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

Duane Waliser
Jet Propulsion Laboratory/Caltech

Chris Mattmann, Paul Loikith, Huikyo Lee, Brian Wilson, etc, JPL
Jinwon Kim, UCLA
& many others, including a number of CORDEX domain working groups

June 2015 Program Review
RCMES Motivation & Goals

GOALS

• Make observation datasets, with emphasis on satellite data, more accessible to the RCM community.
• Make the evaluation process for regional climate models simpler, quicker and physically more comprehensive.
• Provide researchers more time to spend on analysing results and less time coding and worrying about file formats, data transfers, etc.

BENEFITS

• Quantify model strengths/weaknesses for development/improvement efforts
• Improved understanding of uncertainties in predictions

This activity includes three objectives:

I) Tailoring RCMES for application to the NCA with NASA contribution in mind (e.g. data sets, metrics, visualization)

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

Evaluation of the NARCCAP hindcast precipitation and the uncertainty in precipitation observations for the US region (Kim et al., 2013, J. Climate.)
### CMIP5 GCMs - observation

- CCSM4
- CFSv2
- CNRM-CM5
- CanCM4
- IPSL-CM5A-LR
- MIROC5
- MPI-ESM-LR
- MRI-CGCM3
- ENS-MODEL

### NARCCAP RCMs - observation

- CRCM
- ECP2
- HRM3
- MMS1
- RCM3
- WRFG
- ENS-MODEL

---

**Capability to Perform Regional Evaluation of GCMs**

**Annual Precipitation Bias**

*Courtesy: Huikyo Lee*
RCMES Motivation & Goals

RCMES - High-Level Architecture - powered by Apache Climate

**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

**Raw Data:**
Various sources, formats, Resolutions, Coverage

**Extractor for various data formats**

**Metadata**

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

**Other Data Centers**
(ESG, DAAC, ExArch Network)

**MySQL**
Extractor for various data formats

**User input**

**Model data**
Extract OBS data
Extract model data

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

**Data extractor** (Binary or netCDF)

**User’s own analyses and VIS.**

**Metrics Calculator**
(Calculate evaluation metrics)

**Visualizer**
(Plot the metrics)

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

**Other Data Centers**
(ESG, DAAC, ExArch Network)

- TRMM
- MODIS
- AIRS
- CERES
- Soil moisture
- ETC

**Final Data:**

- Soil moisture
- ETC
- Other Data Centers
- RECMES – High-Level Architecture – powered by Apache Climate

**Metadata**

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

**Extractor for various data formats**

**MySQL**
Extractor for various data formats

**User input**

**Model data**
Extract OBS data
Extract model data

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

**Data extractor** (Binary or netCDF)

**User’s own analyses and VIS.**

**Metrics Calculator**
(Calculate evaluation metrics)

**Visualizer**
(Plot the metrics)

**URL**
Use the re-gridded data for user’s own analyses and VIS.
Reference data for model evaluation

**obs4MIPs**
Over 30 satellite variables on ESGF
*(Similarly for analyses & ana4MIPs)*

**Other Data Centers**
(e.g. DAAC, Climate Data Guide, NCEI)

**RCMED**
(e.g. TRMM, CRU, UDEL)
Now limited to a few datasets for training purposes only.

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

**User input**

**Model data**

**Extract OBS data**
**Extract model data**

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

**Data extractor**
*(Binary or netCDF)*

**Metrics Calculator**
*(Calculate evaluation metrics)*

**Visualizer**
*(Plot the metrics)*

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

**Jinny Lee** - Summer intern; M.S. Student at Cal State Los Angeles in Geology/Hydrology; Web documentation and plans to use RMCES for her M.S. thesis.

**Kim Whitehall** - Howard University/Prof. G. Jenkins Advisor (PhD completed; hired at JPL in Data Science) JPL Intern summer 2012 + 2013; Incorporating RCMES and adding capability for her PhD studies.

**Jesslyn Whittell** - Previous Marymount HS student and now a undergrad student at UC Berkeley Intern at JPL in summer 2012 + 2013 and worked on RCMES development with the IT staff.

**Alexander Goodman** - Previous UIUC undergrad, Now a graduate student at CSU, Atmos. Science. Intern at J PL in summer 2013 and improved visualization software.

**Danielle Groenen** - Graduate student at Florida State University, Meteorology W/ V. Misra. Intern at JPL in summer 2014, will work on climate model evaluation in N. and C. America.

**Melanie Cooke** - Graduate student at U. Toronto w/ P. Kushner Short term visit to J PL to learn RCMES for research on RCM of Arctic

**Training Sessions or Webinars**

- **CORDEX-Related**
  - 2012-3 Africa, S. Asia, E. Asia
  - 2014: L. America, RCM Workshop (Sweden)
  - 2014: MENA Workshop (Cyprus)

- **Asia-Pacific Economic Cooperation Climate Center’s (APCC) Training Program**
  - Statistical downscaling using RCMES
  - 27 trainees from South Asia, South America and Africa. 24 of them thought that the RCMES tutorial was excellent.
Classroom Instruction

- In 2014 and 2015 spring semesters, Climate Dynamics course at University of Illinois (Prof. Donald Wuebbles) provides RCMES for graduate students who learn about uncertainties in climate models and model evaluation metrics.
  - 2014: 11 students, 2015: 8 students
- RCMES is currently installed on a Linux-based cluster system of the atmospheric sciences department. Using RCMES, even students with no programming background can evaluate GCMs or RCMs over a region of their interests. Incorporated into spring semester homework assignment.
Developing 3 Ways to Learn/Use RCMES
Based on feedback from users/trainings

**Level 1:** Command line interface (Initial Education/Training)
- Intuitive but purposely **limited** menu-driven interactive tool.
- Designed for introduction to RCMES.
- Performs simple evaluation examples.
- Outputs configuration file for illustration/further flexibility.

**Level 2:** Configuration file (Intermediate Education/Training)
- User provides input to a configuration file template.
- Execution of configuration file performs evaluation.
- Allows for more customization than RCMES CLI.
- Rerun and illustrate on other CORDEX & N.A. domains

**Level 3:** Python scripting using Apache OCW library (Advanced Education/Training)
- Requires installation of Python libraries on user’s machine.
- Requires use of Python and the Open Climate Workbench (OCW) open source library.
- Most customizable way to use RCMES, allows users to contribute to OCW development.
New RCMES Website (fall’14) & Documentation Development (sum’15)

New Structure & Development Interface

Key Requirement
Readily editable by team members

Summer’15 Objective
Summer intern to develop better documentation for training purposes - particularly the 3 interfaces; and the Kim et al. NCA and CORDEX paper examples, and change in database framework.

Summer intern - Jinny Lee, M.S.
Student at Cal State Los Angeles in Geology/Hydrology; Plans to use RMCES for her M.S. thesis work.
Publications

**NARCCAP/NCA**


**Select Related/CORDEX**


Problem: Temperature extremes are associated with severe societal impacts and are expected to be affected by climate change. To have confidence in future predictions the skill of climate models to reproduce observed extremes must be measured.

Results: NARCCAP RCM/GCM climate models simulate the observed features relatively well for plausible physical reasons, although in some cases, especially summer, skill is lower and extremes occur for unrealistic reasons.
Short-tailed Temperature Distributions over North America and Implications for Future Changes in Extremes
Paul C. Loikith

Problem: Locations where the temperature distribution has a short warm side tail would experience a greater increase in extreme warm days than a location without a short tail if there were a uniform mean warming across the distribution.

Results: Short warm tails are common in both winter and summer over North America. Some places would see a temperature that is exceeded 5% of the time today as much as 60% of the time due to few degrees of mean warming.

Significance: Places with short warm tails may be more susceptible to increases in extreme warm temperatures in future decades than places with longer tails. These features must be represented in climate model simulations.

From a model development as well as climate impacts assessment, the precipitation is important to represent correctly.

Metrics are needed that limit data transfer or re-gridding needs.

Higher resolution important for realistic precipitation extreme distributions

Useful information can be obtained from native resolutions

References:
Lee, Waliser, Braverman, 2015: In Prep
**Problem:** Changes in temperature due to global warming will impact society. Climate models must be able to simulate the observed temperature distribution in order to be trusted to make realistic future predictions.

**Results:** The climate models evaluated (from the North American Regional Climate Change Assessment Program) were often warmer or colder than observations at all percentiles. Higher moments were mostly simulated well in winter and less so in summer.

**Significance:** When the temperature distribution is simulated well, confidence in future projection of temperature is stronger. When the temperature distribution is simulated poorly, models may not be suited for future projections of temperature and temperature extremes. These provide targets for further analysis and model development.

K. Kunkel (NCEI/NOAA) - provided critical analysis/input based on observations to the 2014/3rd report and is interested in providing more analysis/critique of model projection information. We expect this to be the case for 4th report.

We are incorporating their favored “nClimDiv” GHCN-based 5km (temp, prec) dataset into RCMES and are working with them to develop model-based evaluation metrics using RCMES’ ESGF interface to CMIP5 and NARCCAP models.

To promote NASA datasets and capabilities into his/this process, we will also leverage metrics developed for extreme weather (i.e. Atmospheric Rivers, NE Storms and MCSs) via the “NASA Downscaling Project”, as well as advance and utilize MERRA, LDAS and other obs4MIPs datasets for the model evaluation Kunkel/NCA are interested in exploring.
Personnel Graduations/Changes

Paul Loikith - NCA Postdoc for 2.5+ years, starting faculty position in Dept. of Geography, Portland State University in August.

Huikyo Lee - NCA Postdoc for 2.5+ years, hired at JPL in Data Analysis and Statistics group - still to contribute to RCMES/NCA.

Kim Whitehall - Previous summer intern 2013 and 2014 hired at JPL in Data Sciences group focusing on MISR and other Data Science

New Postdoc? - hoping to hire someone in fall to take Paul’s place.

Jinny Lee - CSLA M.S. student and summer (and likely longer) intern.

Computer Science folks - a number of changes
Summary

- Infrastructure changes/improvements - ESGF, database framework, training and interaction tools, website, and TBD documentation developed over 2015 summer.

- The development and application of a number of model evaluation methodologies and model performance metrics pertaining to climate extremes (temperature, precipitation and circulation) has led to ~5-6 peer reviewed journal articles.

- A number of RCMES training/education activities have been undertaken, including workshops, classroom and specific student use.

- FY’16 work will focus on impacting 4th NCA via NCEI collaborator Kunkel and incorporation of above/more metrics into RCMES.
N. America - NARCCAP via NCAR/Mearns for U.S. NCA
Africa - collaboration with UCT/Hewitson & Rossby Ctr/Jones
E. Asia - exploring collaboration with KMA & APCC, particip. in Sep’11 & Nov’12 mtgs
S. Asia - collaboration with IITM/Sanjay, participated Oct’12 & Sep’13 mtgs.
Arctic - participated in initial Mar’12 mtg, Nov’13 mtg, Jun’14 mtg.
Caribbean, S. America - participated in 1st major mtg Sep’13 and 2nd mtg Apr’14.
Middle East - N. Africa - participating in initial coordinating team and ISSI proposal.

Typically try to support meetings by sending a climate scientist and an IT expert, provide an overview and a tutorial/training.

Have hosted scientists & students at JPL/UCLA

Learning RCM
User Needs
Infusing Support into CORDEX
Example: Surface Energy Budget - Shortwave Radiation

NARCCAP RCM biases in surface insolation against GEWEX-SRB

K-means clustering used to group the January surface temperature PDFs into 5 categories.

Cluster assignments
- The red curve is the average of all PDFs shaded in red on map, etc.
- Clusters primarily reflect variance, with some skewness

Cluster analysis can provide a basis for identifying regions of common PDF morphology

Bivariate PDF skill score

- Measure models’ skill in simulating related variables.
- The example evaluates the cloudiness-surface insolation relationship in the NARCCAP hindcast.
- Results can be visualized using a portrait diagram.