A Real-Time Wood Smoke Indicator Method

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Acknowledgments:

Rich Poirot, VT-DEC

Pete Babich CT-DEP (with VT-DEC when this work was done)

Introduction

- Wood smoke is a significant player in PM2.5 and regional haze
    → wildfire [summer], space heating [winter]

- Traditional WS tracer/indicator methods are integrated samples
    → examples: KNON [non-soil potassium], Levoglucosan
    → usually 24-hour samples [smear sub-daily patterns]
    → data not available for weeks/months

- Highly time resolved [hourly] data can provide greatly enhanced insight into source characterization
    → data are available immediately

- Anecdotal evidence of enhanced UV absorption by WS aerosols
    → is the 2-channel Aethalometer a viable realtime WS indicator?

Overview:

- Method to semi-quantitatively measure wood smoke PM in real-time
  → 2-wavelength Aethalometer: 880 nm (BC) and 370 nm (UV-C)

- WS PM: enhanced optical absorption at 370 relative to 880 nm ("Delta-C")
  → DC is specific "indicator" of WS PM, but alone is not quantitative

- Collocate Aeth with continuous PM2.5 for semi-quantitative WS PM

- Pilot study: Rutland, VT-DEC site: Aeth, FDMS PM2.5, SO2, CO, NOx
  → February 11 to July 19, 2004

- UNMIX used to apportion measured PM2.5 into several source categories:
  → WS, oil burning (space heating), mobile sources, transported PM

- WS PM was associated only with the Aethalometer Delta-C
  → even with substantial local mobile source and oil-burning aerosols

- UNMIX receptor model was employed in a "non-traditional" manner
  → gases <u>don't</u> contribute directly to the apportioned source's PM2.5 mass
  → gases <u>do</u> help discern/interpret resulting source categories
  → results normalized to the total PM2.5 mass

- T, WS, stability employed to help interpret and evaluate the UNMIX results

- Results: a 5-Source UNMIX "solution":

1. Wood Smoke: <u>24% of the PM2.5</u> and 99% of the DC (7% of WS PM)

2. Oil: <u>26% of the PM2.5</u> and 56% of the total measured SO2

3. Fresh Motor Vehicle: <u>10% of the PM2.5</u> and high BC mass fraction (18%);
   81% of NO, 31% of CO, 25% of SO2

4. Aged MV: <u>23% of the PM2.5</u> and relatively high BC mass fraction of 9%;
   55% of CO, only 11% of NO
   → higher CO:NO ratio in this "aged" source

5. Secondary Aerosol: <u>17% of PM2.5</u>; FDMS volatile: 80% of PM (nitrate?)
   → virtually no BC, Delta-C or gaseous species associated with this source

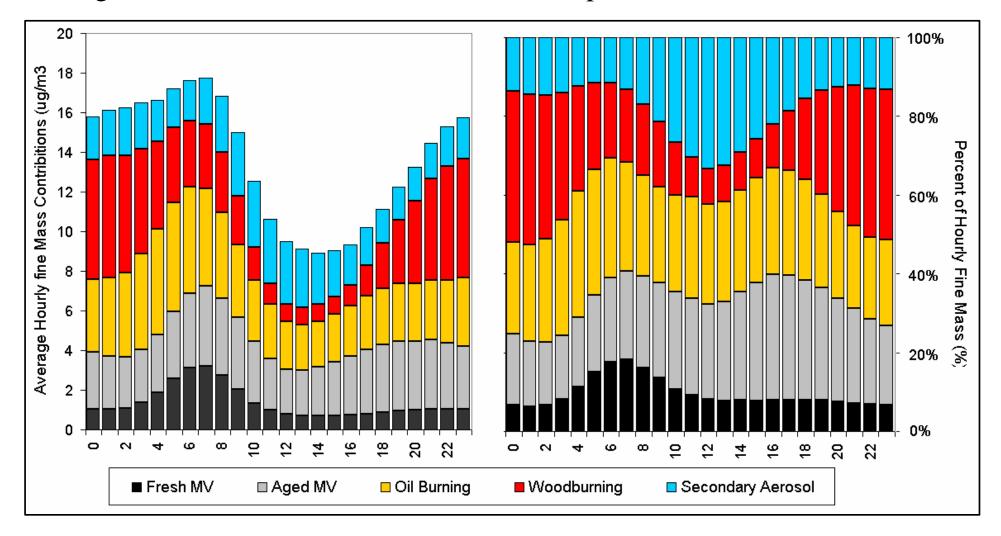**Table 1. Unmix Modeled Source Compositions for Rutland, VT, 2/11/04 - 4/30/04.**

Source Mass Compositions and Gaseous Contributions	Wood Smoke	Oil Burning	Fresh MV	Aged MV	Secondary Aerosol
Average Fine Mass (ug/m3)	3.3	3.5	1.4	3.1	2.3
BC (% Source Mass)	4	3	18	9	0
Delta-C (% Source Mass)	7	0	0	0	0
Non-Vol Mass (% Source Mass)	95	100	99	99	20
Volatile Mass (% Source Mass)	5	0	1	1	80
SO2 (Source % of Total SO2)	12	56	25	4	1
NO (Source % of Total NO)	5	5	81	11	0
CO (Source % of Total CO)	12	1	31	55	2

Take-Home: Aethalometer "Delta-C" (UV-C minus BC) signal:
1. IS specific WS indicator even with substantial local mobile source aerosol, other local combustion-related PM-sources
2. Is NOT a significant or useful indicator of fresh diesel sources
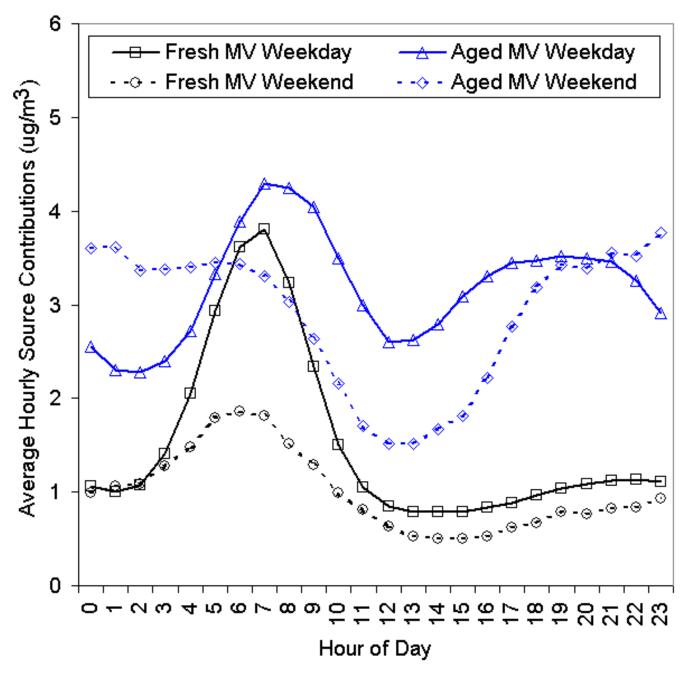   Despite manufacturer's anecdotal examples/claims
    Consistent with many other Aethalometer user observations.

Average diurnal PM2.5 mass contributions and percent contributions:

Motor vehicle sources: distinct morning rush hour peak, smaller afternoon peak. Secondary aerosol source peaks at mid-day; wood and oil combustion sources peak at night (heating fuels); wood source low mid-day.
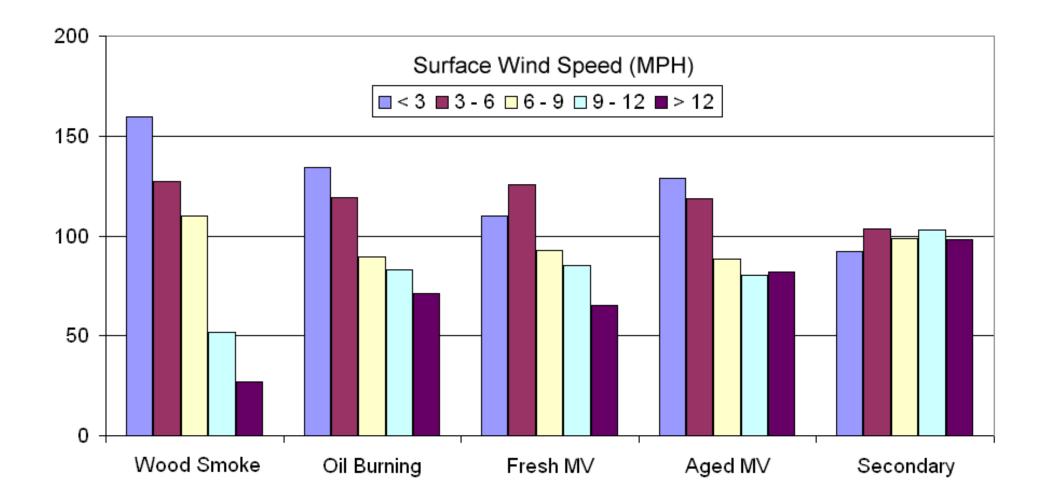
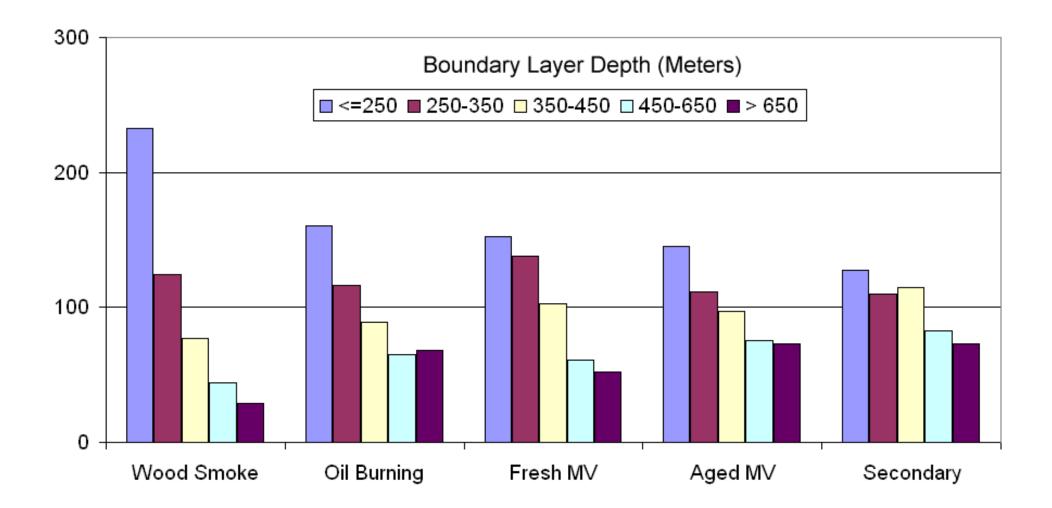# Weekday/Weekend diurnal mobile source influence

Fresh MV source:
Sharp weekday AM-only rush hour peak; weaker weekend peak. Similar pattern seen in many other urban areas.

Aged MV source:
Broader weekday AM and PM peaks, night-time weekend increases; consistent with a more distant (city or valley-wide) influence
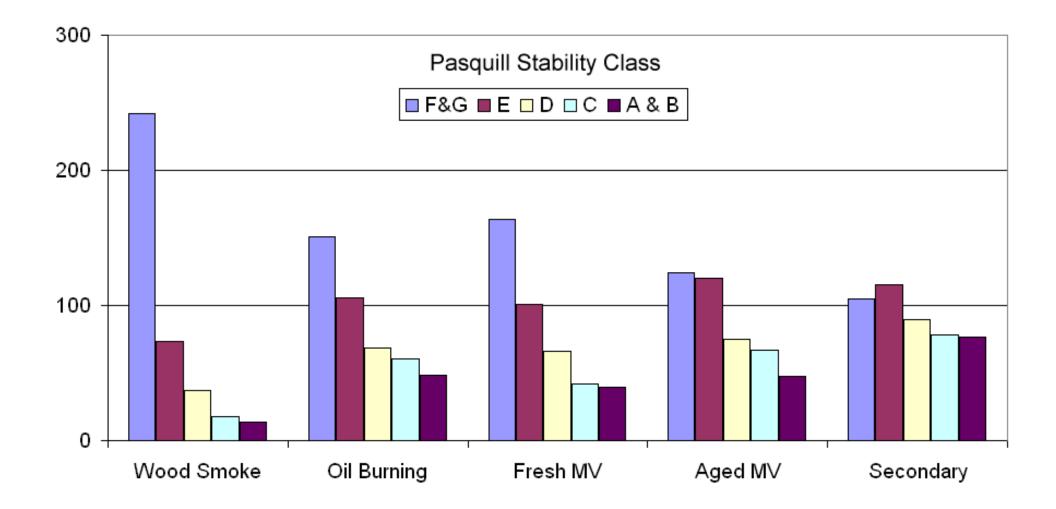
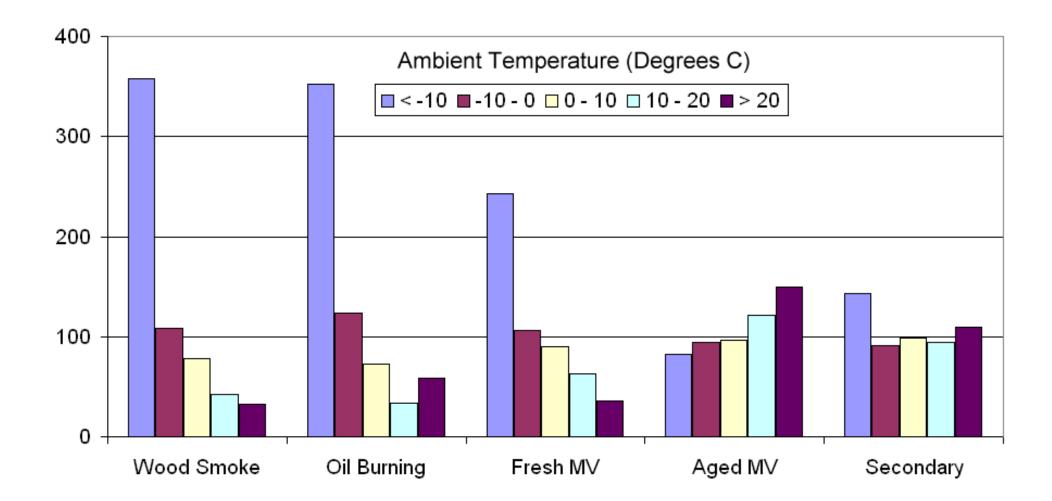# Percentage Change in Average Source Contribution by Surface Wind Speed

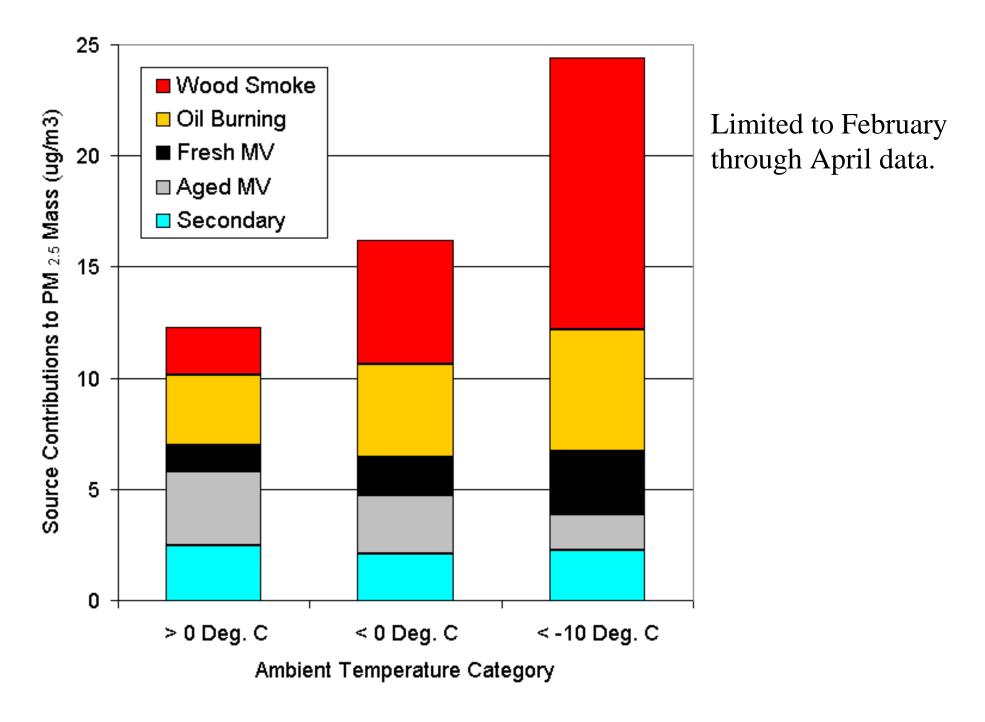Percentage Change in Average Source Contribution by Boundary Layer Depth

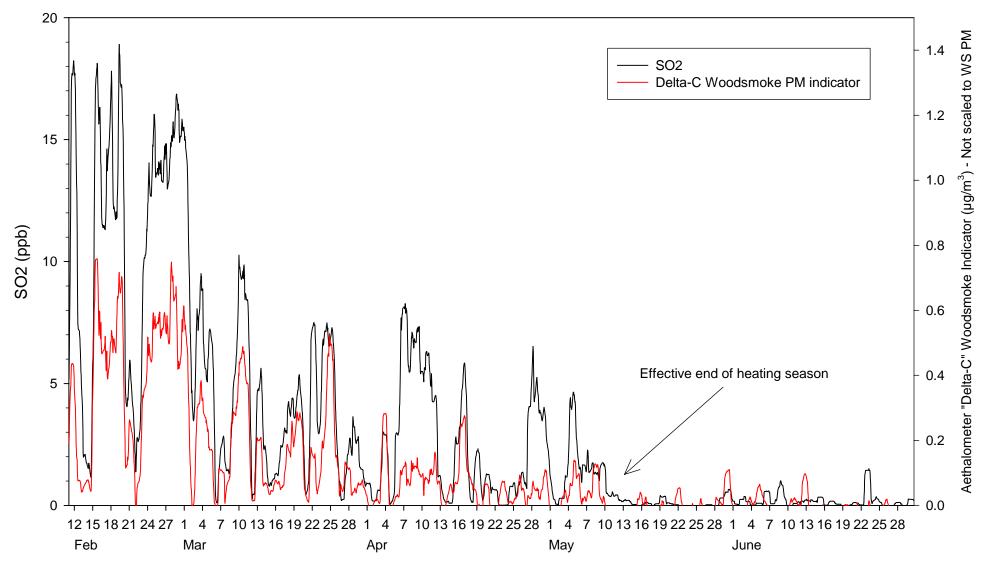# Percentage Change in Average Source Contribution by Pasquill Stability Class

Percentage Change in Average Source Contribution by Ambient Temperature

Source categories contribution to PM2.5 by temperature.

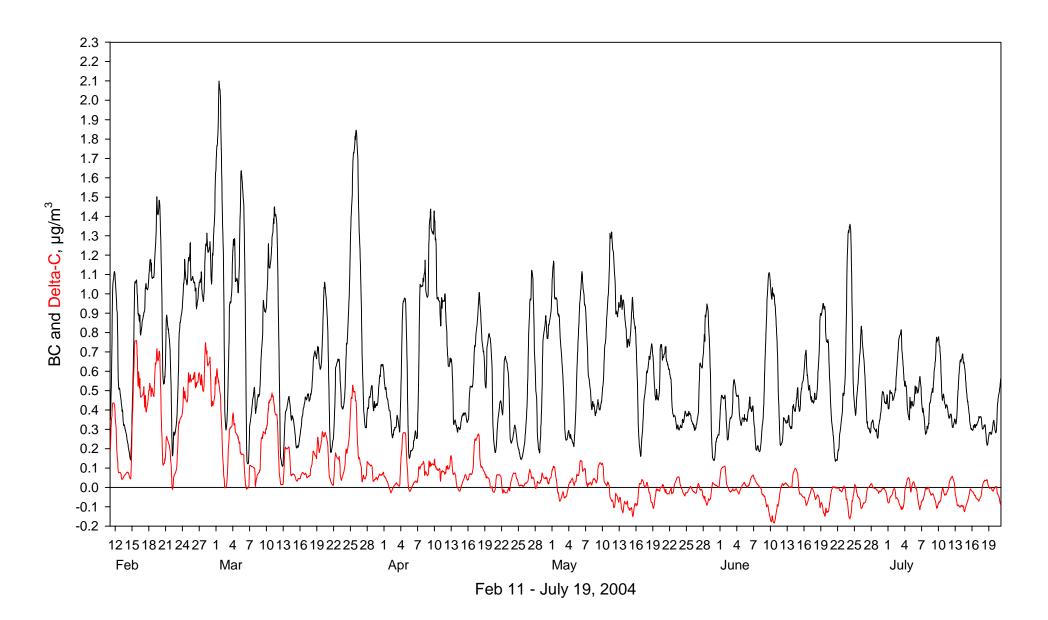Limited to February through April data.

SO2 and Delta-C 24-hour running average (February through June, 2004)
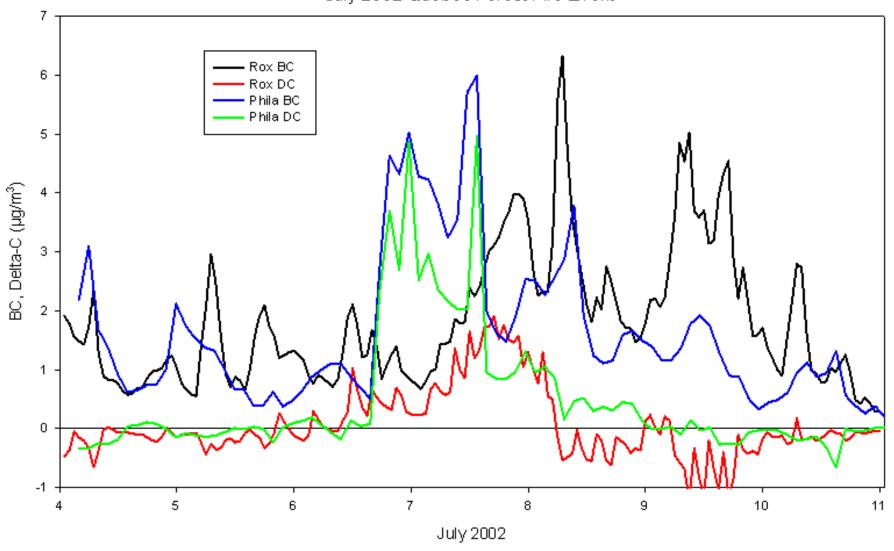SO2 is primarily local oil burning; DC is Wood smoke

February 11 - June 30, 2004

BC and Delta-C 24-hour running average (February to July, 2004).

Roxbury and NE Phila BC and DC
July 2002 Quebec Forest Fire Event

Conclusions

- 2-channel Aethalometer Delta-C signal is a <u>specific</u> indicator of WS PM
  → even with substantial local mobile source aerosols and oil burning (!)

- DC x 15 $\approx$ WS-PM → a method for WS related PM2.5 in near real-time
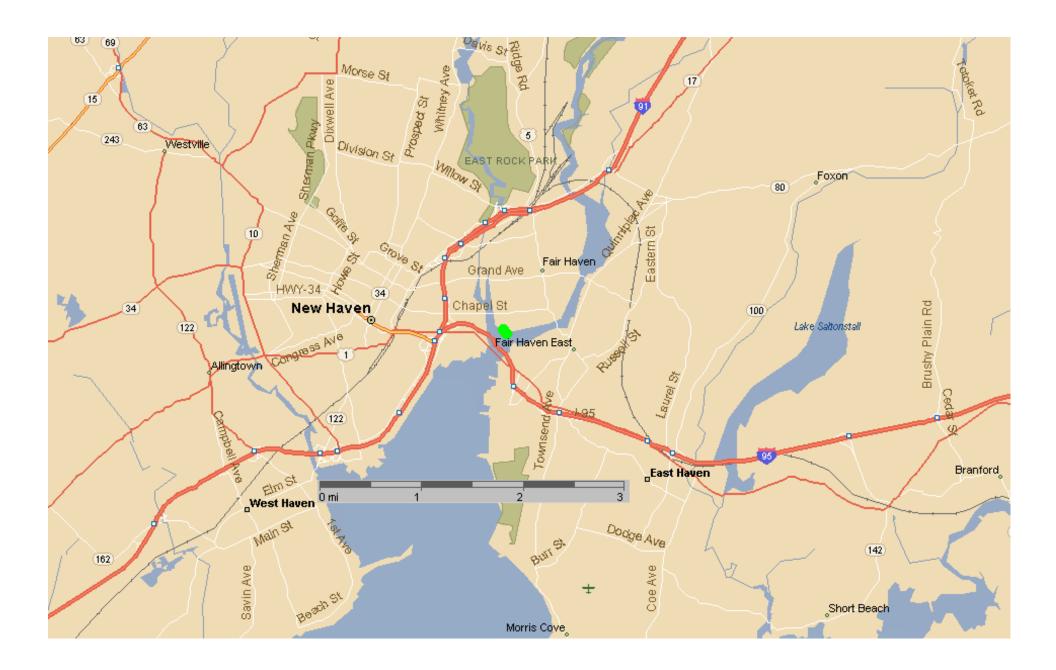
- WS PM measurement improved with collocated PM2.5

Future work:

- Run UNMIX for non-space heating season
  → assess the stability of the mobile source parameters.

- Uncertainty of WS to PM factor not quantified
  → short term basis, across sites, local versus aged WS

- Comparison against more traditional (integrated) WS indicators:
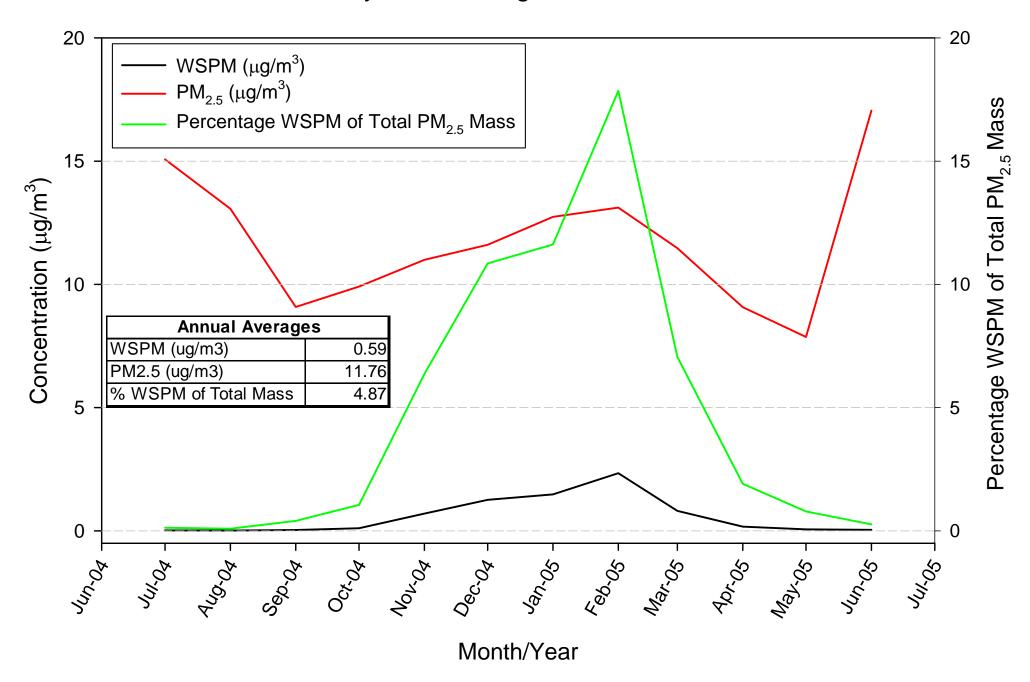 → KNON (non-soil potassium)

More details on the method and results in an 2004 AWMA conference proceedings paper at:

http://tinyurl.com/gqct6

Application of this method at an urban-scale site in New Haven CT for one year:

Wood Smoke Particle Matter (WSPM) and Total PM$_{2.5}$ Mass
Criscuolo Park, New Haven
July 2004 through June 2005

Legend:
- WSPM ($\mu g/m^3$)
- PM$_{2.5}$ ($\mu g/m^3$)
- Percentage WSPM of Total PM$_{2.5}$ Mass

Annual Averages	
WSPM (ug/m3)	0.59
PM2.5 (ug/m3)	11.76
% WSPM of Total Mass	4.87

Y-axis (left): Concentration ($\mu g/m^3$)
Y-axis (right): Percentage WSPM of Total PM$_{2.5}$ Mass
X-axis: Month/Year

CT-DEP/Nescaum Woodsmoke/OWB study:

Fall 2006 - Spring 2008

Two major components:

1. <u>Ambient</u>: Perform contribution assessment of WS to total wintertime PM2.5
    at 6-8 sites throughout CT using the Delta-C method described above

    Primarily rural and small town sites, plus New Haven and Springfield MA
    Can assess scale of WS source at each site using frequency-domain analysis

2. <u>OWB source</u>: Assess real-world OWB stack emissions at 3-4 locations.
    Real-time PM, PAH; cannister toxics
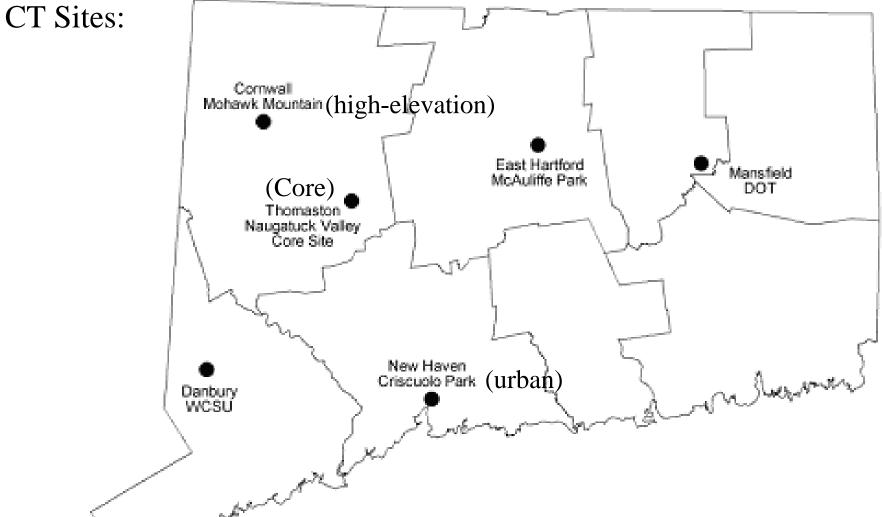   Methods/Locations TBD...

    Phase 1 is lab verification of realtime PM method - this fall.
    Phase 2 is in-use field measurements - this/next winter.

This work expands on Rutland 2004 Pilot Study:

Ambient measurements at 7 sites (6 in CT plus Springfield, MA)

Sampling: 18-20 months (2 winters, one summer)

Other air toxics also measured at some sites:
    some real-time (PAH)
    some integrated (Benzene, Formaldehyde ...)

CT Sites:

Cornwall Mohawk Mountain (high-elevation)

(Core)
Thomaston Naugatuck Valley Core Site

East Hartford McAuliffe Park

Mansfield DOT

Danbury WCSU

New Haven Criscuolo Park (urban)

Cornwall, Thomaston, New Haven have full suite of measurements.
    (SO2, CO, NOx, Aeth, real-time EC/OC and Sulfate aerosol, Met)
Thomaston also has real-time PAH and integrated toxics sampling;
Other sites have at least continuous PM and Aethalometer;
Springfield MA has full suite except real-time EC/OC and Sulfate.