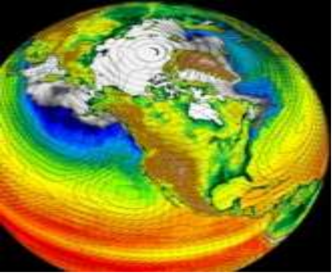
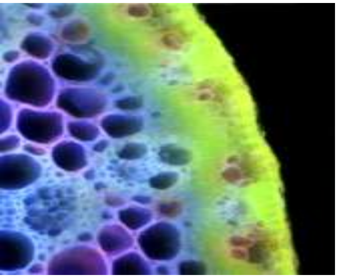
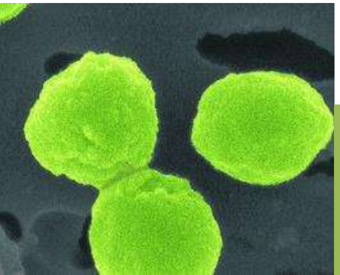


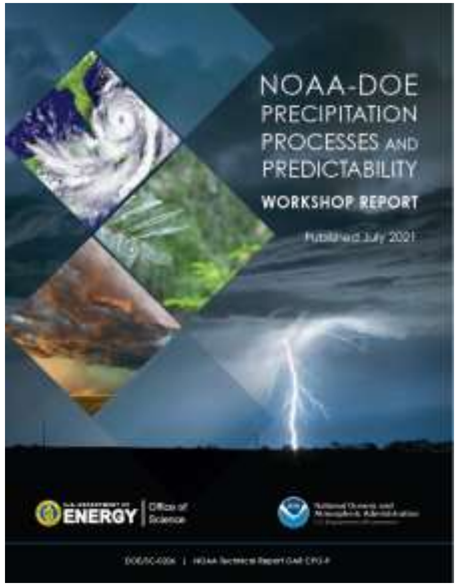




U.S. DEPARTMENT OF ENERGY | Office of Science

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

NOAA-DOE PRECIPITATION PROCESSES AND PREDICTABILITY WORKSHOP

November 30 - December 2, 2020



Renu Joseph

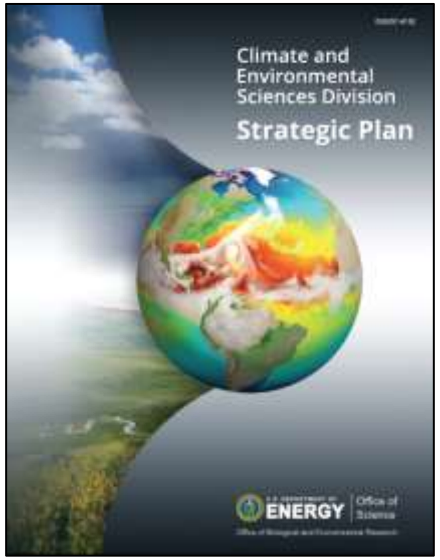
Earth and Environmental Systems Modeling
Earth and Environmental Systems Sciences Division

Workshop Co-Chairs: Jin Huang (NOAA/CPO), Renu Joseph (DOE/EESSD), Sandy Lucas (NOAA/CPO), Sally McFarlane (DOE/EESSD), Mike Patterson (US CLIVAR), Yan Xue (NOAA/NWS)

DOE and Precipitation Predictability

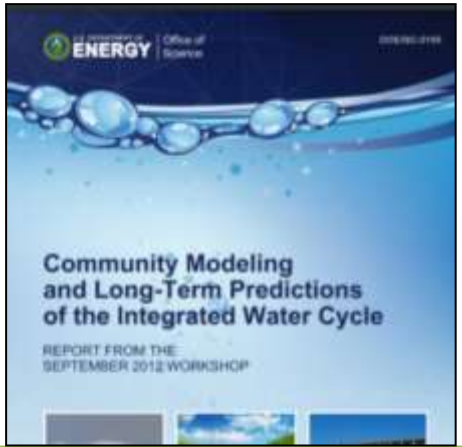
- Relevant to all 5 goals of the EESSD Strategic Plan:

  Integrated Water Cycle | High Latitudes | Observation-Model Integration
  Biogeochemistry | Drivers & Responses in the Earth System



- Relevant to the EESSD
  - Modeling (EESM), Atmospheric (ASR), and Terrestrial (ESS)
  - User Facilities and Infrastructure (ARM)

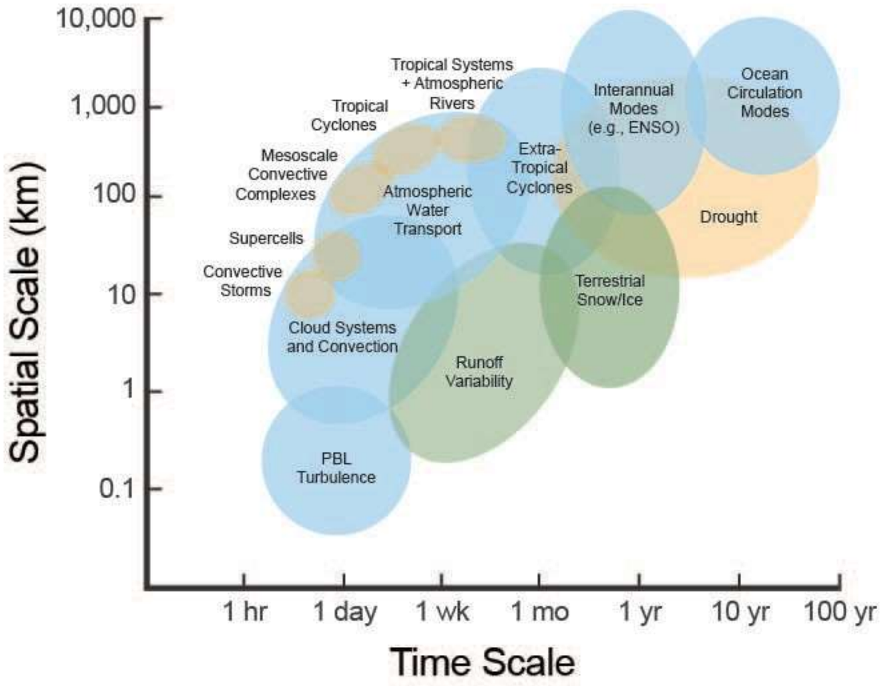
- Water Cycle + Precip Workshops:
  - Community Modeling and Long-Term Predictions of the Integrated Water Cycle
  - Atmospheric River Tracking Method Intercomparison Project (ARTMIP)
  - Benchmarking Simulated Precipitation in ESMs



NOAA-DOE Joint Workshop

NOAA's Precipitation Predictability Grand Challenge

DOE Interest in Precipitation



NOAA-DOE Joint Workshop

- Emphasized a **comprehensive** look at precipitation (process understanding, predictability, prediction skill, model biases, observations).

- Focus on **integrating different ways of studying precipitation** (process interactions, interdisciplinary processes, end-to-end integration of model development, process studies, prediction).

- Discussion benefited from **modern / cutting-edge technologies and accomplishments** (global storm-resolving models, regional refined meshes, machine learning + artificial intelligence)

- Spanned a **range of timescales** from weather to multidecadal.

NOAA-DOE

Precipitation Processes and Predictability Workshop

Active participants (400) and Slack channel

A **community workshop** is jointly organized by NOAA and DOE in partnership with USGCRP and US-CLIVAR

Workshop Scope: Contiguous U.S. in the context of global models; Subseasonal to multi-decadal timescales

Major Themes:

- Sources and limits of predictability
- Key processes critical to precipitation biases
- Interdisciplinary processes
- Regional precipitation

Scientific Committee

- Magdalena Balmaseda
- Ana Barros
- **Samson Hagos**
- **Ben Kirtman**
- **Hsi Yen Ma**
- Yi Ming
- **Angeline Pendergrass**
- Vijay Tallapragada

Program Organizing Committee

- Jin Huang
- **Renu Joseph**
- Sandy Lucas
- **Sally McFarlane**
- Mike Patterson
- Yan Xue

Facilitators and Rapporteurs

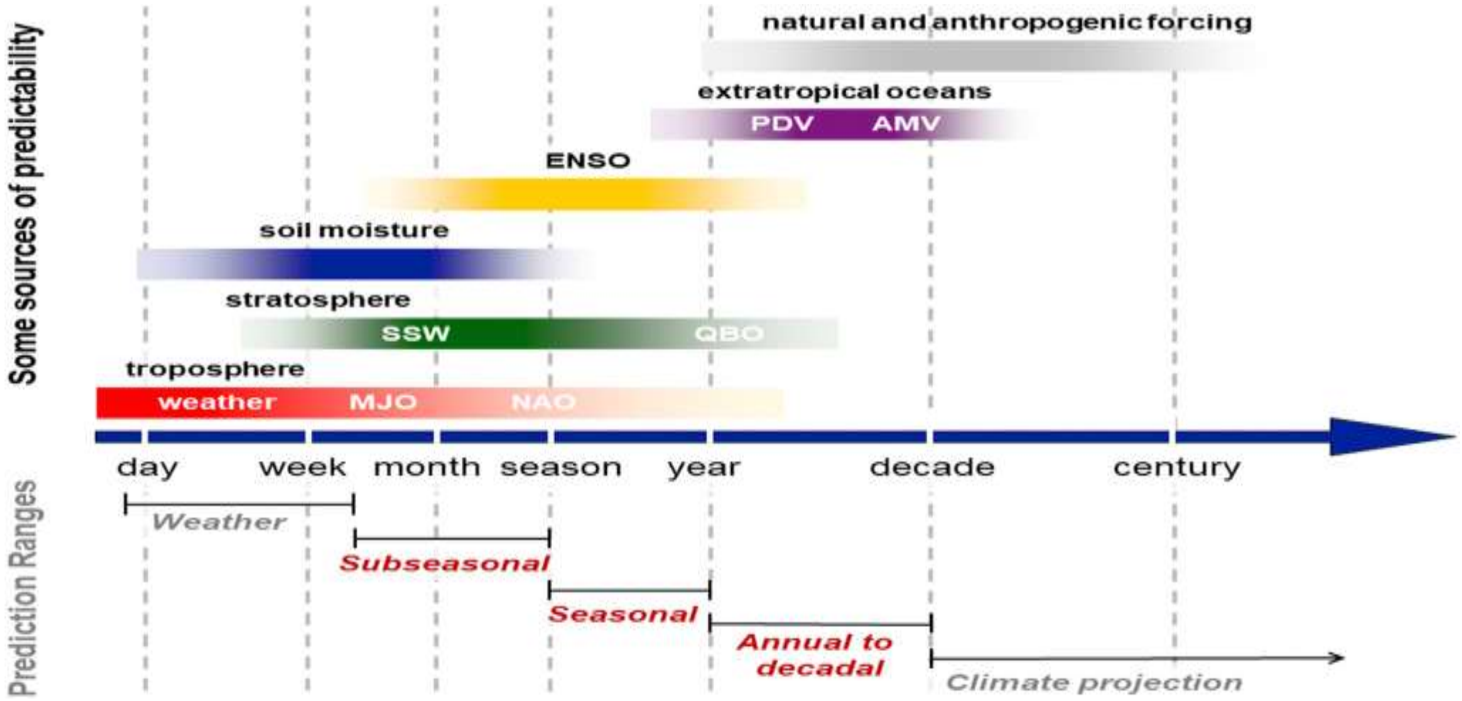
- Victoria Breeze
- LuAnn Dahlman
- John Coggins
- **Zhe Feng**
- **Bryce Harrop**
- **Huaping Huang**
- Ali Stevens
- **Die Wang**

Each Theme was organized around and addressed the following questions:

1. What are the **sources of predictability** that have the biggest influences on precipitation at weather, sub- seasonal-to-seasonal (S2S), and multi-decadal timescales, including extremes?
2. What are the key physical processes that have the strongest imprint on the **model biases** and precipitation predictions and projections?
3. How can we most effectively take advantage of **existing observations and data** (satellite and in situ) to advance process-level understanding?
4. What are the gaps and needs for **targeted observations and process studies** to improve understanding and model representations of those key processes?
5. How do we benefit from **national and international collaboration** to make significant progress?

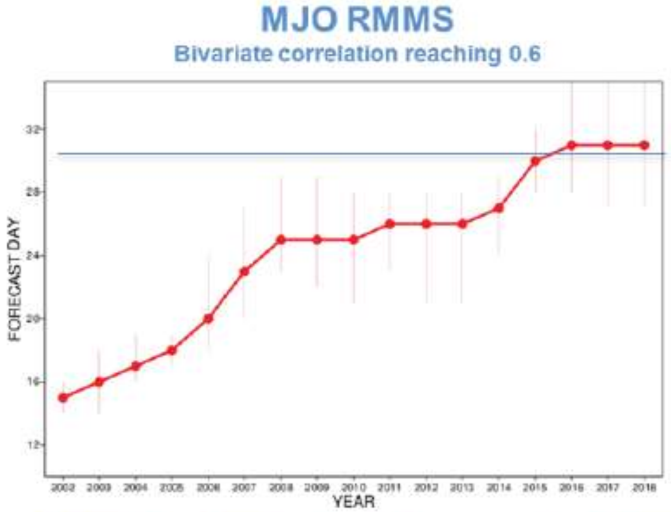
Theme 1: Limits And Sources of Predictability

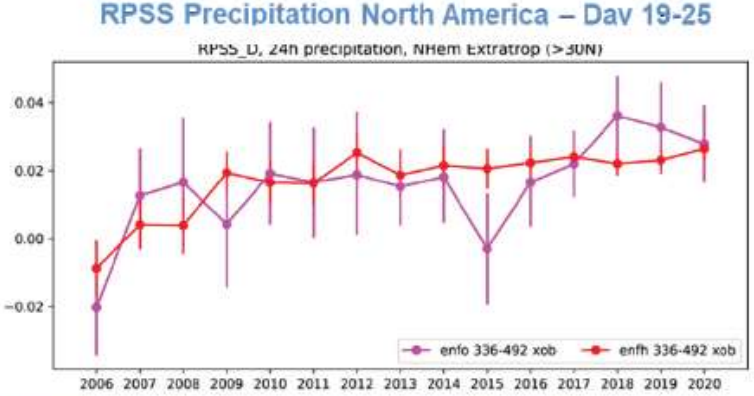
Temporal ranges and (top) sources of predictability for weather and climate prediction



While there has been significant progress in the prediction of MJO and associated largen-scale environment, skill for prediction of precipitation remains limited

North American precipitation forecast skill trend in ECMWF forecast system





Theme 1: Strategies for Advancing Understanding of Predictability

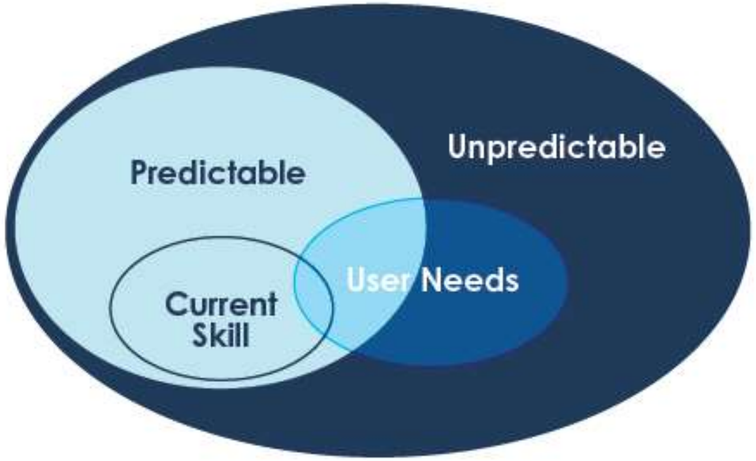


Figure: A schematic representing the general concept of predictability, including understanding predictability limits and strategies for realizing them as prediction skills that meet user needs.

Understand sources and limits of predictability

- Research in air-sea and air-land coupling and precipitation processes, modes of variability, and their impacts on prediction and predictability
- Diabatic heating as a source of predictability

Connection to regional precipitation

Modeling underlying mechanisms

Exploiting forecasts of opportunity

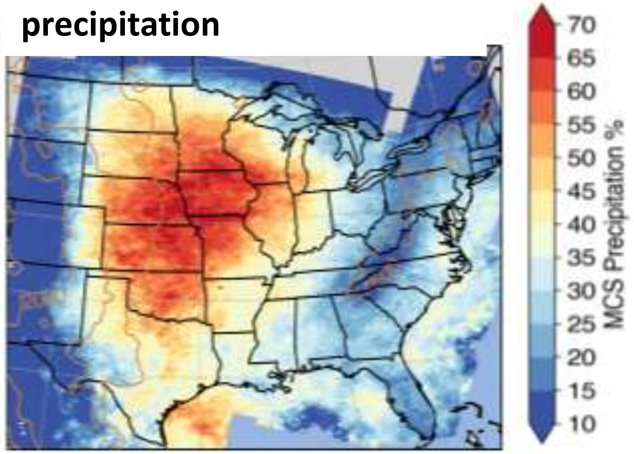
- Resolving multi-scale processes including unified or seamless modeling
- Systematic investigations of impacts of model bias on predictability estimates
- Machine Learning assisted development of reduced dimension models
- End-to-End integration of model development, process level studies and prediction as well as engagement of prediction users

Theme 2: Key Processes Critical to Precipitation Biases

Some common Model Errors in Precipitation over US

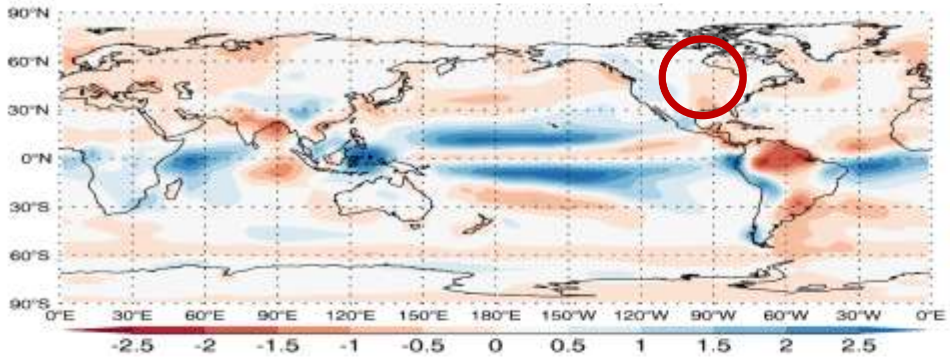
- More than 50% of rainfall over the central US in summer originates from Mesoscale Convective systems
- Processes controlling mesoscale organization are not well understood or modeled

Contribution of MCSs to JJA precipitation



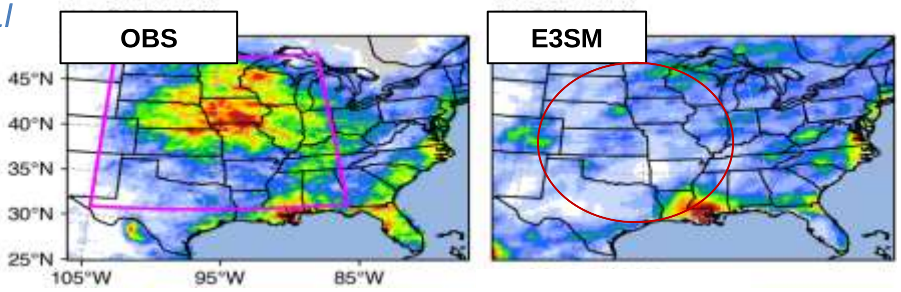
Feng et al. (2019) JCLI

CMIP6 MMM Biases



Courtesy of Baijun Tian (JPL)

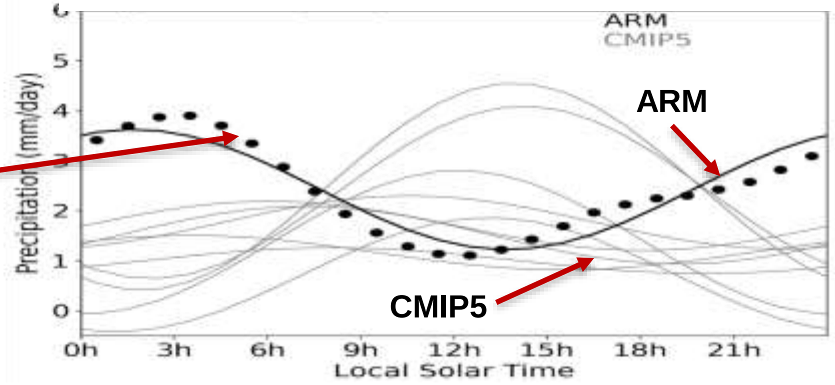
JJA MCS Precipitation in E3SM



Xie, Leung et al. (2020) DOE Q4 Metric Report

JJA Diurnal Cycle of Precipitation in CMIP5 at ARM SGP Site

Miss the nocturnal peak



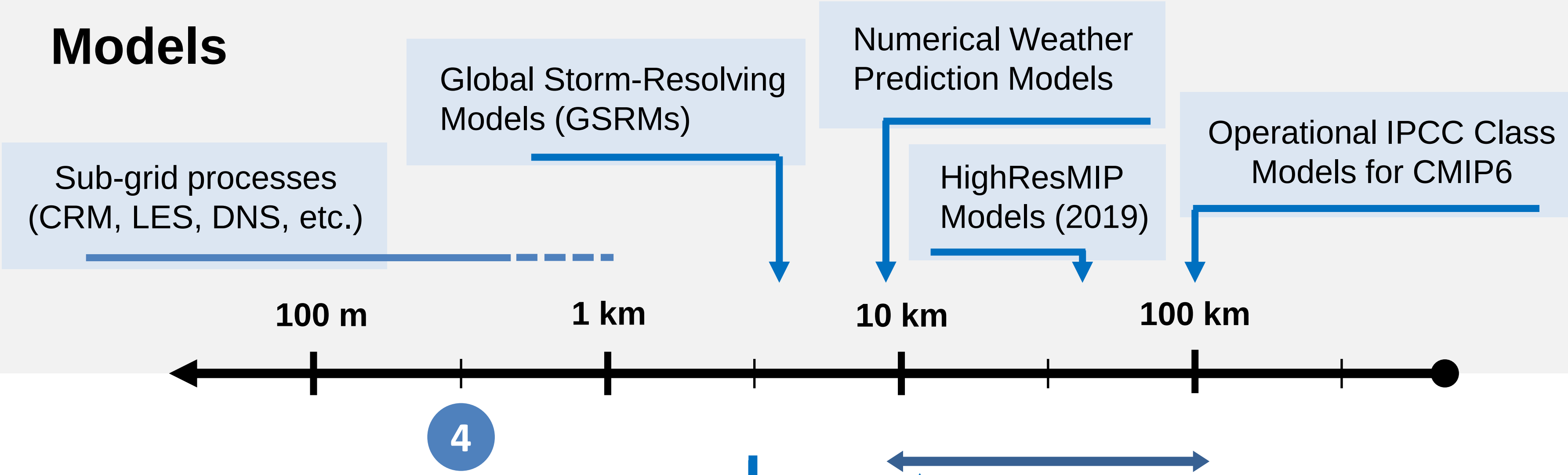
Black: ARM observations *Zhang, Xie et al. (2020) BAMS*

Grey lines: CMIP5 model results,

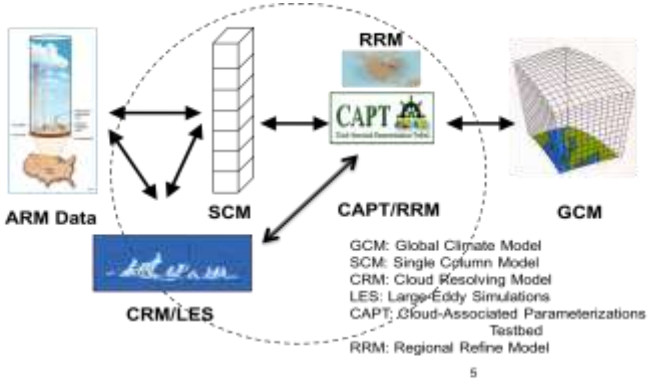
- Dry bias over central US
- Weaker MCS precipitation
- Wrong diurnal cycle

Theme 2: Strategies for Addressing Precipitation Biases

Models

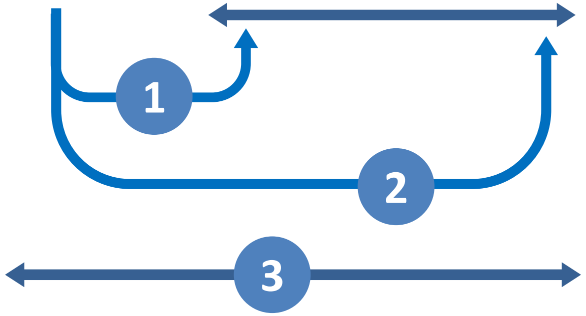


A hierarchy modeling framework supported by DOE



1. Processes / models: Conventional Parameterizations – more focus on convective parameterizations.

2. Processes / models: ML-based convective parameterizations – more tuning in weather forecast mode.



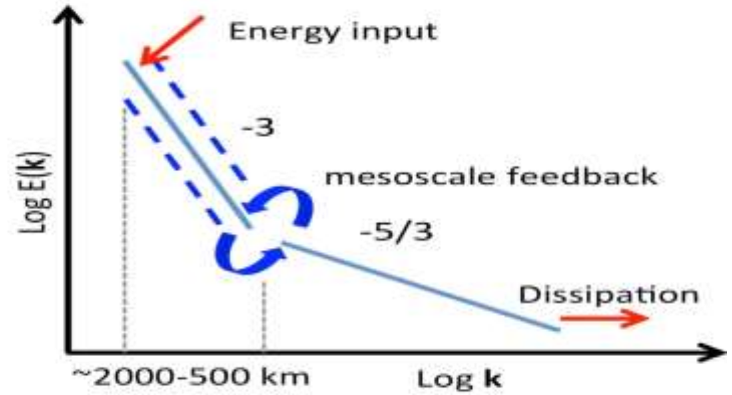
3. Phenomena / observations: Organized convection (MCS, convective-large scale interactions) – more observations (lacks theory)

4. Unresolved convection: What about shallow convection, planetary boundary layer and microphysics (aerosols)?

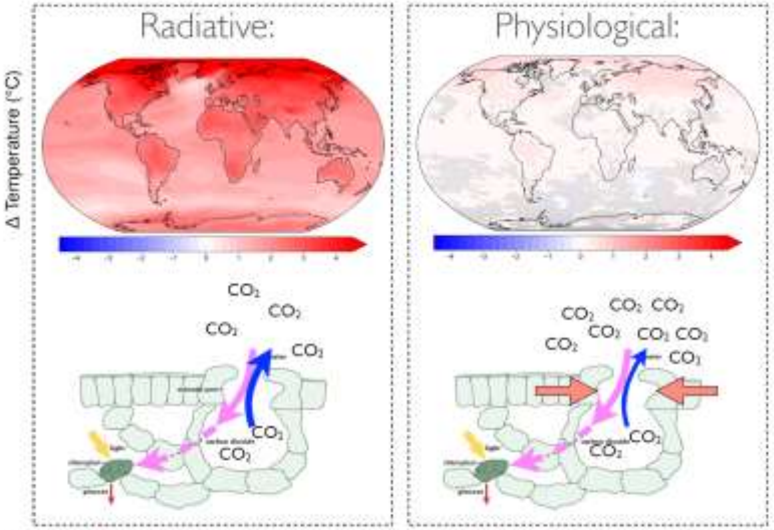
- Detailed field observations are critical for improving our understanding of organization of mesoscale convective systems
- A hierarchy modeling framework acts to bridge the gap between field data and model developments
- Critical analysis tools need to be developed to support such as a model framework, process-oriented model diagnostics / evaluation / improvement (such as being developed in NOAA and DOE)
- Parameterization applications of machine learning

Theme 3: Interdisciplinary Processes

- Ocean-atmosphere, land-atmosphere, and troposphere-stratosphere connections and interactions among aerosols, clouds and precipitation microphysical processes affect precipitation over CONUS.



Some warming just from stomata closing

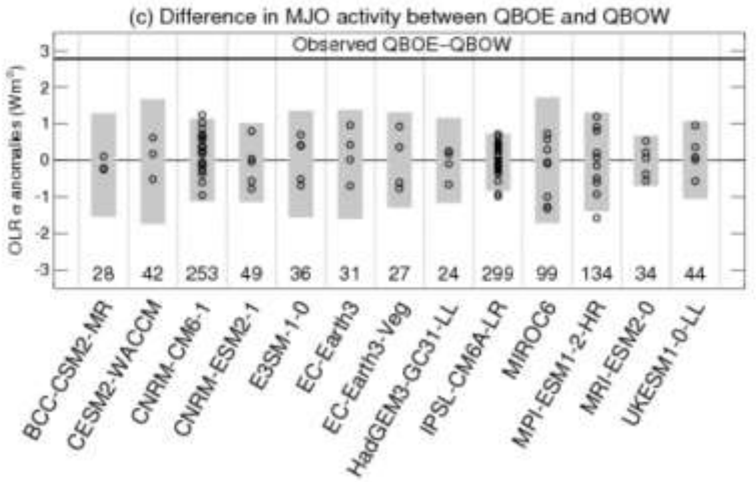


Increase in temperature in 12 CMIP6 models due to $2xCO_2$

Theme 3: Strategies for advancing understanding of interactions related to precipitation

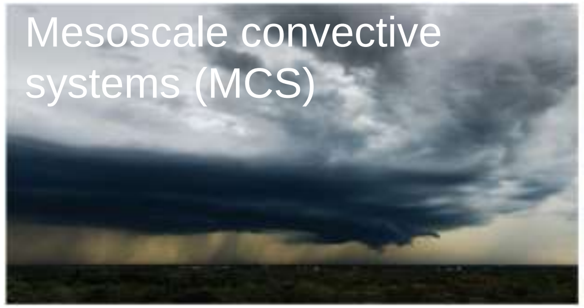
- Unified Modeling systems that span weather to climate that includes capturing these interdisciplinary processes
- More observations and data needed to constrain these models and more collaboration across both with easy access to centralized data archives (e.g., surface-atmosphere & aerosol-cloud interactions)
- Better characterization of land-surface properties
- The sinks and sources of energy and moisture (i.e., dissipation across scales) need to be accounted for and identified in observations and models.
- Improvements in the vertical resolution of models in the stratosphere and their representation of gravity waves
- Observations key climate regions known to impact CONUS precipitation predictions and predictability, such as the Maritime Continent, far western Pacific Ocean, coastal zones of the U.S., and the Arctic

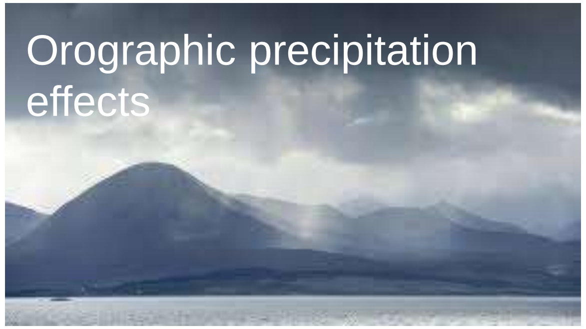
No CMIP6 model reproduces the observed QBO-MJO relationship



Theme 4: Regional Precipitation

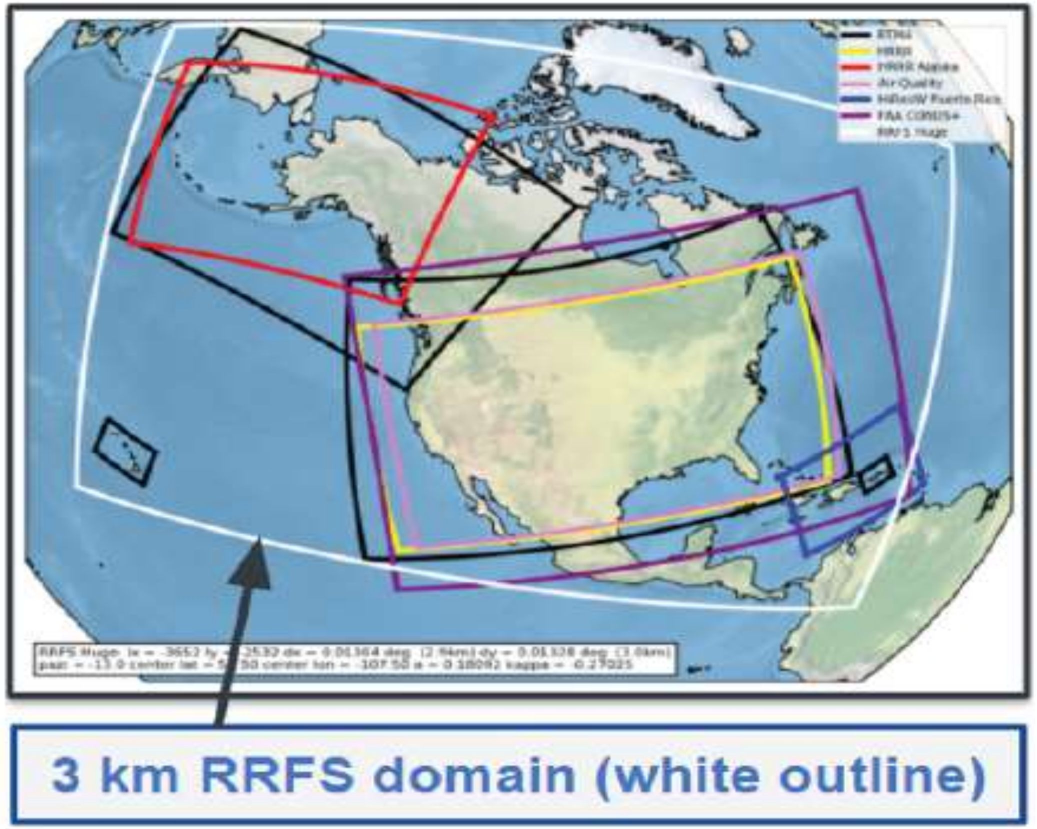
- Precipitation forecast skill over the CONUS, although slightly improved in the past decade, lags other forecast improvement metrics like hurricane track and intensity and
- Factors influencing the poor precipitation forecast skill for weather prediction include underestimation of heavy rain, overestimation of light rain, inaccurate representation of the diurnal cycle of precipitation (especially with precipitation maxima too early in the day);
- Weather ensemble systems also suffer from overconfident ensembles





A partial list of precipitation phenomena over CONUS

Theme 4: Strategies for advancing prediction of regional precipitation



UFS-based Regional Rapid Refresh Forecast System (RRFS) to replace several mesoscale modeling systems currently in use at National Centers for Environmental Prediction (NCEP) operations

- Using higher-resolution global and regional models, as well as improved physics and data assimilation, well-calibrated ensembles, and sophisticated post processing techniques (including use of ML/AI).
- Development of the unified forecasting system as a community-based, coupled, comprehensive ESM.
- Variable-resolution grids, which allow high resolution regionally along with the full physics and global water and energy budget representation.
- Enhanced Observations (both from field campaigns and Satellites) to address the uncertainties for the various precipitation features.
- Modeling and observational communities to work hand in hand to address critical gaps in understanding of the physical processes and provide better data sets for initialization and evaluation.
- Development of standard benchmarking capabilities for evaluating the quality of different precipitation products.
- Invest in standardizing and streamlining precipitation product data.

What are the sources of
redictability that have the biggest
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What are the gaps and needs for
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How do we benefit from national
and international collaboration
to make significant progress?

Sources of Predictability Influencing Precipitation

SESSION 1
Sources and limits of predictability

SESSION 2
Key processes critical to precipitation biases

- Large-scale variability (e.g., MJO, NAO, ENSO, AMV, PDO)
- Slowly varying processes (e.g. SST, soil moisture, vegetation, sea ice)
- Phenomena (e.g., cyclones, atmospheric rivers, mesoscale convective systems)

Physical Processes Representation and Biases

SESSION 3
Interdisciplinary processes

- Improving representation of local (e.g. aerosol-cloud interactions) and remote (e.g. tropical diabatic heating) processes
- Systematic characterization of model biases

Modeling and Observational Strategies

SESSION 4
Regional precipitation

- Global storm resolving models
- Hierarchical modeling
- Phenomena-based model evaluation
- Community modeling infrastructure
- Enhance model observation integration
- More observations to constrain models
- Collaboration between modeling and observation teams
- ML/AI

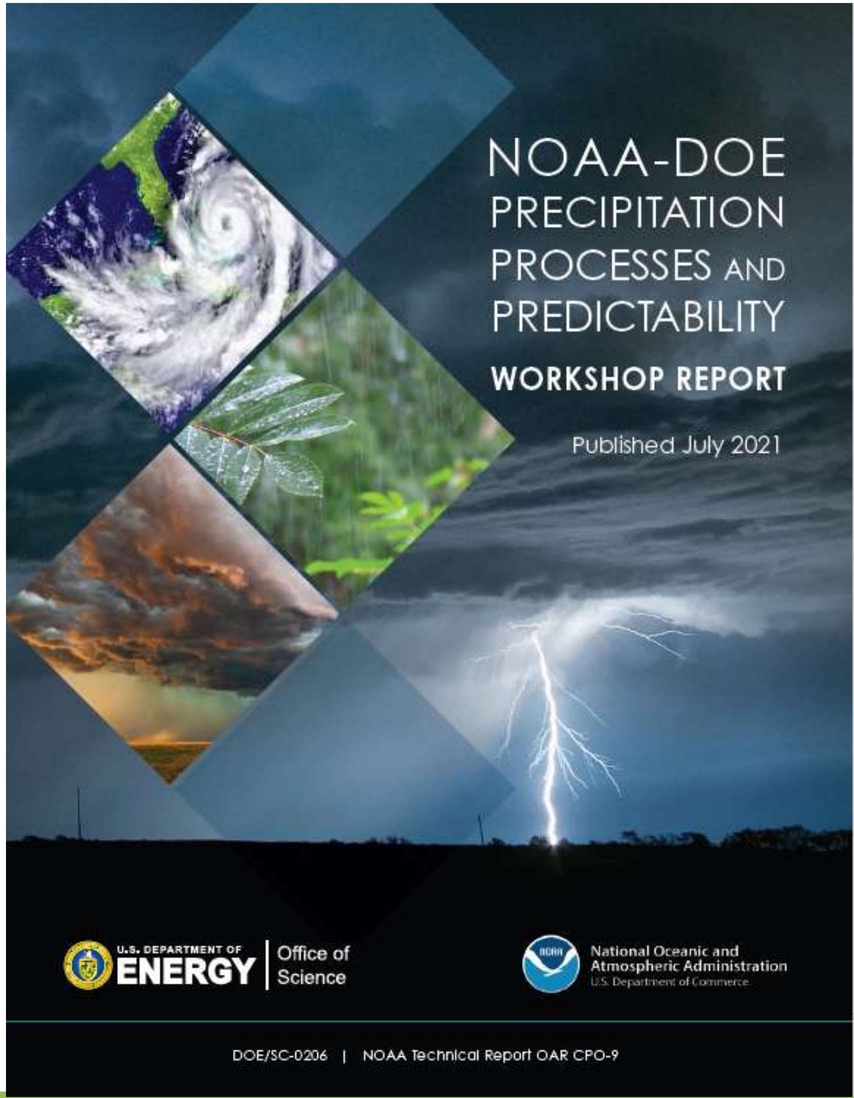
Stakeholder Engagement and Interagency Collaboration

Successes and Next Steps

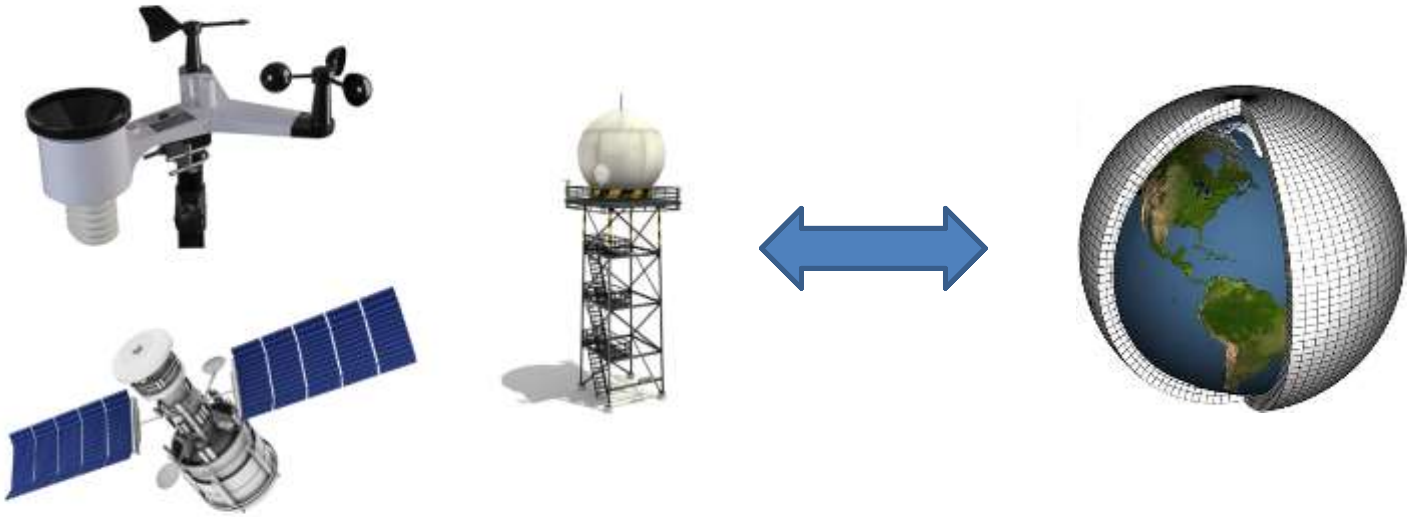
- **Interagency Front**
  - At **USGCRP** exploring ways to enhance interactions on Precipitation Predictability & Water Cycle across agencies
  - NOAA is seeking national and international partnership for **Global Precipitation Experiment**.
  - Explore activities like the **Climate Process Teams** that can work on (e.g., US Climate Modeling Summit working together)
- **Within DOE**
  - **EESM & ASR FOA's** are informed by and refer to the Precipitation Predictability report (as well as other reports)
  - Provides ideas for potential applications of AI in earth system predictability (**AI4ESP**)
  - Coordination on **process metrics, diagnostics, and benchmarks**
  - ARM instrumentation, data product, and campaign priorities informed by workshop; current campaigns TRACER and SAIL highly relevant to workshop goals
- **Attendees**
  - Several scientists indicated that **cross-interagency interactions** at the meeting were productive
  - Enables **better collaboration**

Thank You!!!!

Balmaseda M, A Barros, S Hagos, B Kirtman, H-Y Ma, Y Ming, A Pendergrass, V Tallapragada, E Thompson. 2020. “NOAA-DOE Precipitation Processes and Predictability Workshop.” U.S. Department of Energy and U.S. Department of Commerce NOAA; DOE/SC-0203; NOAA Technical Report OAR CPO-9.



Strategies for advancing observation-model integration



- A variety of observational and reanalysis-based precipitation products exist that provide precipitation at different spatial and temporal scales, cover different regions and time periods, and available in different formats.
- No standard benchmarking capability exists for evaluating the quality of different precipitation products.
- Format differences can lead to roadblocks in the employ of observational datasets for evaluating model performance.
- Investments are necessary in streamlining and standardizing precipitation products to support observation-model integration.