GLOBAL TRANSPORT OF POLLUTION:
Linking Science and Policy at Multiple Scales

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23 March 2009

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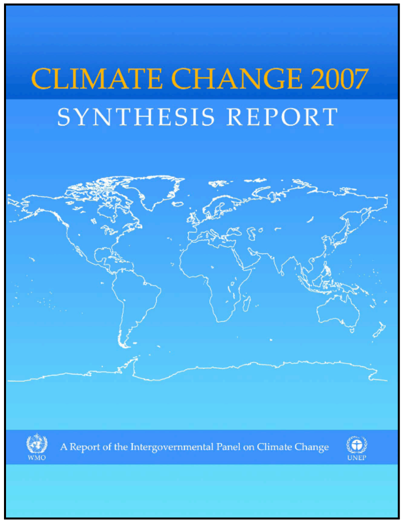
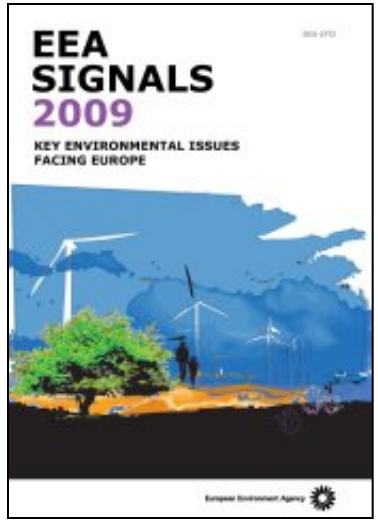
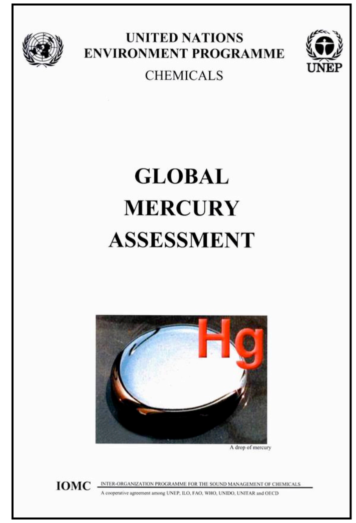
INTERNATIONAL POLLUTANT SCIENCE AND POLICY

"You are not the same as your great-grandparents were. You are partly synthetic." --United Nations Environment Programme (2005)*







[Photo - IISD: F.Dejon]

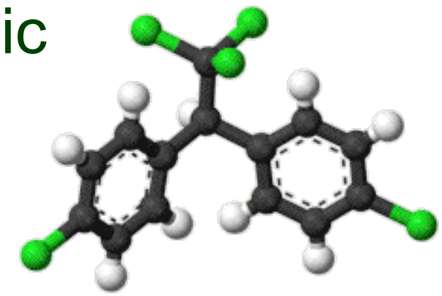
*From information pamphlet on the Stockholm Convention

RESEARCH QUESTIONS: OUTLINE

1. **How does science influence global environmental negotiations? What lessons can scientists and policy makers draw from previous experience?**
   - **Challenges of scale, salience/relevance**
   - **Example: POPs**
2. What scientific information can better inform policy across multiple political scales?
   - Example: Mercury
3. How can science link policy choices to potential damages that are relevant to decision-making?
   - Example: Air pollution, climate and health

1. LESSONS FOR SCIENCE-POLICY FROM POPs

- Stockholm Convention on Persistent Organic Pollutants (2001): addresses "dirty dozen" globally-distributed, persistent, bioaccumulative, toxic chemicals



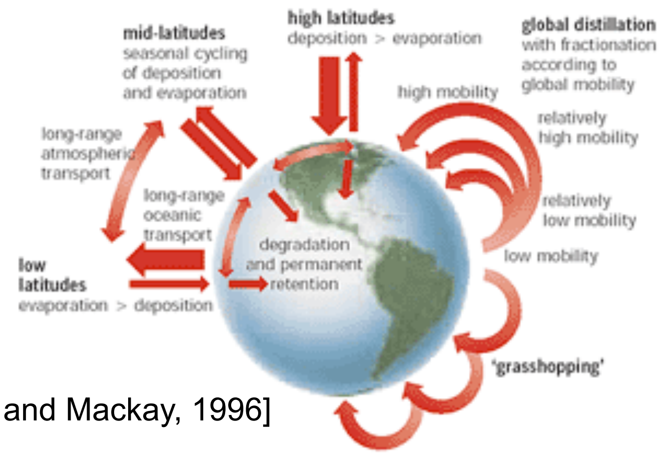
- Widespread concern in the Arctic, where high levels contaminate traditional foods

- Case study of scientific assessments informing a regional, then global political negotiating process (1991-2001) and subsequent implementation*

*interviews and data collected 1997-2008

[*Selin and Selin, 2008; Selin, 2006; Eckley,2002*]

1. CHALLENGES OF SCALE AND SALIENCE



[Wania and Mackay, 1996]

[Greenpeace]

Dominant (UNEP, Northern) framing of the POPs issue: long-range, intercontinental transport

To many developing countries, the POPs problem is about stockpiles, local contamination, and minimal capacity for chemicals regulation

Also, exposure happens on local scales

- **SCALE:** International scientific assessments focused on the global nature of the problem. What about regional and local effects?
- **SALIENCE:** How to provide information that is salient/relevant to policy makers at various political levels?

[*Selin, 2006*]

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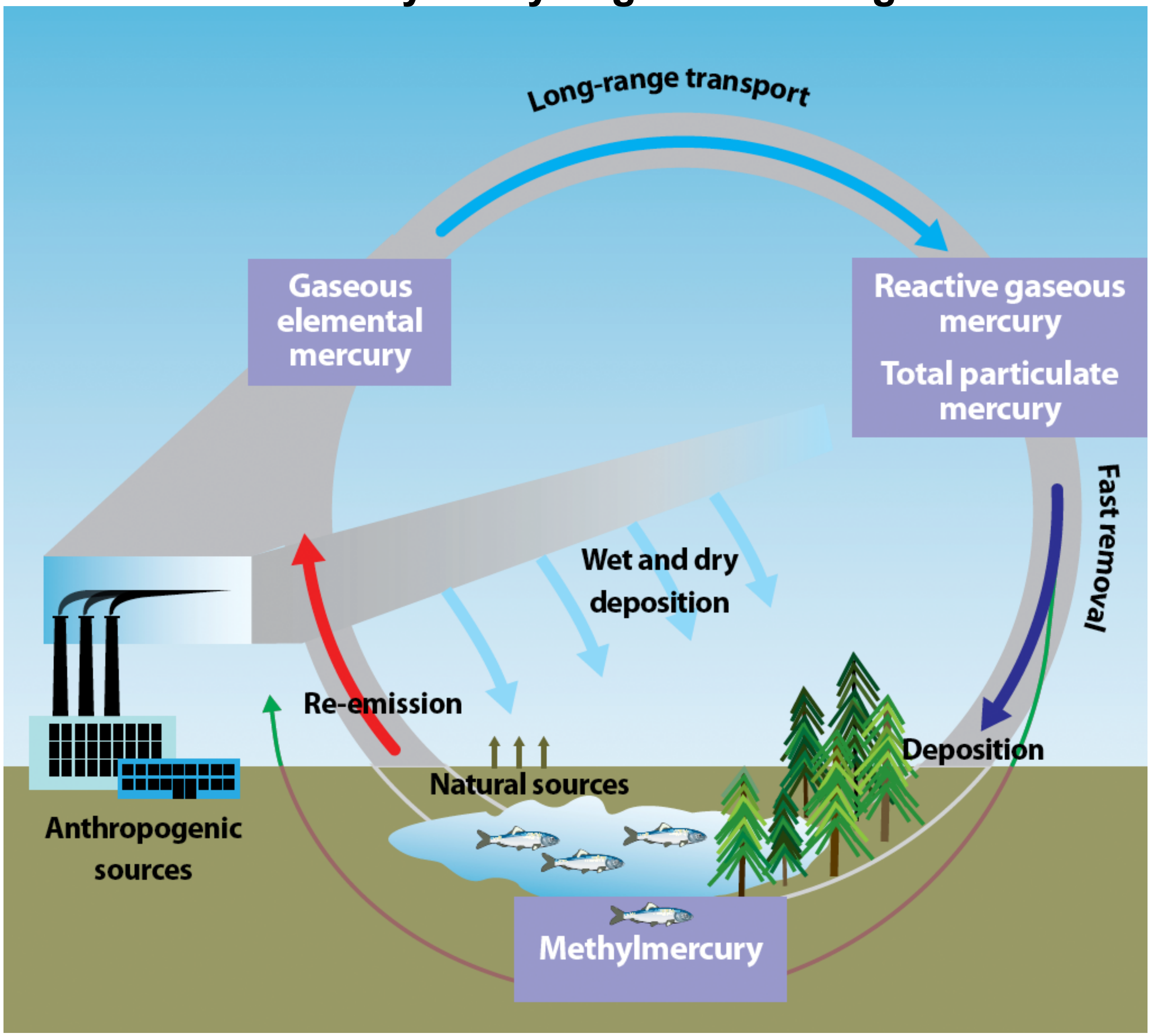
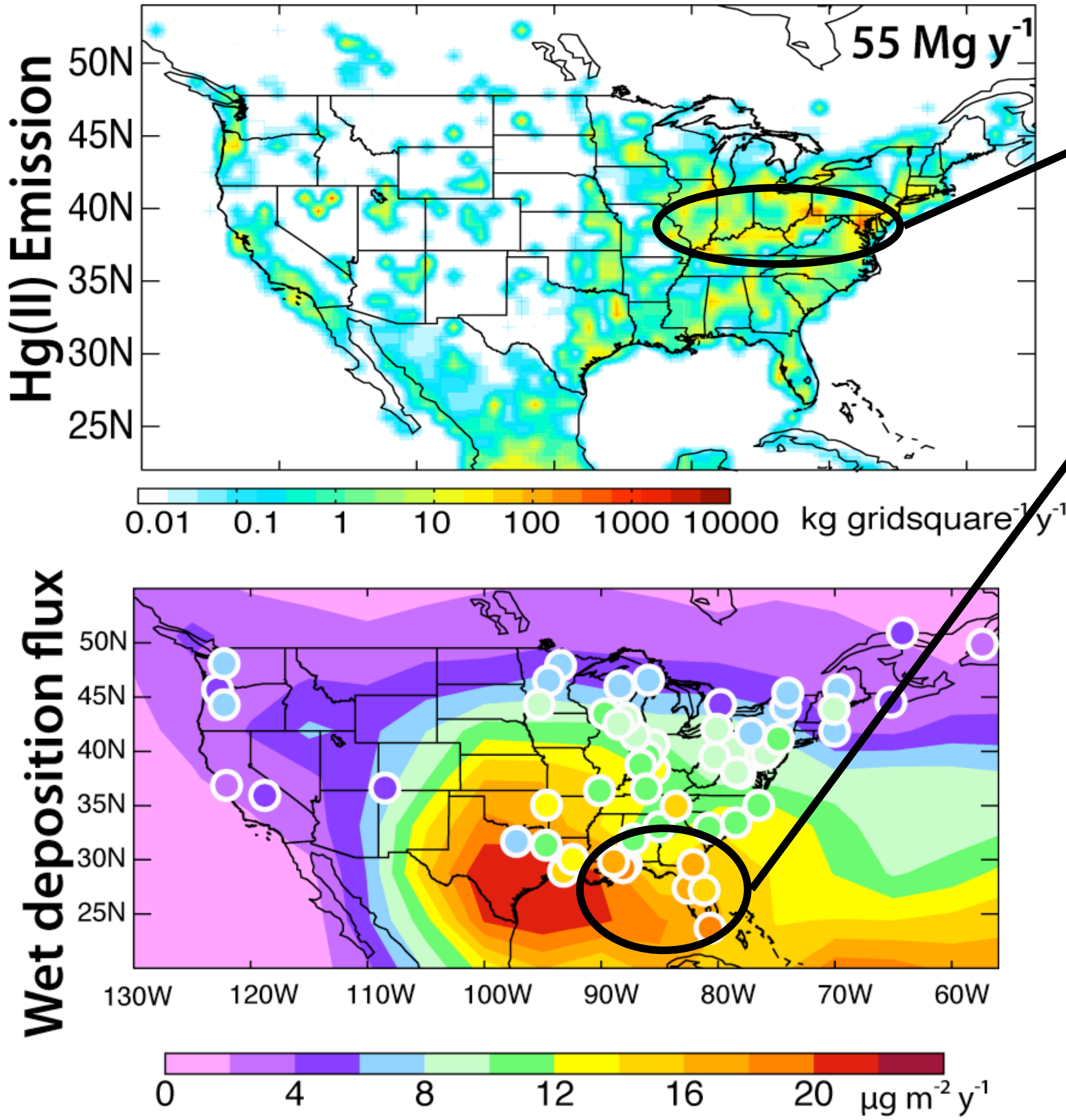
2. CHALLENGES OF SCALE: GLOBAL HG POLICY

Global mercury treaty negotiations begin in 2010



[UNEP, 2008]

2. DEPOSITION PATTERNS IN THE UNITED STATES



Highest Emission:
Ohio River Valley

Highest Deposition:
Florida/Gulf Coast

Why doesn't the area of highest Hg(II) emission have the highest deposition?

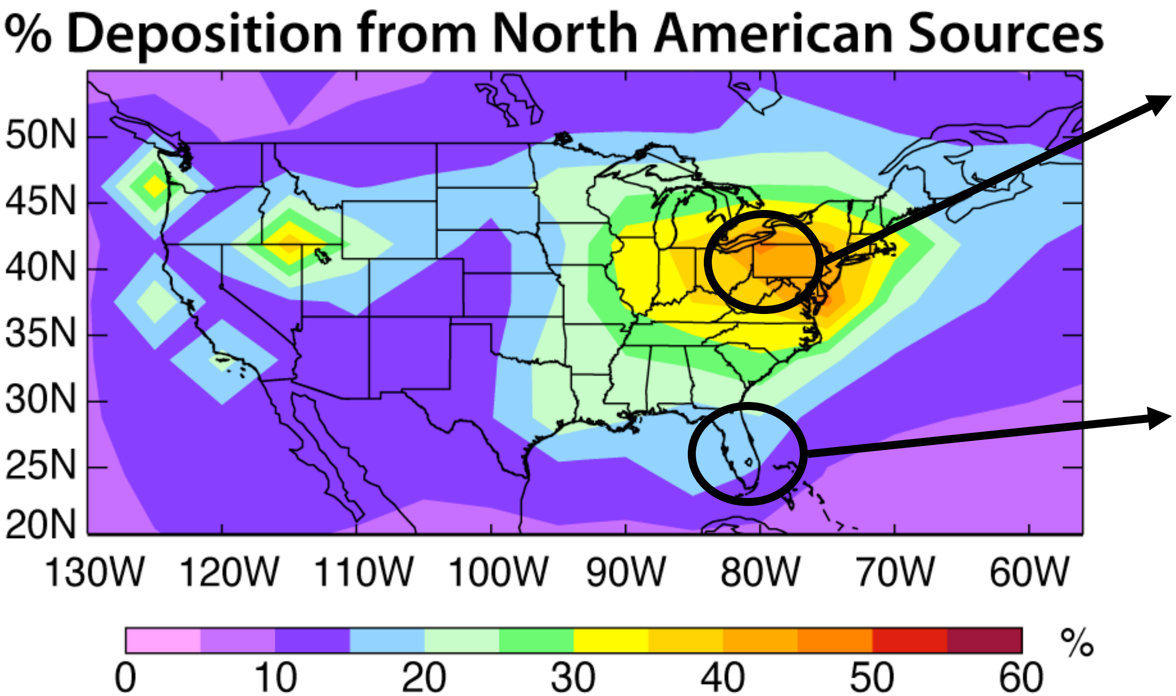
GEOS-Chem captures magnitude and spatial variation of measured wet deposition

We can use the model to gain insights into deposition processes.

[Measurements: Mercury Deposition Network; Model: *Selin & Jacob, AE 2008*]

2. NORTH AMERICAN VS. INTERNATIONAL DEPOSITION

Results from GEOS-Chem global land-ocean-atmosphere Hg model [Selin et al., 2007, 2008]



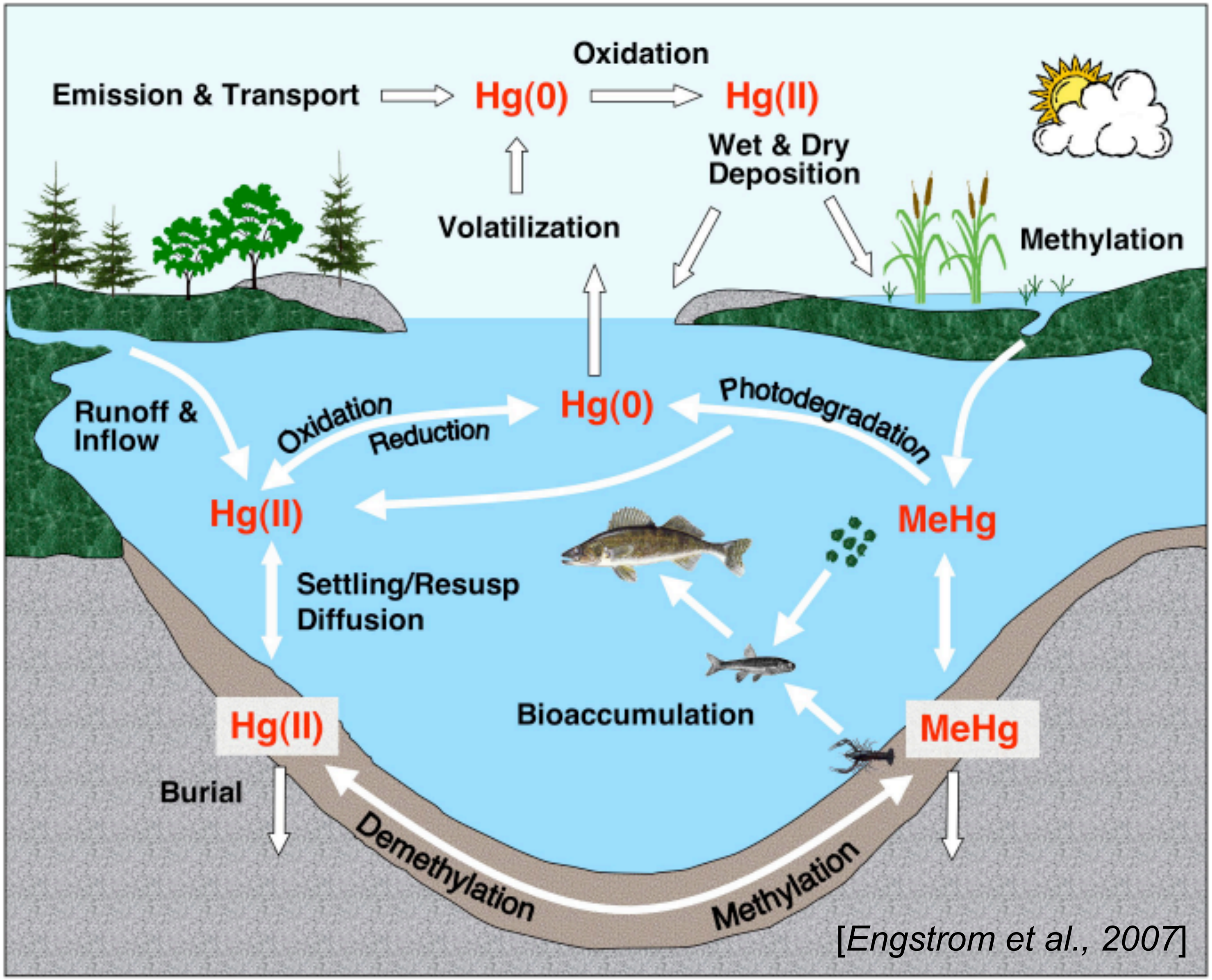
Up to 60% of deposition in Midwest/Northeast is from domestic sources

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 & Jacob, AE 2008*]

2. FROM DEPOSITION TO FISH METHYLMERCURY



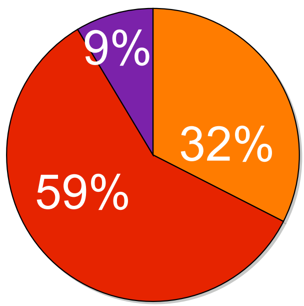
[*Engstrom et al., 2007*]

2.FRESHWATER DEPOSITION AND SOURCE ATTRIBUTION

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

Northeast U.S.

24.21 μg m^{-2} y^{-1}



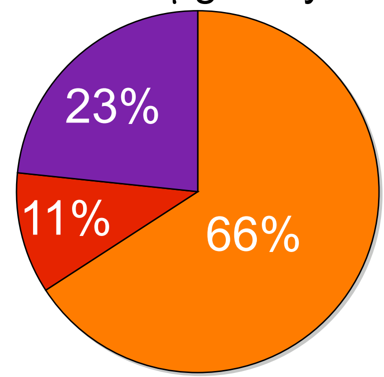
International Anthropogenic

Pre-industrial + Historical

N. American Anthropogenic

Southeast U.S.

34.08 μg m^{-2} y^{-1}



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

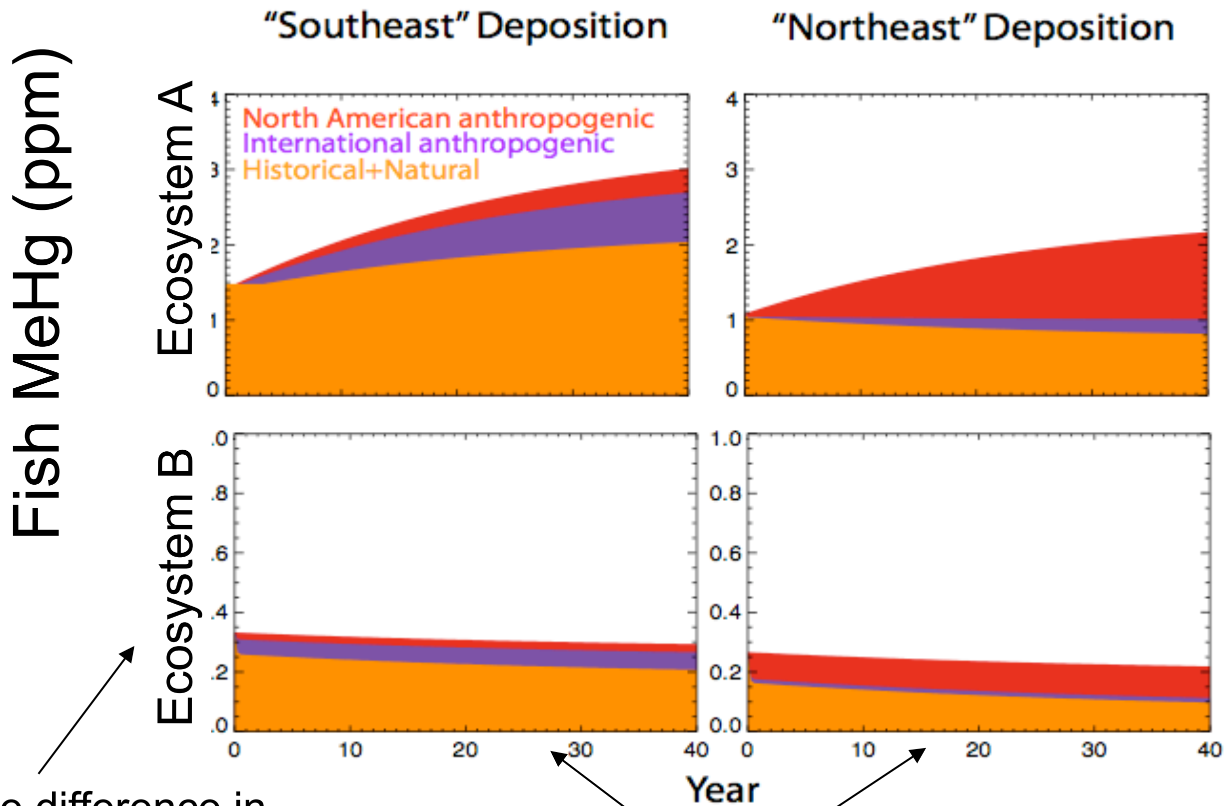
Policy and Timescale Analysis

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

2. FRESHWATER TIMESCALE ANALYSIS

Each ecosystem driven by present-day deposition for 40 years (10-year spin up)

Policy experiment: All Hg is "historical" at t=0. How is anthropogenic signal reflected in fish, and on what timescale?



Same deposition,but different ecosystem dynamics lead to very different source attributions (and concentrations) over time

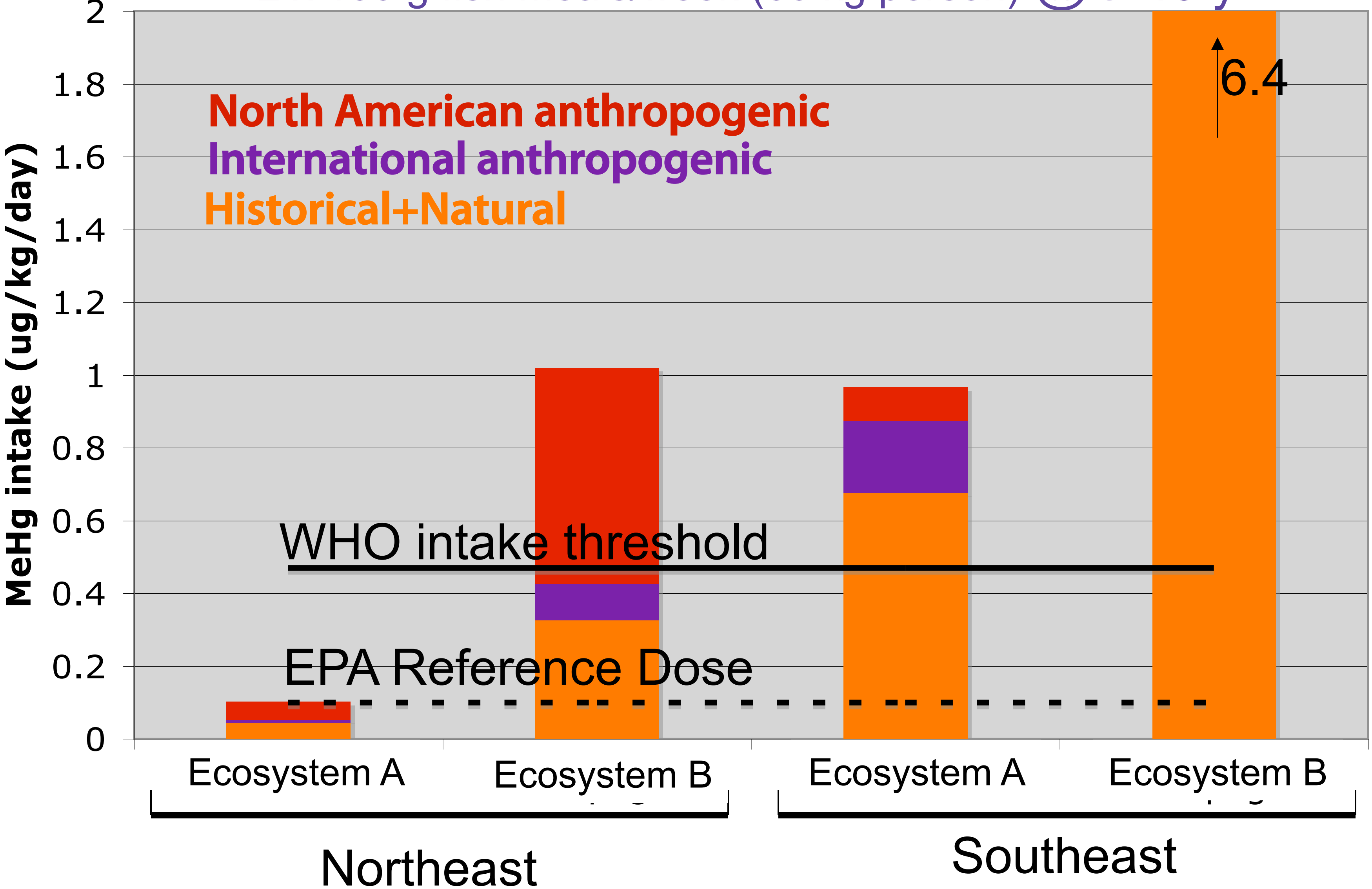
Note difference in scale!

Regional differences in deposition sources lead to different attributions in similar ecosystems

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

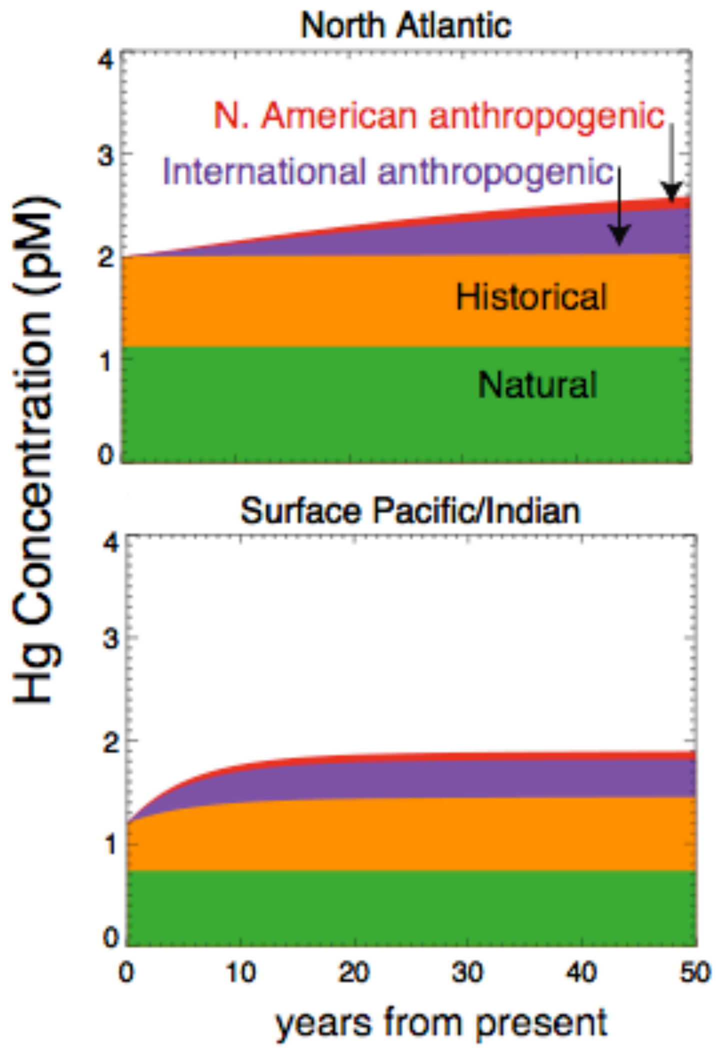
2. LOCAL EXPOSURE FROM FRESHWATER FISH

2 x 100 g fish meals/week (60 kg person) @ t=40 y



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

2. POPULATION-WIDE EXPOSURE FROM MARINE FISH



"current emissions" scenario

14-box ocean model: Sunderland and Mason, 2007

No mechanistic link (yet) from oceanic Hg concentration to fish methylmercury

Historical exposure could continue to increase, complicating policy decision-making

Different challenges on different scales (local to global)

Adaptation and mitigation necessary? (Learning lessons from other issue areas)

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

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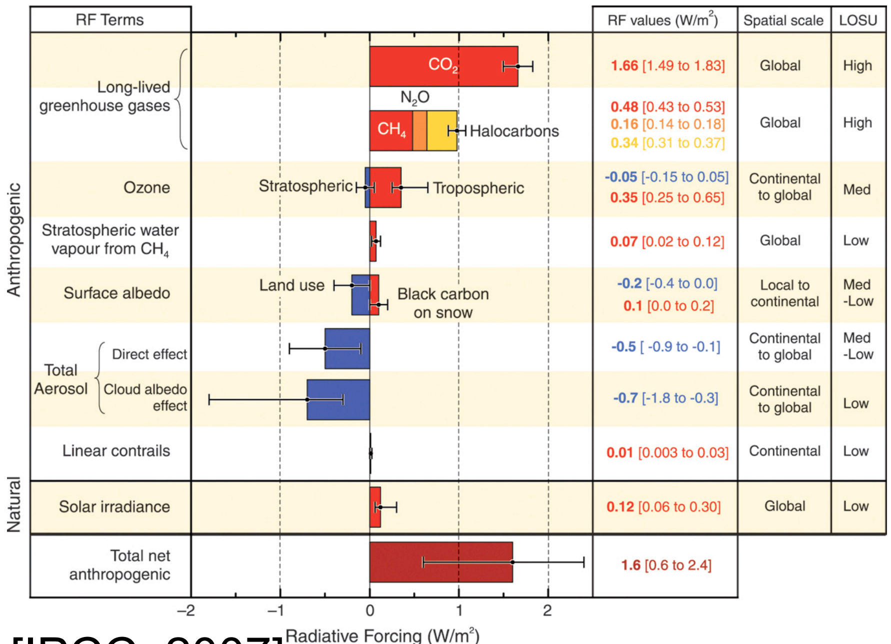
3. AIR POLLUTION AND CLIMATE POLICY LINKAGES

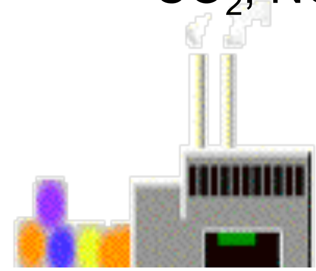
Ozone, aerosols have climate impacts, and are emitted from some of the same sources as greenhouse gases



[IPCC, 2007]

Ozone, fine particulates also have health impacts (cardiovascular/ respiratory impacts, acute mortalities)

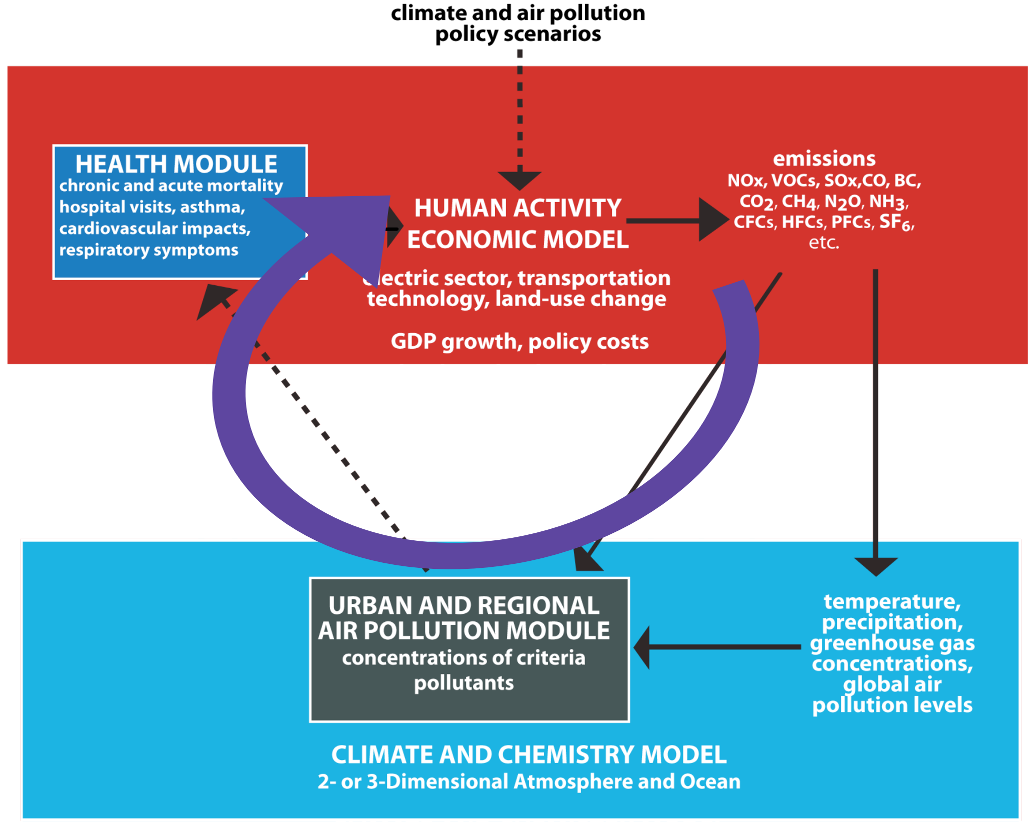
CO_2, NOx, etc.



Policies to reduce GHGs could have co-benefits for urban and regional air pollution (or not).

How can we quantify these potential benefits?

3. POLLUTION-HEALTH CONCEPTUAL FRAMEWORK



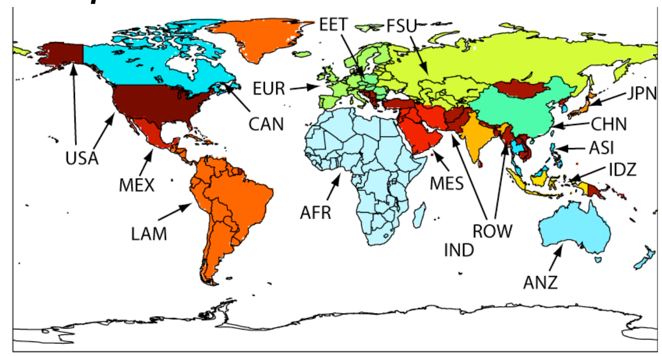
Goal: evaluate impacts of coupled climate and air pollution policy on health, economy, and emissions

Here: conceptual framework for health, driven by climate and policy scenarios (not quite a closed loop), using GEOS-Chem results and health module

3. 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, ozone (EU Extern-E, 2005)

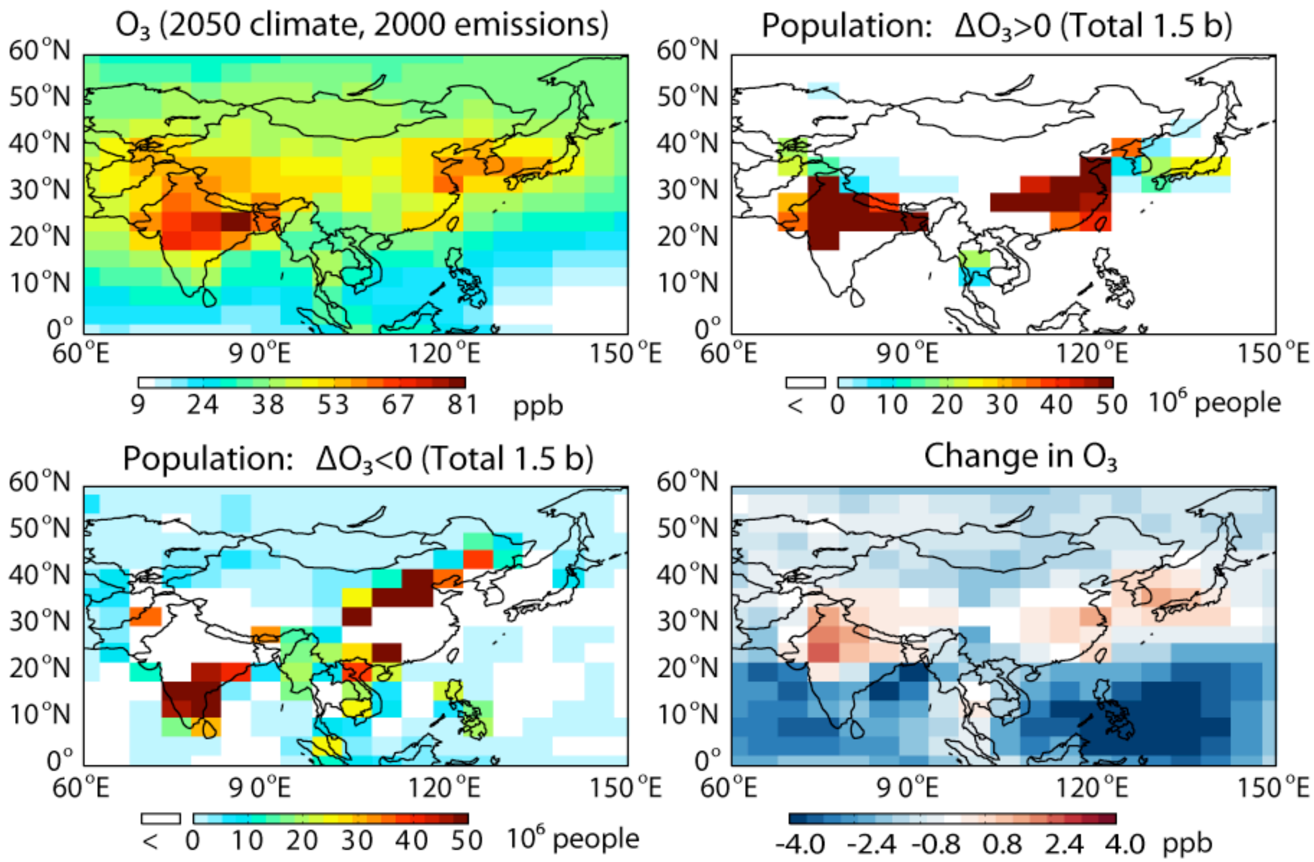
Outcome	Exposure-response function[1]	Cost (€2000)
Acute mortality	0.03%[2]	25,000[3]
Respiratory hospital admission	1.25E-5	2000
Respiratory symptom day	3.3E-2	38
Minor restricted activity day	1.15E-2	38
Asthma attack	4.29E-3	53
Bronchodilator usage	7.30E-2	1
Lower respiratory symptoms (wheeze) in children	1.60E-2	38

[1] Units are cases yr^{-1} $person^{-1}$ μg^{-1} m^3
[2] Bickel and Friedrich (2005). Units are Δannual mortality rate μg^{-1} m^3
[3] Assuming €50,000/year of life lost, and an average of 0.5 years lost per acute mortality

Loss of labor, capital and equilibrium economic effects (2000-2100)

EPPA-HE US model: Matus et al., Climatic Change, 2008

3. POPULATION-WEIGHTED OZONE CONCENTRATIONS



Emissions: IPCC A1B scenario

[GEOS-Chem model: Wu et al, 2008; Selin et al. in prep]

3. FUTURE OZONE MODEL

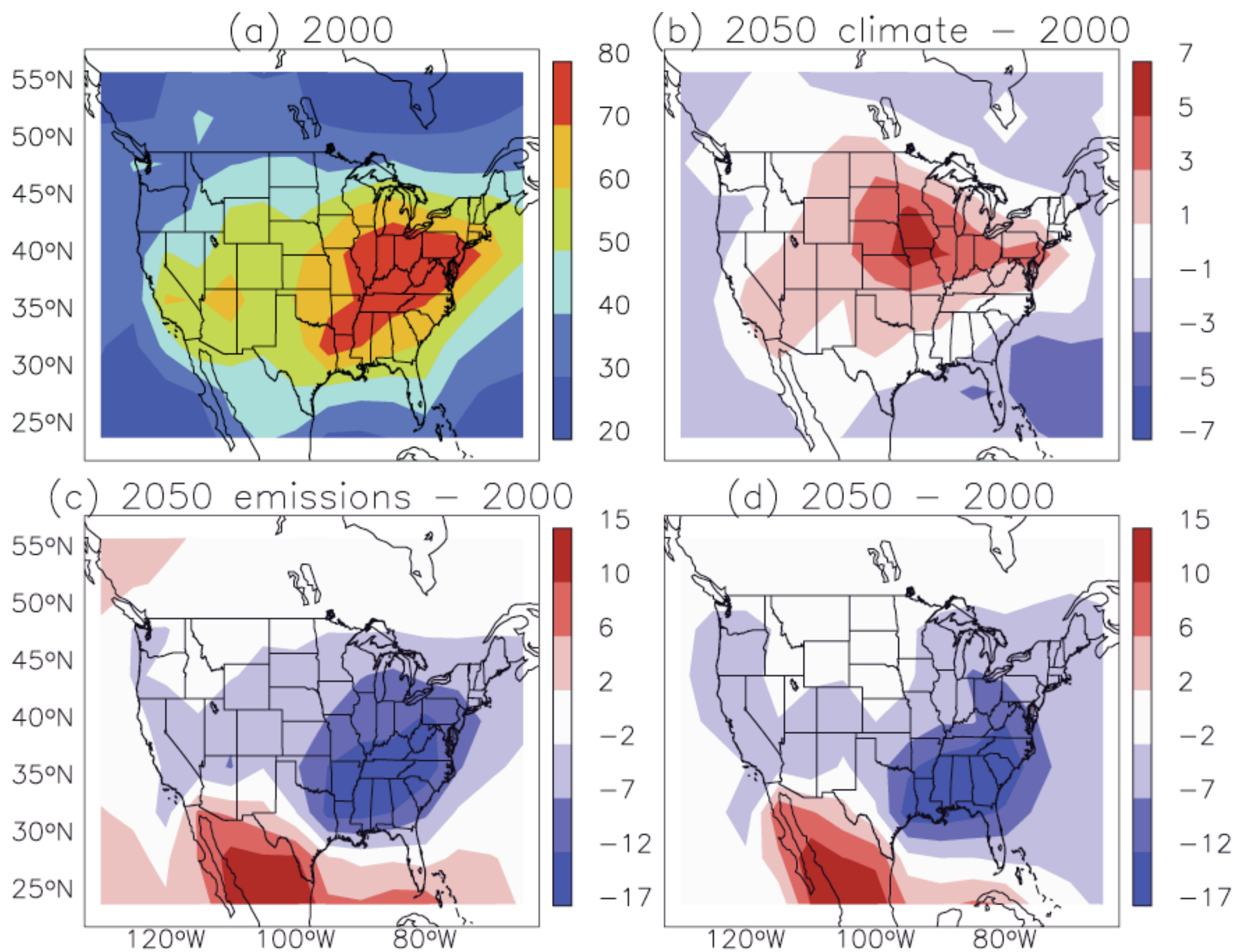


Figure 2. Simulated mean daily maximum 8-hour average surface ozone (ppb) in summer (June–August) for (a) 2000 conditions and perturbations from 2050 changes in (b) climate, (c) anthropogenic emissions of ozone precursors, and (d) both climate and anthropogenic emissions. Note the difference in scales between panels.

[Wu et al., 2008]

3. ΔPOPULATION-WEIGHTED OZONE BY REGION

Region	2000 [O_3]	2050 [O_3]	ΔO_3, climate	ΔO_3, emissions	ΔO_3 (2050-2000)
AFR	33.2	43.2	-0.2	10.3	10.1
ANZ	31.3	30.4	0.0	-0.9	-0.9
ASI	41.4	53.4	0.1	11.9	12.0
CAN	41.7	37.3	0.2	-4.6	-4.4
CHN	47.7	55.7	-0.1	8.2	8.1
EET	43.2	43.5	-1.1	1.3	0.2
EUR	43.5	45.2	0.2	1.5	1.7
FSU	40.4	39.3	-0.9	-0.2	-1.1
IDZ	29.5	44.0	-1.2	15.7	14.4
IND	61.0	85.4	0.4	24.0	24.4
JPN	50.9	48.4	0.9	-3.4	-2.5
LAM	28.3	39.5	0.3	10.9	11.2
MES	48.4	58.8	-0.5	10.9	10.4
MEX	46.3	53.4	-1.6	8.6	7.1
ROW	48.4	60.1	-0.2	12.0	11.8
USA	50.1	45.2	0.2	-5.1	-4.9

Population-weighted ozone concentration by EPPA region, ppb

3. RESULTS FROM HEALTH IMPACTS MODEL

Region	ΔMortalities Climate	ΔMortalities Emissions	ΔMortalities Climate+ emissions	Excess mortalities O_3>10ppb
AFR	-2643	130120	127477	391178
ANZ	-1	585	584	3983
ASI	135	44480	44615	98489
CAN	45	190	235	6808
CHN	-564	90464	89900	402999
EET	-489	1555	1066	16208
EUR	297	5205	5502	66029
FSU	-1262	4891	3629	47427
IDZ	-2144	27388	25244	61806
IND	3735	317371	321106	769961
JPN	534	1284	1818	24309
LAM	1185	46112	47297	113964
MES	-1254	33827	32573	127123
MEX	-1300	7940	6640	37993
ROW	-1361	108383	107022	361519
USA	444	-2474	-2030	79832
Total	**-4,643**	**817,321**	**812,678**	**2,609,628**

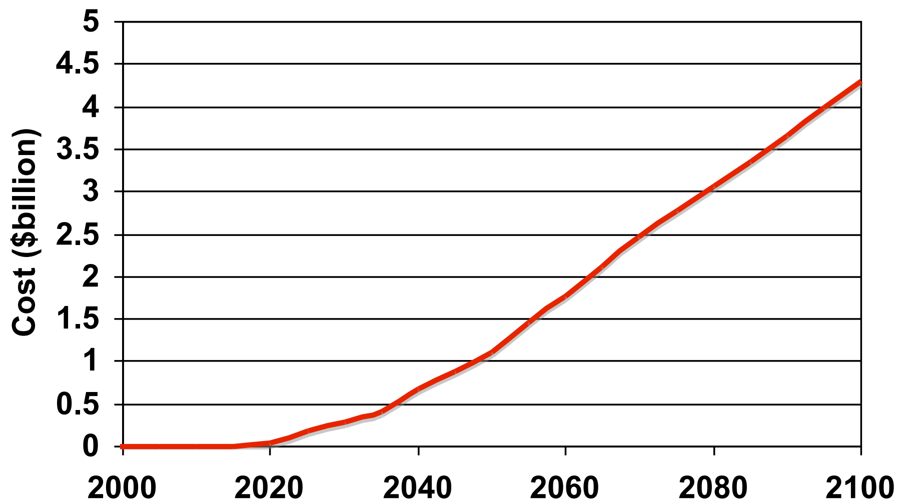
3. ECONOMIC IMPACTS (€2000, billions)

Region	ΔWelfare Climate	ΔWelfare Emissions	ΔWelfare Climate+ Emissions	ΔWelfare (2050) O_3>10ppb
AFR	0.10	-5.60	-5.5	-14.53
ANZ	0.00	-1.88	-1.88	-8.12
ASI	-0.01	-2.43	-2.44	-4.70
CAN	-0.11	-0.74	-0.85	-13.21
CHN	0.13	-20.33	-20.2	-81.46
EET	0.61	-2.64	-2.03	-15.65
EUR	-0.67	-12.81	-13.48	-107.62
FSU	1.28	-6.86	-5.58	-37.99
IDZ	0.16	-2.16	-2	-4.08
IND	-0.80	-61.98	-62.78	-153.44
JPN	-2.08	-4.06	-6.14	-78.03
LAM	-0.05	-2.22	-2.27	-4.54
MES	0.05	-1.99	-1.94	-6.84
MEX	1.65	-12.07	-10.42	-37.77
ROW	0.09	-6.73	-6.64	-21.30
USA	-1.13	2.49	1.36	-143.49
Total	**-0.78**	**-142.01**	**-142.79**	**-732.77**

One-third of costs are from accumulated economic burden of previous concentrations!

3. APPLICATION TO MERCURY

- IQ deficits from mercury exposure [Axelrad, 2007] cost 2.5% of income per point lost [Salkever, 1995]
- Calculate additional cost of US emissions for general population (marine) exposure beginning in 2000



Other estimates: $1.3b for US power plants alone (Trasande et al., 2005); $119m-4.9b (Rice et al. 2005)

[*Selin et al., in prep.*]

FUTURE RESEARCH GOALS

Challenge: Inform the design of effective policies that reduce risk at multiple scales (local to global)

- Explore the coupled air pollution and climate impacts of future energy developments (coal, biofuel, hybrids, renewables)
- Address air pollution challenges that have global drivers but local impacts (using nested models?)
- Identify the pathways of pollutant transport to sensitive ecosystems and populations, especially the Arctic (links to climate-chemistry interactions)
- Further scientific understanding of toxic air pollutants (Hg, other metals, POPs) to inform global negotiations