UNIVERSITY OF ALBERTA
SCHOOL OF PUBLIC HEALTH

Evaluation of air quality indicators in Alberta – An international perspective

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NATIONAL POST

CANADA

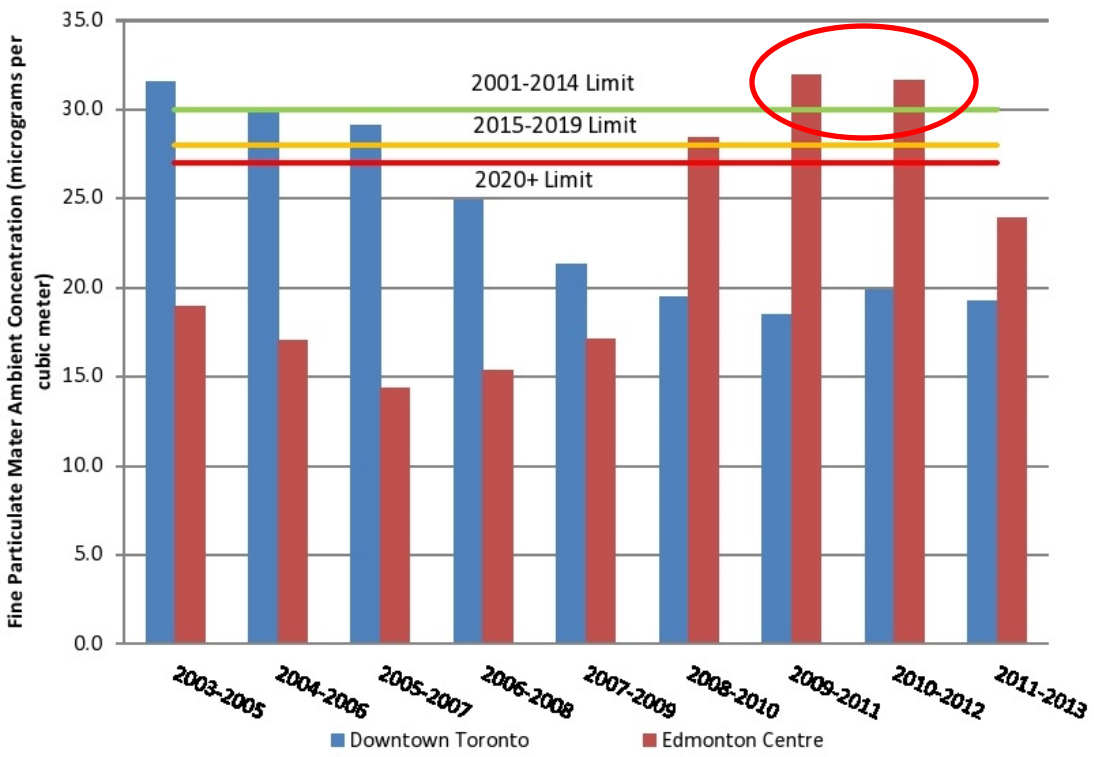
TRENDING Donald Trump | NHL playoffs | Real estate | Marijuana | Lotto Max | North Korea

Edmonton's air quality is often worse than Toronto's, which has five times more people

NP POSTMEDIA NEWS | April 14, 2015 3:32 PM ET
More from Postmedia News

April 14, 2015

A smoggy winter Edmonton day in 2009.



http://news.nationalpost.com/news/canada/edmontons-air-quality-is-often-worse-than-torontos-which-has-five-times-more-people

Core scientific question intended to address

- **What is the state and current trends in local and regional air quality in Alberta?**

- **How is Alberta's air quality compared to other Canadian and international cities?**

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Evaluation of air quality indicators in Alberta, Canada – An international perspective

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Available online 9 April 2016

Bari and Kindzierski, 2016. Environment International 92–93, 119–129

Criteria air pollutants

Inorganic pollutants

- Nitrogen dioxide (NO_2)
- Sulfur dioxide (SO_2)
- Ground-level ozone (O_3)
- Fine particulate matter ($PM_{2.5}$)
- Total hydrocarbons (THC)
- Carbon monoxide (CO)

Methodology

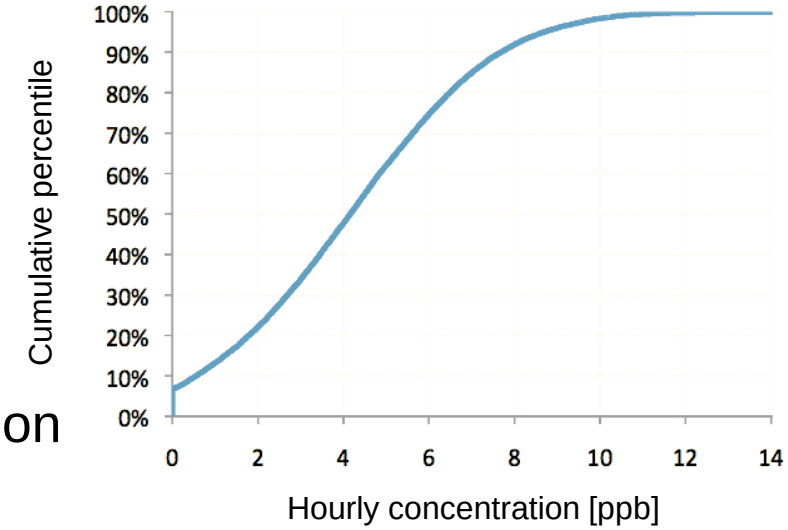
- **Selected study period: 1998 – 2014**
- **Temporal concentration profiles**
- **Diurnal hourly profiles**
- **Long-term air quality trend analysis**
  - **Parametric**
  - **Non-parametric**
- **National and international comparison**

Study areas in Alberta

- **Major urban areas (population over 1 million)**
  - **Edmonton (2 stations: central and east)**
  - **Calgary (2 stations: central and east)**

- **Communities in Athabasca Oil Sands Region**
  - **Fort McKay**
  - **Fort McMurray (Athabasca Valley)**

Trend analysis – parametric approach



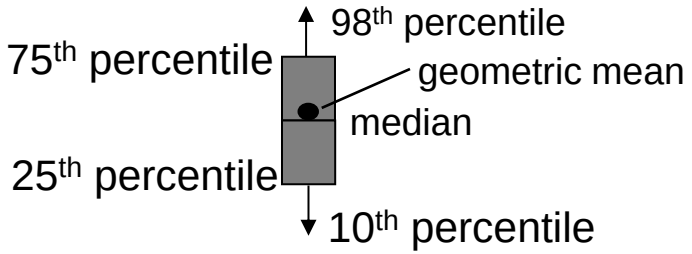
- Hourly datasets
- Characteristics of datasets examined:
  trends in response variables
  - mid- to upper- 1-hour concentration values from annual cumulative frequency distributions (**50th**, 65th, 80th, 90th, 95th, and 98th percentiles)
  - linear regression used to detect trend in response variable (α =0.05)
    - Annual median (50th percentile) used for trend analysis
- Autocorrelation & seasonality can be ignored where only selected values from a cumulative frequency distribution curve (50th percentile) are used.

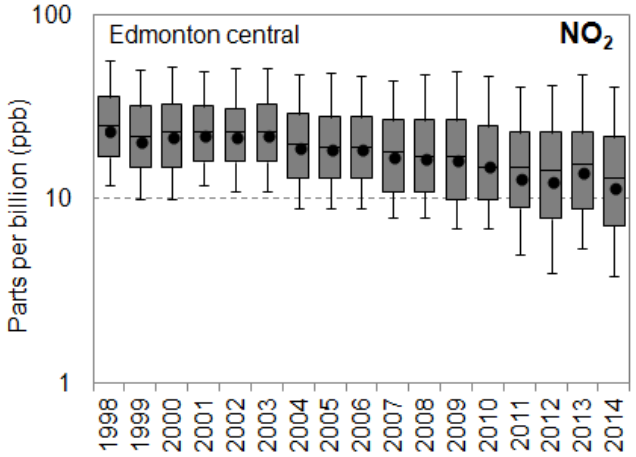
Trend analysis – Non-parametric approach

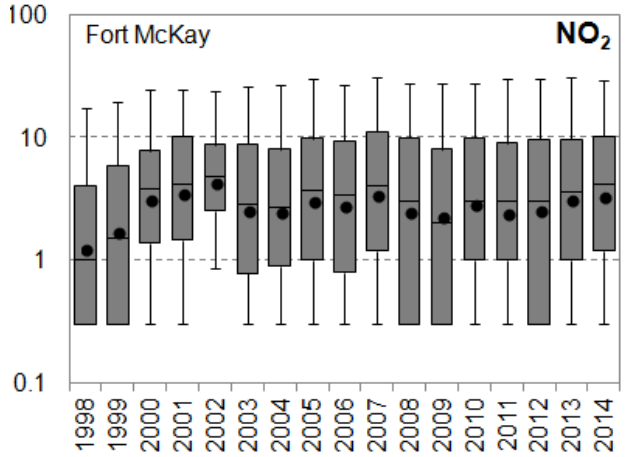
- Hourly or 24-hr datasets (using annual geometric mean)
- Mann-Kendall test: determine the presence of monotonic trend (
- Theil-Sen's slope : estimate the magnitude of the rate of change per year

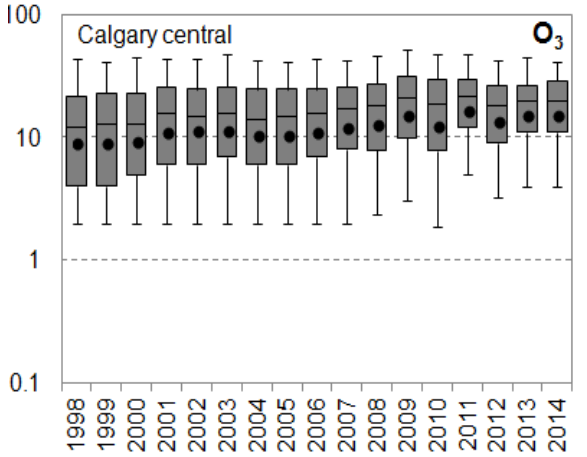
- ***A similar result for both parametric and non-parametric methods – indication of a direction of a trend (upward, downward or no change).***

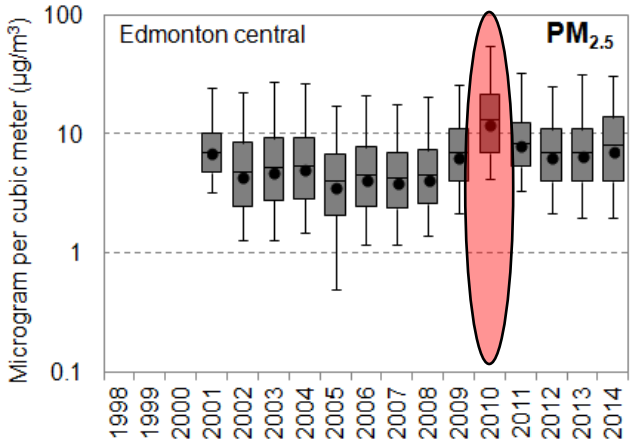
Temporal profiles of hourly concentrations

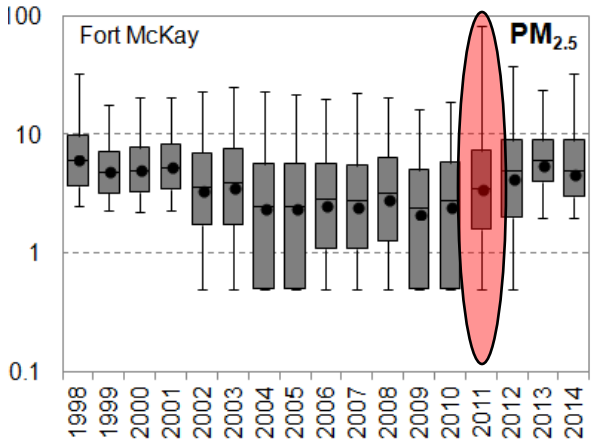


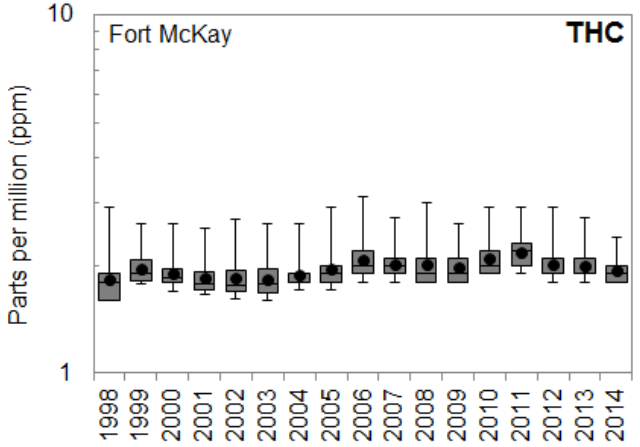




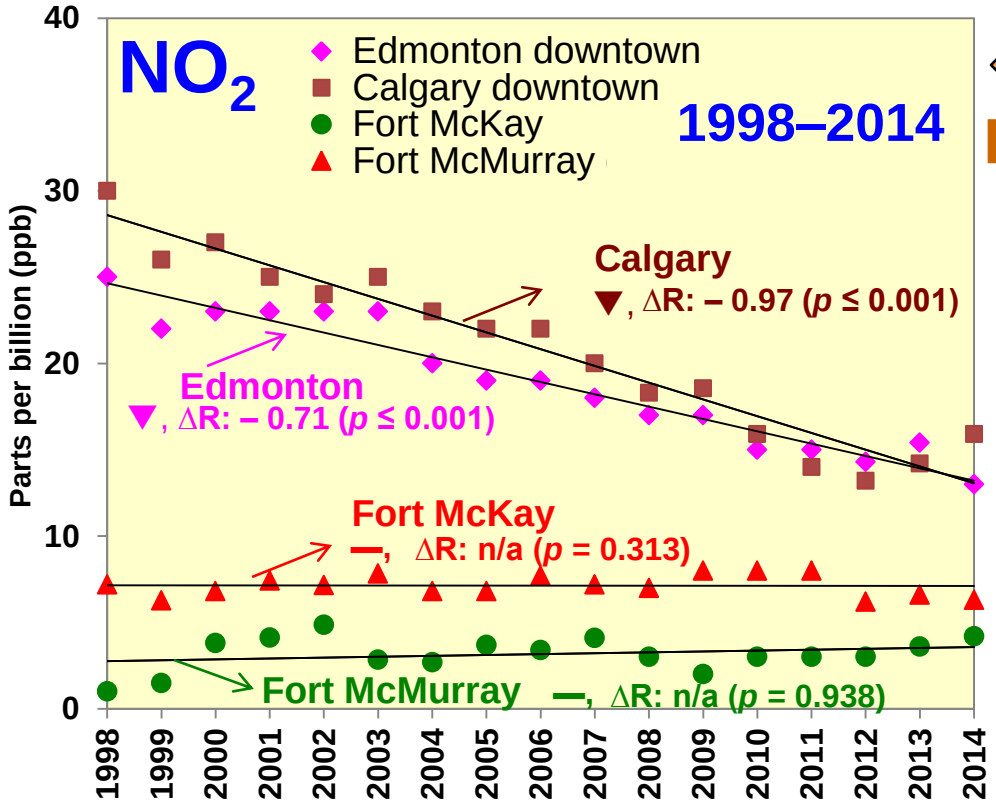








Results



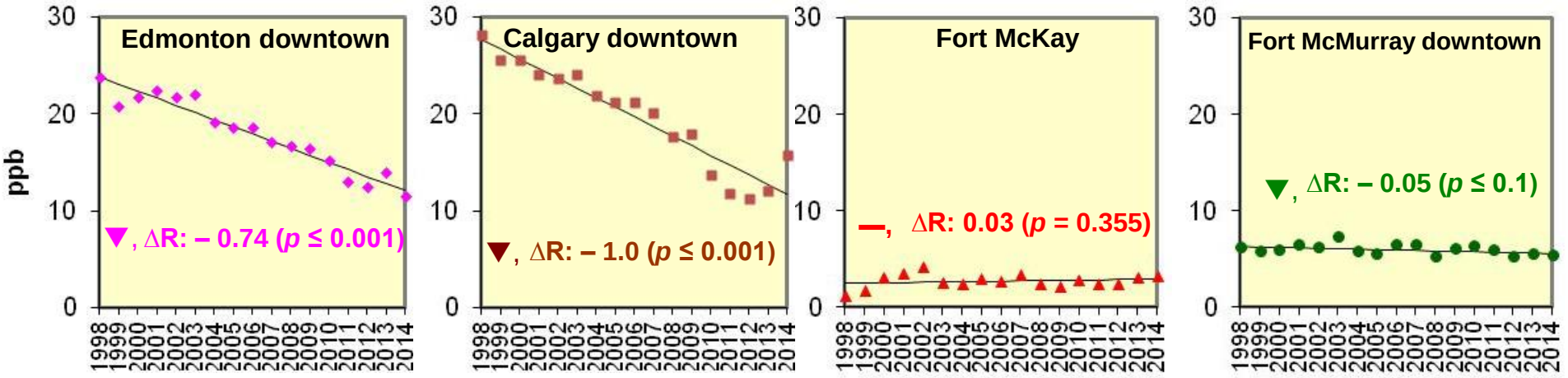
Parametric trend (median)

1998–2012

Con.	Fort McKay		Fort McMurray Athabasca Valley	
(p = 0.05)	Trend	ΔR/year	Trend	ΔR/year
50th percentile	—	n/a	—	n/a
65th percentile	—	n/a	—	n/a
80th percentile	▲	0.31 ppb	—	n/a
90th percentile	▲	0.47 ppb	▲	0.12 ppb
95th percentile	▲	0.58 ppb	▲	0.19 ppb
98th percentile	▲	0.71 ppb	▲	0.21 ppb

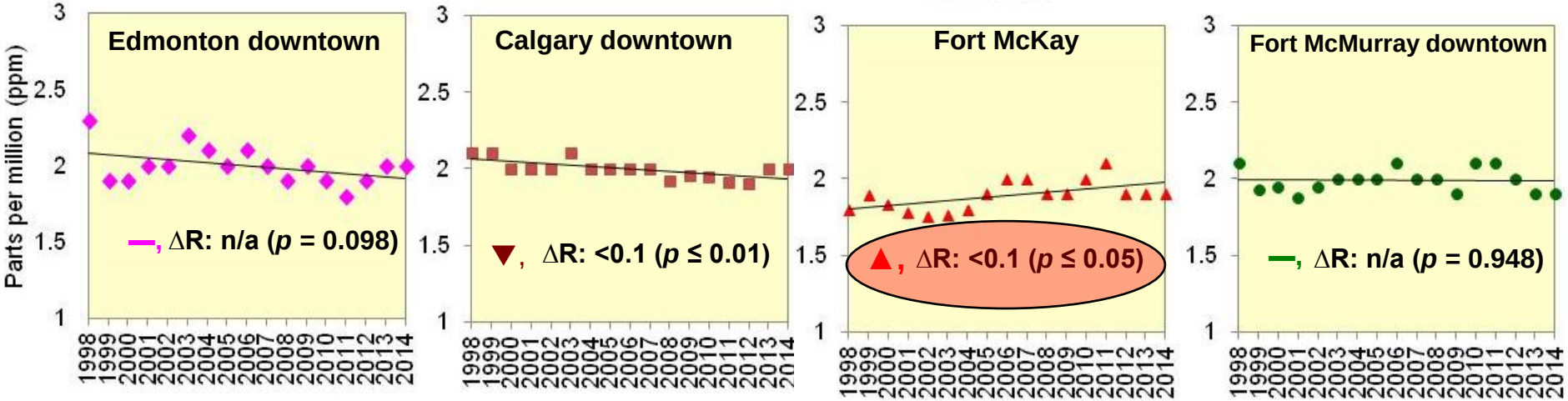
Bari and Kindzierski, 2015: Environ. Int. 74, 200–208

Non-parametric trend (geometric mean)

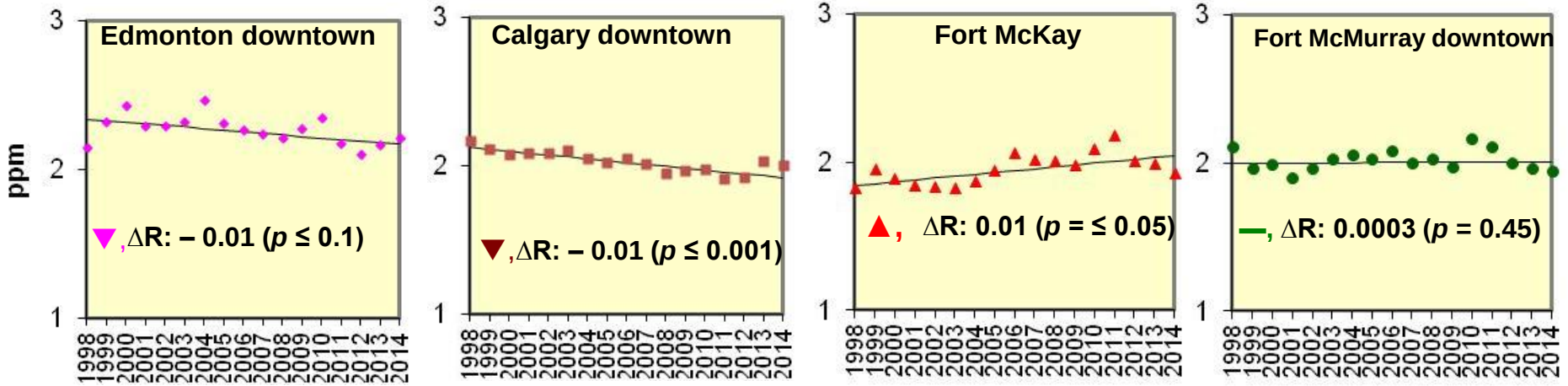


THC

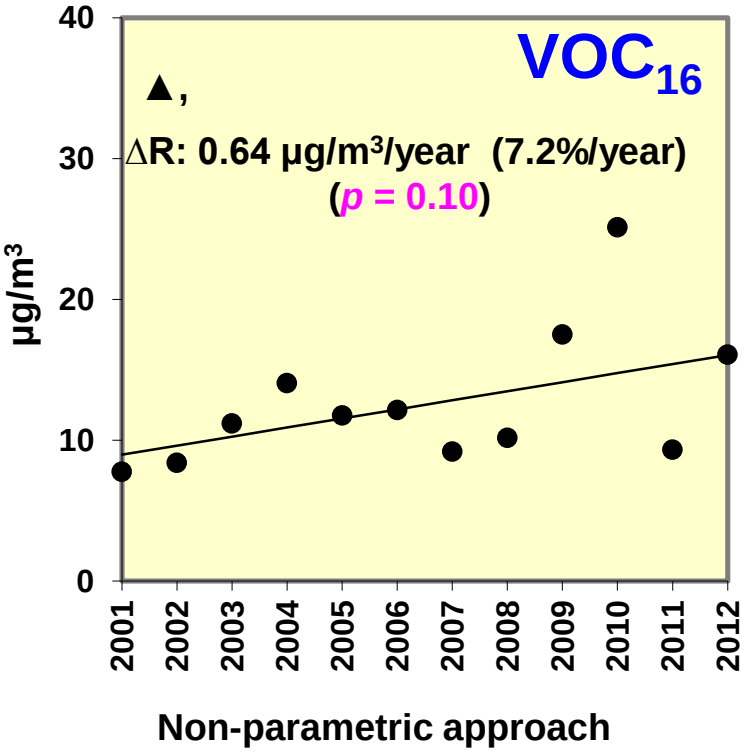
Parametric trend

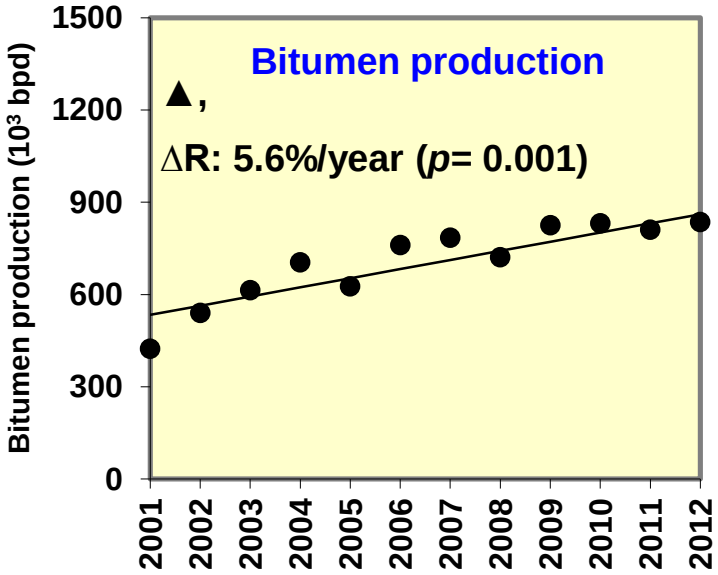


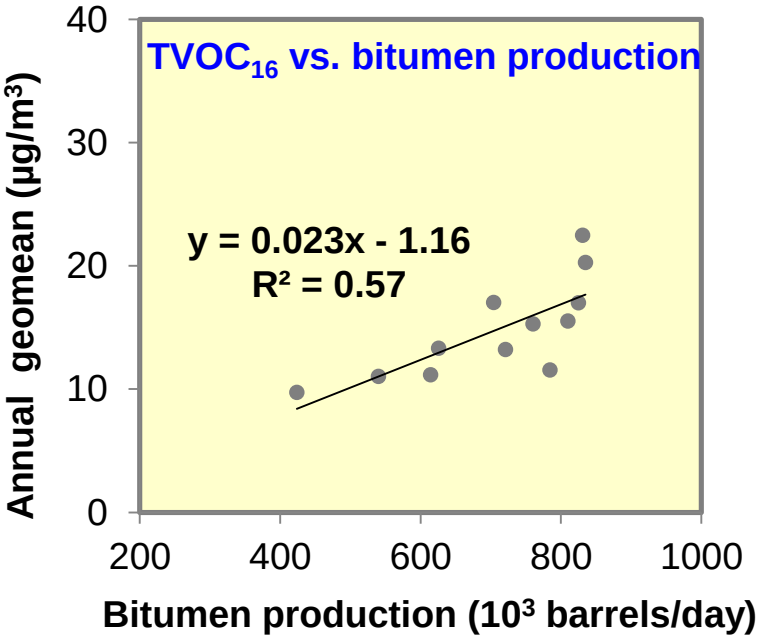
Non-parametric trend



A 12-year trends in ambient volatile organic compounds (VOCs) in a oil sands community (Fort McKay: 2001–2012)







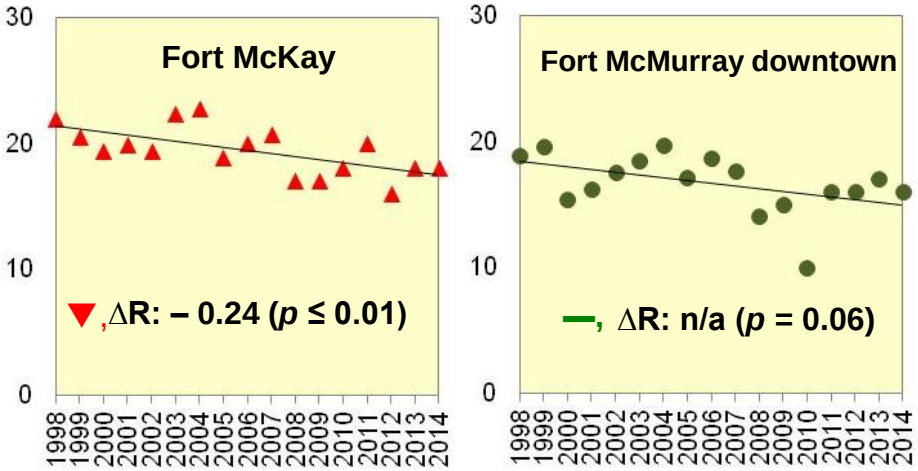
Bari et al., 2016: Environment International 91, 40–50

Results

O_3

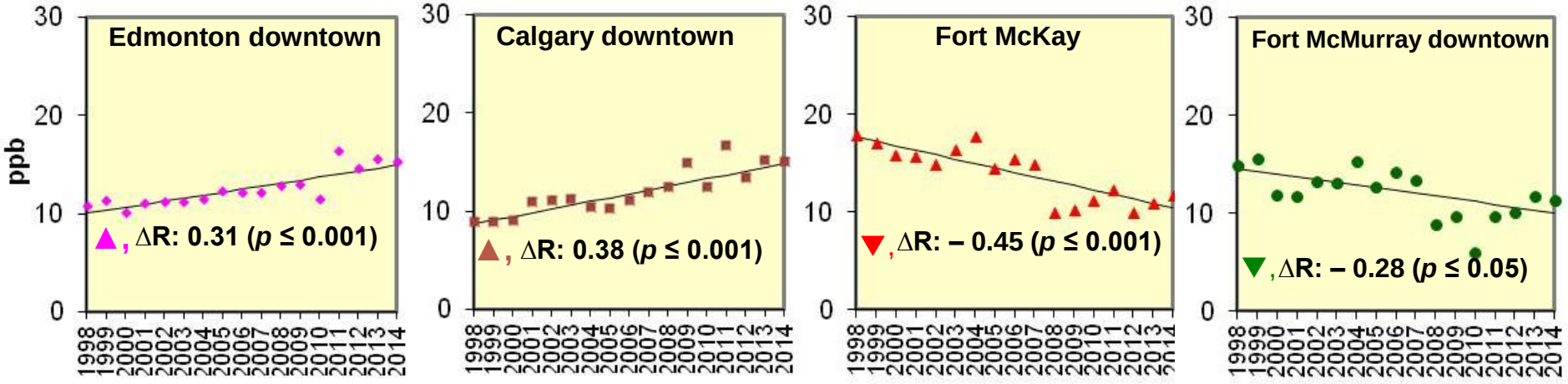
Parametric trend

1998 – 2012 Con.	Fort McKay		Fort McMurray Athabasca Valley	
(*p* = 0.05)	Trend	ΔR/year	Trend	ΔR/year
50th percentile	▼	0.27 ppb	▼	0.31 ppb
65th percentile	—	n/a	▼	0.27 ppb
80th percentile	—	n/a	▼	0.24 ppb
90th percentile	—	n/a	—	n/a
95th percentile	—	n/a	—	n/a
98th percentile	—	n/a	—	n/a



Bari and Kindzierski, 2015: Environ. Int. 74, 200–208

Non-parametric trend



Parametric trend

$PM_{2.5}$, SO_2, CO

		Edmonton central			Calgary central			Fort McKay			Fort McMurray		
	Unit	T	ΔR	R^2 (*p*-value)	T	ΔR	R^2 (*p*-value)	T	ΔR	R^2 (*p*-value)	T	ΔR	R^2 (*p*-value)
$PM_{2.5}$	µg/m³	—	n/a	0.24 (0.079)	—	n/a	0.09 (0.250)	—	n/a	0.02 (0.586)	—	n/a	0.004 (0.808)
SO_2	ppb	–	–	–	–	–	–	—	n/a	n/a	—	n/a	n/a
CO	ppm	▼	<0.1	0.93***	▼	<0.1	0.94***	–	–	–	▼	<0.1	0.28*

Non-parametric trend

		Edmonton central				Calgary central				Fort McKay				Fort McMurray			
	Unit	T	ΔR	% ΔR	*p*-value	T	ΔR	% ΔR	*p*-value	T	ΔR	% ΔR	*p*-value	T	ΔR	% ΔR	*p*-value
$PM_{2.5}$	µg/m³	—	0.21	5.8	0.063	—	0.07	0.9	0.355	—	–0.06	–1.5	0.242	—	–0.06	–1.7	0.268
SO_2	ppb	–	–	–	–	–	–	–	–	▼	–0.01	–1.0	**	▼	–0.01	–0.9	+
CO	ppm	▼	–0.03	–5.2	***	▼	–0.03	–4.9	***	–	–	–		▼	–0.01	–3.6	***

***$p \le 0.001$
**$p \le 0.01$
*$p \le 0.05$ +$p \le 0.1$

T: Direction of trend:
— no change; ▲ increasing; ▼ decreasing;

ΔR = rate of change (unit per year)
n/a: not applicable; –, not measured.

Air quality comparison – national & international urban areas (year 2012)

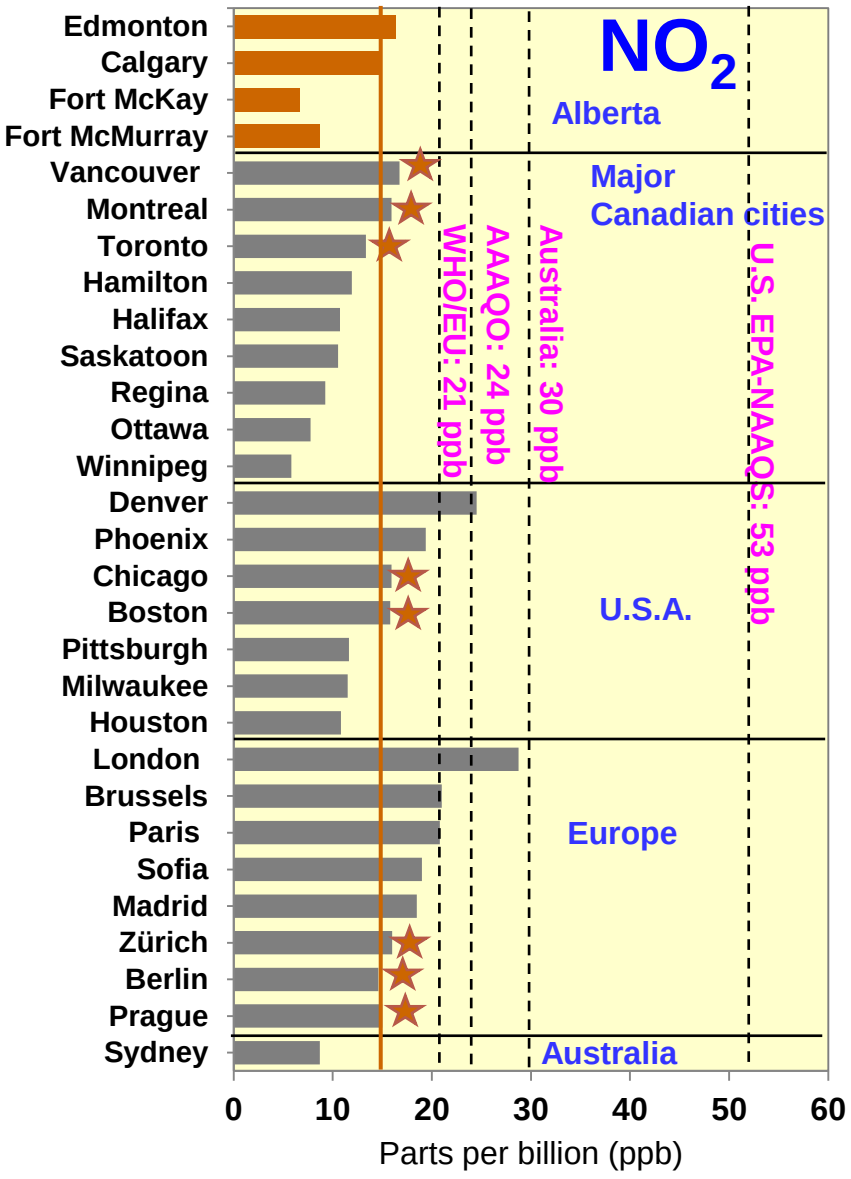
- International urban areas with comparable populations over 1 million.

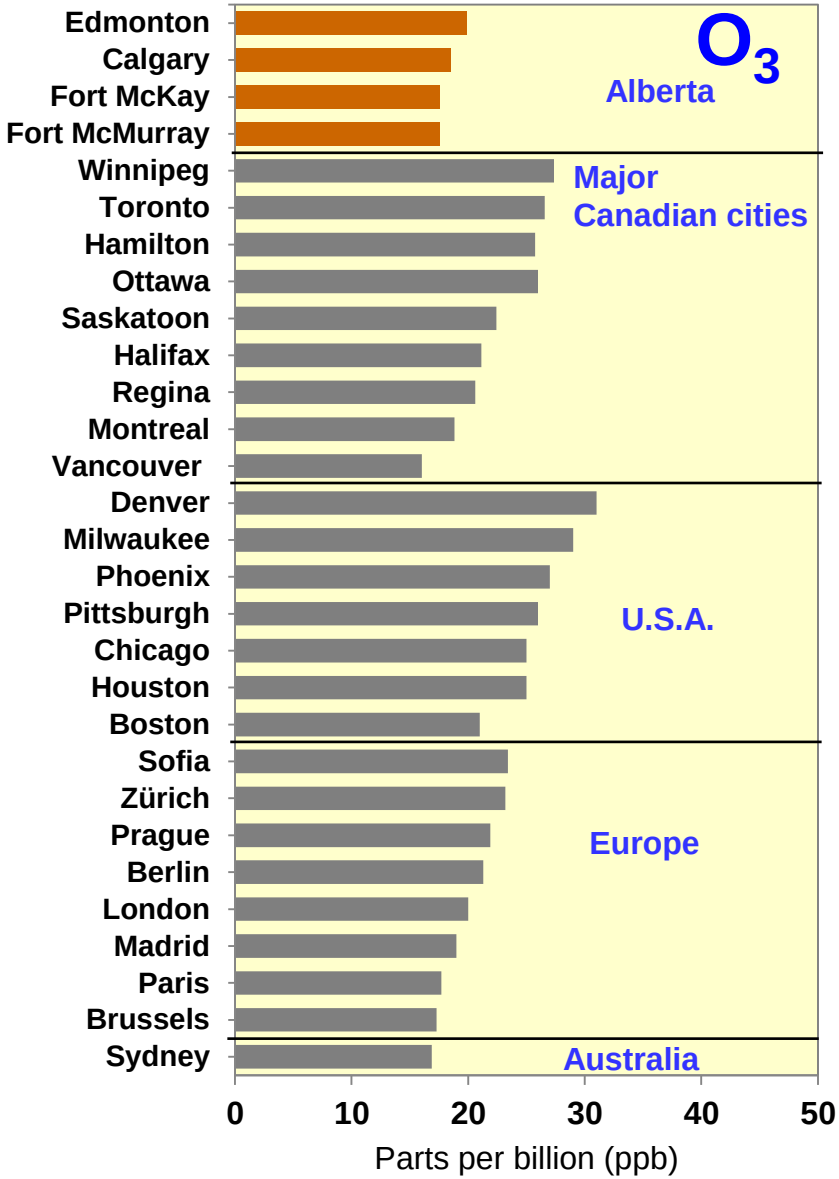
Region	City	Station ID	$PM_{2.5}$ Monitoring methods
Canadian cities	Edmonton	90130	TEOM-FDMS
	Calgary	90228	TEOM-FDMS
	Fort McKay	90801	SHARP 5030
	Fort McMurray	90701	SHARP 5030
	Toronto	60433	TEOM-SES
	Montreal	50109	TEOM-FDMS
	Vancouver	100118	TEOM-SES
	Ottawa	60104	TEOM-SES
	Hamilton	60512	TEOM-SES
	Winnipeg	70118	SHARP 5030
	Regina	80110	BAM
	Saskatoon	80211	TEOM
	Halifax	30118	BAM
U.S. urban areas	Denver	08-031-0025	R & P Model 2025 $PM_{2.5}$ Sequential
	Phoenix	04-013-0019	R & P Model 2025 $PM_{2.5}$ Sequential
	Chicago	18-089-2004	R & P Model 2025 $PM_{2.5}$ Sequential
	Boston	25-025-0042	R & P Model 2025 $PM_{2.5}$ Sequential
	Pittsburg	42-003-0064	R & P Model 2025 $PM_{2.5}$ Sequential
	Milwaukee	55-079-0026	R & P Model 2025 $PM_{2.5}$ Sequential
	Houston	48-201-1035	R & P Model 2025 $PM_{2.5}$ Sequential
EU urban areas	Prague	CZ0ARIE	BAM
	Brussels	BETR001	Rupprecht & Patashnick TEOM 1400a
	Berlin	DEBE068	Gravimetry
	Zurich	CH0010A	Gravimetry (Digitel HIVOL)
	Sofia	BG0050A	Beta-absorption
	Madrid	ES0126A	Gravimetry
	Paris	FR04143	TEOM
	London	GB0566A	TEOM-FDMS
Australia	Sydney	Earlwood	BAM

NO_2: Chemiluminescence
O_3: Ultraviolet Absorption
SO_2: UV Fluorescence

Data source: Canada: Environment Canada NAPS, United States: USEPA Air Quality System, EU: European Air Quality Database System (AirBase), Australia: Office of Environment and Heritage, New South Wales

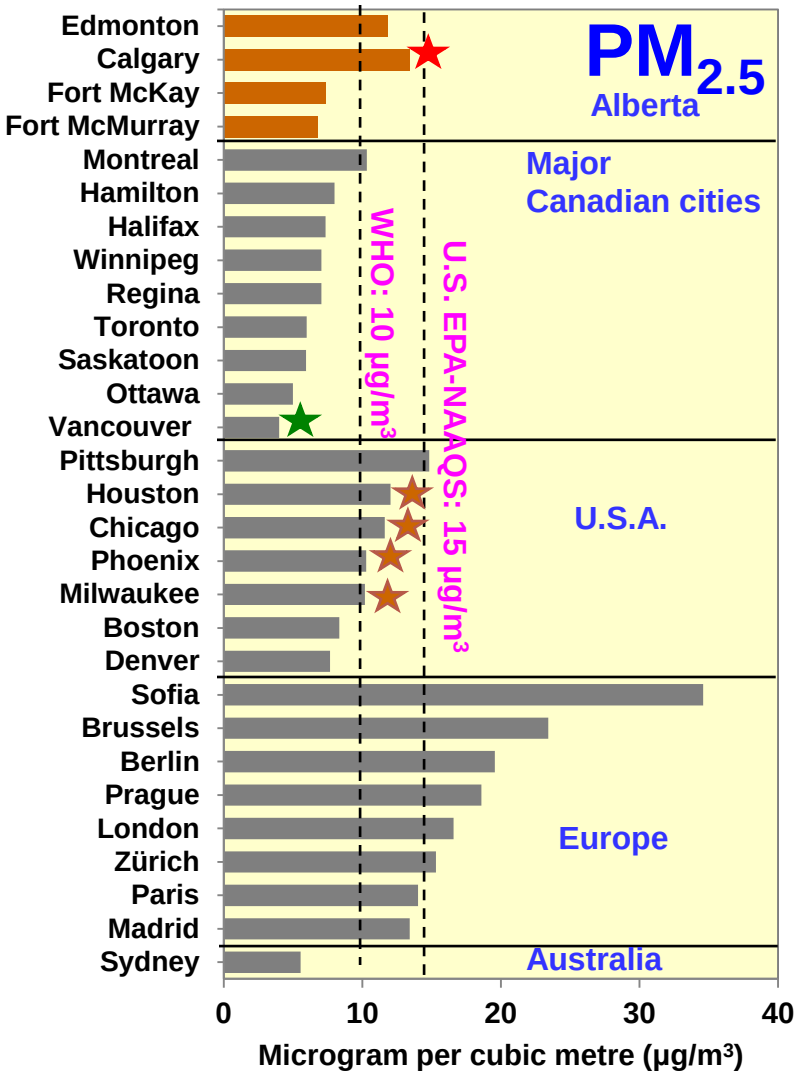
Air quality comparison – national & international urban areas (Annual average : year 2012)



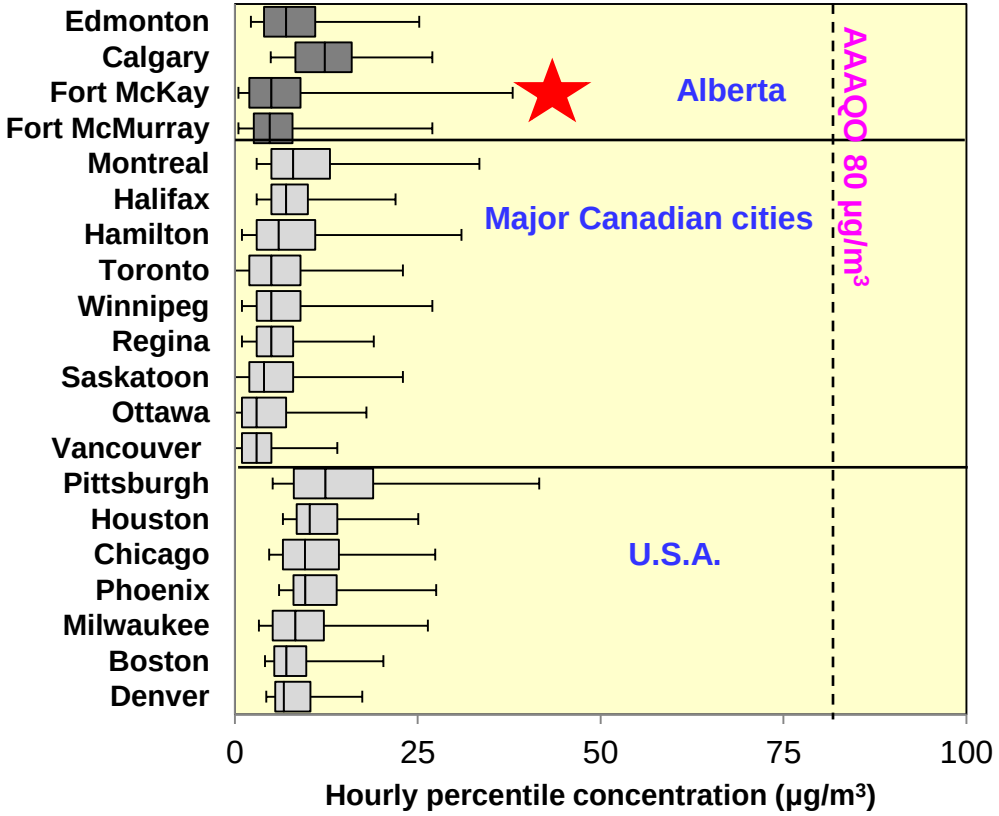


Comparison of $PM_{2.5}$ values with national and international urban areas

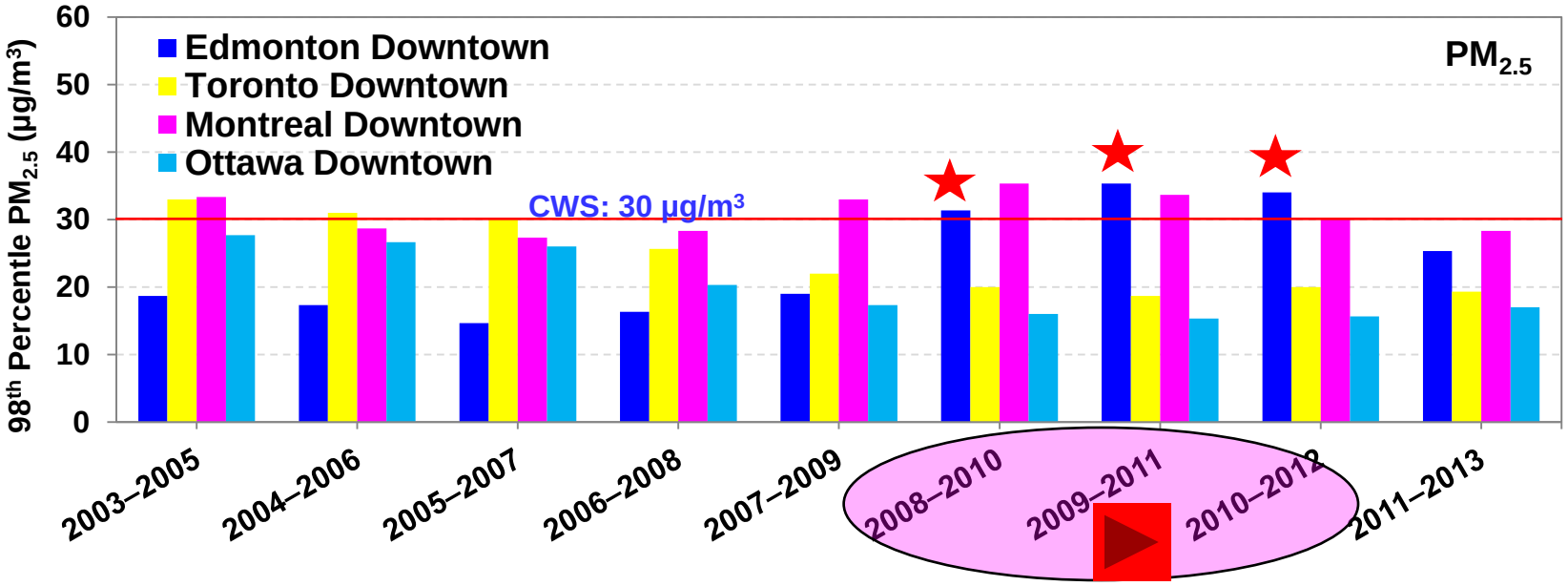
2010–2012 (3-yr average of 24-h)

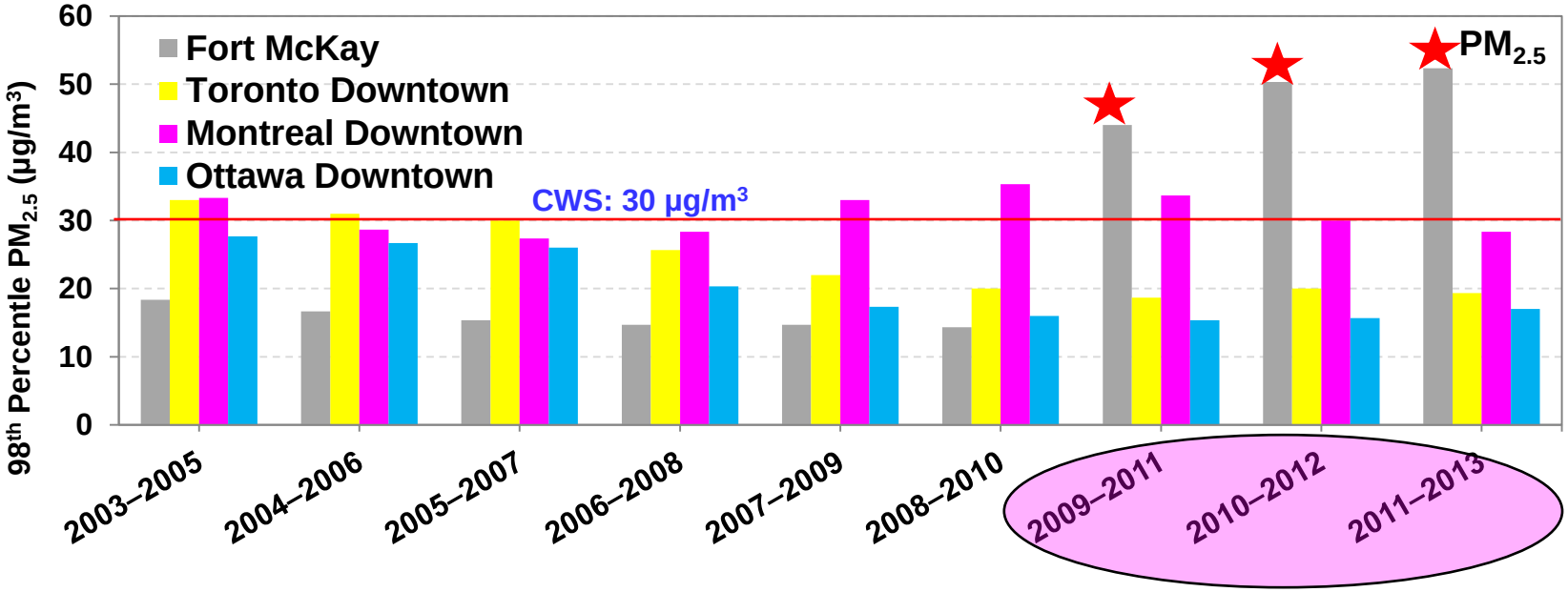


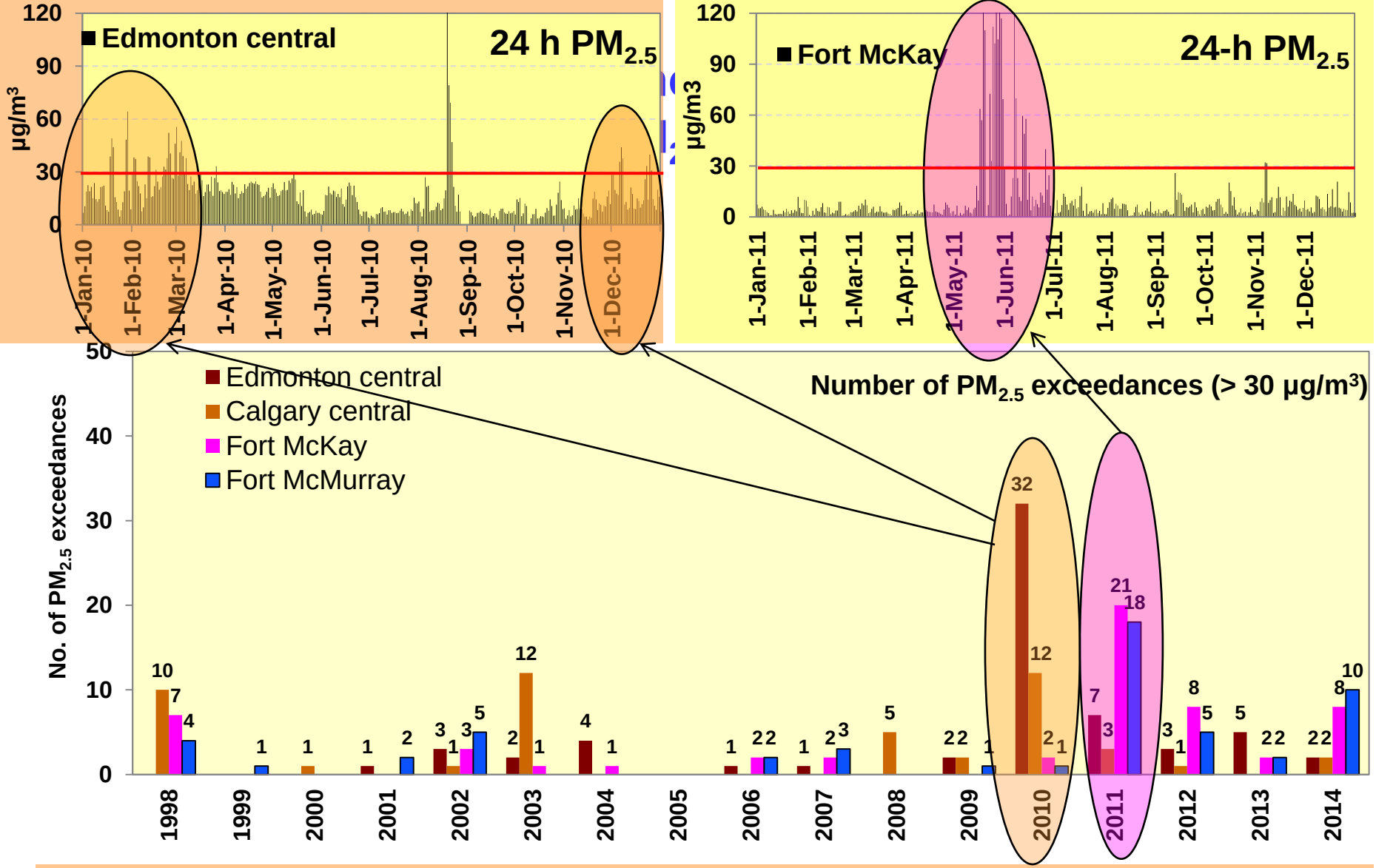
2012 (1 h percentile concentration)



Comparison of the 3-year average of the annual 98th percentile of the daily 24 h $PM_{2.5}$



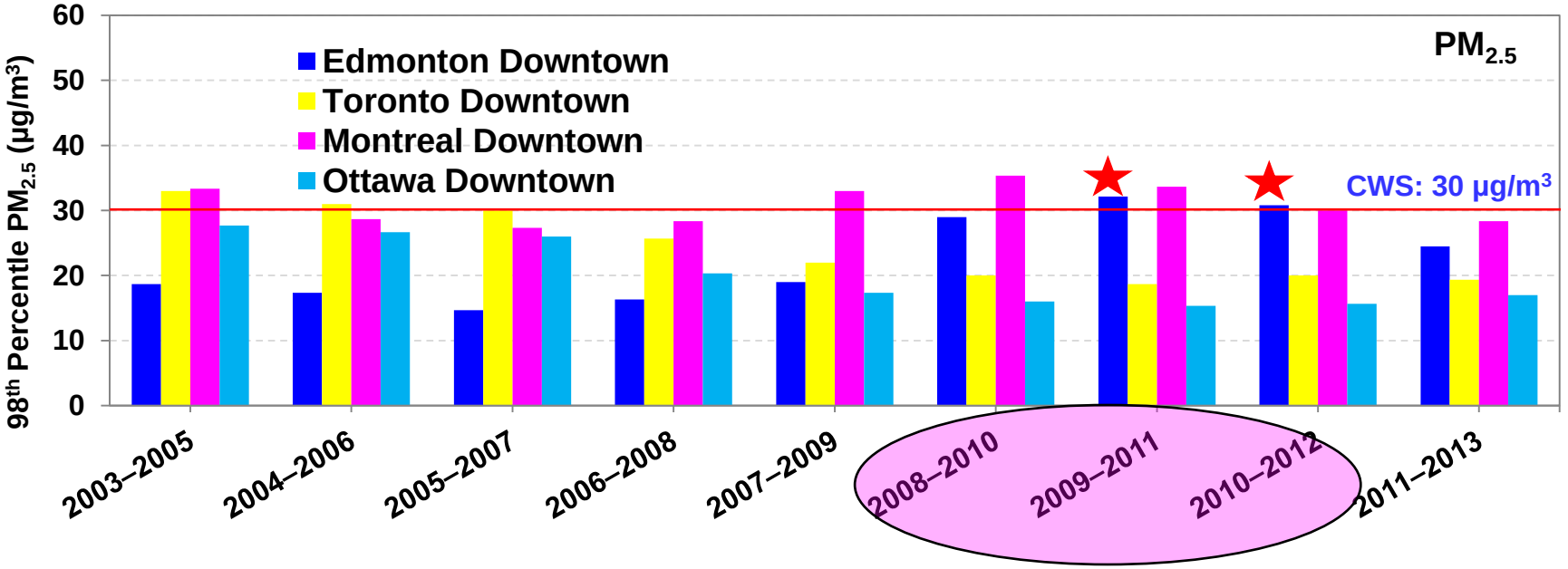


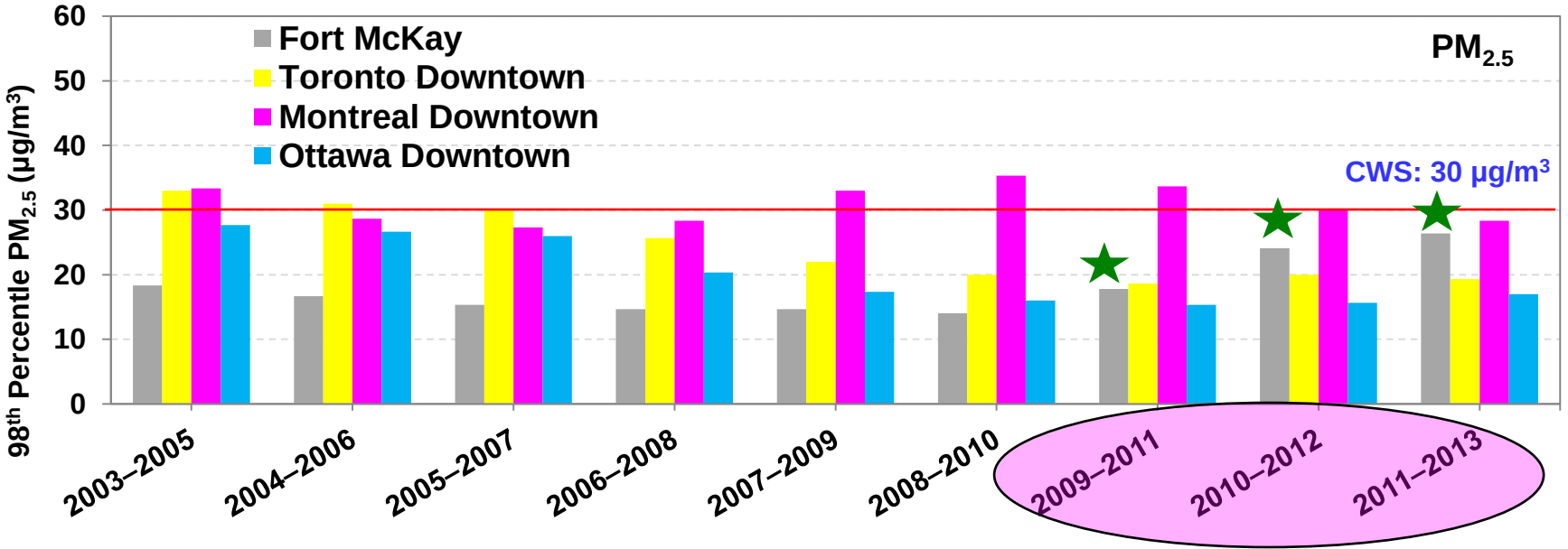


2010 : Edmonton/Calgary – adaptation of upgraded monitoring method (TEOM-FDMS) from 2009, influence of biomass burning emissions, winter inversions.

2011 : Fort McKay – influence of biomass burning emission (wildfires)

Annual 98th percentile 24 h $PM_{2.5}$ (excluding major wildfire days in 2010 (Aug 19–22, Edmonton) and 2011 (May 17–31, Jun 7–8, Fort McKay))





Summary findings

Urban areas in Alberta

- Consistent decreasing trend for NO_2 (< 1 ppb/yr) and CO (< 0.1 ppm/yr).
- Decreasing for THC (< 0.1 ppm/yr) and increasing for O_3 (≤ 0.5 ppb/yr).
- No change observed for $PM_{2.5}$ over a 17-year period.

Oil Sands Communities

- Little consistency in trend detection observed among two methods.
- Possible increasing trend for THC at Fort McKay and decreasing for O_3 at Fort McMurray.
- No trend detected for $PM_{2.5}$.

❖ ***Forest fire smoke plays key role for $PM_{2.5}$ exceedances at all stations.***

Implications for future work

- Longer-term air quality monitoring (20- to 30-year) needed to establish whether trends reported here are real.

Thank you very much for your attention!

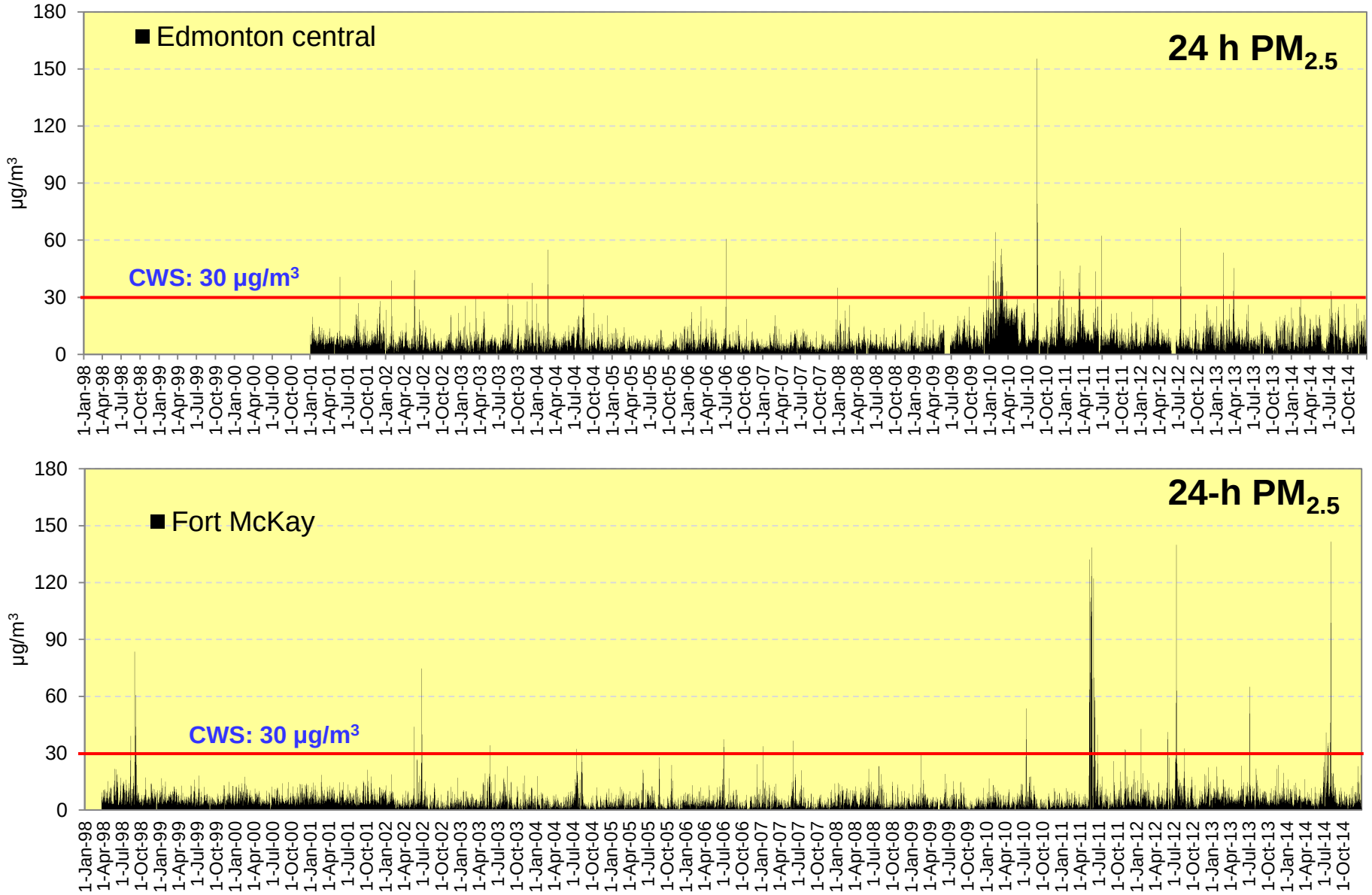
Additional slides

Exceedances of Alberta Ambient Air Quality Objectives (AAAQO): 1998 – 2014

Location/No. of exceedances	NO_2		$PM_{2.5}$[a]			O_3		SO_2			CO[b]	
	1 h	Annual	1 h	24 h	Annual	1 h	8 h	1 h	24 h	Annual	1 h	8 h
Edmonton central	0	0	103	63	0	6	1	0	0	0	1	–
Edmonton east	0	0	146	80	0	8	5	1	0	0	0	–
Calgary central	0	0	85	49	0	0	0	0	0	0	0	–
Calgary east	3	0	58	24	0	0	0	0	0	0	1	–
Fort McKay	0	0	348	56	0	9	10	1	0	0	–	–
Fort McMurray	3	0	285	54	0	2	0	0	0	0	0	0
Provincial and international standards and limits (ppb)												
AAAQO	159	24	80[c]	30*	n/a	82	65*	172	48	8	13	5
U.S. EPA	100	53	n/a	35	15	n/a	75	75	n/a	n/a	35	9
European Union	106	21	n/a	25	n/a	n/a	60	123	44	n/a	n/a	9
WHO	106	21	n/a	25	10	n/a	50	n/a	7	n/a	n/a	n/a
Australia	120	30	n/a	25	8	100	n/a	200	80	20	n/a	9

[a]µg/m^3; [b]ppm; [c]Alberta Ambient Air Quality Guidelines,
*Canada-Wide Standard; –, not measured; n/a, not available

$PM_{2.5}$ concentrations (24 h) at Edmonton and at AOSR over the study period (1998–2014)



Comparison of levels of $PM_{2.5}$ and its selected components between Edmonton and Toronto for 2007–2014

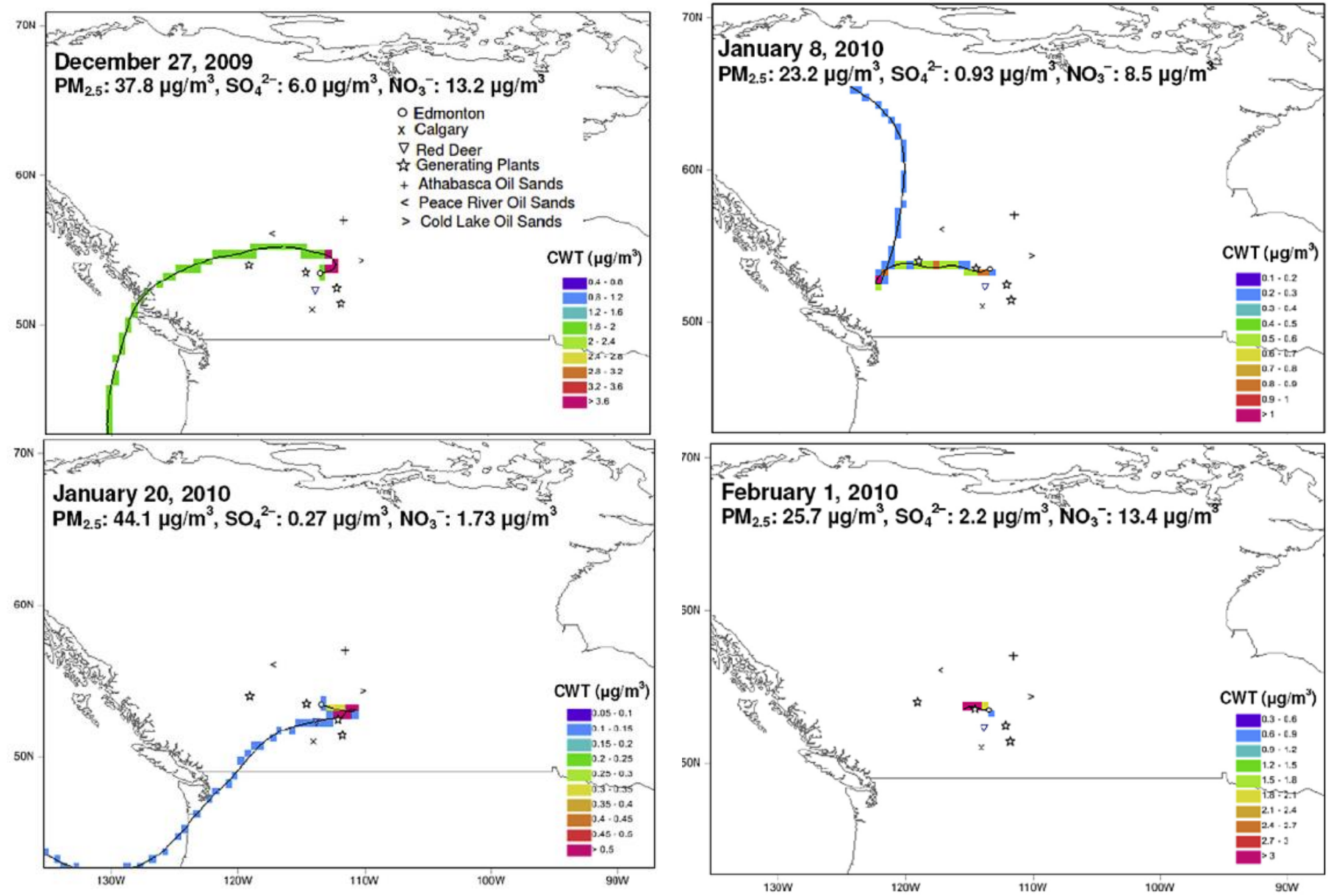
	Units	Difference in median	Median	*p*-value Paired *t*-test
$PM_{2.5}$	µg/m^3	–1.36	EDM<TOR	0.001
OC	µg/m^3	–0.36		0.487
EC	µg/m^3	0.15	EDM>TOR	<0.0001
SO_4^{2-}	µg/m^3	–0.67	EDM<TOR	<0.0001
NO_3^-	µg/m^3	–0.03	EDM<TOR	0.036
NH_4^+	µg/m^3	–0.27	EDM<TOR	<0.0001
Na+	µg/m^3	–0.02	EDM<TOR	<0.0001
Cl^-	µg/m^3	–0.02	EDM<TOR	<0.0001
K^+	µg/m^3	–0.01	EDM<TOR	<0.0001
As	ng/m^3	–0.14	EDM<TOR	<0.0001
Ba	ng/m^3	–0.02	EDM<TOR	0.025
Cd	ng/m^3	–0.02	EDM<TOR	0.007
Cr	ng/m^3	0.18	EDM>TOR	<0.0001
Cu	ng/m^3	–0.31	EDM<TOR	0.007
Mn	ng/m^3	1.90	EDM>TOR	<0.0001
Ni	ng/m^3	0.16	EDM>TOR	<0.0001
Pb	ng/m^3	–0.88	EDM<TOR	<0.0001
Sb	ng/m^3	–0.08	EDM<TOR	<0.0001
Se	ng/m^3	–0.16	EDM<TOR	<0.0001
V	ng/m^3	–0.12		0.293
Zn	ng/m^3	–1.84	EDM<TOR	0.046

Dominant sources and potential source regions of air toxics (HAPs) on $PM_{2.5}$ event and non-event days for 2009–2011

Date	$PM_{2.5}$ ($\mu g/m^3$)[a]	SO_4^{2-} ($\mu g/m^3$)[a]	NO_3^- ($\mu g/m^3$)[a]	Dominant sources	Potential local and long-range source regions	Traffic $\mu g/m^3$	SOA $\mu g/m^3$	Fossil fuel combustion $\mu g/m^3$	Biomass burning $\mu g/m^3$	Evidence
27-Dec-09	37.8	6.0	13.2	Fossil fuel combustion, traffic	Immediate northeast	12.59	0.20	9.48	1.43	HYSPLIT
8-Jan-10	23.2	0.93	8.5	Traffic	Local	22.31	0.34	1.22	0.97	HYSPLIT
20-Jan-10	44.1	0.27	1.7	Traffic	Local	11.79	2.35	0.74	0.80	HYSPLIT
1-Feb-10	25.7	2.2	13.4	Fossil fuel combustion	West generating plants	6.86	1.64	4.47	−0.10	HYSPLIT
25-Feb-10	25.2	0.86	10.6	Traffic	Local	13.04	2.34	0.99	0.35	HYSPLIT
3-Mar-10	23.4	1.3	8.8	Traffic	Local	17.25	3.02	0.83	0.24	HYSPLIT
6-Aug-10	22.5	1.7	0.08	Biomass burning, SOA	Southern Alberta forest fires	4.14	3.07	0.70	0.16	HYSPLIT
24-Aug-10	7.1	0.26	n/a	Biomass burning, SOA	British Columbia forest fires	4.38	3.27	1.08	0.68	HYSPLIT
29-Oct-10	23.0	6.6	4.1	Traffic	Local	8.82	2.39	0.96	0.43	HYSPLIT
22-Dec-10	25.5	2.1	6.3	Traffic, fossil fuel combustion, biomass burning	Local, southern Alberta, U.S. regions	15.49	0.38	3.09	2.78	HYSPLIT
10-Mar-11	18.9	4.5	6.6	Fossil fuel combustion	Northeast, south, southeast, southwest	1.08	1.33	2.38	−0.08	HYSPLIT

Bari and Kindzierski, 2017. Chemosphere 173, 160–171

Potential source regions of fossil fuel combustion on $PM_{2.5}$ event days for 2009–2010

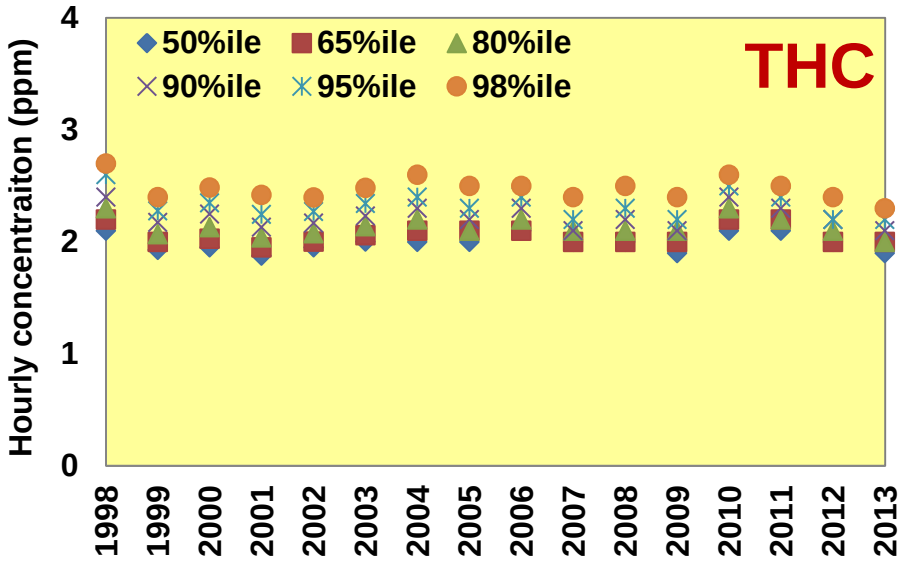


Bari and Kindzierski, 2017. Chemosphere 173, 160–171

Trends (1998–2013) – Total Hydrocarbon (THC)

Fort McKay

Concentration	Trend	Rate of change /year
50th percentile	▲	<0.1 ppm
65th percentile	▲	<0.1 ppm
80th percentile	▲	<0.1 ppm
90th percentile	▲	<0.1 ppm
95th percentile	▲	<0.1 ppm
98th percentile	–	n/a

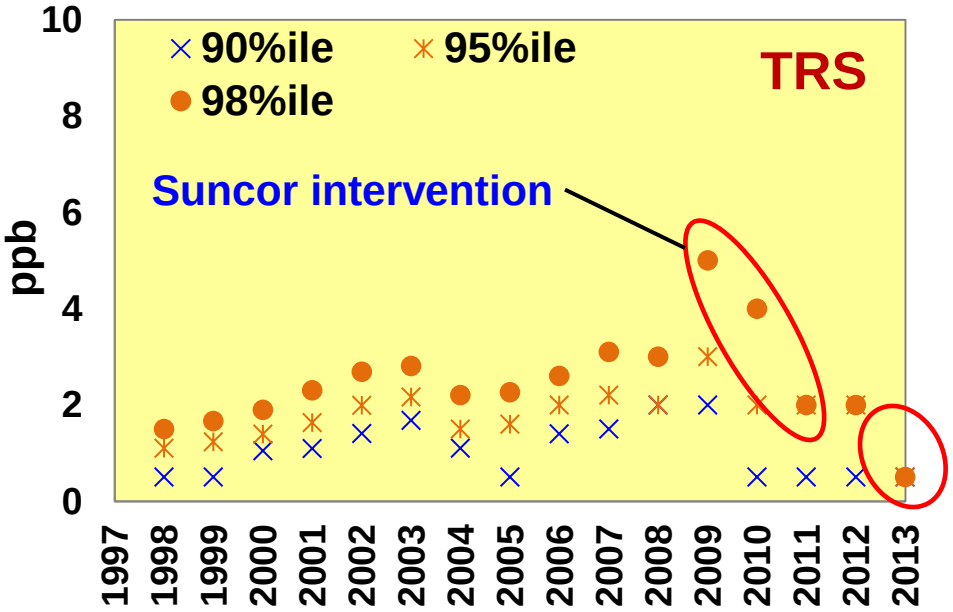


Fort McMurray
Patricia McInnes

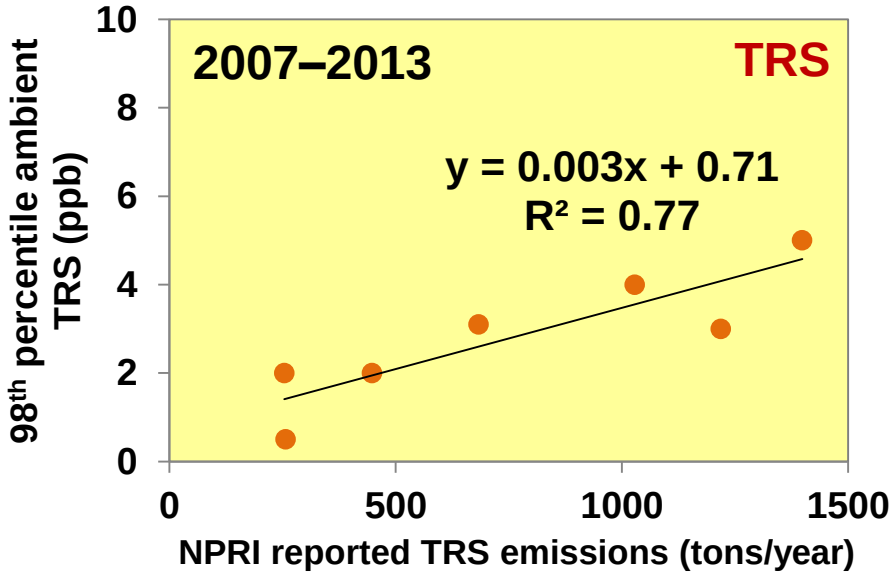
Concentration	Trend	Rate of change /year
50th percentile	▲	<0.1 ppm
65th percentile	▲	<0.1 ppm
80th percentile	–	n/a
90th percentile	–	n/a
95th percentile	–	n/a
98th percentile	–	n/a

Direction of trend (p = 0.05), ▲ increasing
– no change

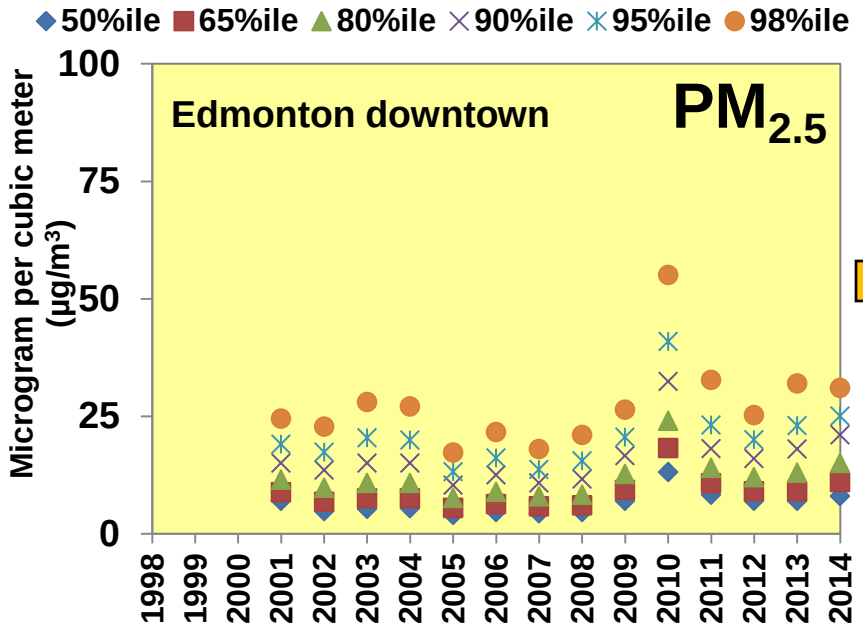
Trends – Total Reduced Sulfur (TRS) at Fort McKay



Associated with odourant compounds

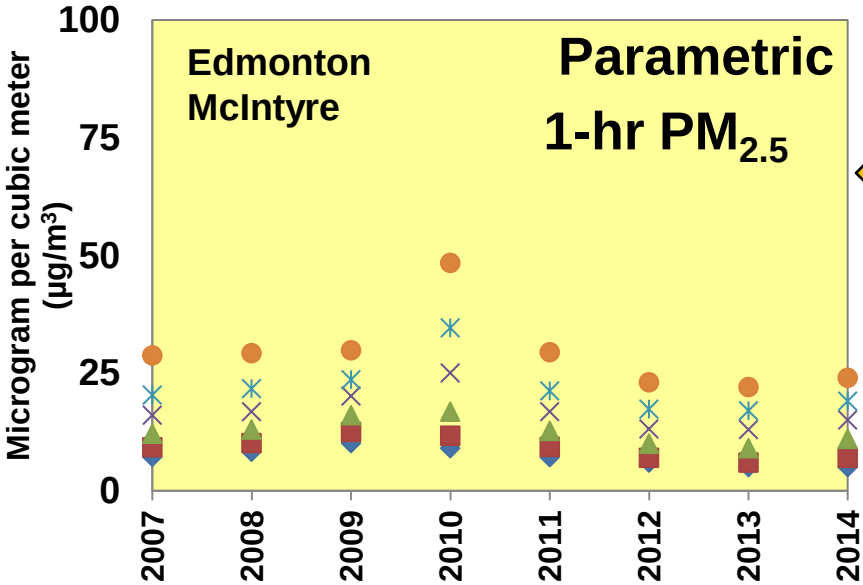


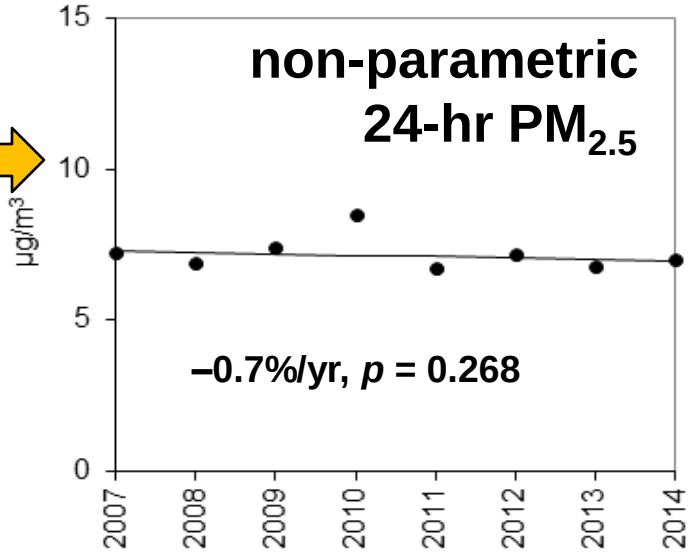
Trend analysis – Edmonton: $PM_{2.5}$



Concentration	Trend	Rate of change /year	R^2
50th percentile	—	n/a	n/a
65th percentile	—	n/a	n/a
80th percentile	—	n/a	n/a
90th percentile	—	n/a	n/a
95th percentile	—	n/a	n/a
98th percentile	—	n/a	n/a

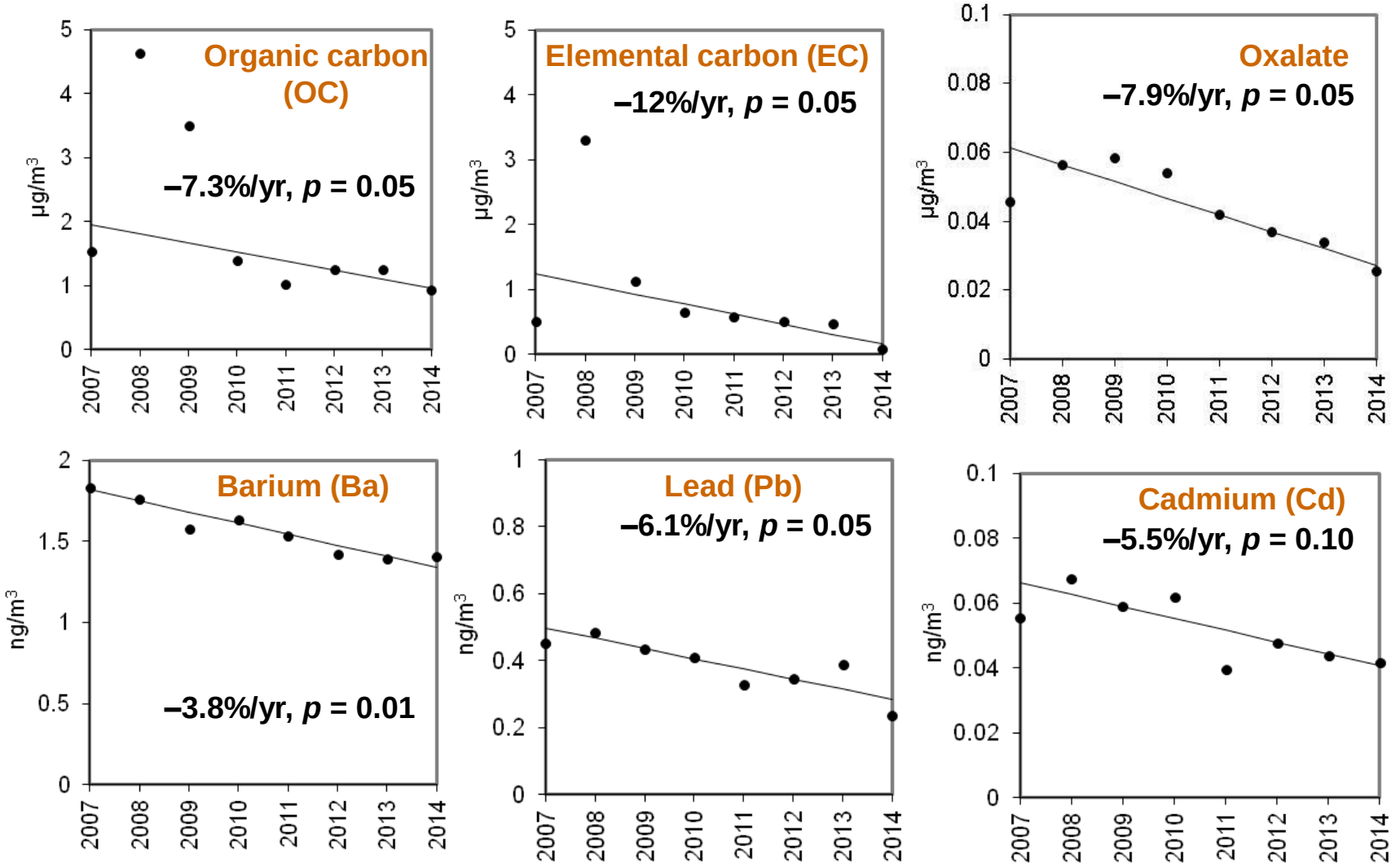
Direction of trend (p = 0.05), — no change
n/a: not applicable





Trends in ambient $PM_{2.5}$ components in Edmonton: 2007–2014

(Mann-Kendall &Theil-Sen methods)



Bari et al., 2016a, Environment International (in press)