The Global Burden of Disease Attributable To Air Pollution:
Latest Results and Future Directions for Source-Specific Burdens

Dan Greenbaum

President, Health Effects Institute

ECT - 2015

New Delhi

5th September 2015

Trusted Science ● Cleaner Air ● Better Health

Air Pollution and the Global Burden of Disease

- Air Quality and Health
  - Estimating the Global Burden of Disease GBD
    - GBD 2010 Review
    - GBD 2013: What's New?
      - 2013 Preliminary Results
  - Looking Ahead:
    - GBD MAPS: Understanding Source-Specific Health Impacts in China, India and Eastern Europe
    - The Special Case of Traffic
- Concluding Thoughts

The Health Effects Institute
Trusted Science ➡ Cleaner Air ➡ Better Health

- An independent non-profit institute providing trusted science on the health effects of air pollution for 35 years
- Balanced Core Support
  - US EPA and Industry (Worldwide Motor Vehicle)
- Partnerships
  - Also WHO, ADB, Clean Air Asia, TERI, Sri Ramachandra Medical School, EU, US DOE, industries, foundations, others
- Independent Board and Expert Science Committees
  - Oversee and intensively peer review all science
  - International experts from India, China, many others
- Over 350 scientific reviews, reanalysis conducted around the world, including increasingly in Asia

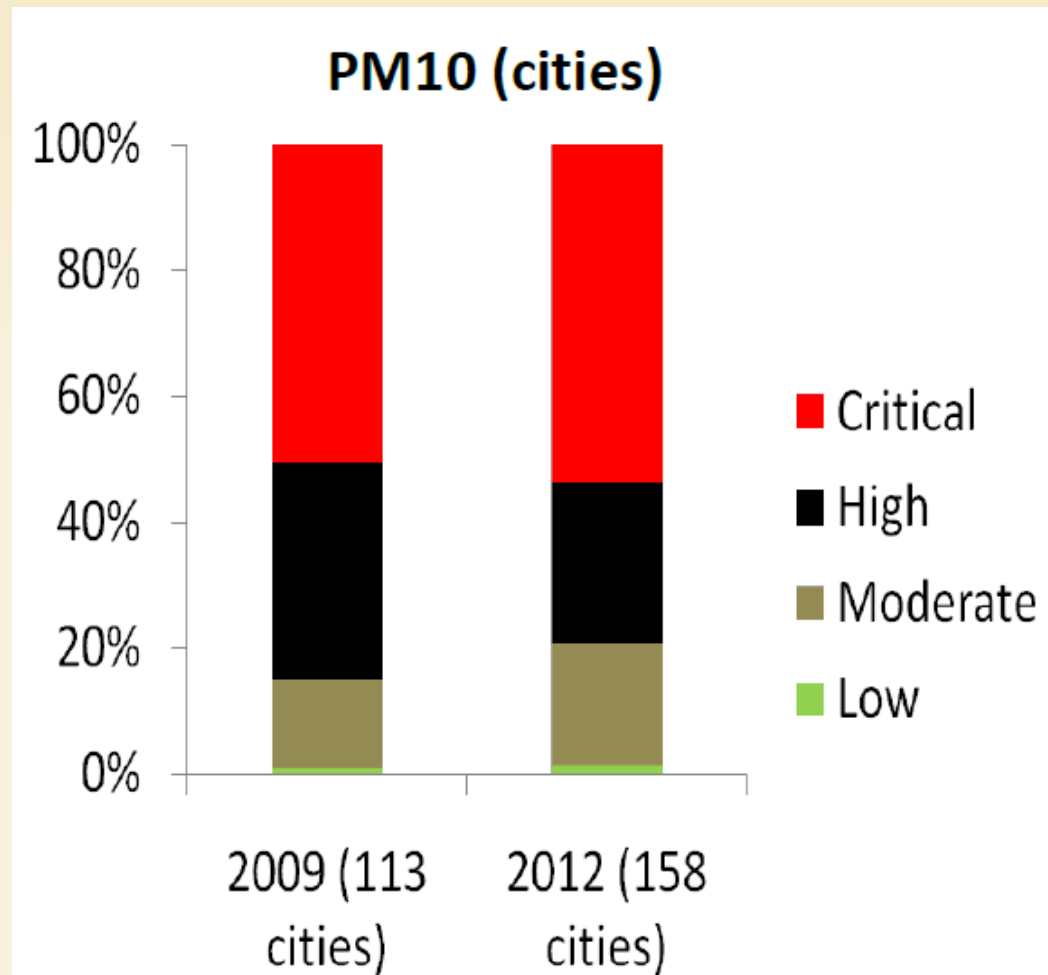*Understanding local impacts in a global context to inform policy*

HEI

India's National Air Quality Challenge:

PM10:

- Number of critically polluted cities has increased from 57 in 2009 to 85 in 2012;

- Nearly half have critical pollution levels

Source: Based on National Ambient Air Quality Status 2009 and 2012

Indian Results:
PM10 Evidence from HEI Chennai study
Approximately 0.3% -0.6% increase in mortality per *10 µg/m³* PM10
Similar Results in Delhi as Well...

Annual Average of PM10 Concentration in Chennai

Concentration of PM10 (mic.gm/cu.m)
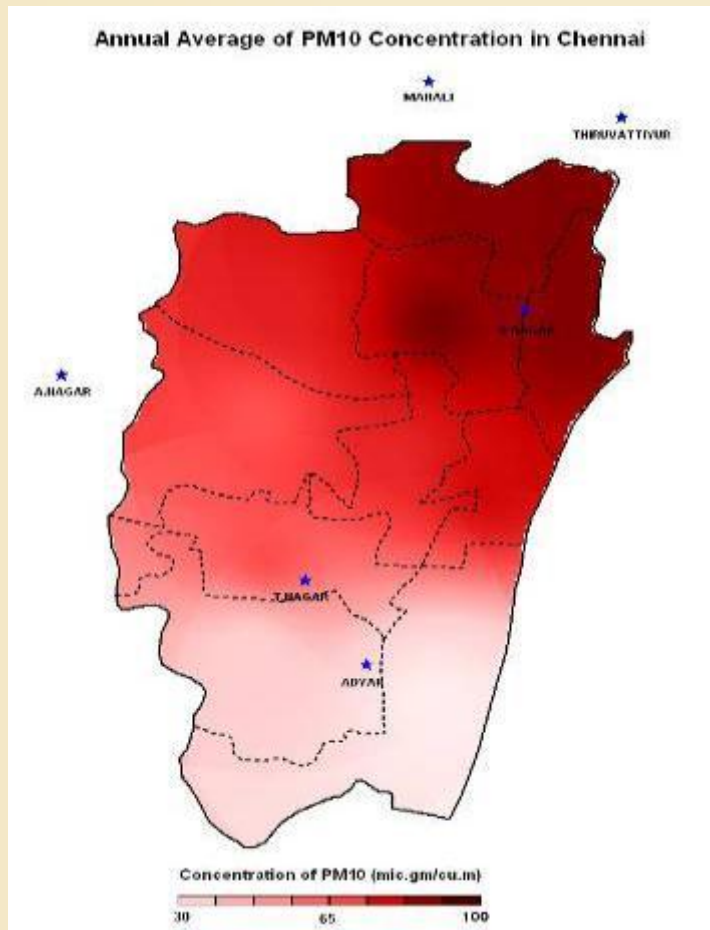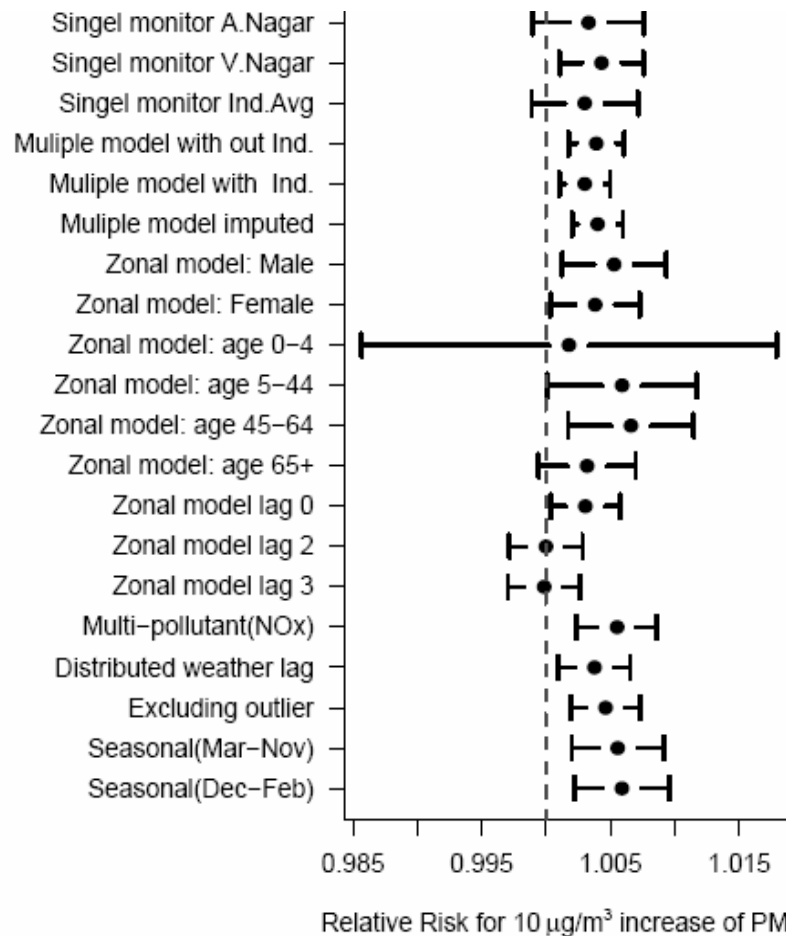
30   65   100

Dr. Kalpana Balakrishnan and
colleagues HEI 2011

Fig. 23: A comparison of the estimated RR's for PM10 obtained from the core
zonal model, alternative models and sensitivity analysis.

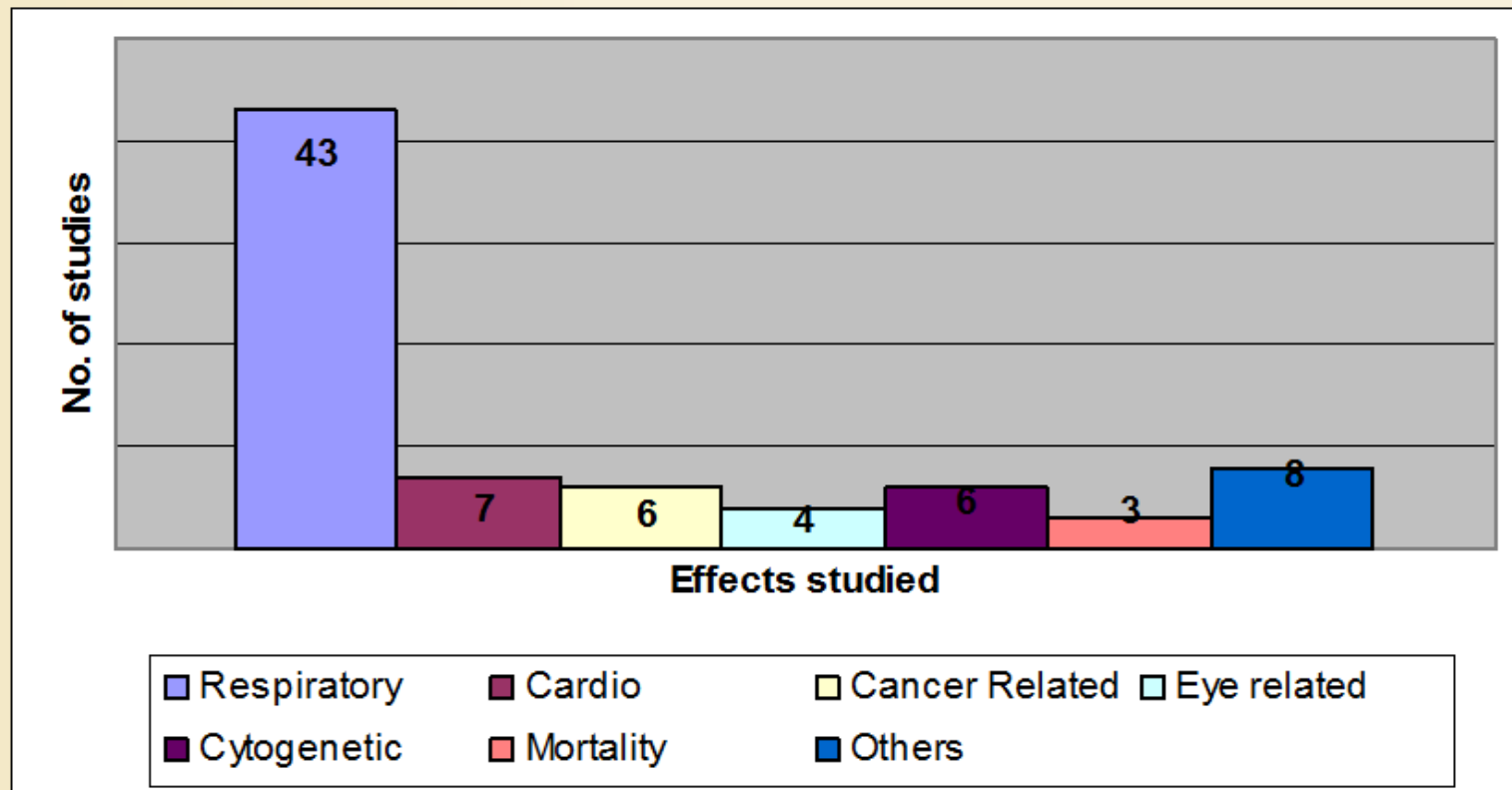Relative Risk for 10 µg/m³ increase of PM10

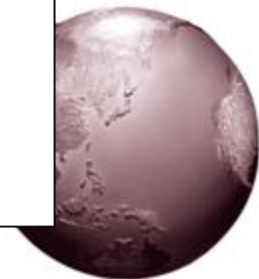# Recent Indian studies look at diverse health end points….

Respiratory health symptoms dominate….
Broadening to include cardiovascular, eye disorders,
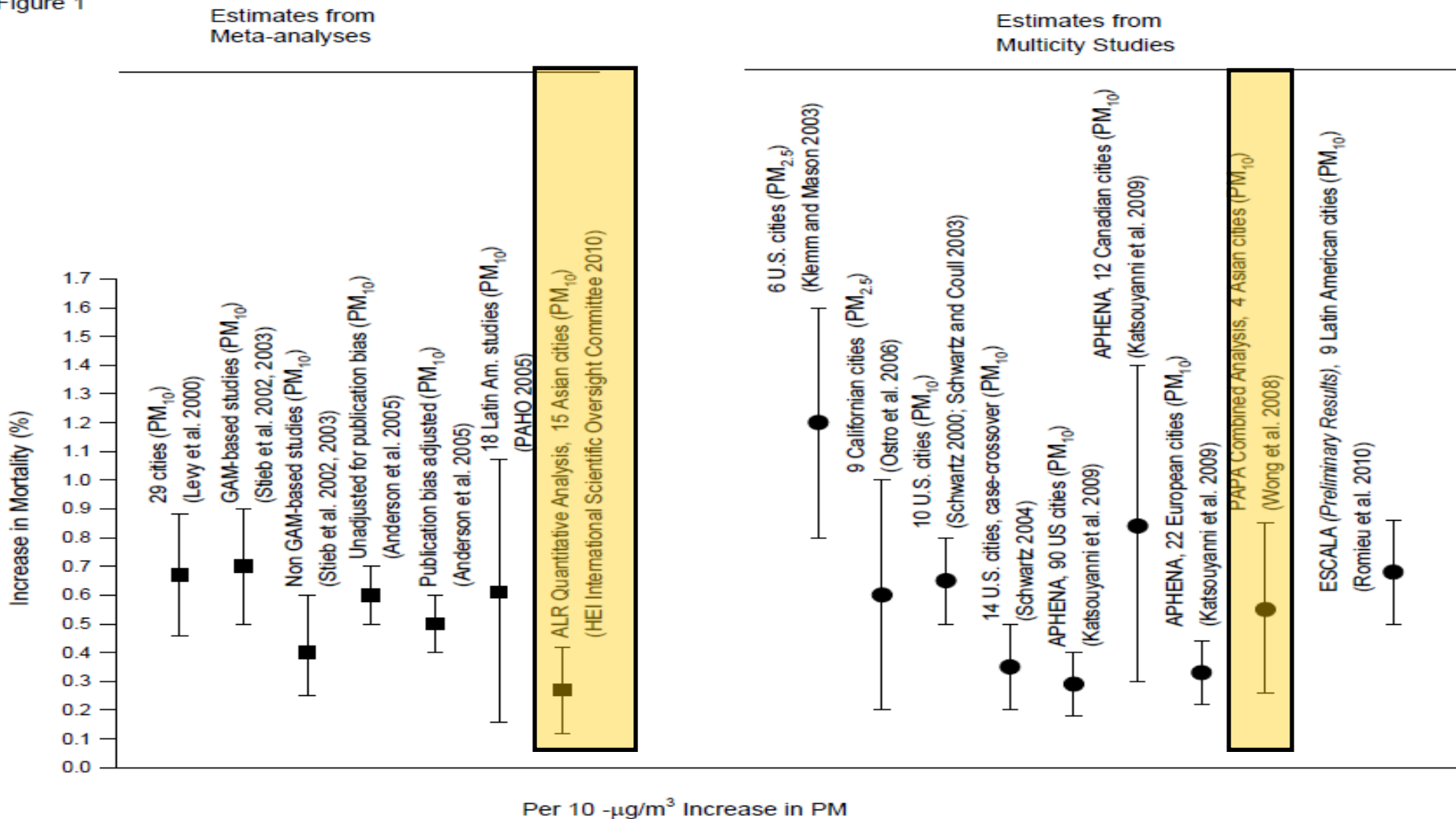*cellular changes, cancer, premature deaths….*

Source: CSE

Asia in a Global Context
(PM$_{10}$ and Daily Mortality)
The effects of pollution are more similar than different …
…and global science can be broadly relevant

Figure 1

The Global Burden of Disease (GBD)

- A systematic scientific effort to quantify the magnitude of health loss from disease and injuries in 187 countries around the world from 1990 to 2010
  - E.g. cardiovascular disease, respiratory disease, HIV-AIDS, cancer, road traffic injuries and
- Risks factors associated with those diseases
  - E.g. smoking, diet, high blood pressure, air pollution, overweight
  - GBD 2010, published in *The Lancet December 2012*
- Organized by the Institute for Health Metrics and Evaluation (IHME), U Wash.
- *HEI leadership for outdoor air pollution*

THE LANCET

The Global Burden of Disease Study 2010
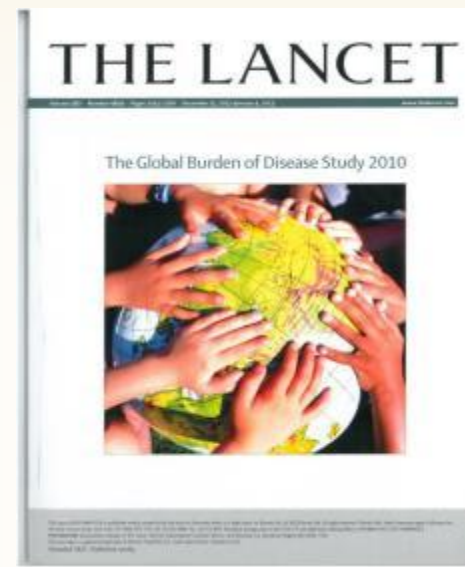
2010: Ambient PM$_{2.5}$ among the leading global risks for mortality and lost years of healthy life

(Lim et al 2012, and http://viz.healthmetricsandevaluation.org/gbd-compare/)

Deaths in Millions

Risk factor	
Dietary risks	
High blood pressure	
Tobacco smoking	
Household air pollution from solid fuels	
High body-mass index	
High fasting plasma glucose	
Ambient particulate matter pollution	
Physical inactivity and low physical activity	
Alcohol use	
High total cholesterol	
Childhood underweight	
Occupational risks	
Lead exposure	
Suboptimal breastfeeding	
Unimproved sanitation	
Low bone mineral density	
Intimate partner violence	
Drug use	
Ambient ozone pollution	
Vitamin A deficiency	

Contributes to ~3 million premature deaths worldwide (2/3 occurred in developing Asia)

THE LANCET

The Global Burden of Disease Study 2010
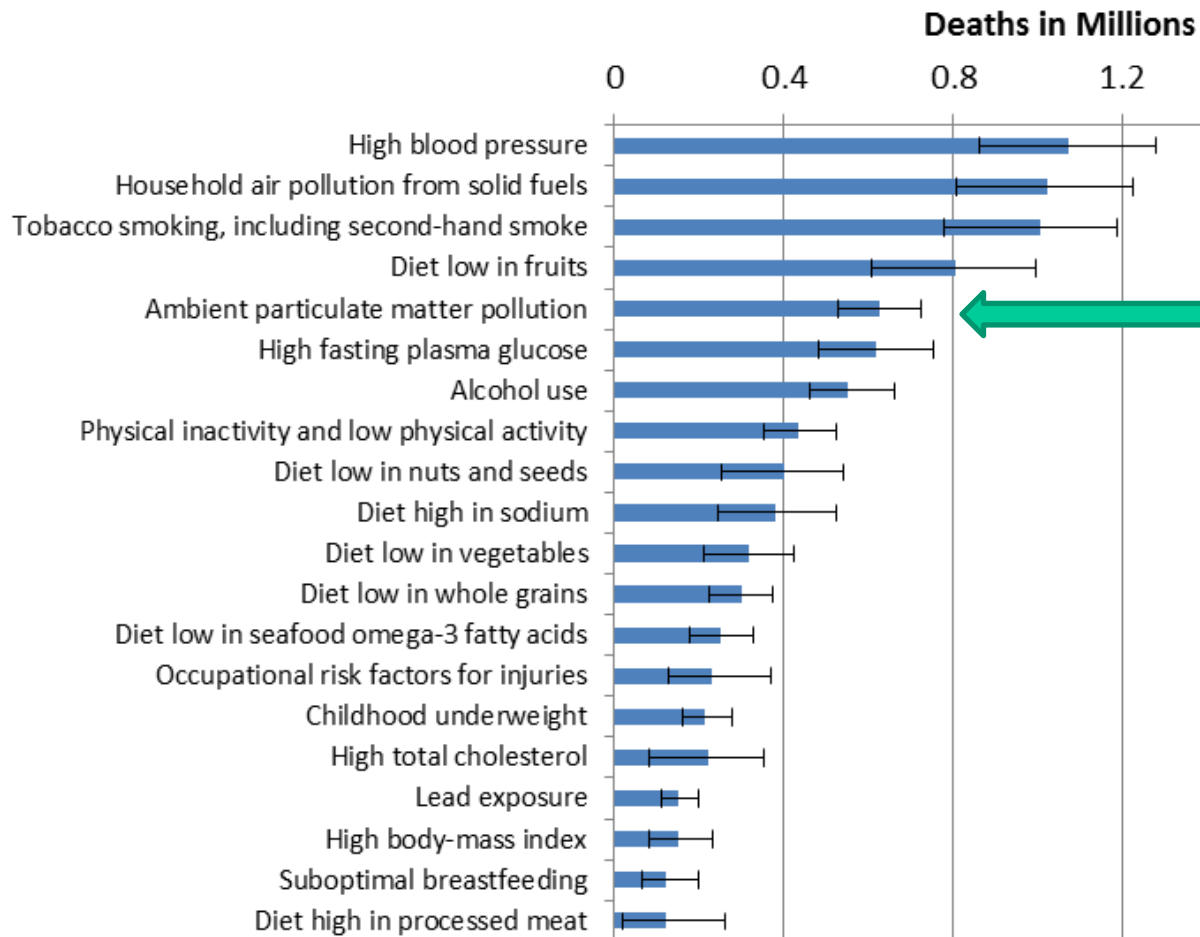
Top 20 Mortality Risk Factors in India for 2010
Ambient PM$_{2.5}$ is 5th leading mortality risk factor

Leading Risk Factors for Deaths in 2010 in India

Deaths in Millions

| | 0 | 0.4 | 0.8 | 1.2 |

- High blood pressure
- Household air pollution from solid fuels
- Tobacco smoking, including second-hand smoke
- Diet low in fruits
- Ambient particulate matter pollution
- High fasting plasma glucose
- Alcohol use
- Physical inactivity and low physical activity
- Diet low in nuts and seeds
- Diet high in sodium
- Diet low in vegetables
- Diet low in whole grains
- Diet low in seafood omega-3 fatty acids
- Occupational risk factors for injuries
- Childhood underweight
- High total cholesterol
- Lead exposure
- High body-mass index
- Suboptimal breastfeeding
- Diet high in processed meat

Ambient PM$_{2.5}$ caused an estimated 627,000 deaths ~6% of all deaths in 2010

HEI

Extensive Press on Global Burden of Disease

GLOBAL TIMES
DISCOVER CHINA, DISCOVER THE WORLD

The New York Times

THE TIMES

n p r

RFA Radio Free Asia

The Green Optimistic
alternative energy news, environmental awareness

Medical Daily

Including detailed coverage in China/India/Western media

- *'Airpocalypse' in China: Air Pollution Kills Over a Million*

THE TIMES OF INDIA

TOP 10 risk factors for disease in 2010 (In Asia/mainly India)

1 Household air pollution from solid fuels
2 Smoking/second hand smoke
3 High blood pressure
4 Childhood underweight
5 Low fruit intake
6 Pollution
7 High plasma glucose
8 Alcohol use
9 Iron deficiency
10 Sub optimal breastfeeding

Top killers across the world
High blood pressure — 9.4
Household air pollution from solid fuels — 3.5
High body-mass index — 3.4
High fasting plasma glucose — 3.4
Air pollution — 3.1
High cholesterol — 2
Low bone mineral density — 0.2

Figs in million for no. of death

Death due to dietary risk factors
Disease attributable to tobacco smoking—6.3 | Alcohol and drug use—5 | Low diet of fruits—4.9 | High sodium diet—4 | Low nuts, seeds diet—2.5 | Low vegetable food—1.8 | Occupational risk factors accounted—0.9 (figs in million)

NEW: *The Global Burden of Disease (GBD) 2013*

More Comprehensive

- *Health loss from over 291 diseases and injuries in 188 countries.*
  - New estimates for all 76 risk factors including *ambient and household air pollution*
  - *Provincial level estimates* for China, UK, Mexico

Advanced Science

- *Expands upon the methodology, datasets and tools in GBD 2010 including for air pollution – PM$_{2.5}$, ozone, household*
  - New improved PM2.5 exposure data from ground level monitors, satellites, transport models

- *PM health risk estimates now include 13 epidemiologic cohort mortality studies including new, large studies published since 2010*
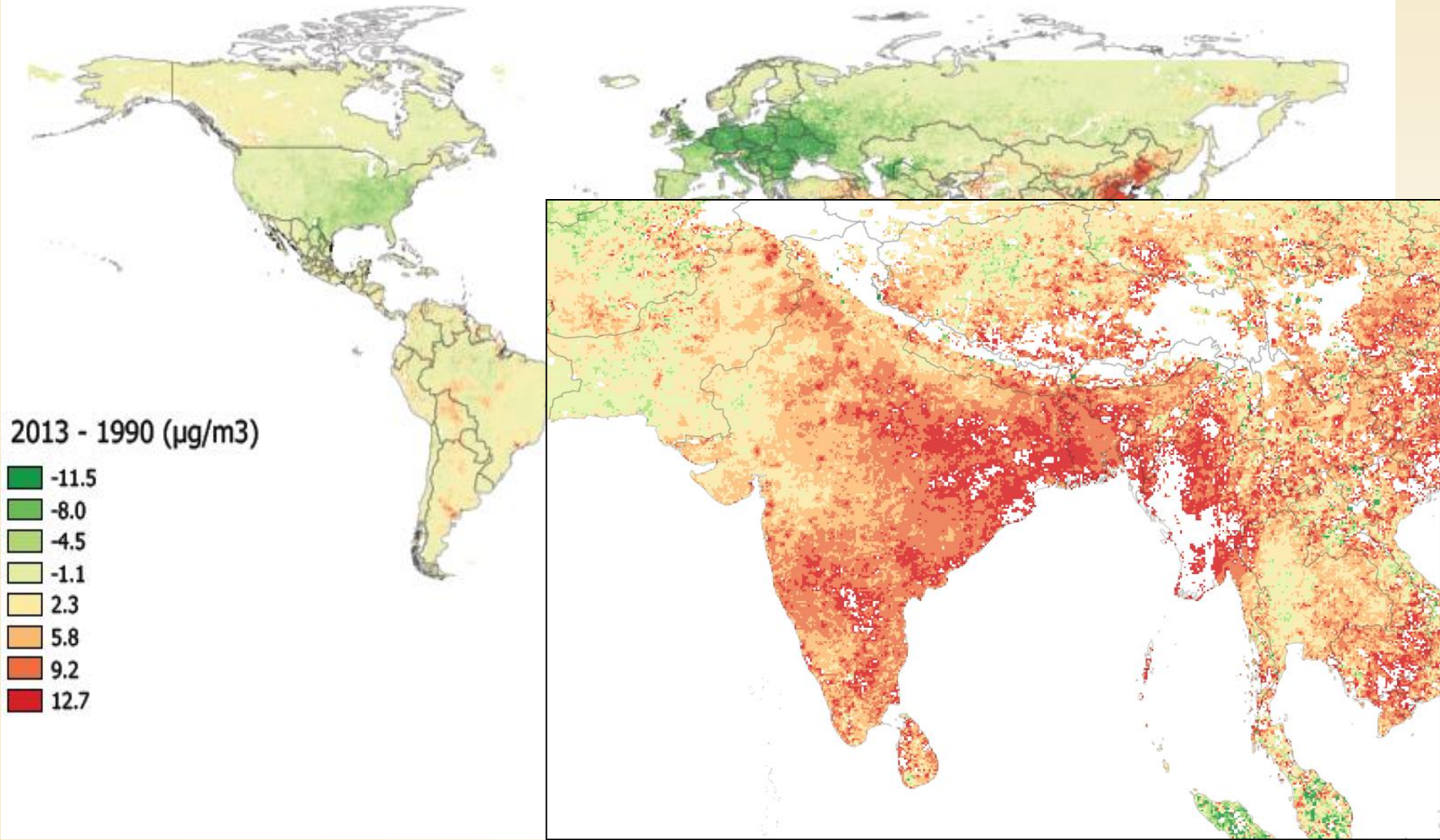 - New data on pneumonia in children and adults

HEI

1990 – 2013 Change in Annual Average PM$_{2.5}$

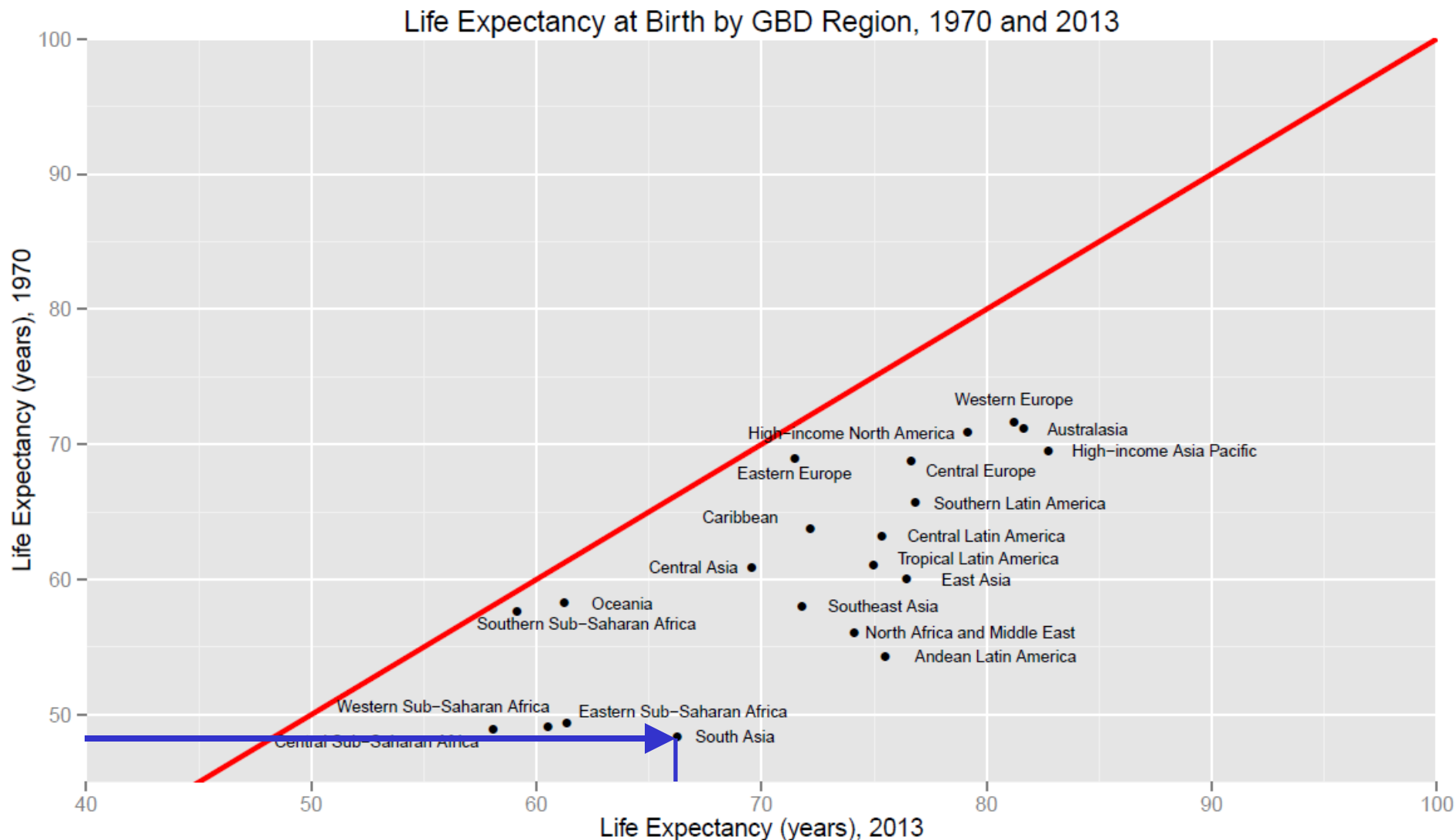*Enhanced ground monitoring and other data*
Leading to higher quality estimates

2013 - 1990 (µg/m3)

- -11.5
- -8.0
- -4.5
- -1.1
- 2.3
- 5.8
- 9.2
- 12.7

Changes in Life-Expectancy at Birth 1970-2013
Longer lives worldwide
More people dying from heart disease

Life Expectancy at Birth by GBD Region, 1970 and 2013

Estimating Mortality Risk for the Global Burden of Ambient PM$_{2.5}$

- **Five Major Diseases related to PM2.5**
  - Ischemic heart disease (IHD)
  - Stroke
  - Lower respiratory infection (Age 0 – 5)
  - Chronic obstructive lung disease(COPD)
  - Lung cancer

Ambient Air Pollution Cohort Adult Mortality Studies Used to Estimate Burden of Disease
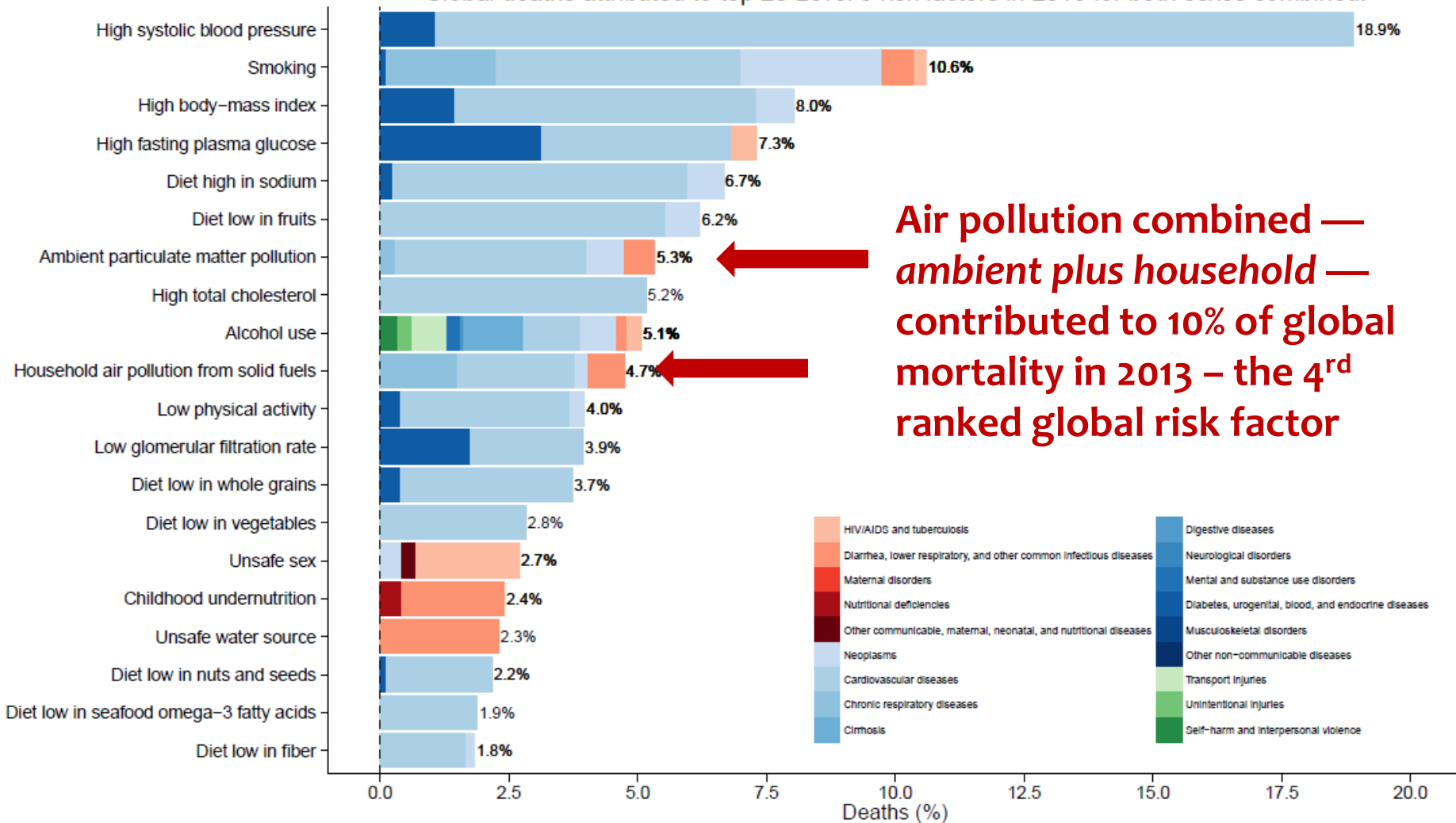### (including additional studies from Europe, Canada, Japan)

New Studies added for GBD 2013 →

| Study	PM$_{2.5}$ Mean (µg/m³)	PM$_{2.5}$ Min (µg/m³)	PM$_{2.5}$ 5th/95th (µg/m³)	IHD HR /10 µg/m³ (95% CI)	CEV HR /10 µg/m³ (95% CI)	COPD HR /10 µg/m³ (95% CI)	LC HR /10 µg/m³ (95% CI)
American Cancer Society[a] (ACS)	14.2 N=486133	5.8	8.8/20.0	1.26 (1.16-1.38) n=29875	1.12 (1.01-1.24) n=9116	1.05 (0.95-1.17) n=9006	1.14 (1.06-1.23) 9,557
Six City[b] (SCS)	17.8 N=8096	8.7	10.2/23.6	1.33 (1.16-1.52) n=1065	0.89 (0.67-1.18) n=317	1.17 (0.85-1.62) n=247	1.37 (1.07-1.75) n=351
California Teachers[c] (CTS)	15.6 N=73,498	3.1	8.3/23.0	1.20 (1.02-1.41) n=773	1.16 (0.92-1.46) N=382	1.21 (0.88-1.68) N=196	0.95 (0.70-1.28) n=234
Adventist Study of Health and Smog[d] (ASHSmog)	29.0 N=3,239	12.9	15.0/45.1	1.00 (0.87-1.15) n=145			
Dutch Study of Diet and Cancer[e] (DSDC)	28.3 N=120,852	23.0	24.8/31.8	0.96 (0.75-1.22) n=3,521	1.62 (1.07-2.44) n=1,175		1.06 (0.82-1.38) n=1,670
Male Health Professionals[f] (MHP)	17.9 N=17,545	5.8	12.3/23.4	0.98 (0.71-1.36) n=746			
Nurses Health[g] (NHS)	13.9 N=66,250	5.8	10.0/17.8	2.02 (1.07-3.78) n=379			
Women's Health Initiative[h] (WHI)	13.5 N=65,893	3.4	7.4/19.6	2.21 (1.17-4.16) n=80	1.83 (1.11-3.00) n=122		
Canadian Census Health & Environment Cohort[i] (CanCHEC)	8.7 N= 2,145,400	2.1	3.6/13.8	1.30 (1.18-1.43) n=43400	1.04 (0.93-1.16) n=13300		
Canadian National Enhanced Cancer Surveillance System Cohort[j] (NECSS)	11.9	3.8	6.7/16.8				1.29 (0.95-1.76) n=2154
English Cohort[k] (ENDOC)	12.9 N= 835,607	8.5	10.6/15.2	1.05 (0.81-1.29) n=8168	1.00 (0.81-1.29) n=5458	1.43 (1.00-1.79) n=4105	1.11 (0.88-1.43) n=5244
Japanese Cohort[m] (JAPAN)	Mean Not Reported N= 63520	16.8	16.8/41.9			0.89 (0.70-1.12) n=64	1.24 (1.12-1.37) n=518
Agricultural Health Study[n]		5.7	7.3/12.6	2.68 (1.04-6.87)	1.78 (0.72-4.42)		0.75 (0.34-1.65)

GBD 2013 Premature Deaths:
Air Pollution among top-ranked *global* risk factors

Global deaths attributed to top 20 Level 3 risk factors in 2013 for both sexes combined.

Air pollution combined — *ambient plus household* — contributed to 10% of global mortality in 2013 – the 4rd ranked global risk factor

GBD 2013 Risk Factor Collaborators ***PRELIMINARY ESTIMATES**

India: Deaths attributable to all Risk Factors 2013


India, Both sexes, All ages, 2013
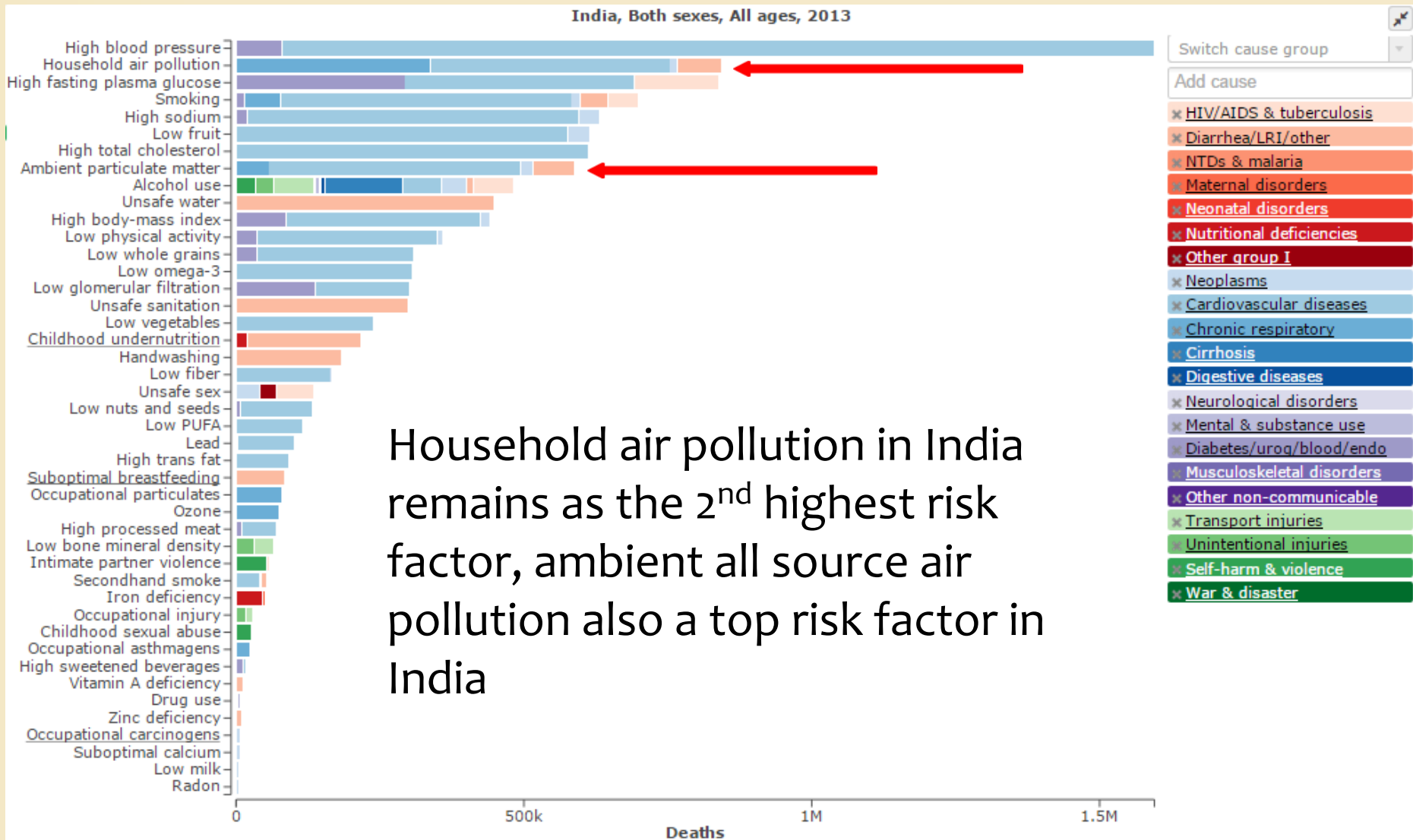
Household air pollution in India remains as the 2nd highest risk factor, ambient all source air pollution also a top risk factor in India

India: Deaths attributable to combined risk factors

India, Both sexes, All ages, 2013

Indoor and outdoor combined are now the 3rd highest risk factor

GBD 2013 Risk Factor Collaborators ***PRELIMINARY ESTIMATES***
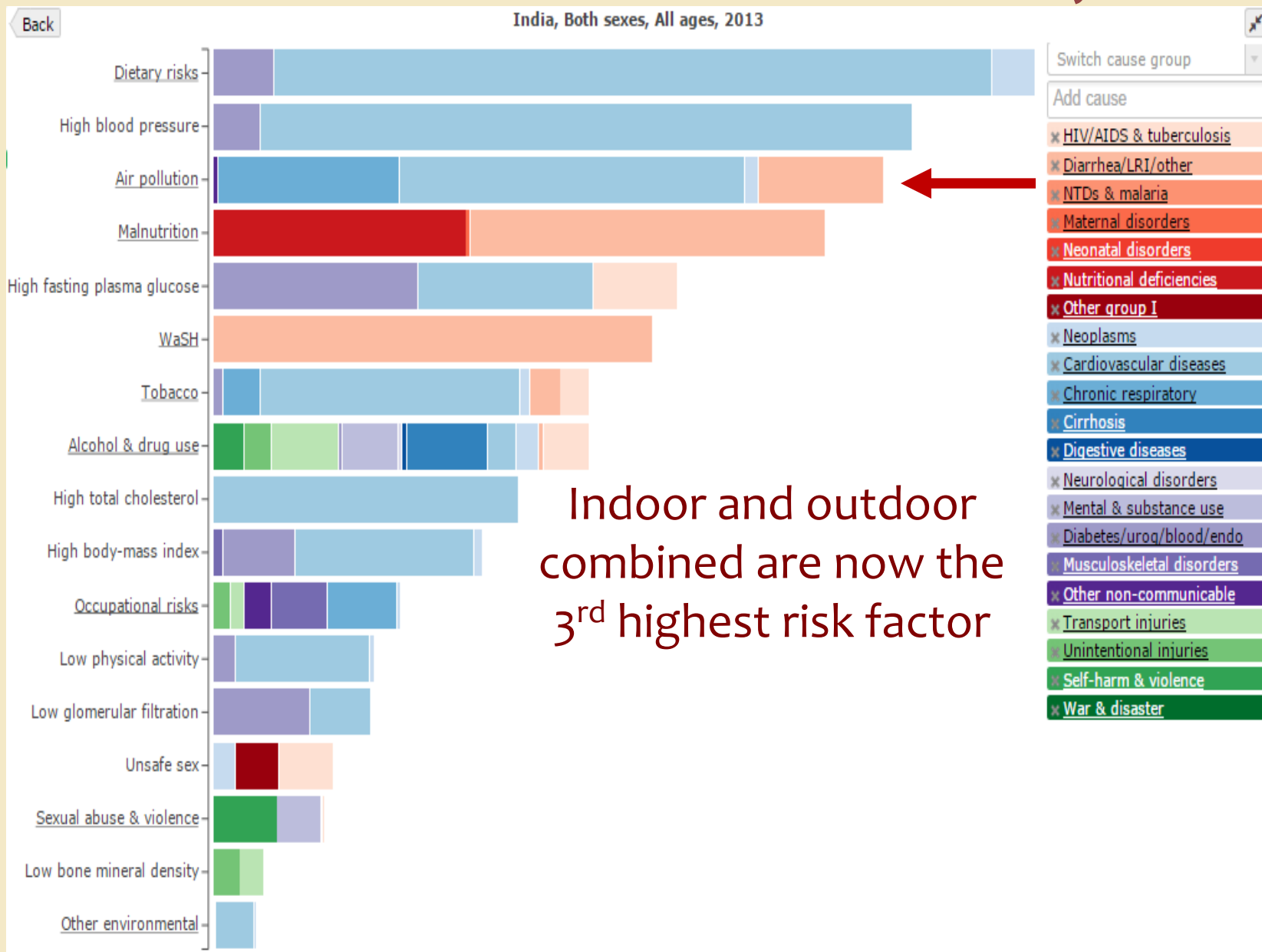
A Key Need for Cleaner Air:
Health Burden from Different Sources

Vehicles ~20% - 30% of total PM2.5 (depending on city and season)
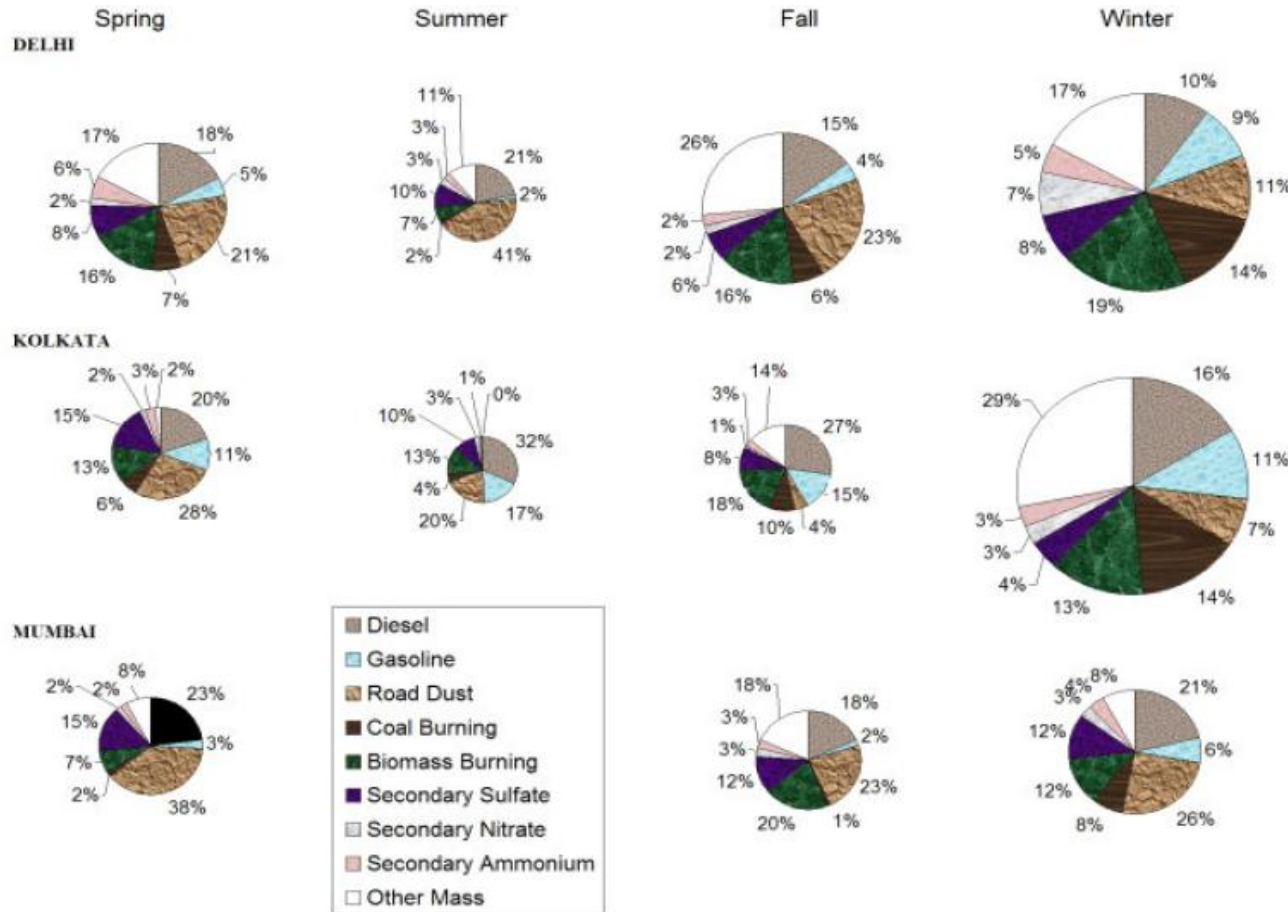
- ■ Fossil fuel and biomass combustion dominates:
  - **Fossil Fuel**
    - Del: 25-33%
    - Kol: 37-53%
    - Mum: 21-35%
  - **Biomass**
    - Del: 7-19%
    - Kol: 13-18%
    - Mum: 7-20%
- ■ Dust dominates during Spring and Summer
  - □ Long range transport and dust from local construction
- ■ Biomass and coal are high in winter
  - □ Heating
  - □ Poor mixing and atmospheric inversion

Legend:
- Diesel
- Gasoline
- Road Dust
- Coal Burning
- Biomass Burning
- Secondary Sulfate
- Secondary Nitrate
- Secondary Ammonium
- Other Mass

Road Dust an additional 10% - 30%

Source: Adapted from Chowdhury et al. (2007).

Many Sources of PM in India

GBD MAPS: Understanding Source Specific Impacts

- Source-specific impacts best inform, drive climate and air pollution control measures
- GBD MAPS: **G**lobal **B**urden of **D**isease from **M**ajor **A**ir **P**ollution **S**ources
- New HEI-IHME initiative to understand source-specific impacts (e.g. coal, transport)
  - *China, India, Eastern Europe*, in a global context
  - Using GBD 2013 methods, data
  - At national, provincial levels
- In partnership initially with leading Chinese, Indian partners (Tsinghua, IIT-B, others)

Underway now; China results expected in 2015;

India in 2016

Trusted Science ● Cleaner Air ● Better Health

GBD MAPS International Steering Committee

Dan Greenbaum / Bob O'Keefe   Health Effects Institute

Terry Keating   US EPA

Hao Jiming   Tsinghua University

Yang Gonghuan   Peking Union Medical College

Christopher Murray   IHME

Majid Ezzati   Imperial College, London

K Srinath Reddy   Public Health Foundation of India, Delhi

Michal Krzyzanowski   Kings College, London

Greg Carmichael   WMO/U Iowa

GBD MAPS Working Group

Michael Brauer (co-chair)	University of British Columbia
Aaron Cohen (co-chair)	Health Effects Institute
Wang Shuxiao	Tsinghua University
Zhang Qiang	Tsinghua University
Ma Qiao	Tsinghua University
Zhou Maigeng	China CDC
Yin Peng	China CDC
Chandra Venkataraman	IIT Bombay
Pankaj Sadavarte	IIT Bombay
Wang Yuxuan	University of Texas, Galveston
Kan Haidong	Fudan University
Randall Martin	Dalhousie University
Aaron van Donkelaar	Dalhousie University
Richard Burnett	Health Canada
Mohammad Forouzanfar	IHME
Joseph Frostad	IHME

GBD MAPS: All the Major Sources

- Transportation (on-road, non-road)
- Household Biomass
- Brick Kilns
- Coal:
  - Power, Industry, Domestic
- Non-coal Industrial
- Agriculture
- Open Burning
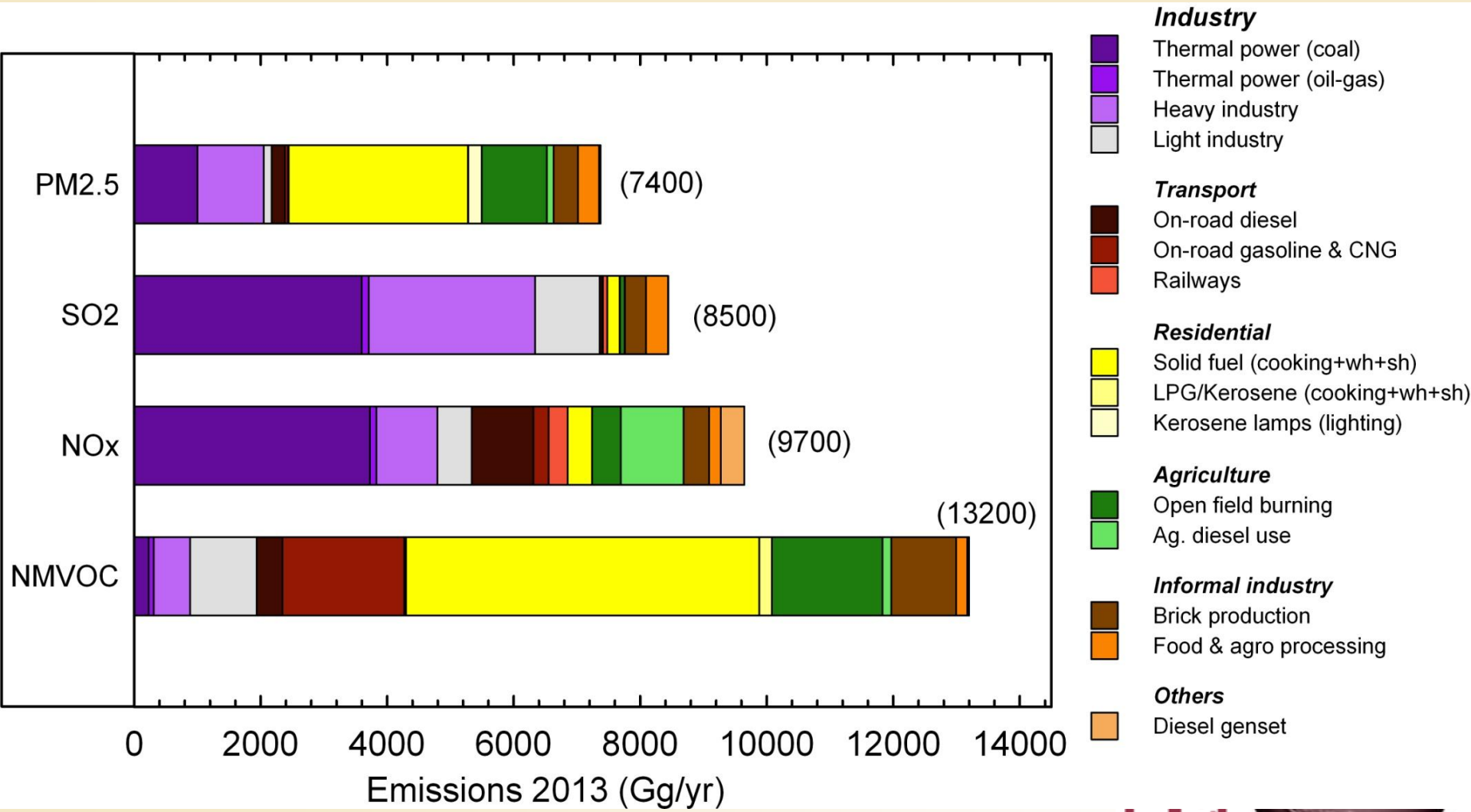- Solvent Use

GBD MAPS Approach

1. Estimate fractions of $PM_{2.5}$ from transport, industry, coal-combustion and other sources

2. Multiply source fractions with ambient $PM_{2.5}$ to estimate source-specific ambient $PM_{2.5}$

3. Combine source-specific ambient $PM_{2.5}$ and GBD $PM_{2.5}$ health estimates to provide source contributions to disease burden

PRELIMINARY ESTIMATES

GBD MAPS: Estimate of source emission contributions to ambient PM$_{2.5}$ using latest available information on current and projected emissions (India 2013)
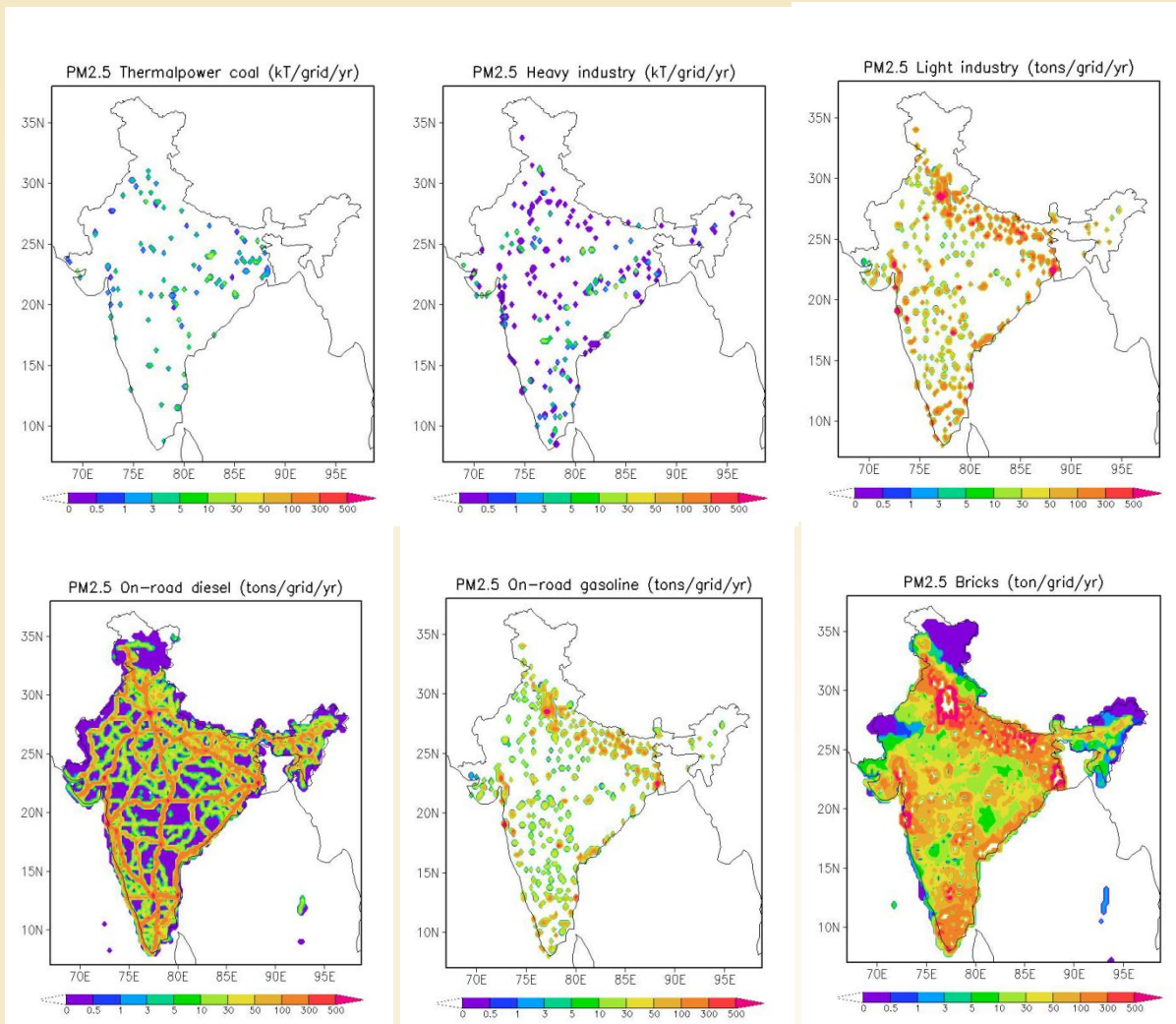
Industry
- Thermal power (coal)
- Thermal power (oil-gas)
- Heavy industry
- Light industry

Transport
- On-road diesel
- On-road gasoline & CNG
- Railways

Residential
- Solid fuel (cooking+wh+sh)
- LPG/Kerosene (cooking+wh+sh)
- Kerosene lamps (lighting)

Agriculture
- Open field burning
- Ag. diesel use

Informal industry
- Brick production
- Food & agro processing

Others
- Diesel genset

PM2.5 (7400)

SO2 (8500)

NOx (9700)

NMVOC (13200)

Emissions 2013 (Gg/yr)

PRELIMINARY ESTIMATES

Source Emission Estimates

Power, Industry

Transport, Brick Kilns

PM2.5 Thermalpower coal (kT/grid/yr) | PM2.5 Heavy industry (kT/grid/yr) | PM2.5 Light industry (tons/grid/yr)

PM2.5 On-road diesel (tons/grid/yr) | PM2.5 On-road gasoline (tons/grid/yr) | PM2.5 Bricks (ton/grid/yr)
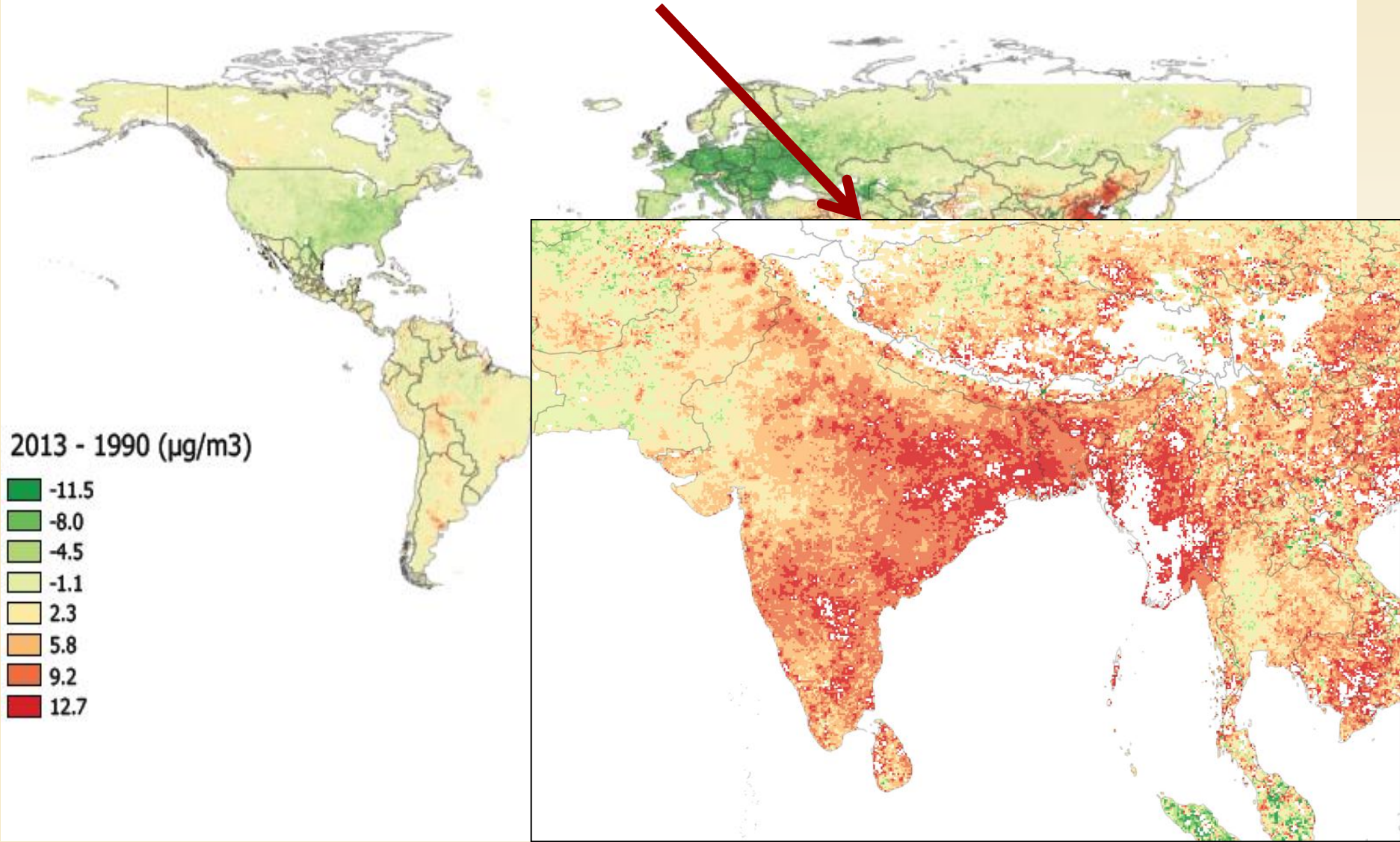
India 2013 PRELIMINARY ESTIMATES

Expect initial GBD MAPS results for India 2016

1990 – 2013 Change in Annual Average PM$_{2.5}$

Emission factors will then be applied to estimate Indian source-specific population exposure

2013 - 1990 (µg/m3)

- -11.5
- -8.0
- -4.5
- -1.1
- 2.3
- 5.8
- 9.2
- 12.7

The Special Case of Traffic Sources

Traffic Related Air Pollution & Health:
An Expert HEI Review
2010

Summarized & synthesized over 700 studies on health effects of traffic
- *However, not **all** of equal quality*

Found :
- ***Highest exposures 300-500 meters from major roads***
- *Growing evidence of effects, especially asthma exacerbation in children*

New:
- **HEI Traffic Exposure, Tunnel Studies underway**
- **Updated traffic expert review to get underway in 2016 (10 more years of data)**

The New York Times

January 13, 2010
Report Links Vehicle Exhaust to Health Problems

A relationship was found between pollution from vehicles and impaired lung function and accelerated hardening of the arteries.

By MATTHEW L. WALD

Exhaust from cars and trucks exacerbates asthma in children and may cause new cases as well as other respiratory illnesses and heart problems resulting in deaths, an independent institute that focuses on vehicle-related air pollution has concluded.

The report, to be issued on Wednesday by the nonprofit Health Effects Institute, analyzed 700 peer-reviewed studies conducted around the world on varying aspects of motor vehicle emissions and health. It found "evidence of a causal relationship," but not proof of one, between pollution from vehicles and impaired lung function and accelerated hardening of the arteries.

It said there was "strong evidence" that exposure to traffic helped cause variations in heart rate and other heart ailments that result in deaths. But among the many studies that evaluated death from heart problems, some did not separate stress and noise from air pollution as a cause, it said.

The Traffic Impact Area in Delhi:
## HEI Analysis: **55% of the Population** within 500 meters of a Freeway; 50 meters of a Major Road

An Important Traffic Concern: Older Diesel Health Effects

- Primary concern is exposure to particulate matter and NO_x from older diesel

- Also, evidence of respiratory effects:
  - *reduced lung function, respiratory irritation, asthma exacerbation*

- Diesel and cancer: IARC 2012
  - *Older diesel a known human carcinogen*
  - *But highlights the changes with New Technology Diesel Engines (NTDE)*
    - *HEI ACES Results*
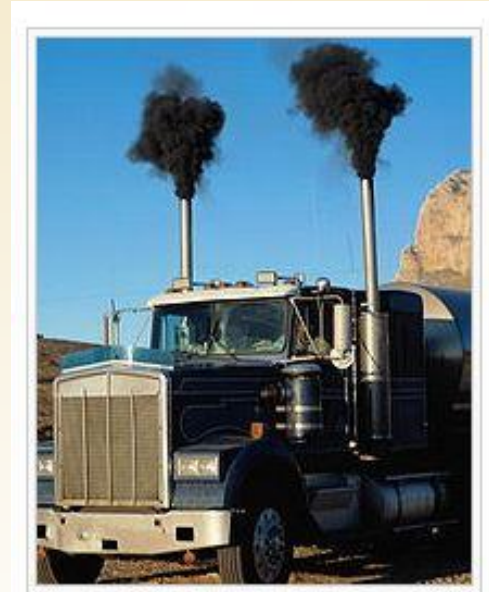
Key IARC Evidence: Diesel Exhaust in Miners Study

(NCI/NIOSH Attfield et al. 2012; Silverman et al. 2012)

- Major occupational study in "non-coal and non-metal" mines
  - *Risk of Lung Cancer **increased 300% to 700%** in exposed workers*
  - Key input into IARC decision
- Some continuing questions about study
  - HEI Systematically reviewing and analyzing the data
  - ***HEI Expert Diesel Epidemiology Report on strength of study - Fall 2015***

HEI

Concluding Thoughts

- We know much more today about the Health Effects of Air Pollution in Asia
  - Growing science base
  - New Short and Long Term Studies
- GBD is increasing understanding of the population health burdens
  - GBD 2010, and now **GBD 2013** including new approaches to exposure and exposure-response
- Important clean air progress underway in China
- Actions beginning in India:
  - AQI, BS V/VI, thermal power plants
- Source-specific impacts are likely to best inform and drive future control measures
  - GBD MAPS
  - New Traffic Review and Studies

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Thank You!

Dan Greenbaum
dgreenbaum@healtheffects.org