NARCCAP Multi-RCM Evaluations using RCMES: Monthly surface air temperatures and precipitation over the conterminous U.S.

NARCCAP Users' Workshop
10-11 April 2012
Boulder, Colorado

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Recent studies have confirmed with high level of confidence that the emissions of anthropogenic greenhouse gases have induced the ongoing global warming trend.

Assessment of the impacts of climate change on regional sectors have become an important concern.

RCMs play a crucial role in climate change impact assessments.

Systematic evaluations of GCMs have been undertaken for some time (e.g., AMIP, CMIP); this is not the case for RCMs.
Observational data are a key component of climate research

- Detection and attribution
- Typical model evaluation is performed by comparing the model and reference data from observations, analysis of observed data and/or observation-based assimilations.
- Easy access to quality reference data facilitates evaluation efforts.
- Remote-sensing at NASA & other institutions can provide fine-scale reference data suitable for evaluating future RCM simulations.

To facilitate RCM evaluation, especially for easy access to remote sensing data, RCMES has been developed via joint JPL-UCLA efforts.
RCMES (http://rcmes.jpl.nasa.gov)
High-level technical architecture

**Raw Data:**
Various 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 Toolkit)
A library of codes for extracting data from RCMED and model and for calculating evaluation metrics

**Extractor**
Metadata
Common Format, Native grid, Efficient architecture

Extract OBS data
Extract RCM data

Regridder
Put the OBS & RCM data on the same grid for comparison

Metrics Calculator
Calculate comparison metrics

Visualizer
Plot the metrics

User's own codes for ANAL and VIS.

Data extractor (Fortran binary)

TRMM
MODIS
AIRS
SWE
Soil moisture
ETC

URL
RCMES Database (RCMED) - Current & near-future archives

- **RCMED Datasets (now or near-term)**
  - MODIS Cloudiness: [2000-2010, daily]
  - TRMM PR: [1998-present, daily], 3B42 & version-7
  - AIRS $T_{SFC}$ and profiles: [2002-2010, daily]
  - NCEP CPC PR analysis: [1948-present, daily, US]
  - CRU v3.0 & v3.1 (pr, T2, $T_{2\text{MAX}}$, $T_{2\text{MIN}}$, cloudiness): [monthly]
  - JPL SWE: [2000-2010], Sierra Nevada
  - CERES Radiation: [1983-2007, monthly], surface and TOA
  - NASA MERRA Reanalysis
  - ERA-Interim Reanalysis
  - NCEP Reanalysis
  - CloudSat, MISR/MODIS aerosol, SMAP SMC, etc.
Near-term applications to WCRP's CORDEX for IPCC

- **N. America**: Funded via NASA for U.S. NCA (NCAR, NARCCAP)
- **Africa**: Collaboration & analysis ongoing (UCT, Rossby Centre)
- **Arctic**: Exploring collaboration (J. Cassano, March 2012 Workshop)
- **E. Asia**: Exploring collaboration (KMA, APCC)
- **S. Asia**: Exploring collaboration

Not Illustrated Here: **Arctic & Antarctic Domains**
The JPL-UCLA team is collaborating with NCAR scientists for providing inputs to National Climate Assessment report.

Monthly data from 5 RCMs for the 24-year (1980-2003) period are obtained on a common grid from NCAR.

Evaluations are performed for the monthly-mean values of:
- Precipitation and the daily-mean surface air temperature

Reference data used:
- CRU3.1 (1901-2010, 0.5deg)

Currently WIP:
- Surface pressure (vs. MERRA Reanalysis data)
- Surface insolation (vs. CERES radiation data)
The data from 5 RCMs and their ENS over the conterminous US region are evaluated.

The RCM simulations are interpolated onto a common grid nest of 0.5-deg horizontal resolution for analysis, evaluation, and inter-comparison.

Fourteen sub-regions (as shown in the figures and table) are selected to examine model performances in various regions of interests.

<table>
<thead>
<tr>
<th>ID</th>
<th>Region</th>
<th>Long Range</th>
<th>Lat Range</th>
<th>i Range</th>
<th>j Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>PNw (Pacific NW - west)</td>
<td>236.25-239.75</td>
<td>42.75-49.25</td>
<td>73-80</td>
<td>56-69</td>
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<tr>
<td>02</td>
<td>PNe (Pacific NW - east)</td>
<td>240.25-247.25</td>
<td>42.75-49.25</td>
<td>81-95</td>
<td>56-69</td>
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<tr>
<td>03</td>
<td>CA (northern California)</td>
<td>236.25-242.25</td>
<td>37.25-42.25</td>
<td>73-85</td>
<td>45-55</td>
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<td>04</td>
<td>CA (southern California)</td>
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<td>32.25-37.25</td>
<td>75-92</td>
<td>35-45</td>
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<tr>
<td>05</td>
<td>SW (SWUS - west)</td>
<td>246.25-251.75</td>
<td>31.25-37.25</td>
<td>94-104</td>
<td>33-45</td>
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<tr>
<td>06</td>
<td>SW (SWUS - east)</td>
<td>251.75-260.25</td>
<td>31.25-37.25</td>
<td>104-121</td>
<td>33-45</td>
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<tr>
<td>07</td>
<td>CO (Colorado)</td>
<td>249.75-258.25</td>
<td>37.25-43.25</td>
<td>100-113</td>
<td>45-57</td>
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<tr>
<td>08</td>
<td>GPn (nor. Great Plains)</td>
<td>260.25-269.75</td>
<td>45.25-49.25</td>
<td>121-140</td>
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<td>09</td>
<td>GPc (central Great Plains)</td>
<td>260.25-269.75</td>
<td>34.75-45.25</td>
<td>121-140</td>
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<td>10</td>
<td>GC (Gulf Coast)</td>
<td>264.25-275.25</td>
<td>29.75-34.75</td>
<td>129-151</td>
<td>30-40</td>
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<td>11</td>
<td>GL (Great Lakes)</td>
<td>270.25-279.75</td>
<td>38.25-44.75</td>
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<td>47-60</td>
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<tr>
<td>12</td>
<td>NE (NE US)</td>
<td>280.25-289.75</td>
<td>38.25-44.75</td>
<td>161-180</td>
<td>47-60</td>
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<tr>
<td>13</td>
<td>SE (SE US)</td>
<td>276.25-284.75</td>
<td>30.75-38.25</td>
<td>153-170</td>
<td>32-47</td>
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<tr>
<td>14</td>
<td>FL (Florida)</td>
<td>276.75-279.75</td>
<td>24.25-30.75</td>
<td>154-160</td>
<td>19-32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model ID</th>
<th>Model Name</th>
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<tr>
<td>M01</td>
<td>CRCM (Canadian Regional Climate Model)</td>
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<tr>
<td>M02</td>
<td>ECP2 (NCEP Regional Spectral Model)</td>
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<tr>
<td>M03</td>
<td>MM5I (MM5 – run by Iowa State Univ.)</td>
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<td>M04</td>
<td>RCM3</td>
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<td>M05</td>
<td>WRFG (WRF – run by PNNL)</td>
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<tr>
<td>ENS</td>
<td>Model Ensemble (Uniform weighting)</td>
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</table>
[1] The daily-mean surface air temperature evaluation
5 RCMs and their ensemble vs. CRU3.1 analysis

• 24 years: 1980-2003
  • Overland only
  • Annual climatology: Spatial variability
  • Seasonal climatology: Interannual variability
• Annual cycle in subregions.
Daily-mean surface air temperatures:  
Climatology and Biases

- Model errors vary systematically according to geography.
- All models show **cold biases** over the coastal and the eastern US regions.
- Most models show **warm biases** in the Great Plains region.
- Model errors in the mountainous WUS region vary widely; **may be related with large orographic variations in the region.**
  - RCMs may experience difficulties in simulating the surface air temperatures in the mountainous WUS with their 50-km horizontal resolutions.
Surface air temperature climatology: Spatial Variability over the land surface

- Evaluation of the spatial variability of the simulated surface air temperature climatology using the Taylor diagram
  - Spatial pattern correlations
  - Spatial variability
  - RMSE

- All models generate spatial patterns reasonably with pattern correlation coefficients of 0.95-0.99 with the CRU analysis.

- The simulated spatial variability is also close to the observations.
  - The standardized deviation ranges from 0.9 to slightly above 1.
  - All models except CRCM underestimate the spatial variability.

- The model ensemble (marked by a red circle) yields the smallest RMSE.
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, Florida and northern California during winter.

All models reasonably simulated the interannual variability of the winter temperatures in most regions.

The interannual variability are generally overestimated for summer temperatures.

The model ensemble is among the best performers for all seasons, regions, and metrics.
[2] Precipitation evaluation
5 RCMs and their ensemble vs. CRU3.1 analysis

- 24 years: 1980-2003
  - Overland only
  - Annual climatology: Spatial variability
  - Seasonal climatology: Interannual variability
  - Annual cycle in subregions.
Model biases in simulating the annual precipitation climatology also varies according to regions.

The most noticeable systematic biases are:
- wet biases in the Pacific NW.
- dry biases in the Gulf coast and southern Great Plains.
- model biases are mixed in the AZ - western NM region that is strongly affected by the North American Monsoon (NAM)
Annual precipitation climatology: Spatial Variability over the land surface

- All models show similar performance in simulating spatial patterns with spatial correlation coefficients of 0.75-0.85 with the CRU analysis.

- Model performance vary more widely in simulating the spatial variability.
  - Three out of five models as well as the model ensemble underestimate the spatial variability.

- The model ensemble (marked by a red circle) yields the smallest RMSE.
Seasonal precipitation climatology: Normalized bias and interannual variability

- Winter precipitation:
  - Most models overestimate the mean and interannual variability in the inland regions.
  - Most models underestimate the mean and interannual variability in GC.
  - Most models perform well for the Pacific & Atlantic coast regions.
- Summer precipitation:
  - Models generally underestimate the mean in the GP, SWUS, and FL.
  - Models generally overestimate the mean in the Atlantic coast and Colorado regions.
  - Large errors in the PNW and CA regions may not be of practical importance.

- Model errors show strong regional variations.
- Model errors in the seasonal mean and interannual variability are closely related:
  - Overestimations (underestimations) of the mean is usually corresponds to overestimations (underestimations) of the interannual variability, especially for winter.
Summary

- Evaluation of climate models is a fundamental step in projecting future climate and assessing their impacts on important sectors.

- JPL/NASA is developing RCMES to facilitate RCM evaluation
  - A number of observed and remote sensing data are available for model evaluations

- Monthly-mean surface air temperatures and precipitation from multiple RCMs participating in the NARCCAP hindcast experiment have been evaluated.

- It has been found that model errors vary systematically according to regions, seasons, variables, and metrics in addition to models.

- Models generate warm and cold biases in the GP and the coastal regions, resp.
  - The warm biases in the GP region occur in both summer and winter.
  - In other regions, biases vary according to seasons.

- All RCMs generate wet and dry biases in the PNW and GP regions, resp.
  - All RCMs perform poorly in simulating the summer precipitation in the SWUS region.

- Overestimations of seasonal mean precipitation is usually accompanied by overestimations of interannual variability.

- *The simple model ensemble is typically among the best performer in all evaluations.*

- The model errors identified in this study can be related to multiple causes including:
  - The lack of horizontal resolution, model physics, errors in reanalysis data

- Need in-depth process studies to identify the causes of model errors.