

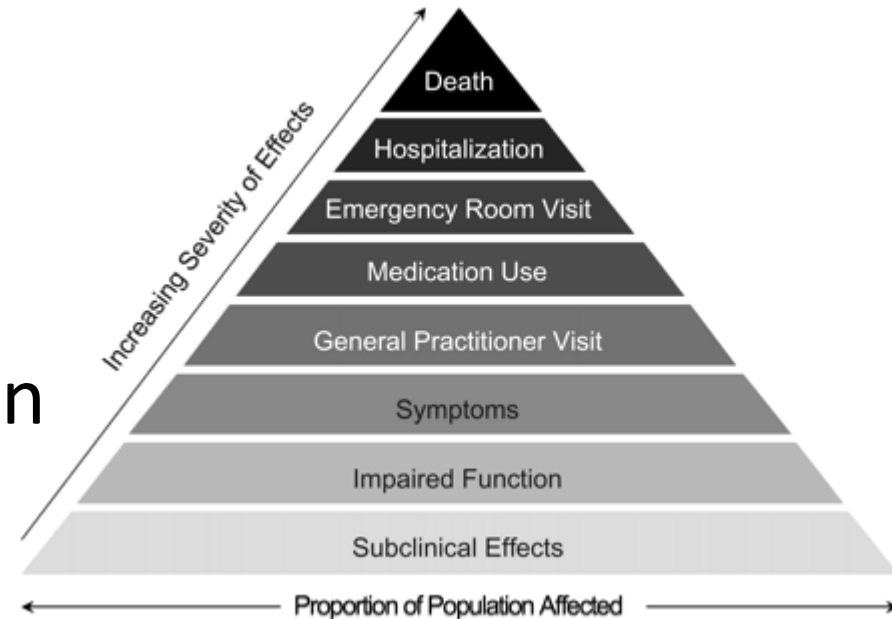
Air pollution and health

- Ambient air pollution (individual) **risk** is small...but large **exposed population** = **large population risk**
 - Drug abuse: Larger risk, smaller exposed population
- Major impacts are on chronic disease progression
- Diseases impacted by air pollution are multifactorial...
- ...Air pollution as a contributing risk factor



Air pollution and health

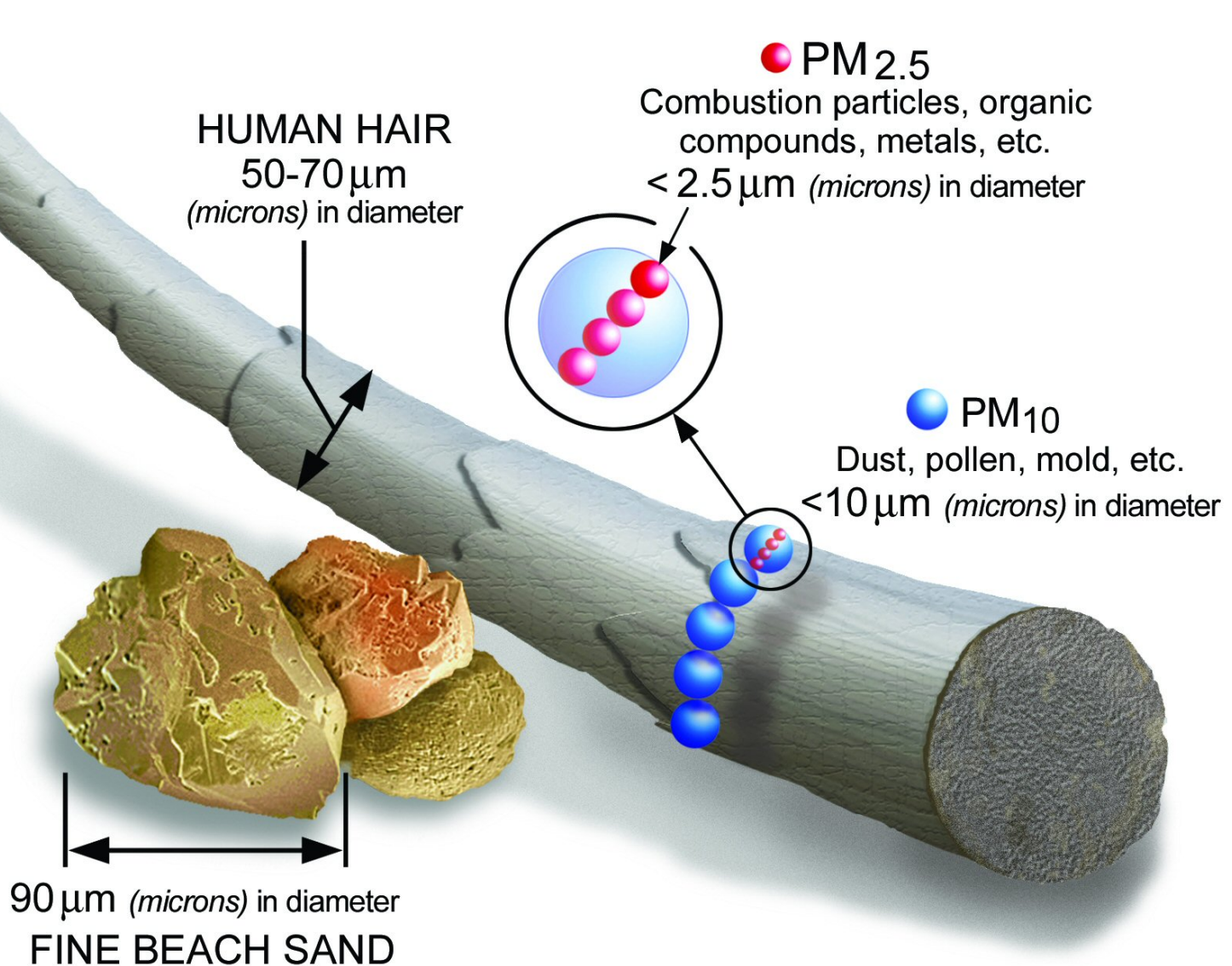
- On **days** with worse air quality, more people die*
- In **more polluted cities**, people die earlier than in less polluted cities...
- ...and, in the **most polluted areas** of cities, there is an increased risk of dying

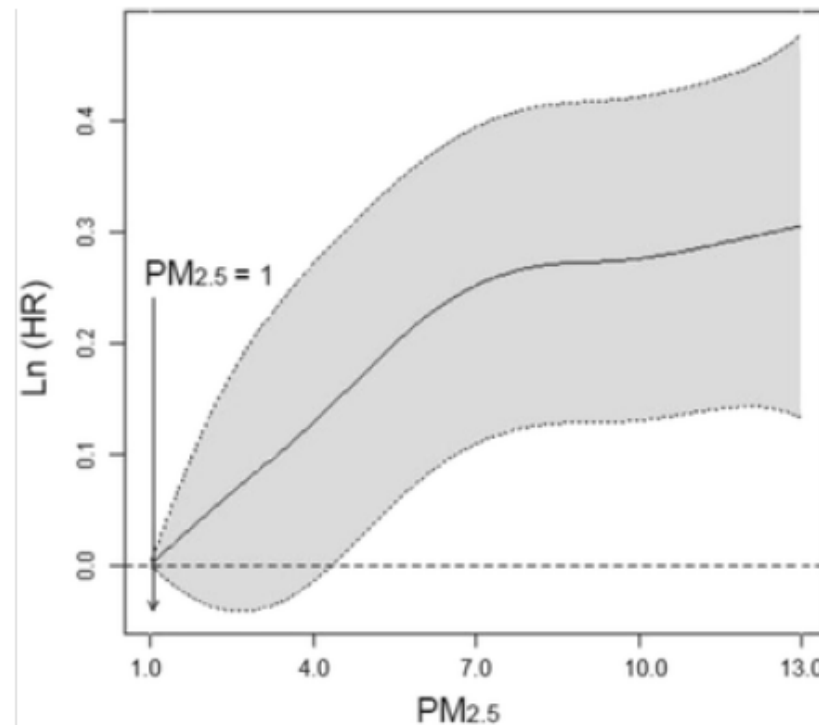
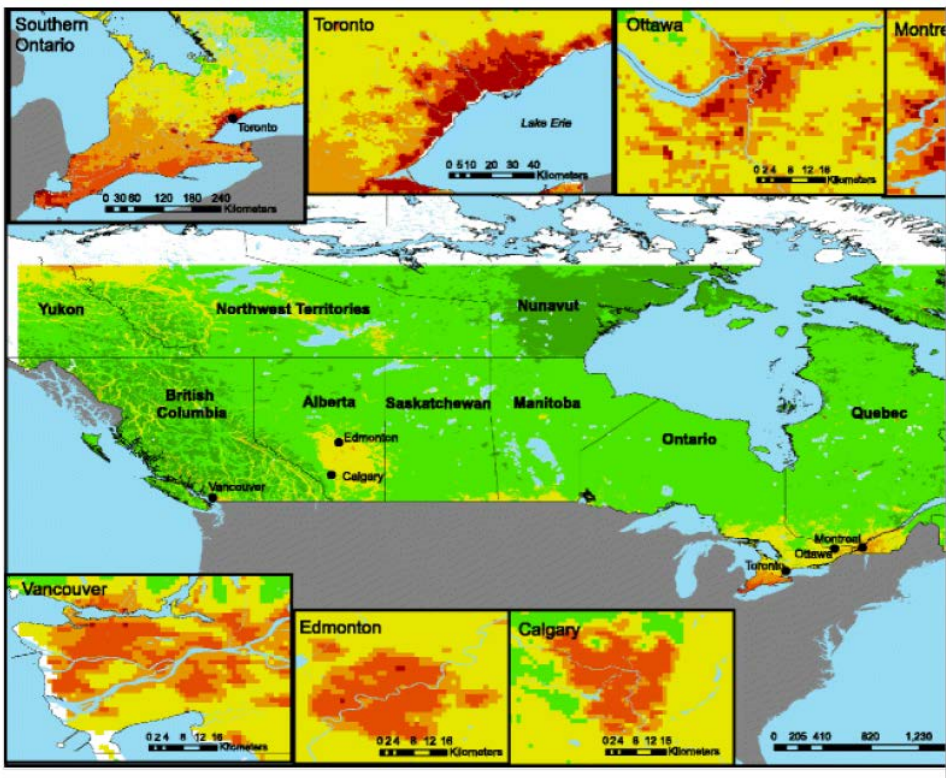


Larrieu et al. Am J Epidemiol, 2009

*out-of-hospital, >65 yrs

Particulate Matter

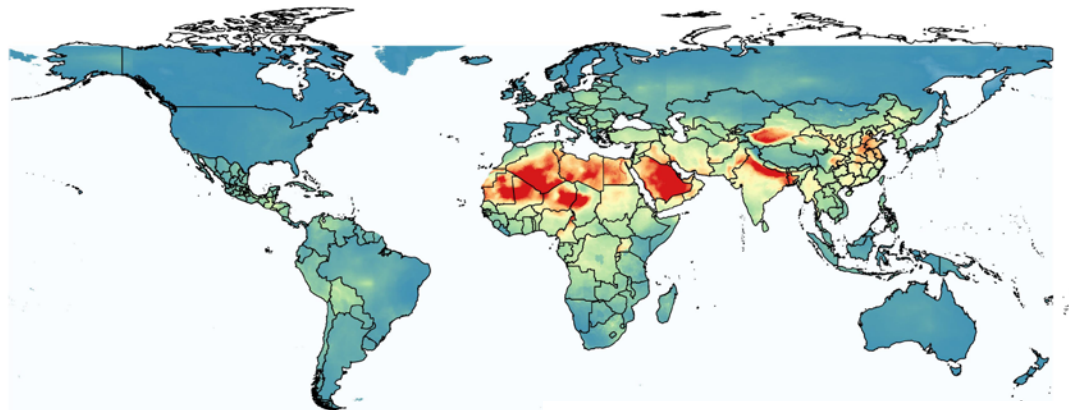




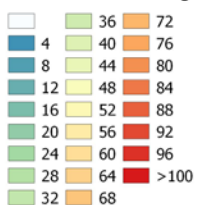
300,000 Adult Canadians (CCHS)
8 – 11 year follow-up

No evidence of threshold above $1 \mu\text{g}/\text{m}^3$ minimum level

Pinault L, Tjepkema M, Crouse D, Weichenthal S, van Donkelaar A, Martin RV, Brauer M, Chen H, Burnett RT. Risk estimates of mortality attributed to low concentrations of ambient fine particulate matter in the Canadian Community Health Survey. *Environmental Health*. 2016. doi: 10.1186/s12940-016-0111-6

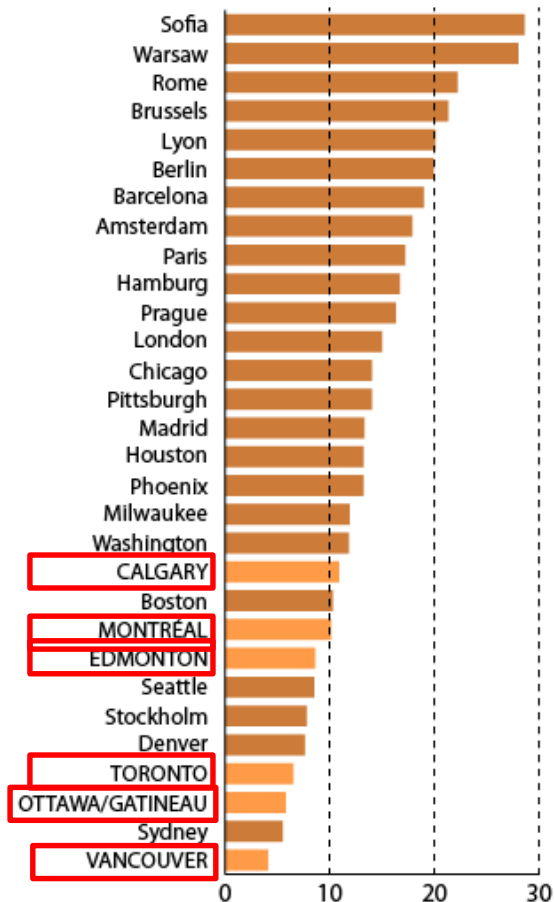


2015 Annual Average PM_{2.5} (µg/m³)



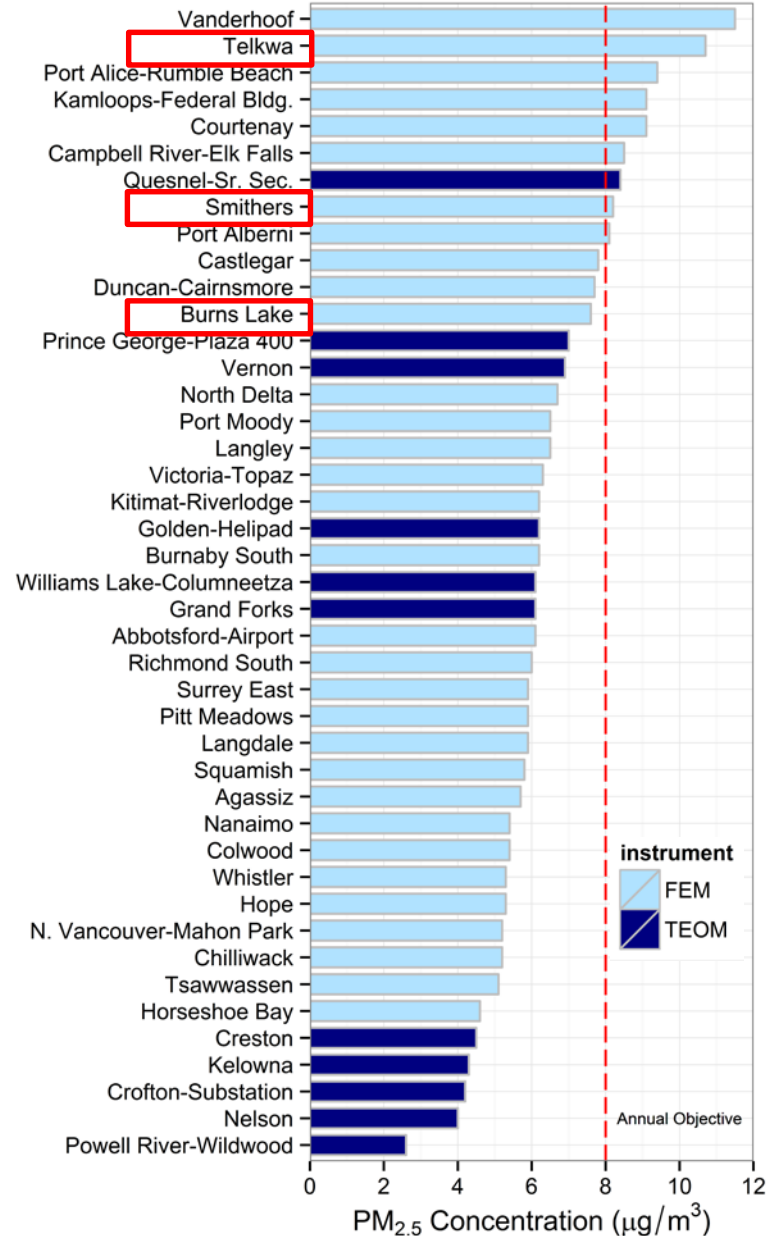
92% global population in areas exceeding WHO Air Quality Guideline (10 µg/m³ PM_{2.5} annual average)

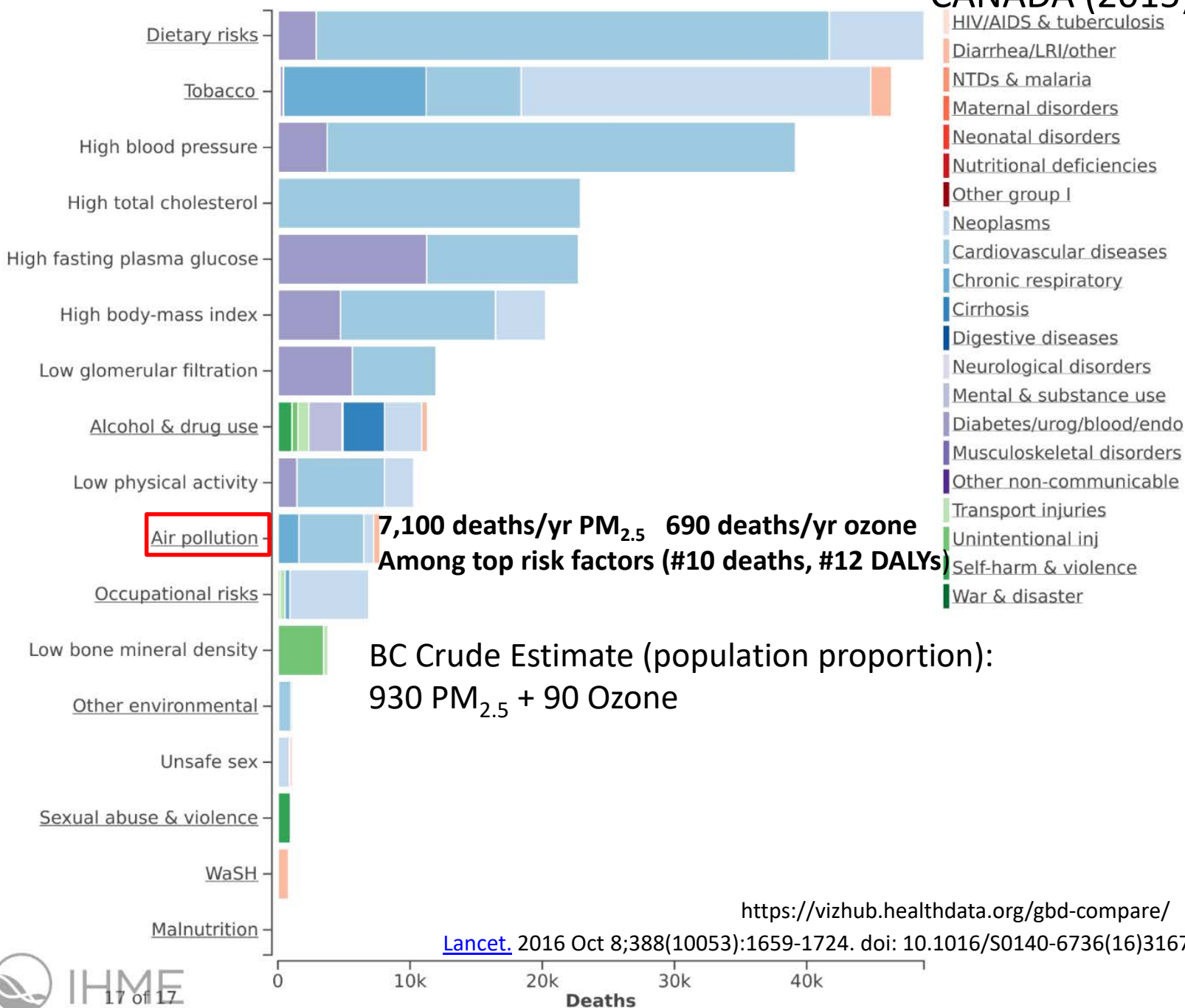
Average ambient concentration (micrograms per cubic metre)



BC State of the Air Report

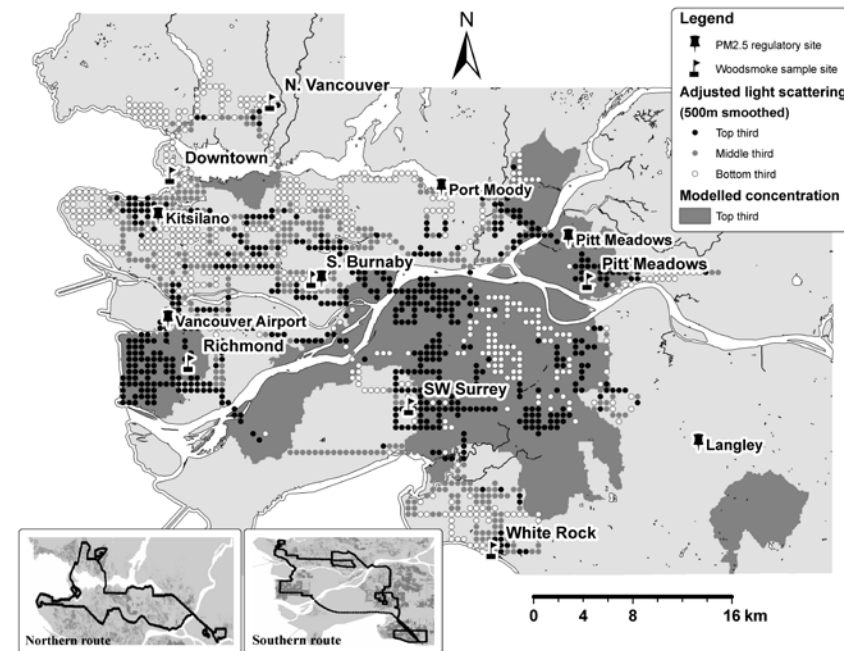
2014 PM_{2.5} Levels in B.C.





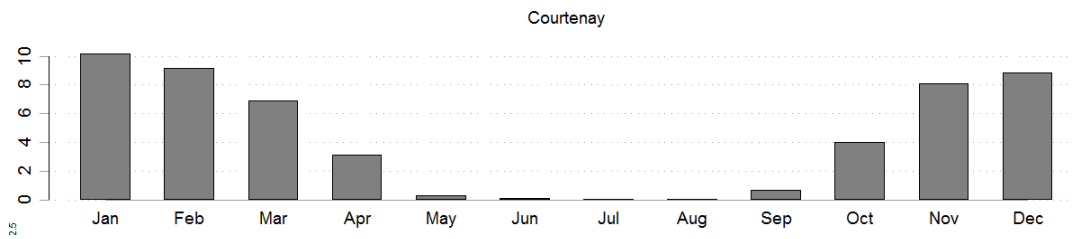
Woodsmoke & multiple health measures

- 15% increase in SGA birth⁺
- 32% increase in otitis media⁺⁺
- 8% increase in bronchiolitis^{*}
- 15% increase in COPD hospitalization⁺
- No associations with:
 - pre-term birth⁻
 - asthma *incidence*⁻
 - cardiovascular, COPD mortality⁻



++ > traffic pollution, + ~traffic, - <traffic

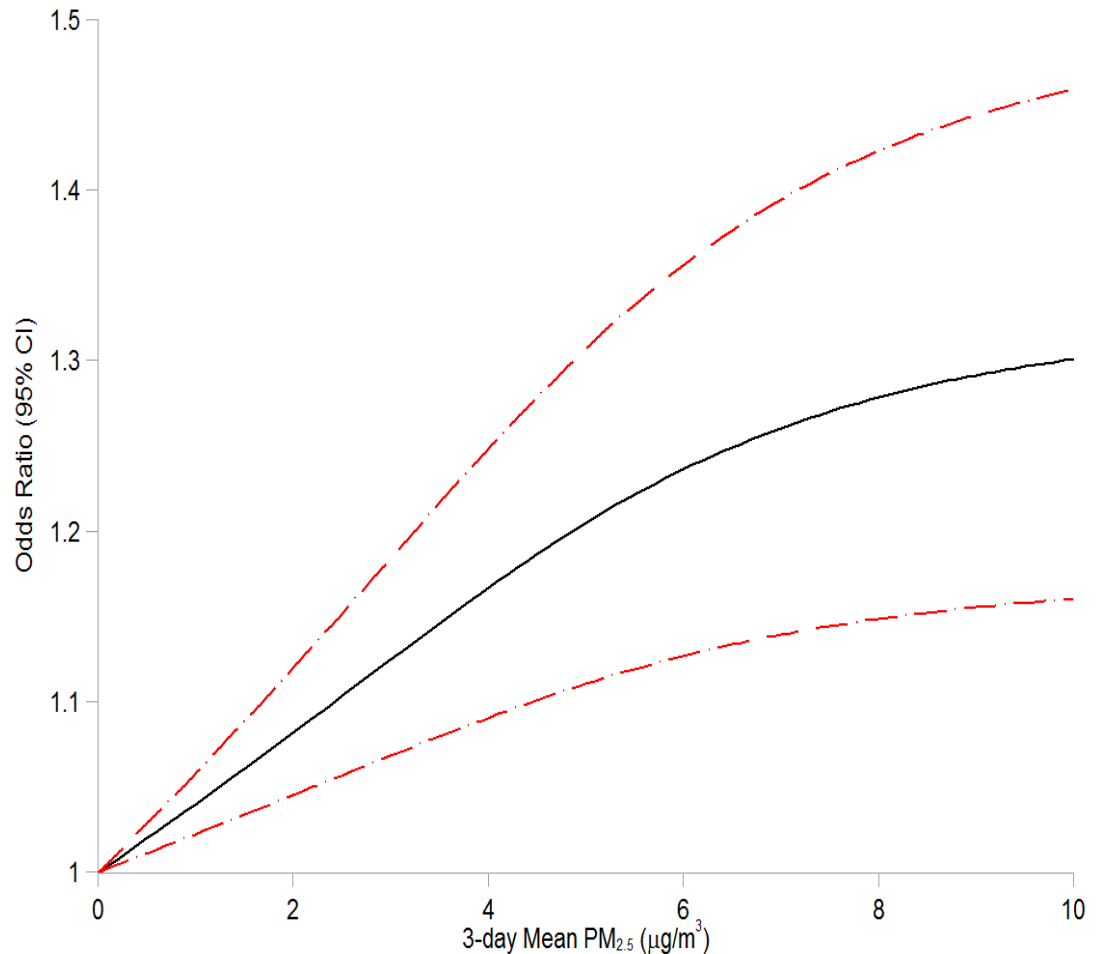
MacIntyre EA et al., Exposure to residential air pollution and otitis media during the first two years of life. *Epidemiology*. 2011 Jan;22(1):81-9.; Karr CJ et al., Influence of ambient air pollutant sources on clinical encounters for infant bronchiolitis. *Am J Resp Crit Care Med*, 2009, 180(10):995-1001.; Clark NA et al., Effect of early life exposure to air pollution on development of childhood asthma. *Environ Health Perspect* 2010, 118(2): 118:284-290; Gan W et al., Associations of Ambient Air Pollution with Chronic Obstructive Pulmonary Disease Hospitalization and Mortality. *Am J Resp Crit Care Med*. 2013. 187(7):721-7. ; Gehring et al., *Epidemiology* 2014. 25(3):351-8.



Monthly mean biomass contributions
(% levoglucosan/PM_{2.5}) to 3-day mean
ambient PM_{2.5}

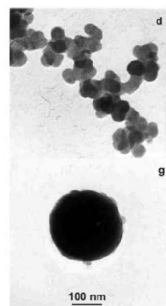
For each 5 µg/m³
increase in 3-day mean
PM_{2.5} **6.0%** increased
risk of MI among elderly
subjects (≥ 65 years)

Restricting to cold days
and days with highest
biomass contribution:
19% increased risk



Woodsmoke and heart attack hospitalization in BC

Combustion conditions, composition & toxicity



Wood smoke soot

■ BC

Wood smoke organic particles (low-temp combustion)

■ Org

from Kocbach et al, Science of the Total Environment, 2005)

"Good" wood pellet combustion PM (alkali salt particles)

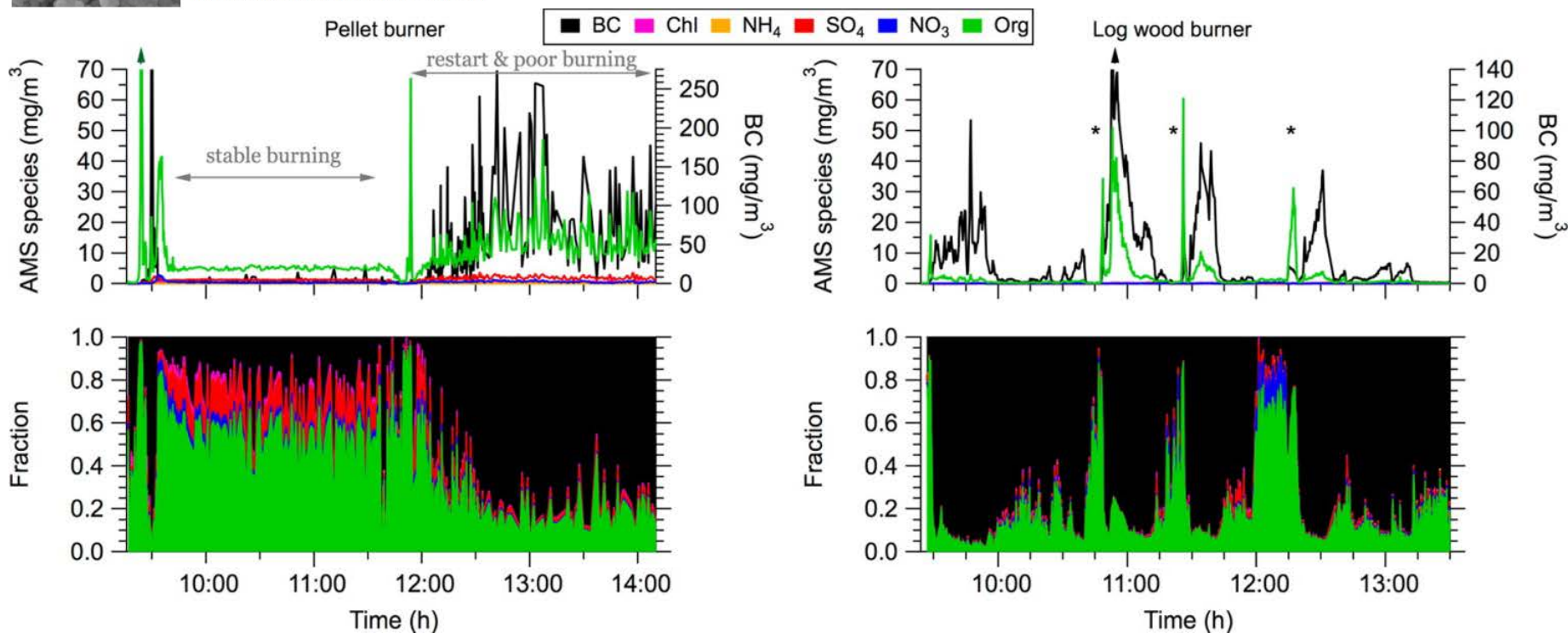
■ Chl ■ NH₄ ■ SO₄ ■ NO₃

from Boman et al, Energy and Fuels 2011;25(1):307-314

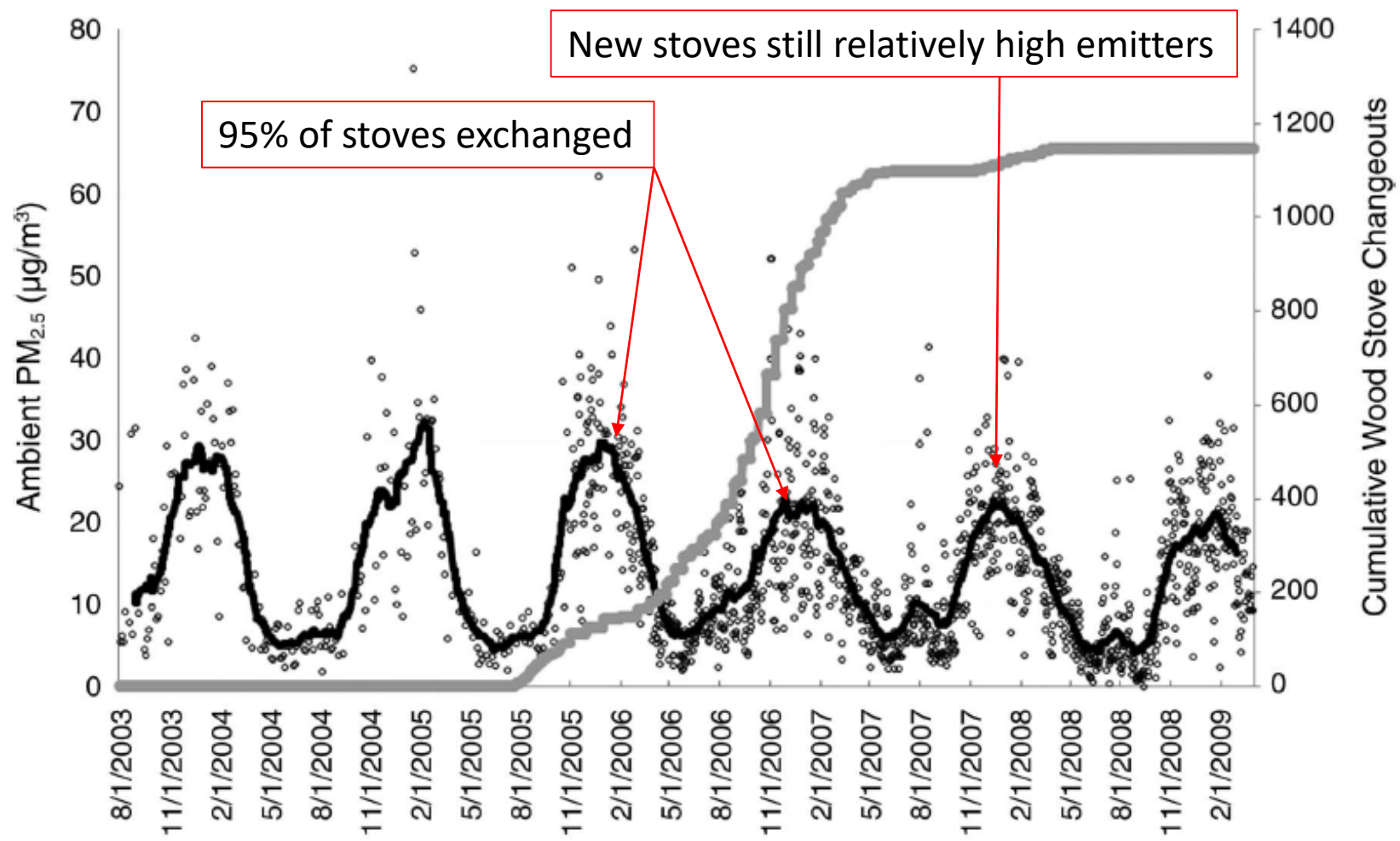
More Toxic: Conventional burning



Less Toxic: "Advanced"

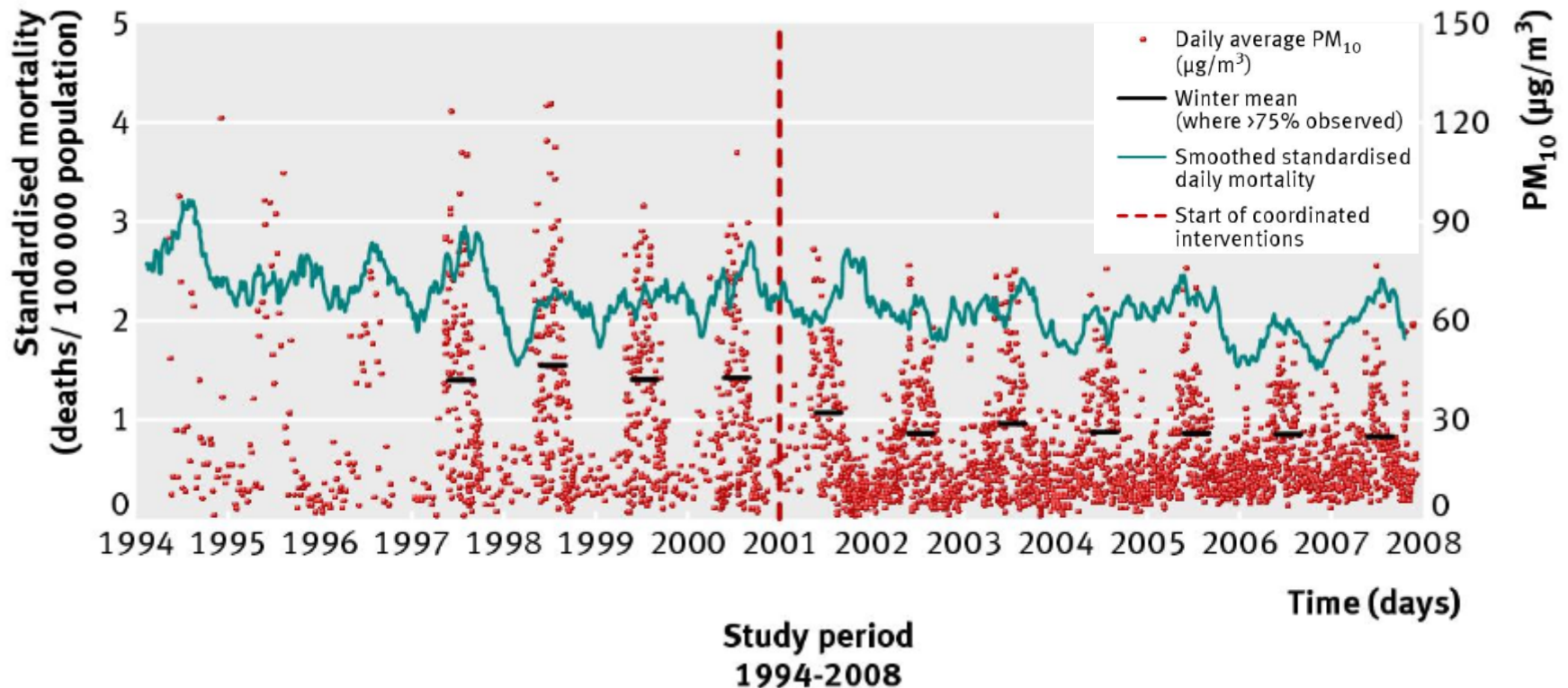


Libby, Montana stove exchange

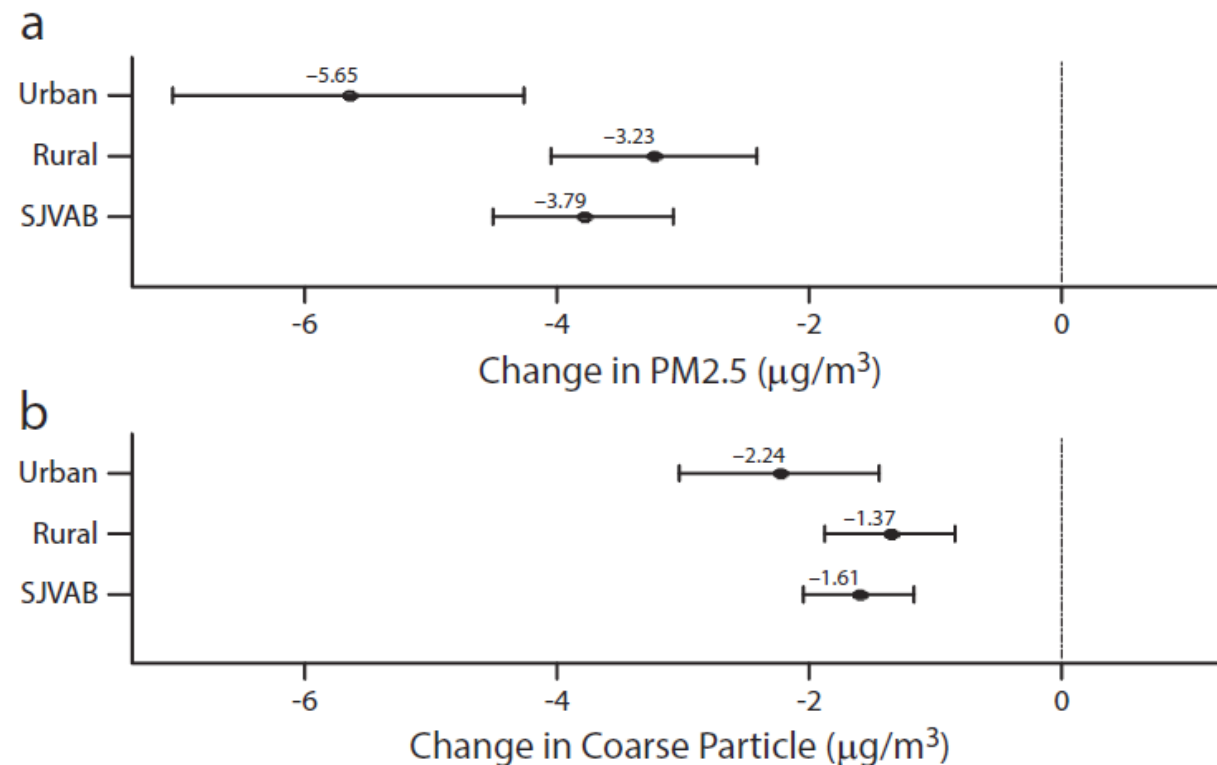


- ~30% reduction in winter PM_{2.5}
- ↓ in childhood wheeze, itchy eyes, sore throat, cold, bronchitis, influenza, throat infections
- School absence associations inconsistent

Tasmania woodstove → electricity



- ~39% reduction in winter PM₁₀
- ↓ winter cardiovascular (-19.6%) and respiratory (-27.9%) mortality
- Similar decreases not observed in control community



PM2.5 Reductions
12% (11% rural, 15% urban)

Adults > 65 yrs
Prevent 7% of CVD and 16% of IHD admissions)

Note. PM2.5 = particulate matter ≤ 2.5 μm in diameter. The results, which compare the pre- and post-Rule 4901 periods (for November through February), are from a combination of data from all 8 counties in the San Joaquin Valley Air Basin (SJVAB). Rural areas were defined as zip codes with an overall population of fewer than 500 people per square mile. The models were adjusted for year and no-burn days.

FIGURE 1—After implementation of Rule 4901, reduction of (a) wintertime PM2.5 and (b) wintertime coarse particles: San Joaquin Valley (California) Air Basin, 2000–2006.

New regulations



Ministry of
Environment

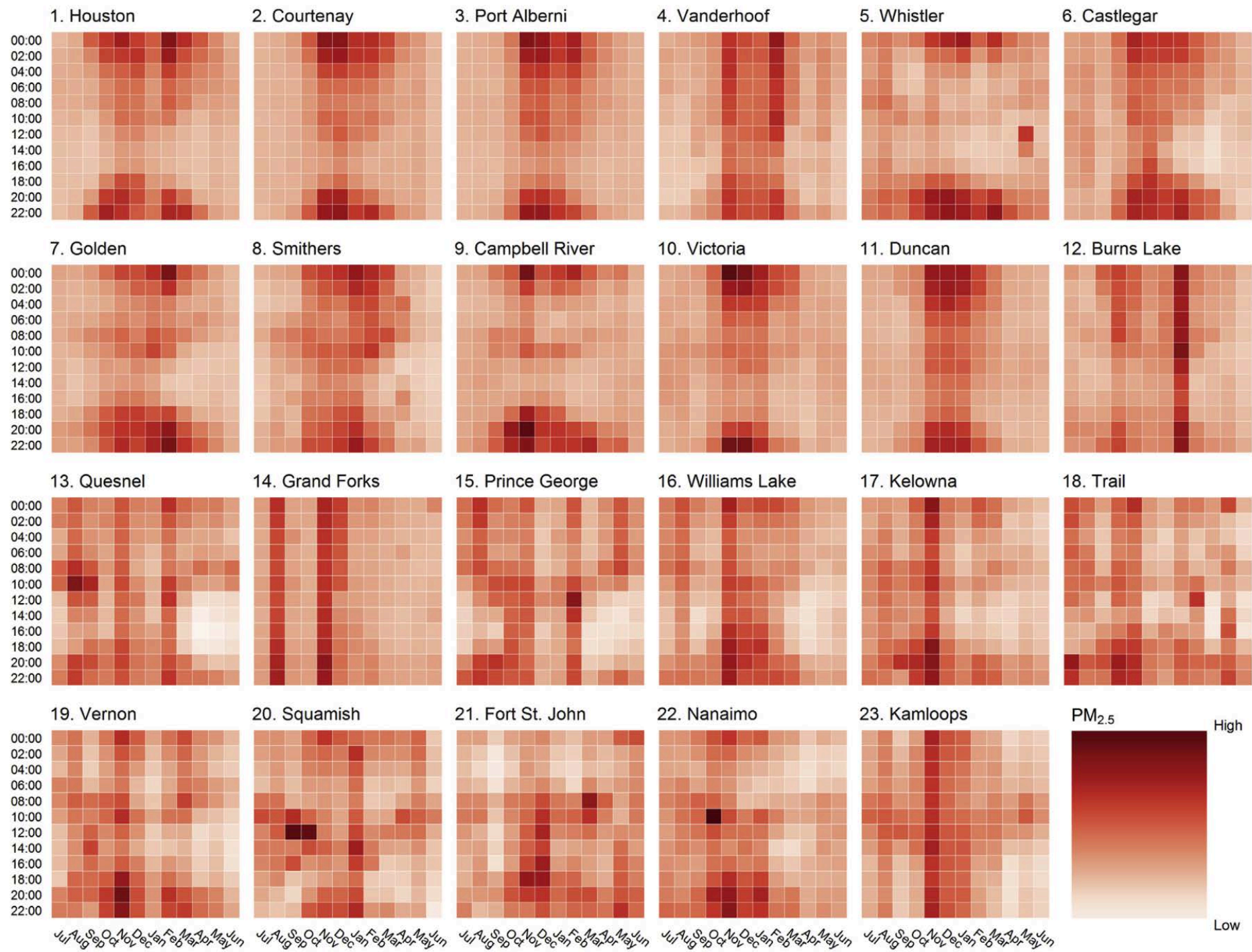
SOLID FUEL BURNING DOMESTIC APPLIANCE REGULATION

Information Update—Policy Intentions

The ministry is revising the Solid Fuel Burning Domestic Appliance Regulation (SFB DAR)

September 2015

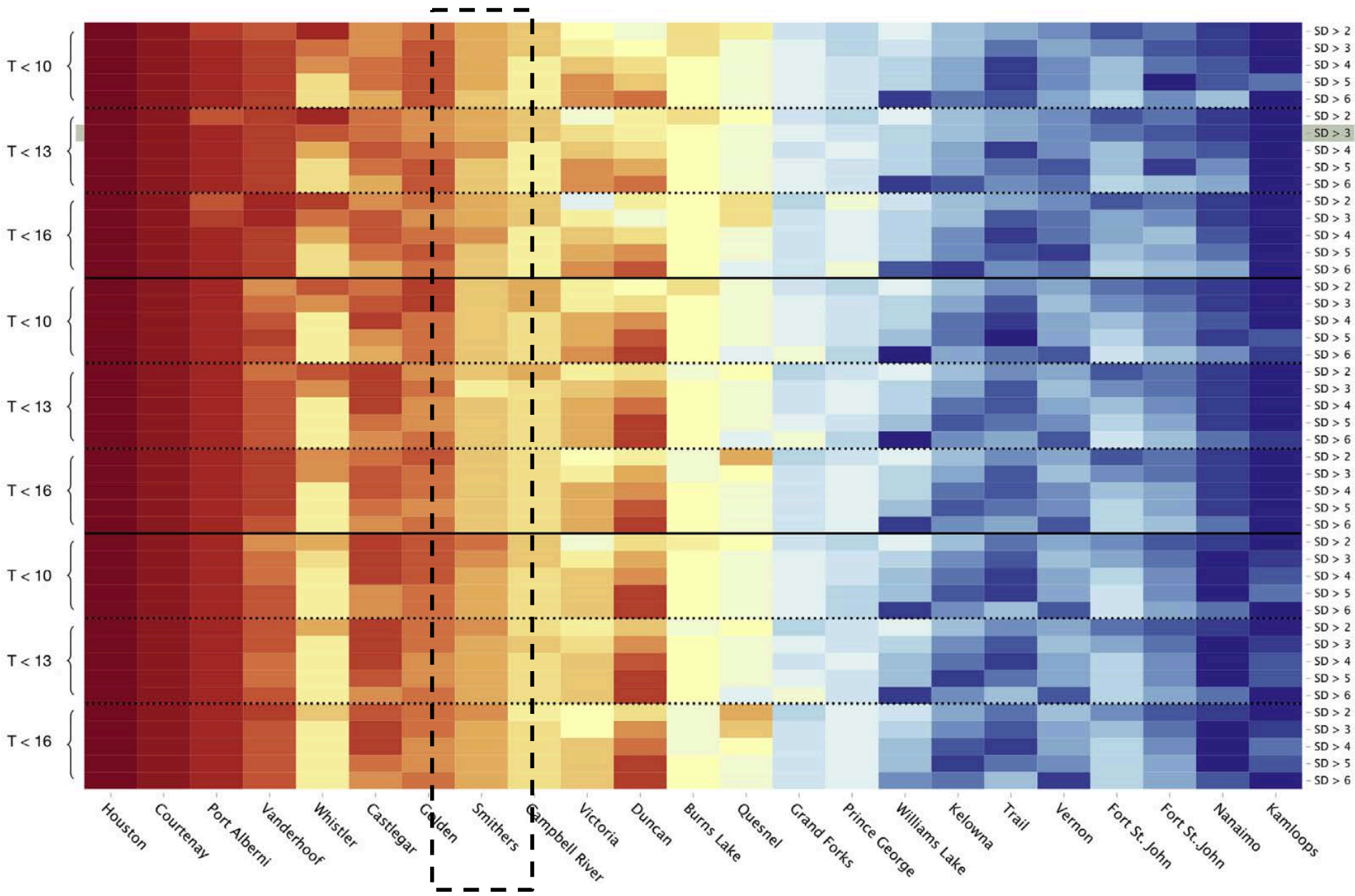
- 2016-17: Only wood and pellet stoves, boilers, furnaces certified to meet new US EPA or CSA emission standards legal to sell in B.C.
- 30 m setback for new Outdoor Wood Boilers (OWBs); Phase-out of older OWBs
- Prohibit burning of undesirable fuels, such as garbage, plastics and treated wood



The number of smoky days within the most recent two years of available data for each community as classified by the algorithm using the most informative parameter values.

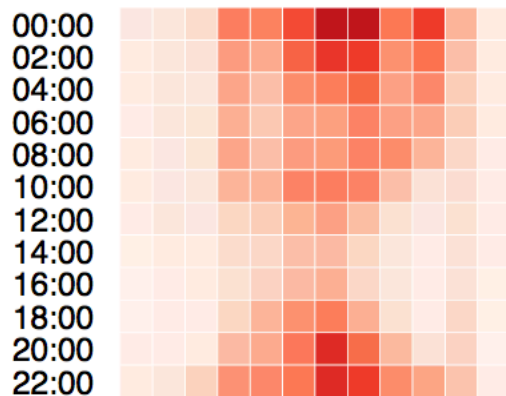
Location	# Smoky Days	# Days with Data (730 max)	% Smoky Days
Houston	277	623 ^a	0.445
Courtenay	211	716	0.295
Port Alberni	143	729	0.196
Vanderhoof	136	712	0.191
Whistler	125	705	0.177
Castlegar	124	710	0.175
Golden	116	722	0.161
Smithers	107	721	0.148
Campbell River	102	720	0.142
Victoria	97	730	0.133
Duncan	91	727	0.125
Burns Lake	89	514 ^a	0.173
Quesnel	80	714	0.112
Grand Forks	58	711	0.082
Prince George	52	706	0.074
Williams Lake	41	729	0.056
Kelowna	25	720	0.035
Trail	17	705	0.024
Vernon	17	698	0.024
Squamish	16	702	0.023
Fort St. John	12	728	0.016
Nanaimo	8	717	0.011
Kamloops	5	711	0.007

^a Data were missing during summer months, so the percentage of smoky days will be higher than if data were missing at random.

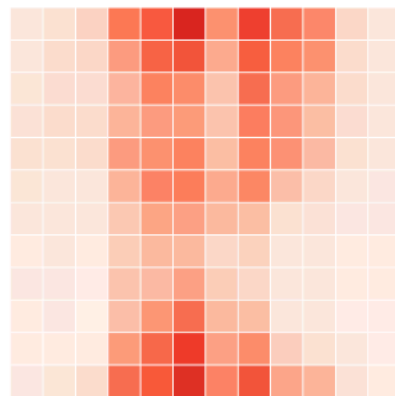


Smithers

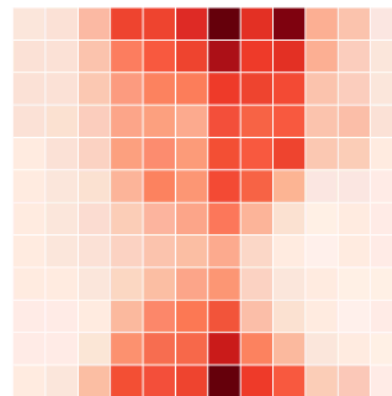
2011



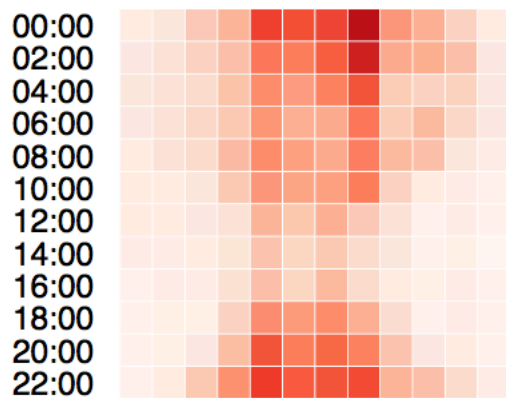
2012



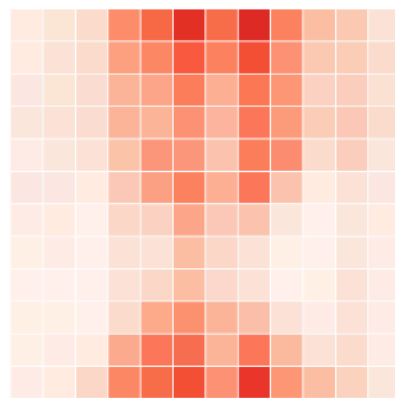
2013



2014



2015



PM_{2.5}



High

Low

Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun

Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun

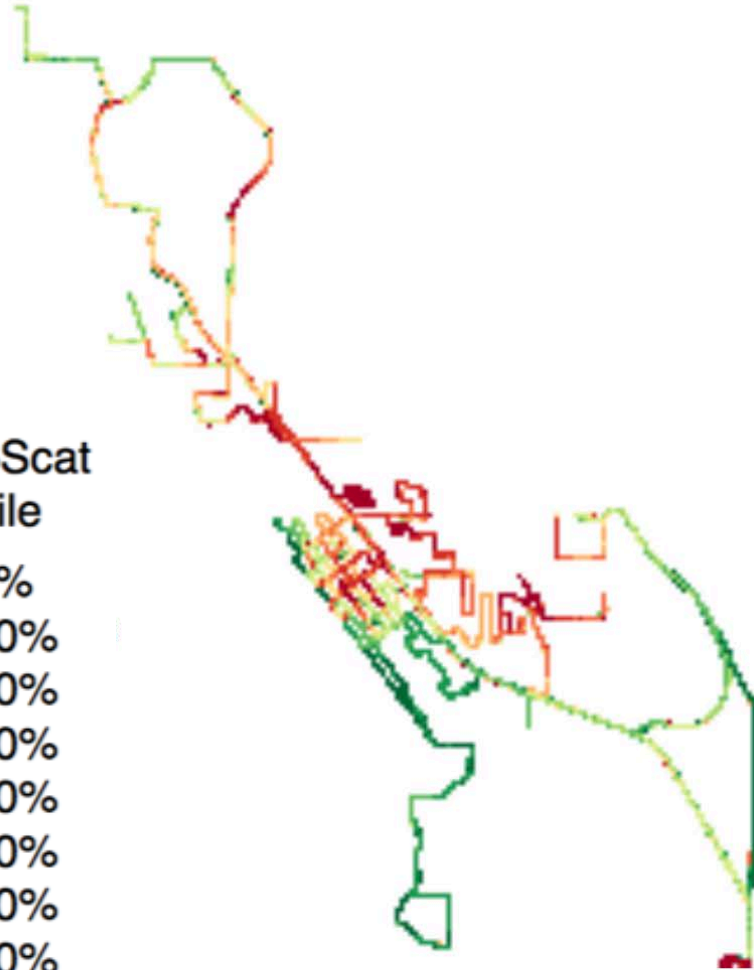
2008_smithers

2014_smithers



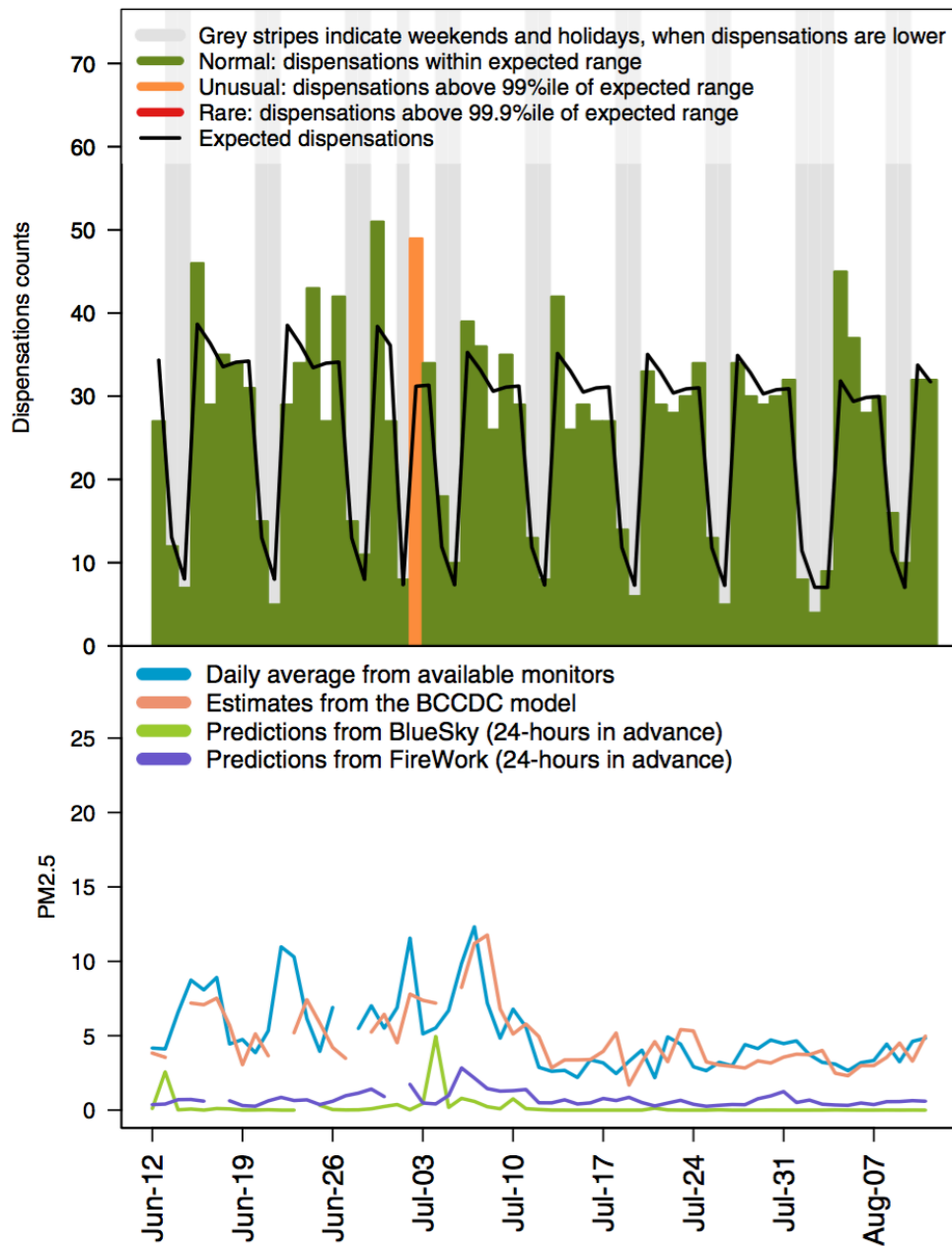
Mobile BScat
Quantile

- 0-10%
- 10-20%
- 20-30%
- 30-40%
- 40-50%
- 50-60%
- 60-70%
- 70-80%
- 80-90%
- 90-100%



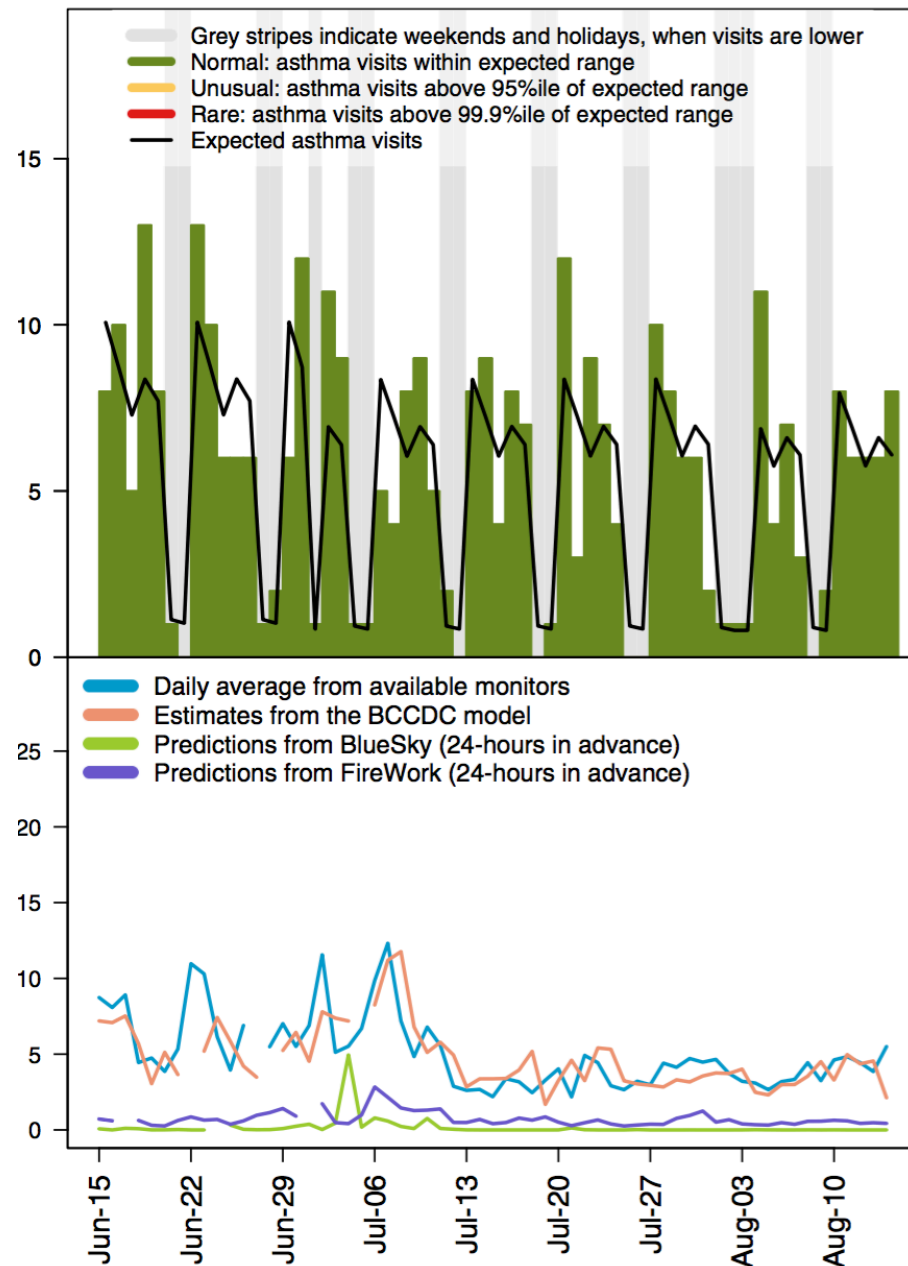
Salbutamol Dispensations for HSDA Northwest (#51)

Update for week of Aug 04 to Aug 11, 2015



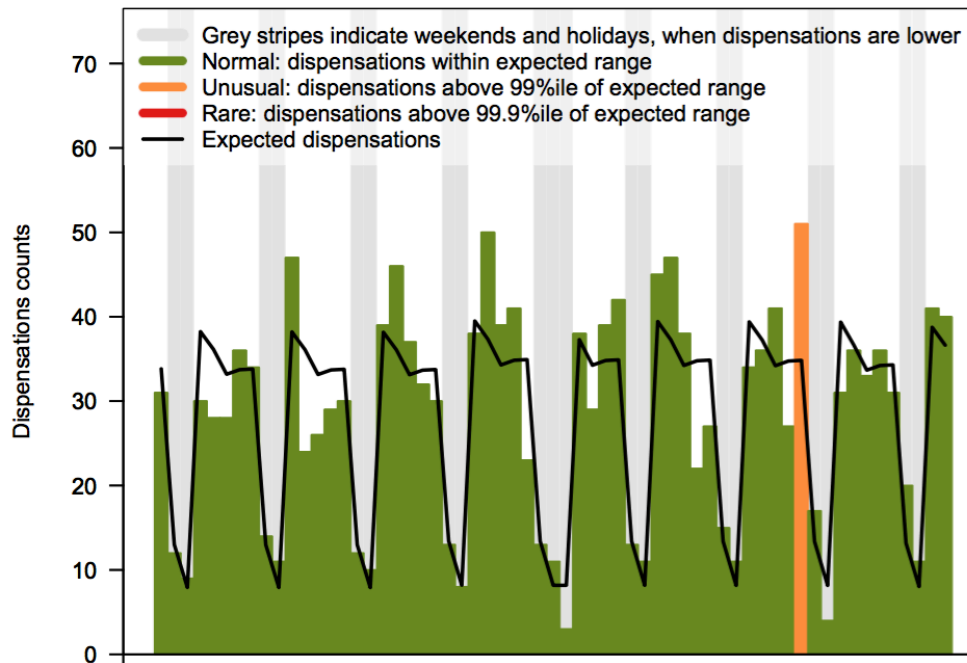
Asthma Physician Visits for HSDA Northwest (#51)

Update for week of Aug 07 to Aug 14, 2015

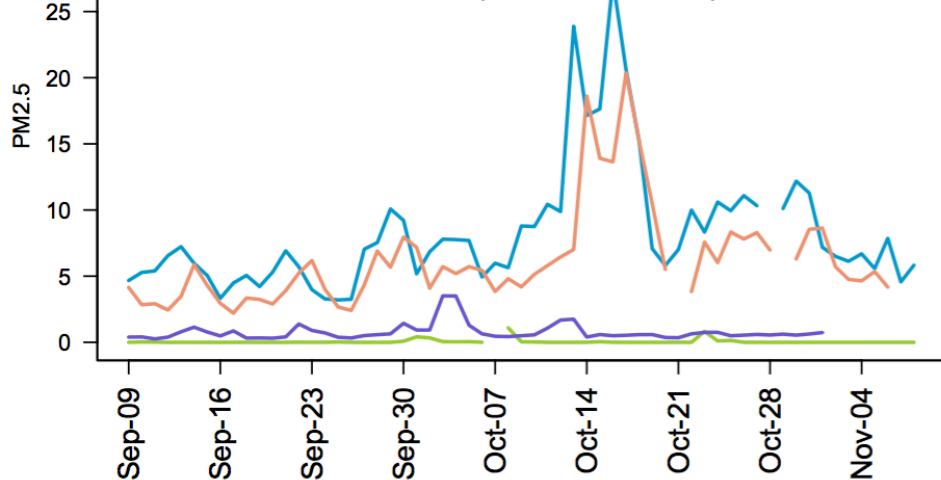


Salbutamol Dispensations for HSDA Northwest (#51)

Update for week of Nov 01 to Nov 08, 2016

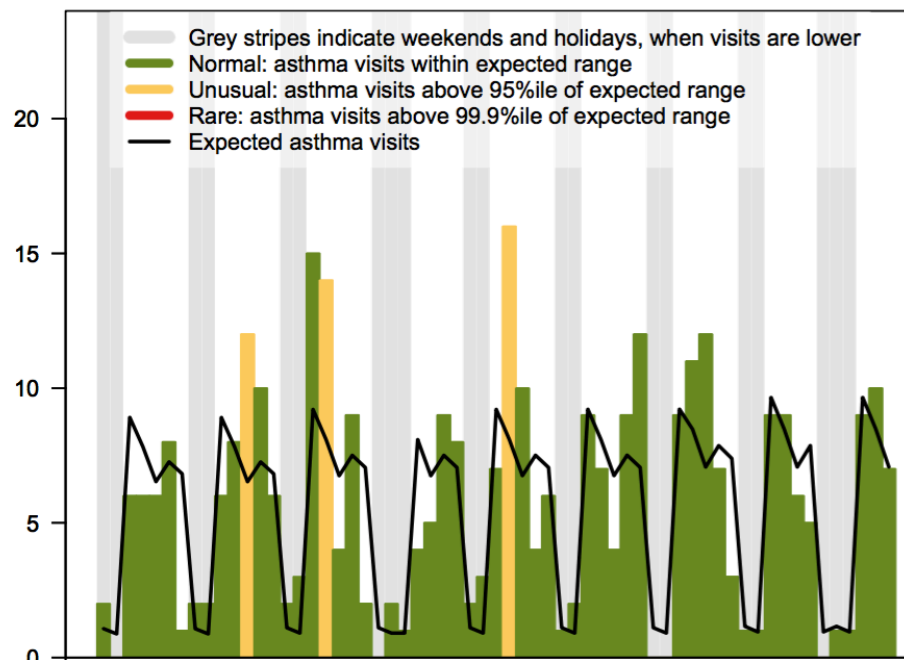


— Daily average from available monitors
— Estimates from the BCCDC model
— Predictions from BlueSky (24-hours in advance)
— Predictions from FireWork (24-hours in advance)

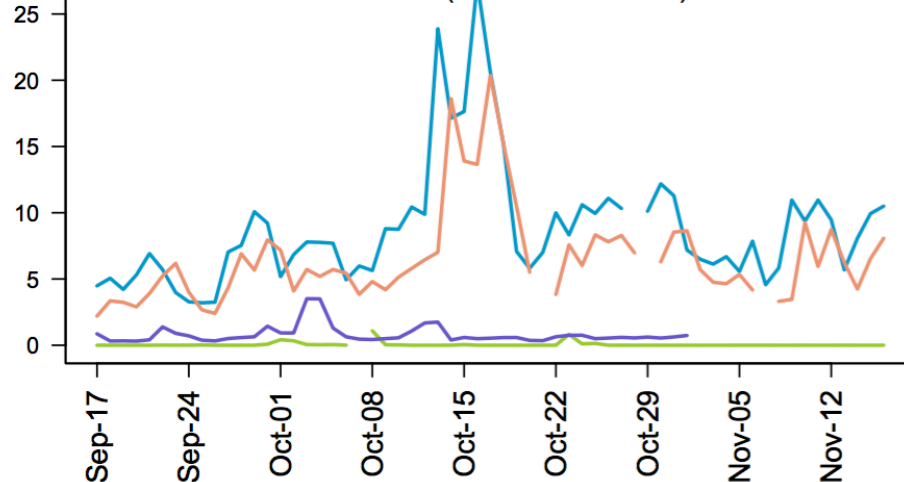


Asthma Physician Visits for HSDA Northwest (#51)

Update for week of Nov 09 to Nov 16, 2016



— Daily average from available monitors
— Estimates from the BCCDC model
— Predictions from BlueSky (24-hours in advance)
— Predictions from FireWork (24-hours in advance)



Thank you!

Questions?

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sarah.henderson@bccdc.ca

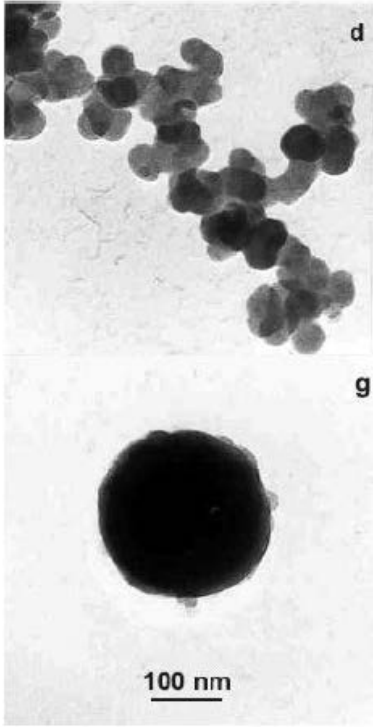
Woodsmoke health effects

“...based on the current, limited experimental findings, we cannot conclude that exposure to residential biomass emissions in developed countries is less harmful than exposure to combustion particles from fossil fuel combustion.”

Epidemiology

- “...emissions from current biomass combustion products **negatively affect respiratory and, possibly, cardiovascular health...**”
- “Epidemiological studies strongly suggest that there are **adverse health effects related to short-term as well as long-term exposure to biomass smoke** in the developed world. Intervention studies performed, to date, suggest **beneficial health effects of reducing exposure to biomass smoke.**”
- We recommend that **emissions from biomass combustion should be kept to a minimum to protect public health.**”

PM composition



Wood smoke soot

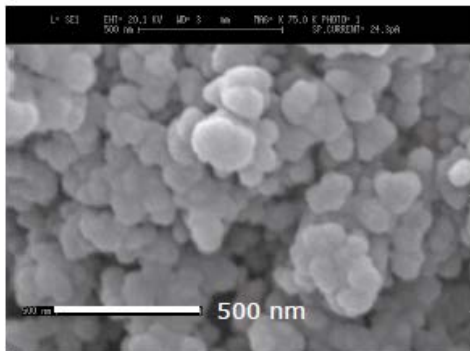


**Wood smoke organic particles
(low-temp combustion)**



“conventional”

from Kocbach et al, *Science of the Total Environment*, 2005)



**“Good” wood pellet combustion
PM (alkali salt particles)**

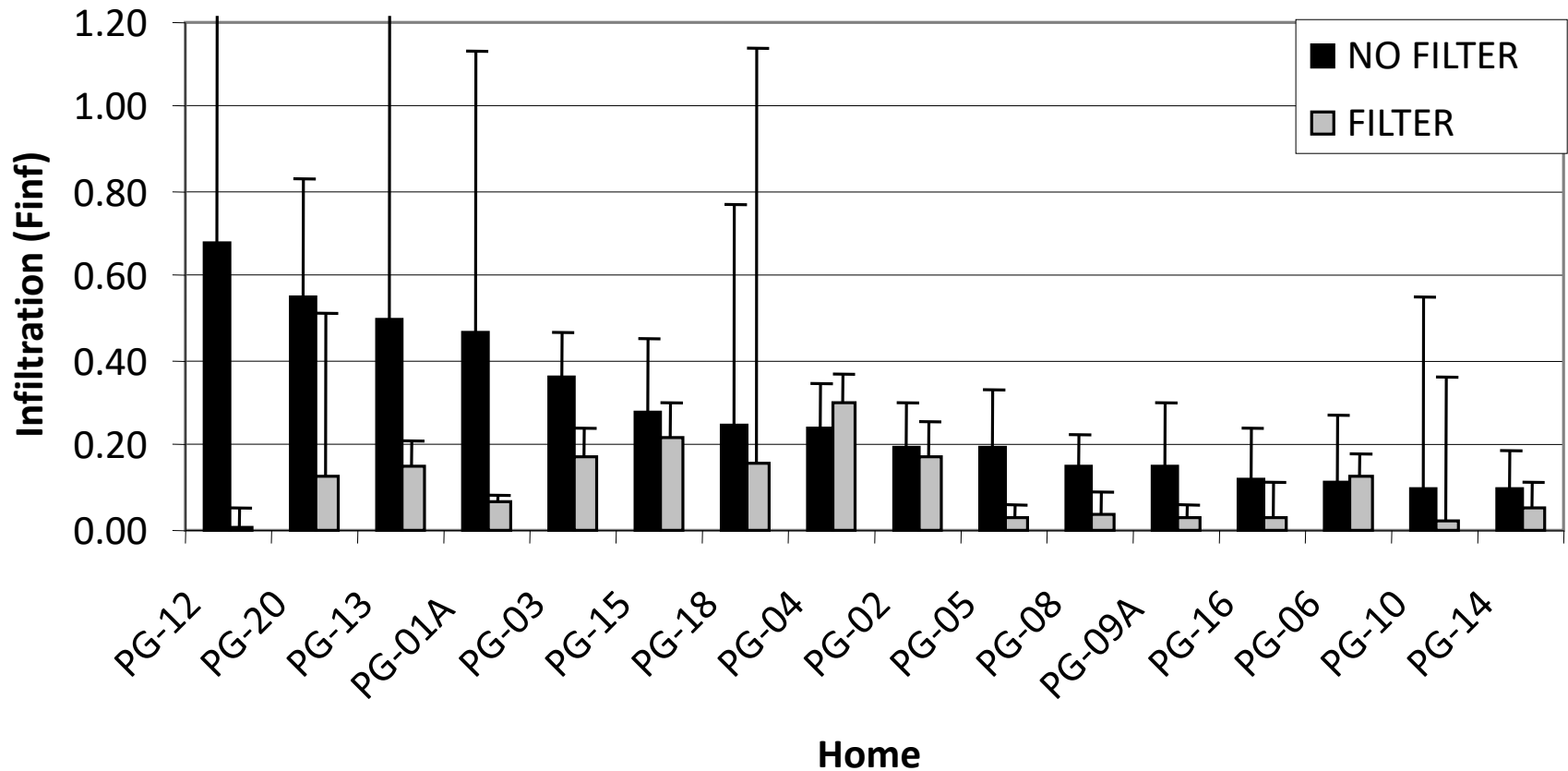


“advanced”

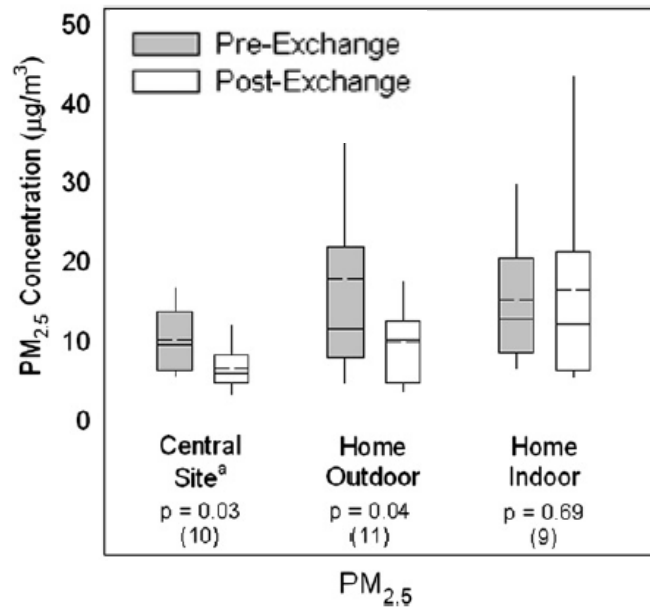
from Boman et al, *Energy and Fuels* 2011;25:(1):307-314

Particle infiltration

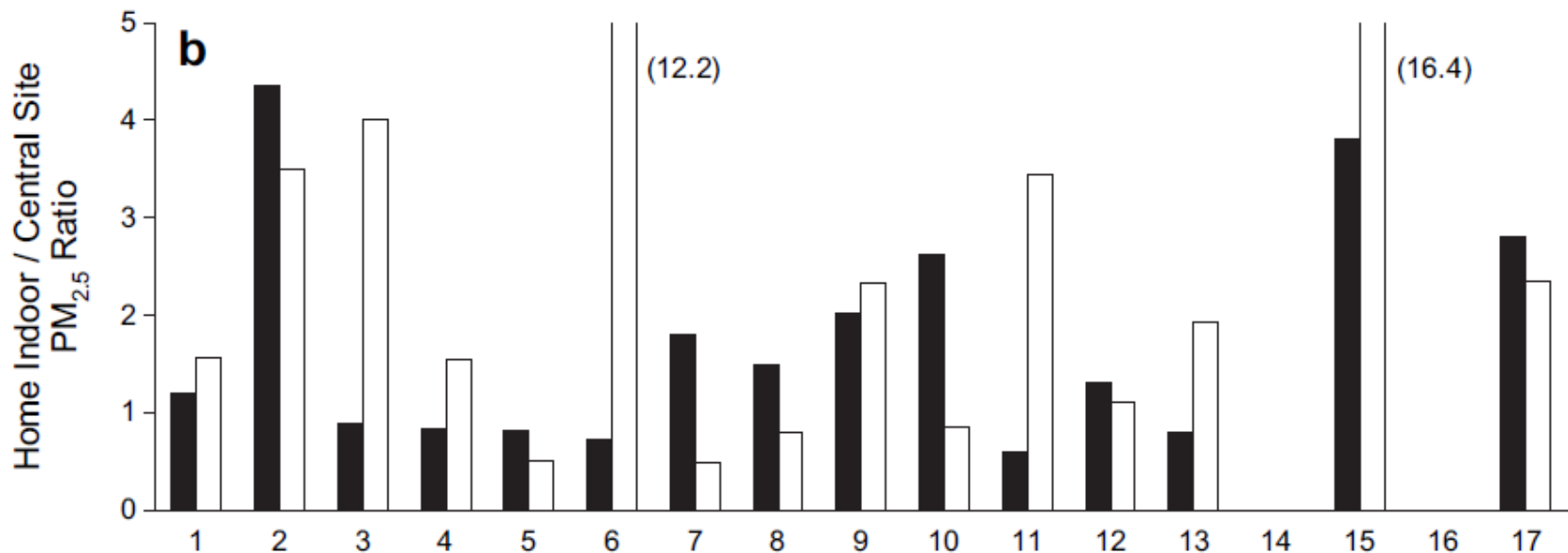
Mean infiltration: 27% no filter, 10% with filter



Stove exchange and indoor levels

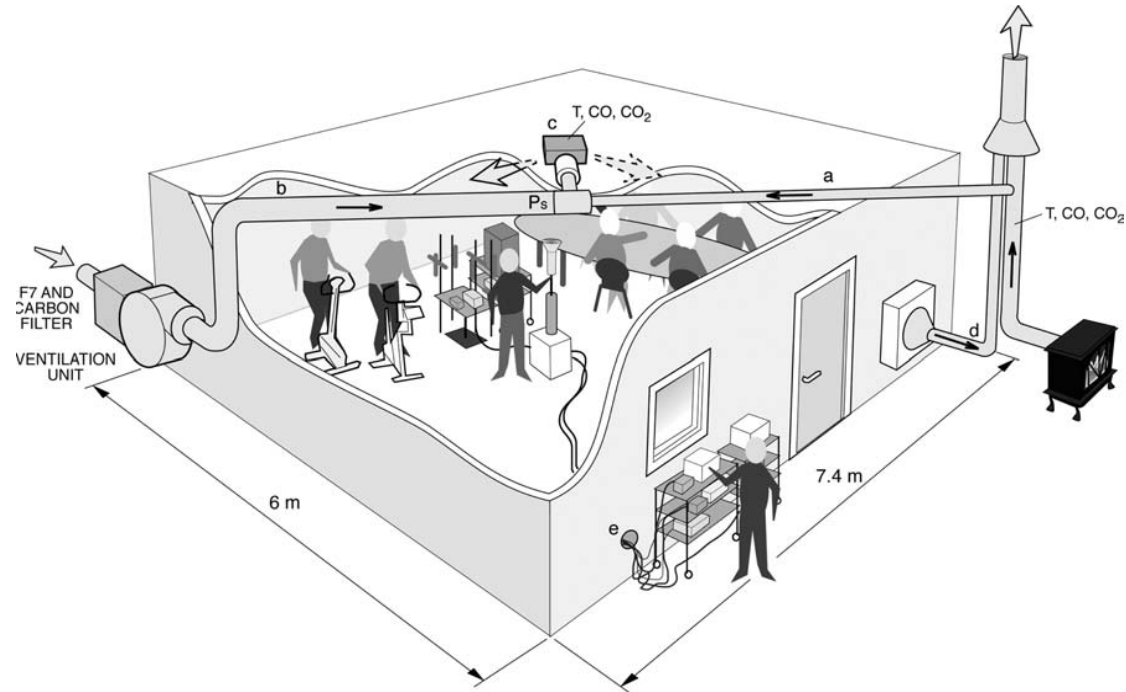


Allen RW, Leckie S, Millar G, Brauer M. The impact of wood stove technology upgrades on indoor residential air quality. Atmospheric Environment, 2009, 43: 5908–5915



Controlled human exposure studies

- **Subjects exposed to realistic (high) concentrations ($\sim 250 \mu\text{g}/\text{m}^3$) of woodsmoke for 4 hrs**
 - Increases in measures of inflammation, oxidative stress post-exposure compared to clean air
- **Pellet stove incomplete combustion**
 - No inflammation
 - Early adaptive protective response

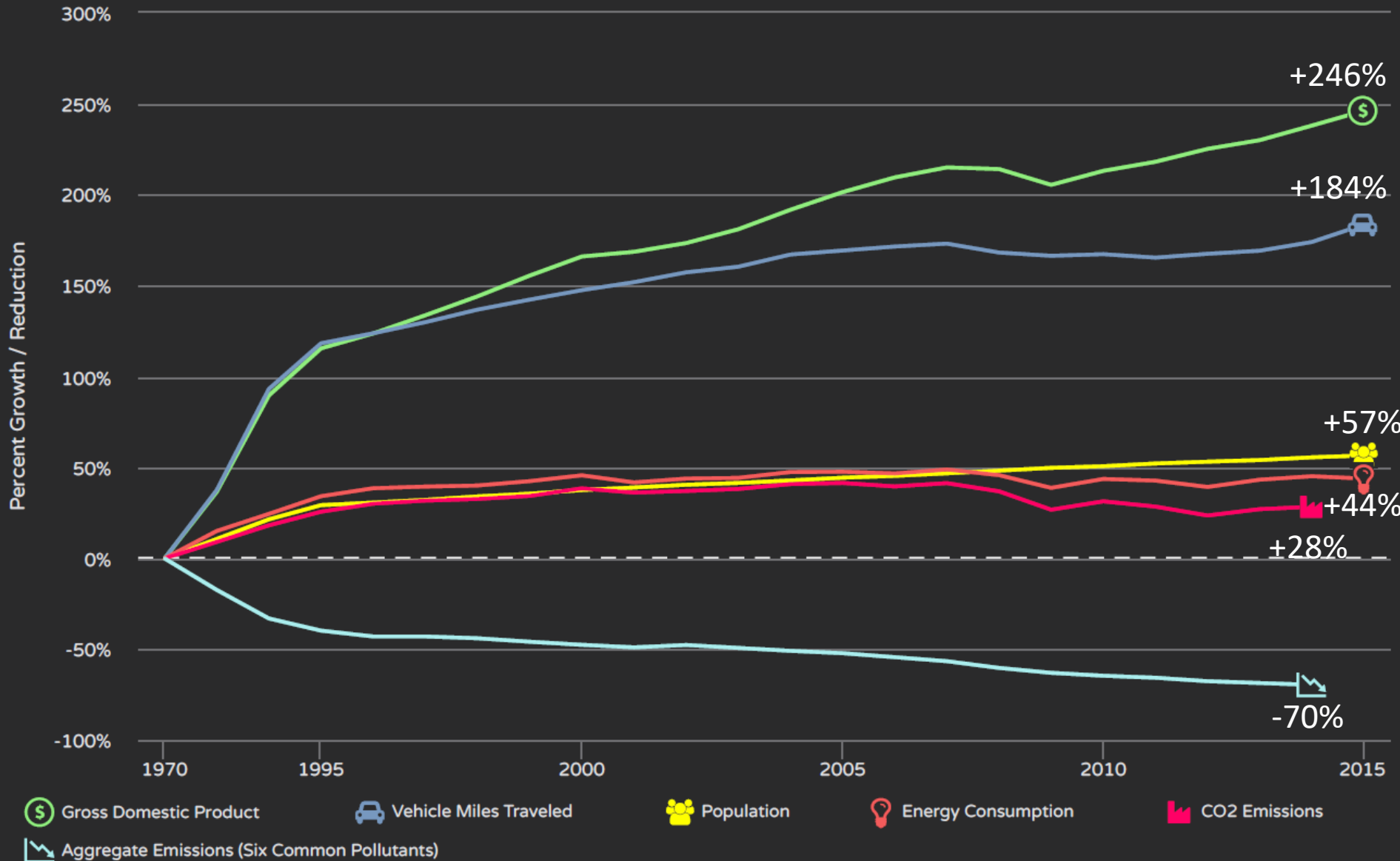


Sallsten, G et al. Experimental wood smoke exposure in humans. *Inhal. Toxicol.* 18(11):855–864.; Barregard L et al. Experimental exposure to wood-smoke particles in healthy humans: effects on markers of inflammation, coagulation, and lipid peroxidation. *Inhal Toxicol.* 2006 Oct;18(11):845-53.; Danielsen PH et al. Oxidatively damaged DNA and its repair after experimental exposure to wood smoke in healthy humans.. *Mutat Res.* 2008 Jul 3;642(1-2):37-42.; Barregard L et al. Experimental exposure to wood smoke: effects on airway inflammation and oxidative stress.. *Occup Environ Med.* 2008 May;65(5):319-24.

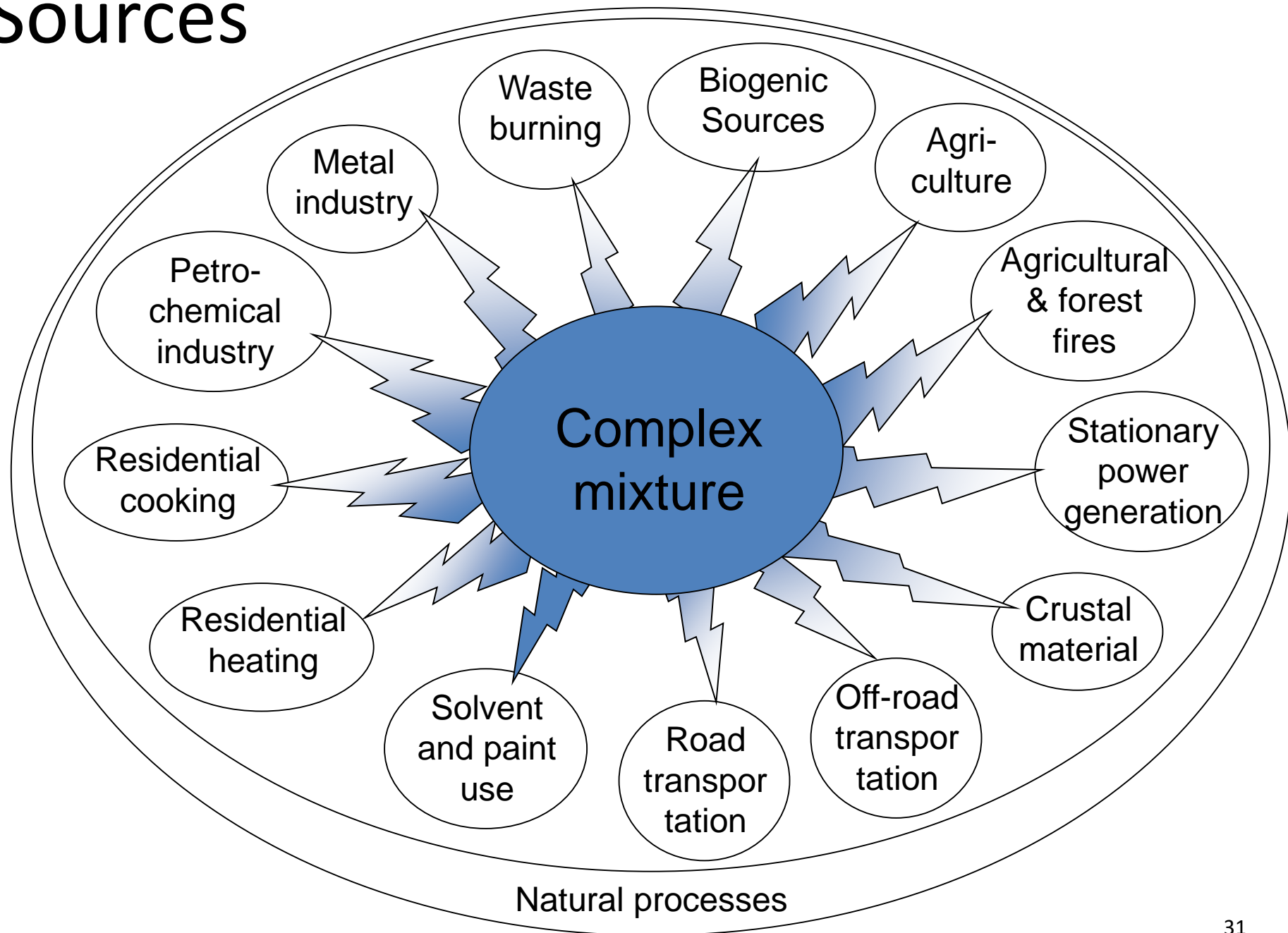
Sehlstedt, M., R. Dove, et al. (2010). "Antioxidant airway responses following experimental exposure to wood smoke in man." *Particle and Fibre Toxicology* 7(1): 21.

COMPARISON OF GROWTH AREAS AND EMISSIONS

1970-2015

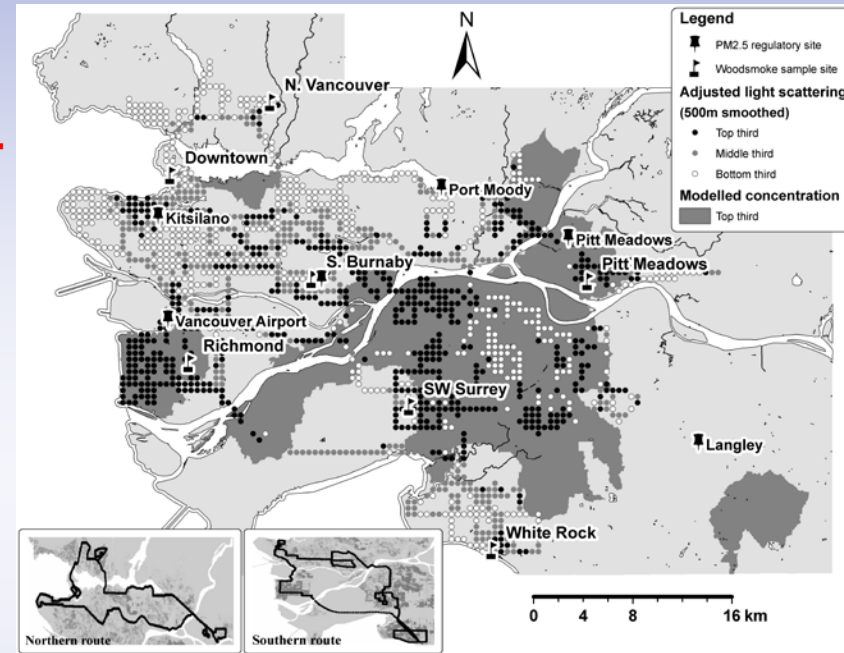


Sources



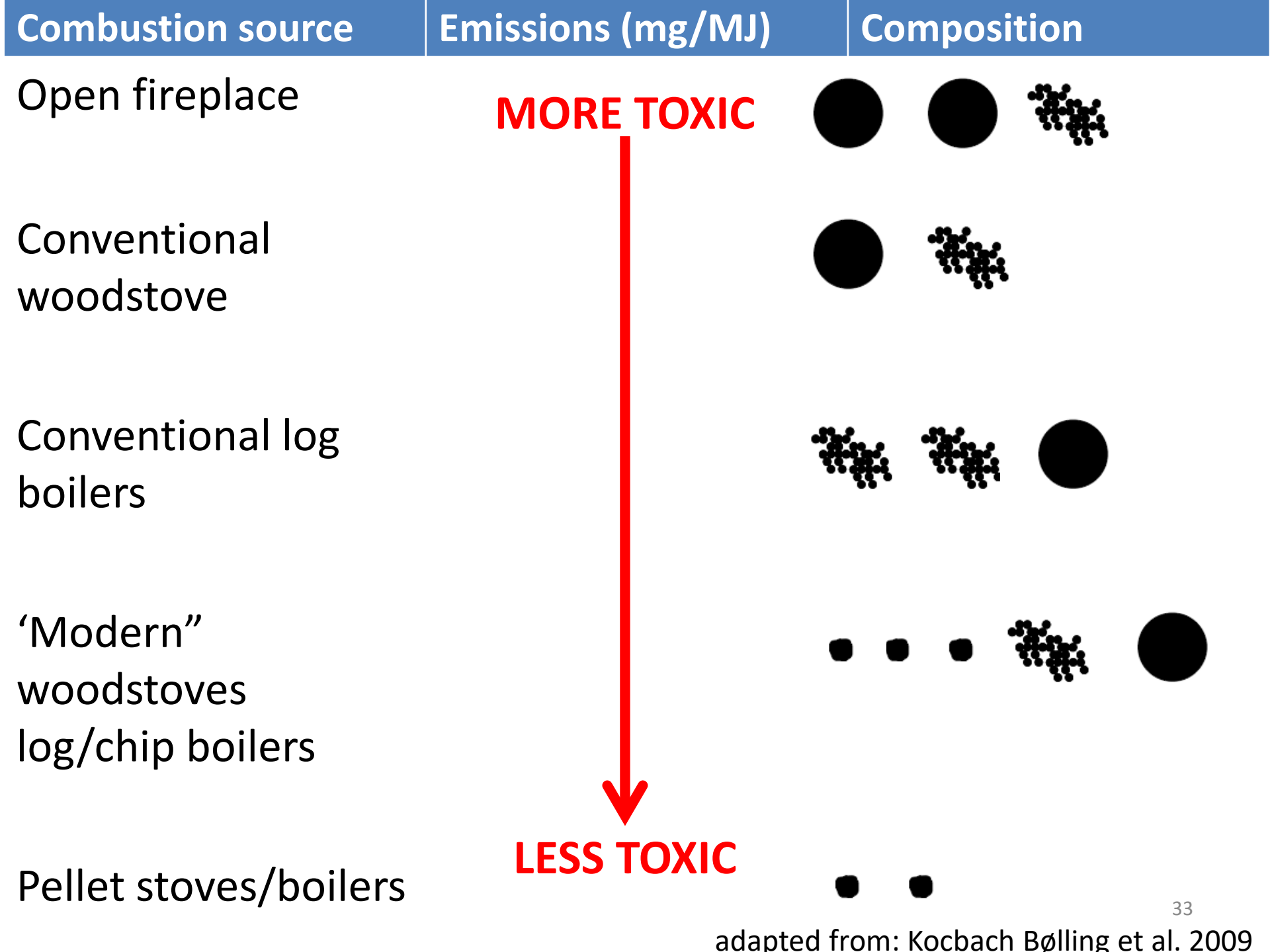
Woodsmoke

- 15% increase in SGA birth⁺
- 32% increase in otitis media⁺⁺
- 8% increase in bronchiolitis^{*}
- 15% increase in COPD hospitalization⁺
- No associations with:
 - pre-term birth⁻
 - asthma *incidence*⁻
 - cardiovascular, COPD mortality⁻



++ > traffic pollution, + ~traffic, - <traffic

BAQS



Animal/Cellular Toxicology

Inflammation: Medium Temp > High Temp

Low oxygen > High oxygen



Soluble inorganic ash particles:

- inflammation in cell culture
- no inflammation in animal inhalation studies
- soluble and cleared from lungs

Cell cytotoxicity:



Biomass smoke and health: evidence

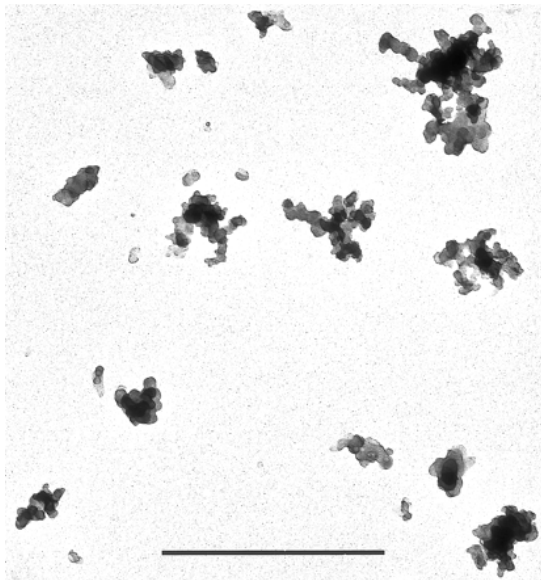
- **Constituents/Composition (PM_{2.5}, aldehydes, PAHs)**
- **Toxicology**
- High concentration, chronic exposures – developing countries
- High concentration acute/sub-chronic exposures – wildland firefighters
- Firesmoke, agricultural burning
- **Controlled human exposures**
- **Residential woodsmoke epidemiology**

- **Very little direct research on health impacts of Industrial / Commercial / Institutional scale combustion**

Do woodsmoke particles pose different levels of risk from other particles?

- Respiratory disease: No
- Cardiovascular disease: ?

Woodsmoke Particles



Bar = 1 μm = 1/1000 of 1mm

Inhalation Toxicology, 19:67–106, 2007
Copyright © Informa Healthcare
ISSN: 0895-8378 print / 1091-7691 online
DOI: 10.1080/08958370600985875

Woodsmoke Health Effects: A Review

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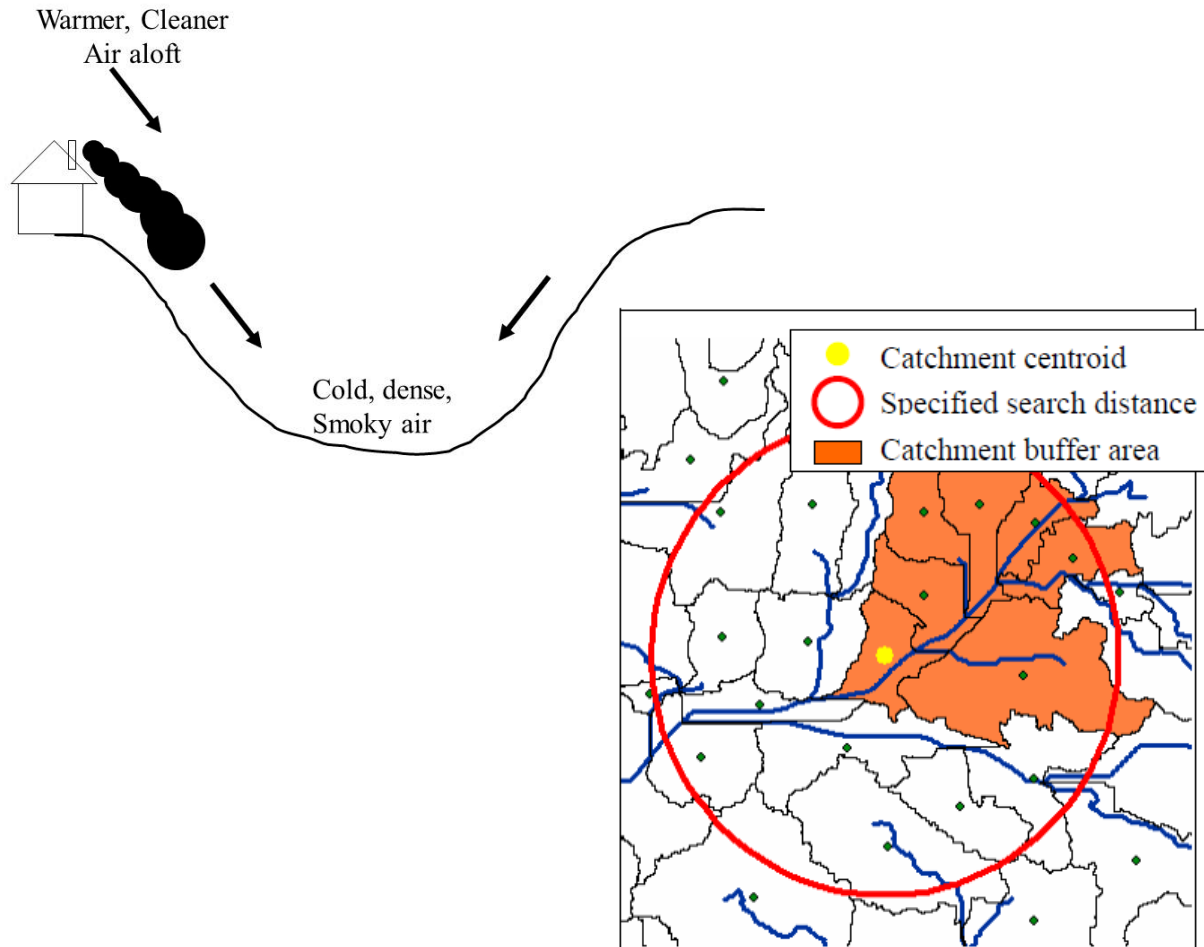
PAH content: **WS > Traffic PM**

Inflammatory potential: **WS \approx Traffic PM**

Kocbach et al. *Toxicology*. 2008, 247(2-3):123-132

Biomass smoke spatial extent

Drainage Flow



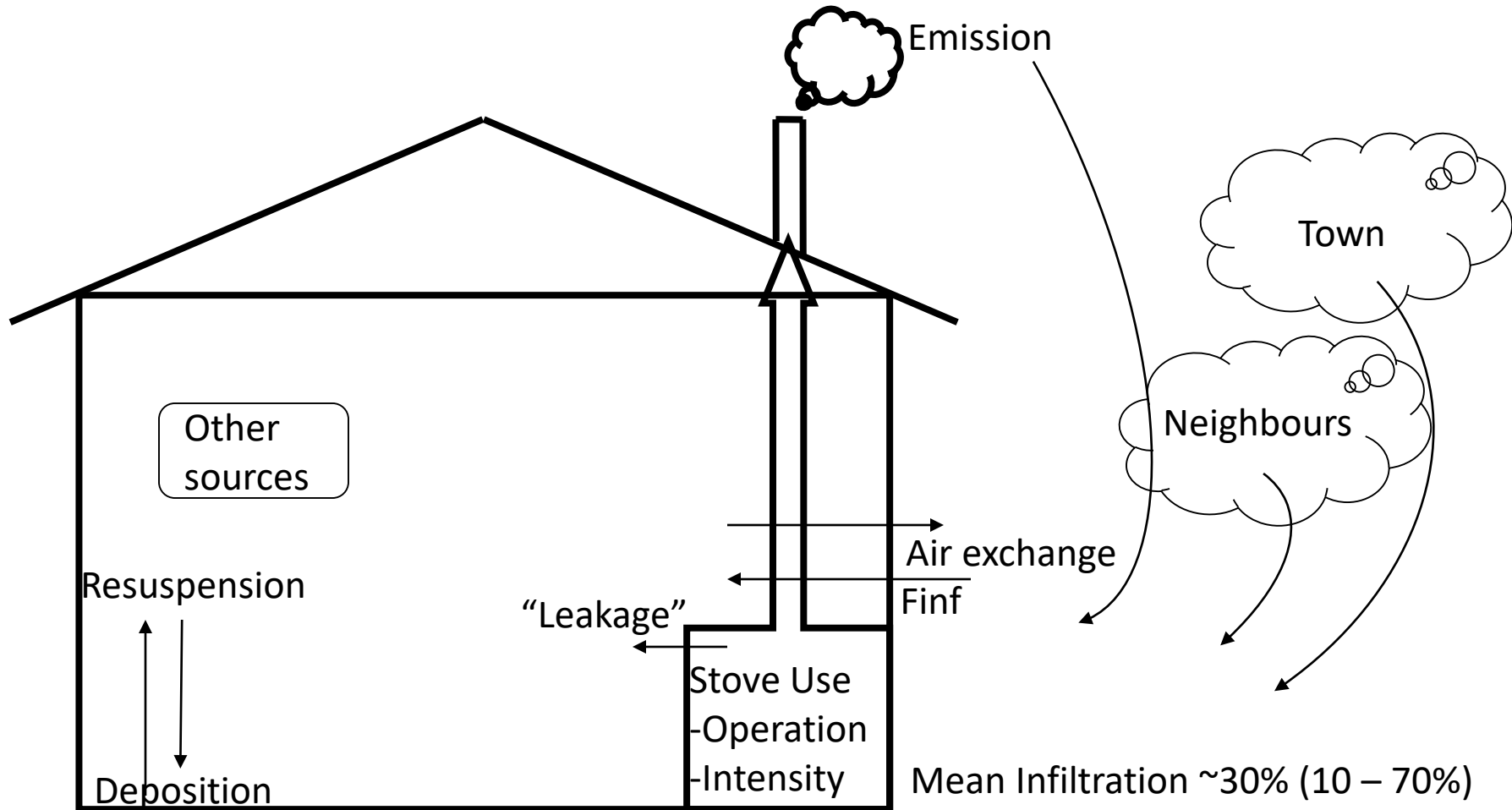
For typical drainage wind speed (1 m/s) maintained over a 3 hour period, upslope influence ~ **10 km**

Catchment modeling^{1,2} suggests upslope influence of **4 – 8 km**

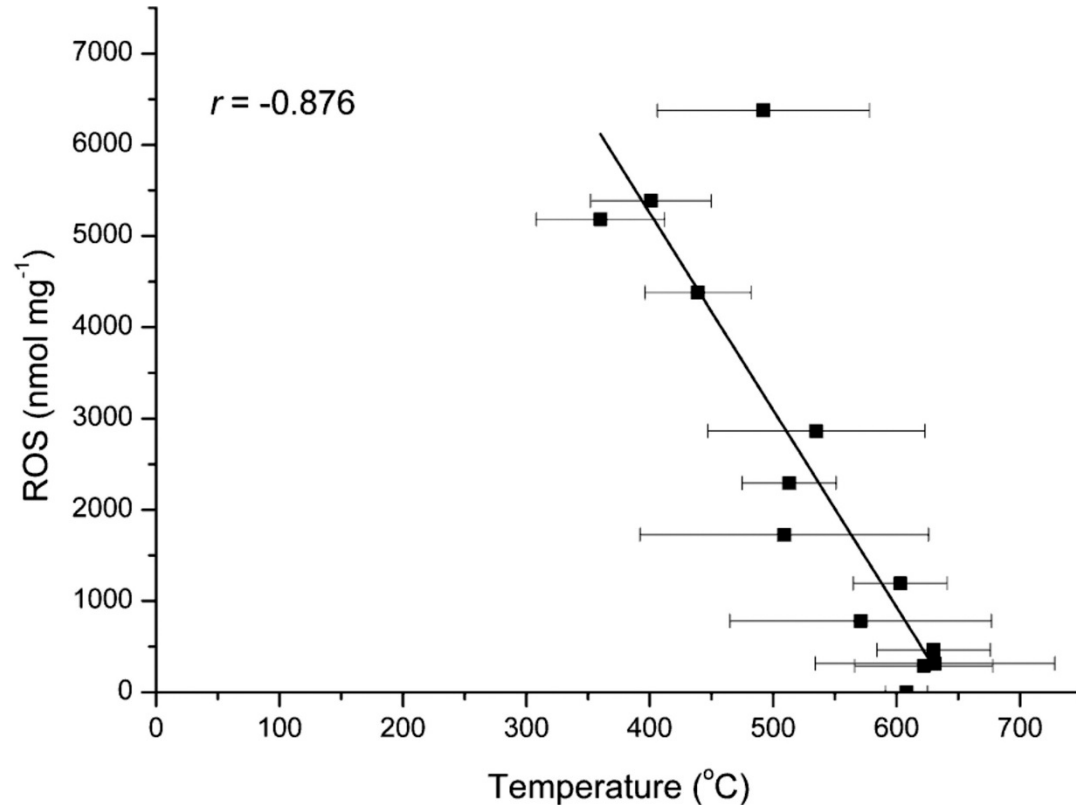
Semivariogram analysis³ suggests spatial extent of **2.7 km**

¹Larson T, Su J, Baribeau A-M, Buzzelli M, Setton E, Brauer M. A Spatial Model of Urban Winter Woodsmoke Concentrations. Environmental Science and Technology. 2007; 41 (7): 2429 -2436.; ²Su JG, Allen GA, Miller PJ, Brauer M. Spatial modeling of residential woodsmoke across a non-urban upstate New York region. Air Quality, Atmosphere and Health, 2011 <http://dx.doi.org/10.1007/s11869-011-0148-1>; ³Lightowlers, C et al. Determining the spatial scale for analysing mobile measurements of air pollution. Atmospheric Environment 42 (2008)

Factors contributing to indoor levels



Combustion conditions and composition

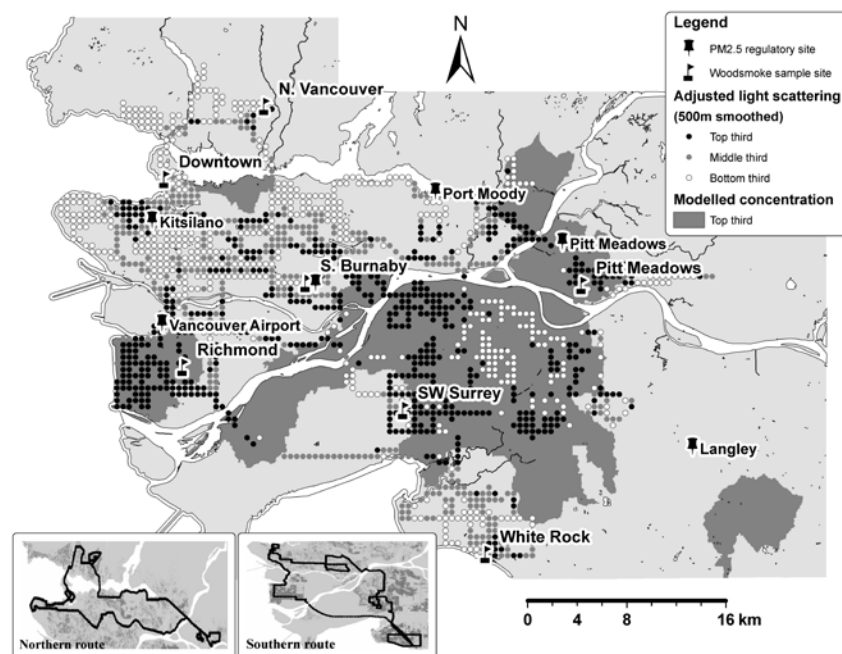


Correlation between the combustion chamber temperature and ROS concentration for logwood burning.

- ROS concentrations not measurable for pellet oven emissions.
- ROS concentrations of logwood burners high for starting conditions and at low temperatures
- Low temperature logwood burner ROS concentrations > primary diesel emissions, cigarette smoke

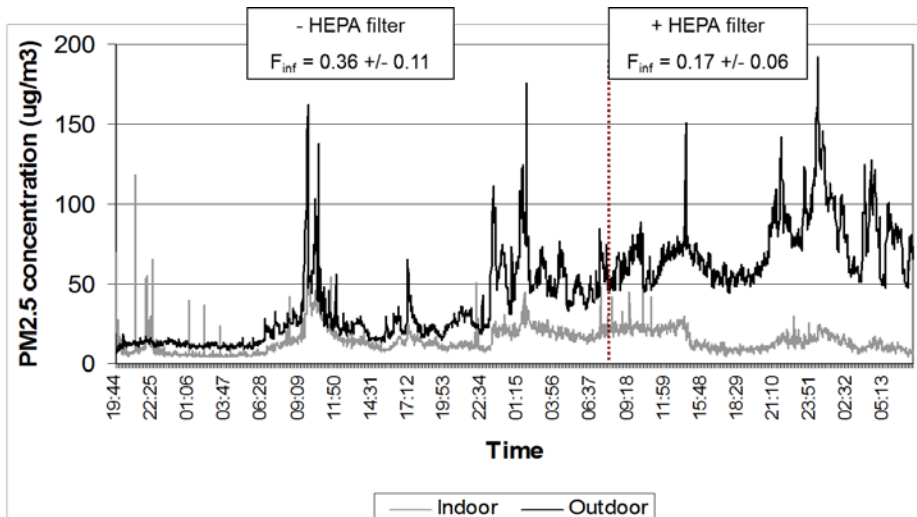
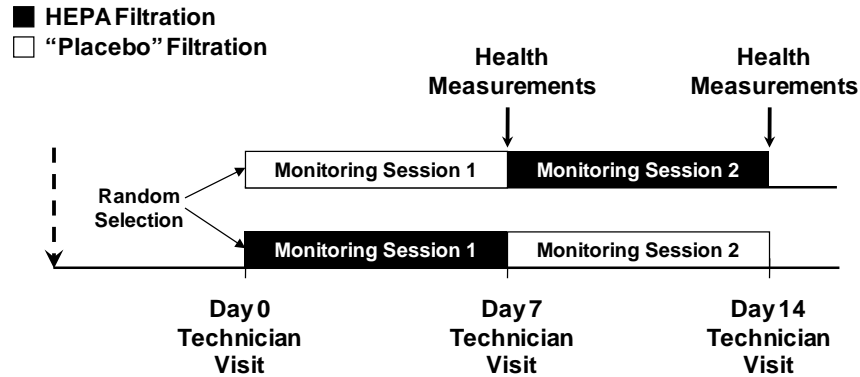
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 - asthma *incidence*⁻
 - cardiovascular, COPD mortality⁻



++ > traffic pollution, + ~traffic, - <traffic

Air filtration



- Portable HEPA filters 60%
↓ in indoor PM_{2.5}
- ↑ endothelial function, ↓
inflammatory markers

Summary Points

- Woodsmoke exposure (acute, sub-chronic) associated with respiratory symptoms, increased medication, decreased lung function, asthma emergency room visits and hospitalizations
 - Larger responses amongst asthmatics
- Associations with CVD and respiratory mortality and CVD hospitalization are mixed
 - Supported by subclinical CVD measures

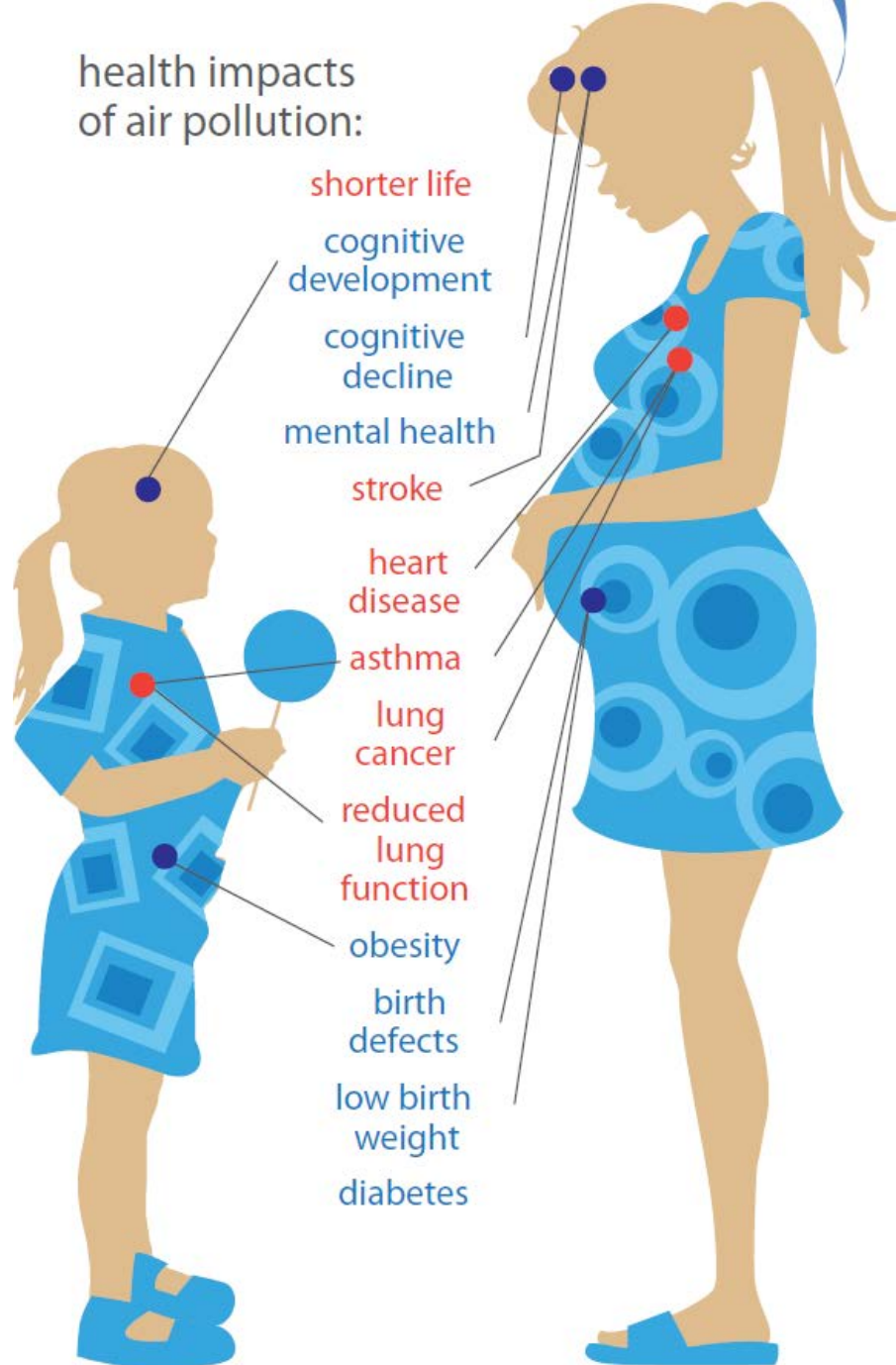
Summary Points (2)

- Limited studies of chronic exposure
- Associations with term birthweight, pre-term birth, incident infant bronchiolitis, otitis media and COPD hospitalization
- No association with COPD mortality or incident childhood asthma
- No studies of lung cancer

Policy implications

- Biomass is an important source of air pollution in many areas
- Evidence for health impacts of magnitude similar to other widely recognized risk factors
 - e.g Eliminating woodsmoke: 10% reduction in otitis media incidence:
 - Maternal smoking during pregnancy or secondhand smoke exposure: 2% reduction
 - Pneumococcal conjugate vaccine: ~6-7% reduction
- Suggests cost-effectiveness of exposure reduction
- Advanced technology combustion
 - Derive max energy
 - Lower mass emissions
 - Lower toxicity

health impacts of air pollution:



● established effects

● possible effects