

Empirical Evaluation of the Aethalometer Spot
Saturation Effect on Ambient Air Using a
Thermodenuder:
Study Design and Preliminary Results

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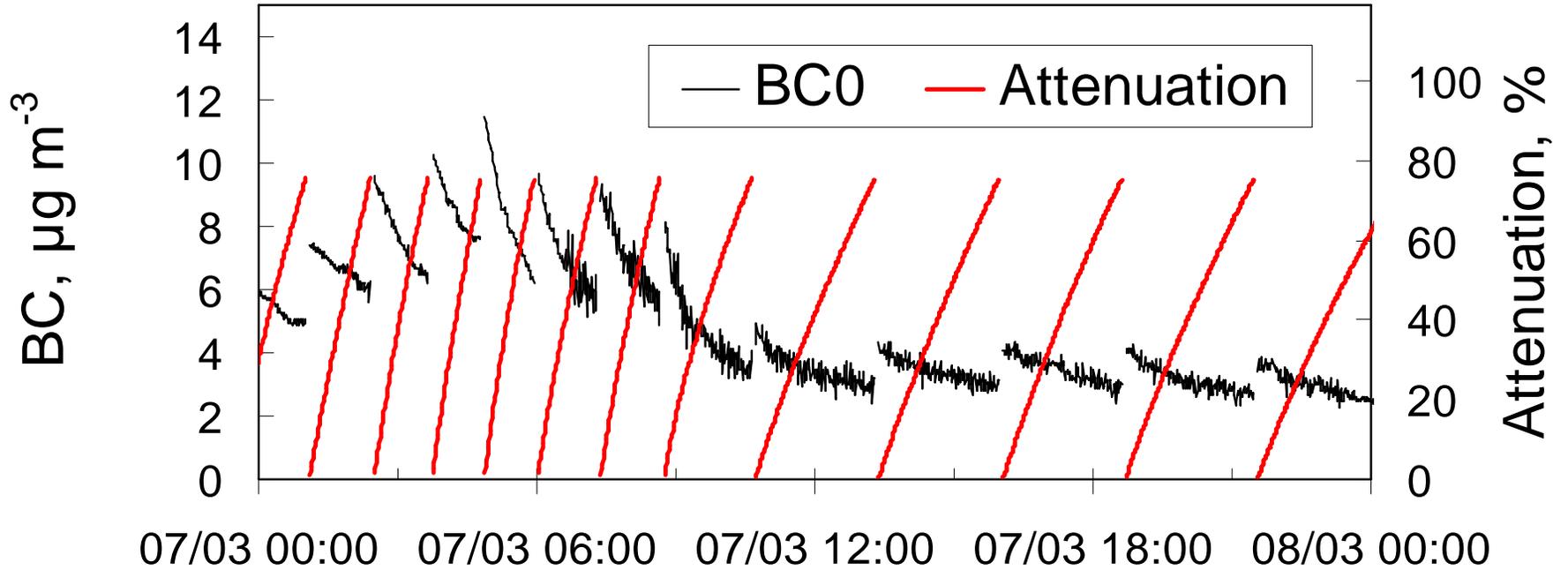
Washington University in St. Louis

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Introduction

- Magee Scientific Aethalometer™: widely used method to monitor atmospheric black carbon (BC) -- optical attenuation on quartz fiber tape
- Several recent articles have shown that reported BC typically decreases with increased spot loading -- saturation effect, function of aerosol matrix
- Jan. 2005 AS&T: 2002 Reno Aerosol Optical Study articles helped clarify the saturation issue (Arnott et al. and others)
- Turner et al. AWMA-2007 SFO Methods Conference paper outlines the background of current work
- Virkkula presented a simple approach to BC data correction
 - IAC/AAAR 2006 meeting, October 2007 JAMWA
 - forms the basis of correction approach used here
 - similar to Kirchstetter and Novakov, Atmos. Environ., 2007



From: Virkkula et al., IAC/AAAR-2006 #14.A4

- This talk: preliminary examination of this effect with Boston MA ambient air during the summer using a range of Aethalometer operating conditions
- Use these data to inform development and evaluation of correction algorithms in post-processing software (the WU-AQL “Data Masher”)
- TSI [Topas] 3065 thermodenuder at 400C and 2-LPM used to remove a substantial fraction of the scattering aerosol on one Aethalometer
 - makes the urban aerosol more “winter” like (less scattering material)
 - limitations of the 3065 are acknowledged...
- Spot loading effect is quantified for 4 other collocated instruments with different Max-Attn settings (15 to 125)
 - data from “15” not used in this preliminary analysis
 - more spot changes, but much smaller pre/post change signal
 - very different; will prove useful in final analysis (once we understand it!)
- B-scat collocated measurements were also made (DR-4)
 - explains some trends in BC artifact

- Virkkula-like data compensation method is examined
 - over a range of operating conditions
- “K” value is developed for each spot change to match old and new spot data
 - correction is function of Attn for each data point
 - = $BC * (1+K*Attn)$
 - smoothed K values typically range from about 0.001 to 0.01
 - K of .004 and attn of 125 = $BC * 1.5$
 - K of .01 and attn of 125 = $BC * 2.25$
- Influence of changes in Aeth filter RH on BC blank response are examined
 - may be the dominant source of noise in current generation Aeths
 - short-term noise degrades this correction process

Measurement Methods:

5 Aethalometers run collocated in Boston, MA June 11 - Sept. 21, 2007

All on a 1-min timebase, single channel configuration (BC only):

1. Small spot 2 lpm with Thermodenuder, max attn = 50
2. Small spot 2 lpm, nafion drier (minimize DP related noise), max attn = 75
3. Small spot 4 lpm, max attn = 75
4. Small spot 4 lpm, max attn = 125
5. Large spot 4 lpm, max attn = 15 (should have minimal spot loading effect)

In this mode, a spot change results in only 5 minutes of missing data.

-- shorter data gap = better correction

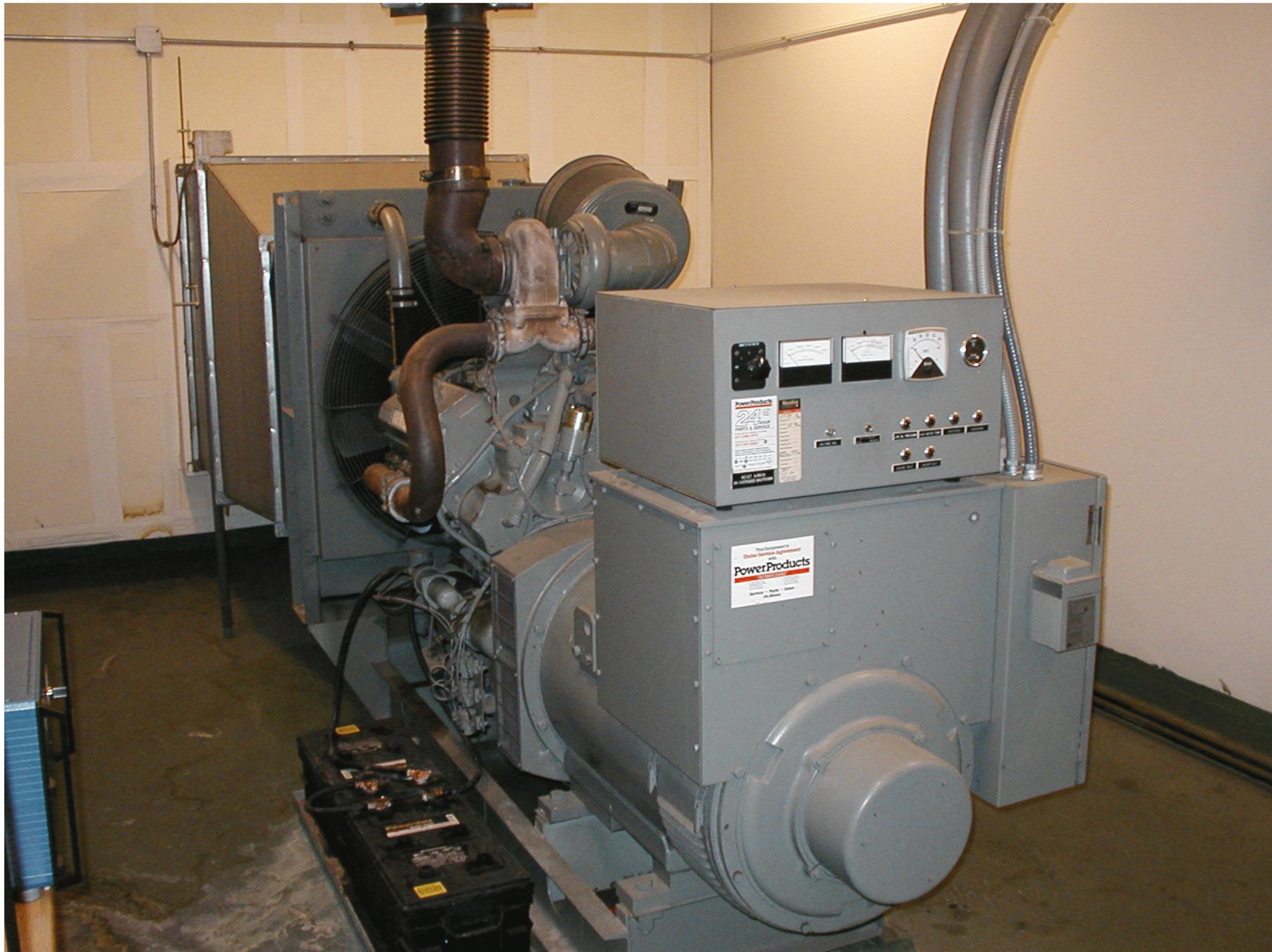
-- no “new spot effect” observed on dynamic blanks after 4 minutes

Other measurements:

Thermo DR4 run in scattering mode, size corr. off (wavelength unclear...)

1-min on-site I/O temp, RH, and dewpoint

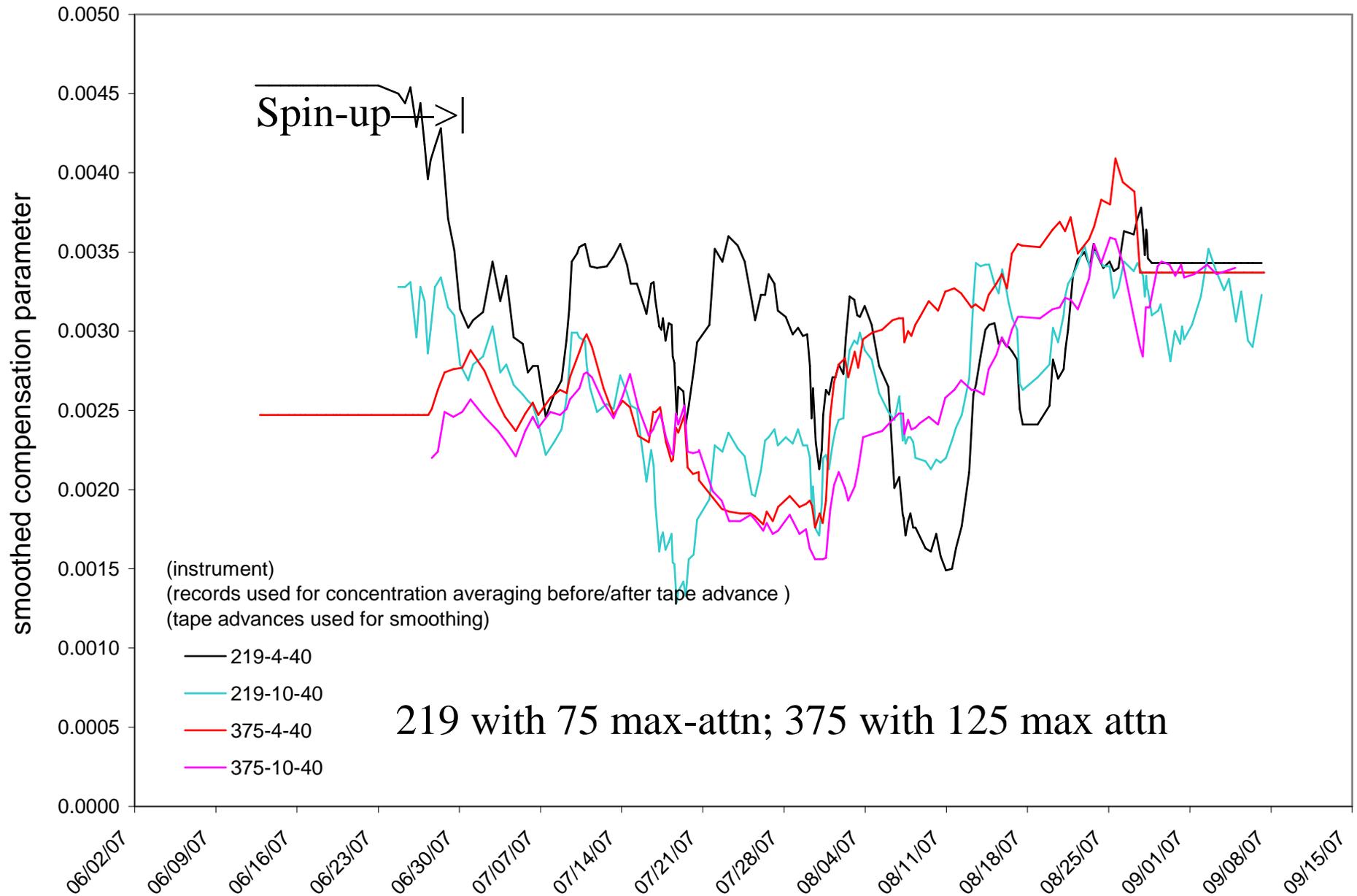




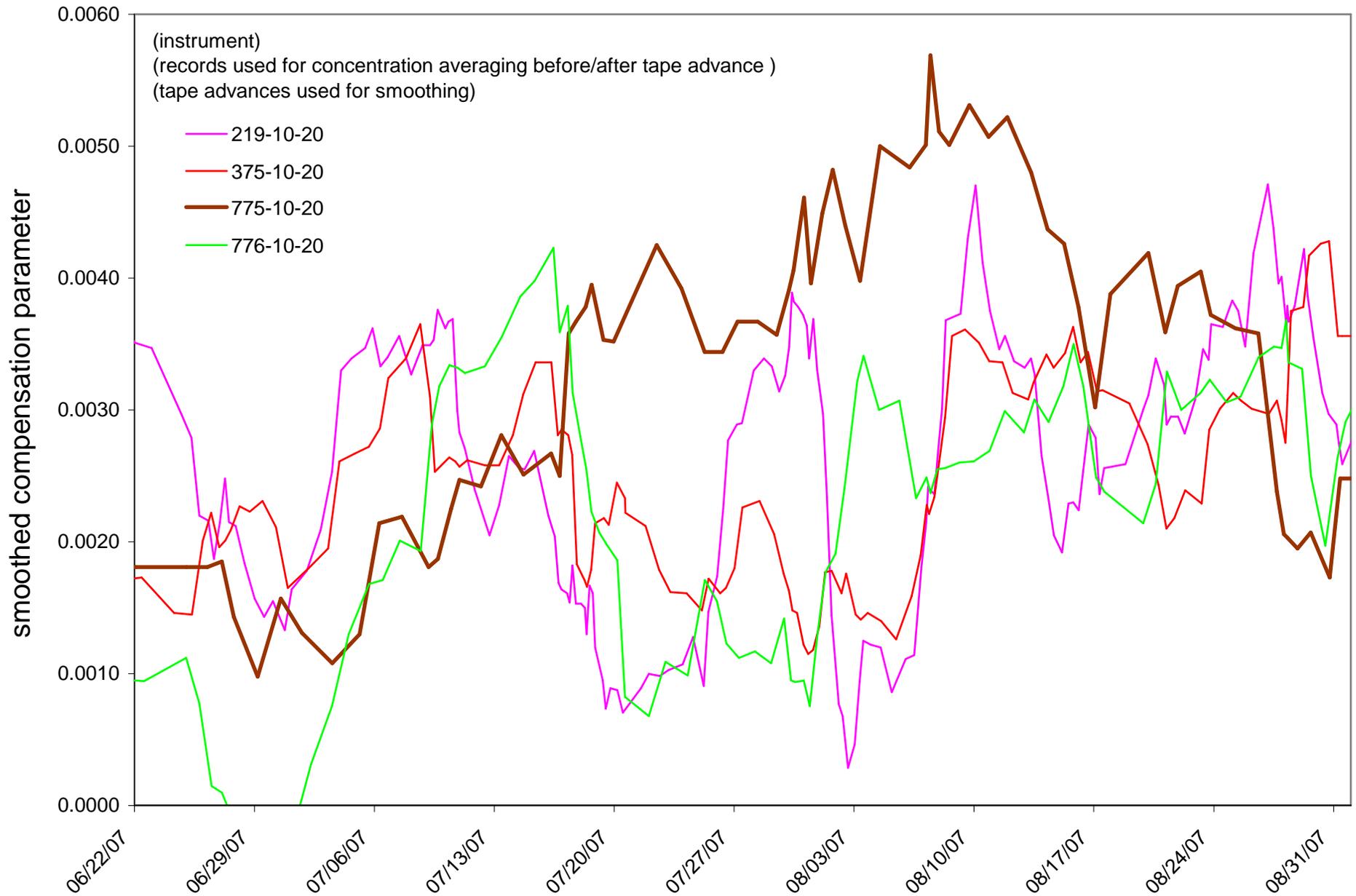
Data processing methods:

- Custom version of WU-AQL Aeth data masher
 - process 1-min data to 5 and 60 min means
 - generate and apply correction factors with different parameters
 - [a] # of 1-min datapoints used for pre and post spot change means
Varies from 4 to 10 minutes; each creates a raw per-spot K factor
 - [b] # of spot changes used to create running mean K for data correction
Varies from 10 to 40
- Varying these parameters changes both the dynamics and precision of “K”

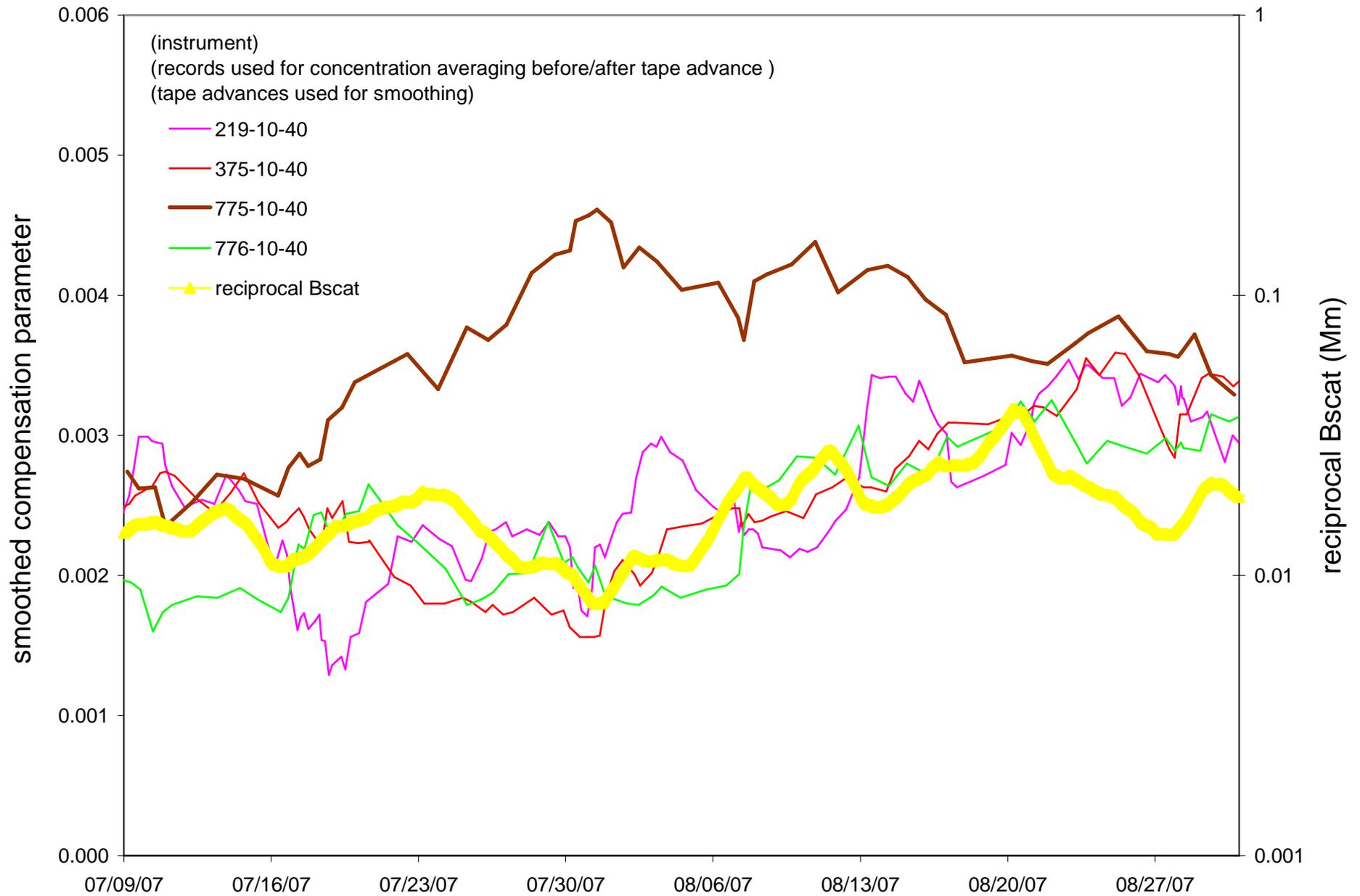
Effect on K of 4 vs. 10 minute average; 40-spot smooth
This needs further analysis to properly optimize.



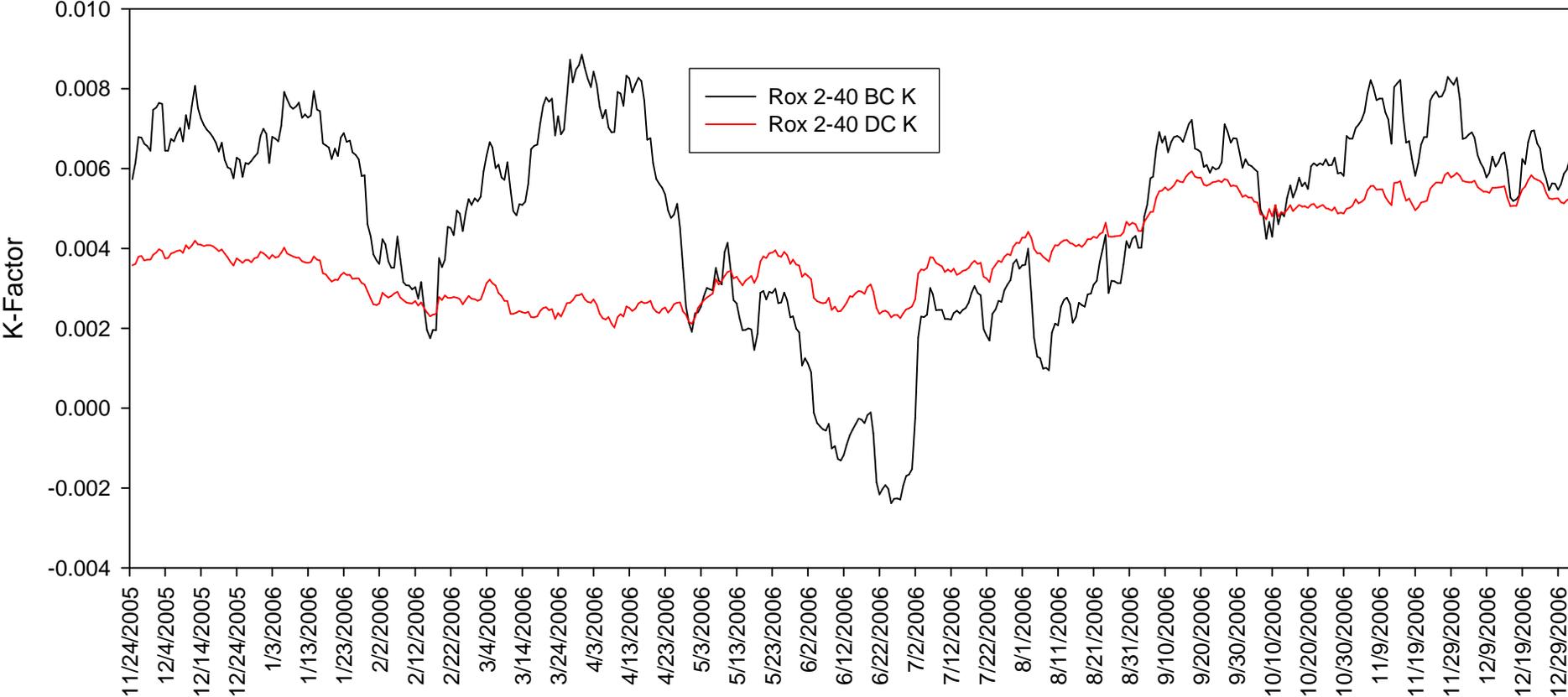
Fully "spun-up" 10-20 smoothed K factor: 3 non-TD and 1 TD Aeths: Noisy...



Fully "spun-up" 10-40 smoothed K factor: 3 non-TD and 1 TD Aeths; 1/Bscat



Roxbury 2006 Aethalometr K factors (2-40 smooth)



Roxbury Aethalometer 21-Day Running Average 11/24/06 - 1/14/07



Humidity Effects on Transient Instrument Noise:

Initial project tests: excessive short-term (1-5 min) dynamic blank noise with stable instrument temperature environment

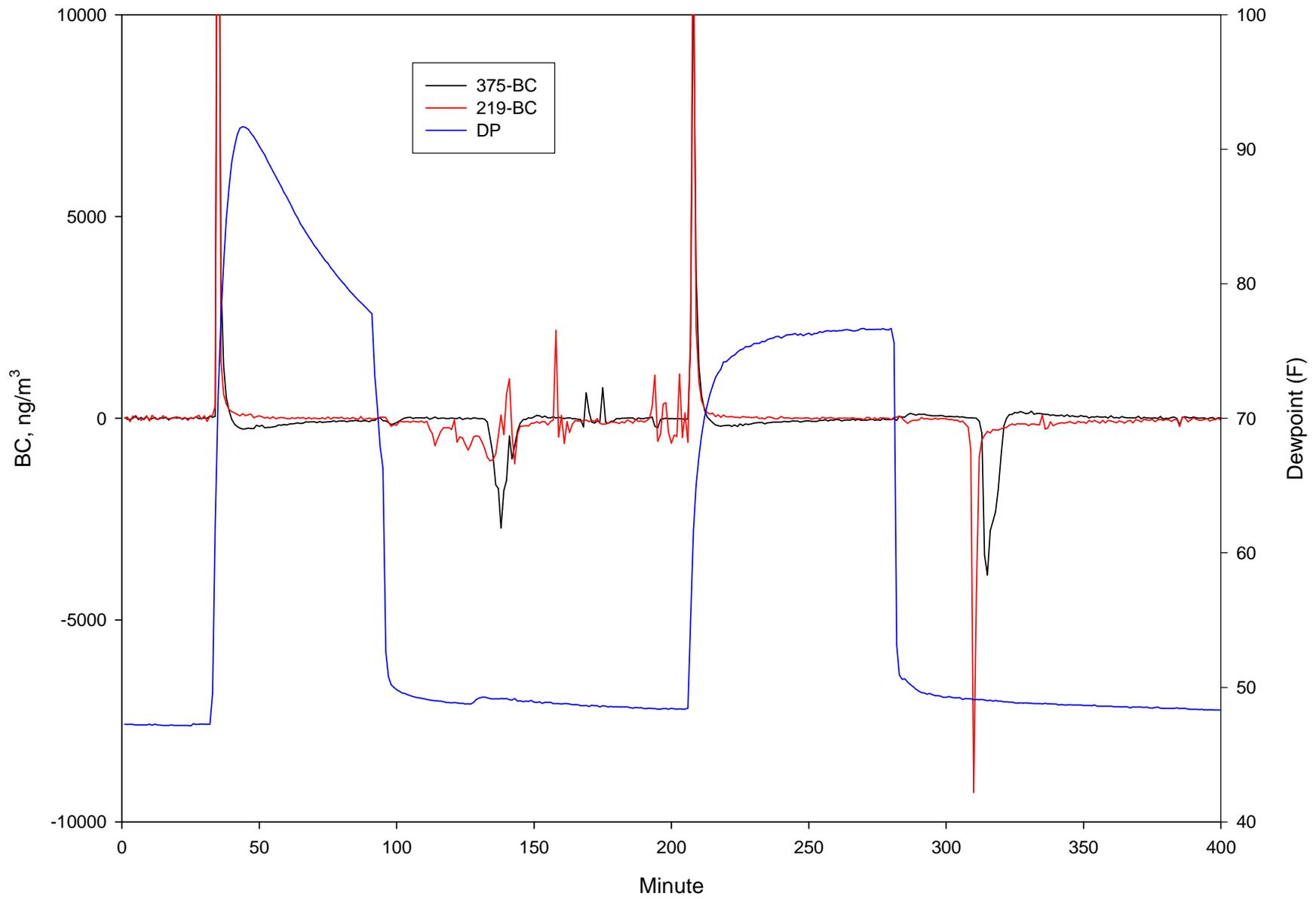
Source: short-term fluctuations in ambient dewpoint causing changes in RH at the Aeth filter

Test to confirm: vary sample RH from low to high on dynamic blank
-- with several instruments

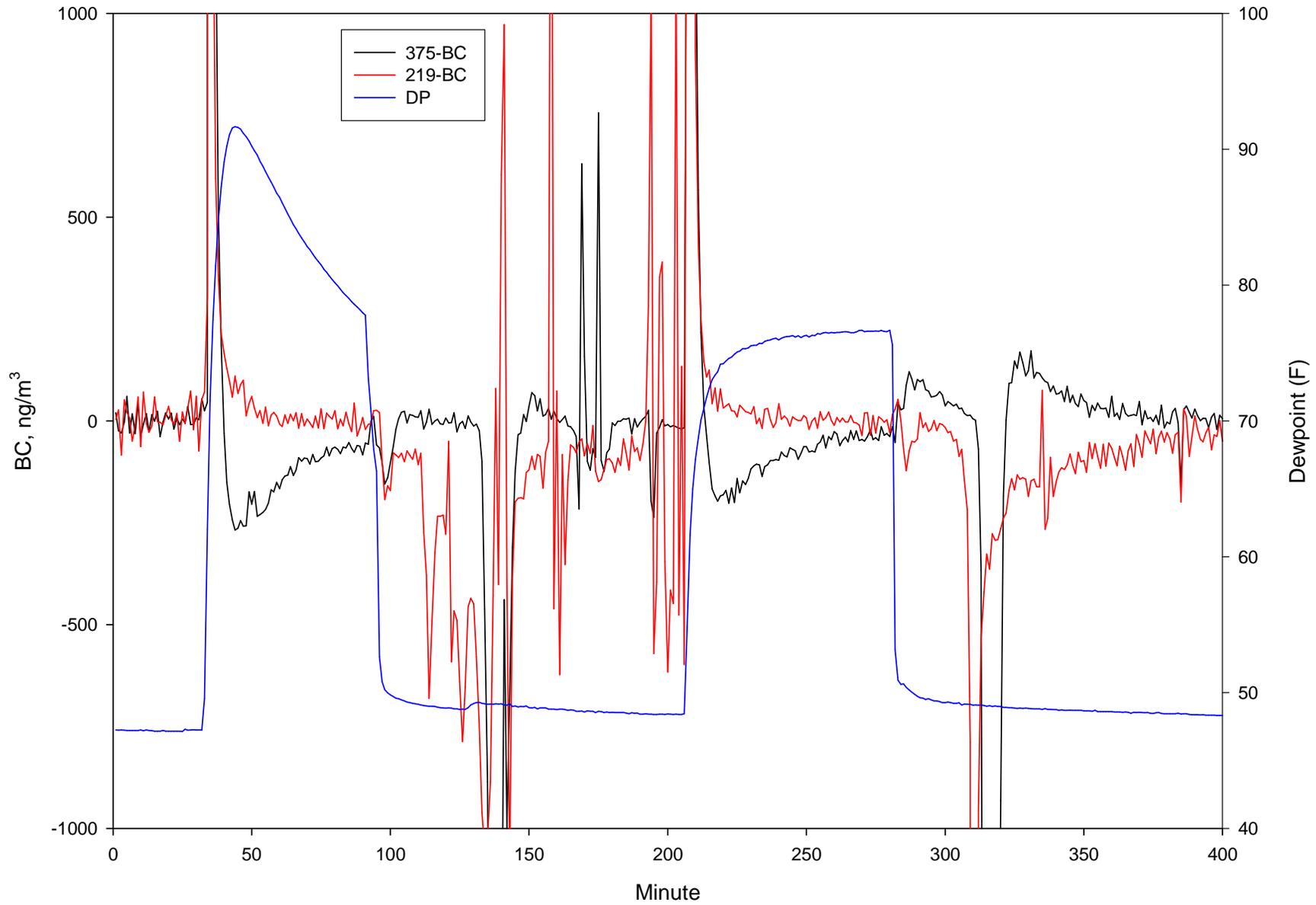
Results clearly show strong filter RH effect on "blank" filters
-- positive RH step change gives short but large positive response
-- followed by lesser negative response

RH effect on filters loaded with aerosol will be larger!!!

Aethalometer blank filter RH effect



Aethalometer blank filter RH effect



Conclusions:

- Advantages of this approach:
 - tightens scatter between instruments with similar aerosol matrix loadings
 - removes the worst of the saturation bias
- Limitations of this approach...
 - required smoothing (30-40 spots) limits dynamics of the correction time scales of weeks to a month or more
 - highly scattering aerosol matrices may cause under-correction
- How to best measure BC with an Aethalometer?
 - use a collo pair, both optimized for low short-term noise (w/drier)
 - generate a more precise per-spot value for K
 - use collo data to determine better “spot change” BC estimate
 - run small spot Aeth config at high flow ==> several spot changes/day
 - should allow much less smoothing of K value
 - much more dynamic correction...

Further Data Analysis Plans:

Assess and integrate data from Aeth with max attn=15

Remove between-instrument bias and compare BC across Aeths

-- with both uncompensated and compensated datasets

Optimize parameters [10/40] for different instrument configs

-- real-world: best settings may be site specific

Investigate scattering/absorption relationships further

Use collo Aeth data to calculate a robust K factor

-- remove “noise” from estimate of K, then use no or little smoothing

-- how much of K noise is real vs. artifact