Integrated Program on Urban, Regional, and Global Air Pollution

Air Quality and Climate Change

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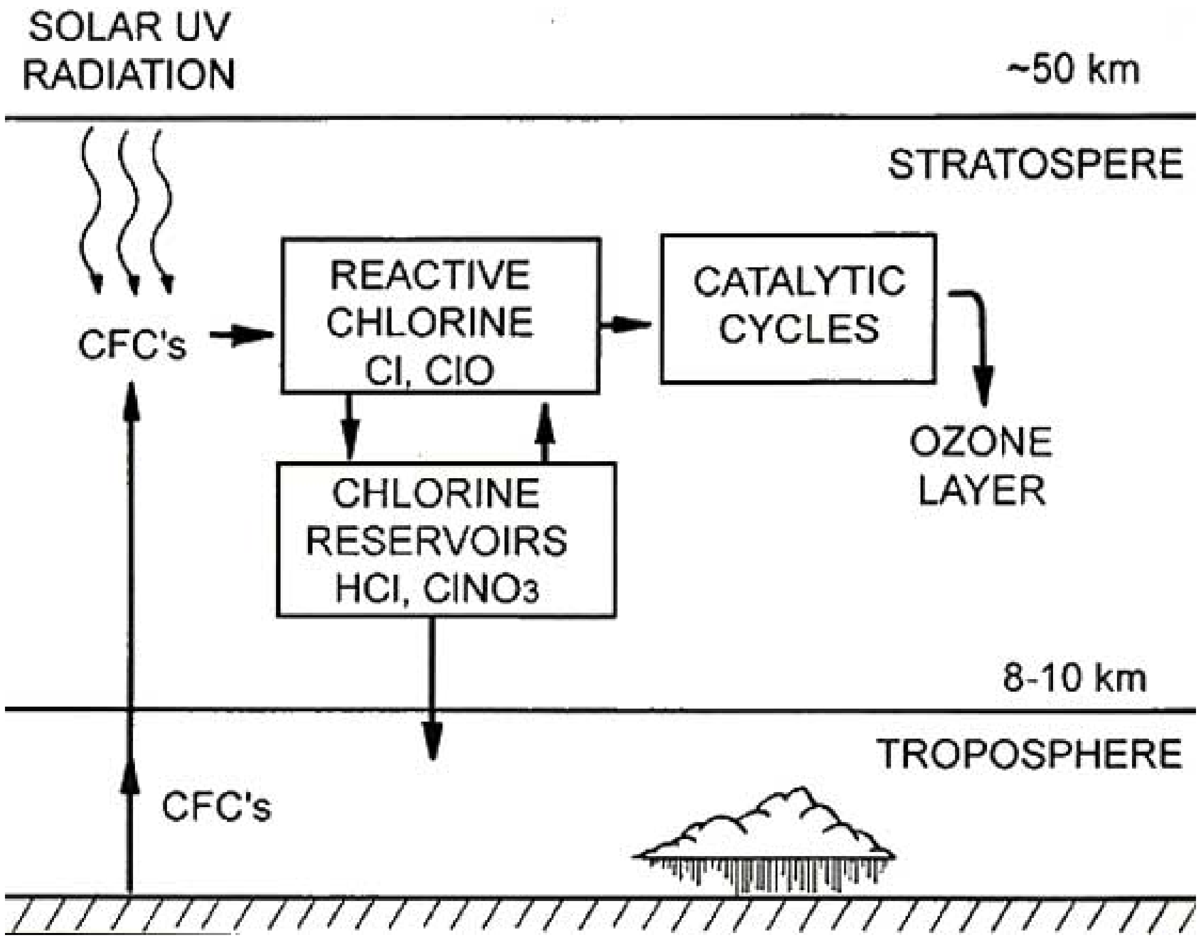
Major Environmental Challenges for the 21st Century

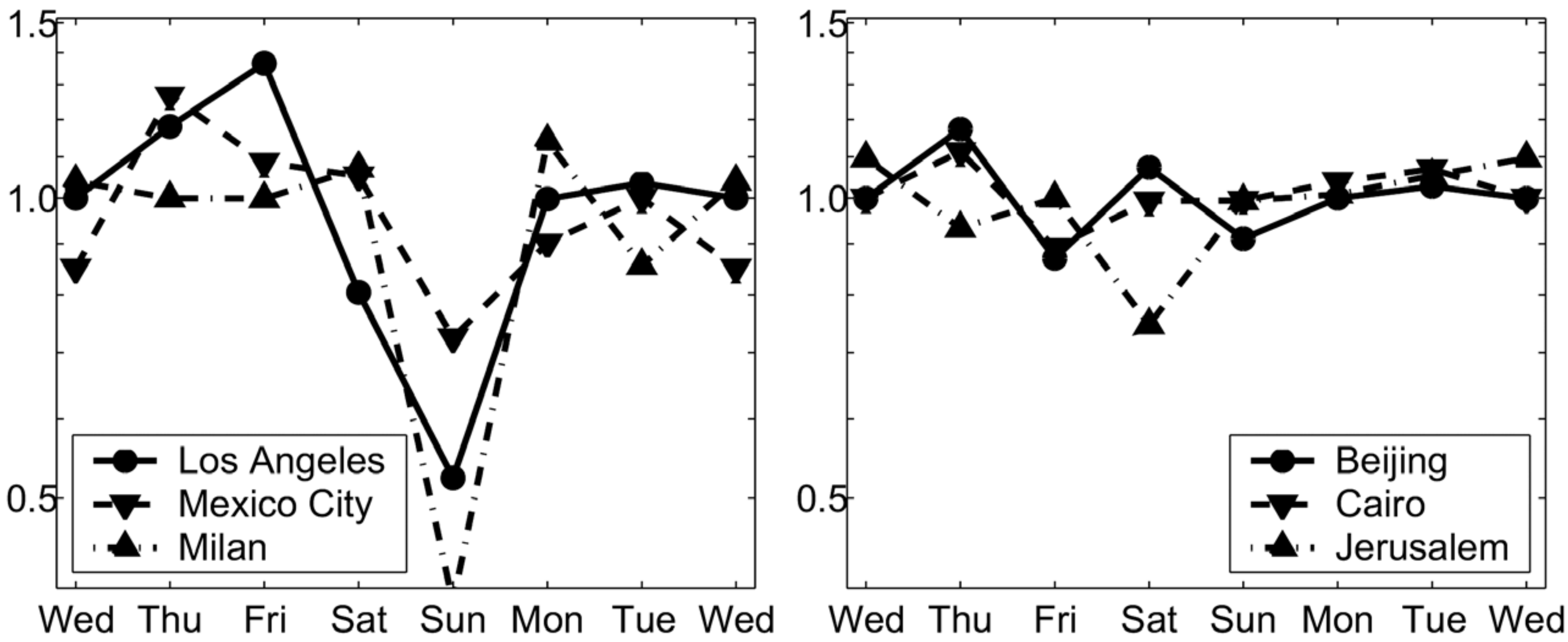
- **Water Supply - Water Quality**
- **Depletion of Natural Resources**
  - Degradation of Land
  - Loss of Biodiversity
  - Deforestation
  - Over-exploitation of Fisheries
- **Disposal of Solid and Hazardous Waste**

- **Air Quality**
- **Global Changes in the Chemical Composition of the Atmosphere**
  - Stratospheric Ozone Depletion
  - Climate change/Greenhouse Effect
  - Tropospheric Ozone and Particulate Matter

CFC-Stratospheric Ozone Depletion Theory



Weekly cycle of mean tropospheric NO_2 vertical column densities for six urban centers



Source: Beirle, S.; Platt, U.; Wenig, M.; Wagner, T.
Weekly cycle of NO_2 by GOME measurements: a signature of anthropogenic sources.
Atmospheric Chemistry and Physics **2003***, 3*, 2225-2232.

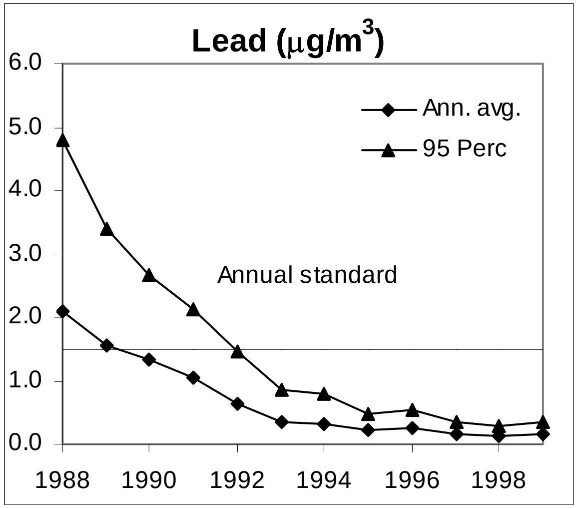
Air Pollution in Cairo

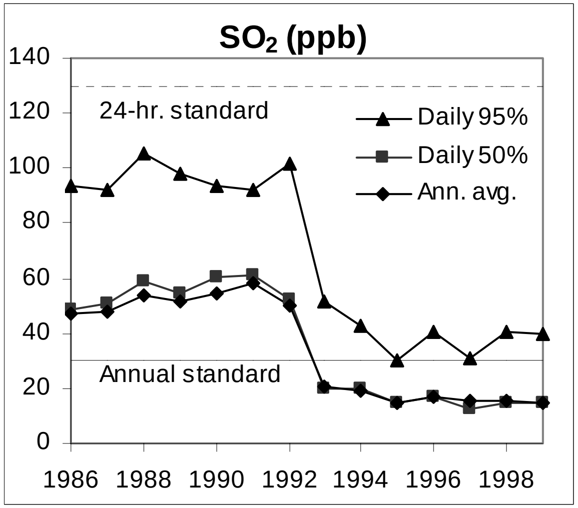
- All of Greater Cairo suffers from high levels of air pollution.
- PM_{10} is dominated by soil dust material, open burning, and mobile source emissions.
- $PM_{2.5}$ is dominated by mobile source emissions, open burning, and secondary species.
- Smelters are the dominant source of airborne lead.
- Sources other than transportation activities need to be addressed.

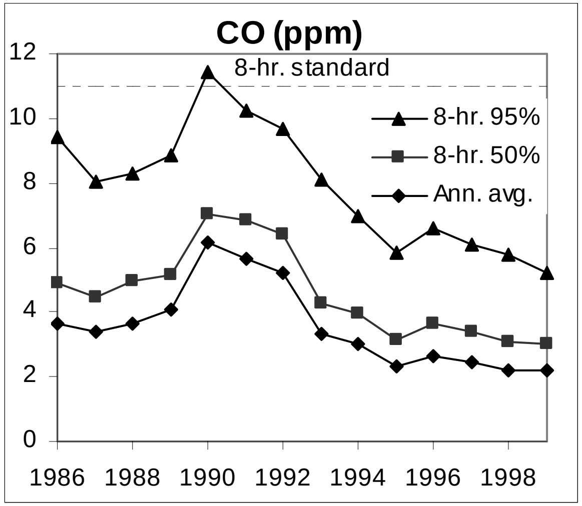
Source: Alan Gertler (DRI)

Trends in criteria pollutant concentrations for the Mexico City Metropolitan Area

(averages of data at five RAMA sites)







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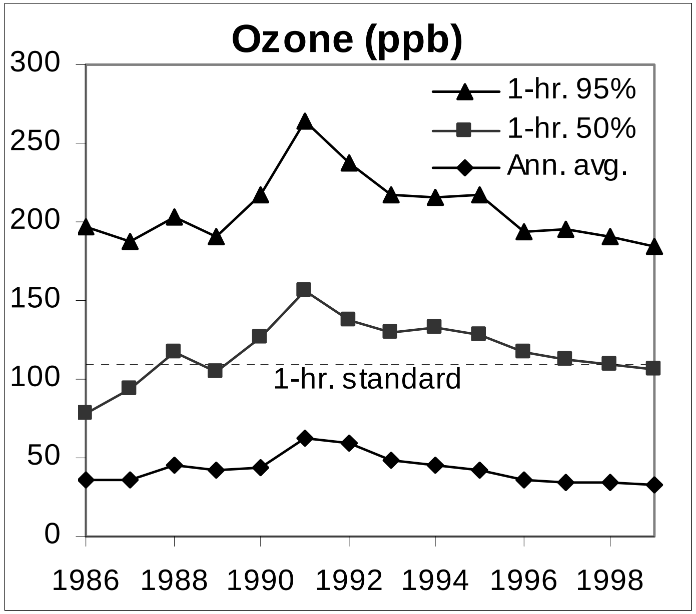
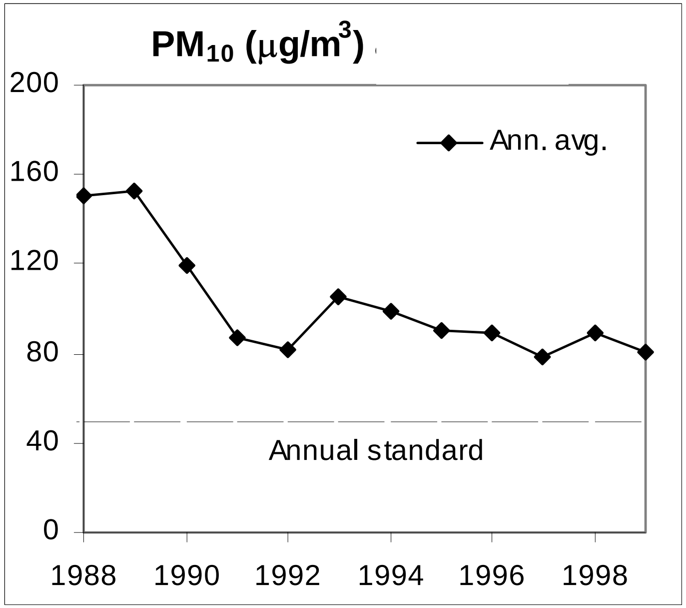




Integrated Program on Urban, Regional and Global Air Pollution: Mexico City Case Study (Mexico City Air Quality Program)

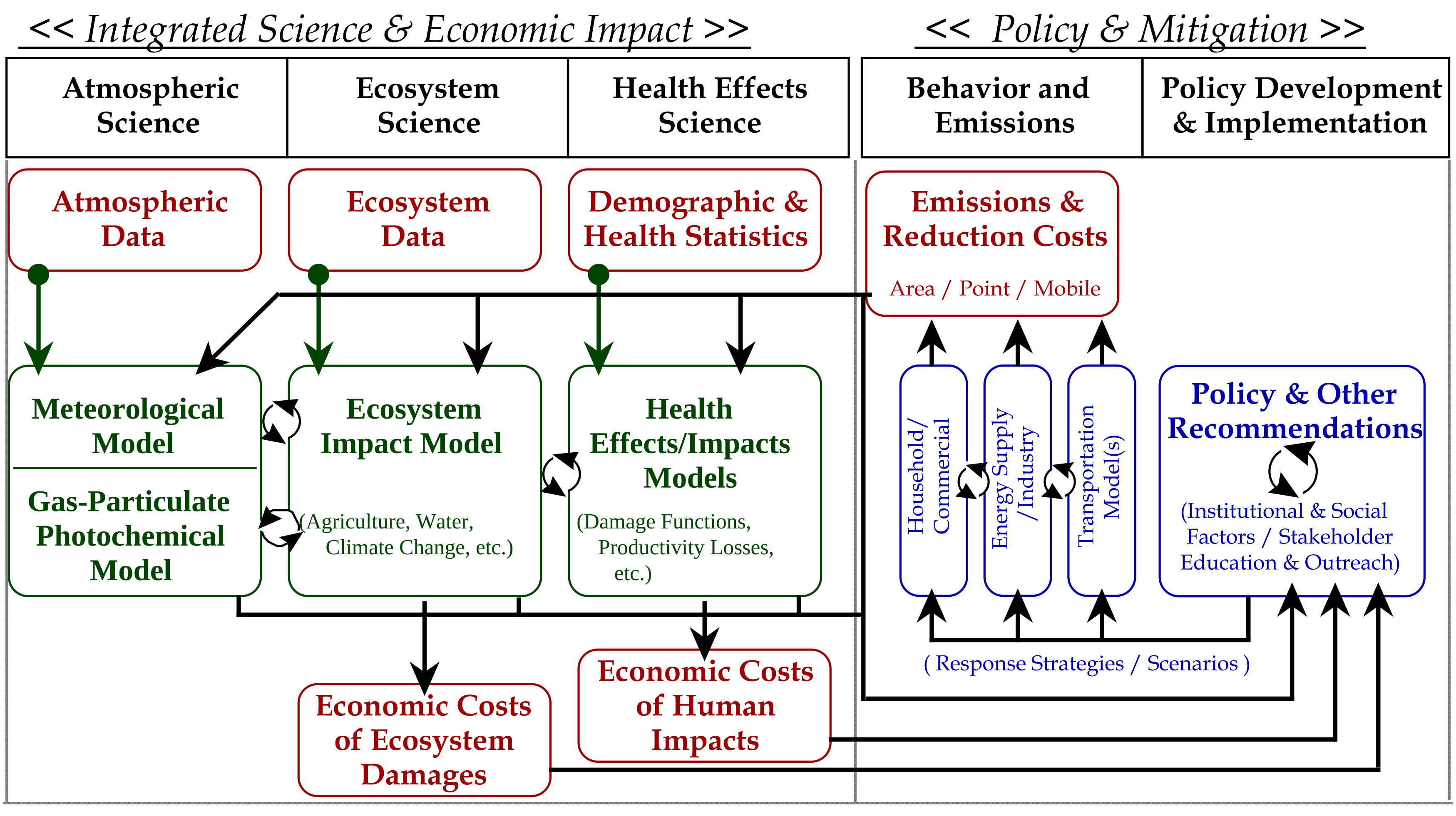
Objective:

Provide objective, balanced assessments of the causes and alternative cost-effective solutions to urban, regional and global air pollution problems through quality scientific, technological, social and economic analysis in the face of incomplete data and uncertainty

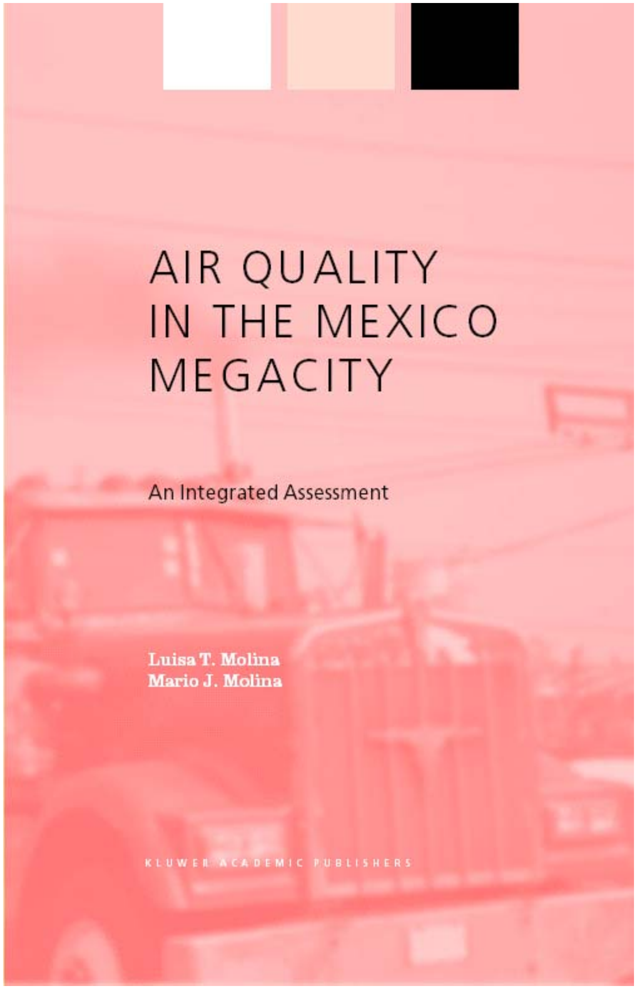
- Use Mexico City as the initial case study
- Develop an approach that applies globally
- Build on strong base of ongoing basic research

Collaborative Research and Education Program involving Mexican, US and other international institutions

A Framework for Integrated Assessment



Summary of the First Phase of the Mexico City Air Quality Program



Chapter 1. Air Quality Impacts: A Global and Local Concerns

Chapter 2. Cleaning the Air: A Comparative Overview

Chapter 3. Forces Driving Pollutant Emissions in the MCMA

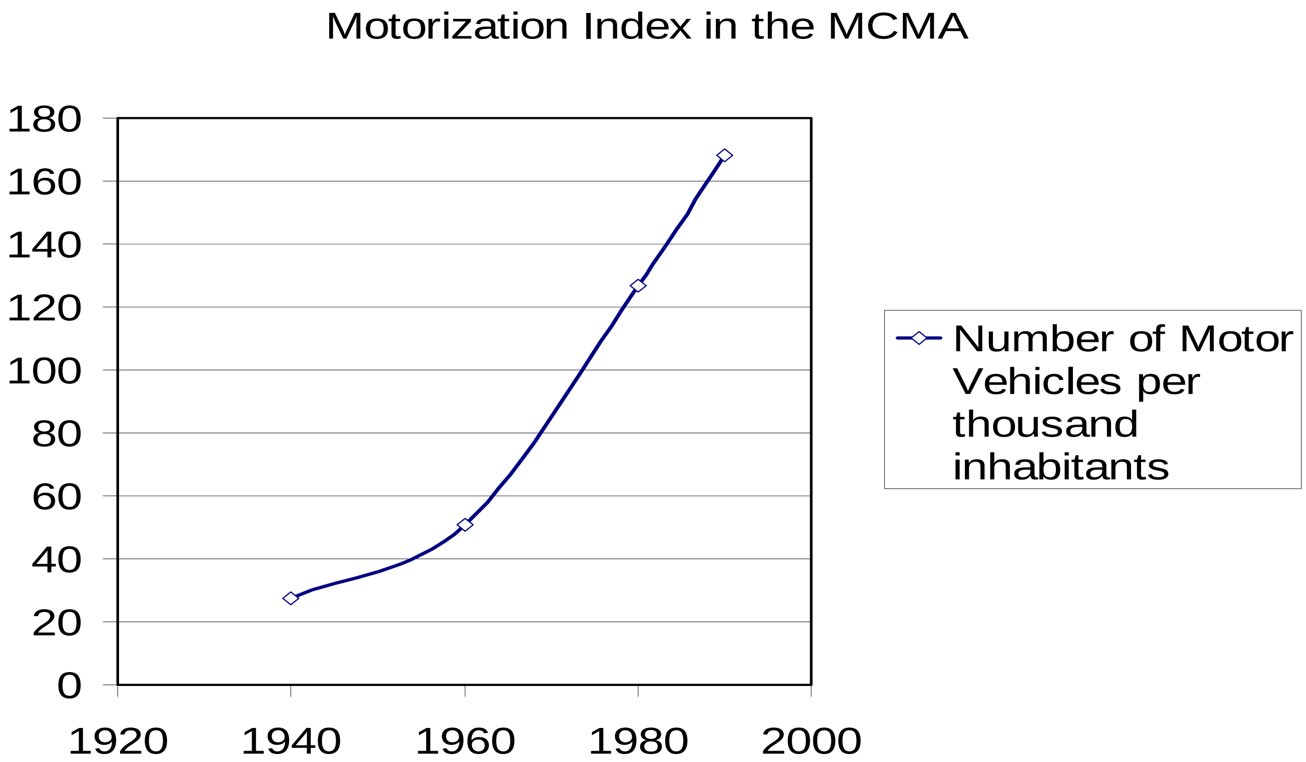
Chapter 4. Health Benefits of Air Pollution Control

Chapter 5. Air Pollution Science in the MCMA: Understanding Source-Receptor Relationships Through Emissions Inventories, Measurements and Modeling

Chapter 6. The MCMA Transportation System: Mobility and Air Pollution

Chapter 7. Key Findings and Recommendations

Increase in Automobiles per Capita in Mexico City



Four-part plan to clean the air in the Mexico City Metropolitan Area

- Launch a program to retrofit or retire the dirtiest fleets of truck, buses, and cars.
- Tighten the “tailpipe standards” on all new cars, trucks, and buses sold in Mexico, so they conform to world class standards.
- Introduce ultra-low sulfur fuels, both gasoline and diesel, which is required for clean car and truck technologies.
- Improve public transportation and reduce congestion.

Air Quality Problems: Future outlook

- **Interdisciplinary research**

  Holistic approach: take into account scientific, technical, economic, social, and political factors, as well as the existing infrastructure.

- **Integrated solutions**

  There is no “magic bullet”: a mix of policy measures is needed to improve air quality. Need to integrate relevant policies for transportation, land use and air quality.

- **Institutional improvement**

  Strong leadership and political will is essential to develop institutional capacity and enforce regulations.

- **Stakeholder involvement**

  Promote participatory processes; develop effective partnerships with all stakeholders of civil society.

Estimated Health Benefits of a 10% Reduction of Pollution Levels in the MCMA

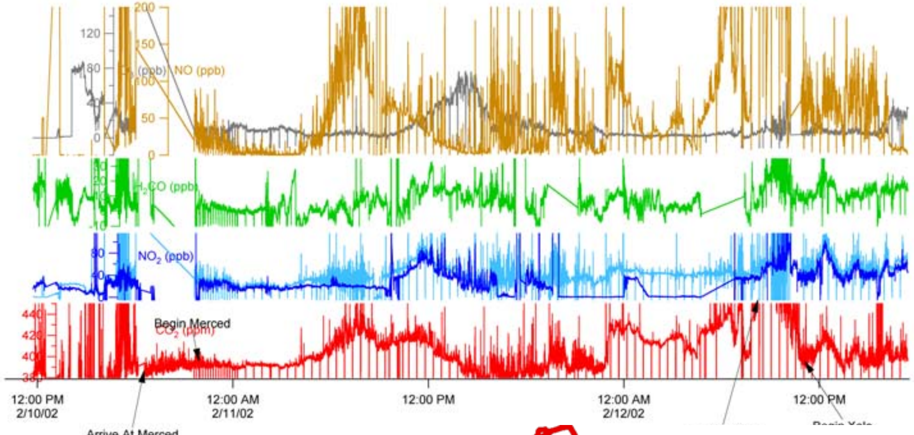
PM10	Background Rate (case-persons-yr)	Risk Coefficient (% per 10µg/m3)	Risk Reduction (cases/yr)
Cohort Mortality	10/1000	3	2000
Time Series Mortality	5/1000	1	1000
Chronic Bronchitis	14/1000	10	10 000

Ozone	Background Rate (case-persons-yr)	Risk Coefficient (% per 10µg/m3)	Risk Reduction (cases/yr)
Time Series Mortality	5/1000	0.5	300
Minor Restricted Activity Days	8000/1000	1.0	2,000,000

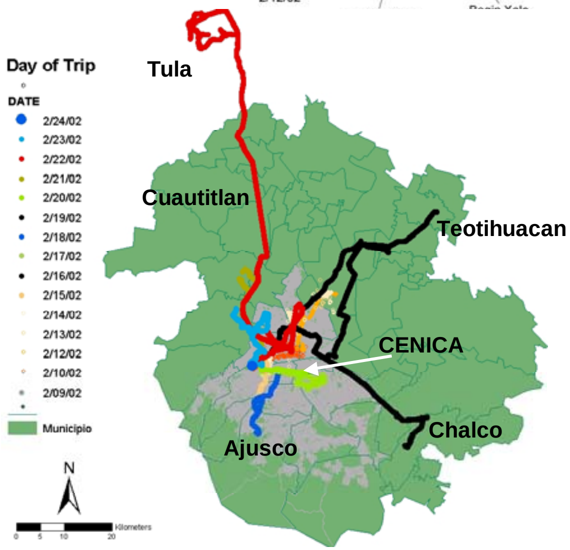
Chapter 4. Health Benefits of Air Pollution Control: *John Evans, Jonathan Levy, James Hammitt, Carlos Santos Burgoa, and Margarita Castillejos*.

Mobile Laboratory Modes of Operation
February 2002, April 2003

Stationary Sampling
High time resolution point sampling
Quality Assurance for conventional air monitoring sites

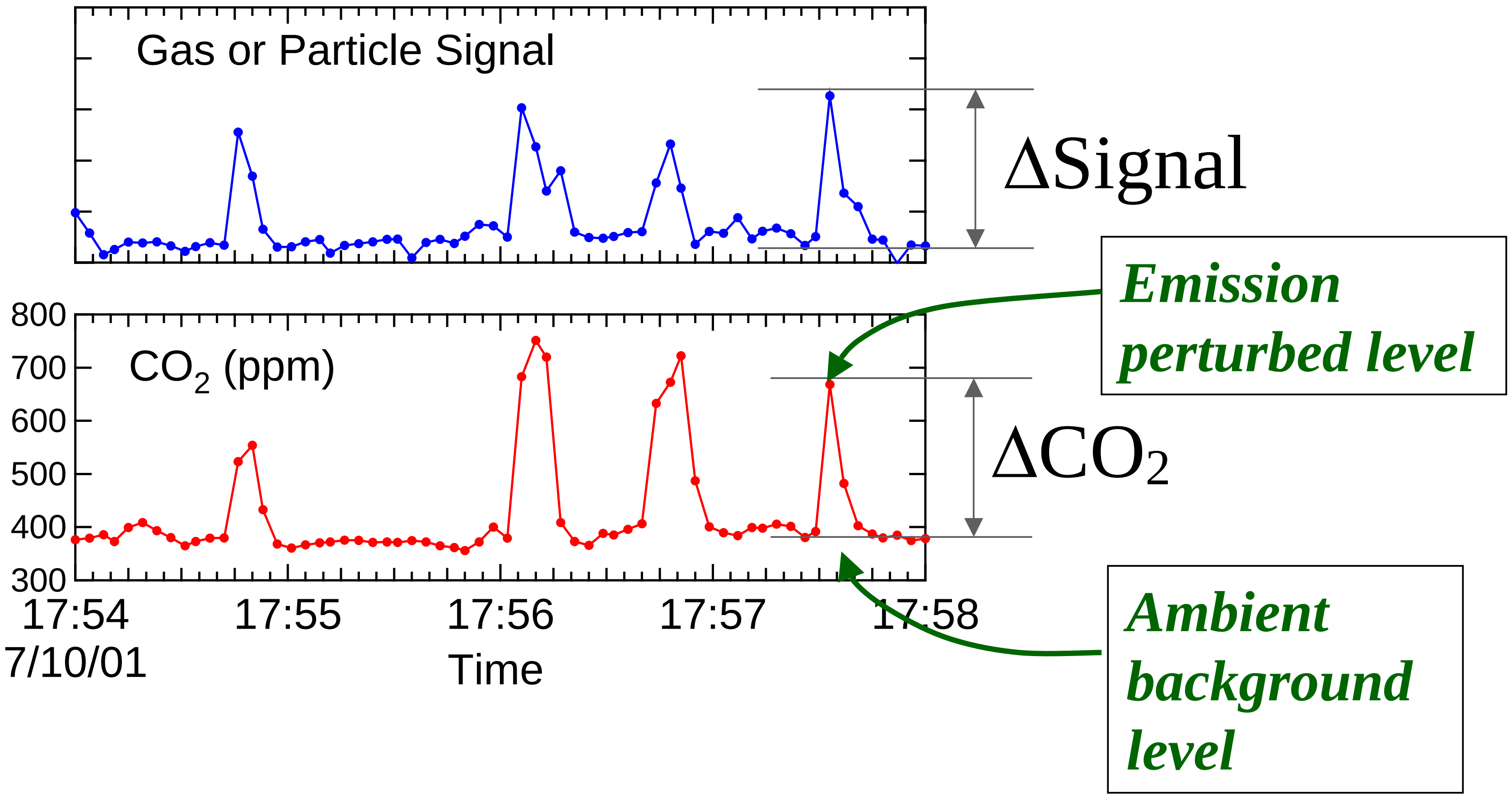


Mobile Sampling/Mapping
Motor vehicle pollution emission ratios
Large source plume identification
Ambient background pollution distributions



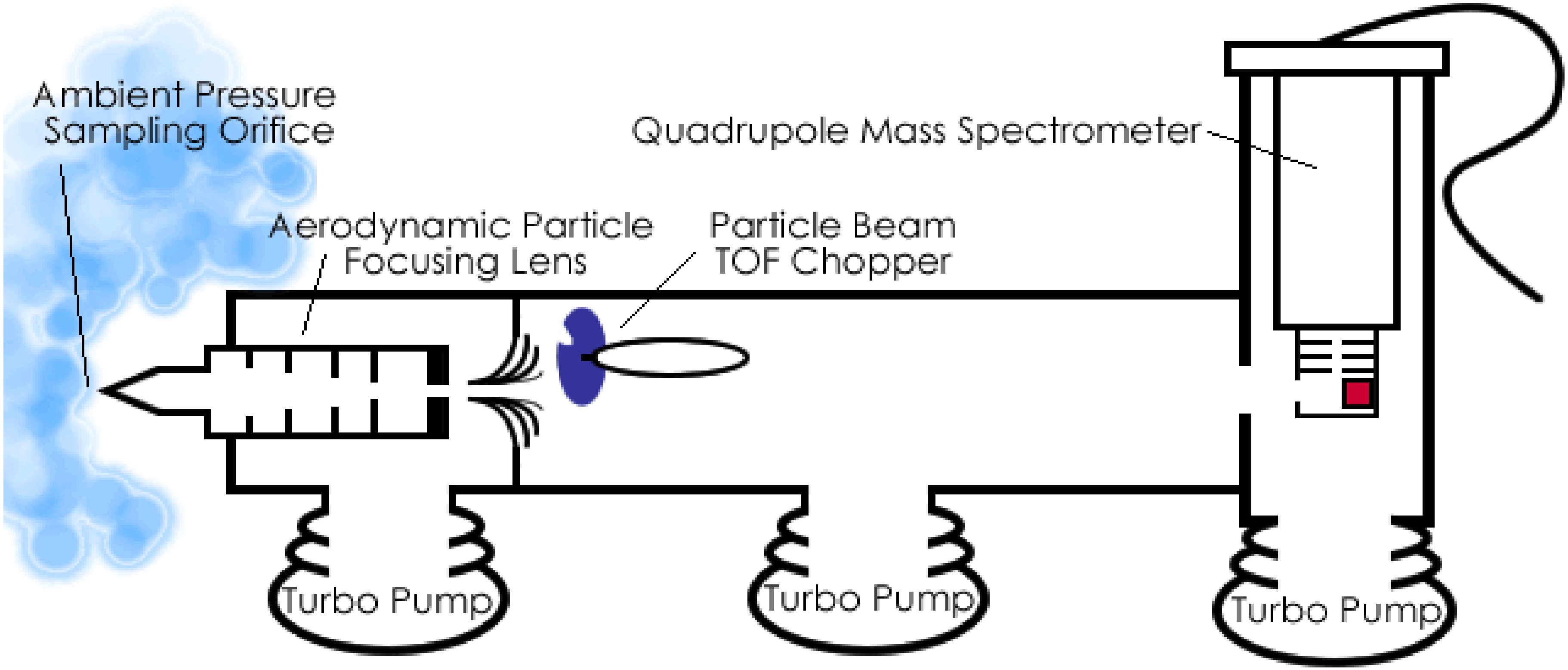
Chase
Detailed mobile source emissions characterization
Plume tracer flux measurements

"*In-plume*" sampling indicated by *above-ambient* CO_2 levels



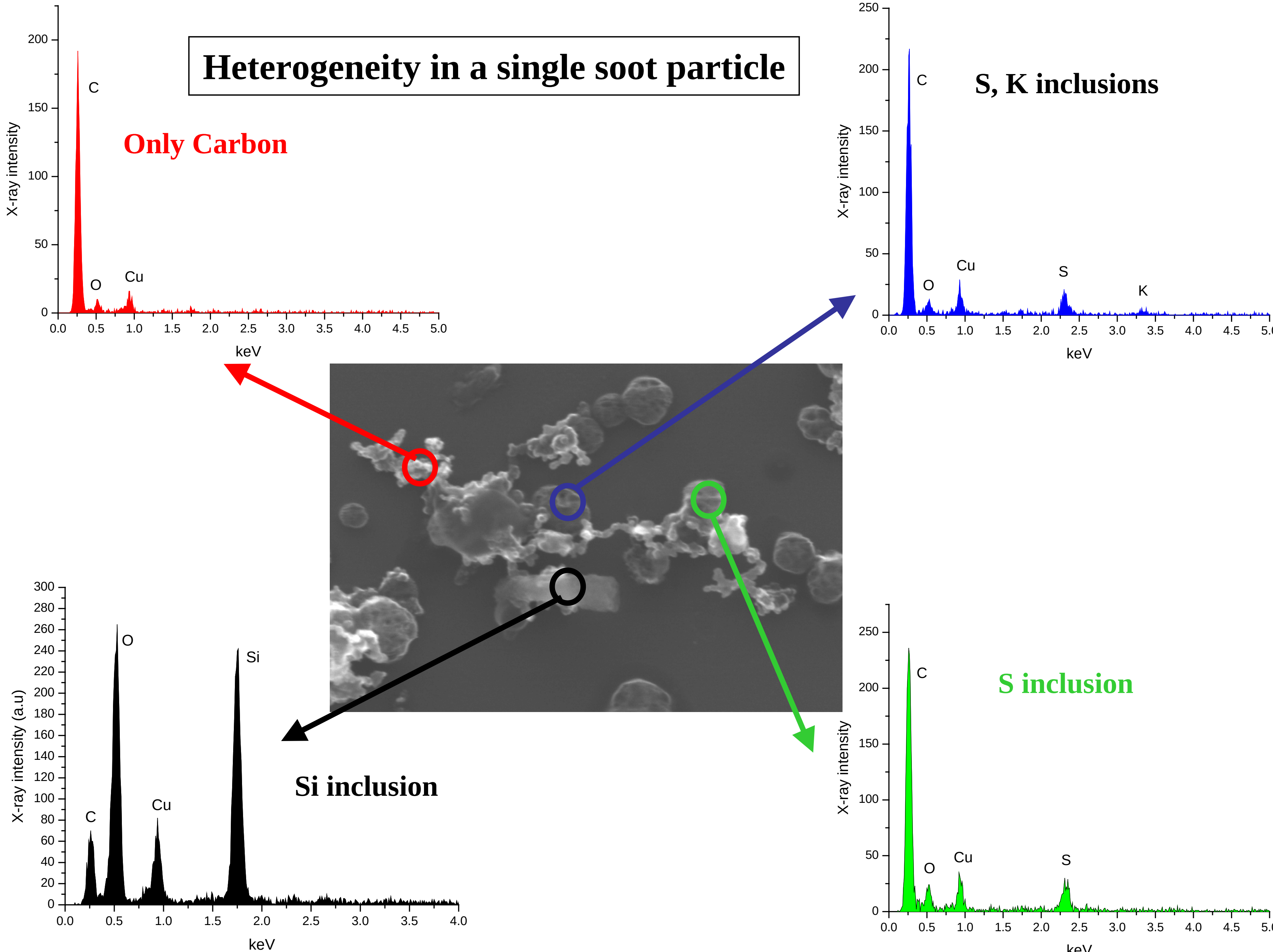
Emission Ratio = ΔSignal/ΔCO_2

Aerosol Mass Spectrometer (AMS) at MCMA



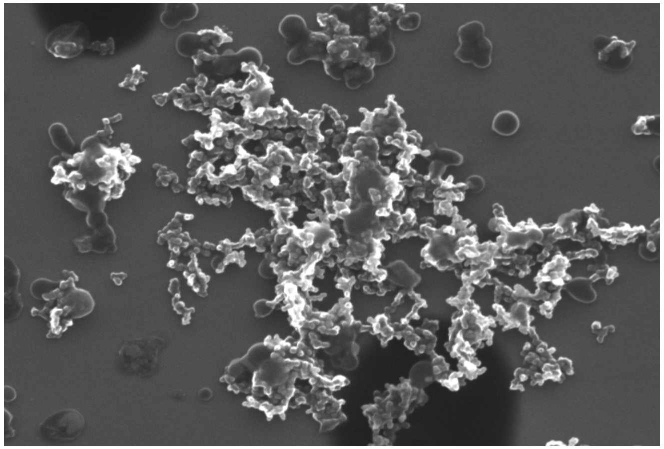
100% transmission (60-600 nm), aerodynamic sizing, linear mass signal.

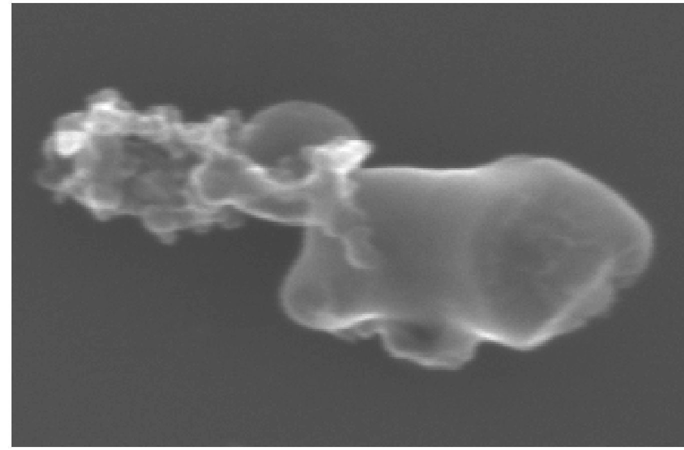
- Jayne et al., *Aerosol Science and Technology* 33:1-2(49-70), 2000.
- Jimenez et al., *J. Geophys. Res.- Atmospheres*, 108(D7), 8425, doi:10.1029/ 2001JD001213, 2003.

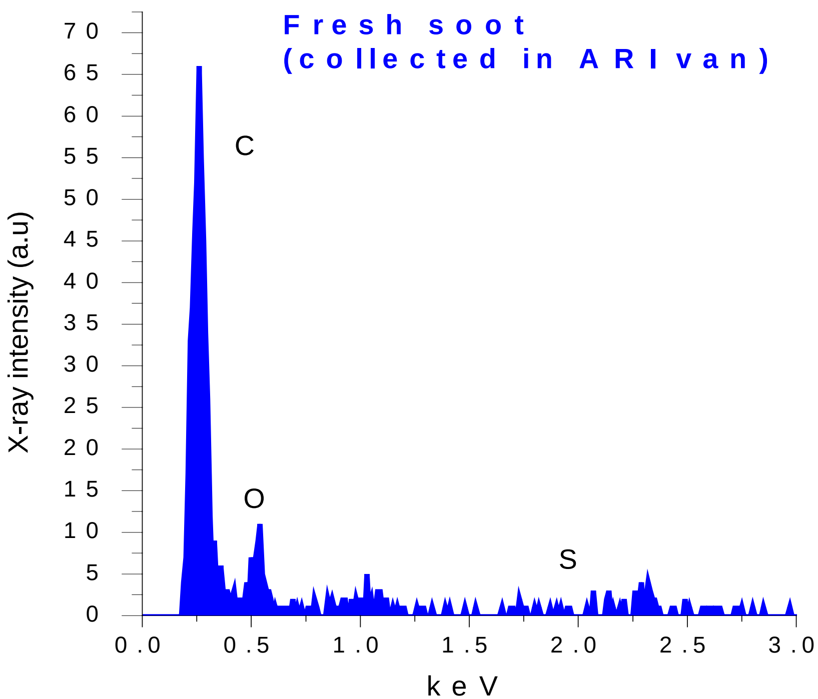


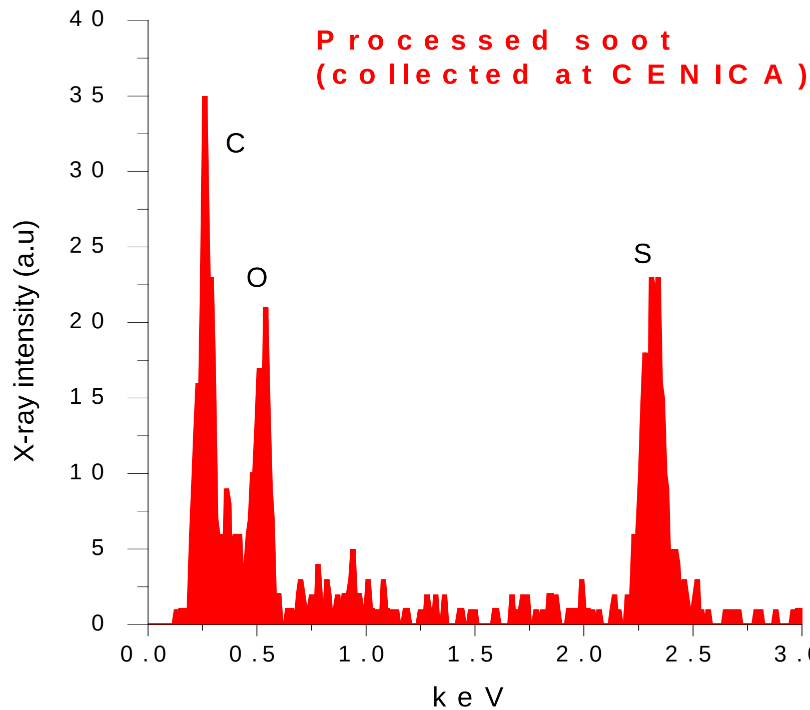
Heterogeneity in a single soot particle
Only Carbon
X-ray intensity
keV
C
O
Cu
S, K inclusions
X-ray intensity
keV
C
O
Cu
S
K
Si inclusion
X-ray intensity (a.u)
keV
C
O
Cu
Si
S inclusion
X-ray intensity
keV
C
O
Cu
S

Fresh soot particles (ARI van) vs Aged soot particles (CENICA)







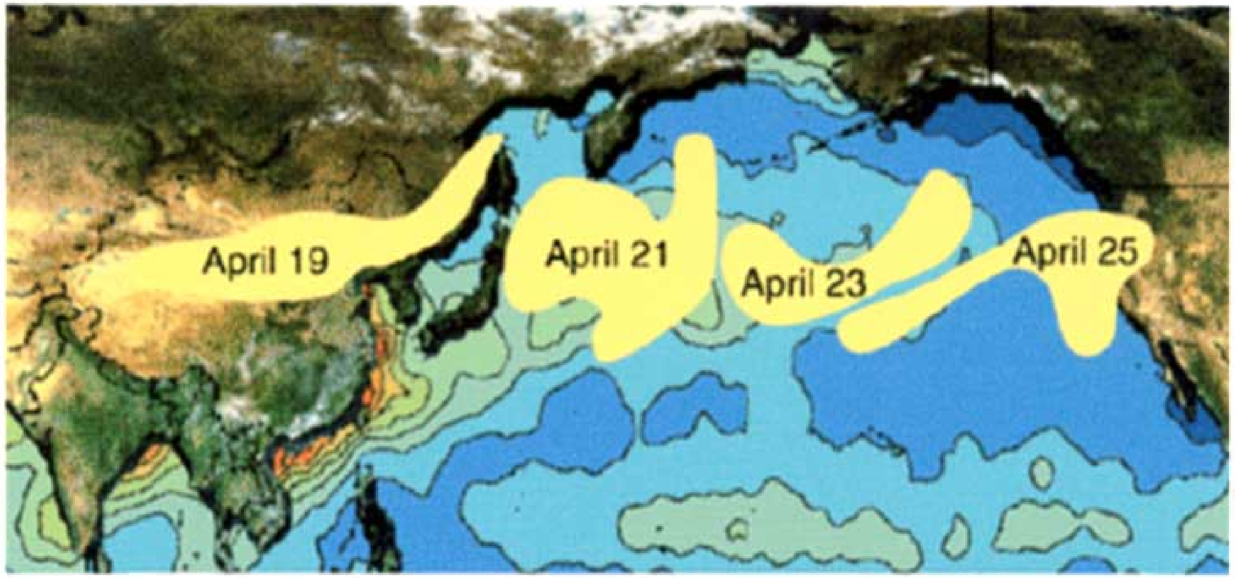


Outflow of Aerosol, Northern India

The skies over Northern India are filled with aerosol particles all along the southern edge of the Himalayan Mountains, and streaming southward over Bangladesh and the Bay of Bengal.

Trans-Pacific Air Pollution

Kenneth E. Wilkening, Leonard A. Barrie, Marilyn Engle



Pollution from afar. Satellite remote sensing images of trans-Pacific transport of aerosols in April 1998 originating from a massive dust storm in China.

SCIENCE, vol 290, October 2000

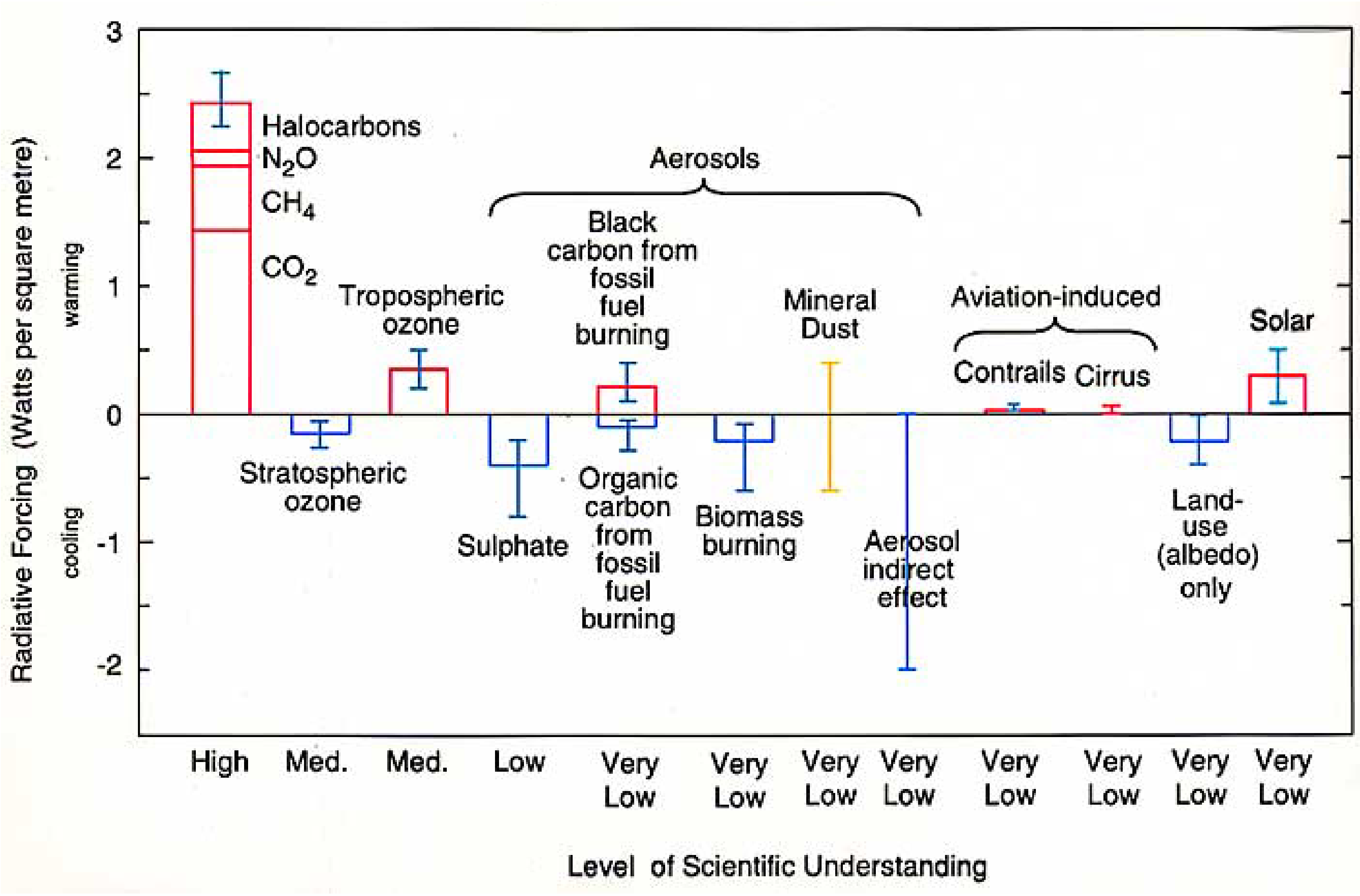
'Global Air Quality' study

motivating factors:

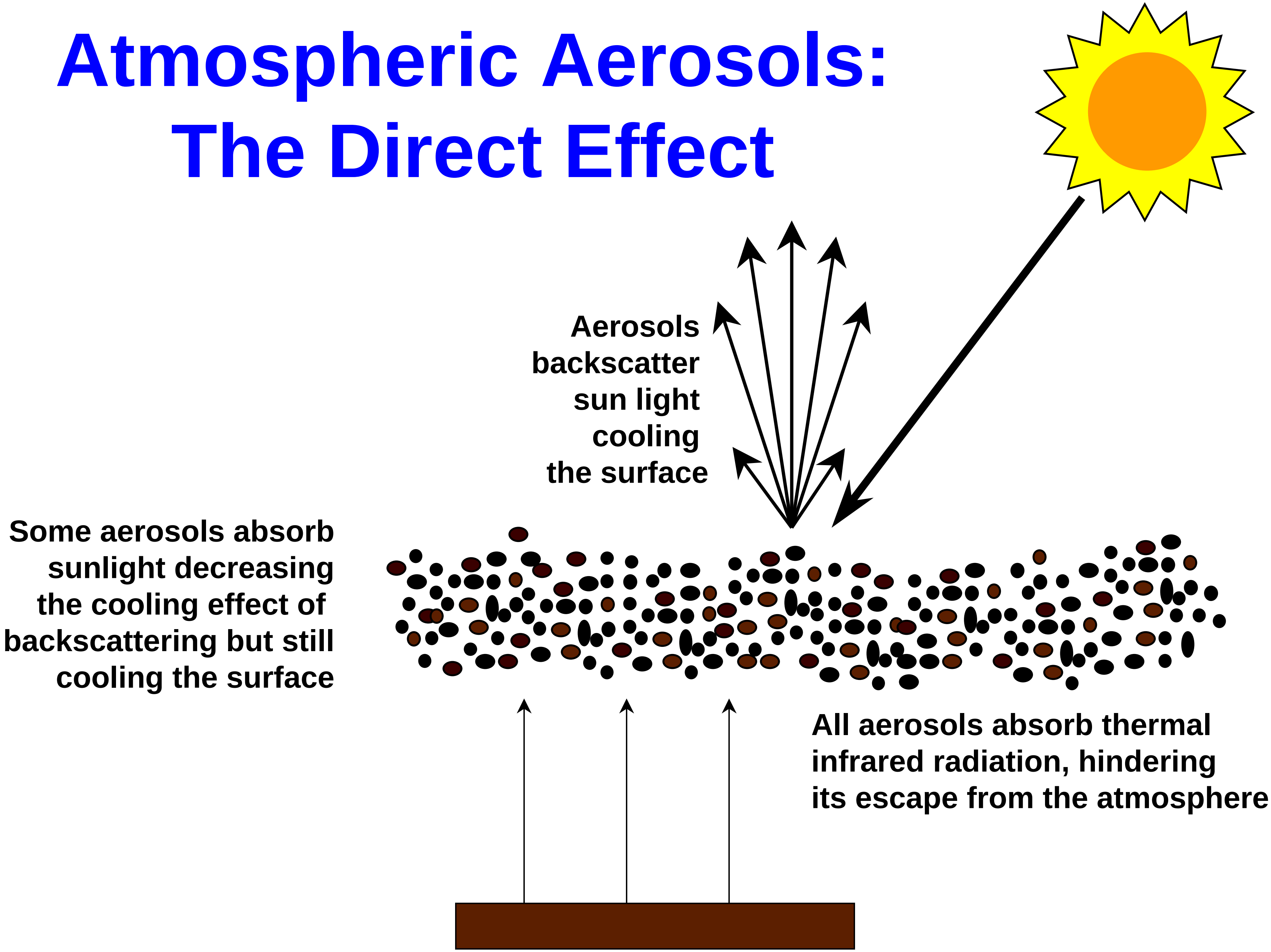
It is projected that over the next few decades, rapid industrialization and growth of 'megacities' in many parts of the world may lead to dramatic increases in total global air pollution emissions. As a result, intercontinental pollution transport is likely to become a growing problem. For instance, studies indicate that in the coming years, pollution transported from Asia could have significant impacts upon U.S. air quality.

Air pollution affects climate through radiative forcing (O_3 and aerosols) and through chemical feedbacks which alter the lifetime of reactive greenhouse gases. In turn, climate change can influence the emissions, formation, transport, and deposition of numerous air pollution species. These climate/chemistry feedbacks need to be better understood, both to make accurate predictions of future climate changes and to design effective long-term air quality management strategies.

The Global Mean Radiative Forcing of the Climate System for the Year 2000, relative to 1750

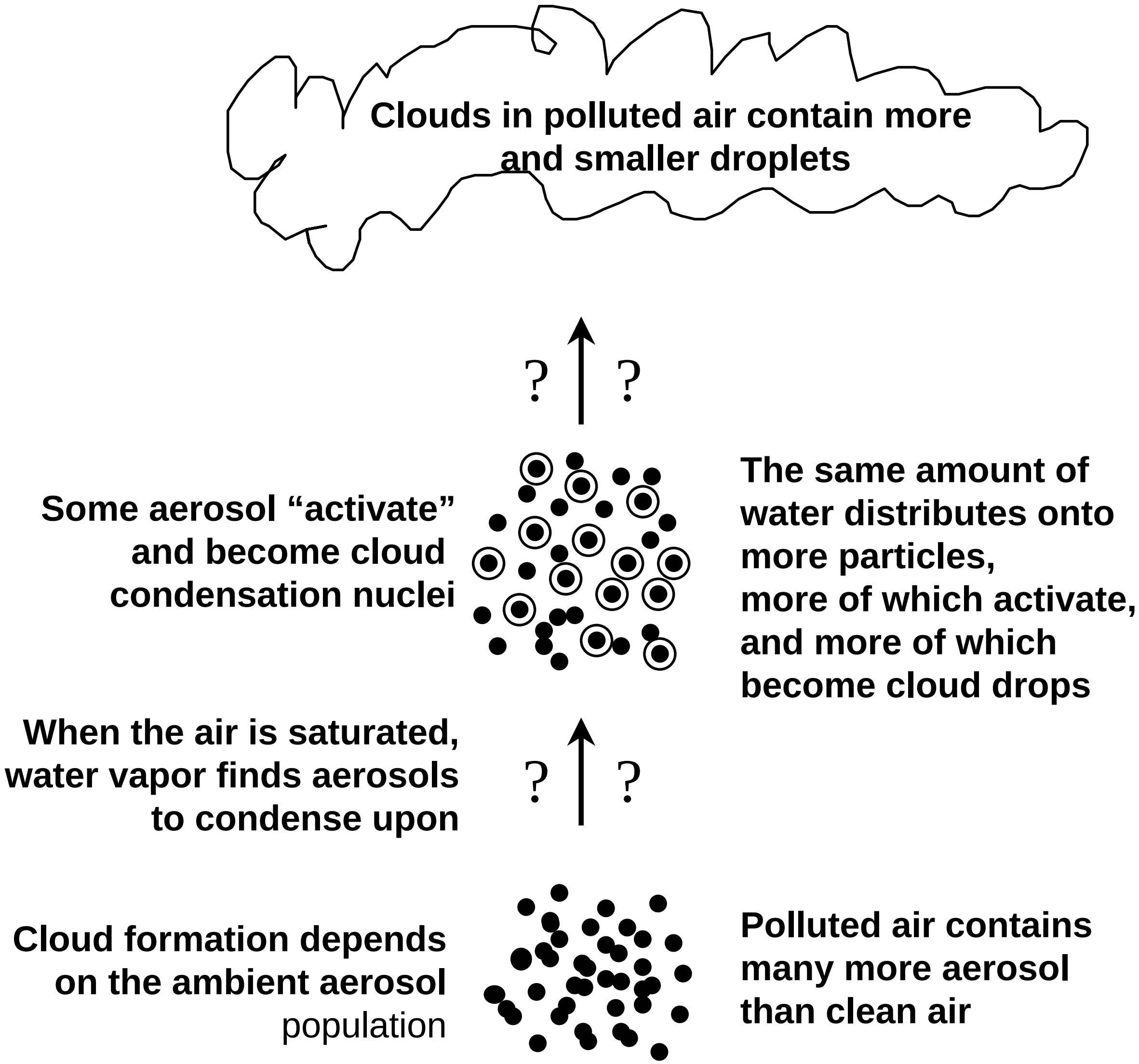


Atmospheric Aerosols: The Direct Effect



The Indirect Effect

Cloud Formation in Polluted Environments



When cloud droplets are smaller:

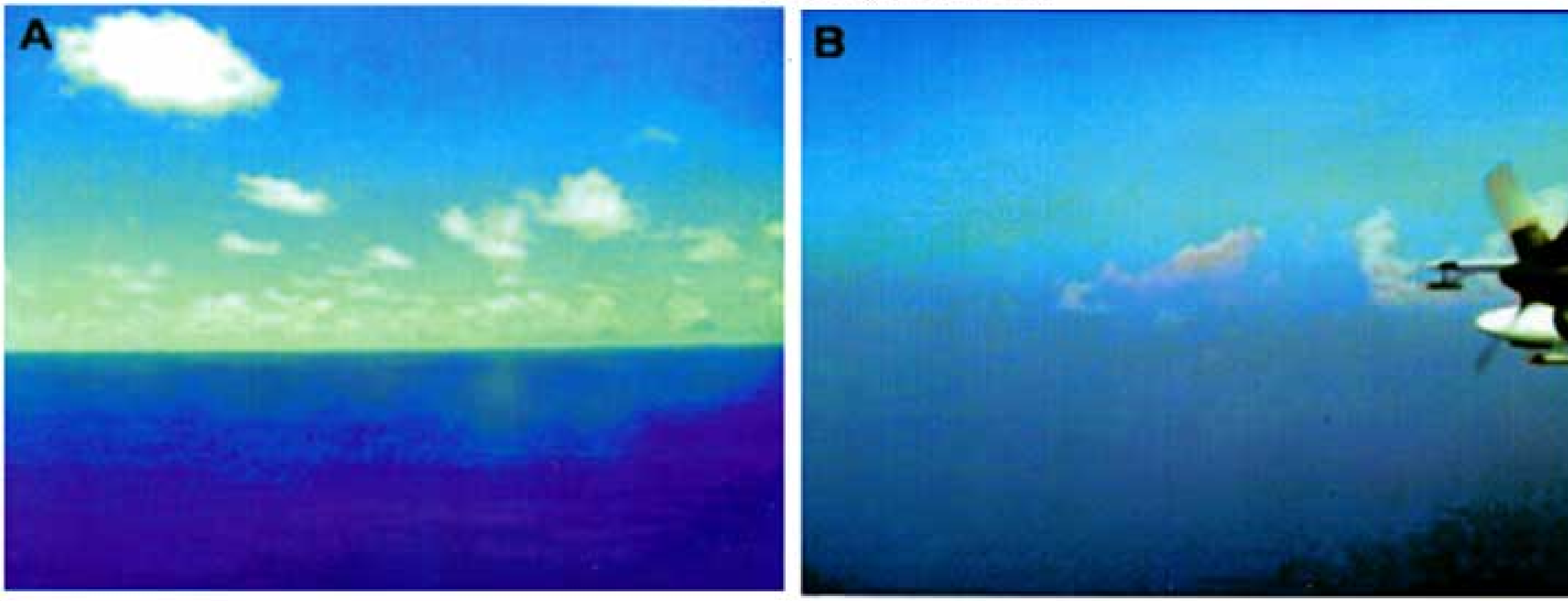
The cloud more effectively reflects incident sunlight, thus cooling the region below (the 1st Indirect Effect)

It is more difficult for droplets to grow very large, suppressing precipitation (the 2nd Indirect Effect)

Reduction of Tropical Cloudiness by Soot

A. S. Ackerman, O. B. Toon, D. E. Stevens, A. J. Heymsfield,
V. Ramanathan, E. J. Welton

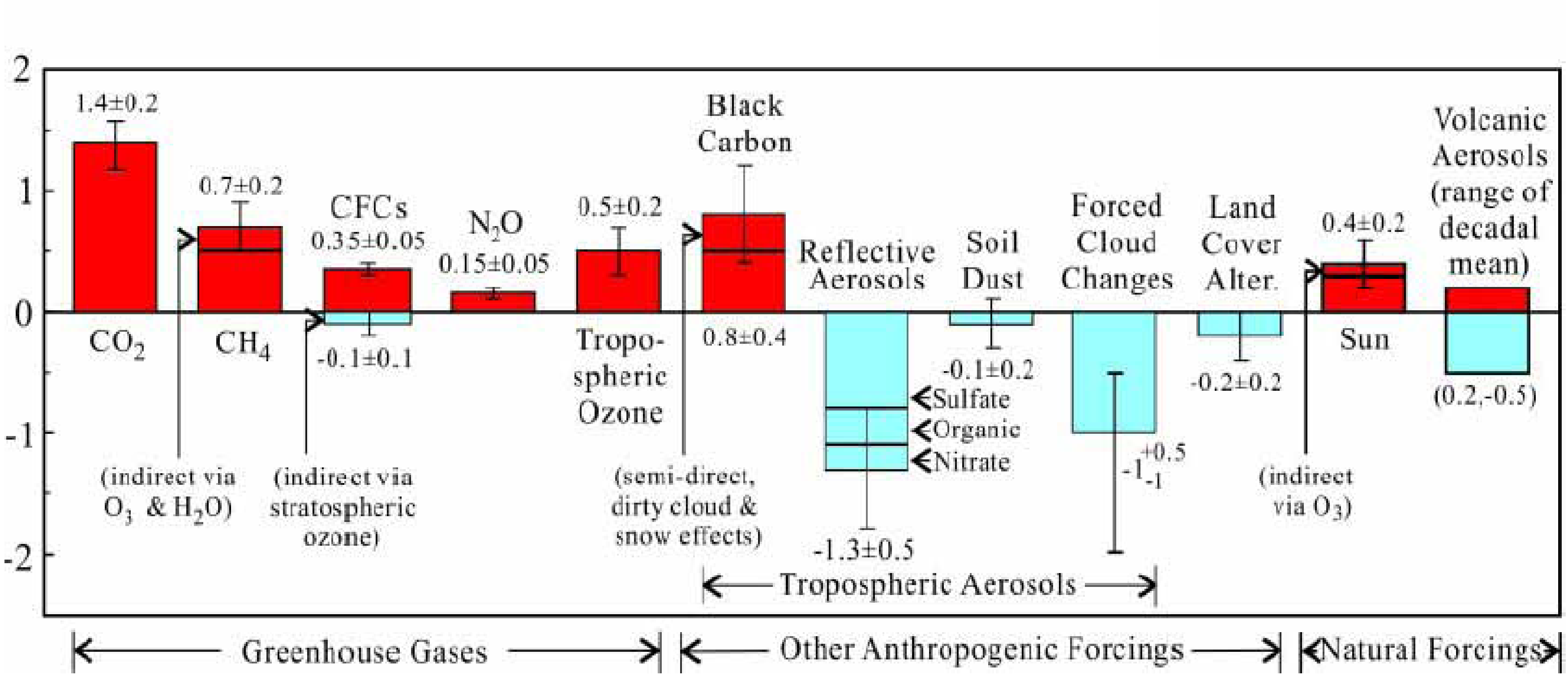
Science, 288, **2000**, 1042-1047



Images of clouds within clean and dirty marine boundary layers obtained during the INDOEX Intensive Field Phase in 1999.

(A) 4.3°S, 73°E in clean air from the southern Indian Ocean
(B) 0.2°N, 73°E in polluted air 1000 km distant from India.

The Global Mean Radiative Forcing of the Climate System for the Year 2000, relative to 1850 [Hansen and Sato, PNAS 2001]



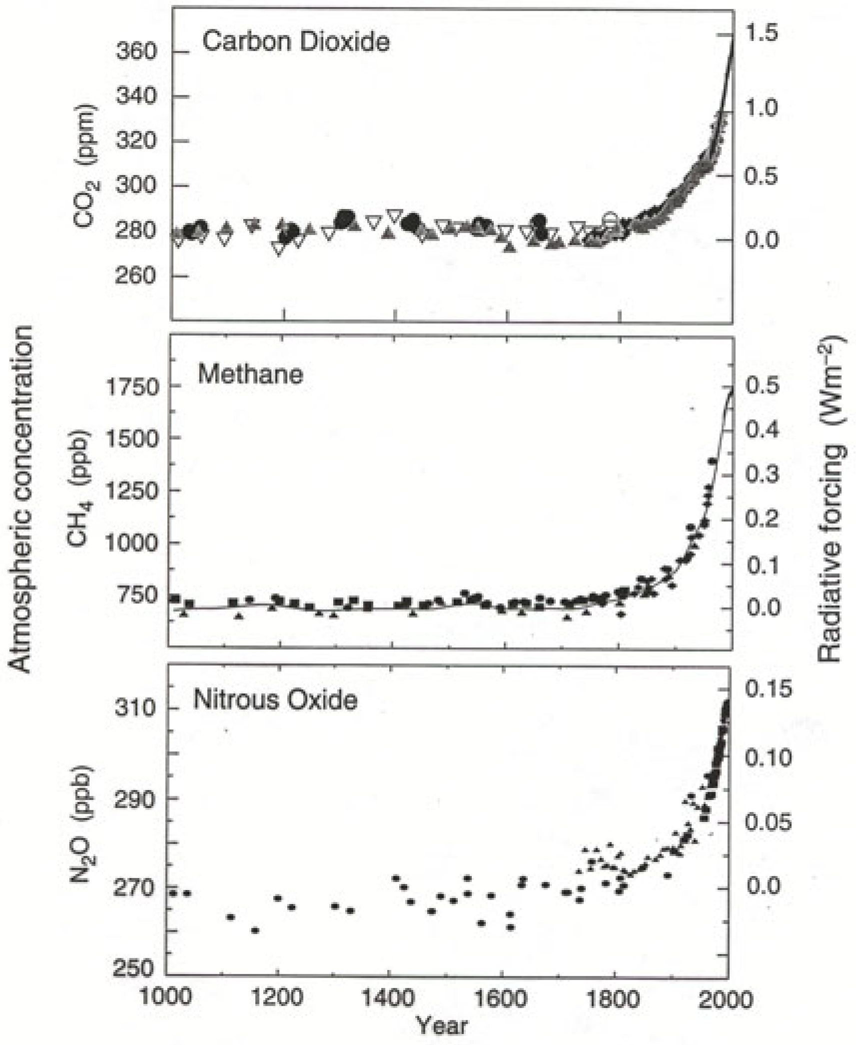
Air Quality-related forcing: 0.7 (CH_4) + 0.5 (O_3) + 0.8 (BC) = 2.0 W m^{-2}

Cooling from anthropogenic aerosols: -1.3 (dir.) – 1.0 (indir.) = -2.3 W m^{-2}

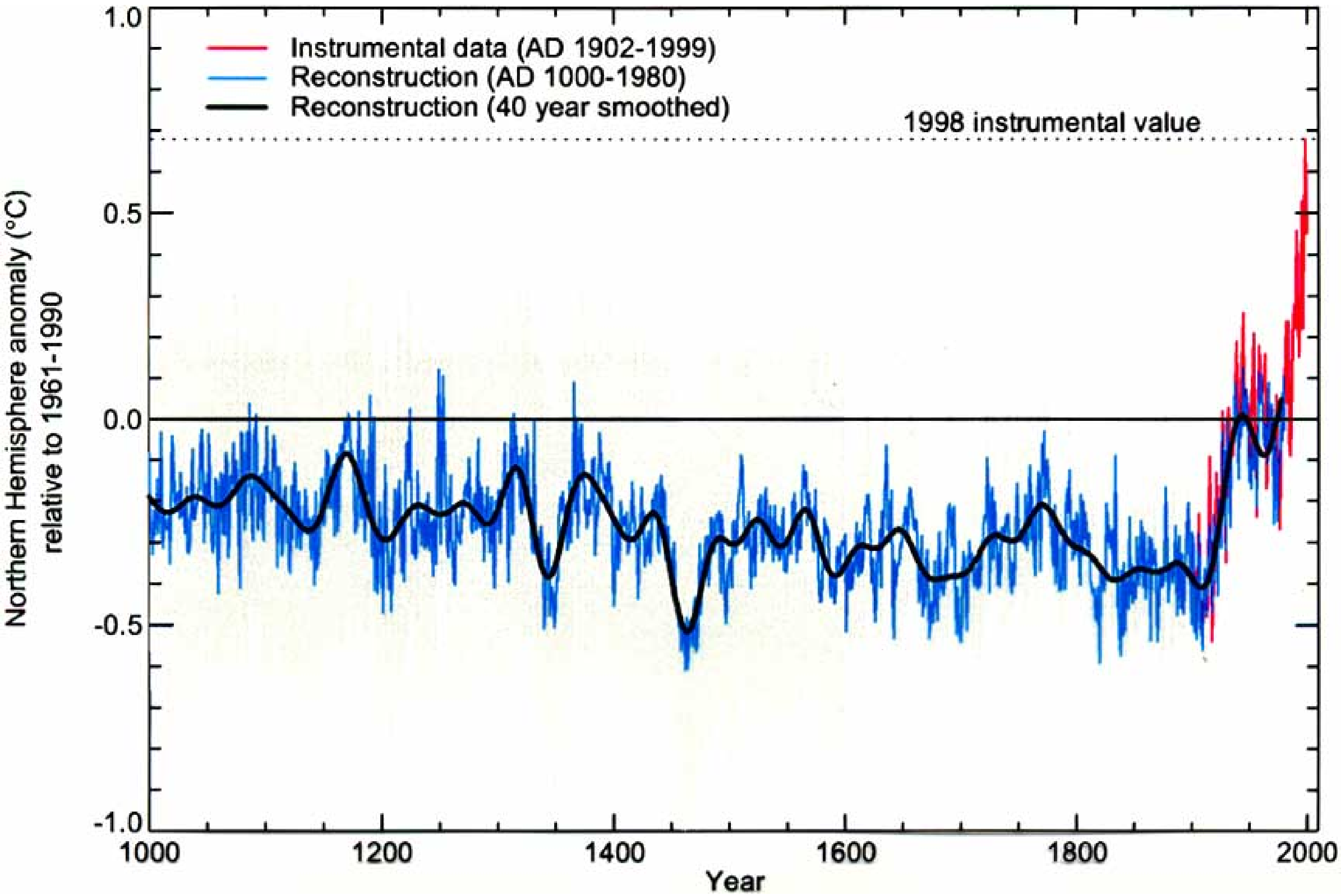
Questions about specific environmental issues:

- Is something significant happening to the environment?
- Is it a consequence of human activities?
- Should society do something about it?
- If so, how should the problem be solved?

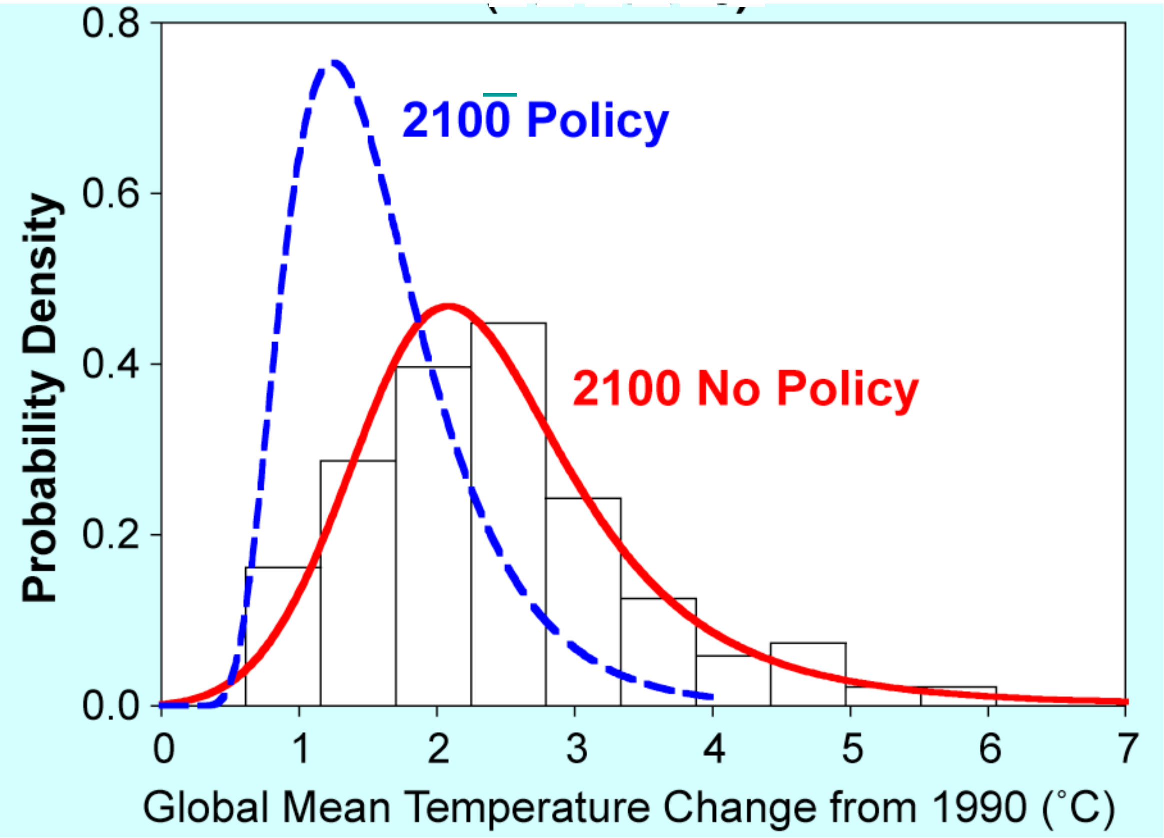
Global Atmospheric Concentrations of Three Greenhouse Gases



Mean Surface Temperature 1000 to 2000



Global Mean Surface Temperature Change (1990-2000)



The solid red line shows the distribution resulting from no emissions restrictions, and the dashed blue line is the distribution under the sample policy.

Source: Webster *et al*. (2002)

Human Population Growth