ARM data-oriented diagnostics to evaluate the climate model simulation of clouds, precipitation, and radiation

Chengzhu Zhang , Shaocheng Xie, Yuying Zhang,
Steve Klein and Hsi-yen Ma
Atmospheric, Earth and Energy Division
Lawrence Livermore National Laboratory

Bring Detailed Field Data to Climate Model Evaluation

Goal: Making ARM observational data more accessible and useful for model developers and community researchers

- **Facilitate the use of long time, high frequency observation data from multiple DOE's sites in climate model evaluation**
- **Provide process-oriented diagnostics to help understand model errors and develop improved physical parameterizations for climate models**
- **Develop an ARM data-oriented metrics and diagnostics package that has the capability to be integrated into PCMDI's metrics package and also be stand alone**
- **Package Design:**

Pre-processed data summary
- ARM data statistical files: Applied stringent QC treating missing data
- CMIP model database

Interface with model to be evaluated
- Read in data to be evaluated
- Process data into required format

Metrics Calculation: Climate Data Analysis Tools (CDAT)

Statistical analysis include:
- Bias, Standard Deviation, Correlation and Root Mean Square Error…
- Fast Fourier Transform

Visualization: Python matplotlib and UV-CDAT

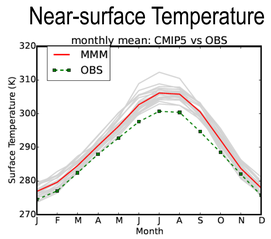
Diagnostic plots include:
- Taylor Diagram
- Line plots of climatology monthly means
- Harmonic Dial plot for diurnal cycles
- Bar plots for probability density function
- Height vs time contour plots of 3d variables (i.e., Cloud fraction)

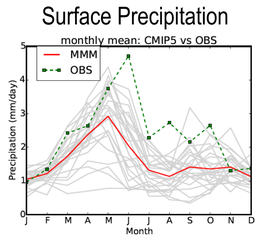
Approach

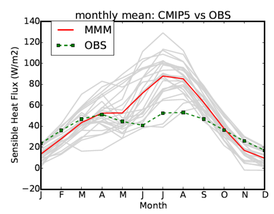
- **Create standard multi-year statistical summary data sets to provide best estimate of these statistics from the original ARM data streams**
- **Basic metrics are provided for the assessment of overall model performance, targeting CMIPs standard output variables**
- **Process-oriented diagnostics focus on individual cloud and precipitation-related phenomena and are useful for the evaluation and development of the model physics parameterizations**
- **Coordinate with PCMIDI metrics package efforts and enable CMIP multi-model analysis**
- **Open source tools managed both on Github and in ARM archive**

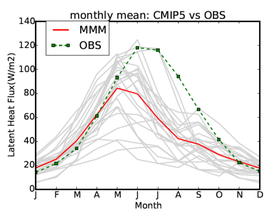
Diagnosis on SGP Near-surface Warm Bias

At SGP site: Monthly means of CMIP5 model comparisons with ARM obs.





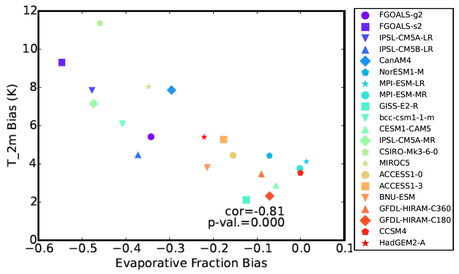




- **Bias in CMIP5 simulations**
- **Near-surface temperature has systematic bias throughout the year**
- **Largest Near-surface temperature bias at warm seasons**
- **Suggest that the warm bias relates to cloud and surface energy budget**

Diagnosis: Possible Sources of Near-Surface Temperature Bias:
(Following Cheruy et al. 2014, GRL)

1. Evaporative Fraction: EF = LH /(LH+SH)

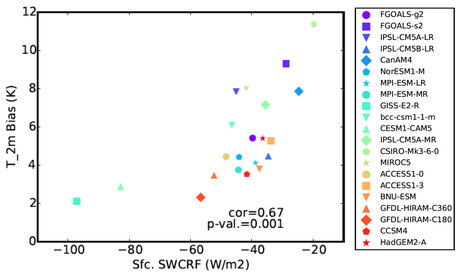


JUNE:T2m Bias vs. EF Bias

- In June, the strong T2m bias corresponds to smaller EF
- Underestimate of EF relates to deficit in soil moisture supply

2. Short Wave Cloud Radiative Forcing

SWCRF= All sky – Clear sky downwelling short wave radiation

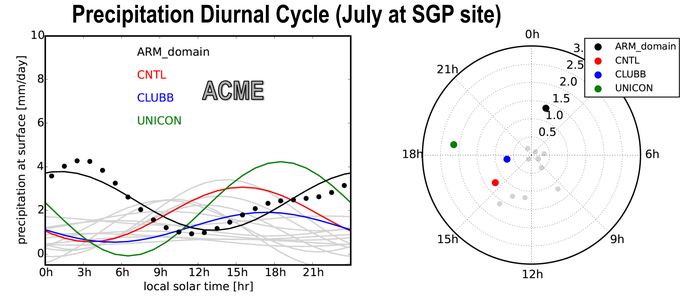


JUNE:T2m Bias vs. SWCRF

- In June, the strong T2m bias corresponds to weaker SWCRF
- Underestimate of SWCRF relates to deficit of clouds

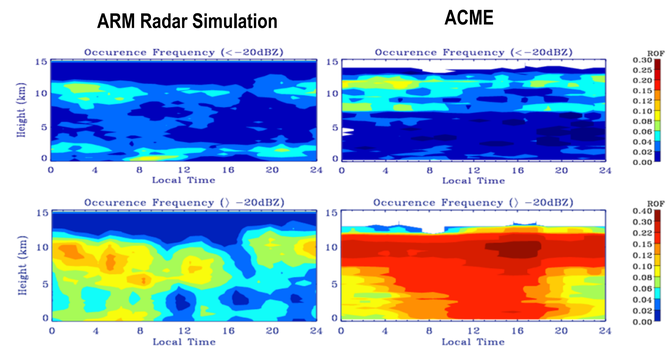
Diagnosis on SGP Diurnal Cycle of Precipitation and Clouds

Precipitation Diurnal Cycle (July at SGP site)



Left: black dots are ARM observation. Curves are the 1st harmonics: grey for CMIP5 model AMIP type of runs. Color curves are from DOE's ACME model with different convection schemes: red for Zhang-McFarlane, blue for CLUBB, green for UNICON. Right: mapping precipitation cycle peak time and amplitude from the 1st harmonics to polar coordinate.

Cloud Fraction Diurnal Cycle



- **ACME is lack of non-precipitating shallow clouds**
- **ACME produces too much precipitating clouds at high levels**
- **ACME shares the common model problem in capturing the observed diurnal cycle at SGP**

Looking Ahead

We envision the following:

- **Process-oriented diagnostics planned to include:**
  - Frequency of occurrence and intensity probability density function of clouds and precipitation
  - Co-variance analysis: e.g., convection onset and transition statistics, causes of warm bias at central US
  - Cloud regime analysis using ARM radar simulator output
  - Diabatic heating/drying study over various cloud regimes
- **Establishment of a repository for community-contributions to the metrics package**
- **Be fully integrated into the PCMDI metrics package, and also be available independently**
- **With all model and observational and model data and programs published in ARM archive**

Acknowledgement: *This work is supported by the DOE Atmospheric Radiation Measurement Program. We would like to thank Karl Taylor, Peter Gleckler, Curt Covey, Chris Terai, Paul Durack, Charles Doutriaux and the ARM community for providing insightful feedbacks and generous support.*

This work is performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. IM release: