Traffic Related Air Pollution and Pediatric Asthma

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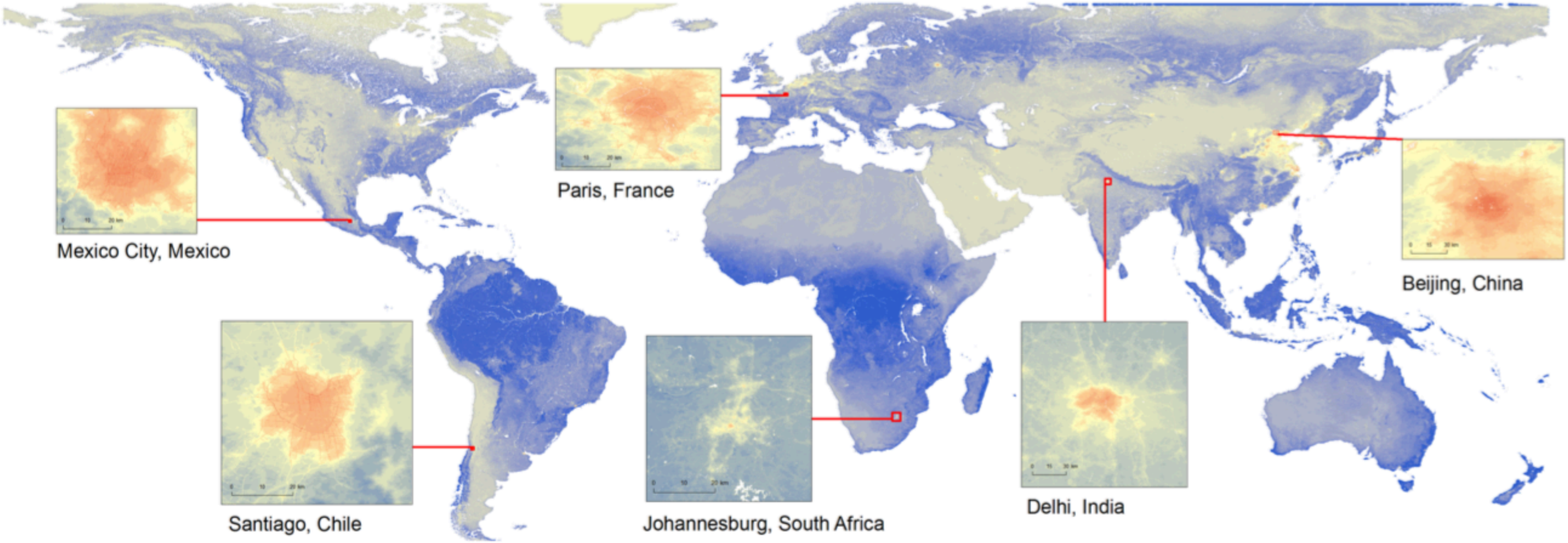
THE UNIVERSITY OF BRITISH COLUMBIA

CHE Webinar, July 23, 2019

THINKSTOCK PHOTO



Global, national, and urban burdens of pediatric asthma incidence attributable to ambient NO_2 pollution: estimates from global datasets

Ploy Pattanun Achakulwisut[1*], Michael Brauer[2,3], Perry Hystad[4], Susan Anenberg[1]

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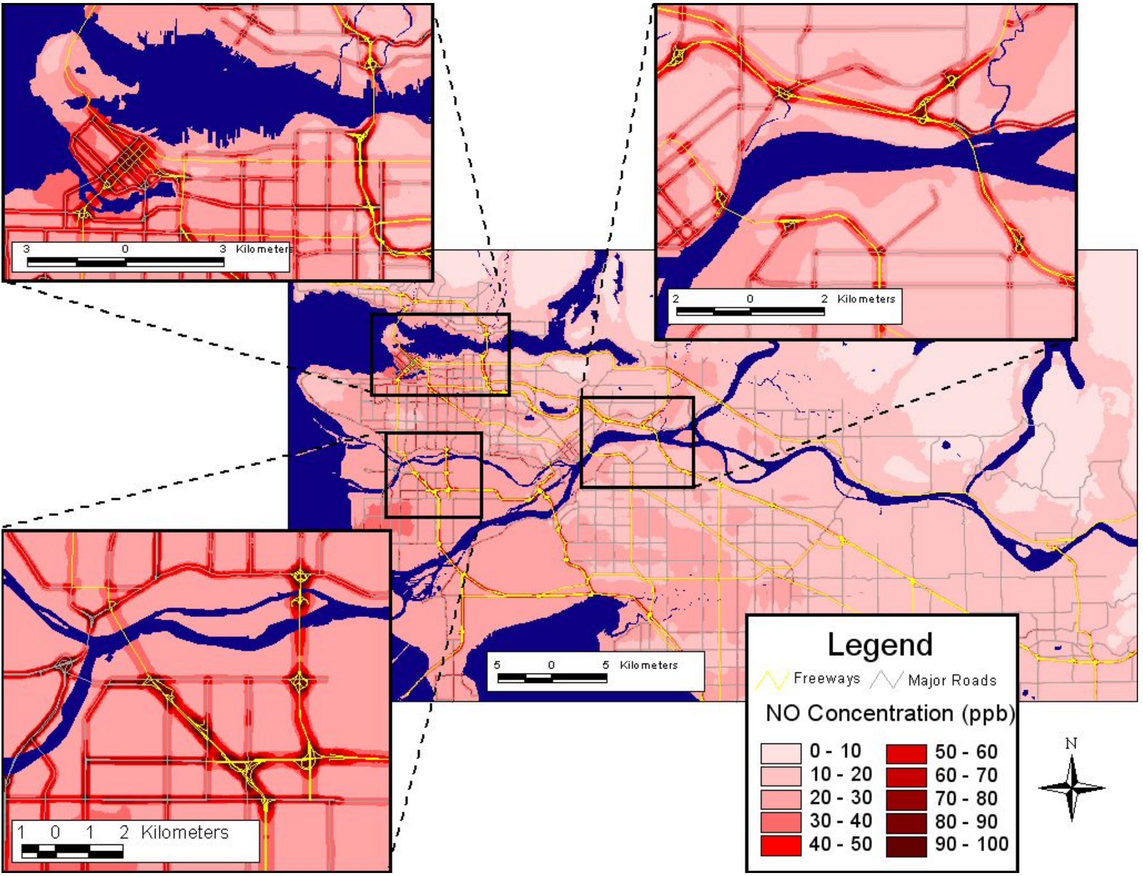
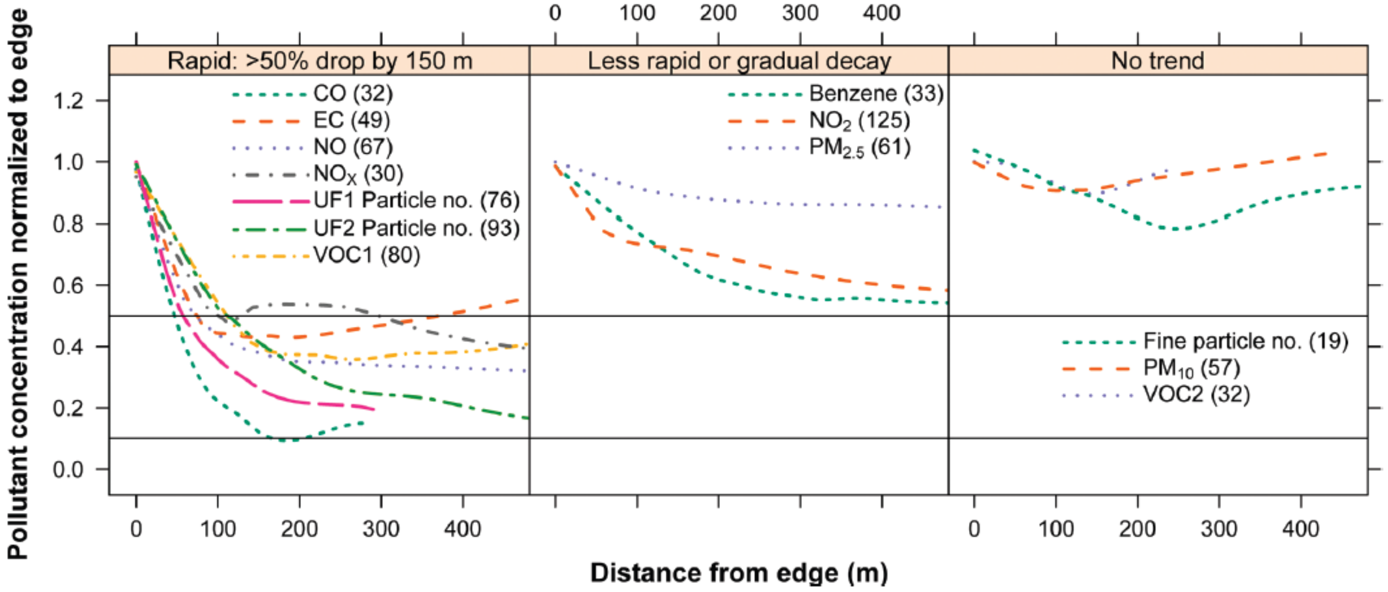
Lancet Planet Health. 2019 Apr;3(4):e166-e178. doi: 10.1016/S2542-5196(19)30046-4

Motivation: Traffic-related air pollution (TRAP)





Karner *et al.* (2010) Environ. Sci. Technol. 44, 5334

Traffic influence zones (<500m from highway or <100m from major road)

- 32% of Canadian population (~10 M)
- 36% of primary schools in large Canadian cities

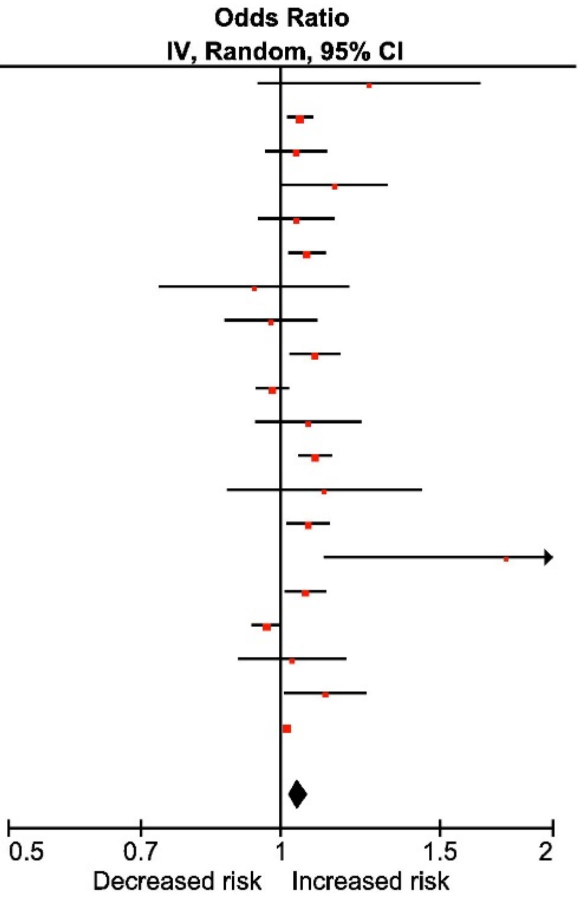
Henderson SB et al. Environmental Science and Technology. 2007; 41 (7):2422 -2428

Motivation: Traffic-related air pollution (TRAP)

Study or Subgroup	log[Odds Ratio]	SE	Weight	Odds Ratio IV, Random, 95% CI
Carlsten et al. 2010 - at 7 y.o.	0.2253	0.1448	0.6%	1.25 [0.94, 1.66]
Clark et al. 2010 LUR - at mean age of 4 y.o.	0.0489	0.0171	9.5%	1.05 [1.02, 1.09]
Dell et al. 2014 LUR - 5 to 9 y.o.	0.039	0.04	5.0%	1.04 [0.96, 1.12]
Deng et al. 2016 - 3 to 6 y.o.	0.1374	0.0689	2.4%	1.15 [1.00, 1.31]
Gehring et al. 2015 b - BAMSE birth to 16 y.o.	0.0397	0.0498	3.8%	1.04 [0.94, 1.15]
Gehring et al. 2015 b - PIAMA birth to 14 y.o.	0.0665	0.0246	7.8%	1.07 [1.02, 1.12]
Gehring et al. 2015b - GINI&LISA North birth to 15	-0.0679	0.1235	0.8%	0.93 [0.73, 1.19]
Gehring et al. 2015b - GINI&LISA South birth to 15	-0.0252	0.0602	2.9%	0.98 [0.87, 1.10]
Jerret et al. 2008 - 10 to 18 y.o.	0.0874	0.033	6.1%	1.09 [1.02, 1.16]
Kim et al. 2016 - 6 to 7 y.o.	-0.0214	0.0219	8.4%	0.98 [0.94, 1.02]
Krämer et al. 2009 - 4 to 6 y.o.	0.0698	0.069	2.3%	1.07 [0.94, 1.23]
Liu et al. 2016 - 4 to 6 years old	0.0877	0.0215	8.5%	1.09 [1.05, 1.14]
MacIntyre et al. 2014 - CAPPS&SAGE only birth to 8	0.1111	0.1268	0.8%	1.12 [0.87, 1.43]
McConnell et al. 2010 - 4th to 6th grade	0.0698	0.0281	7.1%	1.07 [1.01, 1.13]
Mölter et al. 2014 b - MAAS only birth to 8 y.o.	0.574	0.2374	0.2%	1.78 [1.11, 2.83]
Nishimura et al. 2013 - 8 to 21 y.o.	0.0632	0.0269	7.3%	1.07 [1.01, 1.12]
Oftedal et al. 2009 - birth to 10 y.o.	-0.0359	0.0196	8.9%	0.96 [0.93, 1.00]
Ranzi et al. 2014 - birth to 7 y.o.	0.0289	0.0701	2.3%	1.03 [0.90, 1.18]
Shima et al. 2002 - 6 to 12 y.o.	0.1136	0.0534	3.5%	1.12 [1.01, 1.24]
Tétreault et al. 2016 - birth to 12 y.o.	0.0153	0.0048	11.6%	1.02 [1.01, 1.03]
Total (95% CI)			**100.0%**	**1.05 [1.02, 1.07]**

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 54.38$, $df = 19$ ($P < 0.0001$); $I^2 = 65\%$

Test for overall effect: $Z = 3.76$ ($P = 0.0002$)



Khreis H, et al. Environ Int. 2017. doi: 10.1016/j.envint.2016.11.012; Macintyre E. et al. Environ Health Perspect. 2014 Apr;122(4):418-24. doi: 10.1289/ehp.1307459.

Motivation

- First estimates published in EHP in October 2018

Research

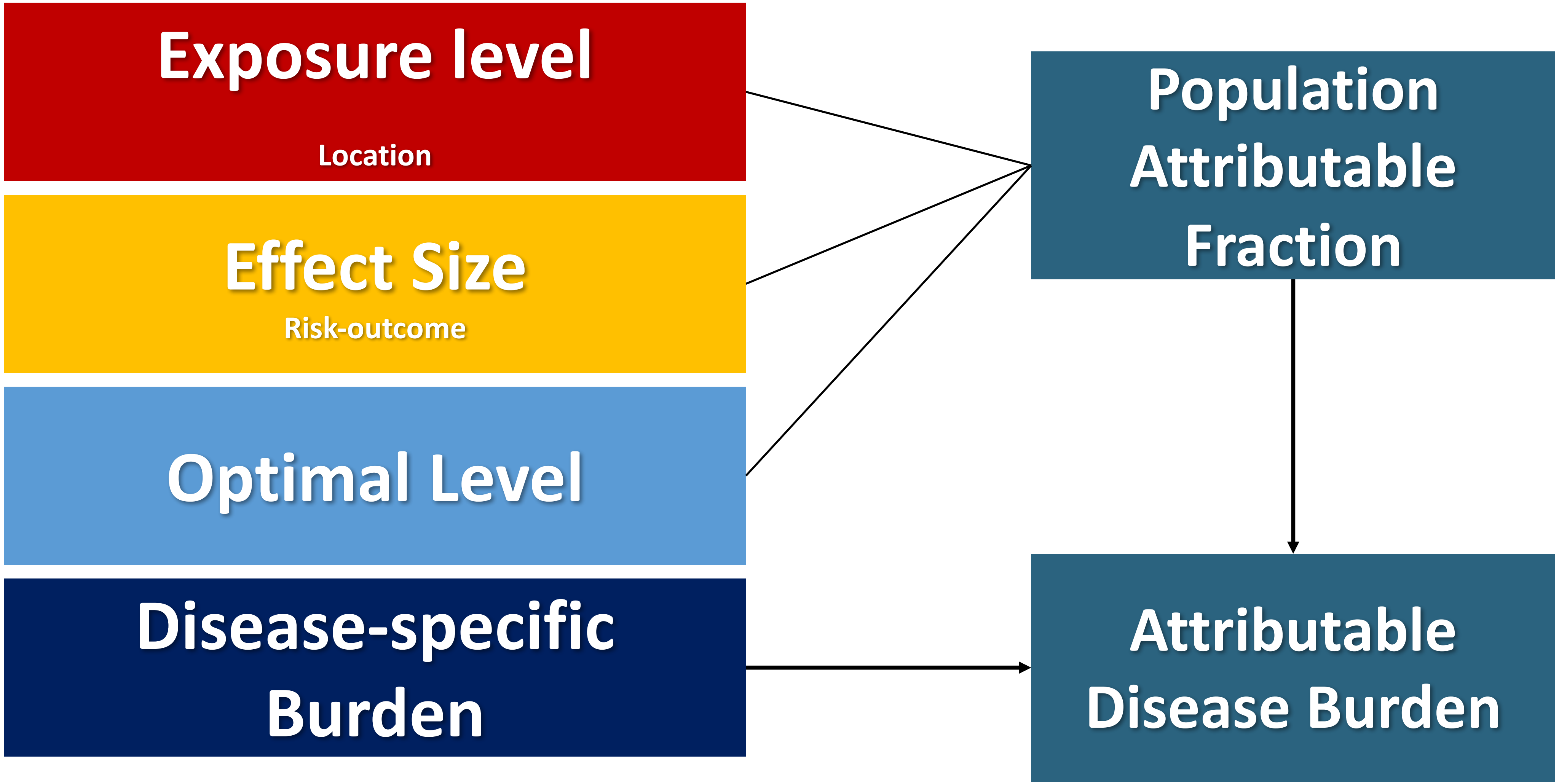
A Section 508–conformant HTML version of this article is available at https://doi.org/10.1289/EHP3766.

Estimates of the Global Burden of Ambient $PM_{2.5}$, Ozone, and NO_2 on Asthma Incidence and Emergency Room Visits

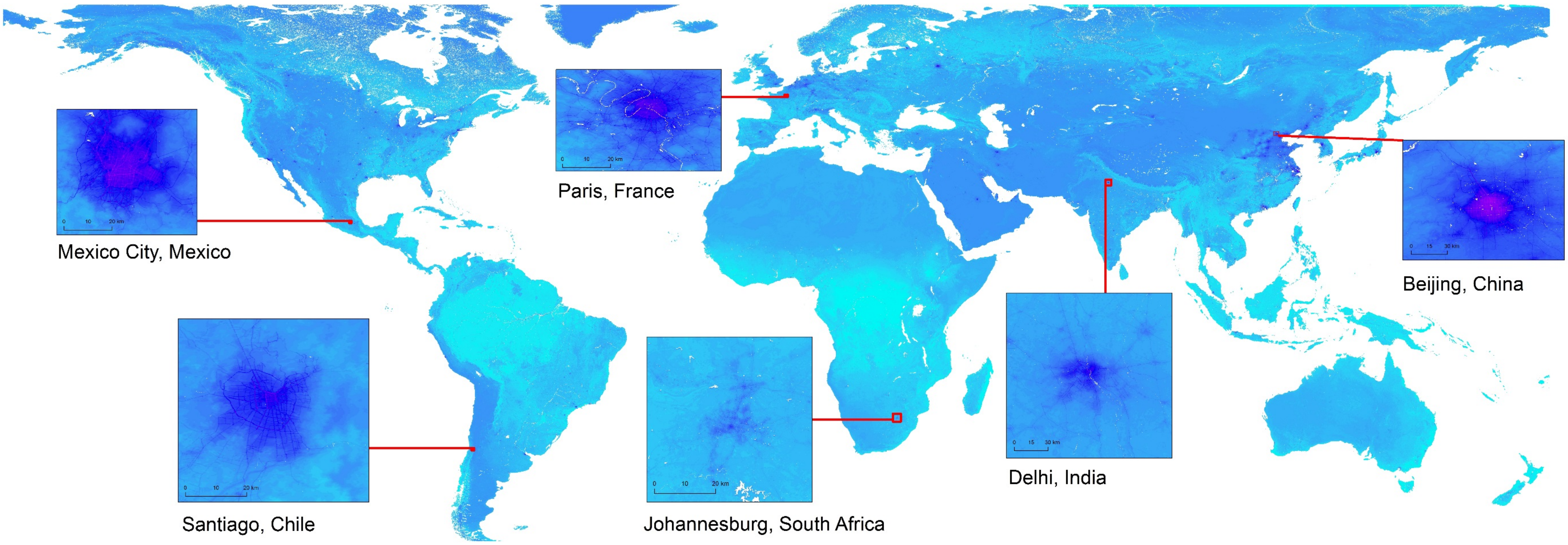
Susan C. Anenberg,[1] Daven K. Henze,[2] Veronica Tinney,[1] Patrick L. Kinney,[3] William Raich,[4] Neal Fann,[5] Chris S. Malley,[6] Henry Roman,[4] Lok Lamsal,[7] Bryan Duncan,[7] Randall V. Martin,[8,9] Aaron van Donkelaar,[8] Michael Brauer,[10,11] Ruth Doherty,[12] Jan Eiof Jonson,[13] Yanko Davila,[2] Kengo Sudo,[14,15] and Johan C.I. Kuylenstierna[6]

- Demonstrated potentially large impacts, but also many uncertainties and methodological refinements needed.
- For **asthma incidence**, strongest evidence for associations with **traffic-related NO_2 and for children**, but our methods were unable to capture realistic near-roadway exposures.

Methods: Estimating asthma burden attributable to NO_2

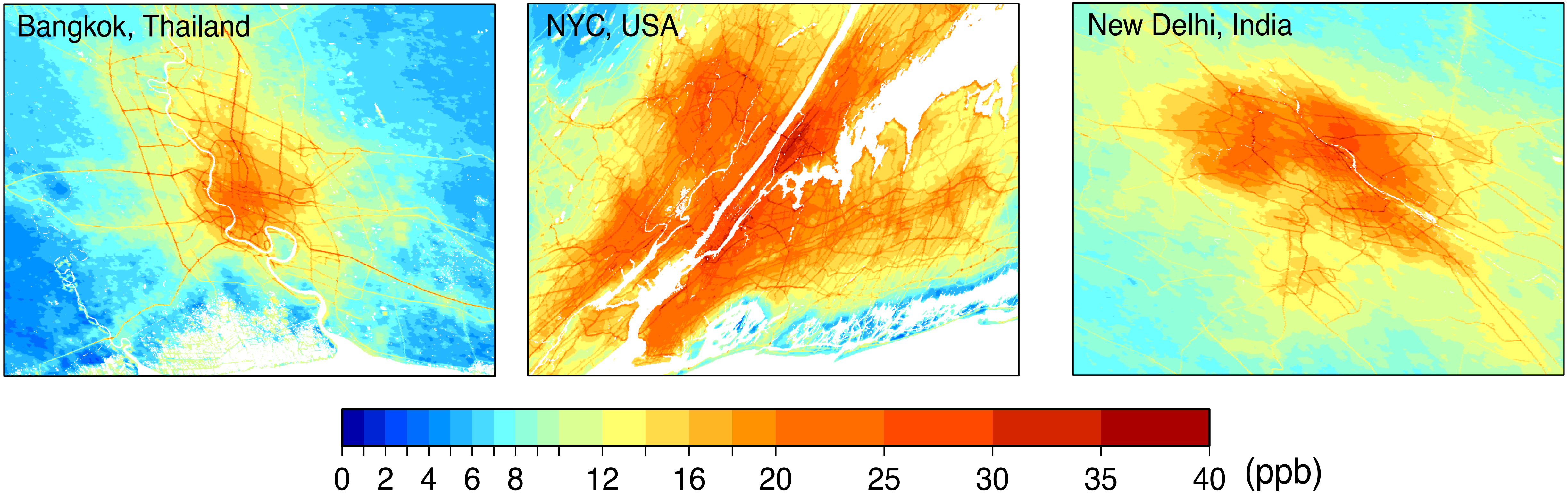


Exposure: Global high resolution (100m) NO_2 model



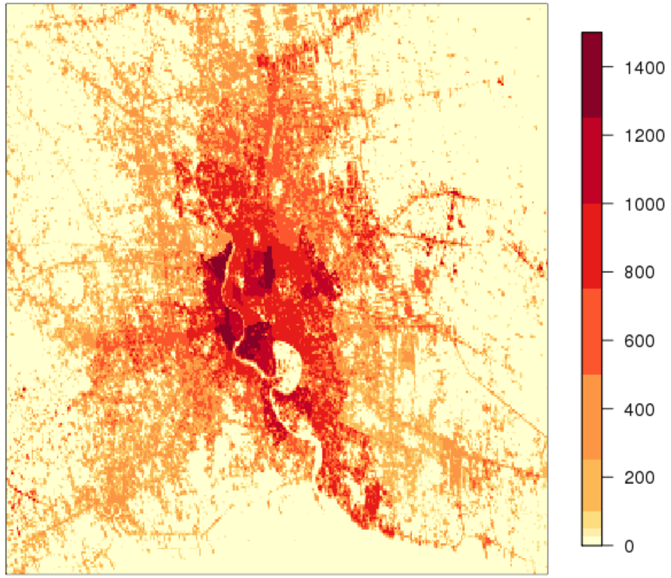
Larkin A, Geddes J, Martin RV, Xiao Q, Liu Y, Marshall JD, Brauer M, Hystad P. A Global Land Use Regression Model for Nitrogen Dioxide Air Pollution. Environmental Science & Technology. 2017

Exposure: Global high resolution (100m) NO_2 model

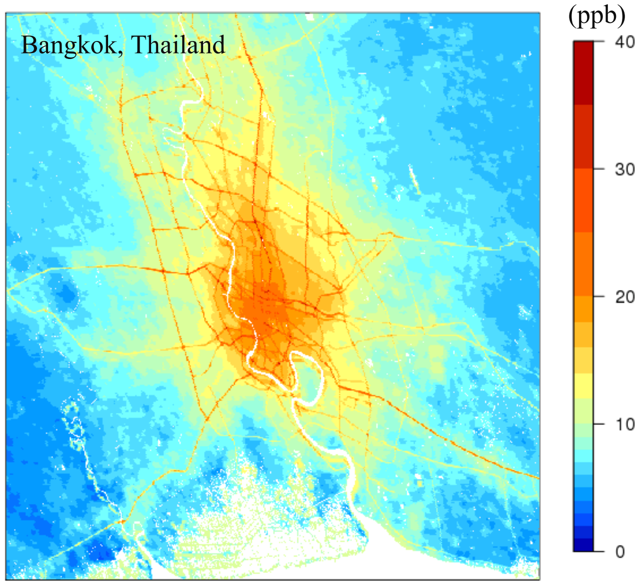


Exposure: Matching exposure to population data

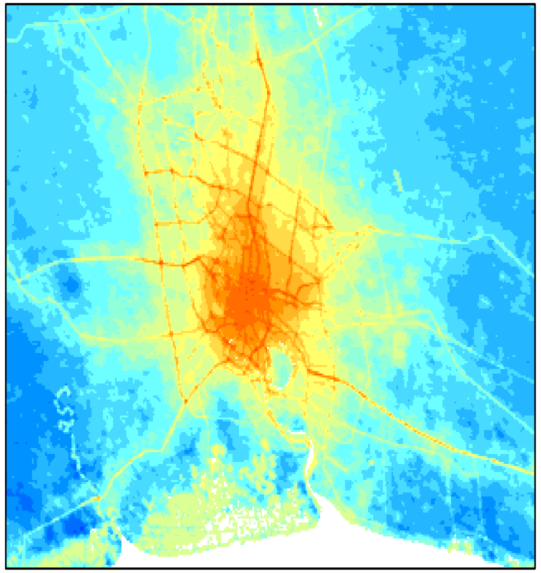
$$Burden = Inc_{c,a} \times \sum_{i,j} Pop_{i,j,a} \times (1 - e^{-\beta X_{i,j}})$$



250m x 250m population (GHS-POP) available for 1975, 1990, 2000, 2015



2010-2012 ground-level NO_2 at 100m x 100m (Larkin et al., 2017)



Regridded and reprojected to match the GHS-POP raster

Methods: Effect size

Literature review: multi-national meta-analyses of traffic-related air pollution (TRAP) exposure and pediatric asthma incidence

Meta-analysis	Relative risk per 10 ppb NO_2	Relative risk per 10 μg m^{-3} $PM_{2.5}$	# of epi studies and locations
Khreis et al. (2017)	**1.26 (1.10-1.37)**	**1.34 (1.11-1.63)**	**41 studies in North America, Latin America, Europe, East Asia**
Bowatte et al. (2015)	1.18 (0.93-1.48)	1.93 (1.00-3.71)	10 studies in Europe, Canada
Anderson et al. (2013)	1.24 (1.06-1.45)	*Not given*	14 studies in Europe, North America, Japan
Gasana et al. (2012)	1.28 (1.12-1.50)	1.40 (0.77-2.56)	9 studies in Europe, North America, Latin America, East Asia

Khreis et al. reviewed the largest number of studies that include all but one of those considered in the other meta-analyses. No apparent regional heterogeneity in reported relative risks

"The overall evidence indicates that there is **likely a causal** relationship between long-term NO_2 exposure and pediatric asthma development." -- EPA, 2016; Health Canada, 2016.

Methods: Estimating asthma burden attributable to NO_2

$$Burden = Inc_{c,a} \times \sum_{i,j} Pop_{i,j,a} \times \left(1 - e^{-\beta X_{i,j}}\right)$$

2015 national incidence rates from IHME (for 1-4, 5-9, 10-14, 15-18 year age groups)

2015 gridded population at 250 m x 250 m from the European Commission Joint Research Center GHS-POP + gridded age-group fractions from 2010 NASA CIESIN GPWv4

Relative risk from Khreis et al. (2017)

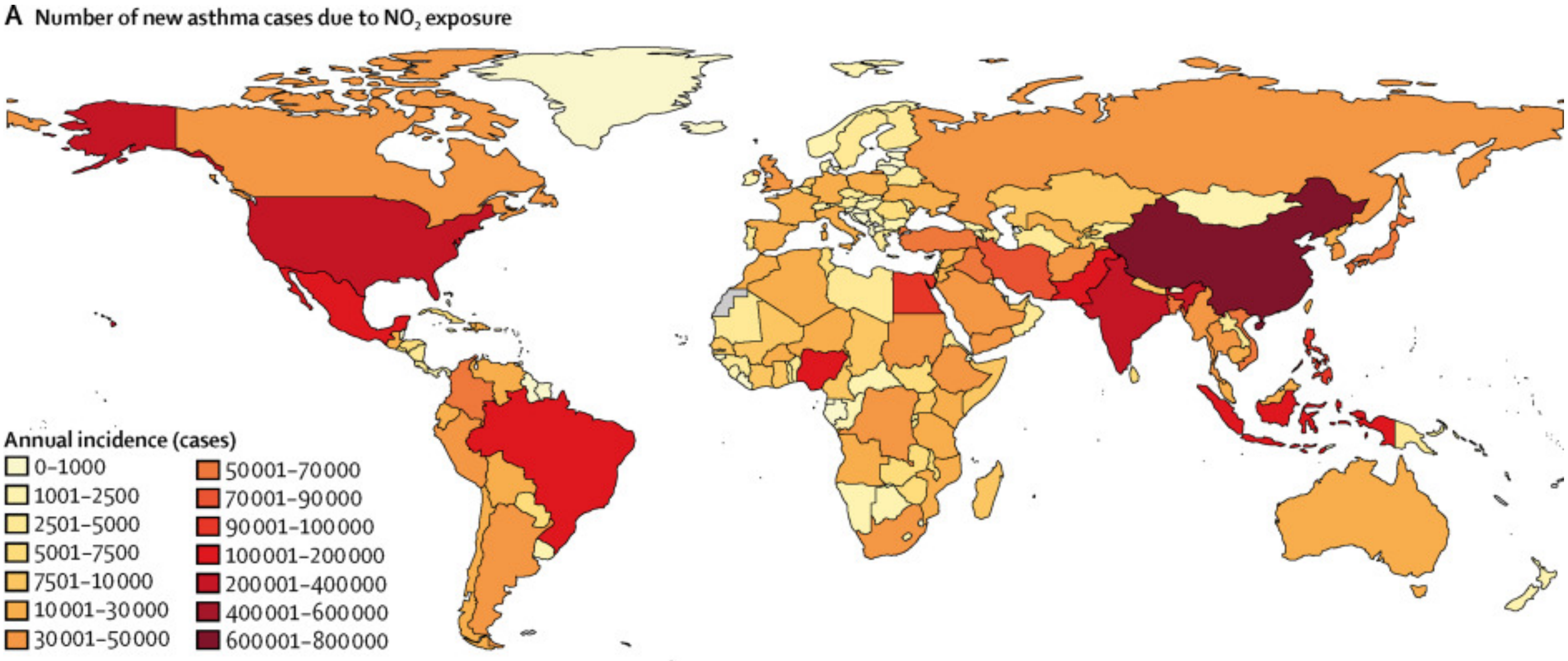
2010-2012 gridded surface NO_2 (100 m x 100 m) from Land Use Regression modeling by Larkin et al. (2017) → aggregated to 250 m x 250 m

Applied in each 250 m x 250 m grid cell globally, and aggregated over 21 regions, 194 countries, and 125 major cities*

Counterfactual concentrations of 0, **2**, and 5 ppb.

*GHS-SMOD city extents (contiguous cells with ≥50,000 people & population density of ≥1,500 inhabitants/km^2 or built-up density >50%.)

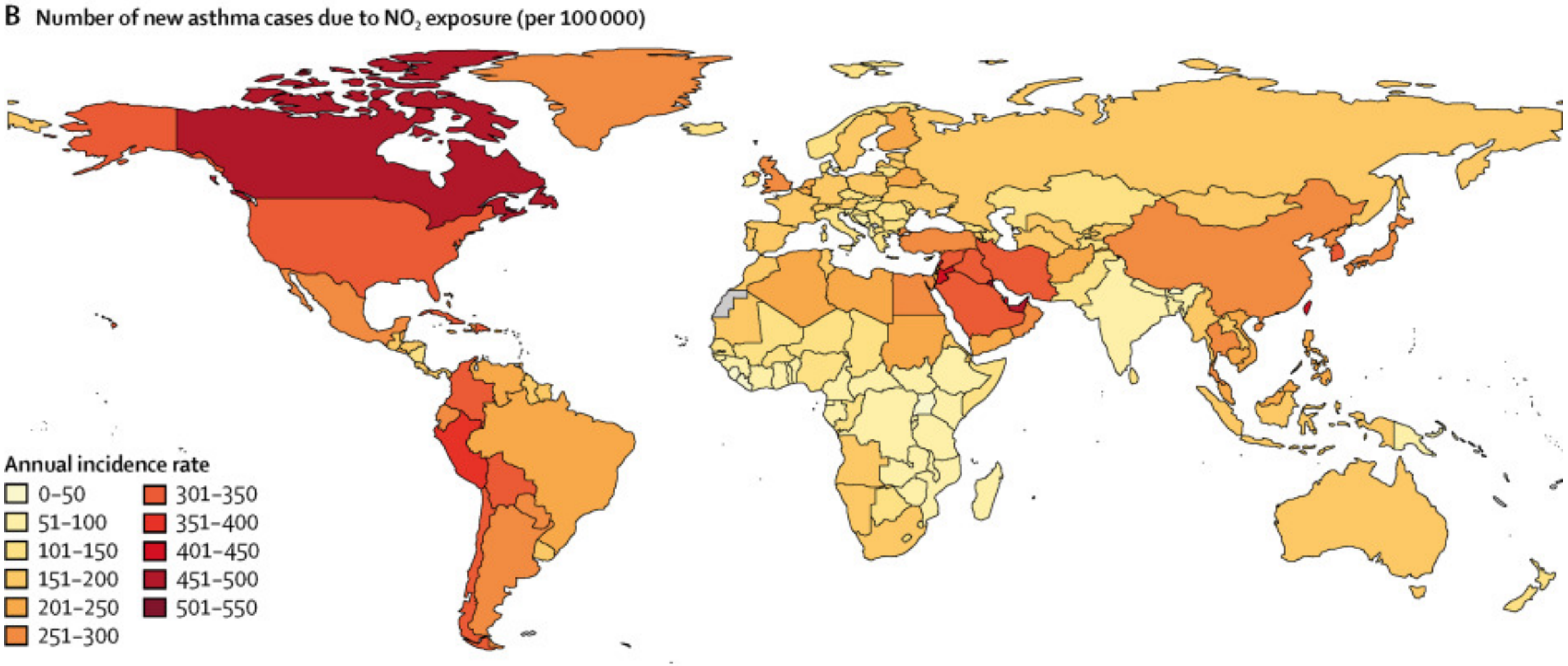
4 million (95% UI 1.8-5.2) children developed asthma due to NO_2 pollution in 2015



- Top 5 national burdens (cases/year): China (760,000), India (350,000), USA (240,000), Indonesia (160,000), and Brazil (140,000).

Achakulwisut et al., 2019, *Lancet Planetary Health*

13% (6-16) of global pediatric asthma burden

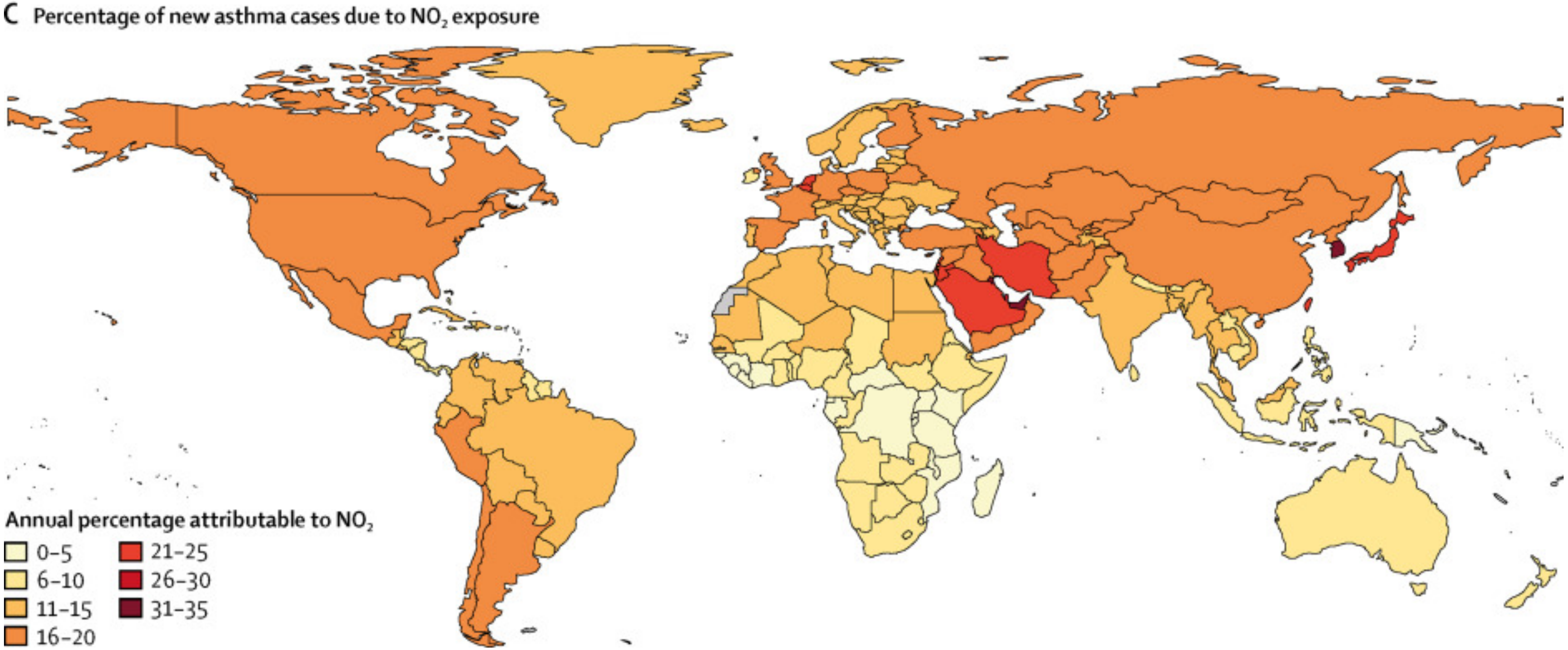


Top 5 national rates (case/year per 100,000): Kuwait (550), United Arab Emirates (460), Canada (450), Taiwan (420), and Qatar (410).

~97% of children lived, and ~92% of NO_2-attributable pediatric asthma incidence occurred, in areas below the current WHO guideline (21 ppb annual average NO_2)

Achakulwisut et al., 2019, *Lancet Planetary Health*

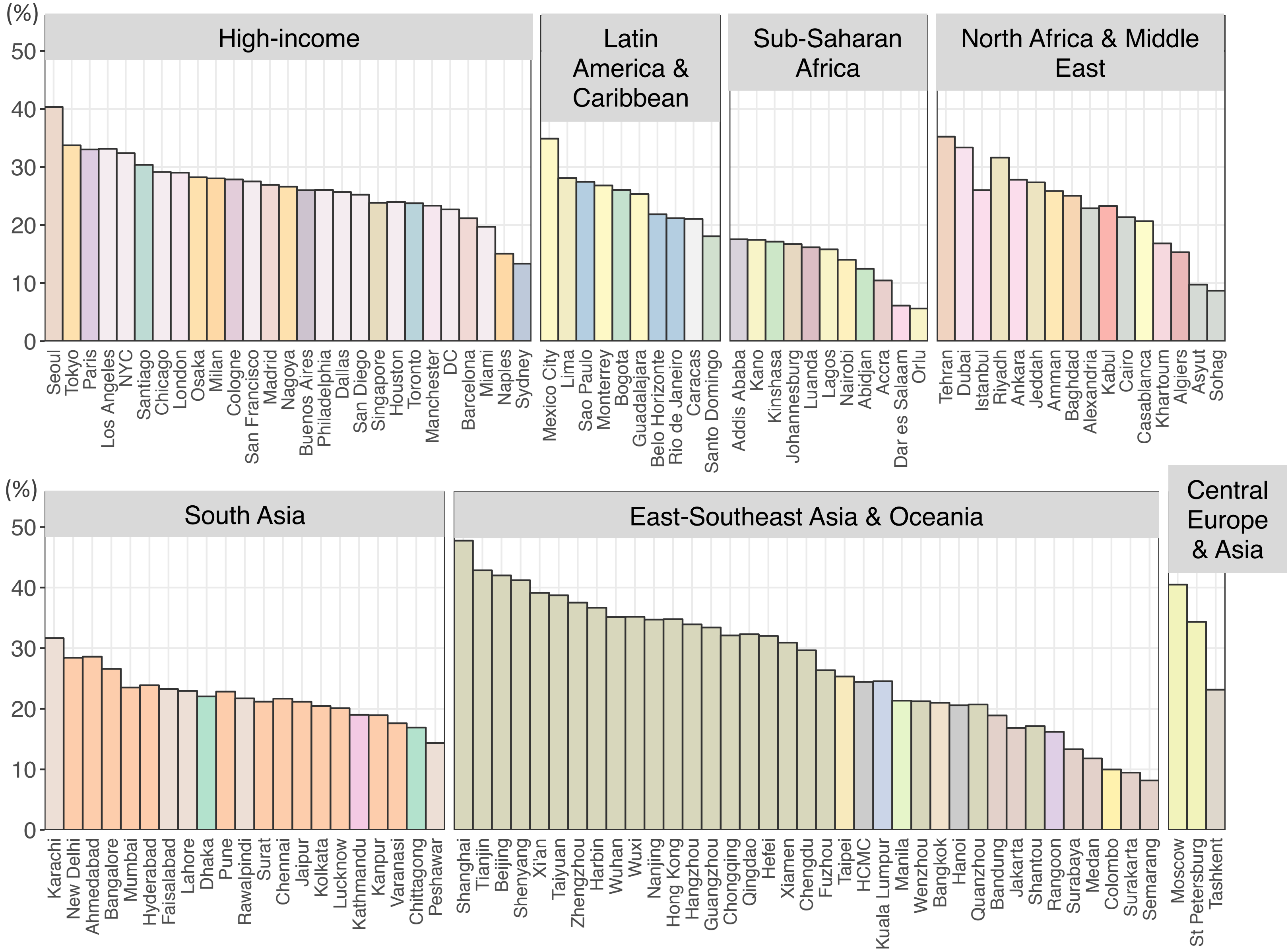
NO_2-attributable pediatric asthma incidence impacts are largest in middle and high-income countries



- Globally, 64% of NO_2-attributable pediatric asthma incidence occurred in urban centers
- ….and exceeded 50% in 106 countries, reflecting the distribution of children living in urban areas and the high NO_2 concentrations in urban centers.

Achakulwisut et al., 2019, *Lancet Planetary Health*

In both developed and developing cities, NO_2 pollution is an important risk factor for pediatric asthma incidence



In 125 major cities, the percentages of new pediatric asthma cases attributable to NO_2:

- Ranged from 6% (Orlu, Nigeria) to 48% (Shanghai, China).
- **Exceeded 20% in 92 cities, located in both developed and developing countries**.
- Highest in 8 cities in China, in Moscow, and Seoul.

Achakulwisut et al., 2019, *Lancet Planetary Health*

Concluding thoughts

- Traffic-related air pollution is responsible for a sizeable proportion (13% globally, > 20% in many cities) of pediatric asthma. 730,000 DALYs in 2015

- While only 3% of children were exposed above the WHO guideline, 4.0 (1.8-5.2, 95% UI) million new pediatric asthma cases attributable to NO_2 pollution in 2015

- Reductions in traffic emissions and/or TRAP exposure could prevent a large portion of pediatric asthma in urban areas.

Thank you

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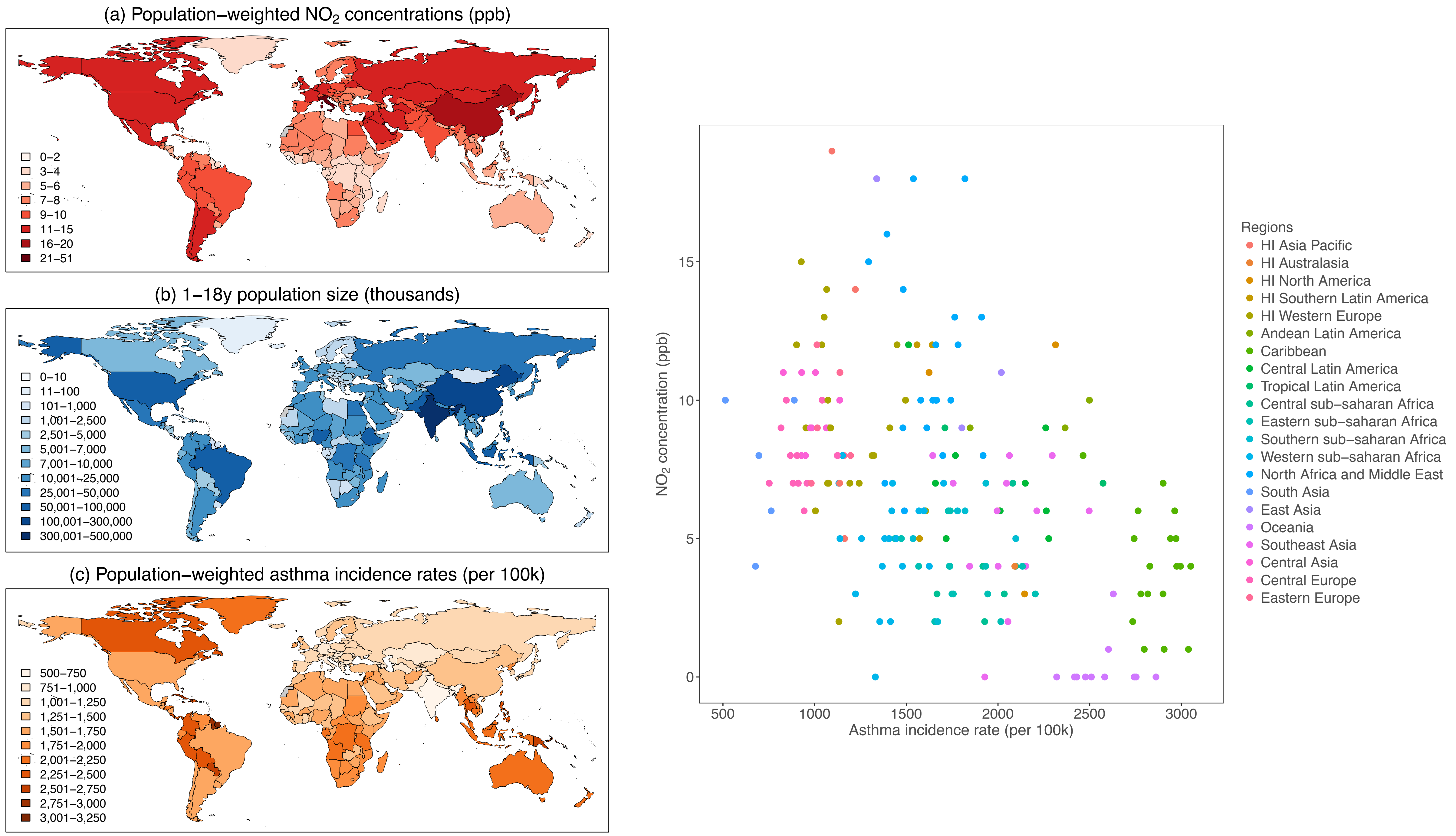
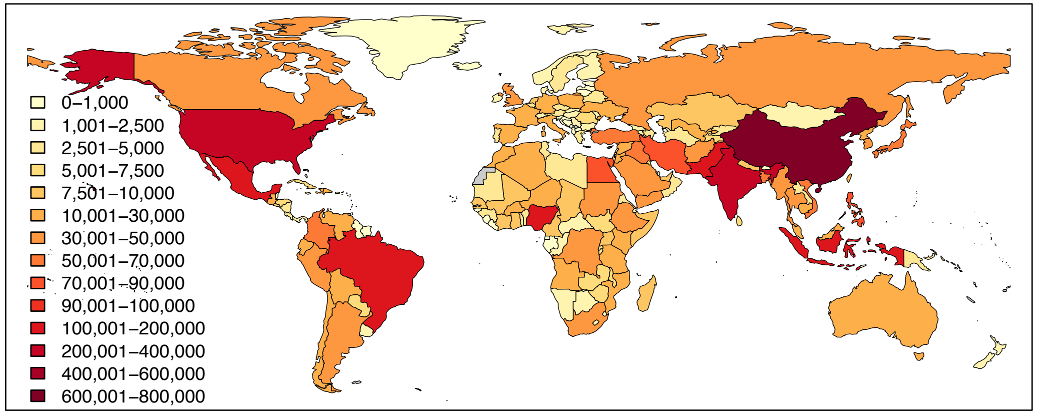
Extra figures


(a) Population−weighted NO2 concentrations (ppb)
0−2
3−4
5−6
7−8
9−10
11−15
16−20
21−51
(b) 1−18y population size (thousands)
0−10
11−100
101−1,000
1,001−2,500
2,501−5,000
5,001−7,000
7,001−10,000
10,001−25,000
25,001−50,000
50,001−100,000
100,001−300,000
300,001−500,000
(c) Population−weighted asthma incidence rates (per 100k)
500−750
751−1,000
1,001−1,250
1,251−1,500
1,501−1,750
1,751−2,000
2,001−2,250
2,251−2,500
2,501−2,750
2,751−3,000
3,001−3,250
NO2 concentration (ppb)
0
5
10
15
500
1000
1500
2000
2500
3000
Asthma incidence rate (per 100k)
Regions
HI Asia Pacific
HI Australasia
HI North America
HI Southern Latin America
HI Western Europe
Andean Latin America
Caribbean
Central Latin America
Tropical Latin America
Central sub−saharan Africa
Eastern sub−saharan Africa
Southern sub−saharan Africa
Western sub−saharan Africa
North Africa and Middle East
South Asia
East Asia
Oceania
Southeast Asia
Central Asia
Central Europe
Eastern Europe

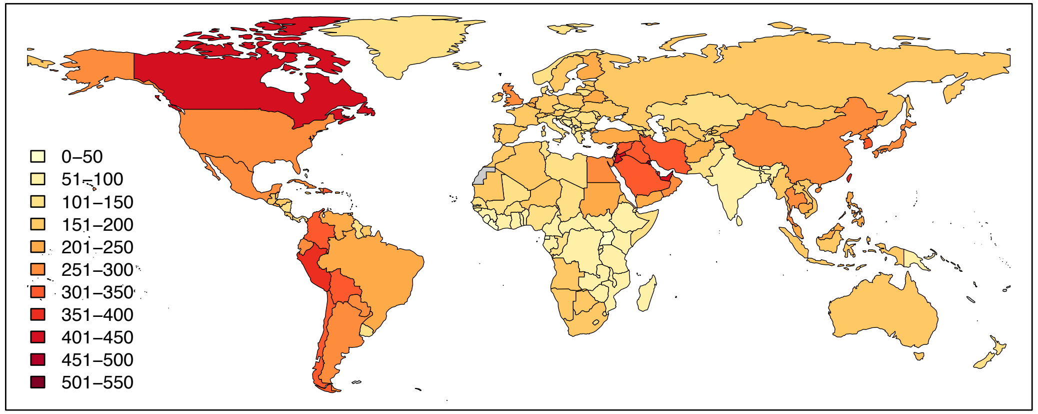
Results: National estimates

(a) Number of new asthma cases due to NO_2 exposure



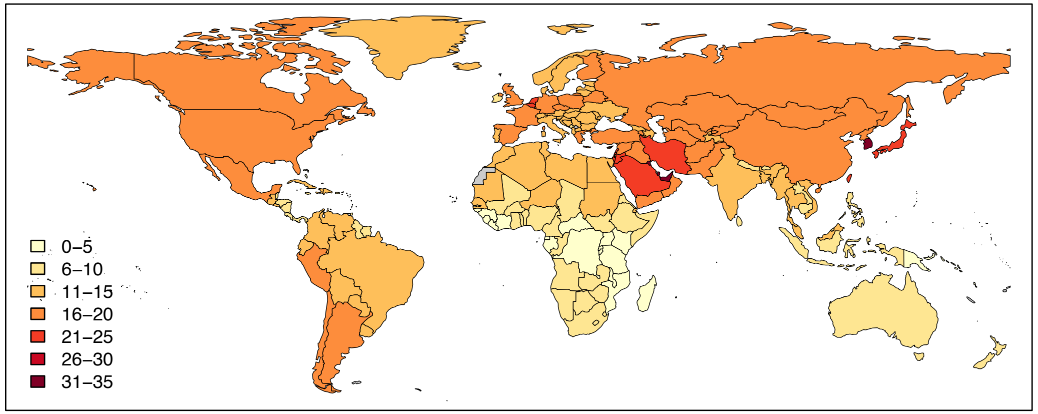
Top 5 national burdens: China (760,000 cases/year), India (340,000), USA (230,000), Indonesia (150,000), and Brazil (140,000)

(b) Number of new asthma cases due to NO_2 exposure (per 100k)



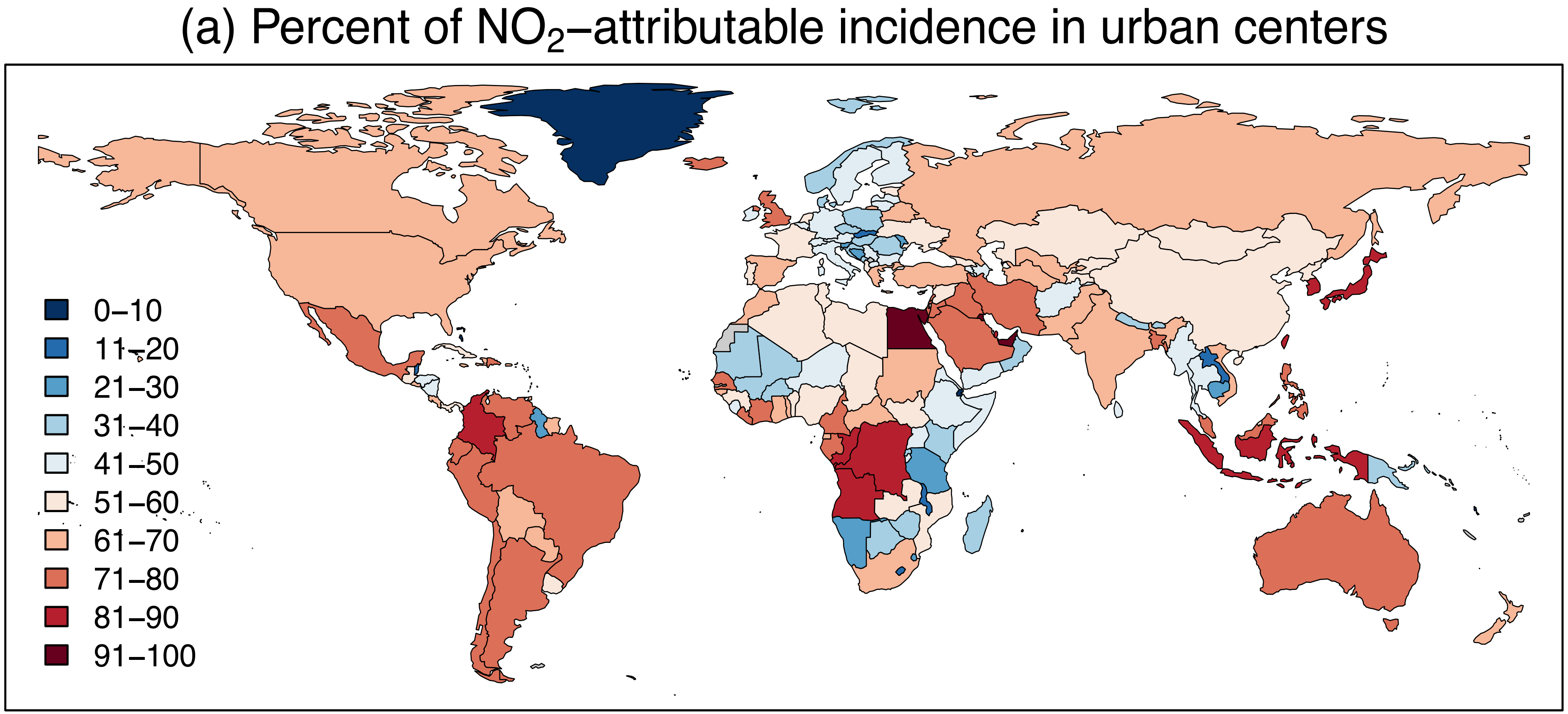
Top 5 national burdens per 100k children: Kuwait (540 cases/year), followed by Canada, United Arab Emirates, Singapore, and Jordan (410-450) due to relatively high asthma incidence rates and/or population-weighted urban NO_2 concentrations.

(c) Percent of new asthma cases due to NO_2 exposure



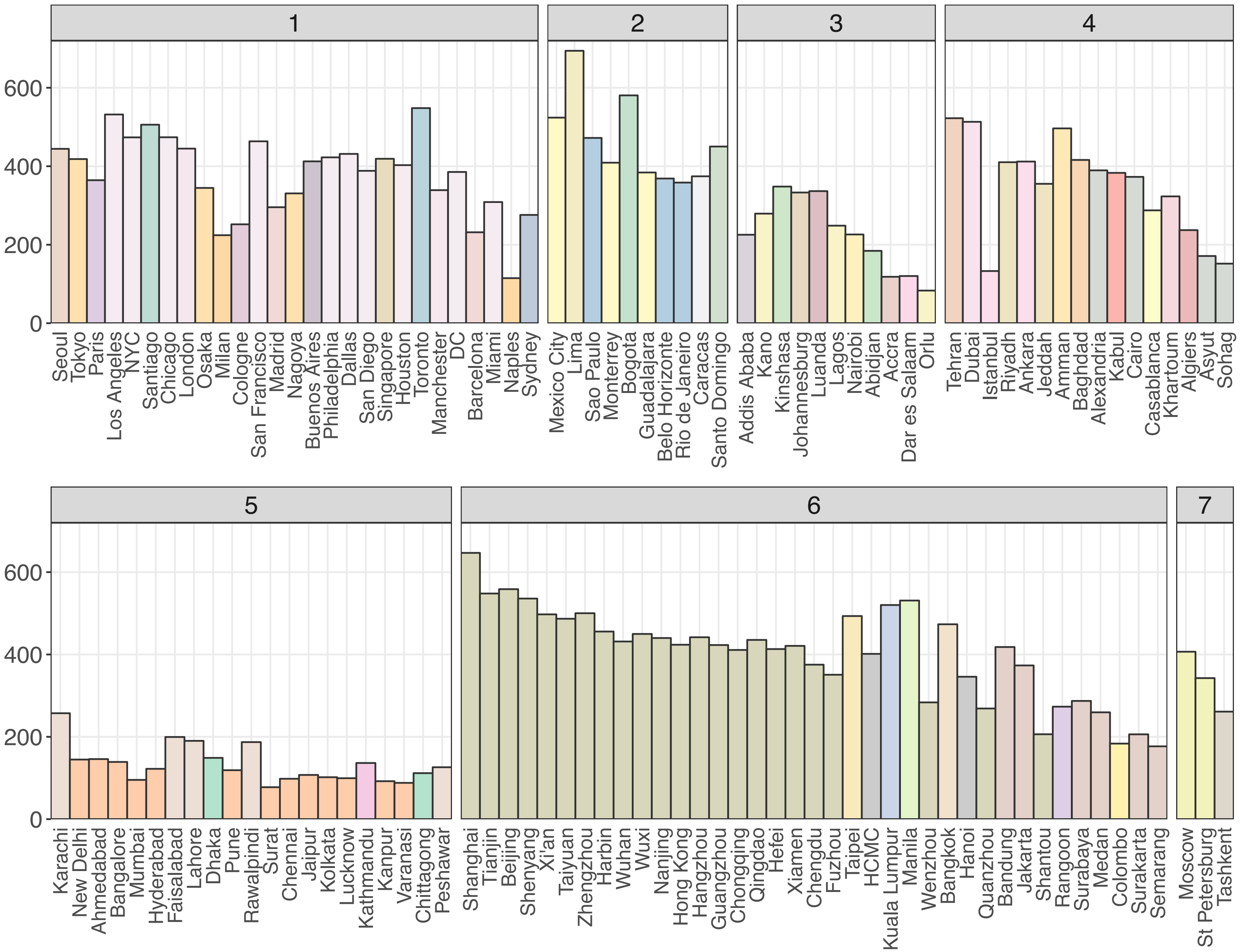
The percentage of NO_2-attributable pediatric asthma incidence exceeds 15% for 51 countries. The highest contributions of around 30% are estimated for South Korea, Qatar, United Arab Emirates, and Kuwait.

Globally, 64% of NO_2-attributable pediatric asthma incidence occurred in urban centers



- This percentage increases to 90% if surrounding suburban areas are also considered.
- On a national level, this percentage exceeded 50% in 106 countries, reflecting both the distribution of children living in urban areas and the prevalence of high NO_2 concentrations found in urban centers.

Achakulwisut et al., 2019, *Lancet Planetary Health (in press)*



1
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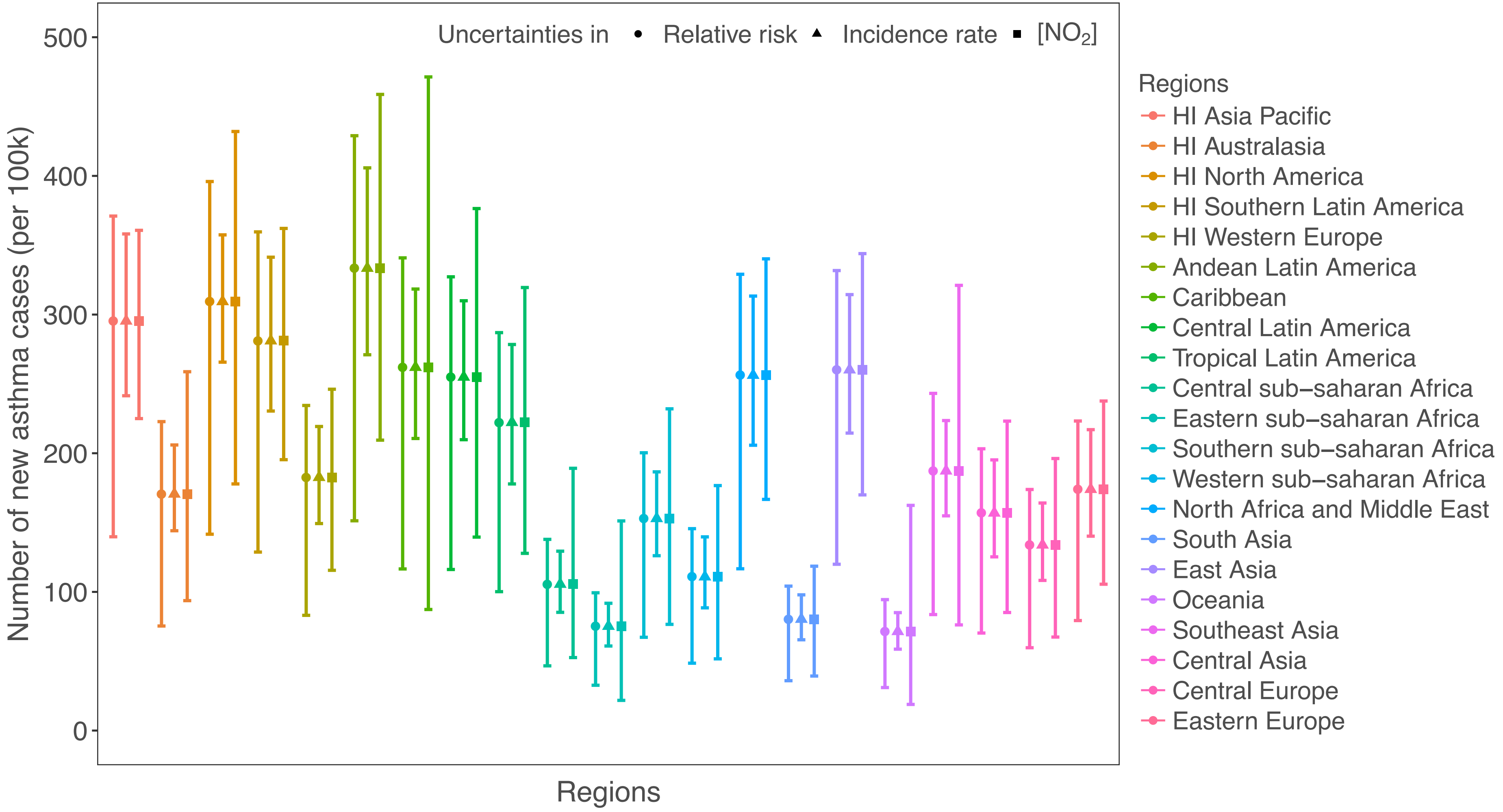
Tokyo
Paris
Los Angeles
NYC
Santiago
Chicago
London
Osaka
Milan
Cologne
San Francisco
Madrid
Nagoya
Buenos Aires
Philadelphia
Dallas
San Diego
Singapore
Houston
Toronto
Manchester
DC
Barcelona
Miami
Naples
Sydney
Mexico City
Lima
Sao Paulo
Monterrey
Bogota
Guadalajara
Belo Horizonte
Rio de Janeiro
Caracas
Santo Domingo
Addis Ababa
Kano
Kinshasa
Johannesburg
Luanda
Lagos
Nairobi
Abidjan
Accra
Dar es Salaam
Orlu
Tehran
Dubai
Istanbul
Riyadh
Ankara
Jeddah
Amman
Baghdad
Alexandria
Kabul
Cairo
Casablanca
Khartoum
Algiers
Asyut
Sohag
Karachi
New Delhi
Ahmedabad
Bangalore
Mumbai
Hyderabad
Faisalabad
Lahore
Dhaka
Pune
Rawalpindi
Surat
Chennai
Jaipur
Kolkata
Lucknow
Kathmandu
Kanpur
Varanasi
Chittagong
Peshawar
Shanghai
Tianjin
Beijing
Shenyang
Xi'an
Taiyuan
Zhengzhou
Harbin
Wuhan
Wuxi
Nanjing
Hong Kong
Hangzhou
Guangzhou
Chongqing
Qingdao
Hefei
Xiamen
Chengdu
Fuzhou
Taipei
HCMC
Kuala Lumpur
Manila
Wenzhou
Bangkok
Hanoi
Quanzhou
Bandung
Jakarta
Shantou
Rangoon
Surabaya
Medan
Colombo
Surakarta
Semarang
Moscow
St Petersburg
Tashkent

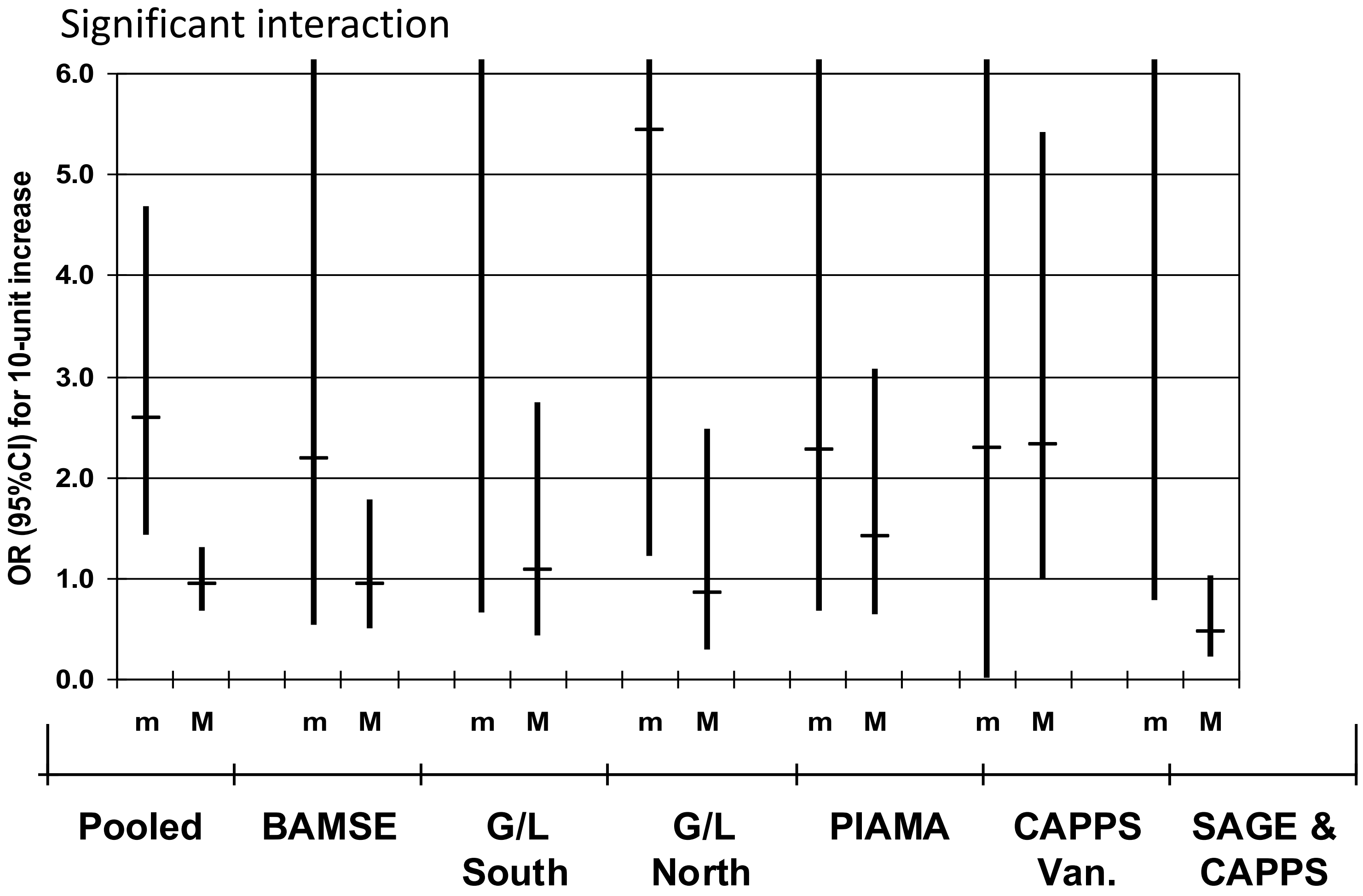
Influence of uncertainties in input variables to regional estimates



Asthma incidence rates have the least influence, given that their uncertainties are relatively small. Uncertainty resulting from those in the RR and NO_2 concentrations are generally comparable.

Traffic pollution, Asthma Genetics (TAG)

NO_2 - Asthma, by GSTP1 rs1138272



m - TT/TC; M - CC

Adjusted for study, city, intervention, gender, maternal age at birth, maternal smoking during pregnancy, environmental tobacco smoke in the home, birth weight and parental atopy

GSTP1 and TNF Gene variants and associations between air pollution and incident childhood asthma: the traffic, asthma and genetics (TAG) study.
MacIntyre EA, Brauer M, Melén E, Bauer CP, Bauer M, Berdel D, Bergström A, Brunekreef B, Chan-Yeung M, Klümper C, Fuertes E, Gehring U, Gref A, Heinrich J, Herbarth O, Kerkhof M, Koppelman GH, Kozyrskyj AL, Pershagen G, Postma DS, Thiering E, Tiesler CM, Carlsten C; TAG Study Group.
Environ Health Perspect. 2014 Apr;122(4):418-24. doi: 10.1289/ehp.1307459.