Use of Regional Models in Impacts Assessments

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Climate Models

Regional models

Global forecast models

Global models in 5 yrs
“Most GCMs neither incorporate nor provide information on scales smaller than a few hundred kilometers. The effective size or scale of the ecosystem on which climatic impacts actually occur is usually much smaller than this. We are therefore faced with the problem of estimating climate changes on a local scale from the essentially large-scale results of a GCM.”

Gates (1985)

“One major problem faced in applying GCM projections to regional impact assessments is the coarse spatial scale of the estimates.”

Carter et al. (1994)
But, once we have more regional detail, what difference does it make in any given impacts assessment?

What is the added value?

Do we have more confidence in the more detailed results?
NCAR CSM Topography
2.8 deg. by 2.8 deg.

RegCM Topography
0.5 deg. by 0.5 deg.
Resolutions Used in Climate Models

- High resolution (50 km) global coupled ocean-atmosphere model simulations are not yet feasible.
- High resolution global atmospheric model simulations are feasible for time-slice experiments ~ 50 km resolution for 10-30 years.
- Regional model simulations at resolution 10-30 km are feasible for simulations 20-50 years (~ 50 km).
Benefits of High Resolution Modeling

- Improves weather forecasts (e.g., Kalnay et al. 1998), down to 10 km and improves seasonal climate forecasts, but more work is needed (Mitchell et al., Leung et al., 2002).
- Improves climate simulations of large scale conditions and provides greater regional detail potentially useful for climate change impact assessments.
- Often improves simulation of extreme events such as precipitation and extreme phenomena (hurricanes).
Regional Climate Modeling

- Adapted from mesoscale research or weather forecast models. Boundary conditions are provided by large scale analyses or GCMs.

- At higher spatial resolutions, RCMs capture climate features related to regional forcings such as orography, lakes, complex coastlines, and heterogeneous land use.

- GCMs at 200 – 250 km resolution provide reasonable large scale conditions for downscaling.
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
Use of Regional Climate Model Results for Impacts Assessments

- Agriculture:
  - Brown et al., 2000 (Great Plains – U.S.)
  - Guereña et al., 2001 (Spain)
  - Carbone et al., 2003 (Southeast US)
  - Doherty et al., 2003 (Southeast US)
  - Tsvetsinskaya et al., 2003 (Southeast U.S.)
  - Easterling et al., 2001, 2003 (Great Plains, Southeast)
  - Thomson et al., 2001 (U.S. Pacific Northwest)
  - Olesen et al., 2007 (Europe)
Use of RCM Results for Impacts Assessments 2

• **Water Resources:**
  - Leung and Wigmosta, 1999 (US Pacific Northwest)
  - Stone et al., 2001, 2003 (Missouri River Basin)
  - Arnell et al., 2003 (South Africa)
  - Miller et al., 2003 (California)
  - Wood et al., 2004 (Pacific Northwest)

• **Forest Fires:**
  - Wotton et al., 1998 (Canada – Boreal Forest)

• **Human Health:**
  - Hogrefe et al., 2004
Examples of RCM Use in Climate and Impacts Studies

- Precipitation and Hydrology over S. Africa
- Water Resources in Pacific Northwest
- European Prudence Program
- NARCCAP
Regional Climate Modeling and Hydrological Impacts in Southern Africa

Arnell et al., 2003,

*J. Geophys. Research*
Climate Simulations of Western U.S.

Strong Effect of Terrain

Model ability to resolve terrain features is critical

Observed snow pack, March, 1998

Leung et al., 2004, Climatic Change
Observed and Simulated El Nino Precipitation Anomaly

RCM reproduces mesoscale features associated with ENSO events
Global and Regional Simulations of Snowpack

GCM under-predicted and misplaced snow
Climate Change Signals

**Temperature**

Temperature change (PCM) DJF

**Precipitation**

Precipitation change (PCM) DJF

**PCM**

**RCM**

Temperature change (MM5) DJF

Precipitation change (MM5) DJF
Effects of Climate Change on Water Resources of the Columbia River Basin

• Change in snow water equivalent:
  – PCM: - 16%
  – RCM: - 32%

• Change in average annual runoff:
  – PCM: 0%
  – RCM: - 10%

Payne et al., 2004
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 GCMs)
Multiple AOGCMs and RCMs over Europe: Simulations of Future Climate

Christensen et al. 2007
The North American Regional Climate Change Assessment Program (NARCCAP)

Initiated in 2006, it is an international program that is serving the climate scenario needs of the United States, Canada, and northern Mexico.

• Exploration of multiple uncertainties in regional model and global climate model regional projections

• Development of multiple high resolution regional climate scenarios for use in impacts assessments.

• Further evaluation of regional model performance over North America.

• Exploration of some remaining uncertainties in regional climate modeling (e.g., importance of compatibility of physics in nesting and nested models).

• Funded by NOAA-OGP, NSF, DOE, USEPA-ORD – 4-year program

www.narccap.ucar.edu
NARCCAP - Team

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* Deceased June 2008
NARCCAP Domain
Organization of Program

• Phase I: 25-year simulations using NCEP-Reanalysis 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 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

• All 6 RCMs have completed the reanalysis-driven runs (RegCM3, WRF, CRCM, ECPC RSM, MM5, HadRM3)

• Results are shown here for 1980-2004 from sample of 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
UDEL obs., DJF seasonal avg, 1980-2004

ECPC+NCEP, DJF seasonal avg, 1980-2004
NARCCAP PLAN – Phase II

A2 Emissions Scenario

GFDL
CCSM
HADCM3
CGCM3

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
PNNL
<table>
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<th>AOGCMs</th>
<th>GFDL</th>
<th>CGCM3</th>
<th>HADCM3</th>
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*CAM3
*GFDL

1 = chosen first GCM
* = time slice experiments
Red = run completed
** = data loaded
Phase II (Climate Change) Results
WRF Model vs Obs

UDEL obs., JJA seasonal avg, 1980-2004

WRFP+NCEP, JJA seas. avg, 1980-1999

Surface Air Temperature
CCSM current vs. WRF

CCSM, JJA seas. avg, 1980-1999
Surface Air Temperature degrees C

WRFP+CCSM, JJA seas. avg, 1980-1999
Surface Air Temperature degrees C
Change in Winter Temperature Canadian Models

Global Model

Regional Model
Change in Winter Precip
Canadian Models

CGCM3 Change in Seasonal Avg Precip
DJF  2040-2070 minus 1970-2000  %

CRCM+CGCM3 Change in Seasonal Avg Precip
DJF  2041-2070 minus 1971-2000  %
NARCCAP Project Timeline

Project Start: 1/06
Phase 1: 9/07
AOGCM Boundaries available: 12/07
Archiving Procedures - Implementation: 9/08
Phase IIa: 1/09
Current climate 1: 7/09
Phase IIb: Time slices
Future climate 1 and Future 2:
The NARCCAP User Community

Three user groups:

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

www.narccap.ucar.edu

To sign up as user, go to web site

mcginnis@ucar.edu
When to Use High Resolution

- Consider the importance of regional detail compared to other uncertainties in project
- High resolution useful when there are high resolution forcings: complex topography, complex coastlines, islands, heterogeneous land-use
- Consider also statistical downscaling
- More guidance on web at: ipcc-ddc