

Impacts of the Fort McMurray wildfire on concentrations of PAHs, VOCs and O₃

Greg Wentworth¹, Yayne Aklilu¹, Yu-Mei Hsu², Matt Landis³

¹Environmental Monitoring and Science Division, Alberta Environment and Parks

²Wood Buffalo Environmental Association

³National Exposure Research Laboratory, U.S. Environmental Protection Agency

Motivation – Health Effects

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Respiratory problems affect 1 in 5 firefighters after Fort McMurray wildfire

'People may develop bigger issues as time goes forward,' says epidemiologist in preliminary research

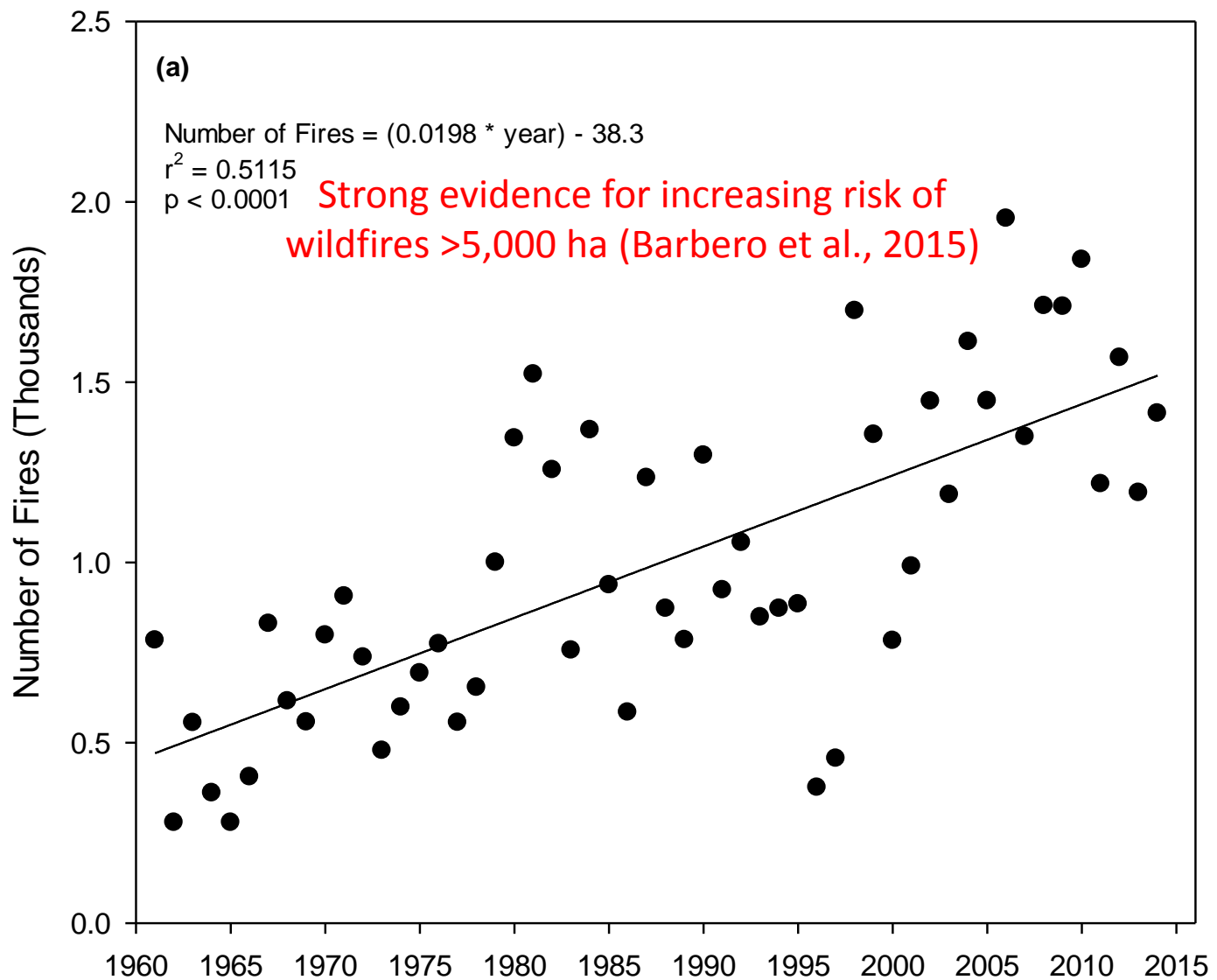
CBC News Posted: Apr 18, 2017 3:00 AM MT | Last Updated: Apr 18, 2017 9:02 AM MT



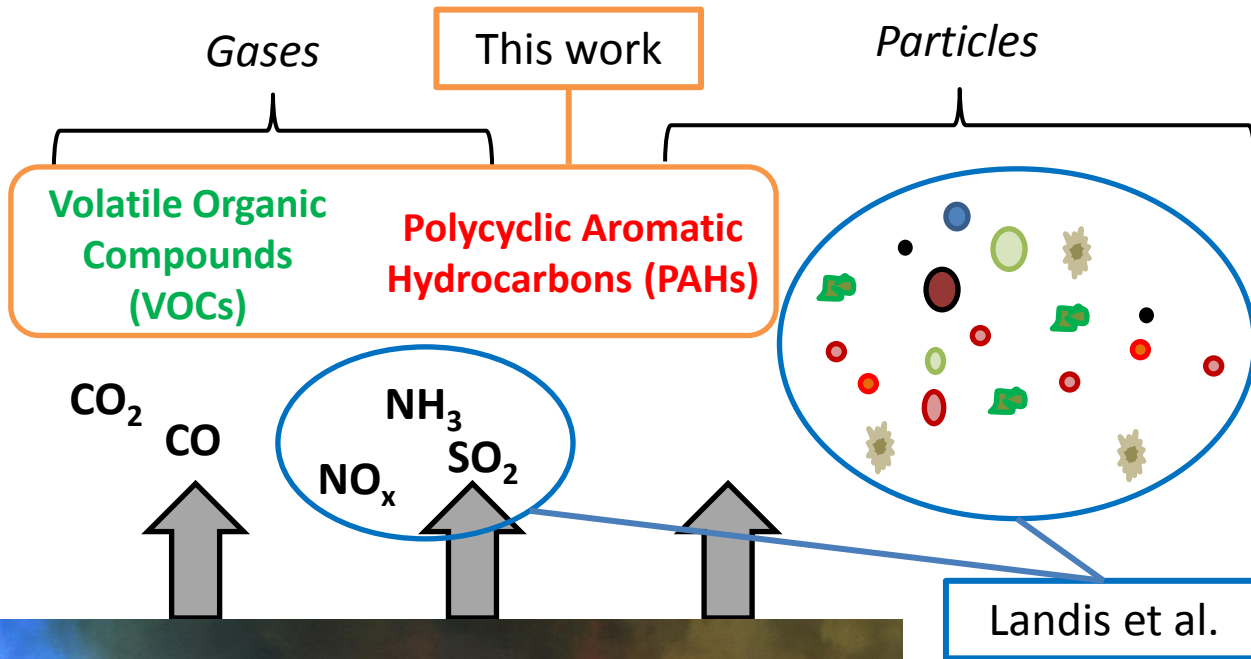
Initial findings from a University of Alberta study show how the Fort McMurray wildfire continues to affect the firefighters who fought it. (Chris Schwarz/Government of Alberta)

“...persistent respiratory issues including coughing, breathlessness, wheezing and chest tightness.”

Motivation – Increasing Frequency



Wildfires and Air Pollutants



Secondary Pollutants:

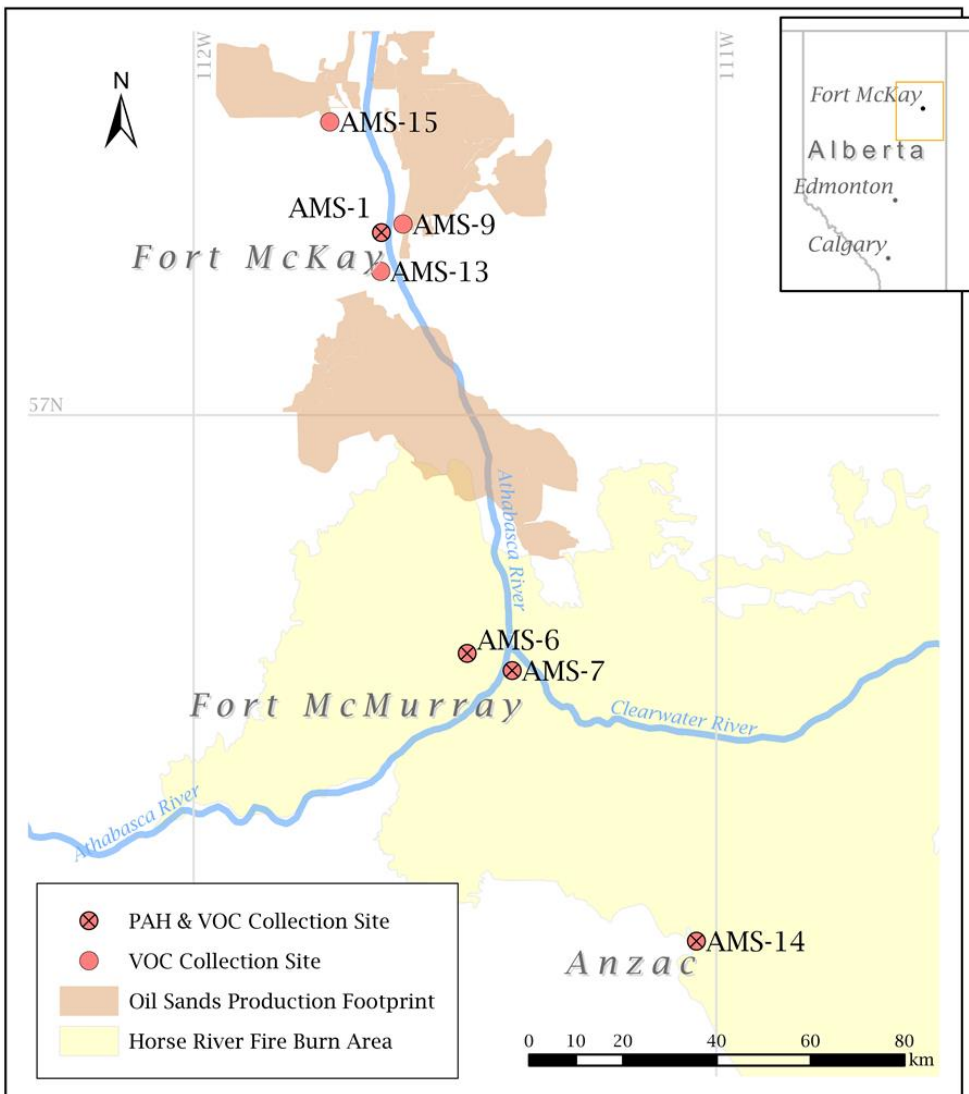
- O₃
- OVOCs
- SOA
- Oxidized-PAHs (PACs)



Wildfire studies on PAHs and VOCs

- Generally increased in wildfire plumes
- Speciation and concentrations vary
- Near-fire measurements are difficult

WBEA Air Monitoring Network



- ~20 Air Monitoring Stations (AMS)
- Hourly averages of various trace gases (NO_x , SO_2 , ...) and $\text{PM}_{2.5}$ mass
- PAHs:
 - Daily averages, every sixth day
 - 4 sites
 - 23 species with PUF/XAD-2/PUF
- VOCs:
 - Daily averages, every sixth day
 - 7 sites
 - 65 species with evacuated canister

Service Layer Credits: T. Auch, 2014 (Production Footprint of Oil Sands Development).
Wood Buffalo Environmental Association, 2017 (Horse Fire Burn Area).













Study Objectives

- 1) Assess PAH and VOC concentrations and composition during/after fire
- 2) Compare PAHs and VOCs against AAAQOs – is there a potential to impact air quality?
- 3) Examine if O_3 is enhanced ~100s km downwind

Results – “Fire Influenced” Samples

- May samples with at least 1-hr of $PM_{2.5} > 25 \mu g m^{-3}$
- Used for 2011 Richardson fire

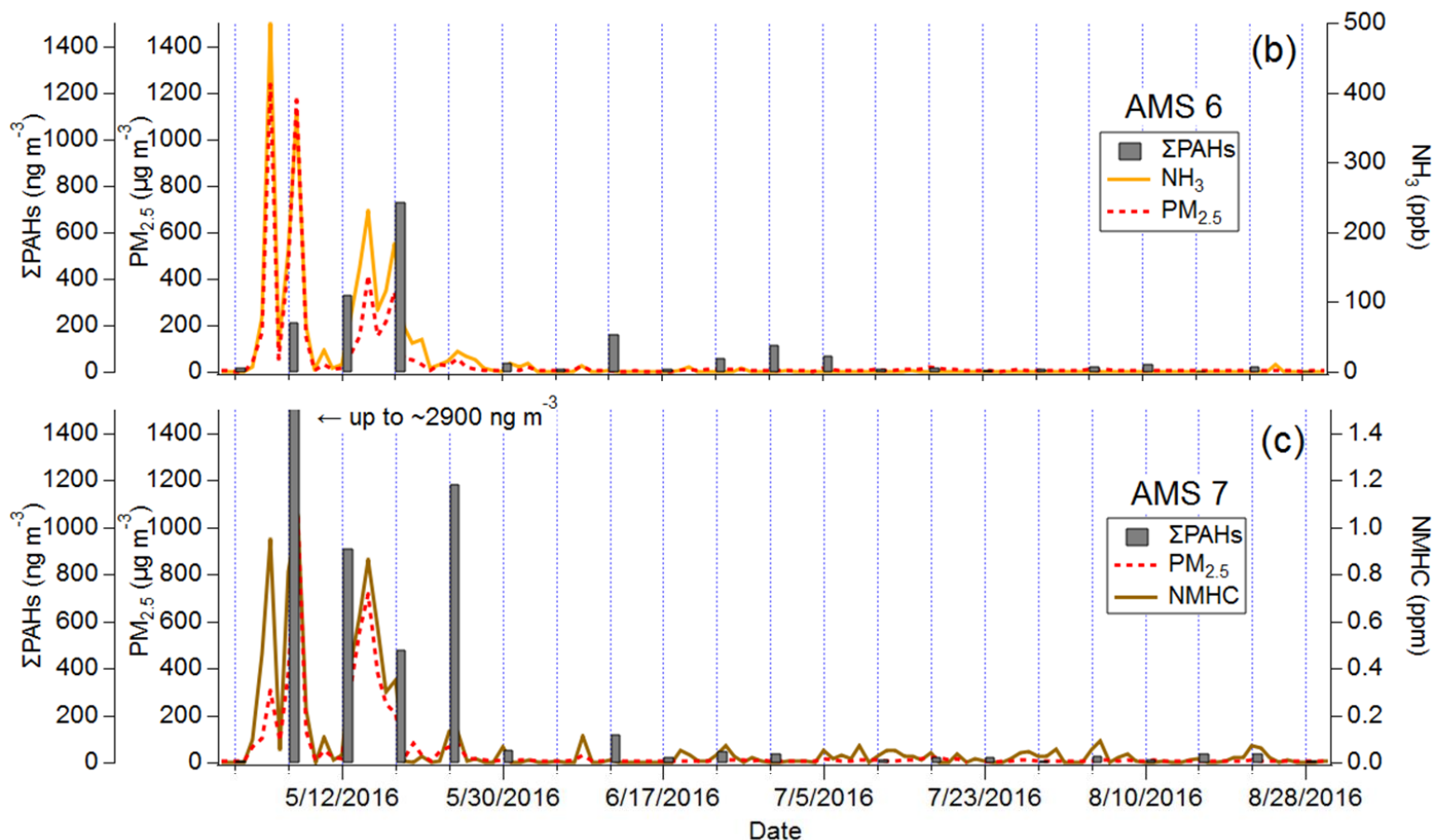
(Bytnerowicz et al., *Sci Total Environ*, 2016)

Date	AMS 1	AMS 6	AMS 7	AMS 14
May 6				N/A*
May 12	No			N/A*
May 18	No			
May 24				
May 30	No	No	No	No

* $PM_{2.5}$ monitor was inoperative

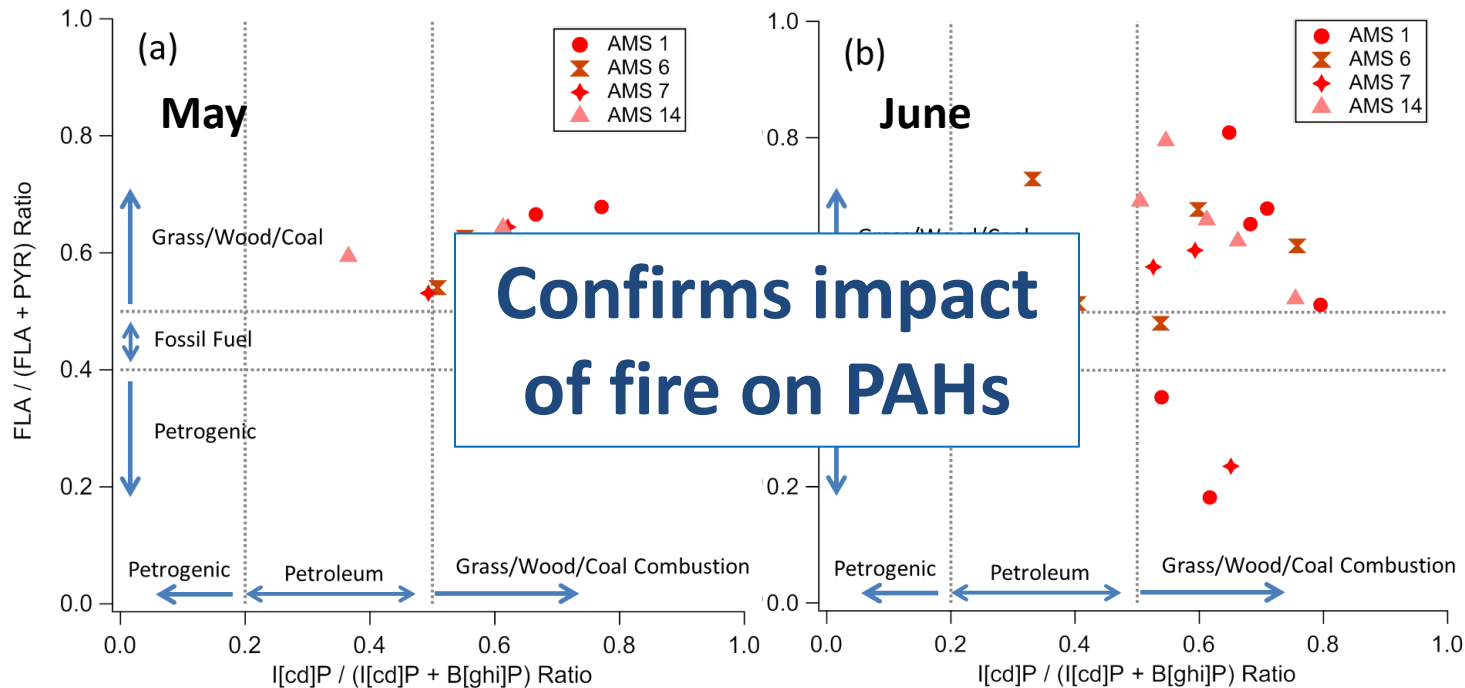
Results – PAH Concentrations

- Σ PAH enhanced by ~ 4 -65x by fire (n = 8)
- Average: 852 ng m^{-3} (fire) vs. 50 ng m^{-3} (non-fire)
- Interquartile range: 300 - 980 ng m^{-3} vs. 13 - 54 ng m^{-3}



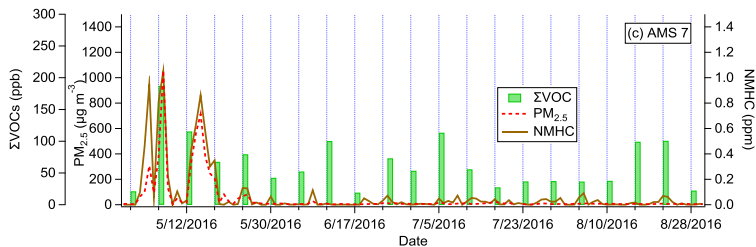
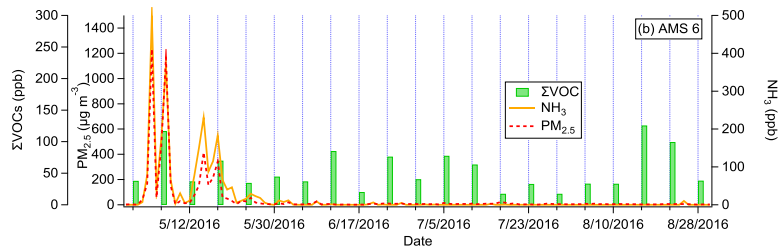
Results – Diagnostic PAH Ratios

- **May:** dominant biomass burning (BMB) source
- **June:** influence from petrogenic/petroleum sources
- **Previous studies:** dominated by petrogenic/petroleum
 - Evans et al. (2016), Schuster et al. (2015), Wnorowski (2017)



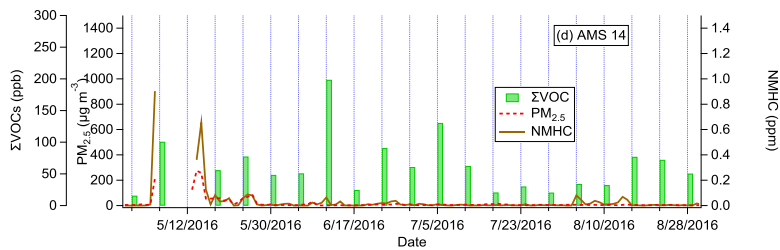
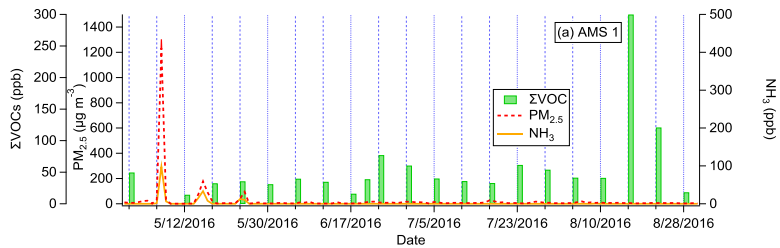
Results – VOC Concentrations

- Σ VOC enhanced by $\sim 1.5x$ by fire (n = 16)
- Average: 63 ppb (fire) vs. 46 ppb (non-fire)
- Interquartile range: 35-79 ppb vs. 32-53 ppb



Results – VOC Concentrations

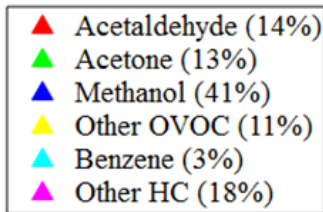
- Aug 16/22: $\Sigma\text{VOC} \sim 120$ ppb



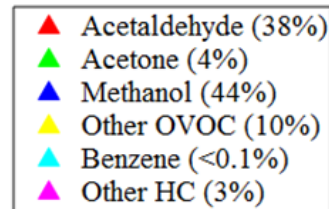
Results – VOC Composition

- OVOCs suggest significant atmospheric processing

(a) Fire Influenced



(c) August 16 and 22



- Aug 16/22: ~82% methanol and acetaldehyde
 - *Acetaldehyde*: oxidation of VOCs ($\geq C_3$ -alkene, $\geq C_2$ -alkanes, ethanol, propanal); some direct emissions
 - *Methanol*: vegetation, biomass decay, oxidation of CH_4

Acetaldehyde Sources: Luechken et al. (2012); Millet et al. (2010)

Methanol Sources: Heikes et al. (2002)

Results – Impacts on Air Quality

Alberta Ambient Air Quality Objectives (AAAQOs)

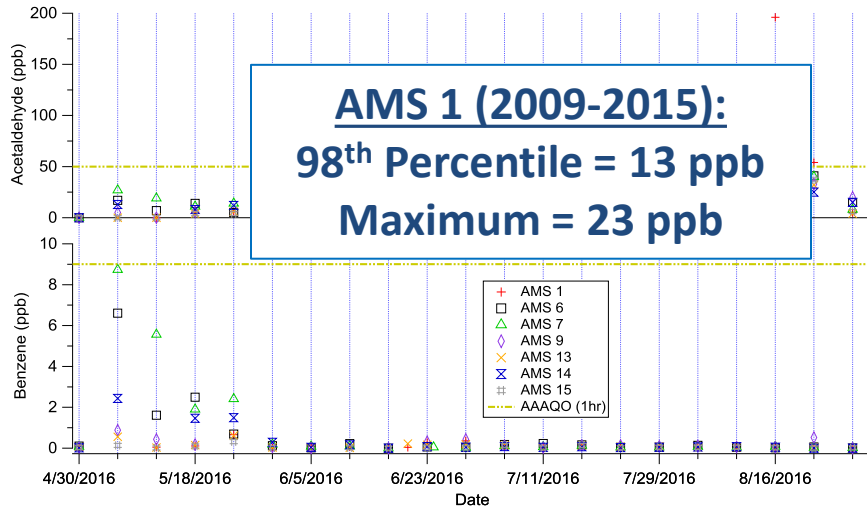
- Based on “...scientific, social, technical and economic factors”
- Exceedances may cause adverse health effects to sensitive persons
- Intended to identify situations that require further investigation

Substance	AAAQO (1-hr, ppbv)	Highest Daily Average (ppb, May-Aug 2016)
Acetaldehyde	50	196
Acetone	2,400	15
Benzene	9.0	8.7
Ethylbenzene	460	1.7
Formaldehyde	40	24
Isopropylalcohol	3,190	2.2
Methanol	2,000	162
n-hexane	5,960	15
o-xylene	530	1.5
Styrene	52	0.3
Toluene	499	4.6

Caveats

- 1) Acute AAAQOs only exist for 11 VOCs and 0 PAHs
- 2) Hourly AAAQOs and daily averages
- 3) No sites regularly monitor speciated VOCs with 1 hour resolution...

Results – Benzene and Acetaldehyde



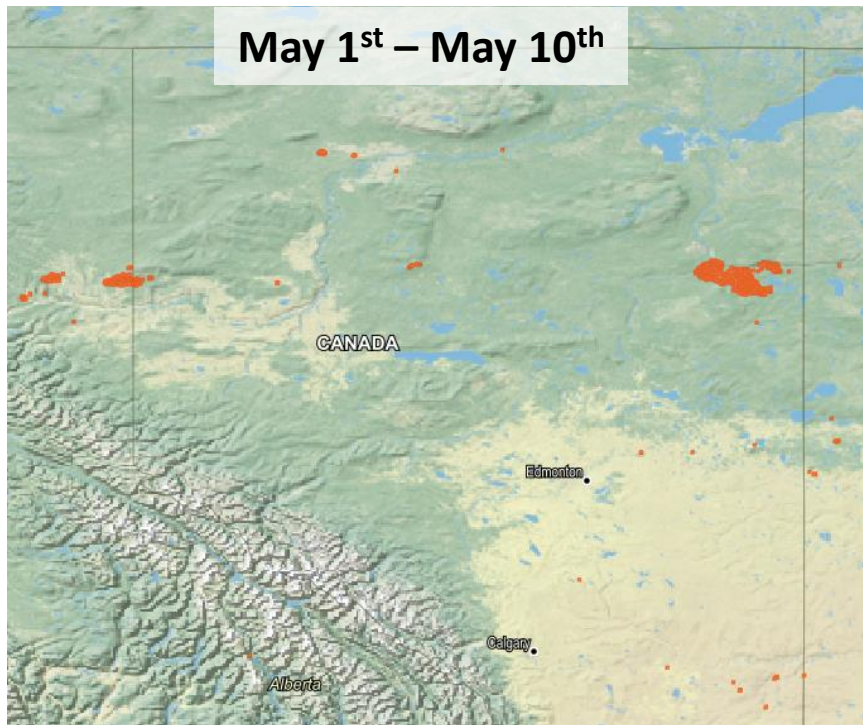
Acetaldehyde is from ???

Benzene is from wildfire

Acetaldehyde from lingering fires?

NASA's Web Fire Mapper Tool

- Near-real time and historical maps of global wildfire activity
- Satellite-based instruments (MODIS and VIIRS) at 1 km² resolution

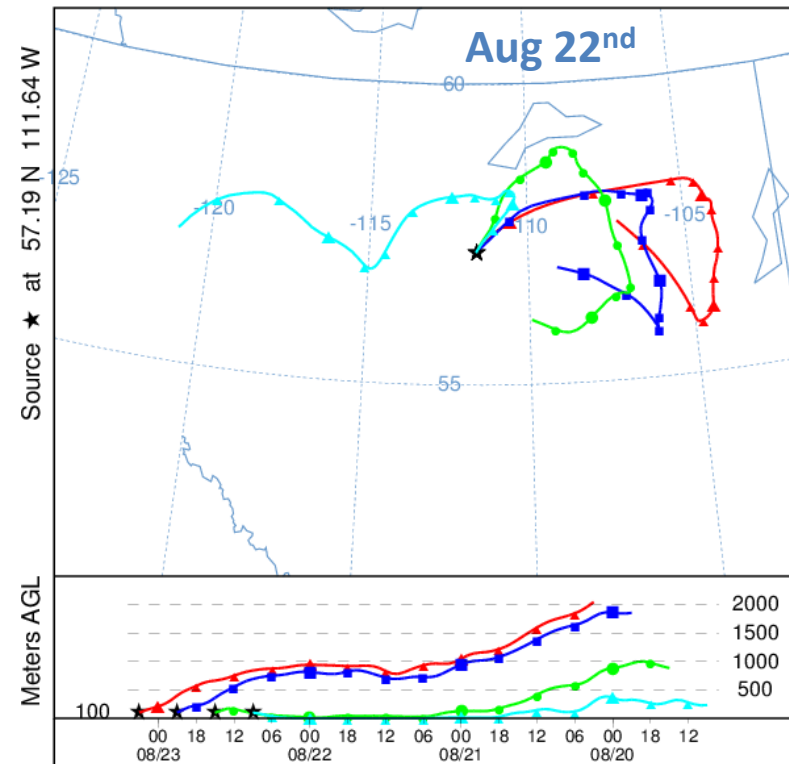
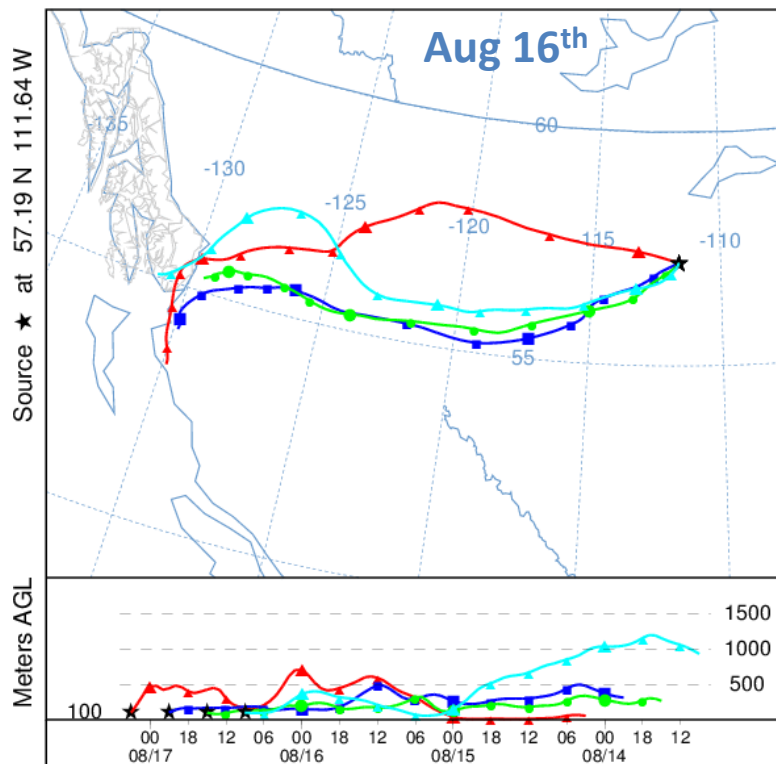


August episodes not from wildfires!

Acetaldehyde from long range transport?

NOAA's HYSPLIT Model

- Models air parcel backtrajectories (i.e. where did the air come from?)
- Arrival times of 3:00, 9:00, 15:00, 21:00 at AMS 1



August episodes probably not from long range transport

Other studies with high acetaldehyde?

1) Biogenic emissions? **Unlikely to be major source**

Previous studies in temperate forests (high biogenic VOCs)

Study	Location	Average (ppb)	Max (ppb)
Ramasamy et al. (2016)	Japan	3.6	10
Yu et al. (2008)	Southern China	3.3	13
Wang et al. (2005)	British Columbia	0.6	1.8
Kajos et al. (2015)	Finland	0.5	~1

2) Urban/industrial emissions? **Likely a contributing factor**

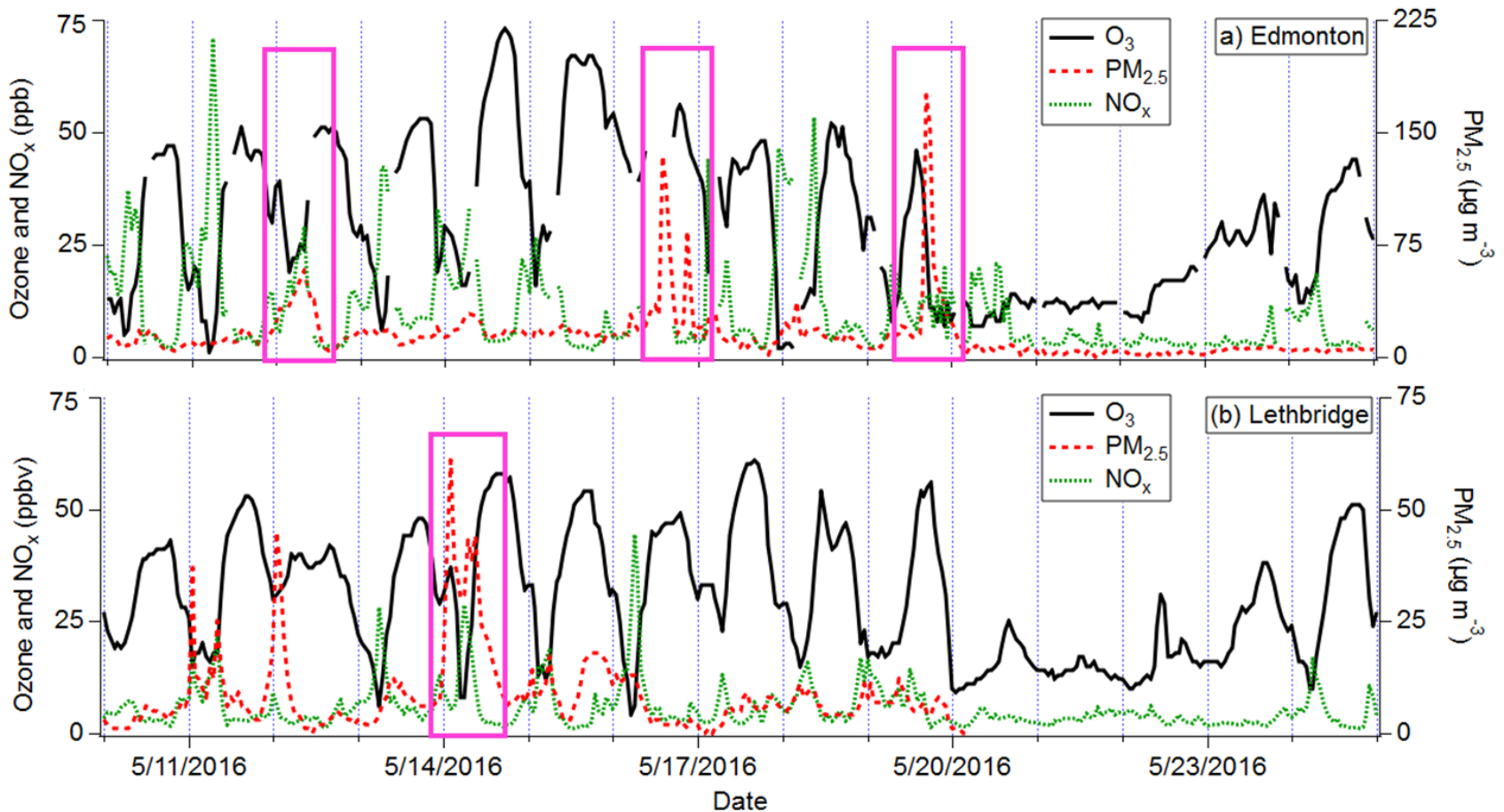
Previous studies in urban/industrial areas (high anthropogenic VOCs)

Study	Location	Average (ppb)	Max (ppb)
Baez et al. (2016)	Mexico City	20	99
Simpson et al. (2013)	Near Edmonton	32*	74
Seo and Baek (2011)	South Korea	4.4	77

*Only considers plume events

Results – O₃ Production Downwind

Assessed wildfire influence with PM_{2.5}, HYSPLIT and Fire Tool



**No evidence for O₃ enhancement ~100s of km downwind
(likely related to meteorology)**

Conclusions

1) PAHs

- Σ PAHs increased by ~ 4 -58x
- Diagnostic ratios indicative of biomass burning

2) VOCs

- Σ VOC increased by less than ~ 1.5 x
- Aug 16th /22nd had Σ VOC larger than fire

3) Air Quality Implications

- Benzene (during fire)
- Acetaldehyde (after fire, likely anthropogenic)

4) Downwind O_3

- No evidence for O_3 enhancement in Edmonton or Lethbridge; likely related to meteorology

Questions?

