Transboundary health impacts of transported global air pollution and international trade

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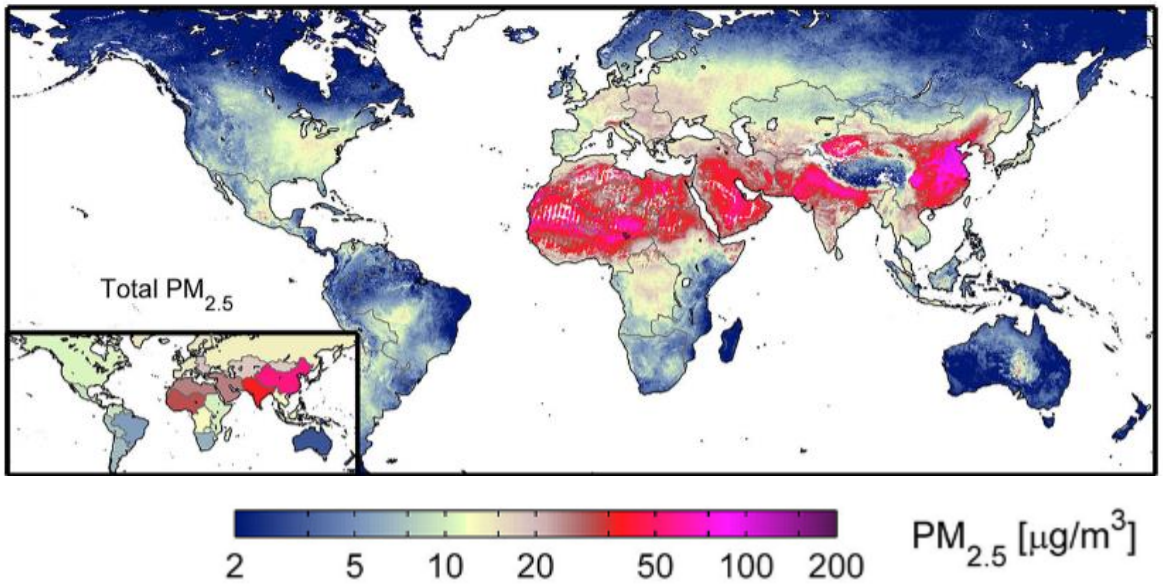
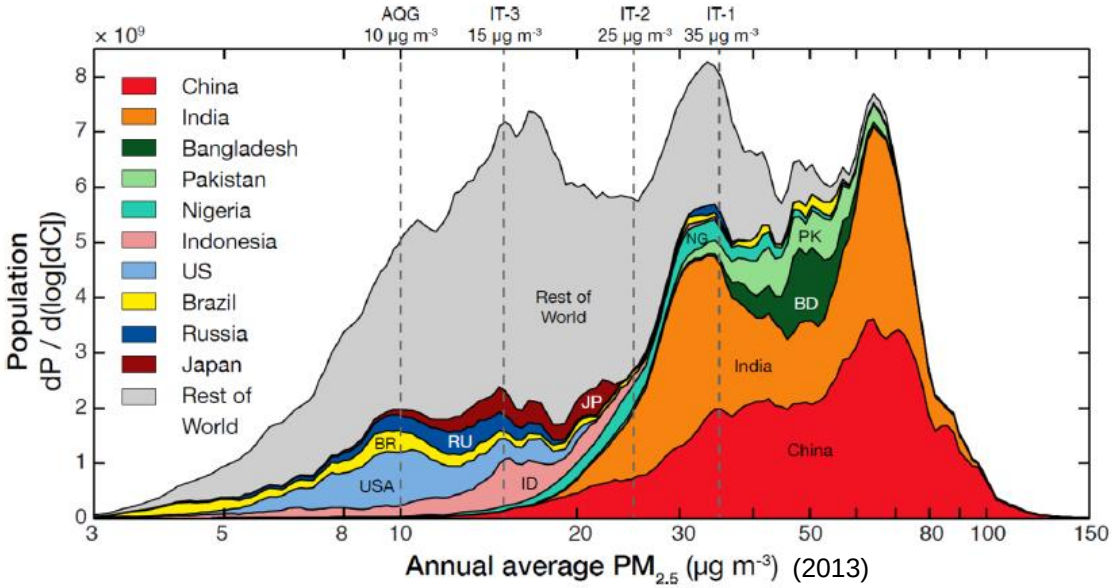
The developing countries are suffering the most serious air pollution around the world

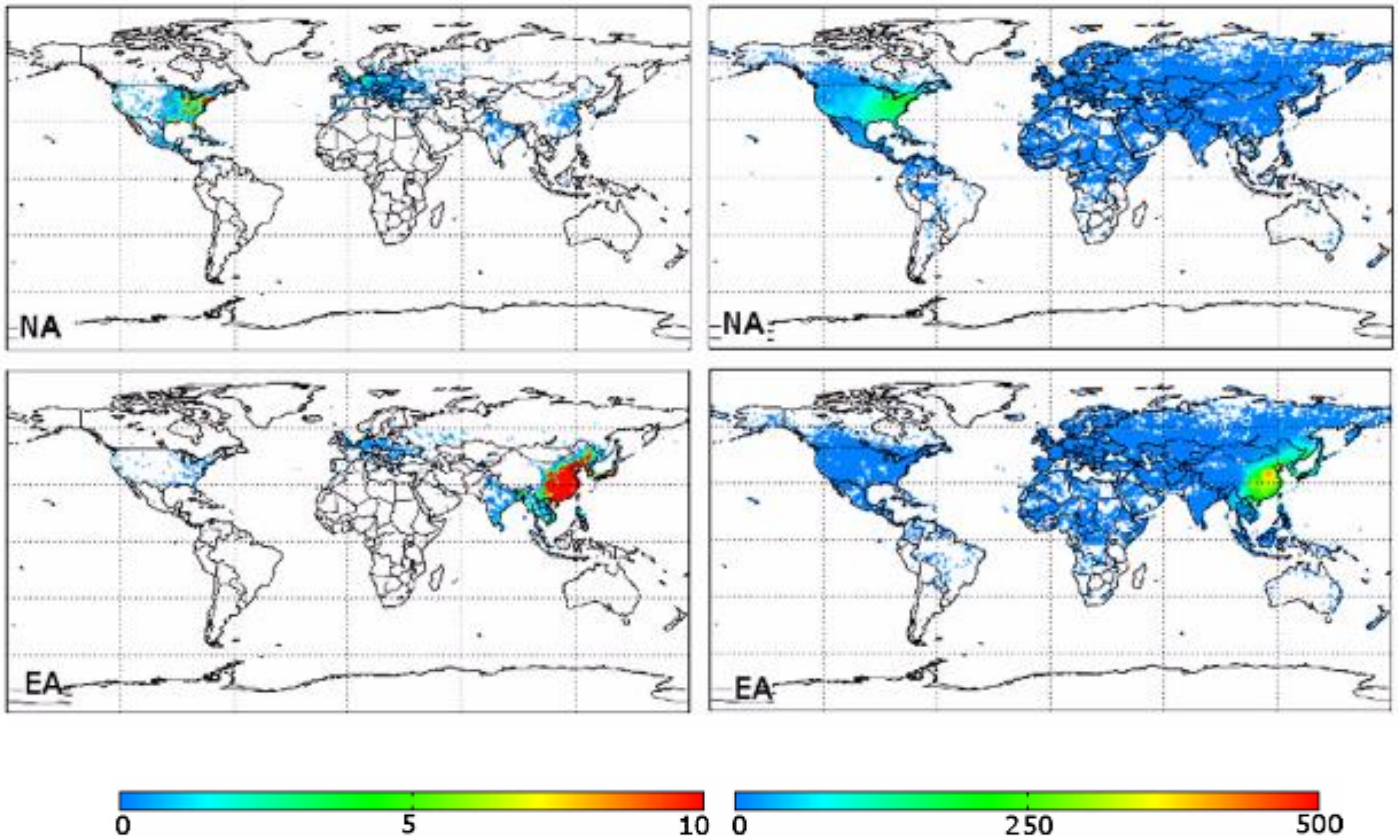


Aaron van Donlelaar, EHP, 2015



Brauer et al., EST, 2015

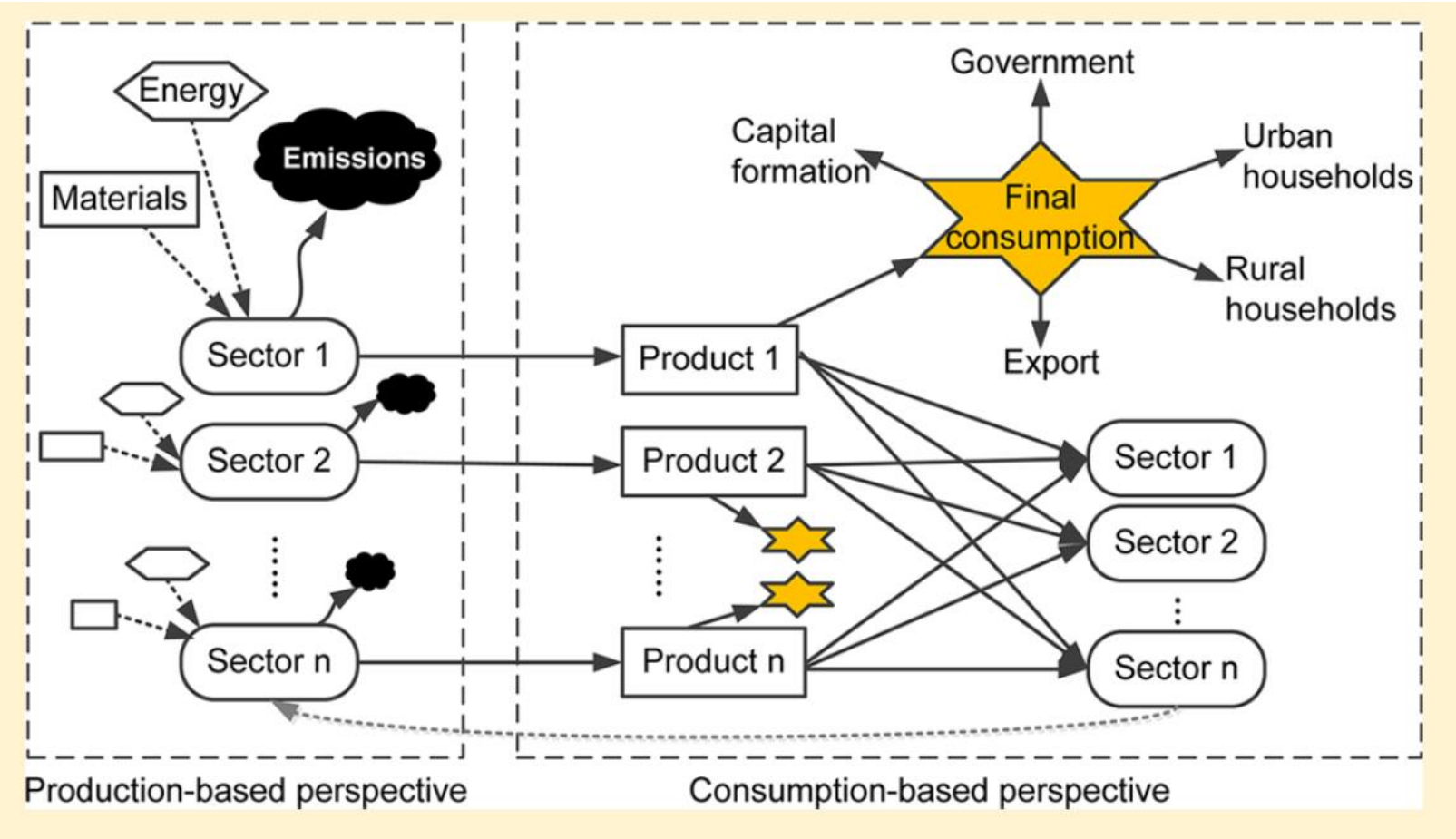
Air pollution can travel long-distance and impact air quality and health in other regions



Annual premature deaths per 1000 km^2 (left) and per million people (right) due to 20% emission reduction in the region

Anenberg et al., AQAH, 2014

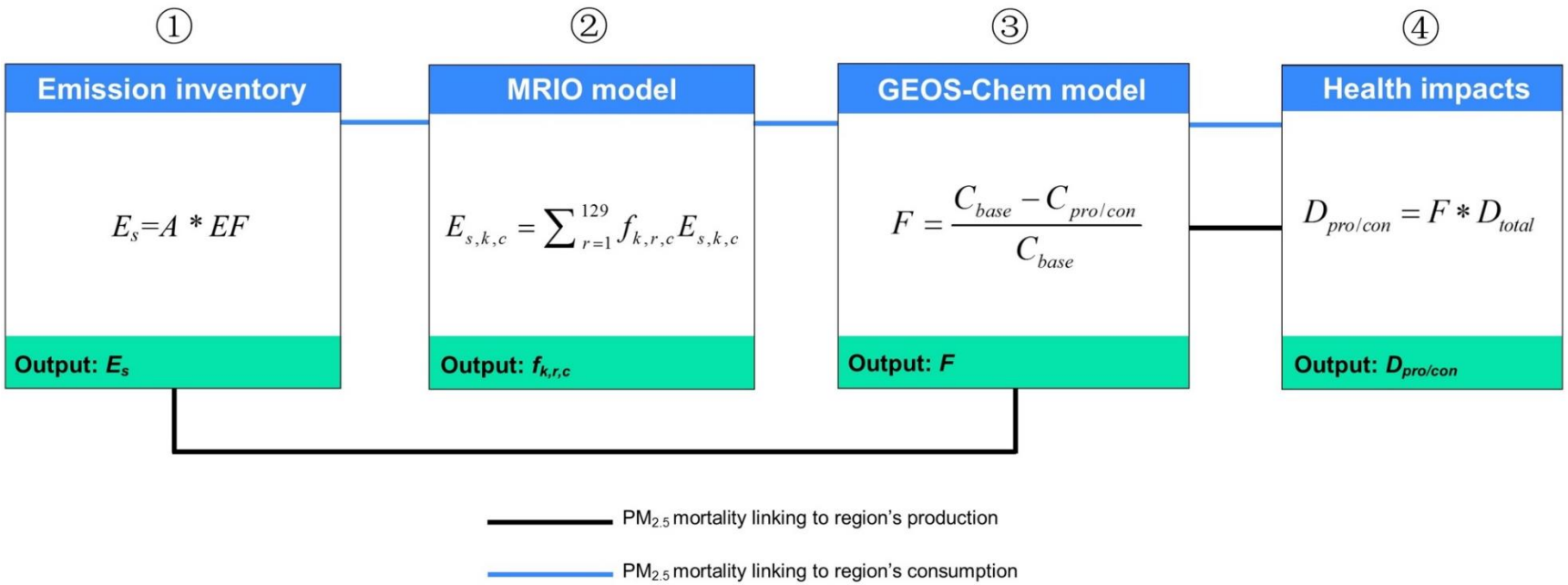
Pollutions are driven by final consumptions



Supply Chains

Huo et al., EST, 2014

An integrated framework developed to access $PM_{2.5}$ mortality from production and consumption for each region (in 2007)



E_s: anthropogenic emissions of species *s* (NO_x, SO_2, CO, BC, OC and NH_3) from 228 countries and regions.

A: activity rates, such as fuel consumption or material production.

EF: emission factor of per unit fuel consumed or production produced.

$E_{s,k,c}$: total production-based emissions from sector *k* in region *c*.

$f_{k,r,c}$: the production (or output) fraction of sector *k* in region *c* induced by consumption activities in region *r*.

C_{base}: the modeled $PM_{2.5}$ concentration from the base case.

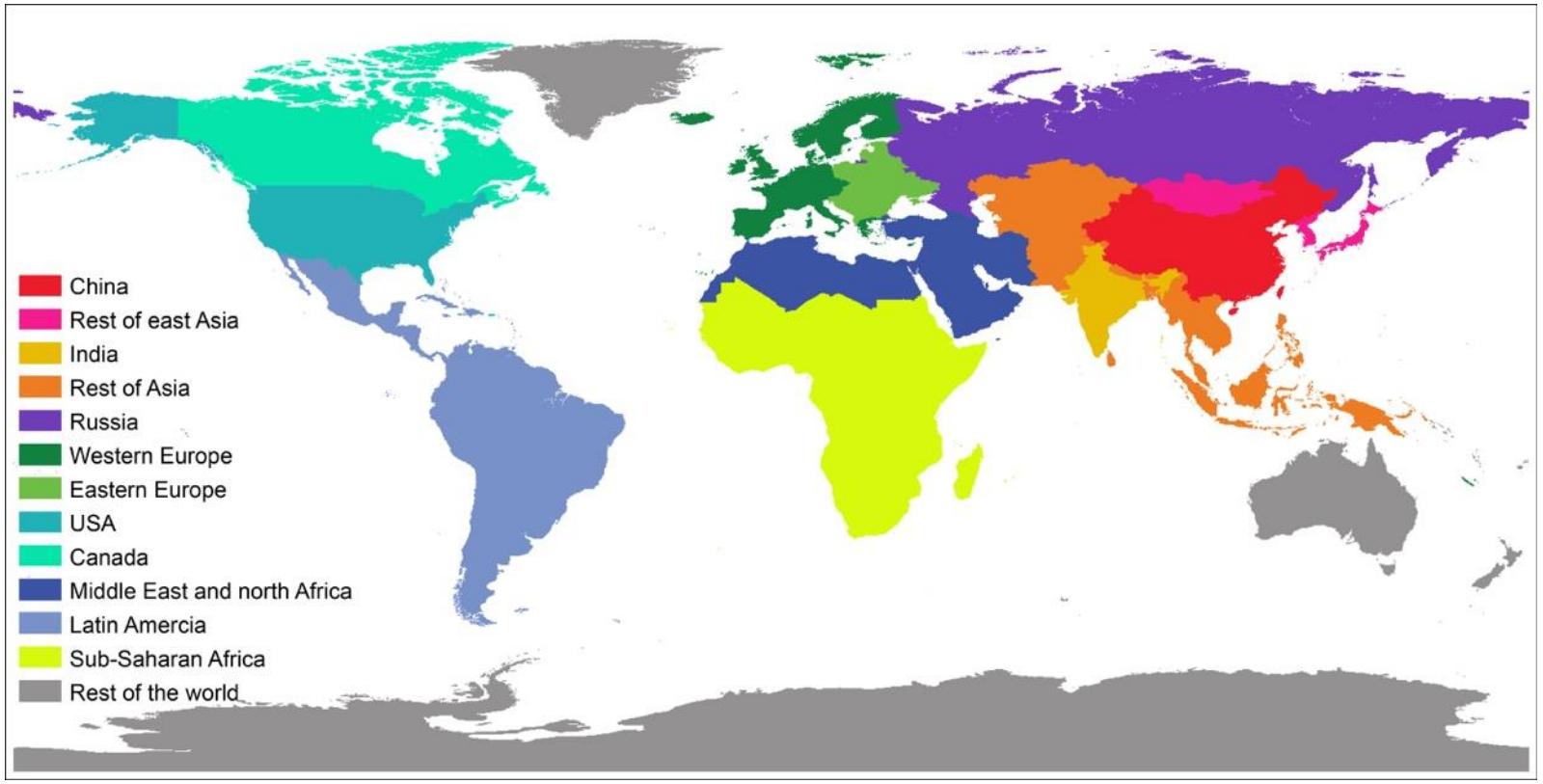
$C_{pro/con}$: the modeled $PM_{2.5}$ concentration from production and consumption scenario.

F: the GEOS-Chem modeled fractional contributions of $PM_{2.5}$ due to production or consumption in a given region.

D_{total}: the grid-based global $PM_{2.5}$-related premature deaths calculated using the IER model and high-resolution $PM_{2.5}$ concentrations from the GBD study.

$D_{pro/con}$: the grid-based premature deaths from a given region's production or consumption.

Definition of the 13 world regions used in this work



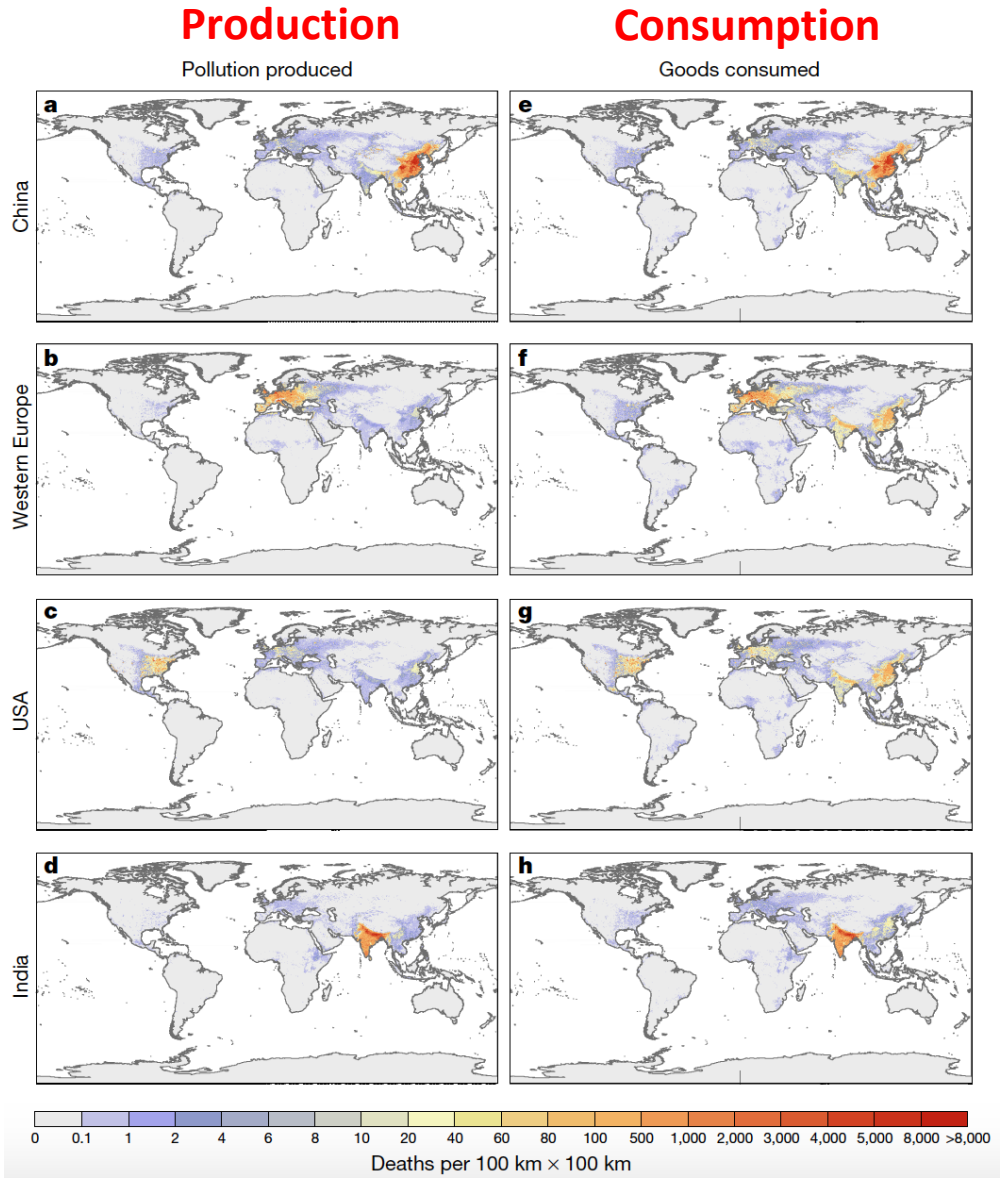
Worldwide premature mortality in 2007 due to production- and consumption-related $PM_{2.5}$ air pollution

China

Western Europe

USA

India



Proportion of $PM_{2.5}$-related deaths in a given region that are linked to emissions produced in that and other regions

12% (411,100) deaths related to transboundary transport

2.2% (1,700) deaths in USA due to emissions in China

9.8% (17,000) deaths in Western Europe due to emissions in Eastern Europe

Deaths occurred

Regions where emission produced

	China	Rest of east Asia	India	Rest of Asia	Russia	Western Europe	Eastern Europe	Middle East and north Africa	USA	Canada	Latin America	Sub-Saharan Africa	Rest of the world	Deaths caused
	994,133	76,231	463,391	276,260	101,444	173,692	196,412	76,875	77,760	8,119	50,218	20,229	721	
China	96.5	40.5	0.9	7.7	3.2	0.8	0.7	0.9	2.2	2.0	0.5	0.2	0.1	1,023,689
Rest of east Asia	1.0	55.5	0.0	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.0	0.0	0.0	53,224
India	0.2	0.1	85.5	26.3	0.1	0.1	0.1	0.3	0.1	0.1	0.1	1.2	0.0	471,484
Rest of Asia	0.9	0.6	11.6	60.5	4.3	0.1	0.3	1.4	0.2	0.3	0.1	0.4	0.1	236,467
Russia	0.5	1.4	0.0	0.6	60.2	0.7	4.8	1.9	0.3	0.6	0.0	0.0	0.0	80,949
Western Europe	0.2	0.4	0.0	0.1	6.5	85.4	24.1	8.3	0.2	0.4	0.0	0.4	0.0	211,639
Eastern Europe	0.1	0.4	0.1	0.3	20.7	9.8	66.1	8.3	0.2	0.3	0.0	0.4	0.0	177,205
Middle East and north Africa	0.3	0.6	1.7	4.0	3.9	1.4	2.6	77.7	0.4	0.5	0.1	4.7	0.0	95,433
USA	0.3	0.4	0.1	0.2	0.8	1.3	1.0	0.8	88.9	47.2	1.9	0.1	0.0	83,808
Canada	0.0	0.1	0.0	0.0	0.1	0.2	0.2	0.1	6.2	48.2	0.1	0.0	0.0	10,090
Latin America	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	1.0	0.1	96.6	0.1	0.9	50,627
Sub-Saharan Africa	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.3	92.5	1.4	19,899
Rest of the world	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.5	971

Regions where deaths occurred

Proportion of $PM_{2.5}$-related deaths in a given region that are linked to goods and services consumed in that and other regions

22% (762,400) deaths related to international trade

5.4% (54,400) deaths in China due to consumption in USA

29.7% (57,600) deaths in Western Europe due to emissions in Eastern Europe

Regions where goods consumed

Deaths occurred

	China	Rest of east Asia	India	Rest of Asia	Russia	Western Europe	Eastern Europe	Middle East and north Africa	USA	Canada	Latin America	Sub-Saharan Africa	Rest of the world	Deaths caused
	1,007,500	72,309	470,481	268,728	97,378	171,586	194,074	77,037	81,202	7,790	48,560	19,870	790	
China	76.4	34.3	1.5	7.2	4.0	1.4	1.2	1.8	3.3	3.3	2.3	1.1	5.6	835,110
Rest of east Asia	3.9	47.4	0.6	1.4	1.5	0.9	0.7	1.2	2.4	2.7	1.3	0.8	6.0	88,657
India	0.6	0.5	77.4	25.1	0.5	0.4	0.4	1.1	0.4	0.6	0.5	1.5	2.6	441,900
Rest of Asia	2.1	1.8	10.7	51.9	4.2	0.8	1.0	1.9	1.0	1.4	0.7	0.8	3.6	223,108
Russia	1.0	1.6	0.2	0.8	46.3	1.3	5.3	2.3	0.4	0.6	0.4	0.2	0.4	74,006
Western Europe	5.4	4.9	3.0	3.9	14.4	77.0	29.7	14.9	4.1	5.4	5.5	3.7	6.0	304,940
Eastern Europe	0.7	0.8	0.3	0.7	17.7	9.3	52.8	7.0	0.5	0.6	0.4	0.5	0.4	152,349
Middle East and north Africa	1.8	1.8	2.9	4.5	6.8	3.0	4.6	63.9	1.8	2.1	1.4	4.1	2.7	118,053
USA	5.4	4.6	2.1	2.8	3.1	3.7	2.7	3.7	77.1	52.3	11.0	1.7	4.1	164,931
Canada	0.5	0.4	0.2	0.3	0.3	0.4	0.3	0.3	4.6	27.1	0.7	0.2	0.5	15,144
Latin America	1.1	1.0	0.4	0.5	0.8	0.9	0.7	0.8	3.7	2.9	74.9	0.5	1.4	58,913
Sub-Saharan Africa	0.6	0.5	0.6	0.6	0.4	0.6	0.4	0.7	0.4	0.5	0.7	84.8	1.4	30,752
Rest of the world	0.5	0.5	0.2	0.4	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.1	65.2	9,382

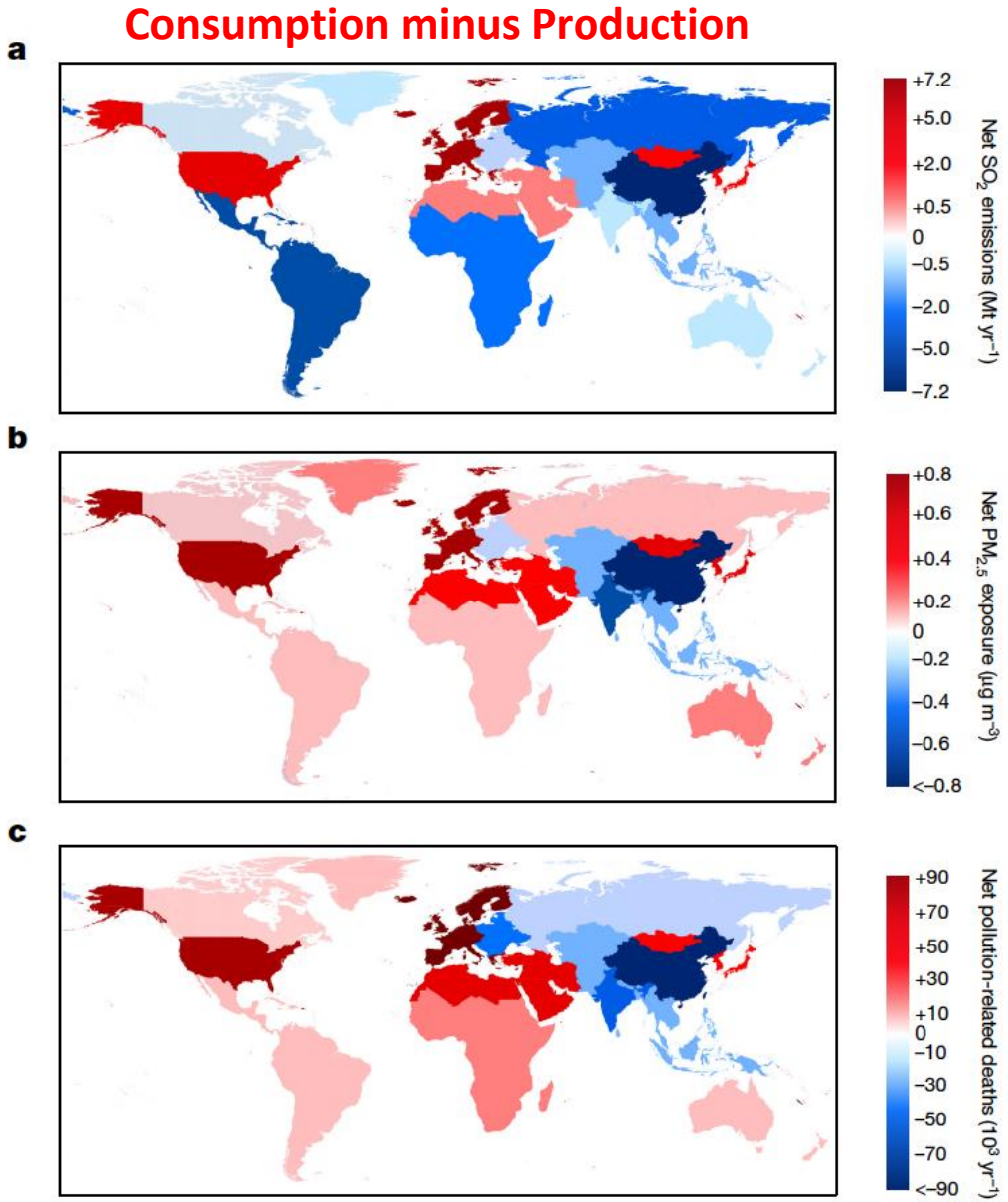
Regions where deaths occurred

Emissions, changes in air quality and premature mortality embodied in trade

Net emissions

Worldwide population-weighted mean $PM_{2.5}$ concentration

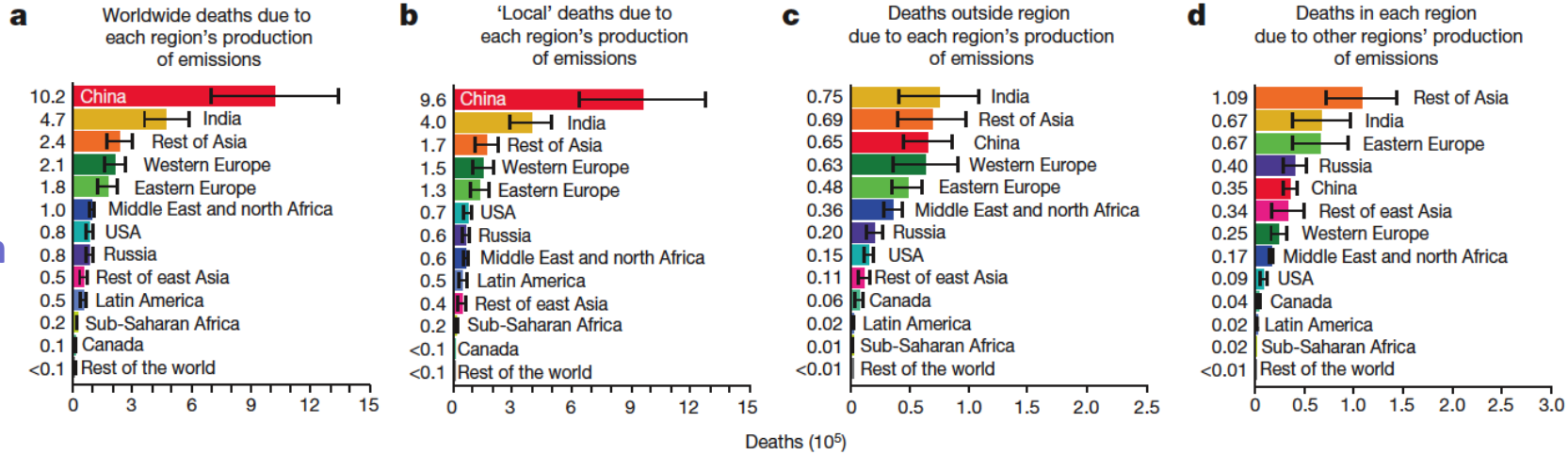
Worldwide premature mortality due to $PM_{2.5}$ exposure



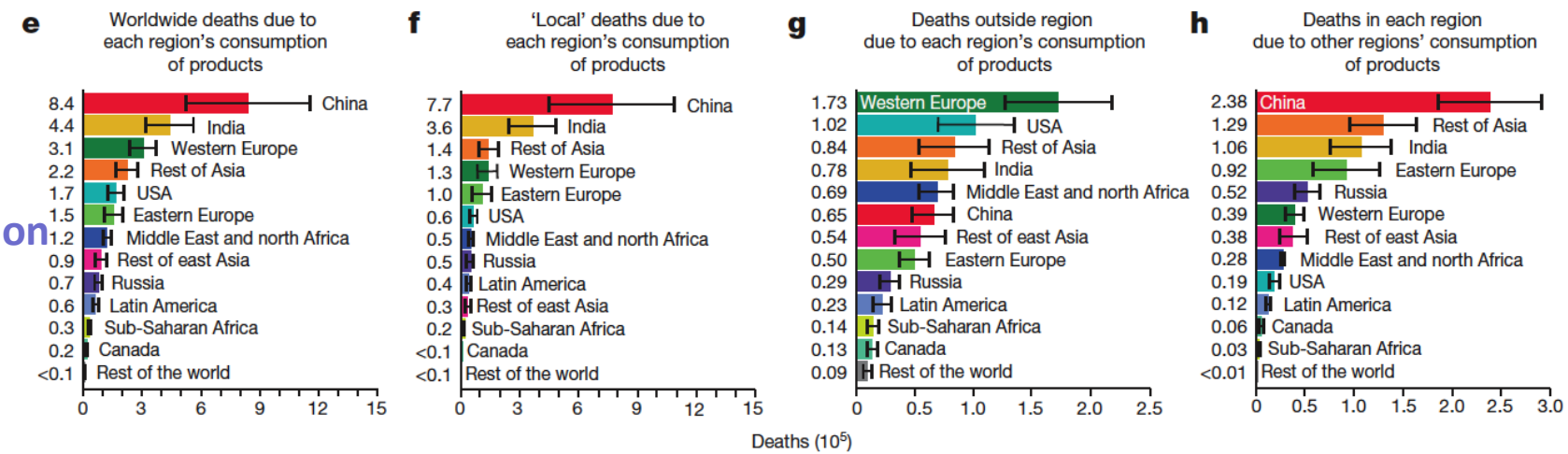
Global premature mortality due to transported $PM_{2.5}$ pollution and traded products

Impact to Worldwide | **Impact to Local** | **Impact to Outside** | **Impact from Outside**

Production



Consumption



Summary

- We combined four global models to estimate premature mortality caused by fine particulate matter ($PM_{2.5}$) pollution as a result of atmospheric transport and the production and consumption of goods and services in different world regions.
- We find that, of the 3.45 million global premature deaths related to $PM_{2.5}$ pollution in 2007, about 12 per cent (411,100 deaths) were related to air pollutants emitted in a region of the world other than that in which the death occurred, and about 22 per cent (762,400 deaths) were associated with goods and services produced in one region for consumption in another.
- Our findings quantify the extent to which air pollution is a global problem. In our global economy, the goods and services consumed in one region may entail production of large quantities of air pollution—and related mortality—in other regions.