Improving the Diurnal Cycle of Precipitation through A Hierarchy Modeling Approach – A GASS Multi-Model Intercomparision Study Project

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Model Errors in Simulating Diurnal Cycle of Precipitation

- Rainfall occurs too early after sunrise and ”too frequent, too weak”
- Fail to capture the nocturnal peak observed in many areas, like the central Great Plains
- Fail to capture the transition from shallow to deep convection
- Poor interaction between convection and its environments

No clear improvement with increasing model horizontal resolution

Summertime Diurnal Cycle of Precipitation at ARM SGP Site

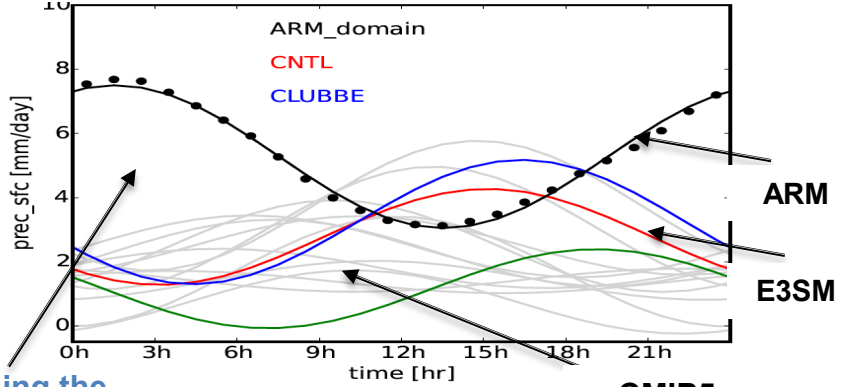


Figure from Chengzhu Zhang (LLNL)

Black: ARM observations
Grey lines: CMIP5 model results,
Colors for E3SM with different convection schemes

Goals

- Evaluate how well current weather and climate models simulate the diurnal cycle of precipitation over different climate regimes
- Understand what processes control the diurnal variation of precipitation in observations and in models
- Identify the deficiencies and missing physics in current GCMs to gain insights for further improving the parameterization of convection in GCMs.

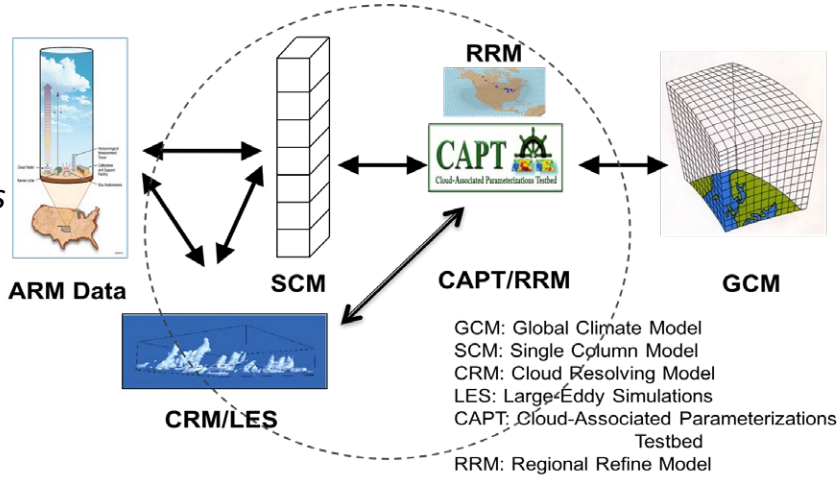
Research Themes

- **Nocturnal convection over land**
  - *What is the role of convective memory (advection), elevated convection initiation, nighttime low-level jet, radiative cooling from cloud tops?*
- **Diurnal cycle of convection over ocean**:
  - *What is the role of the "direct radiation–convection interaction" (or lapse-rate) mechanism on diurnal cycle of convection over ocean?*
  - *What is the role of the "dynamic cloudy–clear differential radiation" mechanism?*
- **Convection transition**
  - *What controls the transition from shallow to deep convection? Free tropospheric humidity or boundary layer inhomogeneity?*
- **Interaction between convection and water vapor**
  - *Which processes are most essential and how can these be improved in weather and climate models?*

Approach

- **A hierarchy modeling approach**
  - *SCMs, CRMs, LESs, Regional Models, Convection Permitting models, and GCMs*
- **Case studies vs. statistical studies**
  - *Major field campaigns*
  - *Multi-year simulations*
- **Short-range hindcasts vs. climate simulations**
  - *The Transpose-AMIP or CAPT approach with models initialized with NWP analysis*
  - *Free AMIP type of runs*
- **Observational studies & modeling tests**
- **Process oriented diagnosis**
  - *Convection onset diagnosis*

A hierarchy of process models is the key to bridge the scale-gap



Participants

- > 20 modeling groups expressed their interests
  - 12 SCMs / 4 CRMs / 3 LES models
  - 13 GCMs / 1 LAM / 1MMF / 1 GCRM
- Data received or coming
  - 9 SCMs (E3SM, SCAM5/6, SAM0-UNICON, SKIM, DALES-ED(MF)^{n} , CMC, SMCPCP, ICON)
  - 1 CRM (Met Office Cloud Model – MONC)
  - 8 GCMs (CAM5-RTF, CMCGEM, ECMWF, KIM, UMGA7, E3SM, TaiESM, SAM0-UNICON)

Experiments

- Case studies for detailed process understanding

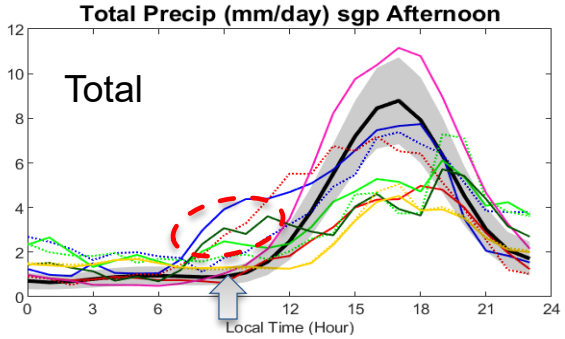
  (all types of models, 5-day hindcasts for GCMs)
  - The Midlatitude Continental Convective Clouds Experiment (**MC3E**), 4/22-6/6/2011
  - The Plains Elevated Convection at Night (**PECAN**), 6/1/-7/15/2015
  - The Green Ocean Amazon (**GOAmazon**), IOP1: 2/15-3/26/2014; IOP2: 9/1-10/10/2014

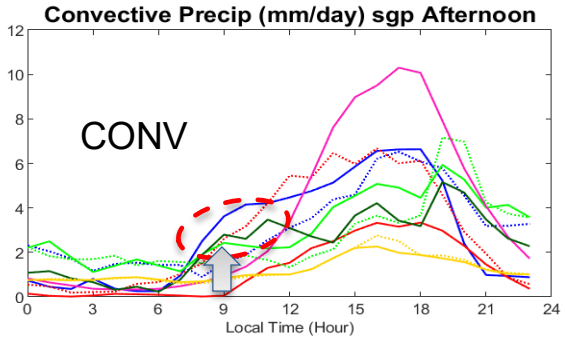
- Multi-year simulations to build statistics
  - SCMs
    - SGP: Long-term (2004-2015);
    - MAO: Long-term (2014-2015) (GoAmazon2014/15)
  - GCMs
    - A single 8-year “AMIP-type” simulation
    - Multi-year 3-day hindcasts

Preliminary Results – Afternoon Precipitation

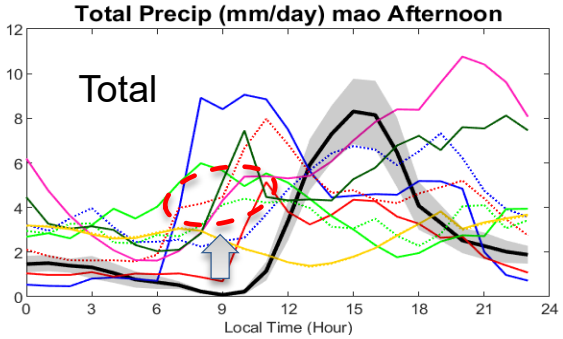
All the models trigger convection too early

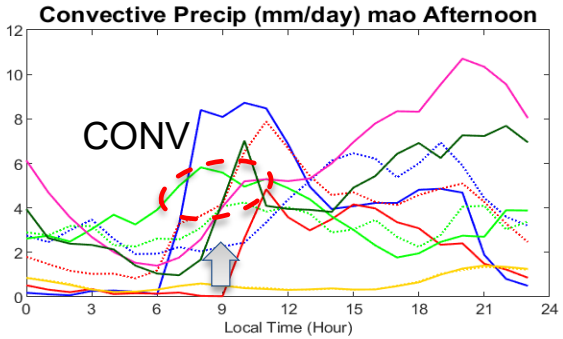
SGP





MAO





Afternoon Precip

- Peak Pr > 1mm/day
- Peak hours*: 1pm (11am) – 8pm
- Peak Pr > 1.5 Pr outside Peak Hrs

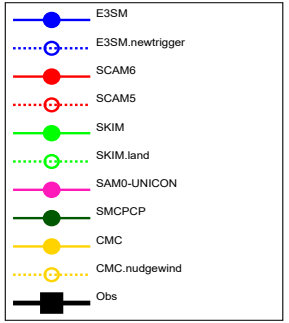


Figure from Shuaiqi Tang (LLNL)

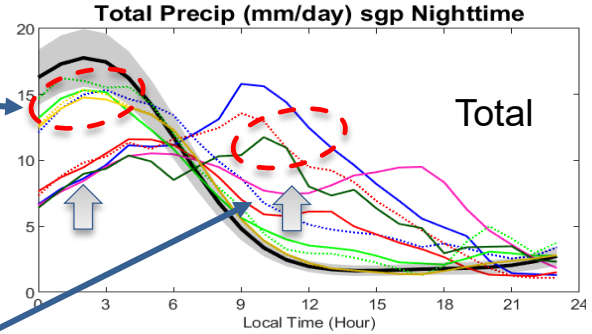
Preliminary Results – Nocturnal Precipitation

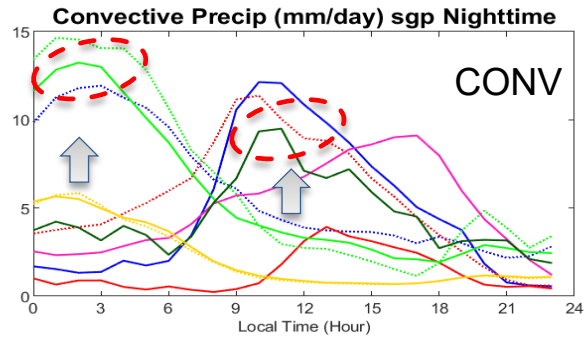
Few models can capture the nocturnal precip

E3SM_MOD
SKIM
CMC

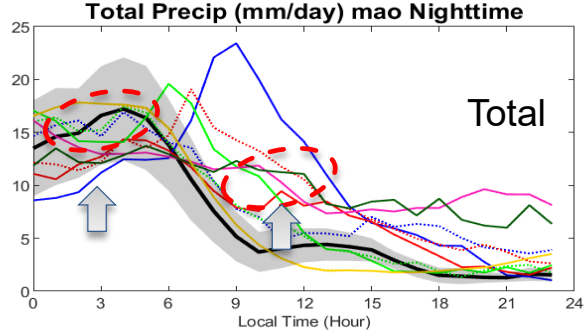
Most models having a morning peak for nocturnal precip events

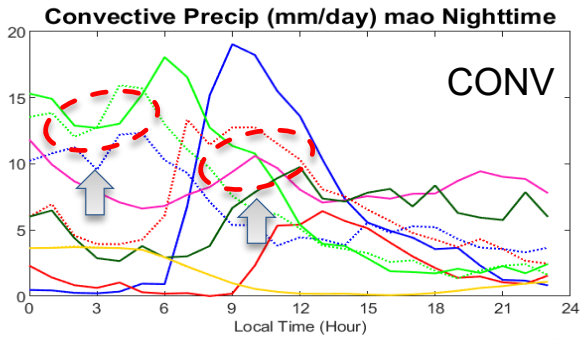
SGP





MAO





Nighttime Precip

- Peak Pr > 1mm/day
- Peak hours: 00Z – 07Z

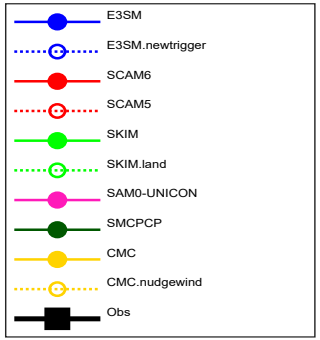


Figure from Shuaiqi Tang (LLNL)

Timelines (3 – 5 year project)

- 1 April 2019: Kick-off the project
- Oct. 2019 – Oct. 2020: Accepting simulation data from participants
- Dec. 2019 – May 2020: Preliminary analysis, revising the plan if needed
- May 2021 – Draft for the first overview paper on SCM/CRM/LES
- Sept 2021 – Draft for the first overview paper on GCMs
- Nov. 2021 – Breakout session at the 3rd pan-GASS meeting in Monterey, CA
- *…..*

Still welcome participations, particularly for CRM, LES, GCM models

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http://portal.nersc.gov/project/capt/diurnal/

Extra Slides

A few Comments on Organized Group Modeling Activities

Pros

- Provide a platform for scientists to interact and collaborate on important issues with current weather and climate models
- Provides a benchmark on targeted model errors for in-depth follow-up individual and/or collaborated studies
- Facilitate use of detailed field observations in process studies
- Promote use of common procedure and data format to initializing and forcing process models

Cons

- Analysis and diagnostics are often thin and may not lead to any major break-through
- Hard to get participants actively involved in (most participants just passively respond)
- Huge efforts needed from the organizers to keep projects moving