Environment Canada Environnement Canada

Canada

$PM_{2.5}$ Monitoring in Canada

October 20, 2011

AWMA Workshop – Toronto, ON

A brief history of how we got here …

- 1969 – National Air Pollution Surveillance (NAPS) program is established – measures TSP using hi-vol (filter-based) sampler.
- 1984 – NAPS begins monitoring fine PM using dichotomous (filter-based) instruments – 24-h samples of both PM_{10} and $PM_{2.5}$ on a mostly 1-in-6 day schedule.
- 1987 – U.S. revises their PM NAAQS, changing the indicator from TSP to PM_{10}, to focus on "inhalable" particles (< 10 µm)
- 1990 – R&P TEOM® continuous monitor receives Class III Federal Equivalency Method (FEM) designation for PM_{10} NAAQS reporting.
- mid-1990's – Canadian monitoring agencies begin to deploy PM_{10} TEOMs.
- 1997 – U.S. sets $PM_{2.5}$ NAAQSs and designates a federal reference method (FRM) for reporting compliance – gravimetric (filter-based) method.
- 2000 – CCME signs CWS for PM and ozone – no method for $PM_{2.5}$ reporting is specified but daily monitoring is required.

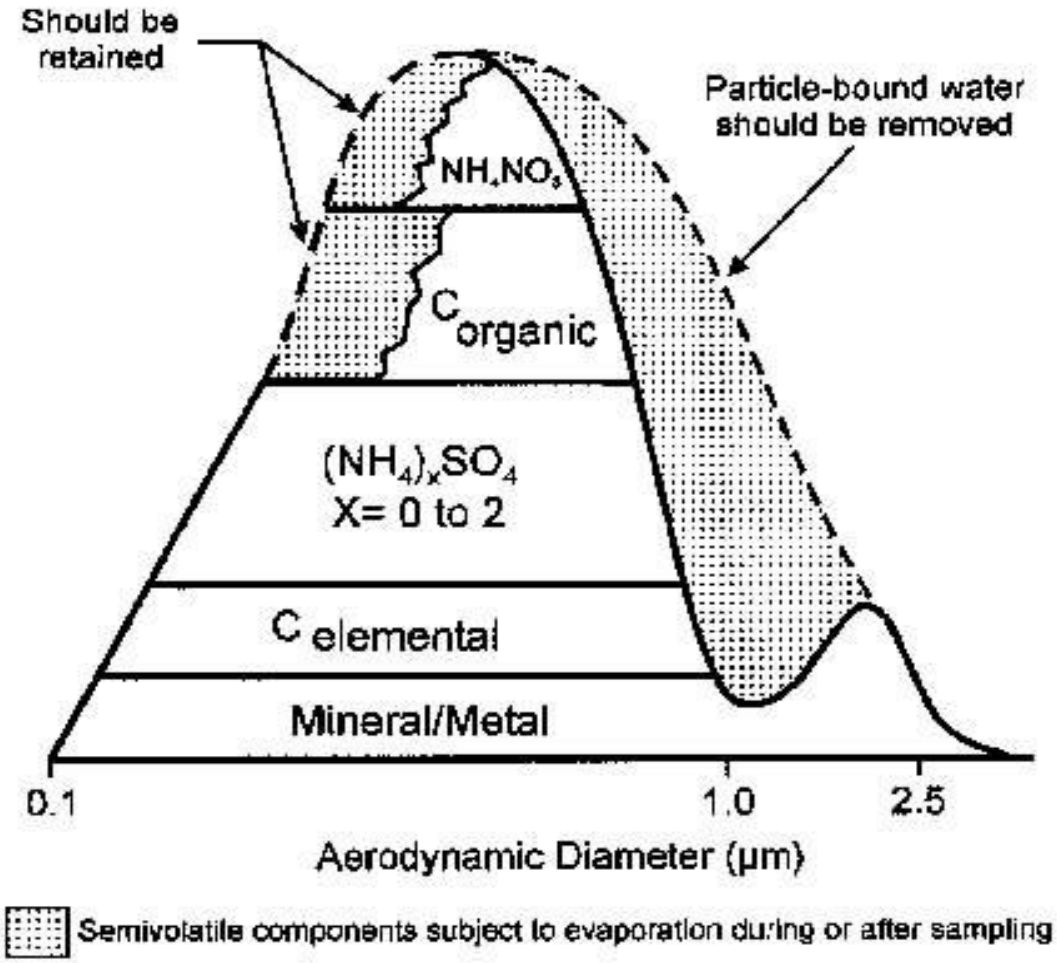
… since 2000

- Post 2000 – $PM_{2.5}$ monitoring network expands – mostly continuous TEOMs (initially).
- 2002 – First $PM_{2.5}$ Continuous Monitoring Workshop held – agree to remove TEOM “offset”, add SES to priority instruments.
- 2004 – CCME asks NAPS to develop recommendations to address $PM_{2.5}$ continuous monitoring issues.
- 2005 – NAPS Managers agree on a definition of $PM_{2.5}$, a reference method for CWS comparison (gravimetric) and to establish an intercomparison network.
- September 2006 - U.S. revises $PM_{2.5}$ NAAQS and releases Class III FEM specifications for continuous instruments to report compliance.
- 2008 – First instrument (Met - One BAM) receives $PM_{2.5}$ FEM designation (currently there are 5 Class III FEM designated instruments).
- 2010 – CWS Monitoring Protocol is completed – includes equivalency criteria for continuous $PM_{2.5}$ instruments (similar to U.S. FEM/ARM).

What is $PM_{2.5}$?

- Atmospheric particulate matter (PM) is a complex mixture of solid and liquid particles INCLUDING the vapour-phase semi-volatile compounds that are adsorbed or absorbed to the particle.
- True measurement of the aerosol is rarely, if ever done, as the act of sampling or measuring usually does not capture the vapour-phase and also disrupts the equilibrium with the compounds making up the solid/liquid particle.
- Realistically, $PM_{2.5}$ can only be defined operationally according to the sampling and mass determination method utilized (e.g., the U.S. has defined a Federal Reference Method (FRM) for sampling $PM_{2.5}$)

Why is $PM_{2.5}$ so challenging to measure?



Removing water from the $PM_{2.5}$ sample

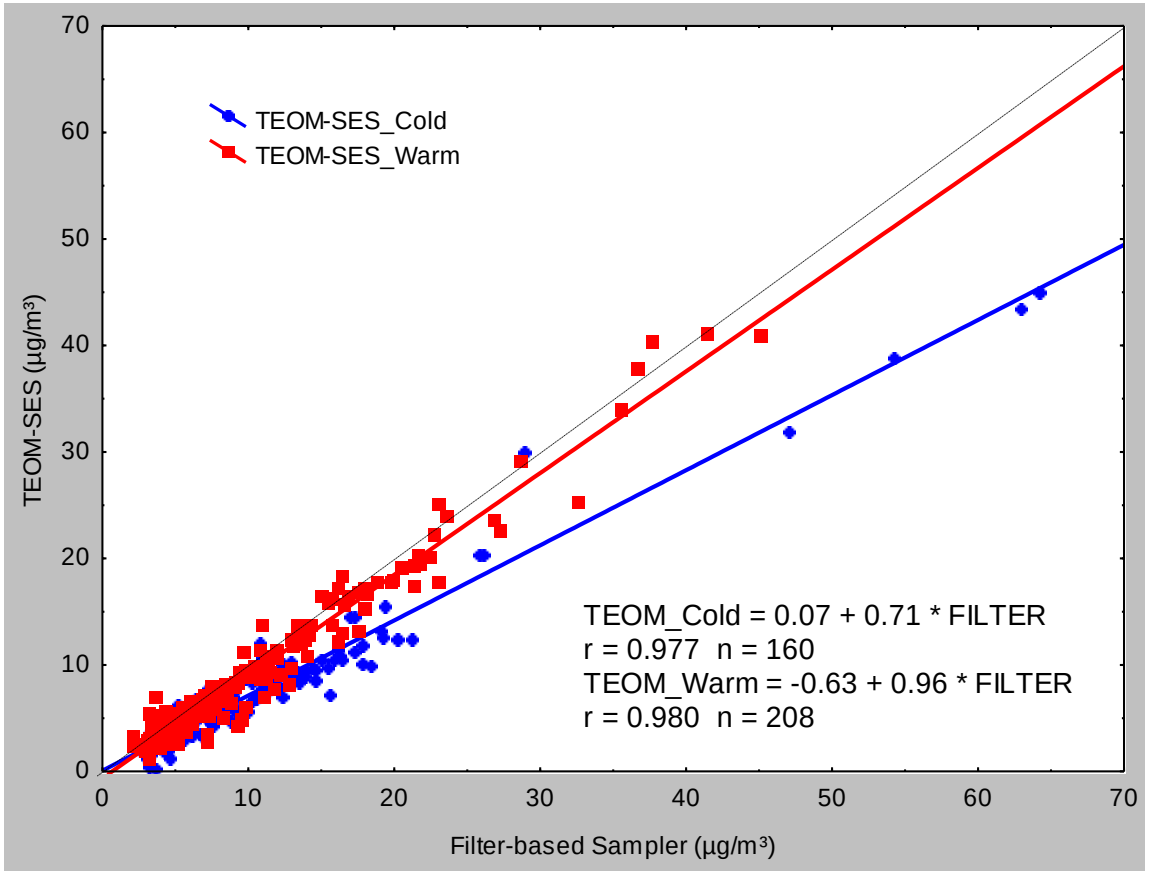
- Because water is assumed to be non-toxic, we want to measure the mass of particulate matter ***without*** particle-bound water.
- For the filter-based reference method measurements, the filter is “conditioned” (equilibrated at 23 ±3 °C and 42 ±5 % relative humidity for 24 hours) prior to weighing. This ***does not*** remove all particle-bound water.
- Continuous methods measure PM indirectly and do not distinguish between PM mass and water, therefore water should be removed before the air sample is analyzed.
- However, it is not possible to remove one semivolatile compound (water) without the loss of other semivolatiles (NH_4NO_3, SVOC).

Tapered Element Oscillating Microbalance (TEOM)

- More than 150 $PM_{2.5}$ TEOMs have been deployed across the NAPS network over the past decade (currently ~ 50 still in operation).
- Based on the fundamental physics of a vibrating reed.
- Initially heated the TEOM to 50 °C (reduced to 40 °C after 1998) which guarantees loss of water and all semi-volatiles.
- After 2002, priority instruments (~75) were fitted with a Sample Equilibration System (SES) which uses a Nafion dryer to remove water.
- The SES allows the TEOM to be operated at 30 °C.
- It has been found to be an improvement but does not provide Reference Method equivalent values.

Linear regression results for 24h data - TEOM-SES Ottawa (2004-2006)

- Warm day (> 10°C) results for the TEOM typically agree closely with the Reference Method sampler.
- However, on cold days (< 10°C), the TEOM under report relative to the RM.



Can we adjust TEOM data to agree more closely with the Reference Method?

Goal:

- Develop transformation approach to adjust TEOM data to better match $PM_{2.5}$ reference method measurements.
- Remove the worst of the across site and season bias.
- Use daily mean temperature as surrogate for TEOM SVM loss.
- Is the simple 10°C split (Tom Dann method) as good as more complex temperature methods?

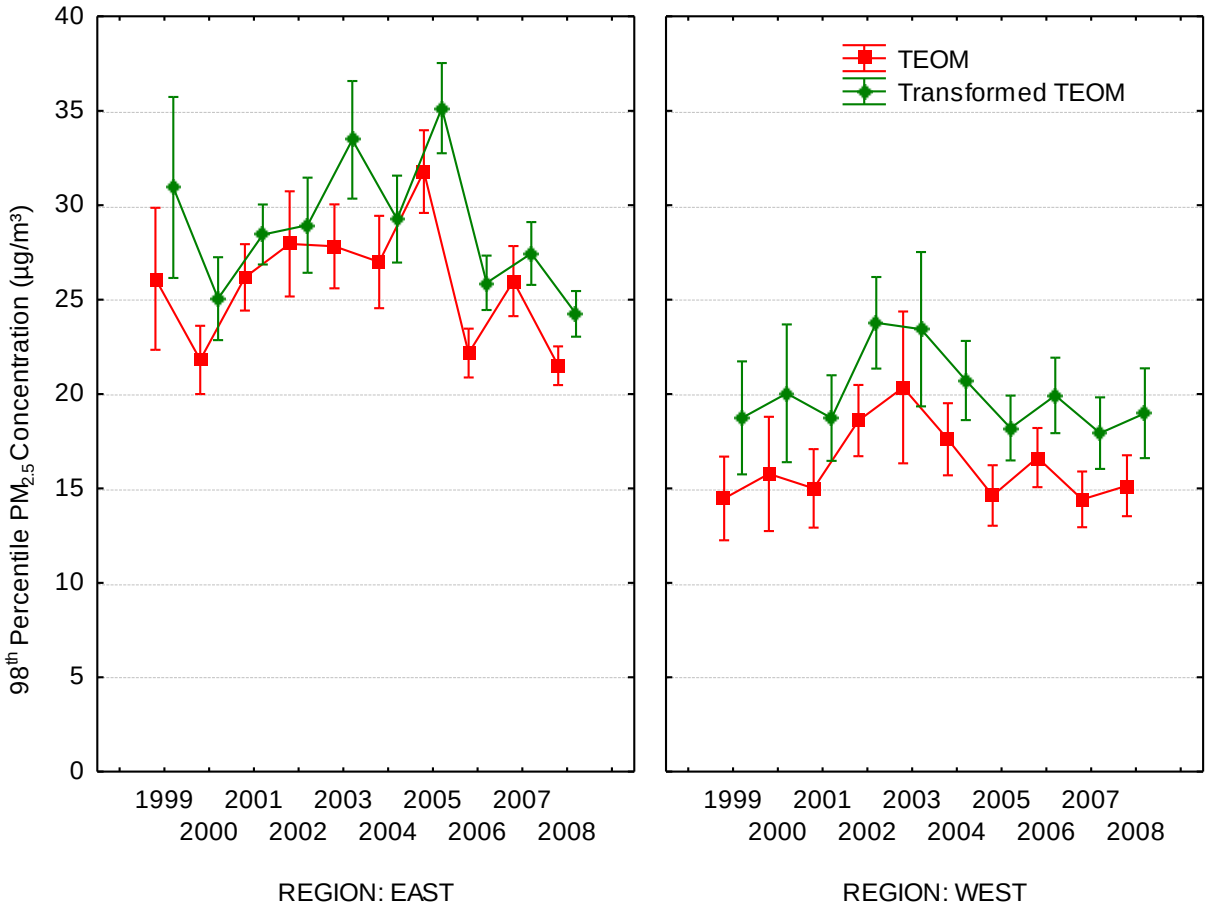
Method:

- RM and TEOM collocated data from 22 sites (>100 pairs)
- Create pooled regional warm & cold regressions - 3 areas
- Ontario-Quebec, Prairies, and BC
- Pooled regional/seasonal regressions applied to TEOM data
- Evaluate suitability of approach to non-collocated sites

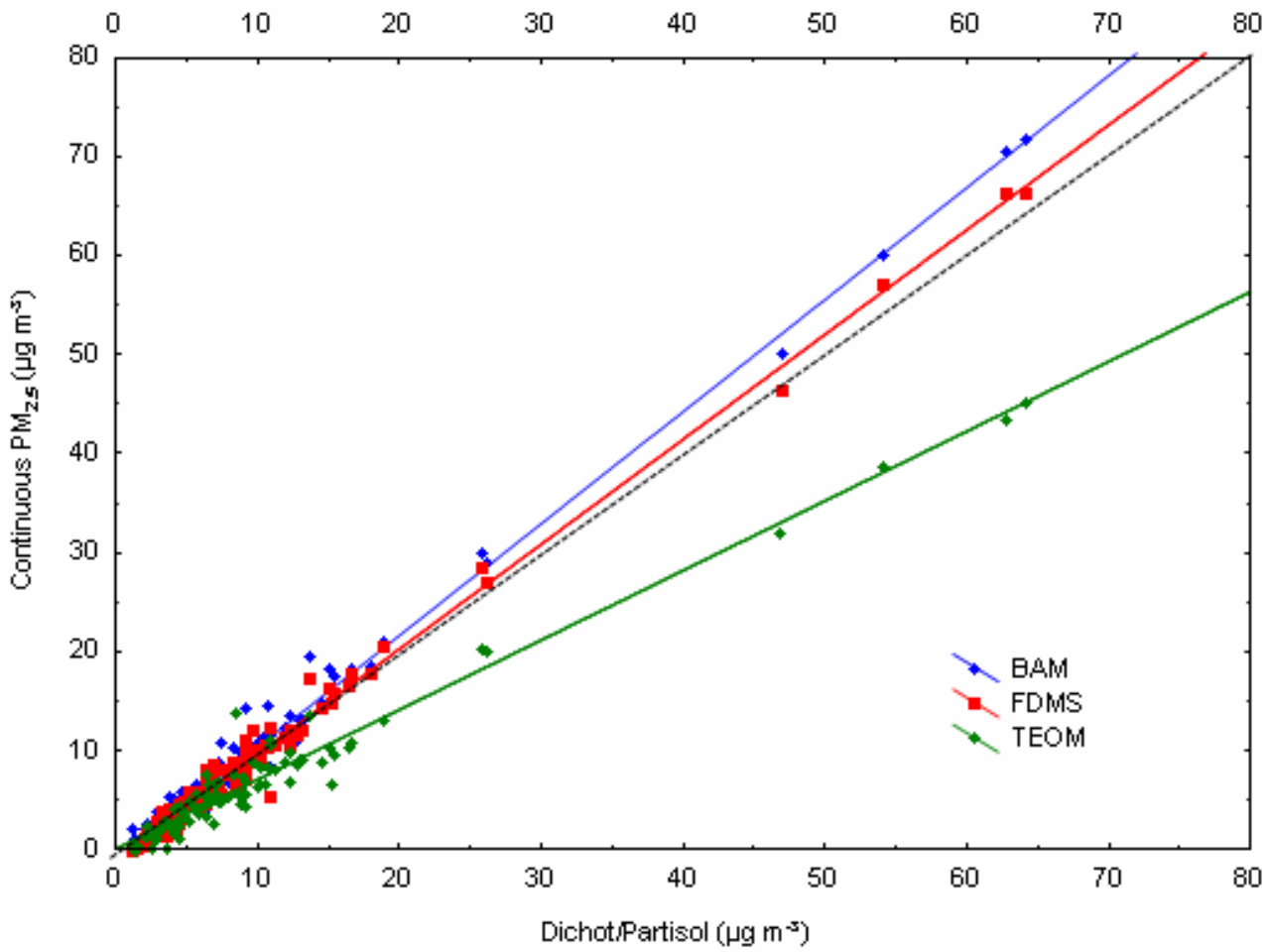
Transformation Report - Conclusions

- A simple warm-cold 10° C split provided results that could not be meaningfully improved by using more complex temperature-based approaches.
- For the most part, the regionally pooled transform approach produced 98th percentile values that were reasonably close to those from the NAPS reference method data.
- This suggests that historical TEOM data could be used with reasonable confidence to assess conformity with this standard.
- There are substantial limitations to any TEOM data adjustment approach, any such use would need to note the uncertainties in the transformed data.
- For assessing trends, the pooled adjustment approach did not perform as well, with mean or median NAPS reference method $PM_{2.5}$ sometimes being different from the mean or median adjusted TEOM data by 10 to 15%.

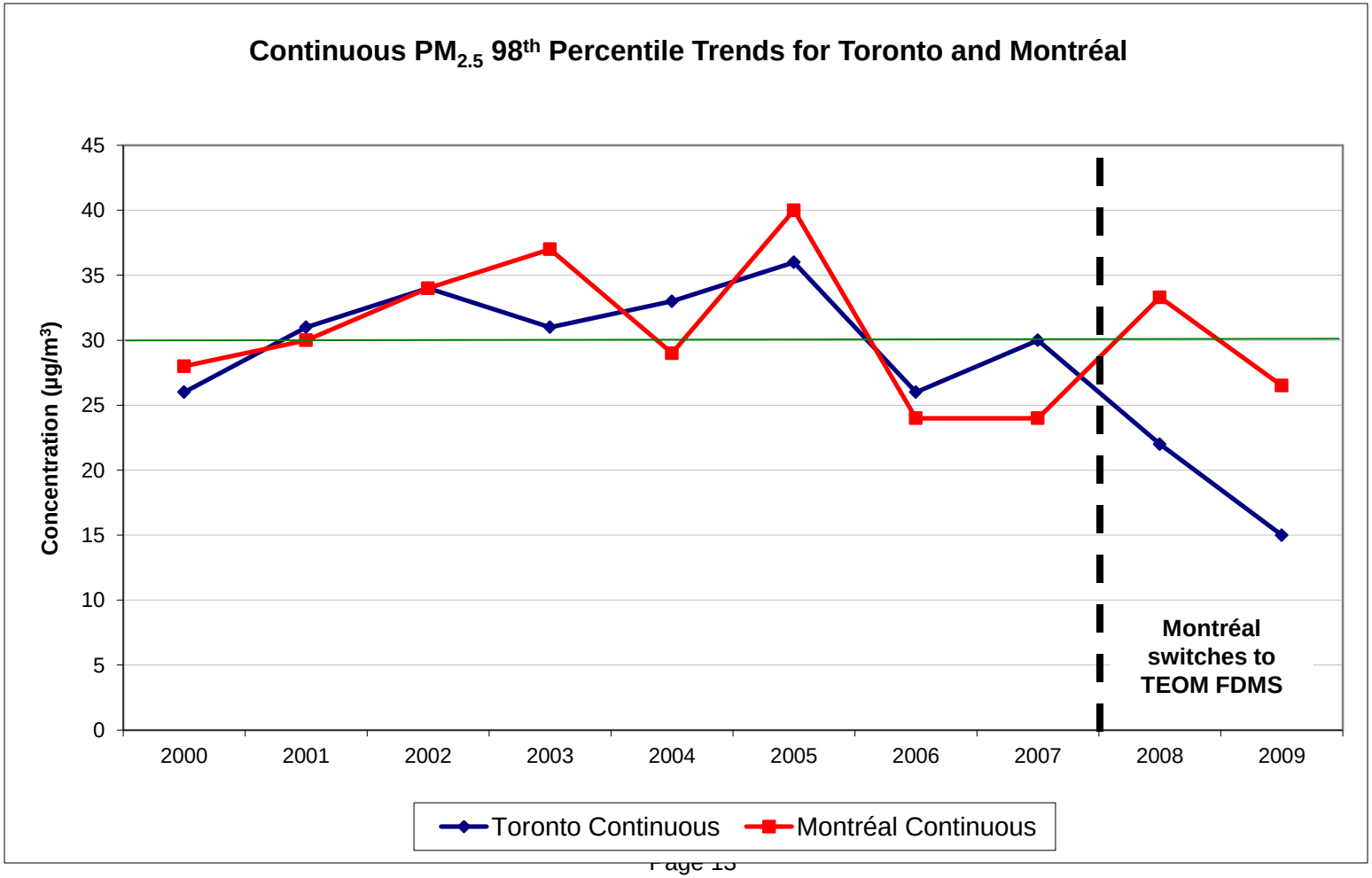
Pooled data transformation – East & West



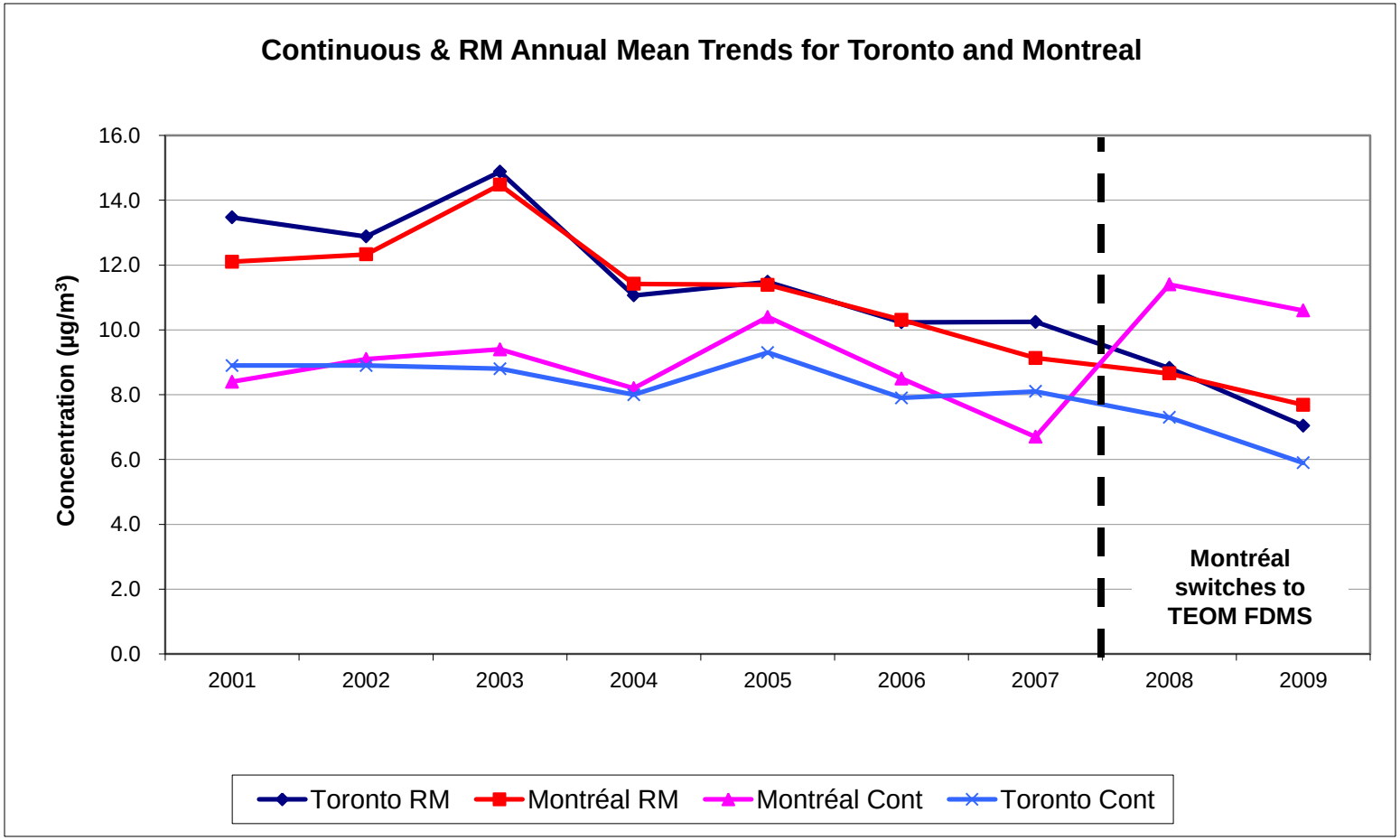
Comparison of Cold Season Performance of RM, FDMS, BAM and TEOM-SES (Ottawa 2004-2005)



A tale of two cities!

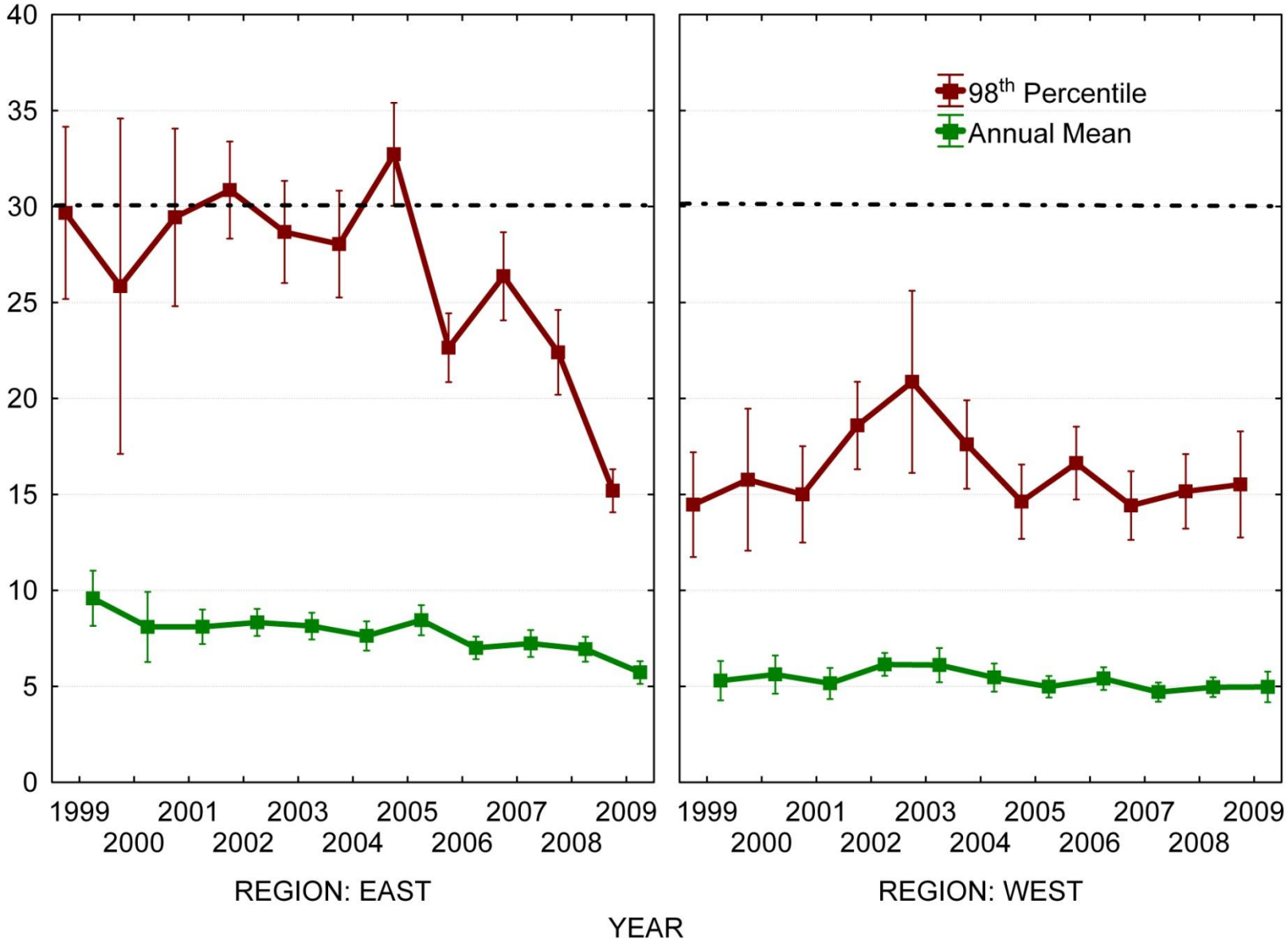


What caused $PM_{2.5}$ go up in Montreal after 2007?



Current deployment of continuous $PM_{2.5}$ instruments across NAPS agencies

$PM_{2.5}$ concentrations are changing in the east.



Summary

- $PM_{2.5}$ is defined according to the NAPS Reference Method (filter-based).
- The TEOM has been the most widely deployed continuous $PM_{2.5}$ instrument across the NAPS network.
- Analysis has shown that the TEOM under reports $PM_{2.5}$ concentrations relative to the NAPS RM (primarily on cold days).
- It is possible to transform TEOM data to make it more RM-like.
- NAPS agencies are transitioning their $PM_{2.5}$ networks to (U.S.) FEM instruments.
- Analysis indicates that FEMs measure higher $PM_{2.5}$ concentrations relative to the NAPS RM.
- Despite the problems associated with $PM_{2.5}$ measurement, it is evident that $PM_{2.5}$ concentrations are decreasing, with what appears to be a rapid decline in eastern Canada.