Quantifying Uncertainty in Climate Assessments: Progress, Challenges, and Next Steps

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18 July 2002
These super weather computers that predict a global warming disaster by 2100...

Are these the same computers that predicted sunny and dry today?
Outline for Today

• Ideal: What do we want to be able to do?

• Review: What’s been done so far?

• Next: What needs to be done?
Some Background

• Views on Probability:
  – Frequentist vs. Bayesian

• Quantify vs. Reduce Uncertainty
  – Decisions Today
  – Decisions in the Future
  – Value of Information
Goal: Provide Useful Information to Decision-Makers

• Inform about the severity of the climate change issue, the magnitude of the risks

• Also, the range of risk-reduction options and their effectiveness

• One way: Describe possible future climate change
Probability Density Function

Is this easy to understand?
Communicating Uncertain Futures

- **Probability distributions**
  - difficult for non-experts to think about
  - Hard to show the complete picture of that one possible future world
- **Scenarios**
  - Pick a small number to explore in detail
  - Logical choices: a “central tendency,” a “high” case, others
Two Scenarios of Future Climate Change

Year
2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100

Global Mean Temperature Change from 1990 (°C)

“High” Case

“Central” Case

Year
2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Two Scenarios of Future Climate Change

- **"High" Case:** 1 in 1,000,000 chance of being higher
- **"Central" Case**
Two Scenarios of Future Climate

“High” Case:
1 in 10 chance of being higher

“Central” Case
How can we choose scenarios with quantified probability?

- Select a model framework
- Conduct Sensitivity Analysis to find the most important parameters
- Construct probability distributions for the uncertain parameters
- Propagate uncertainty through model: Monte Carlo
- Use the probability distributions of outcomes to select a particular quantile of interest, use those parameter values to construct a scenario
Studies to Quantify Uncertainty in Physical Science

• Several Recent Studies

• GCM’s:
  – Still hard to do Monte Carlo
  – Don’t want to use range of model outcomes as a distribution of the uncertainty

• Simple and Intermediate Complexity Models
  – Monte Carlo studies of key uncertain parameters
  – BUT, what emissions to force them with?
Studies to Quantify Uncertainty in Socio-Economic Trends

- **IPCC SRES Approach**
  - Describe different “storylines”
  - No explicit likelihood given

- **Quantify Uncertainty in Emissions**
  - Apply Monte Carlo methods to economic models
  - Uncertainties: economic growth, technological change, population growth
  - Several Studies: Edmonds & Reilly, Nordhaus, Manne & Richels, Morgan & Dowlatabadi, MIT, others
IPCC SRES Marker Scenarios

(a) CO₂ emissions

- Scenarios: A1B, A1T, A1F1, A2, B1, B2, IS92a

- CO₂ emissions (Gt C/yr)
- Year (2000 to 2100)
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Challenges to Quantifying Uncertainty (I)

- Analyzing uncertainty at the appropriate spatial/temporal scales for regional assessment
- Treating model/structural uncertainty
- Communicating Uncertainty
Challenges to Quantifying Uncertainty (II)

- Econ: Can’t project forward only based on the past – must also use subjective judgment

- How to perform UA on large calibrated models (GCMs, ecosystems, etc)

- Experts Disagree!
Next Steps (I)

• Use data on past trends in economic growth & technical change

• How to combine past variability with subjective judgment?

• How to construct a small # of scenarios to span the uncertainty in multiple outcomes, with multiple gases?
Probabilistic Scenario Design

CO₂ (Probability)  Other GHGs (Conditional Probability)  Other Pollutants (Conditional Probability)

- 97.5% → 97.5
- 50% → 50
- 2.5% → 2.5

50 → 50 → 50
Next Steps (II)

- Incorporate work on climate detection to constrain uncertainties in the physical systems
- Use efficient MC techniques to propagate physical and economic uncertainties through a variety of models
- Develop procedures for communicating likelihoods of outcomes even though we disagree
Communicating the Odds of Temperature Change
Communicating the Role of Policy

No Policy

Stringent Policy
"BE CAREFUL! All you can tell me is 'BE CAREFUL'?"
Using Parameters to Capture Model Uncertainty
Uncertainty in Global Mean Temperature Change
Global Mean Temperature Change

- Median: 2.3
- Lower 95%: 0.9
- Upper 95%: 5.3
Zonal Mean Temperature Change for 2090-2100

Decadal Average Temperature Change since 1990 (°C)

- 95% Probability Bounds
- 67% Probability Bounds
- Median

Latitude:
- S90, S60
- S60, S30
- S30, N30
- N30, N60
- N60, N9
Framing the Question

<table>
<thead>
<tr>
<th>Decision Today</th>
<th>Decision in 10 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Kyoto Protocol</td>
<td>More Abatement</td>
</tr>
<tr>
<td>No Abatement</td>
<td>Less Abatement</td>
</tr>
<tr>
<td>Learn</td>
<td></td>
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<tr>
<td>b) Kyoto Protocol</td>
<td>More Abatement</td>
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<tr>
<td>No Abatement</td>
<td>Less Abatement</td>
</tr>
<tr>
<td></td>
<td>No Learning Before Future Decision</td>
</tr>
</tbody>
</table>

2010 2020
THE VERY LAST TREE

THE VERY LAST CHAIR
“Persons pretending to forecast the future shall be considered disorderly under subdivision 3, section 901 of the criminal code and liable to a fine of $250 and/or six months in prison.”

Section 889, New York State Code of Criminal Procedure
Reverse CDF of Temperature Change

Global Mean Temperature Change in 2100 (°C)

- 99%: 5.2°C
- 97.5%: 4.7°C
- 95%: 4.1°C
- 90%: 4.0°C