Develop ARM Metrics and Diagnostics to Support Climate Model Evaluation and Development

Shaocheng Xie, Chengzhu Zhang, Yuying Zhang, Qi Tang, Shuaiqi Tang, and Xiao Chen
Lawrence Livermore National Laboratory

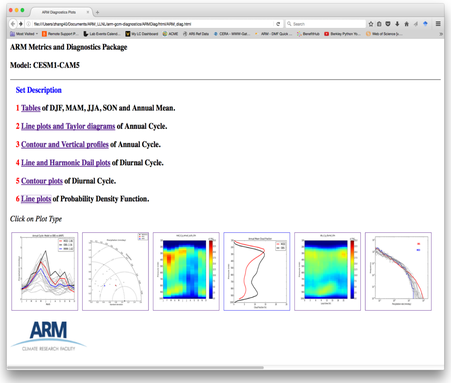
ARM Metrics and Diagnostics

The overall goal is to facilitate use of detailed ARM data for model evaluation and development

- Provide basic metrics to routinely assess climate model performance specifically on **clouds, aerosols, precipitation, and radiation**.
- Provide **process-oriented diagnostics** to help understand model errors particularly in **convection** and **land-atmospheric coupling.**
- Provide tools to improve model-observation comparison, e.g., the **ARM radar simulator** for cloud evaluation with detailed ARM cloud observations.
- Provide model evaluation at **different climate regimes** with ARM data collected at both its permanent sites and mobile facilitate sites.

ARM Metrics and Diagnostics Package (ARM-DIAG)

Stand alone analysis package with tools and data



Status:

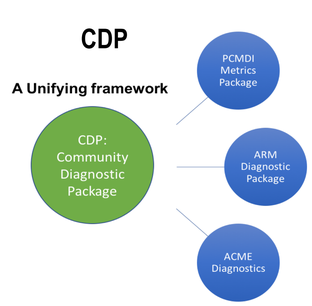
- Analysis tools including 6 sets of diagnostics focus on SGP released through ARM github repo and website

Ongoing work:

- Extending to multiple ARM sites
- Implementing to other CDP based diagnostics package
  - E3SM diags
  - PCMDI's metrics package

Integrated into the Community Diagnostic Package (CDP) platform to work with E3SM and PCMDI Metrics

Configuration management
Metrics calculation
Parallelization
Output viewer
Provenance capture...



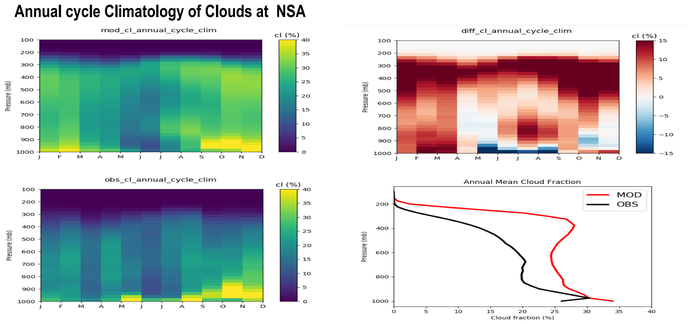
CDP is ESGF Funded Project

- **Goal:**
  ❖ Effectively interact with other model diagnostics efforts in DOE.
- **Benefits:**
  ❖ Modular and object-oriented in design
  ❖ Flexible to implement new diagnostics
- **Status:**
  ❖ Configuration: Load user input
  ❖ Execution
  Optional command line parser are implemented in same fashion for three projects

Contributors: Zeshawn Shaheen, Chris Golaz, Charles Doutriaux, Dean N. Williams and Peter Gleckler

Implementing a subset of ARM-DIAG into E3SM-DIAG

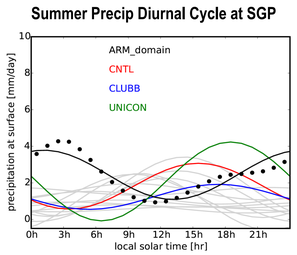
Annual cycle Climatology of Clouds at NSA



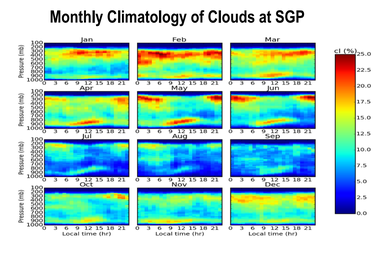
Unique ARM Diagnostics

Diurnal Precipitation and Seasonal Variation of Clouds

Summer Precip Diurnal Cycle at SGP

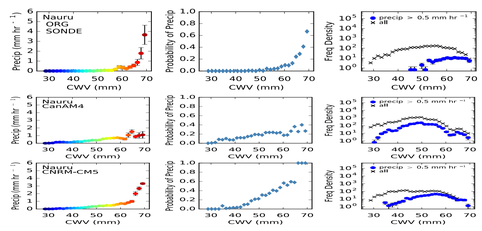


Monthly Climatology of Clouds at SGP

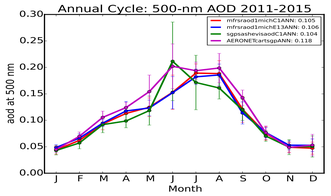


Diagnosis of Convective Onset in Tropics

Ongoing collaboration work with David Neelin's group of UCLA



Aerosol Optical Depth at 550 nm



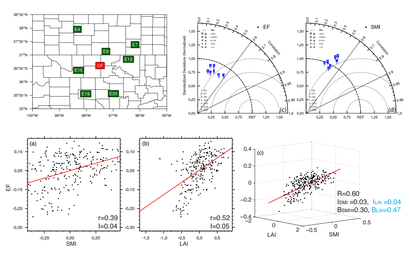
- Use AOD comparison tool from Data Quality Office
- **mfrsr** has better availability and QC, than **sashevis**
- Convert AOD at 415-615 nm to AOD at 550 nm

(Contributors: Laura Riihimaki, Connor Flynn, Justin Monroe)

New L-A Coupling Metric

- The new metric represents multiple land-atmosphere (LA) coupling mechanisms better than traditional metrics.
- Relative contributions from individual drivers to LA coupling are quantified consistently, facilitating comparisons at different locations.
- Moderate coupling with large spatial variations is found at SGP. The relative importance of soil moisture vs. vegetation varies by location.

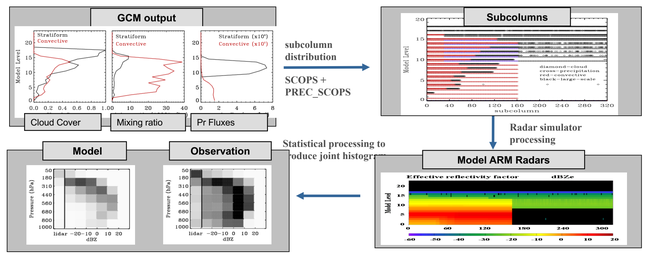
LA coupling at SGP



Tang, Q., Xie, S., Zhang, Y., et al., Heterogeneity in warm-season land-atmosphere coupling over the U.S. Southern Great Plains, *J. Geophys. Res.*, under review.

ARM Radar Simulator for GCMs

- Bridge the gap between detailed ARM cloud observations and GCM clouds
- Modify the COSP radar simulator to mimic the way how cloud mask was generated from ARM cloud radar observations
- Merge ARM cloud radar simulator into COSP for climate model applications

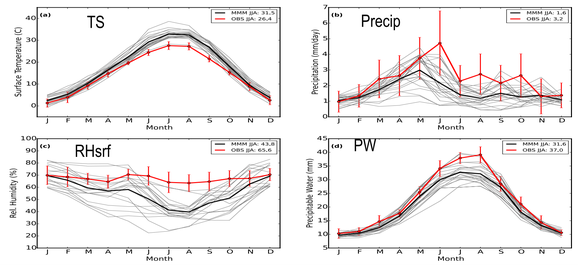


Zhang, Y., S. Xie, et al., 2017: ARM Cloud Radar Simulator for Global Climate Models – A New Tool for Bridging Field Data and Climate Models. BAMS, https://doi.org/10.1175/BAMS-D-16-0258.1.

Application to GCM Evaluations

Diagnosis of Summertime Warm Bias at SGP

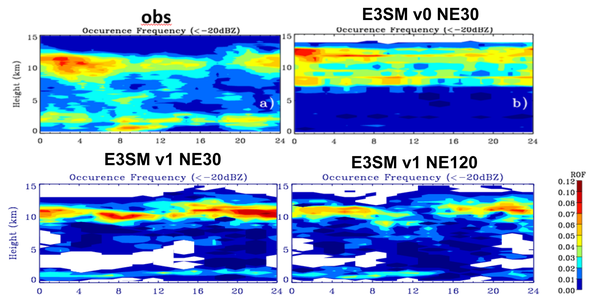
Monthly means: CMIP5 vs. ARM at SGP



- All the CMIP5 models show a warm bias during the summer season. Accordingly all of the models underestimate the surface precipitation and tend to predict a drier atmosphere compared to the ARM observations.

Zhang, C., Xie, S., Klein, S. A., Ma, H.-y., Tang, S., Van Weverberg, K., Morcrette, C. J. & Petch, J. (2018). CAUSES: Diagnosis of the Summertime Warm Bias in CMIP5 Climate Models at the ARM Southern Great Plains Site. Journal of Geophysical Research: Atmospheres, 123. https://doi.org/10.1002/2017JD027200

Validating E3SM v1 Clouds at Low- and High-Resolution with the ARM Cloud Simulator

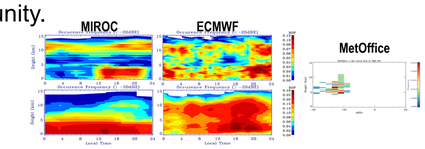


- The issue with the lack of shallow non-precipitation clouds in E3SM v0 has been largely improved in E3SM v1 and in particular in the high-res model, likely due to the inclusion of a high-order turbulence scheme (CLUBB) for PBL and shallow convection. Improvements are also seen in the non-precipitating high clouds.

Zhang, Y, Xie, S., et al.. (2018), Evaluation of EAMv1 simulated clouds and their sensitivity to model resolution with satellite and ground-based simulators, to be submitted to JAMES.

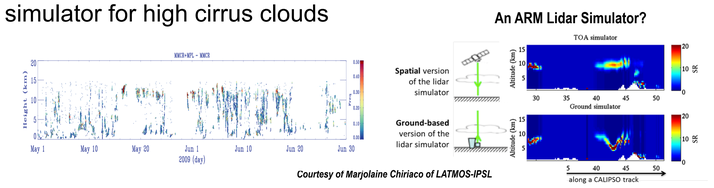
Future Work

- Extend the ARM-DIAG package to all ARM primary research sites and selected AMF sites.
- Enhance the package with more process-oriented diagnostics developed by ASR and other cloud modeling communities.
- Integrate ARM-DIAG into the E3SM and PCMDI metrics packages for use by a broader community.
- Assist the implementation of the ARM radar simulator into major modeling center's models



- Plan a potential ARM lidar simulator to complement the radar simulator for high cirrus clouds

An ARM Lidar Simulator?



Courtesy of Marjolaine Chiriaco of LATMOS-IPSL

Acknowledgement: The work presented here is supported by the DOE ARM program. We thank all the ARM/ASR scientists and infrastructure staff who have provided both scientific input and data support to the project. We thank Peter Gleckler for constructive suggestions to this work. David Neelin's group at UCLA is acknowledged for providing the convection onset diagnostic set to the ARM diagnostics package.

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: LLNL-POST-747666