

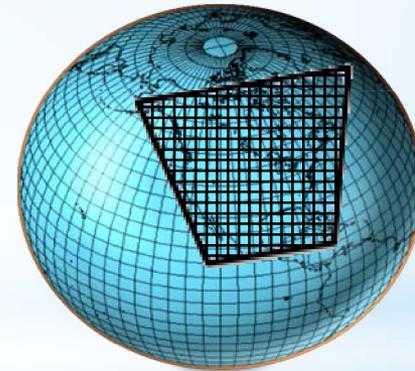
Enabling Regional Climate Model Evaluation: *Combining Observations & IT to Establish Core Climate Model Assessment Capabilities*

Principal Investigator

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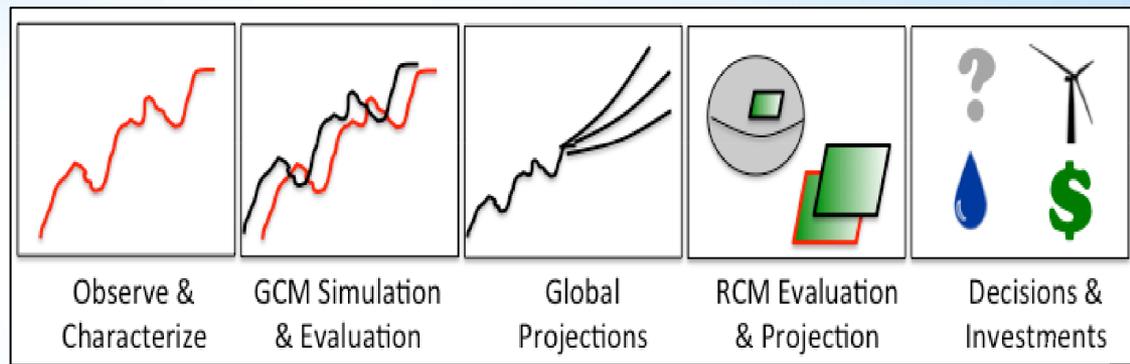


Co-Investigators

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Chris Mattmann, JPL

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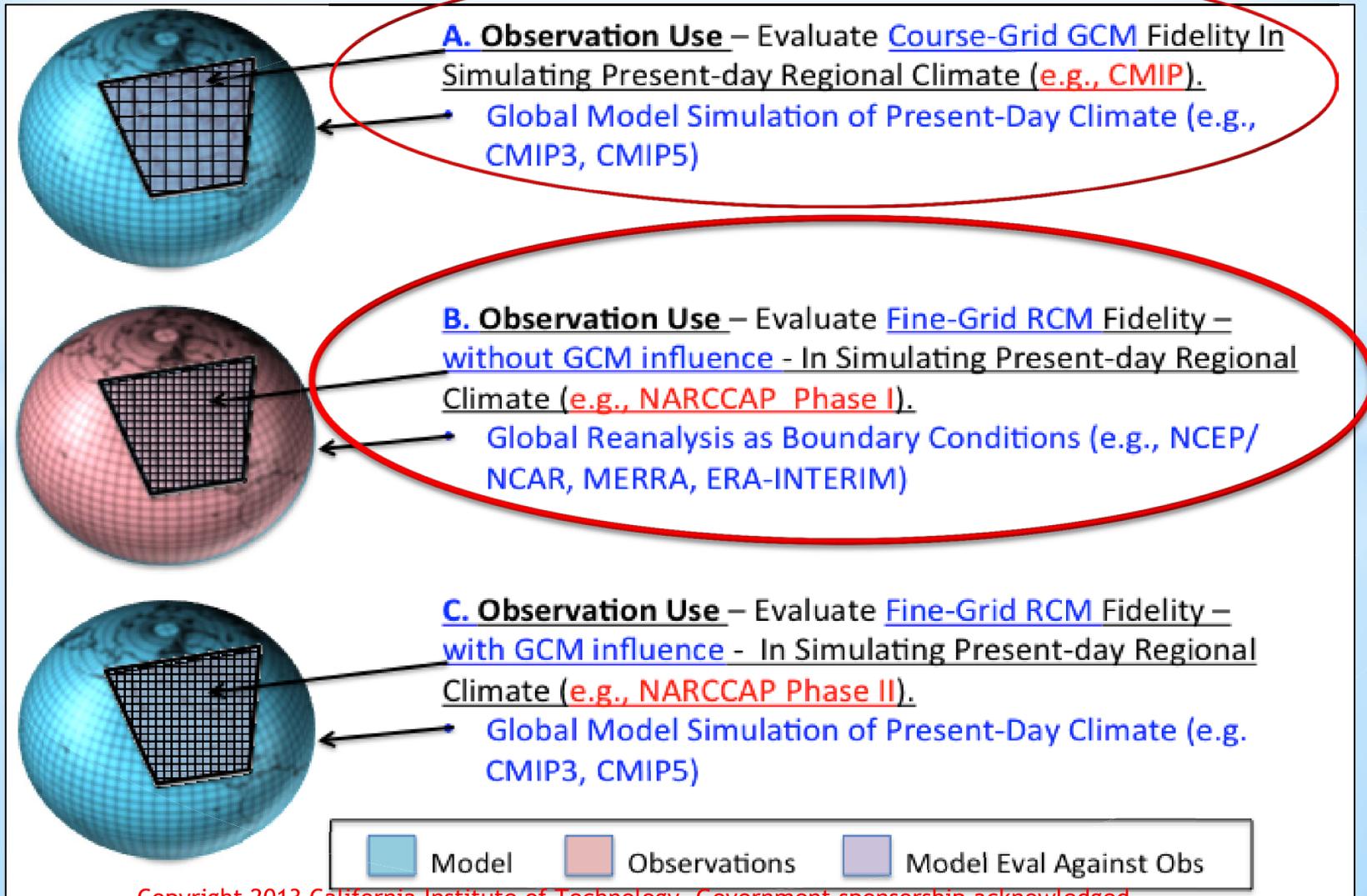


CORDEX Workshop, Brussels, November 2013

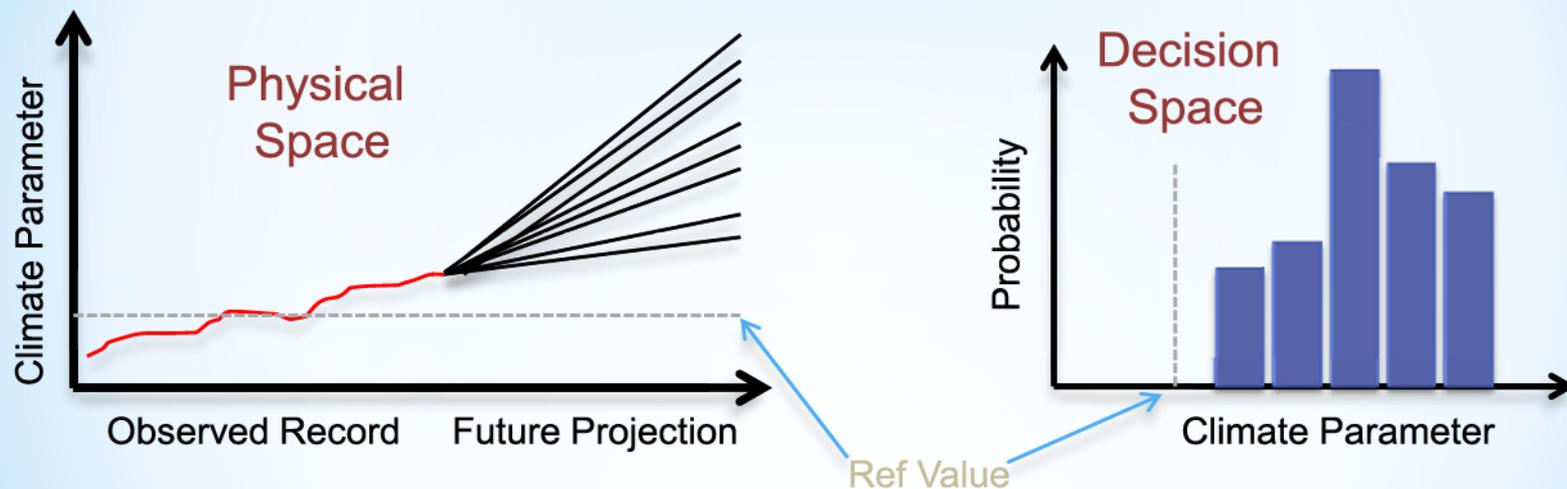
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Using NASA Observations for model evaluation relevant to the NCA



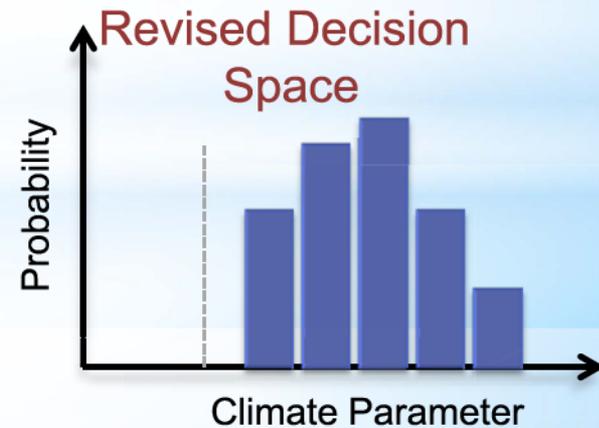
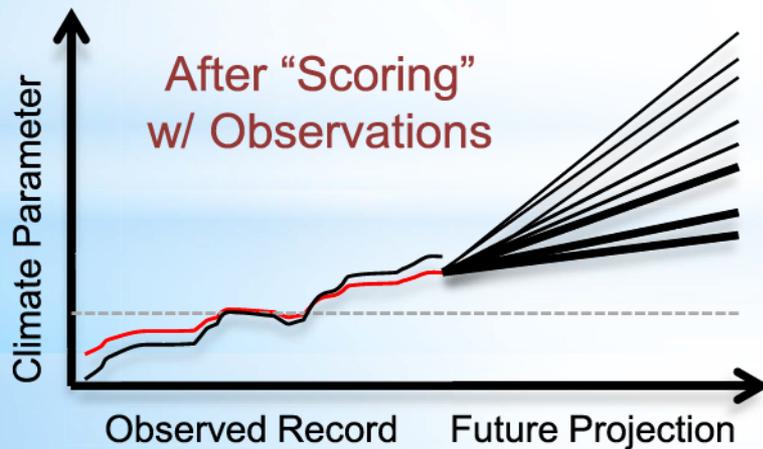
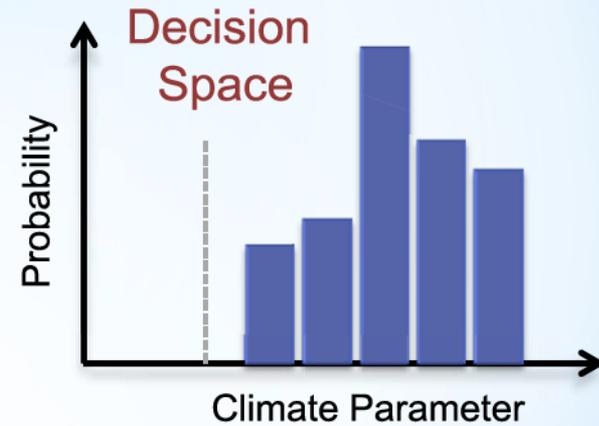
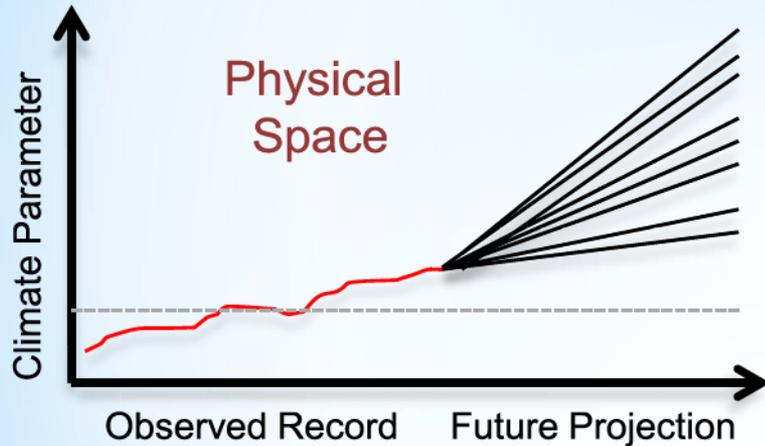
Observations, Performance Metrics & Projection Weighting



Climate Parameter

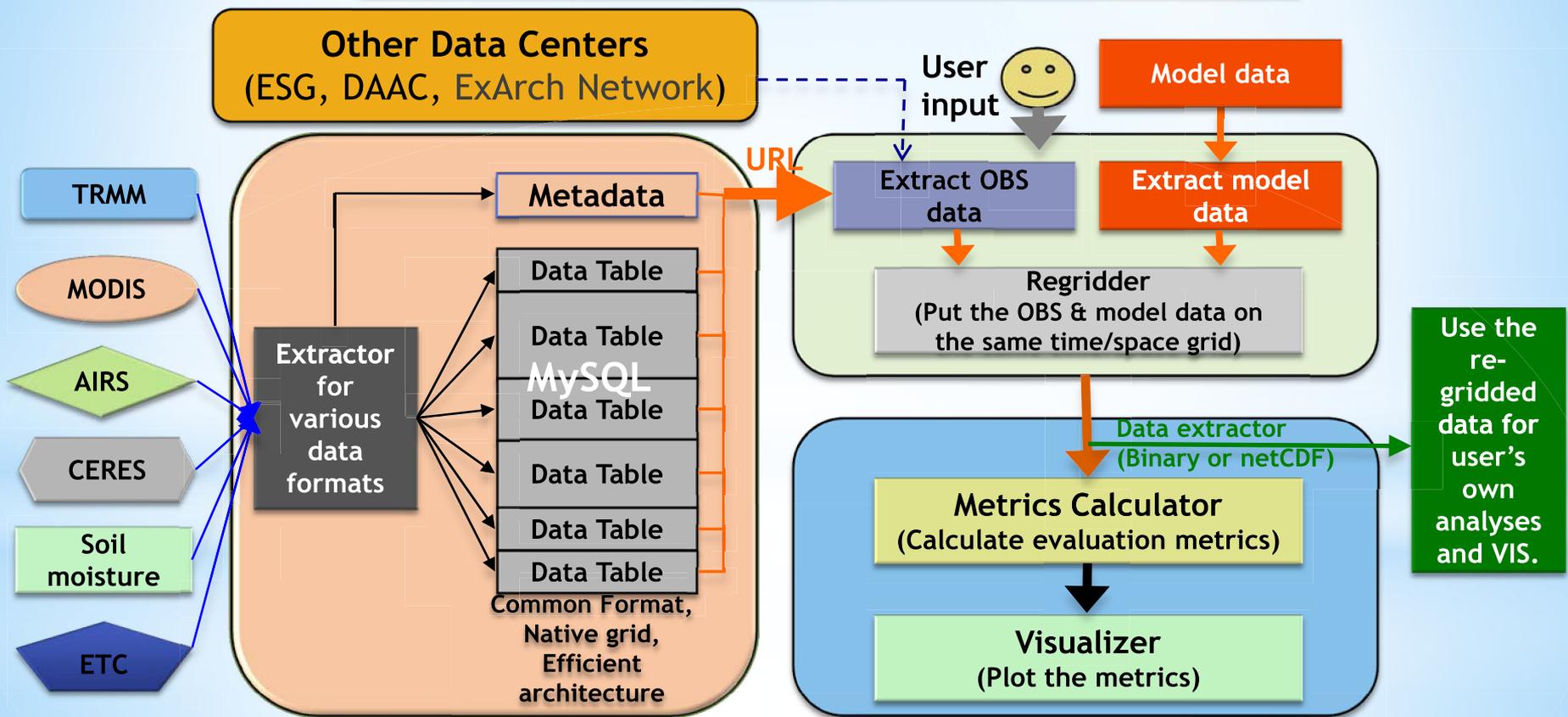
- Sierra Mtn Snowpack at Start of Summer
- Number of Summertime Harmful Ozone Days
- W. Pacific Tropical Cyclone Intensity/Frequency
- An Ice-free Arctic Passage by July
- East Coast Storm Surge Intensity/Frequency
- Frequency of N-Year Drought Conditions in Country X
- etc

Observations, Performance Metrics & Projection Weighting



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

RCMES v2.0 - High-Level Architecture



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

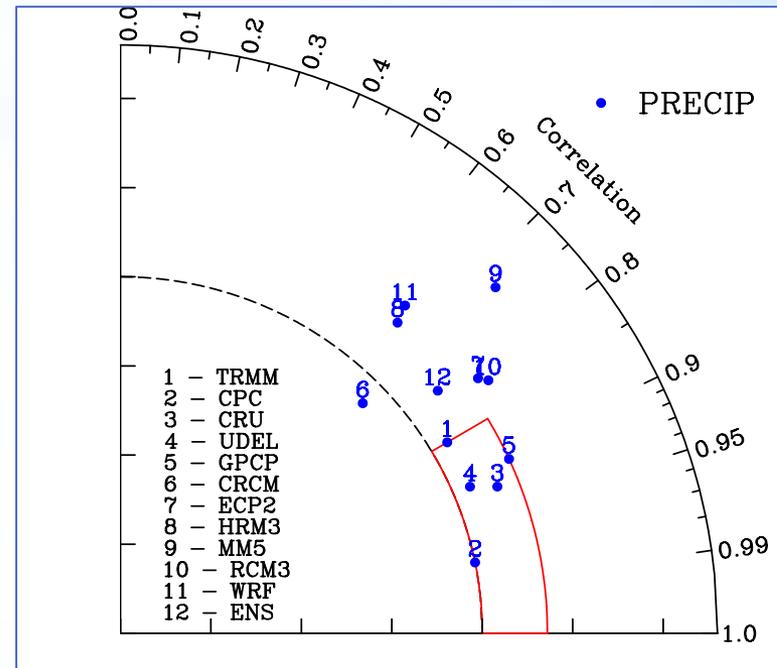
Ingest obs/models, re-gridding, calculate metrics (e.g, bias, RMSE, correlation, significance, PDFs), and visualize results (e.g., contour, time series, Taylor).

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./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.)

RCMES

High-level technical architecture

AVAILABLE

- **Satellite retrievals:** AIRS gridded daily 3D temperature and water vapor; MODIS daily Cloud fraction and snow cover; CERES surface & TOA radiation; Snow Water Equivalent (SWE) data (Sierra Nevada); QuikSCAT winds; MEaSURES sea-level height
- **Satellite-based precipitation data:** TRMM 3B42 3-hourly gridded daily precipitation; GPCP 2.5deg
- **Reanalysis data:** MERRA (Sea level, Surface pressure); ERA-Interim (surface temperature & dewpoint, 3D temperature & geopotential)
- **GEWEX-SRB radiation:** CERES Surface and Top of the atmosphere
- **Gridded surface station analyses:** University of Delaware and CRU precipitation & temperature (0.5deg); APHRODITE Monsoon Asia precipitation (0.25deg); NCEP daily Unified Rain gauge Data (0.25deg)
- **Gridded surface atmosphere and land fields:** GSFC NLDAS

FUTURE

- CloudSat atmospheric ice and liquid, Satellite-based snow (Himalayas), ISCCP cloud fraction, MERRA (water vapor, surface and pressure-level variables), Fine-scale SST, More APHRODITE regions (Eurasia), etc.

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

Progress Tailoring RCMES

*RCMED - database

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

*RCMET - toolkit

- * Evaluation metrics: Bias, RMSE, correlations, PDFs, Bivariate PDFs, etc.
- * Visualization: Contour maps, Taylor & Portrait diagrams, x-y line plots, etc.
- * Constructed Virtual Box and VMWare images for easy deployment and user support
- * Released RCMET 2.1.1 multi-model & multi-observation analysis version of toolkit. The toolkit is currently used in NARCCAP and CORDEX South Asia
- * Open source approach using the Apache environment for the development and distribution of RCMES.

*Public Website/Portal for RCMES and database

- * <http://rcmes.jpl.nasa.gov>

NARCCAP Multi-decadal Hindcast Evaluation Results

Figure 1. The conterminous US domain. The boxes indicate the locations of the 14 subregions.

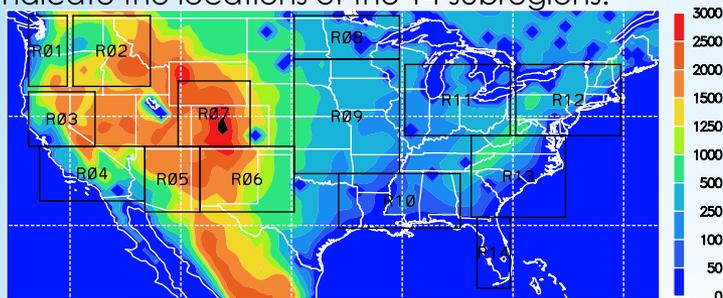


Figure 2. RCM biases in surface insolation against GEWEX-SRB

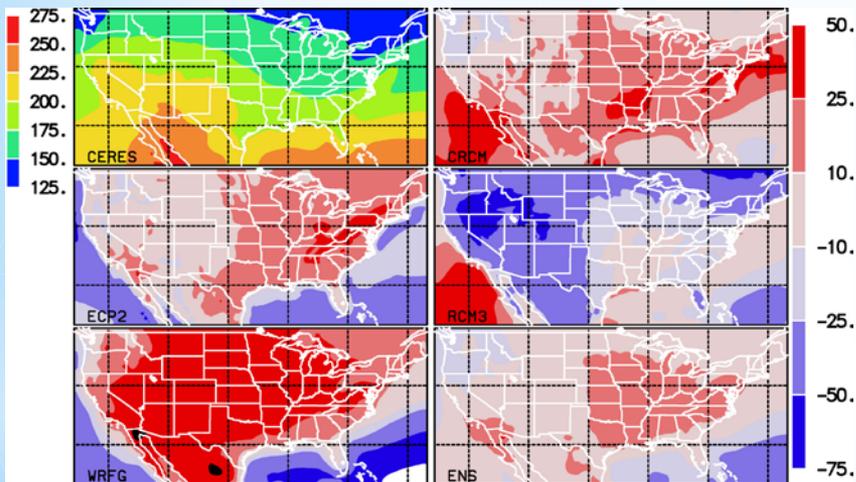


Table 2. The relationship between precip & insolation biases.

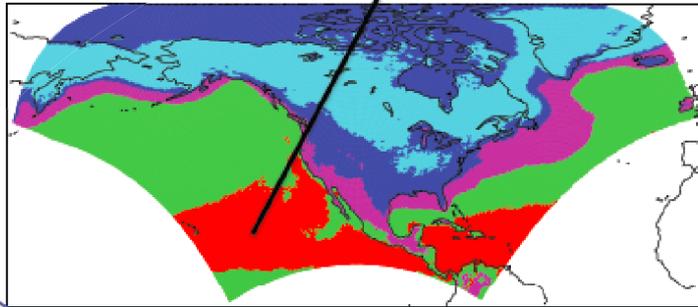
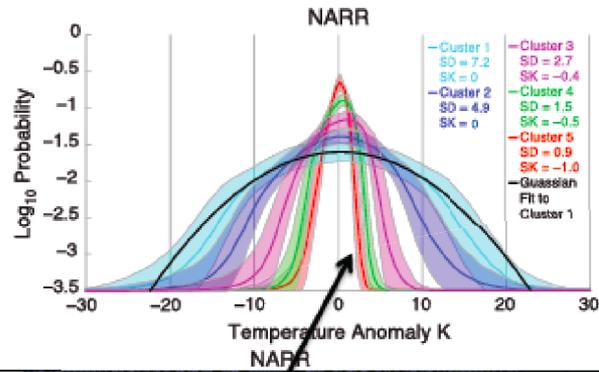
Model	Land-mean bias - Precipitation (mm/d)	Land-mean bias - Insolation (Wm^{-2})	Bias pattern Correlation
CRCM	0.33	10.2	-0.47
ECP2	0.41	9.0	-0.28
RCM3	0.54	-29.9	-0.50
WRFG	-0.08	30.4	-0.18
ENS	0.25	4.9	-0.62

- The monthly-mean **precipitation and surface insolation** over the conterminous US region from **five RCMs** (Table 1) that have participated in the **NARCCAP hindcast experiment** have been evaluated against the GEWEX-SRB data for the 24-year period 1980-2003 (table 2 and Figure 2).
- 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).
- Kim, J., D.E. Waliser, C.A. Mattmann, L.O. Mearns, C.E. Goodale, A.F. Hart, D.J. Crichton, and S. McGinnis, 2013: Evaluations of the surface air temperature, precipitation, and insolation over the conterminous U.S. in the NARCCAP multi-RCM hindcast experiments using RCMES. *J. Climate*.

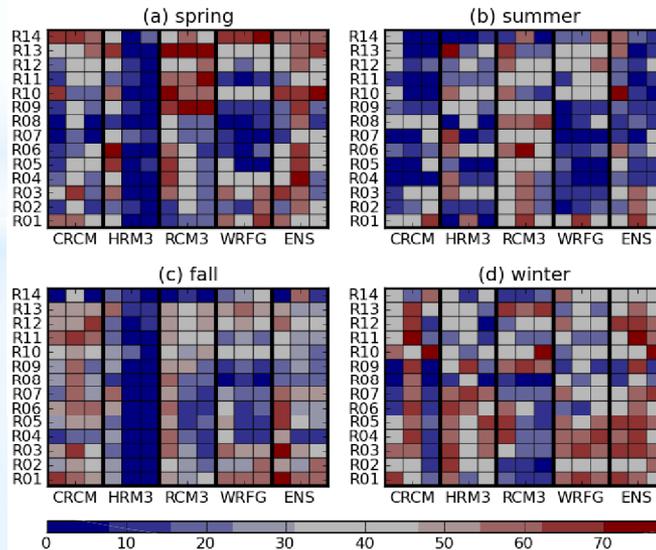
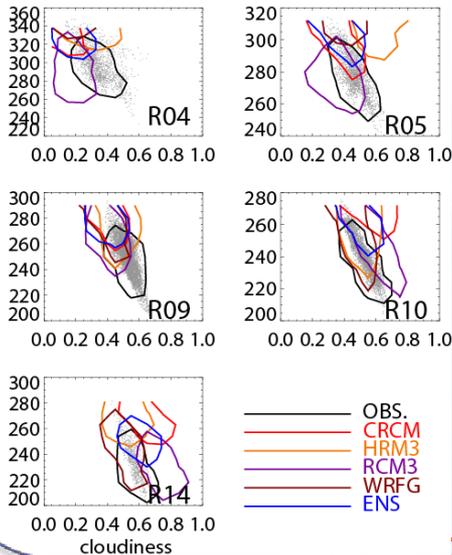
Table 1. The RCMs evaluated in this study.

Model ID	Model Name
M01	CRCM (Canadian Regional Climate Model)
M02	ECP2 (NCEP Regional Spectral Model)
M03	MM5I (MM5 – run by Iowa State Univ.)
M04	RCM3
M05	WRFG (WRF – run by PNNL)
ENS	Model Ensemble (Uniform weighting)

Development of new metrics based on PDFs



- * K-means clustering used to group the January surface temperature PDFs over the NARCCAP domain into 5 categories.
- * (Top) Mean PDFs ofr each cluster. Shading indicates $\pm 1 \sigma$.
- * Cluster assignments
 - * The red curve is the average of all PDFs shaded in red on map, etc.
 - * Cluster assignments primarily reflect variance, with some skewness
- * Cluster analysis can provide a basis for identifying regions of common PDF morphology
- * REF: Loikith et al., 2013, *Geophys. Res. Lett.*, 40, 3710-3714.



- * Bivariate PDF skill score
 - * Measure models' skill in simulating related variables.
 - * Results can be visualized using a portrait diagram.
 - * The example evaluates the cloudiness-surface insolation relationship in the NARCCAP hindcast.
- * REF: Lee et al., 2013, *J. Geophys. Res.*, submitted.

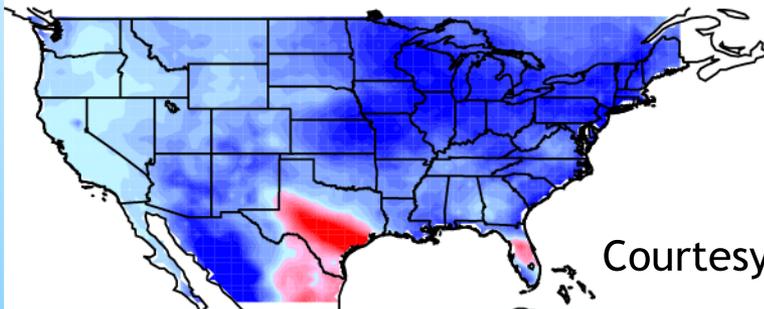
Capability to Perform Regional Evaluation of GCMs

CMIP5 GCMs vs NARCCAP RCMs

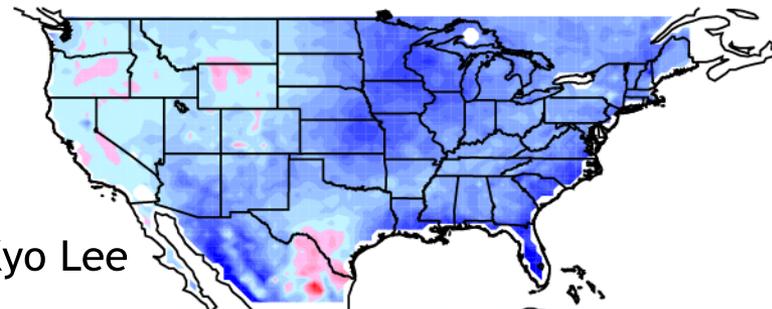
- * RCMES can be also used to conveniently evaluate multiple global-scale models (GCMs) in various regions using multiple observation data and compare GCMs with RCMs
- * Related NASA CMAC effort is provide direct connection between RCMES and ESGF – the IT host for CMIP output.
- * Overall, NARCCAP RCMs show better performance in simulating precipitation in the contiguous U.S.

Precipitation Bias for July

CMIP5 GCMs - observation



NARCCAP RCMs - observation



Courtesy: Kyo Lee



SYNERGISTIC INTERACTIONS

* **NARCCAP = Precursor to CORDEX North America and model basis for NCA.**

- * Two papers have been published and two more are currently under review.
- * Participated in the recent NCPP workshop and contributing to CORDEX North America planning.

* **Other CORDEX regions**

* Africa:

- * In collaboration with U. Cape Town (Hewitson), Rep of S. Africa, and Swedish Meteorological and Hydrological Institute, Sweden. Partial support from Climate & Knowledge Development Network (CKDN; <http://cdkn.org/>)

* South & East Asia

- * Installed the latest release RCMES-VM version at IITM for the CORDEX-South Asia evaluation study.
- * Provided tutorials at the second CORDEX South Asia workshop (August 2013) with the latest release (v 2.1.1)
- * A joint paper with IITM is underway based on the analyses/evaluation of multiple observations/model data
- * Attended (1st and) 2nd CORDEX E. Asia meeting in October, 2012.

* EXPLORING ADOPTION OF RCMES for CORDEX Caribbean, South America, Australia, Arctic, Middle East – N. Africa

- * RCMES for use in climate training: 1st user lab in Apr 2012 in Dakar; Workshop in Cape Town (Sep 2013)

* **Student involvement:**

* Kim Whitehall – Howard University/Prof. G. Jenkins Advisor

- * Visited JPL during summer 2012 and 2013; Incorporating RCMES and adding capability for her PhD studies.
- * Developed idea for WMO Bulletin article – see later slide.

* Jesslyn Whittell – A summer student from Marymount High School and is a new undergrad student at Berkeley

- * Visited JPL in summer 2012 and 2013 and worked on RCMES development with the IT staff.

* Alexander Goodman – Previous undergrad at UIUC, New graduate student in Atmospheric Sciences at CSU.

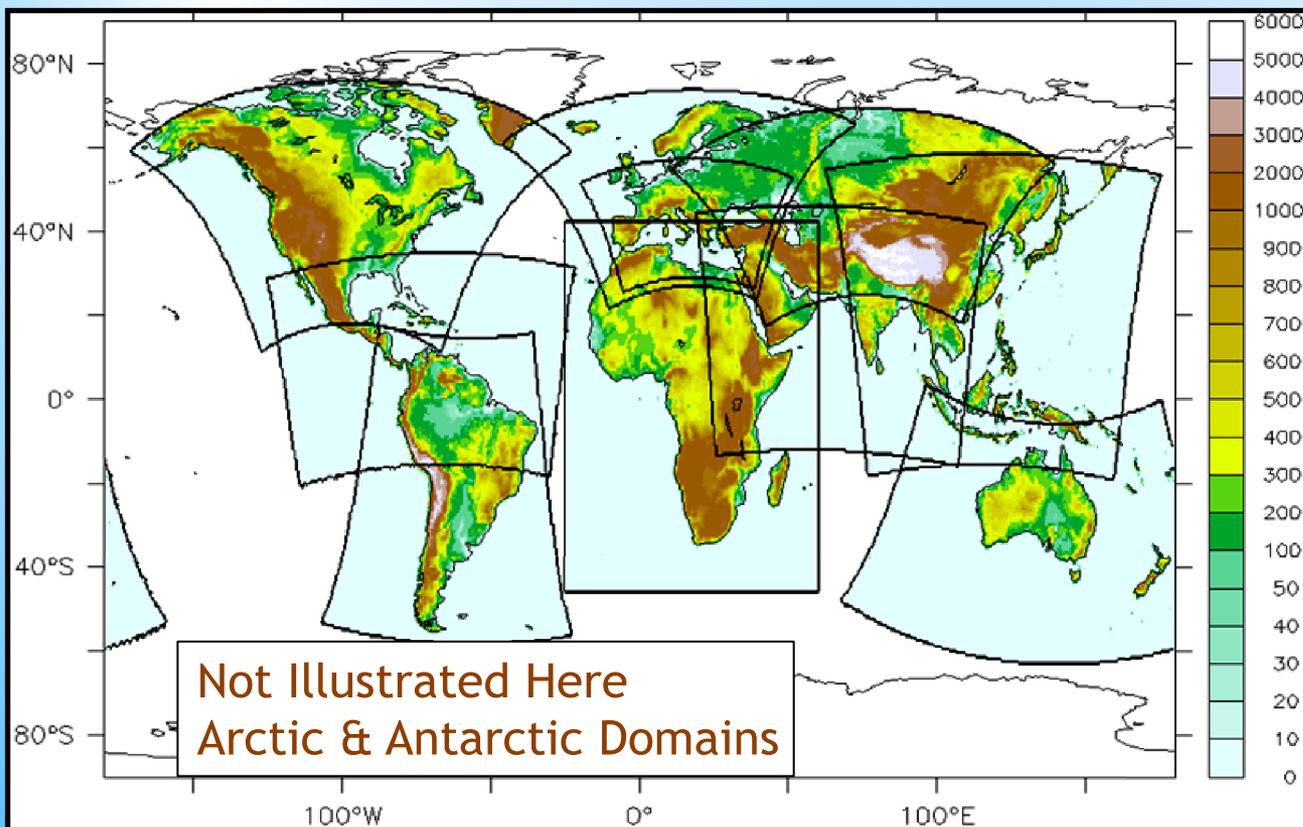
- * Visited JPL in summer 2013 and improved visualization software

* Rama Rao M. V. S. – IITM, India/J. Sanjay

- * Applying RCMES to CORDEX-S. Asia as model evaluation/data handling tool for his research in land-atmosphere interaction

Synergistic Interactions

- **N. America** - funded via NASA for U.S. NCA (NCAR, NARCCAP)
- **Africa** - collaboration & analysis ongoing (UCT, Rossby Ctr), funded by CDKN, NSF
- **E. Asia** - exploring collaboration (KMA, APCC), participated in both workshops
- **S. Asia** - hosted organizer Dr. Sanjay (IITM) at JPL, att Oct'12 and Sep'13 mtgs.
- **Arctic** - participated in initial mtg; hosted M. Cooke from Paul Kushner (U. Toronto)
- **Caribbean, S. America** - participated in initial planning mtg Sep'13
- **Middle East - N. Africa** - invitation by WCRP to participate in coordinating team



**Learning
RCM User
Needs**

**Infusing
Support into
CORDEX**



Summary and Plans

Publications from NARCCAP Model Evaluation Studies

- * Kim, J., D.E. Waliser, C.A. Mattmann, L.O. Mearns, et al., 2013: Evaluation of the surface climatology over the conterminous United States in the NARCCAP hindcast experiment using RCMES. *J. Climate*, **26**, 5698-5715.
- * Loikith, P.C., B.R. Lintner, Jinwon Kim, H. Lee, et al., 2013: Classifying reanalysis surface temperature probability density functions (pdfs) over North America with cluster analysis. *Geophys. Res. Lett.*, **40**, 3710-3714, doi: 10.1002/grl.50688.
- * Lee, H., J. Kim, D. Waliser, P. Loikith, et al., 2013: Evaluation of simulation fidelity for precipitation, cloud fraction and insolation in the North American Regional Climate Change Assessment Program (NARCCAP), *J. Geophys. Res.*, submitted.
- * Loikith, P., J. Kim, H. Lee, B. Lintner, C. Mattmann, J.D. Neelin, D. Waliser, L. Mearns, and S. McGinnis, 2013: Evaluation of surface temperature probability distribution functions in the NARCCAP hindcast experiment. *J. Climate*, submitted.

Select Related papers

- * Kim, J., D. Waliser, C. Mattmann, C. Goodale, A. Hart, P. Zimdars, D. Crichton et al., 2013: Evaluation of the CORDEX-Africa multi-RCM hindcast: systematic model errors. *Clim Dyn*, DOI 10.1007/s00382-013-1751-7.
- * Mattmann, C., D. Waliser, Jinwon Kim, C. Goodale, A. Hart, P. Ramirez, D. Crichton, et al., 2013: Cloud computing and virtualization within the Regional Climate Model Evaluation System. *Earth Sci. Informatics*, doi 10.1007/s12145-013-0126-2.

RCMES development

- RCMED database – inclusion of a number of additional satellite and other datasets
- RCMET toolkit – additional metrics, multi-observation handling capability
- Improved user interface and portability – moving toward more community use (e.g. CORDEX) via open source
- Website improvement to include training videos

Two formal NCA Inputs (+ formal reviews of IPCC Ch. 9 Model Evaluation)

Community interactions & collaborations

- CORDEX N. America, Africa, S. Asia, S. America, Caribbean, E. Asia, Arctic

Training 2 (partially supported) Postdocs & a number of Students

Near-term plan

- RCMES updates with additional datasets, evaluation metrics and user-oriented analyses
- Improved user Interface and portability via GUI and virtual machine
- Evaluation of high-frequency (daily) variability in the NARCCAP hindcast data
- Regional evaluations of CMIP5
- Cultivate related CORDEX opportunities to gain insight into user and decision-support needs.

