ARM data-oriented metrics and diagnostics package for GCMs (ARM-Diags)

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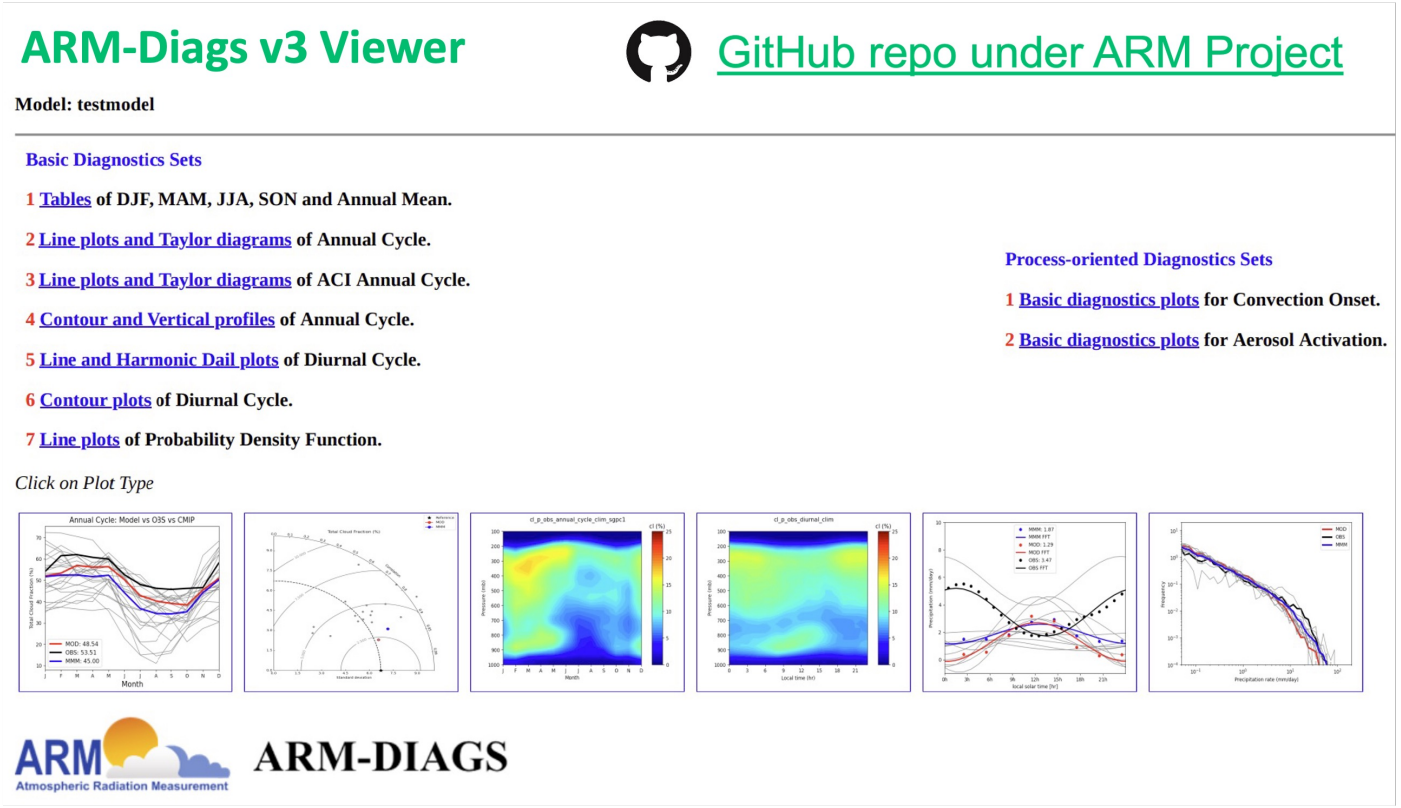
Overview

Objective: To facilitate the use of ARM ground-based in-situ measurements in climate model evaluation and model inter-comparison.

- Utilize ARM high-frequency long-term continuous measurements of clouds, aerosols, radiation, and precipitation.
- Provide process-oriented diagnostics to help understand model errors and improve physical parameterizations.
- Python package for file I/O, metrics calculation, graphics, generating viewer, available from GitHub ARM project space.



Major components

The ARM-Diags includes four major components:

- A **Python-based** analysis program;
- An **ARM-based** collection of mean and diurnal and seasonal cycle climatology as well as high time frequency data for process-oriented diagnostics;
- A database of simulation data from models contributed to the **CMIP** project;
- Relevant technical documentation for ARM-Diags.

Currently available for the SGP, NSA Barrow, TWP Manus, Nauru and Darwin sites, ENA and MAO sites.

Observational data derived from: VARANAL, ARMBE, ACRED, SWATS and other VAP products.

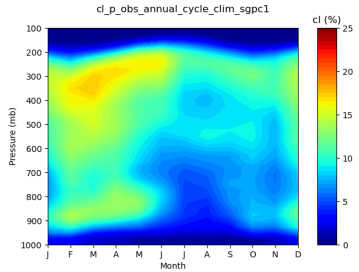
Quantities	ARM data products	Data source/ instruments	Time resolution	Spatial info
Surface screen-level temperature/humidity	ARM continuous forcing dataset	Surface Meteorological Observation System (SMOS), Oklahoma and Kansas Mesonet stations (OKM and KAM) (Xie et al. 2004)	Month, day, hour	SGP domain averaged
Temperature/humidity profile/wind speed/ large-scale tendencies	Same as above	NOAA/NCEP Rapid Update Cycle (RUC) analysis data (Xie et al. 2004)	Month, day, hour	SGP domain averaged
Surface precipitation	Same as above	Arkansas–Red Basin River Forecast Center (ABRFC)	Month, day, hour	SGP domain averaged
		NEXRAD radar precipitation estimates with rain gauge		
Precipitable water	Same as above	Microwave radiometer (MWR) water liquid and vapor along line of sight (LOS) path (MWRLOS)	Month, day, hour	SGP domain averaged
Surface all sky radiative fluxes	Same as above	Data Quality Assessment for ARM Radiation Data (QCRAD) (Long and Shi 2006, 2008)	Month, day, hour	SGP domain averaged
Aerosol optical depth 550 nm	MFRSRAOD1MICH	Multifilter Rotating Shadow-band Radiometer (MFRSR) (Knootz et al. 2013)	Month	Averaged over SGP Site C1 and E13
Surface latent/ sensible heat	BAEBBR	Best-Estimate Fluxes from EBBR Measurements and Bulk Aerodynamics Calculations (Cook and Sullivan 2011a)	Month	SGP domain averaged
	QCECOR	Quality Controlled Eddy Correlation Flux Measurement (Cook and Sullivan 2011b)	Month	SGP domain averaged
Surface soil moisture content (10 cm)	SWATS	Soil Water and Temperature System (Bond 2005)	Month	SGP domain averaged
Cloud fraction	ARSCL	Active Remote Sensing of Clouds (Clothiaux et al. 2001)	Month, day, hour	SGP Site C1

Zhang et al. (2020), BAMS.

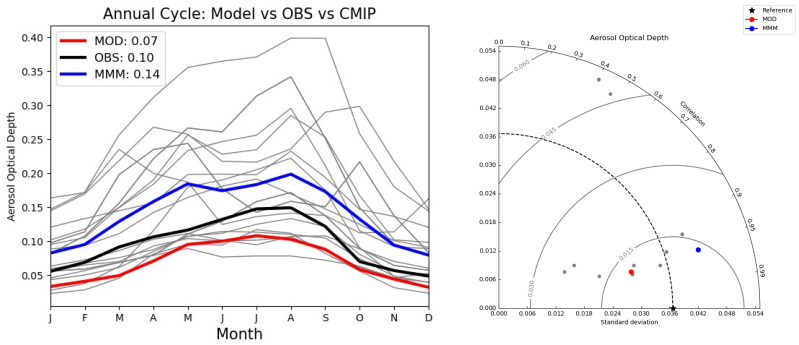
List of metrics and diagnostics (ARM-Diags v3)

- A set of **basic metrics tables**: mean, mean bias, correlation, and root-mean-square error based on annual cycle of each variable;
- **Line plots and Taylor diagrams** for annual cycle variability of each variable;
- **Contour and vertical profiles** of annual cycle and diurnal cycle of cloud fraction;
- **Line and Harmonic dial plots** of diurnal cycle of precipitation;
- **Probability density function (PDF)** plots of precipitation rate;

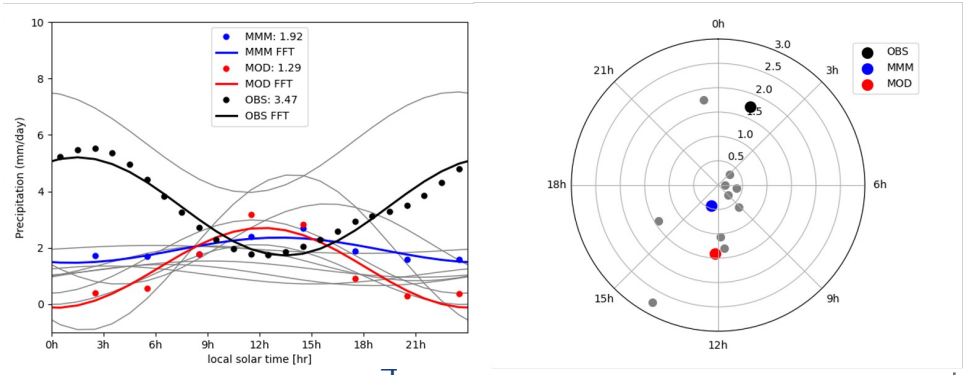
Annual cycle of cloud fraction



Line plots and Taylor diagrams of Aerosol Optical Depth



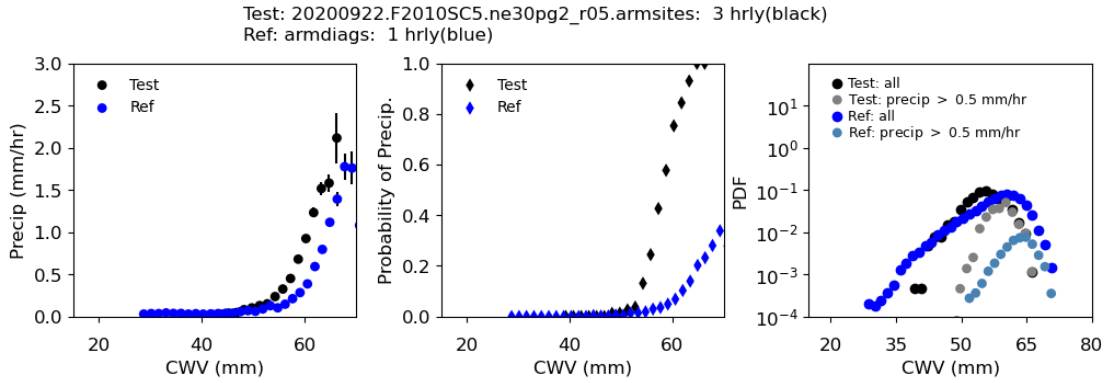
Diurnal Cycle of Precipitation



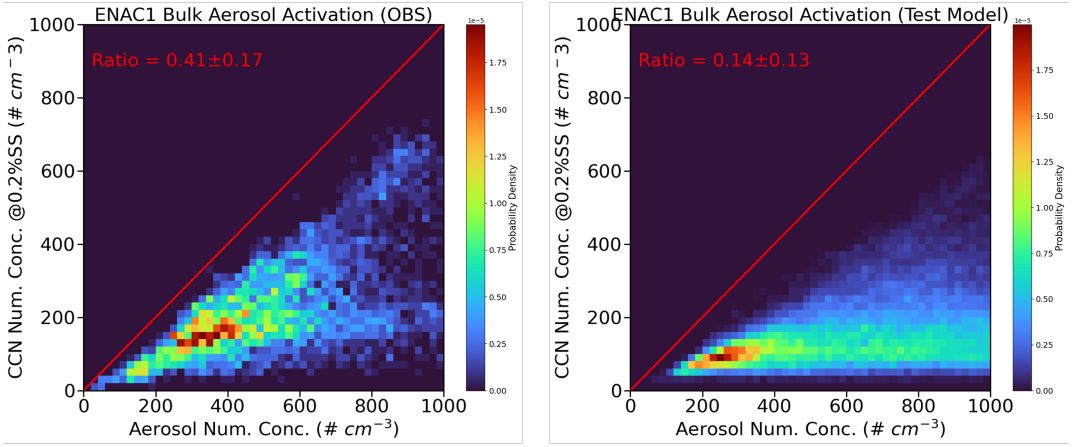
List of metrics and diagnostics (ARM-Diags v3)

- **Convection onset metrics** showing the statistical relationship between precipitation rate and column water vapor;
- **Aerosol-CCN activation metrics** showing the percentage distributions of how many aerosols can be activated as CCN under certain supersaturation levels.

Convection onset metrics (contributed by UCLA)



Aerosol-CCN activation metrics (contributed by U. of Arizona)



ARM-Diags: Quick Guide for Users

ARM-Diags: Install

For downloading data:

- Go to the ARM webpage for **ADCME**: https://www.arm.gov/data/data-sources/adcme-123
- Include both observational data sets, and climate model simulation data sets from CMIP5 and CMIP6.

For installing the package:

- GitHub repository: https://github.com/ARM-DOE/arm-gcm-diagnostics
- Include all Python-based analysis codes and step-by-step procedure to set up a working prototype.
- Dependencies include Python libraries: **cdat (*deprecated soon), matplotlib, numpy, scipy**, etc. and plan to migrate towards **xarray** based tools.

The flowchart of creating the diagnostic results by applying the diagnostics tool

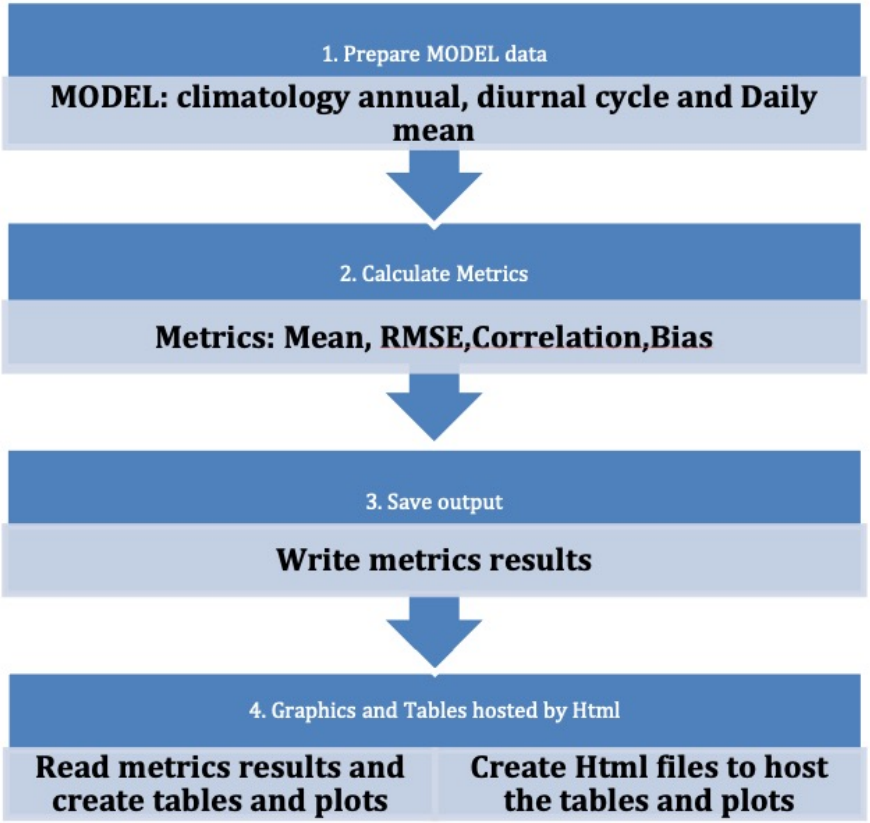


Figure 1. Workflow of the diagnostics package.

ARM-Diags: Set Up a Test Case

Step 1: Install the ARM-Diags on your local computer (~50 MB).

https://github.com/ARM-DOE/arm-gcm-diagnostics

Step 2: Download and place all the observation, CMIP data, test data under directories:

<Your directory>/arm_diags/observation

<Your directory>/arm_diags/cmip

<Your directory>/arm_diags/model

Step 3: Edit parameter file <basicparameter.py> to set 'base_path' to <Your directory> and 'output_path' for where the results will be saved.

Step 4: Run the package:

python arm_driver.py -p basicparameter.py

ARM-Diags: Set Up a Test Case

To view the diagnostics results:

For Mac OS:

open <Your directory>/arm_diags/case_name/html/ARM_diag.html

For Linux:

xdg-open <Your directory>/ arm_diags/case_name/html/ARM_diag.html

ARM data-oriented Diagnostics package (ARM-DIAGS-V3)

Metrics and Diagnostics

Model: testmodel

Basic Diagnostics Sets

1 Tables of DJF, MAM, JJA, SON and Annual Mean.

2 Line plots and Taylor diagrams of Annual Cycle.

3 Line plots and Taylor diagrams of ACI Annual Cycle.

4 Contour and Vertical profiles of Annual Cycle.

5 Line and Harmonic Dail plots of Diurnal Cycle.

6 Contour plots of Diurnal Cycle.

7 Line plots of Probability Density Function.

Process-oriented Diagnostics Sets

1 Basic diagnostics plots for Convection Onset.

2 Basic diagnostics plots for Aerosol Activation.

ARM-Diags: Set Up a New Case

Step 1: Install the ARM-Diags on your local computer (~50 MB).

https://github.com/ARM-DOE/arm-gcm-diagnostics

Step 2: Download and place all the observation, CMIP data, test data under directories:

<Your directory>/arm_diags/observation

<Your directory>/arm_diags/cmip

<Your directory>/arm_diags/model

Step 3: Edit parameter file <basicparameter.py> to set 'base_path' to <Your directory>.

Step 4: Run the package:

python arm_driver.py -p basicparameter.py

To apply this package to any CMIP output provided within our dataset, just copy the CMIP model data from

<Your directory>/ arm_diags /cmip

to

<Your directory>/ arm_diags /model

ARM-Diags: Set Up a New Case

Step 1: Install the ARM-Diags on your local computer (~50 MB).

https://github.com/ARM-DOE/arm-gcm-diagnostics

Step 2: Download and place all the observation, CMIP data, test data under directories:

<Your directory>/arm_diags/observation

<Your directory>/arm_diags/cmip

<Your directory>/arm_diags/model

Step 3: Edit parameter file <basicparameter.py> to set 'base_path' to <Your directory>.

Step 4: Run the package:

python arm_driver.py -p basicparameter.py

To apply this package to your own model output, just replace the model data in
<Your directory>/ arm_diags /model
with your **own model output**.

*Note that the file name should follow the test data files provided to be readable by the software package.

ARM-Diags: Debug mode

Run the package for certain metrics and/or ARM sites:

- Check out the /examples/ folder under <Your directory>/ arm_diag

```
bash-3.2$ cd examples/
bash-3.2$ ls
diags_all_multisites_v3_cmip6_aerosol_activation.json   diags_set2_cmip5.json
diags_all_multisites_v3_cmip6_annual.json               diags_set3_cmip5.json
diags_all_multisites_v3_cmip6_cf_zt.json                diags_set4_cmip5.json
diags_all_multisites_v3_cmip6_onset.json                diags_set6_cmip5.json
diags_all_multisites_v3_cmip6_precip.json               diags_sets_cmip5.json
diags_all_v2_cmip5.json                                 test_convection_onset_cmip5.json
diags_set1_cmip5.json
bash-3.2$
```

- Edit the 'XXX.json' file in **arm_driver.py** to specify the metrics of interest

```
def make_parameters(basic_parameter):
    #f_data = open('examples/diags_set3.json').read()
    #f_data = open('diags_all_multisites_for_cmip5.json').read()
    f_data = open('diags_all_multisites_for_cmip6.json').read()
    json_file = json.loads(f_data)

    parameters = []
    for key in json_file:
        print((json_file[key],key))
        for single_run in json_file[key]:
            p = copy.deepcopy(basic_parameter)
            for attr_name in single_run:
                setattr(p, attr_name, single_run[attr_name])
            parameters.append(p)
    return parameters
```

ARM-Diags: Future Plan

- **Expanding analysis capability** by orchestrating diagnostics and metrics developed from ARM/ASR and broader community.
  - Collaborated with UCLA for convection onset, with U. of Arizona for aerosol cloud interaction.
  - Ongoing effort to include land-atmosphere coupling.
  - Welcome to contribute new modules!
- Facilitating application of ARM-Diags in **climate model evaluation**, e.g. E3SM, CESM, GFDL and CMIP formatted model output, e.x:
  - Make modules easily portable to other analysis systems.
  - Update ARM-Diags results for CMIP and make them publicly available.
- Technical enhancement: migrate toward using tools **from xarray based** Python libraries, e.g. xCDAT.

Questions and/or Feedbacks? Please contact Cheng Tao (tao4@llnl.gov).