Evaluation of a New Approach to Real-time Woodsmoke Monitoring: a Pilot Study in Rutland VT, Winter 2004

George Allen - NESCAUM
Pete Babich, Rich Poirot - VT DEC

Air Quality Monitoring & Data Analysis
National Conference (aka SAMWG)

Point Clear, AL May 15, 2004

Issue: How can we ID woodsmoke's contribution to PM2.5 with high time resolution?

Approach:

Two-wavelength Aethalometer: BC (880 nm) and UV-C (370 nm)

WS PM has "enhanced" optical absorption at 370 relative to 880

No other significant ambient PM component does this

(Aeth mfg. has sold UV-C as fresh diesel indicator; not true)

Aeth "Delta-C" (UVC - BC) is a very specific "indicator" of WS PM;

Alone is not a quantitative measurement

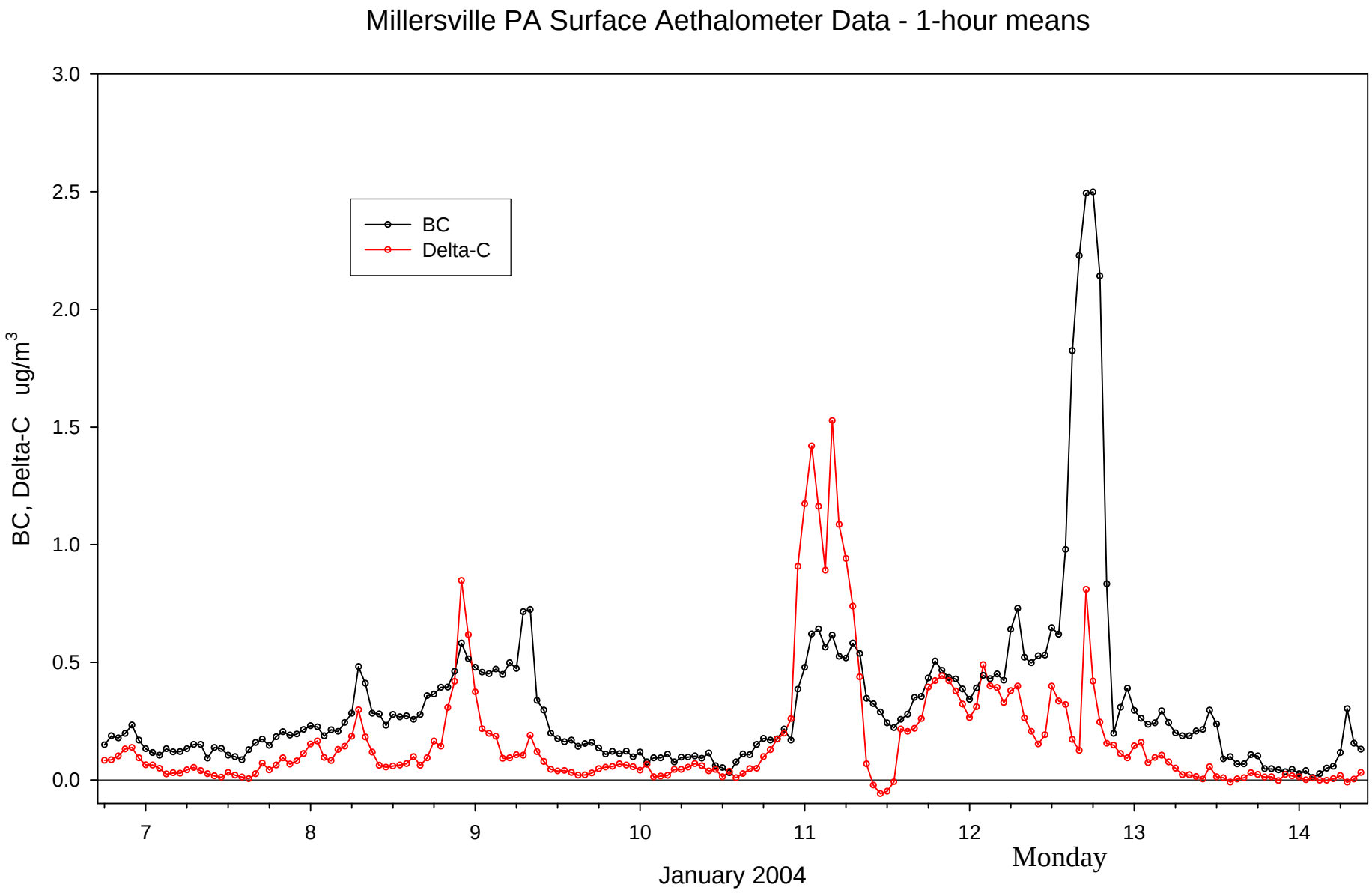
==> May be "semi-quantitative" - TBD in this pilot

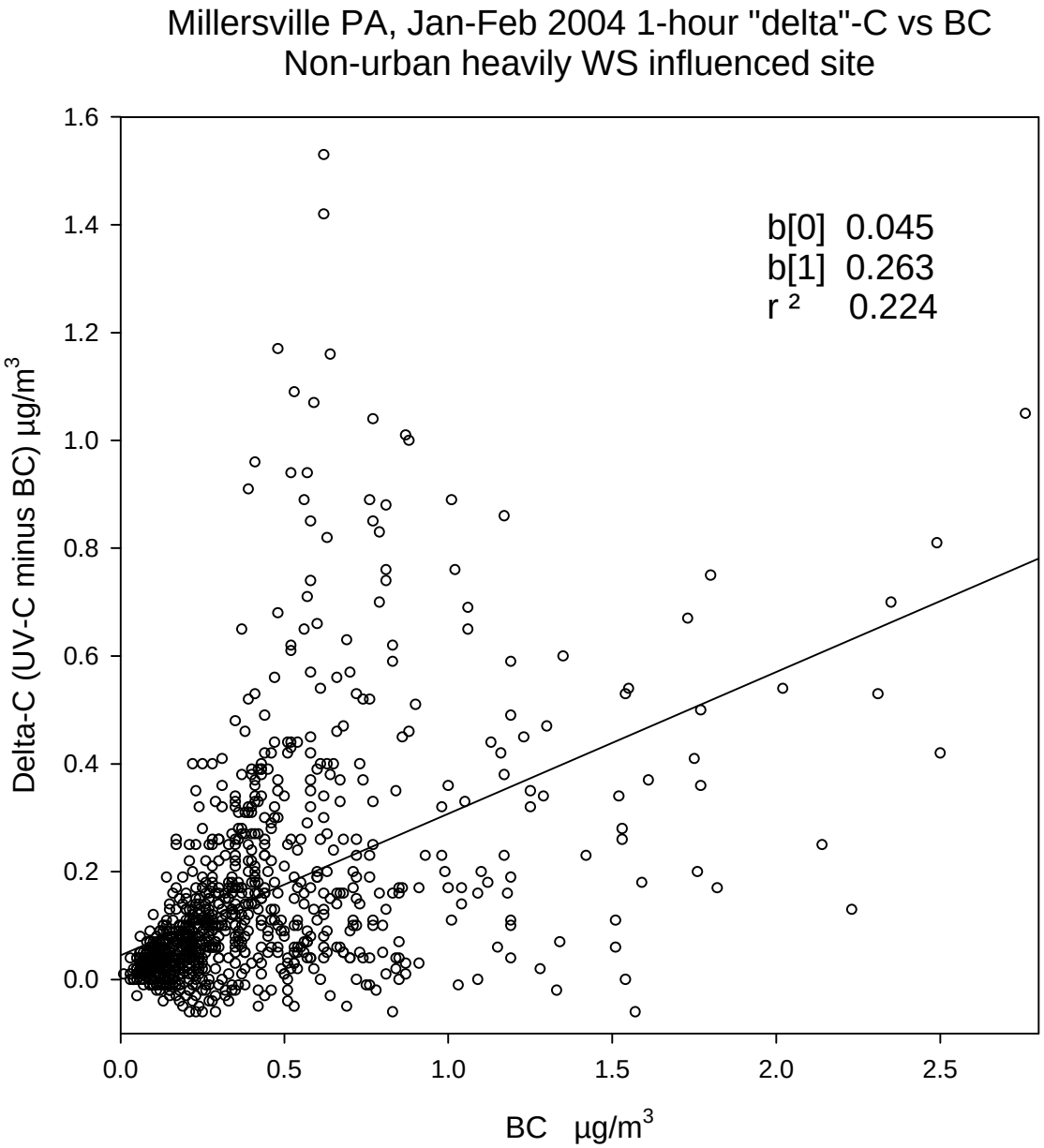
Improve quantitation when collocated with other measurements

Continuous PM2.5

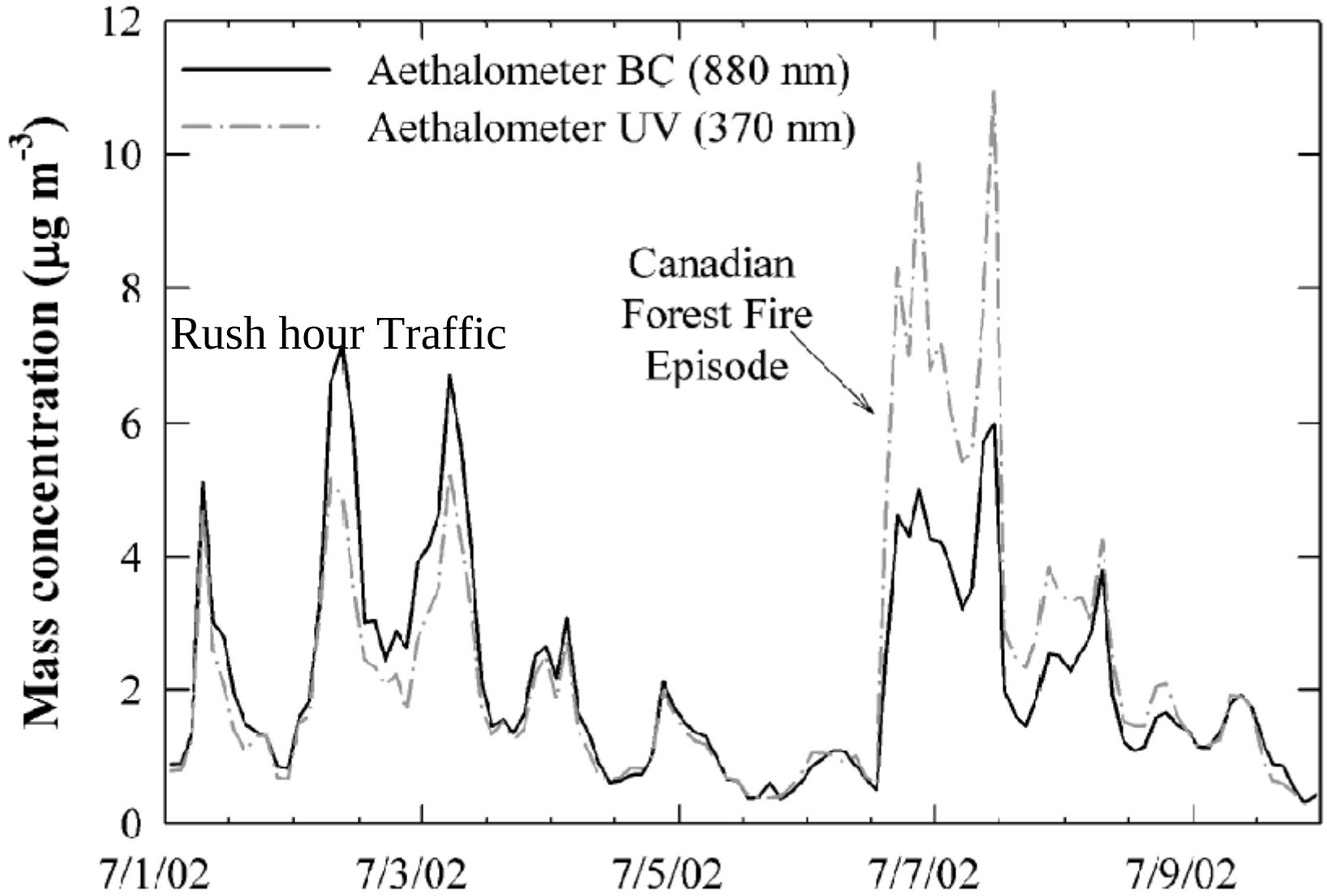
NOx, SO2, CO, continuous Organic Carbon, SO4, NO3

Examples of WS signatures from earlier work (Mane-Vu, Hopke):


Millersville PA Surface Aethalometer Data - 1-hour means
BC
Delta-C
BC, Delta-C ug/m3
3.0
2.5
2.0
1.5
1.0
0.5
0.0
7
8
9
10
11
12
13
14
January 2004
Monday


Millersville PA, Jan-Feb 2004 1-hour "delta"-C vs BC
Non-urban heavily WS influenced site
b[0] 0.045
b[1] 0.263
r ² 0.224
Delta-C (UV-C minus BC) µg/m3
BC µg/m3
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
0.0
0.5
1.0
1.5
2.0
2.5

Source: Hopke et. al. (2004)



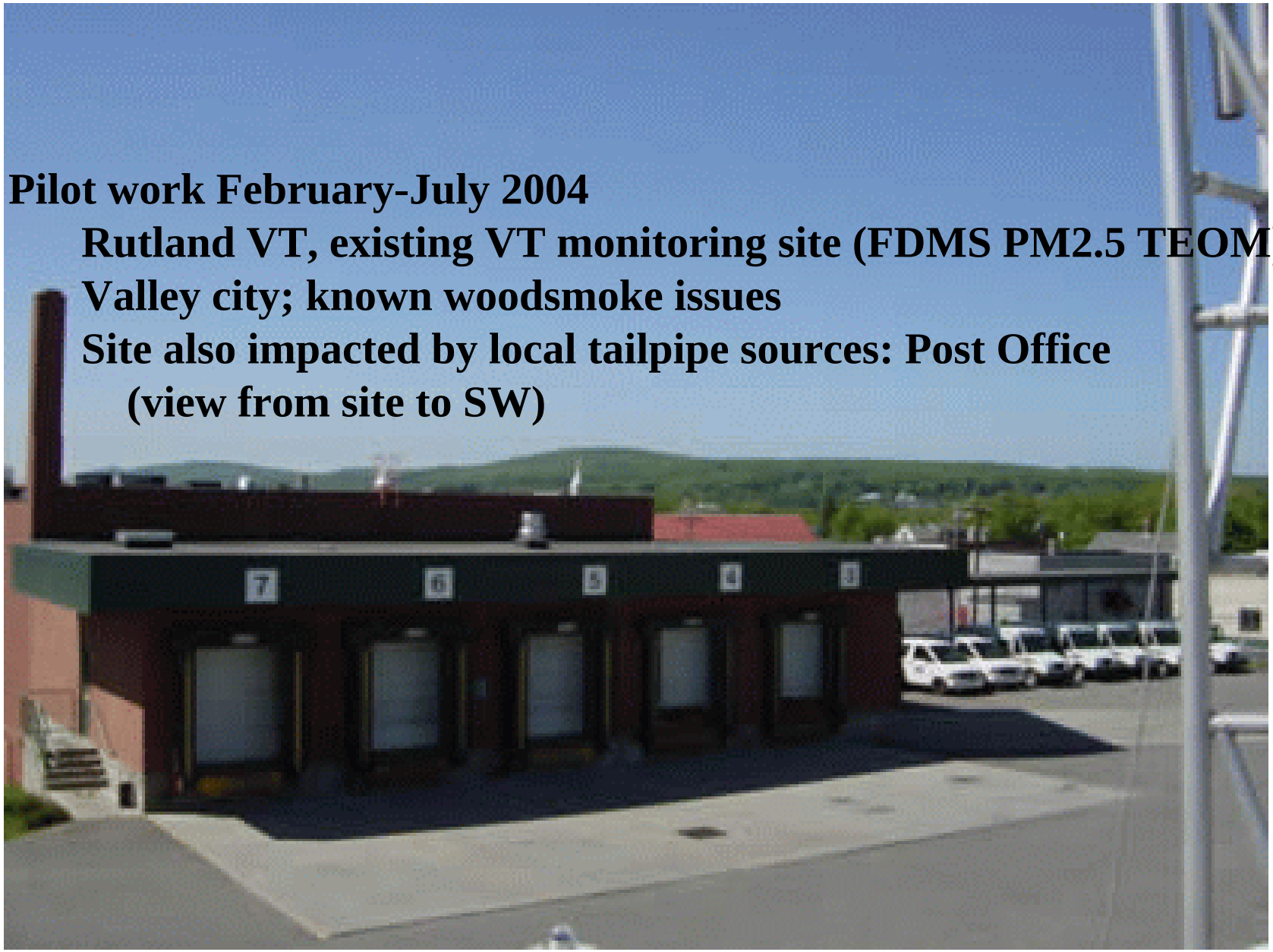
Pilot work February-July 2004

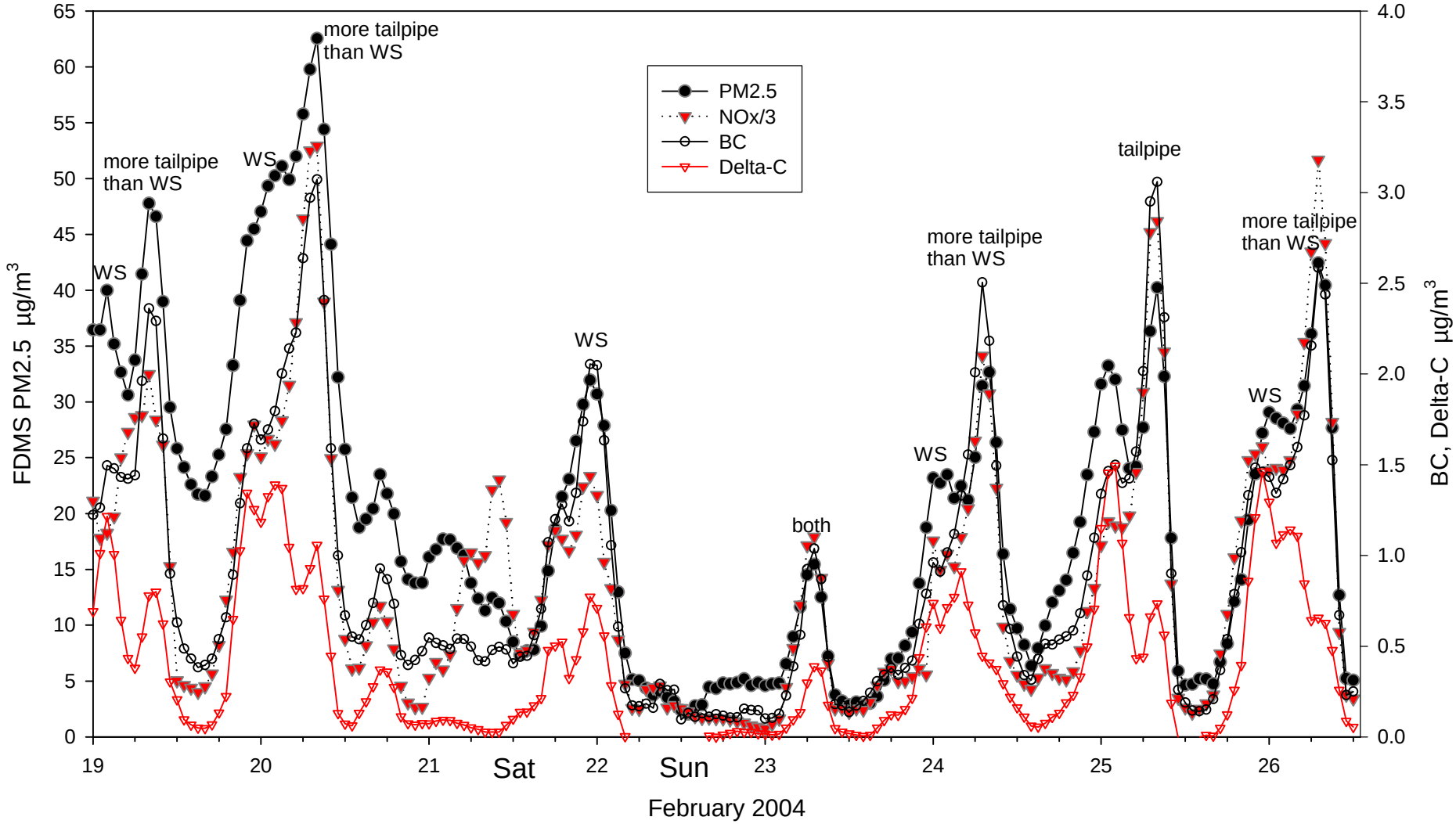
Rutland VT, existing VT monitoring site (FDMS PM2.5 TEOM)

Valley city; known woodsmoke issues

Site also impacted by local tailpipe sources: Post Office

(view from site to SW)




Rutland VT Woodsmoke, Week 2
3-hour running averages
PM2.5
NOx/3
BC
Delta-C
more tailpipe than WS
WS
more tailpipe than WS
WS
more tailpipe than WS
WS
both
WS
more tailpipe than WS
tailpipe
WS
more tailpipe than WS
FDMS PM2.5 µg/m3
BC, Delta-C µg/m3
0
5
10
15
20
25
30
35
40
45
50
55
60
65
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
19
20
21
Sat
22
Sun
23
24
25
26
February 2004

Model hourly FDMS Teom PM using BC, delta-C, and NOx
to determine an average mass coefficient for delta-C
(for locally generated WS)

BC is both local tailpipe signature and WS; tailpipe dominated
Delta-C is WS signature only
NOx is primarily tailpipe, and presumably some WS

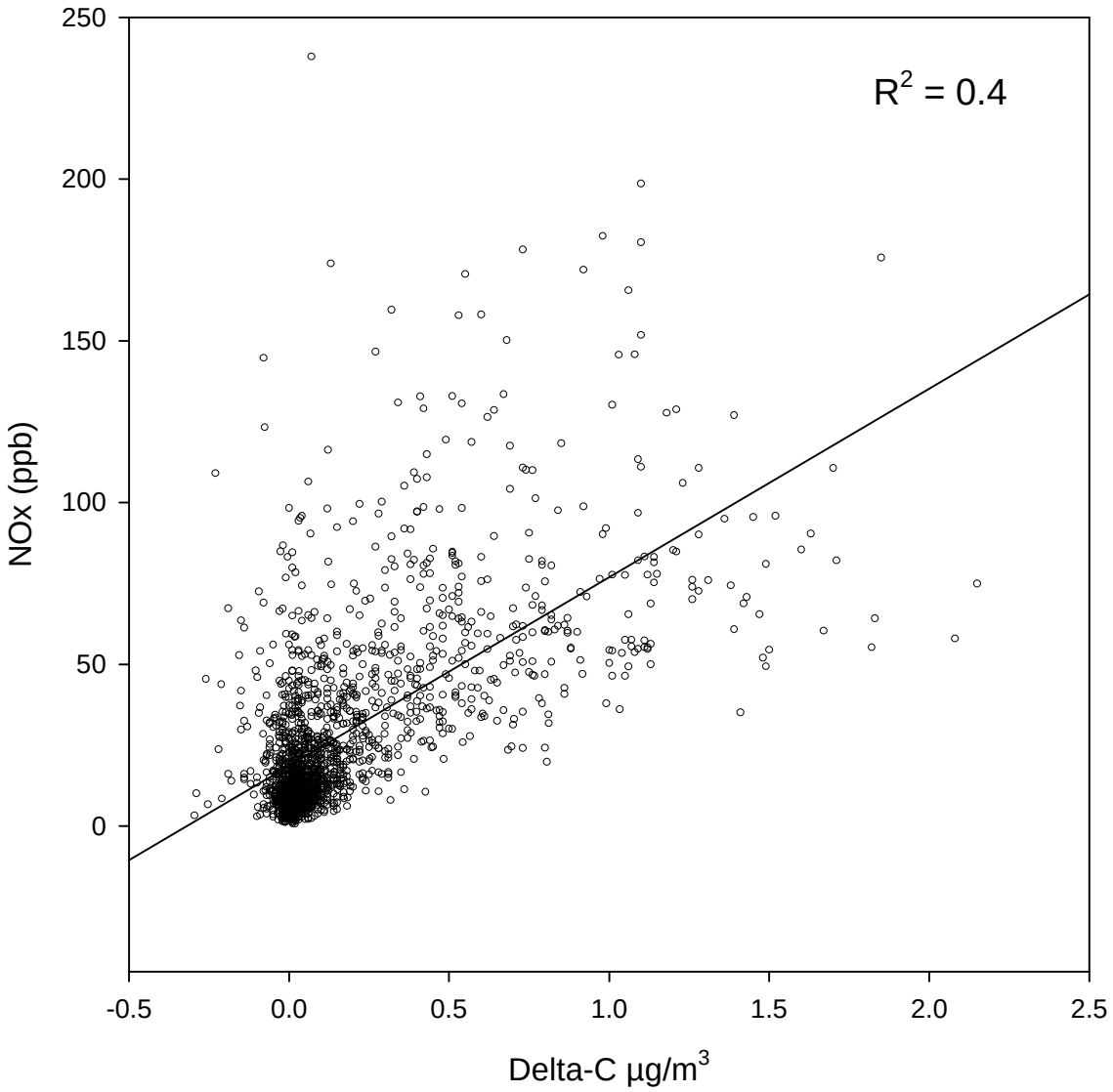
Try various forms of multivariate linear regressions
make physical sense
reasonably independent input variables
reasonable model correlation
broadest model application

Evaluate range of delta-C coefficient:
how sensitive is it to model form?

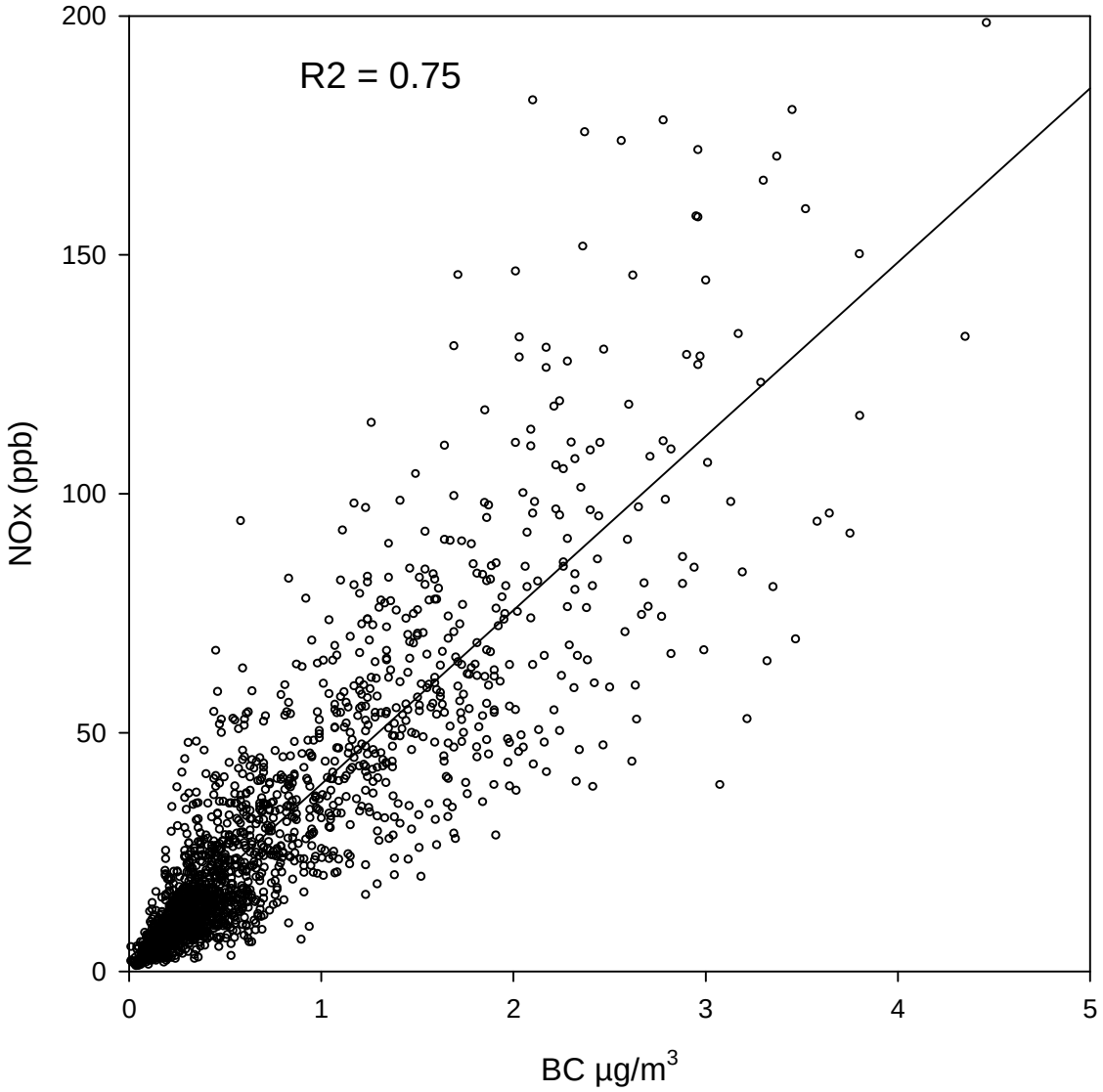
Association between hourly input variables (cold wx season only):

Data Pair	R2
BC/NOx	0.75
Delta-C/NOx	0.40
BC/Delta-C	0.34
BC/UV-C	0.92 (not used)

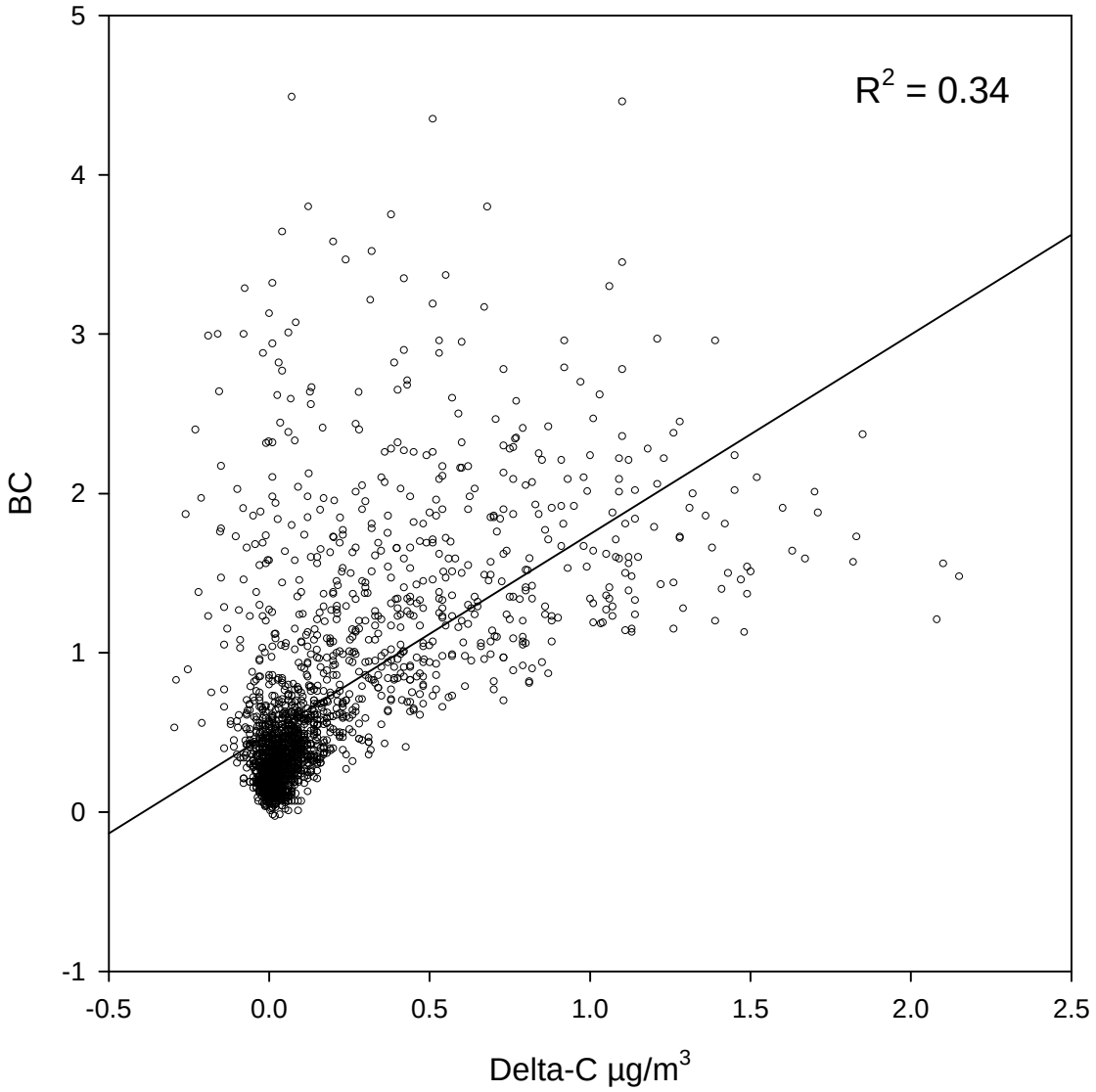
NOx vs. Delta-C



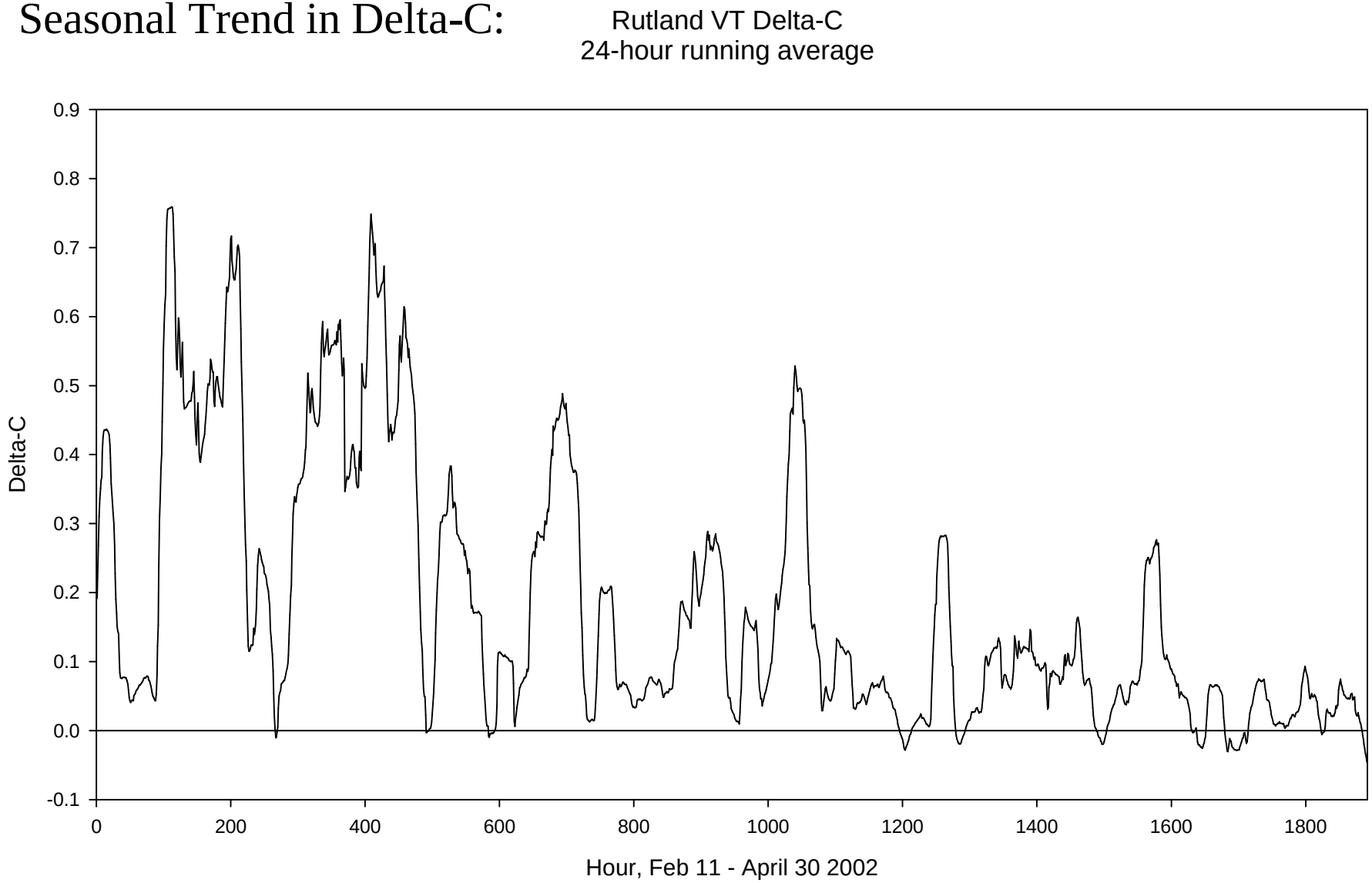
NOx vs. BC


Rutland VT Feb 11 to April 30 2004 1-hour means
R2 = 0.75
NOx (ppb)
BC µg/m3
0
50
100
150
200
0
1
2
3
4
5

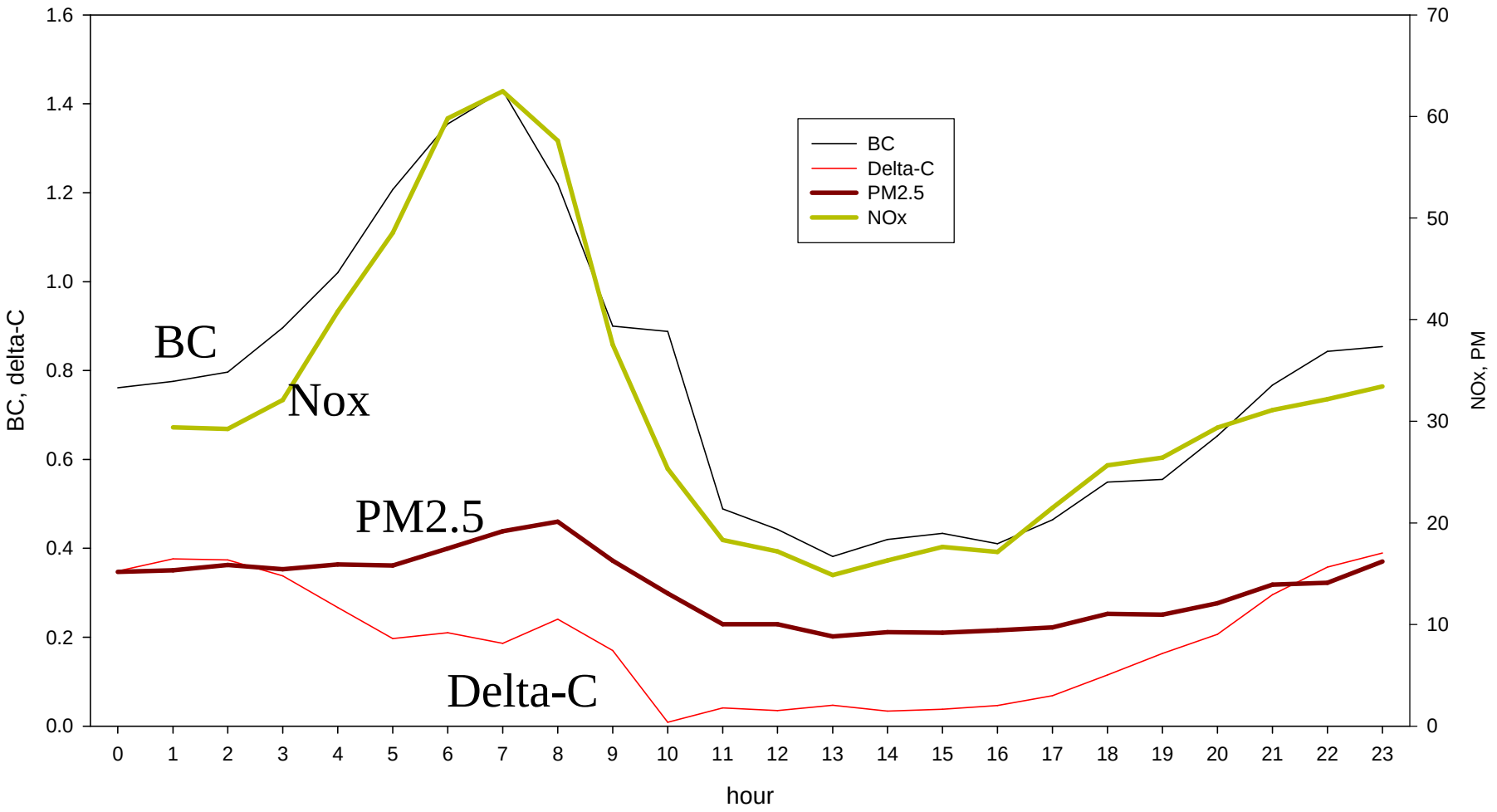
BC vs. Delta-C


Rutland VT Feb 11 to April 30 2004 1-hour means
R^2 = 0.34
BC
Delta-C µg/m^3
5
4
3
2
1
0
-1
-0.5
0.0
0.5
1.0
1.5
2.0
2.5

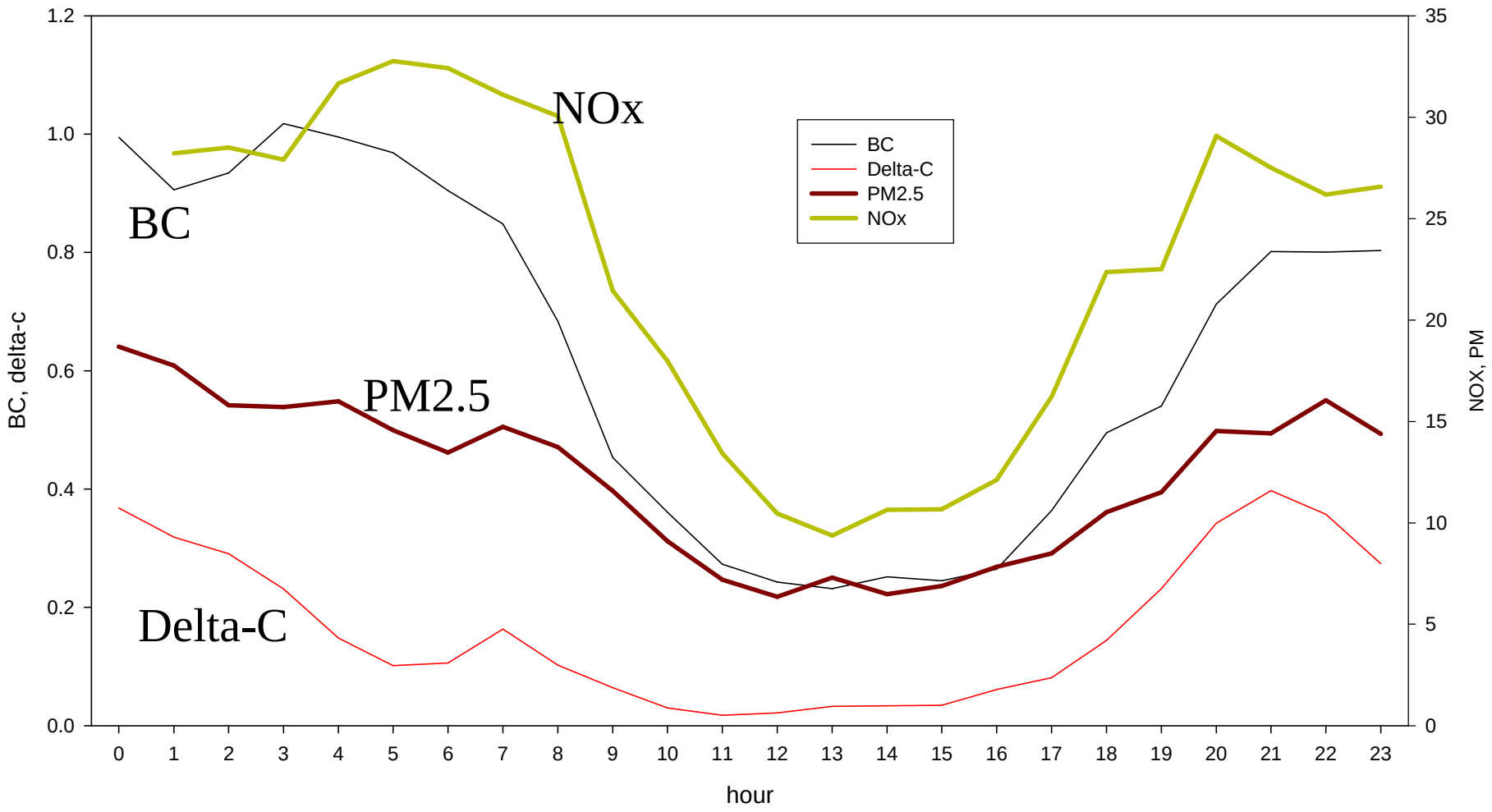
Seasonal Trend in Delta-C:



Weekdays:


Rutland Diurnal Weekdays, Feb 11 to April 30, 2002
BC
Delta-C
PM2.5
NOx
BC
Nox
PM2.5
Delta-C
BC, delta-C
NOx, PM
hour
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
0
10
20
30
40
50
60
70
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

Weekends:


Rutland Diurnal Weekends, Feb 11 to April 30, 2002
NOx
BC
PM2.5
Delta-C
BC
Delta-C
PM2.5
NOx
BC, delta-c
NOX, PM
hour
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
5
10
15
20
25
30
35
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

Simple multivariate linear regression hourly model results:

Model	Delta-C WS term	Model R2
NxBcDc	9.7	0.68
NxDc	10.7	0.64
NxBcDcTmp	11.3	0.69
BcDc	11.3	0.67
NxDcTmp	12.9	0.66

(intercepts range from 4 to 5 µg/m^3)

Dc only	23.3	0.44

Nx: Nox
Bc: BC
Dc: Delta-C (UV-C minus BC)
Tmp: Ambient Temperature

First “quick and dirty” UNMIX results, with every parameter available:

Three resulting sources

1. Motor Vehicle (strong weekday AM peak & high NOx)
2. Woodsmoke (strong late evening peak, higher on weekends)
3. Everything else not directly measured:
    transport & some mid-day secondary (sulfate, other OC)
    high volatile fraction (NO3?)

This “makes sense” for Rutland PM in the winter.

"woodsmoke" source:
    moderate negative correlation with temperature (-0.45)
    strong positive correlation with "delta C" (0.98)

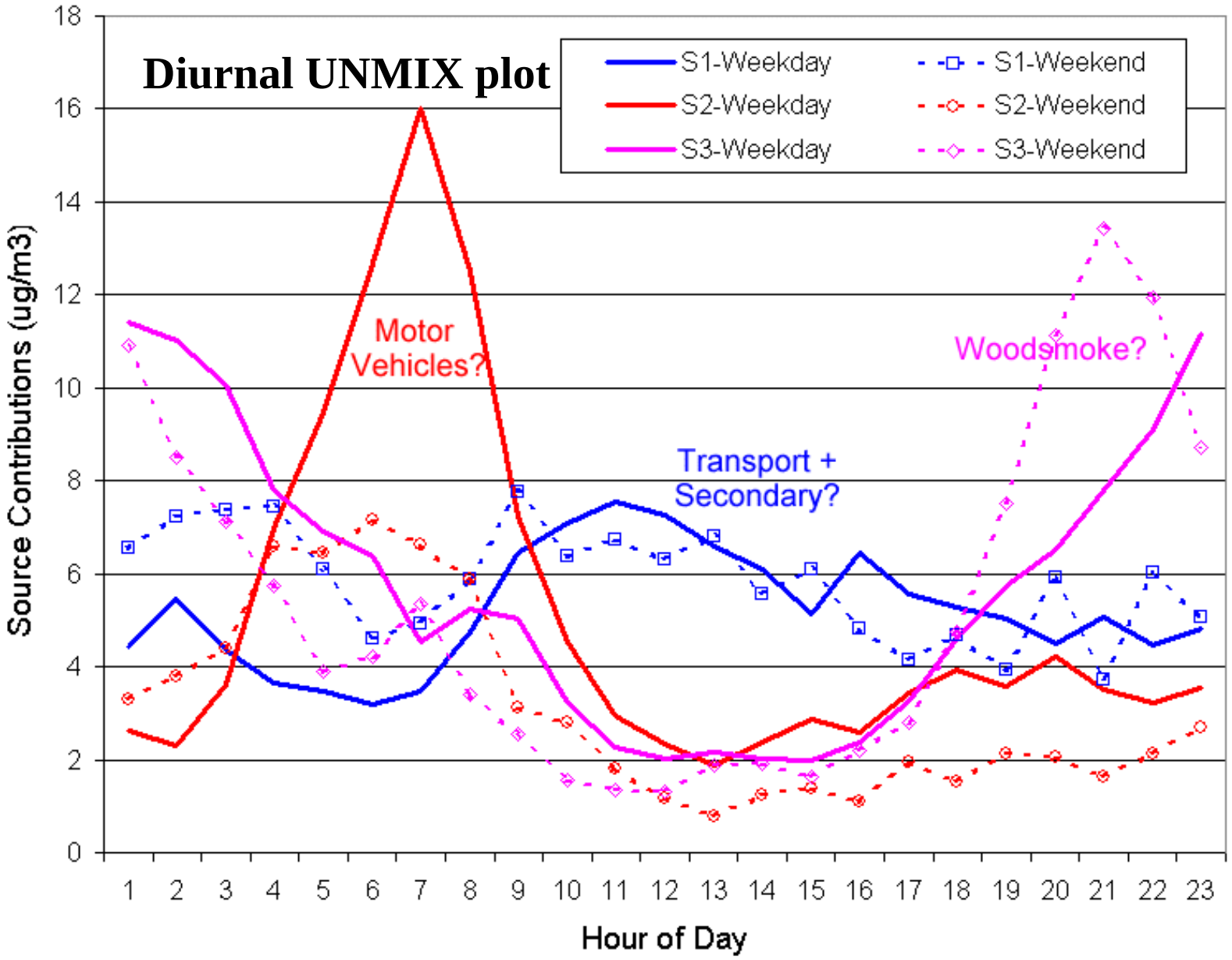
Prelim Rutland VT UNMIX Sources Compositions & Diurnal Patterns, 2/12/04 - 4/30/04

	Source 1	Source 2	Source 3
fdms_PM2.5	5.5 ug/m3	4.5 ug/m3	5.6 ug/m3
30C_PM2.5	64%	93%	93%
svm_PM2.5	36%	7%	7%
BC	3%	8% <======>	5%
UVC	1%	9%	9%
Delta-C	0.0%	0.4% <======>	4.5%
NO	-45%	286%	70%
NOx	38%	412%	191%
BC/UVC	1.7	1.0	0.5
Vol/NonVol	0.6	0.1	0.1
	Transport + 2ndary	Motor Vehicle	Woodsmoke

Quantitative estimate of woodsmoke PM-2.5 mass: about 20 x Delta-C

Likely over-estimate (high-end bound) because of limited inputs

On a monthly basis, average woodsmoke mass concentration declined from about 9.5 µg/m^3 in Feb to 2.5 µg/m^3 in April.


Diurnal UNMIX plot
S1-Weekday
S1-Weekend
S2-Weekday
S2-Weekend
S3-Weekday
S3-Weekend
Motor Vehicles?
Transport + Secondary?
Woodsmoke?
Source Contributions (ug/m3)
Hour of Day
0
2
4
6
8
10
12
14
16
18
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

Conclusions

Delta-C is a very specific indicator of WS

even in areas with strong local mobile source influence

Range of scaling to WS PM is probably between 10 and 20x DC

Actual value is expected to vary with composition by up to 2x

Aged vs local may be different; this work = local

Hopke July 2002 Quebec smoke BC/UVC plot:

Delta-C hourly data peaks approx 6 µg/m^3

Sunset Labs 2-hour raw C as OC peaks approx 45 µg/m^3

Assume factor of 2, OC mass approx 90 µg/m^3

DC to WS PM factor from these data is approx 15

reasonably consistent with Rutland work

Not local, but may not be representative of aged WS either

Next Steps:

Wait for warm weather data

- continue measurements into early July 2004
- use as control when there is no WS

Refine analysis -- UNMIX and other approaches

- Run XRF on FRM filters for WS indicators, sulfate, etc.
- Add SO2 and CO (available at Rutland)