Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle *Since 1965*

ASR Workshop on Convection

Samson Hagos Robert Houze

Supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Feb 3-5 2016 Pacific Northwest National Laboratory, Richland WA

Objective: To map a strategy for the treatment of convection in the next generation climate models

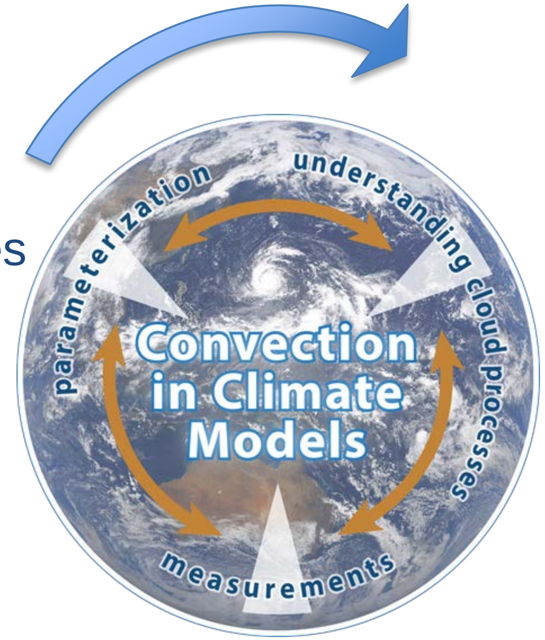
- **Whitepapers that address the following questions were solicited**
  - What are the challenges/opportunities?
  - How can ASR meet (take advantage of) them given DOE capabilities (ARM, high performance computing) and needs (ACME and other model development efforts)?
- A total of 24 white papers are received from which specific discussion questions were identified.

The Agenda

- **Overview talks and discussion items**

Discussed each item with emphasis on:

- What are the challenges?
- Can they be met? How?
- Can they be met in short term using existing resources (~3 years) or do they require new capabilities and/or long term investments (~10 years)?



- **Prioritizing and planning the report**
  - Summary of priorities
  - Timeline and assignment of written contributions to the report, "**The treatment of convection in the next generation climate models: Challenges and Opportunities**".

Participants

Mitch Moncrieff (NCAR), Ed Zipser (Utah), Greg Thompson (NCAR), Sungsu Park (Korean National Univ.), Chidong Zhang (Univ. of Miami), Courtney Schumacher (Texas A and M), Russ Schumacher (CSU), Robert Plant (Univ. of Reading)

Daehyun Kim (Univ. Washington)

Chris Williams (NOAA), Sue Vanden Heever (CSU), Yunyan Zhang (LLNL), Shaocheng Xie (LLNL), Scott Collis (ANL), Jeff Trapp (Univ. Illinois) Chris Golaz (LLNL), Steven Rutledge (CSU), Angela Rowe (Univ. of Washington),

Steve Klein (LLNL), Scott Giangrande (BNL), Chris Bretherton (UW), Hugh Morrison (UCAR)

Vince Larson (Univ. of Wisconsin) , Tony Del-Genio (NASA GISS)

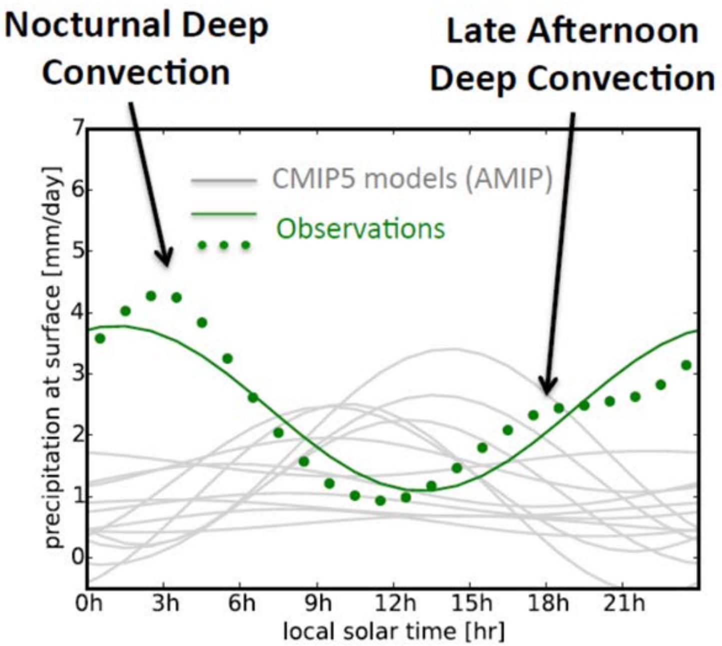
Samson Hagos (PNNL), Robert Houze (PNNL), Jim Mather (PNNL), Phil Rasch (PNNL), Jiwen Fan (PNNL), Jerome Fast (PNNL)

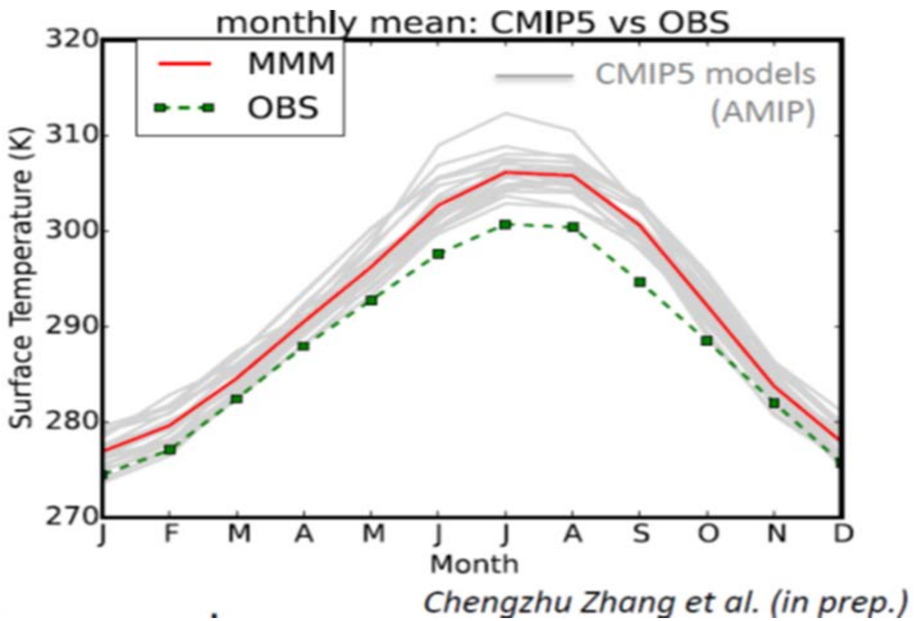
Keyword frequency from notes.

	Times Mentioned		Times
Vertical Velocity/Updraft	45	Vertical Velocity/Updraft	61
Ice / Microphysics	29	Ice / Microphysics	55
Cold pool	22	Cold pool	51
Plume/cloud size/radius	18	Organization	29
Entrainment	13	Plume/cloud size/radius	28
Organization	13	Transitions	25
Shear	12	Shear	24
Environment	12	Environment	23
Latent Heating	11	Entrainment	21
Transitions	7	Regime	17
Upscale	4	Aerosols	15
Diurnal	3	Latent Heating	12
Gravity Waves	3	Upscale	11
Aerosols	2	Diurnal	10
Regime	2	Turbulent	10
Turbulent	1	Gravity Waves	4

- Top three mentioned key words were vertical velocity, Ice microphysics and cold pools.

Model biases: Central US precipitation and temperature



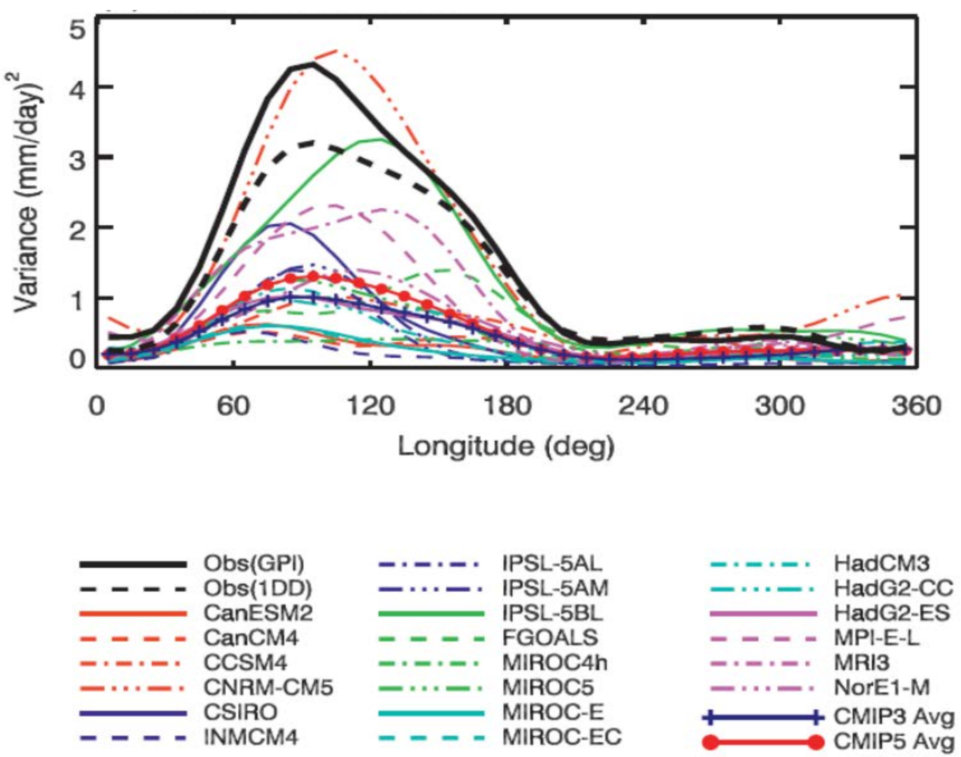


(a) Diurnal cycle of June-July-August precipitation from observations and CMIP5 models and (b) the seasonal cycle of surface temperature at the location of ARM's Southern Great Plains site.

- **The nocturnal precipitation is very weak in the models.**
- **The model land surfaces are considerably warmer.**

Model biases: Madden-Julian Oscillation

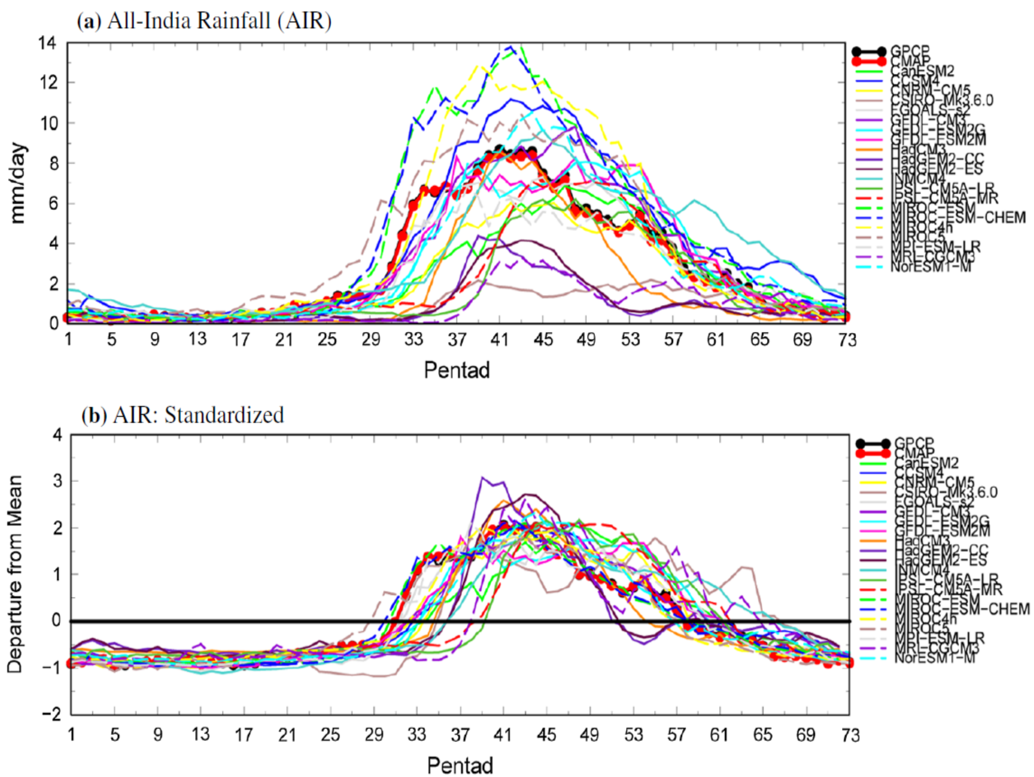
VAR MJO 5S-5N



- MJO variance is generally underestimated in comparison to observations.

CMIP5 variance of the MJO mode along the equator averaged between 5° N and 5° S (From Hung et al. 2013).

Model biases: Indian Monsoon

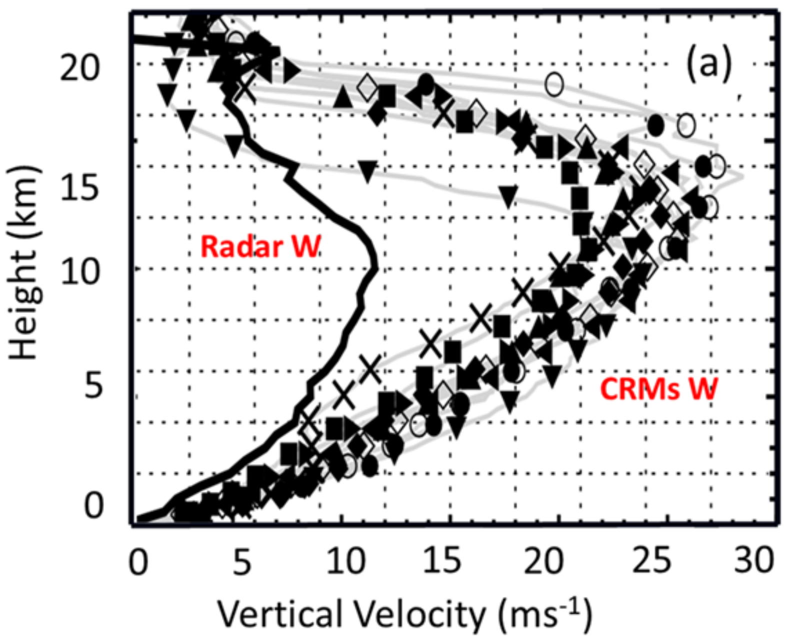


- **Type 1: Large spread among the models.**
- **Type 2: Most models delay the monsoon onset.**

TOP: CMIP5 Simulated and observed annual cycle of All-India Rainfall (AIR).

BOTTOM: Standardized annual cycle of AIR. (From Sperber and Annamalai 2014)

Model biases: Vertical velocity in CRMs



- Vertical velocity is generally vastly overestimated in CRMs.

Median profiles of maximum vertical velocity for convective updrafts for the period of 1310Z to 1750Z on 23 January 2006. Observations are represented by the solid black line (from Varble et al. 2014).

1. Basic understanding of cloud processes

- How boundary layers evolve in a way that leads to cloud populations containing deep and mesoscale convection including cold pool dynamics,
- Intensities, sizes of updraft/downdrafts, and internal variability of their properties,
- Microphysical feedbacks,
- Aggregation of convection,
- Inducement of mesoscale circulation—including gravity wave response to aggregated convective elements,
- Adjustment of mesoscale motions to environment profiles of stability and shear, and
- The role of stochastic processes

2. Parameterization

- A fundamental rethinking of the **objective of**, **approach to, and assumptions** in convection parameterization are needed.
- Parameterization must represent the **sub-grid processes, and their interactions with resolved processes as parts of the same continuum**.
- The scale-separation assumption, commonly used in the past, needs to be replaced by an important and stringent **requirement of scale awareness**.
- In addition, the assumption that all deep convection arises from the boundary layer needs to be broadened to include **the formation of "elevated," intense convective systems** that are disconnected from the boundary layer (such as nocturnal systems).

Parameterization Approaches

- Modifications to quasi-equilibrium mass flux schemes
- Prognostic parameterization of processes
- Non-local parameterization of processes
- PDF-based turbulent schemes
- Explicit approaches: Superparameterization and global CRMs
- Dynamically based parameterization for organized convection

3. Observational Needs

Three action items were proposed. These are

- **Development of merged products:** integrated datasets on convection and microphysical processes from existing of ARM IOPs and permanent sites.
- **Short-term adaptive observation strategy:** Adaptive observing strategy based on forecast is proposed. This strategy could be accompanied by increased frequency of soundings and targeted LES and limited area CRM runs.
- **Long-term observation strategy:**
  - S-band scanning research radars,
  - a research aircraft capable of penetrating intense convection.
  - organizing and carrying out a coordinated, large-scale, multi-agency campaign aimed at examining these key scientific issues over a tropical environment.

4. Integration

An effective strategy to better represent convection in climate models requires integration among 1) – 3) so that observations can be meaningfully used for model validation and hypothesis testing.

- The development of instrument simulators.
- a hierarchical approach to modeling is essential, where one takes full advantage of progress across the range of other modeling frameworks, such as **LES, limited area CRMs, and variable resolution and operational high resolution models**, and the various ways observations have been used to validate and improve them.

Conclusion:

Was the workshop successful?, How does one measure success?

Level 1. Were the goals accomplished?

- The state of our understanding of convection processes and their representation in a hierarchy of models and mapped a coherent strategy for moving forward.
- The workshop was well attended, and encountered very few technical and logistical issues.

Conclusion:

Level 2: "To what degree have the key scientific problems and observational and parameterization issues raised at the workshop been addressed, and have these activities led to improved high resolution climate models?"

- A review of scientific articles published over the defined period of time and examination of how/if they were influenced by the outcome of this workshop.
- Standard metrics for usage of ARM facilities can indicate the impact of the investment decisions informed by the outcome of the workshop.
- Measurable improvement in model simulation of the important climatological features (diurnal cycle of precipitation over land, the MJO, monsoons, ENSO, the structure of the ITCZ and others elements of the general circulation).

Acknowledgement

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- **Participants**
- **Jerome Fast** and **the ASR SFA at PNNL** provided the financial support.
- **Emily Davis** and **Alyssa Cummings** handled the workshop logistics.
- **Angela Rowe** and **Zhe Feng** took very detailed notes on which this report is based.
- **Shaima Nasiri** and **Ashley Williamson** and the ASR Program for their encouragement and input through the planning and execution of the workshop.