# 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

J. Kim[1], D.E. Waliser[2], C. Mattmann[2], L. Mearns[3], C. Goodale[2] A. Hart[2]. Crichton[2], S. Mcginnis[3]

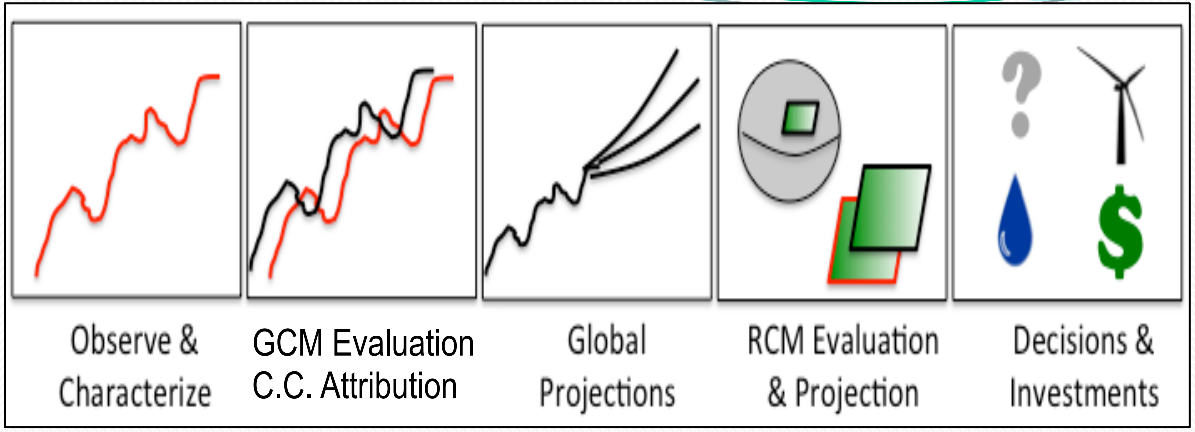
[1]: Joint Institute for Regional Earth System Sci. and Eng./UCLA
[2]: Jet Propulsion Laboratory/NASA
[3]: National Center for Atmospheric Research

## Background: Regional Climate Model Evaluation

- 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.

## JPL Regional Climate Model Evaluation System (RCMES)

## Facilitate Model Evaluation via User-friendly Data Infrastructure

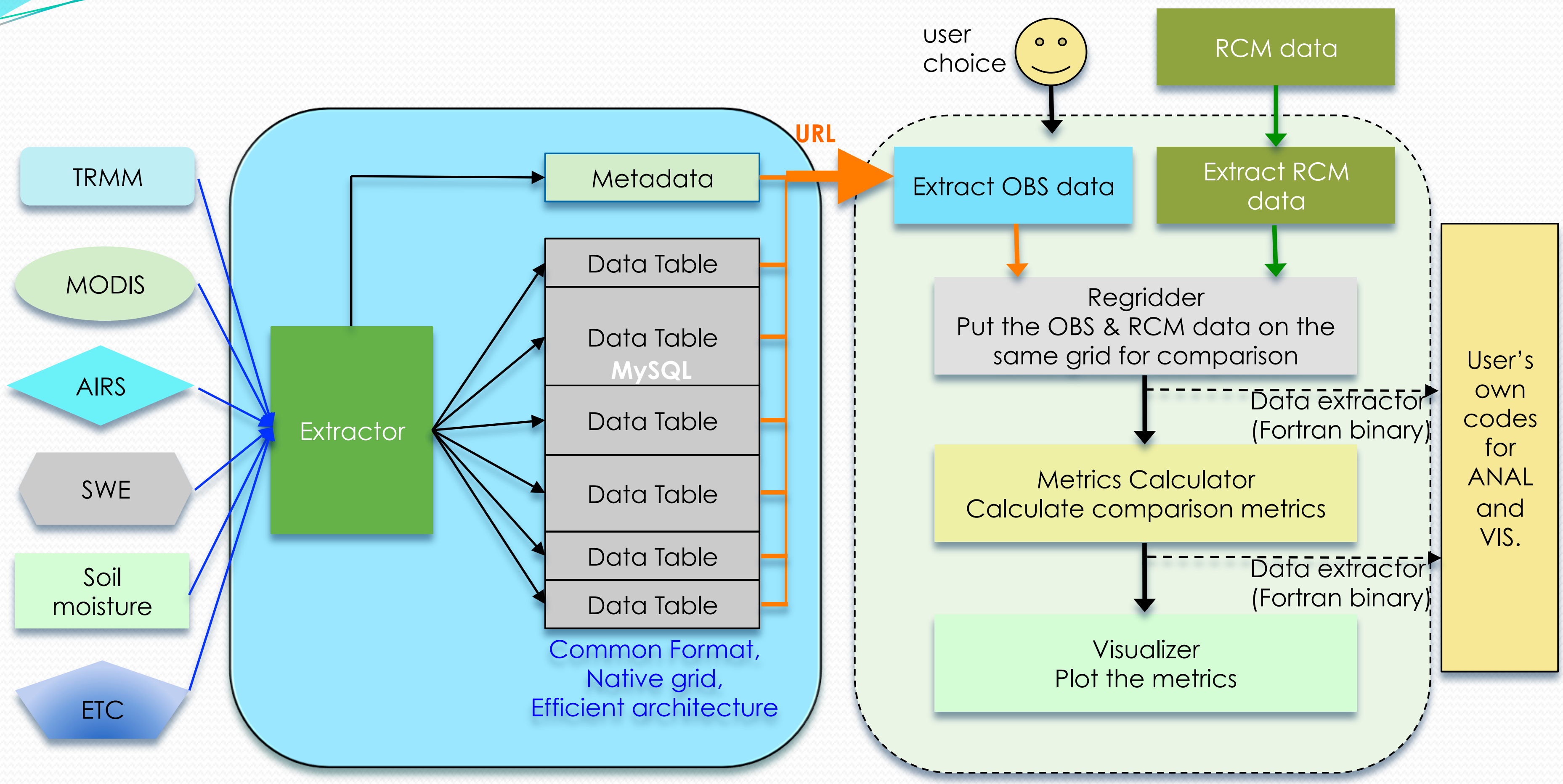



- Observational data are a key component of climate research
  - *Detection* and *attribution*
  - Typical model evaluation is performed by comparing the model and reference data from *observations*, *analysis of observed data* and/or *observation-based assimilations*.
  - *Easy access to quality reference 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

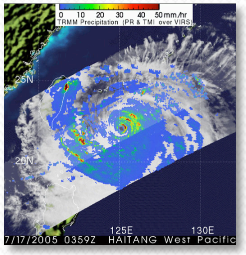


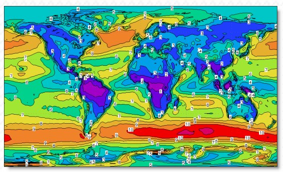

**Raw Data:**
Various formats, Resolutions, Coverage

**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

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

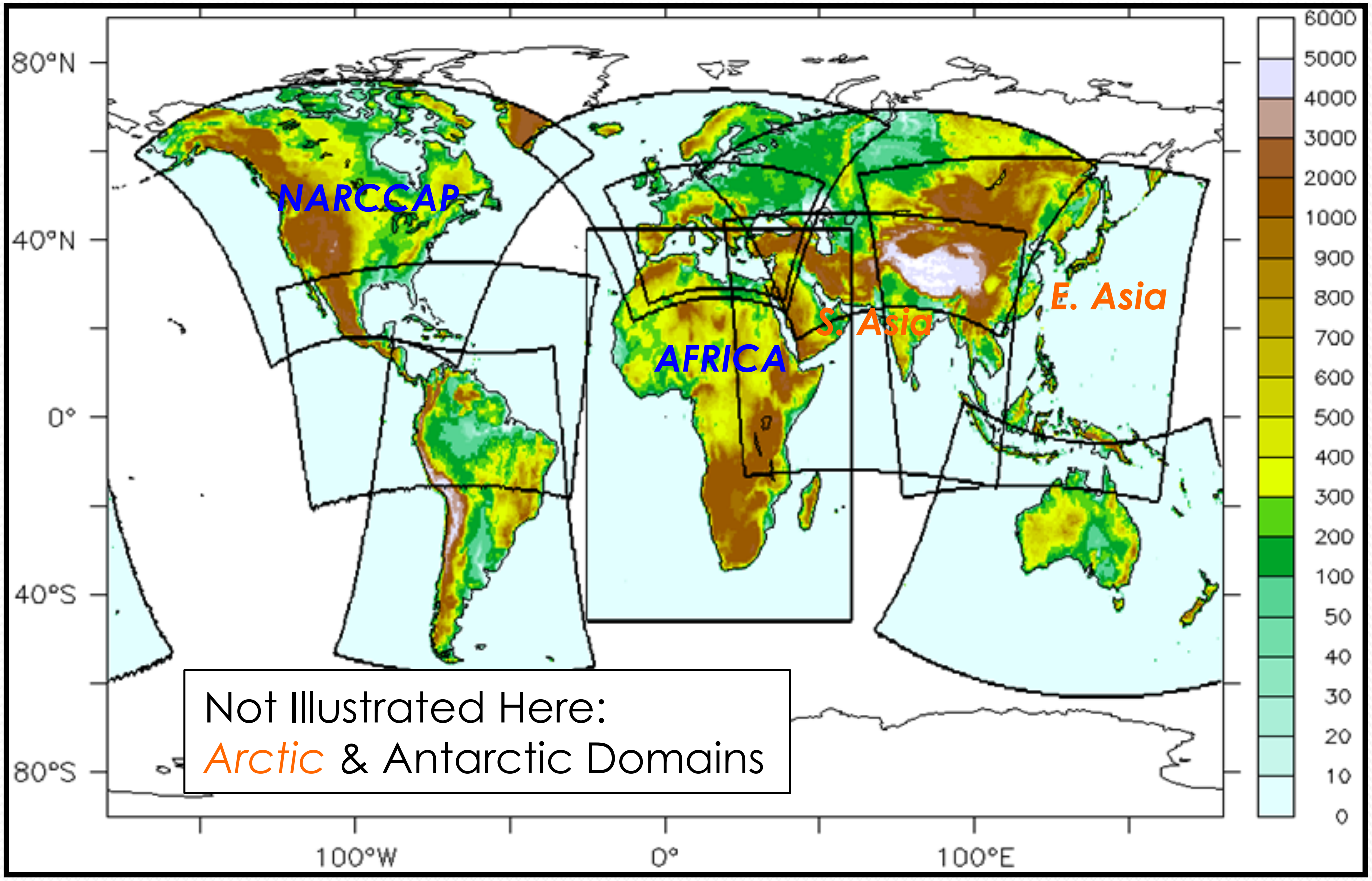


- RCMED Datasets (now or near-term)
  - MODIS Cloudiness: [2000-2010, daily]
  - TRMM PR: [1998-present, daily], 3B42 & version-7
  - AIRS $T_{SFC}$ and profiles: [2002-2010, daily]
  - NCEP CPC PR analysis: [1948-present, daily, US]
  - CRU v3.0 & v3.1 (pr, T2, $T2_{MAX}$, $T2_{MIN}$, cloudiness): [monthly]
  - 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

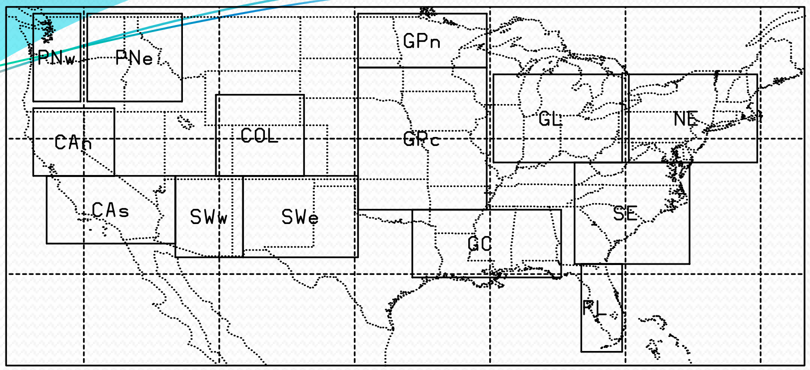
- *N. America*: Funded via NASA for U.S. NCA (NCAR, NARCCAP)
- *Africa*: Collaboration & analysis ongoing (UCT, Rossby Centre)
- *Arctic*: Exploring collaboration (J. Cassano, March 2012 Workshop)
- *E. Asia*: Exploring collaboration (KMA, APCC)
- *S. Asia*: Exploring collaboration

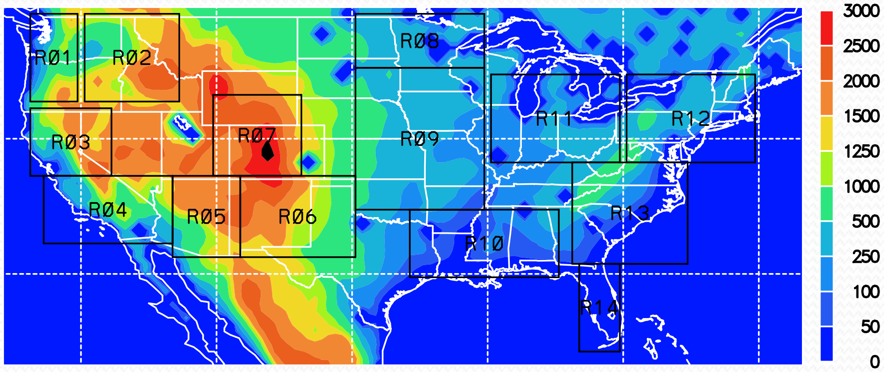


# NARCCAP Multi-RCM Evaluation:
## Monthly precipitation and surface air temperatures

- 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)

# RCMs and the Analysis Domain




- 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.

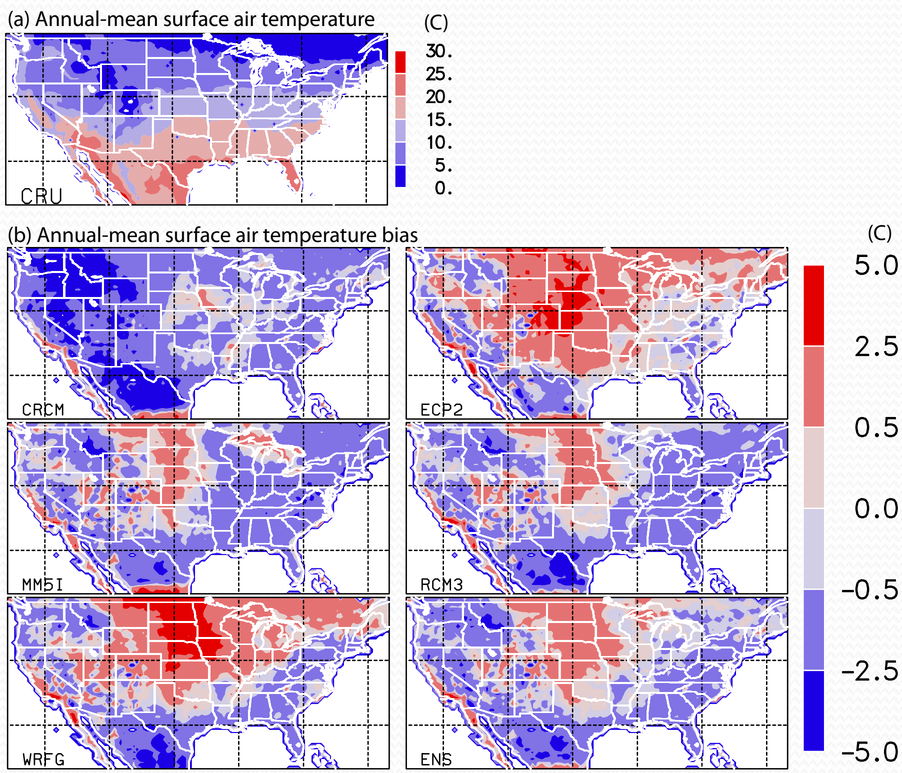
| ID | Region | Long Range | Lat Range | i Range | j Range |
|---|---|---|---|---|---|
| 01 | PNw (Pacific NW – west) | 236.25-239.75 | 42.75-49.25 | 73-80 | 56-69 |
| 02 | PNe (Pacific NW – east) | 240.25-247.25 | 42.75-49.25 | 81-95 | 56-69 |
| 03 | CAn (northern California) | 236.25-242.25 | 37.25-42.25 | 73-85 | 45-55 |
| 04 | CAs (southern California) | 237.25-245.25 | 32.25-37.25 | 75-92 | 35-45 |
| 05 | SWw (SWUS – west) | 246.25-251.75 | 31.25-37.25 | 94-104 | 33-45 |
| 06 | SWe (SWUS – east) | 251.75-260.25 | 31.25-37.25 | 104-121 | 33-45 |
| 07 | COL (Colorado) | 249.75-256.25 | 37.25-43.25 | 100-113 | 45-57 |
| 08 | GPn (nor. Great Plains) | 260.25-269.75 | 45.25-49.25 | 121-140 | 61-69 |
| 09 | GPc (central Great Plains) | 260.25-269.75 | 34.75-45.25 | 121-140 | 40-61 |
| 10 | GC (Gulf Coast) | 264.25-275.25 | 29.75-34.75 | 129-151 | 30-40 |
| 11 | GL (Great Lakes) | 270.25-279.75 | 38.25-44.75 | 141-160 | 47-60 |
| 12 | NE (NE US) | 280.25-289.75 | 38.25-44.75 | 161-180 | 47-60 |
| 13 | SE (SE US) | 276.25-284.75 | 30.75-38.25 | 153-170 | 32-47 |
| 14 | FL (Florida) | 276.75-279.75 | 24.25-30.75 | 154-160 | 19-32 |

| 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) |

## [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.

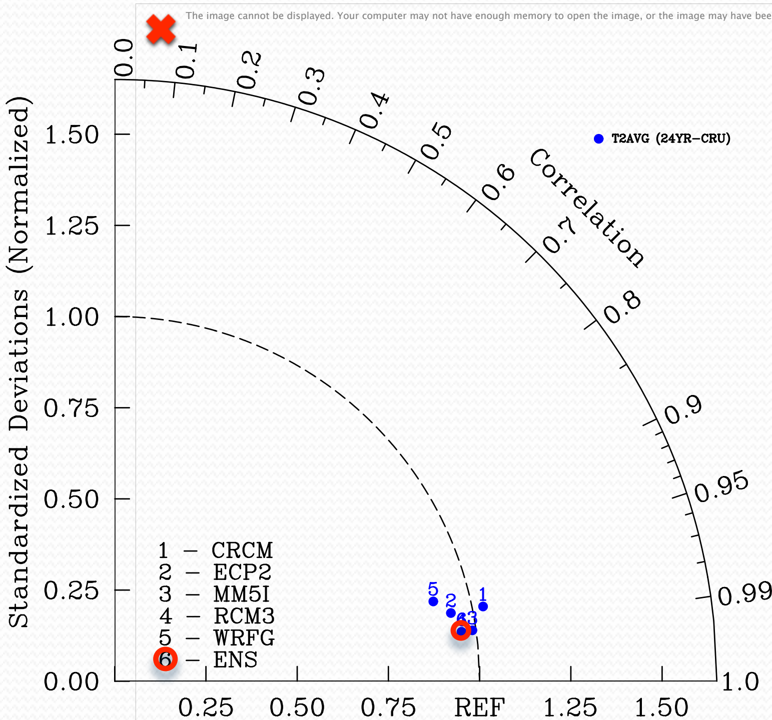
# Daily-mean surface air temperatures: Climatology and Biases



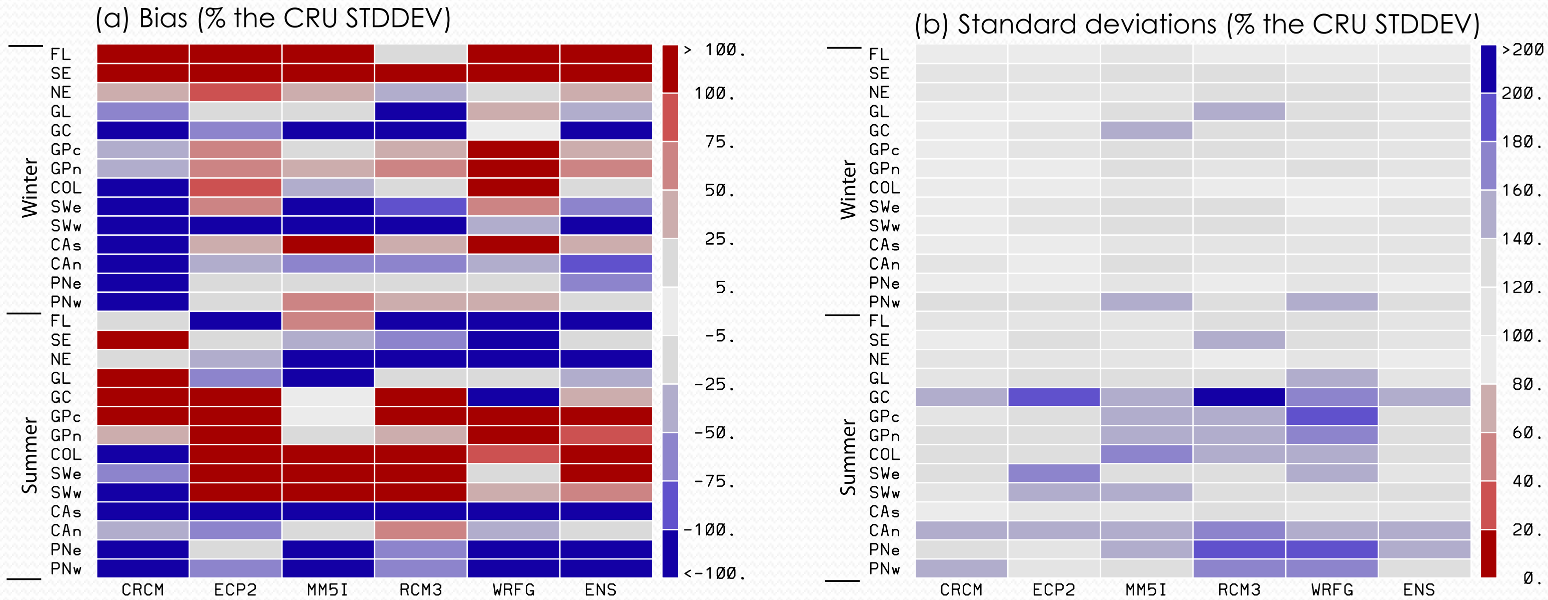

- Model errors varies systematically according to geography.
- All models show cold biases over the coastal and the eastern US regions.
- Most models show warm biases in the Great Plains region.
- Model errors in the mountainous WUS region vary widely; *may be related with large orographic variations 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.



# Seasonal surface air temperature climatology: Normalized bias & interannual variability

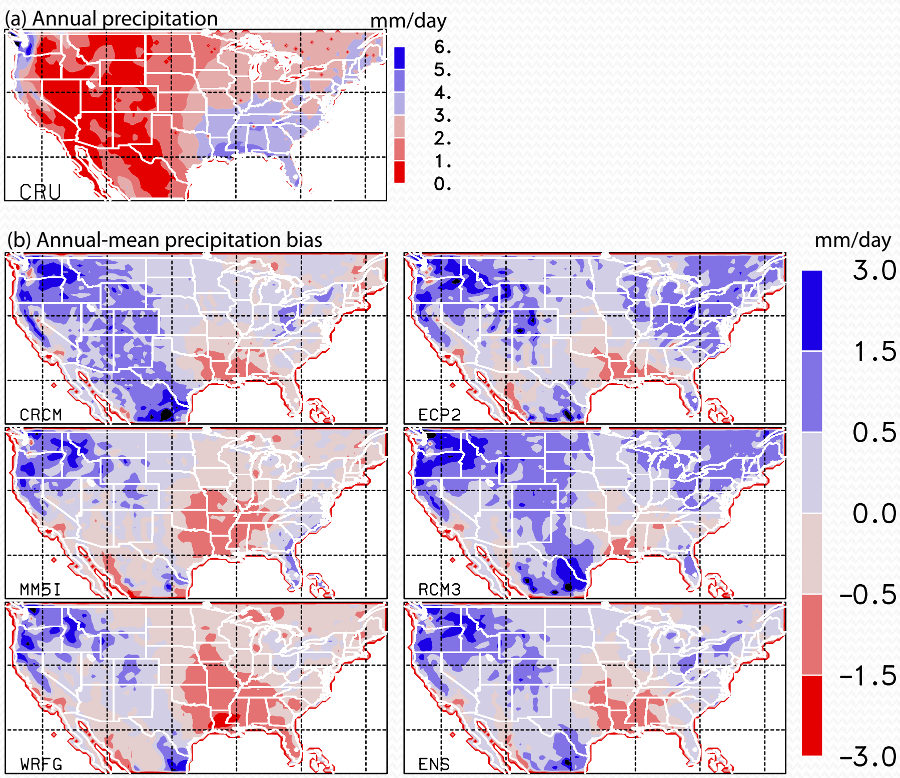



- Mean biases vary, quite systematically, according to geography and season
  - Warm biases in the Great Plains area for both summer and winter
  - Cold biases in the Pacific, Gulf, and Atlantic coast regions in summer
  - Warm biases in the Atlantic coast, Florida and northern California during winter.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

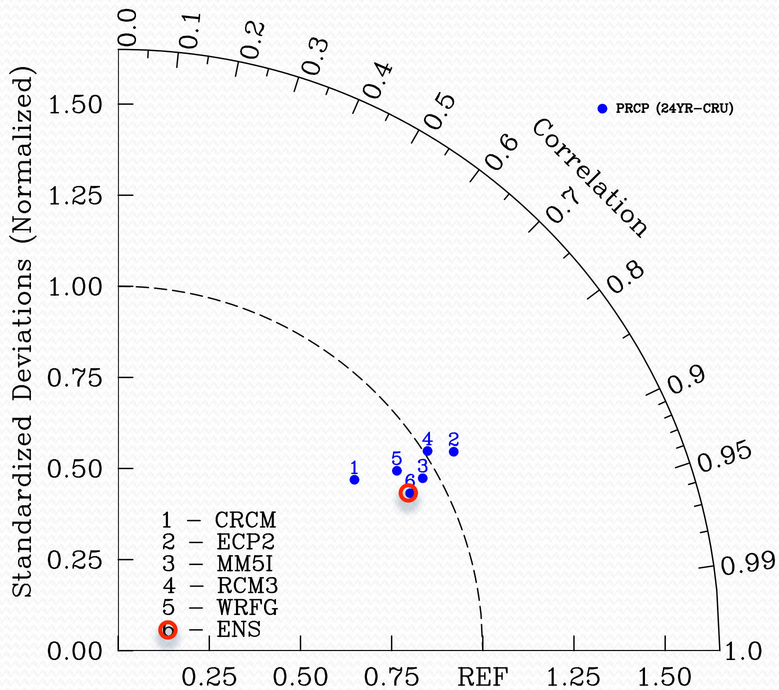
- 24 years: 1980-2003
- Overland only
- Annual climatology: Spatial variability
- Seasonal climatology: Interannual variability
- Annual cycle in subregions.

# Annual precipitation: Climatology and Biases



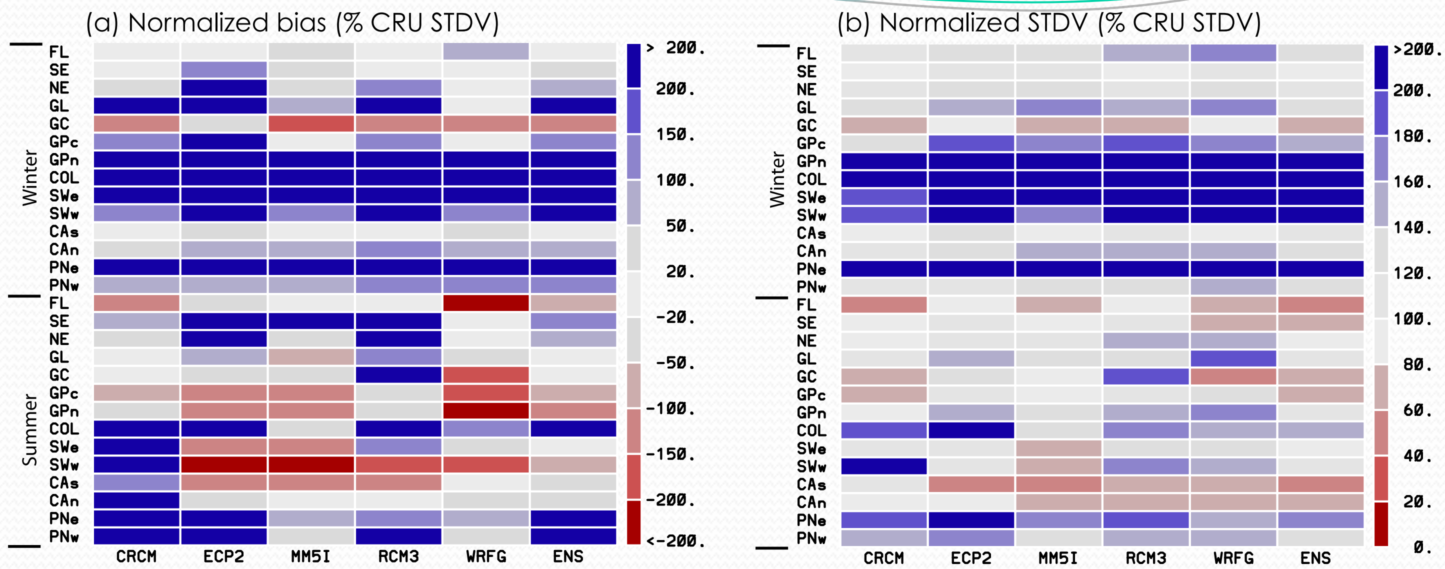

- Model biases in simulating the annual precipitation climatology also varies according to regions.
- The most noticeable systematic biases are:
  - wet biases in the Pacific NW.
  - dry biases in the Gulf coast and southern Great Plains.
  - model biases are mixed in the AZ - western NM region that 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 underestimates 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.