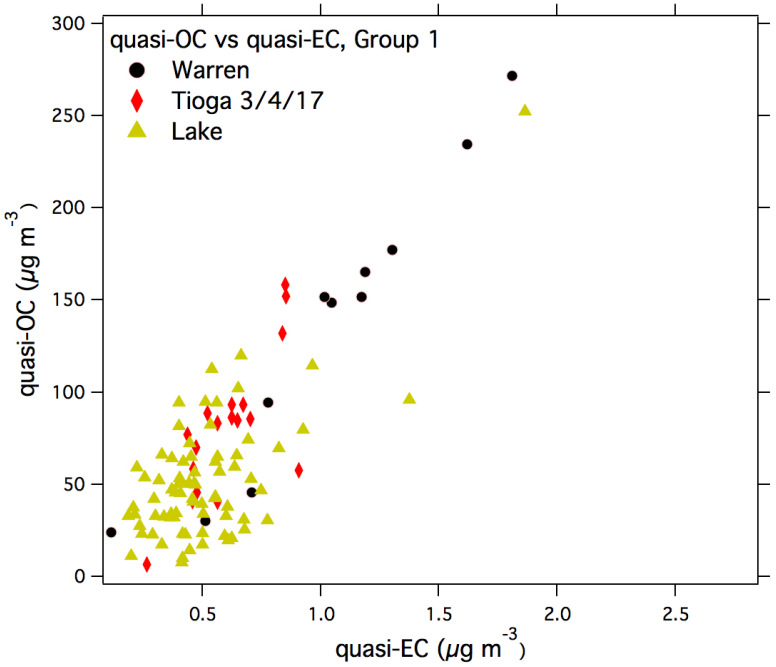
Group 1 - Dirty burning

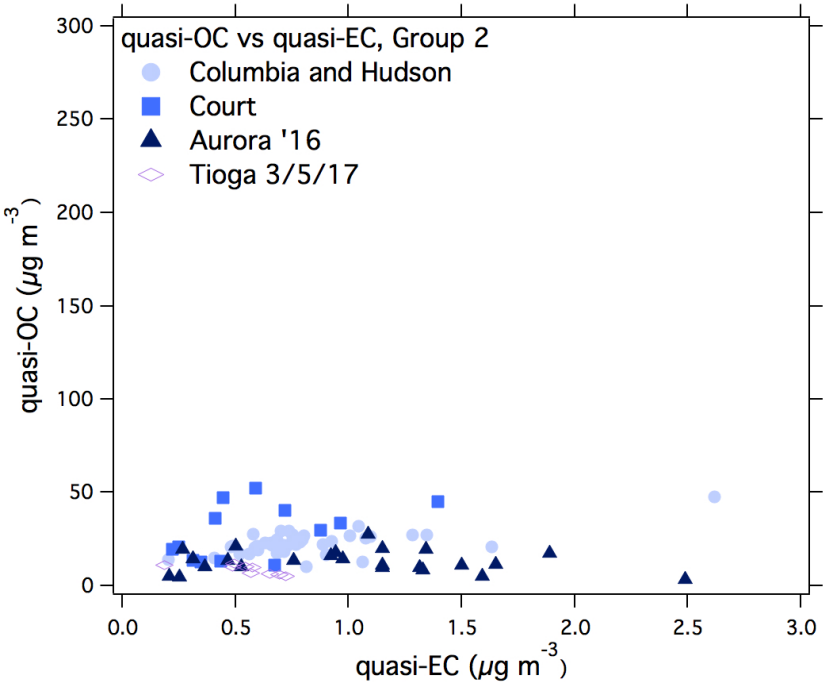
- Steep trend lines
- 2016 was very dirty and noticeable
- Feb 2017 was slightly cleaner

Group 2 - Clean burning

- Homeowner adopted new burning practices
- Fewer plumes detected
- Woodsmoke was hot and rose quickly

Results: Classification of sources





Group 1 – Dirty Burning:

- Steep slope, large OC/EC ratio
- Tight pattern, large r^2 correlation

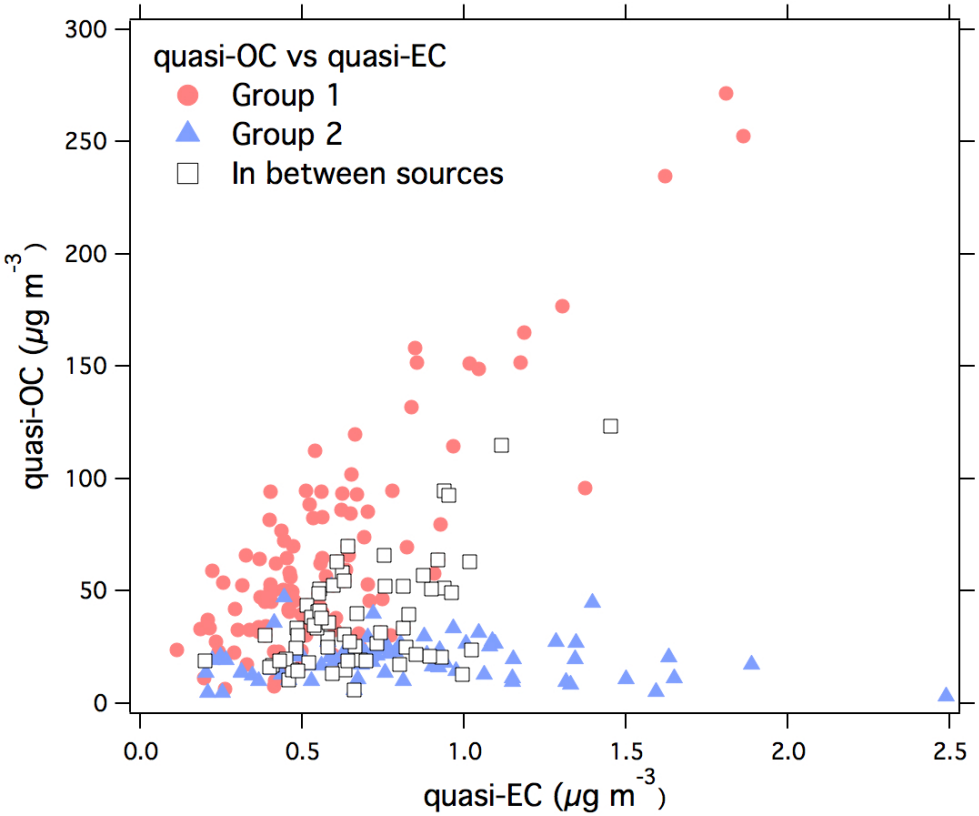
Group 2 – Clean Burning:

- Slope close to 0, small OC/EC ratio
- OC remains similar while EC increases

Results: Classification of sources

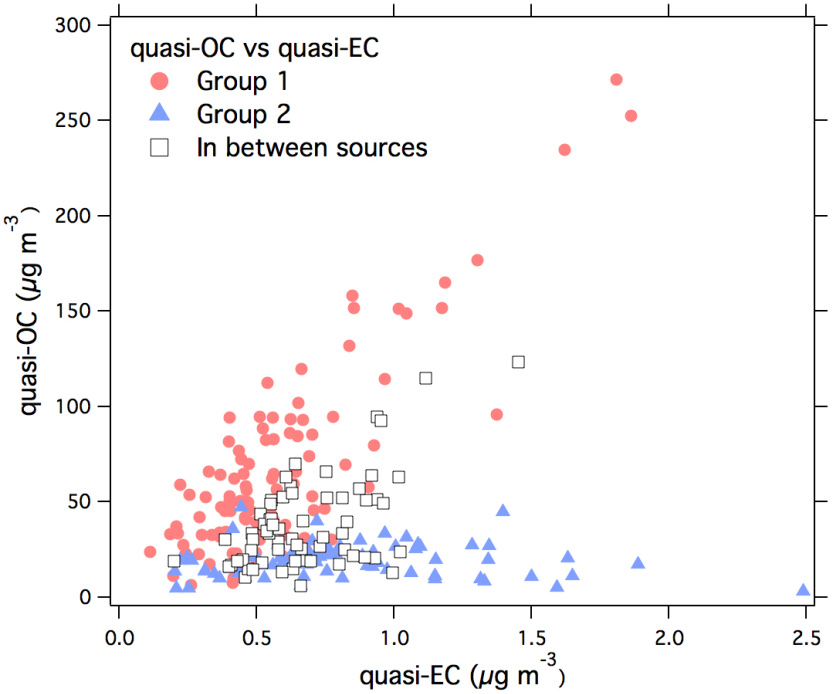
- Group 1 – “upper limit”
- Group 2 – “lower limit”
- Many in-between sources
  - depends on operation
  - data has larger range

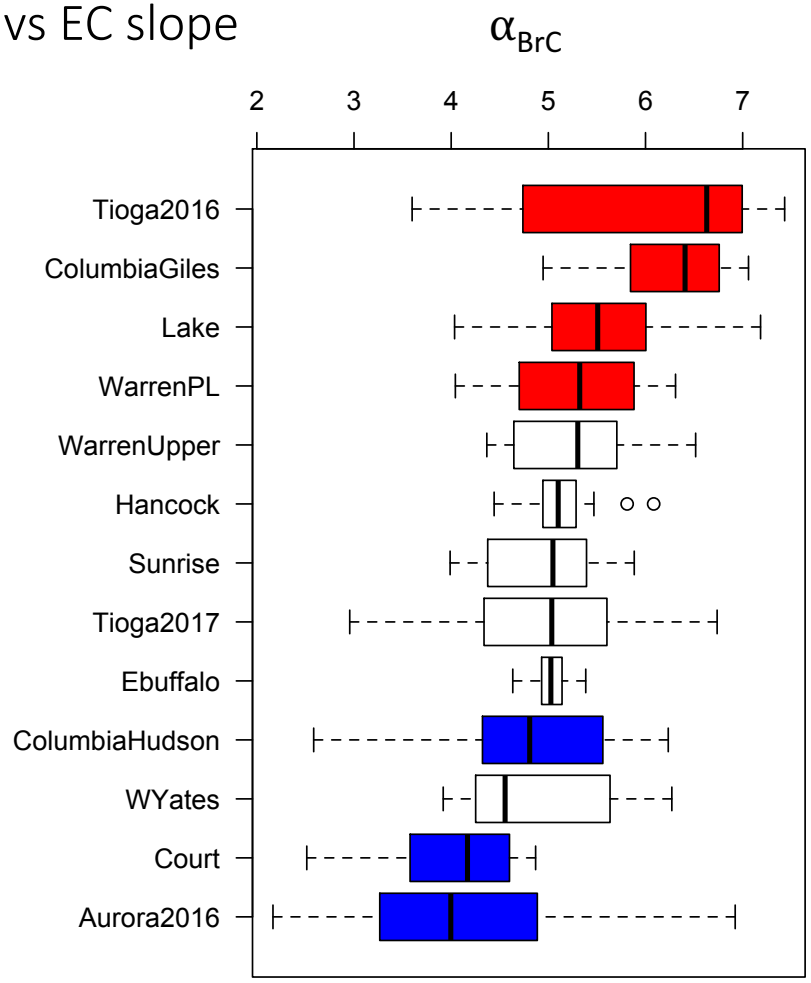
- Similar to α_{BrC}
  - OC vs EC is a range not a constant
  - Different sources have different average slope values



Results: α_{BrC} and OC vs EC

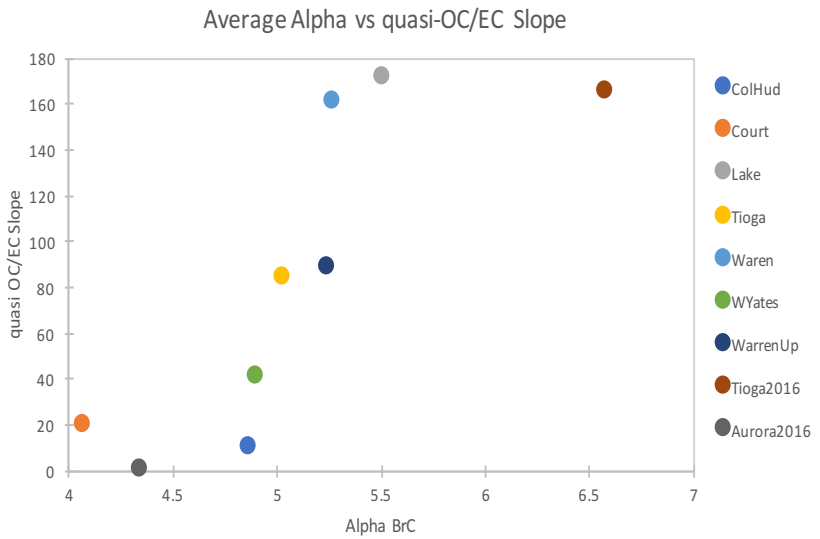
- Positive correlation between α_{BrC} and OC vs EC slope





Summary

- First reported real-time measurements of real-world, source-specific RWC sources
- Large collection of real-world RWC sources
- Sources can be differentiated by α_{BrC} ranging from 4-6
  - Most literature assumes α_{BrC} is a constant (around 1.6-2.2)
  - α_{BrC} similar to that found in Chen, 2015 lab studies
- Sources can also be differentiated by OC vs EC plots
  - Dirty sources have high OC vs EC slopes
  - Correlates with α_{BrC}
  - This can be done relatively inexpensively
- Larger α_{BrC} and larger OC vs EC slopes indicate dirtier burning



Acknowledgements

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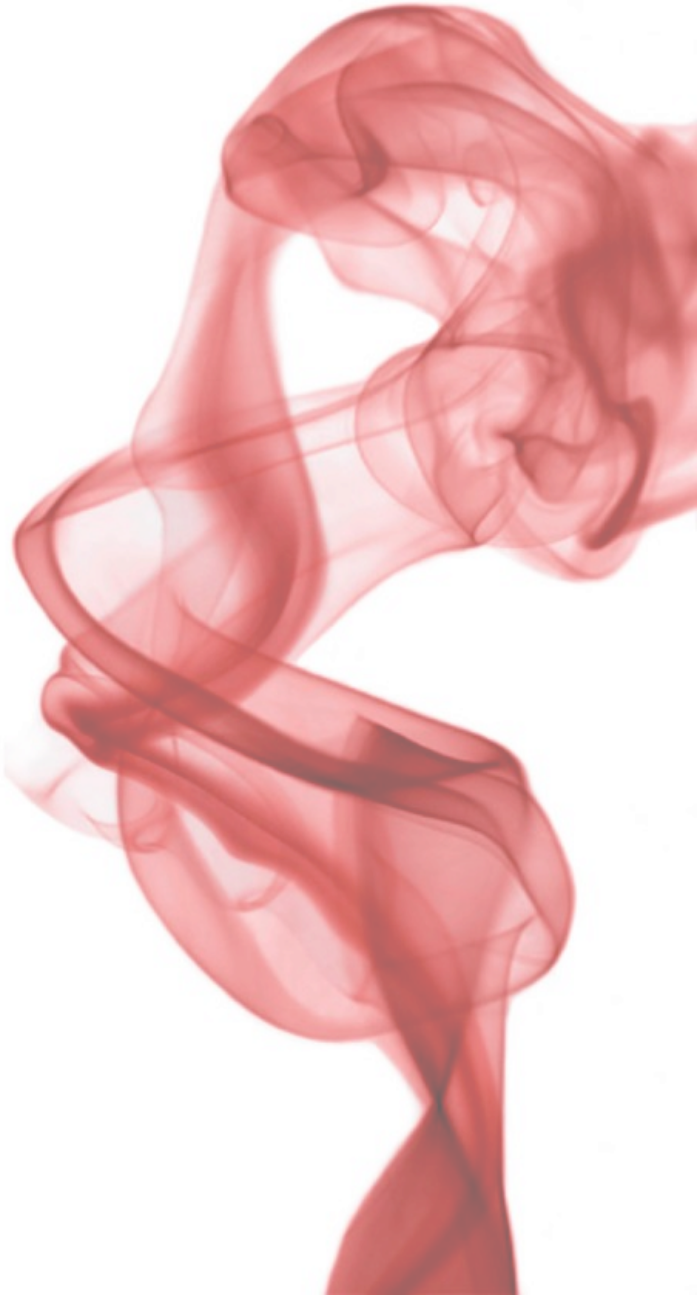

Questions?