Assessing the Health Outcomes of Air Quality Actions

EMPA Conference

Albany, Nov 15, 2010

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Health Effects Institute

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HEI

What is the Health Effects Institute?

- Independent non-profit research institute, founded in1980
- Joint funding from:
  - Government (**U.S. EPA**, DOE, CARB, European Commission)
  - Industry (**Motor Vehicle Manufacturers**, Oil, Chemical, Others)
- Independent Board and Expert Science Committees
  - Activities: targeted research, timely science reviews, re-analysis, improved methods
  - Competitive research selection
  - Separate intense peer review before publication
  - Over 250 studies on health effects of air pollution
  - Many special reports and communications
- Full Transparency
  - All Results – positive and negative – published
  - Investigators free to public in the literature
  - Data made accessible
- HEI does *not* take policy positions

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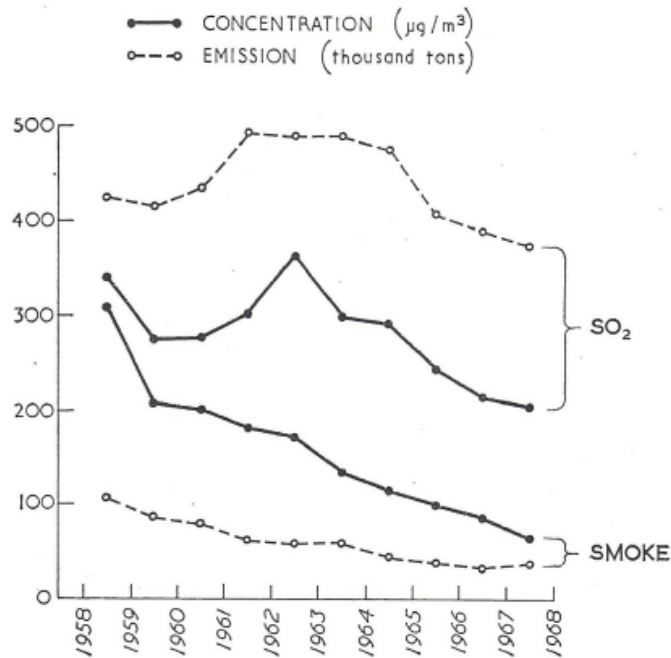
Air Pollution in London, 1952

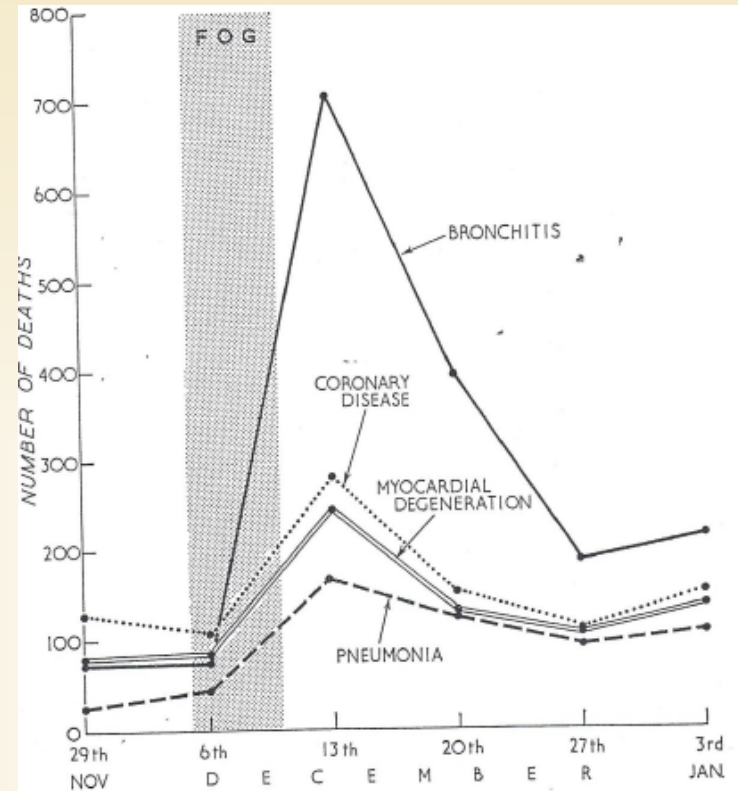FIGURE 13   CHANGES IN THE EMISSION OF SMOKE AND SULPHUR DIOXIDE AND THEIR CONCENTRATION IN LONDON AIR

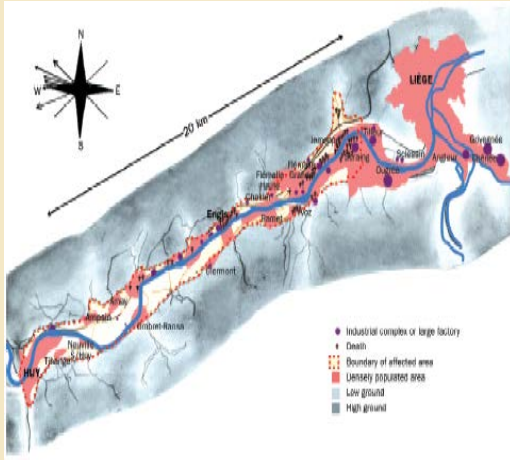FIGURE 3   DEATHS FROM DISEASES OF THE LUNGS AND THE HEART AT THE TIME OF THE FOG OF DECEMBER 1952

Key Air Pollution Events of the Mid-20ᵗʰ Century

The Fog Disaster in the **Meuse Valley, 1930**...led to the first scientific proof of the potential for atmospheric pollution to cause deaths and disease, and it clearly identified the most likely causes. 60 deaths that were attributed to the fog occurred on Dec 4 and 5. *Nemery et al. Lancet 2001*

Beginning on **October 26, 1948,** sparse air movement contributed to a temperature inversion in the atmosphere over western Pennsylvania, Ohio, and areas of neighboring states. A fog laden with particulates and other industrial contaminants saturated the air of **Donora**, a small industrial town on the banks of the Monongahela River, some 30 miles south of Pittsburgh. Visibility was so poor that even locals lost their sense of direction. An estimated 5000 to 7000 persons in a town of 14000 residents became ill, some 400 required hospitalization, and 20 died before rain dispersed the killing smog on October 30 and 31, 1948. *Helfand et al. AJPH 2001*

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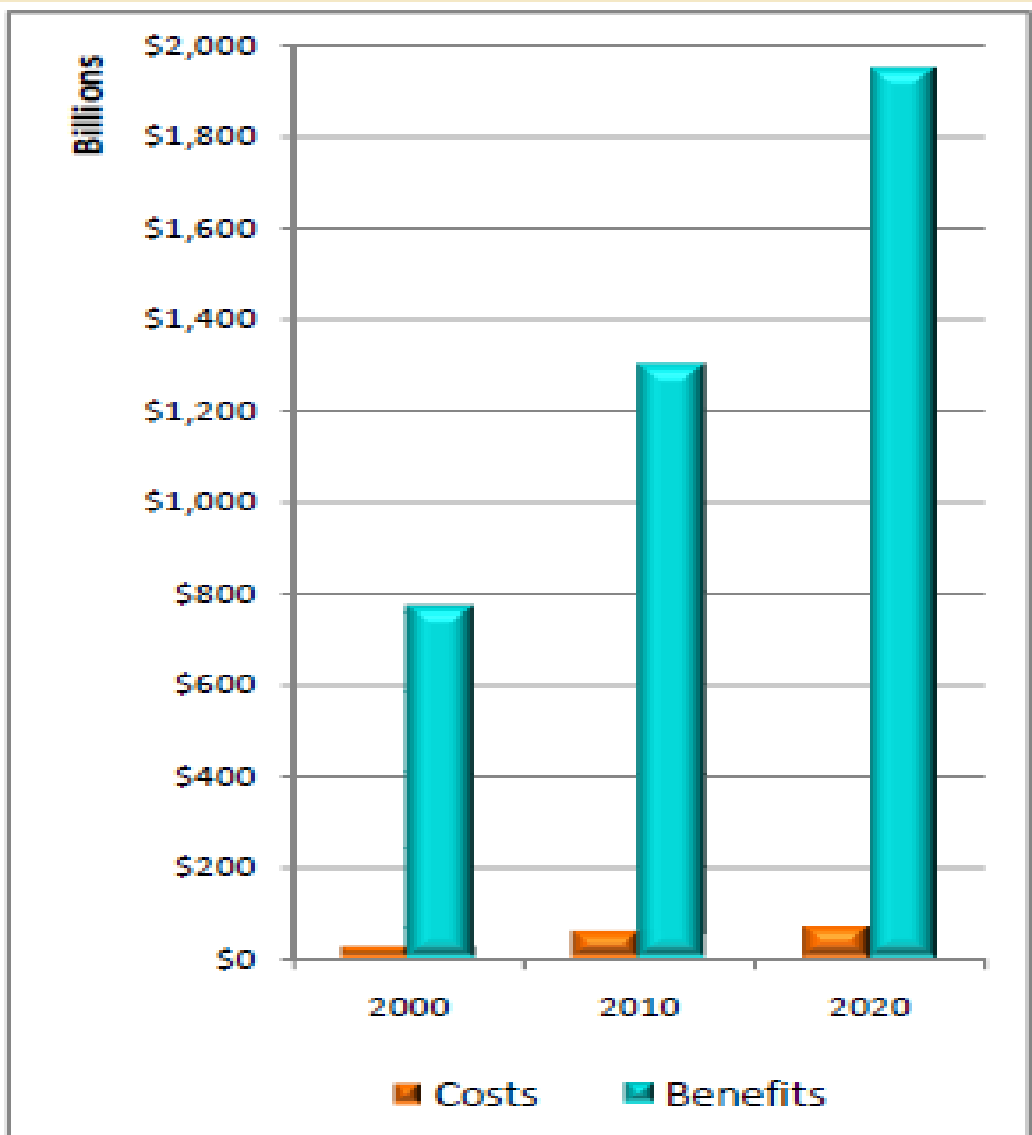
Exhibit 1. Primary Central Estimates of direct benefits and direct costs for the 2000, 2010, and 2020 study target years. (In billions of 2006 dollars). The graph shows the extent to which benefits exceed costs throughout the study period.

Source: US EPA, Office of Air and Radiation. (2011). "The Benefits and Costs of the Clean Air Act from 1990 to 2020. Summary Report. Washington DC
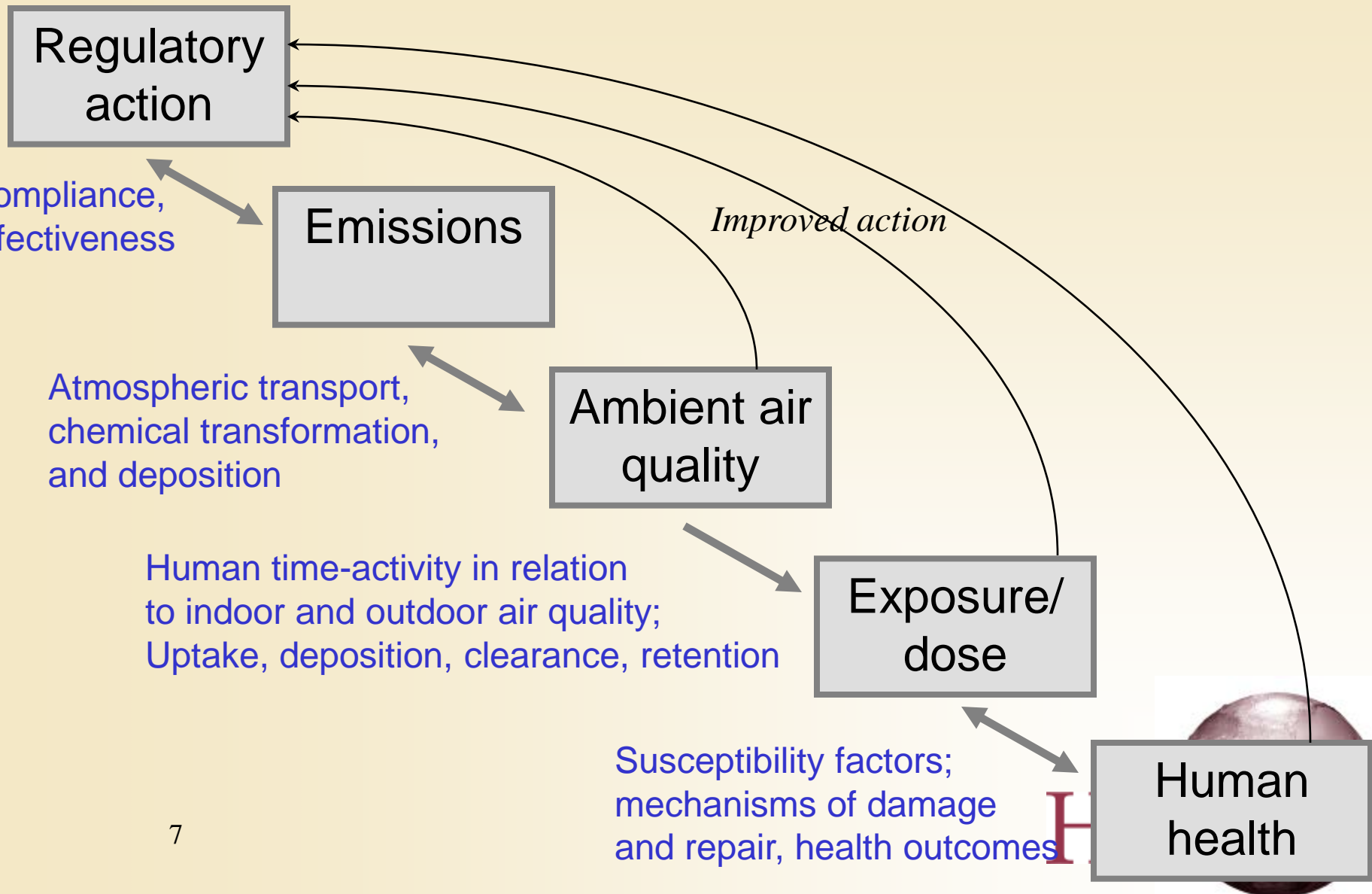
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Health Outcomes Research

- **What** is Health Outcomes Research: Evaluate the extent to which air quality regulations improve public health (this is a part of a broader effort to assess the performance of environmental policy)

- **Why** Study Outcomes?

  – In North America and Western Europe, air quality has improved substantially over the past decades

  – Further improvements are becoming more costly

  – Need to ensure that current and future regulations are achieving the intended public health benefits

  – Develop and amass data on trends in AQ and health changes

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The Accountability Chain

Regulatory action

Compliance, effectiveness

Emissions

Improved action

Atmospheric transport, chemical transformation, and deposition

Ambient air quality

Human time-activity in relation to indoor and outdoor air quality; Uptake, deposition, clearance, retention

Exposure/ dose

Susceptibility factors; mechanisms of damage and repair, health outcomes

Human health

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Challenges of Outcome Studies

- Temporal and Geographic Heterogeneity
  - Implementation over a period of time
  - Effects gradual and slow; possible delays
  - Geographic variations in implementation
  - Confounding with secular trends
- Factors Beyond AQ Actions
  - Economic activity and commerce
  - Demographic and behavioral changes
  - Other unrelated events: e.g., forest fires
  - Changes in health care/delivery
- Complexity of Human Response
  - Time scale of effects (e.g., COPD, Cancer)
- Availability and Access to Relevant Data
- Conceptual Issues: Analytical and statistical challenges; Association vs Causality

Types of Accountability Studies

Actions Implemented Over a Short Term

- Into full force quickly (step-change)
- Other variables (diet, smoking, migration, health status, socio-economic factors) do not change appreciably
- Require daily health outcome and air quality data over short periods
- Often local or regional scale

Actions Implemented Over an Extended Period

- Implementation occurs gradually
- Trends in other variables (smoking, migration, health status, economy, etc), make it more difficult to isolate health impact
- Require health tracking, air quality, & monitoring data over many years

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Respiratory Disease Association with Community Air Pollution and a Steel Mill, Utah Valley*

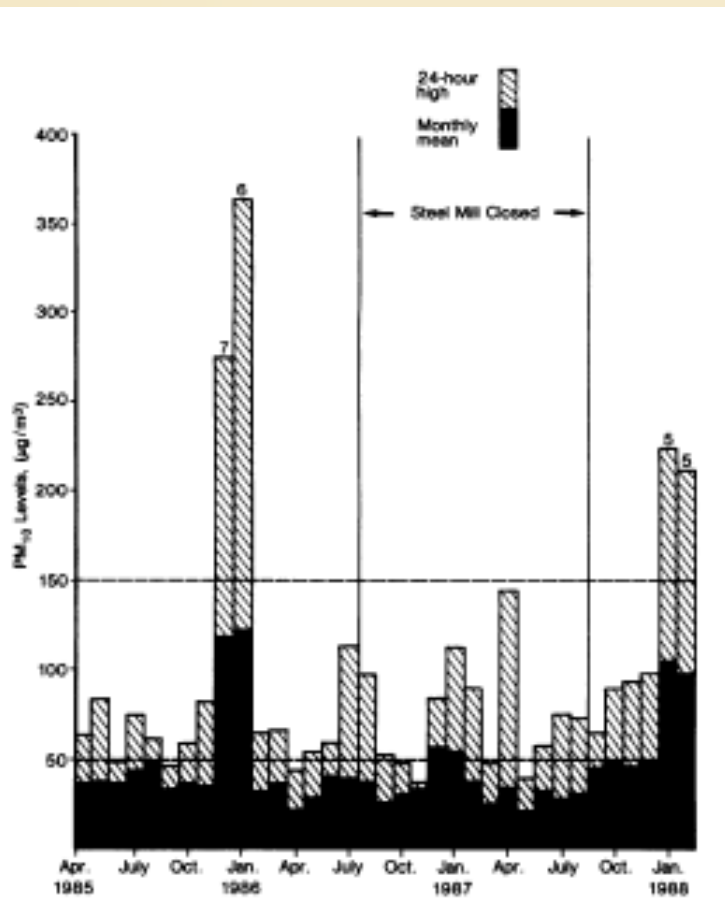## Hospital Admissions (Children and All) and PM10 during 4/85 – 2/88

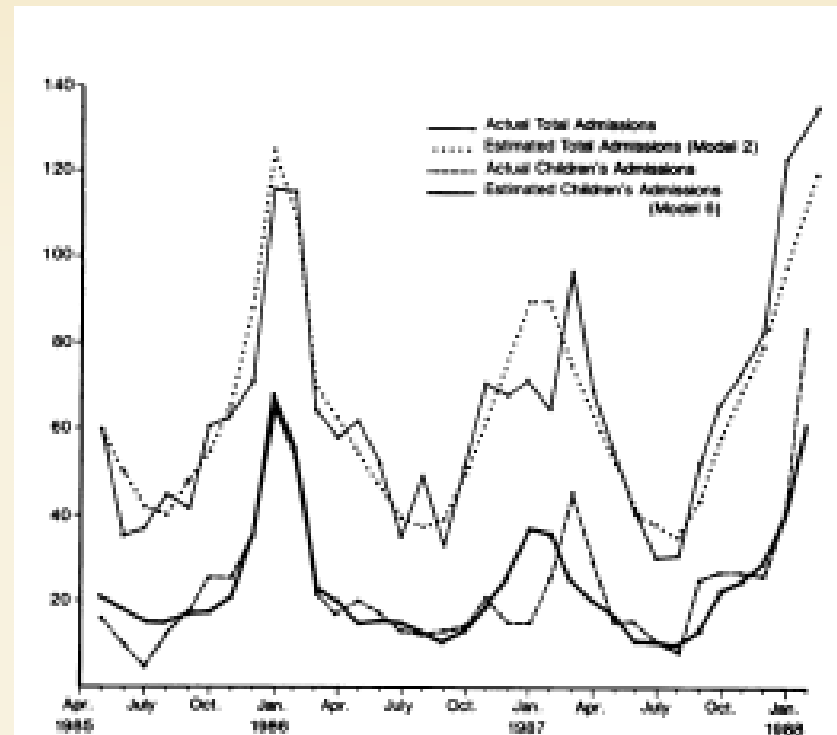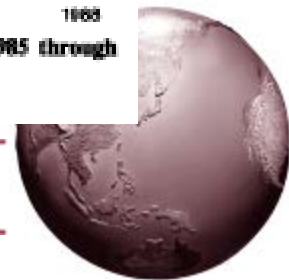FIGURE 2—Monthly Mean and 24-Hour High PM₁₀ (fine particulate pollution) Levels, Utah Valley, April 1985–January 1988

FIGURE 3—Actual and Estimated Hospital Admissions, April 1985 through January 1988, Utah Valley

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*CA Pope. AJPH 1989 79: 623-628

SHORT-TERM STUDY
*The Atlanta Olympics Study**

- Impact of Improved Air Quality During the 1996 Summer Olympic Games in Atlanta on Multiple Cardiovascular and Respiratory Outcomes; Jennifer Peel, et al., HEI Report # 148 (April 2010).
  - Actions taken to reduce traffic volume and congestion and the concurrent reductions in air pollution.

* Slides courtesy of J. Peel

Rationale

- Previously published study reported decreases in pediatric Medicaid asthma ED and hospitalization claims during the Olympic time period compared to 4 weeks before and after (Friedman et al., JAMA 2001) (RR=0.48; 95% CI 0.44, 0.86)
  - Smaller reductions in pediatric asthma ED visits (RR=0.93; 95% 0.71, 1.22)
  - Reductions attributed to reduced traffic
  - Questions about confounding by time trends, including seasonal patterns, and behavioral changes during the Olympics
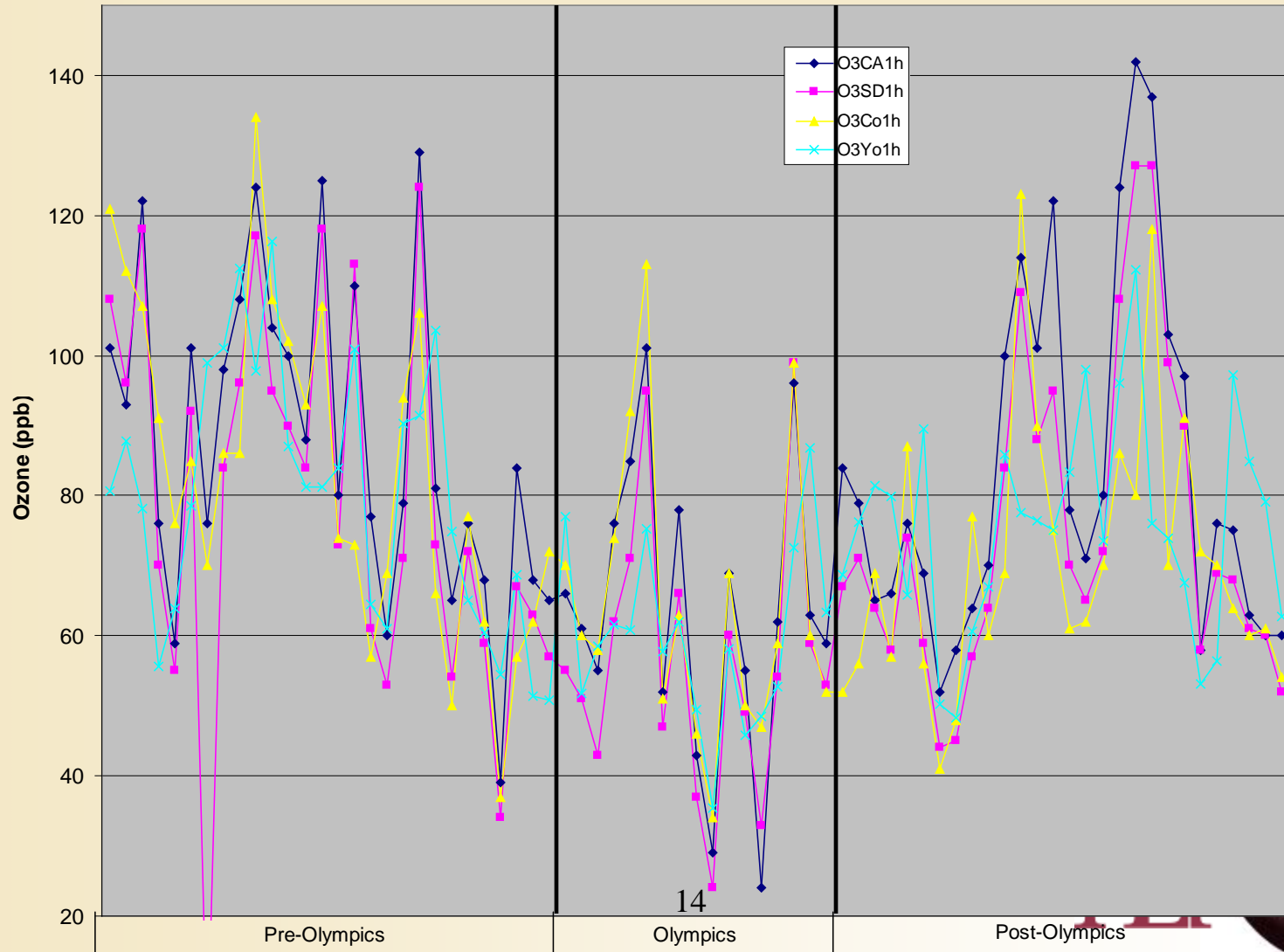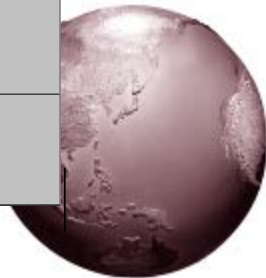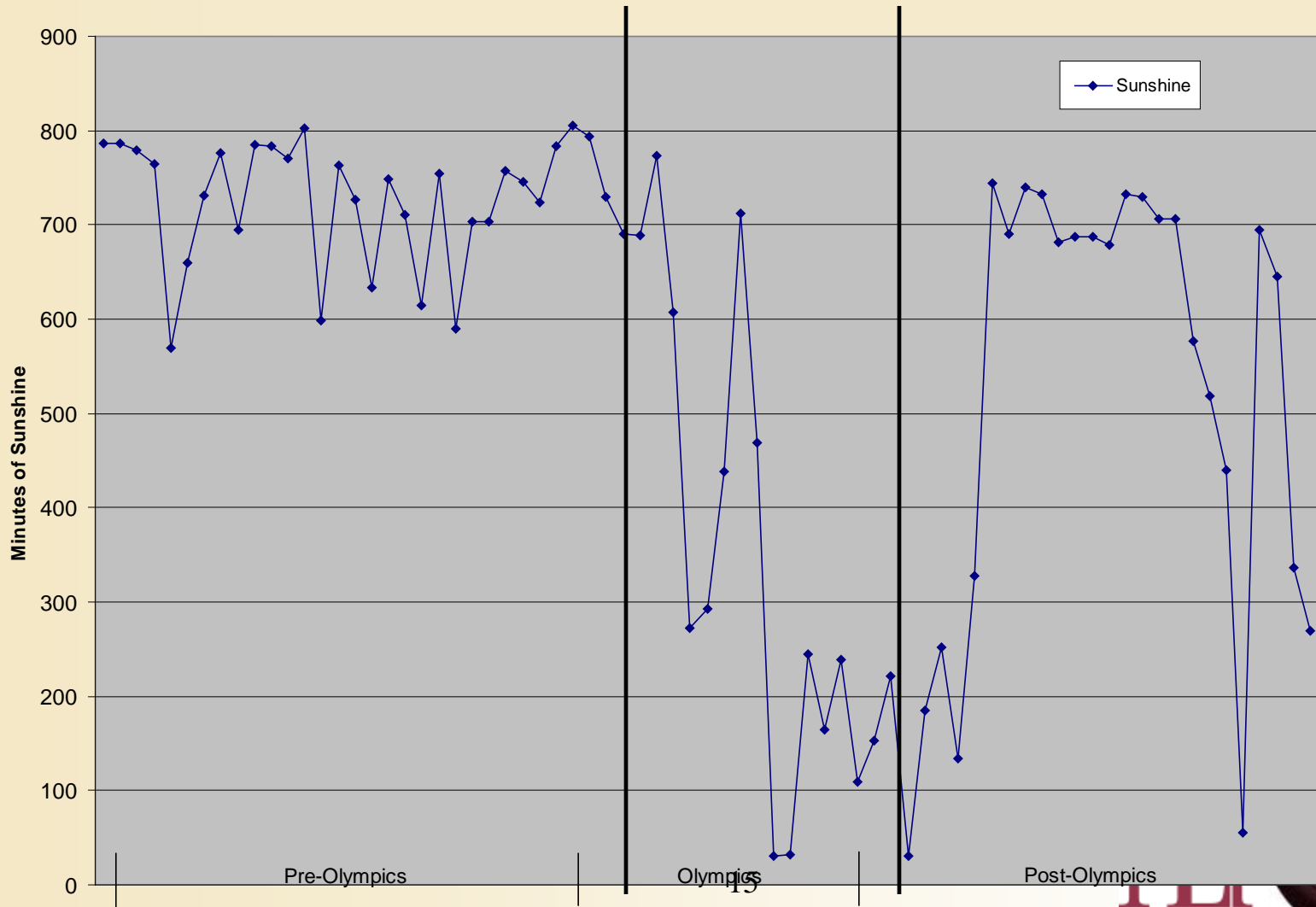
Objective

- Assess impact of reduced air pollution levels during the 1996 Olympics on multiple cardiovascular and respiratory outcomes
  - ED visits (pediatric and other age groups)
  - Various controls for time trends
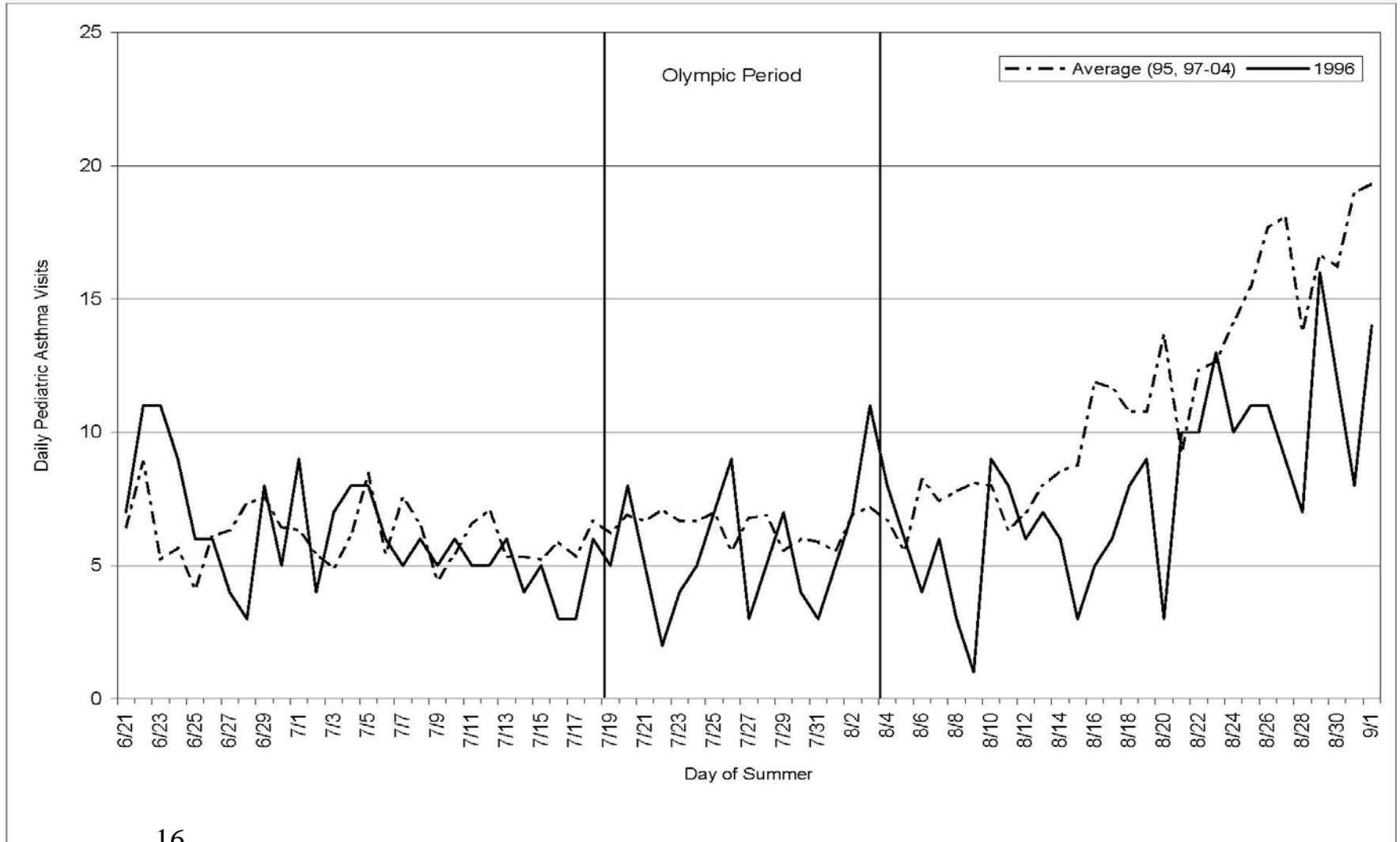
Results – Ozone (1-hour max)

Chart legend: O3CA1h, O3SD1h, O3Co1h, O3Yo1h

Y-axis: Ozone (ppb) — 20, 40, 60, 80, 100, 120, 140

X-axis categories: Pre-Olympics, Olympics, Post-Olympics
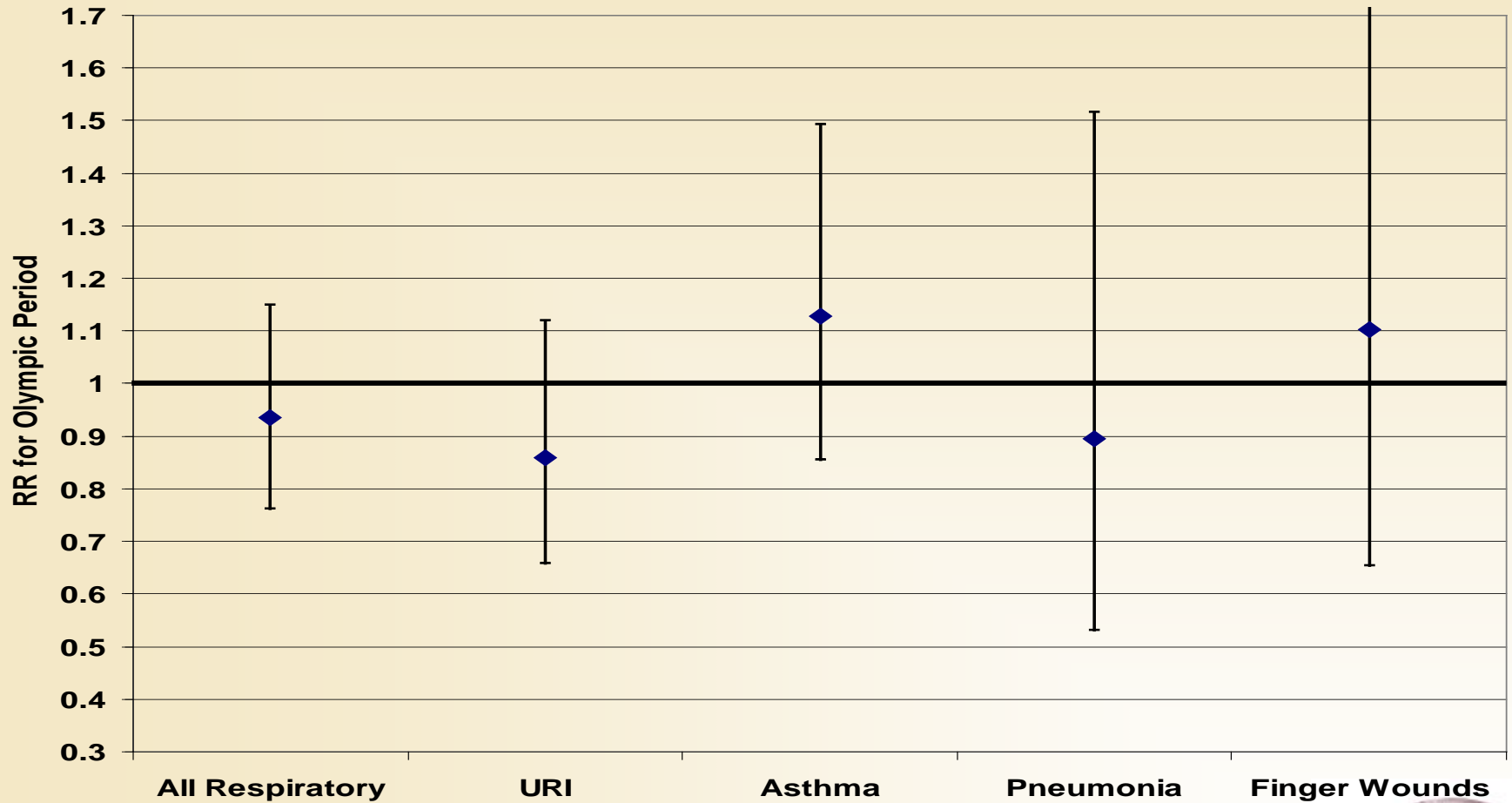
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Hours of Sunshine

Results – Pediatric Asthma Visits

Figure 3. Time-series plot of daily pediatric asthma emergency department counts from two pediatric hospitals in the five-county Atlanta area for 1996 and the average of years 1995, 1997-2004
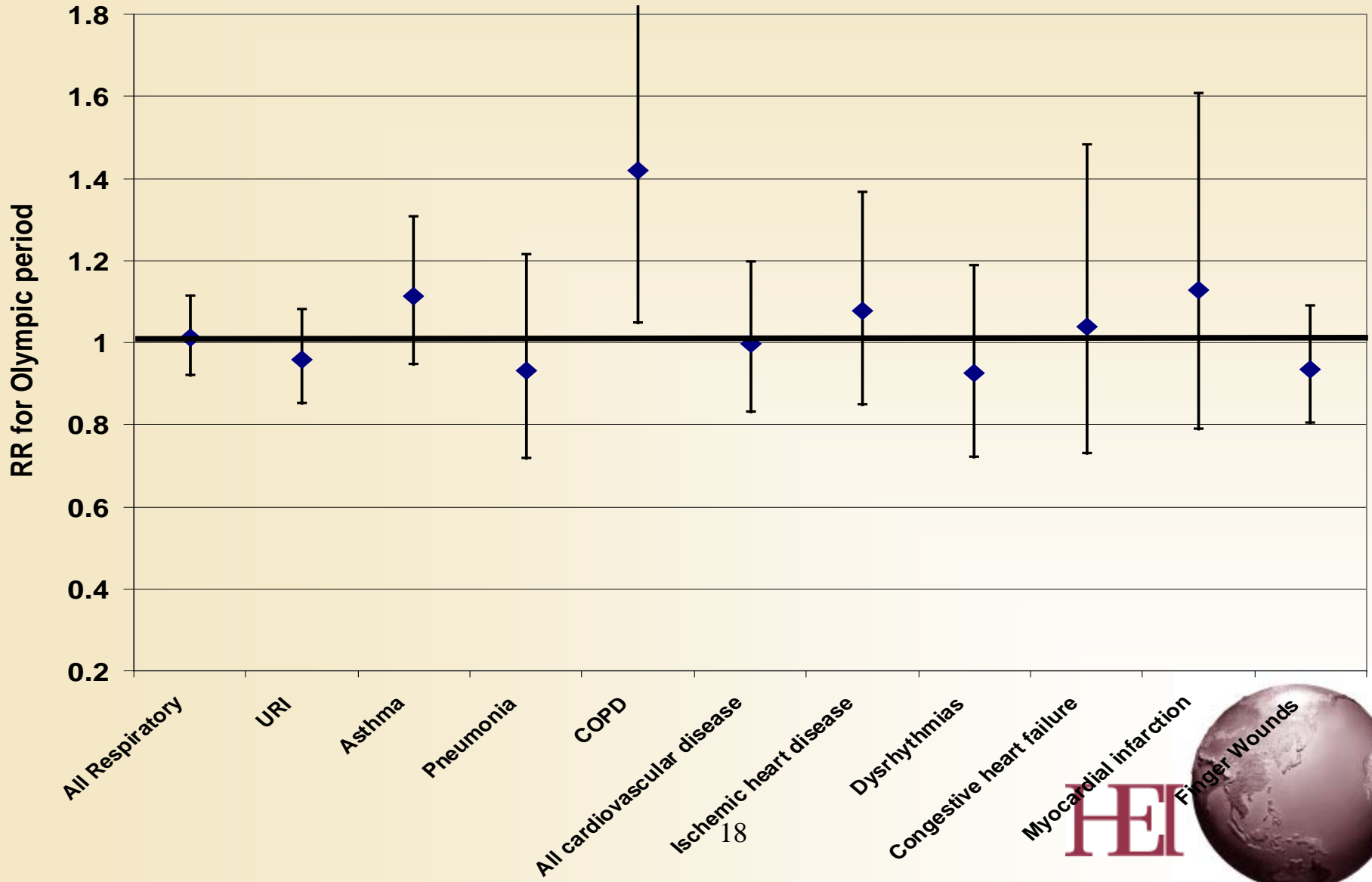
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Pediatric ED Visits

ED Visits (all ages)

Y-axis: RR for Olympic period

X-axis categories: All Respiratory, URI, Asthma, Pneumonia, COPD, All cardiovascular disease, Ischemic heart disease, Dysrhythmias, Congestive heart failure, Myocardial infarction, Finger Wounds

Summary

- 1-hour max (<u>morning rush hour</u>) traffic counts reduced ~10-15%; Overall daily traffic counts unchanged

- Ozone levels ~30% lower during Olympics compared to 4 weeks before and after
  - PM_{10}, NO_2, CO also slightly lower

- Observed similar reductions in ozone at various sites throughout the Southeast

- Both the intervention and prevailing meteorology likely played a role in reduced ozone
  - Regional evidence suggests meteorology
  - Impact of reduction in traffic counts – not primary

- Observed NO significant reduction in emergency department visits

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Caveats

- Study addresses unresolved questions from Friedman et al. (2001) results; carefully designed and executed
- Seasonal / meteorological patterns affected O_3 levels
- Daily number of ED visits low; behavioral changes may be responsible:
  - Residents may have reduced ED usage
  - Residents may have left the city
- Limited monitoring sites for pollutants, traffic
  - No info on EC, vehicle fleet composition, speed/flow, age
- Study underscores the importance controlling for temporal trends

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LONG-TERM STUDY
Impact of German reunification in Erfurt, Germany

- The Influence of Improved Air Quality on Mortality Risks in Erfurt, Germany. Annette Peters et al. HEI Report 137 (February 2009); follow up to Wichmann et al. (HEI: 98, 2000)

- Reunification led to industrial restructuring, reduced emissions, changes in auto fleet

- Nearly complete change in fuel sources: from brown coal to natural gas

- Daily PM and other pollutant measurements available before, during and after reunification (1992-2002)

- "Natural experiment" to investigate pollutant concentrations and health effects

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Daily Average Concentrations of Select Pollutants
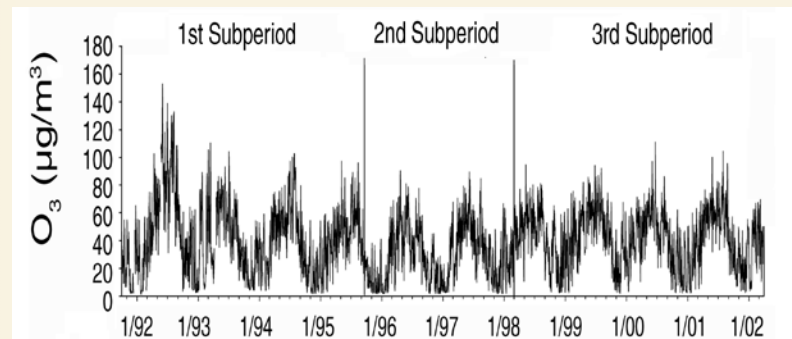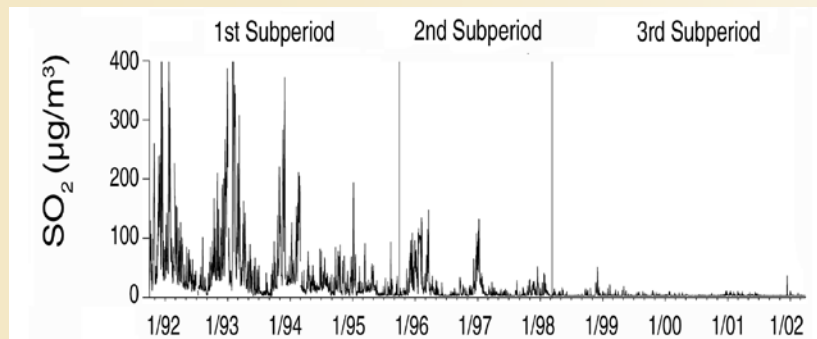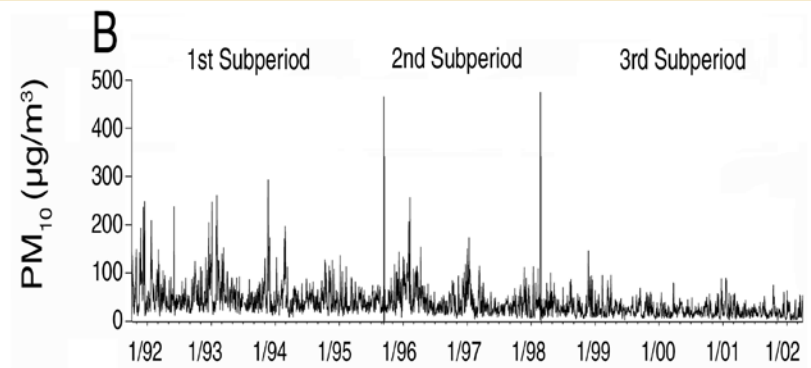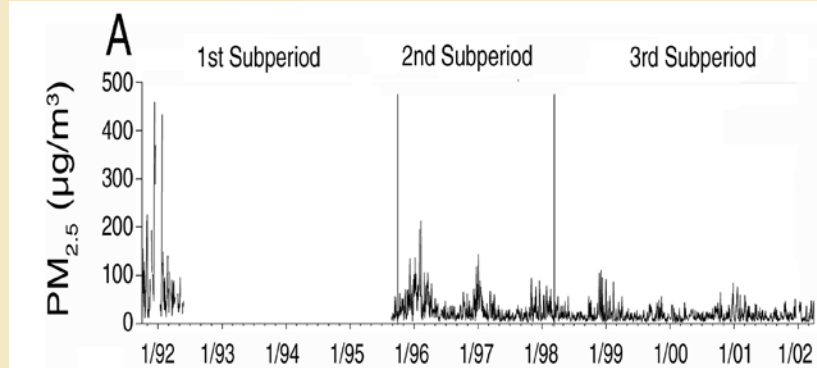
Commentary Table 4. Percent Change in Daily Deaths per IQR for Exposures Lagged 0 to 5 Days Before Death[a]

Pollutant	Percent Change in Daily Deaths per IQR (95% CI)					
	Lag Day 0	Lag Day 1	Lag Day 2	Lag Day 3	Lag Day 4	Lag Day 5
NO_2	−0.8 (−3.8 to 2.4)	0.7 (−2.1 to 3.5)	0.2 (−2.5 to 3.0)	▓▓▓▓▓▓▓	0.7 (−2.0 to 3.5)	−0.6 (−3.3 to 2.1)
SO_2	−0.8 (−1.6 to 0.1)	−0.6 (−1.5 to 0.2)	−0.4 (−1.3 to 0.4)	−0.4 (−1.2 to 0.5)	0.2 (−0.6 to 1.0)	0.3 (−0.5 to 1.0)
CO	0.0 (−2.3 to 2.3)	0.2 (−2.0 to 2.4)	1.3 (−0.9 to 3.5)	0.7 (−1.4 to 2.9)	**1.2 (−1.0 to 3.4)**	−0.5 (−2.6 to 1.7)
Ultrafine particles	2.0 (−0.7 to 4.9)	0.1 (−2.5 to 2.9)	−0.3 (−2.8 to 2.3)	1.2 (−1.4 to 3.8)	▓▓▓▓▓▓▓	0.6 (−1.9 to 3.2)
PM_{10}	−0.8 (−2.7 to 1.1)	−0.2 (−2.0 to 1.6)	0.0 (−1.7 to 1.8)	**−1.0 (22.7 to 0.8)**	0.5 (−1.2 to 2.3)	0.7 (−1.0 to 2.5)

[a] Boldface type indicates the change for the lag days that were selected as producing the most significant results. Data from Investigators' Report Tables 16 (for NO_2, CO, and ultrafine particles), 18 (for SO_2), and 19 (for PM_{10}).

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Summary & Conclusions

- Extensive and meticulous work
- Application of novel statistical methods (time-varying coefficient modeling [TVCM])

- "Association between daily mortality and UFP and combustion-related gases (lag days 3 or 4)," but these are small effects

- TVCM showed that RR of death per unit of exposure for O_3, CO, UFP and NO_2 not stable during study period; highest RR occurred during the transition period (1995 – 1997) when pollutant sources were changing most rapidly

Limitations

- Confounder Control
  - Residual Autocorrelation issue
  - Control for time varying trends (Akaike Information Criteria)
  - Residual Confounding: Presence and direction not clear
- Issue of Number of Days Lag
  - Choice of lag days based on strength of association
  - Distributed lag model better
- Results re change in toxicity per unit exposure – difficult to interpret due to limited power
- Little evidence for PM effects
- Overall:
  - Small population; low statistical power
  - Concomitant sweeping social and economic changes

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The HEI Health Outcomes Program

- During the last ten years, HEI has published three monographs outlining the concepts, methods, challenges, lessons and opportunities for outcomes research

- Through five RFAs, HEI has completed 9 studies and is about to initiate another 3-4 studies

- Detailed information available at
  www.healtheffects.org

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Lessons and Recommendations - I

- Importance of exposure contrast:
  - Establish the size of AQ improvement before starting a health study: adopt a staged approach
  - Continuous improvement of measurement techniques and air pollution modeling
  - Consider increasing sensitivity of network – more roadside monitoring & spatial and temporal resolution
- Research of shorter-term and small scale actions under well-defined circumstances: useful, achievable, though with some challenges, generalizability a consideration
  - Sufficient study power: focus on AQ "step changes" in compressed timeframes
  - Include studies of control measures such as abatement actions, fuel changes, engineering controls
  - Consider "pooled studies" – actions at multiple locations, such as road construction

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Lessons and Recommendations - II

- Research for long-term, national scale actions needed, though remains most challenging
    - Need for quality data collected continuously (health tracking, monitoring)
    - Develop publicly available platforms for key research data (data warehouse)
    - Account for other concurrent changes that affect health over the same time frame
- Overarching Issues
    - Studies encompassing the whole "accountability chain" remain very difficult
    - Further development of tool kits and statistical methods including analysis for trends, sensitivity, confounding and causality
    - Need for collaboration among health and atmospheric scientists and regulatory agencies
    - Integrate outcomes research into policy implementation

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Thank you

Rashid Shaikh

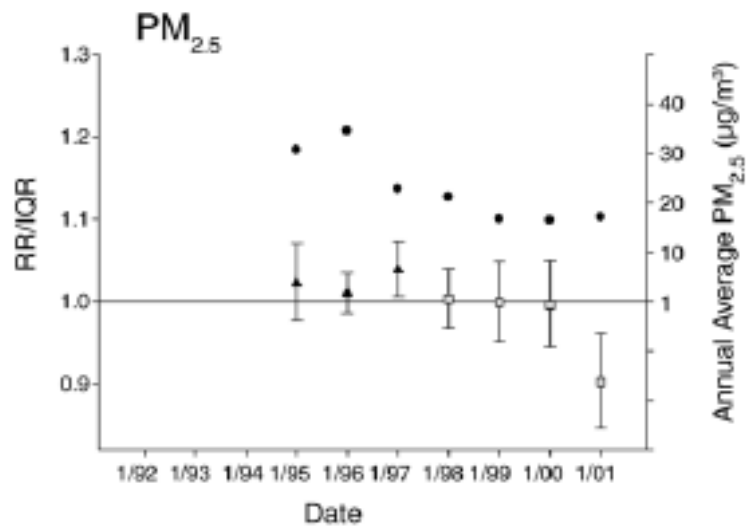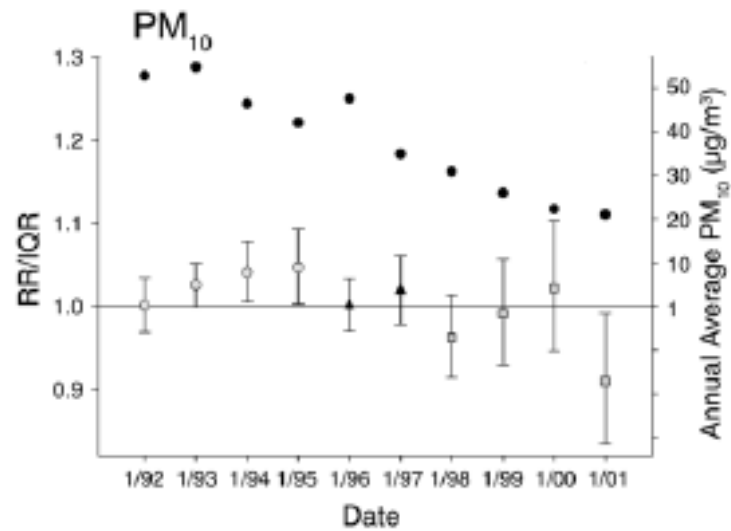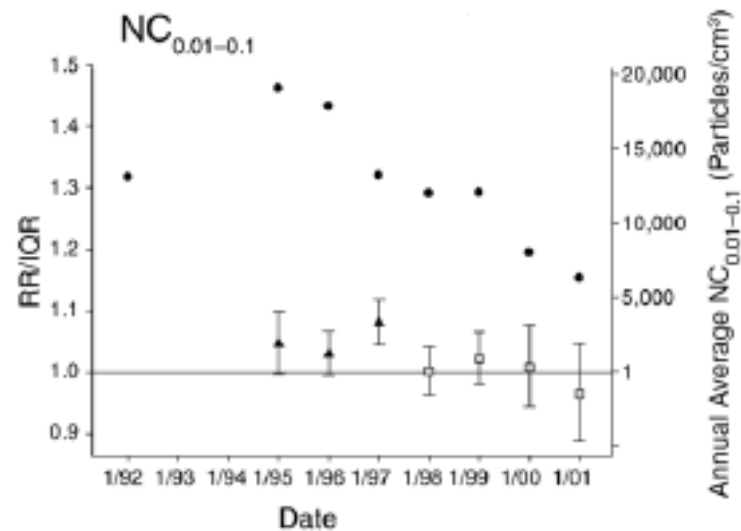Director of Science

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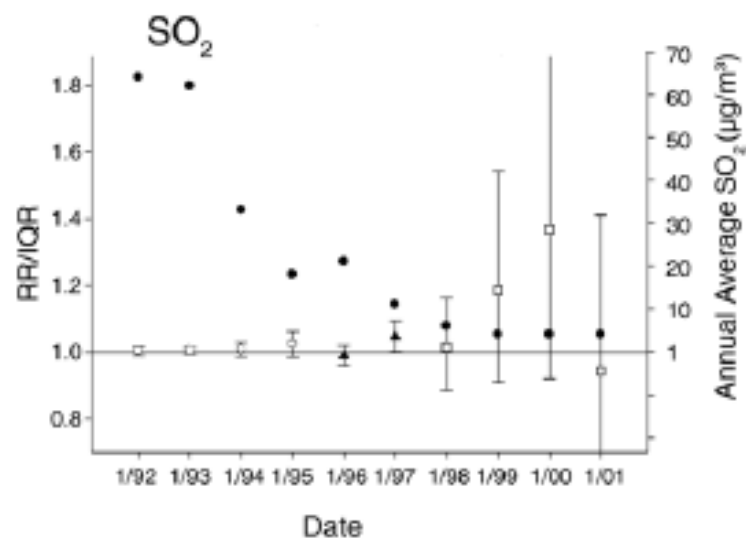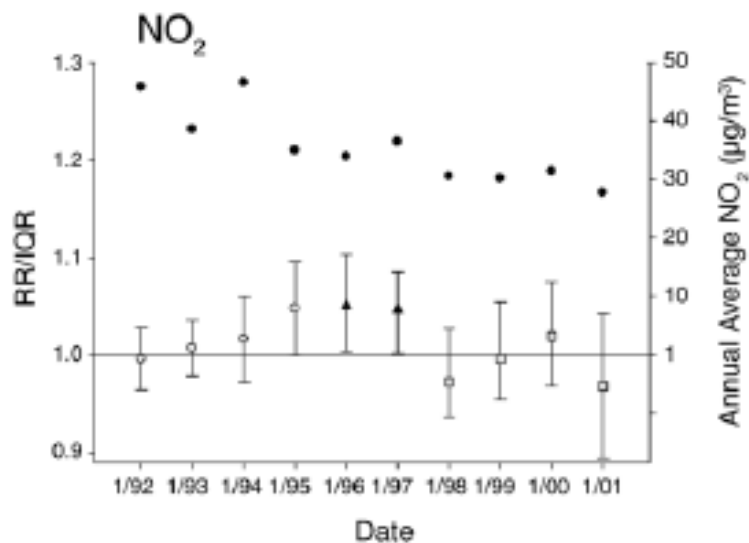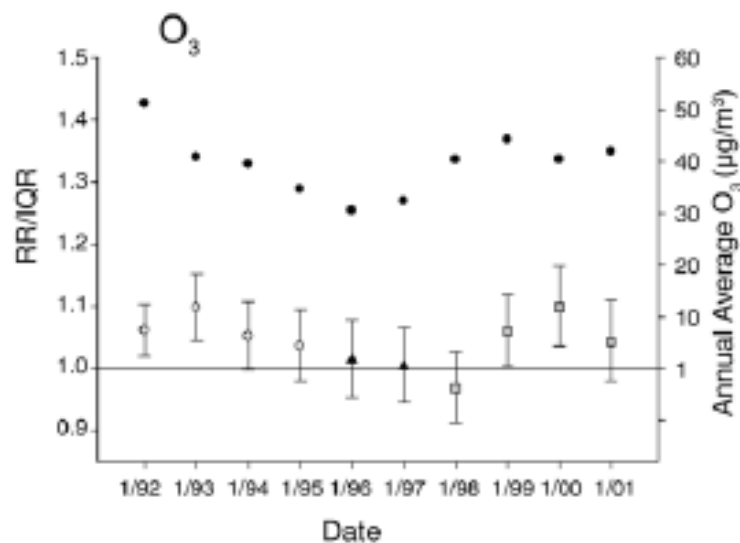# HEATING FUEL CHANGES
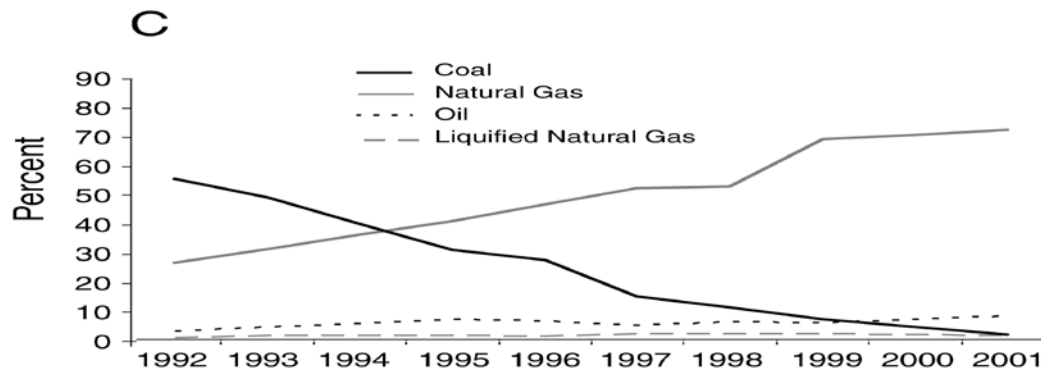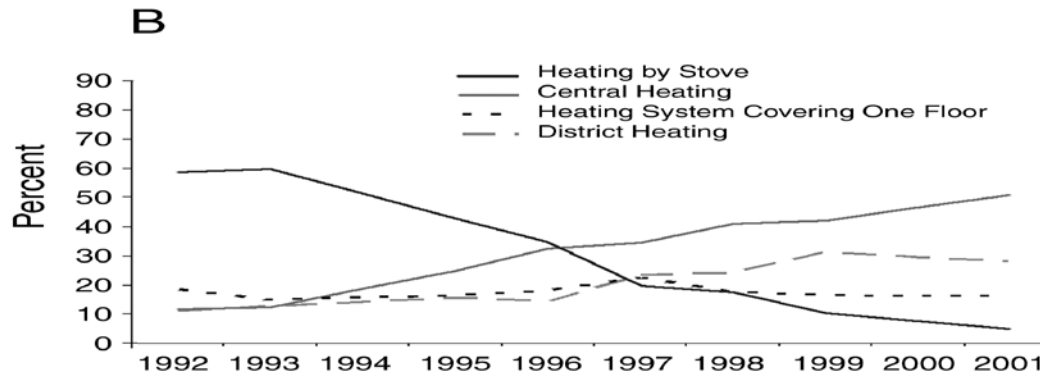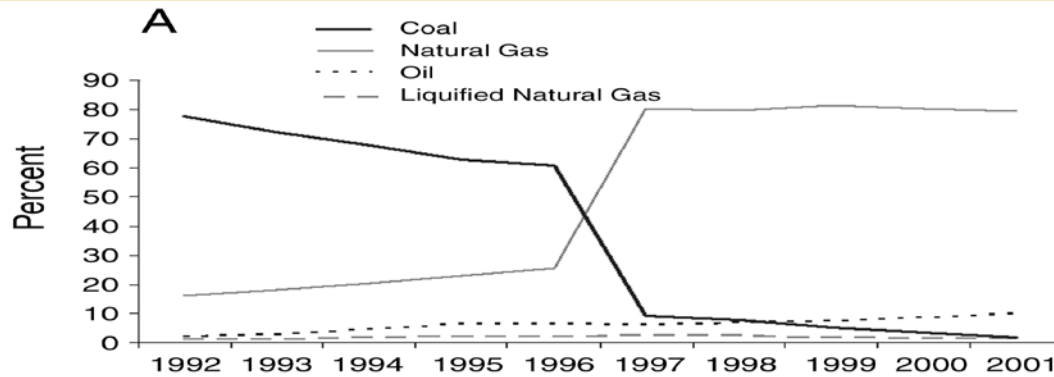
Heating Systems

Fuels used in Erfurt's older areas

Commentary Figure 1. Annualized RR/IRQ values for all-cause mortality and particulate pollutants. Black dots indicate annual average pollutant concentrations. Gray dots, black triangles, and gray boxes indicate RR/IQR values for subperiods 1, 2, and 3, respectively. Bars indicate 95% CI.
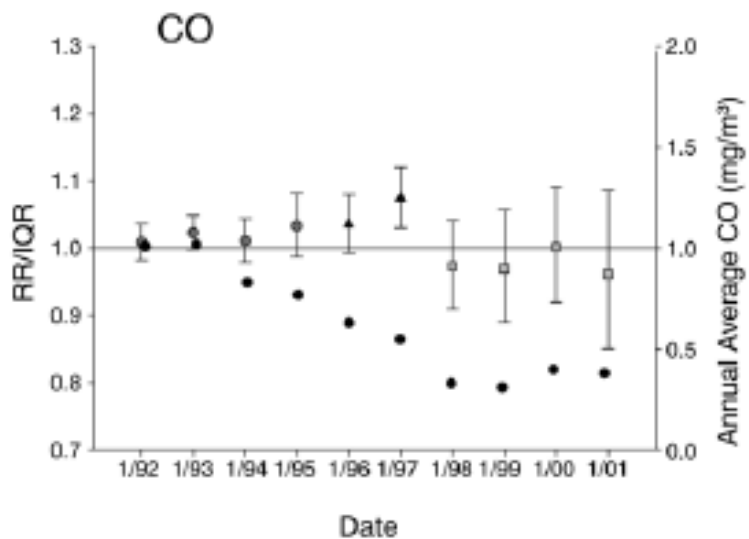
Commentary Figure 2. Annualized RR/IRQ values for all-cause mortality and gaseous pollutants. Black dots indicate annual mean pollutant concentrations. Gray dots, black triangles, and gray boxes indicate RR/IQR values for subperiods 1, 2, and 3, respectively. Bars indicate 95% CI.