Air Pollution and Global Warming

- Getting to win, win, win

- Joel Schwartz
- Harvard School of Public Health
- Harvard Center for Risk Analysis

Prisoner's Dilemma

	Prisoner B stays silent	Prisoner B betrays
Prisoner A stays silent	Each serves 1 month	Prisoner A: 1 year Prisoner B: goes free
Prisoner A betrays	Prisoner A: goes free Prisoner B: 1 year	Each serves 3 months

Greenhouse Gas Emissions

	Country B Spends Money	**Country B does not Spend Money**
Country A Spends Money	Warming slows, both out money	Warming slows some, only A out money
Country A Does not Spend Money	Warming slows some, only B out money	Warming continues, neither out money

How do we Break the Prisoner's Dilemma?

- The costs of controlling climate change are local, while the benefits are global
- The costs of controlling air pollution are mostly local, and the benefits are mostly local
- Can we find air pollution control strategies that slow global warming?

Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security

- Results of the UNEP Project

UNEP/WMO Integrated Assessment of Black Carbon and Tropospheric Ozone

Substance	Lifetime
Carbon dioxide	Decades to centuries and about 20 per cent will persist for many millennia
Ozone	4 – 18 days
Methane	12 years
Black carbon	3-8 days

Emission Control Measures in the Analysis

IIASA ranked mitigation measures by the net GWP of their emission changes (considering CO, CH_4, BC, OC, SO_2, NO_X, nmVOCs, and CO_2), picked the top measures

‘Methane measures’

- extraction and long-distance transport of fossil fuels (~25%)
- waste management; municipal, landfills & wastewater (~10%)
- agriculture; livestock manure & intermittent rice aeration (~5%)

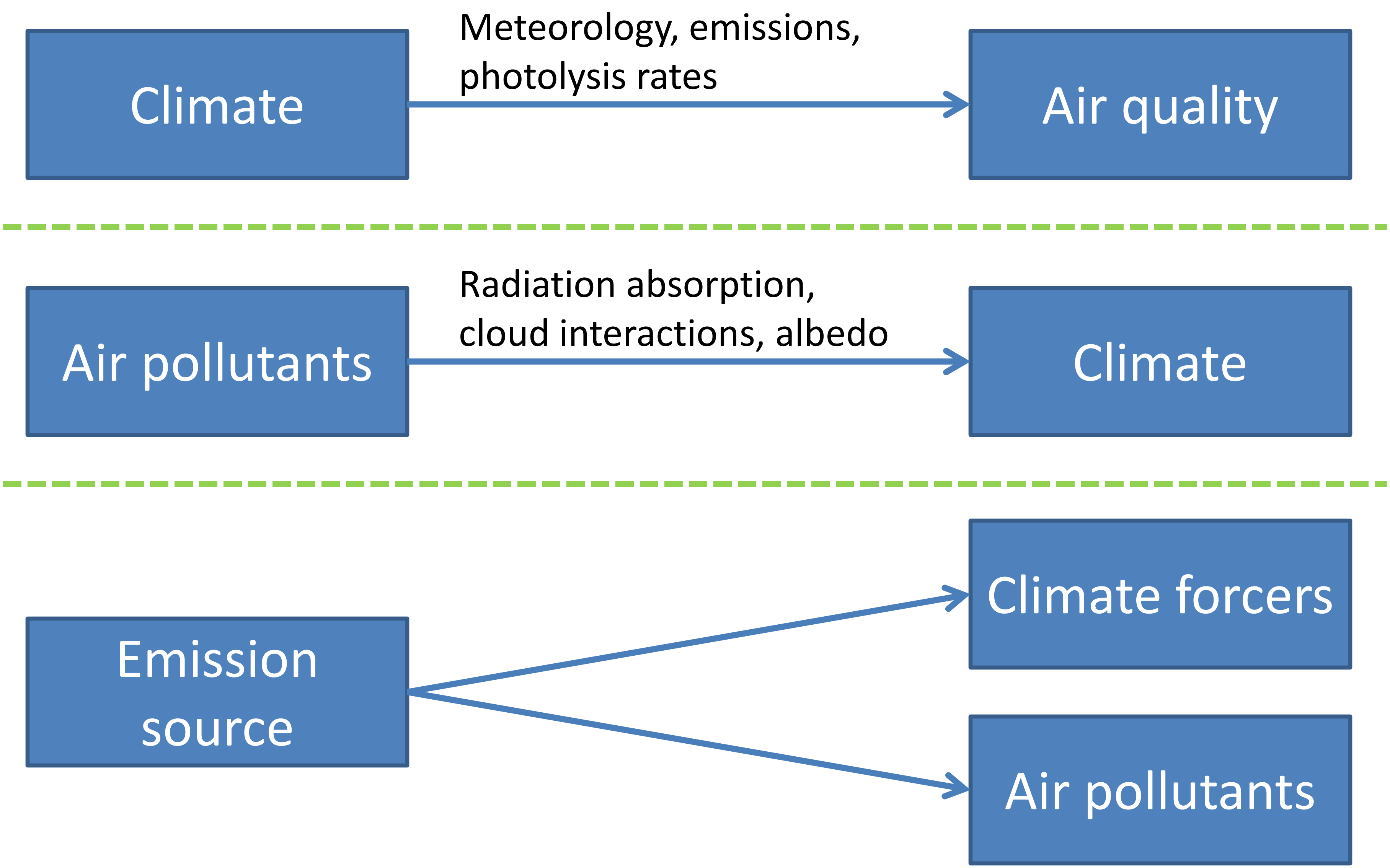
(% reduction in 2030 relative to reference)

Black Carbon Measures

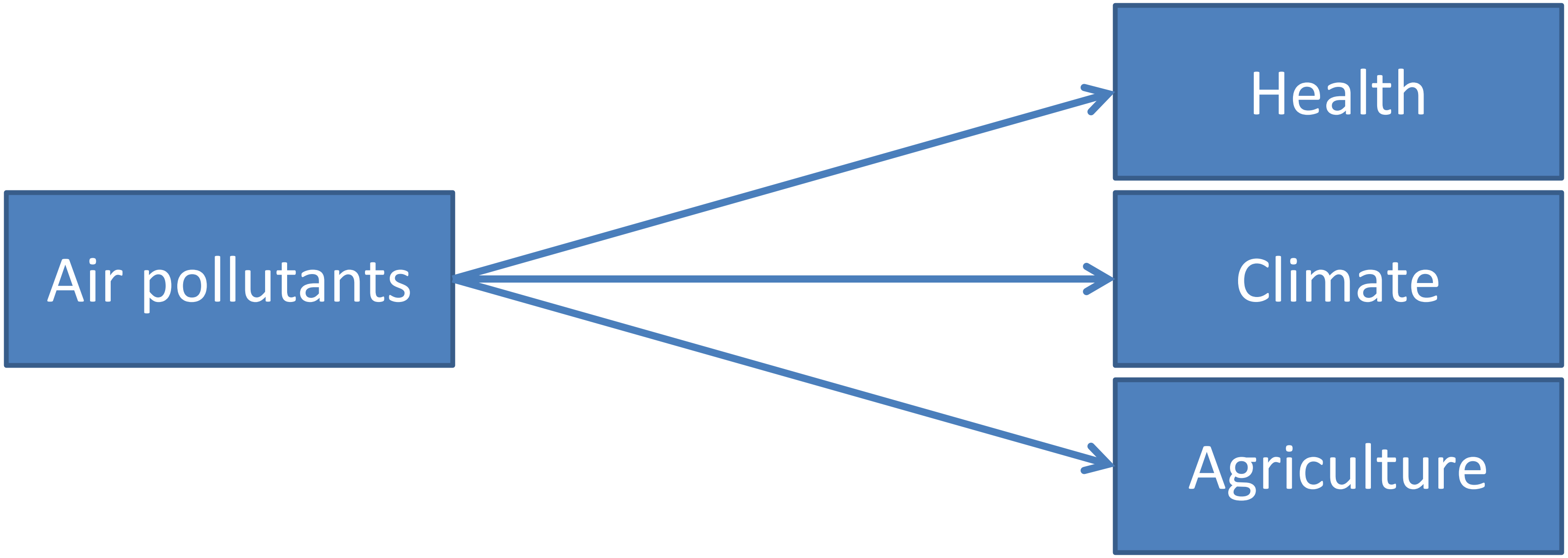
'BC Measures' that reduce emissions of black carbon and co-emissions (e.g. OC, CO)

- Diesel vehicles (particle filters+)
- Coal briquettes replacing coal in residential stoves
- Pellet stoves & boilers replacing residential wood burning in industrialized countries
- Clean-burning cookstoves in developing countries
- Modern brick kilns
- Modern coke ovens
- Ban of open burning of agricultural waste

Air quality-climate interactions



Finding near-term solutions



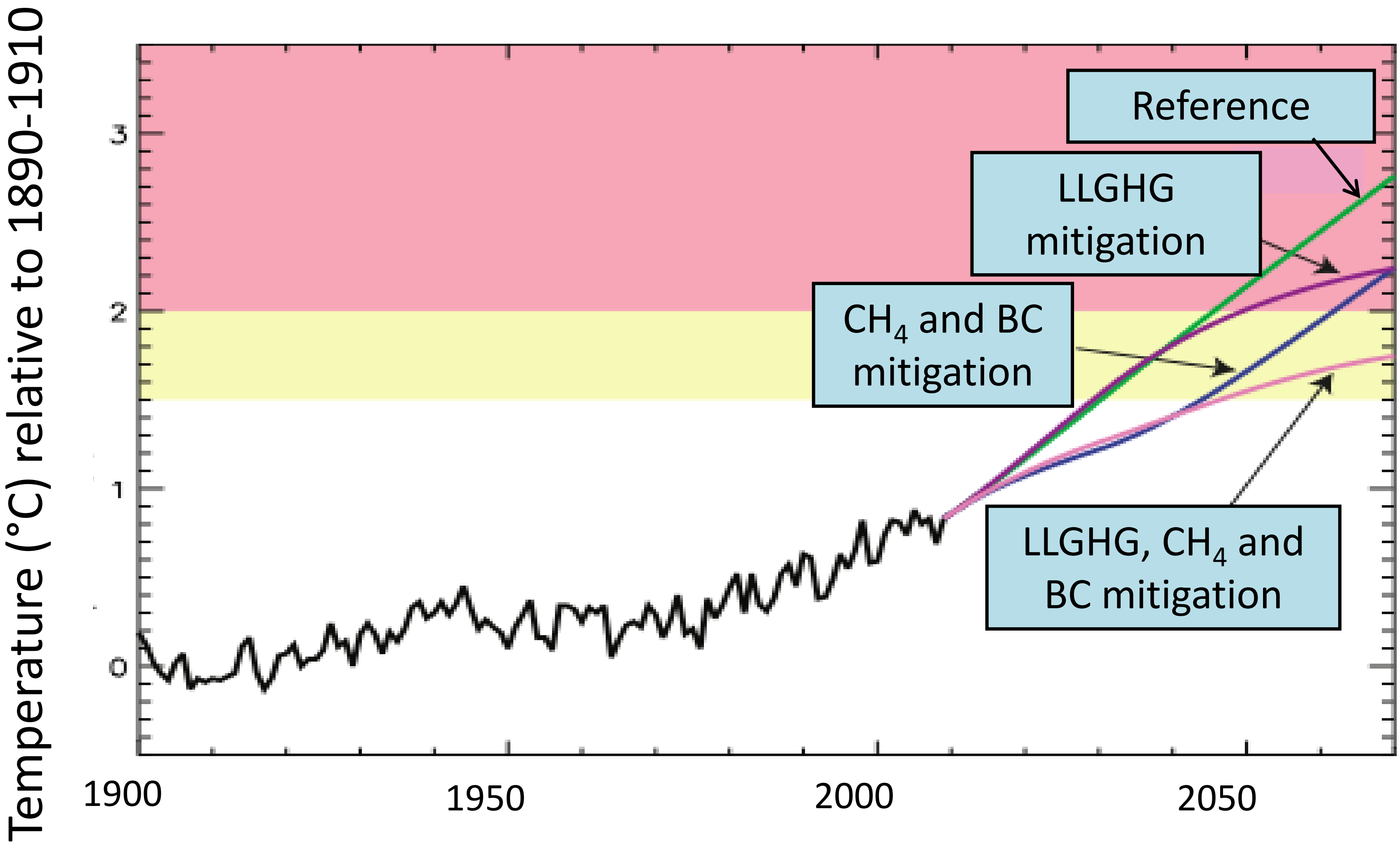
- Mitigation measures targeting $PM_{2.5}$ and ozone are employed around the world
- Those that target black carbon (BC) and methane may have climate co-benefits

What are the climate, health, and agricultural benefits of further implementing climate-friendly air pollution mitigation measures that have already been employed around the world?

UNEP/WMO Integrated Assessment of Black Carbon and Tropospheric Ozone

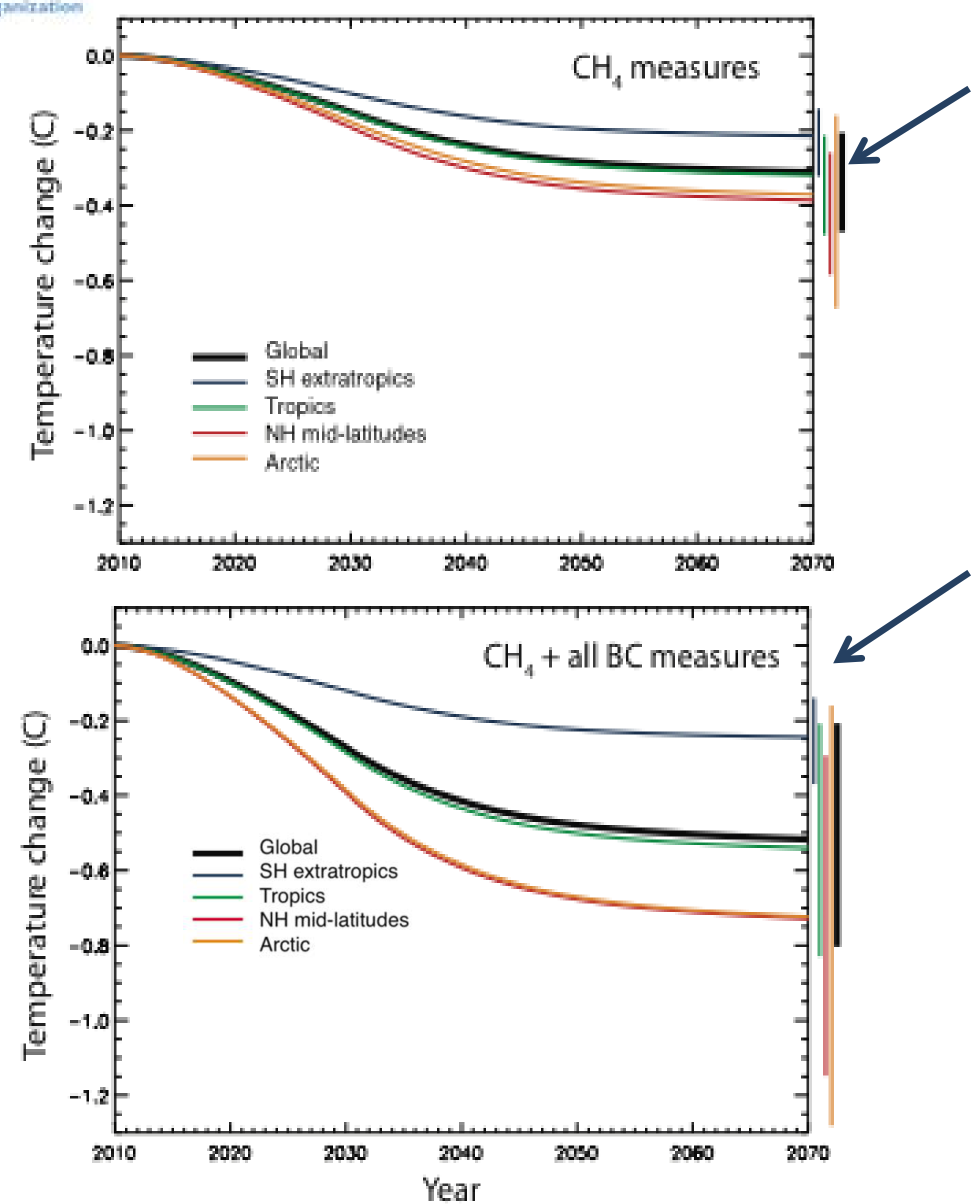
- Screened ~2000 emission control measures in GAINS database
- Identified 14 specific BC and methane emission control measures based on potential benefits for near-term climate
- Examined 5 emission scenarios:
  - Present-day (2005)
  - 2030 reference (business as usual)
  - **Methane** measures
  - Methane + **BC Group 1** measures (technological – i.e. diesel particulate filters, improving biomass cook stoves)
  - Methane + BC Group 1 + **BC Group 2** measures (policy – i.e. elimination of high-emitting vehicles and biomass cook stoves)
- Calculated climate, health, agricultural, and economic benefits of the 3 groups of measures

Near-term climate benefits



UNEP/WMO Integrated Assessment of BC and Ozone, 2011

Global and Regional Temperature Change Relative to the Reference Scenario (hybrid modelling of GISS, ECHAM informed by the literature)

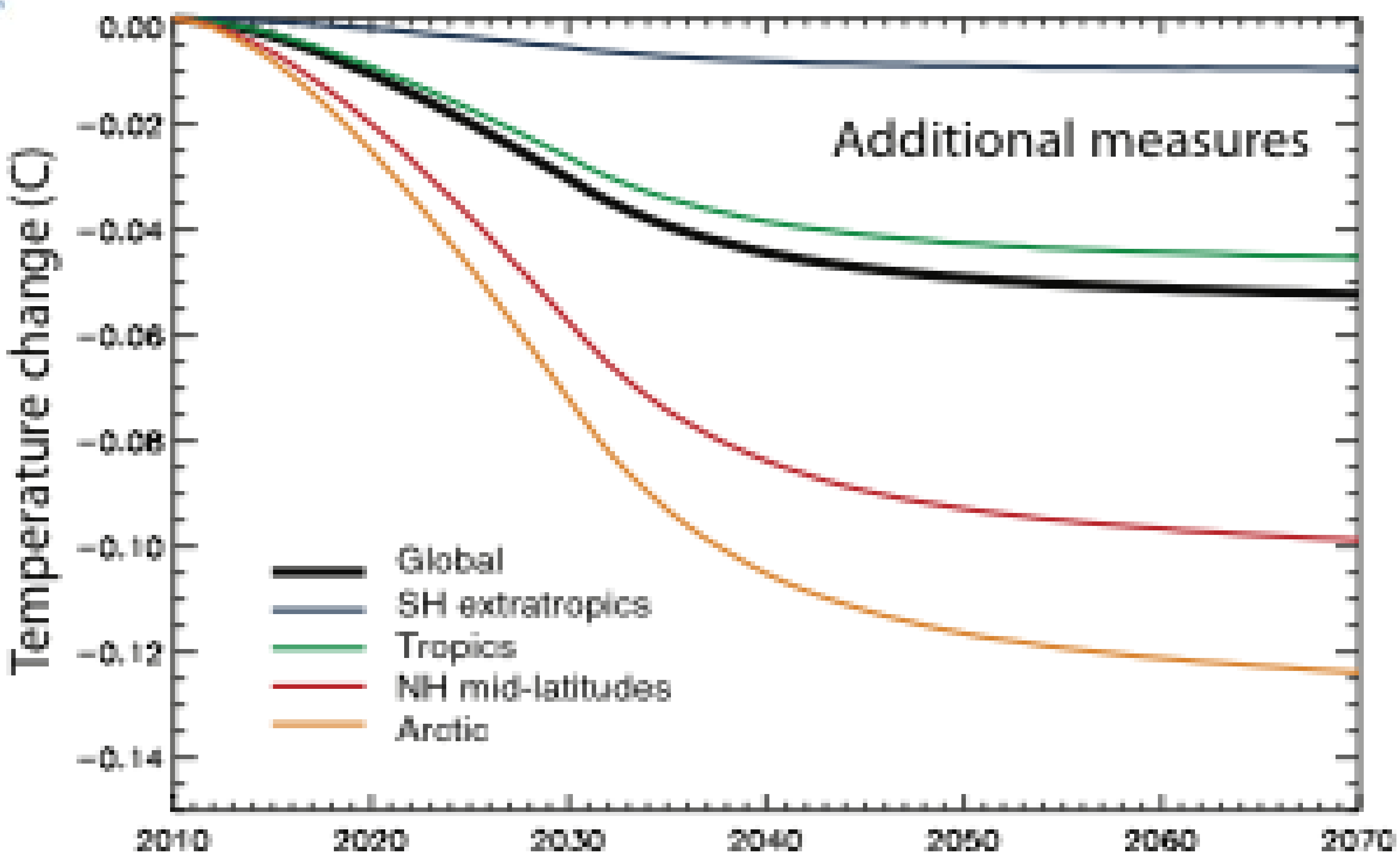


Methane measures:
Relatively uniform benefits, low uncertainty

BC measures:
Larger benefits in North, greater uncertainty for temperature (large regional precipitation & glacial melting benefits)

Reduced Arctic warming by 0.7°C by 2040 compared to the reference Scenario, with measures taken 2010---2030. **Mitigating ~2/3 of projected 1.2°C warming**

Global and Regional Temperature Change Relative to the Reference Scenario (modelling using of GISS)

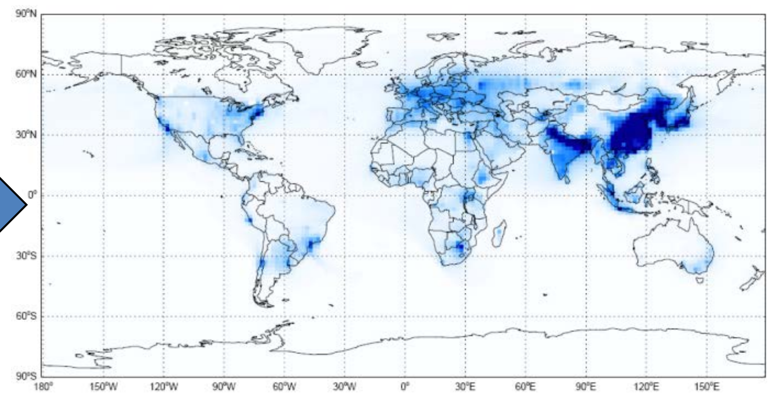


Global and regional temperature changes due to widespread use of pellet stoves and boilers in industrialized countries and coal briquettes in the residential sector in China.

Global air quality and health co-benefits of methane and BC emission controls

Methodology for outdoor health impact assessment:

Δ emissions - CH_4, BC, OC, NO_x, VOC, CO, SO_2, CO_2



Δ $PM_{2.5}$ and ozone concentration

Δ $PM_{2.5}$ and ozone-related mortality

Two global composition-climate models

GISS-PUCCINI (2°x2.5°), ECHAM-HAMMOZ (2.8°x2.8°)

1. **Downscale to 0.5°x0.5° based on population**
2. **Health impact function**

$$\Delta Mort = (1 - e^{-\beta \Delta X}) \times Pop \times y_0$$

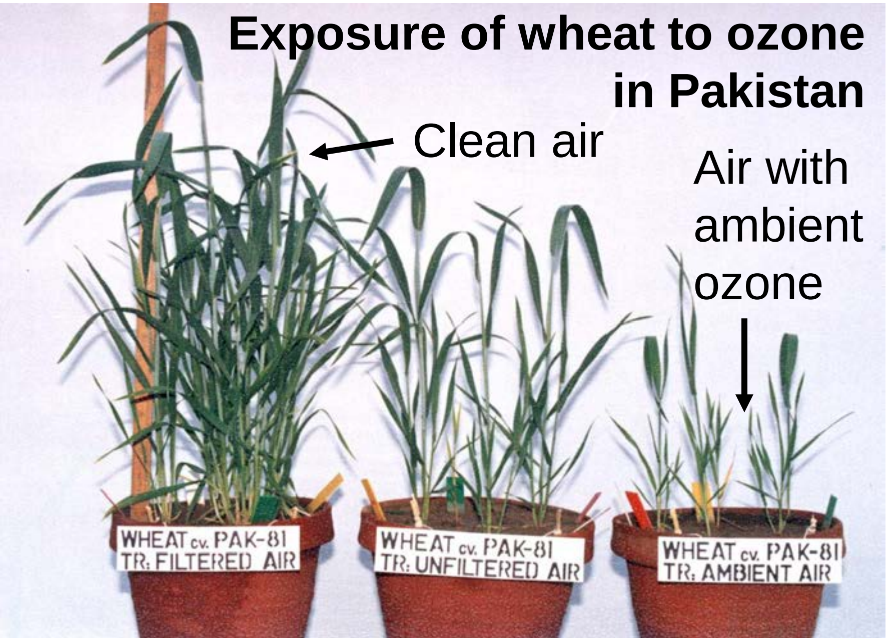
β = concentration-response factor

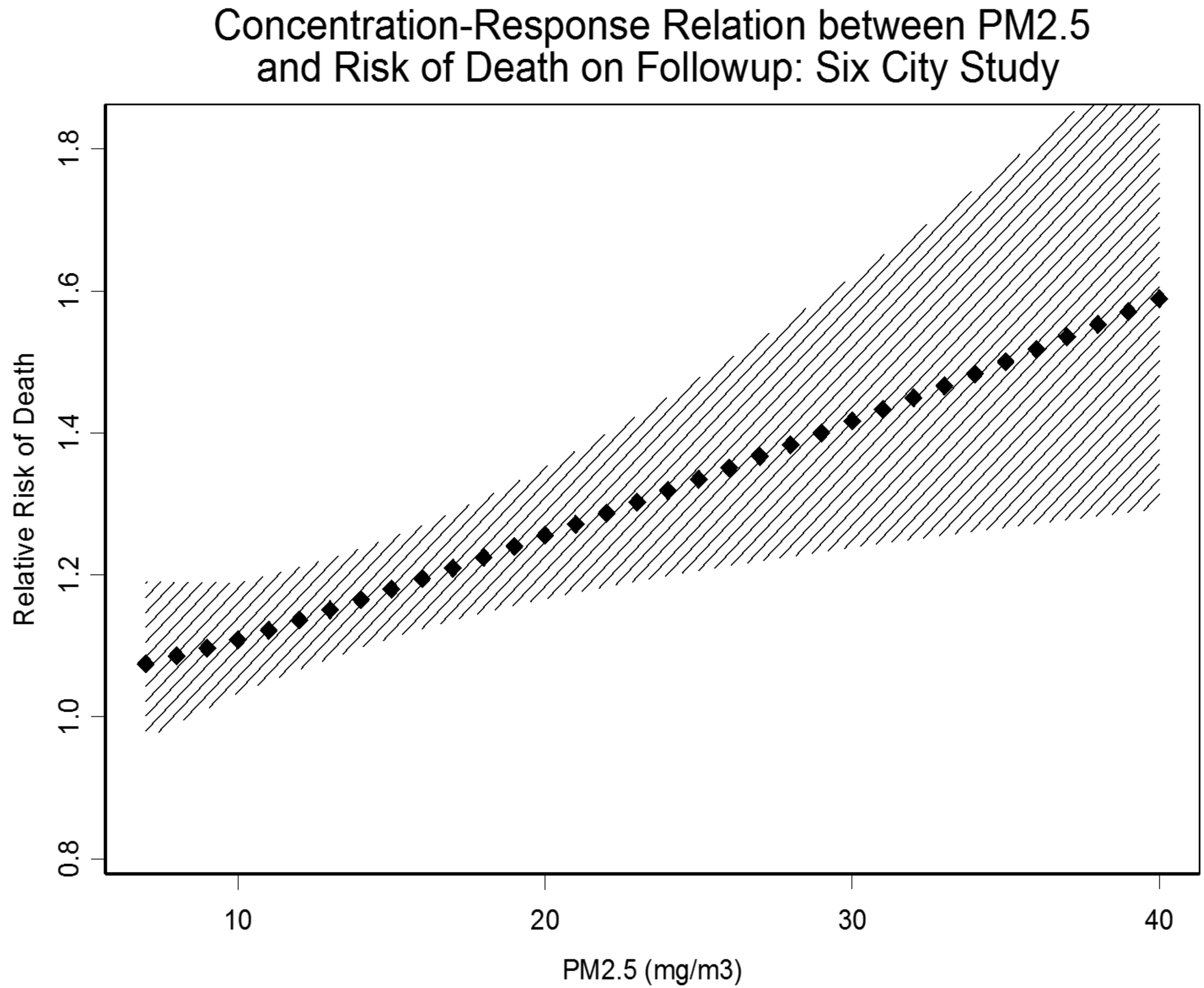
ΔX = change in $PM_{2.5}$ or ozone concentration

y_0 = baseline mortality rate

Impact of the Measures on Health and Crop yields

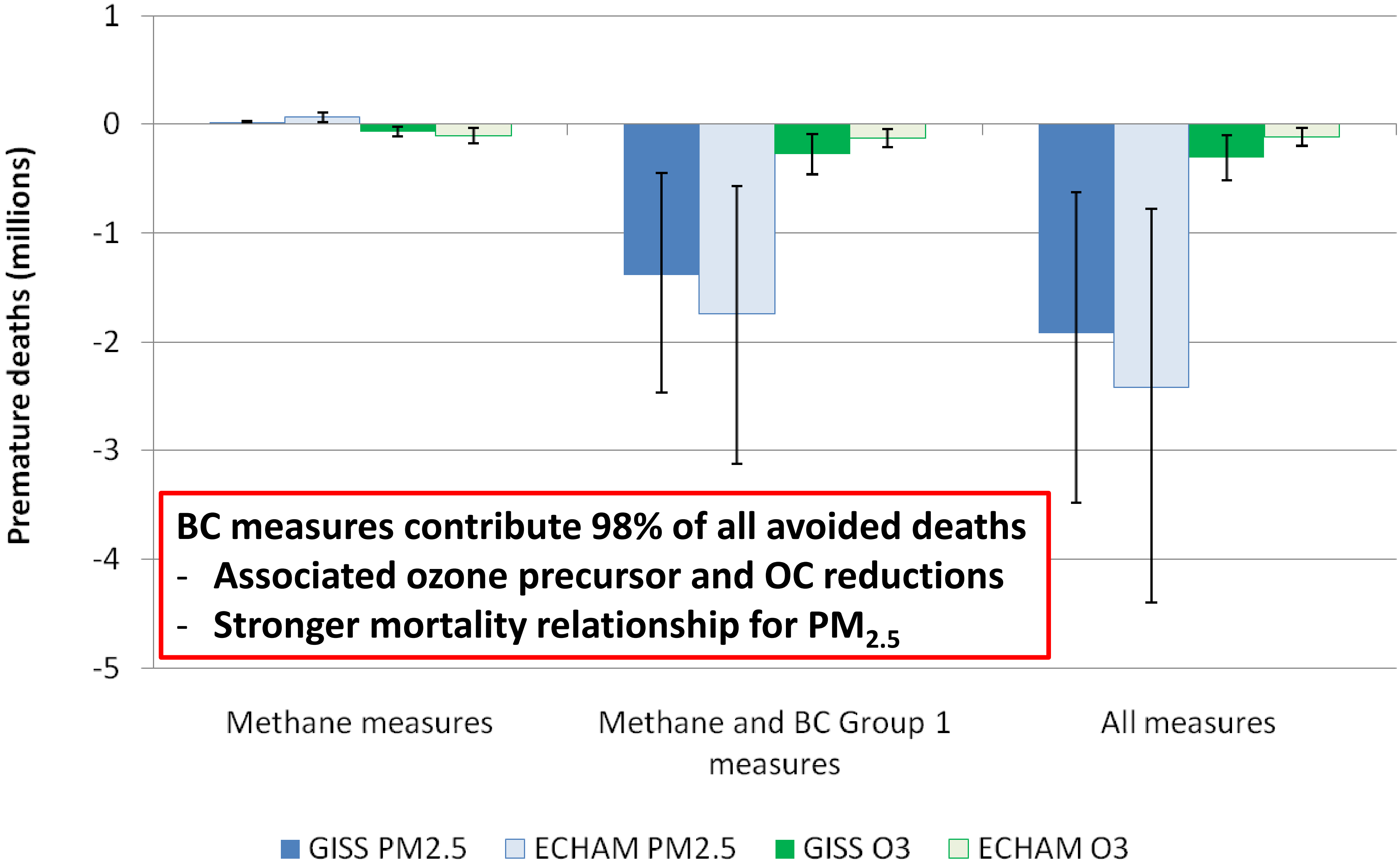
- Models give **$PM_{2.5}$ and ozone concentrations** for health and crop yield impact assessment
- Concentration-response relationships from literature used to evaluate global impacts





Concentration-Response Relation between PM2.5
and Risk of Death on Followup: Six City Study
Relative Risk of Death
0.8
1.0
1.2
1.4
1.6
1.8
10
20
30
40
PM2.5 (mg/m3)

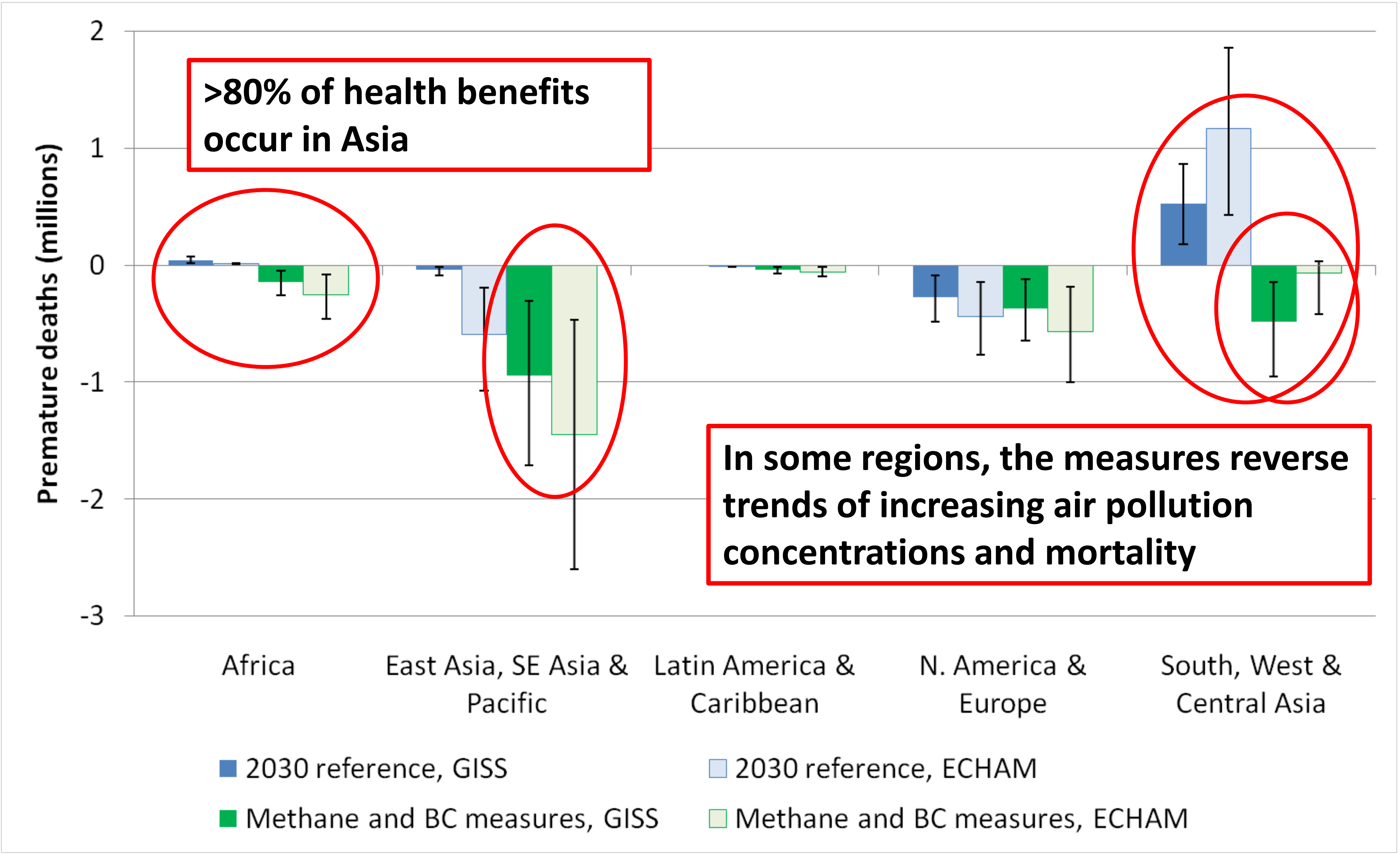
Change in $PM_{2.5}$ and ozone-related premature deaths relative to 2030 reference



BC measures contribute 98% of all avoided deaths

- **Associated ozone precursor and OC reductions**
- **Stronger mortality relationship for $PM_{2.5}$**

Change in $PM_{2.5}$ and ozone-related premature deaths relative to 2005



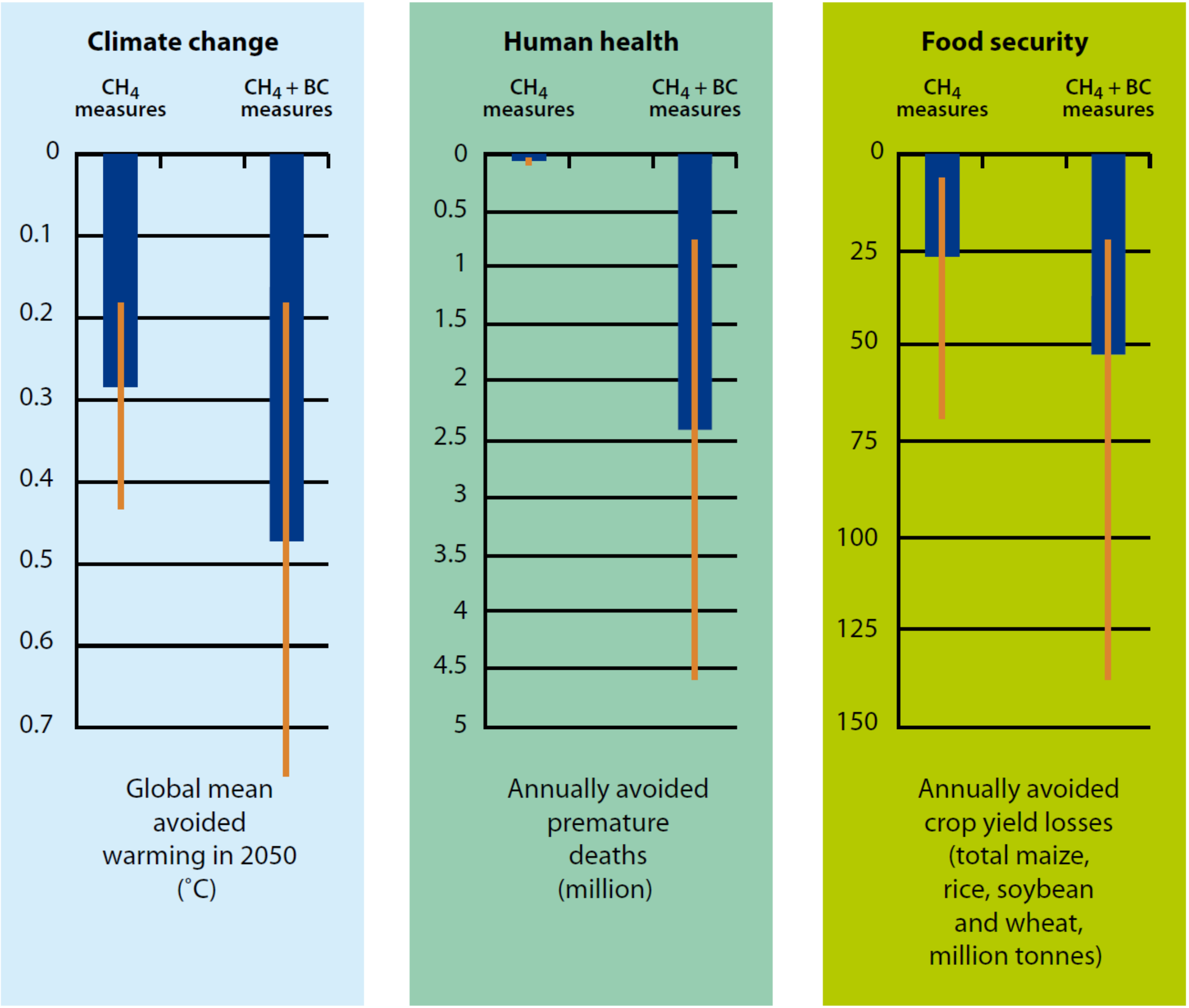
So far I have Spoken about Climate

- What about health and food security?
- Crop benefits are substantial – *could* **avoid loss of 52 million tonnes** (30-140 million) of maize, rice, wheat and soybean, each year
- The identified **measures are all currently in use** in different regions around the world; much wider and more rapid implementation is required to achieve the full benefits

In Addition

- Experimental studies show that grains grown in higher CO_2 atmospheres have lower Zinc and Iron content
- Zinc deficiency is widespread in the developing world and accounts for a substantial burden of disease

Benefits of mitigating short-lived climate forcers



Not Included

- Direct impacts of temperature on health
- Direct impacts of temperature on crop yields

What do we know about the Direct Effects of Temperature?

- We have a large number of time series studies which look at day to day changes in weather and day to day changes in mortality
- They show more people die when it gets hot, and more people die when it gets cold
- What does this tell us about what will happen as the climate changes?

Nothing

- Why?
- In cold cities it needs to get a lot colder before people start dying
- In hot cities it needs to get a lot hotter before people start dying
- So what happens when these cities get warmer?

Options

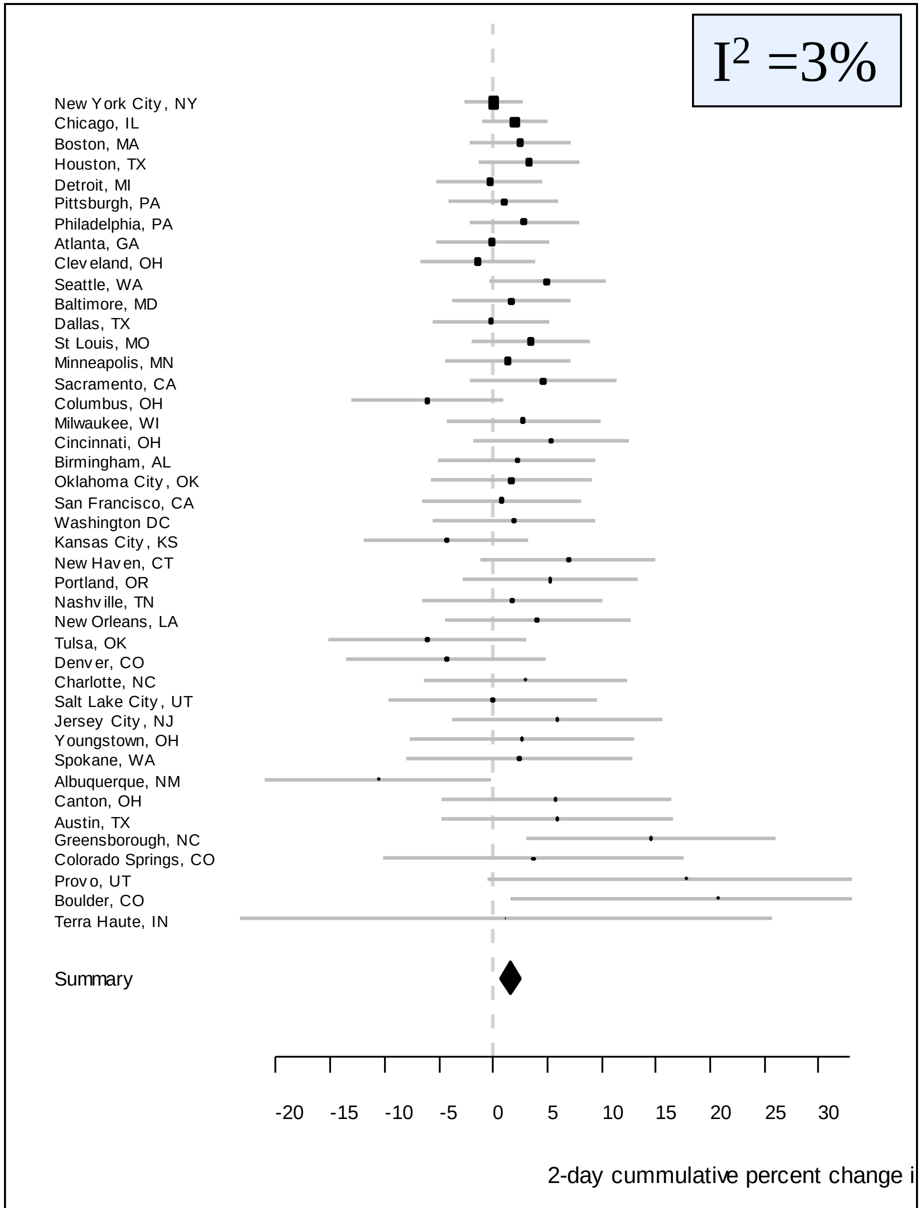
- Nothing, people adapt
- Something
  - More deaths (more heat waves)
  - Fewer deaths (fewer cold spells)

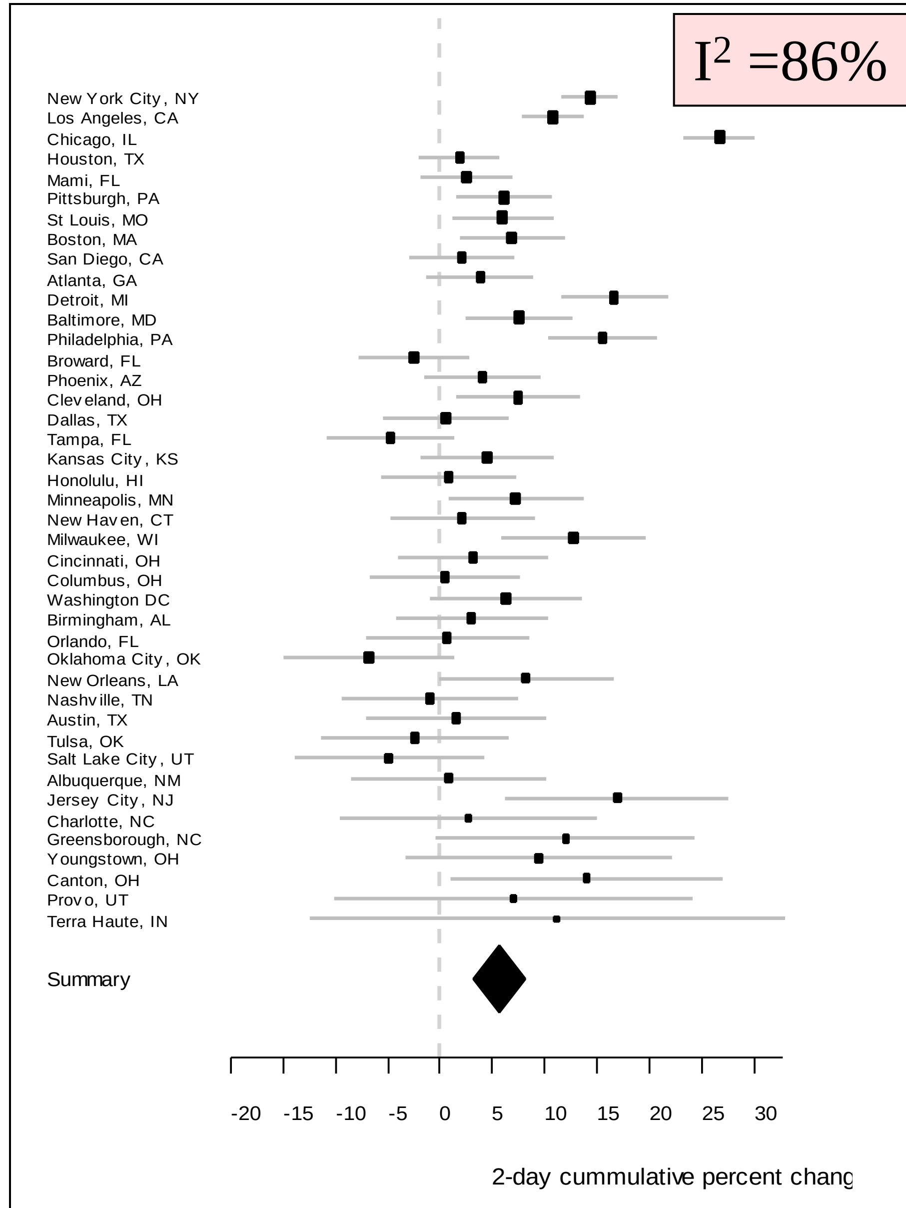
We Studied 50 US Cities

- Looked at the effect of the coldest 1% of days in each city
- And the hottest 1% of days in each city
- Compared to the rest

Extreme cold effect

Extreme heat effect





So it looks like

- The effects of the coldest 1% of days are the same everywhere in the US
- So warming the winter is unlikely to reduce deaths

- The effects of the hottest 1% of days differs substantially across US cities
- So even if we use the dose-response from city A which already has the predicted temperature for city B, we will expect changes in mortality

Cohort Study of Medicare Participants in 135 US Cities

- Follow a population over time and look at life expectancy
- What is the Exposure?
  - *Problem*
  - Life expectancy in Finland and Greece is about the same
  - *Possible Answer*
  - Variability of summer temperature predicts mortality differences

Statistical methods for Cohort Study

- *Problem*
- Temperature variability increasing, mortality rates decreasing over time
- Remove time trends in each city, and examine whether year-to-year variations in summer temperature standard deviation correlates within each city with year-to-year variations in survival.
- No confounding across city, or by time trend within city

Table 2. HR and 95% CI for a 1 °C increase in yearly summer temperature SD across 135 US cities in each of the four cohorts studied, 1985–2006

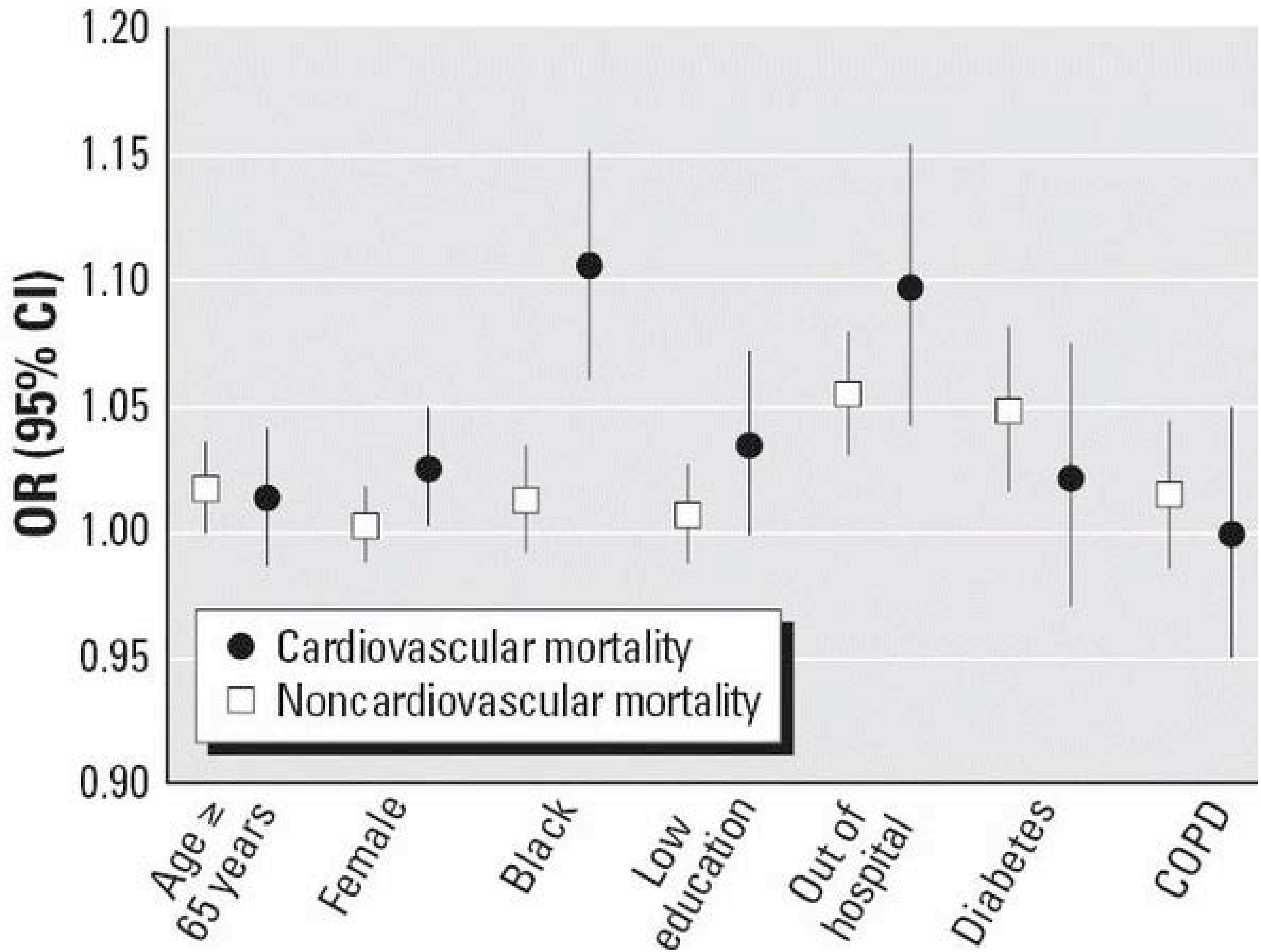
	HR	95% CI
COPD	1.048	1.029–1.067
Diabetes	1.055	1.035–1.076
MI	1.050	1.030–1.069
CHF	1.038	1.024–1.052
Adjusting for ozone		
COPD	1.037	1.019–1.055
Diabetes	1.040	1.022–1.059
MI	1.038	1.021–1.055
CHF	1.028	1.013–1.042
Adjusting for heat waves		
COPD	1.069	1.052–1.087
Diabetes	1.076	1.058–1.095
MI	1.073	1.055–1.091
CHF	1.061	1.047–1.076
Adjusting for ozone and heat waves		
COPD	1.064	1.044–1.083
Diabetes	1.052	1.036–1.069
MI	1.071	1.051–1.092
CHF	1.065	1.047–1.083

Risk Assessment Questions

- How does this extrapolate across time?
- How does this extrapolate to other places?
- What about Equity?
  - Suppose there are high risks in subgroups of the population?

Medina Ramon et al Studied 50 Cities, 8 million deaths

- Case only analysis for effect modifiers



OR (95% CI)
1.20
1.15
1.10
1.05
1.00
0.95
0.90
Cardiovascular mortality
Noncardiovascular mortality
Age ≥ 65 years
Female
Black
Low education
Out of hospital
Diabetes
COPD

Distribution of vulnerability to heat waves