Estimating uncertainties in global and regional climate change projections using a multi-thousand member climate model ensemble

Derek Rosendahl[1] and Dr. David Karoly[2]

[1] University of Oklahoma, School of Meteorology; [2] University of Melbourne, School of Earth Sciences

1. Introduction

Information on the uncertainties in projections of future climate change is vital for their effective use across a wide range of applications. A multi-thousand member perturbed-physics ensemble of climate model simulations is used to better estimate model uncertainties in climate change projections for the globe, North American region and sub-regions within the United States. Ensemble members have been generated by the distributed computing project climate*prediction*.net at the University of Oxford, where thousands of simulations have been run on individual computers across the globe, each running a different coupled atmosphere-ocean general circulation model with perturbed physics parameters. The following presents an overview of the North America analysis and its research objectives as well as some preliminary results from the control simulation ensemble.

2. Climate Model Simulations

Climate*prediction*.net

- Distributed computing project (Over 60,000 active hosts worldwide)
- Each computer running a slightly different climate model simulation
- Physics and forcing parameters are varied across current range of uncertainty

Climate Model HadCM3L

- Version of the UK Met Office Hadley Centre model (HadCM3)
- Coupled atmosphere-ocean general circulation model
- Atmosphere (19 vertical levels; 2.5° lat by 3.75° long horizontal resolution)
- Ocean (20 vertical levels; 2.5° lat by 3.75° long horizontal resolution)

Simulation Experiments

- Generate 1921-2080 control simulation ensemble (constant forcing)
- Generate 1921-2080 transient simulation ensemble (forcing varies)
  - 1921-2000: Apply historical forcings based on observations
  - 2001-2080: Apply possible future forcings (using SRES A1B)
- Vary model parameters within current range of uncertainty across ensembles
- Result in more than 3400 control simulations and 6900 transient simulations

Simulation Output

- Globally gridded 10-year means (2.5° latitude by 3.75° longitude)
- Global and regional time series monthly means (1921-2080)

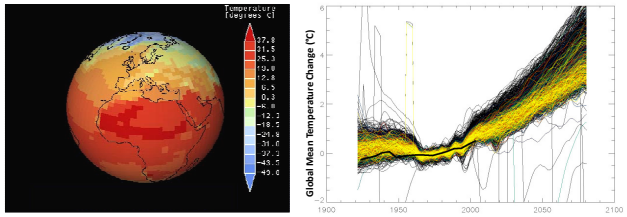


Figure 1: Globally gridded, 10-year mean surface air temperature (left) and annual average global mean surface temperature change (relative to 1961-2005) (right) from the climateprediction.net HadCM3L model. Colors on the time series plot correspond to each simulation's goodness-of-fit to observed global temperatures (think black line) from 1961-2005. From climate*prediction*.net group.

3. Research Objectives

Initial Goals

- Compare simulated 20th century climate variations to observed variations at global level and for North American regions (WNA, CNA, ENA) and sub-regions
- Generate 21st century climate change projections by weighting ensemble members according to their goodness-of-fit to 20th century observations
- Produce probability distributions of future climatic conditions

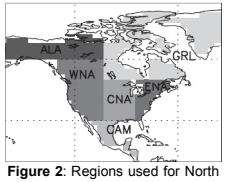


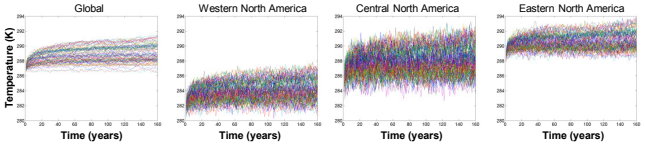
Figure 2: Regions used for North America analysis. From Giorgi and Francisco (2000).

Long-term Goals

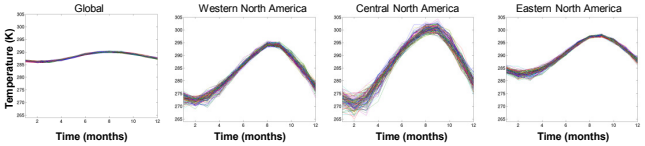
- Evaluate uncertainties in regional climate change projections for variations in model physics parameters
- Conduct optimal fingerprint analysis on North America and sub-regions
  - separate contributions of greenhouse gas, aerosol, and natural forcings to climate changes across 20th century
  - use scaled forcings to constrain climate change projections
  - develop probability distributions for changes in key climate variables
- Evaluate relationship between global-mean climate changes and regional climate change

4. Preliminary Control Run Temperature Results

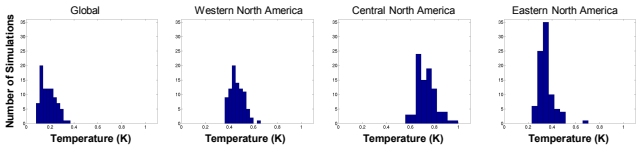
Annual Average Surface Air Temperatures (1921-2080; 86 simulations)



Monthly Mean Surface Air Temperatures (1961-2080 ensemble; 1 simulation)

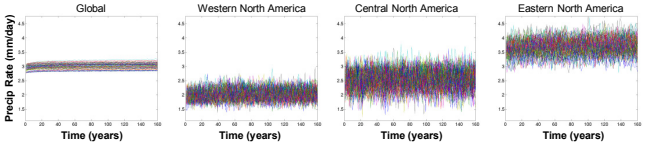


Interannual Variability of Surface Air Temperatures (1961-2080; 86 simulations)



5. Preliminary Control Run Precipitation Results

Annual Average Precipitation Rate (1921-2080; 86 simulations)



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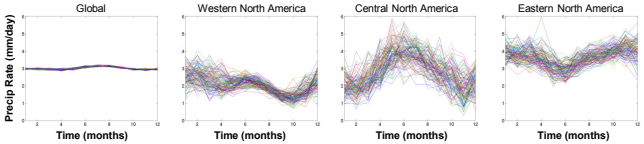
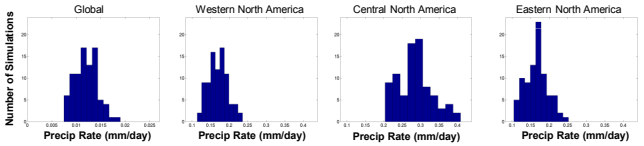


Interannual Variability of Precipitation Rate (1961-2080; 86 simulations)



6. Next Steps

- Compare all control simulations (over 3400) with detrended observational data
  - seasonal cycle, interannual and decadal variability, etc.
- Create "transient minus control" simulation pair results (removes model drift)
  - over 6900 simulations covering 1921-2080 available
- Compare "transient minus control" results with observational data and proceed with initial research objectives
- Analyze smaller regions within U.S. (down to 2.5° lat by 3.75° long regions)

7. Research Significance

- Analyzes largest climate model simulation ensemble available
- Generates probability distributions (i.e., probabilistic forecasts) of regional climate changes within North America and the United States out to 2080
- Provides assessment of model uncertainties in future projections of regional climate change
- Quantifies contribution of greenhouse gas forcing and other forcings to regional climate change

References

Giorgi, F., and R. Francisco, 2000: Uncertainties in regional climate change predictions. A regional analysis of ensemble simulations with the HadCM2 coupled AOGCM. *Climate Dyn.*, 16, 169-182.

Acknowledgements

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