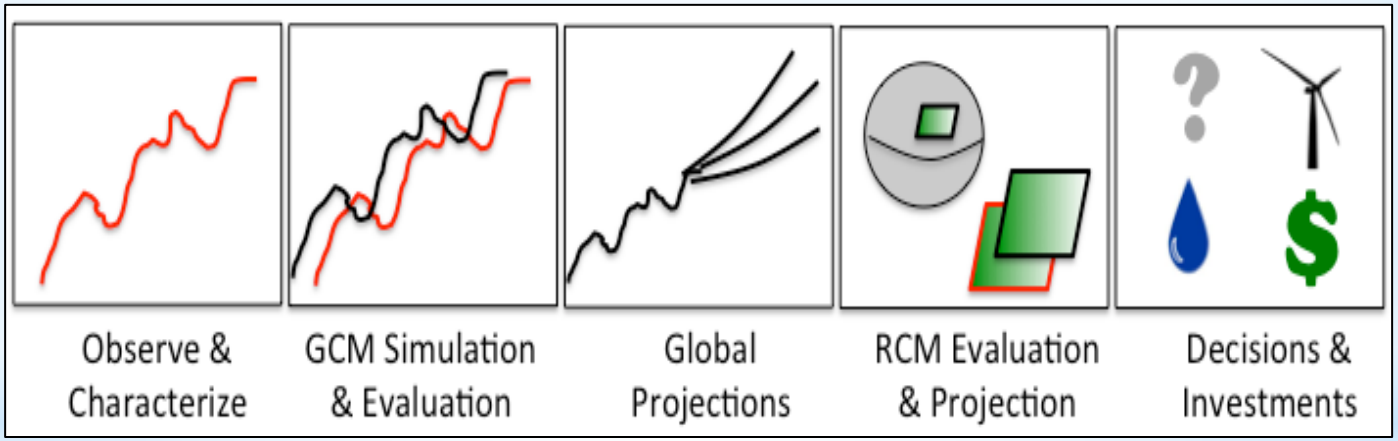
Enabling Regional Climate Model Evaluation: A Critical Use of Observations for Establishing Core NCA Capabilities

RCMES.JPL.NASA.GOV



From Whitehall et al. 2012, WMO Bull.

Duane Waliser

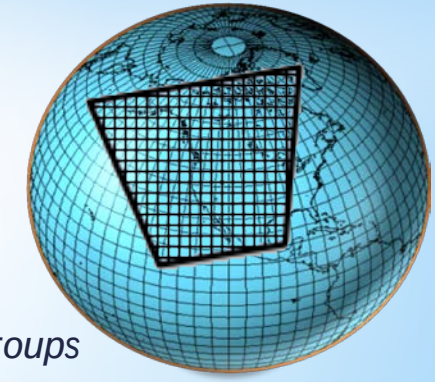
Jet Propulsion Laboratory/Caltech

Chris Mattmann, Paul Loikith, Huikyo Lee, etc, JPL

Jinwon Kim, UCLA

Linda Mearns, NCAR

& many others, including a number of CORDEX domain working groups



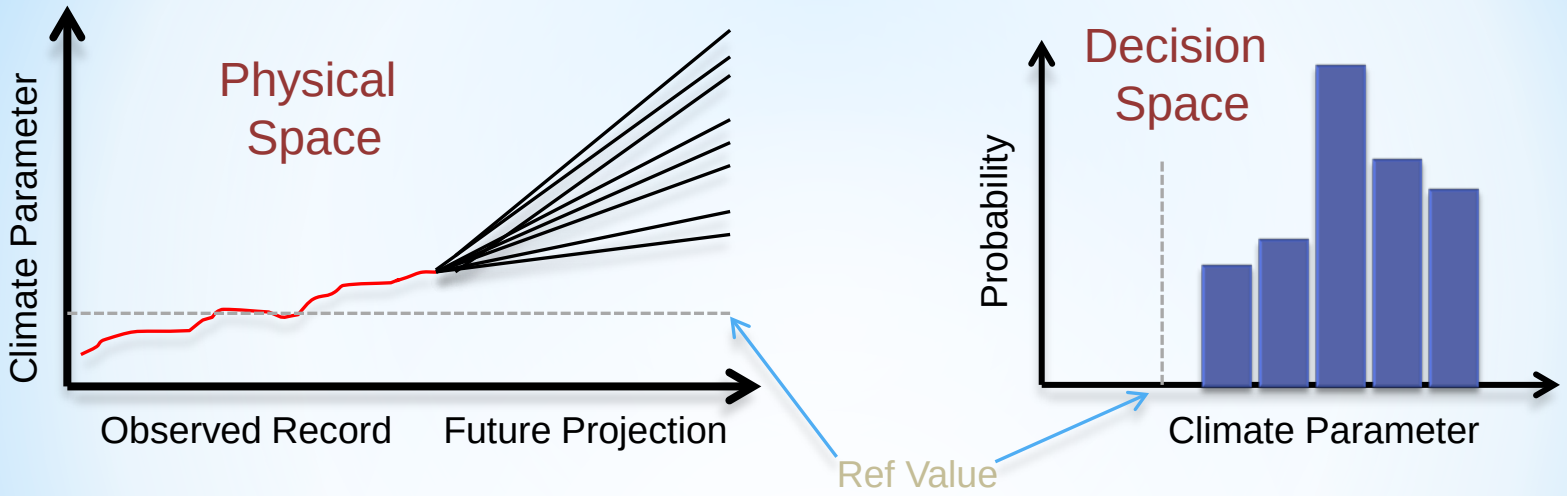
Leverages support from CMAC & ESTO (PI: Mattman) & NSF G8 Initiative for CORDEX

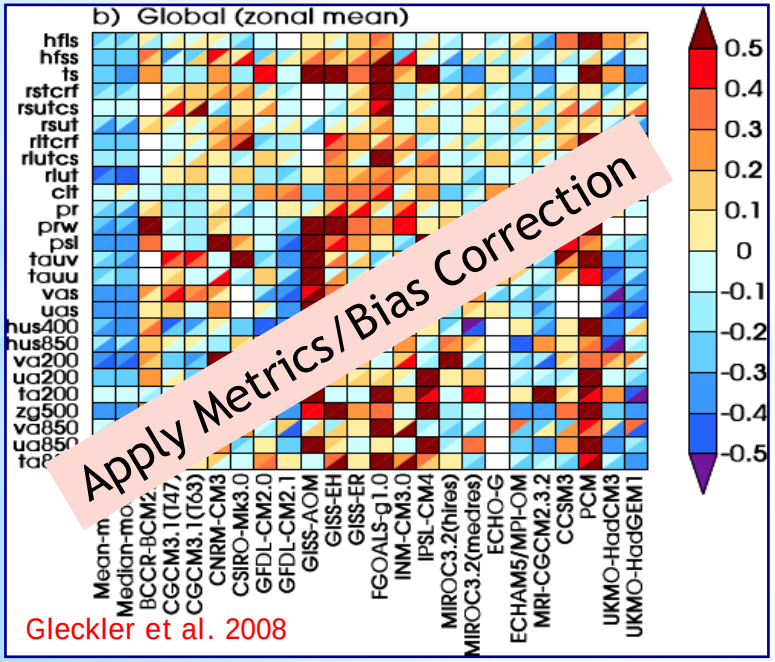
Essential Roles of Observations in Climate Modeling/Projection

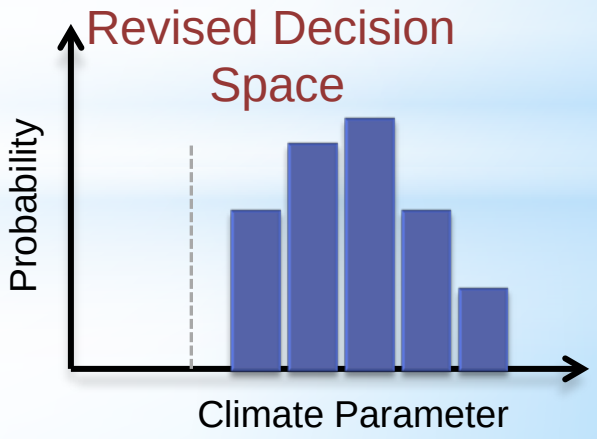
1. Model Development & Improvement, Evaluation

2. Model Evaluation for Uncertainty Consideration/Quantification

OBSERVATIONS: Model Evaluation & Uncertainty Consideration/Quantification



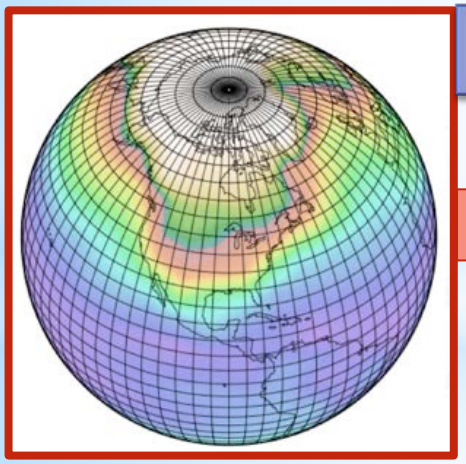




Bridging Models and Observations

Global Models

Global Modeling



Systematic IT Support & Infrastructure

Systematic Model Development & Improvement

AMIP I&II | ESGF | xMIPs

CMIP 1&2 | CMIP 3&5

Systematic Model Experiments

Closing Gap

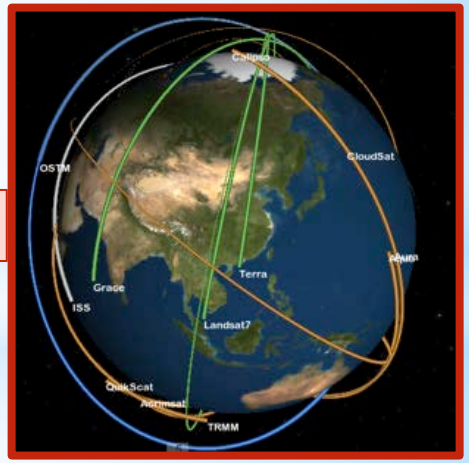
Systematic coordination of obs for MIPs

obs4MIPs

Clim Metrics Panel

Systematic Application of Metrics

Observations

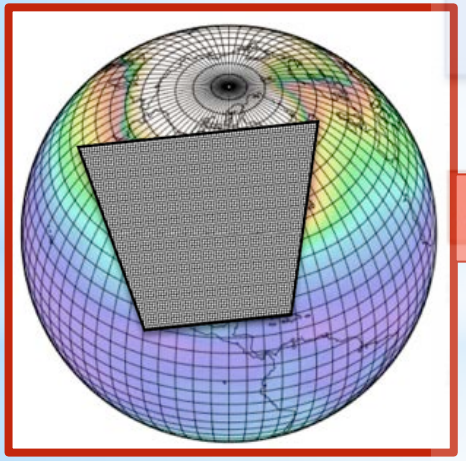


2+ Decades of Directed Progress

Bridging Models and Observations

Regional Models

Regional Modeling



Ensembles & NARCCAP

ESGF

CORDEX

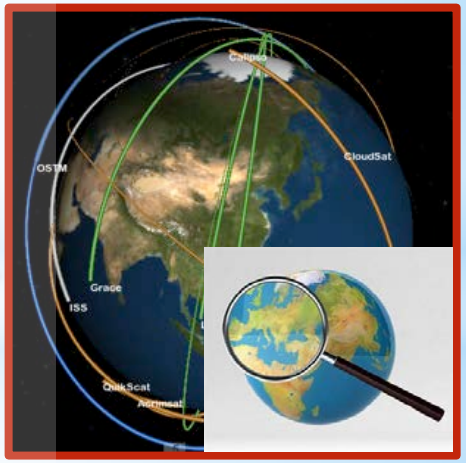
Systematic Model Experiments

GCM heritage can be utilized

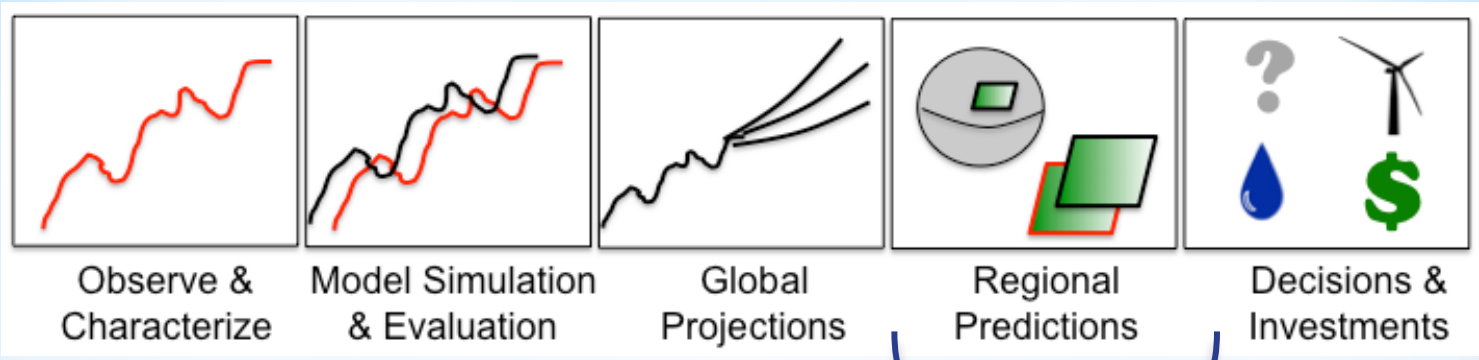
< Bigger Model-Obs Gap >

RCMES

Observations



RCMES Motivation & Goals



GOALS

- Make observation datasets, with some 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 tasks:

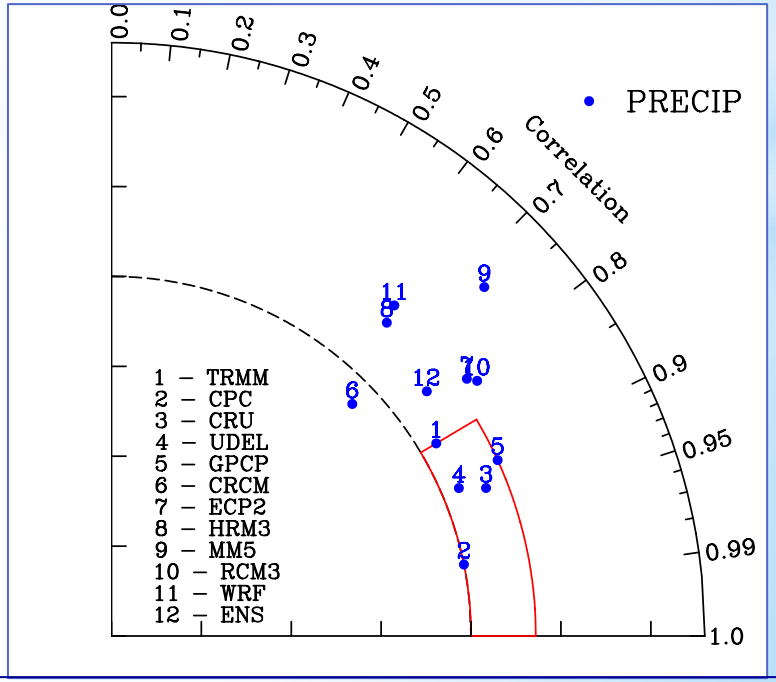
I) Tailoring RCMES for application to the NCA.
(e.g. data sets, metrics, visualization, GUI)

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

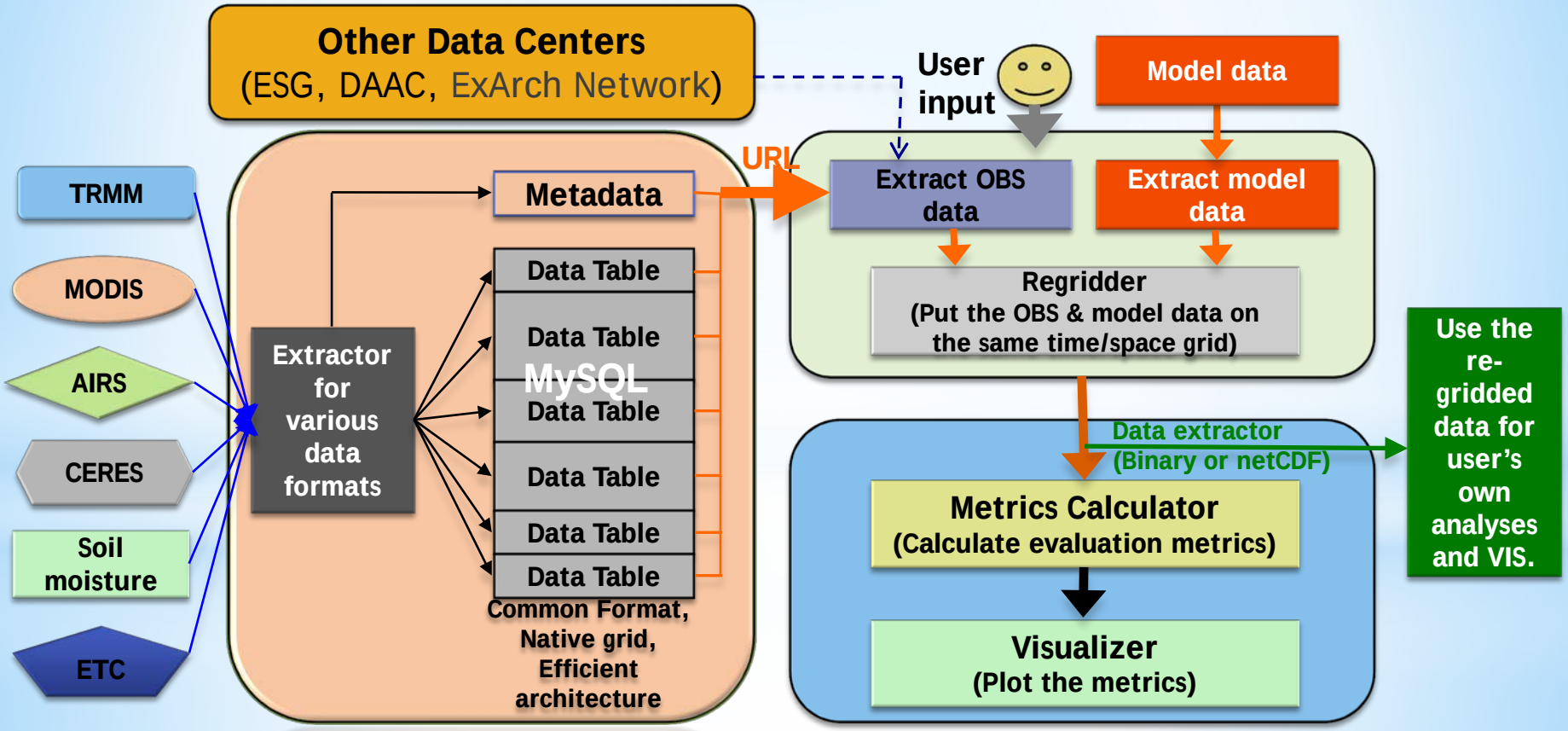
Observation-based model performance metrics for modeling regional climate.



Evaluation of the NARCCAP hindcast precipitation and the uncertainty in precipitation observations for the US region (*Kim et al., 2013, J. Climate.*)

RCMES Motivation & Goals

RCMES – High-Level Architecture – *powered by Apache Climate*



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-grid, calculate metrics (e.g, bias, RMSE, correlation, significance, PDFs), and visualize results (e.g., contour, time series, Taylor).

RCMES Observations and Analysis Tools

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); AMSR-E SST, QuikSCAT winds; AVISO sea-level height
- **Satellite-based precipitation data:** TRMM 3B42 precipitation (0.25deg); GPCP 2.5deg
- **Satellite-based Evapotranspiration** (J. Fisher/JPL) 1deg (0.5 pending)
- **Reanalysis data:** MERRA (Sea level, Surface pressure); ERA-Interim (surface temperature, dewpoint, & precipitation; 3D temperature & geopotential); NLDAS (a number of hydrology related variables)
- **Gridded surface station analyses:** University of Delaware and CRU precipitation & temperature (0.5deg); APHRODITE Monsoon Asia precipitation (0.25deg); NCEP/CPC Unified Rain gauge Data (0.25deg), Global Precipitation Climatology Center (0.5deg)
- **Gridded surface atmosphere and land fields**: GSFC NLDAS, GLDAS (in progress)

FUTURE

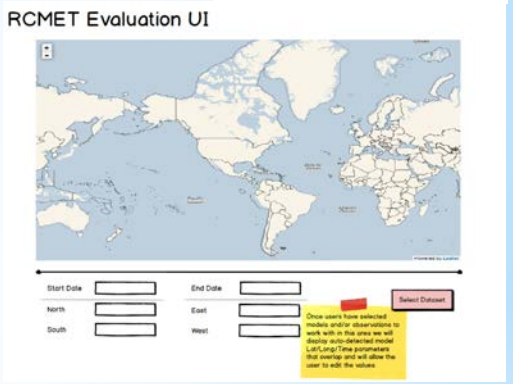
- CloudSat atmospheric ice and liquid, Satellite-based snow (Himalayas), ISCCP cloud fraction, MERRA (water vapor, surface and pressure-level variables), Fine-scale SST, More APHRODITE regions (Eurasia), ESA soil moisture content (in progress), etc.

Evaluation metrics: Bias, RMSE, correlations, PDFs, Bivariate PDFs, etc.
Visualization: Contour maps, Taylor & Portrait diagrams, time series, etc.

3 Ways to Use RCMES

- **Easy**: Graphical user interface (UI) version.
  - Point and click model evaluation.
  - See demo video at rcmes.jpl.nasa.gov/training/videos.
  - Runs in a virtual machine (VM) environment.

RCMES User Interface

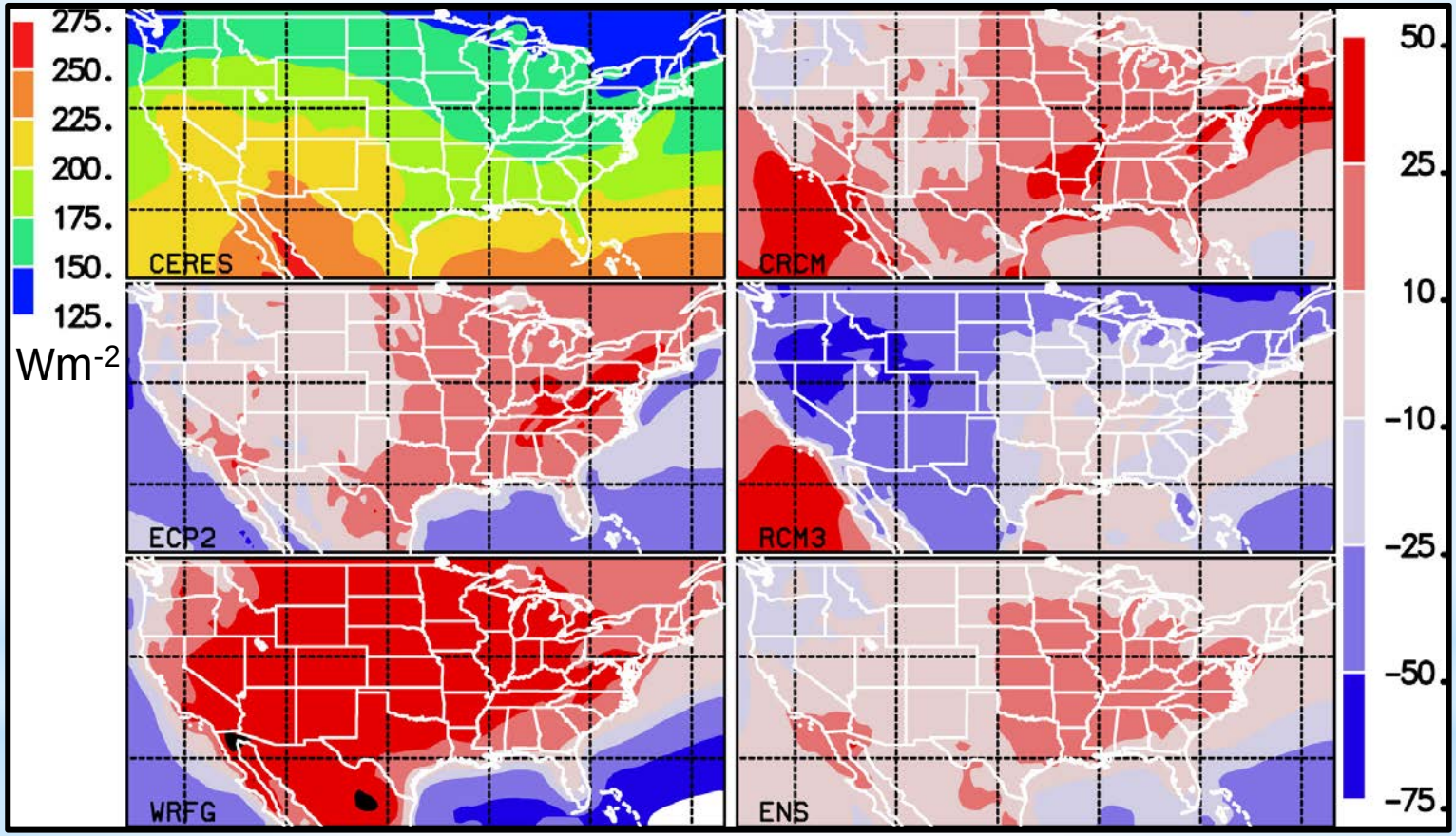


- **Intermediate**: Command line version (also in VM)
- **Advanced**: Check out **open source** code at: https://github.com/apache/climate.
  - Requires installation of Python libraries on user's machine.
  - Allows users to contribute to RCMES development

* All downloads are available at rcmes.jpl.nasa.gov *

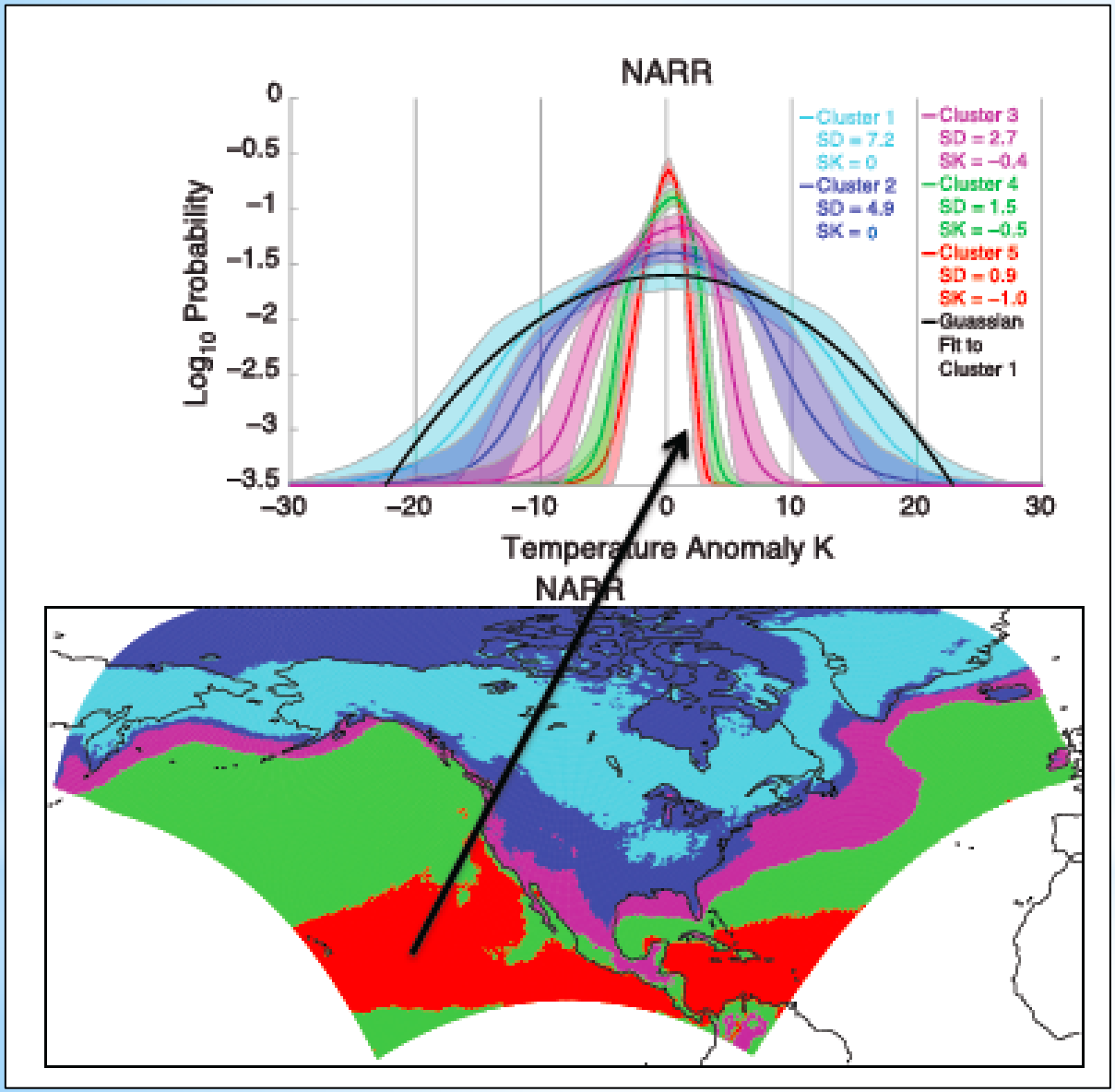
Example: Surface Energy Budget – Shortwave Radiation

NARCCAP RCM biases in surface insolation against GEWEX-SRB



Kim, J., D.E. Waliser, C.A. Mattmann, L.O. Mearns, C.E. Goodale, A.F. Hart, D.J. Crichton, and S. McGinnis, 2013: J. Climate.

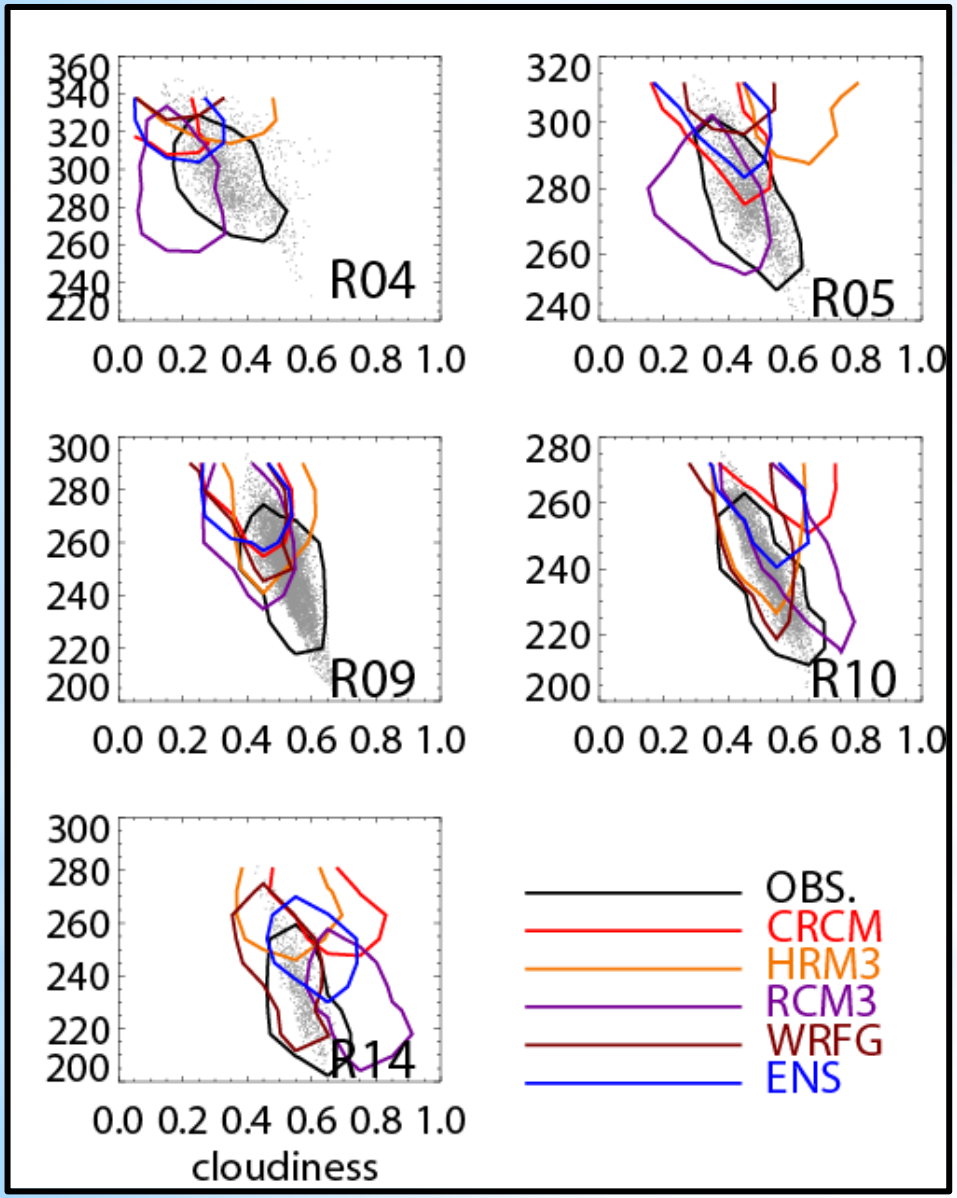
Development : PDFs and Quantifying Extremes



* 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

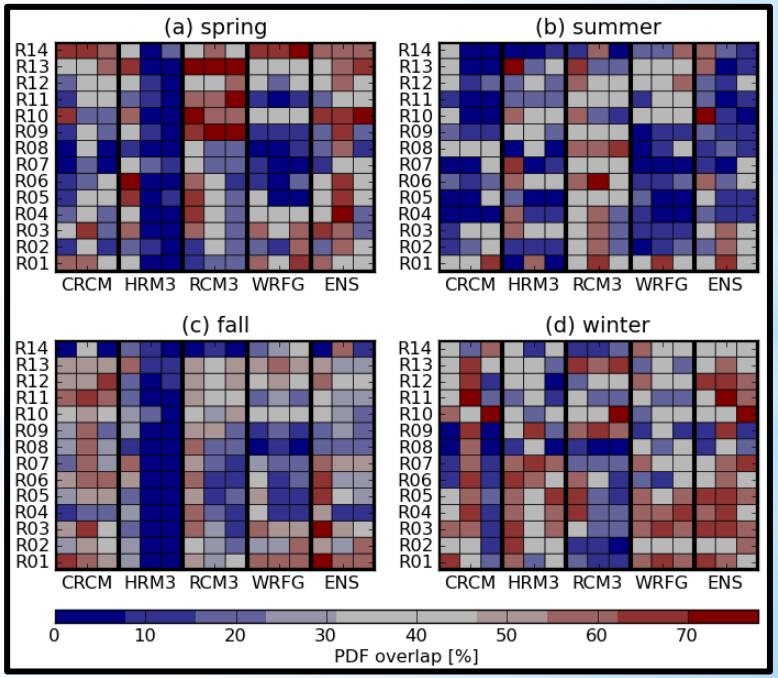
Loikith et al., 2013, *Geophys. Res. Lett.*, 40, 3710-3714.

Development : PDFs and Quantifying Extremes



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.

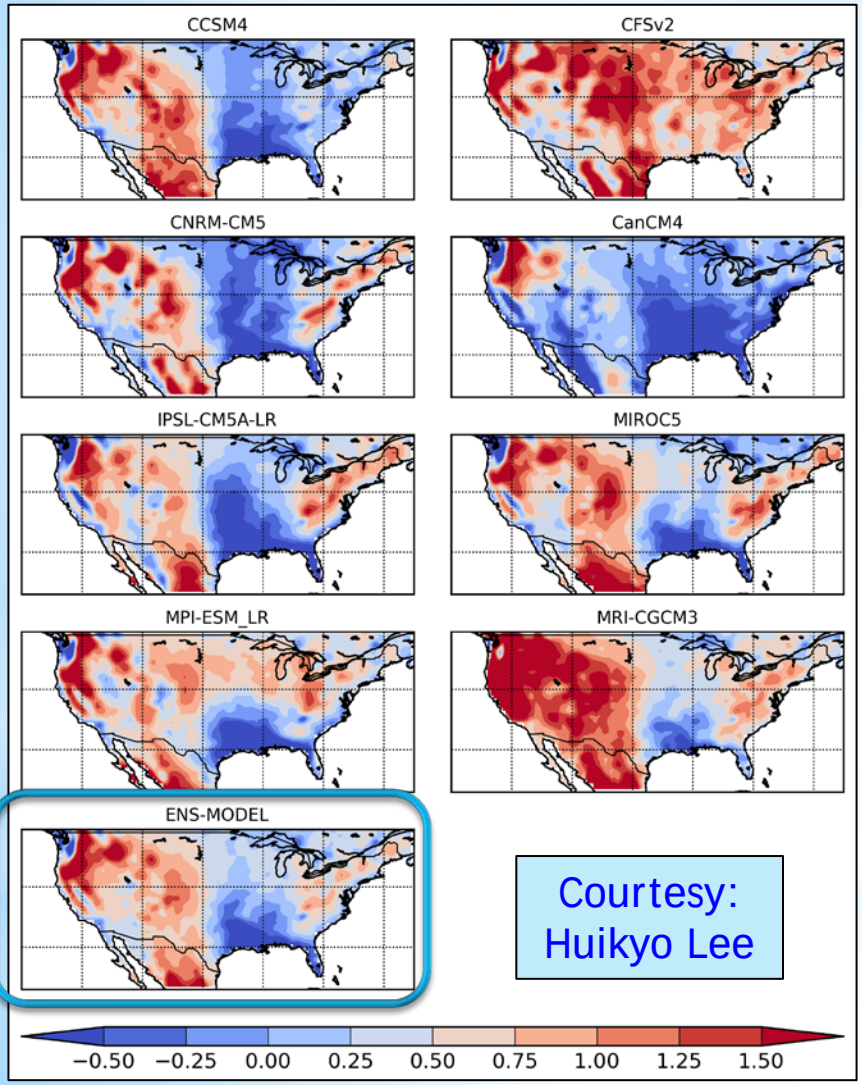


Lee et al., 2013, *J. Geophys. Res.*, submitted.

Capability to Perform Regional Evaluation of GCMs

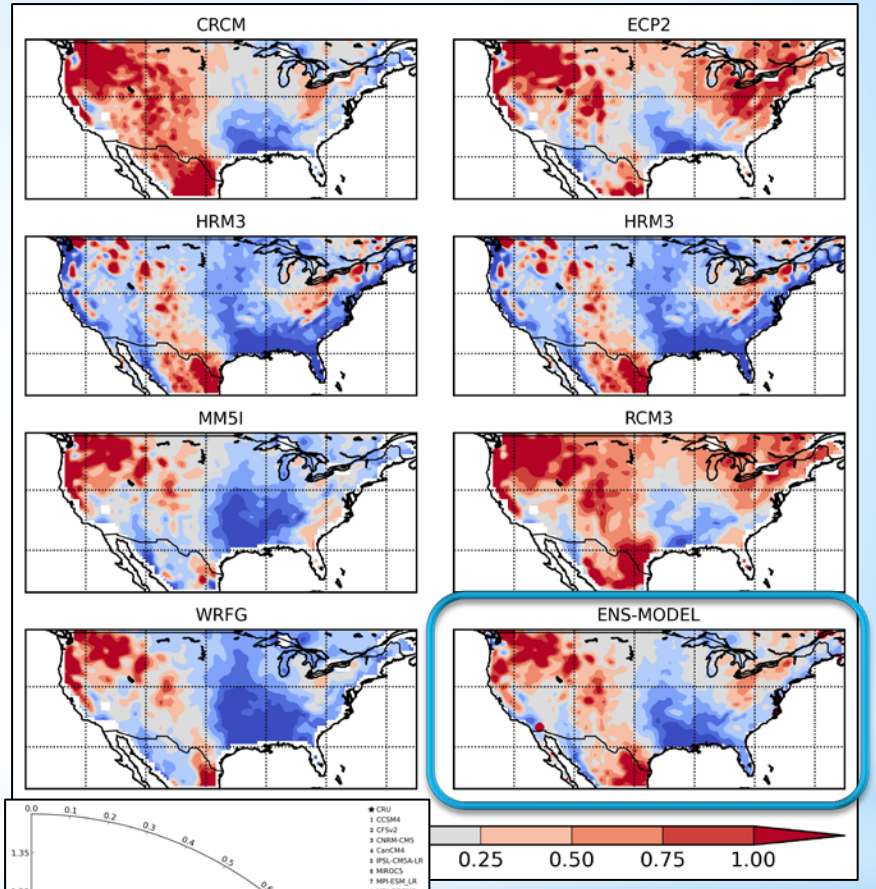
Annual Precipitation Bias

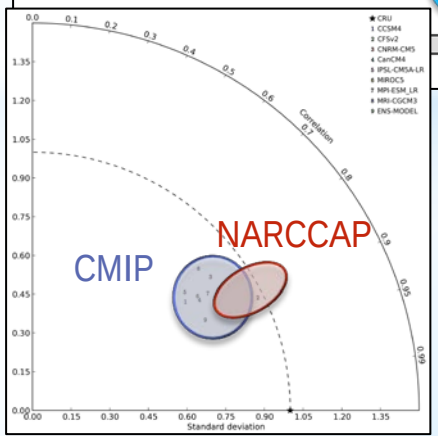
CMIP5 GCMs - observation



Courtesy: Huikyo Lee

NARCCAP RCMs - observation





Direct Access to ESGF in Progress

Publications & NCA Inputs

Other Ongoing Science Analyses - Publications in Preparation

P. Loikith – Extremes, skewness & associated circulation features

H. Lee – Bayesian ensemble averaging

J. Kim – Evaluation of observed and modeled Precipitation over India and Hydrological Cycle in Western US.

NARCCAP/NCA

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., 2014: 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/CORDEX

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.

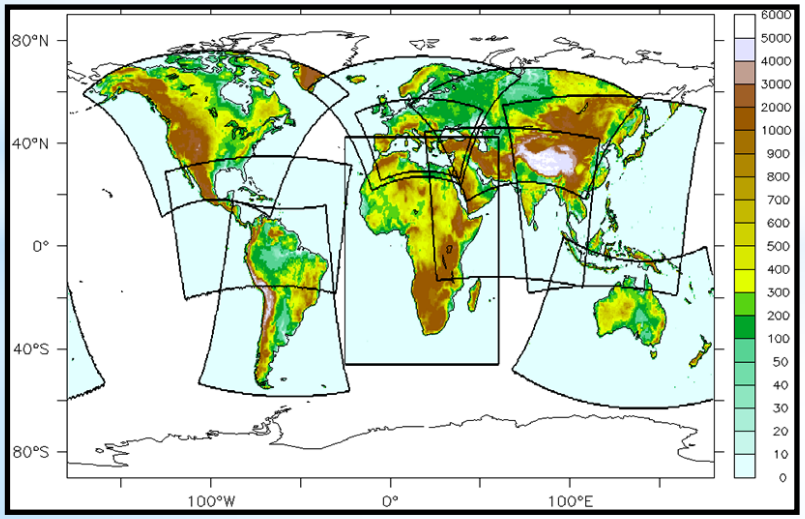
Two formal NCA Inputs (Model Evaluation from Science and IT Perspectives)

CORDEX Interactions & Support

- **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

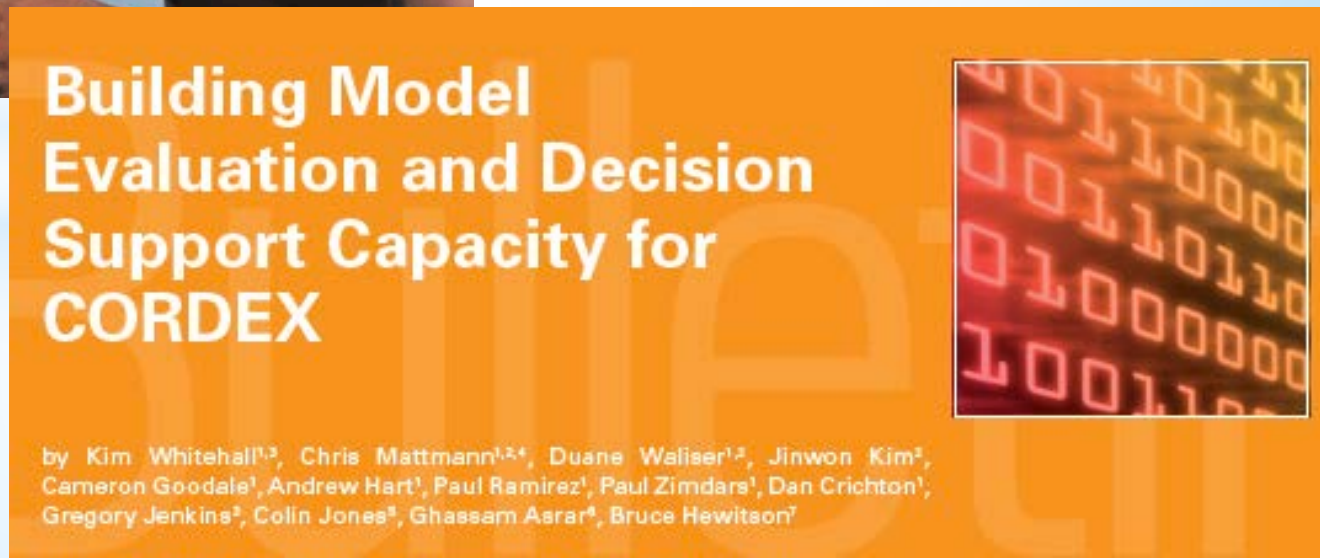


Learning RCM User Needs

Infusing Support into CORDEX

RCMES article in the Oct 2012 issue of the WMO Bulletin highlighting its potential role in WMO's new Global Framework for Climate Services

Kim Whitehall is a Howard University graduate student. She spent 2 summers at JPL learning & contributing to RCMES.



Education and Training

Student involvement

Kim Whitehall – Howard University/Prof. G. Jenkins Advisor
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 JPL 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 evalution in N. and C. America.

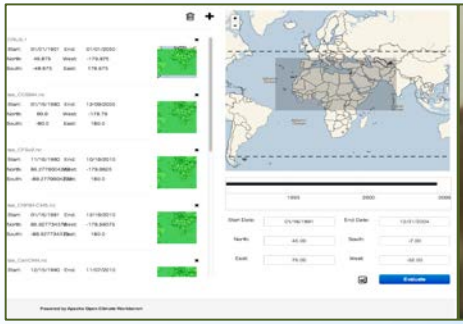
Melanie Cooke – Graduate student at U. Toronto w/ P. Kushner
Short term visit to JPL to learn RCMES for research on RCM of Arctic

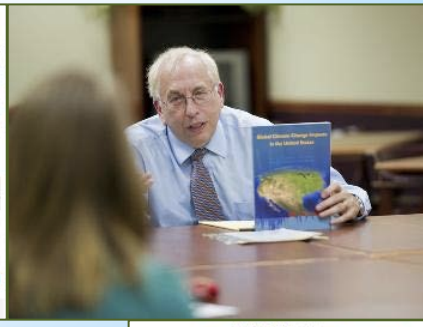
Training Sessions or Webinars

CORDEX-Related

2012-3 Africa, S. Asia, E. Asia

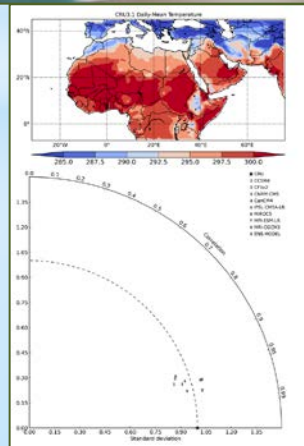
2014: L. America, Arctic





Classroom Instruction

* In 2014 spring semester, 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.
* 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 recent homework assignment.



Summary

- An RCM evaluation system (RCMES) has been developed to support RCM/NCA model evaluation and improvement.
- RCMES provides single point access to wide range of global and regional observation data sets, with some emphasis on satellite data sets.
- RCMES provides basic analysis and visualization tools.
- RCMES will have full function access to ESGF (CMIP or CORDEX) soon.
- RCMES database and tools are extensible – an intrinsic capability in some areas and via an open source code approach.
- RCMES easy (web/slow), intermediate (virtual machine), and expert (open source) access.
- **There is a long way to go and many things RCMES could/should do but doesn't (yet).** Your input and participation is welcome.
  - ✓ Database expansion, more metrics/diagnostics, improved GUI, training

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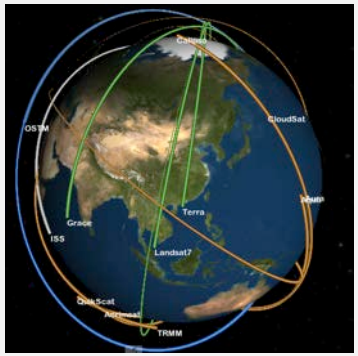
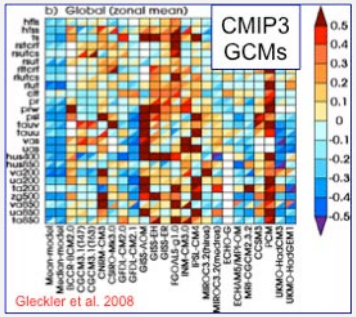
Recommendations

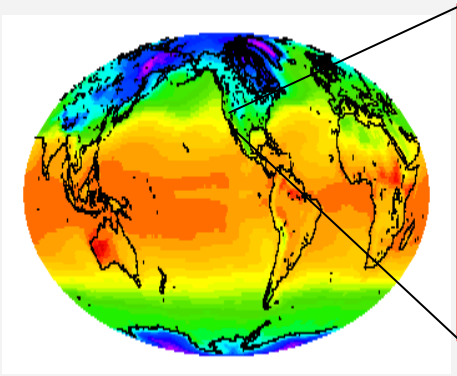
- In general: Systematic observation-based RCM evaluation needs continued growth and high priority within NCA (and CORDEX/CORDEX-NA). "Performance Metrics" are not enough; "Process-oriented diagnostics" are needed too.
- A more substantive, top-down means to be engaged hand-in-hand with the principals architecting and driving the NCA process, along with clearer requirements defintions of needs from NCA.

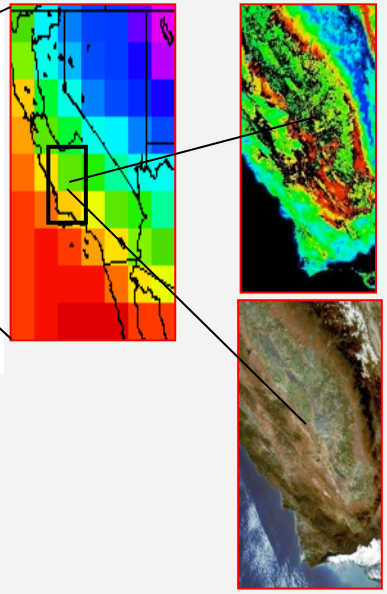
RCMES Overview

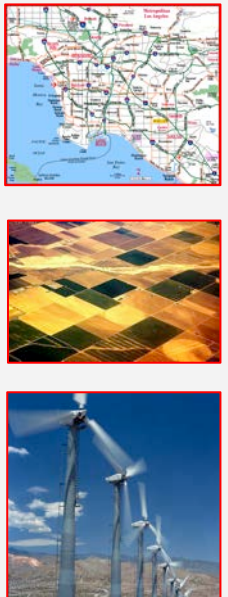




Global Climate Projections → Regional Downscaling → Decision Support







RCMES provides observations & IT tools to carry out regional climate model evaluations and in turn support quantitative climate assessment activities and inform decision support agencies.