THREAD Overview

ASR Atmospheric System Research

Science Focus Area (SFA)

ARM/ASR PI meeting

August 8th, 2023

Yunyan Zhang

Tying in High Resolution E3SM with ARM Data (THREAD)

Lawrence Livermore National Laboratory
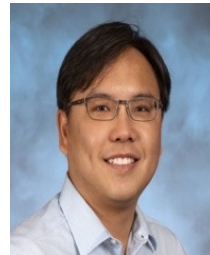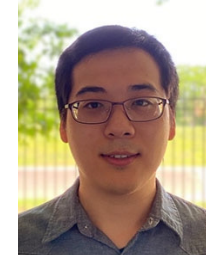

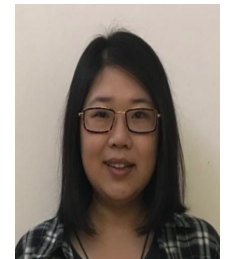Hsi-Yen Ma   Xue Zheng   Peter Bogenschutz   Hewei Tang   Meng Zhang   Steve Klein   Jingjing Tian
(former member, now at PNNL)

Key Collaborations

Peter Caldwell (LLNL)
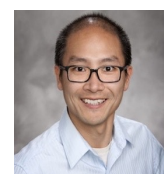*E3SM SCREAM Development Team*

Po-Lun Ma (PNNL)
Aerosol-Cloud Interaction EAGLES project

Shaocheng Xie (LLNL)
ARM Infrastructure E3SM NGD Team

Paul Ullrich (UC Davis/LLNL)
E3SM RRM & RRM-SCREAM

**Qi Tang (LLNL)**
E3SM RRM Atmos/Coupled

Outline

- Introduction of THREAD
  - Motivation
  - Science Foci and Questions
  - Project Objectives and their Organizations

- Progresses and Preliminary Results
  - DP-SCREAM
  - RRM-SCREAM
  - Machine Learning
  - SCREAM against ARM observations

Motivation of THREAD

- Booming developments of global storm resolving models (GSRMs)

- **Process-oriented** diagnosis and improvement of E3SM/SCREAM using ARM data

the Simple Cloud-Resolving *E3SM* Atmosphere Model
(*SCREAM, 3.25 km globally*)
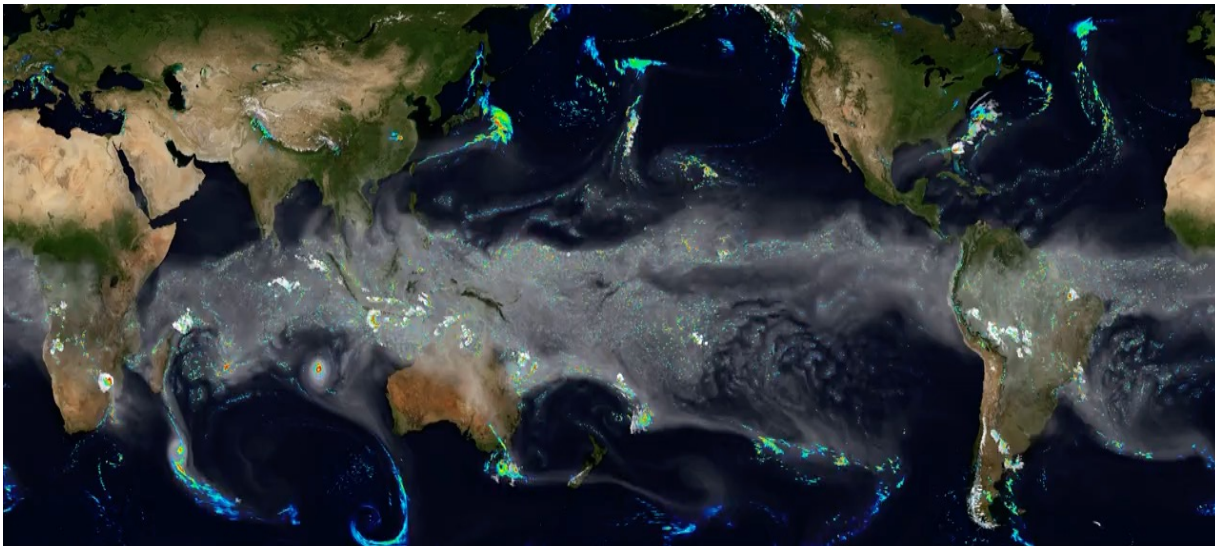
ARM world-wide deployments

Courtesy of R. Lang
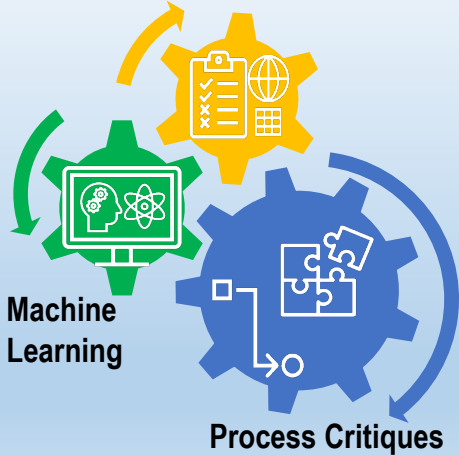
Science Foci/Questions

- **Model improvement with observations:** How can we effectively diagnose a model's strengths and weaknesses and transfer process-level understanding based on observations into improvements in global storm resolving models?

- **Resolved mesoscale versus Sub-grid parameterized processes:** How well can SCREAM represent the interactions between the resolved mesoscale variability and the parameterized sub-grid scale turbulence, cloud microphysics, and aerosol processes?

- **Fast physical interactions with land:** How well can SCREAM represent the fast interactive physics of local land-atmosphere coupling at short-time scales (e.g., land-surface heterogeneity and orographic effects) and the feedbacks to longer time scales?

Tying in High Resolution E3SM with ARM Data (THREAD)

Project objectives and their organization

Obj 4: Marine Boundary Layer Cloud transition

Obj 5: Shallow to Deep Convection Transition and Organized MCS

Obj 6: The Effect of Land Surface Heterogeneities

Obj 1: DP-SCREAM Initial Survey

Obj 3: Machine Learning Model Calibration

Obj 2: RRM-SCREAM Hindcast Capabilities

Marine mixed-phase cloud transition from stratiform to cellular clouds during cold air outbreaks (CAO)
COMBLE

Marine warm-phase cloud transition from stratiform to trade cumulus
MAGIC

Daytime clear sky Convective Boundary Layer (CBL) over Land
SGP LAFE

Fair weather nonprecipitating land-surface forced shallow cumulus (ShCu)
SGP LASSO

Shallow cumulus and Congestus over tropical forests
GoAmazon

Shallow to deep convection transition generated locally in the afternoon
GoAmazon

Organized propagating mesoscale convective system (MCS)
SGP M3CE GoAmazon CACTI
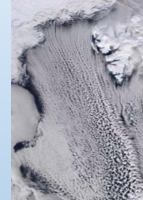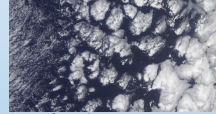
Orographic clouds, and convective precipitation
CACTI

Coastal urban heat island, land sea breeze and convection
TRACER
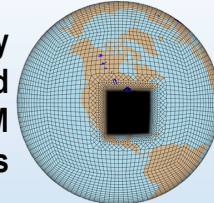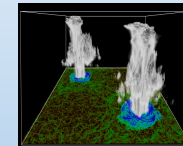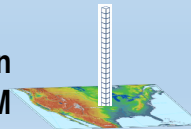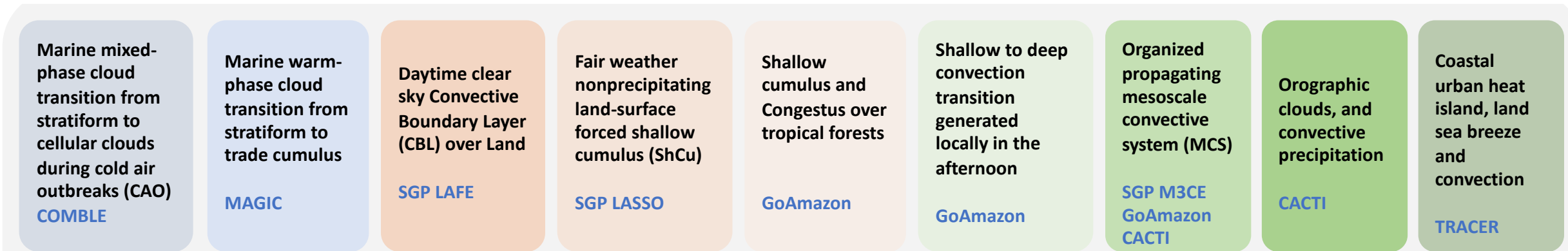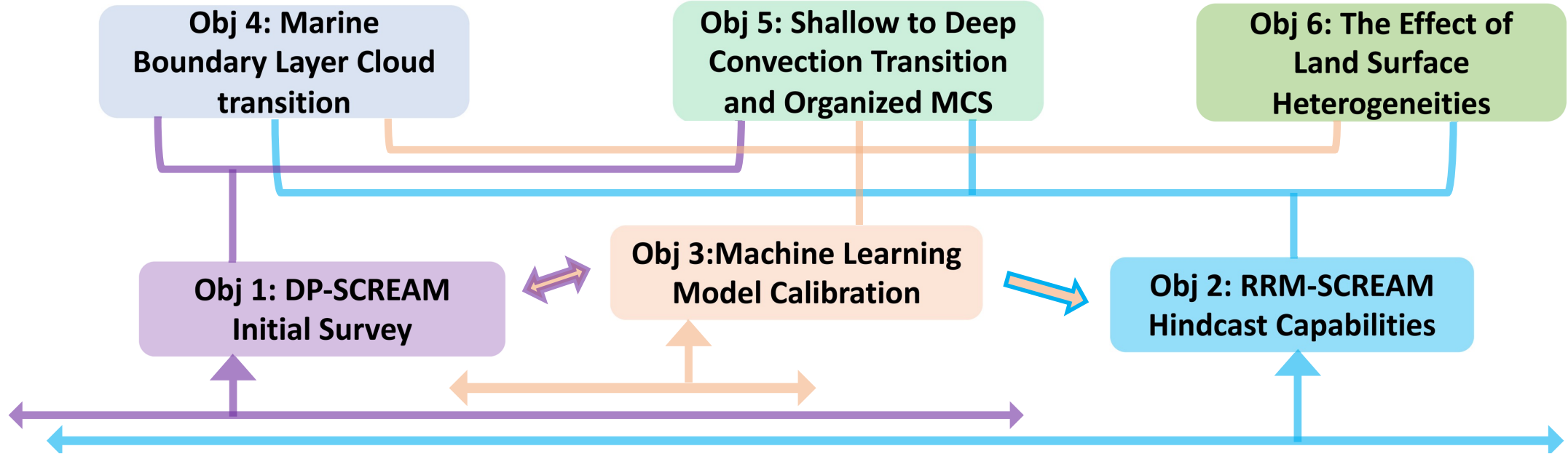
THREAD ARM CASE LIBRARY for DP-SCREAM and RRM-SCREAM on mesoscale variability

Progresses & Preliminary Results

THREAD

LLNL ASR SFA

Initial Survey of DP SCREAM

Peter Bogenschutz Poster 70

- **DP-SCREAM THREAD case library for representative regimes and mesoscale variabilities**

- **DP-SCREAM is being tested across a range of horizontal and vertical resolution.**

  1. LAFE (clear sky PBL)

  2. SGP CASS (continental shallow Cu)

  3. MAGIC (Marine stratiform to trade Cu)

  4. COMBLE (high-lat MCAO, from stratiform to cloud streets to cellular convection)

  5. GoAmazon (tropical rainforests, from shallow to isolated deep convection and upscale into MCS)

MAGIC Cloud Fraction
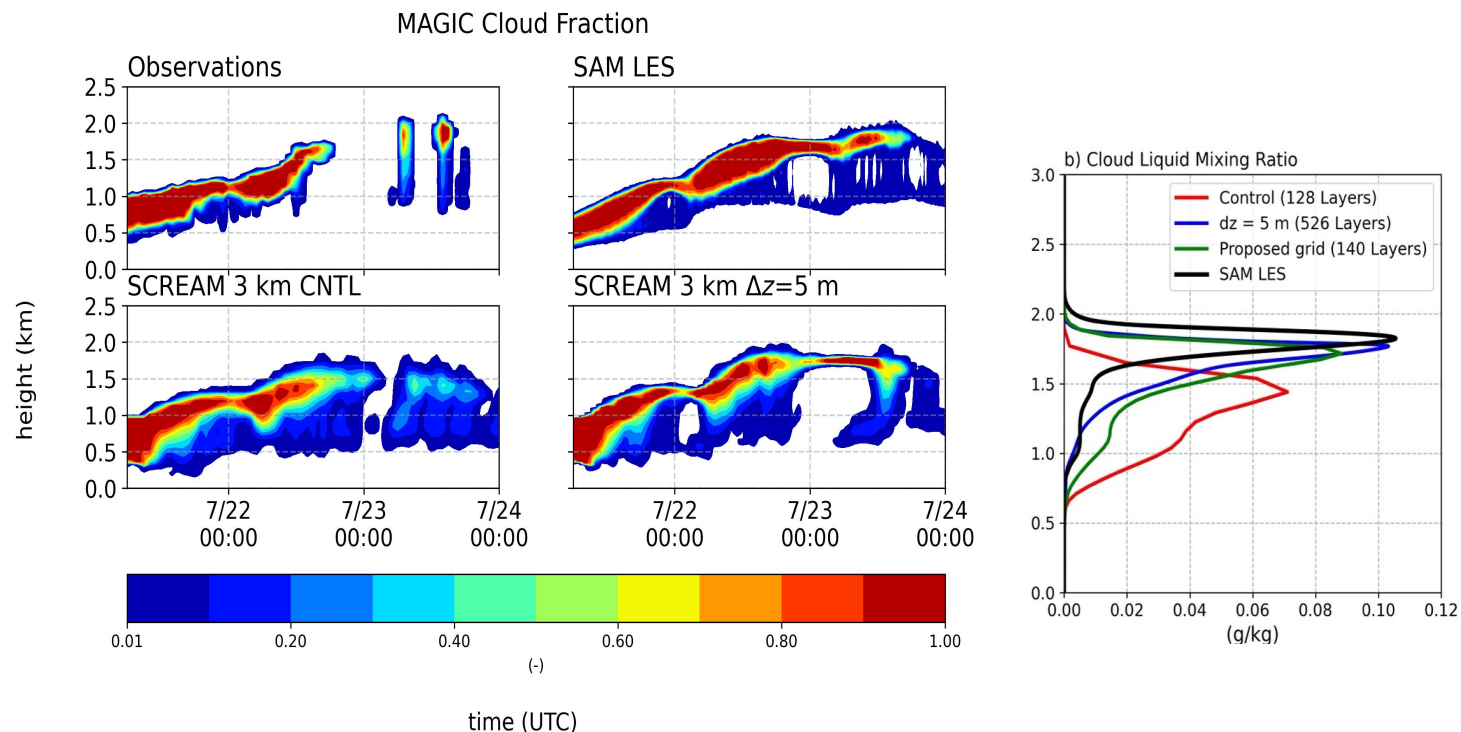
For cloud transition like MAGIC, a moderate increase of vertical levels between 1 and 2 km improves model performance!

In collaboration with C. Tao and S. Xie (LLNL)

RRM-SCREAM at ARM sites

GO-Amazon RRM domain
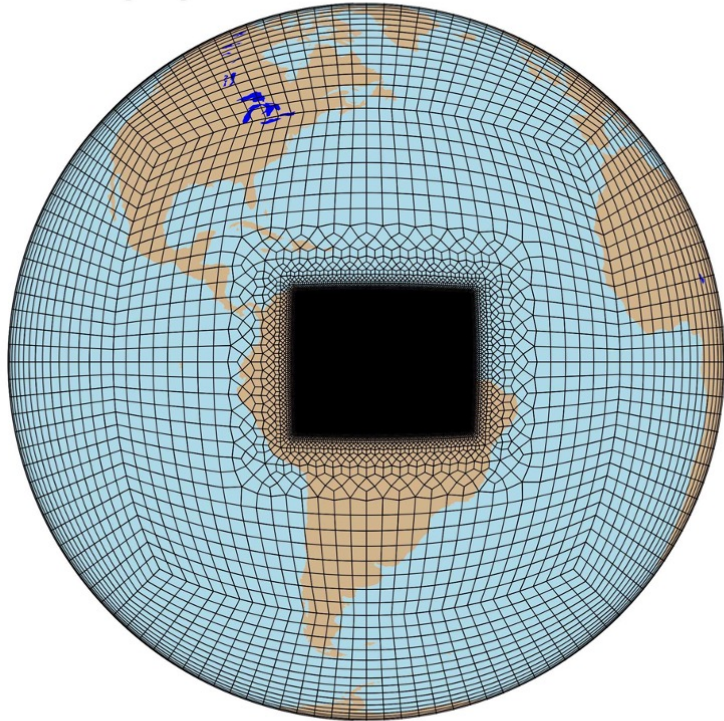
THREAD team builds RRM-SCREAM hindcasts as an effective and efficient tool to facilitate day-to-day ensembles and long-term statistics comparison between model and observations
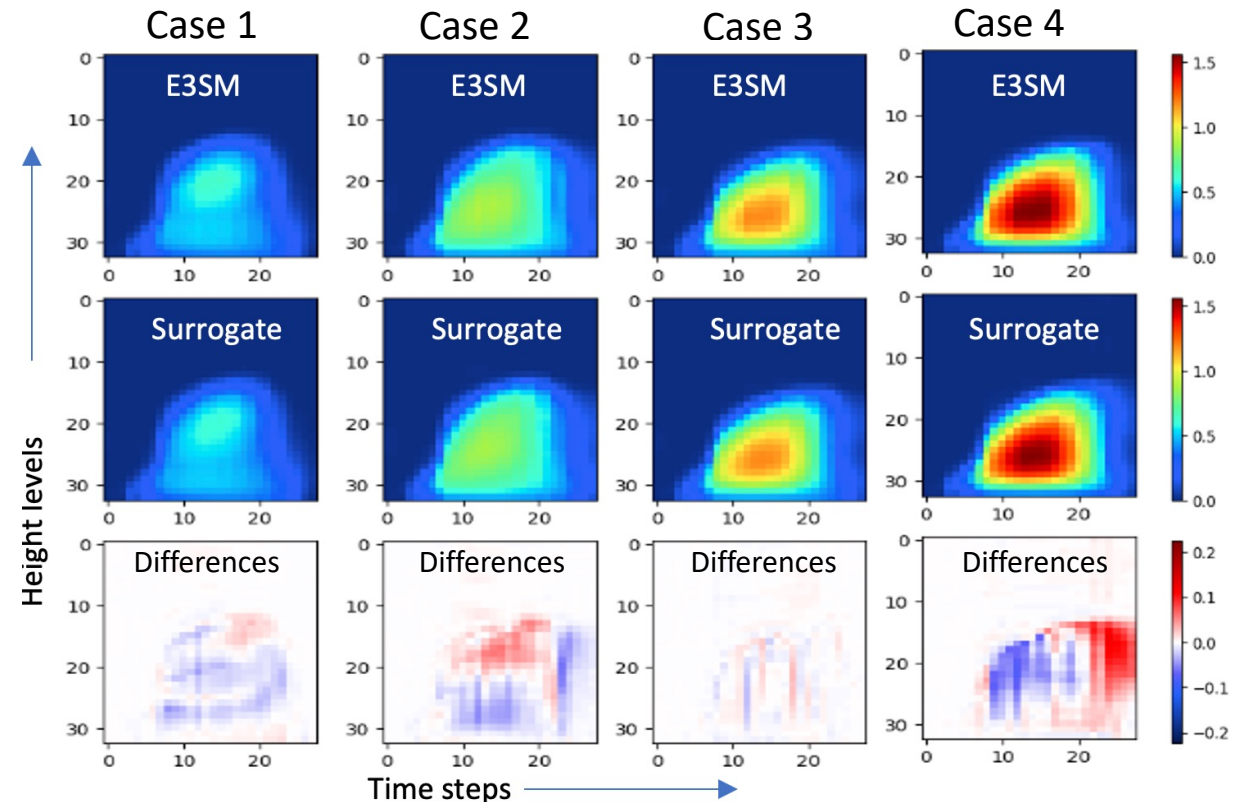
Precipitation of GoAmazon domain

OBS

SCREAMv0 — Global 3-km run

RRM 3-km Nudged — RRM (Nudge)

RRM 3-km No Nudge — RRM (No Nudge)

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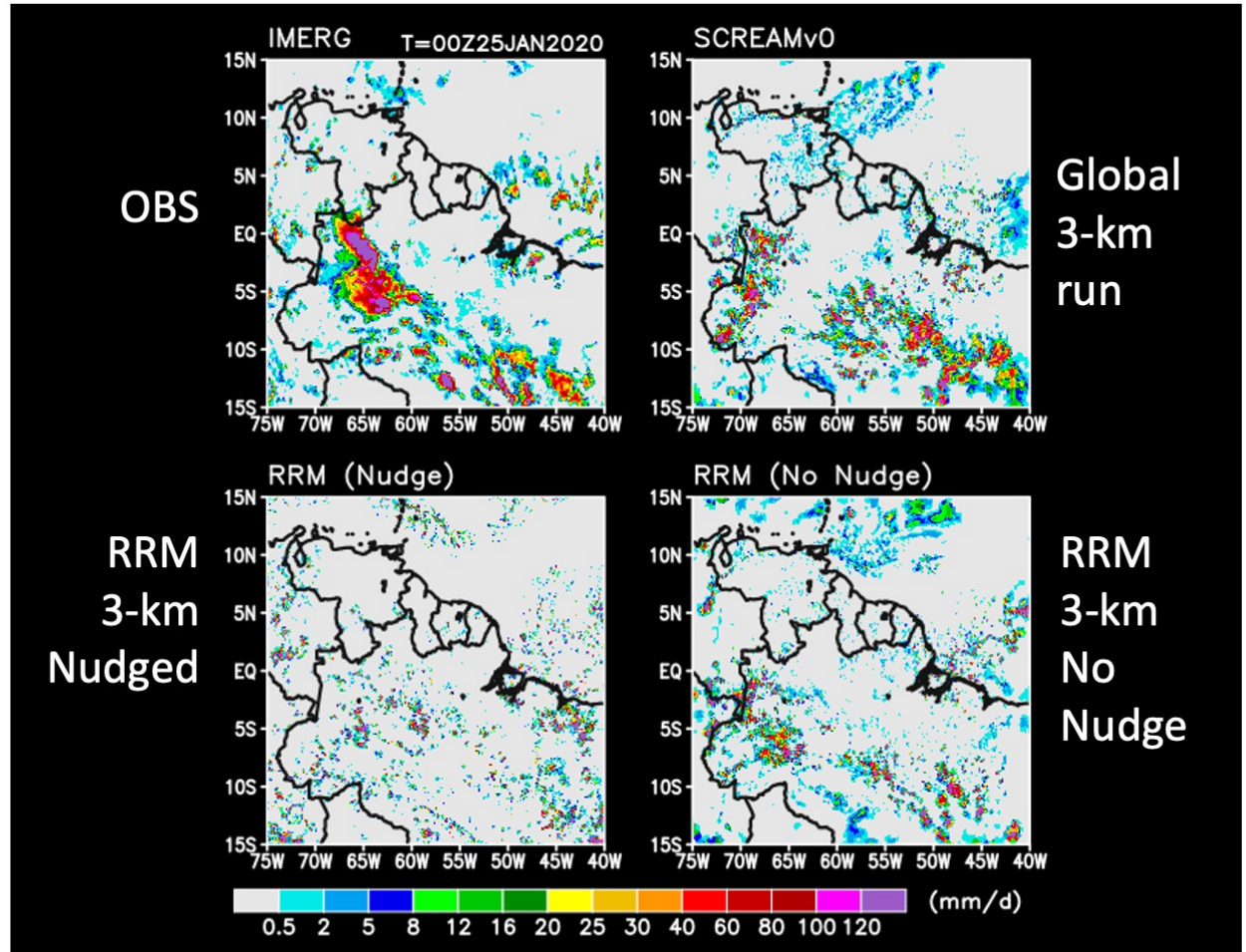
Machine Learning based SHOC Calibration

- Convective regime oriented

- Start from simple: LAFE and CASS

- Perturbed Parameter Ensembles

- MCMC sampling of Parameter Space

- SCM/DP-SCREAM surrogates

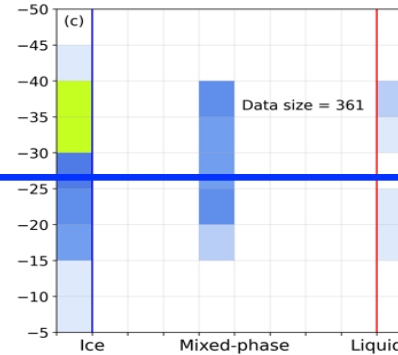Sub-cloud layer vertical velocity variances

Marine Cold Air Outbreak - COMBLE

MODIS

SCREAMv0

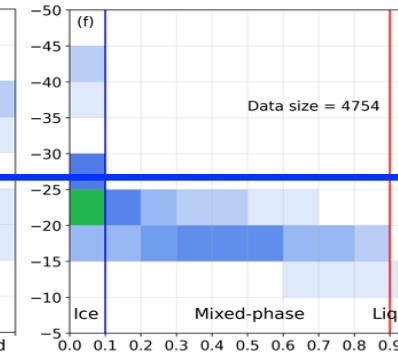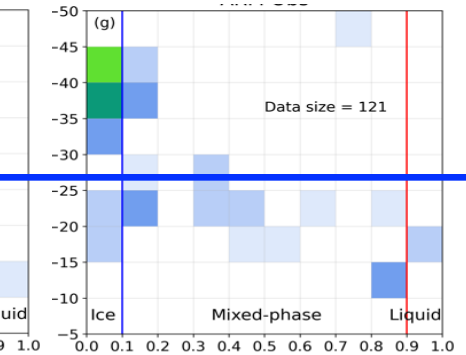CloudSat

SCREAM

ARM

Cloud Liquid Water Fraction (X) versus cloud top temperature (Y)

X. Zheng et al in preparation for GRL
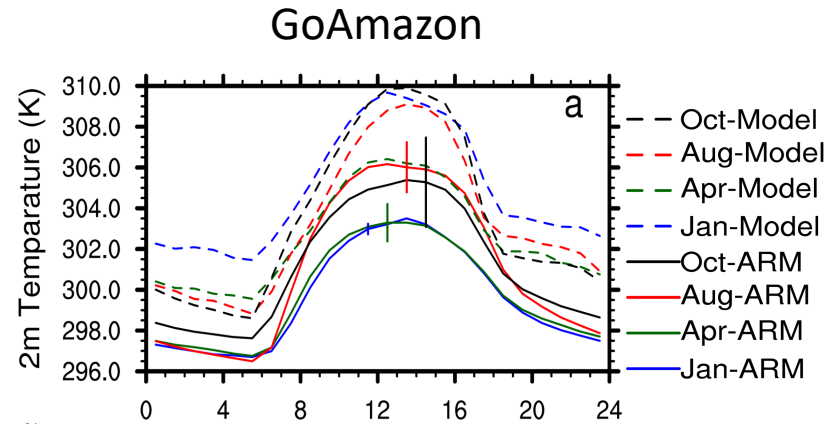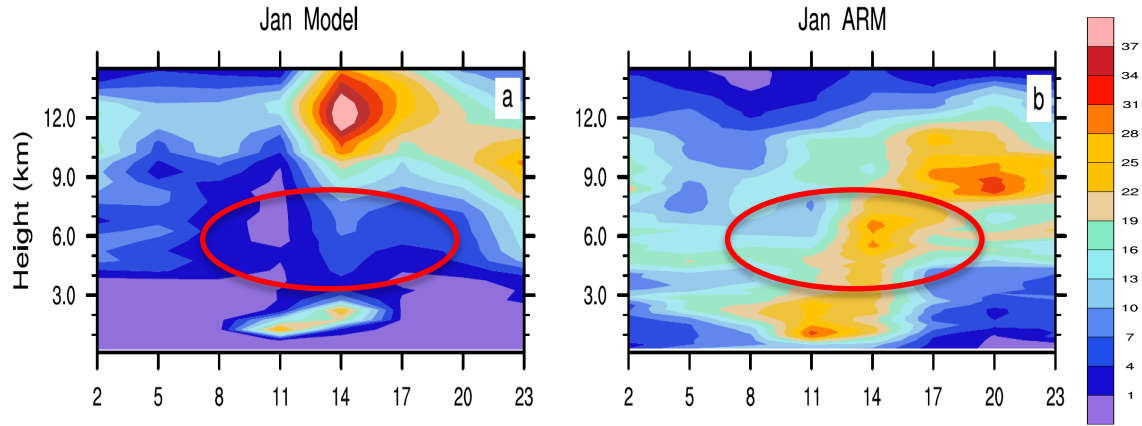In collaboration with Z. Zhang (UMBC) and M. Deng (BNL)
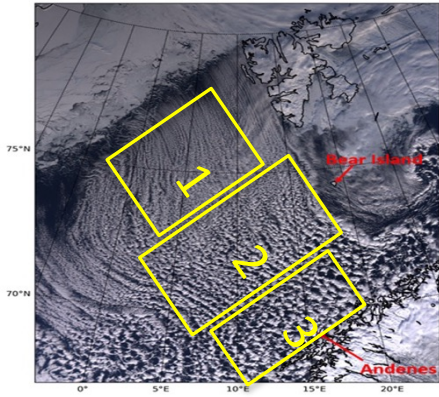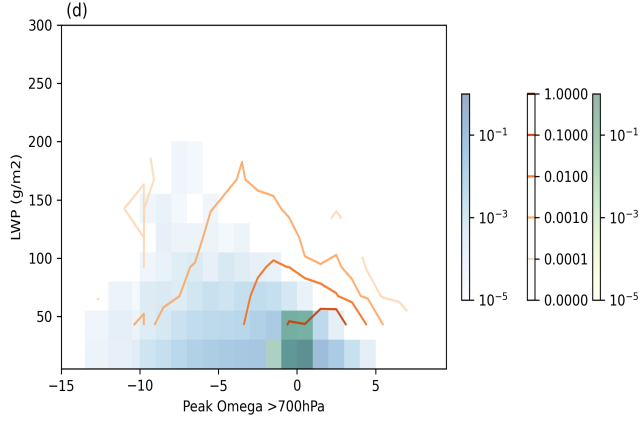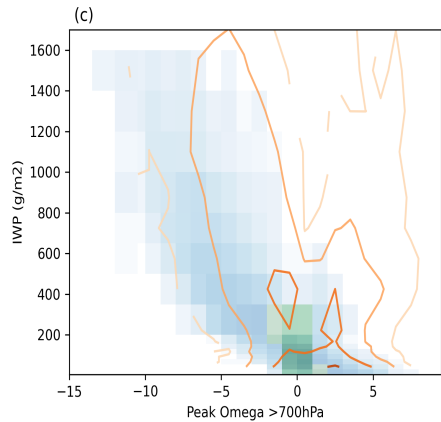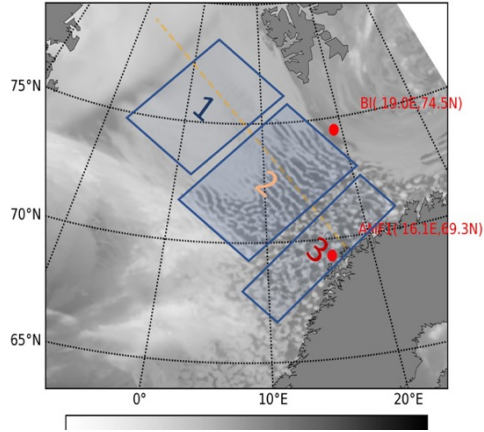
SCREAM simulated ice water path is strongly correlated with updraft velocity

Work on DP-SCREAM and E3SM/SCM with COMBLE modeling team

SCREAM Global Outputs at 7 ARM sites
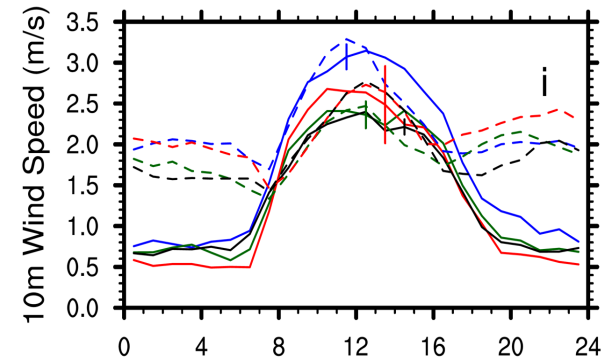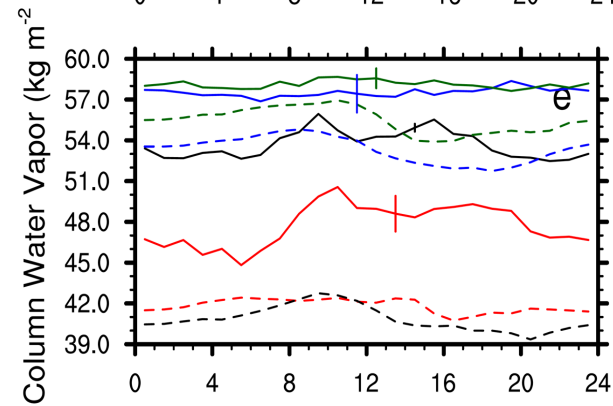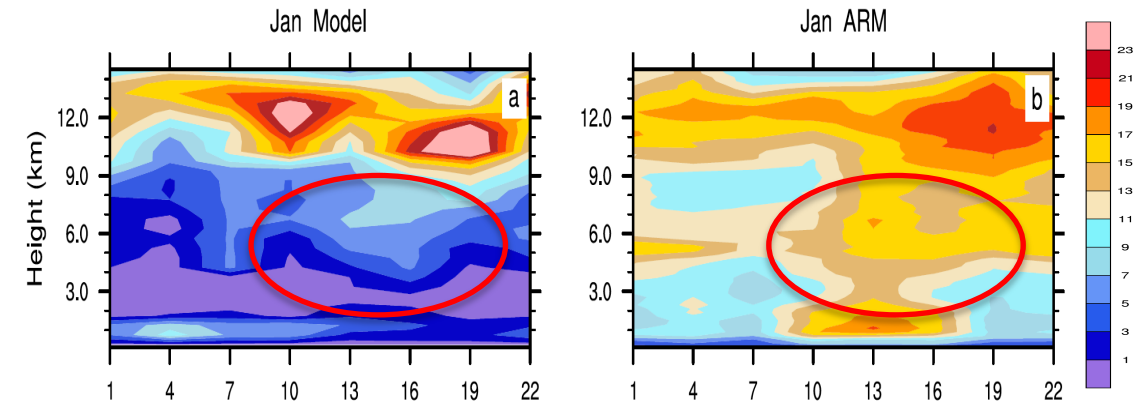
Yunyan Zhang
Poster 43

Cloud Fraction (%) GoAmazon (-3.2, -60.5)

GoAmazon

**Model Surface bias:
Warm and Dry
Excessive Winds**

Cloud Fraction (%) Tropical Western Pacific Manus (-2, 147.4)

Donahue et al, 2023, SCREAMv1 Overview Paper
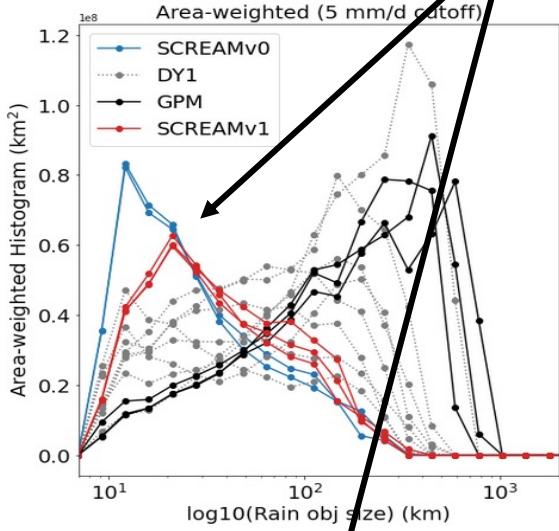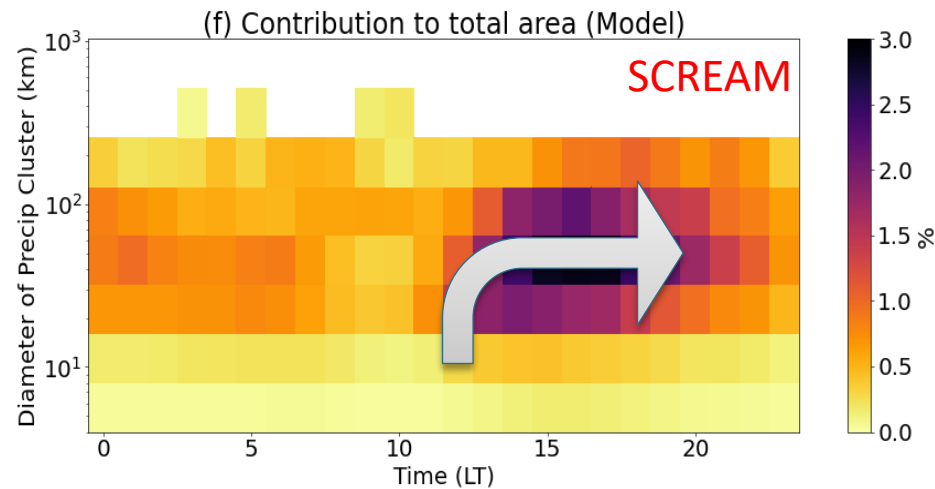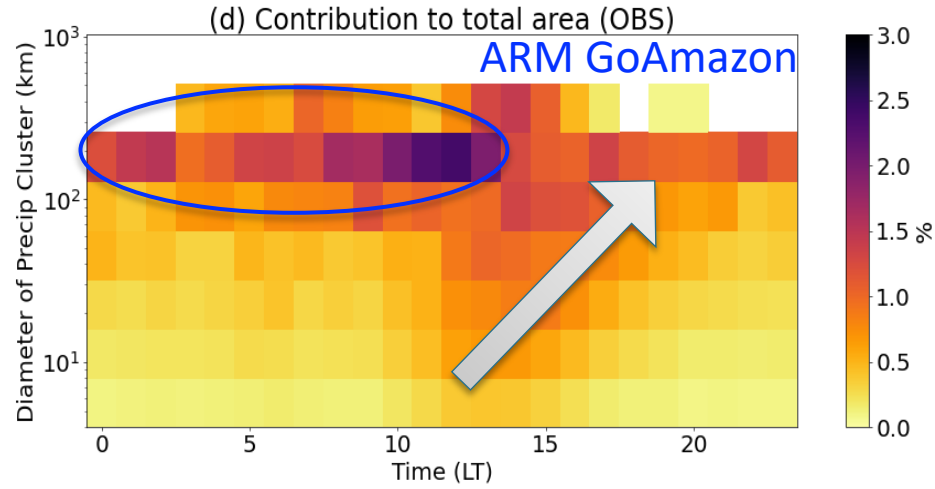
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"Popcorn" Convection Bias

Figure curtesy of C. Terai and P. Caldwell

ARM GoAmazon
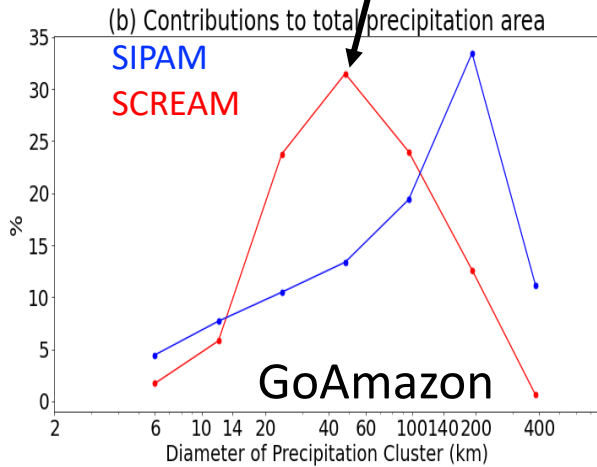
SCREAM

Large areas of negative sensible heat fluxes cut off convection

J. Tian et al. in preparation for GRL

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Y. Tian et al. (2022) GRL

- Observational based LES benchmark simulation (in collaboration with Y. Tian at NCAR)
- DP-SCREAM (P. Bogenschutz)
- RRM-SCREAM (Hsi-Yen Ma)

Yang Tian
Poster 52

Kilometer breakout
Wedn. 4:15

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Looking Forward...

- Continue to enrich DP-SCREAM THREAD case library (P. Bogenschutz, Y. Zhang)

- Regionally Refined Mode of SCREAM (RRM-SCREAM) (H.-Y. Ma)
  - GoAmazon (active validation now)
  - TRACER, CACTI, COMBLE, EPCAPE/MAGIC, and SEUS/SGP

- SHOC calibration based on DP-SCREAM of LAFE and CASS (Y. Zhang, H. Tang, P. Bogenschutz)

- DP-SCREAM testing of MAGIC and COMBLE cases (P. Bogenschutz, X. Zheng, Meng Zhang)

- Convection aggregation testbed and analysis (Y. Zhang, Y. Tian, P. Bogenschutz, Hsi-Yen Ma)

- Analysis of DYAMOND simulations at ARM sites (Y. Zhang)

Questions or Comments?

THREAD

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