Model Errors in Precipitation, Cloudiness, and Radiation in the NARCCAP Hindcast Experiment

J. Kim[1], D.E. Waliser[1,2], L.O. Mearns[3], C.A. Mattmann[1,2], C.E. Goodale[2] A.F. Hart[2]. D.J. Crichton[2], S. McGinnis[3], and H. Lee[2]

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

Introduction

- Precipitation and surface insolation are among the most crucial variables in shaping the energy and water cycle, especially in the surface climate.
- These variables directly affect agriculture, water resources, snowpack, and natural ecosystems that are key targets in a number of climate change impact assessment studies for practical applications.
- Thus, model errors in simulating precipitation and insolation are an important concern in climate simulations and their application to impact assessments.
- The relationship between the model errors in these variables may provide clues *for the source of model errors* and/or *for improving climate model performance*.

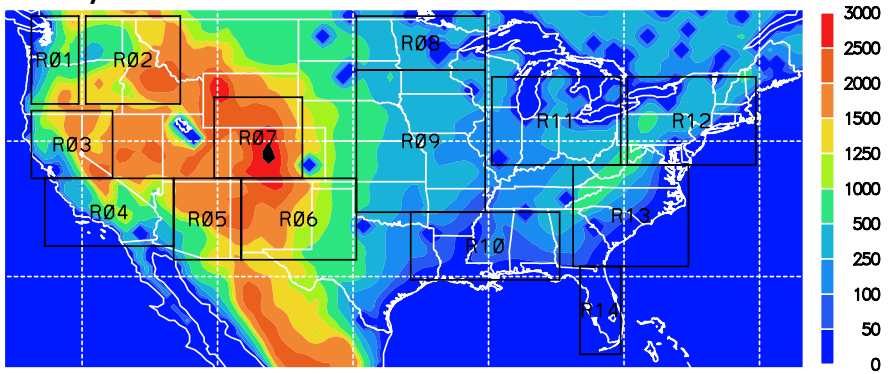
Experiment

- We examined the relationship between the model biases in precipitation, cloudiness, and surface insolation over the conterminous United States in the NARCCAP multi-RCM climate hindcast experiment.
- Cloudiness is selected to represent "*cloud effects*".
  - The cloud effects are determined by, in addition to cloudiness, the content, size distribution, and phase of cloud particles.
- Data from 4 RCMs and their *ENS* are used (Table).
- Reference datasets include the *station-based* CRU3.1 for precipitation and *satellite-based* Clouds and the Earth's Radiant Energy System (CERES) datasets for cloudiness and surface insolation.
  - The JPL Regional Climate Model Evaluation System (RCMES) is used to access and process the reference and model data in this study.

Table: RCMs incorporated in this study

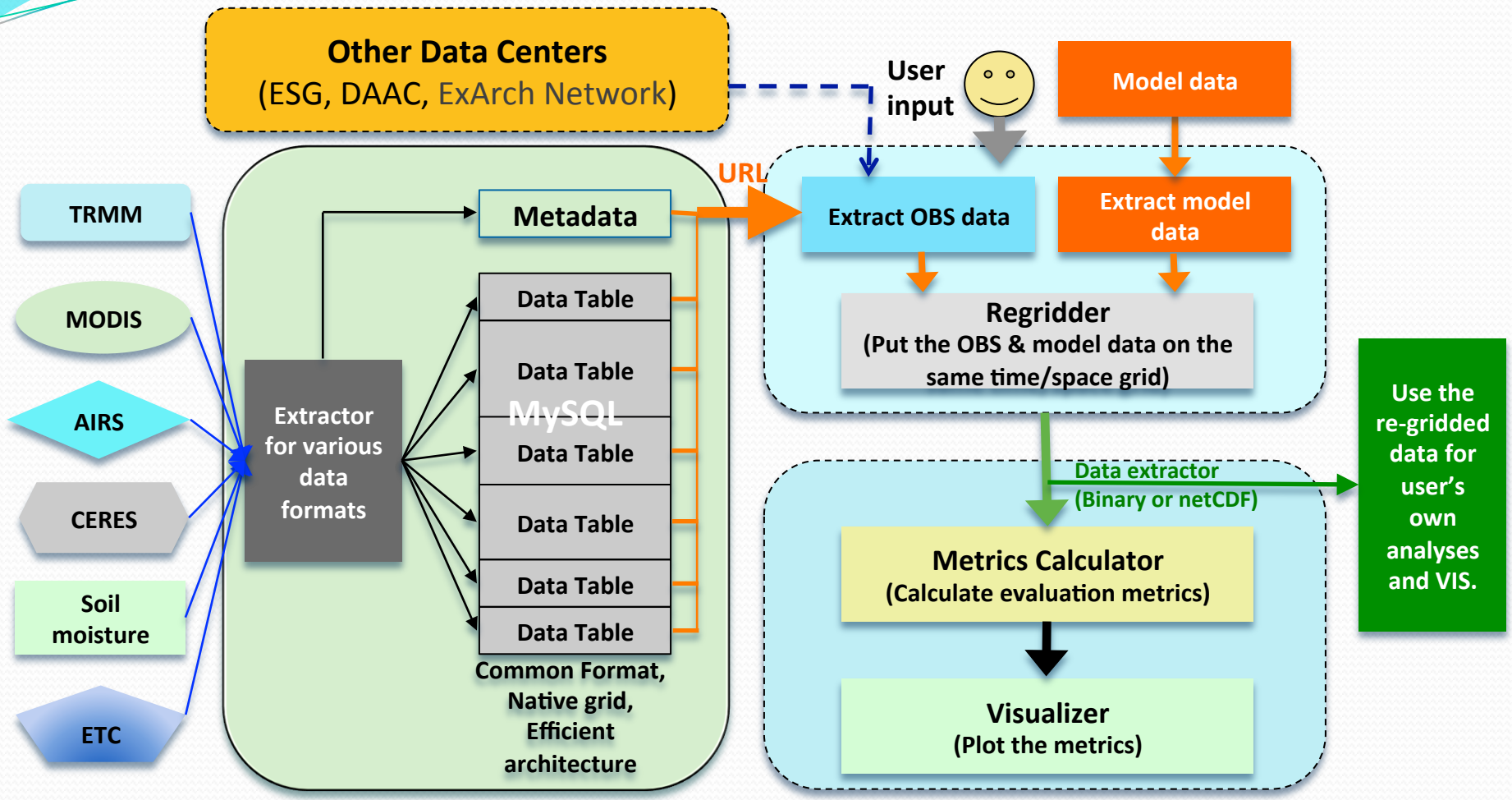
ID	Model Name
CRCM	Canadian Regional Climate Model
HRM3	NCEP Regional Spectral Model
RCM3	RegCM version3
WRFG	Weather Research and Forecast Model
ENS	Uniform-weighted multi-model Ensemble

Analysis domain



RCMES2.0

(http://rcmes.jpl.nasa.gov)



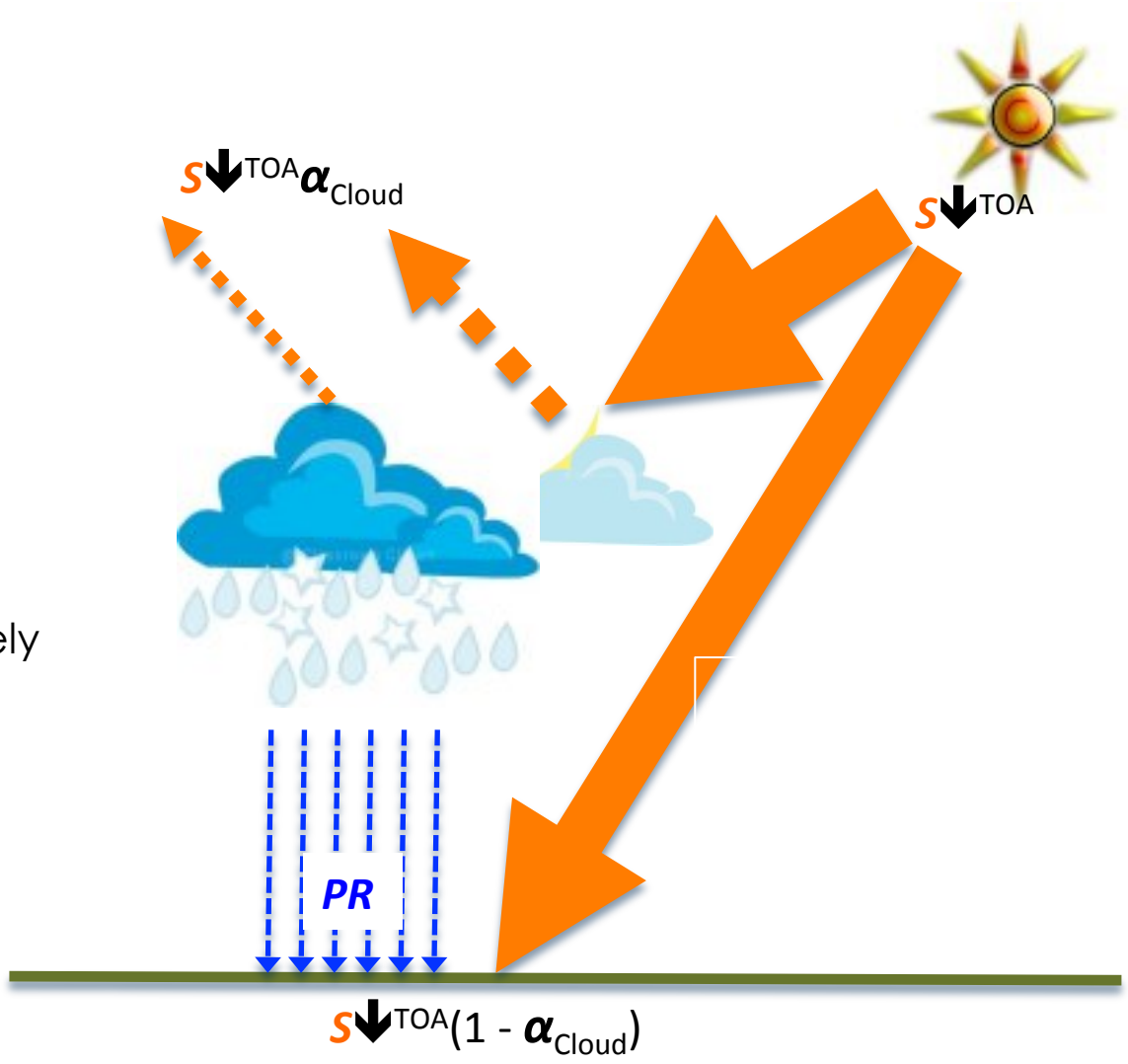
Raw Data:
Various sources, formats, Resolutions, Coverage

RCMED
(Regional Climate Model Evaluation Database)
A large scalable database to store data from variety of sources in a common format

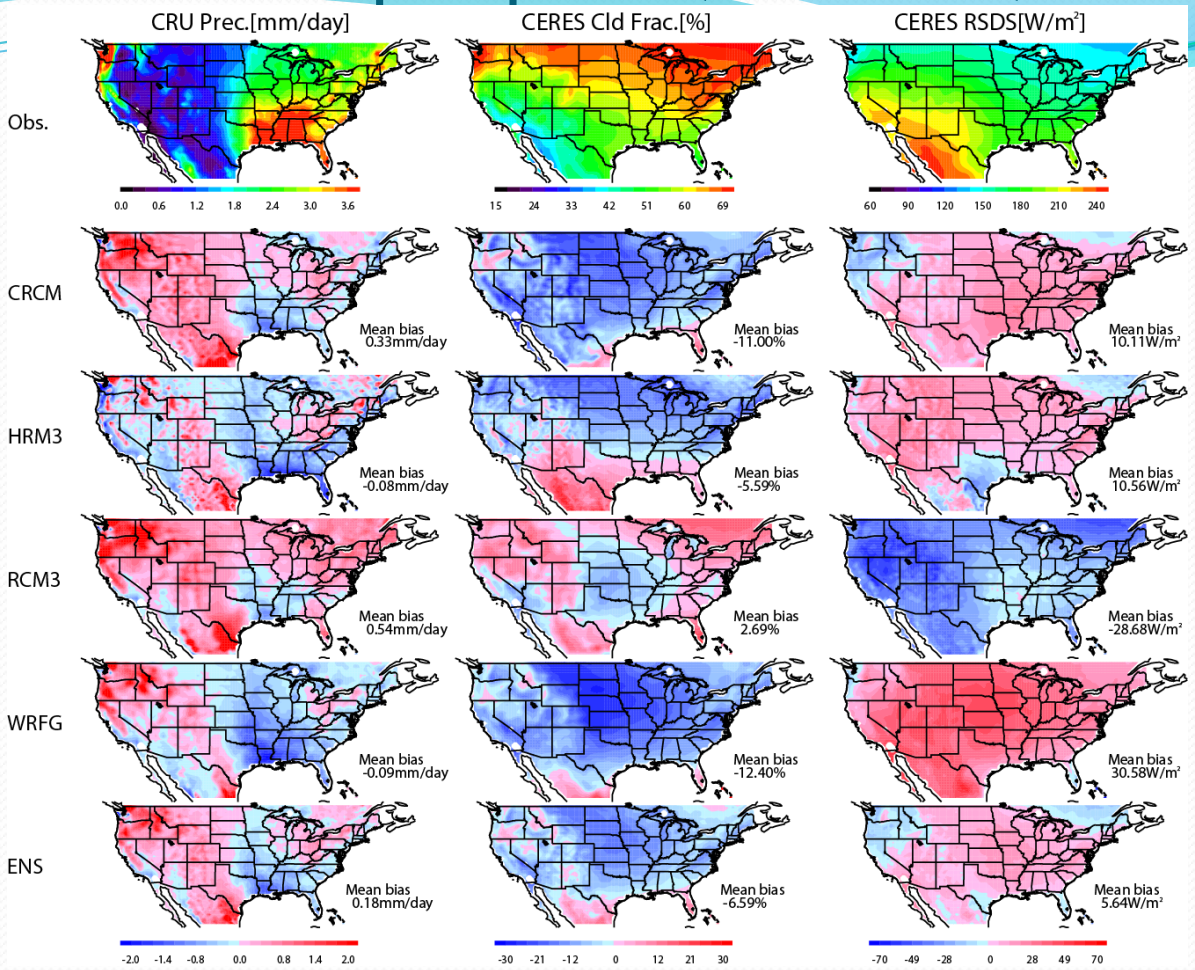
RCMET
(Regional Climate Model Evaluation Tool)
A library of codes for extracting data from RCMED and model and for calculating evaluation metrics

Precipitation, Surface Insolation, and Clouds

- Precipitation and surface insolation are related via clouds.
- Calculations of these three fields are among the most uncertain components in today's climate models.
- Working Hypothesis:
  1. The biases in precipitation and cloudiness are positively correlated,
  2. The surface insolation bias is negatively correlated with the biases in precipitation and cloudiness.

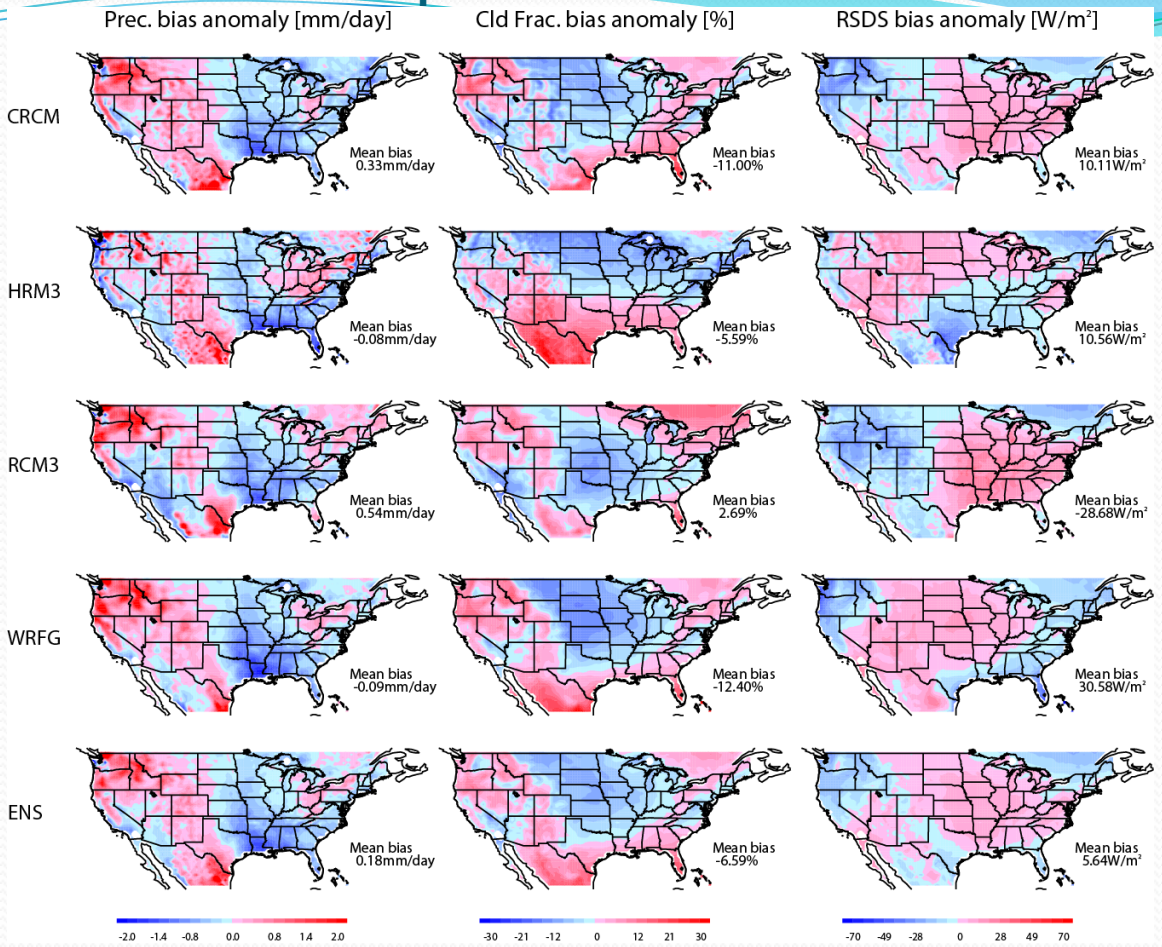


Biases in Annual-mean precipitation, Cloudiness, and Insolation



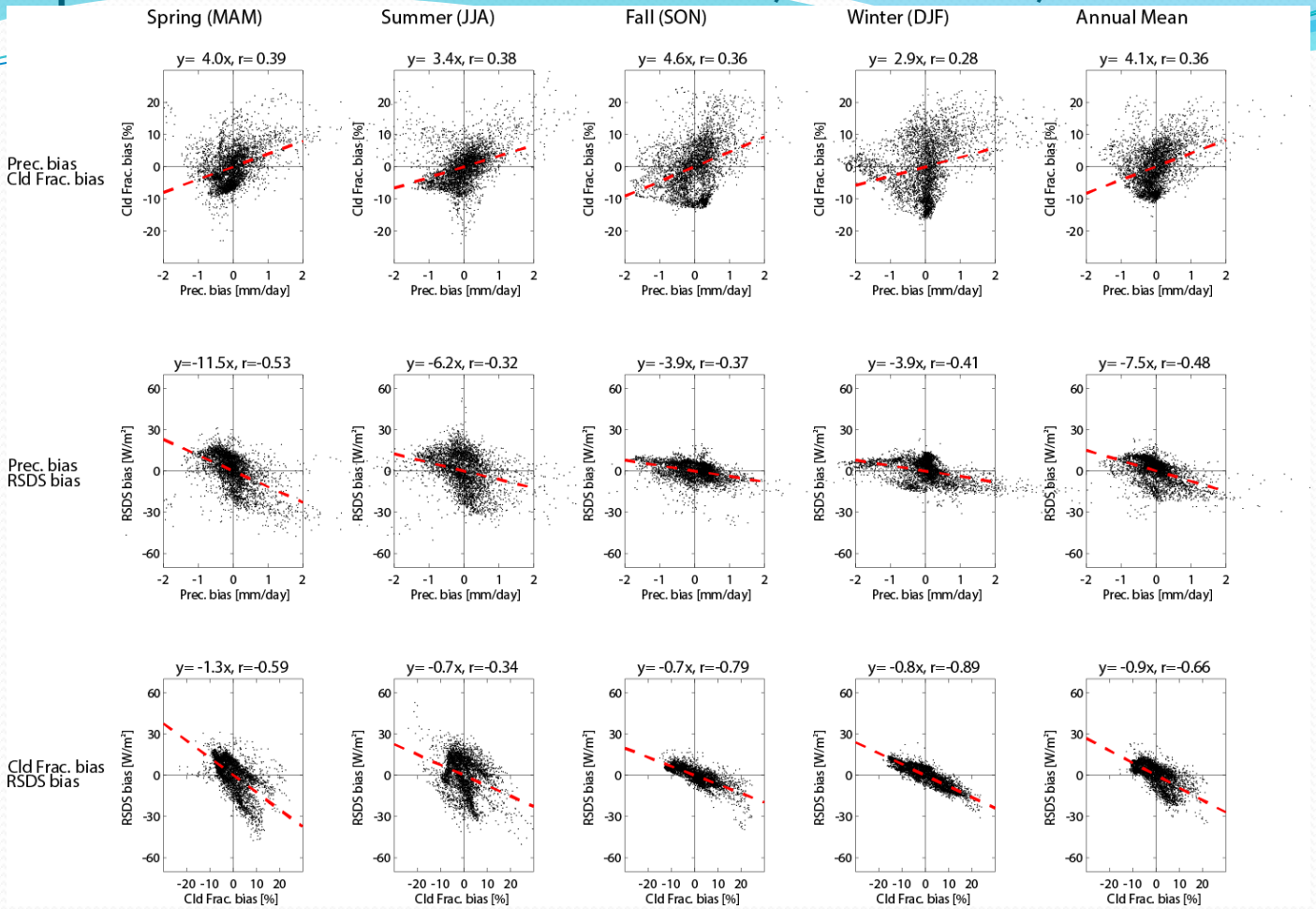
- Model biases show regionally systematic variations. E.g.,
  - Wet/Dry biases in the western US/Gulf of Mexico
  - Overall negative cloudiness biases in the US (Less –'ve or +'ve biases in WUS)
  - General +'ve biases in insolation except in the Pacific NW (Less –'ve or +'ve biases in EUS/Gulf of Mexico)
- RCM3 shows very different bias fields for cloudiness and insolation.
- The relationship between the three bias fields are not clear.

Biases in Annual-mean precipitation, Cloudiness, and Insolation Spatial Anomalies



- Spatial anomalies of model biases show noticeable patterns
  - Most RCMS show positive/negative precipitation bias anomalies in WUS/EUS, most notably in the Pacific NW/Gulf of Mexico-Atlantic coast regions.
  - Insolation bias anomalies matches with those in precipitation (opposite signs).
  - Cloudiness bias anomalies are similar to those in precipitation (same signs).

Relationship between the model errors in PR, Cloudiness, and Insolation: *ENS*



- The bias anomalies of multi-model ensemble shows consistent relationship between precipitation, insolation, and cloudiness for season totals as well as annual totals.
  - Positive correlation: PR vs. Cloudiness
  - Negative correlation: PR vs. Insolation & Cloudiness vs. Insolation
- The strongest correlation between cloudiness and surface insolation; the weakest for precipitation and cloudiness.

Biases in Precipitation, Cloudiness, and Insolation

	Model	PR (mm/day)	Cloudiness (%)	Insolation (W/m2)
All Year	CRCM	0.33	-11.0	10.1
	HRM3	-0.08	-5.6	10.6
	RCM3	-0.54	2.7	-28.7
	WRFG	-0.09	-12.4	30.6
	ENS	***0.18***	***-6.6***	***5.6***
Spring	CRCM	0.60	-12.8	10.7
	HRM3	0.22	-5.7	-43.5
	RCM3	0.96	5.5	-26.7
	WRFG	0.23	-12.9	35.6
	ENS	***0.50***	***6.5***	***-6.0***
Summer	CRCM	0.45	-11.7	29.9
	HRM3	-0.18	-7.9	31.0
	RCM3	0.62	-7.4	-28.1
	WRFG	-0.44	-16.9	49.6
	ENS	***0.11***	***-11.0***	***20.6***
Fall	CRCM	-0.04	-6.9	3.9
	HRM3	-0.51	-3.9	66.6
	RCM3	0.01	3.1	-32.9
	WRFG	-0.34	-11.9	23.5
	ENS	***-0.22***	***-5.1***	***15.2***
Winter	CRCM	0.32	-12.6	-3.8
	HRM3	0.16	-5.1	-11.6
	RCM3	0.57	8.8	-27.0
	WRFG	0.16	-8.0	14.3
	ENS	***0.31***	***-4.3***	***-7.0***

- The relationship between the spatial anomalies of model biases in PR, Cloudiness, and Insolation are consistent for nearly all models and seasons.
- The expected relationship between the biases in precipitation, cloudiness, and insolation does not exist for the land-mean biases.

Biases in Precipitation, Cloudiness, and Insolation

	Model	PR vs. Cloudiness	PR vs. Insolation	Cloudiness vs. Insolation
All Year	CRCM	0.24	-0.48	-0.46
	HRM3	0.29	-0.30	-0.51
	RCM3	0.47	-0.49	-0.64
	WRFG	0.36	-0.22	-0.60
	ENS	***0.36***	***-0.48***	***-0.66***
Spring	CRCM	0.30	-0.43	-0.45
	HRM3	0.36	-0.43	-0.49
	RCM3	0.59	-0.52	-0.75
	WRFG	0.39	-0.26	-0.75
	ENS	***0.39***	***-0.53***	***-0.59***
Summer	CRCM	0.42	-0.35	-0.58
	HRM3	0.00	-0.33	0.03
	RCM3	0.59	-0.07	-0.22
	WRFG	0.22	-0.14	-0.56
	ENS	***0.38***	***-0.32***	***-0.34***
Fall	CRCM	-0.06	-0.34	-0.50
	HRM3	0.40	-0.36	-0.58
	RCM3	0.53	-0.61	-0.57
	WRFG	0.40	-0.40	-0.44
	ENS	***0.36***	***-0.37***	***-0.79***
Winter	CRCM	0.08	-0.28	-0.72
	HRM3	0.27	-0.35	-0.75
	RCM3	0.37	-0.49	-0.82
	WRFG	0.38	-0.41	-0.79
	ENS	***0.28***	***-0.41***	***-0.89***

- The relationship between the spatial anomalies of model biases in PR, Cloudiness, and Insolation are consistent for nearly all models and seasons.

Summary

- Relationships between model biases in simulating precipitation, insolation, and cloudiness over the conterminous US region are examined from the NARCCAP hindcast experiment data.
- The relationship between the domain-average biases between these variables are not clearly defined (except in fall).
- The spatial anomalies of model biases (*biases* – "*domain-mean bias*") show consistent relationships between precipitation-and-insolation (negative), cloudiness-and-insolation (negative), and precipitation-and-cloudiness (positive) for all seasons and (nearly) all models.
  - These relationships are expected.
  - This also suggests that the effects of clouds on surface insolation may be approximated in terms of cloudiness.
- These results may suggest that the RCMs examined in this study possess useful skill in simulating