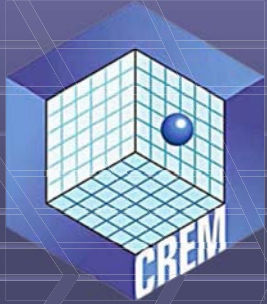


Politics and Modeling at the U.S. Environmental Protection Agency

Elsie Sunderland

Harvard School of Public Health

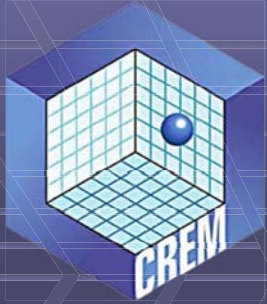
Department of Environmental Health



A Brief History of ...Modeling

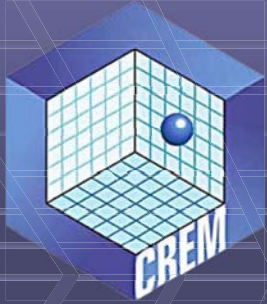
- **1896:** Arrhenius publishes model assessing greenhouse effect after calculating the earth's surface energy balance by hand
- **1915:** Taylor publishes on atmospheric plume motion
- **1924:** Crowther describes human dose-response relationships
- **1925:** Lotka publishes predator-prey relationships
- **1970 onward:** Massive growth in the use of modeling to support decision-making, particularly related to quantitative risk analysis





Truth Generating Machines?

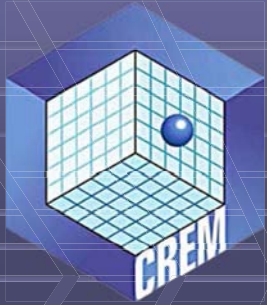
- At some point models switched to being tools (Beck et al., 1997):
 - *Archives* of information
 - *Interpreters* of links between environment & health
 - *Instruments* of analysis and prediction
 - *Devices* for communicating science
 - *Exploratory vehicles* for discovery



Driven by Legal Action

- Origins of quantitative risk analysis in the U.S. often cited as the Supreme Court “Benzene Decision” (Industrial Union Dept, AFL CIO v. American Petroleum Industry, 1980)
- Requirement for factual support for deciding a risk to health is “significant” enough to merit regulation





Many environmental problems require decisions about actions

- To fix current situation
- To prevent future occurrences

Safe Air and Water Quality

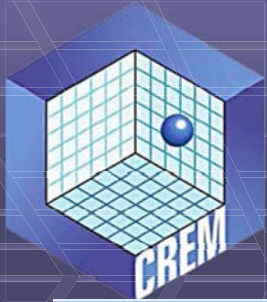
Climate Change

Loss of Biodiversity

Flooding



Common features of decision problems



Complex structure

Large variability

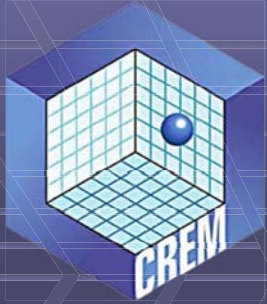
Imperfect information

Pervasive uncertainties!
Best decisions not clear

Unclear management objectives

Imperfect forecasts:
- Natural system
- Human responses

Causal mechanisms are confounded



Why Use Models?

- Incomplete measurement data (we cannot measure all things at all times)

**Natural
Ecosystems**

**Mechanistic
Models**

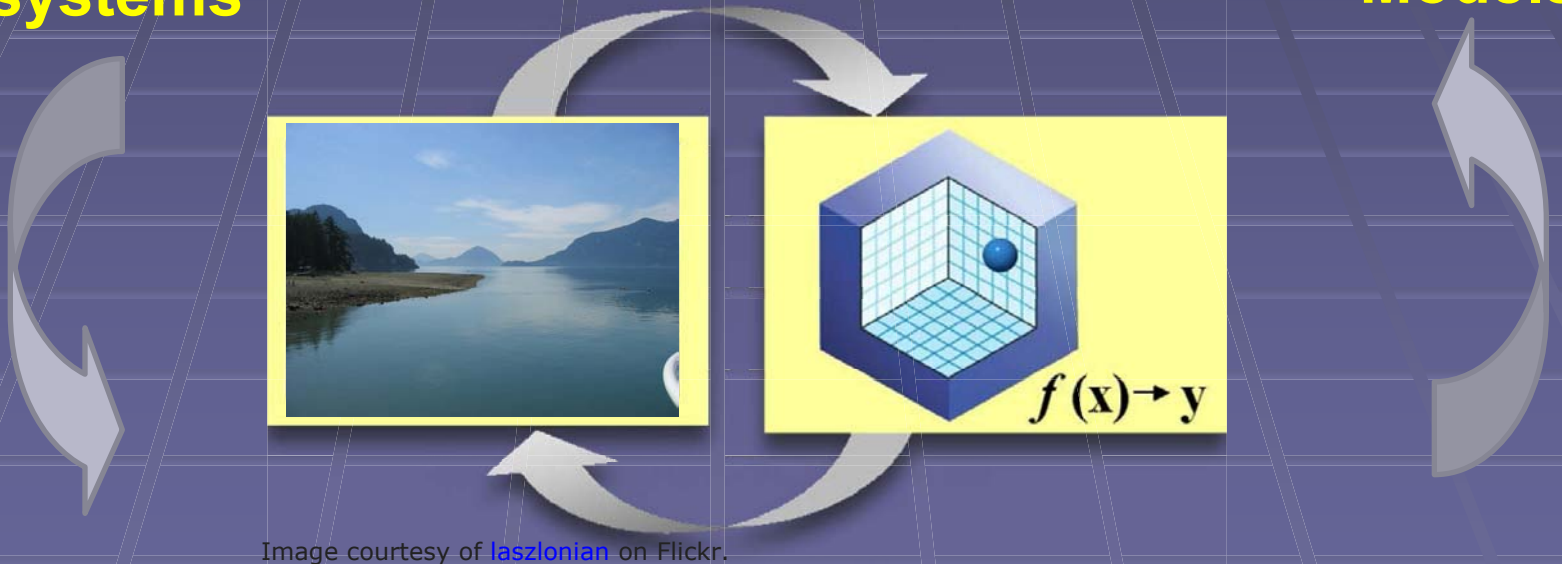
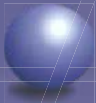


Image courtesy of [laszlonian](#) on Flickr.

**Observations
(Sample Data)**

Empirical Models

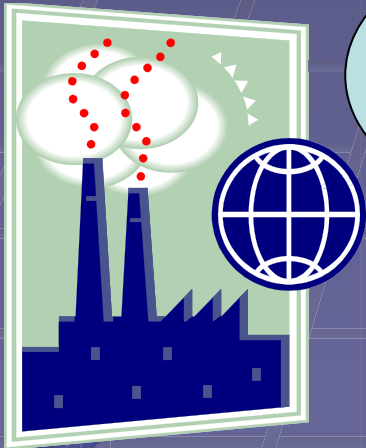




Why Use Models?

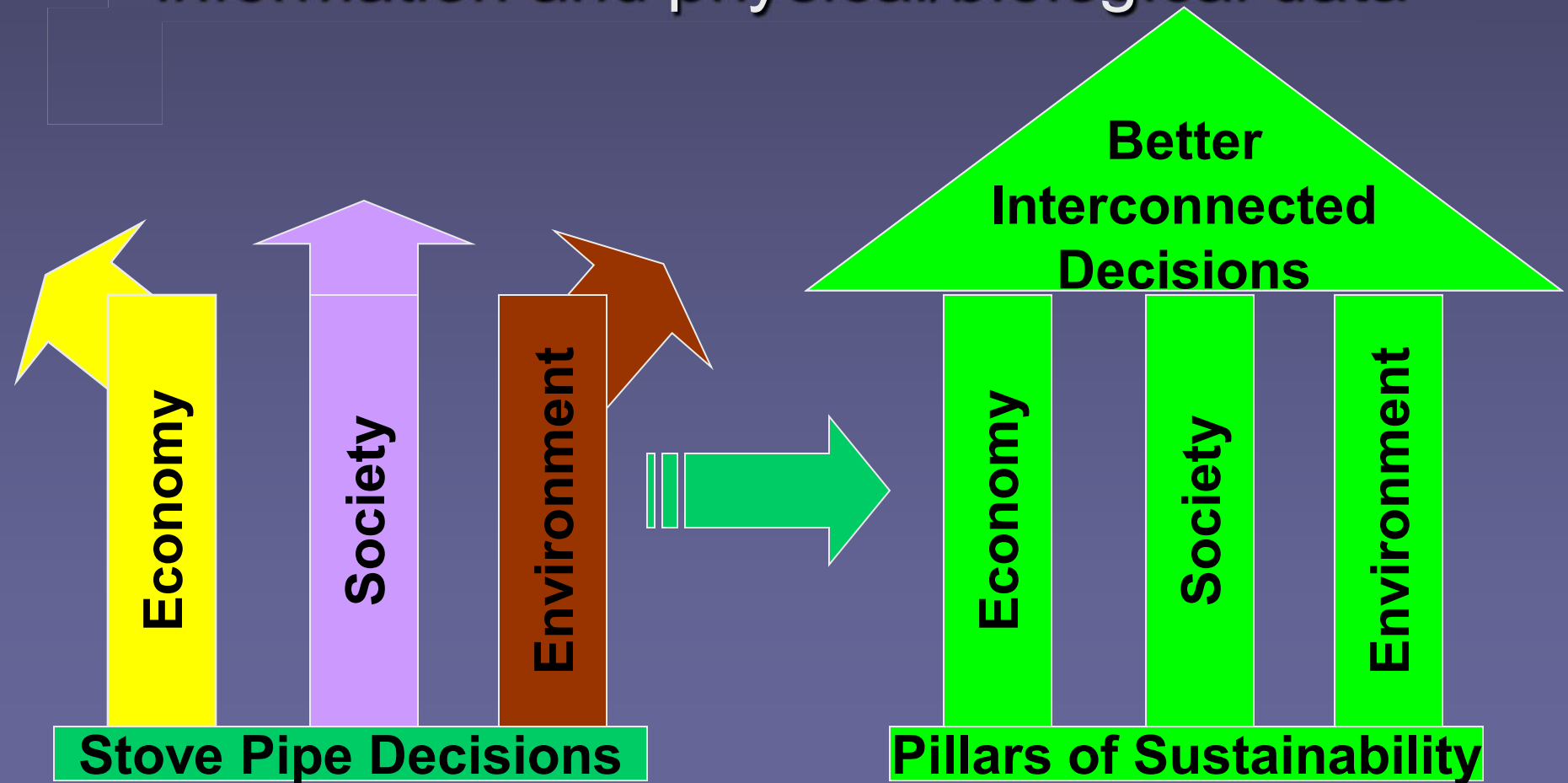
- **Decisions often require anticipating the results of decisions or actions on future environmental quality**

- **How will climate change affect the benefits from planned emission reductions?**
- **How robust are the results?**



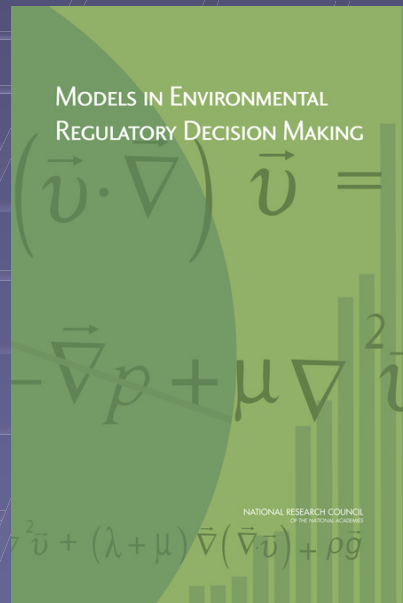
Why Use Models?

- Policies need to integrate socio-economic information and physical/biological data



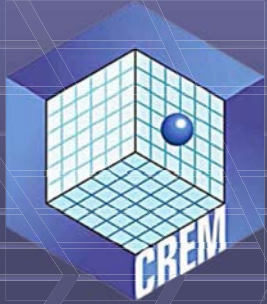
Why establish best-practices for modeling?

http://books.nap.edu/catalog.php?record_id=11972



- 2007 NRC Recommendations for Best Practices for Model Development, Application and Evaluation
- EPA Final Guidance on Environmental Models in 2009.

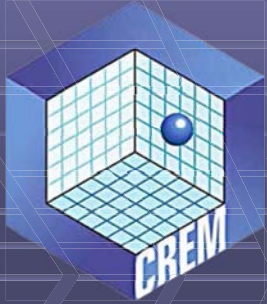
Courtesy of [The National Academies Press](#). Used with permission.



EPA has diverse regulatory authority

- Toxic Substances Control Act
- **Clean Air Act**
- Federal Insecticide, Fungicide, and Rodenticide Act
- **Federal Food, Drug, and Cosmetic Act**
- Safe Drinking Water Act
- **Resource Conservation and Recovery Act (Superfund)**





Setting the stage: Uncertainty & the first term of George W. Bush

**Consider...counting six million of anything.
....no court of law can determine, with
sufficient accuracy, what the true count
actually was.**

Op-Ed by Mathematician John Paulos
on the Bush-Gore Elections, NY Times,
Nov. 22, 2000



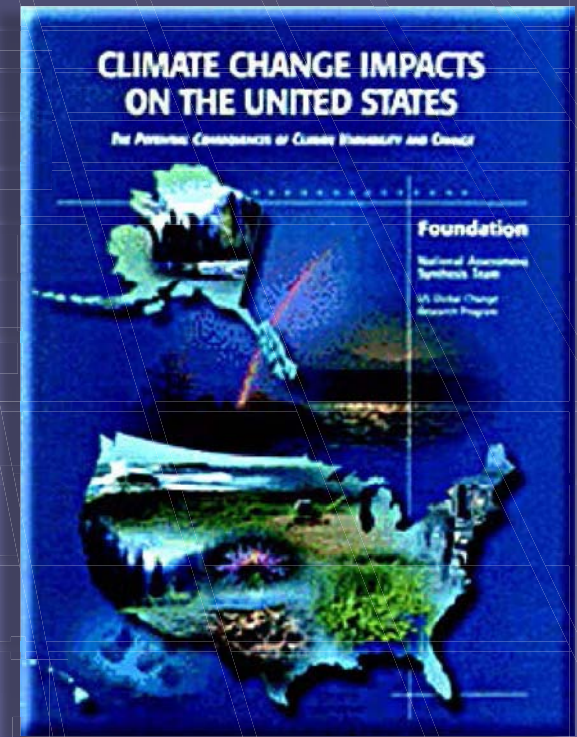
Image by MIT OpenCourseWare.



Challenges to Regulatory Decision-Making

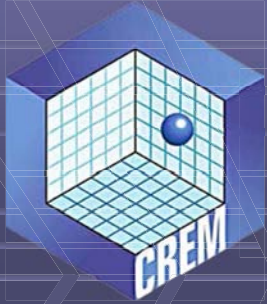
“The (model) ...produces much larger errors than ... the natural noise of the data. That is a simple test of whether or not a model is valid...and both of those models fail.”

Patrick Michaels, Professor of Environmental Sciences at University of Virginia



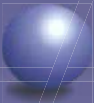
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Quoted in *Petition to Cease Dissemination of the National Assessment on Climate Change*, submitted February 2003.



Data Quality Act (2001)

- Two-sentence rider in a spending bill
- “procedural guidelines” for information quality and dissemination
- Administrative mechanism – “petitions process” targeted at EPA and models
- Basis for “Information Quality Guidelines”
- Used to remove all climate research information from EPA website in 2003





Why focus on models?

Emerging Technologies

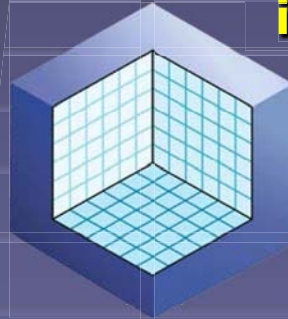
- **Object-oriented software**
- **Moore's law**
- **Data from advanced monitoring technologies**
- **Genomics/Proteomics/Metallomics/Metabolomics**

Data Quality Act

Models should be useful, objective, transparent, reproducible. Models used for risk assessment should rely on best available, practicable science.

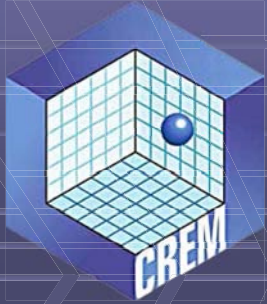
Courts' "hard look"

EPA's use of a model is arbitrary if the model bears no rational relationship to the reality it purports to represent



EPA Charge to NRC

A National Research Council committee will provide advice concerning the development of **guidelines and a vision for the selection and use of models at EPA**. The committee will consider cross-discipline issues related to **model use, performance evaluation, peer review, uncertainty, and quality assurance/quality control**. The objective [is] to provide a report that will serve as a fundamental guide for the selection and use of models in the regulatory process. As part of its work, the committee will need to carefully consider the **realities of EPA's regulatory mission** so as to avoid an overly prescriptive and stringent set of guidelines.

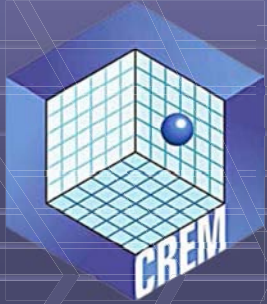


www.epa.gov/crem

**“Build the
black box
out of
plexiglass.”**



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CREM Background

Directives from the EPA Administrator:

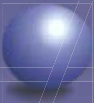
May 2002

... to improve the Agency's policy-making process to better integrate the highest quality science ... revitalize the Council for Regulatory Environmental Modeling (CREM).

February 2003

CREM to work on:

- Guidance to develop, evaluate, and use models
- Web-based Knowledge Base of EPA models
- National Academy of Sciences report on modeling



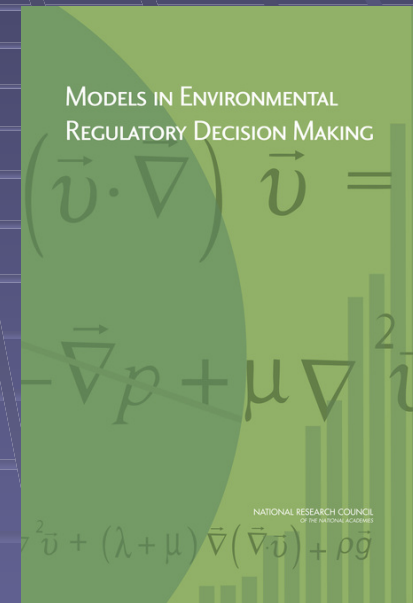
WHAT IS A MODEL?

- **A system of postulates, data, and inferences presented as a mathematical description of an entity or state of affairs**

--Websters New Collegiate Dictionary, 1981

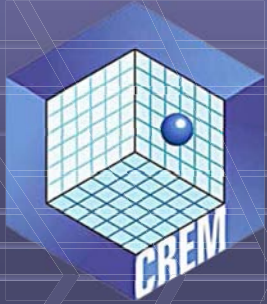
What is a Regulatory Model?

“A computational model used to inform the environmental regulatory process. The approaches can range from single parameter linear relationship models to models with thousands of separate components and many billions of calculations.”



Courtesy of [The National Academies Press](#). Used with permission.

Source: NRC, 2007. *“Models in Environmental Regulatory Decision-Making”*



Model Parsimony

Occam's razor: Models should capture all essential processes for the system but no more

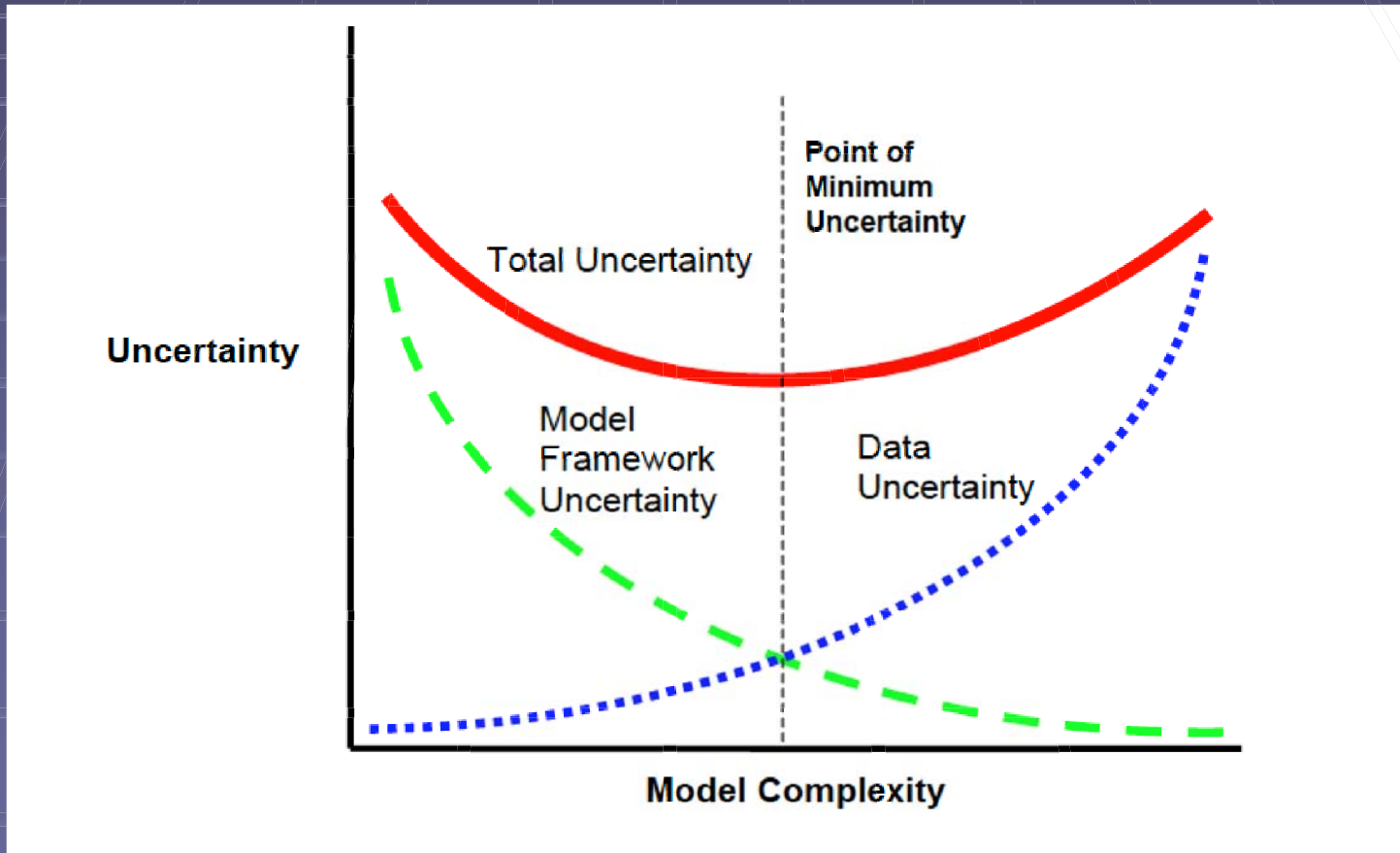
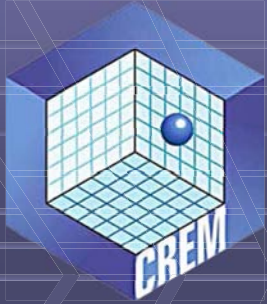


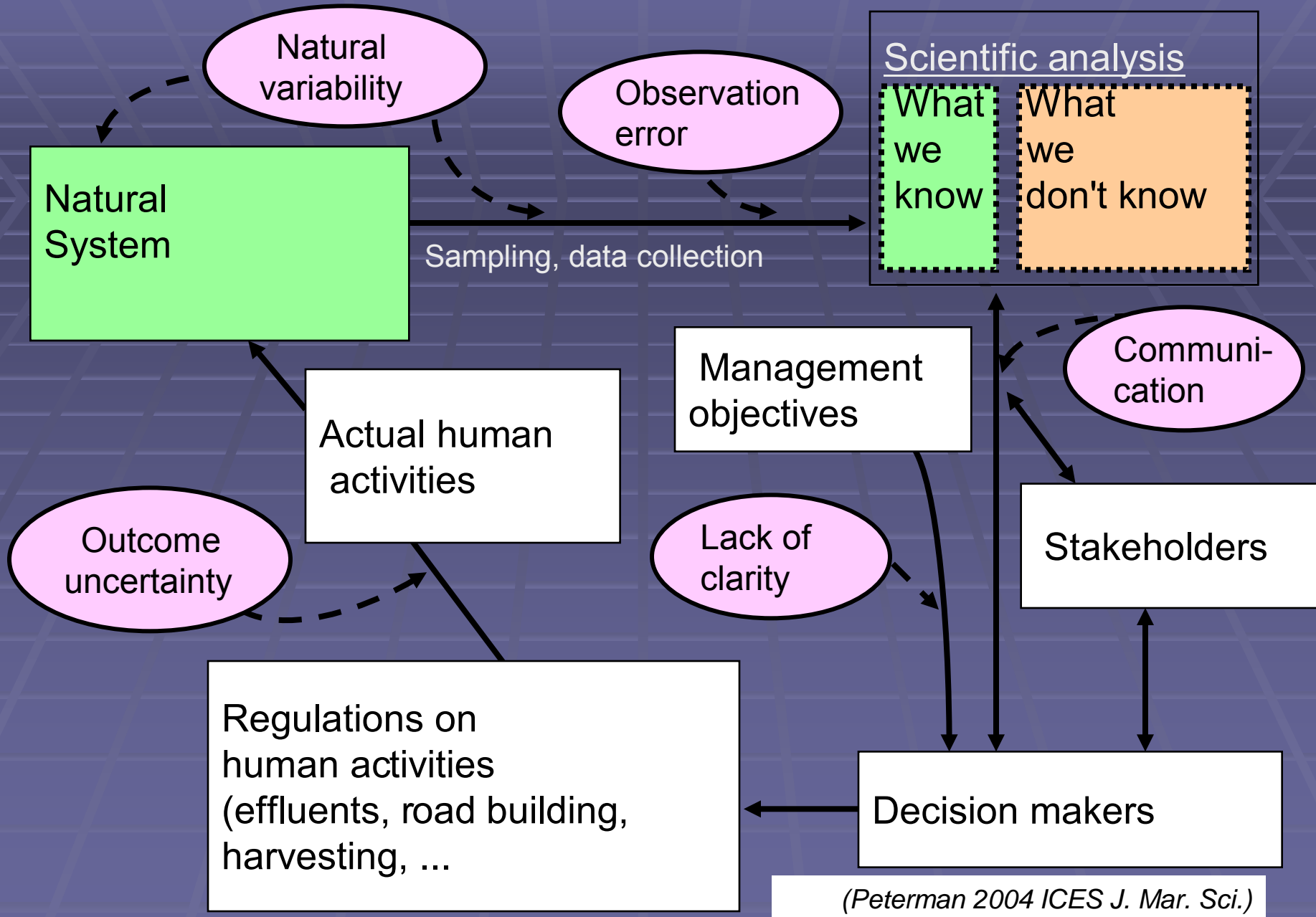
Figure by the Environmental Protection Agency.



Challenge

- When is a model, despite its **uncertainties**, sufficient to serve as the basis for a regulatory decision?







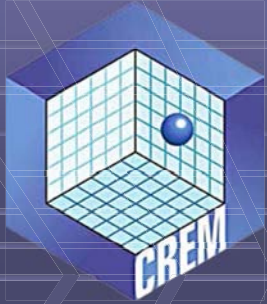
Two Major Categories of Uncertainty

Stochasticity/ Variability

- Natural variability in ecological processes
- Measurement errors
- Influences model parameterization

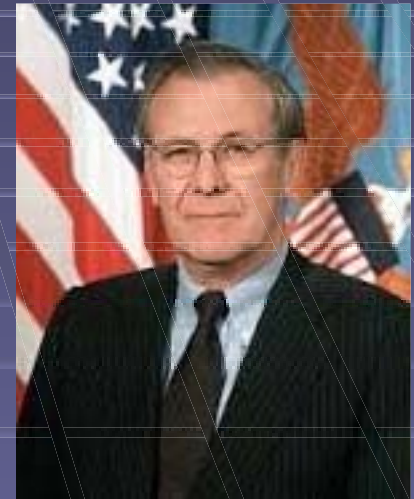
Epistemic

- Things we do not know
- Structural errors in model formulation



As summarized by Donald Rumsfeld

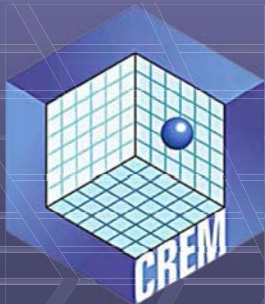
“There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know.”



Photograph in the public domain.

U.S. Secretary of Defense, 2002





Uncertain Uncertainty

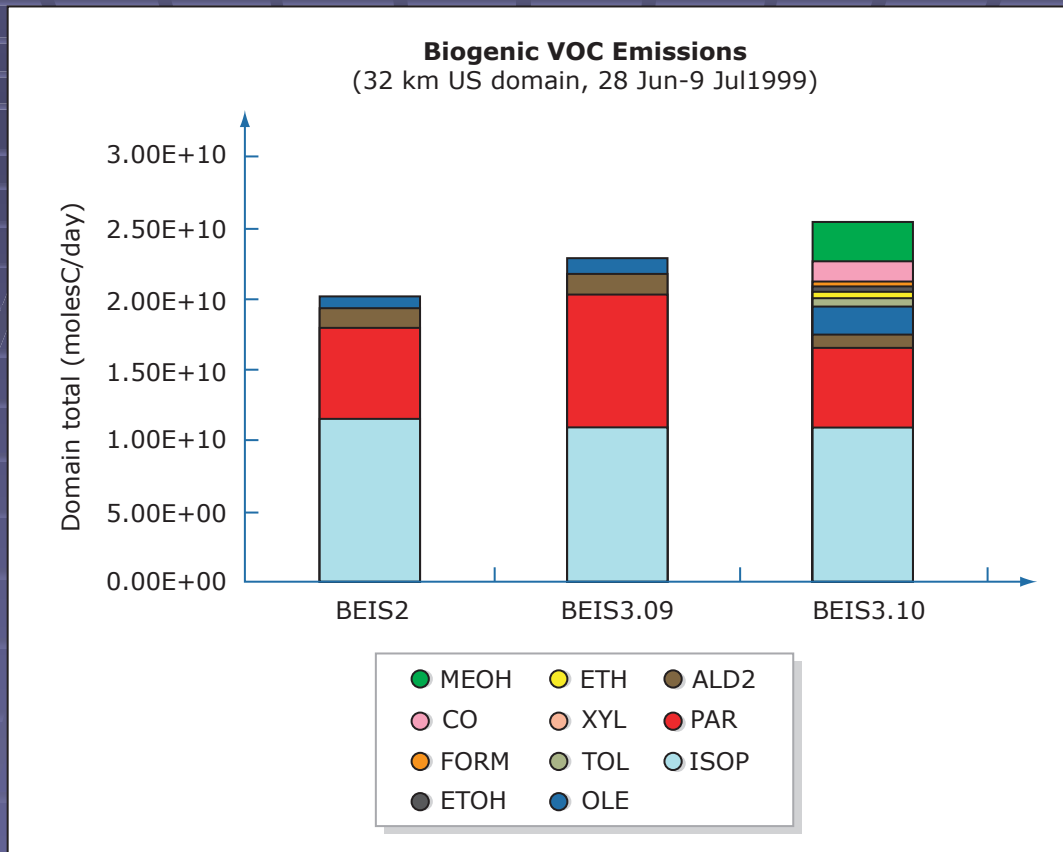
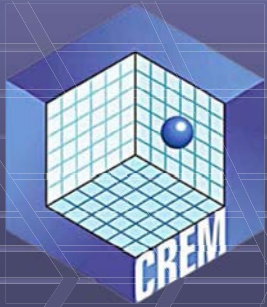


Image by MIT OpenCourseWare.

Changes in biogenic VOC emission estimates: BEIS2 (ca 1996) increased isoprene emissions by x3 over BEIS1. With BEIS3, recently “discovered” oxygenated VOCs have been added to the inventory. These uncertainties are largely unknown and unquantifiable.



Uncertainty in Modeling Analysis

Data
limitations

Science
limitations

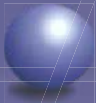


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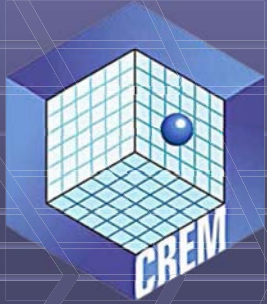
Cost & Time
Constraints

=

Model
Uncertainty



What is a verified and validated model?



Oreskes et al. (1994)

- Verification and validation of numerical models of natural systems is impossible...natural systems are never closed and model results are always non-unique. Models can be confirmed by the demonstration of agreement between observation and prediction, but confirmation is inherently partial.





Is the model valid?

- Proven to correspond exactly to reality
- Demonstrated through experimental tests to make consistently accurate predictions

Source: Suter, 1993



NRC: Model Use in the Regulatory Process

- Models always constrained by computational limitations, assumptions, and knowledge gaps
- Environmental models can never be completely “validated” in the traditional sense. But they can be “evaluated”
- Regulatory models are typically used to describe important, complex, and poorly characterized problems
- Models in the regulatory process best seen as tools providing inputs, as opposed to “truth generating machines”

Source: NRC, 2007

Implications for Regulatory Model Use

- Evaluation of regulatory models requires different tradeoffs than those for research models
- Not simply how well do model estimates **match observations**, but also how **reproducible, transparent**, and **useful** a model is to the regulatory decision
- Requires regulatory models must be managed to be updated in a timely manner and assist users and others to understand conceptual basis, assumptions, input data requirements, and life history

Source: NRC, 2007

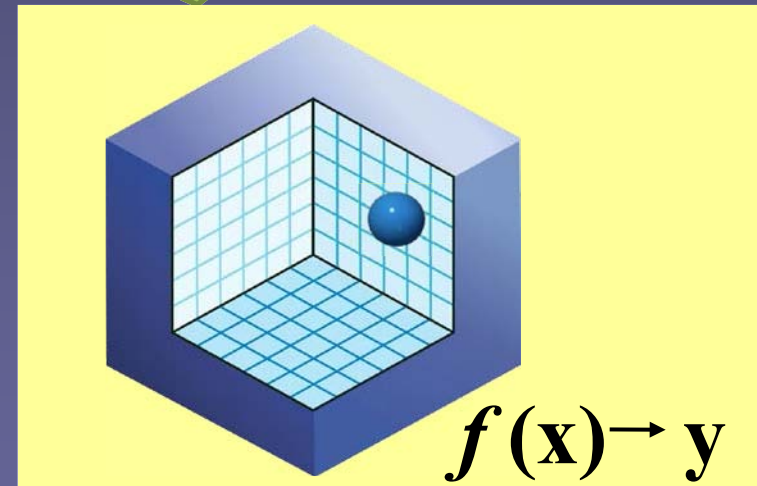
How do we Evaluate Environmental Models? (U.S. EPA Guidance on Environmental Modeling)

Evaluation Information includes: peer review of models; data quality assessment; model corroboration; sensitivity and uncertainty analysis

Reasonably approximates the real system?

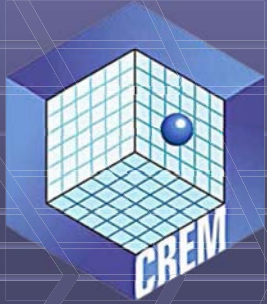


Supported by quality and quantity of available data?



Perform the specified task?

Based on sound science?



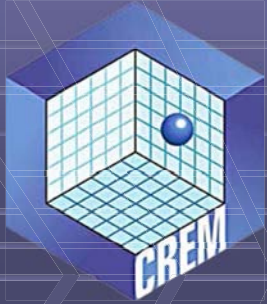
Model Evaluation

- Qualitative: Model formulation review, Expert Elicitation, Peer Review
- Quantitative: Statistical uncertainty and sensitivity analysis, corroboration with field observations



Life-cycle Model Evaluation

Problem Identification	<ul style="list-style-type: none">• What is the goal of the model?• Who will use it?• What types of decisions will it support?• What data are available to support the model?
Conceptual Model	<ul style="list-style-type: none">• Available and alternative theories• Assumptions• Uncertainties• Peer Review
Constructed Model	<ul style="list-style-type: none">• Spatial/ temporal resolution• Algorithm choices• Assumptions• Data availability/ software tools• Quality assurance/ quality control• Test scenarios• Corroboration with observation• Uncertainty/ sensitivity• Peer review
Model Use	<ul style="list-style-type: none">• Appropriateness of model for problem• Assumptions• Model extrapolation• Input data quality• Comparison with observation• Uncertainty/ sensitivity analysis• Peer review



Life-cycle Model Evaluation

- EPA should pay special attention to the **peer review** of models throughout their life-cycle
- EPA could consider promulgating a **generic rule** for the process of evaluation and adjustments of models

Source: NRC, 2007

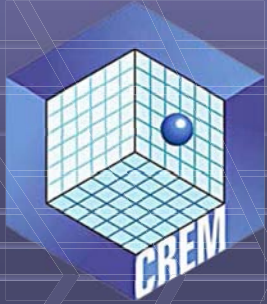


NRC Recommendations

Cont'd

- **Retrospective Analysis**
 - EPA should conduct and document results of retrospective analyses of regulatory models not only on individual models but classes of model.
 - **What are potential problems with this?**





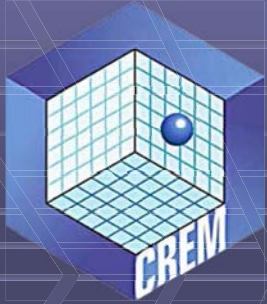
Scientific vs. Policy Uncertainty

“...science has always informed decisions at EPA, but science is not always exact. A big part of my frustration was that scientists would give me a range. And I would ask, “Please just tell me at which point you are safe, and we can do that.” But they would give a range, say, from 5 to 25 parts per billion (ppb). And that was often frustrating.”



Photograph in the public domain.

- Christine Todd Whitman, Former EPA Administrator
quoted in Environmental Science & Technology Online,
April 20, 2005



Uncertainty in Environmental Modeling

Decision-Maker's Perspective

**Model & Monitoring
Uncertainty**

Uncertainty on agenda setting

Action Uncertainty

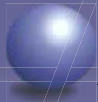
Yield Uncertainty

**Uncertainty about costs and
benefits of alternative options**

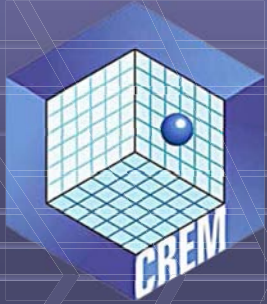
Goal Uncertainty

Political Uncertainty

**Uncertainty on goals and
Preferences**



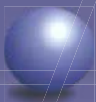
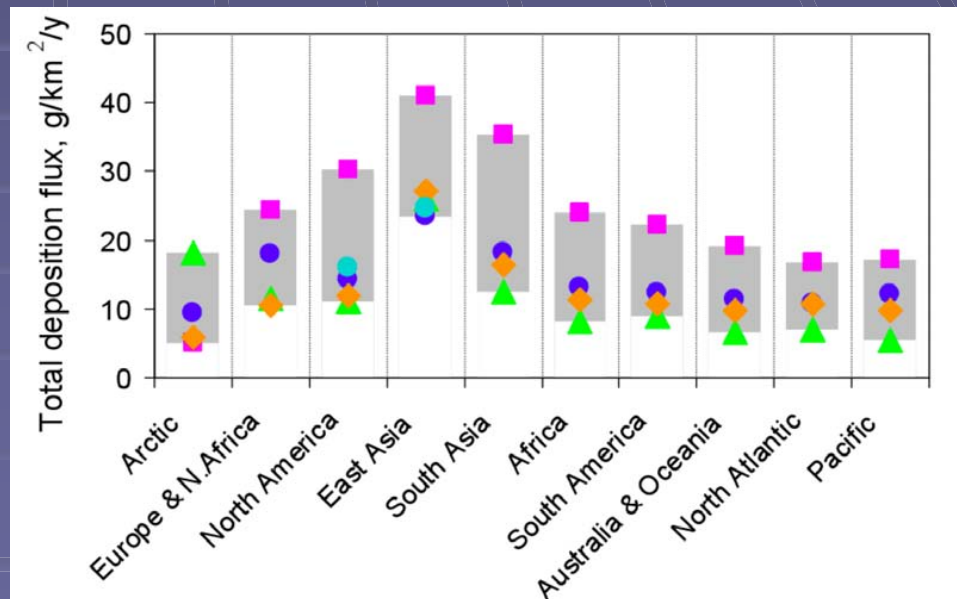
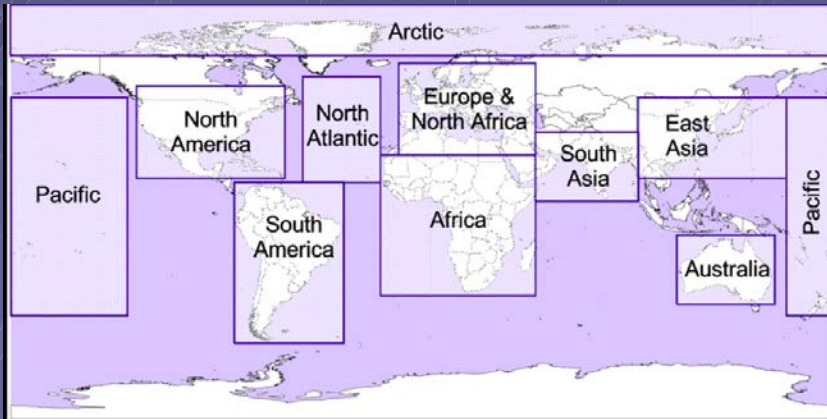
Adapted from ICIS (2000) Uncertainty in Integrated Assessment

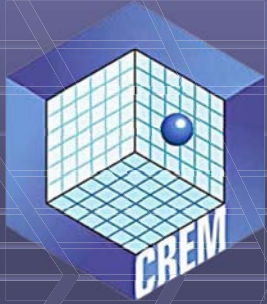


Example: Global Mercury Deposition

2010 HTAP Model Intercomparison: Total Mercury Deposition

● CTM-Hg
 ■ GEOS-Chem
 ▲ GRAHM
 ◆ GLEMOS
 ● CMAQ-Hg
 ▲ ECHMERIT

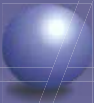




Scientific vs. Policy Uncertainty

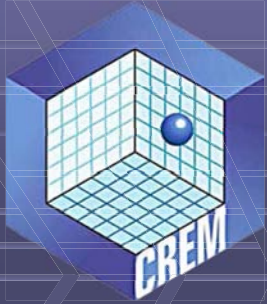
The models predict comparable Hg deposition levels in Europe, North America and South Asia, and differ by a factor of 1.5 for the deposition in East Asia...It is particularly remarkable taking into account the fact that one of the models (GEOS-Chem, ver. 8.2) utilized completely different assumptions on Hg atmospheric chemistry...An exception is the Arctic where the inter-model deviation is much higher...

Travanikov et al., HTAP 2010 Assessment Chapter B4



Other Guidance: Proprietary Models

- Use proprietary models only when:
 - No practicable alternative
 - Owners show effort to protect code and show competitive loss
- Document that models adhere to guidance
- To the extent practicable, provide means to replicate model results



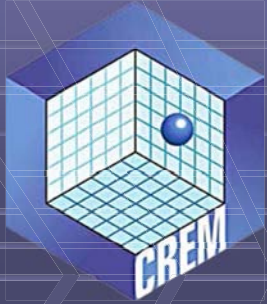
Legal Aspects of Modeling

“An ounce of *ex ante* explanation is worth a pound of *post hoc* rationalization.”

Wagner & McGarity (2003) - Legal Aspects of the Regulatory Use of Environmental Modeling

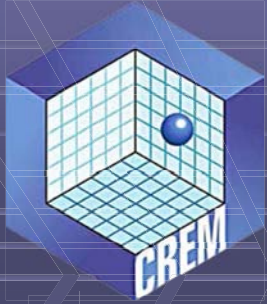
(An analysis of 30 years of judicial challenge on EPA use of models.)





Legal Challenges

- General deference to EPA on science
- “Arbitrary” oversimplifications a problem (e.g., **Flue-Cured Tobacco vs. U.S. EPA, 1998** – similarity between direct and indirect smoke exposure)
- Arbitrarily failing to adjust parameters in default models
- Aggregation of activities within an industry sector being regulated
- Model placeholders based on policy are inappropriate
- Outdated studies
- Data are inappropriate or inadequate (rare to judge negatively on this)



Summary of Lessons

- Courts are tolerant of imperfection with explanation
- Modeling does not require perfect data
- Courts do not expect Agencies to incorporate data that are only available close to or after the rulemaking
- Consistency is helpful but not required
- Peer review makes a difference

- **If the Model Doesn't Fit Don't Wear It**
- **Reality Trumps a Model's Representation of Reality**

McGarity and Wagner, 2003



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ESD.864 / 12.844J Modeling and Assessment for Policy
Spring 2013

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