A Workshop on Modeling Uncertainty in Integrated Assessment Models

Ian Foster

Computation Institute

Argonne National Lab & University of Chicago

UNCERTAINTY WORKSHOP 2008

HOME AGENDA READING ATTENDEES LOGISTICS CONTACT US

A WORKSHOP ON MODELING UNCERTAINTY IN INTEGRATED CLIMATE ASSESSMENT MODELS

July 21-22, 2008
Chicago, Illinois

Research aimed at understanding human dimensions of climate change must address issues of uncertainty in both the data used to develop numerical models of p... simulations performed...

http://uncertainty2008.ci.uchicago.edu/

Sponsors

- DOE Office of Science
- Argonne National Laboratory
- Northwestern University
- University of Chicago
- University of Illinois at Urbana-Champaign

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Organizing Committee

- Neil Blair, Northwestern
- Ian Foster, Argonne and U.Chicago
- Steve Goldberg, Argonne
- Howard Guenther, UIUC
- Don Hanson, Argonne
- Ken Judd, Hoover Institution
- Rao Kotamarthi, Argonne
- Todd Munson, Argonne

Purpose

- To characterize **the changing information needs of decision-makers** and the demands this will place on future science-based models and tools, especially as it relates to uncertainty analysis
- To engage leading thinkers on the **many sources and levels of uncertainties** in Integrated Assessment Modeling and the implications for the growing connections among the IAM, ESM, and IAV communities
- To reveal **promising methods, models, and computational capabilities** that can be brought to bear for **characterizing, analyzing, and communicating** uncertainty in Integrated Assessments
- To consider new opportunities in a **context appropriate for the field,** recognizing the inherent differences (and similarities) in modeling human and natural earth systems

Invitees

- Integrated assessment modelers
- Climate scientists
- Economists
- Computational mathematicians
- Policy makers

Introductory Presentations

- Bob Vallario: Welcome and perspectives
- Bob Rosner: Modeling uncertainty in computational science
- Gary Yohe: Climate impacts, uncertainty, and policy
- Ted Parson: Uncertainty and adaptation in navigating the transition to climate stabilization
- Don Wuebbles: Uncertainty in climate science and models
- Michael Ferris: Optimization tools in an uncertain environment
- Ken Judd: Overview on uncertainty methods [in computational economics]
- Mark Peters: Technology futures

Questions

- What is uncertainty?
- What are sources of uncertainty?
- How do we quantify uncertainty?
- How do we model uncertainty?
- How do we communicate uncertainty?
- How do we reduce uncertainty?

What is Uncertainty?
A View from Economics

- Intrinsic stochasticity
  - Uncertainty faced by the economic actors as they make decisions
- Parametric and structural uncertainty
  - Uncertainty faced by a modeler
  - Economic agents may themselves be uncertain about parameter values

Source: Ken Judd

Layers of Uncertainty

- Risk: know probabilities but not outcome
  - E.g., 1/6 chance of a 1 if we know dice are fair
- Uncertainty: don’t know probabilities
  - We worry that the dice is unfair
  - Rationality implies we act as if we believe the probabilities to be some specific values: Bayesian approach
  - We may learn probabilities through trial
- Structural uncertainty
  - Perhaps the probabilities change over time
  - We don’t know how many sides the dice has

Source: Ken Judd

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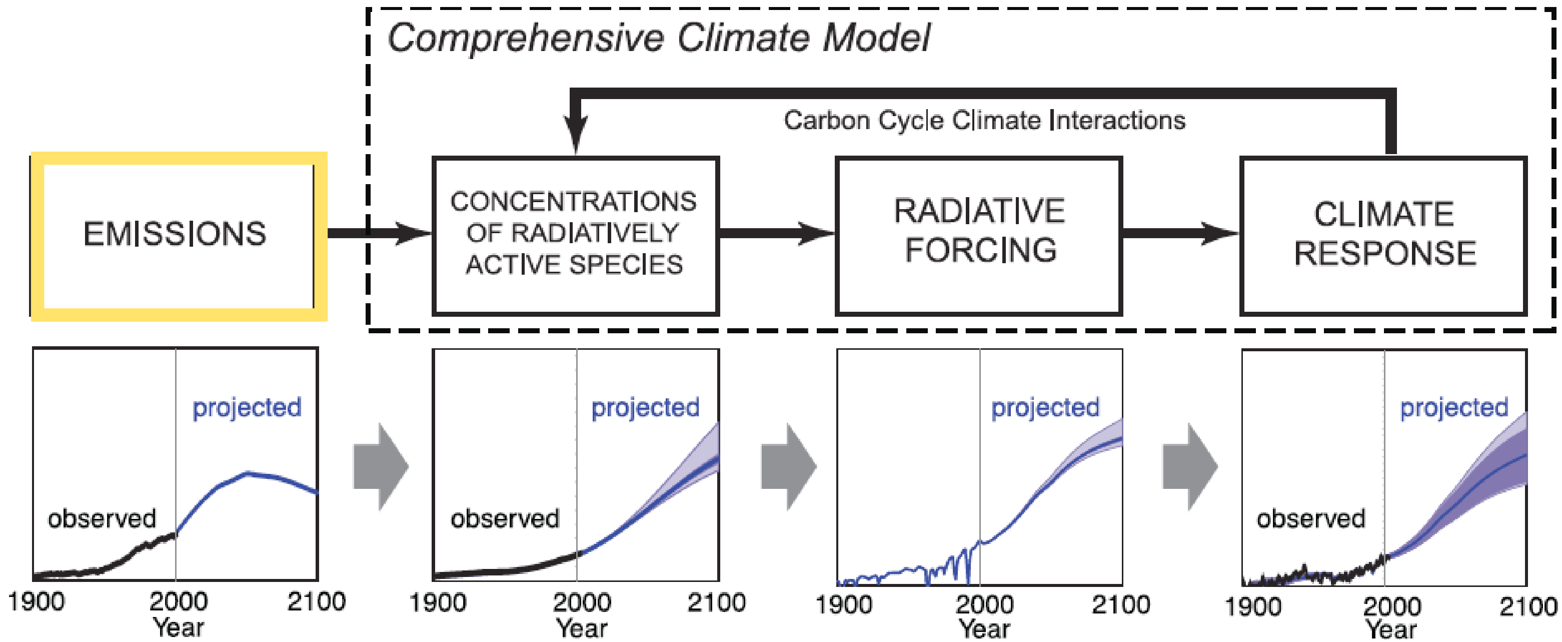
Sources of Uncertainty

Emissions Scenarios:
How will our society evolve?
How will new technologies develop?
What mitigation strategies will we employ?



IPCC AR4, WG I

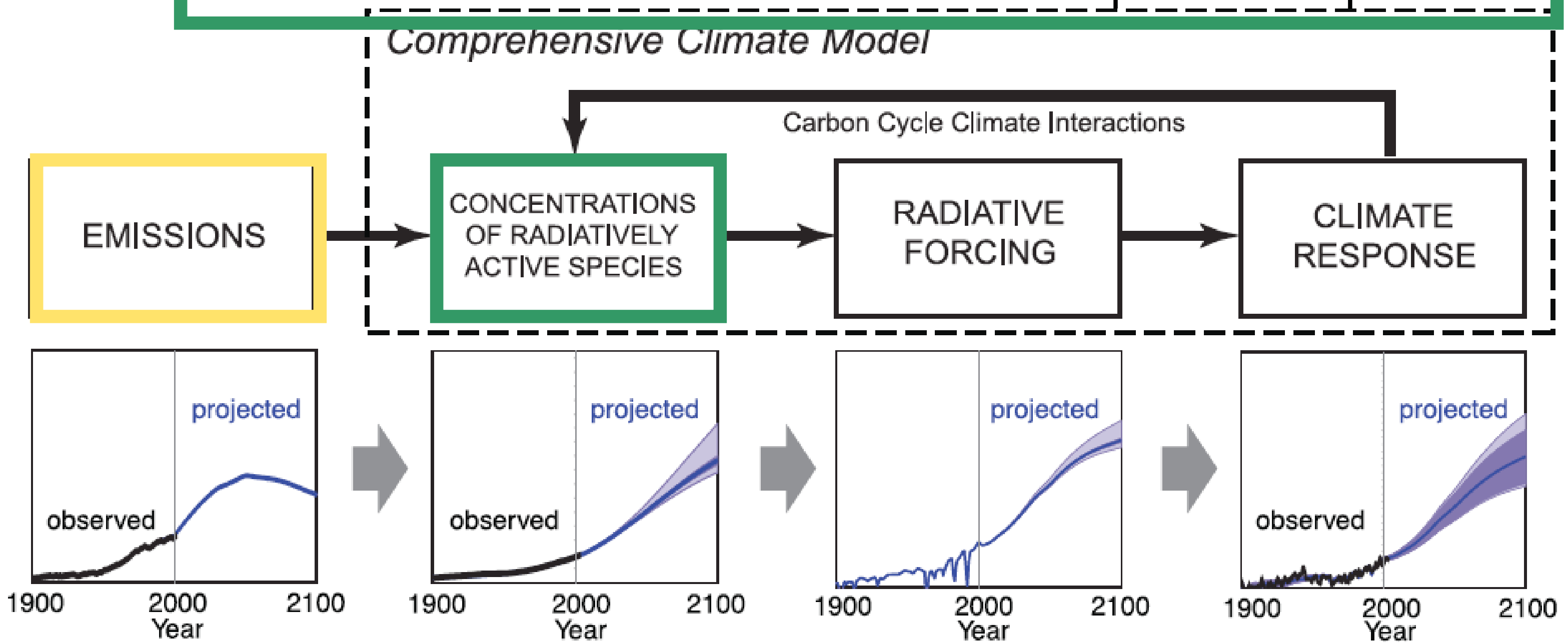
Source: Don Wuebbles

Sources of Uncertainty

Concentrations of Greenhouse Gases & Particles

What are the life-spans of different gases and particles in Earth's Atmosphere?

How do human, terrestrial and ocean sources / sinks alter future atmospheric composition?



IPCC AR4, WG I

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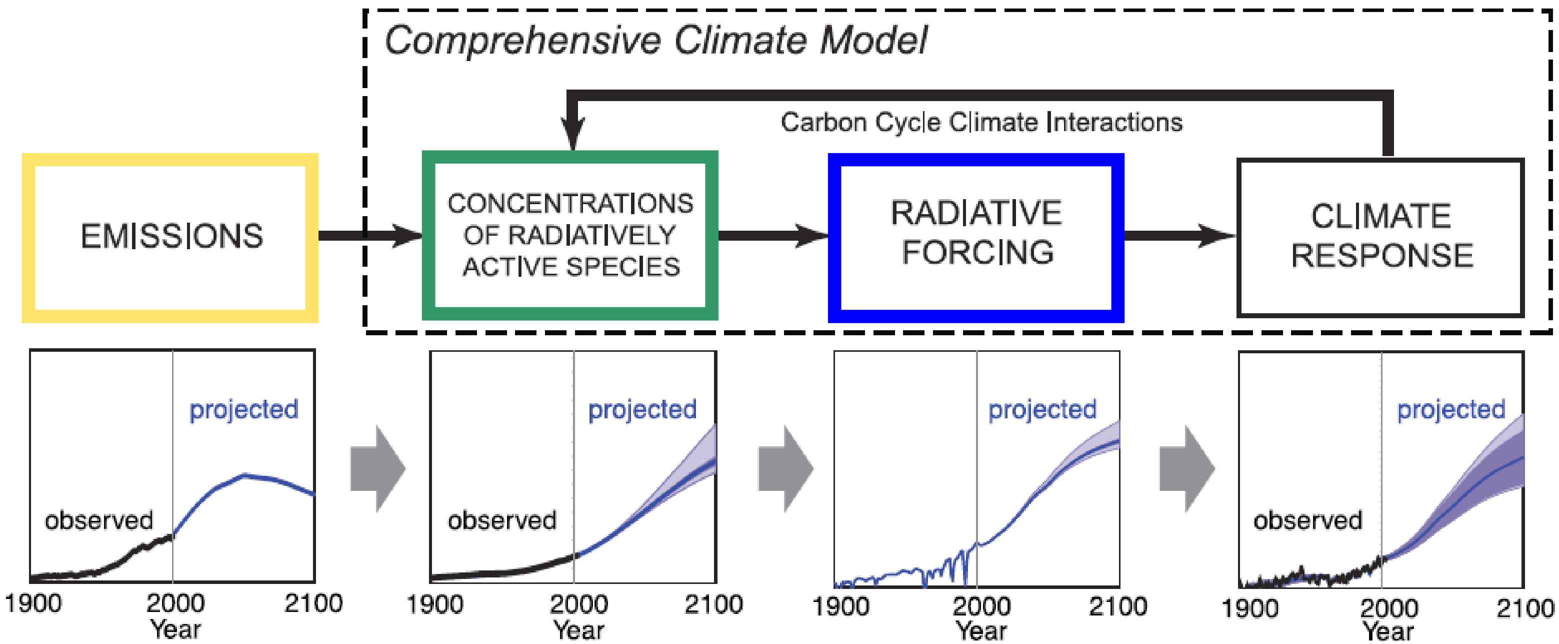
Sources of Uncertainty

Radiative Forcing

How do natural and human-induced changes affect the net forcing on climate?

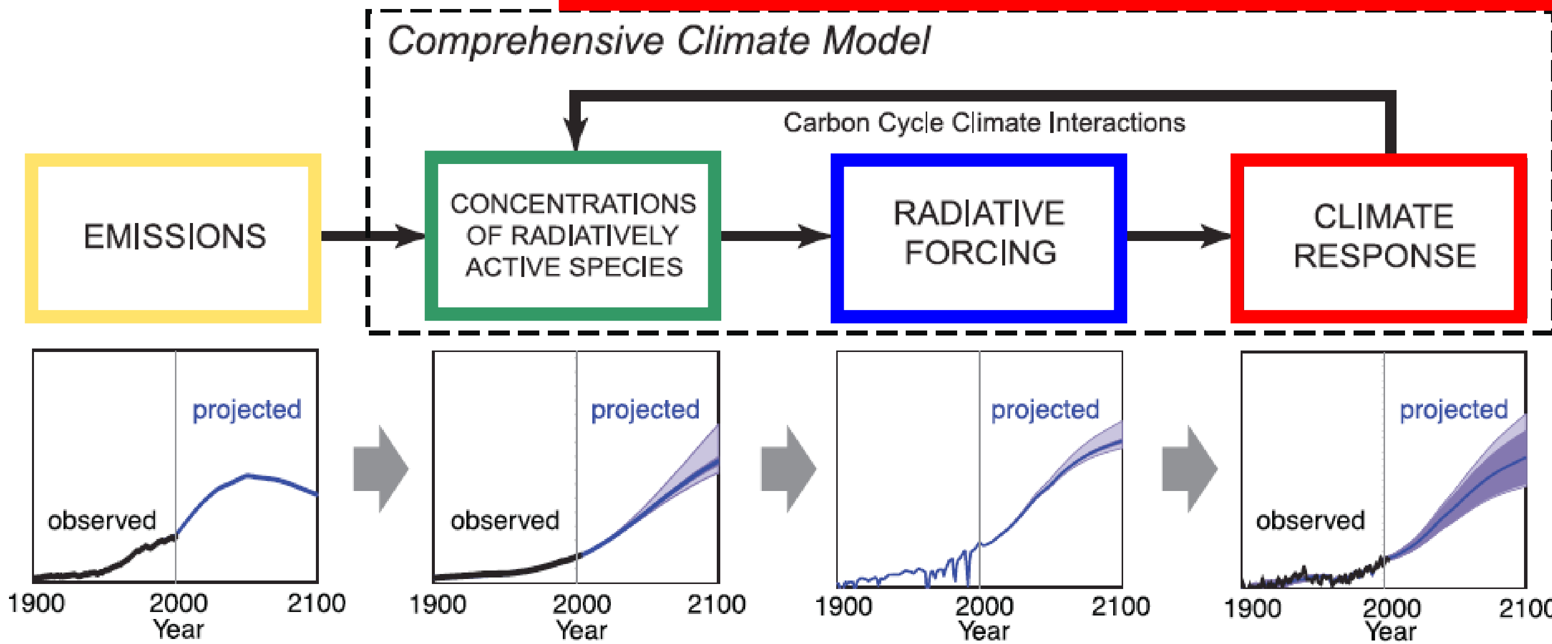


IPCC AR4, WG I

Source: Don Wuebbles

Sources of Uncertainty

Climate Response:
What climatic processes alter the way that Earth responds to changing forcing?
What is the range of natural variability?
Can we account for model bias and uncertainties?



IPCC AR4, WG I

Source: Don Wuebbles

Critique of Scenarios

- Ted Parson
  - They preclude consideration of unlikely but serious trajectories
  - By not addressing likelihoods, they delegate to others the task of estimating that information
- Economists
  - We must account for adaptive responses, which inevitably involve human agents, and thus incentives, markets, and other economic forces

Sources of Uncertainty, Revisited

- Climate sensitivity and damage functions
- Technological innovation
- Human response to past and future anticipated climate disruption—and to uncertainty in same
- Rate of new knowledge acquisition (i.e., when do uncertain things become certain?)
- Structural barriers to mitigation, adaptation, and innovation

Key Themes from Gary Yohe

- Uncertainty is ubiquitous
- Risk and vulnerability are the common denominators
- Risk management is the most appropriate policy lens
- Focusing on risk broadens the perspective beyond “high confidence” vulnerabilities
- Criteria for “key vulnerabilities” need to be applied to focus research and attention effectively

Risk = Probability x Consequence

The Importance of Time Frame

- Operating decisions
  - Immediate
- Investment decisions
  - 10-30 years
- Long-term damage
  - 100+ years

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Quantifying/Bounding Uncertainty

- Sets of scenarios (e.g., IPCC)
- Available model outputs
- Historical/prehistorical data
- Expert judgment
- Parameter sweeps to study sensitivity
- Physical laws, e.g., conservation
- Laugh test

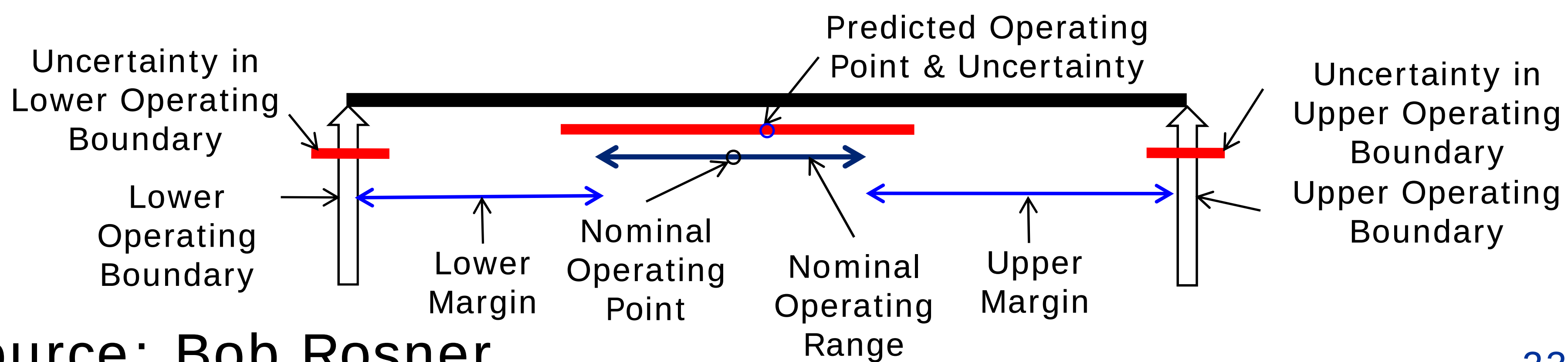
Verification & Validation (V&V) and Quantification of Margins & Uncertainties (QMU)

- V&V are the procedures by which ...
  - We try to undercover outright blunders
  - We correct inappropriate or inaccurate algorithms
  - We correct (if possible) mistaken or incomplete models/theories
- QMU is the process by which
  - We bound the "operating conditions" of the system under study such that it is still described by the model: the margins
  - We bound the errors of the simulation predictions describing the system under study: the uncertainties

Source: Bob Rosner

Quantification of Margins and Uncertainties ("QMU")

- "Quantification of Margins and Uncertainties is a formalism for dealing with the reliability of complex technical systems, and the confidence which can be placed in estimates of that reliability." (Jasons 2005)
- In common use within the engineering community (e.g., risk-based safety assessments) & nuclear weapons community



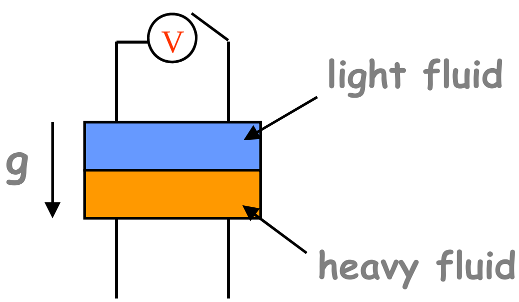
Source: Bob Rosner

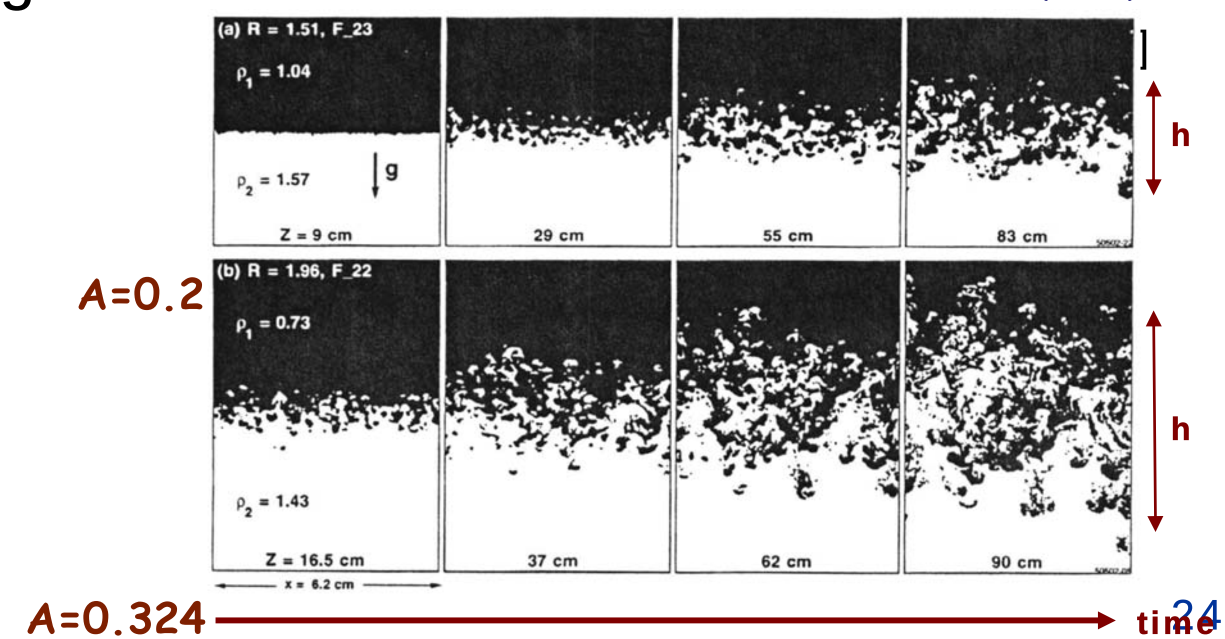
Is the Notion of Increased Confidence Derived from Agreements Between Disparate Models Justified?

- Consider a particularly simple physics/fluids experiment: the Rayleigh-Taylor instability of a heavy fluid lying on top of a light fluid ...
- Experiments have shown that the mixing layer width **h** obeys a simple scaling relation

$$\mathbf{h} \sim \alpha \cdot gAt^2$$

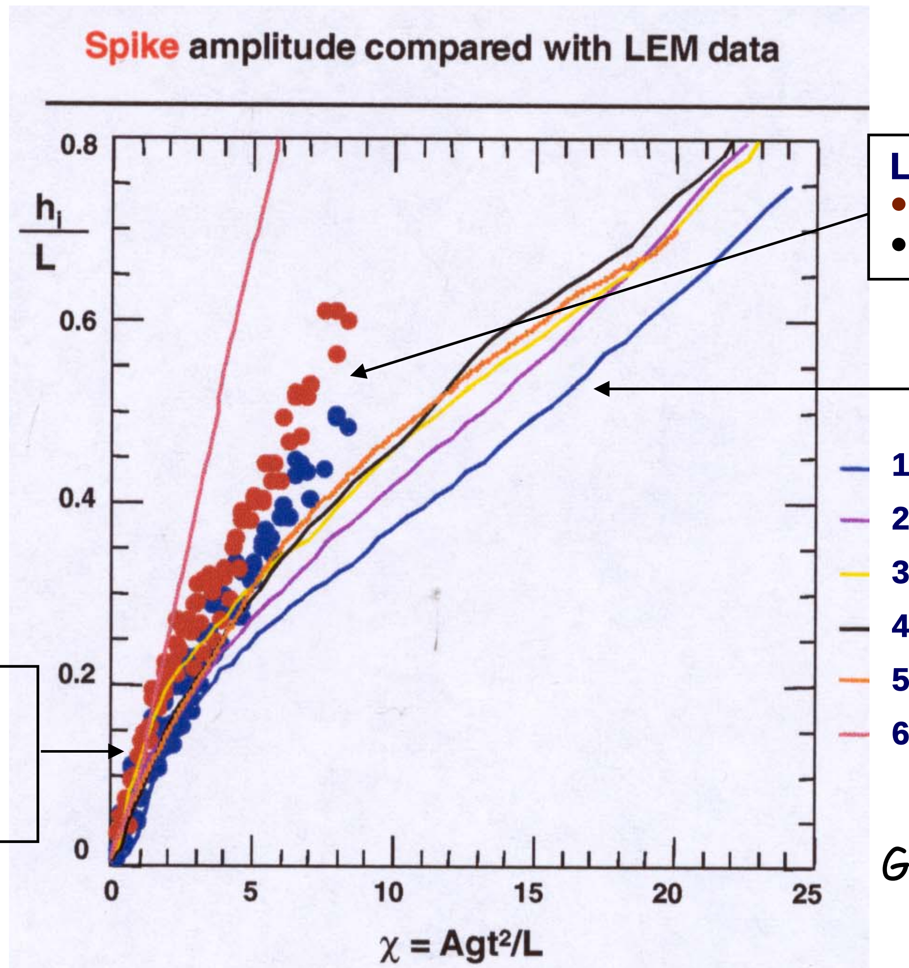
Dimonte & Schneider (2000)





Source: Bob Rosner

Comparing 6 Different Simulations with One Another – and with the Data …



LEM: 0.32<A<0.48
- **Spike**
- **Bubble**

The nonlinear regime:
- $h \sim \alpha \cdot gAt^2$
- $\alpha \sim ?$

The linear regime:
- $h \sim \exp(\gamma t)$
- $\gamma \sim (gAk)^{1/2}$

Guy Dimonte et al. (2004)

Source: Bob Rosner

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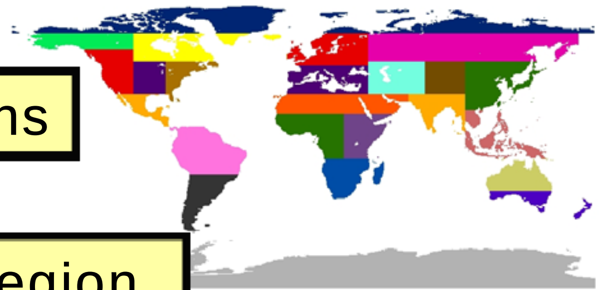
Modeling Uncertainty: A Wide Variety of Methods

- Applications of optimization methods to problems with uncertain variables [Ferris]
- Stochastic uncertainty: Fit functional forms to solutions of the Bellman stochastic PDE [Judd]
- Structural uncertainty: parameter studies of various sorts
- Divide the problem into periods with information revealed at each point [Hanson]

Uncertainty Coupling

(Meredith Franklin, Rao Kotamarthi)



Define global regions

Obtain data for each region
- Ensemble climate model output
- Observations

Define distributions
- Likelihoods
- Priors (uninformative)

Posterior-likelihood x Prior
MCMC Gibbs Sampling

Posterior distribution of parameter(s)

AMIGA economic model

Posterior distribution of parameter(s)

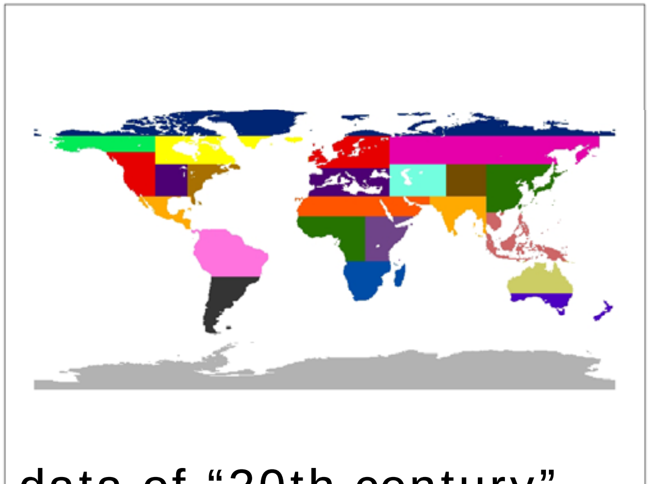
Next model

Data and Methods

- **Regionalization:**
  - defined 22 global regions and two climate periods: present (1960-1990) and future (2030-2060).

- **Data:**

1. Observed: global meteorological station data interpolated to 0.5-degree grid at the Climate Research Unit (CRU, University of East Anglia). Averaged for each region (excluding Antarctica) from 1960-1990.

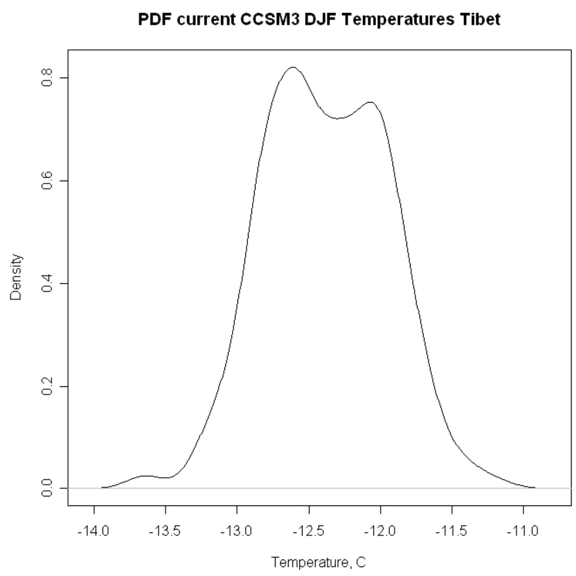


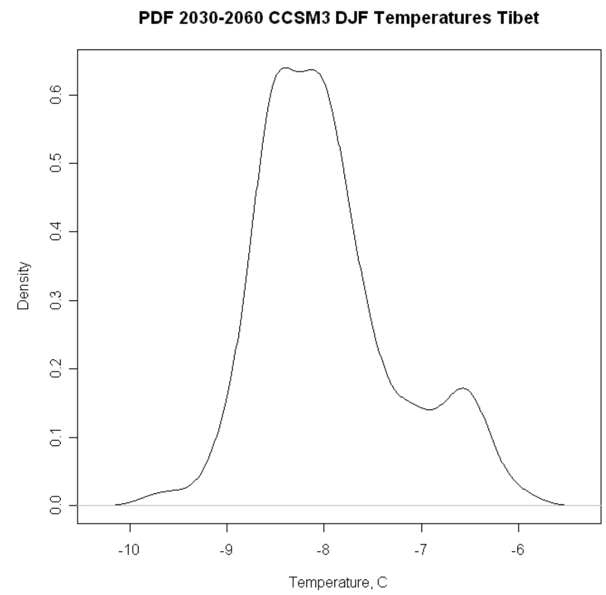
2. Modeled: global CCSM output data of "20th century" run for comparison with observed data, and 30-member ensemble "A1B" SRES scenario from 2030-2060. Averaged over each region.

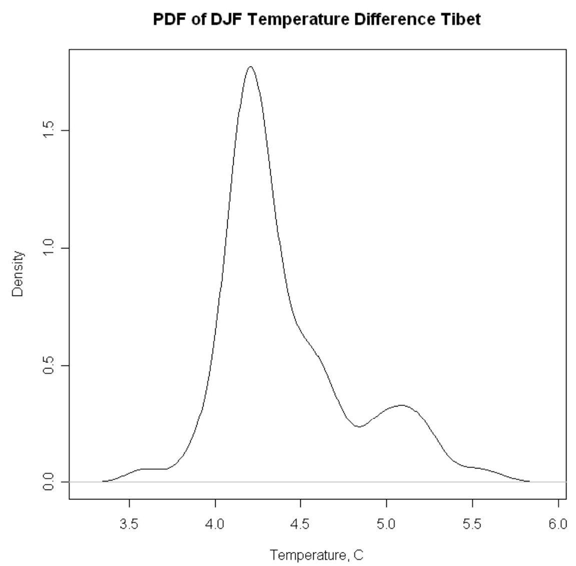
- **Methods:** Bayesian framework for producing posterior distributions of uncertain parameters (i.e. future temperature under a particular scenario) by incorporating model "bias" and "convergence" (Giorgi and Mearns 2002, 2003; Tibaldi et al 2005) with respect to observed data and multi-ensemble member average.

Source: Meredith Franklin

Results: Temperature PDFs for present, future and change







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Q: Should I build a new dam?
(Yes or no answer: 30+ year investment)

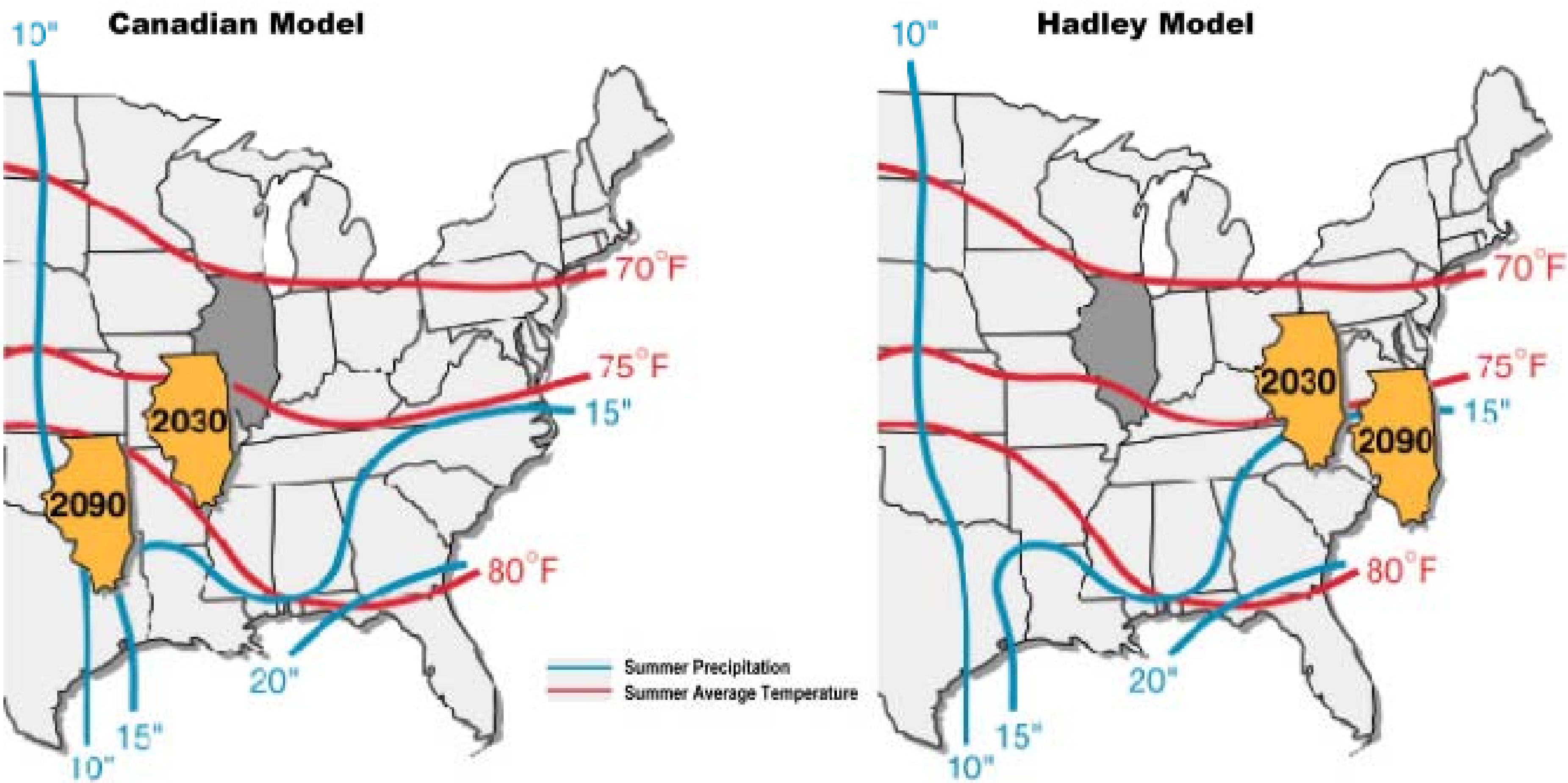

Illustration of how the summer climate of Illinois would shift under the Canadian and Hadley model scenarios. Under the Canadian scenario, the summer climate of Illinois would become more like the current climate of southern Missouri in 2030 and more like Oklahoma's current climate in 2090. The primary difference in the resulting climates of the two models relates to the amount of summer rainfall.

Other Comments

- We should look at the experience of the intelligence community

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Potential Steps Forward

- Tools for analyzing & communicating uncertainty when faced with outputs from multiple models
- Case studies to evaluate the effectiveness of economic models (e.g., oil price surge)
- Study intra-model sensitivity/uncertainty (e.g., work of Mort Webster, Don Hanson)
- Study inter-model sensitivity
- Reduce structural uncertainty by improving treatment of technology improvement (etc.)
- Work with mathematicians to experiment with modern methods for modeling uncertainty

Ken Judd's Conclusions

- Uncertainty analysis is critical for climate change analysis, and for any social policy analysis
- We need to
  - Develop computational models that can address uncertainty
  - Apply new insights on human response to uncertainty
  - Implement existing mathematical tools
  - Team up with mathematicians to develop new methods