# Research Objective 4:
# Develop improved parameterizations of boundary-layer clouds and turbulence for use in MMFs and GCRMs

Steve Krueger and Chin-Hoh Moeng

CMMAP Site Review
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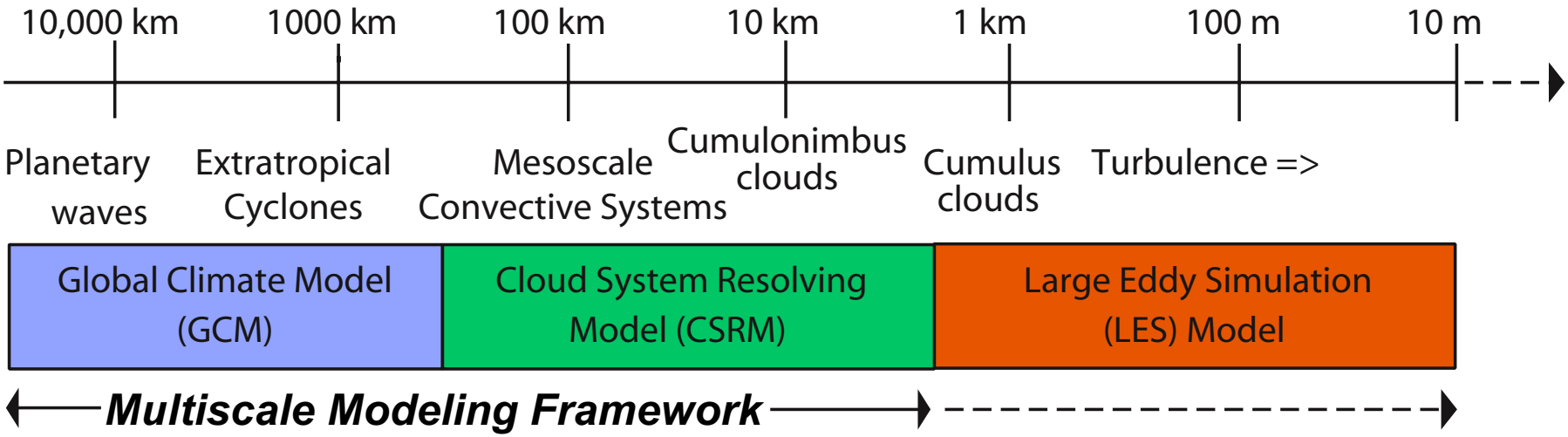
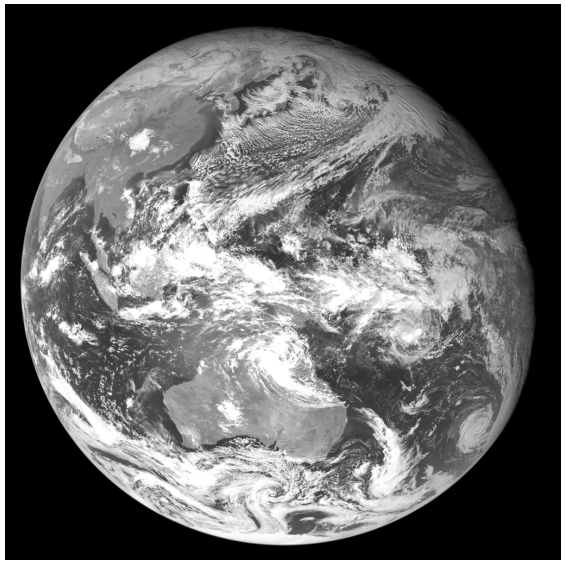
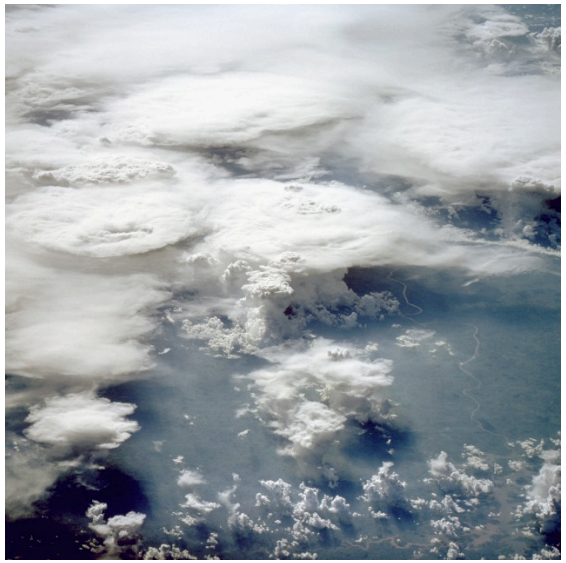
## Scales of Atmospheric Motion





# Boundary layer cloud systems

- Marine stratocumulus
- Trade cumulus
- Shallow convection over land (with diurnal cycle)
- Transition from shallow to deep convection
- Deep precipitating convective
- Cold-air outbreaks over mid-latitude oceans
- Convective plumes from leads during winter
- Boundary layers over inhomogenous surfaces or terrain

# Boundary layer clouds in cloud system resolving models (CSRMs)

- CSRMs used in MMFs have horizontal grid sizes of 4 km or more.
- Such CSRMs are expected to represent all types of cloud systems.
- However, many boundary layer clouds are not resolved by such CSRMs.
- Our objective is to improve the representation of boundary layer clouds and turbulence in CSRMs used in MMFs.

# Shallow cumulus clouds and mesoscale organization

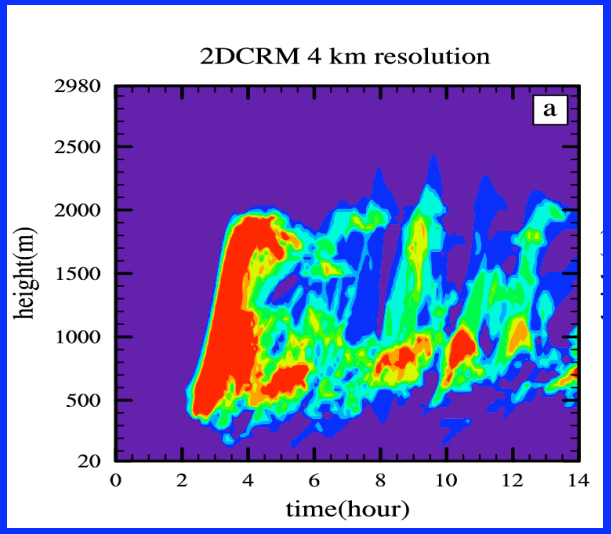
- Typical CSRMs grid sizes are too large to resolve shallow cumulus.
- A CSRM with a suitable SGS parameterization should be able to represent SGS shallow cumulus and resolve their mesoscale organization.
- Evaluate parameterization with LES and observations.

# Meeting the Objectives

**Develop and test i**mproved representations of SGS convection and turbulence in CSRMs.

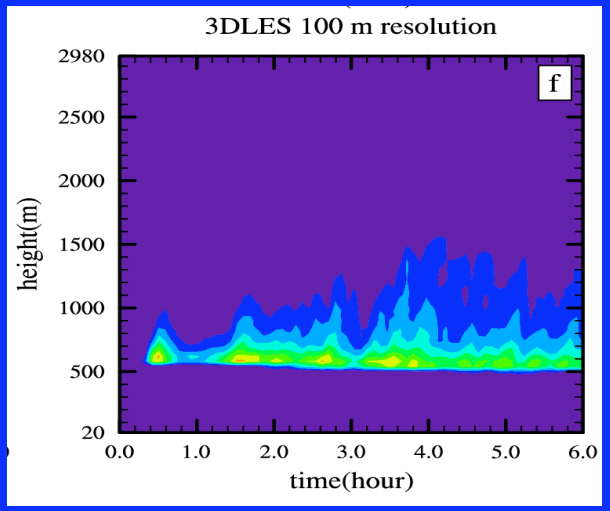
- **Parameterizations under consideration**
  - *PDF/HOC (probability density function/high-order closure):* Predicts statistics of turbulence to infer SGS cloud properties
  - *Two-scale MMF:* 2D LES model predicts a sample of cloud properties.
- **Additional physics to be included**
  - Effects of *surface inhomogeniety* (elevation, land surface properties)
- **Evaluation methods**
  - Use 3D LES *benchmark simulations*
  - Compare to *observational datasets*

# Cloud fraction evolution for BOMEX shallow cumulus

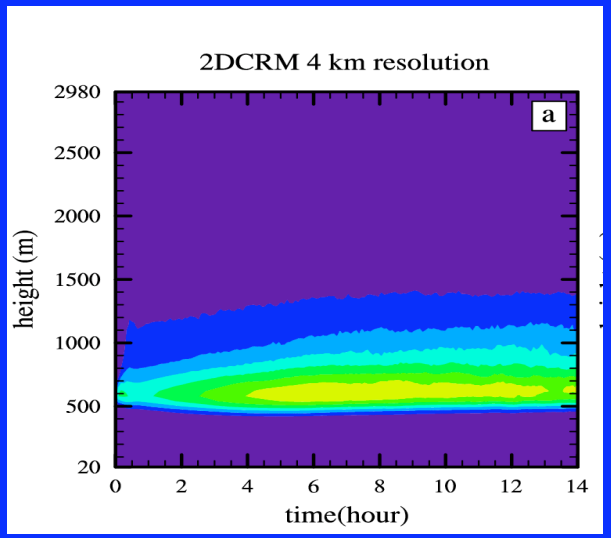



CSU System for Atmospheric Modeling (SAM)
CRM with LOC and IP-HOC, and LES version

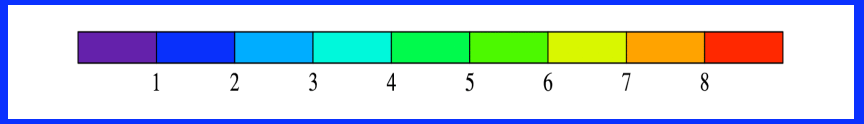
LOC




LES

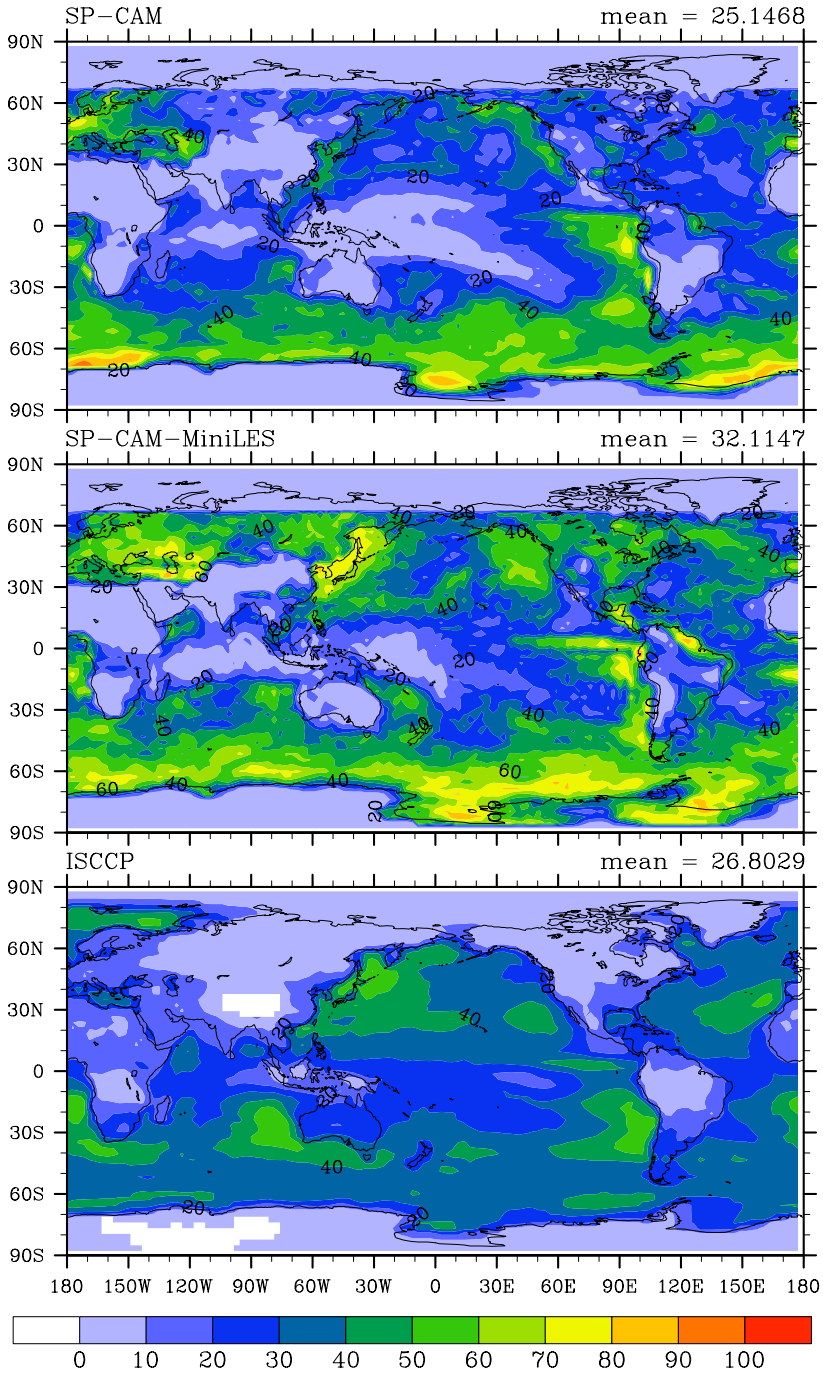



IP-HOC




(%)

Low-cloud fraction results obtained in tests of a "mini-LES" parameterization of turbulence, coupled with the MMF. The top panel shows results from a control run with the standard MMF, the middle panel shows results from the mini-LES version of the MMF, and the bottom panel shows observations from ISCCP.



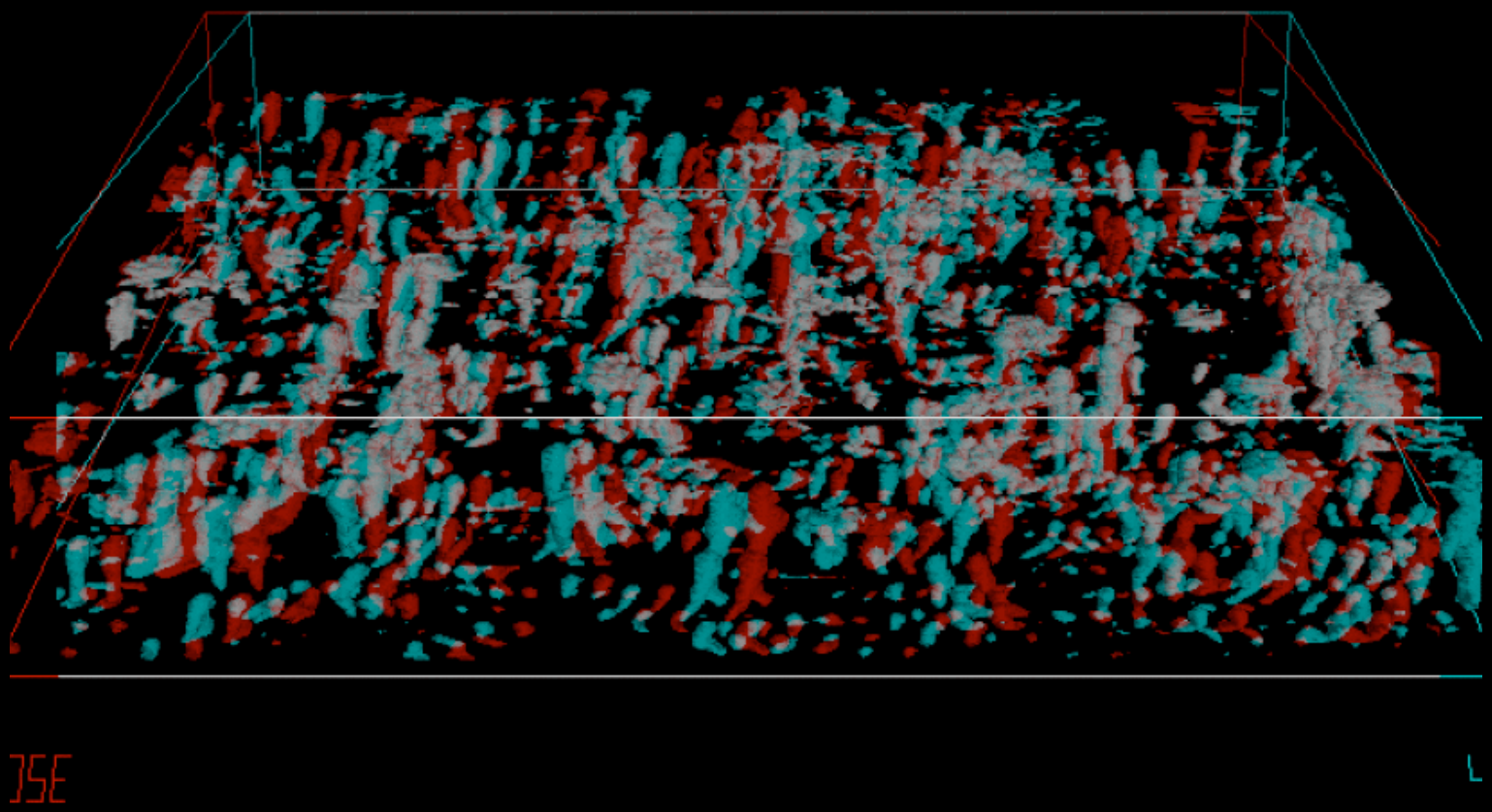

SP-CAM

SP-MLES-CAM

# Evaluation Methods

- **Benchmark simulations**
  - Large-domain LES (e.g., 100 km x 100 km domain, 100-m grid size)
  - Compare to CSRM results using various SGS parameterizations.
  - Analyze results to gain insight into scale interactions, etc.

# Large domain LES of trade wind cumulus




40 km x 40 km domain, 100-m grid size

Vis5D

# Evaluation Methods

- **Observational datasets**
  - High-resolution cloud properties from satellite measurements
  - Vertical structure of clouds from ground and satellite-based cloud radars
  - Aircraft-based measurements during field experiments

# Shallow cumulus clouds and mesoscale organization

- Typical CSRMs grid sizes are too large to resolve shallow cumulus.
- A CSRM with a suitable SGS parameterization should be able to represent SGS shallow cumulus and resolve its mesoscale organization.
- LES is used to provide benchmark simulations.

# High-Resolution Simulation of Shallow-to-Deep Convection Transition over Land

(Khairoutdinov and Randall 2006)

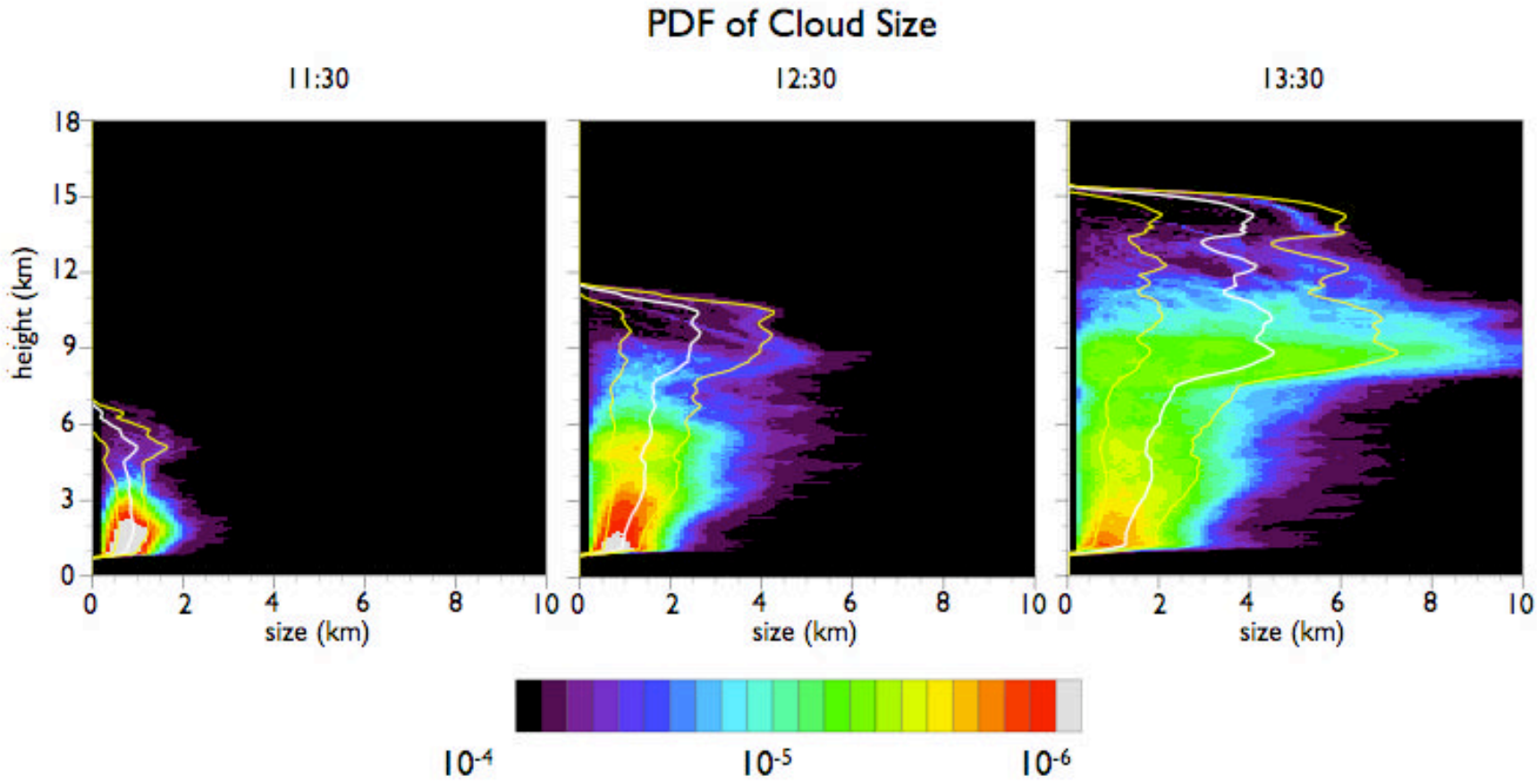



Figure 8. PDF of cloud size as a function of height shown for three different simulation times. Mean and standard deviations are shown by the white and yellow lines, respectively.

150 km x 150 km, 100 m grid size, 6 h

*Time-height cross section of cloud fraction simulated by SAM CRM with the Cheng-Xu PDF/HOC for BOMEX. The horizontal grid sizes range from 4 km (a) to 250 m (e). Results from the SAM LES are also shown in (f).*