Air Pollution Trends and Impacts: Assessing Transportation in the Context of Global Change

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Transportation@MIT Seminar
29 March 2011

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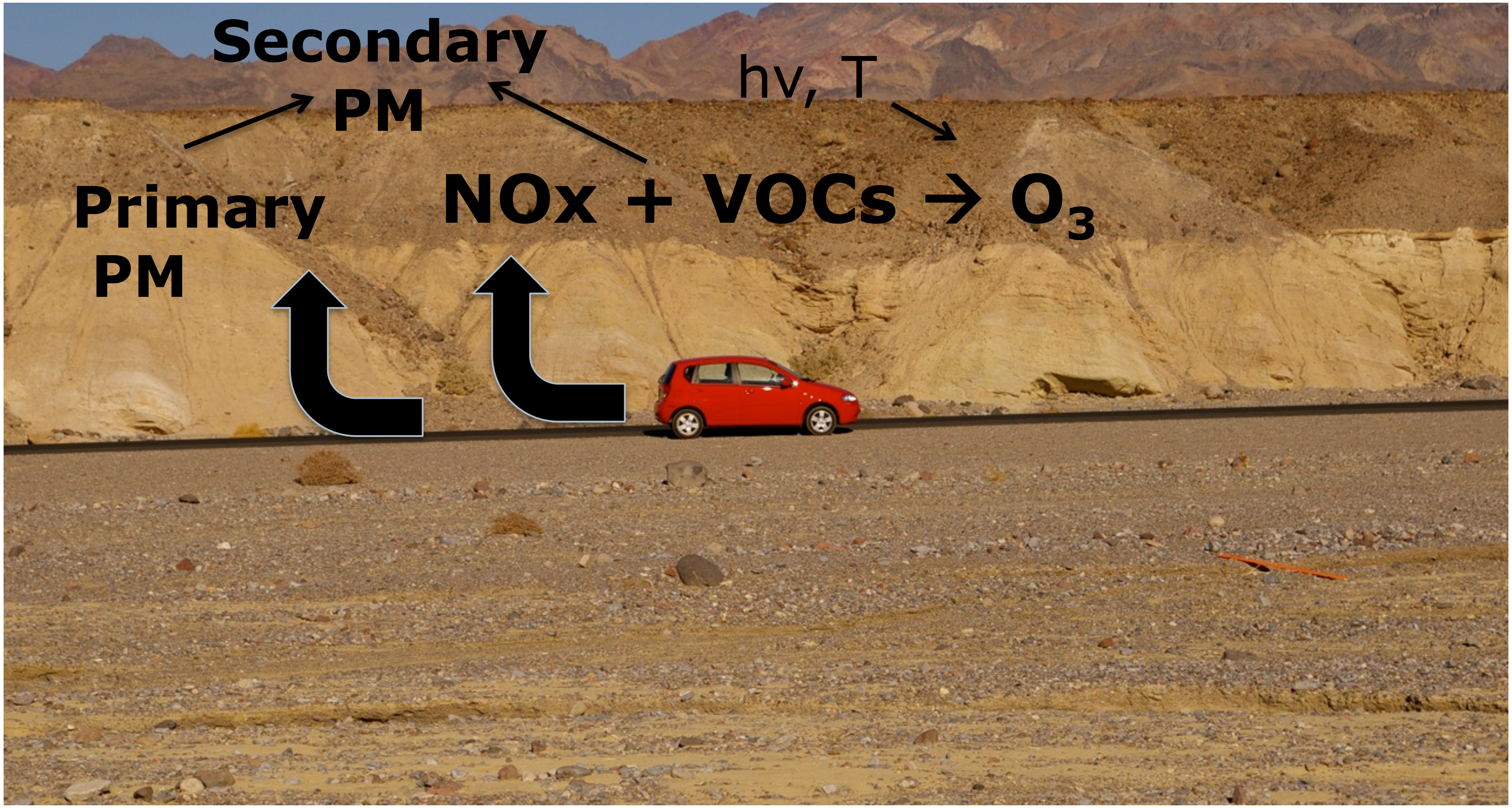
EAPS

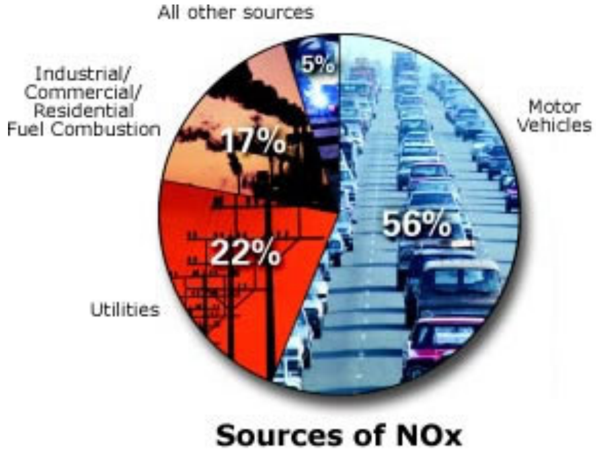
Air Pollution Trends and Impacts: A Systems Approach

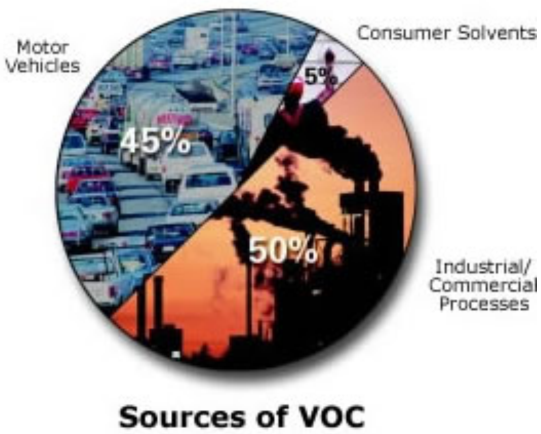
- Research Focus: Understanding how present and potential future human activities influence air pollution and its impacts, and informing more effective management
- Current Research Topics:
  - Assessing impacts of air pollution and climate policies
  - Transport and fate of toxic pollutants (e.g. mercury, persistent organic pollutants, other air toxics)
  - Science and policy of hazardous substance management
- Tools:
  - Atmospheric chemistry modeling
  - Economic and health impact modeling
  - Social science techniques

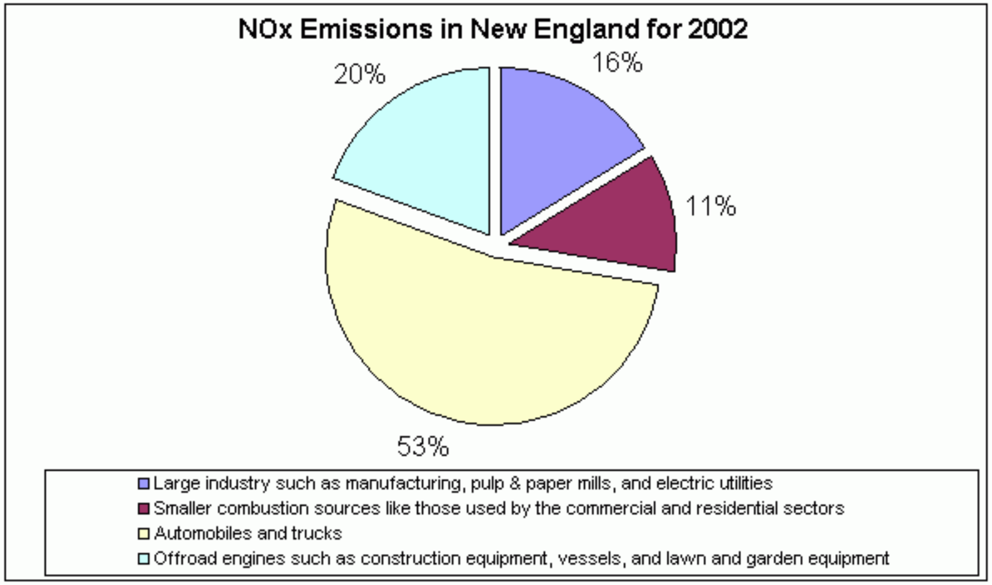
Air Pollution: What's the Problem?



Transport contributes a large fraction of pollutant emissions

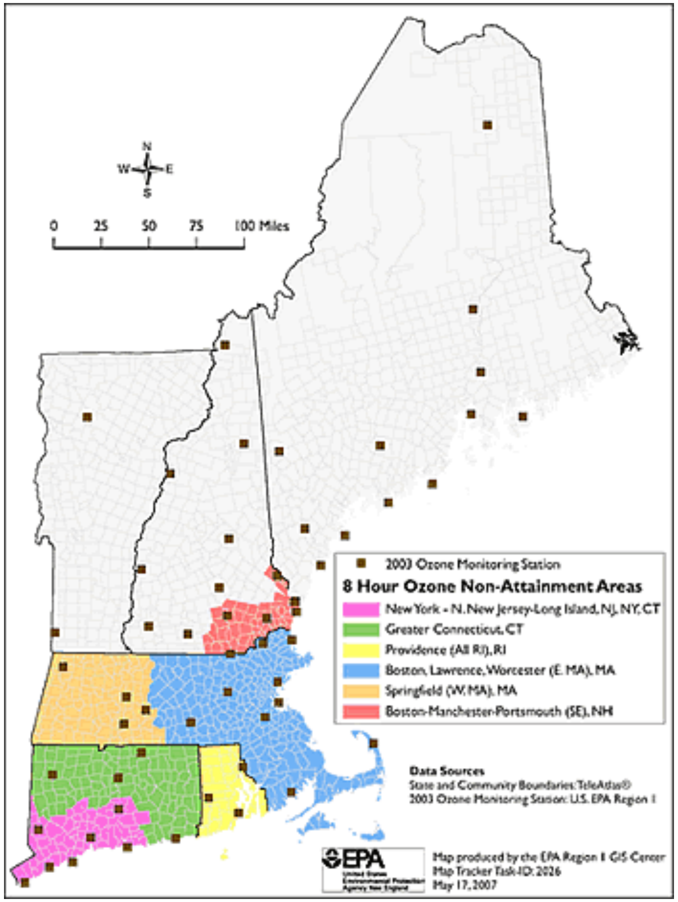






Source: U.S. EPA

U.S. EPA Air Quality Regulations



OZONE

1997 Standard: 0.08 ppm (8-hour)
2008 Standard: 0.075 ppm (8-hour)

2010-2011 revisions: will be proposed between 0.060-0.070 ppm by July 2011

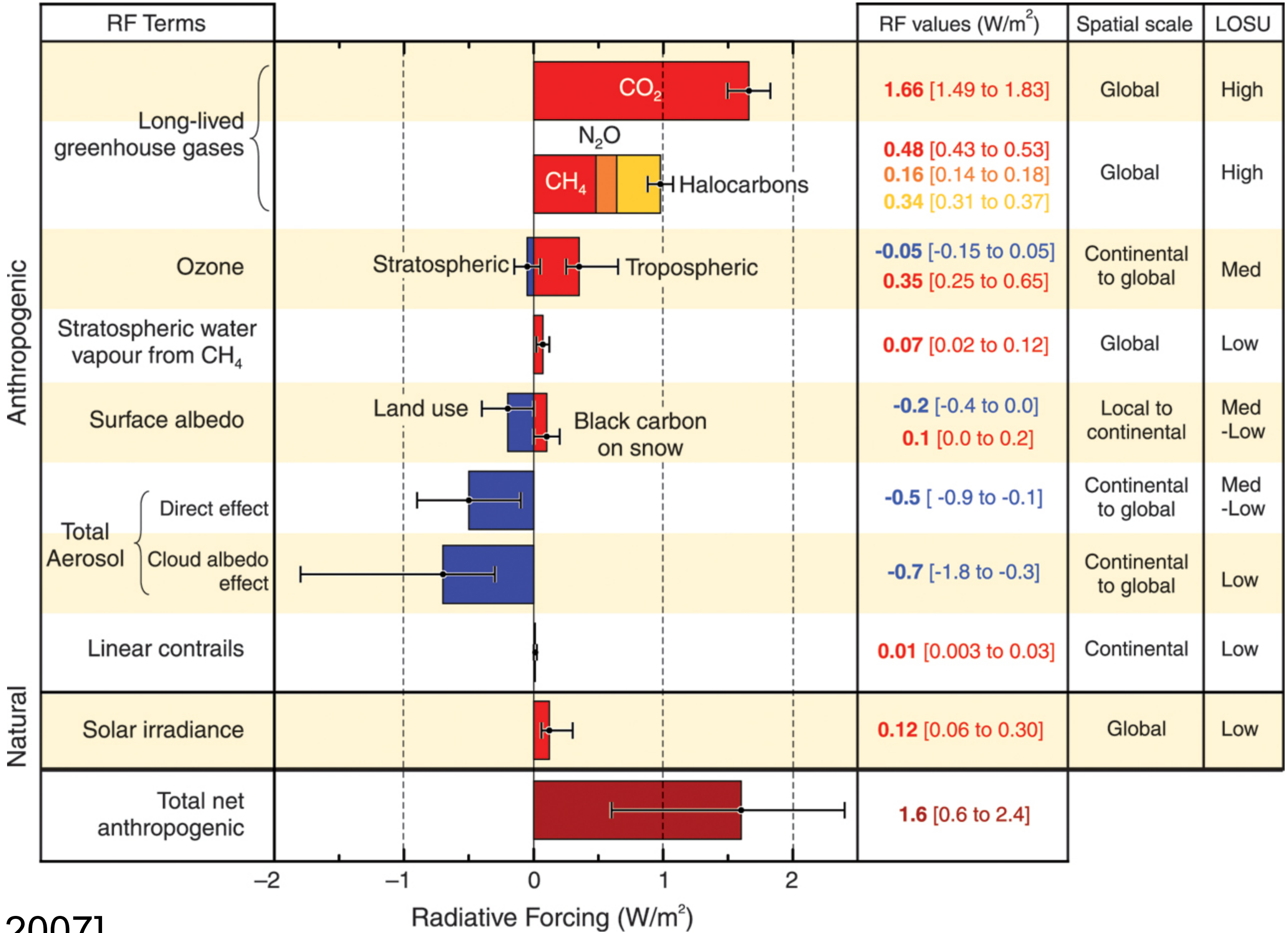
To meet the standard: 3-year average of 4^{th} highest daily maximum O_3 at each monitor over a year.

PARTICULATE MATTER

$PM_{2.5}$: 15.0 µg/m^3 (annual mean)
35.0 µg/m^3 (24hr 98^{th} percentile)

Health impacts research suggests no threshold for ozone, particulate matter damage

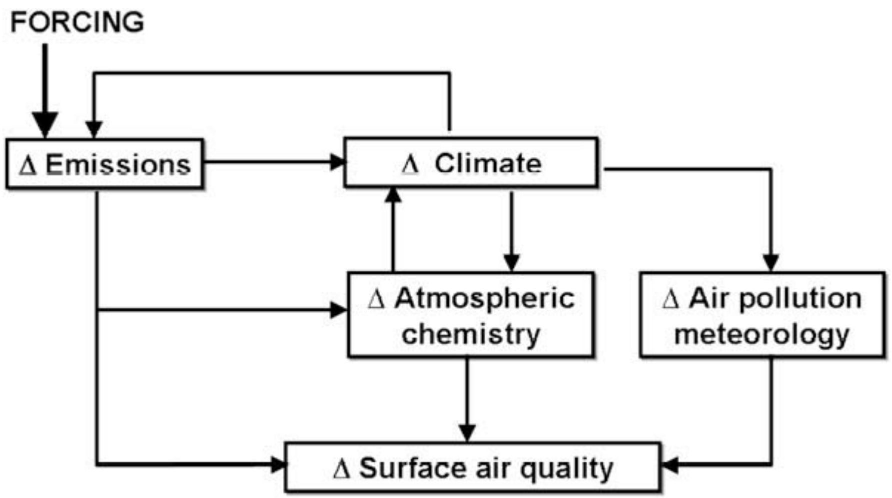
Links between Air Pollution and Climate



[IPCC, 2007]

Links between Climate and Air Pollution

- Climate change affects ozone, PM
- Ozone, PM affect climate change
- Policies to mitigate air pollution and climate change affect same sources – can be win-win, lose-lose



[Jacob and Winner, 2009]

Links between Climate and Air Pollution

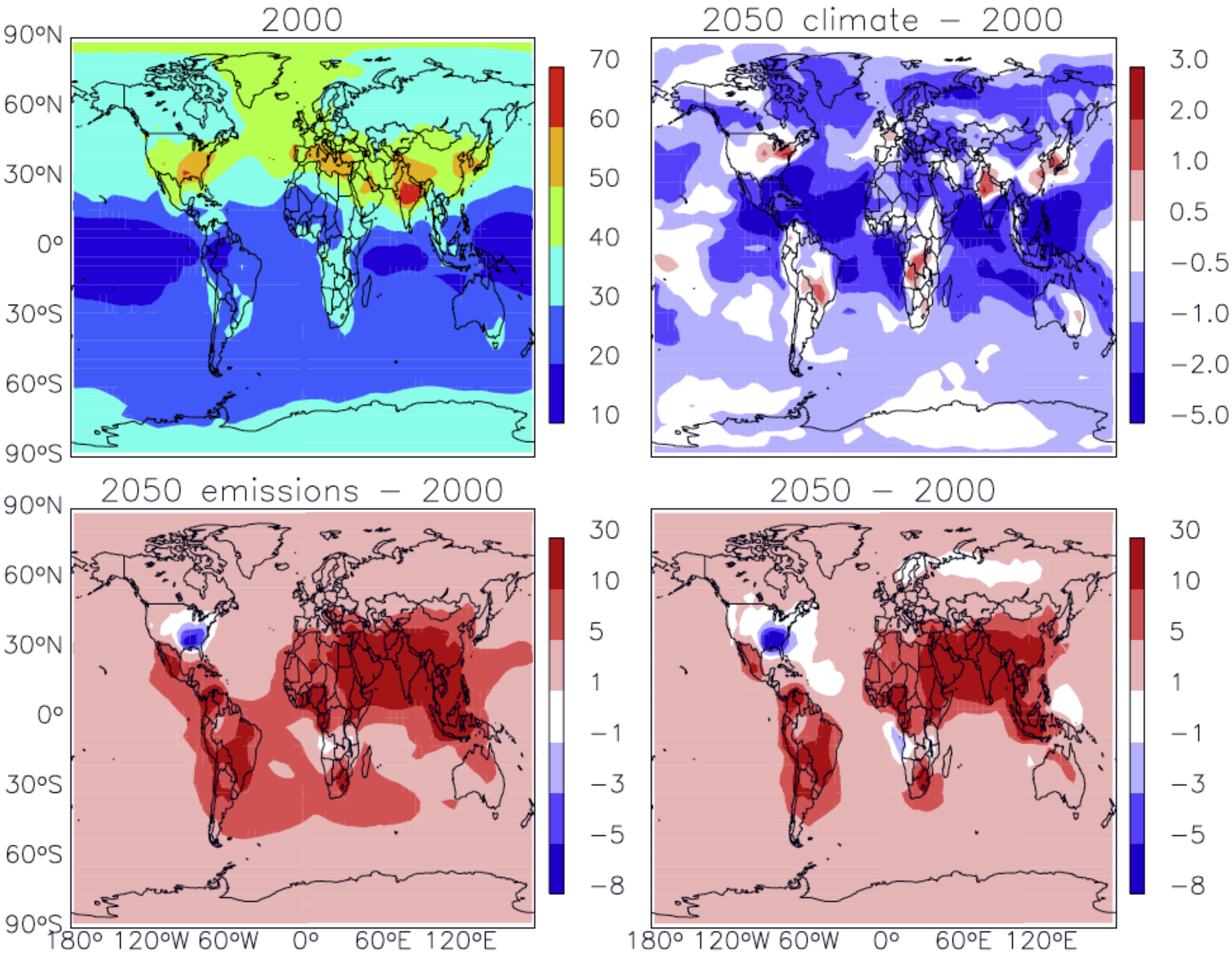


Figure 1b. Same as Figure 1a, but for annual mean afternoon (1300–1700 local time (LT)) surface ozone in ppb and with perturbations shown as absolute differences. Note differences in scales.

[Wu et al., 2008]

How will transportation technologies impact air quality and human health in 2050?

Our approach: Develop coupled methodology to assess future air quality and human impacts (& associated uncertainties), quantify costs and benefits, and benchmark through Northeast US case study

Case Study of Northeast U.S. and electric vehicles

Hybrid, Plug-in hybrid & electric vehicles

www.chevrolet.com/electriccar

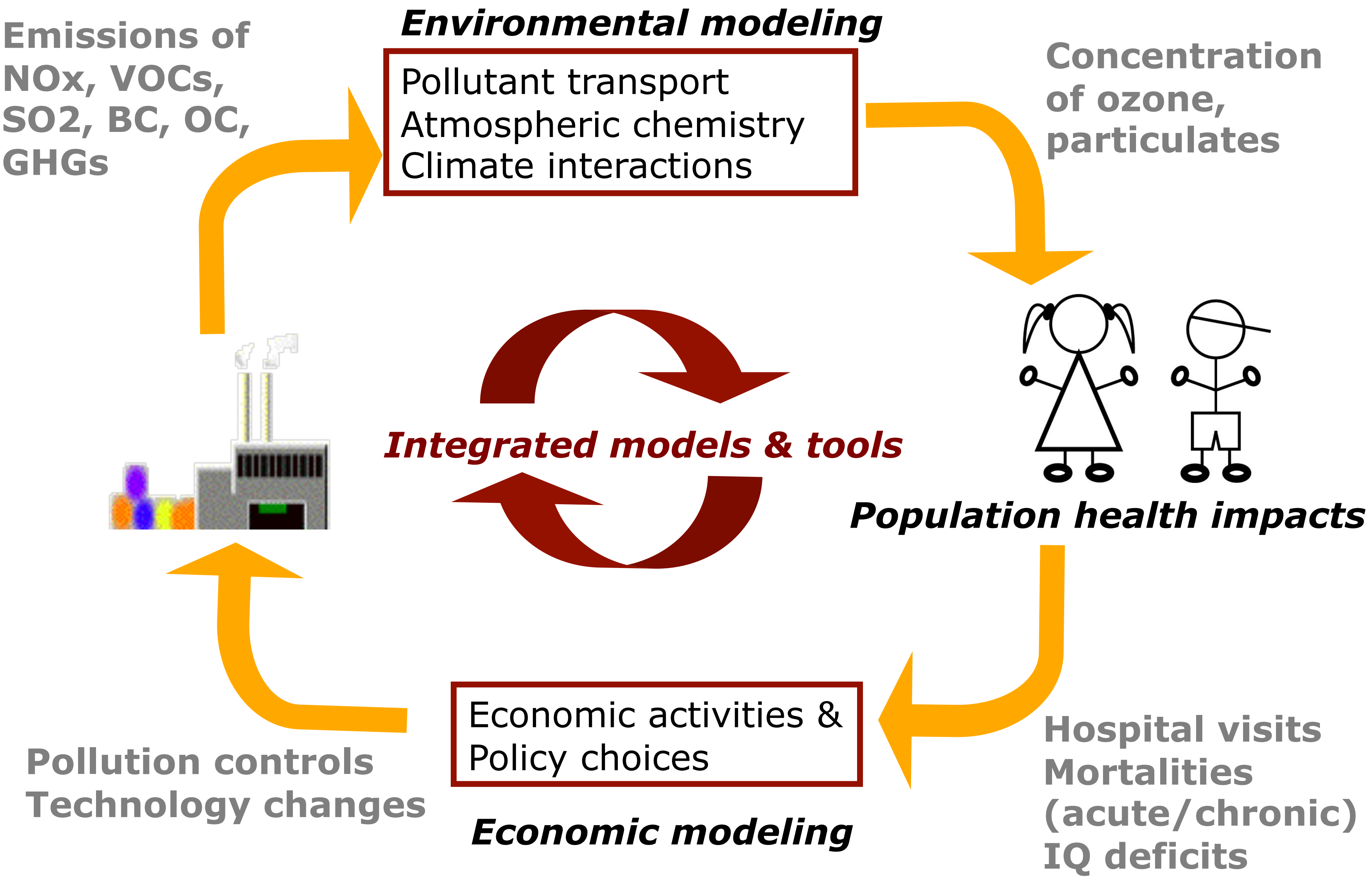
U.S. EPA STAR Grant, 2009-2012,
with M. Webster (ESD) and P. Amar (NESCAUM)

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD-83427901-0

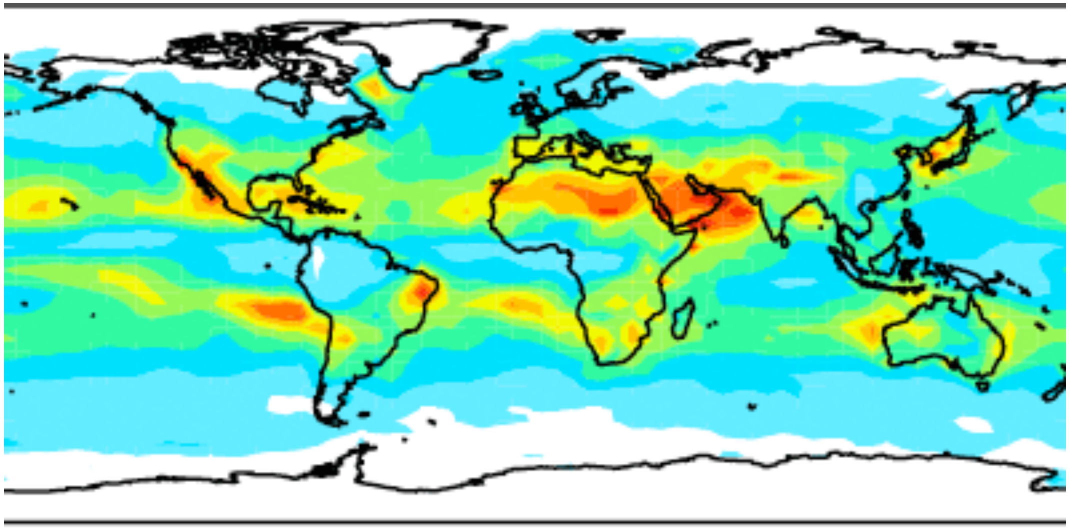
Challenges to integrated assessment of air pollution and health impacts

- **Lack of coupling**: assessment of impacts not necessarily consistent with atmospheric model assumptions, and feedbacks not usually taken into account
- **Uncertainty assessment**: often not taken into account, and detailed regional modeling is too computationally-intensive to apply quantitative uncertainty analysis

Framework for assessing air pollution impacts



Methodology I: Atmospheric Modeling



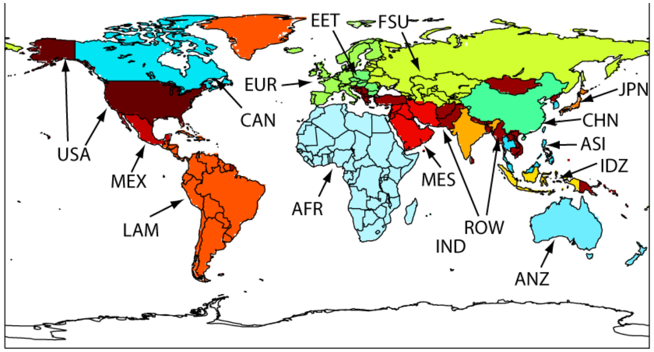
- Develop ways to deal with scale, uncertainty, computational issues
- Enforce emissions consistency and improve policy and impacts analysis

- Models: GEOS-Chem, CAM, CAMx
- Climate and air quality simulations
- Scale: regional to global

Methodology II: MIT EPPA Health Effects Model

Emissions Prediction and Policy Analysis model: general equilibrium economic model

Concentration of O_3, particulates (data, model): Population-weighted concentration per global region (16 regions)



Morbidity and mortality outcomes and costs

Outcome	Concentration–response function[a]	95% confidence interval[b]	Cost EU[c] ($2000)	Std error cost[d]	Cost China ($2000)
Mortality from acute exposure	0.03%[e]	(0.01%, 0.04%)	23 000	3100	690
Respiratory hospital admission (adults >65 years)	1.25×10^{-5}	$(-5.0 \times 10^{-6}, 3.0 \times 10^{-5})$	1800	570	290
Respiratory symptom day	3.3×10^{-2}	$(5.7 \times 10^{-3}, 6.3 \times 10^{-2})$	35	11	<1
Minor restricted activity day	1.15×10^{-2}	$(4.4 \times 10^{-3}, 1.9 \times 10^{-2})$	35	11	<1
Asthma attack	4.29×10^{-3}	$(3.3 \times 10^{-4}, 8.3 \times 10^{-3})$	49	16	4.6
Bronchodilator usage	7.30×10^{-2}	$(-2.6 \times 10^{-2}, 1.6 \times 10^{-1})$	0.92	0.29	<1
Lower respiratory symptoms (wheeze) in children	1.60×10^{-2}	$(-4.3 \times 10^{-2}, 8.1 \times 10^{-2})$	35	11	<1

[a] Units are cases yr^{-1} $person^{-1}$ μg^{-1} m^3.
[b] Normal distributions applied for symmetric confidence intervals, and beta distributions applied for asymmetric confidence intervals. Confidence intervals are cut off at zero and negative values are not assessed.
[c] Converted from €2000 using exchange rate $1 = €1.085 (mean for year 2000).
[d] Normal distributions applied for costs.
[e] Units are Δ annual mortality rate μg^{-1} m^3

Loss of labor, capital and equilibrium economic effects (2000-2100); global economic activity and emissions

[*Selin et al.*, *ERL*, 2010]

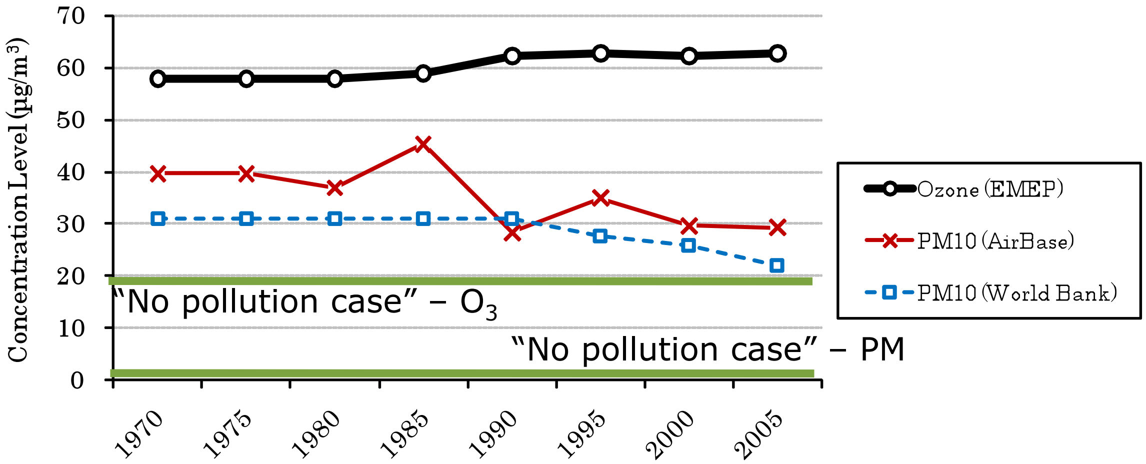
US Regional Energy Policy (USREP) Model

Health impacts module under development
(following global EPPA methodology) by R. Saari (ESD PhD 1st year)

[Rausch et al., 2010; Saari, Rausch & Selin in prep]

Health Costs of Air Pollution in Europe

Applied historical concentrations from measurements, models (EU15+Norway, Iceland, Switzerland)



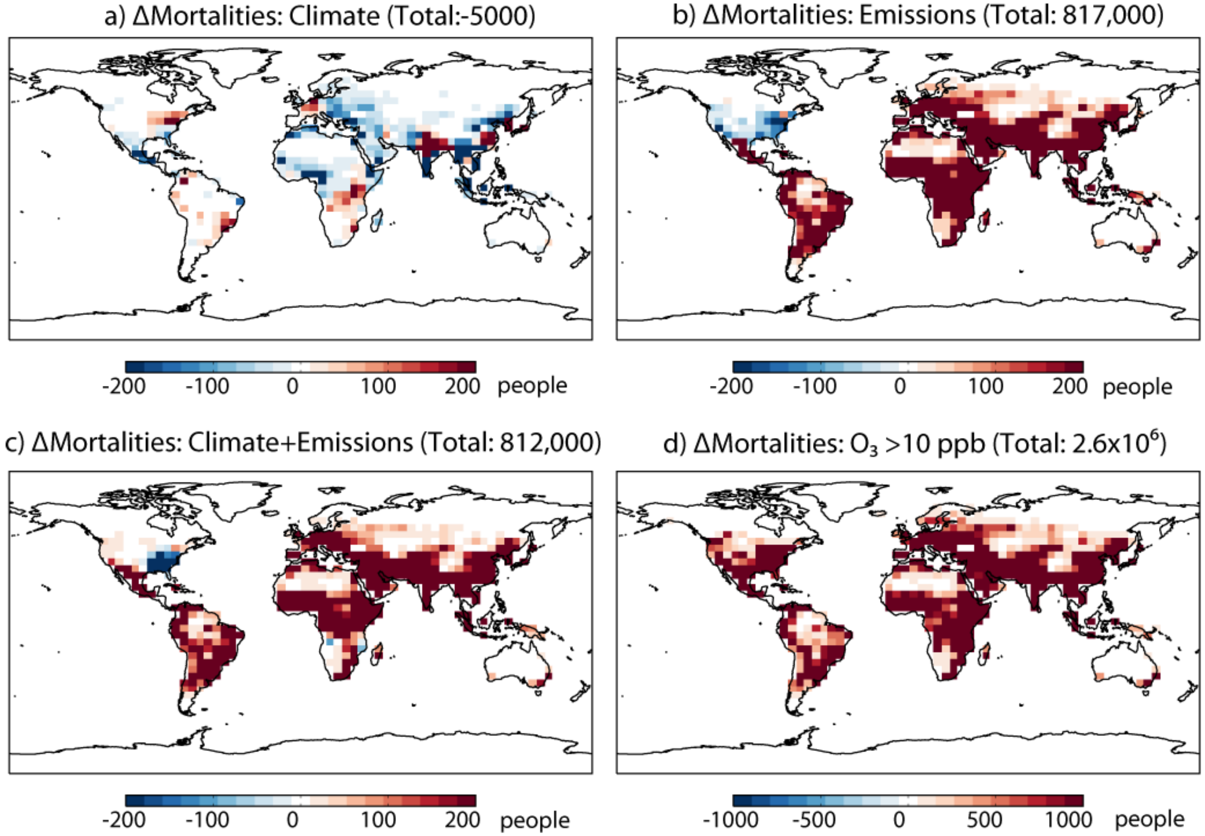
Compared economy with historical pollution vs. "no pollution case"

Air pollution results in annual consumption loss of **€220 billion** (year 2000 prices), or 3% of total consumption.
Uncertainty range: €107-335 billion

Total welfare loss: **€370 billion** (taking into account leisure)
Uncertainty range: €209-550 billion
About half of losses from accumulated damages

[Nam, Selin et al., Energy Policy, 2010]

Global Impacts of Ozone Pollution in 2050

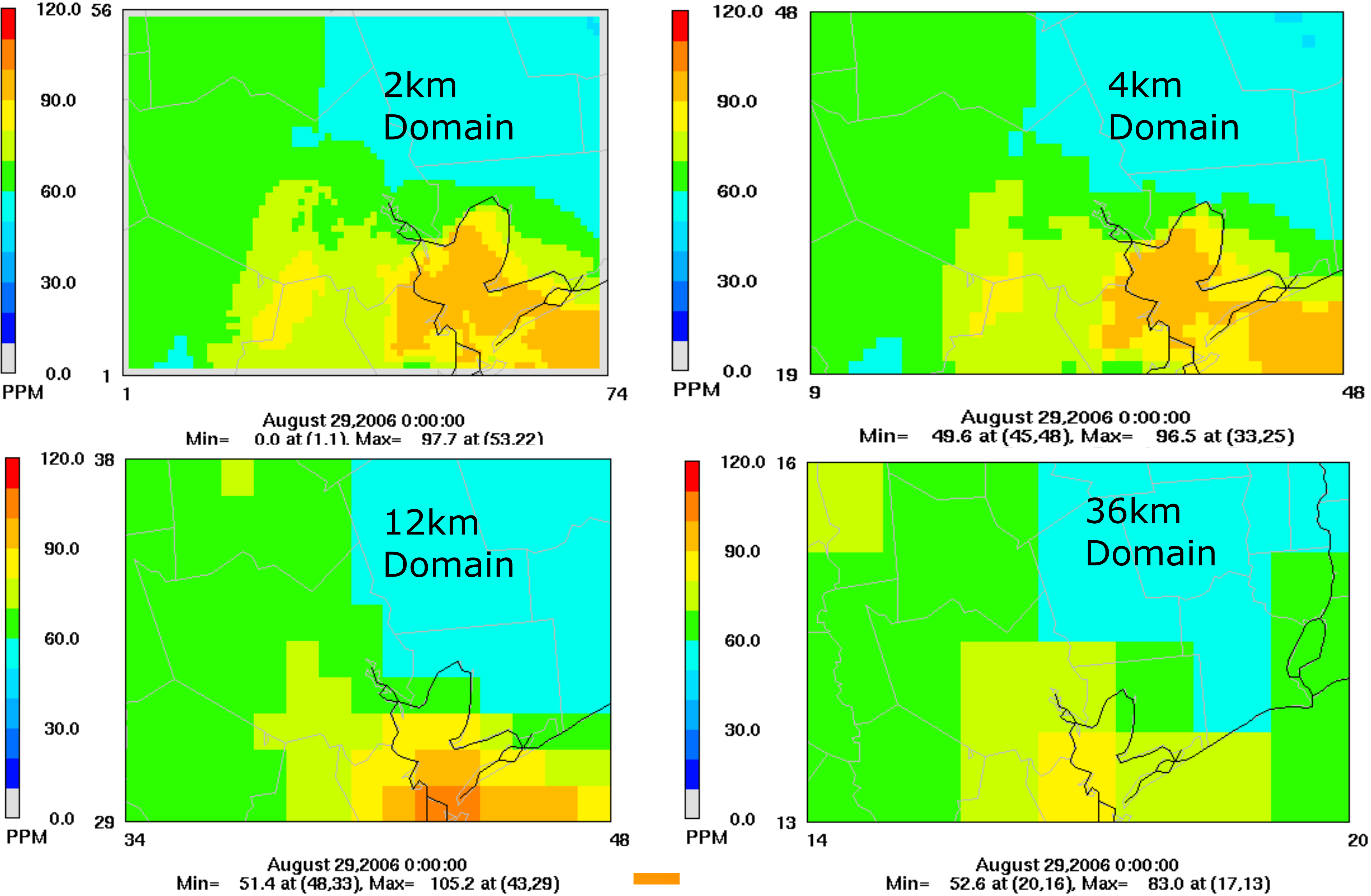


- O_3 from A1B scenario [Wu et al., 2008] to 2050
- Calculate change in mortalities due to health impacts of ozone changes, separately for emissions and climate drivers

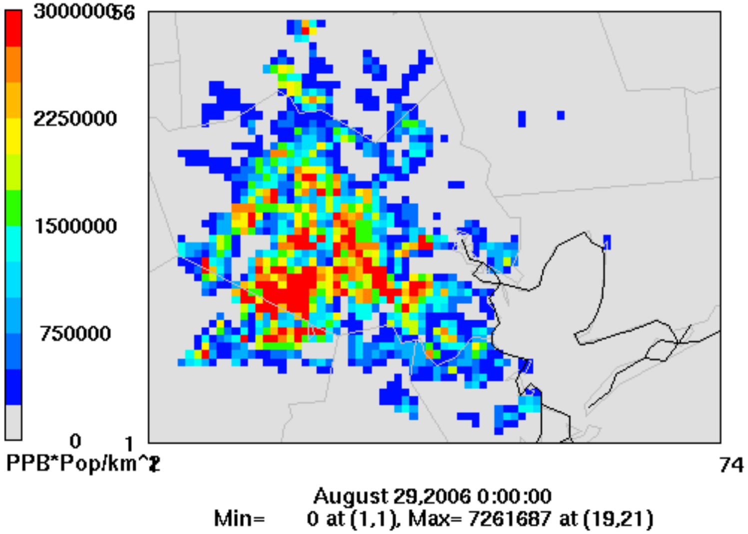
- 2050 mortalities from O_3, climate only scenario: -4600
- 2050 mortalities from climate+precursor changes: 800,000
- 2050 mortalities from all O_3 above background: >2 million

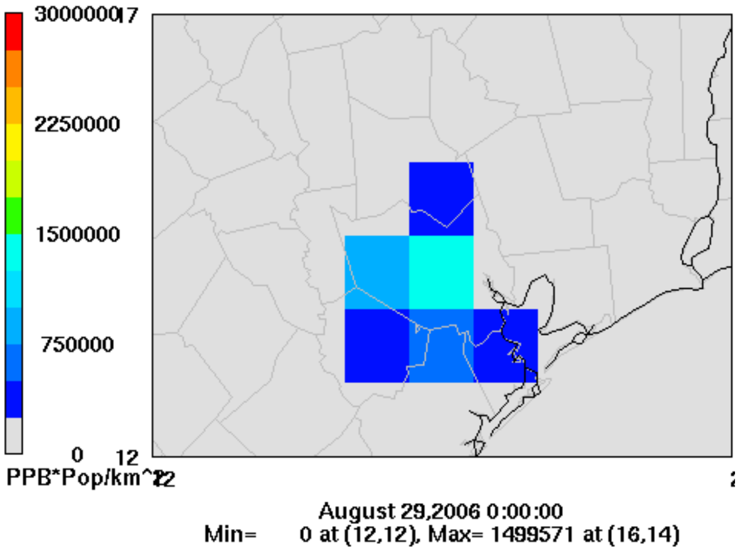
[*Selin et al.*, ERL, 2009]

What is the impact of model resolution on calculating exposure to and impacts of air pollutants? (1 hr O3)



What is the impact of model resolution on calculating exposure to and impacts of air pollutants?



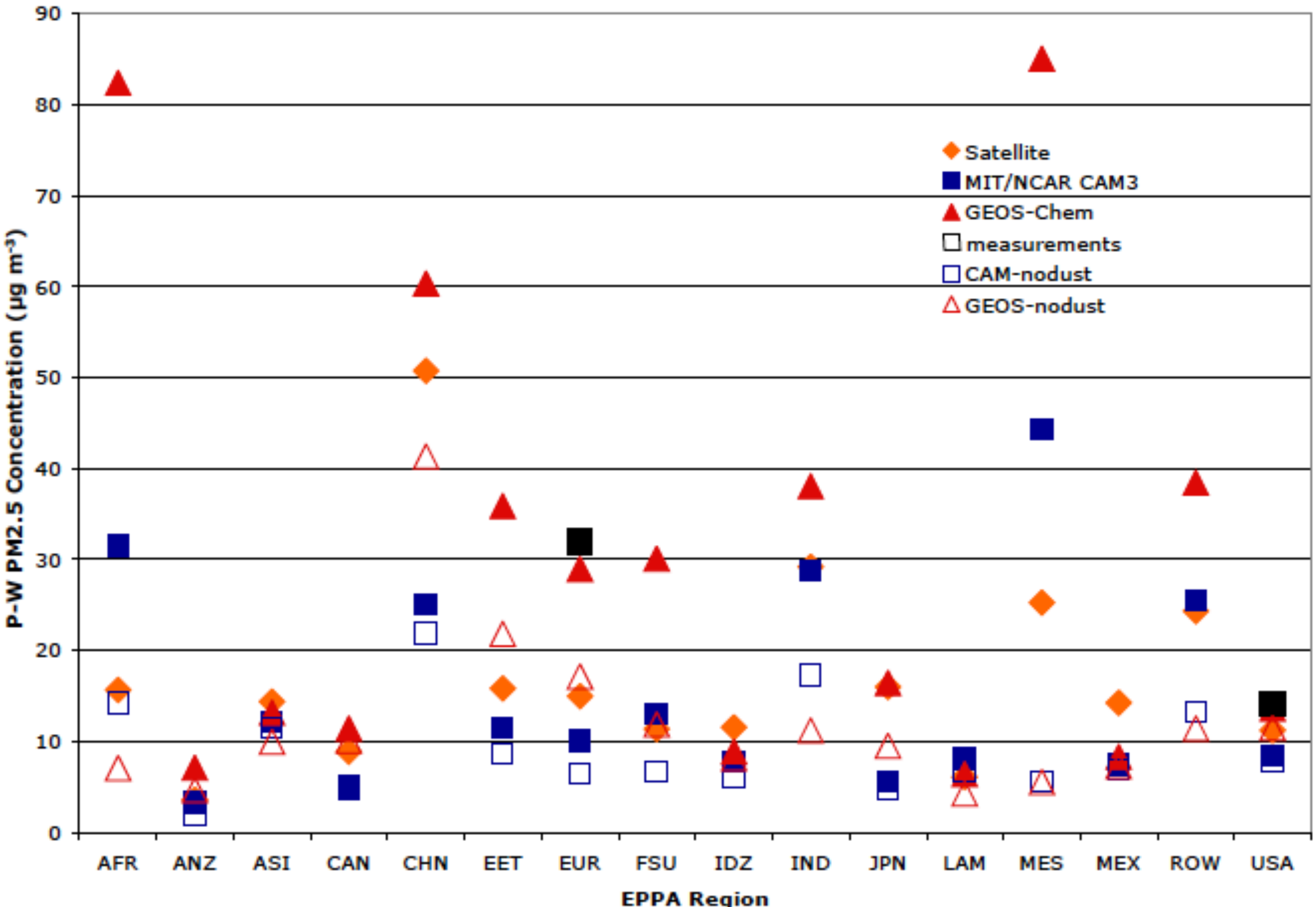


Population Weighted Daily Exposure						
% Change from 2k Resolution to:	**29-Aug**	**30-Aug**	**31-Aug**	**1-Sep**	**2-Sep**	**3-Sep**
4k Resolution	-0.2%	-0.1%	-0.1%	0.0%	-0.1%	-0.2%
12k Resolution	-0.8%	-4.2%	-0.9%	5.0%	-1.3%	-6.5%
36k Resolution	-2.5%	-4.5%	2.6%	7.4%	-2.6%	-8.1%

- How do uncertainties in atmospheric modeling compare with impacts uncertainties?
- What is resolution necessary for assessing health impacts?

[Thompson, Selin et al. in prep.]

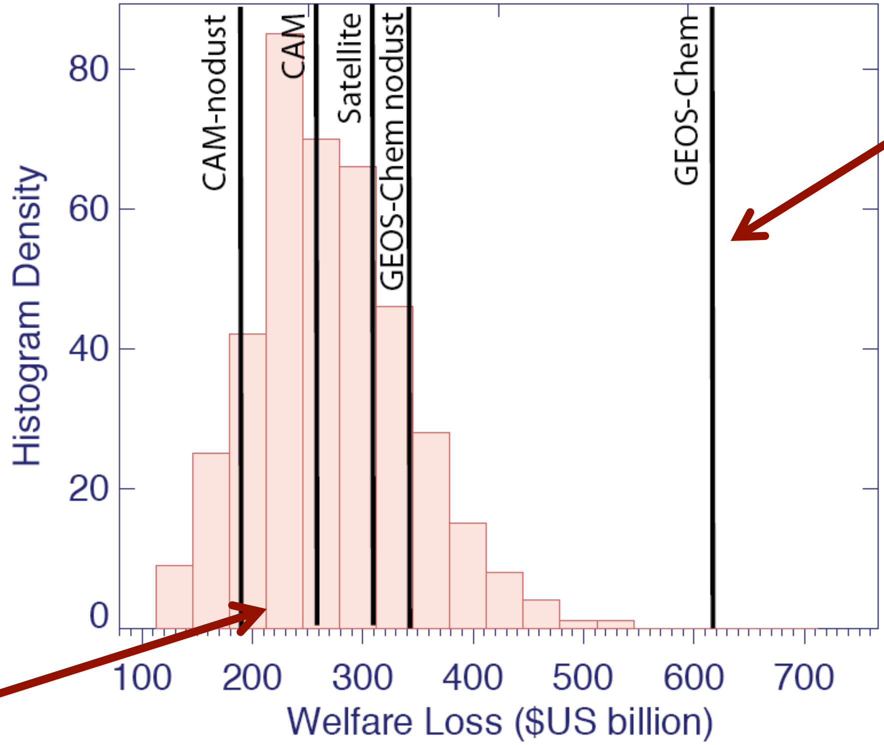
What is the relative degree of uncertainty in atmospheric modeling vs. health impacts and economics?



[Selin et al., in prep.]

Assessing uncertainties in coupled modeling

Monte Carlo analysis of PM2.5 health impacts and related costs: relative uncertainties in different global PM2.5 estimates, compared with uncertainty in health and economic variables



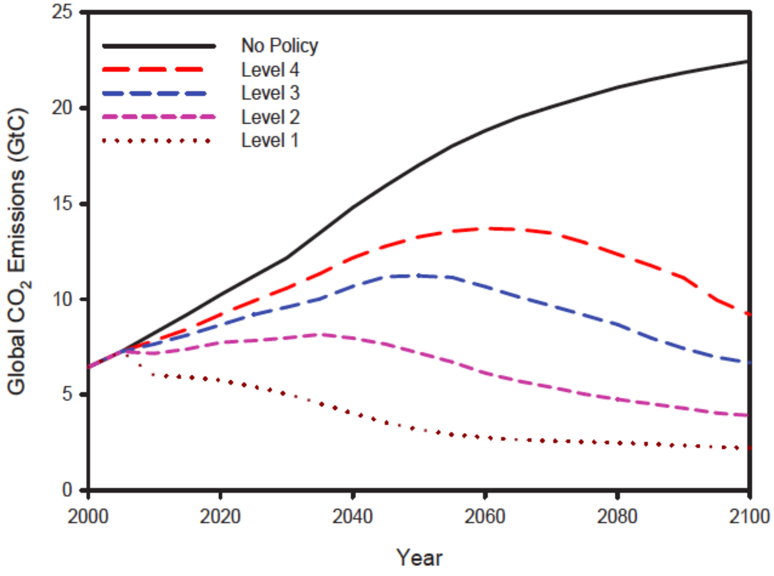
Black vertical lines: calculated cost for different PM2.5 estimates/models, holding health/ economic functions constant

Pink: uncertainty range spanned by health/ economic uncertainty, with selected PM2.5 estimate (satellite product) held constant

Bottom line: atmospheric modeling contributes substantially to overall uncertainty!

[Selin et al., in prep.]

Co-Benefits of Climate Policy for PM2.5 health impacts (2050)



Emissions scenarios from MIT EPPA: Webster et al., 2009

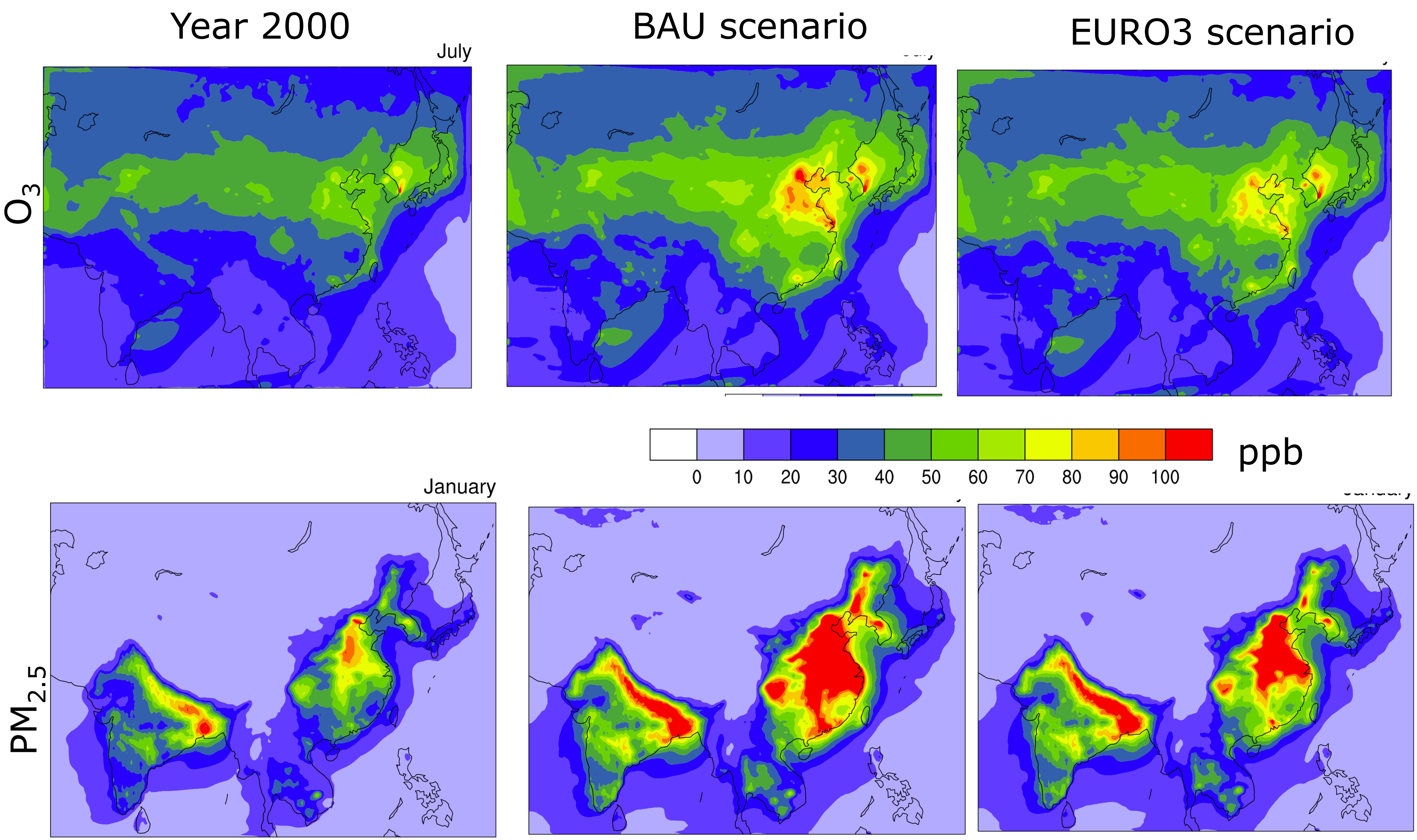
Atmospheric Modeling: MIT/NCAR CAM [Kim et al., 2008]

For comparison,
climate change policies cost 0.4-6.7% of global consumption in 2060

Climate policy	Change in welfare relative to no policy case ($US billion, year 2000)	Change in welfare relative to no policy case (%)
No policy	--	--
Climate change only	$12	0.006%
Level 4	$140	0.06%
Level 3	$220	0.10%
Level 2	$330	0.15%
Level 1	$330	0.15%

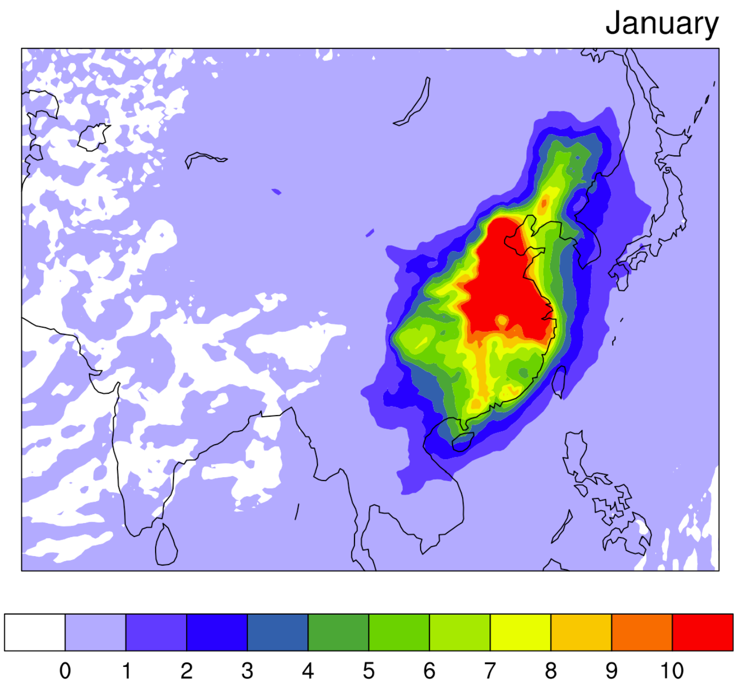
[Selin et al., in prep]

Health Impacts of Vehicle Pollution Control in China

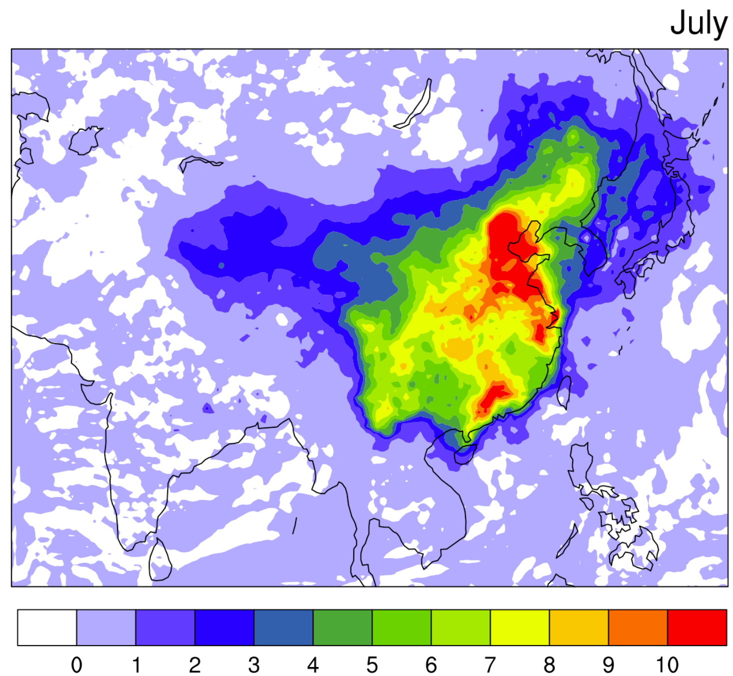


[Saikawa et al, submitted]

Health & Economic Benefits of EURO3 implementation in China (2020)



2020 Euro 3 - BAU monthly average $PM_{2.5}$ ($\mu g/m^3$)

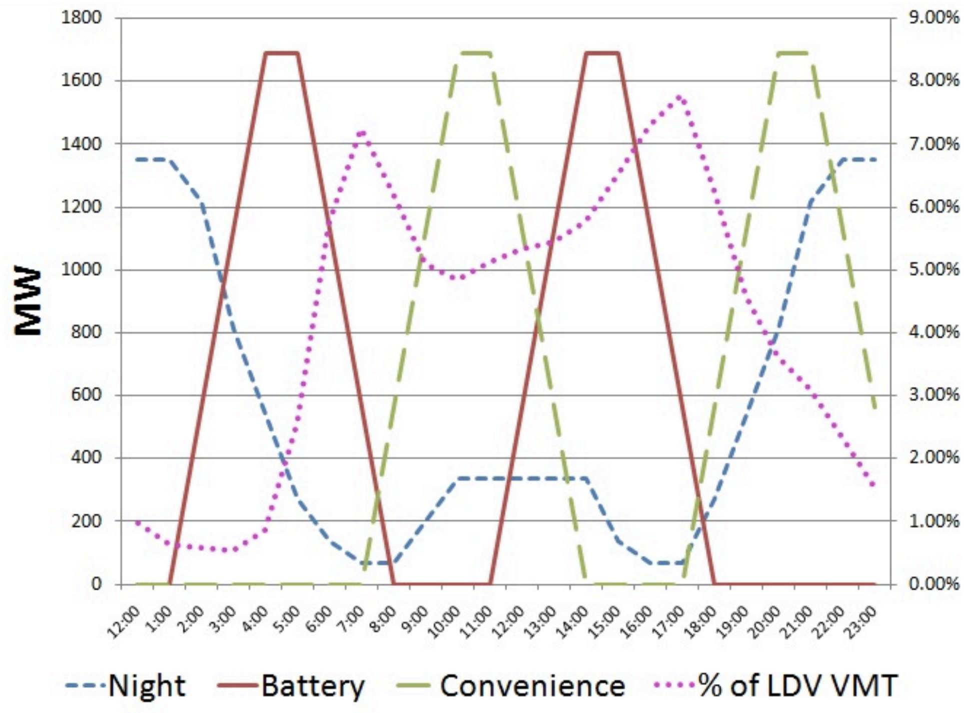


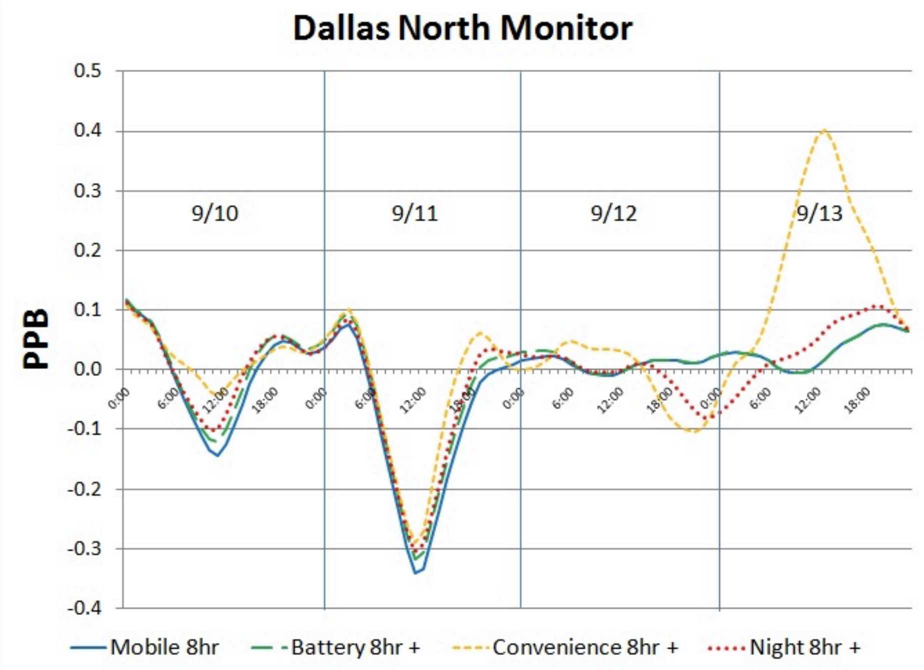
2020 Euro 3 - BAU monthly average O_3 (ppbv)

Total welfare difference is $30 billion (2000 undiscounted value), which equals 3% of China's GDP. There is also a small welfare gain in Japan by China's implementation of the Euro 3 standards.

[Saikawa, Selin et al. in prep]

Impact of EV on ozone air quality in Texas





Bottom line: Electric vehicles can have a varied impact on air quality depending on charging scenarios, spatial distribuiton

[Thompson et al., ERL, in press]

Emissions and policy scenarios for plug-in hybrid electric vehicles

Off-grid hybrid vehicle (HEV)

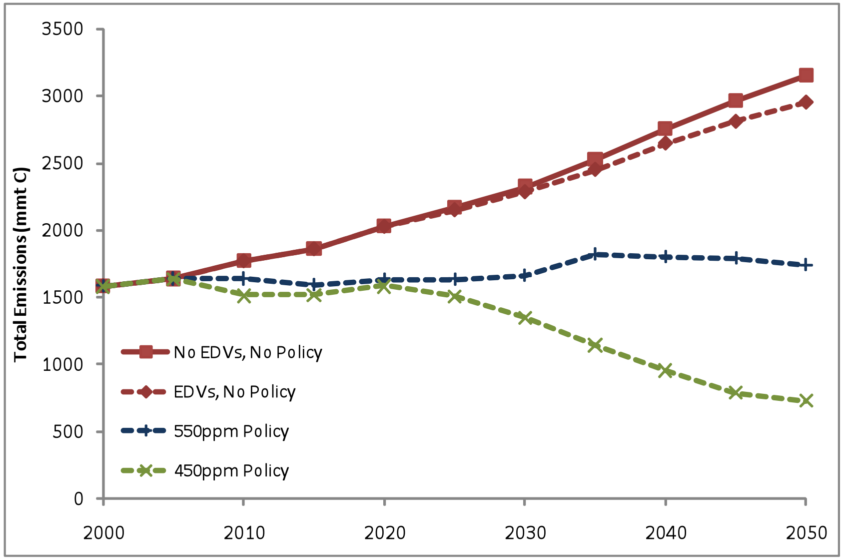
http://z.about.com

Plug-in hybrid electric vehicle (PHEV)

www.chevrolet.com/electriccar

Electric-only vehicle (EV)

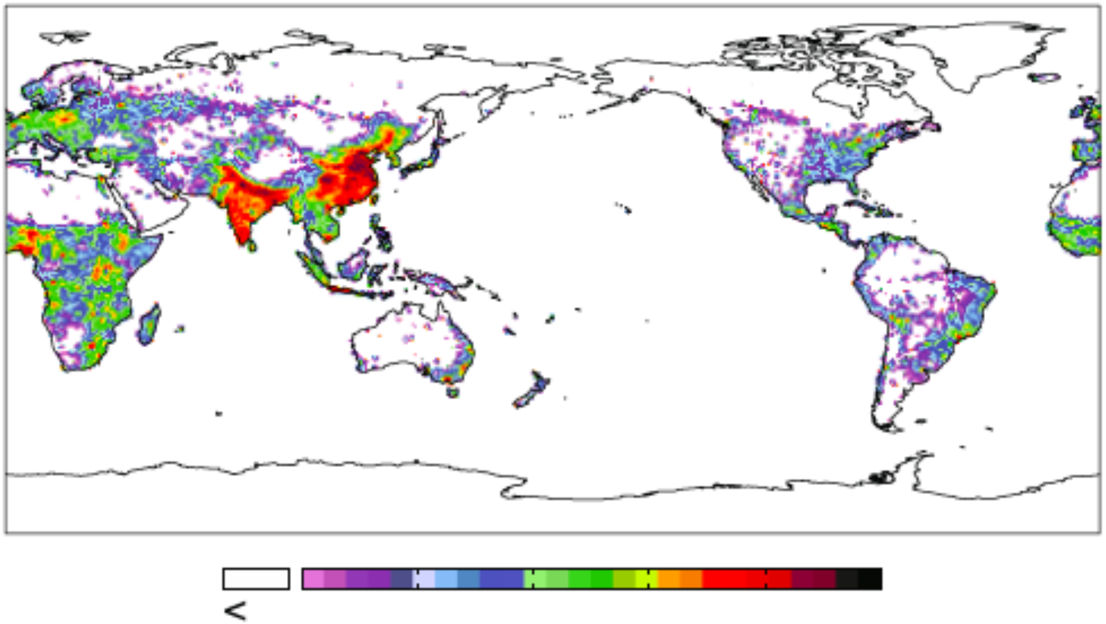
www.marketplace.publicradio.org



Climate impact of hybrid vehicles and technology adoption under policy constraints incorporated in EPPA; work ongoing on associated air pollutant emissions and response to pollution policy

[Karplus et al., in prep.]

Long-Range Transport of PAHs



Global Emissions inventory for benzo(a)pyrene [Zhang and Tao, 2009]

What is the influence of particle-phase atmospheric reactions on PAH long-range transport?

Developing a GEOS-Chem POPs model

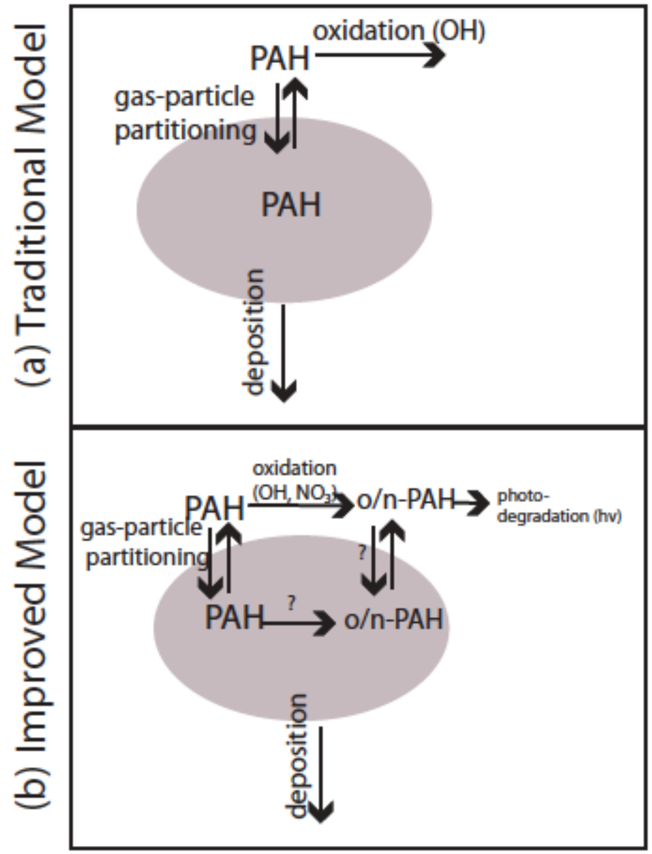


Figure 1. Conceptual models of PAH atmospheric fate.

[Friedman and Selin, in prep]

The Selin Group 2011

- **Postdocs:**
  - Carey Friedman (PhD, URI): Transport and fate of persistent organic pollutants
  - Tammy Thompson (PhD, U. Texas): Regional-to-global atmospheric chemistry modeling
  - Eri Saikawa (PhD, Princeton): Health impacts of future China vehicle pollution (primary advisor: R. Prinn)
- **Doctoral Students:**
  - Rebecca Saari, ESD 1st yr: Future climate policy and air pollution health impacts
  - Leah Stokes, DUSP 1st yr: Mercury science-policy (primary advisor: L. Susskind, DUSP)
- **Master's students:**
  - Caleb Waugh (TPP 2nd year), air pollution from hybrid/electric vehicles (primary advisor: J. Reilly)
- **Undergraduates:**
  - Anastasia Maheras (EAPS Senior): Mercury data analysis
  - Kristen Watkins (DUSP/Political Science Senior): GIS data analysis for future air quality project

Acknowledgments

- **U.S. EPA:** Science to Achieve Results (STAR) Program, "Air Pollution, Health and Economic Impacts of Global Change Policy and Future Technologies: An Integrated Model Analysis," 9/09-9/12
- **NSF:** Atmospheric Chemistry Program, "CAREER: Understanding Chemistry, Transport and Fate of Mercury and Persistent Organic Pollutants through Global Atmospheric Modeling," 3/11-3/16
- **MIT Research Support Committee Ferry fund:** POPs model development, 9/10-9/11
- **MIT Joint Program on the Science and Policy of Global Change** and its government, industrial and foundation sponsors