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School of Public Health

Connecting air pollutant mixtures and health risk

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Overarching concepts/questions

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- We are exposed to complex mixtures of PM2.5 constituents and multiple gaseous pollutants
- Mixtures characteristics are linked to local and regional sources so will vary geographically.
- The Air Quality Health Index (AQHI) considers mixtures.
- Can we define a chronic exposure index that considers mixtures?
- What evidence is there that mixtures matter?

Quick tour of some relevant Canadian studies

Research

A Section 508-conformant HTML version of this article is available at http://dx.doi.org/10.1289/ehp.1409276.

Ambient $PM_{2.5}$, O_3, and NO_2 Exposures and Associations with Mortality over 16 Years of Follow-Up in the Canadian Census Health and Environment Cohort (CanCHEC)

Dan L. Crouse,[1,2] Paul A. Peters,[2] Perry Hystad,[3] Jeffrey R. Brook,[4,5] Aaron van Donkelaar,[6] Randall V. Martin,[6] Paul J. Villeneuve,[7] Michael Jerrett,[8] Mark S. Goldberg,[9,10] C. Arden Pope III,[11] Michael Brauer,[12] Robert D. Brook,[13] Alain Robichaud,[14] Richard Menard,[14] and Richard T. Burnett[1]

"$PM_{2.5}$ alone does not fully characterize the toxicity of the atmospheric mix"

"efforts should be made to model the toxicity of atmospheric mixtures when modeling population burden of disease attributable to air pollution exposure"

www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

Impact of Oxidant Gases on the Relationship between Outdoor Fine Particulate Air Pollution and Nonaccidental, Cardiovascular, and Respiratory Mortality

Scott Weichenthal[1,2], Lauren L. Pinault[2] & Richard T. Burnett[2]

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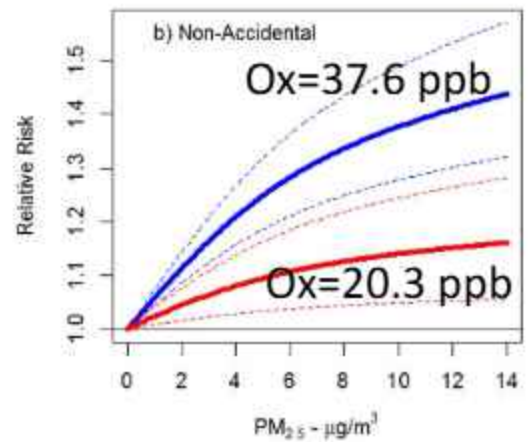
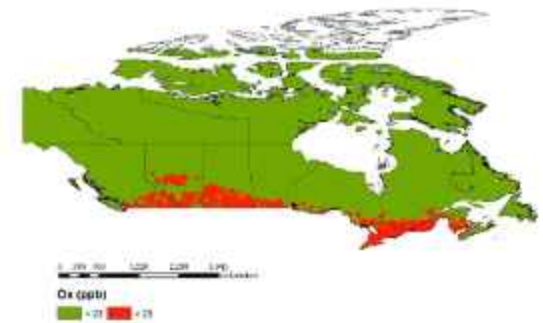
Published online: 27 November 2017



"our findings suggest that oxidant gases enhance the chronic health risks of $PM_{2.5}$"

"reductions in O_x concentrations may have the added benefit of reducing the public health impacts of $PM_{2.5}$ even if mass concentrations remain unchanged"



Quick tour of some relevant Canadian studies

Christidis et al. Environmental Health (2019) 18:84
https://doi.org/10.1186/s12940-019-0518-y

Environmental Health

RESEARCH Open Access

Low concentrations of fine particle air pollution and mortality in the Canadian Community Health Survey cohort

Tanya Christidis[1*], Anders C. Erickson[2], Amanda J. Pappin[1,13], Daniel L. Crouse[3], Lauren L. Pinault[1], Scott A. Weichenthal[4,5], Jeffrey R. Brook[6,12], Aaron van Donkelaar[7,11], Perry Hystad[8], Randall V. Martin[7,9,11], Michael Tjepkema[1], Richard T. Burnett[10] and Michael Brauer[2]

"$PM_{2.5}$ is associated with mortality and that the inclusion of gaseous co-pollutants, O_x in particular, may better characterize the biologically active aspects of $PM_{2.5}$ "

- *a 24% difference in mortality risk between low and high Ox exposures*

"knowledge of interactions between $PM_{2.5}$ and oxidant gases leading to adverse health will improve risk management activities and public health"

Quick tour of some relevant Canadian studies


Weichenthal et al. Environmental Health (2016) 15:46
DOI 10.1186/s12940-016-0129-9

Environmental Health

RESEARCH Open Access

Ambient $PM_{2.5}$ and risk of emergency room visits for myocardial infarction: impact of regional $PM_{2.5}$ oxidative potential: a case-crossover study

Scott Weichenthal[1*], Eric Lavigne[1], Greg Evans[2], Krystal Pollitt[3] and Rick T. Burnett[1]


Research

A Section 508-conformant HTML version of this article is available at https://doi.org/10.1289/EHP949

Association of Sulfur, Transition Metals, and the Oxidative Potential of Outdoor $PM_{2.5}$ with Acute Cardiovascular Events: A Case-Crossover Study of Canadian Adults

Scott Weichenthal,[1,2] Eric Lavigne,[2,3] Alison Traub,[4] Dana Umbria,[4] Hongyu You,[2] Krystal Pollitt,[5] Tim Shin,[2] Ryan Kulka,[2] Dave M. Stieb,[6] Jill Korsiak,[1] Barry Jessiman,[2] Jeff R. Brook,[7] Marianne Hatzopoulou,[8] Greg Evans,[4] and Richard T. Burnett[6]

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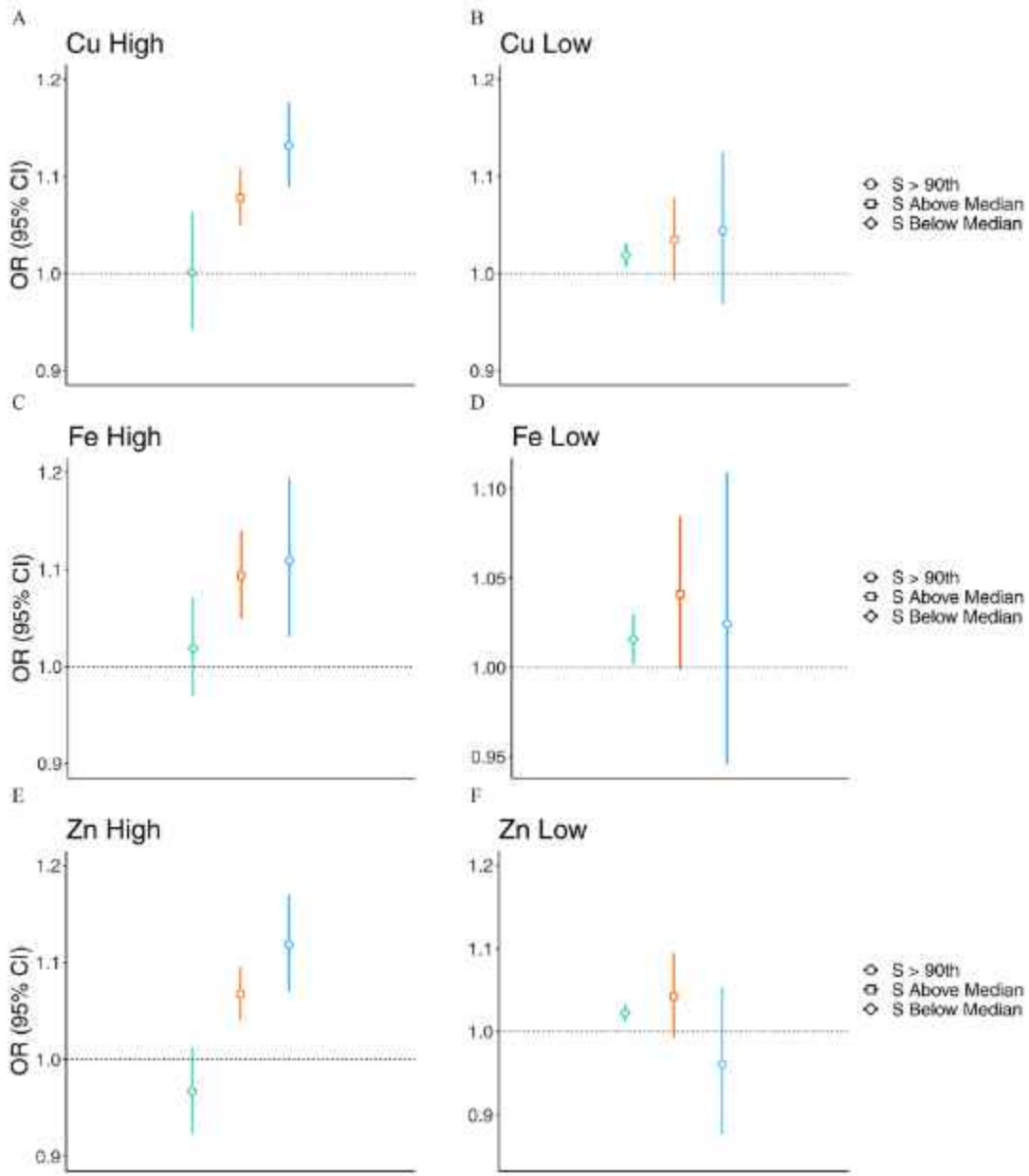
[8]Department of Civil and Mineral Engineering, University of Toronto, Toronto, Canada

"Regional $PM_{2.5}$ oxidative potential may modify the impact of $PM_{2.5}$ on the risk of myocardial infarction. The combined oxidant capacity of NO_2 and O_3 may magnify this effect."

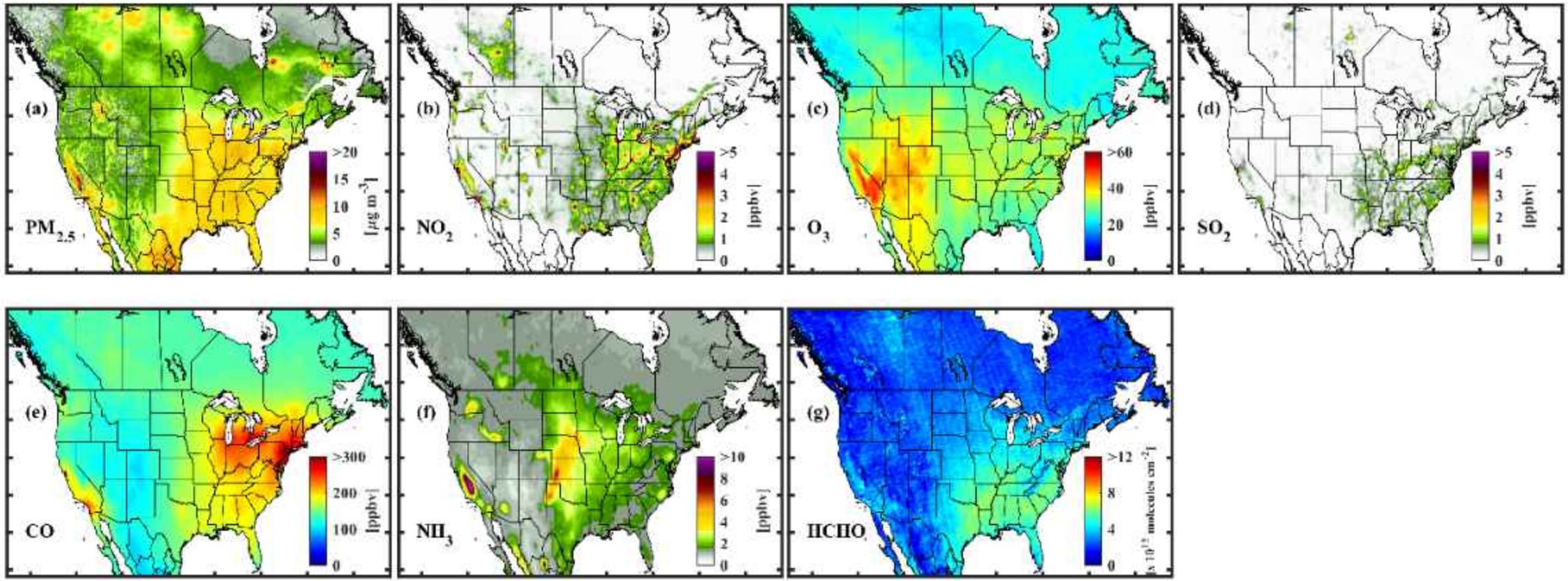
- Strength of the PM2.5 association with acute cardiovascular events influenced by proportions of transition metals and sulfur.
- Oxidative potential (OP) metrics capture this trend in part because they are more strongly correlated with transition metals in PM2.5 when S content is higher.
- These results provide new information on why we continue to see adverse health effects of PM2.5 at low mass concentrations.


A
Cu High
B
Cu Low
C
Fe High
D
Fe Low
E
Zn High
F
Zn Low
OR (95% CI)
S > 90th
S Above Median
S Below Median

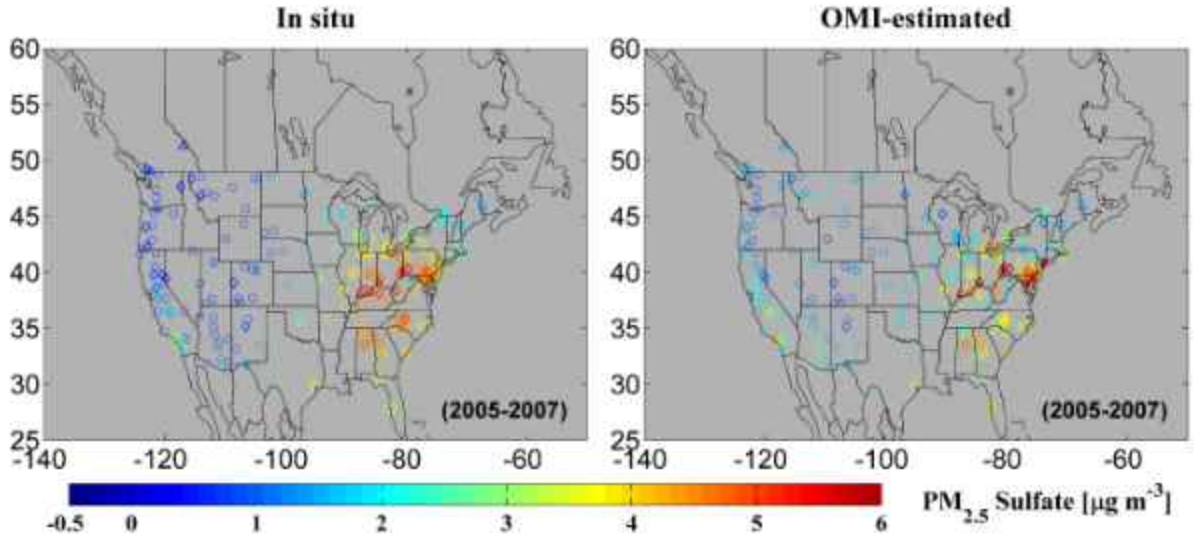
Development of a chronic exposure index

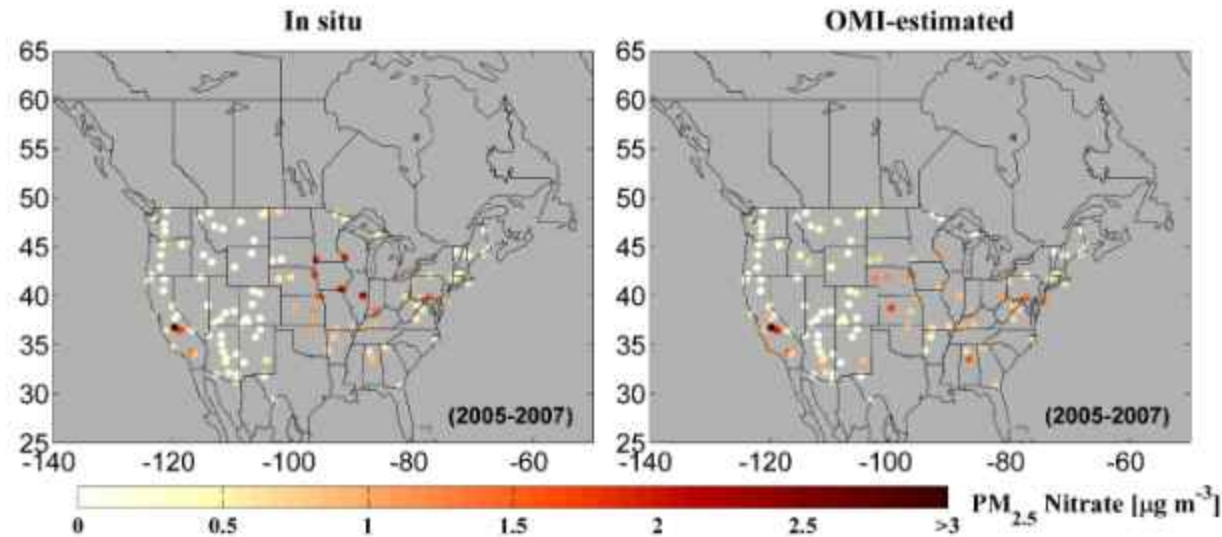
- considers mixtures
- can be derived for the globe

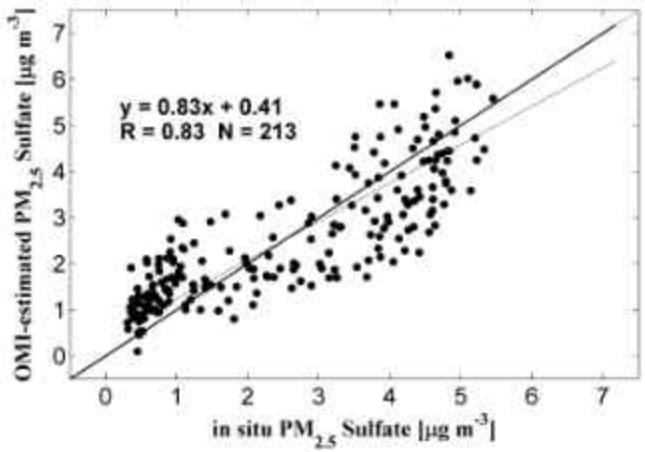
2012-14 Principal Component Analysis (PCA) Inputs for North American Domain

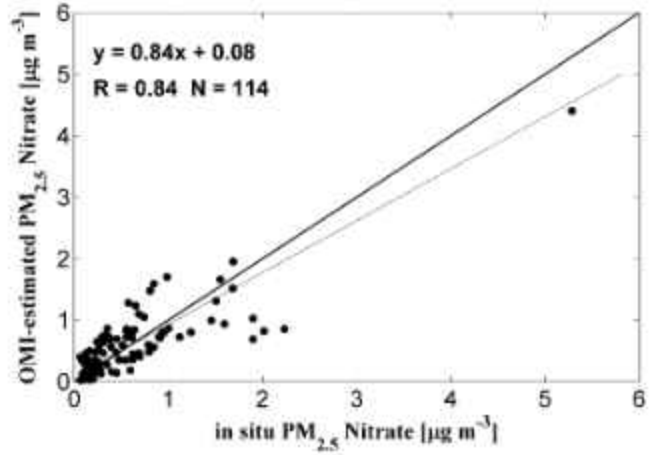


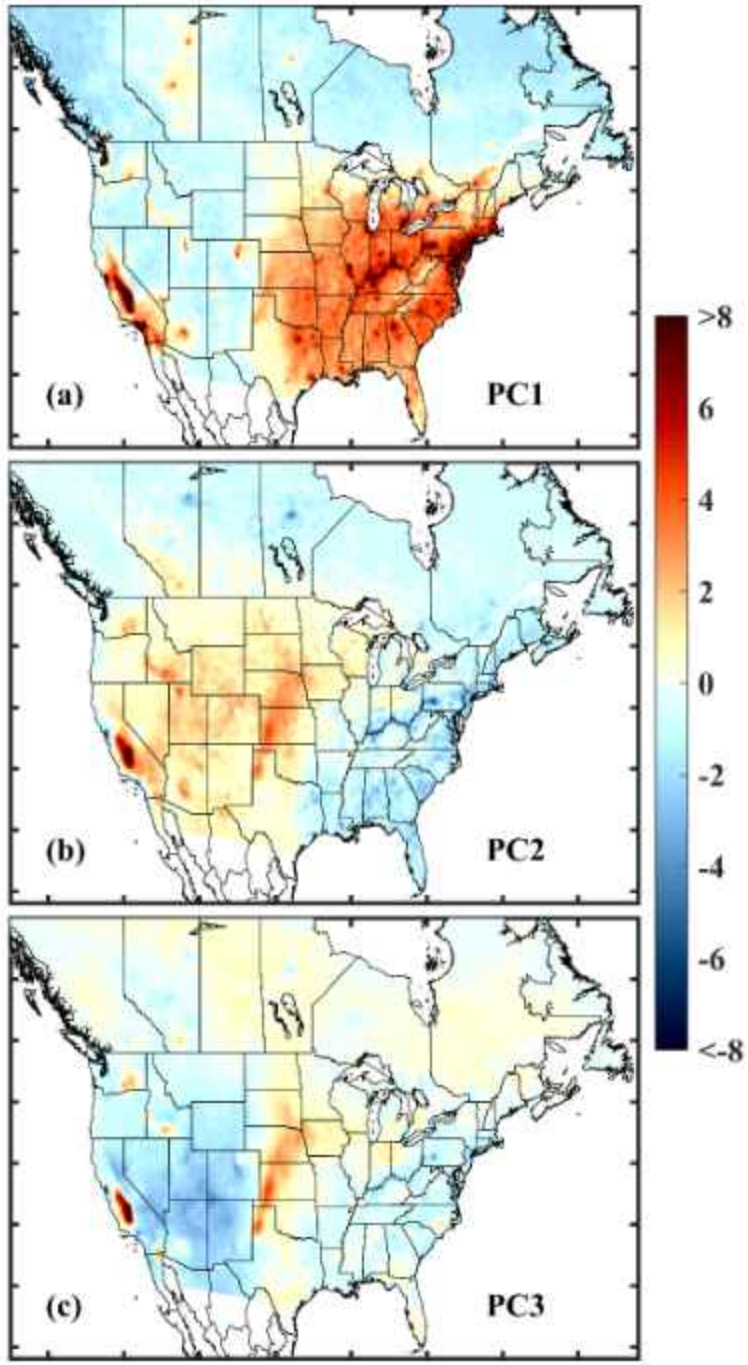
Satellite mixtures reflect PM2.5 speciation

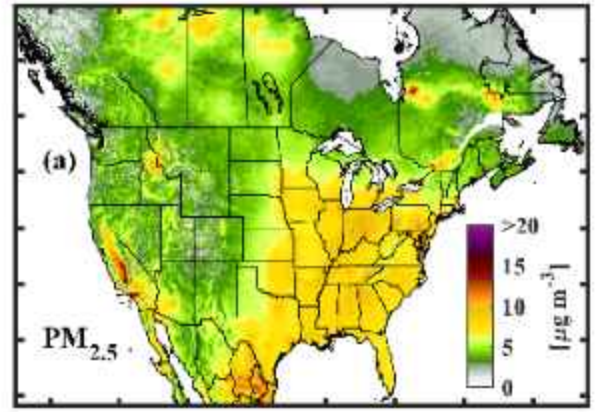


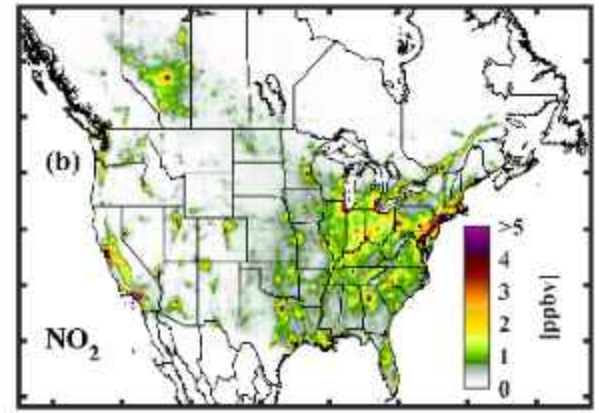








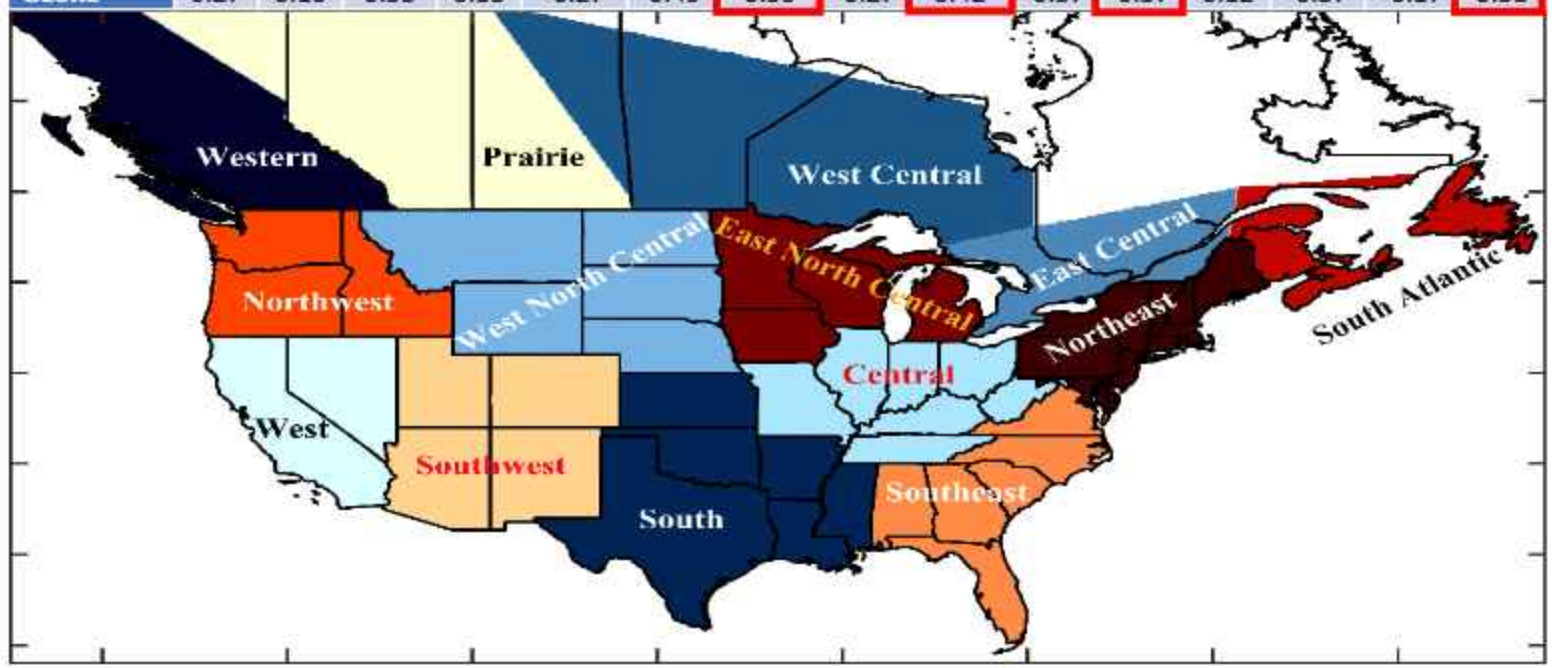




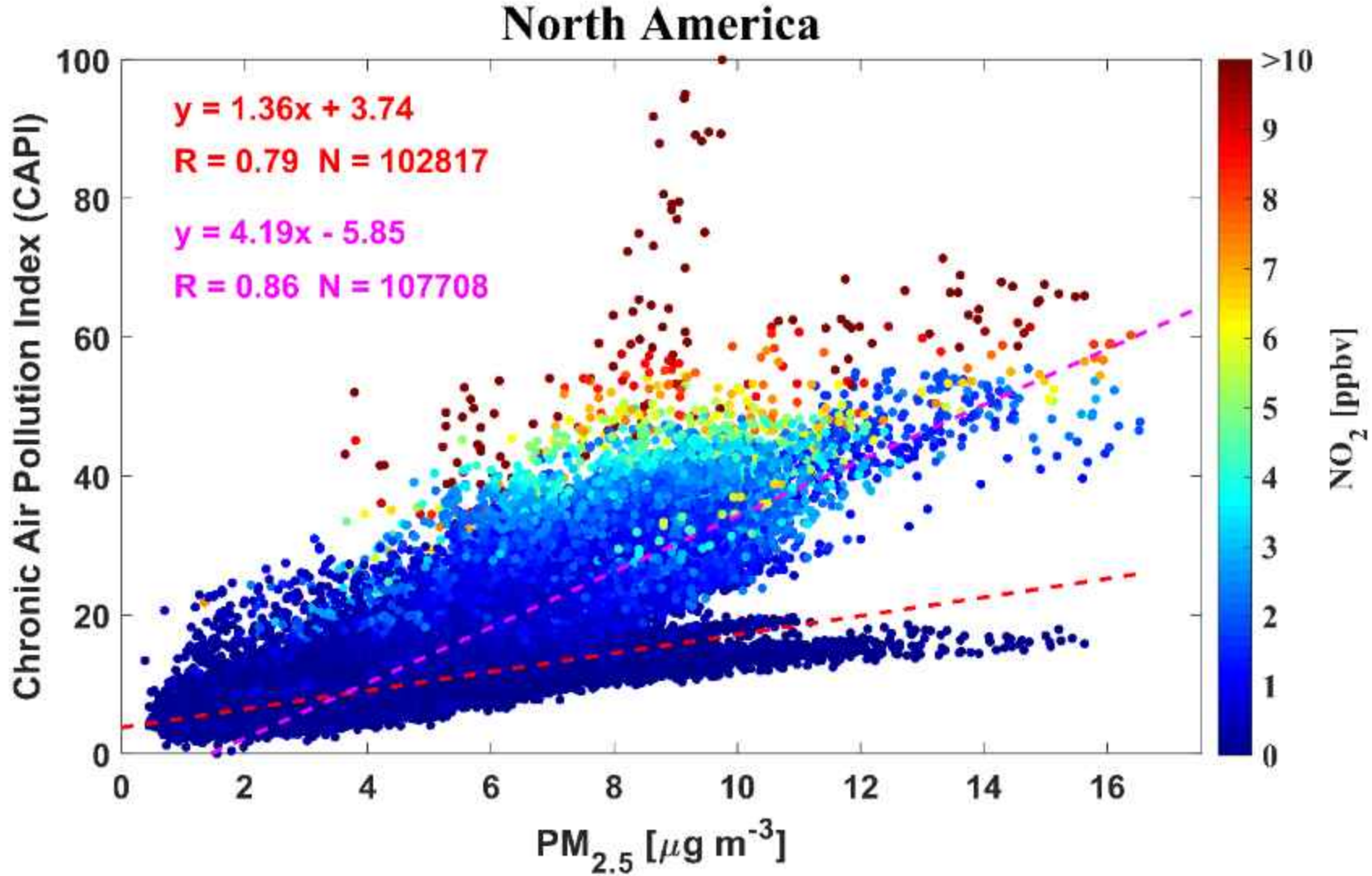
Pollutants	PC1	PC2	PC3
NO_2	0.41	-0.10	-0.18
SO_2	0.36	-0.47	-0.25
$PM_{2.5}$	0.43	0.06	0.11
HCHO	0.41	-0.07	0.06
NH_3	0.30	0.50	0.67
CO	0.44	-0.26	0.13
Ozone	0.27	0.67	-0.65

Regional variation in mixtures

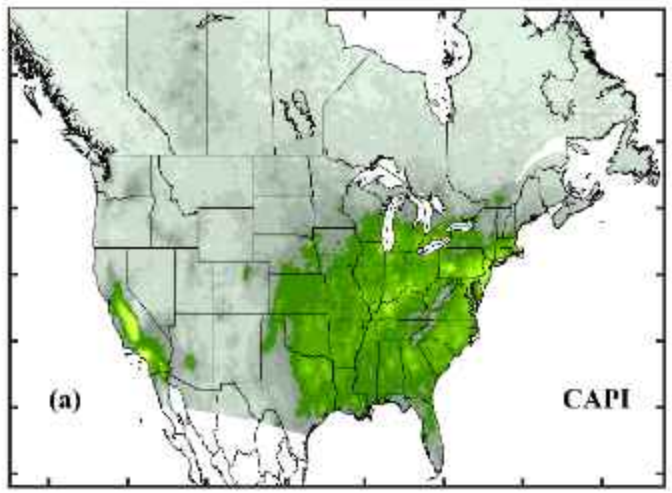
Pollutants	NA	WE	NW	P	WNC	WC	ENC	C	EC	SA	NE	W	SW	S	SE
NO_2	0.41	0.54	-0.32	0.51	0.38	0.46	0.37	0.55	0.33	0.39	0.34	0.38	0.26	0.32	0.32
SO_2	0.36	0.47	-0.39	0.01	0.06	-0.14	0.18	-0.08	-0.02	0.38	0.32	0.39	-0.10	0.37	0.34
$PM_{2.5}$	0.43	0.43	0.20	0.29	0.43	-0.07	0.49	0.55	0.43	0.43	0.45	0.44	0.45	0.46	0.37
HCHO	0.41	0.02	0.30	0.30	0.33	0.11	0.40	-0.06	0.38	0.30	0.43	0.40	0.47	0.48	0.43
NH_3	0.30	0.10	0.21	0.29	0.47	0.53	0.31	-0.06	0.42	-0.20	0.33	0.37	0.40	-0.24	0.28
CO	0.44	0.52	-0.53	0.60	0.51	0.48	0.44	0.55	0.45	0.50	0.39	0.44	0.45	0.49	0.49
Ozone	0.27	0.10	0.53	0.35	-0.27	0.49	0.39	-0.27	0.42	-0.37	0.37	0.12	-0.37	-0.17	0.38

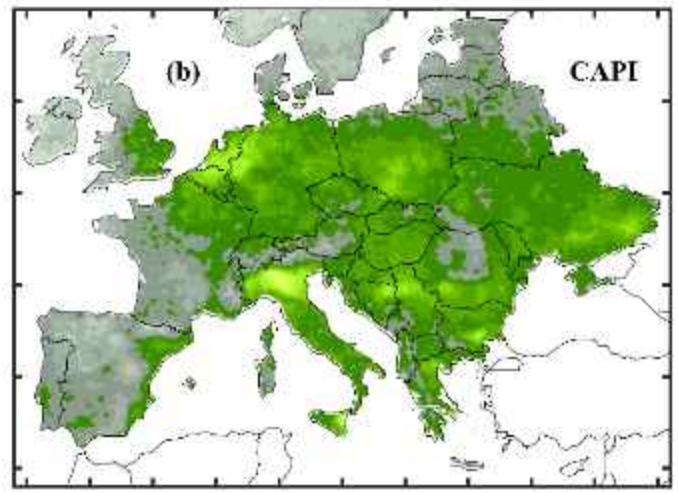


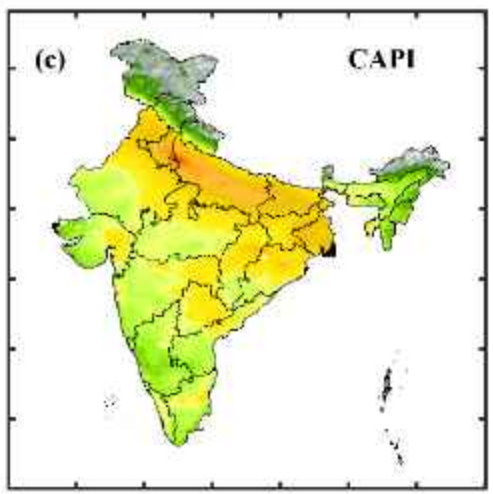
$PM_{2.5}$ means different things

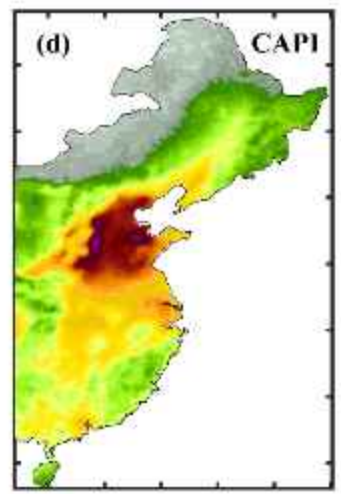


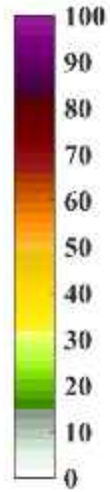
Continental variation in CAPI

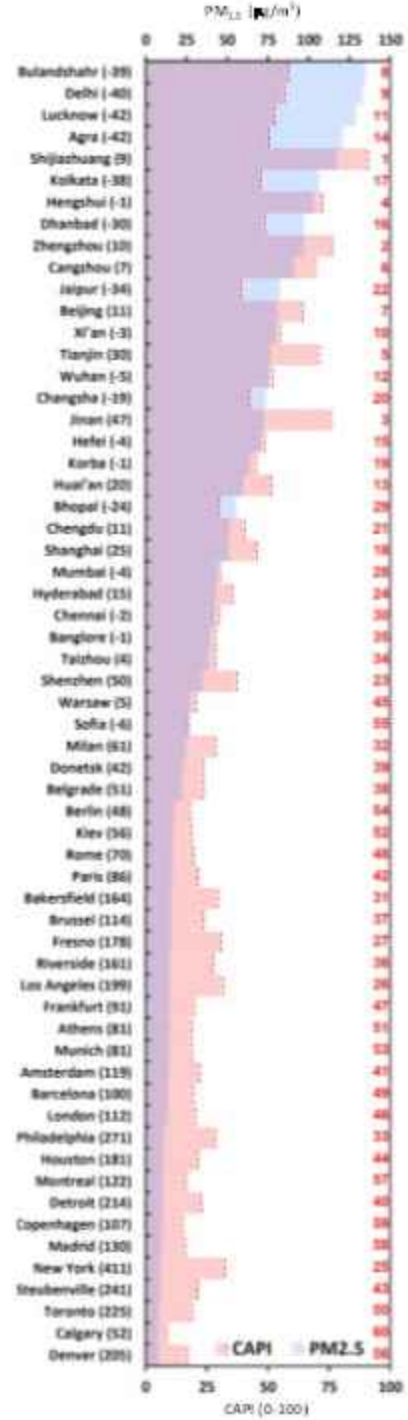












Original Research Article

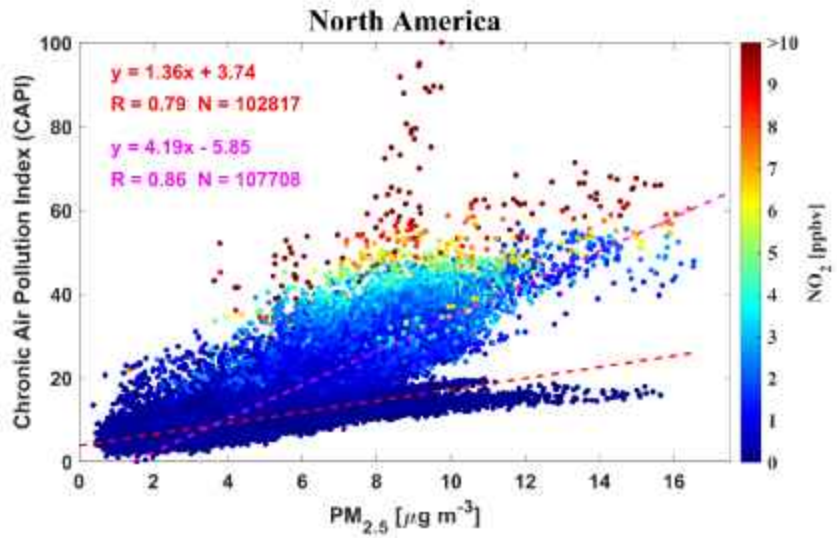
ISEE Environmental Epidemiology

OPEN

Air pollution mixture complexity and its effect on $PM_{2.5}$-related mortality

A multicountry time-series study in 264 cities

Pierre Masselot[a,*], Haidong Kan[b], Shailesh K. Kharol[c,d], Michelle L. Bell[e,f], Francesco Sera[g], Eric Lavigne[h,i], Susanne Breitner[j,k], Susana das Neves Pereira da Silva[l], Richard T. Burnett[m], Antonio Gasparrini[a], Jeffrey R. Brook[n], on behalf of the MCC Collaborative Research Network



Mixture complexity index = CAPI/PM2.5

Health Relevance of the CAPI

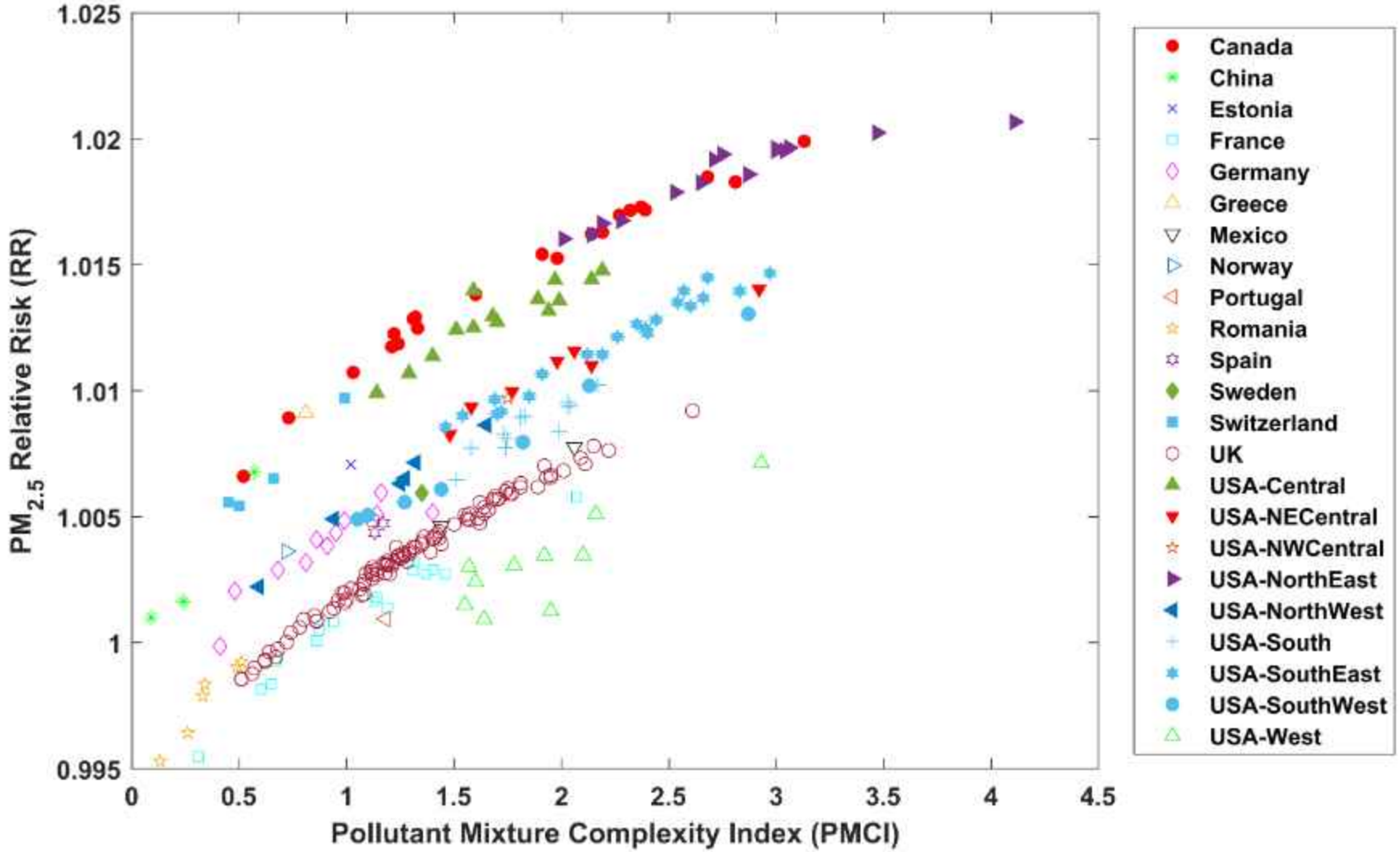
Table 2.

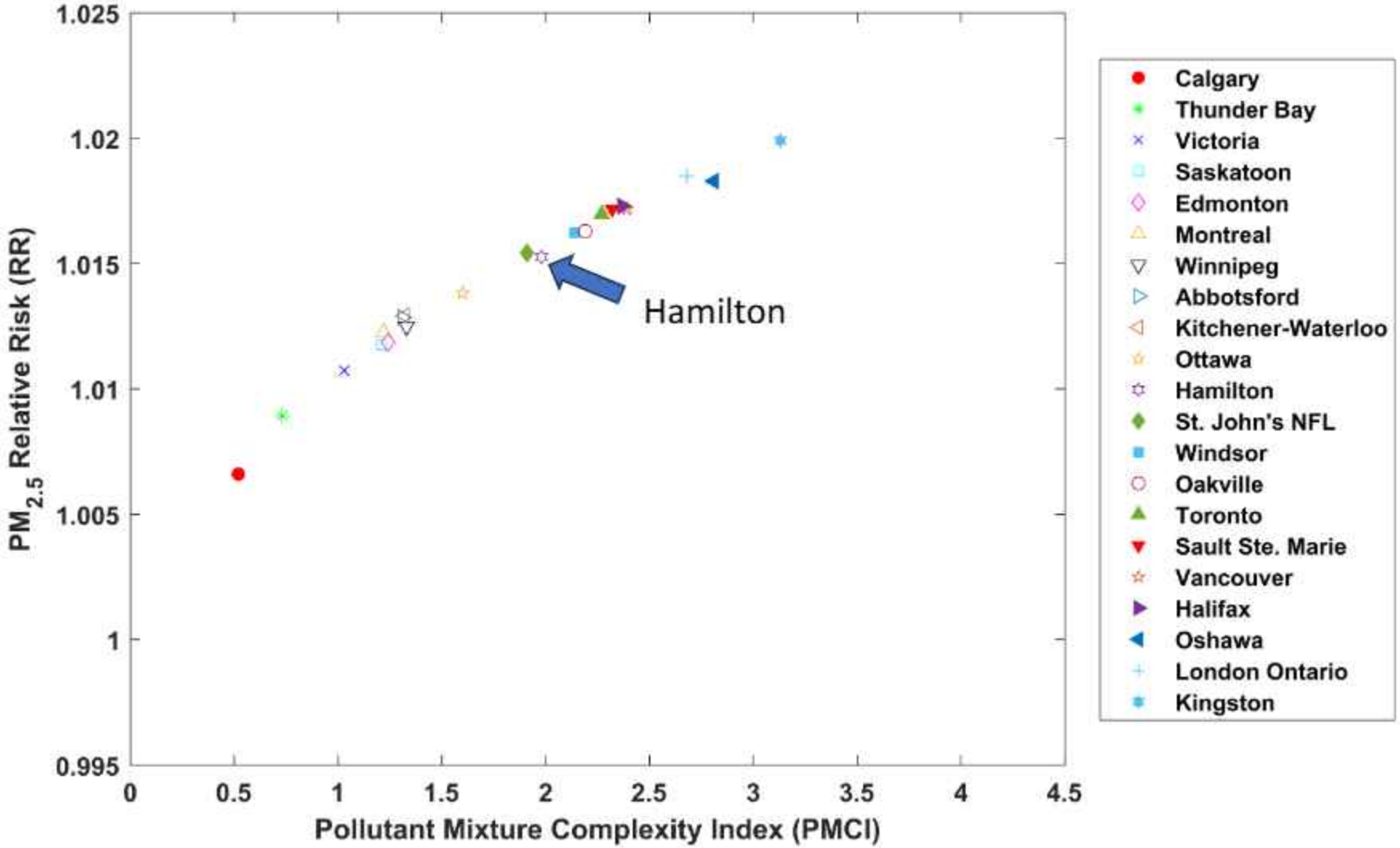
Results of the main and benchmark models, including the relative excess risk (RER) associated with an interquartile range increase of the effect modifier, as well as the *P* value from a likelihood ratio test (LRT), the (corrected) Akaike information criterion (AIC), and Bayesian information criterion (BIC)

Model	RER (95% CI)	LRT *P* value	AIC	BIC
Main		**0.0000**	**−1566.22**	**−1545.09**
PMCI	1.0042 (1.0023, 1.0061)			
Null			−1550.96	−1533.31
Gas mixture		0.0006	−1561.82	−1523.54
NO_2	0.9994 (0.9983, 1.0005)			
SO_2	0.9990 (0.9978, 1.0002)			
O_3	0.9995 (0.9982, 1.0008)			
HCHO	1.0028 (1.0013, 1.0044)			
CO	1.0015 (1.0003, 1.0026)			
NH_3	0.9999 (0.9997, 1.0001)			
O_x		0.6883	−1549.03	−1527.90
O_x	0.9996 (0.9978, 1.0014)			
$PM_{2.5}$ composition		0.0096	−1555.06	−1516.77
SO_4^{2-}	1.0017 (0.9945, 1.0090)			
NH_4^+	1.0031 (1.0002, 1.0059)			
NO_3^-	0.9971 (0.9955, 0.9987)			
BC	1.0020 (0.9992, 1.0049)			
OC	1.0011 (0.9991, 1.0031)			
SS	0.9977 (0.9913, 1.0042)			
DUST	0.9882 (0.9738, 1.0029)			

Best values for each criterion are indicated in bold.

BC, black carbon; DUST, mineral dust; OC, organic carbon; SS, sea salt.


1.025
1.02
1.015
1.01
1.005
1
0.995
PM2.5 Relative Risk (RR)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Pollutant Mixture Complexity Index (PMCI)
Canada
China
Estonia
France
Germany
Greece
Mexico
Norway
Portugal
Romania
Spain
Sweden
Switzerland
UK
USA-Central
USA-NECentral
USA-NWCentral
USA-NorthEast
USA-NorthWest
USA-South
USA-SouthEast
USA-SouthWest
USA-West


1.025
1.02
1.015
1.01
1.005
1
0.995
PM2.5 Relative Risk (RR)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Pollutant Mixture Complexity Index (PMCI)
Hamilton
Calgary
Thunder Bay
Victoria
Saskatoon
Edmonton
Montreal
Winnipeg
Abbotsford
Kitchener-Waterloo
Ottawa
Hamilton
St. John's NFL
Windsor
Oakville
Toronto
Sault Ste. Marie
Vancouver
Halifax
Oshawa
London Ontario
Kingston

Conclusions

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- Clear epidemiological evidence in Canada of the impact of air pollution mixtures on health outcomes
- Continental to global observations of spatial air pollutant patterns reveal a common thread related to photochemical processing of combustion emissions
- The importance of this mixture relative to PM2.5 explains within country/region variations in acute PM2.5 mortality impacts

Next Steps

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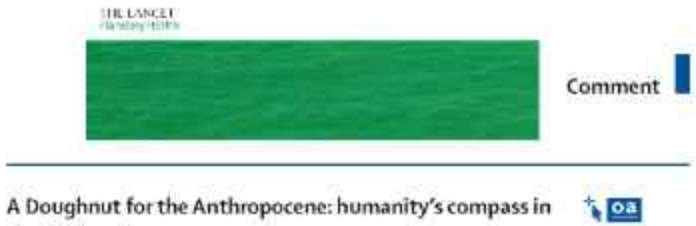
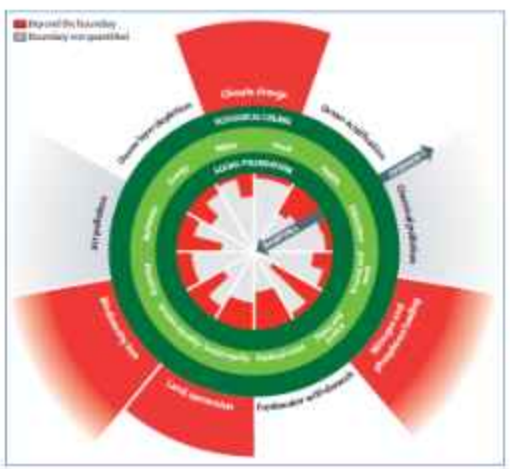
- Explain the different curves in RR vs. PMCI
- Expand to globe and more recent years
- Promote use in epidemiological research
  - CANUE.CA
- Enhance AQ models to predict CAPI
- Assess how geographically-varying RR impacts air pollution burden estimates
- Promote as single Environmental Performance Indicator for air pollution
  - chronic exposure to $PM_{2.5}$ is the only indicator in terms of air quality and health, indicators for other pollutants, such as SO_2 and NO_2, are included separately





Raworth, 2017