Tracking Toxic Atmospheric Constituents: Linking Science and Policy

Noelle E. Selin
Assistant Professor of Engineering Systems and Atmospheric Chemistry
Massachusetts Institute of Technology

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selin@mit.edu
http://mit.edu/selin
http://mit.edu/selingroup

MIT ESD
Massachusetts Institute of Technology
Engineering Systems Division

EAPS

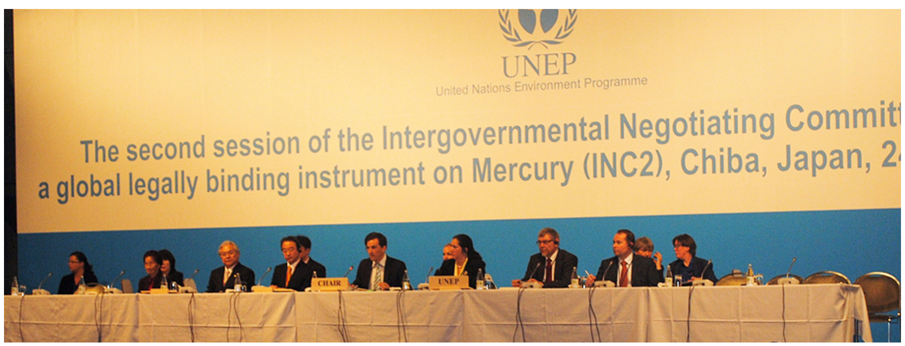
Which pollutants are we concerned about?

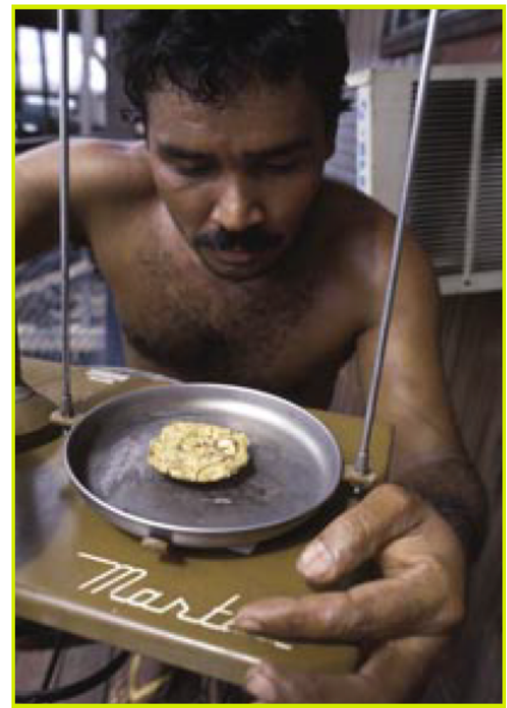
- Persistent, bioaccumulative, toxic substances
  - Mercury
  - Persistent Organic Pollutants (e.g. PCBs, DDT, PAHs, PFOS/PFOA, PBDEs)
- Air pollutants of health concern
  - Ozone
  - Particulate Matter

Policy Context: International

Stockholm Convention on persistent organic pollutants (POPs)

LRTAP
Long-range Transboundary Air Pollution





Policy Context: U.S.

FEDERAL REGISTER

The Daily Journal of the United States Government

Proposed Rule

National Emission Standards for Hazardous Air Pollutants From Coal- and Oil-Fired Electric Utility Steam Generating Units and Standards of Performance for Fossil-Fuel-Fired Electric Utility, Industrial-Commercial-Institutional, and Small Industrial-Commercial-Institutional Steam Generating Units

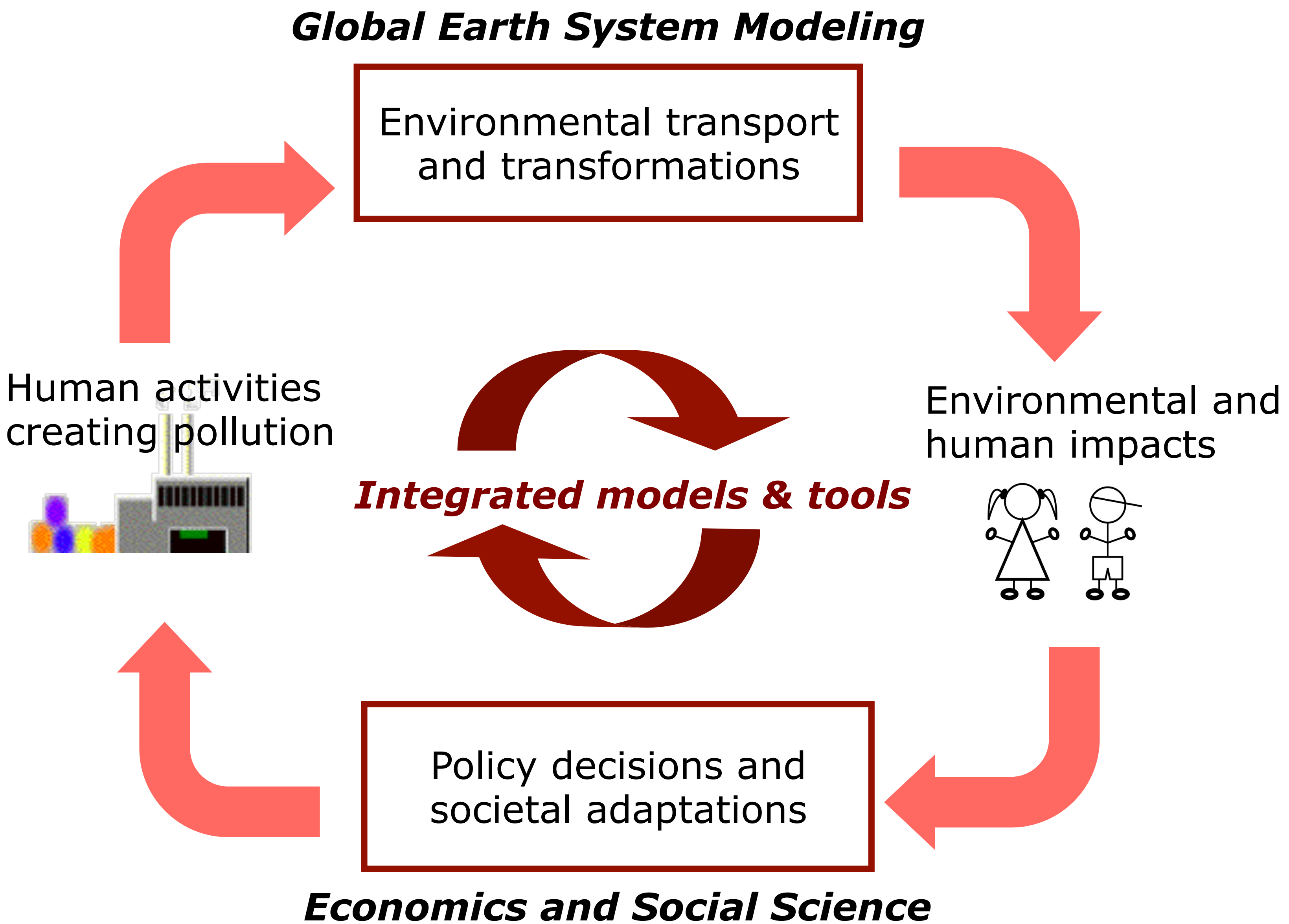
A Proposed Rule by the Environmental Protection Agency on 05/03/2011

Final Mercury and Air Toxics Standards (MATS) rule to be issued today!

Research Questions

- How can we better understand the transport and fate of toxic atmospheric constituents, in ways relevant to policy?
  - What are the pathways by which pollutant emissions impact people?
  - What are the feedbacks and interactions between pollutants and society?

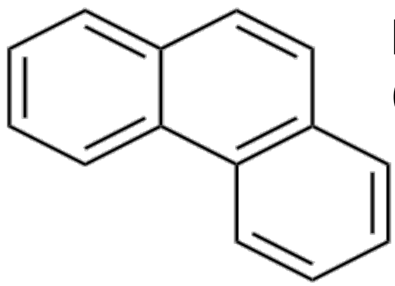
Framework for assessing pollution and impacts



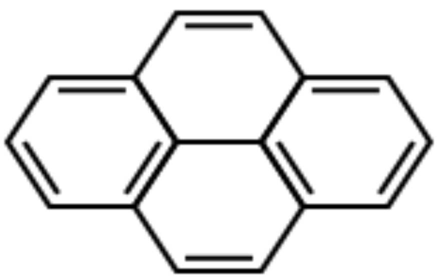
GEOS-Chem POPs Simulation

Polycyclic Aromatic Hydrocarbons (PAHs)

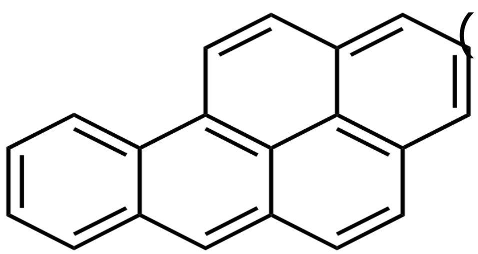
GAS-PHASE



Phenanthrene (PHE)

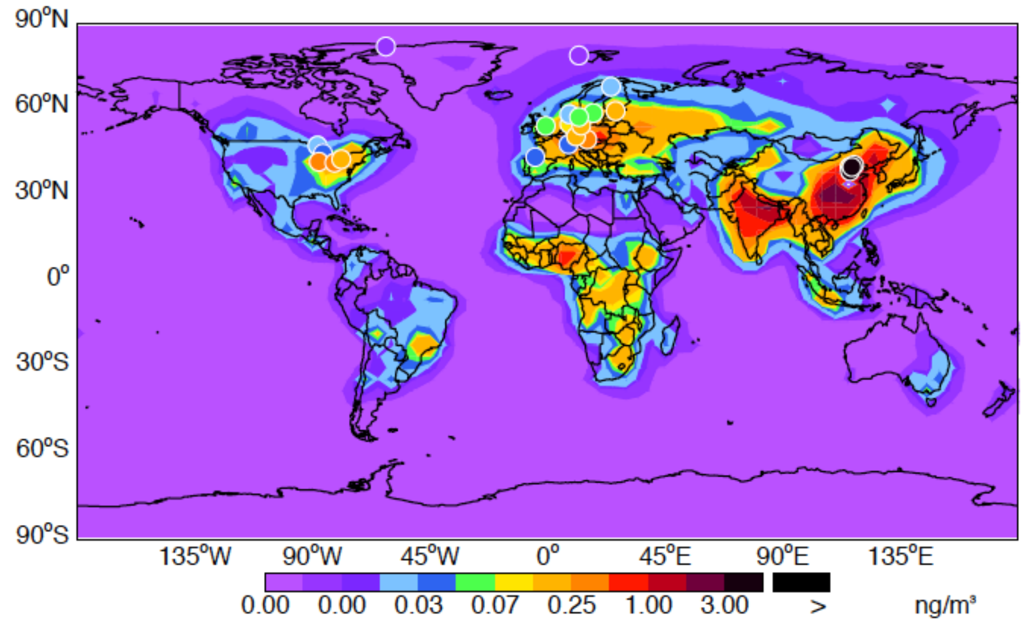


Pyrene (PYR)



Benzo[a]pyrene (BaP)

PARTICLE-PHASE

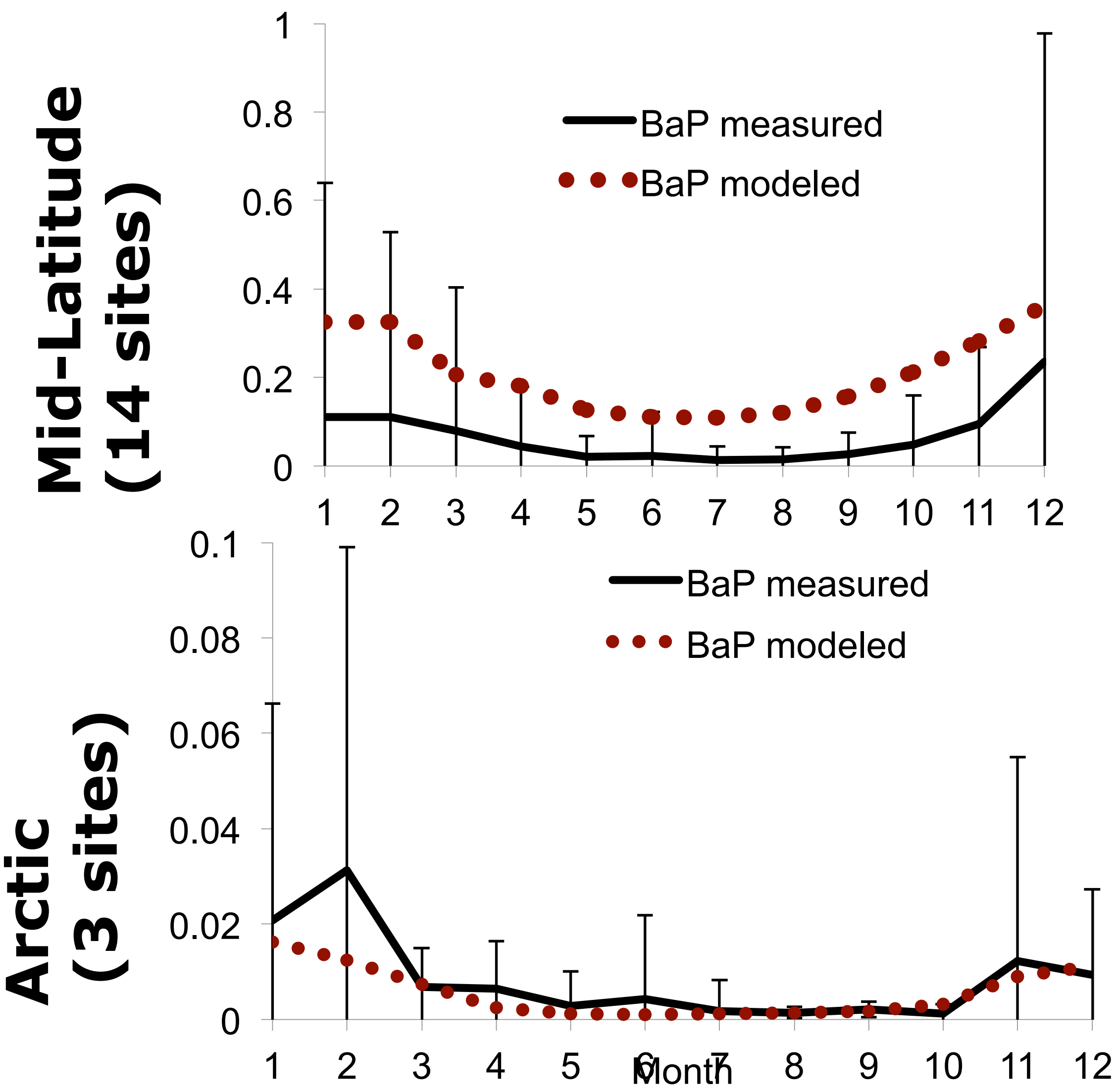


Annual average benzo[a]pyrene vs. observations, mean 2005-2009

Emissions from Zhang and Tao [2009], GEOS-Chem at 4°x5°; includes gas-particle partitioning (to BC/OC), gas-phase oxidation by OH; wet/dry deposition; (particle-phase oxidation)

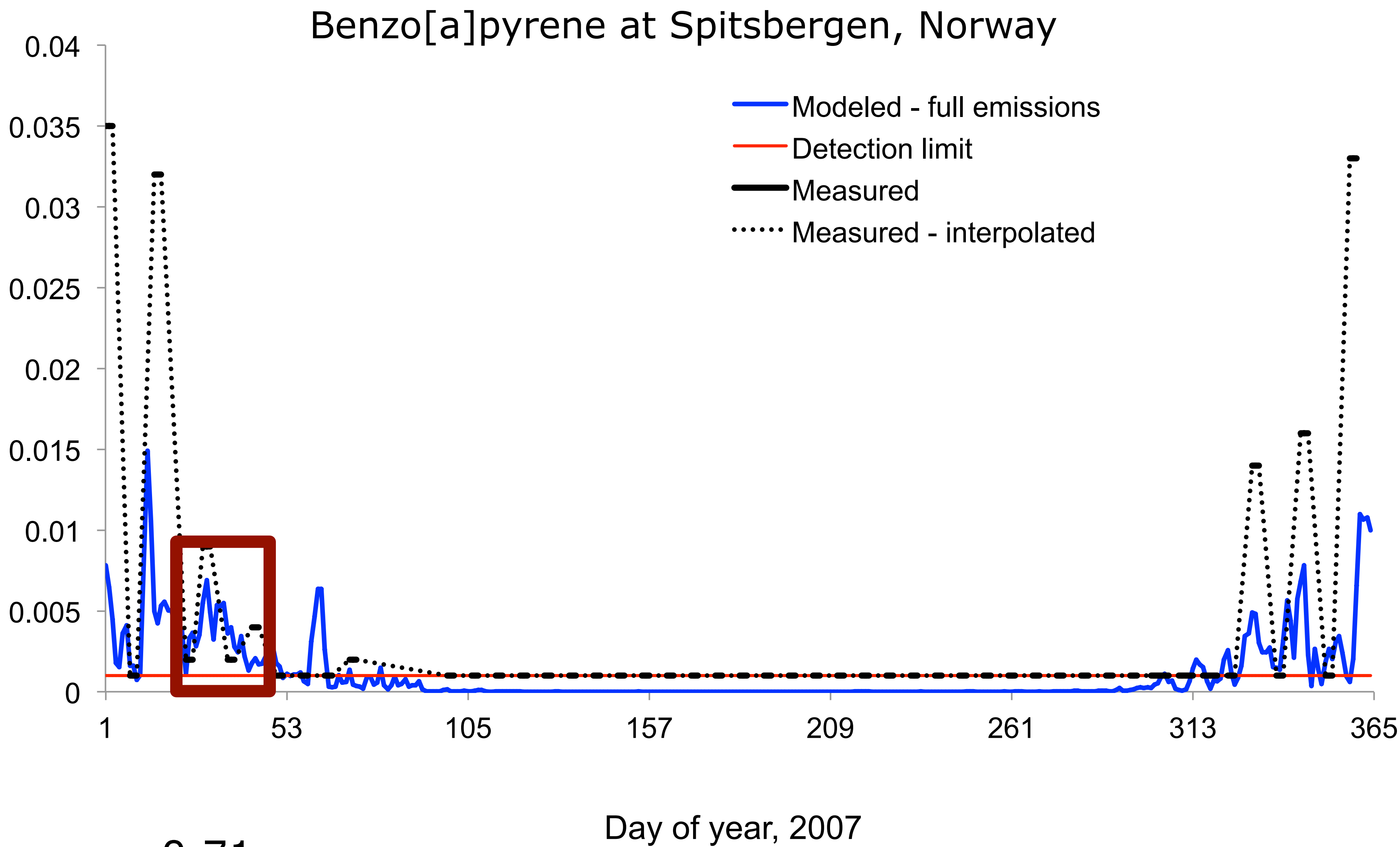
[Friedman and Selin, in revision]

Lifetime of PAHs vs. International Criteria



- ❑ We capture mid-latitude and Arctic concentrations (roughly)
- ❑ Our atmospheric lifetime (0.7 days) is 4x lower than the “threshold” criteria for regional/global action (2.8 days)
- ❑ Same for all PAHs
- ❑ Simulation sensitive to: temperature sensitivity of partitioning, on-particle oxidation

Episodic Transport to the Arctic

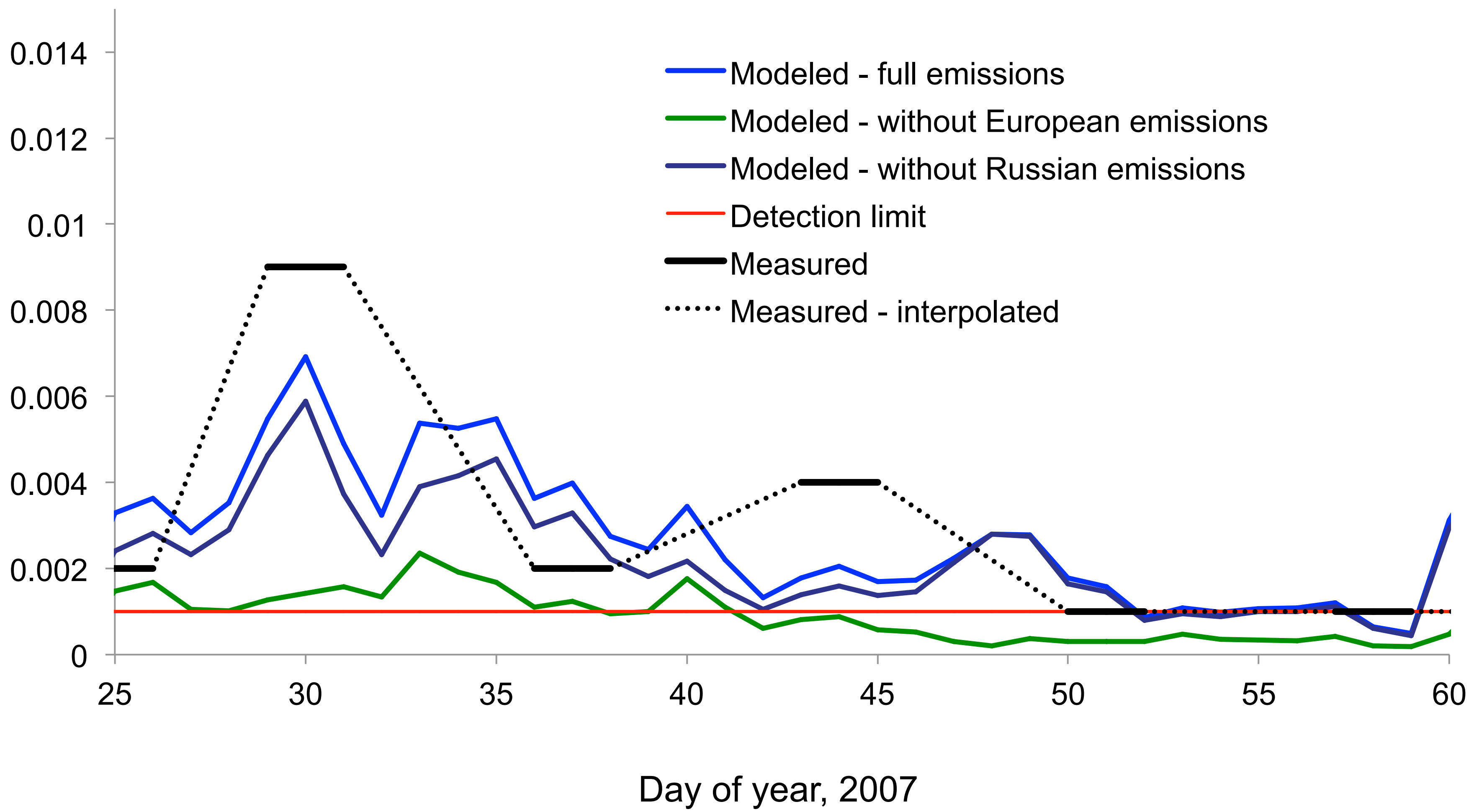


r = 0.71

Data: EMEP

Elevated concentrations at Spitsbergen come from Europe and Russia

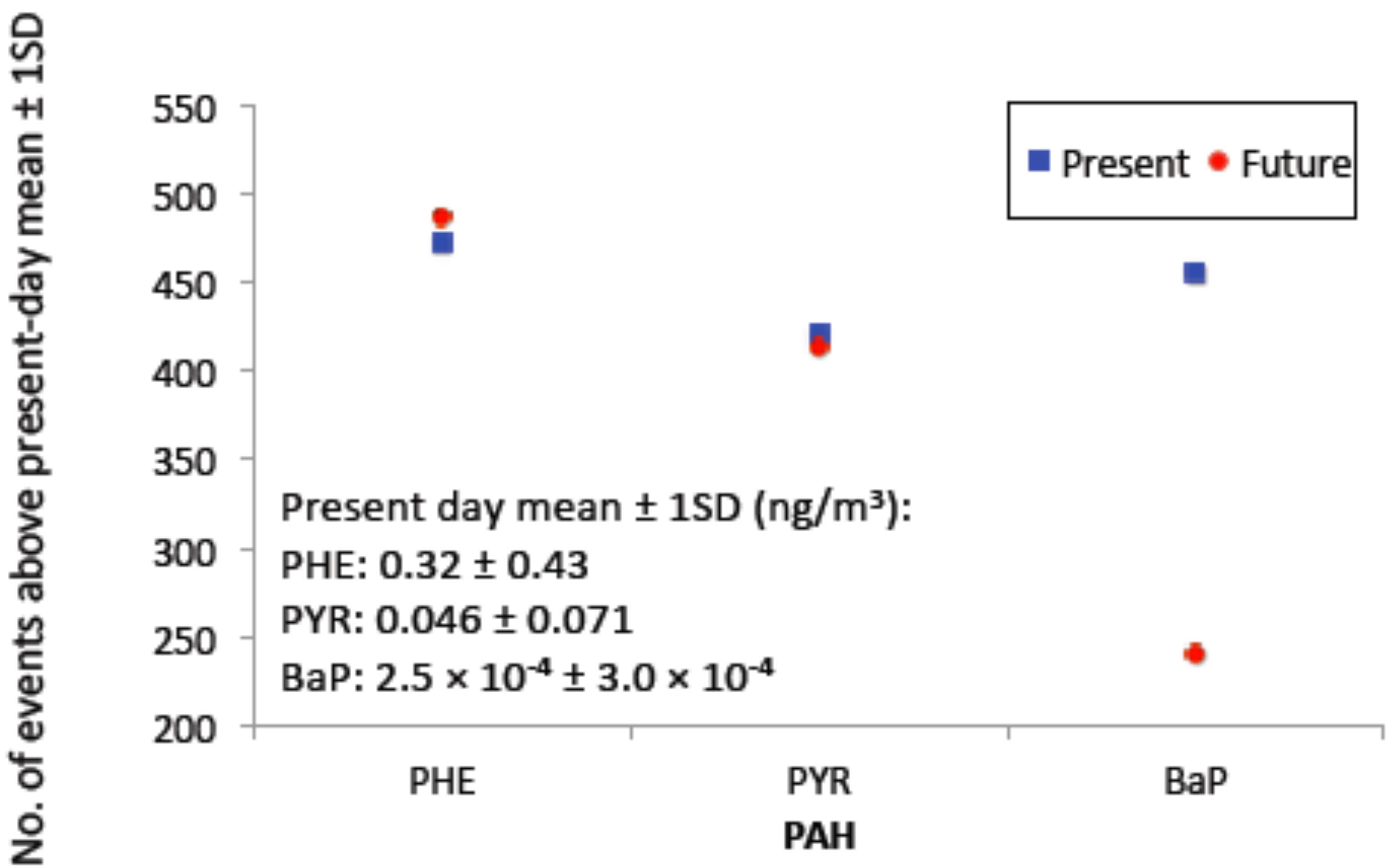
Benzo[a]pyrene at Spitsbergen, Norway



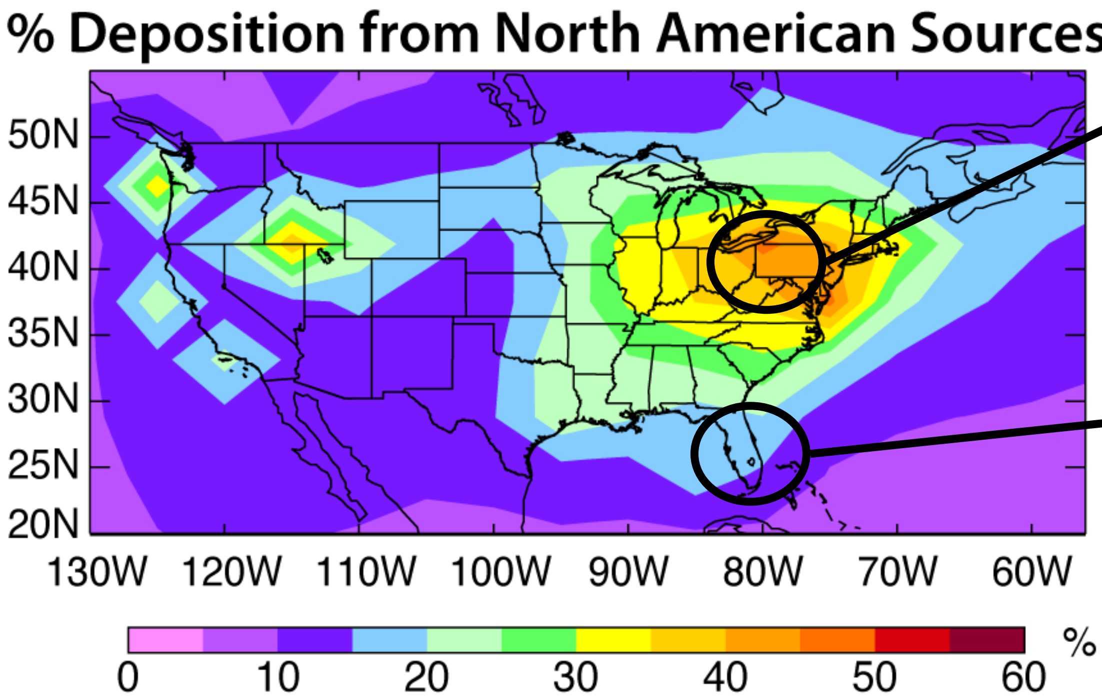
Data: EMEP

Future climate and episodic transport

at Spitsbergen, Norway



Policy-Relevant Modeling of Pollutant Transport: Mercury (Hg) Pollution



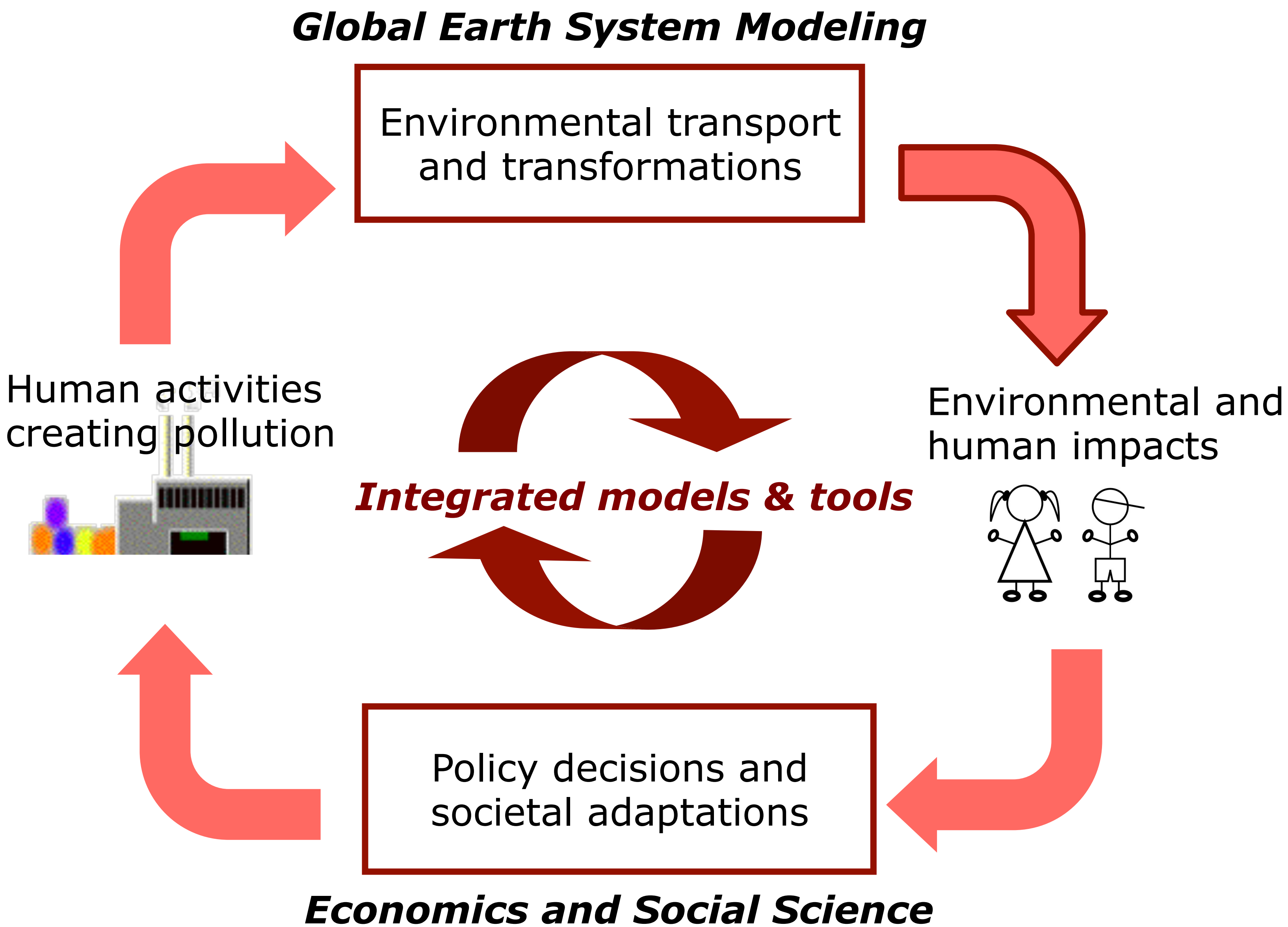
Up to 60% of deposition in Midwest/Northeast is from domestic sources

Florida has highest deposition in the U.S., but mostly from non-US sources

Policy implications: *Reducing deposition in both Midwest and Southeast will require policy actions on multiple political scales (national and global)*

[Selin et al., JGR, 2007; Selin et al., GBC, 2008; Selin and Jacob, AE, 2008]

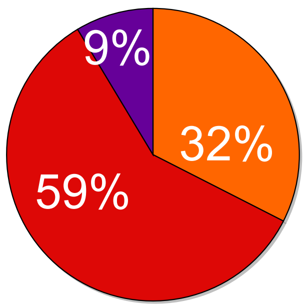
Framework for assessing pollution and impacts



How do sources affect fish methylmercury, and on what timescales?

Northeast U.S.

24.21 $\mu g\ m^{-2}\ y^{-1}$



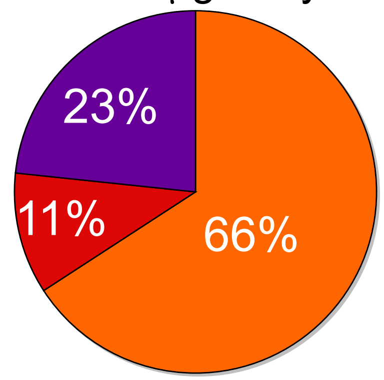
International Anthropogenic

Pre-industrial + Historical

N. American Anthropogenic

Southeast U.S.

34.08 $\mu g\ m^{-2}\ y^{-1}$

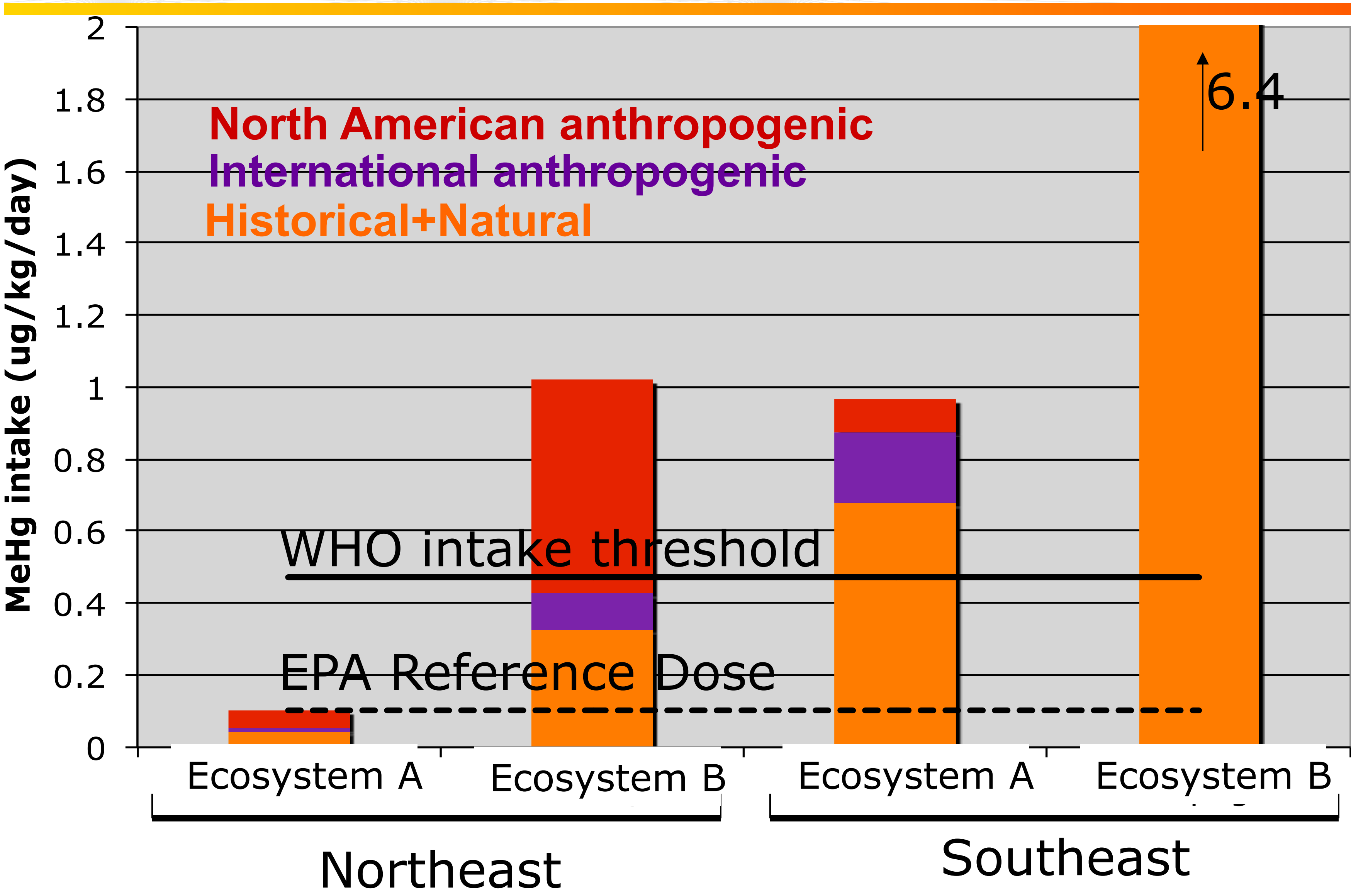


SERAFM: Lake model ***WASP7***: River model ***WCS (MLM)***: Watershed loading
BASS: Aquatic food web [Knightes et al., 2009]

Policy and Timescale Analysis

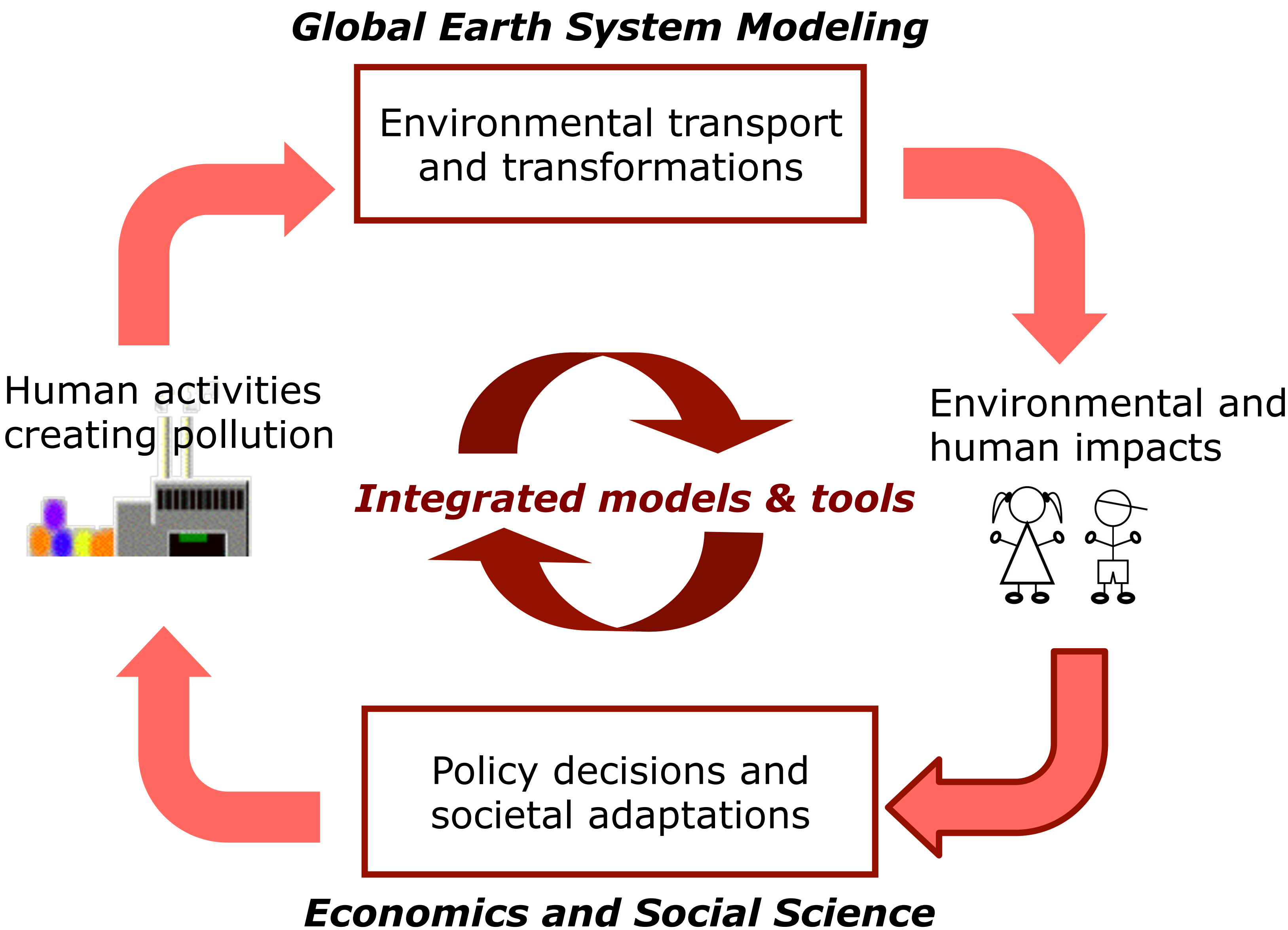
[*Selin et al., EHP,* 2010]

Linking Models to Quantify Human Impacts



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

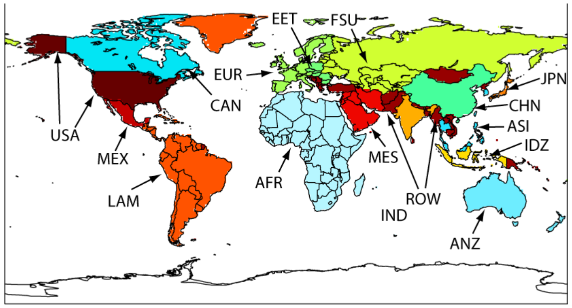
Framework for assessing pollution and impacts



How do air pollution impacts affect humans and societies?

MIT Emissions Prediction and Policy Analysis model: general equilibrium economic model (Paltsev et al.); global health Impacts version

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



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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

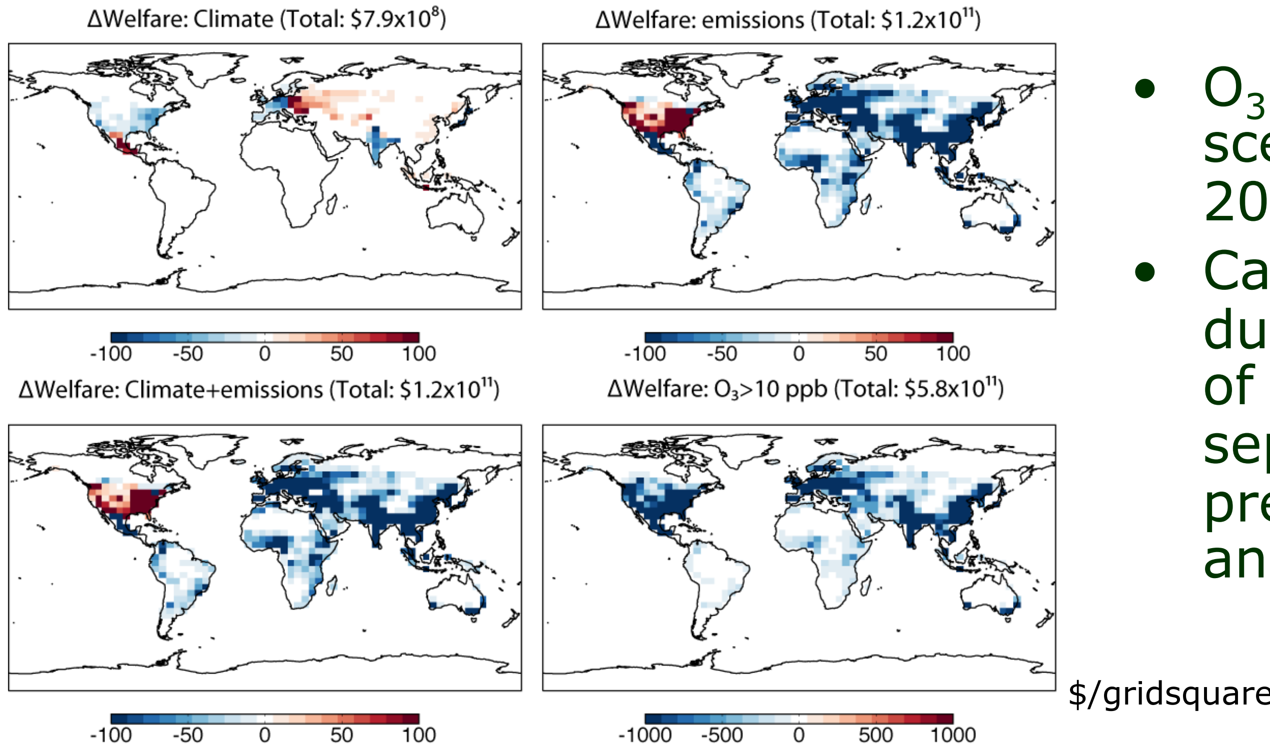
[a] Units are cases yr^{-1} $person^{-1}$ μg^{-1} m^3.
[b] Normal distributions applied for symmetric confidence intervals, and beta distributions applied for asymmetric confidence intervals. Confidence intervals are cut off at zero and negative values are not assessed.
[c] Converted from €2000 using 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., Environmnetal Research Letters*, 2009]

Global Impacts and Cost of Ozone Pollution in 2050: Linking atmospheric and impact modeling



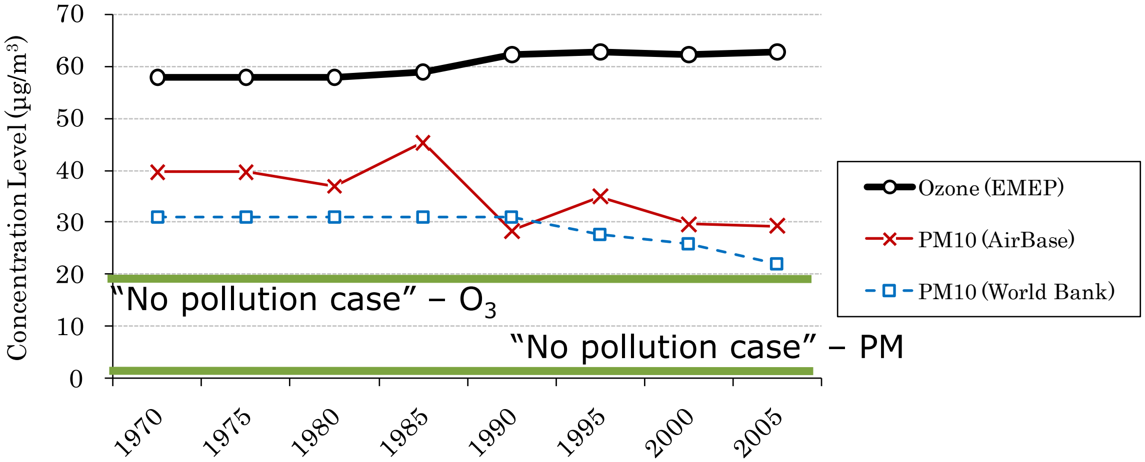
- O_3 from IPCC A1B scenario [Wu et al., 2008] to 2050
- Calculate Δwelfare due to health impacts of ozone changes, separately for precursor emissions and climate drivers

- 2050 welfare loss from O_3 health impacts, climate only scenario: *$790 million* (year 2000 $) [95% probability: $13 million – 190 billion]
- 2050 welfare loss from climate+precursor changes: *$120 billion* [95% probability: $100 billion – 1.5 trillion]
- 2050 welfare loss from all O_3 above background: *$580 billion*

[*Selin et al., Environmnetal Research Letters*, 2009]

Health Costs of Historical 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)

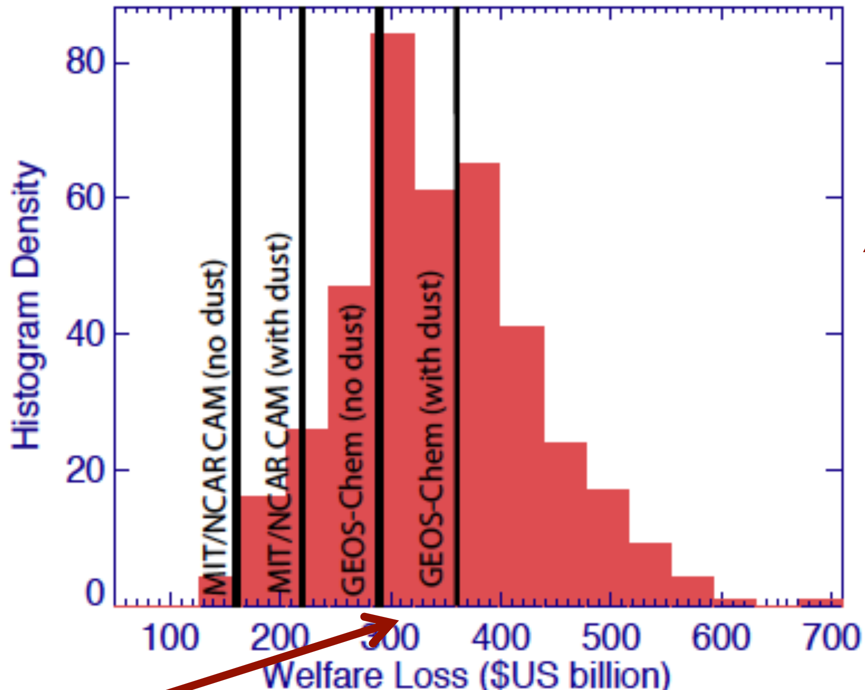
Uncertainty range: €209-550 billion

About half of losses from accumulated damages

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

How does atmospheric model variability compare with impacts-related uncertainty?

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



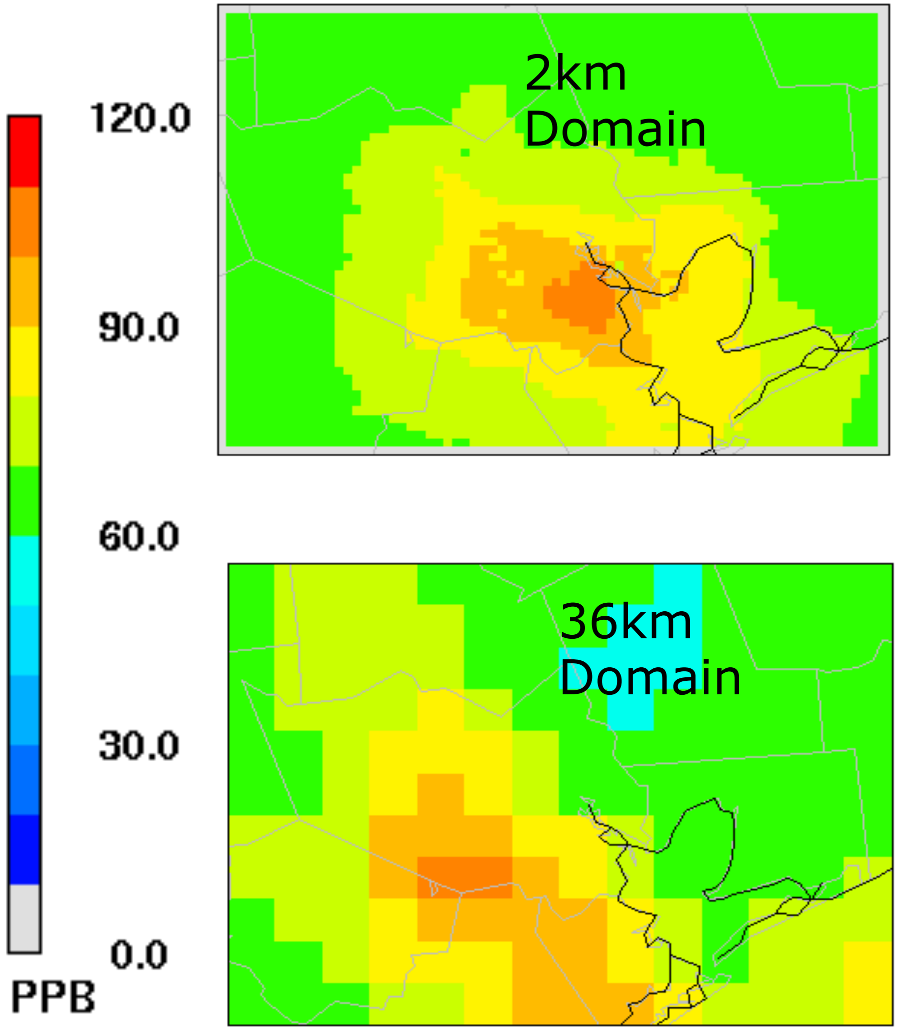
Black vertical lines: calculated cost for different PM2.5 estimates/models, holding health/ economic functions constant

Red: 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!

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

8-hr daily max ozone over Houston



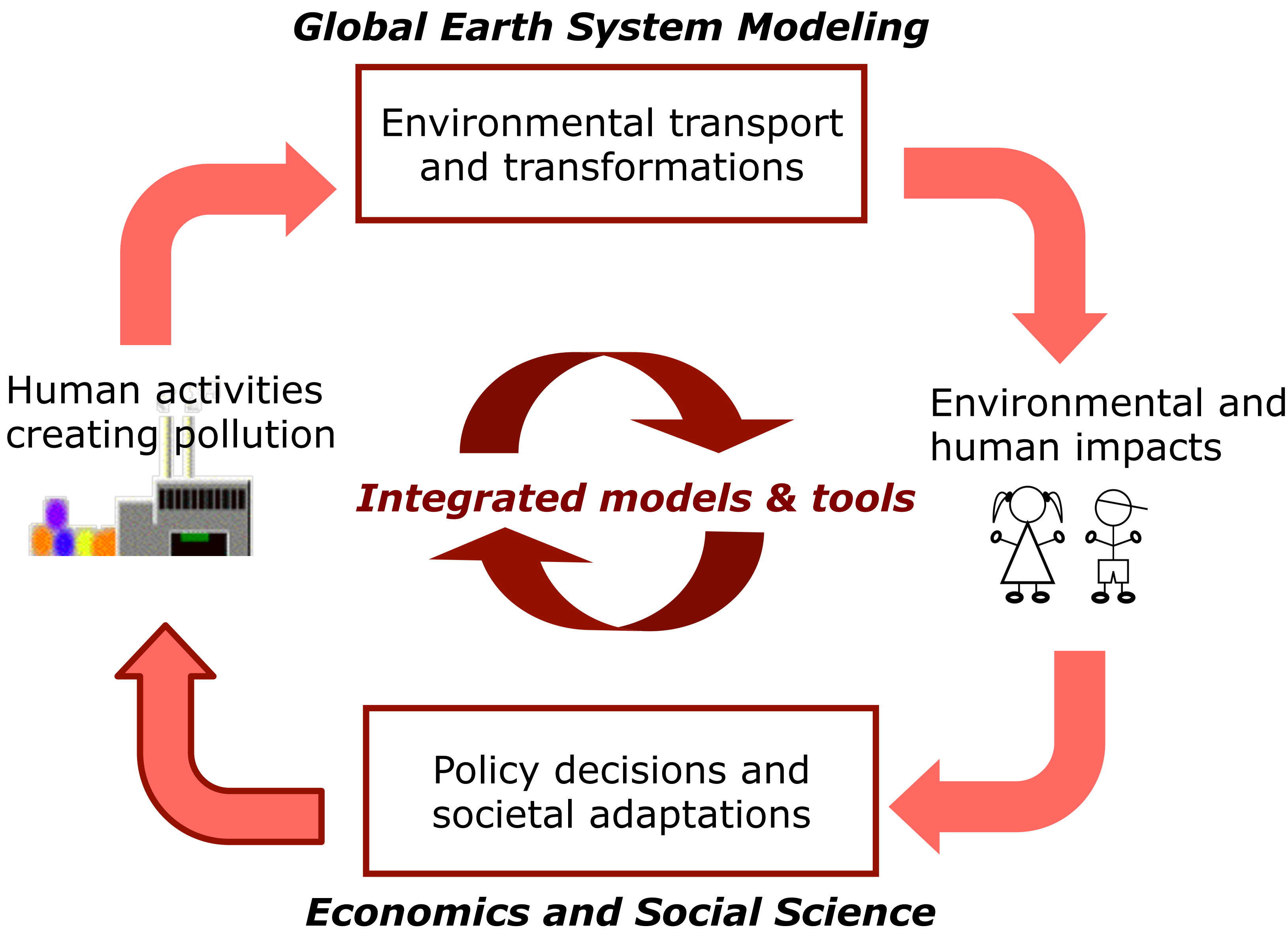
Model:CAMx

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

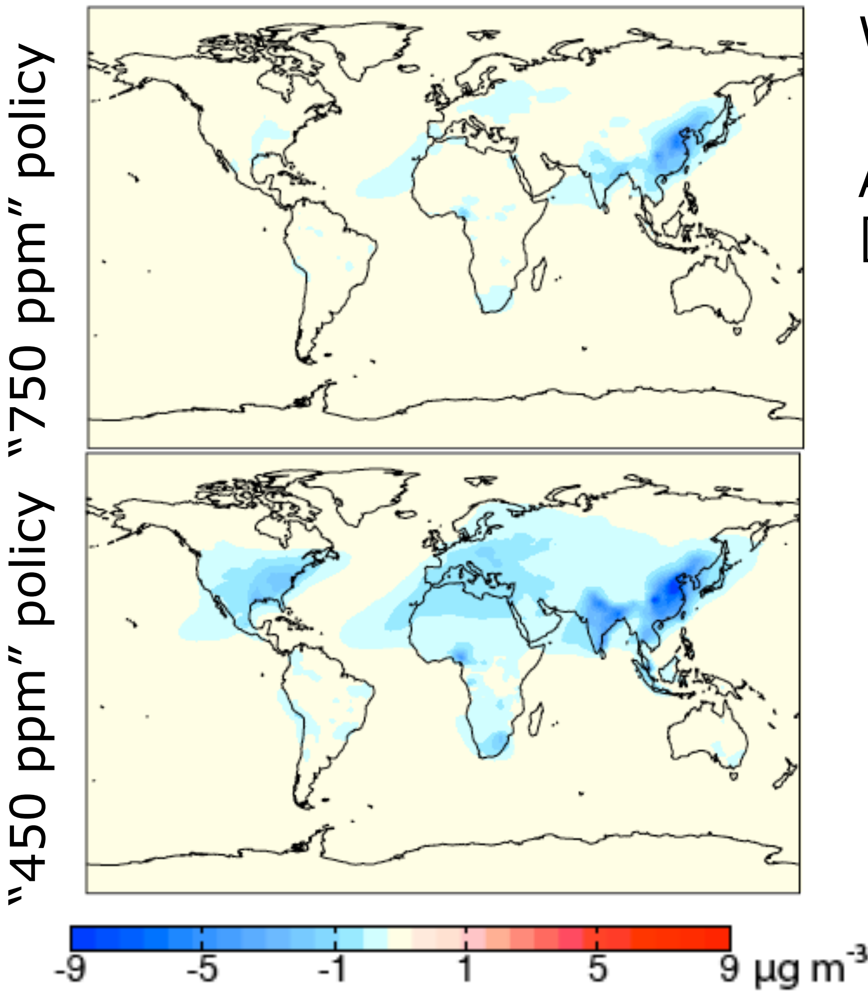
Degrading model resolution to 36 km has minimal impact on calculating health benefits of regulation given uncertainties

[Thompson, Selin et al. in review]

Framework for assessing pollution and impacts



Co-Benefits of Climate Policy for particulate matter health impacts (2050)



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

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

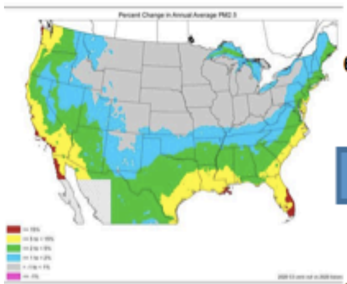
Health-related "co-benefits" of BC, OC, SO2 reductions valued at 0.03-0.09% of global GDP

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

Future work: model sensitivity, uncertainty analysis

Economic/Air Quality/Human Health Modeling Linkage

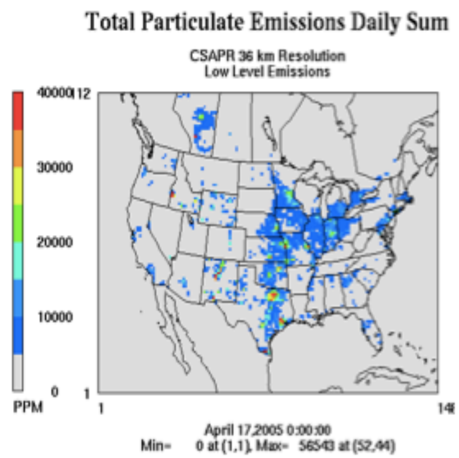
USREP
(Rausch et al.)



Link economic sector with SCC code, and economic region with state FIPS

to create a control input file

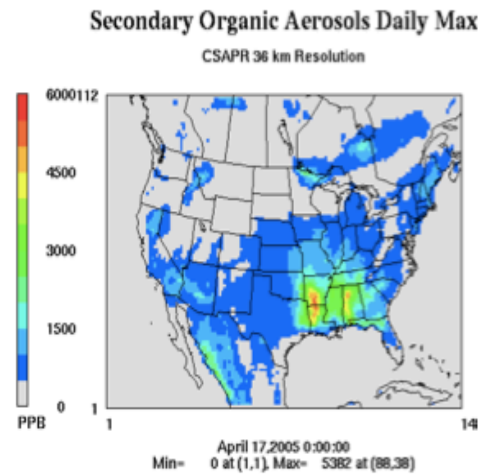
Via SMOKE



Input emissions inventories into air quality model to compare policy scenarios

with BAU "Basecase" Air Quality

CAMx

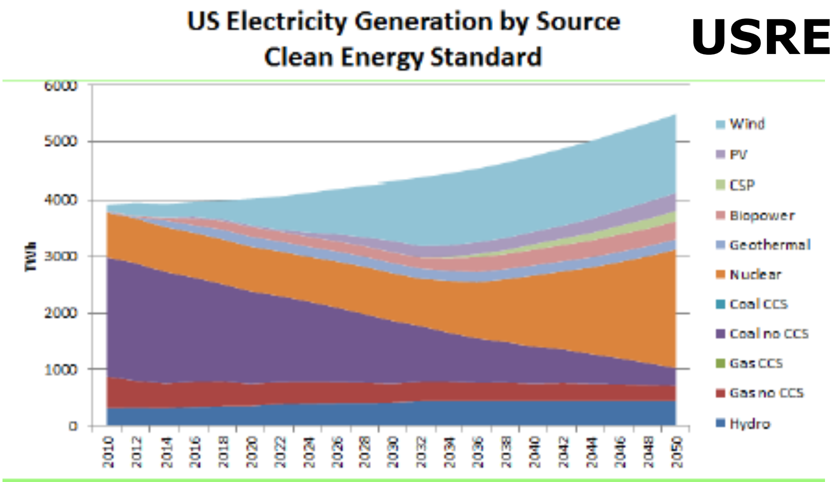


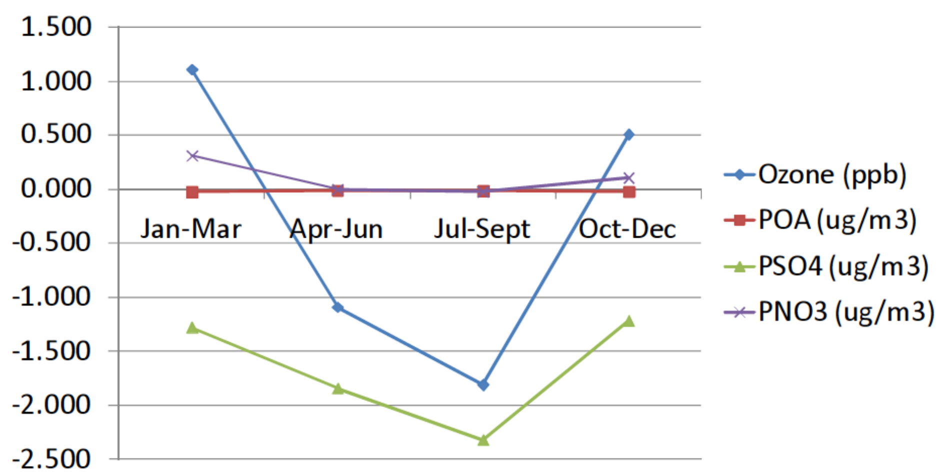
Health Impacts in USREP

With Tammy Thompson, Rebecca Saari, Sebastian Rausch

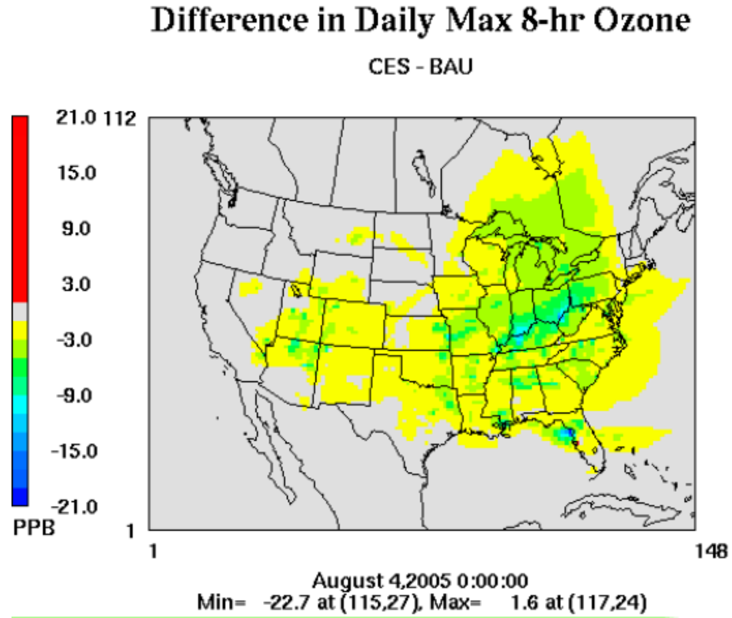
Model Links: Proof of Concept
Impact of Clean Energy Standard on Ozone (2050)

USREP





CAMx

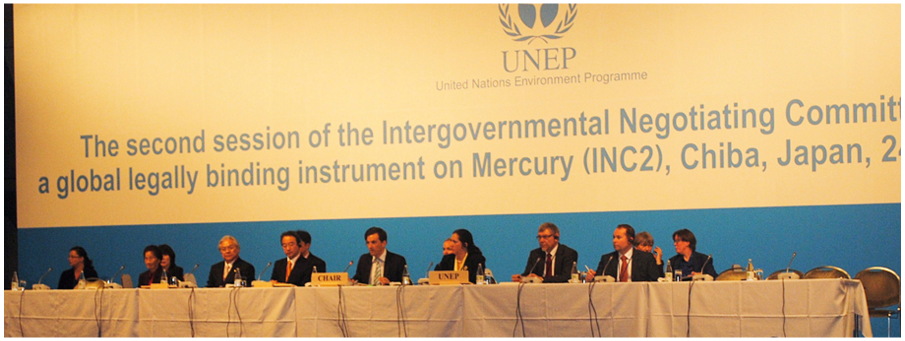


Average across 42 US Cities

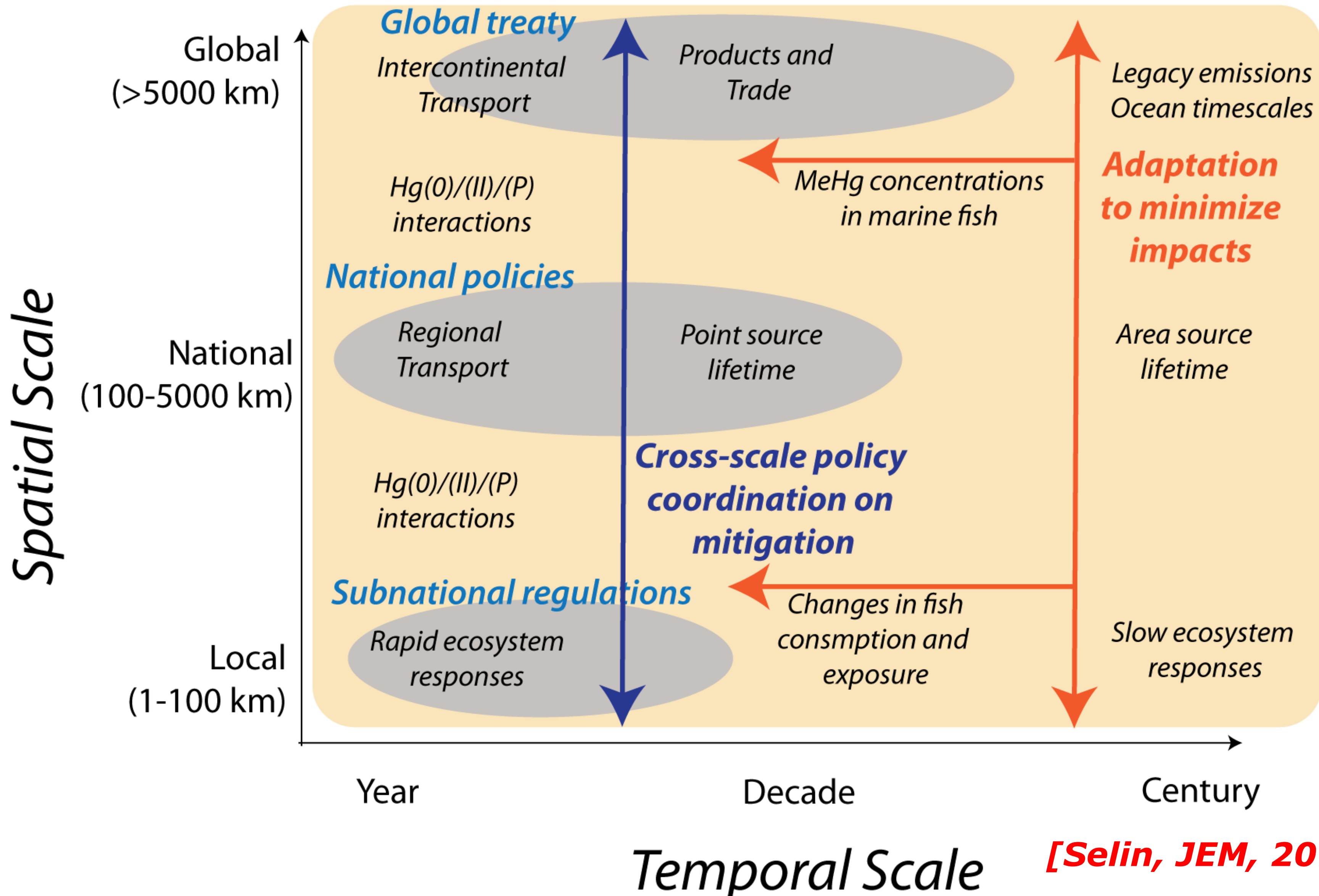
Thompson, Selin et al.:
See AGU 2011 poster

Preliminary results: more to come!

What about Policy?



Policy interfaces imperfectly with scientific timescales (example: Mercury)



[Selin, JEM, 2011]

Improving Knowledge of Policy Responses to Pollutant Impacts

Research questions:
- ❑ How does scientific information inform global environmental policies?
- ❑ What are best practices for scientists and engineers to have an impact?

Negotiations for global mercury treaty began June 2010

Methods: Development of a "Mercury Game"– a negotiation simulation with dual goals:
- ❑ Understand the ways in which science is used in global policy
- ❑ Teach scientists and engineers about the process and how to participate

Play the game! http://mit.edu/mercurygame

Many thanks to Harvard Team-Hg who helped test and review the game!

With Leah Stokes, Lawrence Susskind

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
- **Graduate Students:**
  - Rebecca Saari, Eng Sys 2nd yr: Air pollution health impacts
  - Ellen Czaika, Eng Sys 2nd yr: Sustainability decision-making
  - Shaojie Song, EAPS, 1st yr: Mercury
  - Colin Pike-Thackray, EAPS, 1st yr (1/2012): POPs
  - Amanda Giang, Technology/Policy 1st yr: Mercury
  - Leah Stokes, Urban Studies/Planning 2nd yr: Mercury science-policy (primary advisor: L. Susskind)

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