The ARM Data-oriented Metrics and Diagnostics Package for Climate Models

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ARM
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Introduction: ARM Data-oriented Diagnostics Package

Goal: Facilitate the use of high value ARM data in climate model evaluation and model inter-comparison.

- Data: ARM high-frequency long-term continuous measurements of clouds, aerosols, radiation, precipitation…are invaluable

- Analysis: Process-oriented diagnostics to help understand model errors and improve physical parameterizations

- Python package: File I/O, metrics calculation, graphics, generating viewer, available from GitHub ARM project space.
(Zhang at el, 2020, BAMS, accepted)
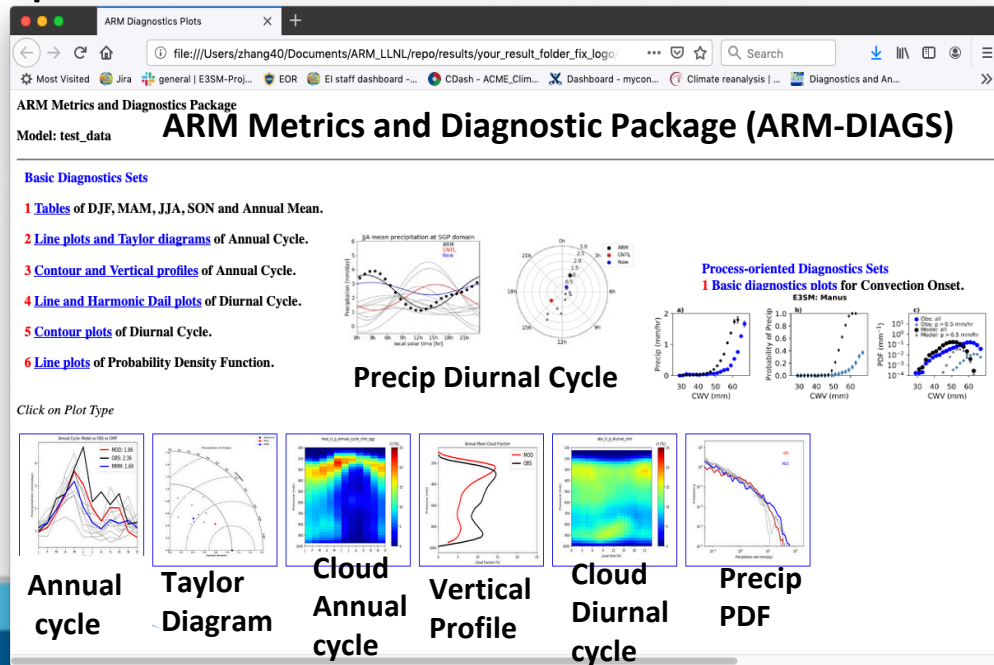
Datasets included in ARM-DIAGS

- Observational data assembled from: **VARANAL, ARMBE**, **ACRED** and other VAP products.

- Included SGP, NSA, and 3 TWP sites. SGP data shown on the right table:

- Reference model data from: **CMIP5** and **CFMIP2** output archived at ESGF.

| Quantities	ARM Data Products	Data Source/ Instruments	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]	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]	sgp domain averaged
Surface Precipitation	Same as above	Arkansas-Red Basin River Forecast Center (ABRFC) Nexrad radar precipitation estimates w/ rain gauge	sgp domain averaged
Precipitable Water	Same as above	Microwave Radiometer (MWR) water liquid & vapor along line of sight (LOS) path (MWRLOS)	sgp domain averaged
Surface All Sky Radiative Fluxes	Same as above	Data Quality Assessment for ARM Radiation Data (QCRAD) [Long and Shi, 2006, 2008]	sgp domain averaged
Aerosol Optical Depth 550nm	MFRSRAOD1MICH	Multifilter Rotating Shadowband Radiometer (MFRSR) [Knootz et al.,2013]	Averaged over sgp Site C1 and E13
Surface Latent/Sensible Heat	BAEBBR	Best-Estimate Fluxes From EBBR Measurements and Bulk Aerodynamics Calculations (BAEBBR) [Cook, 2011a]	sgp domain averaged
	QCECOR	Quality Controlled Eddy Correlation Flux Measurement [Cook, 2011b]	sgp domain averaged
Surface Soil Moisture Content (10 cm)	SWATS	Soil Water and Temperature System (SWATS)) [Bond, 2005]	sgp domain averaged
Cloud Fraction	ARSCL	Active Remote Sensing of Clouds [Clothiaux et al, 2001]	sgp Site C1
Ice Water Content/Liquid Water Content	ACRED	ARM Cloud Retrieval Ensemble Dataset [Zhao et al. 2012]	sgp Site C1

CAUSES: Summertime Warm Bias in CMIP5 over SGP
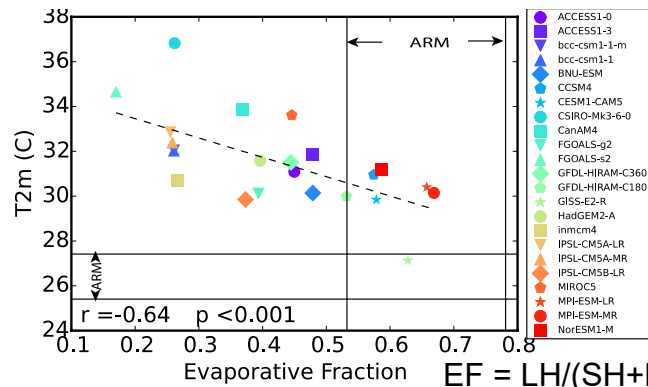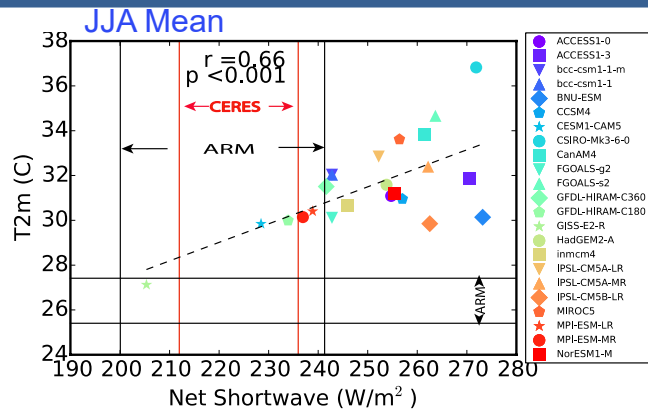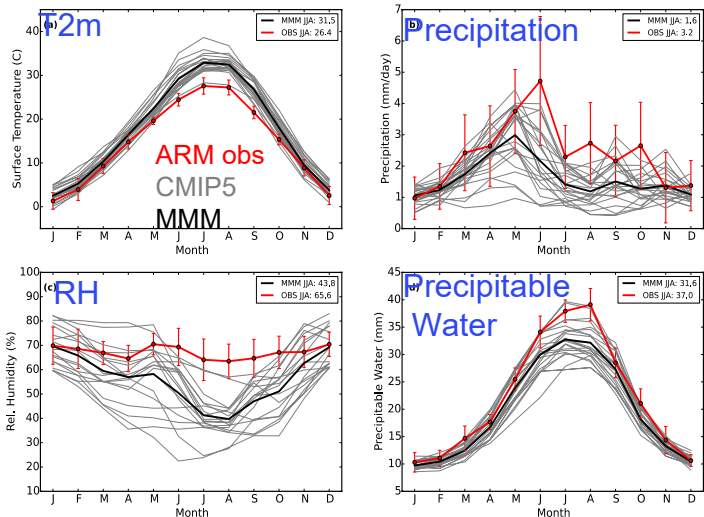
- Modeled summertime climate over SGP is too warm and dry in CMIP5 AMIP simulations

- Overestimated surface shortwave radiation and underestimated Evaporative Fraction [EF = LH/(SH+LH)] contribute to the warm bias

(Zhang at el, 2018, JGR)

Convection Onset Metrics for E3SM (Energy Exascale Earth System Model)

E3SM: Manus

OBS

EAMv1

*Critical water vapor for onset is too low*
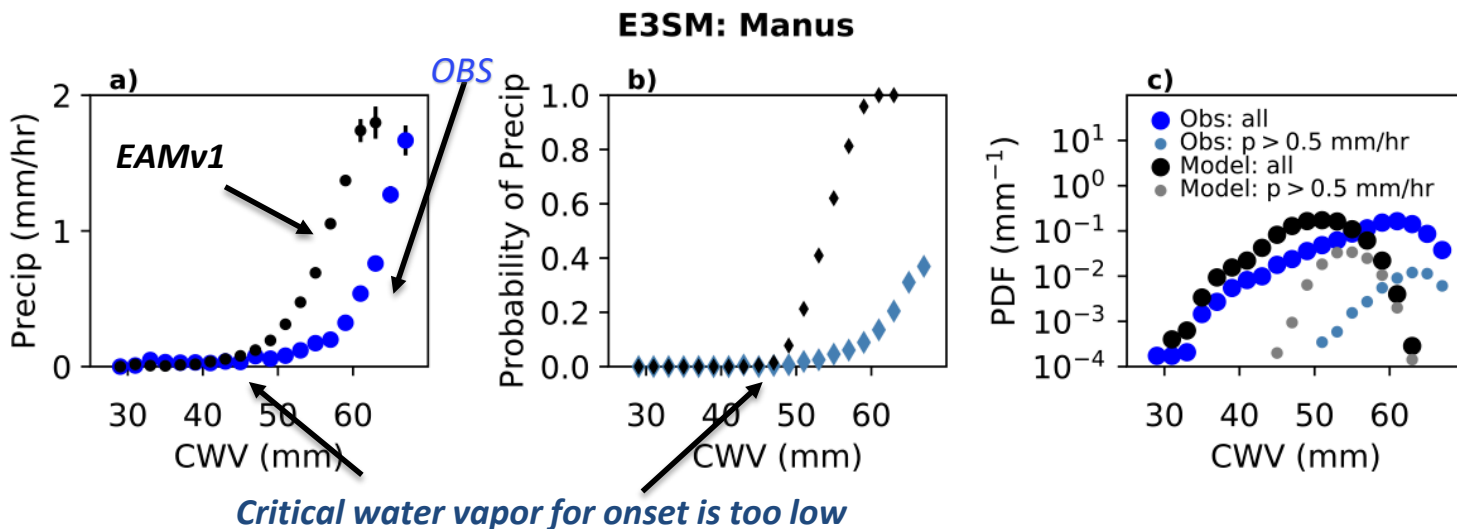
- Robust relationships between precipitation and column water vapor (CWV).
- Sharp increase or "pickup" in conditional-average precipitation rate above a critical CWV value
- E3SM EAMv1 results: Pickup and precipitation does well in form and magnitude, critical water vapor for onset is too low, as a result, peak of water vapor PDF also too low.

Figure provided by D. Neelin &T. Emmenegger (UCLA)

Diurnal Cycle of Precipitation

JJA mean precipitation at SGP domain
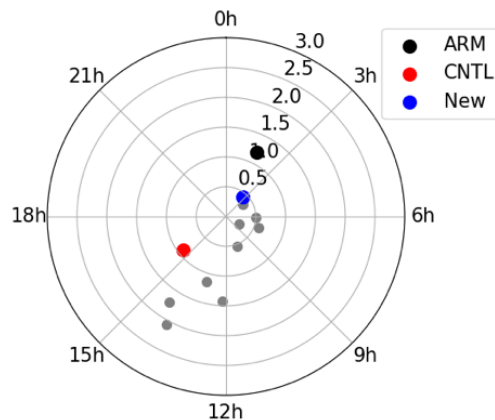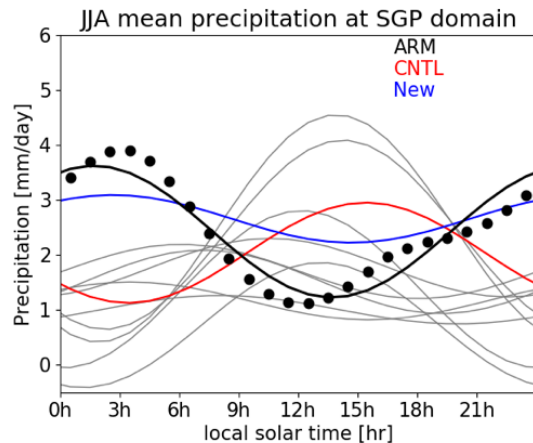
Black: ARM observations

Grey lines: CMIP5 model results

Red: E3SM v1

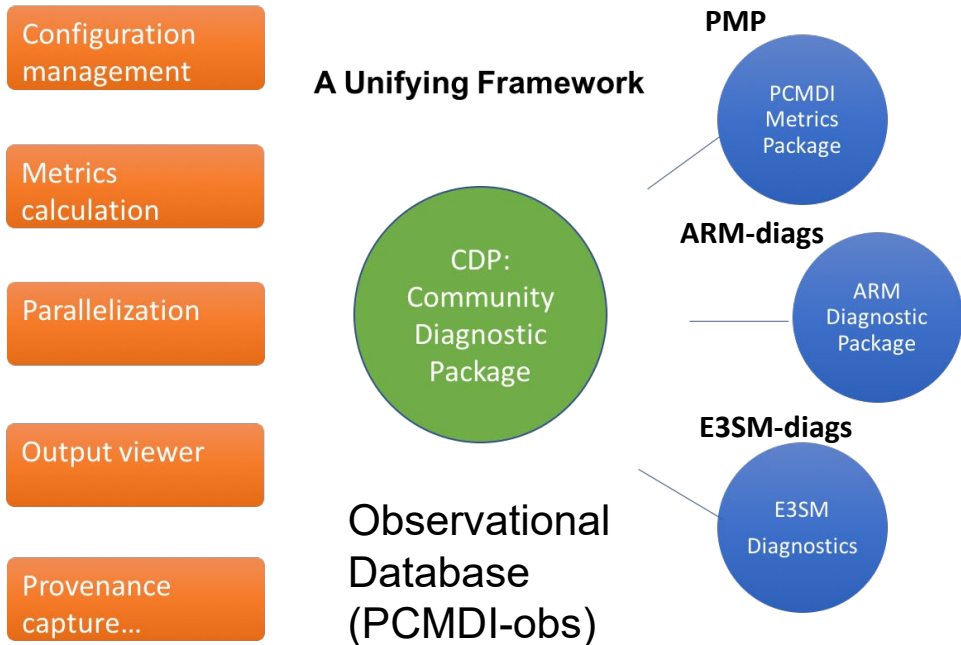Blue: New Trigger in E3SM

- Models fail to capture the observed nocturnal peak which is often associated with the eastward propagation of MCSs.

- A recently developed convective trigger in E3SM started to pick up the early morning peak time.

- The intensity is still too weak.

(Xie et al (2019), JAMES)

Engagement in E3SM and PCMDI projects

A Unifying Framework

PMP

PCMDI Metrics Package

ARM-diags

ARM Diagnostic Package

E3SM-diags

E3SM Diagnostics

CDP: Community Diagnostic Package

Observational Database (PCMDI-obs)

Configuration management

Metrics calculation

Parallelization

Output viewer

Provenance capture...

- **Goal:**
  - ❖ Effective synergy with these model diagnostics efforts in DOE.
- **Status:**
  - ❖ Python-based package with similar dependencies
  - ❖ Similar way of config and run by using **CDP**
  - ❖ Transition to use **PCMDI-obs**
- **Engagement Plan for ARM-Diags:**
  - ❖ With E3SM: Fully integrate ARM-DIAGS in **E3SM diagnostics** workflow**.**
  - ❖ With PCMDI: Contribute data to **PCMDI-obs,** analyses to **PMP**, and diagnostics results to a coordinated website (CMEC) for public access.

Summary and Future Plan

- The ARM metrics and diagnostics package is designed and developed to facilitate the use of ARM ground-based in-situ measurements in climate model evaluation and to create a central location for collecting valuable analyses developed from ARM/ASR.

- To make the package to be utilized broadly, we are integrating it into other commonly used Python-based packages (E3SM-diags and PMP) to provide routine model evaluation at ARM sites.

Future plan:
- Focus on adding process-oriented diagnostics: Updated convection onset metrics, warm bias attribution diagnostics, land-atmosphere coupling diagnostics.
- Datasets: New variables and ARM sites; CMIP6 datasets; Other obs sources.
- Investigate the incorporation of ARM radar simulator.