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Data and Modeling Challenges for the Next Generation of Integrated Assessment Research

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Plenary Session

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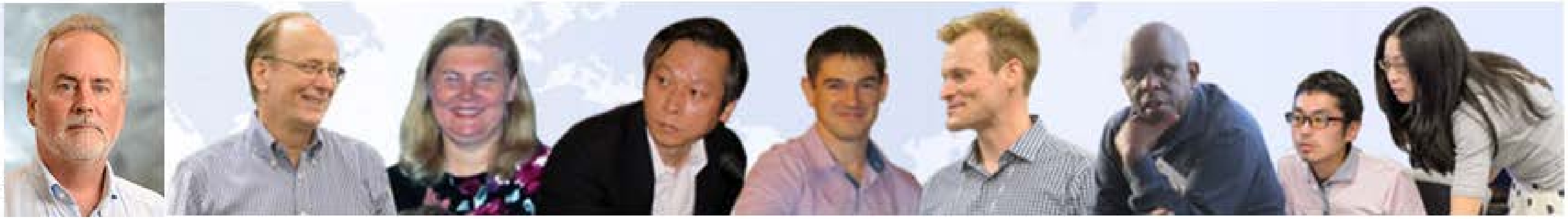
U.S. DEPARTMENT OF ENERGY

Thanks to GTAP!

- Thanks for a wonderful conference
- And, thanks to GTAP for all the data and models!
- And thanks for the opportunity to speak to this meeting today!

PURDUE UNIVERSITY
GTAP
Global Trade Analysis Project



Research and Data Frontiers—A Personal Agenda

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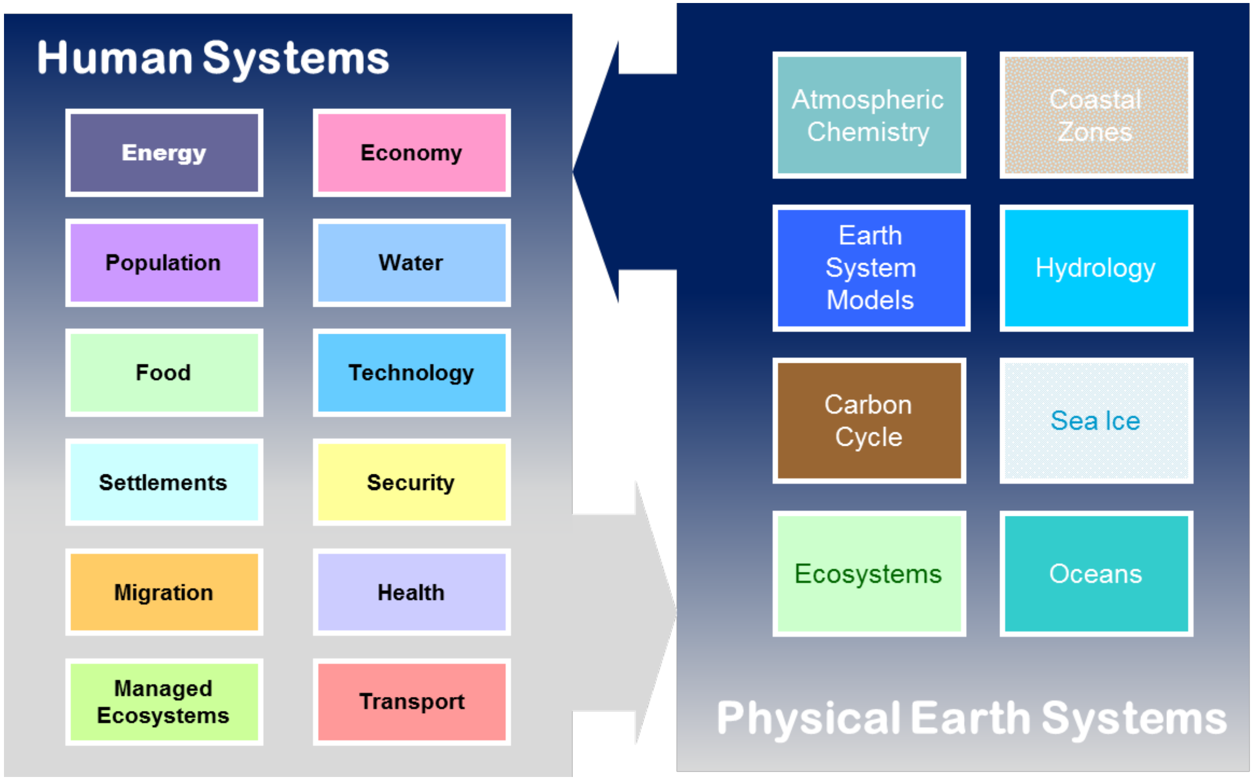
- My perspective is that of an integrated assessment modeler
- I have been working with the Global Change Assessment Model (GCAM) since the 1970s—that experience forms the background for today's remarks
- IAMs bring together all of the pieces of the global change puzzle to provide insights that would not otherwise be available from disciplinary research alone

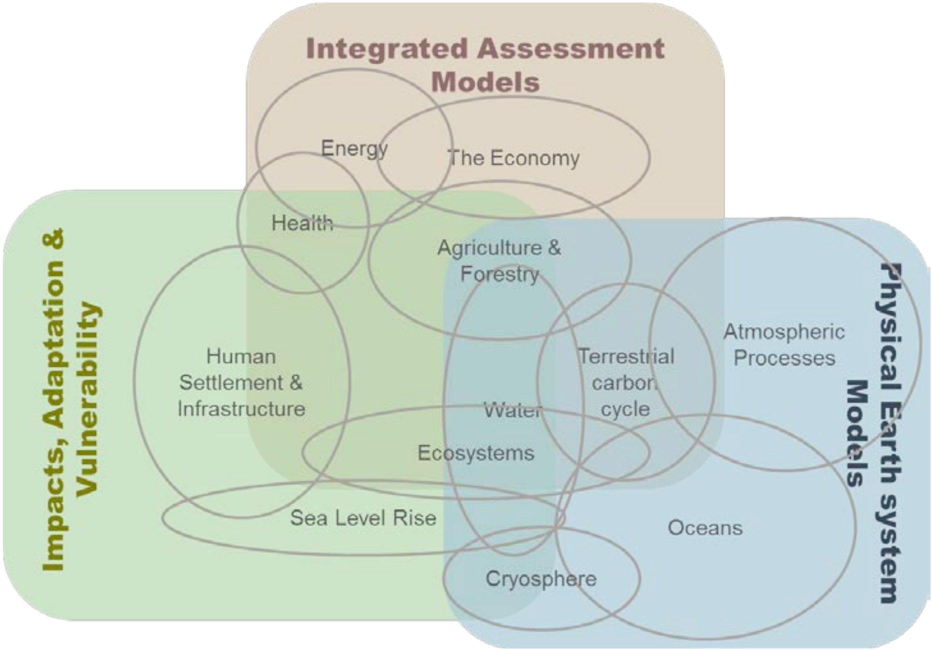


Which Integrated Assessment Models?

- Integrated assessment models divide into two major branches:

- **Highly Aggregated Models**, where the central problem is determining the **social cost of carbon,** and

- **Highly Resolved Models**, whose primary problem is describing the detailed **interactions of human and physical Earth systems, in physical units**
  - The Energy-Water-Land Nexus is a good example of a highly resolved IAM problem



I will be discussing the research agenda for the **Highly Resolved** class of IAM

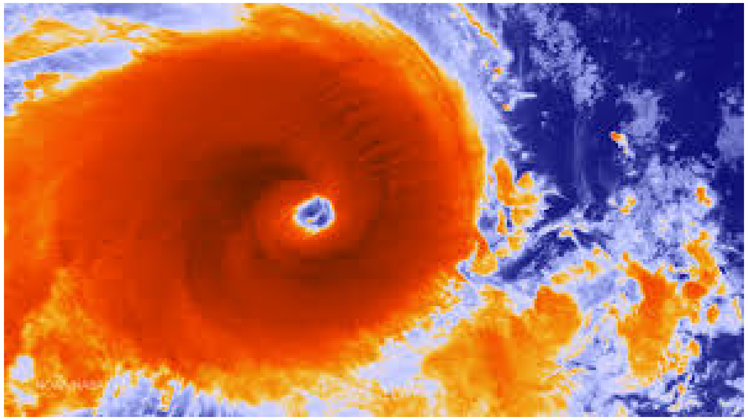
The First Law of Modeling

- **Start with the user problems** and then work backwards to the methods, models and data
- Scenarios, tools, analysis and products need to be matched to user needs
- It may be possible to define **a finite number of typologies** that can make future research and scenario development tractable.

Some of the problems needing to be addressed

- Emissions Mitigation
- Impacts, Adaptation and Vulnerability
- Addressing a Multiplicity of Concurrent Goals and Objectives

Source: http://www.ipemed.coop



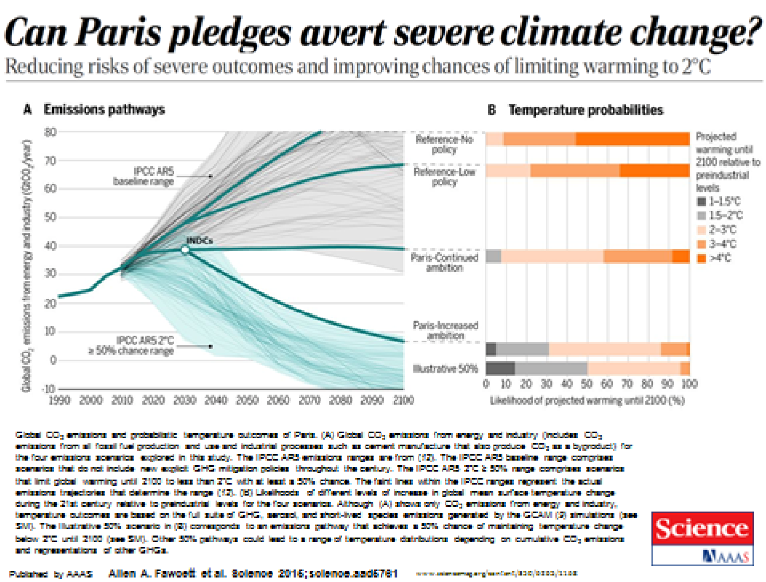
https://www.climate.gov/news-features/event-tracker/tropical-cyclone-winston-causes-devastation-fiji-tropical-paradise

Emissions Mitigation

- The New Paris Agreement
- The Paris Agreement employs Nationally Determined Contribution (NDC) a bottom up approach to emissions mitigation.

Emissions Mitigation—Researchable Questions for IA

- How will national circumstances, institutions and goals influence the implementation of NDCs and what are their emissions implications?
- Can new international institutions make NDCs more effective?
- What are the best measures of progress toward long-term objectives—2 degrees /1.5 degrees—for the Global Stocktake?
- Can Sustainable Development Goals be achieved simultaneously with the goals of the Paris Agreement?
- What roles will technology and control of non-energy emissions play in achieving NDCs and the long-term Paris goals?



Impacts, Adaptation and Vulnerability (IAV)—Researchable Questions for IA

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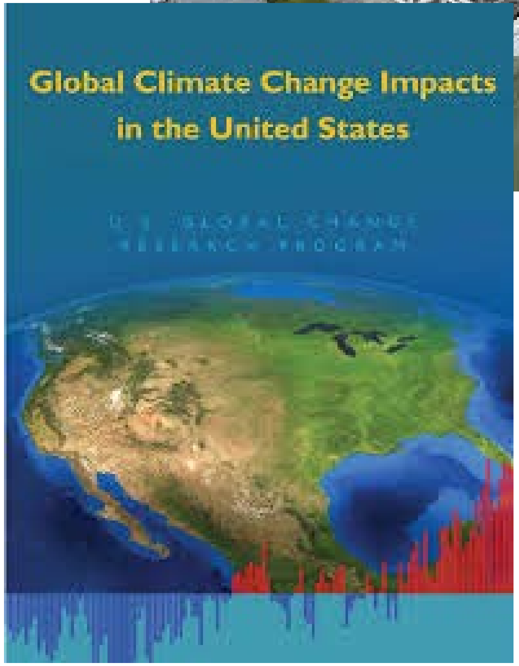
- IAV addresses questions from a much broader set of users, concerned with a much broader set of interests across, temporal, spatial, and sectoral scales.
- Future needs are being shaped by multiple forces at multiple scales
- Capturing interactions between systems, e.g. energy, water, land, climate and the economy increases in importance



Multiplicity of Goals

- IA is has entered the domain in which the assumption that climate policies can be assessed independently of other human goals and objectives is no longer tenable
- Interaction effects are likely too large to ignore
- Policies that pursue multiple objectives—violating the one objective, one policy rule—need to be assessed

Building Capability to Address the New User Needs

Research and Data Frontiers

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1. Methods and Models
2. Closing the system
3. Data
4. Validation and Documentation
5. Risk and Uncertainty
6. Extreme Events
7. Developing a Community of Practice

1. Models and Methods

- While I am a big fan of GCAM, there is no perfect model

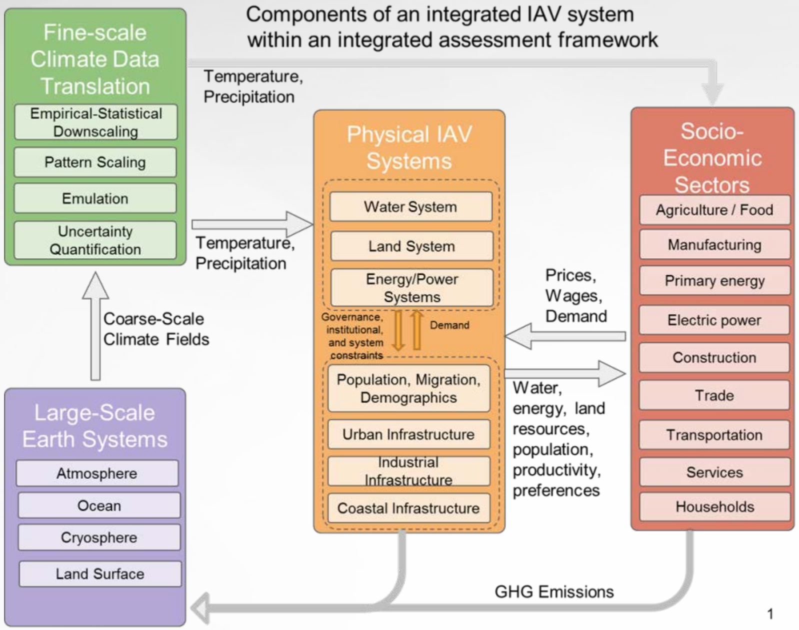
- Many methods and models are available, but no model does everything best.

- At a recent workshop on multi-scale and economics there were calls for more and better **simple models**, more and better **complex models**, more and better **sectoral models**, and more and better **regional models**.

There is no "one model to rule them all."

1. Models and Methods

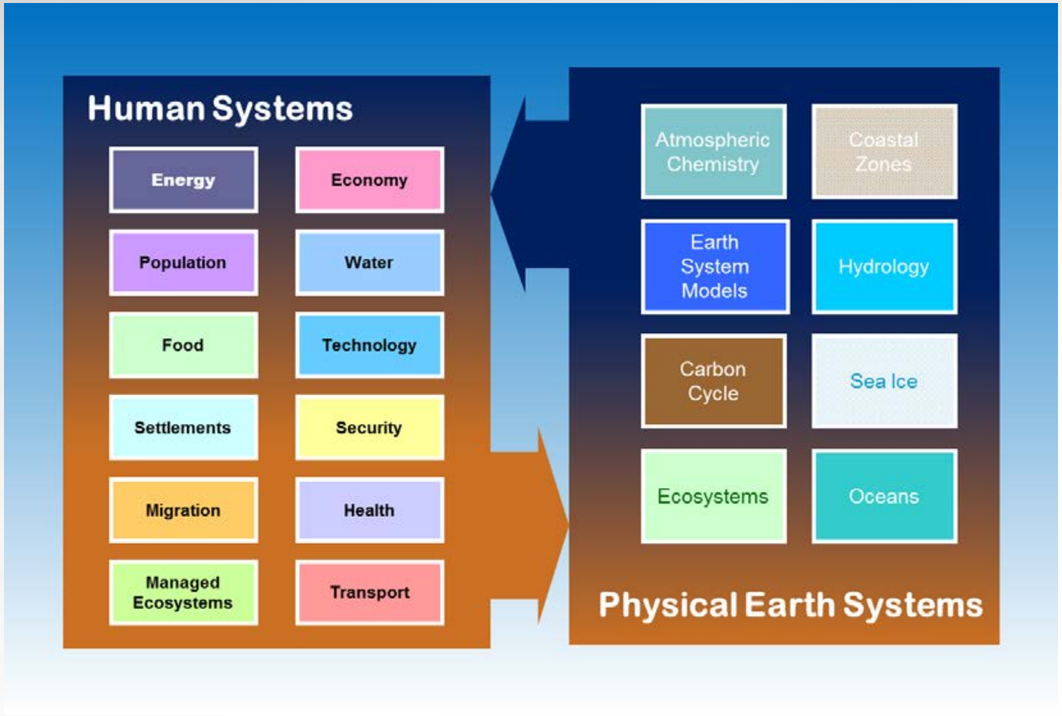
- Need for **multiple modeling tools and methods** to serve varying user needs, at **multiple scales, forced by multiple drivers**
- Not just models, but also **analysis and methods**
- Need to create the ability to **mix and match interoperable methods and models**—as dictated by the problem
- Need an **architecture** for coupling models that represents feedbacks appropriately.



The challenge is to develop a suite of models that can be run interoperably, sometimes hard coupled, sometimes soft-coupled, and sometimes in combination with analysis to address user-defined problems.

2. Closing the System

- Research and scenarios have acted as if the human activities driving change, e.g. climate, are unaffected by the changes e.g. impacts and adaptations they induce.



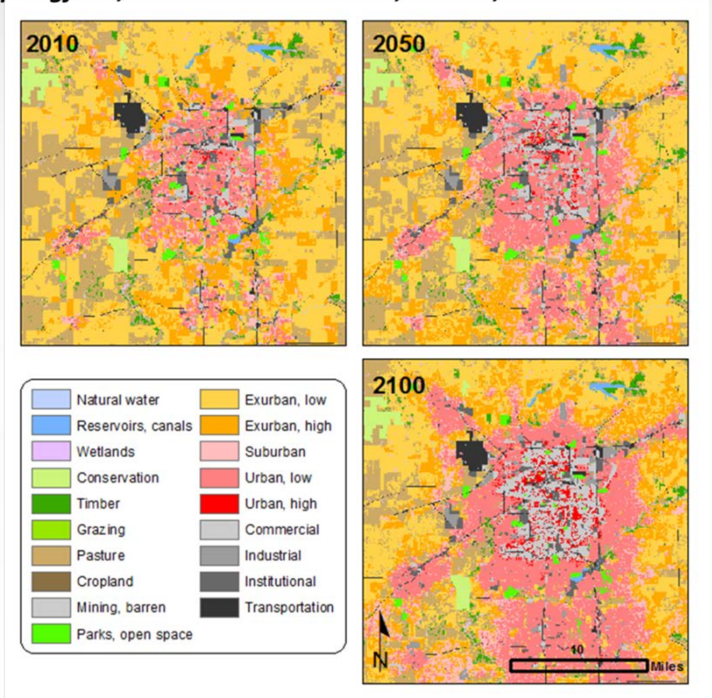
- Future scenarios and research needs to include two-way interactions between all components of human and physical Earth systems. That is, assessments need to “close the system”

3. Data

- Consistent, high-quality data across multiple sectors, scales, and variables are needed to drive models, undergird analysis, and inform decisions

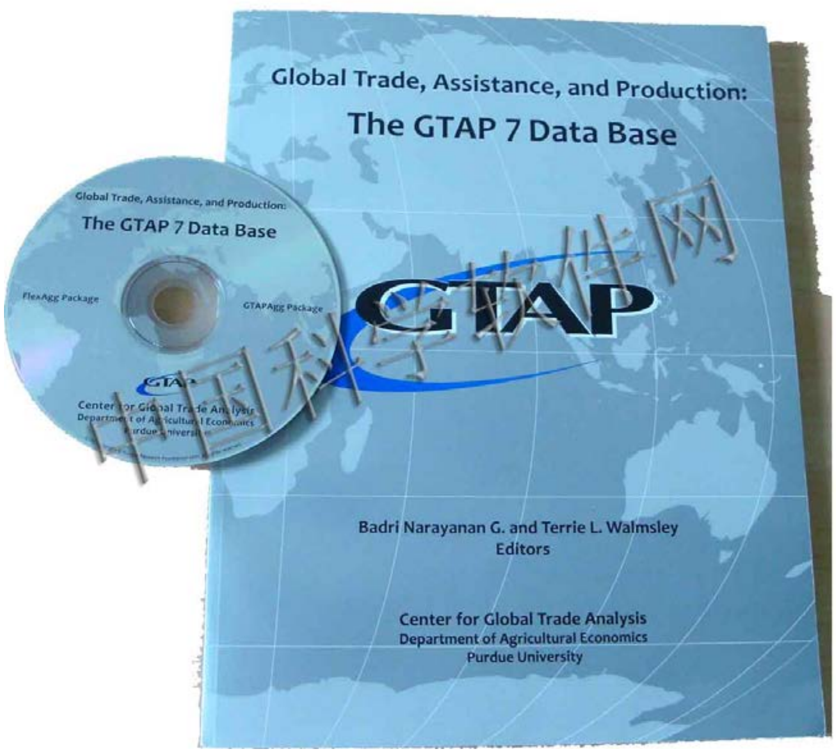
- **Integration/harmonization of data** — data are collected with a wide range of primary motivations leading to a wide range of system boundaries and definitions that make data sets difficult to use together. Modelers and analysts produce reconciled data sets. Those data sets need to be documented and made available to the community.

Example of ICLUS Land use Output
Springfield, MO Metro Area: SSP5, RCP8.5, HadGEM2-AO



3. Data

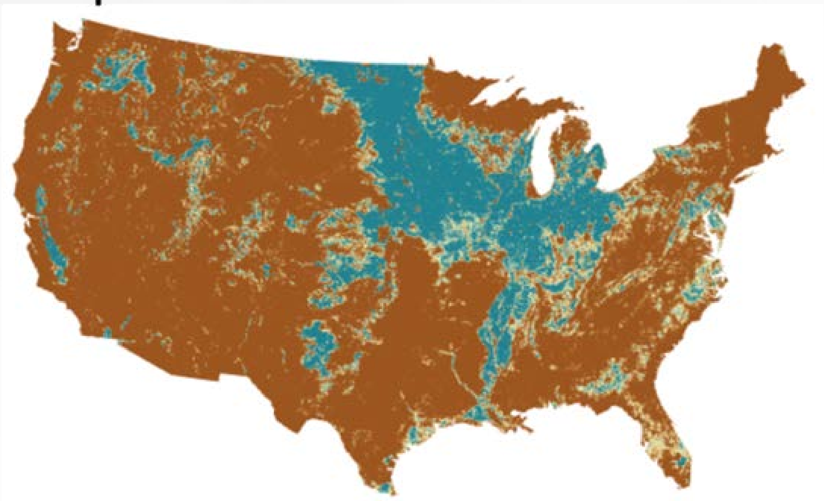
- GTAP has been one of the most influential organizations in the field of integrated assessment
- It is a place where high quality data are synthesized from disparate primary sources in a transparent and reproducible way



3. Data

- **Model and analysis products are data, too**—need to archive, document and make those data available
- **Need for comparability across models' data sets to improve the scientific process**
- **Public versus private data**—both public and private data are available, but the former may be of lower quality.
- Need to explore **"big data"** and crowd-sourced data for research and analysis

Cropland area in 2005 at a 0.05° Resolution



4. Validation and Documentation

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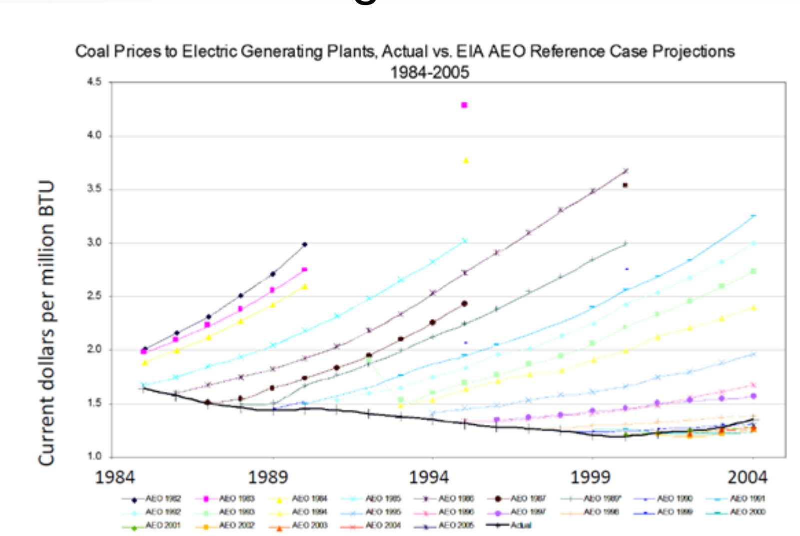
- Models should be suitable for the purpose to which they are applied
  - Since there is no perfect model, **model purpose and fitness should be considered together**.
  - Models that are valid for near-term analysis may perform poorly when applied to long-term problems; and models that behave well under normal circumstances may break down when applied to extreme events.
  - Model outputs depend on both the model and **external assumptions** that drive model results

- Many techniques are available to validate models including:
  - Hindcasting
  - Model intercomparison
  - Model reproducibility
  - Model structure
  - Diagnostic evaluation
  - Among others



5. Risk and Uncertainty

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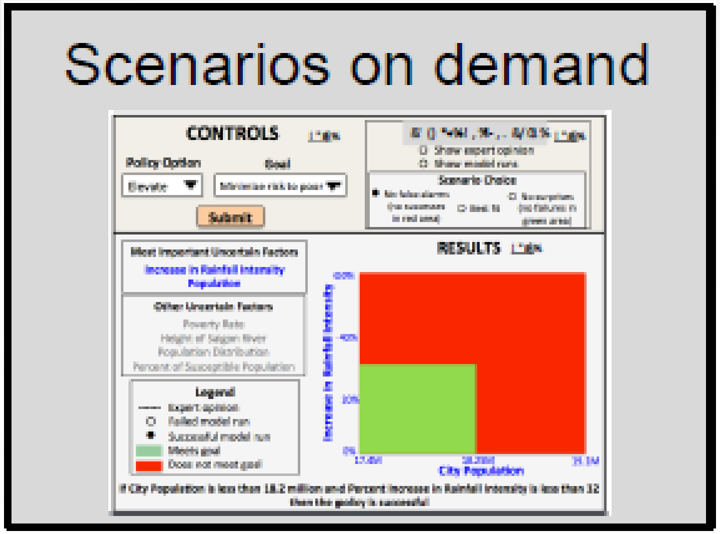
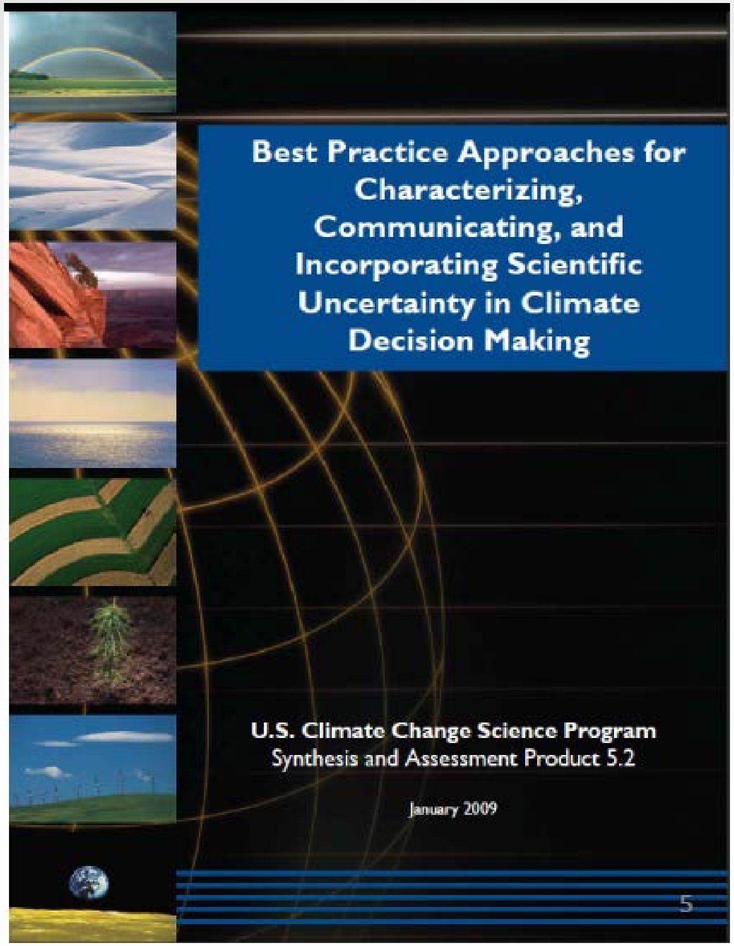
- **Assessing, communicating and managing risk in an uncertain world is a major challenge**
- Important to understand the sources, magnitudes and drivers of uncertainty relevant to the problem at hand.
- When future events span a broad range of uncertainty, scenarios can help clarify issues.
  - Examine a wider range of futures, combining quantitative and qualitative methods
  - Use quantitative methods to help identify from these futures a small number of policy-relevant scenarios
  - Evaluate and iteratively improve scenario methods for decision support



5. Risk and Uncertainty

- Before making a projection it is important to think about how it will be used.
  - Individual scenarios may be simple to communicate, but create a unrealistic impression of certainty.
  - Uncertainty needs to be attached to scenarios and uncertainty bounds need to be developed with rigor.
  - When using numerical models to develop scenarios, simpler is better.



5. Extreme/Disruptive Events

- **Tools are needed** to explore the implications of potential events that lie well **outside the domain of experience**, e.g. climate or disruptive technology change, that have potentially large consequences, even if lower likelihood
- Will require greater attention to **model structure**—models that capture trends are not best suited to explore extreme events
- Can be explored using a variety of models and techniques including **structural models, agent-based models, and stochastic simulation models; as well as non-model-based scenarios and analysis**.

6. Developing a Community of Practice

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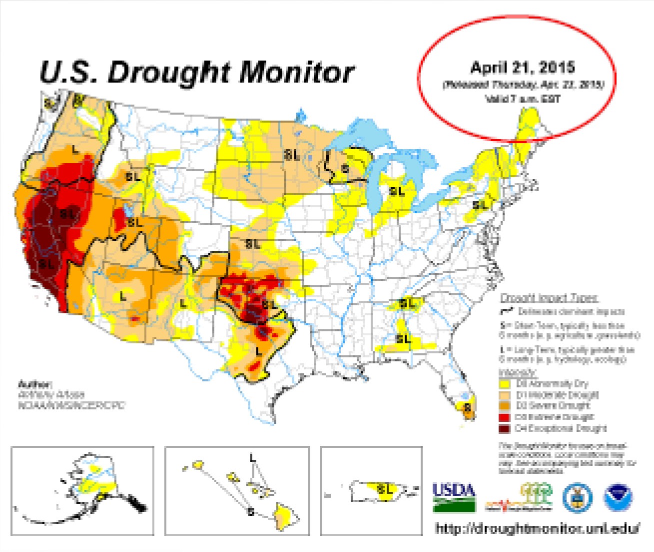
- Improving the quality of research and scenarios requires both the development of new research tools and a **community of practice**
  - Need for transparency of model and scenario results
  - Consistency in reporting results—consistent units of measure and reporting
  - Need for translators who understand the science as well as how to communicate



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