Benchmarking Simulated Precipitation in Earth System Models

Min-Seop Ahn (LLNL), Peter Gleckler (LLNL), Christian Jakob (U Monash), Jiwoo Lee (LLNL), Ruby Leung (PNNL), Angie Pendergrass (Cornell), Paul Ullrich (UCDavis), Michael Wehner (LBL)

and many collaborators

TALK OUTLINE

- Motivation, US DOE July 2019 Precipitation Metrics Workshop
- Benchmarking Simulated Precipitation
- Exploratory Metrics
- Connections with WGNE

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Motivation

Despite significant progress, errors in many aspects of simulated precipitation limit the use of ESMs both in understanding Earth system variability and change and for decision-making

Goals

- *What* Accelerate efforts to improve ESMs by designing a capability to comprehensively evaluate simulated precipitation in ESMs

- *How* Enable ESM developers to better understand their models and provide them with quantitative targets for demonstrating improvements

Precipitation Metrics Workshop

https://climatemodeling.science.energy.gov/news/doe-host-precipitation-metrics-workshop

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

Identify targets for improvement

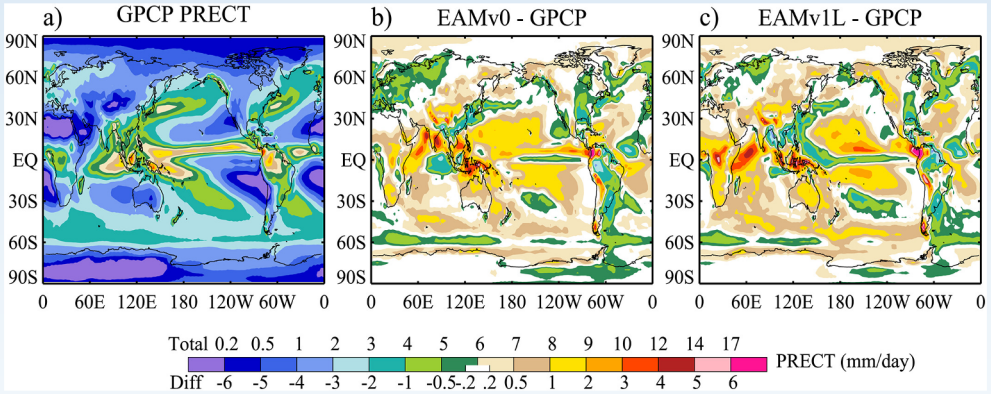
Team of experts identifies useful measures for gauging how well models simulate precipitation

Develop capability to gauge model quality

Baseline metrics incorporated into a model evaluation capability and used to assess current models

Improve simulated Precipitation

Modelers provided with metrics capability to serve as a target for improving newer model versions



Xie et al., 2018
https://doi.org/10.1029/2018MS001350

Establishing a pathway to help guide modelers

1) Identify a holistic set of observed rainfall characteristics that can be used to define metrics for gauging the consistency between ESMs and observations

1) Assess existing methods used to evaluate simulated rainfall and identify areas of research for exploratory metrics to improve understanding of model biases and meet stakeholder needs

International Participants with a diverse spectrum of expertise

Workshop attendees included

- Model developers interested in improving simulated precipitation
- Observational experts liaising with international teams
- Experts in model analysis of precipitation including the mean state, a broad range of variability and event characteristics including extremes, and distributions of precipitation rates
- Practitioners gauging model-obs agreement with performance metrics
- Experts in impact-related and use-inspired metrics
- Scientists involved in research topics where established metrics are lacking but desired (fronts, tropical cyclones, atmospheric rivers, etc.)

Outcomes

DOE 2019 Precipitation Metrics Workshop

- An agreed upon set of baseline precipitation metrics to be developed to gauge ESM performance
- A summary of topics that hold promise for developing more in-depth metrics encompassing a broad range of processes and phenomena
- Formation of two working groups to advance “baseline” and “exploratory” metrics
- DOE & BAMS workshop report (Pendergrass et al., 2020), multiple papers in progress
- Strategy to develop a repository of codes and data to enable community use with all current and future generations of ESMs

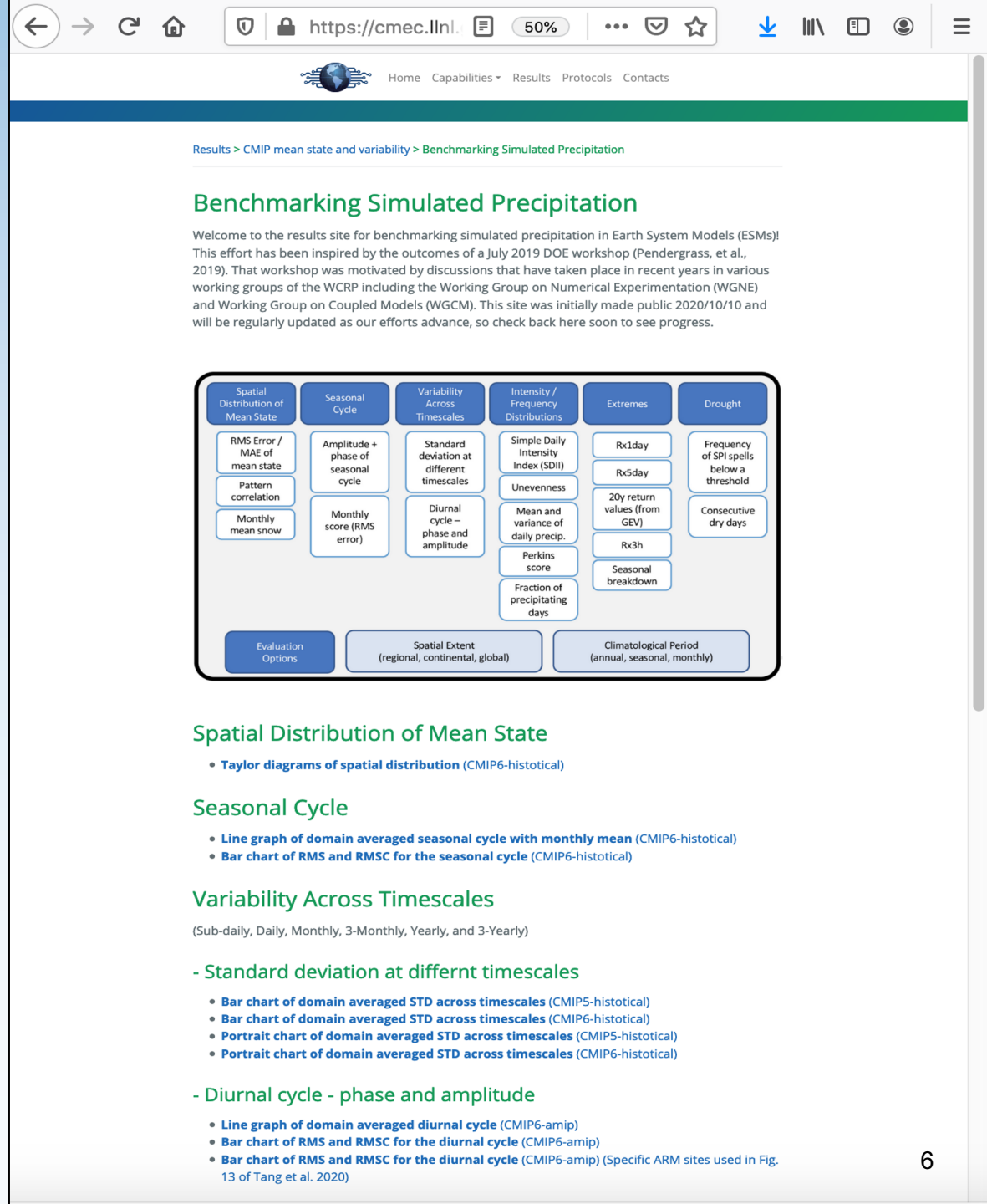
Preliminary results available

https://cmec.llnl.gov/results/precip

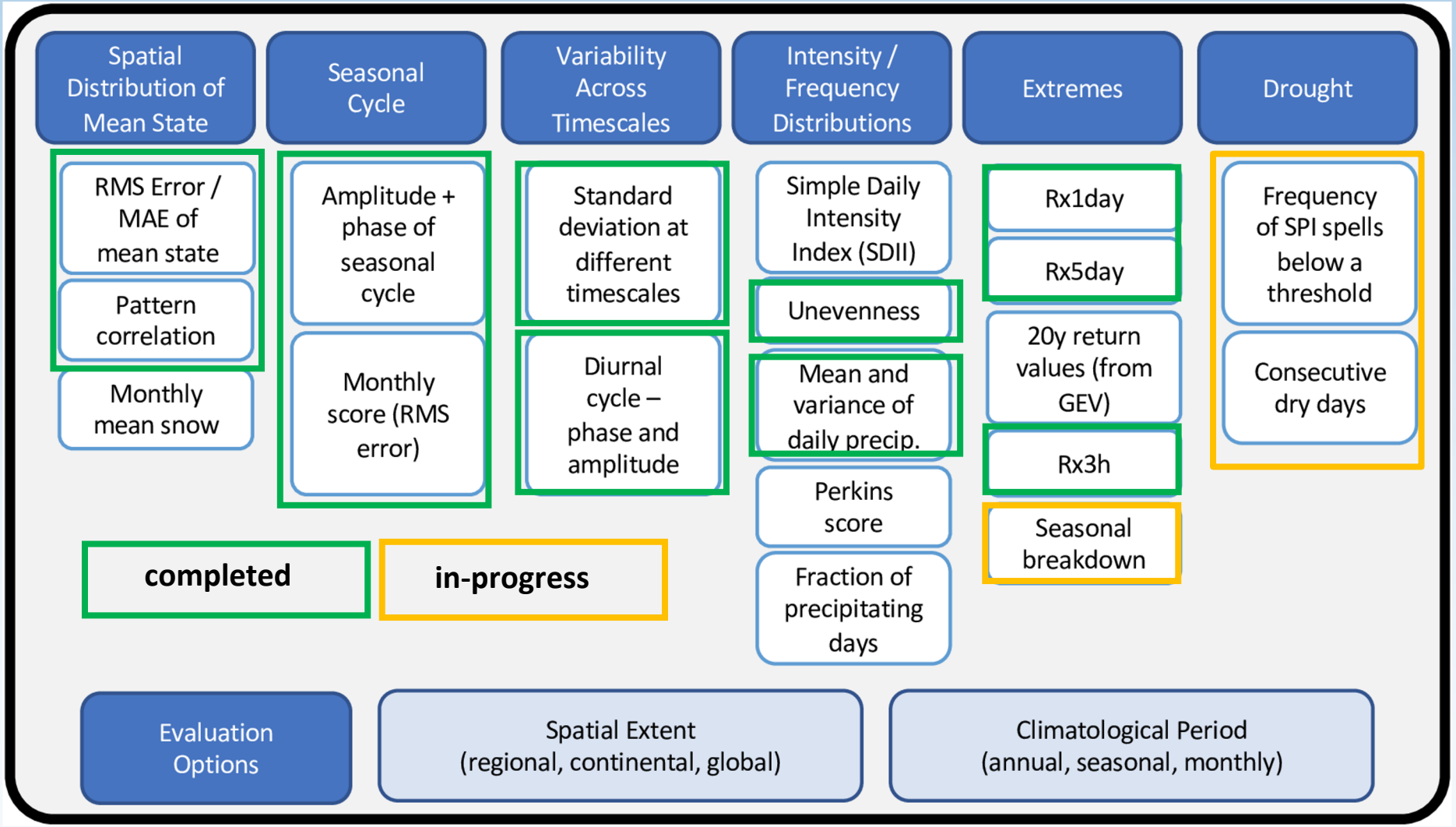
- Baseline metrics are being developed and applied to CMIP6 and earlier generations
- Implemented into a set of Coordinated Model Evaluation Capabilities (CMEC)
- Results include interactive navigation from summary statistics to underlying diagnostics
- Underway: strict version control for all data, results and codes

PCMDI Earth System Model Evaluation Project

Leads: **M. Ahn (post-doc)**, J. Lee, P. Gleckler



Progress
Precipitation baseline benchmarking



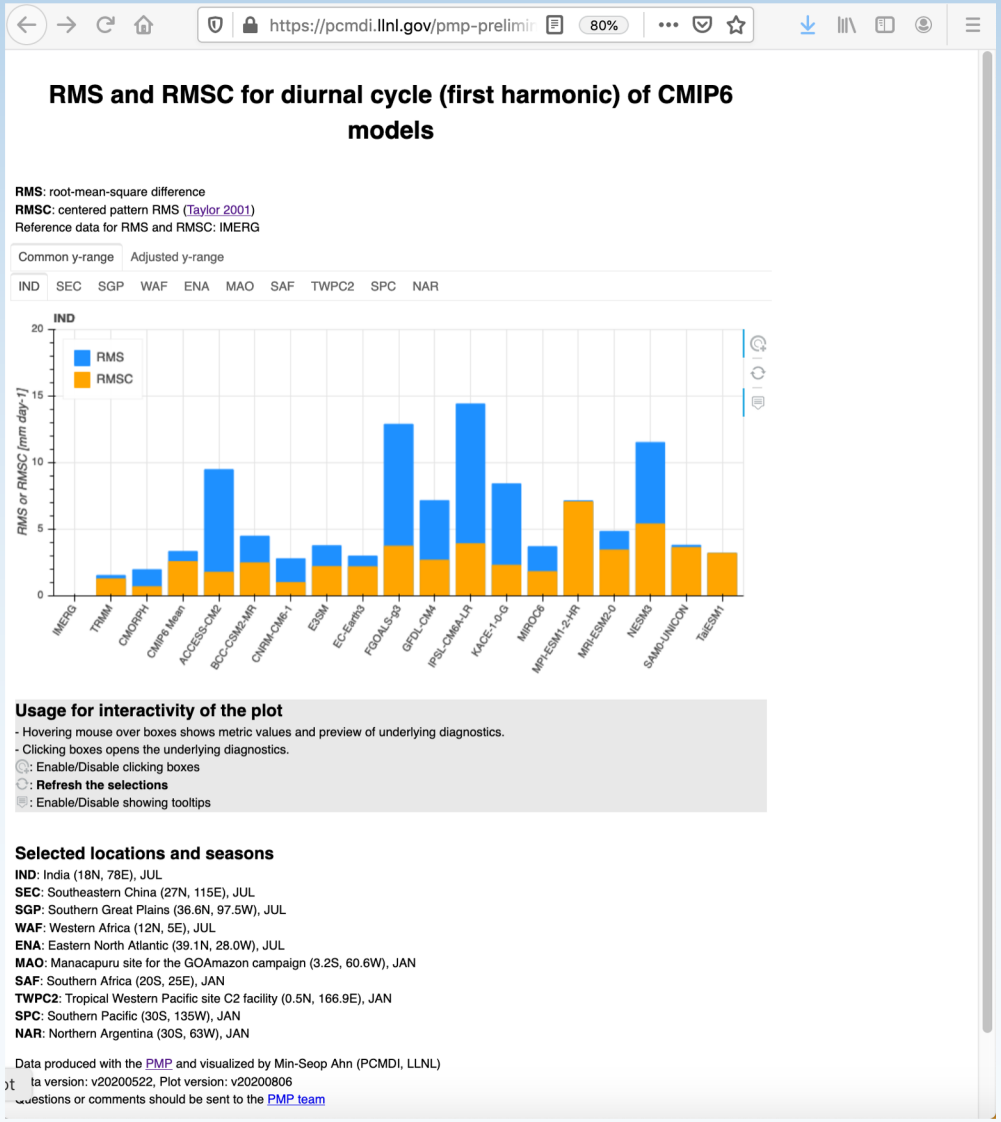
Proposed metrics: Tiers 1 and 2, resulting from DOE workshop breakout discussions (Fig 4).

PCMDI Earth System Model Evaluation Project

Diurnal cycle (courtesy M. Ahn)
Example

- Comparisons to multiple satellite data on regional to large scales

- Model and obs time series available directly from bar chart as “dive down” diagnostics



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Tang, S. et al., submitted J Clim

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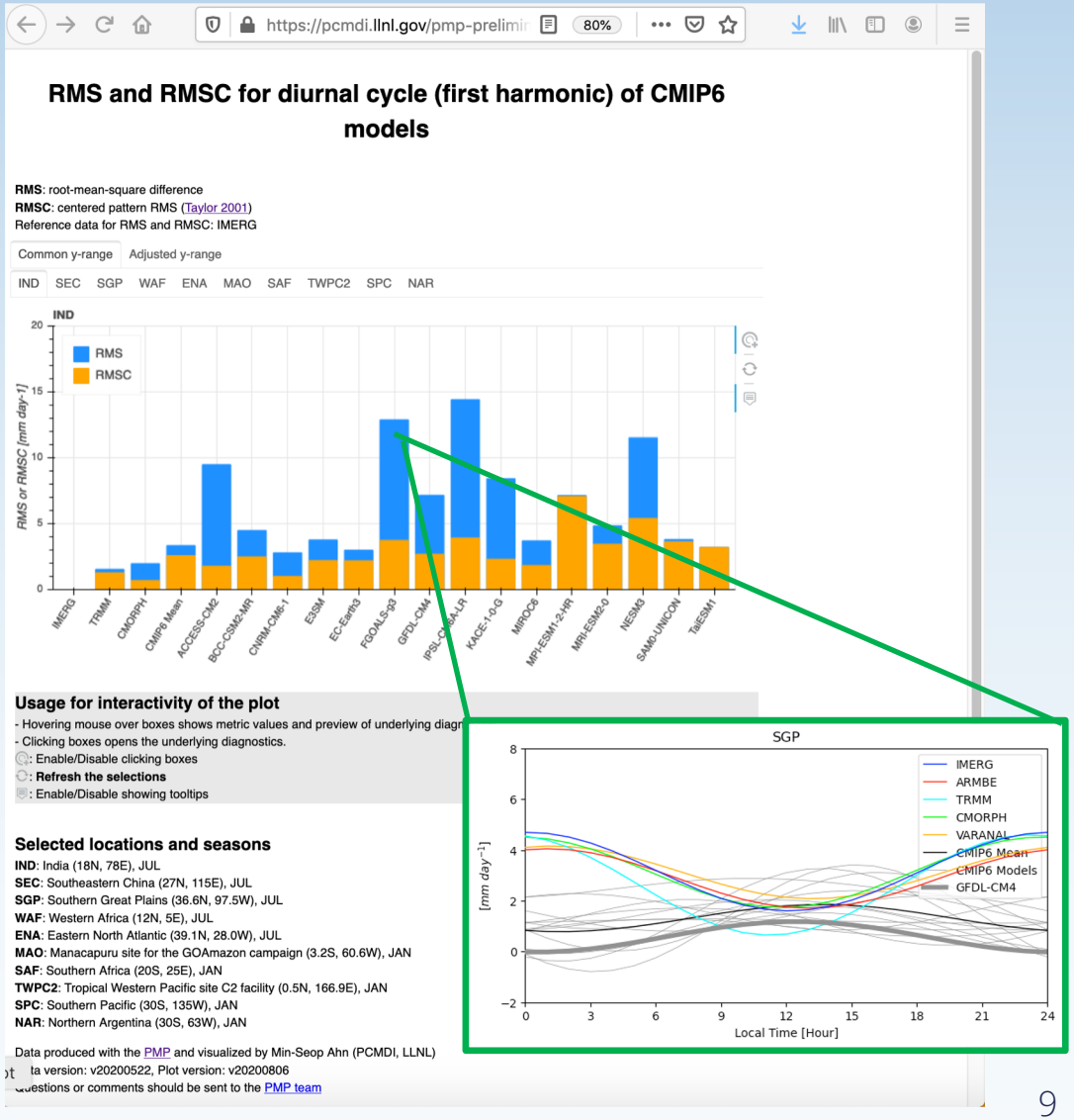

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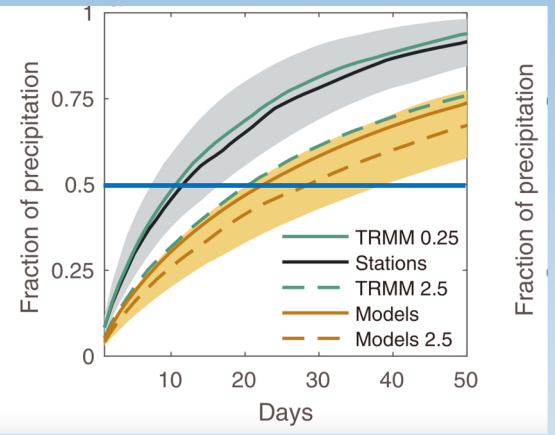
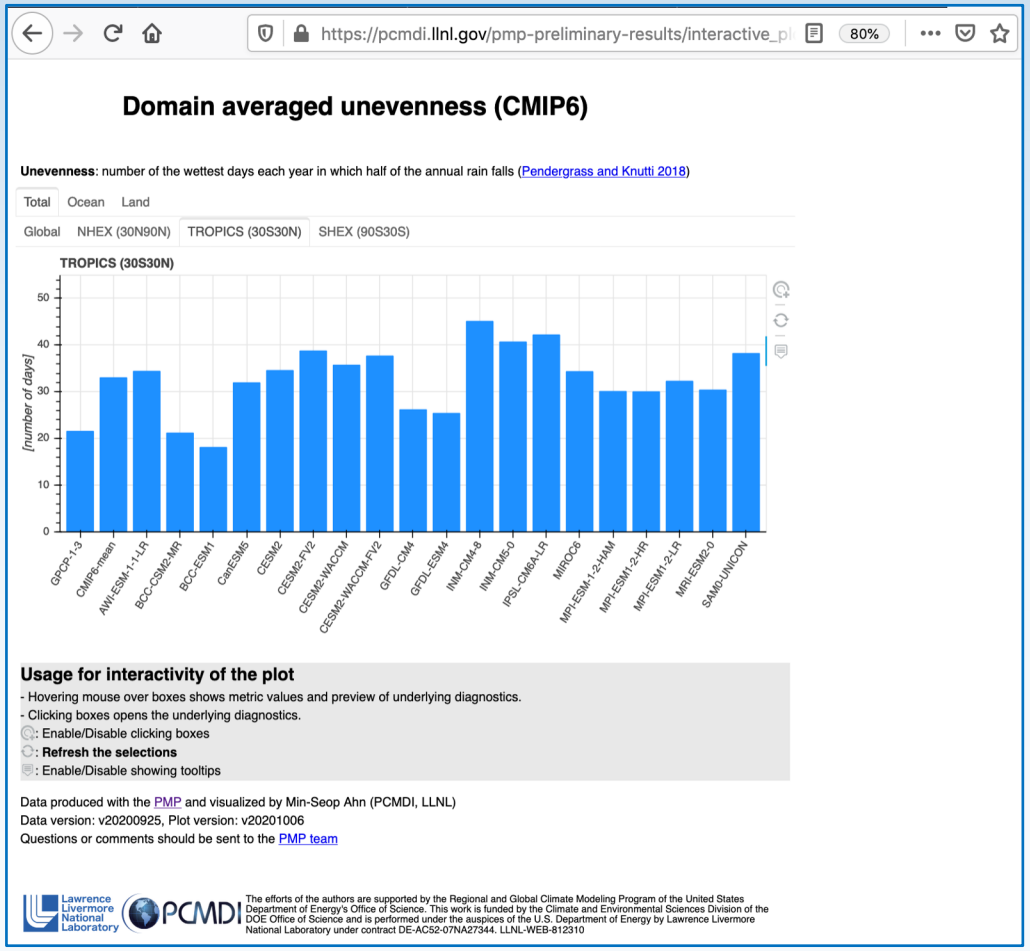
Precipitation Intensity and Frequency distribution
Example ii



- Robust "unevenness" metric defines number of days in a year accounting 50% of annual rainfall (Pendergrass and Knutti, 2018)
- Applied to large scale domains (Global, Tropics, Ex-tropics, land, ocean)
- Will be complimented with additional distribution-based metrics



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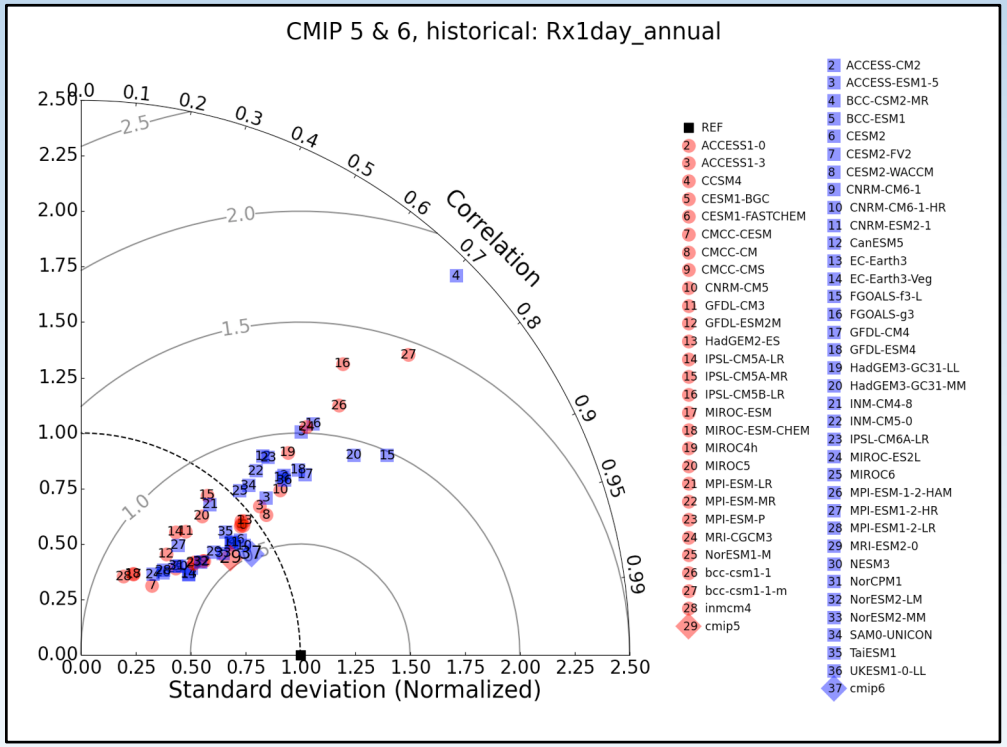
Extreme precipitation

Example iii

- Global-regional Rx1day implemented: comparison of CMIP5 and CMIP6 simulations
- At their standard resolutions, there are no meaningful differences between the two generations in their quality of simulated extreme daily precipitation
- Rx3hr in progress



Wehner et al., 2020

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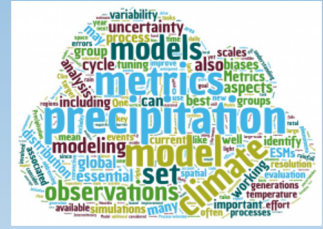
Looking ahead
Precipitation baseline benchmarking

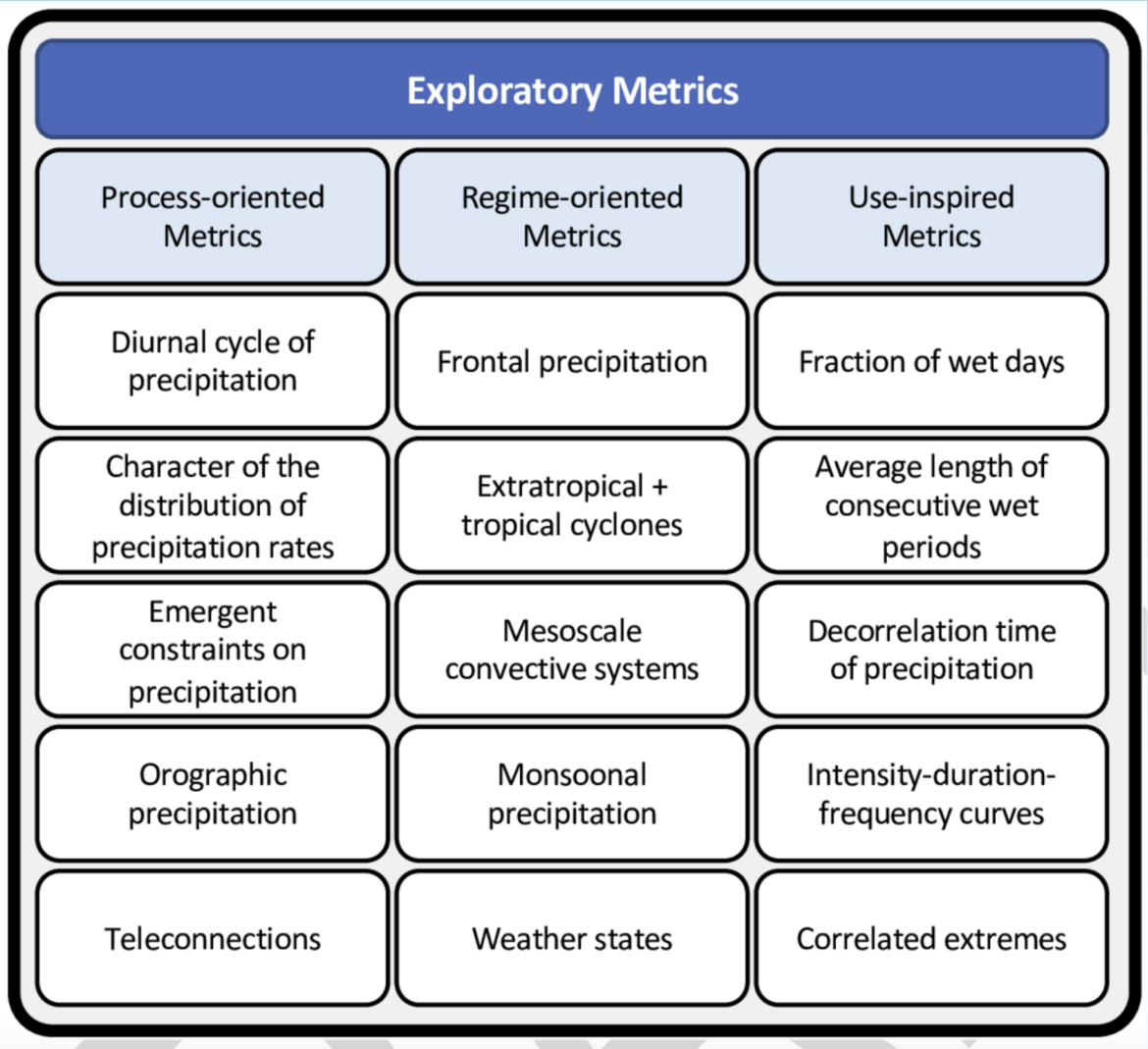


- Implementation of additional benchmarks, updating CMIP results on public website
- Further exploit available observational products
- Benchmarking: quantify improvements made over time by individual modeling centers
- Additional manuscripts summarizing effort and results
- Complete software documentation with end-to-end examples and supporting data
- Assist modeling groups to use the baseline precipitation benchmarks

Exploratory metrics: overview

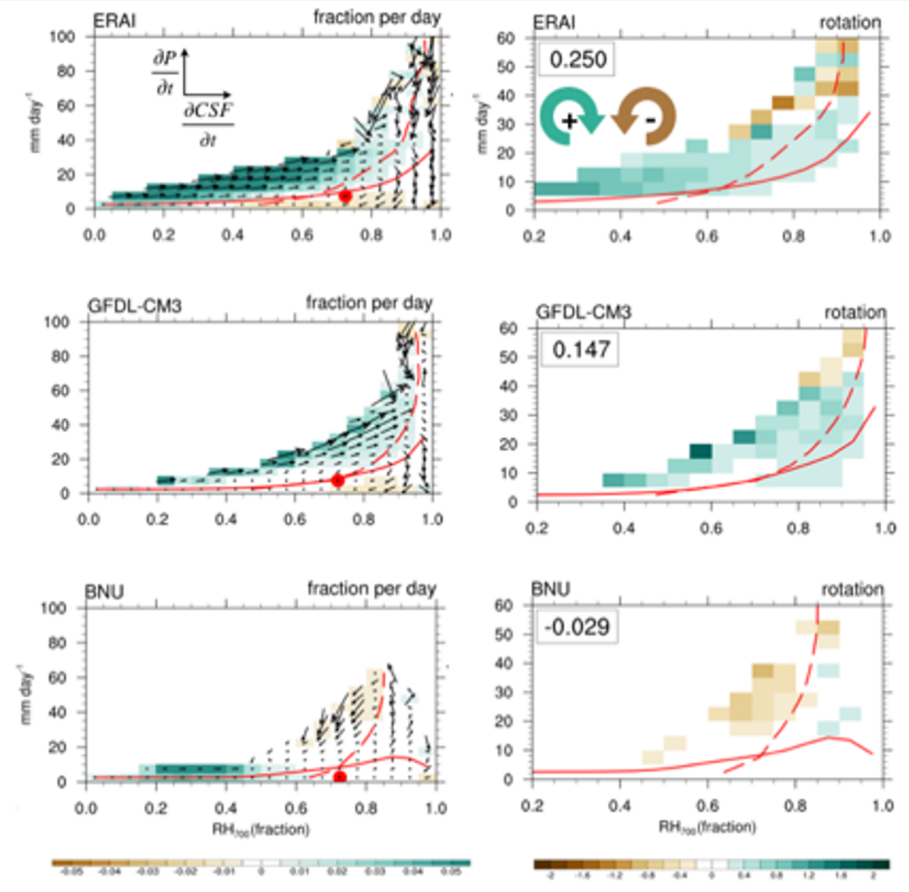
- Purpose: To develop benchmarks of increasingly diverse aspects of precipitation to meet the needs of different user communities (model developers, earth system scientists, impact researchers and stakeholders)

- Exploratory metrics often require more than just precipitation data

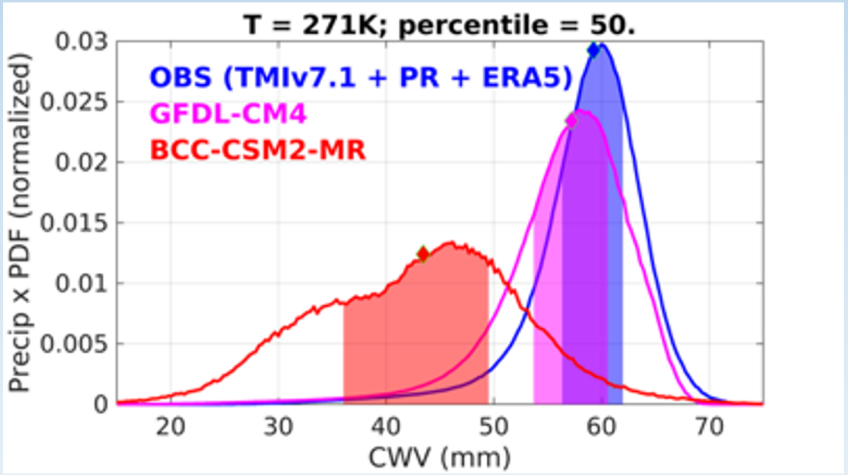


Process-oriented metrics: precipitation-moisture-temperature relationships and diurnal precipitation

Rainfall-moisture coupling

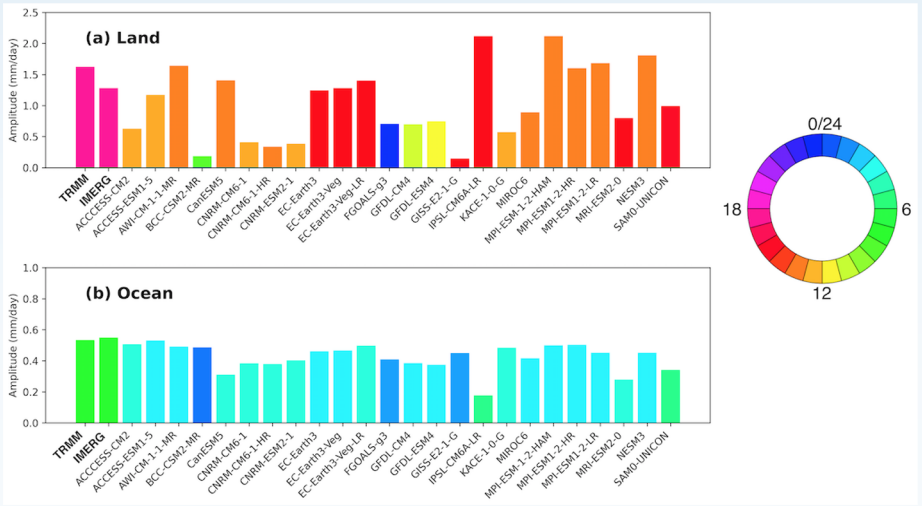


(Charlotte DeMott)



Precipitation contribution and temperature-water vapor environment

(Yi-Hung Kuo and David Neelin)



Diurnal precipitation timing

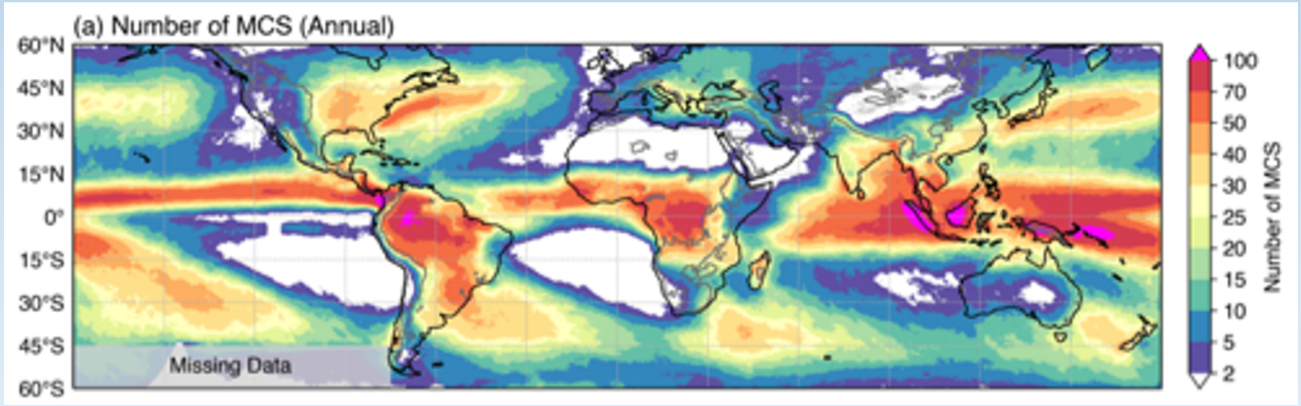
(Shaocheng Xie and Cheng Tao)

Regime/Phenomena-oriented metrics: precipitation generation mechanisms

Precipitation regimes:

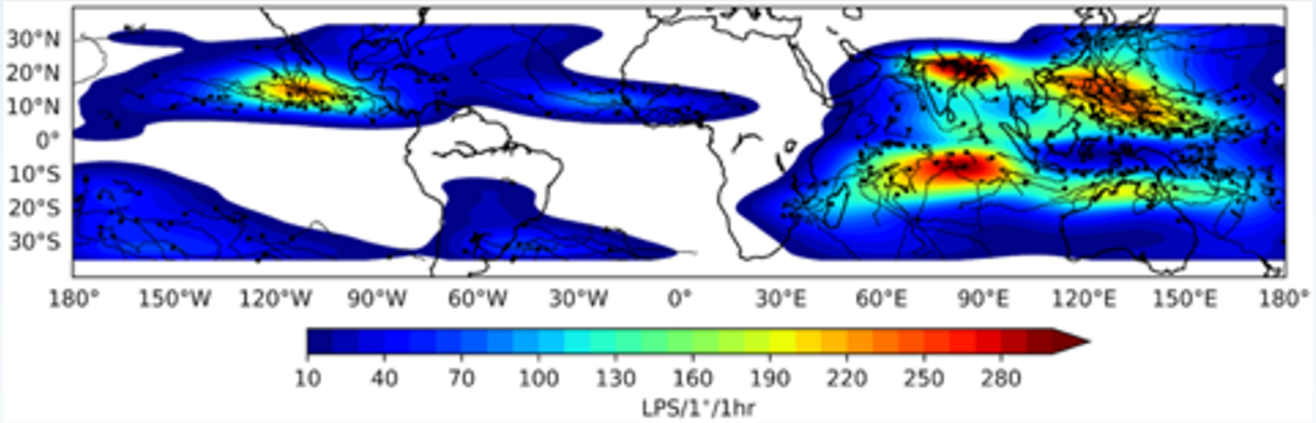
- Frontal systems
- Extratropical cyclones
- Atmospheric rivers
- Tropical cyclones
- Mesoscale convective systems
- Orographic systems
- Monsoon depression

Global distribution of mesoscale convective systems



(Ruby Leung and Zhe Feng)

Global distribution of monsoon and tropical low pressure systems



(Bill Boos)

Summary

- Implementation and application of baseline benchmarks is rapidly advancing
- Process-oriented diagnostics are being used to develop exploratory metrics
- Working to enable modeling groups to use precipitation benchmarks via a Coordinated Model Evaluation Capabilities (CMEC; https://cmec.llnl.gov)
- Once the analysis capability is sufficiently advanced, it can serve as a guide to *challenge and assist* modelers in improving simulated precipitation – engagement with WGNE will be important at this stage