Enabling Regional Climate Model Evaluation: A Critical Use of Observations for Establishing Core NCA Capabilities

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Response to: NASA Center’s Call for Proposals
To Support The National Climate Assessment

PI Telecon : November 20, 2012
Global Climate Models (GCMs) provide the only quantitative, physically-based means for predicting climate change. Regional climate models (RCMs) are a key tool to downscale the global predictions for characterizing and quantifying climate change impacts on scales relevant to decision-support and climate assessment activities (e.g. NCA).

It is imperative that GCMs and RCMs are evaluated against observations so that their strengths and weaknesses can be quantified and model shortcomings can be improved.

Systematic evaluation studies of GCMs have been undertaken for some time (e.g., AMIP, CMIP, CFMIP), however there has been less attention/consideration made to systematic evaluation of RCMs.

NASA can provide critical and unique observational resources and technological leadership to facilitate RCM evaluation and thus make key contributions to the NCA process.
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Using NASA Observations for model evaluation relevant to the NCA

**A. Observation Use** – Evaluate Course-Grid GCM Fidelity In Simulating Present-day Regional Climate (e.g., CMIP).
- Global Model Simulation of Present-Day Climate (e.g., CMIP3, CMIP5)

**B. Observation Use** – Evaluate Fine-Grid RCM Fidelity – without GCM influence - In Simulating Present-day Regional Climate (e.g., NARCCAP Phase I).
- Global Reanalysis as Boundary Conditions (e.g., NCEP/NCAR, MERRA, ERA-INTERIM)

**C. Observation Use** – Evaluate Fine-Grid RCM Fidelity – with GCM influence - In Simulating Present-day Regional Climate (e.g., NARCCAP Phase II).
- Global Model Simulation of Present-Day Climate (e.g. CMIP3, CMIP5)
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NARCCAP is the North America Regional Climate Change Assessment Program (PI: L. Mearns, NCAR).

Several RCMs downscaling future climate change projections from GCMs.

RCM performance needs to be characterized against observations using present-day simulations.

NARRCAP is the U.S./N.A. contribution to CORDEX.
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RCMES v2.0 - High-Level Architecture

Other Data Centers
(ESG, DAAC, ExArch Network)

TRMM
MODIS
AIRS
CERES
Soil moisture
ETC

Extractor for various data formats

MySQL

Metadata

Data Table
Data Table
Data Table
Data Table
Data Table
Data Table
Common Format, Native grid, Efficient architecture

Data extractor
(Binary or netCDF)

Metrics Calculator
(Calculate evaluation metrics)

Visualizer
(Plot the metrics)

Regridder
(Put the OBS & model data on the same time/space grid)

Extract OBS data
Extract model data

User input

Model data

Use the re-gridded data for user’s own analyses and VIS.

Raw Data:
Various sources, formats, Resolutions, Coverage

RCMED
(Regional Climate Model Evaluation Database)
A large scalable database to store data from variety of sources in a common format

RCMET
(Regional Climate Model Evaluation Tool)
A library of codes for extracting data from RCMED and model and for calculating evaluation metrics

Ingest obs/models, re-gridding, calculate metrics (e.g., bias, RMSE, correlation, significance, PDFs), and visualize results (e.g., contour, time series, Taylor).
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**RCMES**

High-level technical architecture

**AVAILABLE**
- AIRS gridded daily 3D temperature and water vapor
- TRMM 3B42 3-hourly gridded daily precipitation
- ERA-Interim 6-hourly surface temperature & dewpoint, 3D temperature & geopotential
- NCEP daily Unified Rain gauge Database (URD), 0.25° resolution
- Satellite-based Snow Water Equivalent (SWE) assimilation data (Sierra Nevada)
- MODIS daily Cloud fraction and snow cover
- Climate Research Units (CRU) monthly precipitation and temperature (Tavg, Tmin, Tmax) at 0.5° resolution.
- MERRA- Sea-level pressure, surface pressure
- CERES radiation – Surface and Top of the atmosphere
- University of Delaware precipitation and temperature analysis

**FUTURE**
- CloudSat atmospheric ice and liquid, Satellite-based snow (Himalayas), ISCCP cloud fraction, MERRA (water vapor, surface and pressure-level variables), Sea-level heights, Fine-scale SST, etc.
This activity includes three tasks:

I) Tailoring RCMES for application to the NCA. (e.g. data sets, metrics, visualization, GUI)

II) Systematic application of observations to evaluate NARCCAP RCM and CMIP GCM simulations over the U.S./N. America.

III) Overall incorporation of model evaluation/assessment results and RCMES infrastructure into the near- and long-term NCA process.

GOAL

Observation-based model performance metrics for modeling regional climate. Gleckler et al. 2008
Progress Tailoring RCMES

* RCMED - database
  * Additional data sets added – see previous slide
  * Exploring the use of MongoDB and other advanced DB architectures.

* RCMET - toolkit
  * Metrics calculation: Bias, RMSE, pattern and temporal correlations, PDFs, etc.
  * Visualization using contour maps, Taylor and Portrait diagrams, x-y line plots, etc.
  * Constructed Virtual Box and VMWare images for easy deployment
  * Delivered RCMET 2.0 multi-model analysis version of toolkit to CORDEX South Asia

* Public Website/Portal Release
  * http://rcmes.jpl.nasa.gov
* North American Regional Climate Change Assessment Project (NARCCAP) = CORDEX N. America, funded via NCA.
  * Paper submitted, under revision.
* CORDEX-Africa
  * In collaboration with University of Cape Town, Republic of South Africa, and Swedish Meteorological and Hydrological Institute (SMHI), Sweden. Partial support from CKDN (see below).
* CORDEX-South Asia
  * In collaboration with Indian Institute of Tropical Meteorology, India. Hosted lead, Dr. Sanjay at JPL. Had science and IT representation at recent October 2012 CORDEX S. Asia meeting.
  * Installed RCMES-VM version at IITM for testing with CORDEX-South Asia data.
* EXPLORING USE OF RCMES with CORDEX ARCTIC, E. Asia.
  * Attended 1\textsuperscript{st} CORDEX Arctic meeting in March, 2012.
  * Attended (1\textsuperscript{st} and) 2\textsuperscript{nd} CORDEX E. Asia meeting in October, 2012.
* Climate & Knowledge Development Network (CKDN; \url{http://cdkn.org/})
  * Synergistic activities with B. Hewitson (PI) & U. of Cape Town (UCT), and Roger Street (Oxford University)
  * Evaluating RCMES and its use in climate training: 1\textsuperscript{st} user lab in April 2012 in Dakar
* Kim Whitehall – Howard University/Prof. G. Jenkins Advisor
  * Incorporating RCMES into her PhD studies on regional Climate Modeling (Africa)
  * Visited JPL during summer 2012.
  * Developed idea for WMO Bulletin article – see later slide.
* Melanie Cooke – University of Toronto/Prof. Paul Kushnir
  * Incorporating RCMES into her PhD studies on regional Climate Modeling (Arctic)
  * Visited JPL during summer 2012.
* Rama Rao M. V. S. – IITM, India/J. Sanjay
  * Applying RCMES to CORDEX-S. Asia as model evaluation/data handling tool.
The monthly-mean time series of the daily-mean surface air temperatures and precipitation over the conterminous US region from five RCMs (Table 1) that have participated in the NARCCAP hindcast experiment have been evaluated against the CRU data for the 24-year period 1980-2003.

The RCM simulations, mostly at 50km horizontal resolutions, are interpolated onto a common grid nest of 0.5-deg horizontal resolution for analysis, evaluation, and inter-comparison (Figure).

Fourteen sub-regions (as depicted in the figures and table) are selected for closer examinations of model performances in various regions of interests (Table 2).

Table 1. The RCMs evaluated in this study.

<table>
<thead>
<tr>
<th>Model ID</th>
<th>Model Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>M01</td>
<td>CRCM (Canadian Regional Climate Model)</td>
</tr>
<tr>
<td>M02</td>
<td>ECP2 (NCEP Regional Spectral Model)</td>
</tr>
<tr>
<td>M03</td>
<td>MM5I (MM5 – run by Iowa State Univ.)</td>
</tr>
<tr>
<td>M04</td>
<td>RCM3</td>
</tr>
<tr>
<td>M05</td>
<td>WRFG (WRF – run by PNNL)</td>
</tr>
<tr>
<td>ENS</td>
<td>Model Ensemble (Uniform weighting)</td>
</tr>
</tbody>
</table>

Table 2. The relationship between precip & insolation biases.

<table>
<thead>
<tr>
<th>Model</th>
<th>Land-mean bias - Precipitation (mm/d)</th>
<th>Land-mean bias - Insolation (Wm$^2$)</th>
<th>Bias pattern Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRCM</td>
<td>0.33</td>
<td>10.2</td>
<td>-0.47</td>
</tr>
<tr>
<td>ECP2</td>
<td>0.41</td>
<td>9.0</td>
<td>-0.28</td>
</tr>
<tr>
<td>RCM3</td>
<td>0.54</td>
<td>-29.9</td>
<td>-0.50</td>
</tr>
<tr>
<td>WRFG</td>
<td>-0.08</td>
<td>30.4</td>
<td>-0.18</td>
</tr>
<tr>
<td>ENS</td>
<td>0.25</td>
<td>4.9</td>
<td>-0.62</td>
</tr>
</tbody>
</table>
The simulated summer (JJA) and winter (DJF) surface air temperatures in the 14 sub-regions are evaluated against the CRU analysis data.

- Standard deviation is used as the indicator for the magnitude of interannual variability.
- Model bias and standard deviation are normalized by the standard deviation of the CRU data.

Mean biases vary, quite systematically, according to geography and season
- Warm biases in the Great Plains area for both summer and winter
- Cold biases in the Pacific, Gulf, and Atlantic coast regions in summer
- Warm biases in the Atlantic coast (NE and SE), Florida (FL) and northern California (CAn) during winter.

All models reasonably simulated the interannual variability of the winter temperatures in almost all regions.
- The interannual variations in the summertime surface air temperature are generally overestimated by almost all models in almost all regions.

The model ensemble is consistently among the best performers for all seasons, regions, and metrics.
Kim Whitehall is a Howard University graduate student. She spent the summer at JPL learning & contributing to RCMES.

RCMES article in the latest issue of the WMO Bulletin highlighting its potential role in WMO’s new Global Framework for Climate Services

GLOBAL FRAMEWORK FOR CLIMATE SERVICES

Building Model Evaluation and Decision Support Capacity for CORDEX

by Kim Whitehall¹,², Chris Mattmann¹,²,³, Duane Waliser¹,³, Jinwon Kim², Cameron Goodale¹, Andrew Hart¹, Paul Ramirez¹, Paul Zimdars¹, Dan Crichton¹, Gregory Jenkins¹, Colin Jones¹, Ghassam Asrar¹, Bruce Hewitson¹
Summary and Plans

* NARCCAP Model Evaluation Study
  Related papers
  Additional IT papers and CMIP5 sierra snowpack study.

* RCMES development (IT team)
  • RCMED database – inclusion of additional satellite and other datasets
  • RCMET toolkit – additional metrics
  • Improved user interface
  • Improved and varied portability – moving toward more community use (e.g. CORDEX)
  • Website developed/released.

* Formal NCA Inputs (+ formal reviews of IPCC Ch. 9 Model Evaluation)
  Waliser, D., J. Kim, C. Mattmann, and L. Mearns, 2012: Regional climate model evaluation: A critical component of the scientific basis and decision support elements of the NCA. Tech. input for consideration to the 2013 Us National Climate Assessment, 19pp.
  Mattmann, C., D. Waliser, and J. Kim, 2012: Developing the technical capabilities of a regional climate model evaluation system to support the NCA process. Tech. input for consideration to the 2013 Us National Climate Assessment, 6pp.

* Community interactions & collaborations – CORDEX Africa, S.Asia, E. Asia, Arctic

* Hired 2 (partially supported postdocs) – science application & database/metric development

* Near-term plan
  • RCMED & RCMET Expansion
  • Improved user Interface and portability
  • Regional evaluations of CMIP5
  • Cultivate related CORDEX opportunities to gain insight into user and decision-support needs.