Uncertainty Quantification of US Southwest Climate from IPCC Projections

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Abstract

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) made extensive use of coordinated simulations by 18 international modeling groups using a variety of coupled general circulation models (GCMs) with different numerics, algorithms, resolutions, physics models, and parameterizations. These simulations span the 20th century and provide forecasts for various carbon emissions scenarios in the 21st century. All the output from this panoply of models is made available to researchers on an archive maintained by the Program for Climate Model Diagnosis and Intercomparison (PCMDI) at LLNL. I have downloaded this data and completed the first steps toward a statistical analysis of these ensembles for the US Southwest. This constitutes the final report for a late start LDRD project. Complete analysis will be the subject of a forthcoming report.
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1 Summary of Accomplishments

- Reviewed literature
- Briefed Tom Hunter & prepared BOD briefing
- Downloaded and analyzed archived data
- Comparison to historical data
- Statistical framework development
- Built ongoing collaboration with UNM
- Convened 2 AGU sessions on UQ/climate
- Organized CCSM Workshop UQ session
2 Presentations

Climate presentations at the following conferences were funded, at least in part, by this project. Abstracts and presentations associated with this project after the end of the fiscal year made use of this project’s results.


June 2010: Community Climate System Model Workshop, Breckenridge.

July 2010: Research Experience in Carbon Sequestration (invited keynote), Albuquerque.

July 2010: American Quaternary Association (invited plenary), Laramie.


3 Selected presentation graphics
Purpose, Goals, Approach

Develop rigorous analysis of uncertainties in regional forecasts using today’s GCMs to help identify needs and metrics associated with performing uncertainty quantification for climate forecasts with tomorrow’s higher-resolution models.

Key Accomplishments

- Reviewed literature
- Briefed Tom Hunter & prepared BOD briefing
- Downloaded and analyzed archived data
- Comparison to historical data
- Statistical framework development
- Built ongoing collaboration with UNM
- Convened 2 AGU sessions on UQ/climate
- Organized CCSM Workshop UQ session

Significance of Results

Objective methods of risk assessment are needed to bridge the gap between science and policy. Uncertainty quantification can be used objectively by decision makers to prepare for and respond to regional climate change. Backus et al. (2010) “Chu Report” used similar methods.

What’s Next

- Programmatic interest: We are already using the experience gained by this project to build collaborations with other labs and for proposals to DOE, DoD, and IC customers
- UQ experience has fed into new NNSA BER climate project and proposed CSSEF project.
- Time to impact: NOW!

IA should provide the following information

1. Which SMU(s) will benefit from this R&D, and over what time frame?

   Primarily ECI (formerly ERN, but now with the word “climate” in the now in the name! Also (DSA, HSD, and STE). ECI is already seeing the benefit, others (<2yrs).

2. What is the impact/legacy of this project?

   Multiple impacts include follow-on work, and new programs including NNSA BER climate project, Greenhouse Gas Information System (GHGIS), Brinkman Initiative (CSSEF) as well as multiple strategic partners.
**Background: Global Climate Sensitivity**

Best estimate is not sufficient. Policy needs uncertainty!

**Climate Sensitivity $\Delta T_{2x}$**

The increase in equilibrium mean global surface temperature due to the equivalent forcing (with short-term feedbacks) of doubled CO$_2$. There is a strong scientific consensus that the best estimate is about 3 °C, but until recently there has been very little effort at uncertainty quantification. The degree of uncertainty is not yet “settled science”.

*This is not useful by itself for assessing regional climate change*

---

**Threat = Probability x Consequences**

![Threat Calculation Diagram](image-url)

**Relative probability**

- Consequences (deaths/year)
  - 1 E+05
  - 1 E+06
  - 1 E+07
  - 1 E+08
  - 1 E+09
  - 1 E+10

- Probability
  - 0%
  - 20%
  - 40%
  - 60%
  - 80%
  - 100%

- Climate sensitivity (C)
  - 0
  - 2
  - 4
  - 6
  - 8
  - 10
Threat = Probability x Consequences

Climate sensitivity (C)

Probability

Relative probability
Cumulative Probability

Consequences (deaths/year)

0 2 4 6 8 10
0% 20% 40% 60% 80% 100%

Probability

Threat = Probability x Consequences

Climate sensitivity (C)

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Relative probability
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Consequences (deaths/year)

0 2 4 6 8 10
0% 20% 40% 60% 80% 100%

Probability
Threat = Probability x Consequences


Figure 2. U.S. GDP impacts (2010–2050) for a 0% discount rate.
Current resolution is too low for regional forecasts

Data taken from IPCC models are based on global grids and underresolved from the perspective of regional climate forecasts.

Parameterizations are used for physical and biological processes that take place on smaller scales. Regional topographic influences and local climates are entirely ignored. Nevertheless, gross changes in climate variables that are influenced by larger-scale processes (e.g. radiative imbalance, ocean temperatures and jet stream location) are properly accounted for.

Adopt NCDC U.S. Standard Region definitions

U.S. Standard Regions for Temperature & Precipitation

National Climatic Data Center, NOAA
NCDC Region Data can be compared to IPCC runs

Southwest Region Precipitation
December, 1895 - 2003

IPCC Experiments

<table>
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<tr>
<th>Exp. #</th>
<th>Name</th>
<th>Description</th>
<th>ID</th>
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<td>Pre-industrial control</td>
<td>No anthropogenic or natural forcing. Simulation up to ~1600.</td>
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<td>Present-day control</td>
<td>No natural forcing and anthropogenic forcings set to present day</td>
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<td>Climate of the 20th century (20C3M)</td>
<td>Verification runs ~1880-present</td>
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<td>Coupled climate change</td>
<td>Present: 2100, warm end of 20C3M as initial condition</td>
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</table>
| 6      | 850 ppm stabilization experiment (G850) (A1B) | Rapid economic growth, global population peaks in mid-century and
|        |                            | stabilization first. Rapid introduction for new technologies. Initialize
|        |                            | at 20C3M and run to 2300. After 2300, hold concentration steady and run to 2390. | G850A1B|
| 7      | 850 ppm stabilization experiment (G850) (B1) | Same as 6 but future is based on clean and resource
|        |                            | efficient technologies. Initialize at 20C3M and run to 2300. After 2300, hold concentrations steady and run to 2391. | G850B1 |
| 8      | 850 ppm CO2 increase experiment (G850) | Hold CO2 fixed after it has doubled. Run is initialized with either pre-industrial or 20C3M. | G850C1 |
| 9      | 850 ppm CO2 increase experiment (G850) | Hold CO2 fixed after it has quadrupled. Run is initialized with either pre-industrial or 20C3M. | G850D1 |
### IPCC Models

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### Size of grid: GISS e_h (USA)  4°

![Precipitation Map](image)

- Precipitation (10^6 kg m^-2 s^-1)
- Date Min = 11.2, Max = 8.10
- Legend: (see image for details)
Size of grid: MRI (Japan) 1.86°

Size of grid: UKMO HADGEM1 (UK) 1.25°
Size of grid: MIROC (Japan) 1.12°

Size of grid: INVG-ECHAM (Italy) 1.12°
**Interpolated: INVG-ECHAM (Italy) 1.12°**

**Contoured: INVG-ECHAM (Italy) 1.12°**
Contoured: INVG-ECHAM (Italy)

GISS e_r (USA) 4° ensemble
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