Pacific Northwest
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Updates on USDOE Research and Activities

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Pacific Northwest National Laboratory

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U.S. DEPARTMENT OF ENERGY BATTELLE

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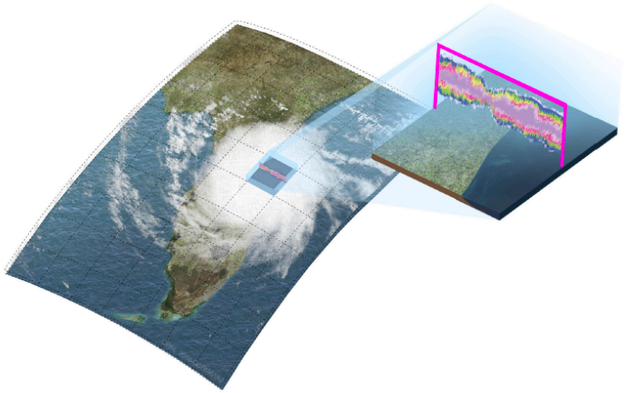
Outline

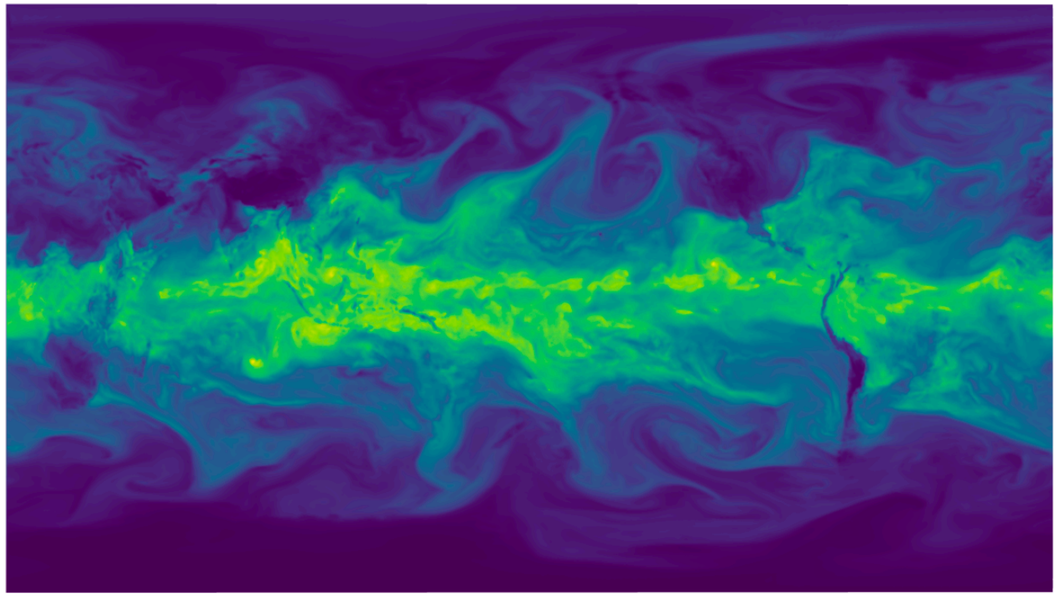
- Updates on selected DOE sponsored research
  - Energy Exascale Earth System Model (E3SM) convective-scale modeling
  - Research on mesoscale convective systems (MCSs)
  - Research on atmospheric rivers (ARs)
- Updates on DOE activities
  - DOE Precipitation Metrics Workshop (July 2019)
  - DOE Atmospheric River Tracking Method Intercomparison Project (ARTMIP) Workshop (October 2019)
  - ARM Decadal Vision 2020

Strategies for convective-scale modeling: super-parameterization



Application performance: 200 PF

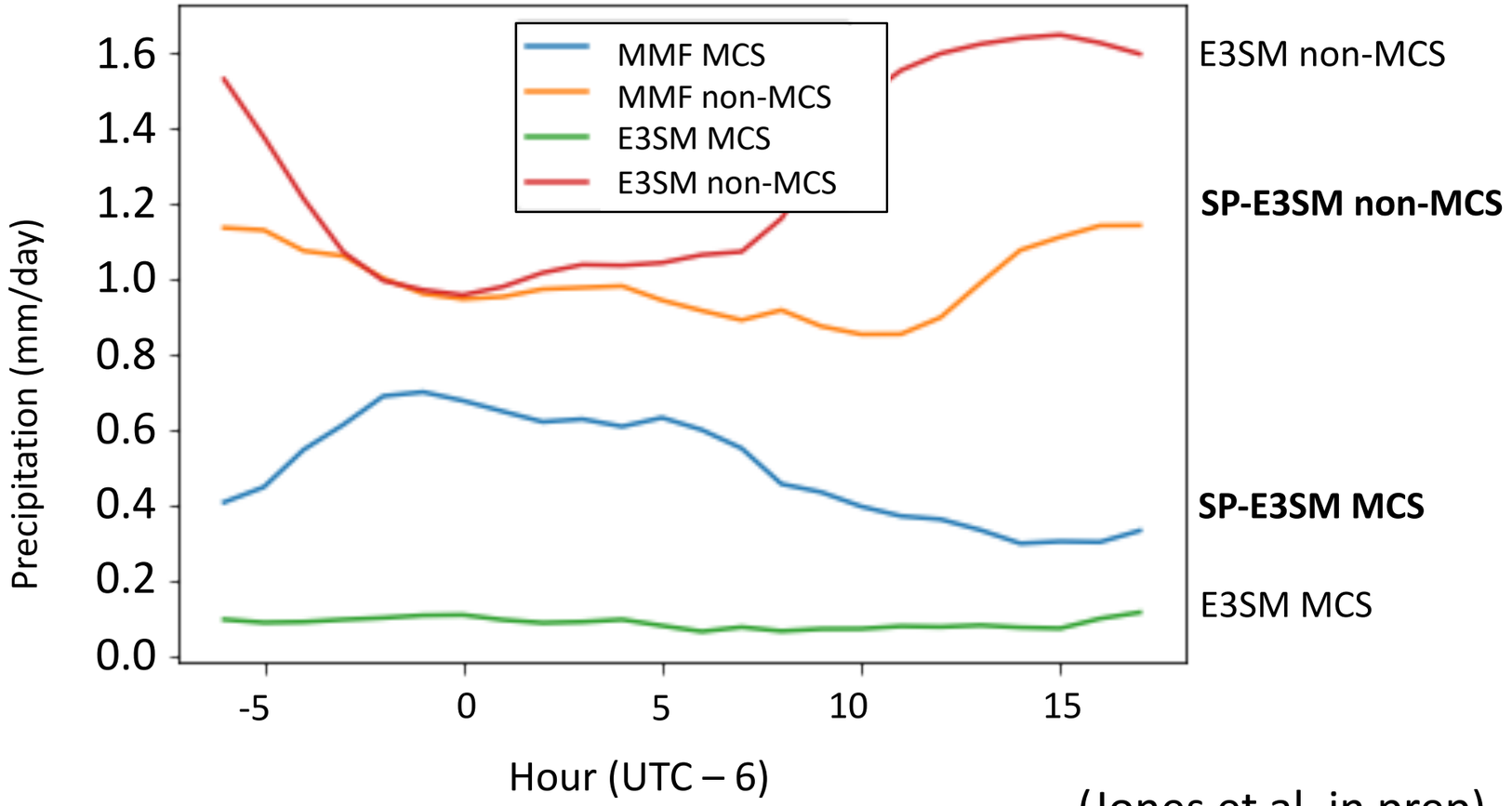
Water vapor contours after 40 days of simulation with **SP-E3SM using a 28km global grid and CRMs with 64 internal columns**



With the **CRM ported to GPUs**, a high-resolution benchmark using all 4,600 nodes on Summit demonstrates the computational capability of this effort in a realistic climate simulation with a full-physics atmospheric model

SP-E3SM improves precipitation diurnal cycle

Diurnal cycle of MCS and non-MCS precipitation (MJJA) over Central US



(Jones et al. in prep)

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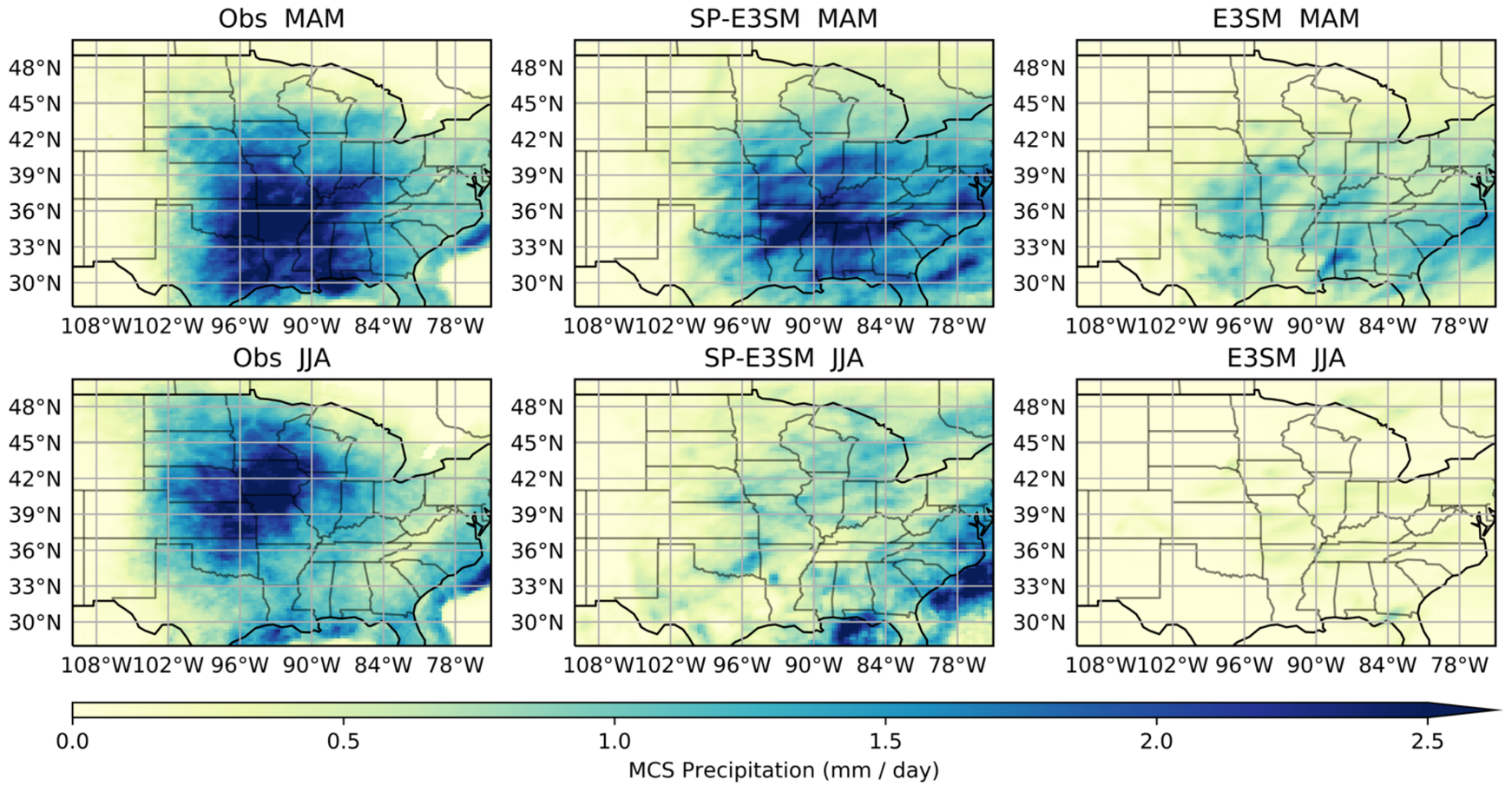
SP-E3SM improves simulations of MCS precipitation

Super-parameterization improves the simulations, but biases are still large in summer

MCS precipitation



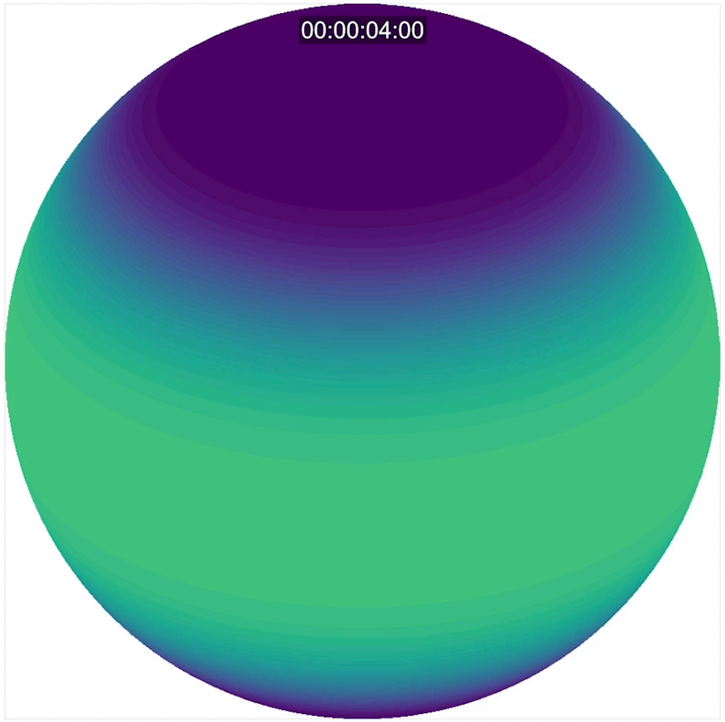
E3SM atmosphere ~ 28 km; CRM – 4 km

(Jones et al. in prep)

Strategies for convective-scale modeling: global storm resolving modeling

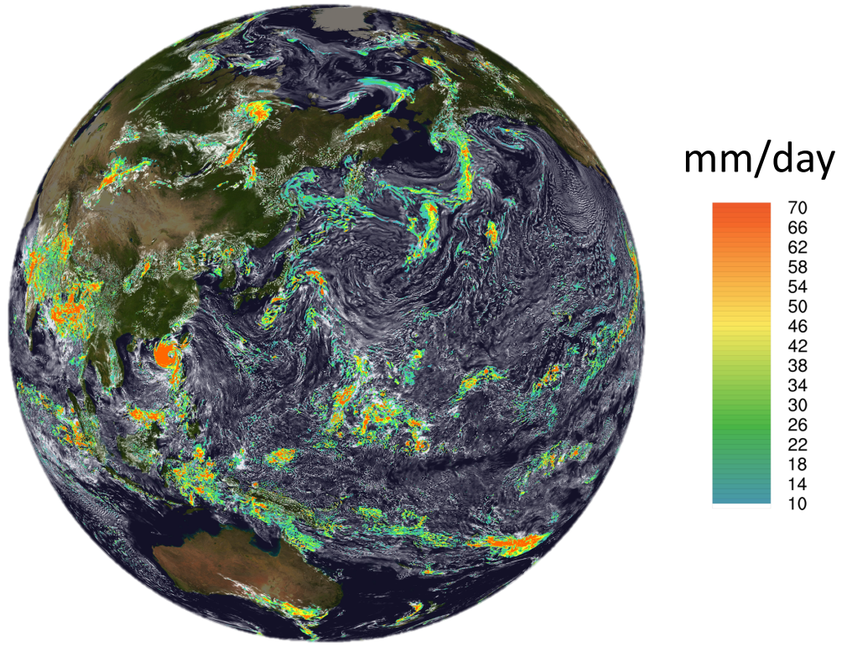
A global nonhydrostatic simulation of baroclinic instability using simple physics at 3 km grid spacing

Turbulent eddies in water vapor at 500 hPa



A global nonhydrostatic realistic simulation using full physics at 3 km grid spacing

2016-08-01 01:00 UTC



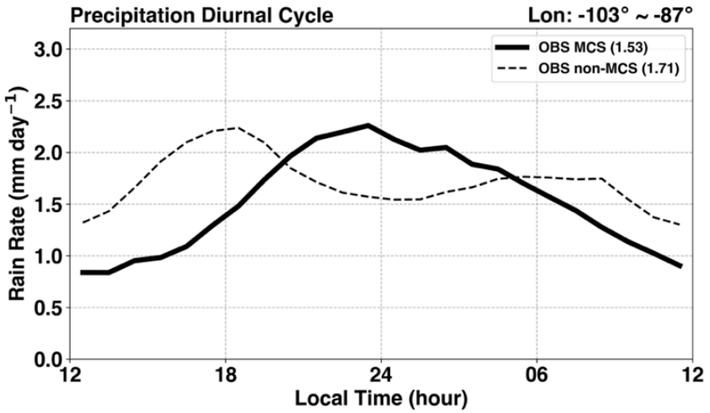
Snapshot of precipitation (color) and liquid water path (opacity with opaque white = 200 g m^{-2}) after 1 hr of simulation

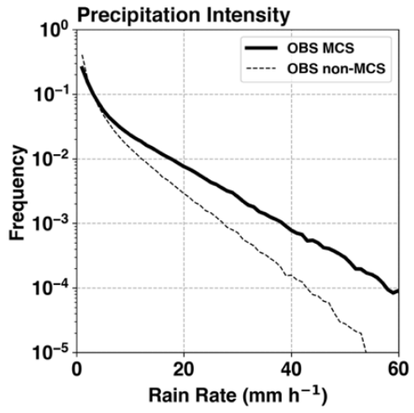
Mesoscale Convective Systems

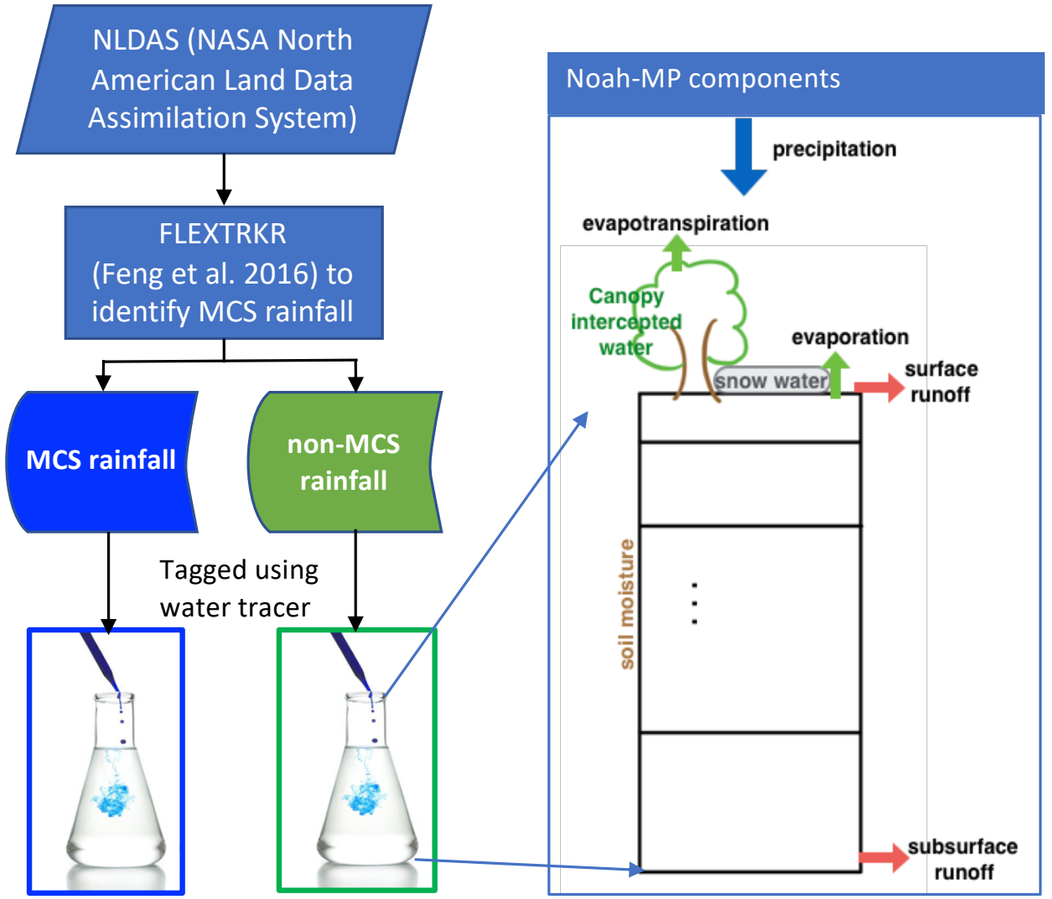
How do MCSs influence surface hydrology and land-atmosphere interactions?

MCS and non-MCS precipitation has distinct surface hydrologic response

A water tagging method is used to discern the surface water balance associated with MCS and non-MCS rainfall







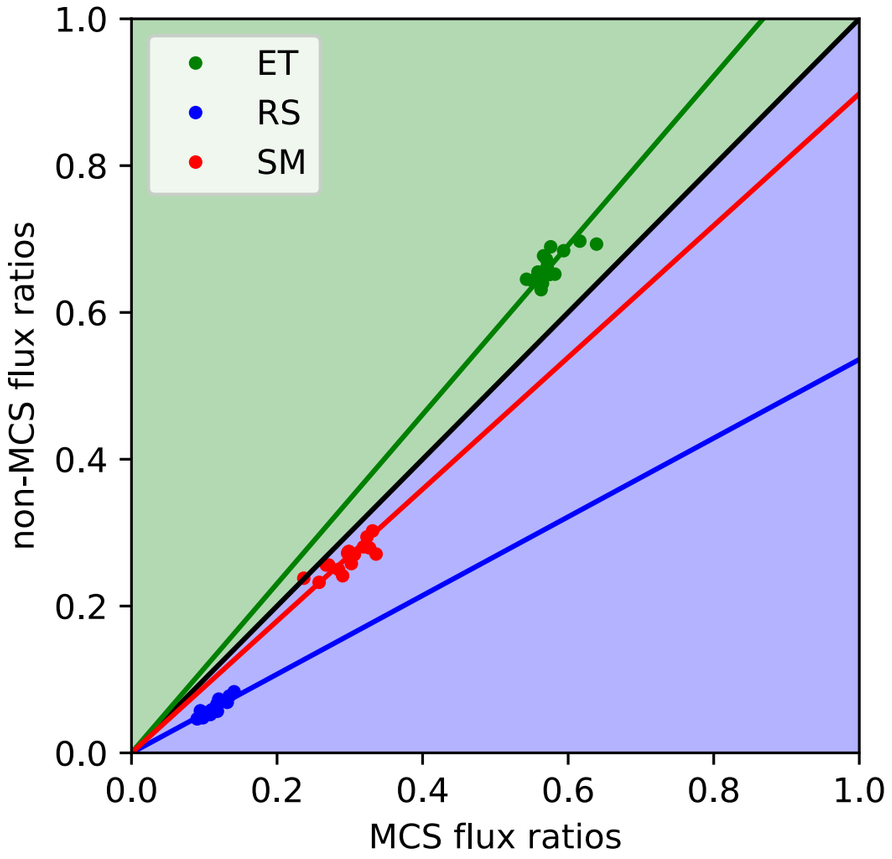
(Hu et al. in prep)

Mesoscale Convective Systems

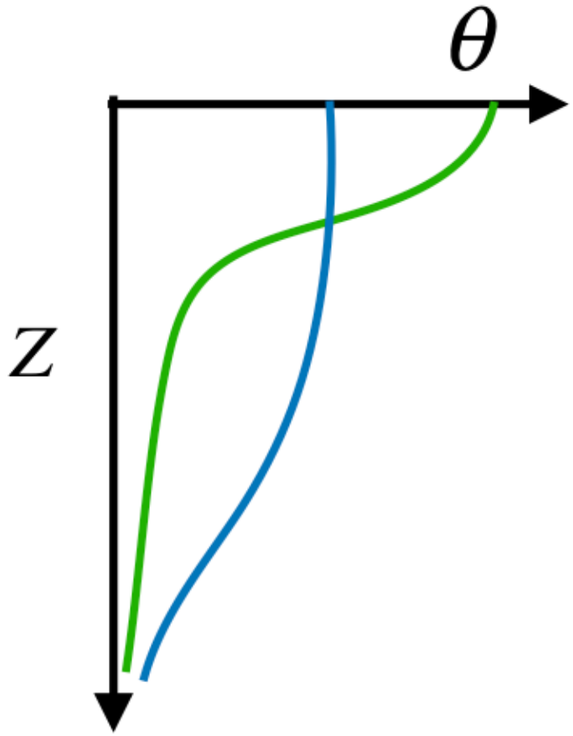
How do MCSs influence surface hydrology and land-atmosphere interactions?

MCS and non-MCS precipitation have distinct surface hydrologic response

Non-MCS rainfall produces more ET while MCS rainfall produces more runoff

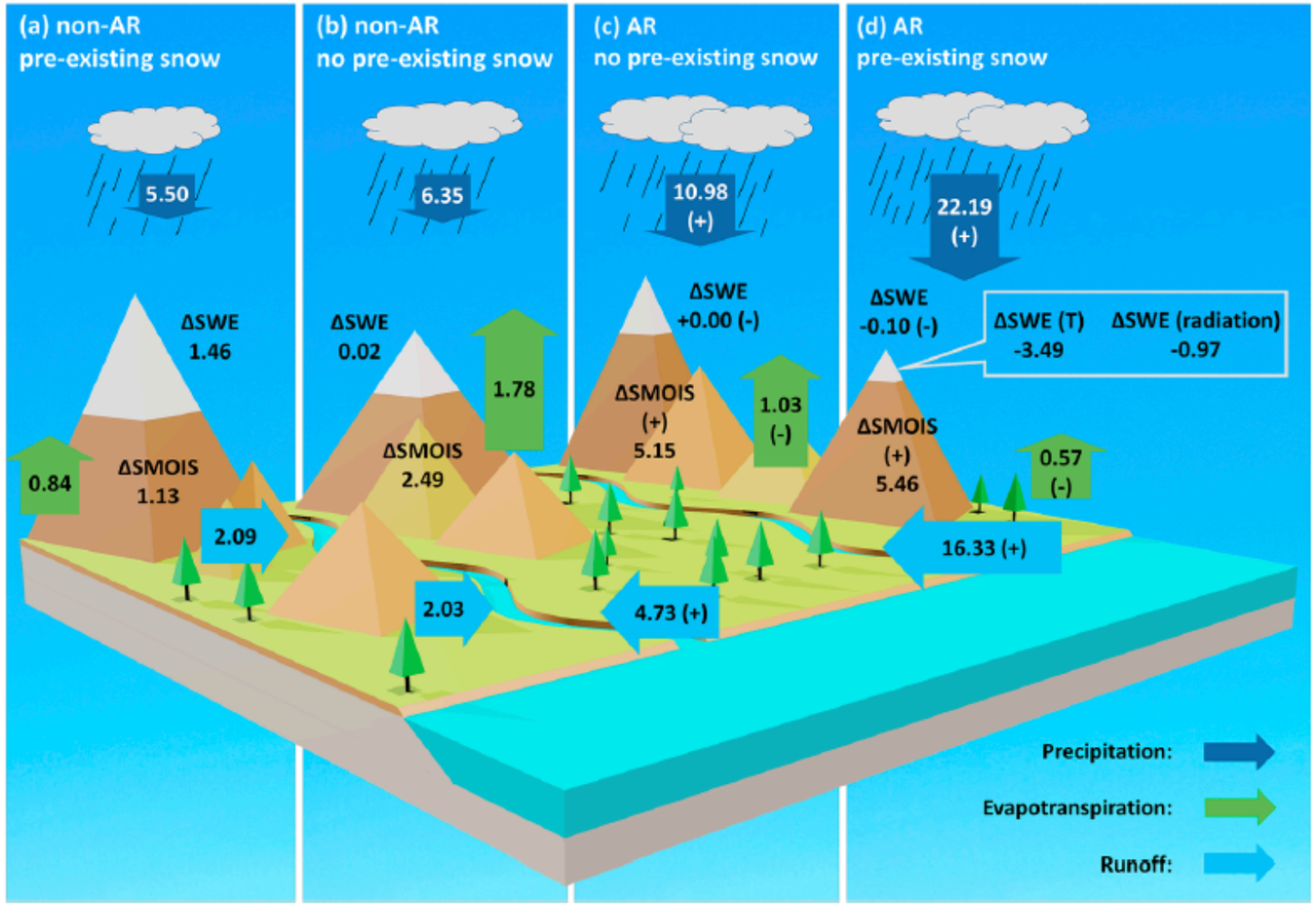


Water from non-MCS rainfall is stored in the upper soil layers and contributes more to soil evaporation



Atmospheric Rivers

AR induces large anomalies of precipitation with hydrologic impacts in western U.S.



AR: more intense precipitation, warmer temperature, higher net radiation

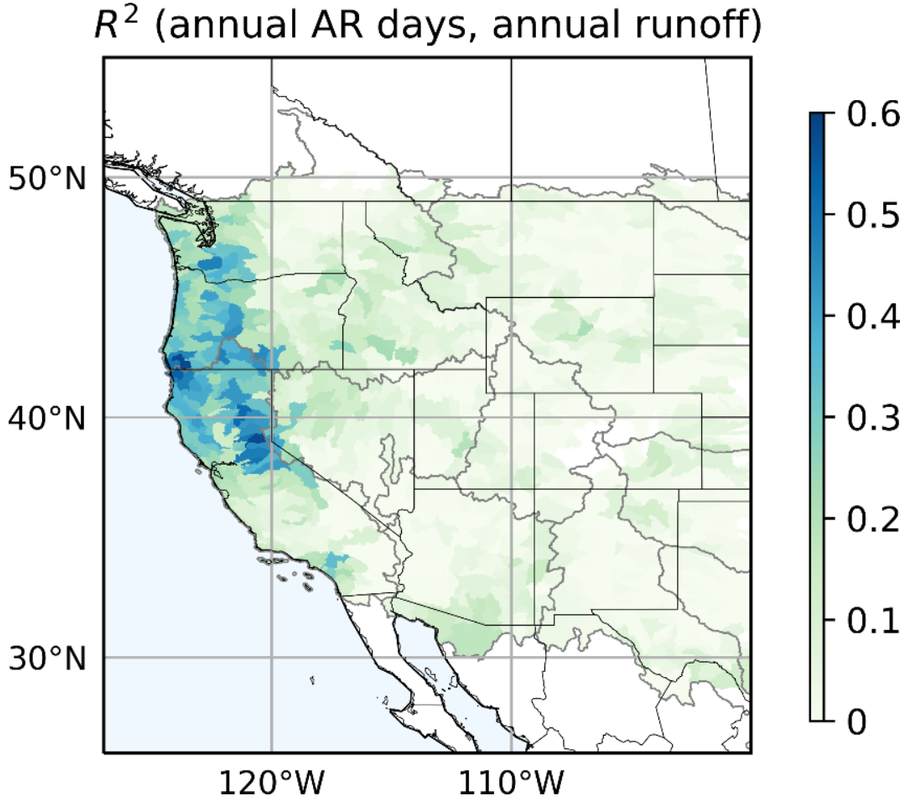
- With pre-existing snowpack:
  - R/P = 0.74 for AR events
  - R/P = 0.38 for non-AR events
- Without pre-existing snowpack:
  - R/P = 0.43 for AR events
  - R/P = 0.32 for non-AR events
- Rain-on-snow events amplify the hydrologic impacts of ARs

(Chen et al. 2019 JGR)

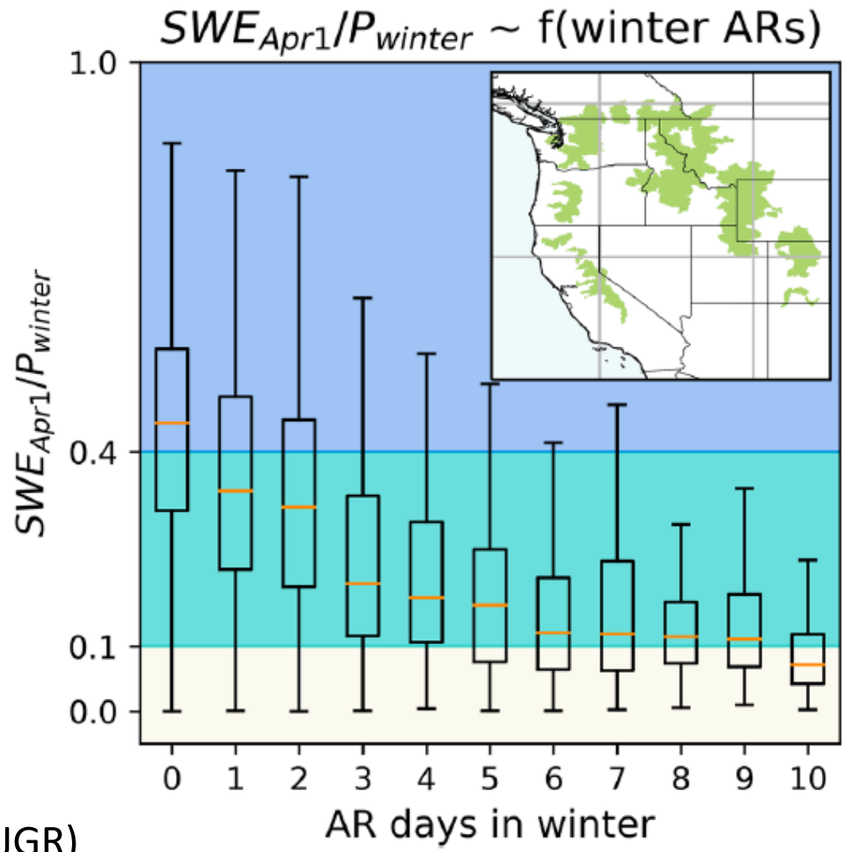
Atmospheric Rivers

Impact of AR on interannual and seasonal water supply

AR frequency explains over 40% of interannual variance of water availability in coastal western U.S.



ARs sharpen the runoff seasonality, reducing April 1st snowpack and summer runoff



(Chen et al. 2019 JGR)

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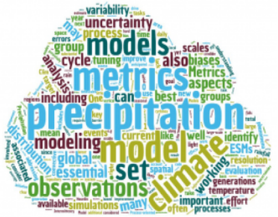
DOE Precipitation Metrics Workshop

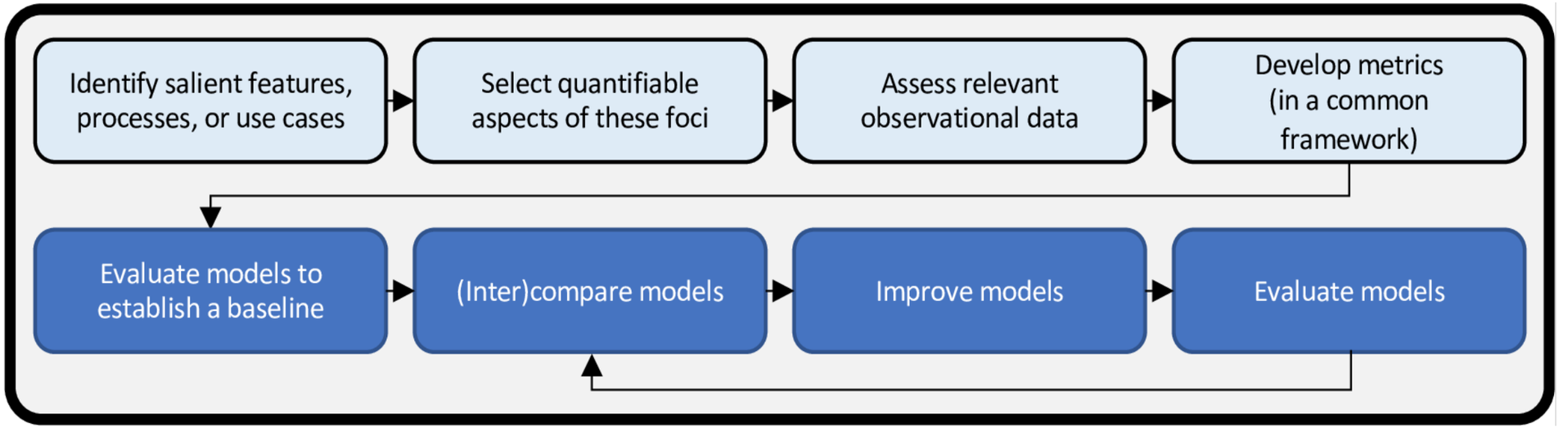


- Inspired by the lack of objective and systematic benchmarking of and the need to improve precipitation simulated by Earth System Models
- Community input via DOE 2018 AGU Town Hall and international modeling working groups
- Date/venue: July 1-2, 2019 in Rockville, MD

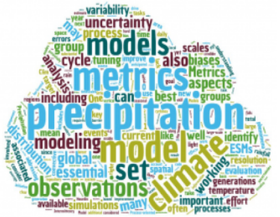
Workshop organizing committee:

Peter Gleckler (LLNL), Christian Jakob (U. Monash), Ruby Leung (PNNL),

Angie Pendergrass (NCAR)



Baseline metrics



- A limited set of observed characteristics to be used for model benchmarking
- Only require observed and simulated precipitation data
- Divided into tier 1 (e.g., global and annual mean) and tier 2 (e.g., regional and seasonal) and to be applied to a common set of simulations (e.g., CMIP6 DECK)

Spatial Distribution of Mean State	Seasonal Cycle	Variability Across Timescales	Intensity / Frequency Distributions	Extremes	Drought
RMS Error / MAE of mean state	Amplitude + phase of seasonal cycle	Standard deviation at different timescales	Simple Daily Intensity Index (SDII)	Rx1day	Frequency of SPI spells below a threshold
Pattern correlation	Monthly score (RMS error)	Diurnal cycle – phase and amplitude	Unevenness	Rx5day	Consecutive dry days
Monthly mean snow			Mean and variance of daily precip.	20y return values (from GEV)	
			Perkins score	Rx3h	
			Fraction of precipitating days	Seasonal breakdown	

Evaluation Options	Spatial Extent (regional, continental, global)	Climatological Period (annual, seasonal, monthly)

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Exploratory metrics

- Benchmark increasingly diverse aspects of precipitation to meet the needs of different user communities (model developers, earth system scientists, impact researchers and stakeholders)
- Often require more than just precipitation data

Exploratory Metrics		
Process-oriented Metrics	Regime-oriented Metrics	Use-inspired Metrics
Diurnal cycle of precipitation	Frontal precipitation	Fraction of wet days
Character of the distribution of precipitation rates	Extratropical + tropical cyclones	Average length of consecutive wet periods
Emergent constraints on precipitation	Mesoscale convective systems	Decorrelation time of precipitation
Orographic precipitation	Monsoonal precipitation	Intensity-duration-frequency curves
Teleconnections	Weather states	Correlated extremes

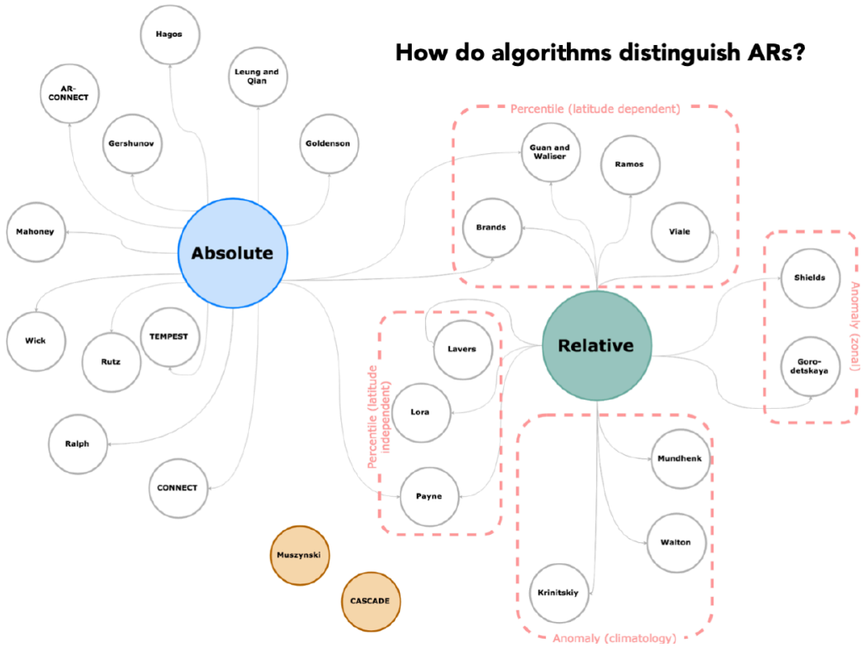
ARTMIP workshops

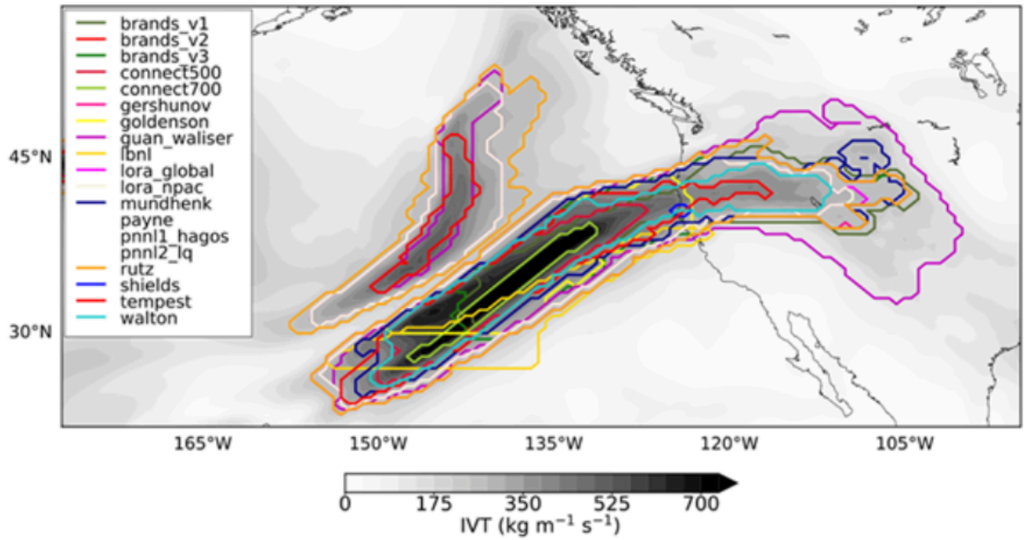
- The Atmospheric River Tracking Method Intercomparison Project (ARTMIP) was launched in 2016
- First ARTMIP workshop (2017): Tier 1 experiments using MERRA reanalysis
- Second ARTMIP workshop (2018): Tier 1 results and Tier 2 experiments using C20C+ and CMIP5/6 historical simulations
- Third ARTMIP workshop (2019)
  - Tier 1 and Tier results
  - Defined 4 new Tier 2 experiments: Tier 2 Reanalysis, Tier 2 High-Latitude, Tier 2 MPAS-ENSO, and Tier 2 paleo-ARTMIP
  - Expert identification of ARs and other weather phenomena for machine learning

ARTMIP Workshops

Gaps and priorities identified at the third ARTMIP workshop

- Go beyond existing AR detection algorithms that are primarily 2D to consider the AR 3D structure
- Develop open-source computational framework to facilitate implementation of existing and new AR detection algorithm
- Research to determine the different flavors of ARs and detection methods needed
- Basic research on the dynamics and lifecycle of ARs
- Objective and physics-informed clustering of AR detection algorithms





ARM Decadal Vision: 2014

Decadal Vision strategic plan identified five focus areas:

- Establish observation modeling “megasites” at the SGP and in the arctic
- Produce routine high-resolution simulations over ARM sites
- Continued focus on measurement excellence
  - Specifically called out aerosol instruments, scanning radars, and frozen precipitation
  - Develop UAS/TBS capabilities and review possible G-1 replacement
- Enhance data products and processes
  - Continue to improve the discoverability of ARM data
  - Improve the characterization and communication of data quality
  - Use DOIs to better link data to background information
  - Integrate ARM data with other BER measurements and simulations
- Strengthen interactions with the user community

https://www.arm.gov/about/future-directions

Update to the Decadal Vision

ARM is drawing on input from many sources to update its long-term plan:

- DOE CESD strategic plan and other DOE guidance
- Community input including
  - DOE and ARM workshop reports
  - ARM constituency groups (e.g. User Executive Committee)
  - Input from ASR meetings and other information gathered by the working groups (e.g. surveys)
  - Information gathered at science conferences and meetings of partner organizations (including GEWEX, other agencies, and related observatories in the EU)
- Input from ARM staff including
  - Data services and instrument mentor meetings
  - Input gathered through the change management process