The North American Regional Climate Change Assessment Program: An Overview

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Kansas NSF EPSCor Conference
University of Kansas
Lawrence, Kansas
October 4, 2010
Temperature, past and future

- TODAY
- All models
- Hadley Centre

Temperature Anomaly (°C)

YEAR

1000 1200 1400 1600 1800 2000 2100
Increases in Greenhouse Gases

The current concentrations of key greenhouse gases, and their rates of change, are unprecedented.
The Climate System

How do we simulate this?
Future concentrations of greenhouse gases in the atmosphere
Overview of Global Temperature Changes
Global Climate Models

Regional Climate Models
Objectives of Downscaling

- Bridge mismatch of spatial scale between that of global climate models and the resolution needed for impacts assessments
- Resolve high resolution processes that are responsible for regional climate
What high res is really good for:

- Can act as go-between between bottom-up and top-down approaches to IAV research (e.g., urban heat wave studies).
- For coupling climate models to other models that require high resolution (e.g. air quality models – for air pollution studies).
- In certain specific contexts, provides insights on realistic climate response to high resolution forcing (e.g. mountains).
But, once we have more regional detail, what difference does it make in any given impacts/adaptation assessment?

What is the added value?

Do we have more confidence in the more detailed results?
Different Kinds of Downscaling

• Simple
  – Adding large scale climate changes to higher resolution observations (the delta approach)
  – More sophisticated - interpolation of coarser resolution results (Maurer et al. 2002, 2007)

• Statistical
  – Statistically relating large scale climate features (e.g., 500 mb heights) to local climate (e.g., daily, monthly temperature at a point)

• Dynamical
  – Application of regional climate model using global climate model boundary conditions

Confusions when the term ‘downscaling’ is used
  – could mean any of the above
Global and Regional Simulations of Snowpack

GCM under-predicted and misplaced snow
Climate Change Signals

Leung et al., 2004

PCM = GCM

RCM (MM5) nested in PCM
Putting Spatial Resolution in the Context of Other Uncertainties

- Must consider the other major uncertainties regarding future climate in addition to the issue of spatial scale – what is the relative importance of uncertainty due to spatial scale?
- These include:
  - Specifying alternative future emissions of ghgs and aerosols
  - Modeling the global climate response to the forcings (i.e., differences among AOGCMs)
  - Internal variability of the climate system
The North American Regional Climate Change Assessment Program (NARCCAP)

www.narccap.ucar.edu

• Explores multiple uncertainties in regional and global climate model projections
  4 global climate models x 6 regional climate models
• Develops multiple high resolution (50 km, 30 miles) regional climate scenarios for use in impacts and adaptation assessments
• Evaluates regional model performance to establish credibility of individual simulations for the future

• Participants: Iowa State, PNNL, LNNL, UC Santa Cruz, Ouranos (Canada), UK Hadley Centre, NCAR

• Initiated in 2006, funded by NOAA-OGP, NSF, DOE, USEPA-ORD – 4-year program - ~ $4 million
NARCCAP - Team

Linda O. Mearns, NCAR
Ray Arritt, Iowa State; Dave Bader, LLNL - ONL;
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Moufouma-Okia, Hadley Centre; Sébastien Biner,
Daniel Caya, OURANOS; Phil Duffy, Climate Central;
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UQAM; Ruby Leung, Yun Qian, PNNL; Larry McDaniel,
Seth McGinnis, Don Middleton, NCAR; Ana Nunes,
Scripps; Doug Nychka, NCAR; John Roads*,
Scripps; Steve Sain, NCAR; Lisa Sloan, Mark Snyder,
UC Santa Cruz, Ron Stouffer, GFDL, Gene Takle,
Iowa State

* Deceased June 2008
Regional Modeling Strategy

*Nested regional modeling technique*

- Global model provides:
  - initial conditions – soil moisture, sea surface temperatures, sea ice
  - lateral meteorological conditions (temperature, pressure, humidity) every 6-8 hours.
  - Large scale response to forcing (100s kms)

- Regional model provides finer scale (10s km) response
The RCM approach
Advantages of higher resolution

North America at typical global climate model resolution

Hadley Centre AOGCM (HadCM3), 2.5° (lat) x 3.75° (lon), ~ 280 km

North America at 50 km grid spacing
NARCCAP Domain
Organization of Program

- **Phase I:** 25-year simulations using NCEP-Reanalysis 2 boundary conditions (1979–2004)

- **Phase II:** Climate Change Simulations
  - Phase IIa: RCM runs (50 km res.) nested in AOGCMs current and future
  - Phase IIb: Time-slice experiments at 50 km res. (GFDL AM2.1 and NCAR CAM3) -- for comparison with RCM runs

- Quantification of uncertainty at regional scales – probabilistic approaches

- Scenario formation and provision to impacts community led by NCAR

- Opportunity for double nesting (over specific regions) to include participation of other RCM groups (e.g., for NOAA OGP RISAs, CEC, New York Climate and Health Project, U. Nebraska).
Phase I

- 6 RCMs (RegCM3, WRF, CRCM, ECPC RSM, MM5, HadRM3): Reanalysis (NCEP)-driven runs
- Results are shown here for 1980-2004 from selected RCMs
- Configuration:
  - common North America domain (some differences due to horizontal coordinates)
  - horizontal grid spacing 50 km
  - boundary data from NCEP/DOE Reanalysis 2
  - boundaries, SST and sea ice updated every 6 hours
Temperature Biases

CRCM

CRCM-UDEL Winter Temps Regridded .5 degree
Area RMSE = 3.14228 C

CRCM-UDEL Summer Temps Regridded .5 degree
Area RMSE = 2.35439 C
Summer Temperature Bias

Ensemble-UDEL Summer Temps Regrided .5 degree

Area RMSE = 1.81307 C
Precipitation Biases

CRCM

% Change CRCM-UDEL Winter Precip .5 degree

Area RMSE = 0.858149 mm/day

% Change CRCM-UDEL Summer Precip .5 degree

Area RMSE = 0.697747 mm/day
## RMSE Temperature - NA

<table>
<thead>
<tr>
<th>RCM</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
</tr>
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<tbody>
<tr>
<td>CRCM</td>
<td>3.1</td>
<td>3.0</td>
<td>2.4</td>
<td>2.5</td>
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<tr>
<td>ECP2</td>
<td>3.6</td>
<td>2.4</td>
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<td>HadRM3</td>
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<td>3.9</td>
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<tr>
<td>MM5</td>
<td>2.8</td>
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<tr>
<td>RegCM3</td>
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<td>1.9</td>
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<tr>
<td>WRF(G)</td>
<td>3.6</td>
<td>4.0</td>
<td>2.3</td>
<td>2.9</td>
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<tr>
<td>ENS</td>
<td>2.8</td>
<td>2.4</td>
<td>1.8</td>
<td>1.8</td>
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</table>
## RMSE Precipitation - NA

<table>
<thead>
<tr>
<th>RCM</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
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<tr>
<td>CRCM</td>
<td>.86</td>
<td>.66</td>
<td>.70</td>
<td>.82</td>
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<tr>
<td>ECP2</td>
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<td>.89</td>
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<tr>
<td>HadRM3</td>
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<tr>
<td>MM5</td>
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<td>.84</td>
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<td>.97</td>
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<tr>
<td>RegCM3</td>
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<td>1.12</td>
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<td>1.15</td>
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<tr>
<td>WRF(G)</td>
<td>.94</td>
<td>.69</td>
<td>.77</td>
<td>.87</td>
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<tr>
<td>ENS</td>
<td>.93</td>
<td>.82</td>
<td>.57</td>
<td>.85</td>
</tr>
</tbody>
</table>

mm/day
Regions Analyzed

- Boreal forest
- Pacific coast
- California coast
- Upper Mississippi River
- Great Lakes
- Maritimes
- Deep South
- Upper Mississippi River
Coastal California

- Mediterranean climate: wet winters and very dry summers (Koeppen types Csa, Csb).
  - More Mediterranean than the Mediterranean Sea region.

- ENSO can have strong effects on interannual variability of precipitation.

R. Arritt
Monthly time series of precipitation in coastal California

1982-83 El Nino

multi-year drought

1997-98 El Nino

small spread, high skill
Correlation with Observed Precipitation - Coastal California

<table>
<thead>
<tr>
<th>Model</th>
<th>Correlation</th>
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<tbody>
<tr>
<td>HadRM3</td>
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<tr>
<td>RegCM3</td>
<td>0.916</td>
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<tr>
<td>RSM</td>
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<tr>
<td>CRCM</td>
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<tr>
<td>WRF</td>
<td>0.918</td>
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<tr>
<td><strong>Ensemble</strong></td>
<td><strong>0.947</strong></td>
</tr>
</tbody>
</table>

All models have high correlations with observed monthly time series of precipitation.

*Ensemble mean* has a higher correlation than any model.
Deep South

- Humid mid-latitude climate with substantial precipitation year around (Koeppen type Cfa).
- Past studies have found problems with RCM simulations of cool-season precipitation.
Two models (RSM and CRCM) perform much better. These models inform the domain interior about the large scale.
Phase II
Climate Change
NARCCAP PLAN – Phase II

A2 Emissions Scenario

- GFDL
  - GFDL
  - Time slice 50 km

- CGCM3
  - CGCM3

- HADCM3
  - HADCM3

- CCSM
  - CCSM
  - Time slice 50 km

Provide boundary conditions

1971-2000 current

2041-2070 future

- MM5
  - Iowa State

- RegCM3
  - UC Santa Cruz

- CRCM
  - Quebec, Ouranos

- HADRM3
  - Hadley Centre

- RSM
  - Scripps

- WRF
  - NCAR/PNNL
## GCM-RCM Matrix

<table>
<thead>
<tr>
<th>RCMs</th>
<th>GFDL</th>
<th>CGCM3</th>
<th>HADCM3</th>
<th>CCSM</th>
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<tr>
<td>MM5</td>
<td>X</td>
<td></td>
<td>X1**</td>
<td>X1**</td>
</tr>
<tr>
<td>RegCM</td>
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<td>X**</td>
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<tr>
<td>CRCM</td>
<td>X1**</td>
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<td></td>
</tr>
<tr>
<td>HadRM</td>
<td>X</td>
<td></td>
<td>X1**</td>
<td></td>
</tr>
<tr>
<td>RSM</td>
<td>X1</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>WRF</td>
<td>X</td>
<td></td>
<td></td>
<td>X1**</td>
</tr>
</tbody>
</table>

- *CAM3
- *GFDL

1 = chosen first GCM

*= time slice experiments

Red = run completed

** = data loaded
NCEP-driven vs. AOGCM-driven

RCM3-UDEL Winter Temps Regridded .5 degree

Area RMSE = 4.46828°C

Difference Winter Temps Common Grid & Area
1971-2000 CGCM3_RCM3-UDEL

Area RMSE = 3.87895°C
Change in Winter Temperature
CCSM-WRF

CCSM Change In Seasonal Avg Temp

WRFG+ccsm Change In Seasonal Avg Temp
Change in Winter Temperature
UK Models

HadCM3 Change In Seasonal Avg Temp

HRM3+HADC3 Change In Seasonal Avg Temp
Change (%) Summer Precip

CCSM Change In Seasonal Avg Precip

WRFG+ccsm Change In Seasonal Avg Precip
Uncertainty across two RCMs nested in same GCM -- % Change in Summer Precipitation
Uncertainty across two RCMs nested in same GCM -- % Change in Winter Precipitation

Regional Model 1

Global Model

Regional Model 2
Effect of two different GCMs driving one RCM – % change in winter precipitation

GCMs
CGCM3

RCM
RegCM3

GFDL
Quantification of Uncertainty

• The four GCM simulations already ‘situated’ probabilistically based on earlier work (Tebaldi et al., 2004, 2005)

• RCM results nested in particular GCM would be represented by a probabilistic model (derived assuming probabilistic context of GCM simulation)

• Use of performance metrics to differentially weight the various model results – will use different metrics but also process level expert judgment - determine sensitivity of final pdfs to various methods
The NARCCAP User Community

Three user groups:

• Further dynamical or statistical downscaling
• Regional analysis of NARCCAP results
• Use results as scenarios for impacts and adaptation studies

www.narccap.ucar.edu

To sign up as user, go to web site – contact Seth McGinnis

Over 300 users registered
Adaptation Planning for Water Resources – Sensitivity to Different DS Methods

- Develop adaptation plans for Colorado River water resources with stakeholders
- Use NARCCAP scenarios, simple DS, statistical DS
- Determine value of different types of higher resolution scenarios for adaptation plans – does it matter?
- NCAR, Bureau of Reclamation, and Western Water Assessment
THE END

THE NEW YORKER
BIG BOOK OF GLOBAL WARMING CARTOONS - 2007 - 2107

ATLANTIC OCEAN

PACIFIC OCEAN

CHINA JAPAN RUSSIA

MEXICO TEXAS UTAH LAS VEGAS ST LOUIS

CHICAGO CANADA PENNSYLVANIA