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# Do we have the science we need to manage the carbon cycle?

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4th NACP All-Investigators Meeting, 4-7 February 2013, Albuquerque NM

The author is grateful to the U.S. Department of Energy's Integrated Assessment Research Program and NASA's Earth System Science Program for research support.

February 7, 2013

U.S. DEPARTMENT OF ENERGY | Office of Science

# Overview

- Management of the global carbon cycle is increasingly urgent
- Management without understanding can be ineffective or even counter-productive
- Carbon cycle research is crucial
- Good news!
  - Lots of progress within CCSP – significant evolution since early 2000s
  - Exciting talks on core science, synthesis, and applications
  - Kudos to NACP community

# Example applications combining social science and carbon cycle science

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- Setting mitigation targets
- Planning bioenergy/renewable energy
- Supporting REDD, agro-forestry negotiations and projects
- Establishing carbon markets
- Designing systems for measuring, reporting, verifying commitments
- Implementing CCS
- Creating urban profiles of inflows and outflows of carbon
- Assessing impacts of changes in the ocean carbon cycle
- …

- Note: not all NACP investigators need to do end-to-end research
  - But all should take note of information needs

# The rest of this talk …

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- To succeed in integrating carbon cycle science in decision making, we need missing science of assessment and decision support
- Illustrations
  - Model development and uncertainty characterization with stakeholders
  - Confidence/uncertainty communication in assessments
  - "Boundary processes" linking experts and decision makers
- Modest suggestions

Arizona State University Decision Theater
Source: Arnim Wiek

# Platform for Regional Integrated Modeling and Analysis (PRIMA)

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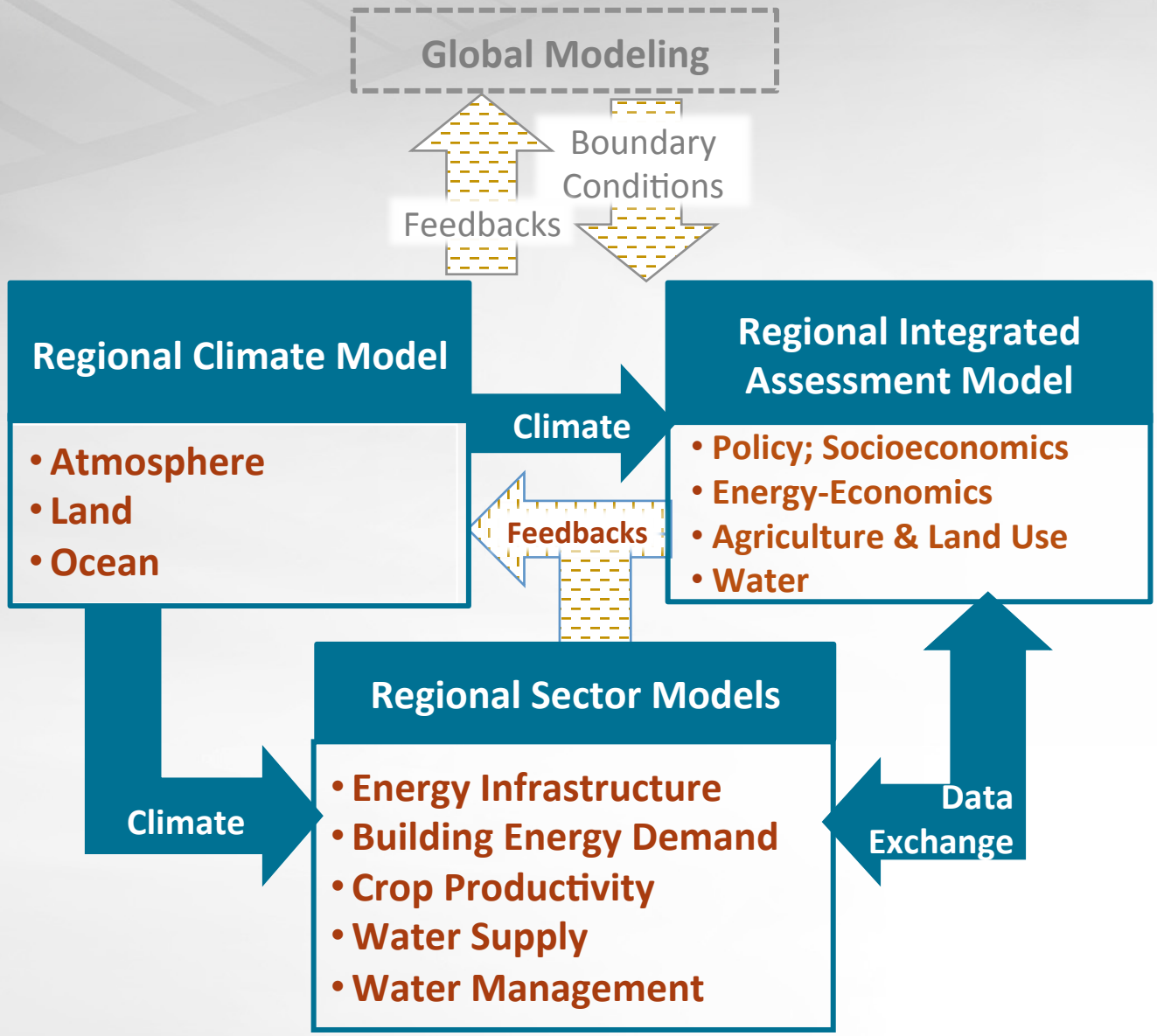

# Characterizing uncertainty in scientific models for decision making

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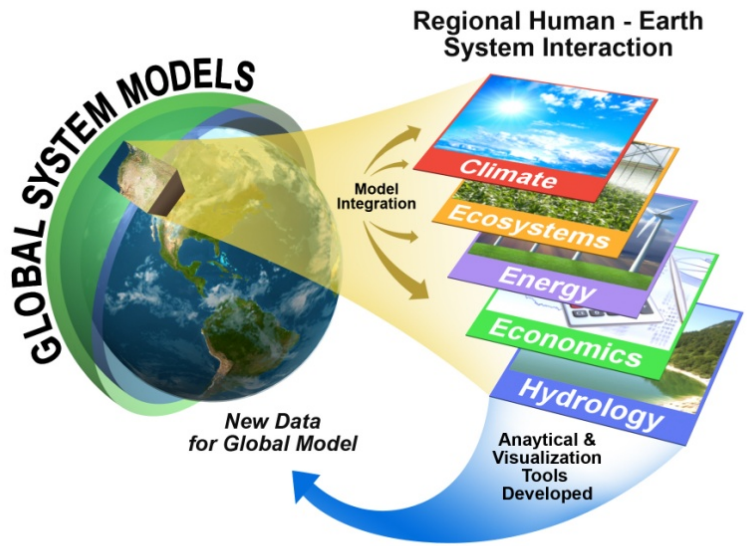
- How can we manage the complexity and dimensionality of uncertainty characterization (UC) in regional scale modeling?




- **Many Thousands of Uncertain Parameters and Modeling Assumptions**
- **Long Run Times**

- New approaches are needed to ensure that UC is relevant and tractable.
  - Guide model development with stakeholder input on needs
  - Give robust input to decision makers with decision-focused UC

# View from a stakeholder perspective

**Regional Socioeconomics**

Population
Growth?
Migration?
GDP?

**Regional Resources and Technologies**

Energy Costs?
Non-Energy Costs?
Availability?
New Technologies?

**Regional Climate**

Hotter?
When?
Colder?
How Much?
Drier?
Wetter?

**Regional Impacts and Interactions**

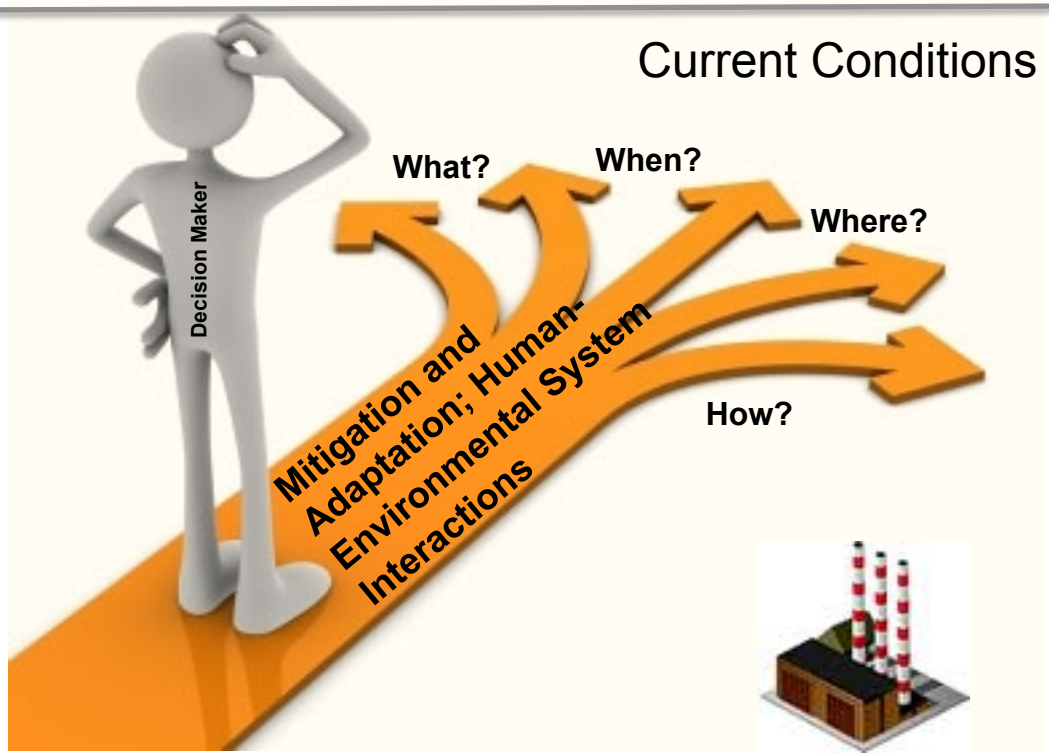
Economic?
Health?
Ecosystems?
Natural Resource Conflicts?

**National or Regional Climate Policy**

None?
Cap and Trade?
AFOLU?

Future

Current Conditions



# Literature review reveals pilot region decisions underway or in prospect

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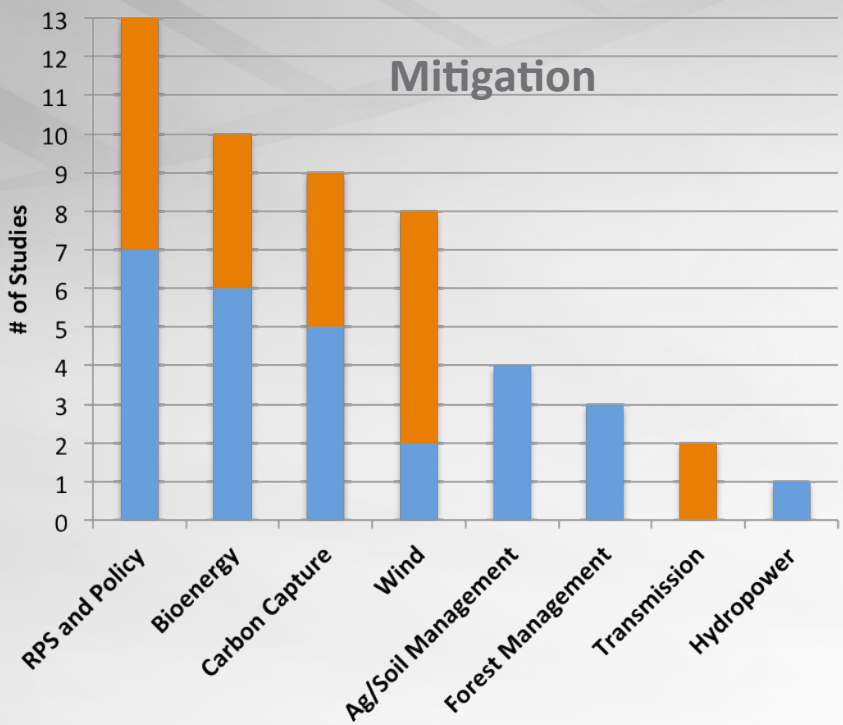


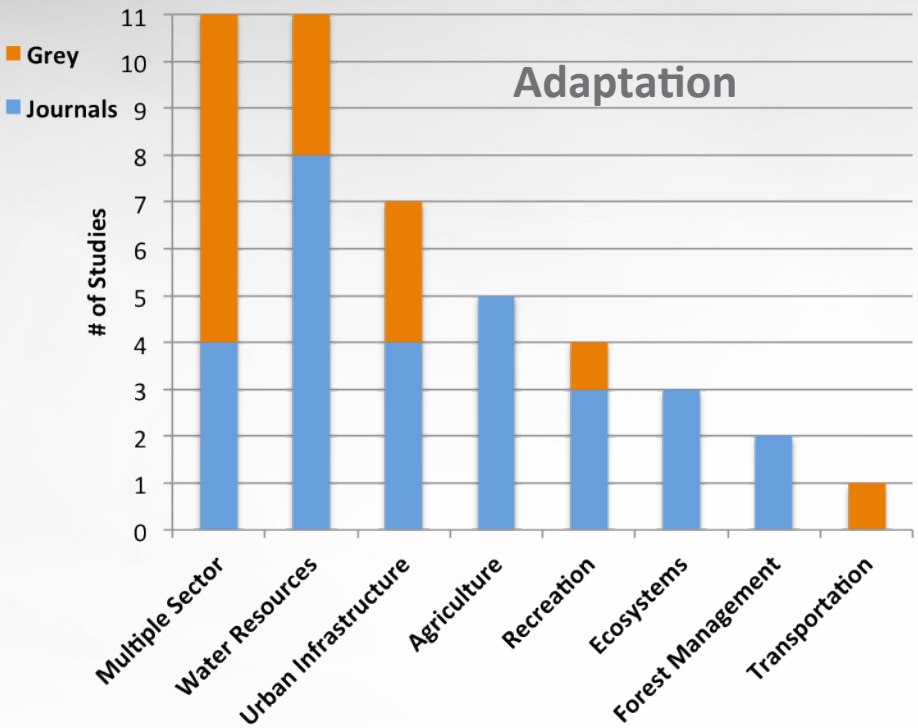


- Also conducted a stakeholder engagement process

Rice, J., RH Moss, PJ Runci, KL Anderson and EL Malone. "Incorporating stakeholder decision support needs into an integrated regional Earth system model." *Mitigation and Adaptation Strategies for Global Change*, 2012, 17(7):805-819. DOI: 10.1007/s11027-011-9345-3.

# Using stakeholder input to guide model framework development and UC

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| Mitigation Types | Adaptation Types | Approach | Stakeholders | Decision Criteria and Other Uncertainties | Decision Processes |
|---|---|---|---|---|---|
| Improve efficiency | Improve building codes | Renewable Portfolio Standard (RPS) | Electricity utilities | Generation costs | Utility shareholders |
| Increase bioenergy use | Retrofit cooling towers | Subsidy | Farming cooperative | Grid stability | System operators |
| Agro-forestry | Increase urban tree cover; green roofs | Regulations | Midwest Governors Association | Food and feedstock prices | Regulatory commission |
| Improve building codes | Storm water management | Pilot projects | State Energy Agency | GHG emissions | Governor's executive order |
| etc. | etc. | etc. | etc. | etc. | etc. |

Malone et al., in prep

# Example decision, stakeholders, and decision criteria

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| etc. | etc. | etc. | etc. | etc. | etc. |

Malone et al., in prep

# Uncertainty characterization process for specific decision criteria

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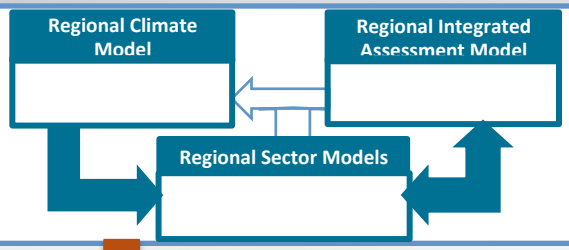
**Characterize Stakeholder Decision Support Needs (Typology)**

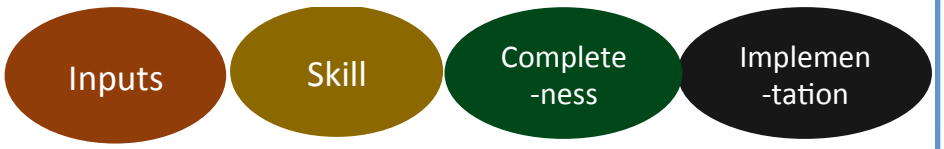
- Decision Criteria
- Options
- Information/ Uncertainties
- Visualization

**Apply Flexible Architecture**




Only Relevant Model Couplings

**Identify Uncertainty Sources**




Decision-Relevant Uncertainties

**Fractional Factorial Sensitivity Analysis**
**(ANOVA- and Regret-Based)**

Sensitive Variables

**Qualitative Methods, Uncertainty Propagation, Robustness Analysis**

Robust Decision Insights

nature climate change

PERSPECTIVE

PUBLISHED ONLINE: 29 MARCH 2011 | DOI: 10.1038/NCLIMATE1080

# The role of social and decision sciences in communicating uncertain climate risks

Nick Pidgeon[1]* and Baruch Fischhoff[2]*

A major challenge facing climate scientists is explaining to non-specialists the risks and uncertainties surrounding potential changes over the coming years, decades and centuries. **Although there are many guidelines for climate communication, there is little empirical evidence of their efficacy**, whether for dispassionately explaining the science or for persuading people to act in more sustainable ways. Moreover, climate communication faces new challenges as assessments of climate-related changes confront uncertainty more explicitly and adopt risk-based approaches to evaluating impacts. Given its critical importance, public understanding of climate science deserves the strongest possible communications science to convey the practical implications of large, complex, uncertain physical, biological and social processes. Here, we identify the communications science that is needed to meet this challenge and the ambitious, interdisciplinary initiative that its effective application to climate science requires.

# Expert judgment process for assessments

- Assessments
  - Synthesis
  - What is known, and how well do we know it?
- Purposes of checklist:
  - Make expert judgment more systematic
  - Develop confidence levels and likelihoods
- Some progress
- Needs evaluation
  - Authors
  - Readers

| Brief statement of conclusion, referenced to report or chapter: |
|---|
| 1. Framing and stakeholder information needs<br>One or more types of stakeholder decisions (or uses of the information) have been considered in formulating the conclusion.<br>Yes / No |
| 2. Initial evaluation of evidence<br>An evidence rating has been assigned, considering the type, amount, quality, and consistency of evidence. In light of the use of the information, the evidence is:<br>Strong / Moderate / Suggestive / Inconclusive |
| 3. Preparation of conclusion<br>The conclusion reflects the diversity of evidence. For quantitative estimates of relevant parameters or metrics, a range is provided (in which there is a 90% chance the true value falls), and a "best estimate" is given, if warranted. High consequence outliers have been considered,<br>Fully / Partially |
| 4. Identification of key uncertainties<br>Sources of uncertainty and steps for improving the information base have been identified.<br>Fully / Partially / Limited extent |
| 5. Assessment of confidence based on evidence and agreement<br>In light of the potential uses of the information, a confidence level has been assigned.<br>High / Moderate / Fair / Low |
| 6. Indication of how likely it is that an outcome or event will occur<br>If you indicate how likely an event is to occur, the standardized numerical ranges and likelihood words have been used.<br>>9 in 10 Very Likely / >2 in 3 Likely / ~1 in 2 Likely as Not / <1 in 3 Unlikely / <1 in 10 Very Unlikely |
| 7. Traceable account: |

Source: Moss and Yohe, 2012

# National climate assessment proposed uncertainty communications

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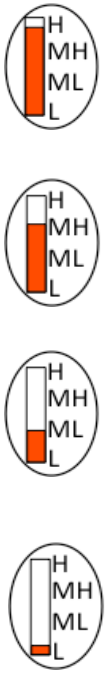
- Traceable accounts:
  - Support for main conclusions
  - Evidence
  - Evaluation of quantity/ quality
  - Uncertainties
  - Level of consensus

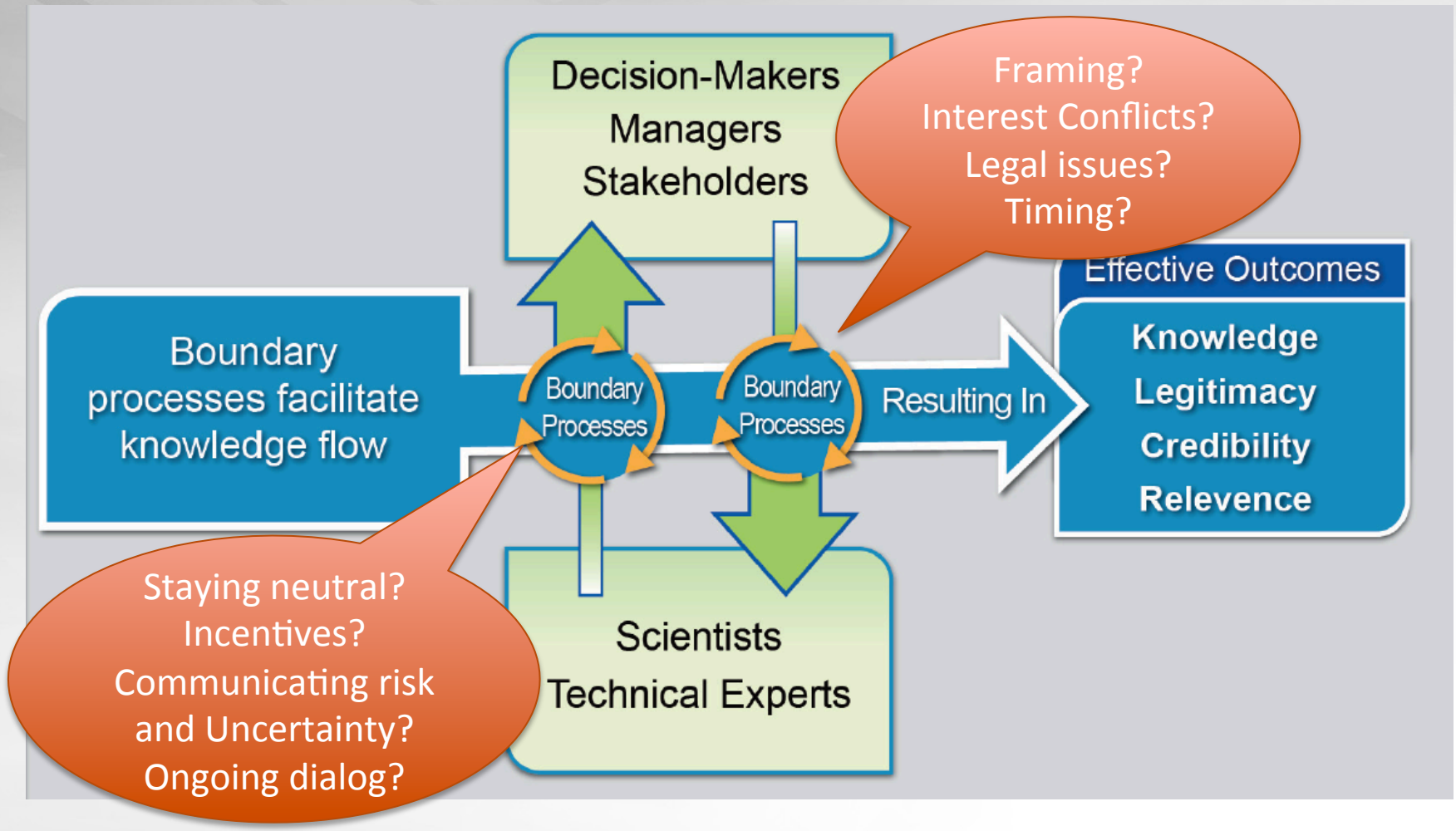
| Confidence Level |
| --- |
| High |
| Moderate |
| Fair |
| Low |




Source: Moss and Yohe, 2012

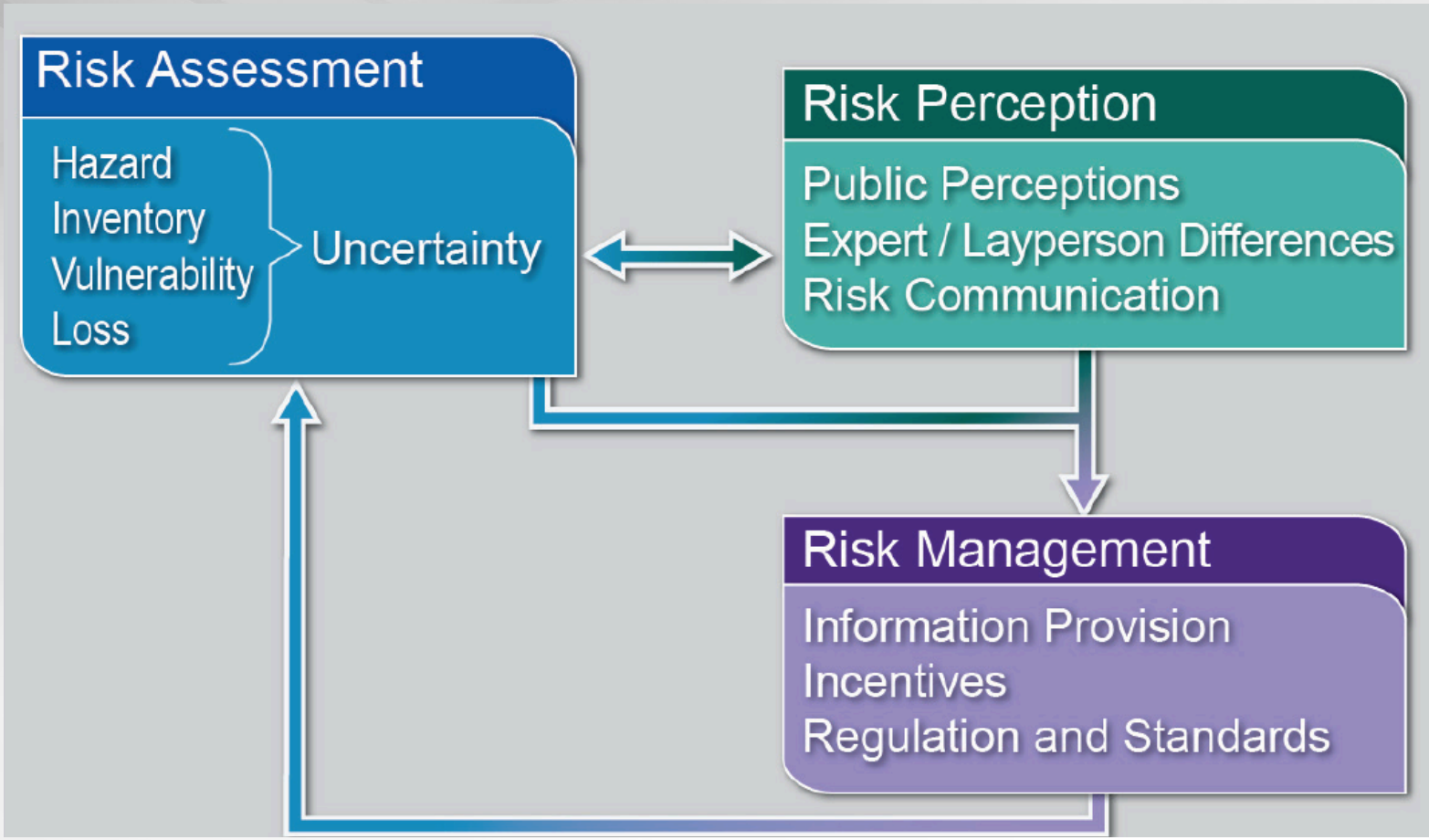
| >9 in 10 | >2 in 3 | 2 | <1 in 3 | <1 in 10 |
| --- | --- | --- | --- | --- |
| Very Likely | Likely | As Likely As Not | Unlikely | Very Unlikely |

# Science of linking experts and decision makers ("boundary processes")




Source: NCA Chapter 26 – Decision Support (v. 11 Jan 2013)

# Risk assessment, perception, and management




Source: NCA Chapter 26 – Decision Support (v. 11 Jan 2013)

# Decision theaters and scenario planning

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- Immersive environments for decision makers to explore the potential consequences of decisions
- Requires
  - Environmental science
  - Understanding of decision making processes and governance
  - Communications research
- Many unanswered questions: Standards? Uncertainty? Ethics?

Source: Stephen Sheppard, UBC

# Moving forward – two modest suggestions and a resource

- Perennial debate about how to foster “human dimensions”
- Making progress with “end-to-end” RFPs
- USGCRP social science task force
  - Valuation
  - Scenarios
  - …
- What else?

# More emphasis on "decision support versions" of science models

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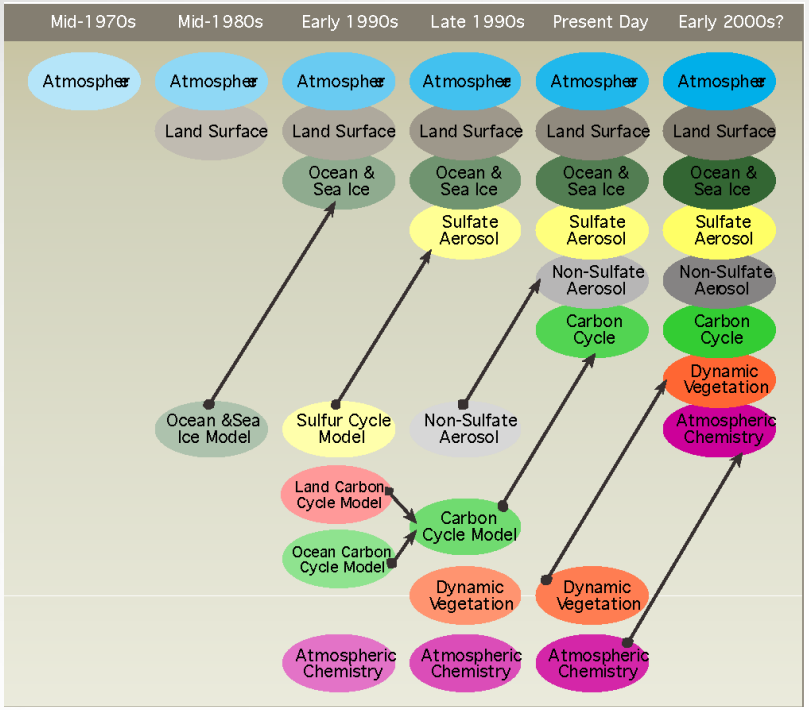
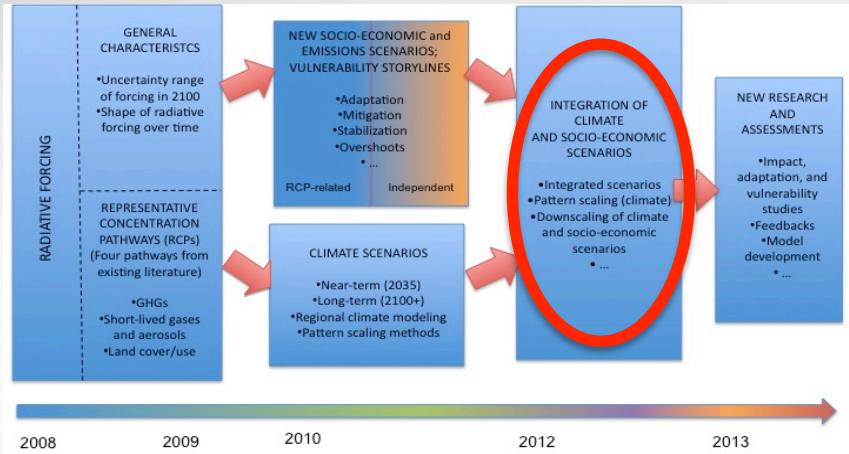
- Our program has developed increasingly complex and "realistic" models
- Modeling programs should ALSO systematically develop "decision support" versions of complex models
  - Enable Monte Carlo analysis and other decision analytic methods
  - Integrated Assessment Models an example
  - How to improve information transfer from full to simple model?
    - Methods behind decision support talks Wednesday pm could provide lessons



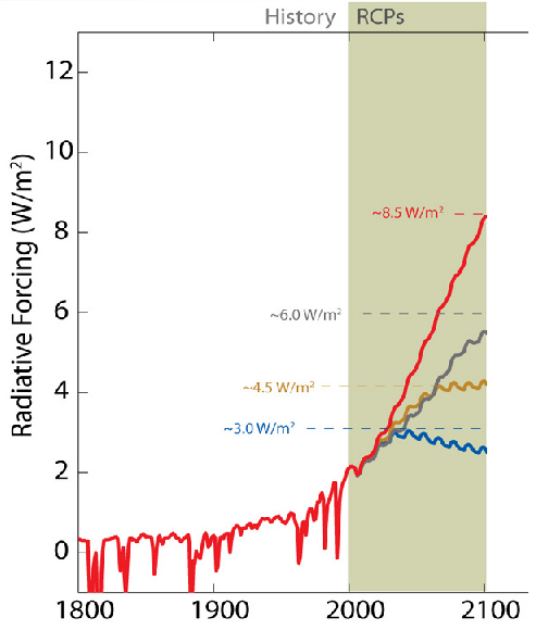

IPCC, 2000; CCSP 2003

# Complete and evaluate RCP process and scenarios

- RCPs not capturing projected emissions range (J.F. Lamarque)
- Radiative forcing doesn't include land use – ceteris paribus, significant differences in radiative forcing (Jones, et al., 2012)
- Integrating and synthesizing CMIP5, IAM, and "impacts" results not really planned
- To better prepare for CMIP6 and AR6 (oh, no!), what do we need to do differently?

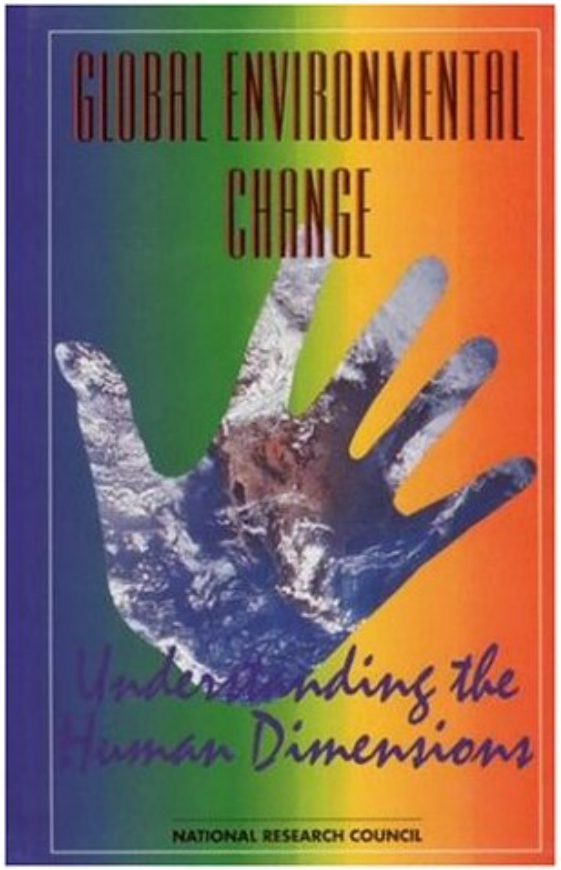



Source: Moss et al. 2010




CLIMATIC CHANGE 109, 1-2 (2011)

# Resource for social science interactions: Board on Environmental Change and Society (BECS)




- Goal: advance science of coupled human-environment systems and inform transitions needed to advance human wellbeing
- Expertise:
  - Energy
  - Vulnerability and adaptation
  - Resources management
  - Socio-ecological systems including environmental health
  - Environmental governance
  - Earth system processes
  - Decision sciences
  - Economic policy and analysis
  - Geography

# BECS research needs by societal challenge

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- Adaptation, e.g.,
  - vulnerability assessment, environmental security, components of resilience
- Limiting environmental degradation, e.g.,
  - influences on technology development and innovation, institutions and carbon markets, effects of green stimulus
- Methods and data, e.g.,
  - integrated social-natural observations, indicators, scenarios, downscaling socioeconomic variables, valuing environmental outcomes
- Cross-cutting topics, e.g.,
  - international institutions and cooperation, decision support science, risk perception and communication, decisionmaking under uncertainty, drivers of public opinion

# BECS Membership

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**Richard H. Moss** *(Chair)*
*Joint Global Change Research Institute*
*University of Maryland*

**Arun Agrawal**
*School of Natural Resources & Environment*
*University of Michigan, Ann Arbor*

**Joseph Arvai**
*Institute for Sustainable Energy, Environment, & Economy*
*University of Calgary*

**Anthony Bebbington**
*Graduate School of Geography*
*Clark University*

**William Chandler**
*Transition Energy*

**F. Stuart (Terry) Chapin, III** (NAS)
*Institute of Arctic Biology*
*University of Alaska*

**Ruth DeFries** (NAS)
*Department of Ecology, Evolution, & Environmental Biology, Columbia University*

**Kristie L. Ebi**
*Technical Support Unit, IPCC Working Group II*
*Carnegie Institution for Science*

**Maria Carmen Lemos**
*School of Natural Resources & Environment*
*University of Michigan, Ann Arbor*

**Dennis Ojima**
*Natural Resource Ecology Laboratory*
*Colorado State University*

**Jonathan Overpeck**
*Institute of the Environment*
*University of Arizona*

**Stephen Polasky** (NAS)
*Department of Applied Economics*
*University of Minnesota*

**J. Timmons Roberts**
*Center for Environmental Studies*
*Brown University*

**James L. Sweeney**
*Precourt Energy Efficiency Center*
*Stanford University*

**Gary W. Yohe**
*Department of Economics*
*Wesleyan University*

# Closing thoughts

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- NACP PIs are integrating their research with social scientists to provide end-to-end analysis of policy/management-related subjects
- Do we have the science we need? We're getting there, but important gaps remain
- Among the gaps are several areas of social science research – without it, methods and information for integration will be missing

# Discussion

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# Decision typology of stakeholder research

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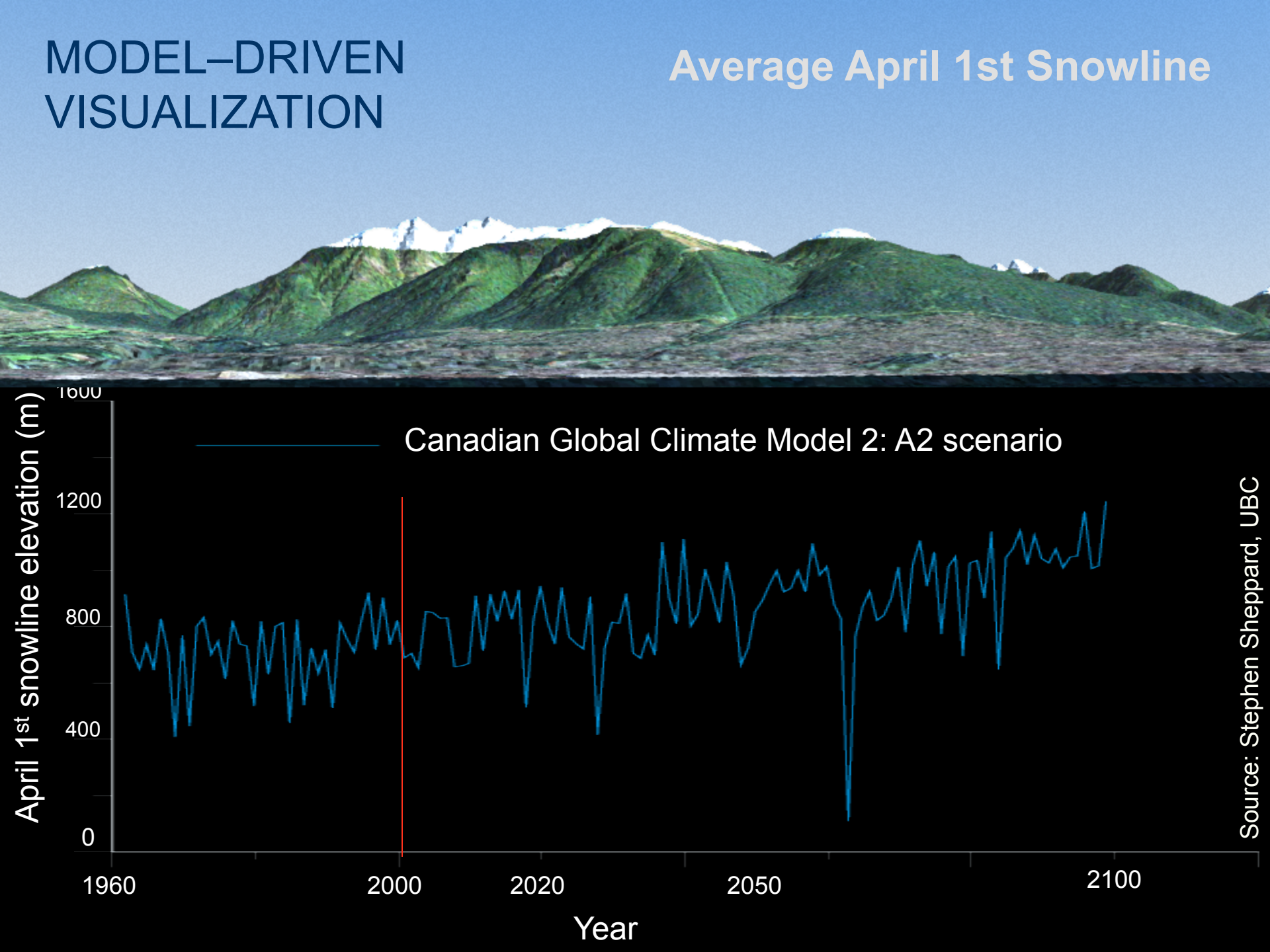
|---|---|---|---|---|---|
| Carbon tax | **Improve building codes** | **Regional policy mandate** | Electricity Sector | **Cost-effectiveness** | **State-level task force** |
| Renewable Portfolio Standard (RPS) | Retrofit cooling towers | Regional incentives | Cities | Energy independence | **Legislation** |
| Cap and trade | Increase urban tree cover; green roofs | In-state only | **Midwest Governors Association** | Heat waves | **Scientific advisory group** |
| **Improve building codes** | Increase generation in urban areas | Pilot sites | State Energy Agencies | **GHG emissions** | **Governor's executive order** |
| etc. | etc. | etc. | etc. | **etc.** | etc. |

Malone et al., in prep

# MODEL–DRIVEN VISUALIZATION

## Average April 1st Snowline