# Introduction


## Yangang Liu
## (Brookhaven National Laboratory)


- **Welcome**
- **Major events since March 2010 ASR meeting**
- **Some operational and scientific highlights not presented here**
- **Group dinner restaurant**

# What is FASTER?

- FASTER = FAst-physics System TEstbed and Research
  -- testbed and research, system, evolving, faster work

- Result from CCPP (ESM) proposal "Continuous Evaluation of Fast Processes in Climate Models Using ARM Measurements"

- Collaborative effort: 21 investigators from 10 institutions

- Co-managed by ESM and ASR programs

**FASTER is a multi-institutional ESM effort to bridge ESM and ASR sciences by fully utilizing ARM measurements to evaluate GCM parameterizations of cloud-related fast processes.**

(Fast processes = GCM subgrid process)

COLUMBIA UNIVERSITY STONY BROOK UNIVERSITY Goddard Institute for Space Studies GFDL BROOKHAVEN NATIONAL LABORATORY UCLA JIFRESSE JPL University of Reading USF UNIVERSITY OF SOUTH FLORIDA TEXAS A&M UNIVERSITY

# Major Events since 2010 ASR meeting

- New Members

-- Dr. Gang Liu (visiting scientist at BNL)
-- Dr. Hua Song (research associate at BNL)
-- Dr. Peter Bass (research associate at KNMI)

- Informal FASTER Review (4 Nov 2010)

-- ASR/ARM managers (Drs. K. Alapaty, A. Williamson, and W. Ferrell)
-- Some Review Committee Members

- Meetings at BNL and GISS(10 Nov 2010)

Most team members **plus Dr. Alan Betts** attended GISS meeting

- FASTER-Lead AGU Fast Physics Section (Dec 2010)

-- Over 50 abstracts and 3 sub-sections; Special JGR issue interest

*Encouraging Sign: We are in a growing field!*

# “Operational” Progress

- FASTER Testbed V1 (up and running, demo by W. Lin)
- Mulitiscale Data Integration (talk by T. Toto)
- Visualization and beyond-fried egg evaluation (3D and animation, talk by T. Toto and W. Lin)
- Configuration of WRF as a CRM driven by large scale forcing (WRF-FASTER, talk by S. Endo)
- Multiscale Data Assimilation System (Talk by Z. Li and P. Bass)
- Integration of SCM-testbed and NWP-Testbed (started)

# Additional Science Highlights

- Aircraft data and entrainment-mixing (Oral by Lu, 8:30 – 8:45 am, Wed)
- Uncertainty quantification of cloud fraction (poster by Wu et al.)
- Uncertainty quantification of microphysical retrievals (drafting by Huang et al., also CLCWG discussion 1:30 – 2:45 pm, Thursday)
- Relation between cloud albedo and cloud fraction (poster by Liu et al)
- Better use of surface radiation measurement (ACP, by Liu et al.)
- Evaluation of reanalysis at SGP (Drafting, by Wu et al)
- 3 papers submitted, and 6+ being drafted

***We are progressing from "warm-up" to regular "IOP" stages!***

# Breakout Agenda

* Update and share results (since last GISS meeting)

* Group discussion

* Group dinner at 7:45 pm, meet ~7:40 pm in lobby area

**Restaurant: Rio Rio Cantina (California Tex-Mex Cuisine)**

**Place: Near the hotel and in the river walk area**

**Go out back of the hotel, make a left, cross over 1st bridge.**

**Reserved under Sharon Zuhoski for FASTER**

# Discussion Items

- Next IOP to focus: RACORO ?

- Emerging commons from GCM, SCM and NWP results
(BAMS article on FASTER Philosophy, Approach and Findings ?)

- Cloud albedo, cloud fraction and their relationship

- More evaluation variables

- Evaluation approach

- Generic issues: type partition; Point measurements to GCM domain; subgrid variability and scale-dependence

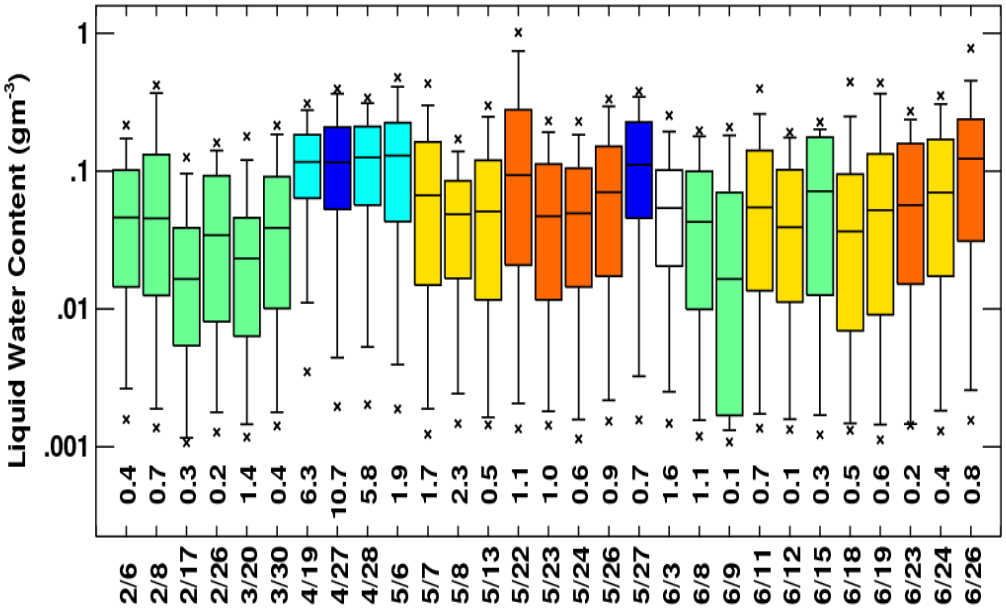
*Time limited, but as always please contact me anytime you have ideas to share!*

# Next IOP to Focus: RACORO ?

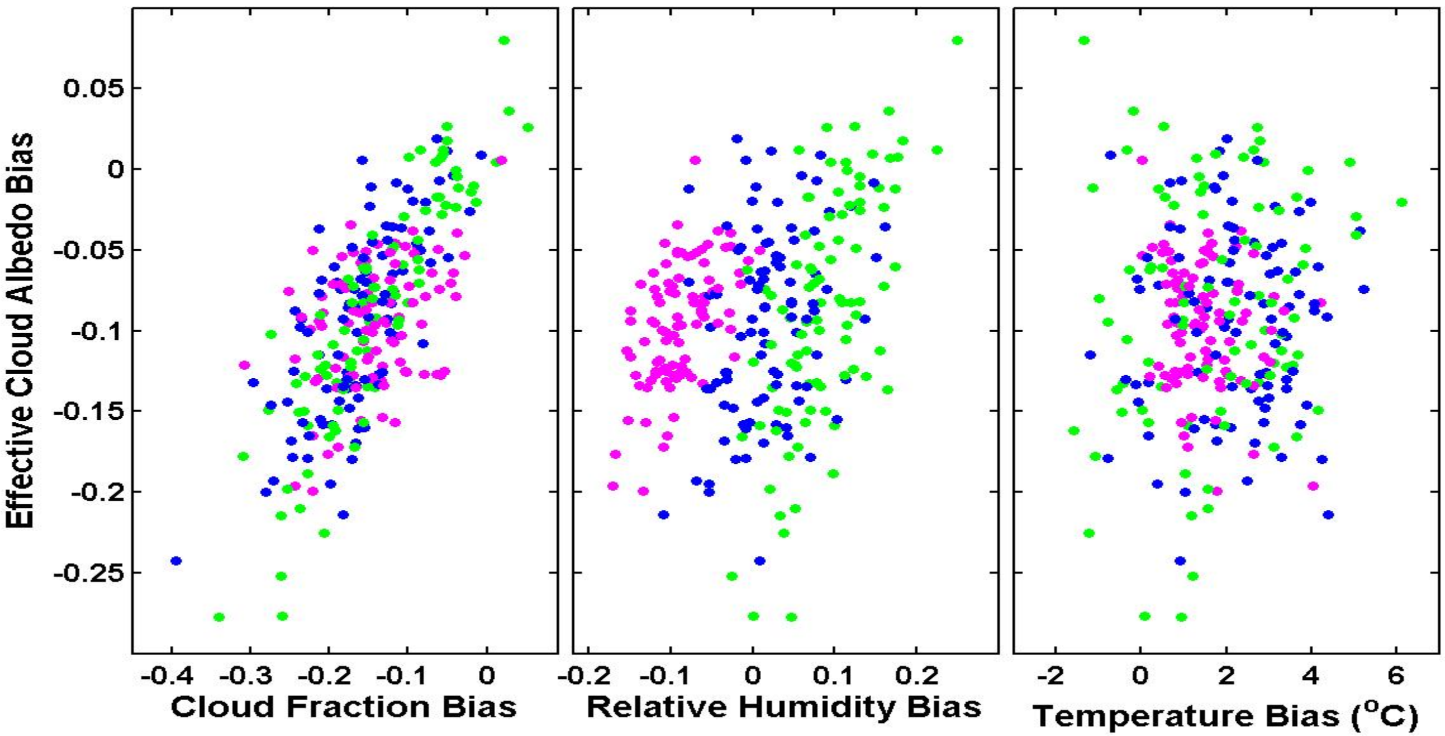
## Focus: Continental boundary layer liquid water clouds

# RACORO

Routine
ARM Aerial Facility (AAF)
Clouds with Low Optical
Water Depths (CLOWD)
Optical
Radiative
Observations




# Emerging Feature one:
# Model Underestimation of low clouds ?

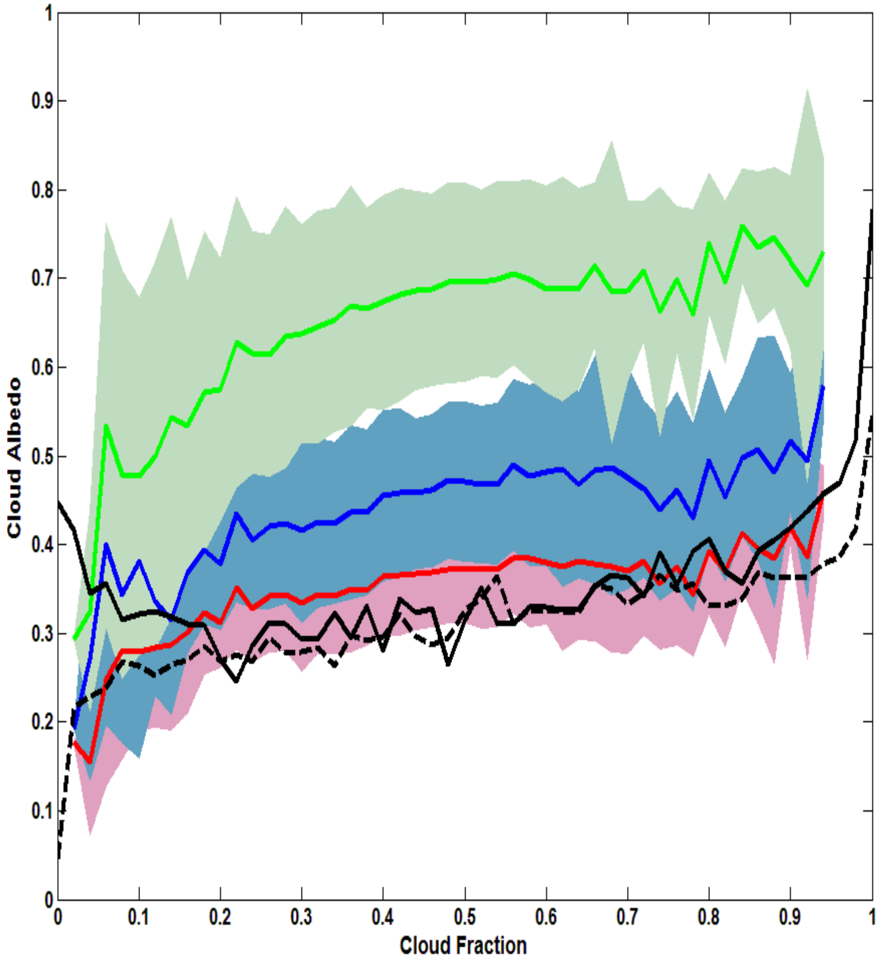



**NCEP/NCAR Reanalysis, NCEP/DOE Reanalysis, ERA-Interim**

***Hypothesis: Error propagation from RH and T to cloud fraction etc cloud properties via parameterizations; roles of PBL and surface layer (esp., surface sensible and latent flux) parameterizations? Updraft and downdraft regimes?***

# Cloud Albedo, Cloud Fraction and Their Relationships: Physics and Tool

**IPCC AR4 GCM Results**




- **Black curves – observations**
- **Color schemes – GCMs**

**Green = total water path;**

**Blue = surface radiation;**

**Red = TOA radiation**

- **Positive correlation, esp. for cloud fraction between 0.2 and 0.9**
- **SCM shows either physics and/or overlap schemes lead to similar results**
- **Theoretical demonstration**
- **How about NWP results?**
- **Compensating errors & tuning issues?**

# More Evaluation Variables

* **Radiation and corresponding effective cloud albedo**
* **Cloud fraction and cloud albedo**
* **Precipitation**

* ***Optical depth, LWP/IWP, other macroscopic properties?***
* ***Water vapor***

***-- Surface turbulent fluxes***
***-- Vertical velocity***
***-- Aerosol***

***-- LWC, IWC, or simulators (e.g., cloud radar)***
***-- CAPE and CIN***
***-- Effective radius***
***-- Cloud droplet concentration***
***-- Spectral dispersion***
***-- Other model outputs ?***

# Evaluation Approaches

* Temperature as vertical coordinate

* Regime based on 500 mb vertical velocity

* Regime based on precipitation

* More general regime classification presented

* Coupling analysis – albedo-fraction relationship

* Other approaches?

# Some Generic FASTER Issues

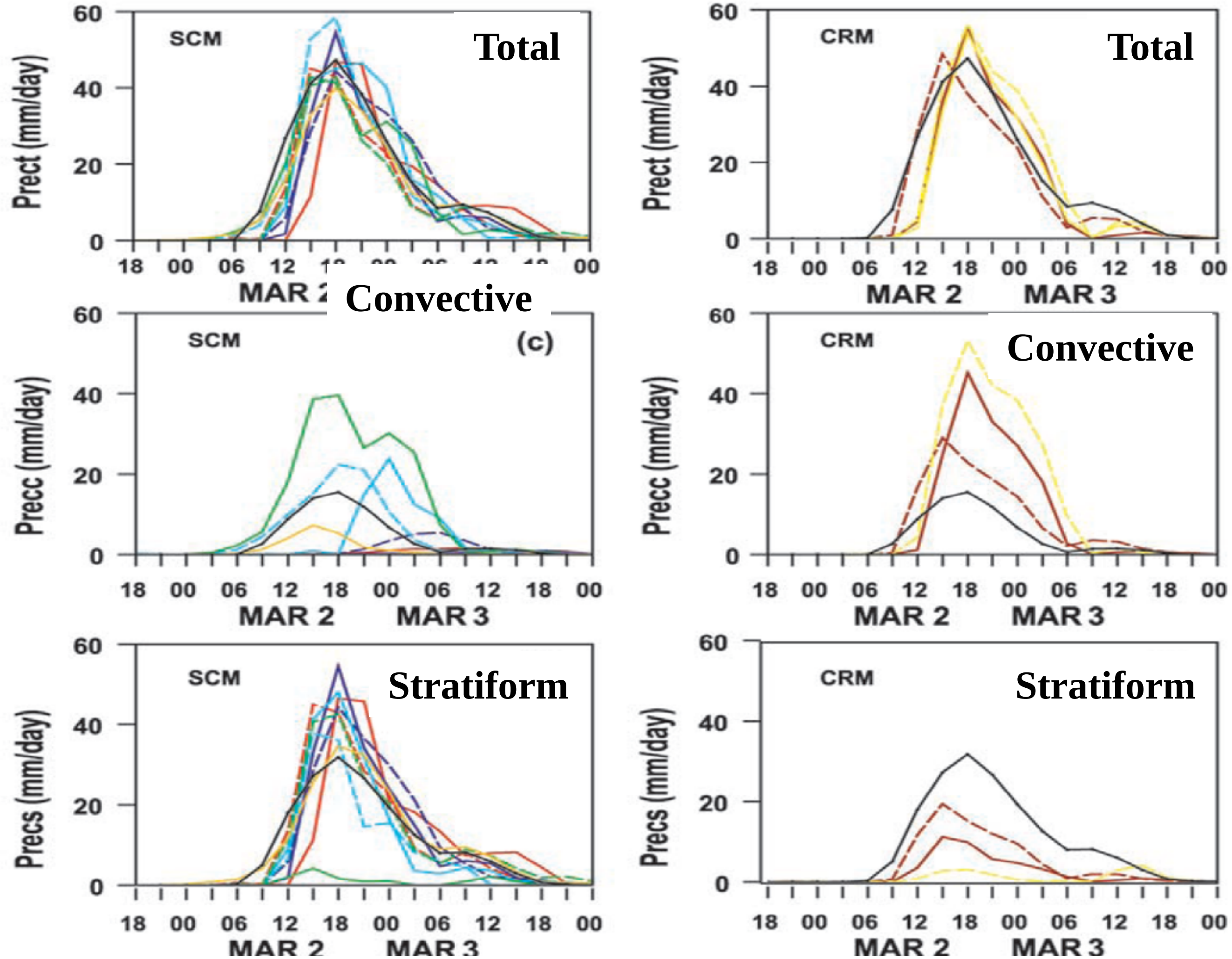
- Consistency of Partition between stratiform-convective clouds and precipitation between models and observations, and among different models of various scales (e.g., GCM vs. CRM)

- Consistency of cloud definition (e.g., including precipitation particles or not) between models and observations and among models of various scales (e.g., GCM vs. CRM)

- Scale mismatch in evaluation of model domain results against ARM pencil-like measurements

- Experiment design to identify model errors

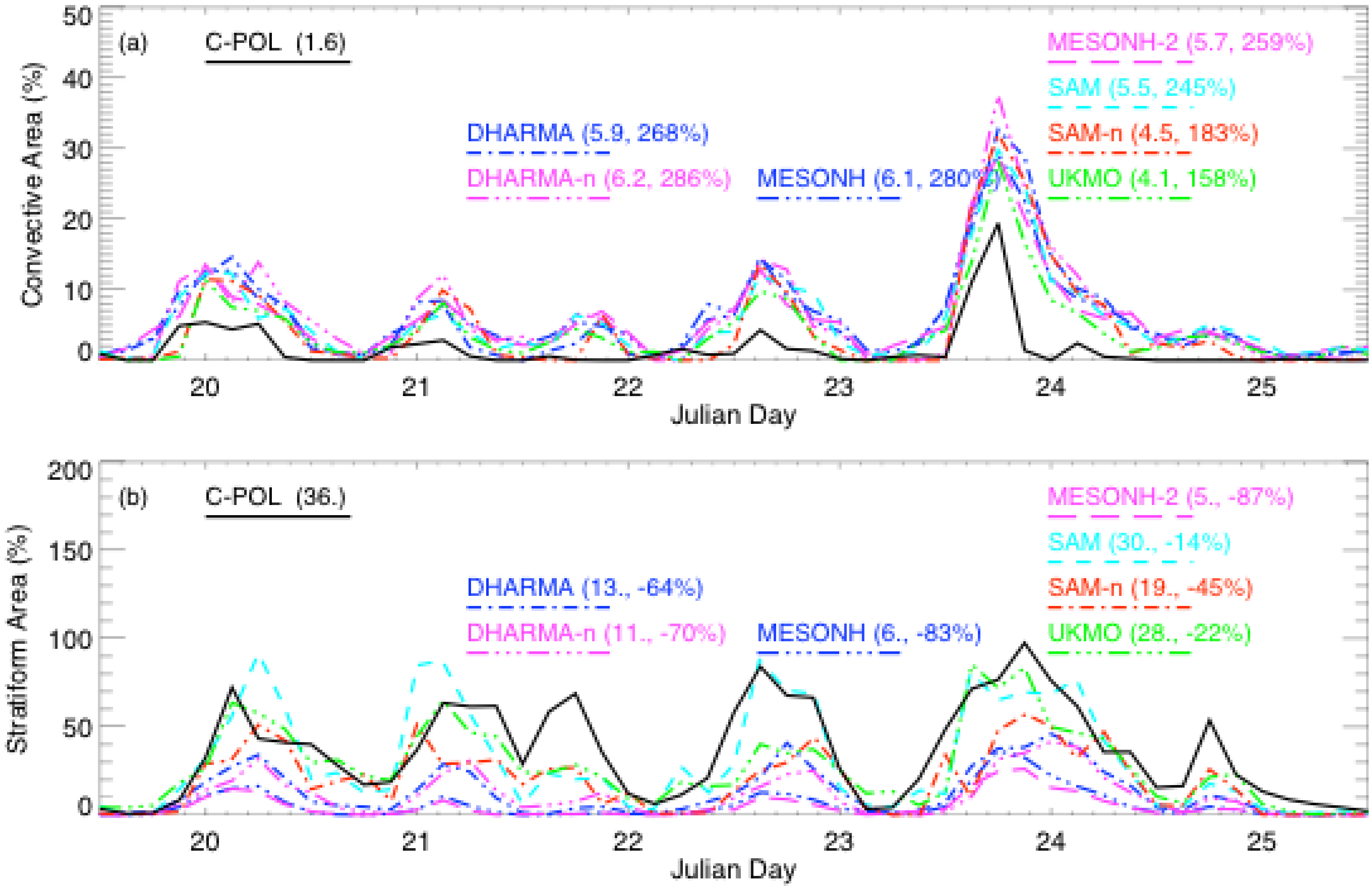
# Cloud type partition is key to intermodel differences in both SCMs and CRMs




**Precipitation rate vs. Time**

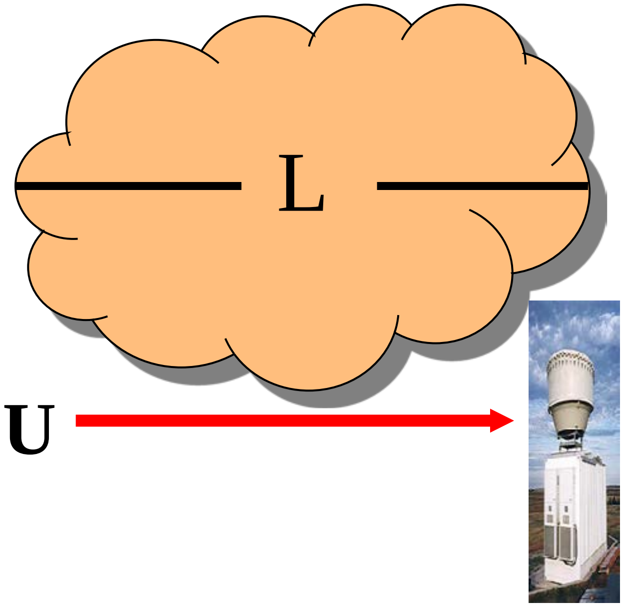
**(Adapted from Xie et al., 2005, JGR, Special issue on March 2000 Cloud IOP)**

# Convective and stratiform areas




(from Fridland)

# Comparison of Data at Different Scales




1. Taylor Hypothesis

$$T \sim \frac{L}{U}$$

Small Variation $\sigma$ < 0.5 Mean

**Temporal average = Spatial average**

2. Ergodic hypothesis → **T***

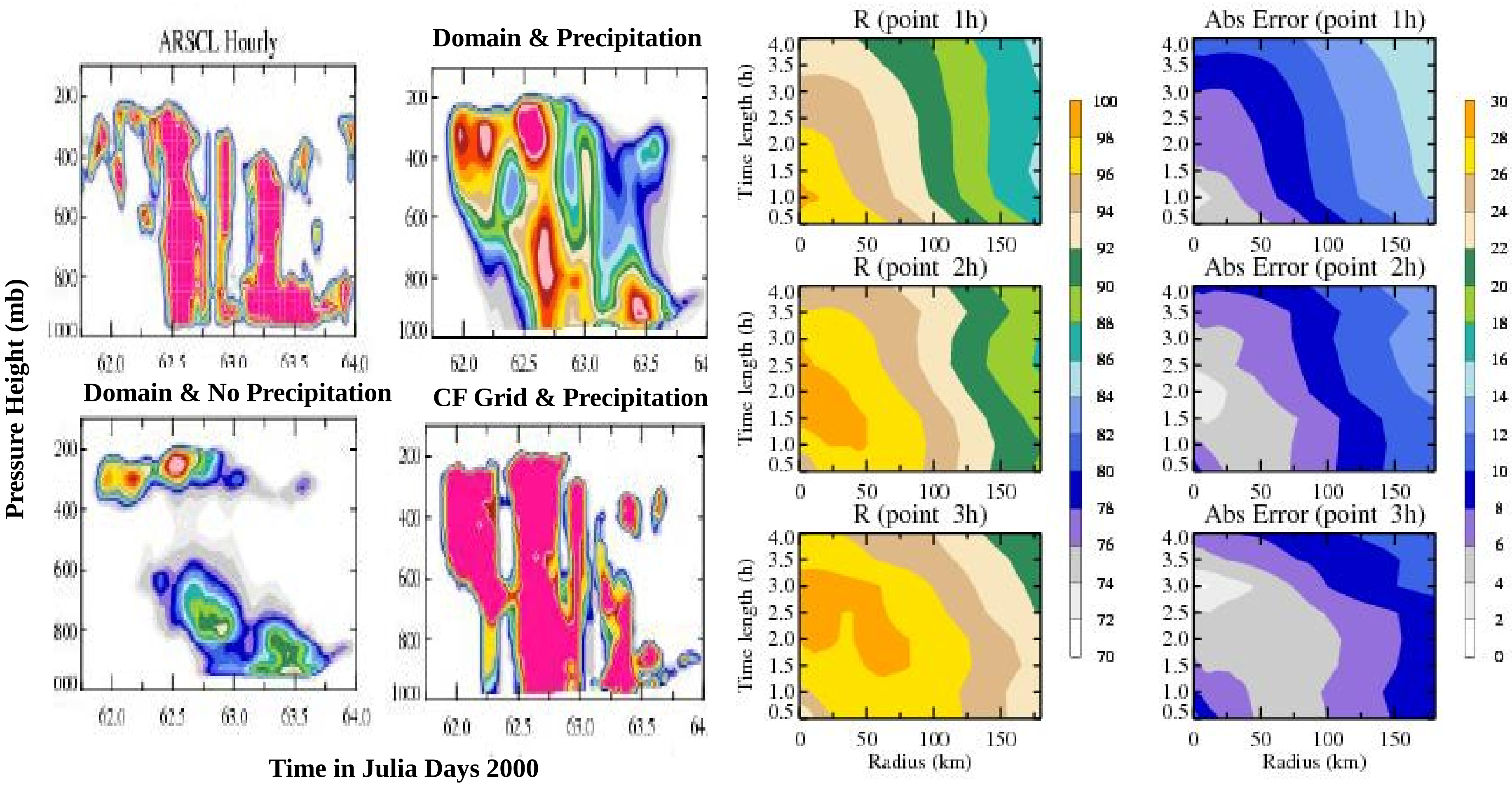
## Explore detailed scale-dependence using CRMs:

Increasing averaging scale

**CF grid, d = 0** **NWP grid** **GCM grid, d***

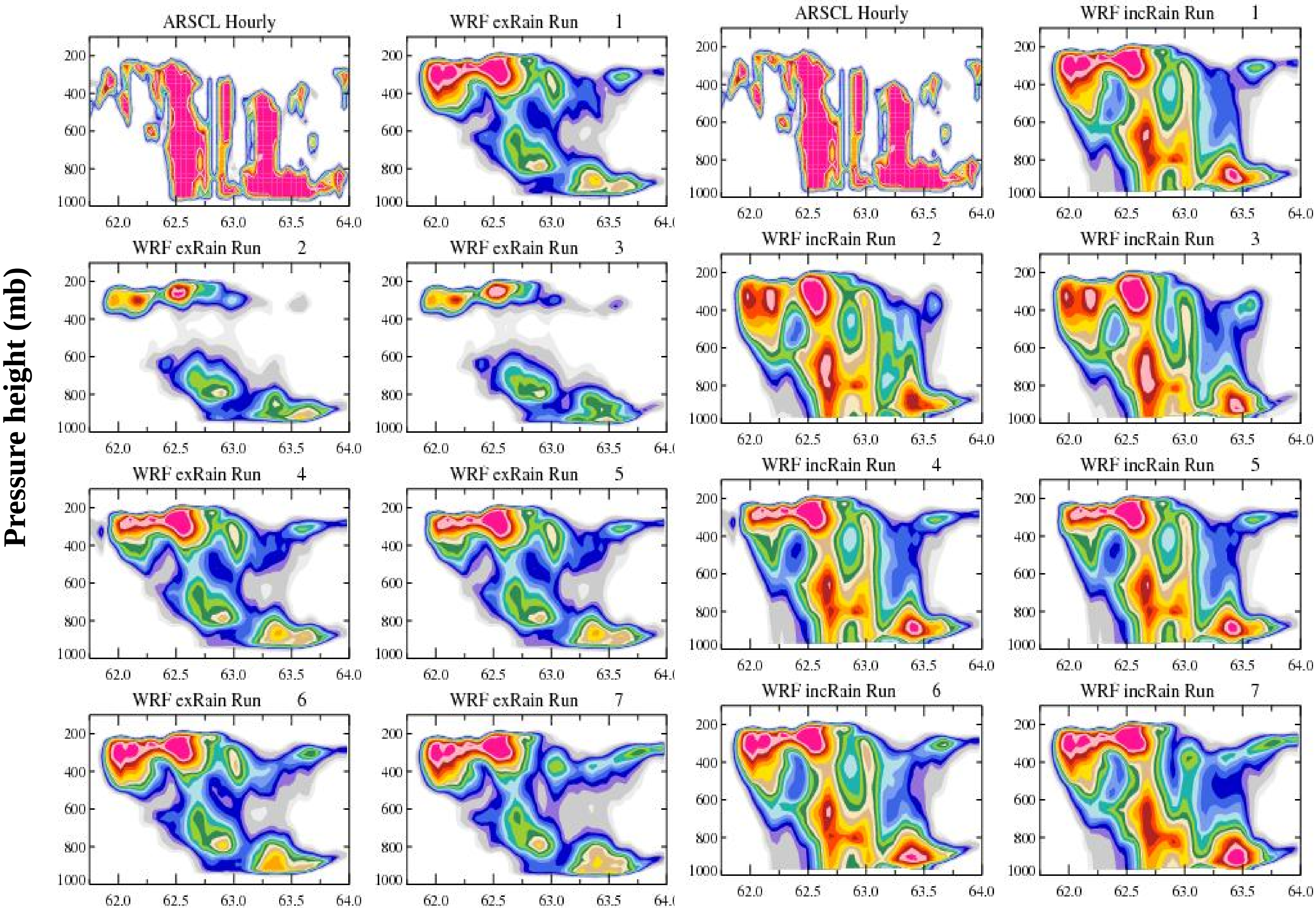
**For a given averaging time**

# Observation-Model Comparison Issues



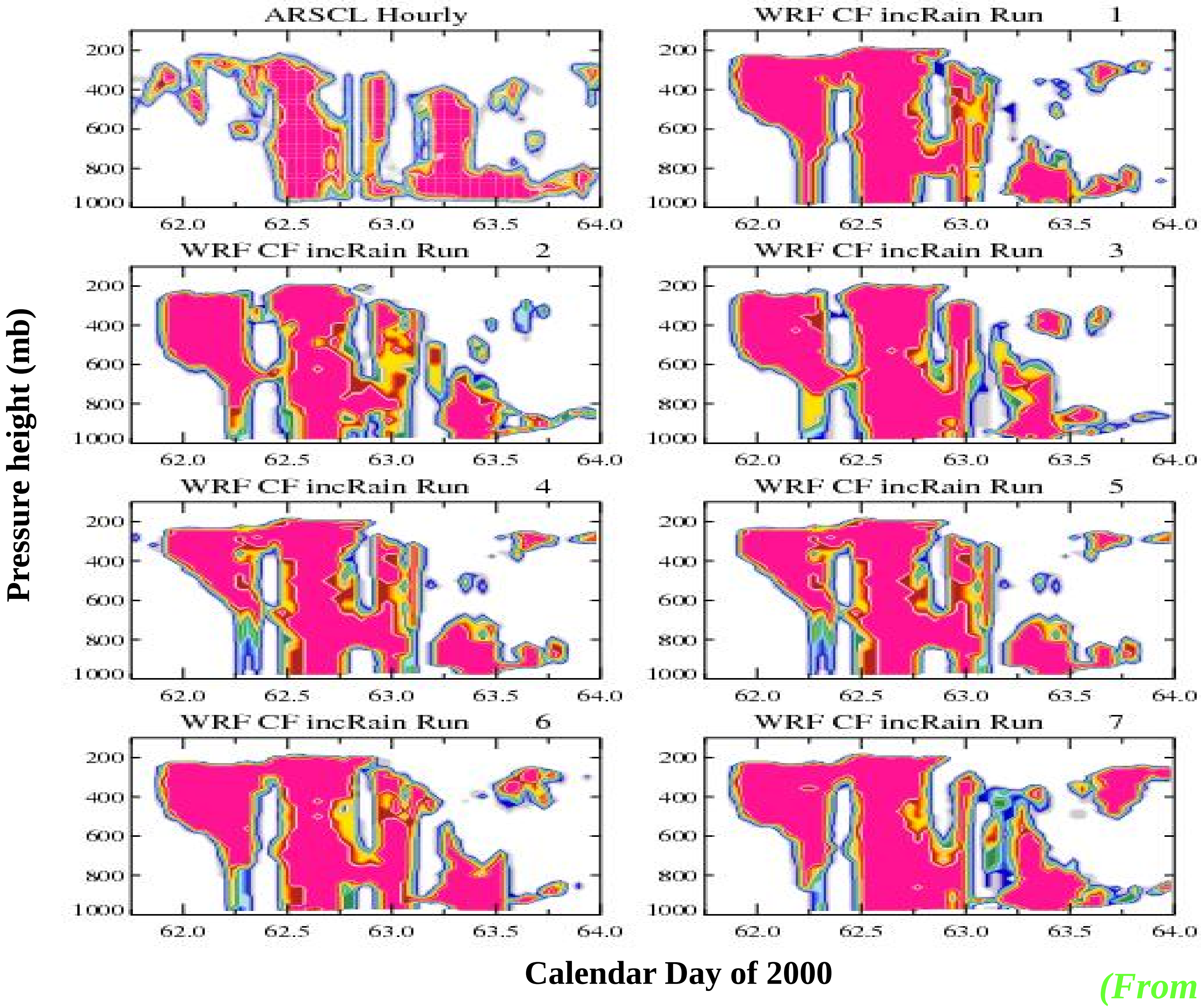

**Two generic issues with evaluation of model results against ARM point-like measurements: Consistency of cloud definition in observation and models; scale-mismatch between point measurements and model domain >> a possible way to deal with these issues via CRMs.**

# Cloud Fraction: ARSCL vs WRF Domain




**Precipitation particles excluded** **Precipitation particles included**

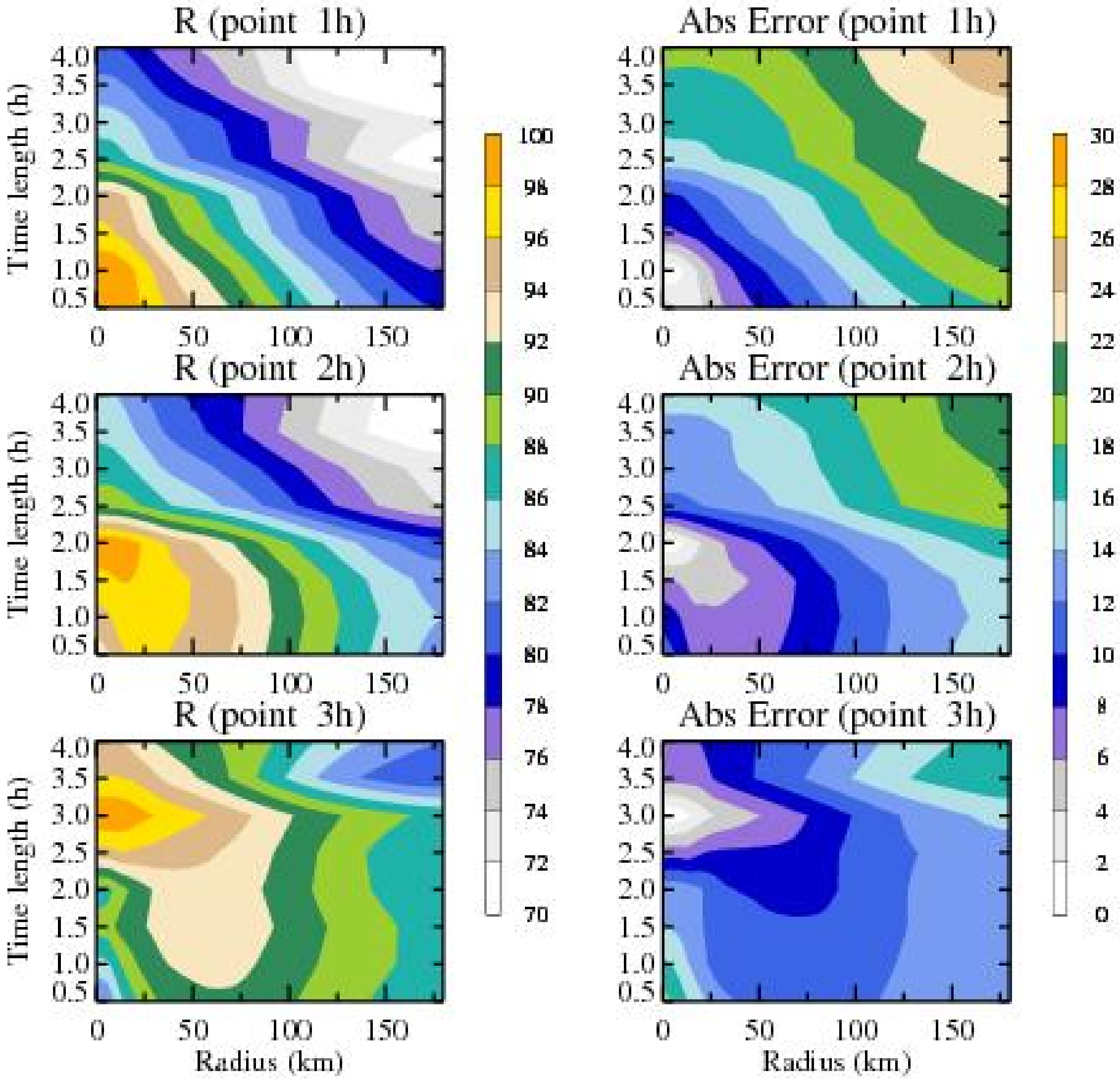
# ARSCL vs. CF Grid Cloud Fraction




*(From W. Lin)*

# Example: WRF High Clouds

Increasing correlation with increasing averaging time




Decreasing error with increasing averaging time

Decreasing correlation with increasing R

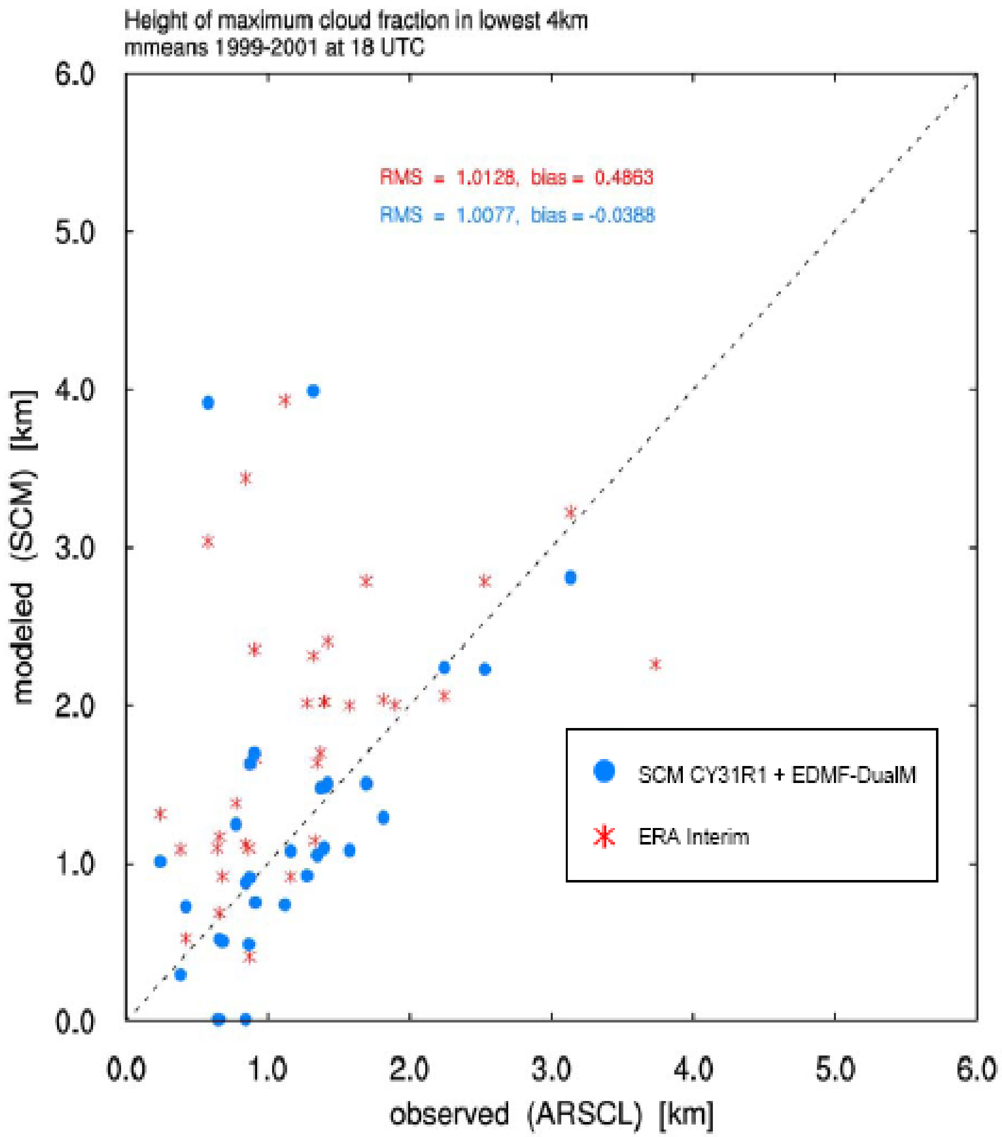
Increasing errors with increasing R

## *Better statistics:*

*Evaluation of the monthly mean height of the maximum cloud fraction in the lowest 4 km at 18 UTC against ARSCL for the period 1999-2001:*

** CY31R1 overestimates this height, reflecting that it overestimates the occurrence of shallow cumulus outflow at the top of the PBL ("anvils")*

** EDMF-DualM agrees better with observations, reflecting that for fair-weather cumulus it typically puts the maximum cloud fraction at cloud base*



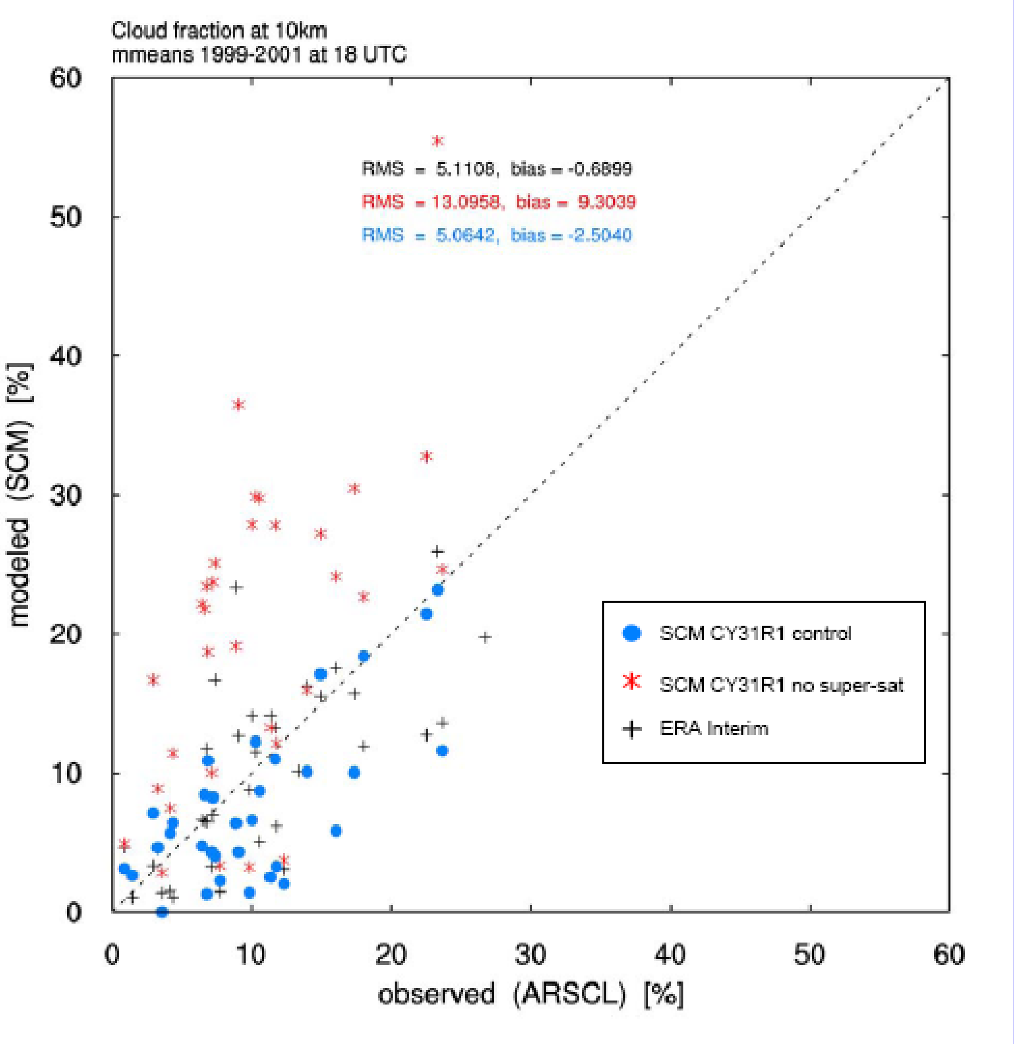
## Better statistics:

*Evaluation of the monthly mean cloud fraction at 10km height at 18 UTC against ARSCL for the period 1999-2001:*

** The March 2000 result is representative of the longer-term*

** The supersaturation function brings a statistically significant improvement*

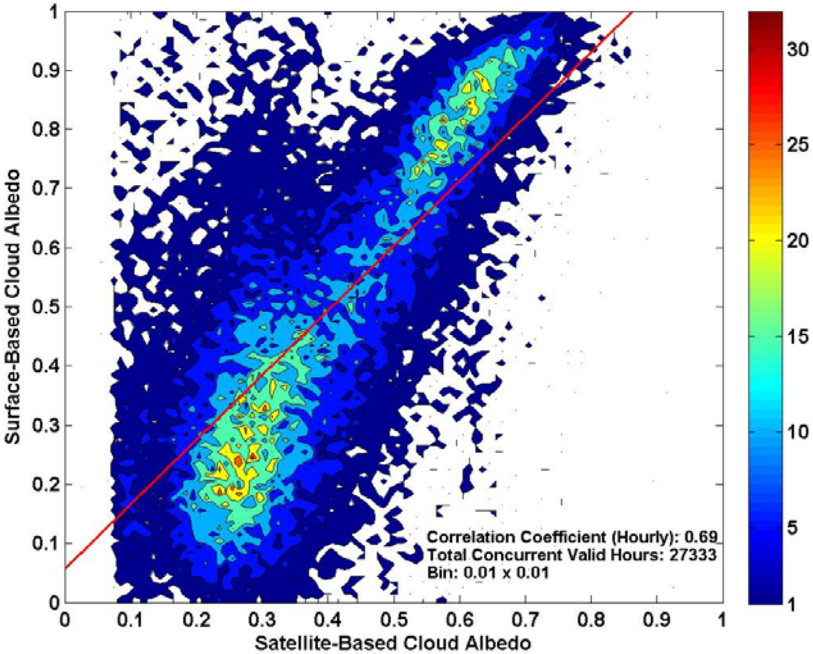
** Not accounting for super-saturation leads to too much high cloud occurrence*



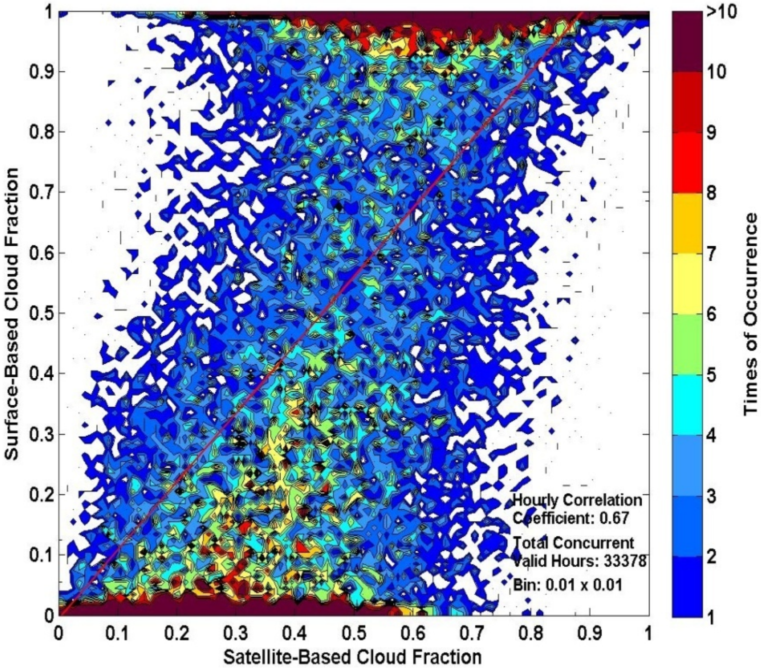
# New Surface-Based Method for Measuring Cloud Albedo

**Hourly data from 1997 to 2009 at SGP**

**Cloud Albedo**




**Cloud Fraction**




**The differences in cloud albedo and cloud fraction seem similar between GOES-based and surface-based Results, why?**

# Work Strategy and Plan

- **Operation guided by ARM data quality/availability; research associated with operation**

- **Warm-up phase, streamlining coordination of different components and focusing on March 2000 Cloud IOP at SGP**

- **IOP phase, focusing on IOPs with high quality ARM data**

- **Continuous phase at SGP**

- **Continuous phase at the other ARM sites**

***• Research is organized around, and progress with operational phases. Better results or new findings are expected as project progresses and accumulates more cases, more cloud types, weather regimes, ever better statistics …. Exceptions?***
***• New strategy in the future: Science-drives operation and research or hybrid?***

# NWP-Testbed Results from Hogan/O'Conner

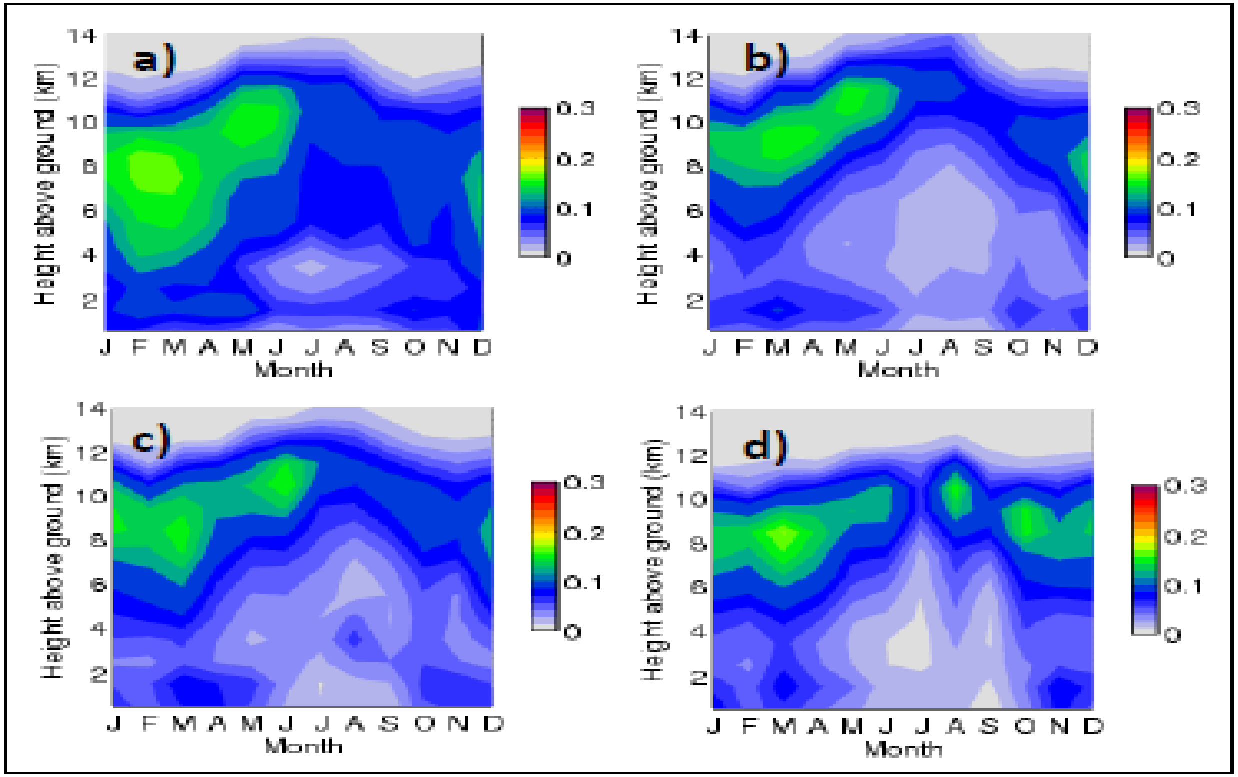
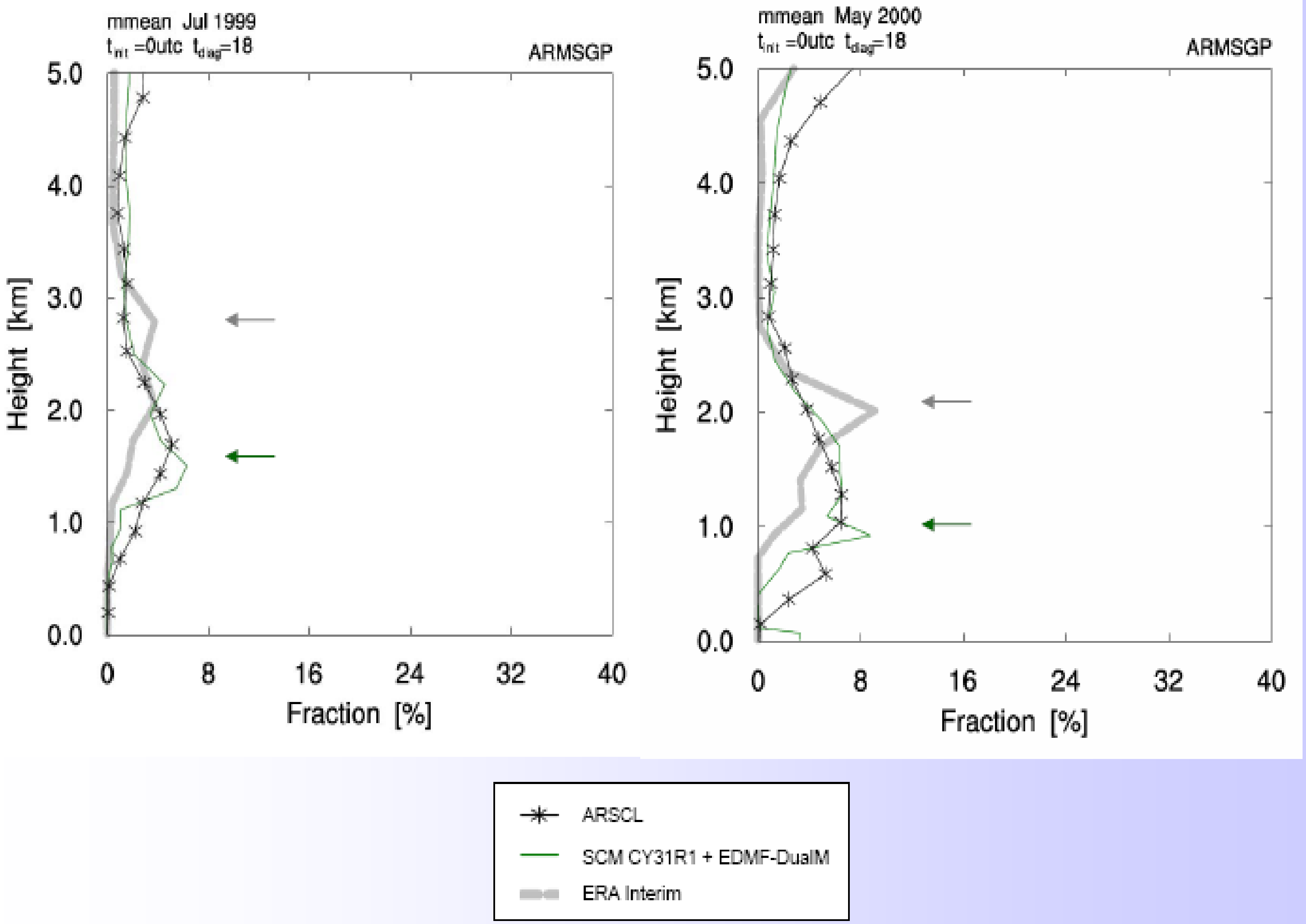



Figure 3. Comparison of the seasonal composites of cloud fraction (a) derived from observations at the ARM SGP site for the years 2004 to 2009 with the values held in (b) the ECMWF model, (c) the NCEP model and (d) the global version of the Met Office model.

*Spring/summer cloud fraction at SGP:*

*EDMF-DualM has its low-level maximum at a lower height compared to ERA Interim (CY31R1)*



## March 2000

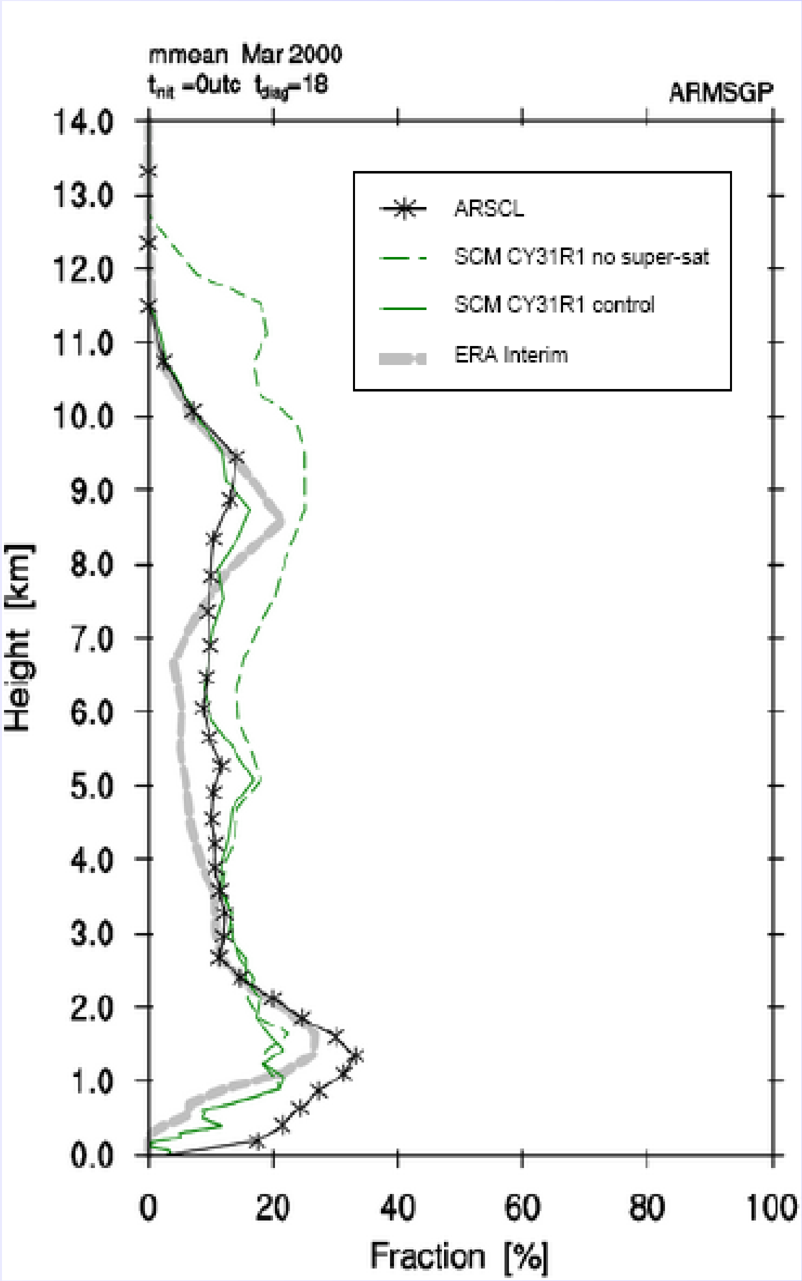
## monthly mean at 18 UTC

*Sensitivity test on ice super-saturation: it reduces the cloud fraction by about 10% at 10km height*

*This is in agreement with the GCM results*

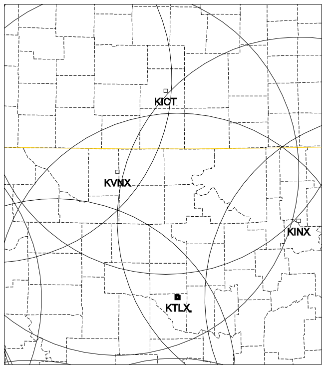
*According to ARSCL this is an improvement (at least for this month)*

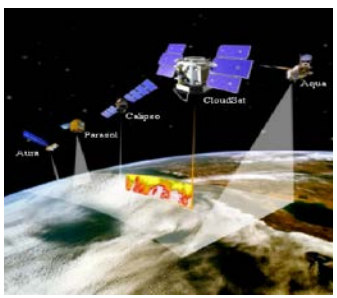
*Also note: the CY31R1 SCM reproduces the cloud structure of ERA Interim (CY31R1 physics) reasonably well, even when driven by an independent forcings dataset*

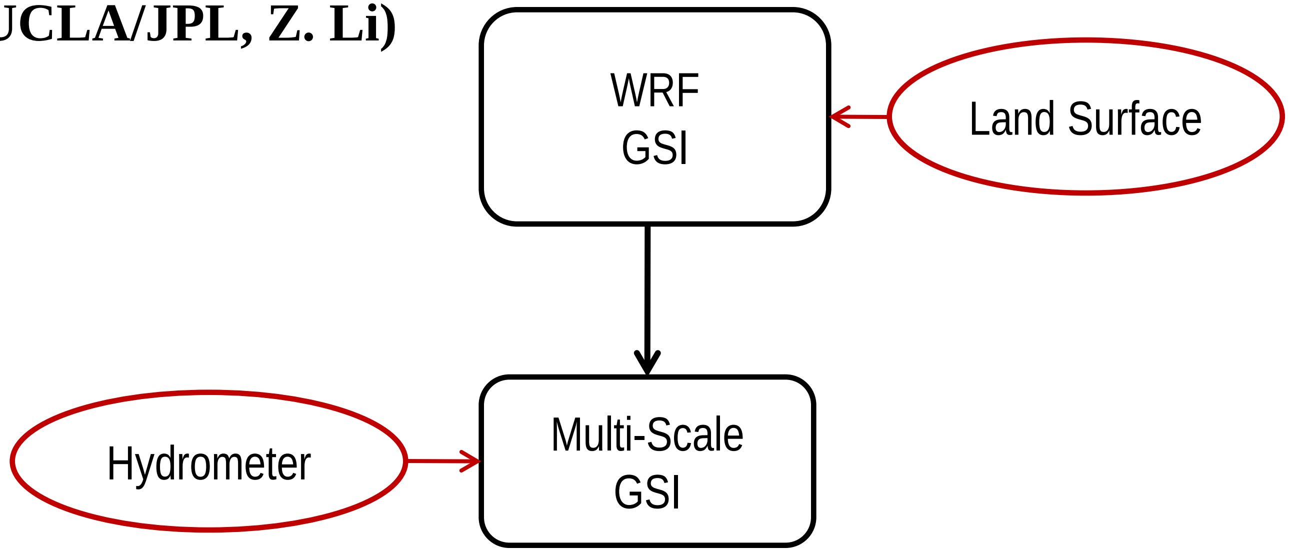


# Multiscale Data Assimilation System

**(Lead by UCLA/JPL, Z. Li)**



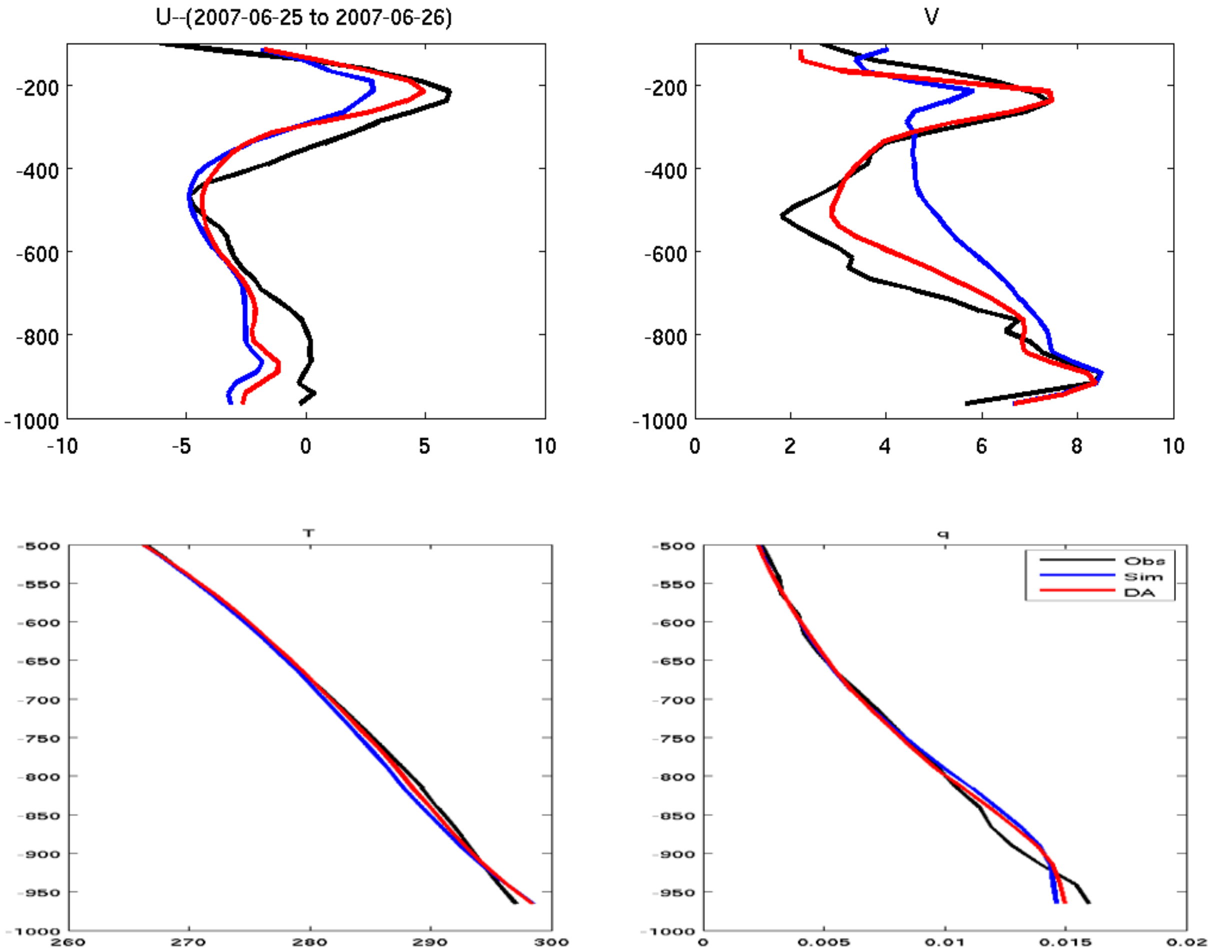



GSI = Grid Space Interpolation, NCEP-3DVAR scheme

Multi-Scale GSI = GSI + JPL Multiscale DA System

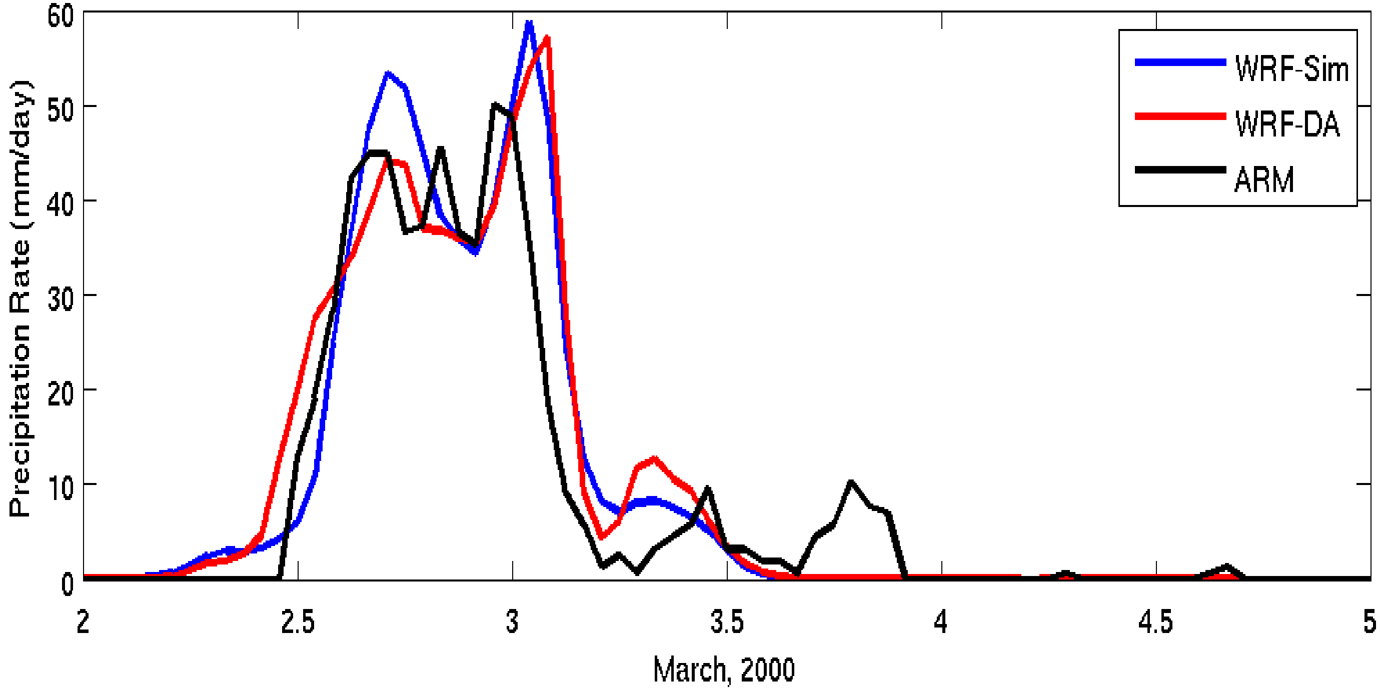
- WRF GSI has been implemented for a three-domain nesting configuration
- ARM Balloon-Borne Sounding (SONDE) profiles have been assimilated
- Conventional and satellite radiance data processed by NCEP have been assimilated
- Three cases investigated( 2-5 March; 15-17 March 2000; 25-28 July2007)
- Temperature/moisture/wind profiles improved significantly;
- Cloud profiles and precipitation improved somewhat

# Impacts of Data Assimilation on Meteorological Profiles



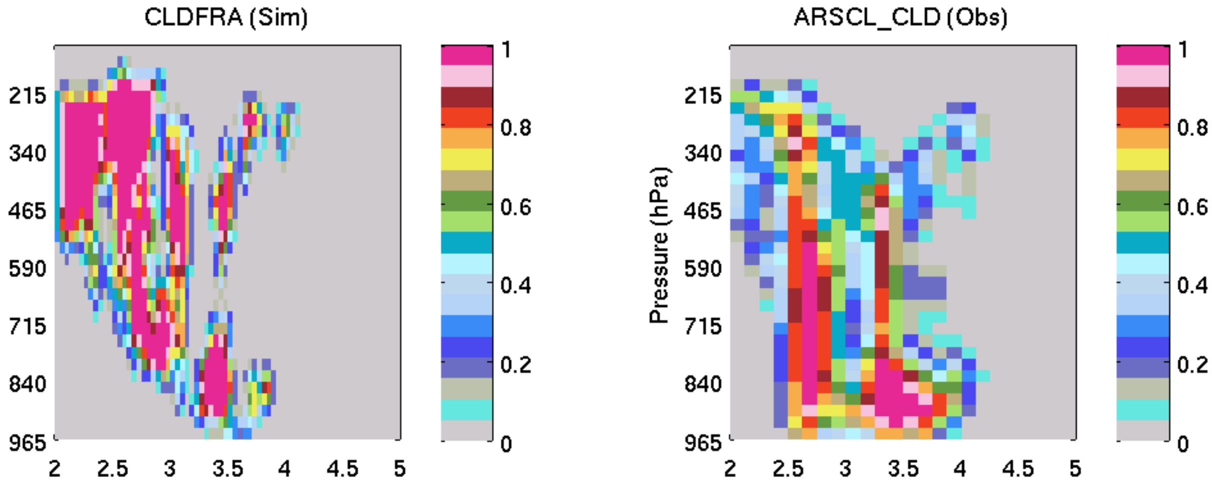

**Data assimilation leads to significant improvement in profiles of the common meteorological variables at the SGP CF.**

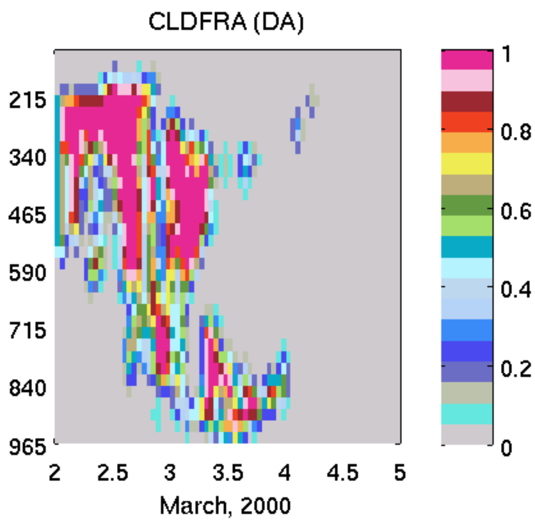
# Impact of Data Assimilation on Domain-Precipitation




**Data assimilation leads to significant improvement in domain-averaged precipitation. But, not in clouds (next)**

# Impact of Data Assimilation on Cloud Fraction




Under-simulated middle and low clouds but over-simulated upper clouds in both traditional WRF and DA-WRF? Why not much improvement in WRF simulated cloud fraction?

# Emerging Patterns from SCMs and NWPs?

- Under-simulated middle and low clouds & over-simulated upper clouds?
  — Can we reduce this bias with improved fine scale vertical velocities?
  — Can we fix high-cloud issues by considering/improving ice supersaturation?

- The problems of sensible and latent heat fluxes
  — What causes the problem, temperature and water vapor mixing ratio?
  — What's the impact on model results?

# Operations

- CIRPAS Twin Otter, based near SGP
  - 24 January to 29 June 2009
  - Long-term observations good for statistics (incl. seasonal var.)
  - Needed simplified operation paradigm, compared to an IOP
    - Standardized flight patterns (Cloud triangles w/ spirals over SGP)
  - 1st long-term aircraft *in situ* sampling of cloud
- 59 Research flights (259 hrs)
  - 31 cloud flights
  - 46 over SGP
  - 46 with EOS overpass


- "Non-Cloud" Flights
  - Aerosol and CCN characterization
  - Boundary layer turbulence
  - Surface albedo mapping
  - Radiometer tilt characterization
- King Air collaborative flights 2-26 June (HSRL, RSP)
  - 15 flights (11 cloud flights; 8 of which over SGP)

# More Discussions

-- Data integration
  * Aerosol data
  * Nexrad data

-- Ensemble of large scale forcing data from, e.g., reanalysis

-- Test development
  * SCM-and NWP-testbed integration
  * Web-based GDFL, GISS, ECMWF SCMs

-- Coordination and team-work !

# *ESM* FASTER:
## *Improving the representation of cloud macrophysics in the RACMO and the IFS*

*A short description of the models*

*Preliminary SCM results for 1999-2001 at ARM SGP. Two research topics:*

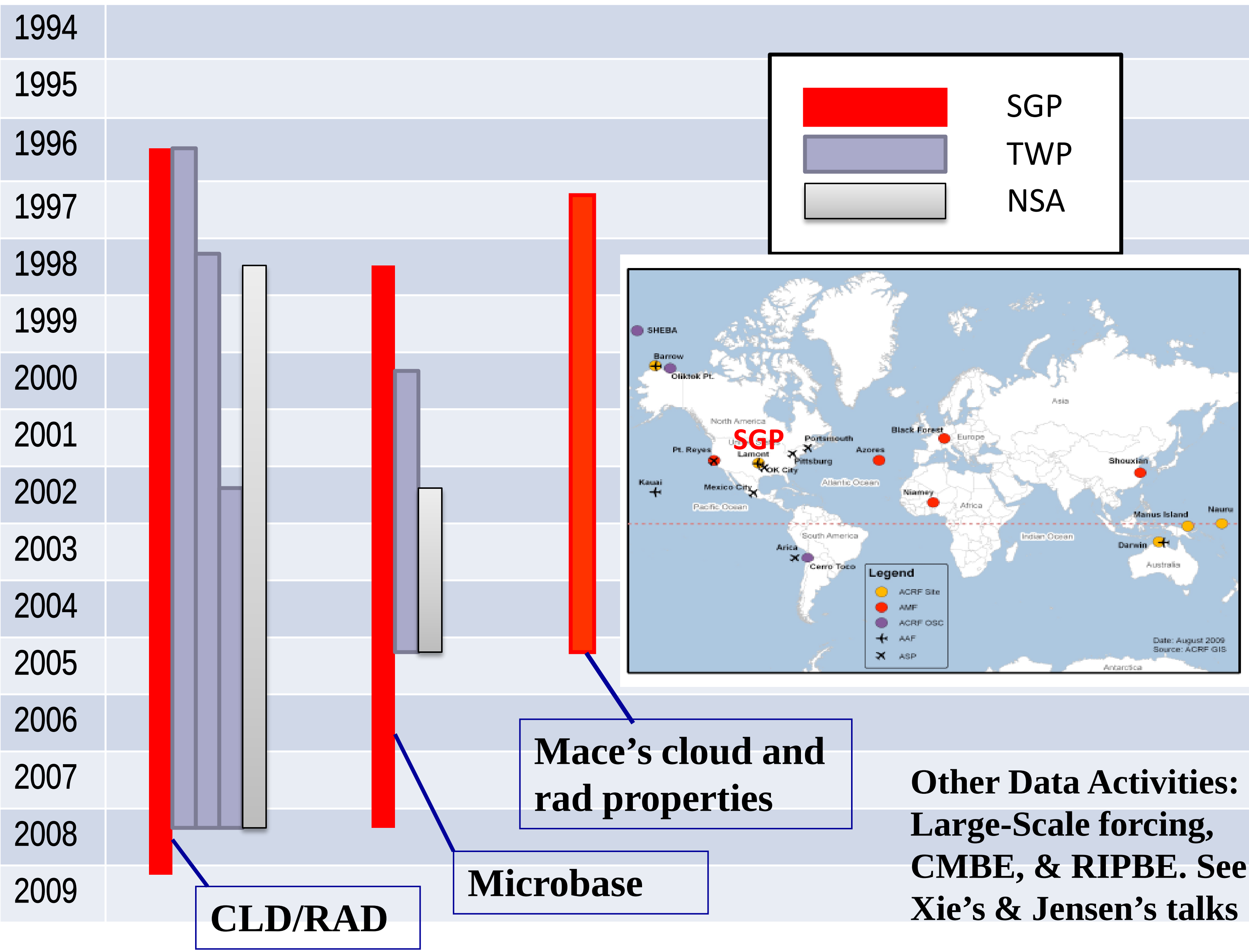
** Evaluation of the impacts of the ice super-saturation function on high cloud occurrence*

** Evaluation of the impact of the new EDMF-DualM boundary layer scheme on the vertical structure of low-level clouds*

*Roel Neggers Peter Baas*

KNMI

# Quick Summary of ACRF Data




**Other Data Activities: Large-Scale forcing, CMBE, & RIPBE. See Xie’s & Jensen’s talks**

# Near-Future Work

- **Continue examination and preparation of various measurements of cloud macrophysical properties and radiation at SGP site.**

- **Continue examination and comparison of various measurements of cloud microphysical properties at SGP site.**

- **Refine fast-physics testbed, website, and model issues**

- **Summarize "warmup" results and submit papers (~ 6 from BNL, other group? BAMS paper?)**

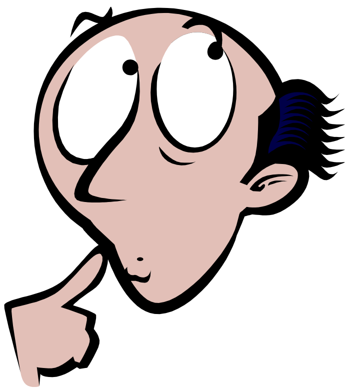
- **Extend warmup to next IOPs (RACORO?) at SGP**

- **Extend SCM/NWP activities from 1999-2001 to 2009**

# Eight Tasks and Major Fast Processes

## Eight Tasks

- Fast-physics testbed (NWP-testbed & SCM-testbed)
- A suite of high-resolution model simulations
- Model evaluation against measurements
  -- Model errors
  -- Error sources
- Evaluation metrics
  -- Statistical measures
  -- Forecast skill
- Theory and parameterization
- Data assimilation
- Full GCM assessment
- Data integration



Evaluation approach

Evaluation variables

## Major Fast Processes

- Microphysics
  -- Warm clouds
  -- Ice clouds
  -- Mixed phase clouds
  -- Mono vs. multi-moment schemes
- Aerosol-cloud interactions
- Radiation
- Shallow convection
- Deep convection
- Entrainment/Detrainment
- Boundary processes
- Subgrid turbulence
- Cloud fraction
- Land-surface-atmosphere interaction

# "ARM-Like Innovation" in Model Evaluation

**<u>Now is the time</u>**

- **ARM has made continuous, comprehensive, decade-long measurements, permitting better statistics, more cloud types, weather regimes ….**
- **SCM/CRM/LES approaches have been well developed and tested by ARM scientists and others.**
- **A smaller scale-SCM-testbed has been recently established by Dr. Neggers et al. at Netherlands**
- **Usefulness of NWP-testbed has been demonstrated by Cloudnet project.**

**<u>ARM-Like Innovation</u>**

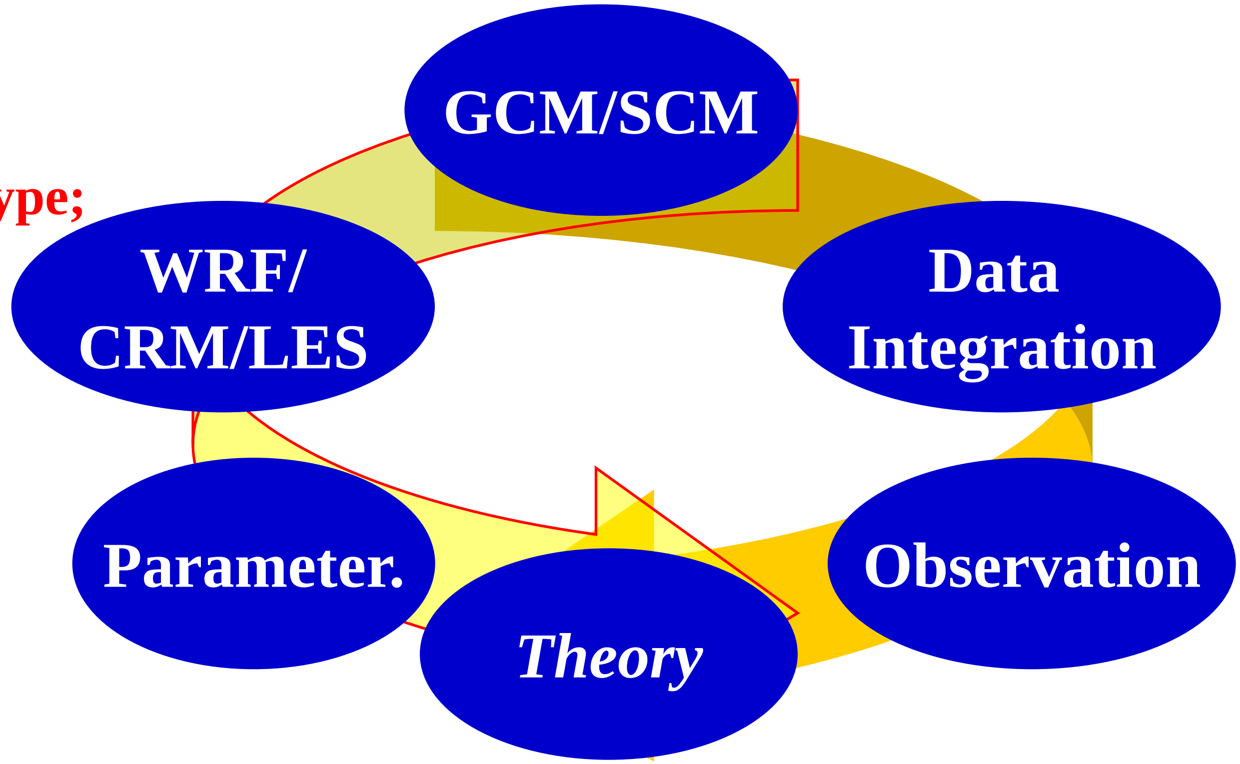
**Ackerman and Stokes on ARM's Innovation (Physics Today, 2003): " …. Even before ARM, scientists had already made such efforts in field campaigns that lasted for a month or two. ARM's unique innovation was to perform the measurements continuously for a decade or more …."**

***To paraphrase: …. This project's unique innovation is to perform the evaluation <u>continuously</u> for a decade or more and in a <u>more focused</u> way …. better statistics, regime-based evaluation, system-based evaluation ….***

# The sheer complexity of the problem are certainly a reason for the slow progress.

**Complexity:**

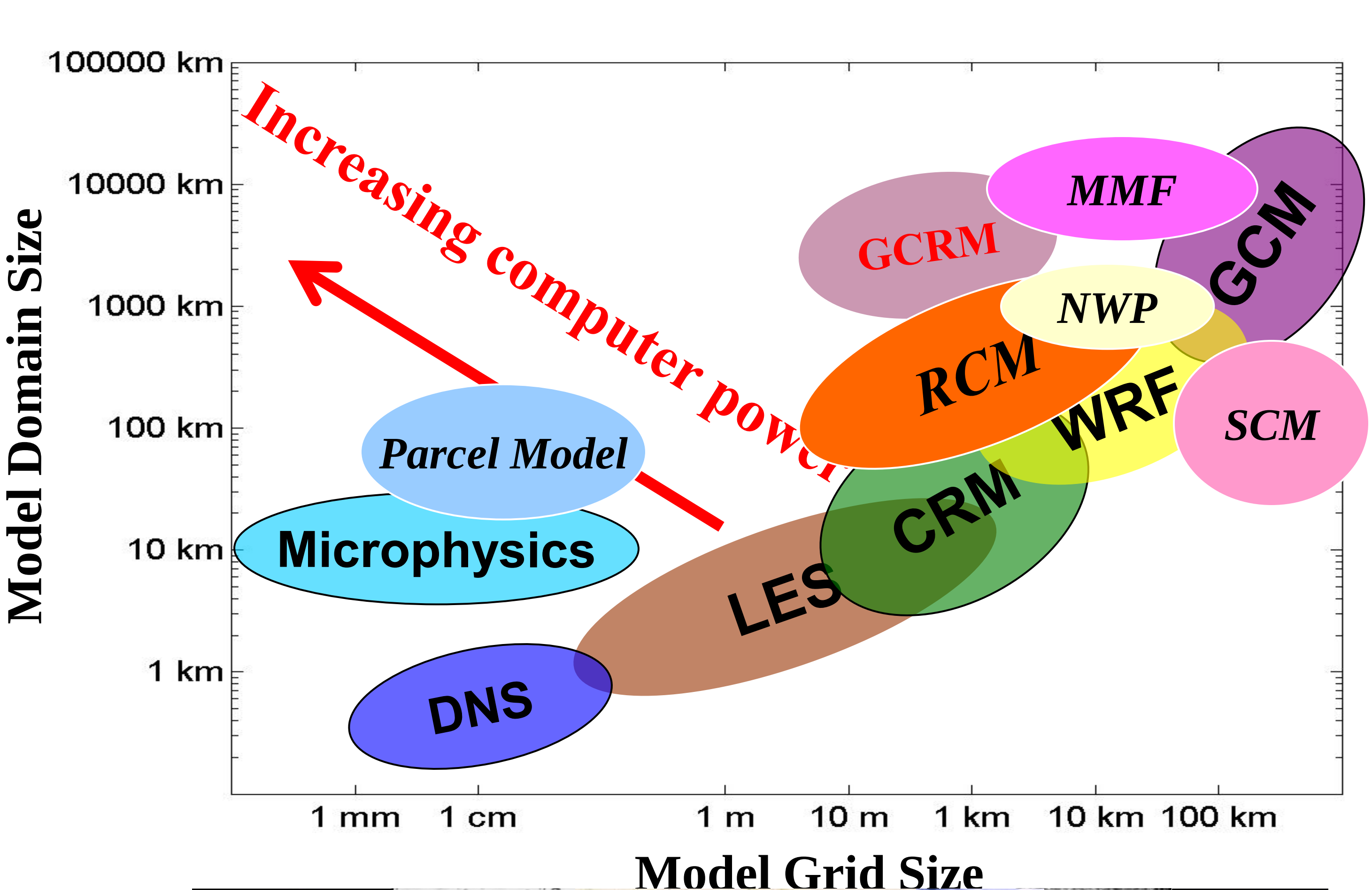
- **Scientific**
  - **--** **4M (multibody; multitype; multiscale; multiD)**
  - **-- Conceptual**
  - **-- Numerical**
  - **-- Coupling**
- **Engineering**
  - **-- Inter-field interactions**
  - **-- Para. imple. in GCMs**
  - **-- …**




***Randall et al. (BAMS, 2003): "A model-evaluation project is complicated in at least two distinctive ways. The technical complexities are obvious and daunting: Data must collected and analyzed, …. An additional and equally complex task is to foster communication and fruit interactions …."***

**Some even considers the complexity as a *valley of death* for GCMs.**

# Complexity Seen in Model Hierarchy





**Poorly understood 4M interactions/feedbacks**

*DNS = Direct Numerical Simulation*

*LES = Large Eddy Simulation*

*CRM = Cloud-Resolving Model*

*WRF = Weather Research and Forecast Model*

*GCM = Global Climate Model*

*RCM = Regional Climate Model*

*GCRM = Global CRM*

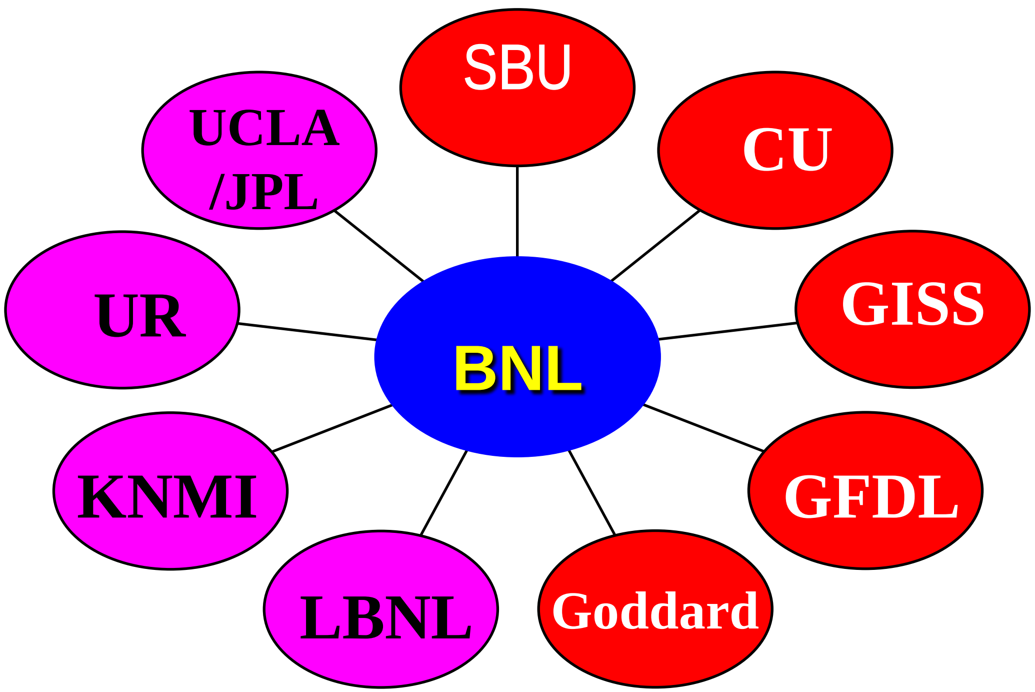
*NWP = Numerical Weather Forecasting*

*SCM = Single Column Model*

# FASTER Team

## BCC (10 institutions and 21 scientists)

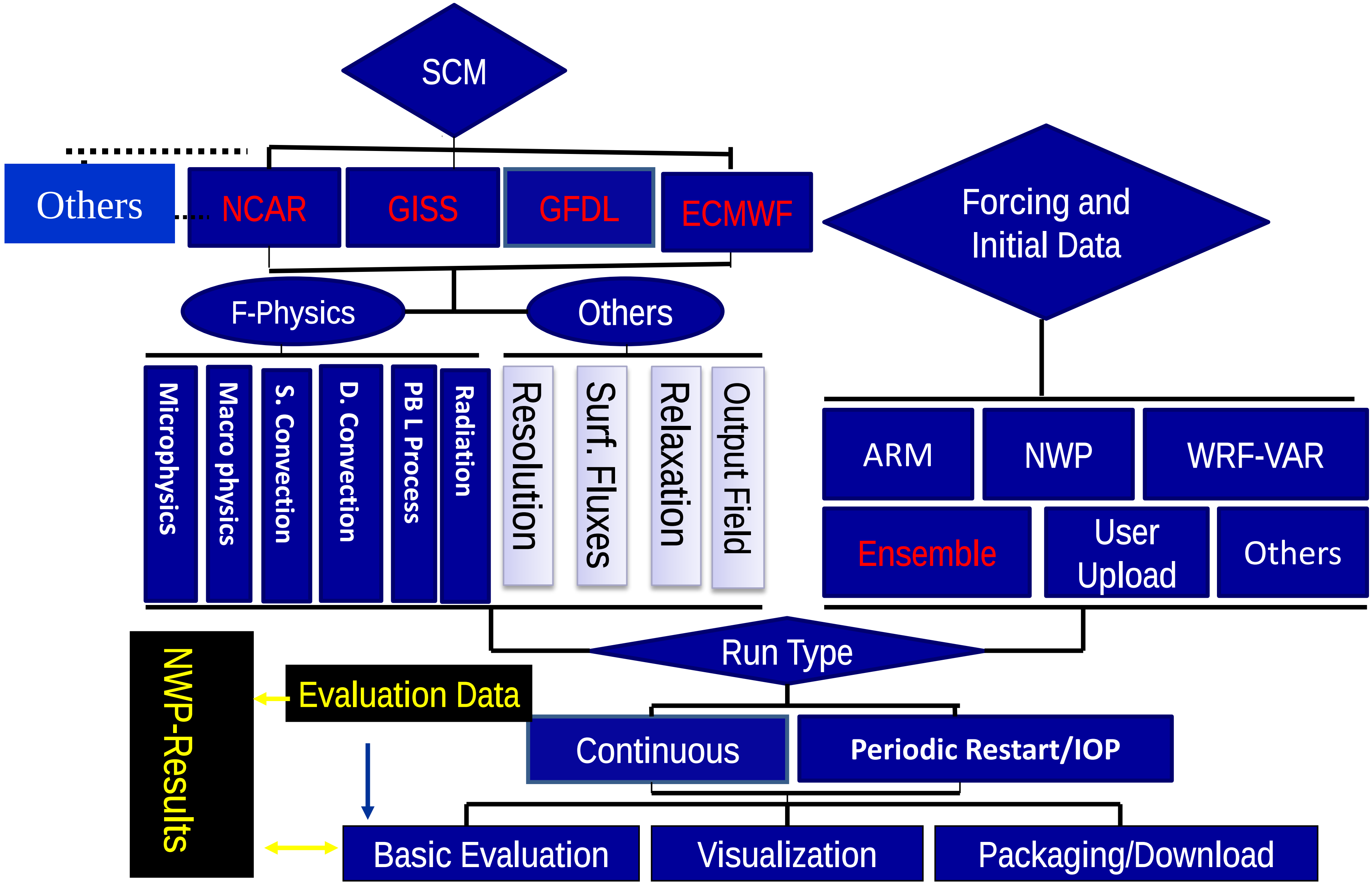
Hub Core Extended



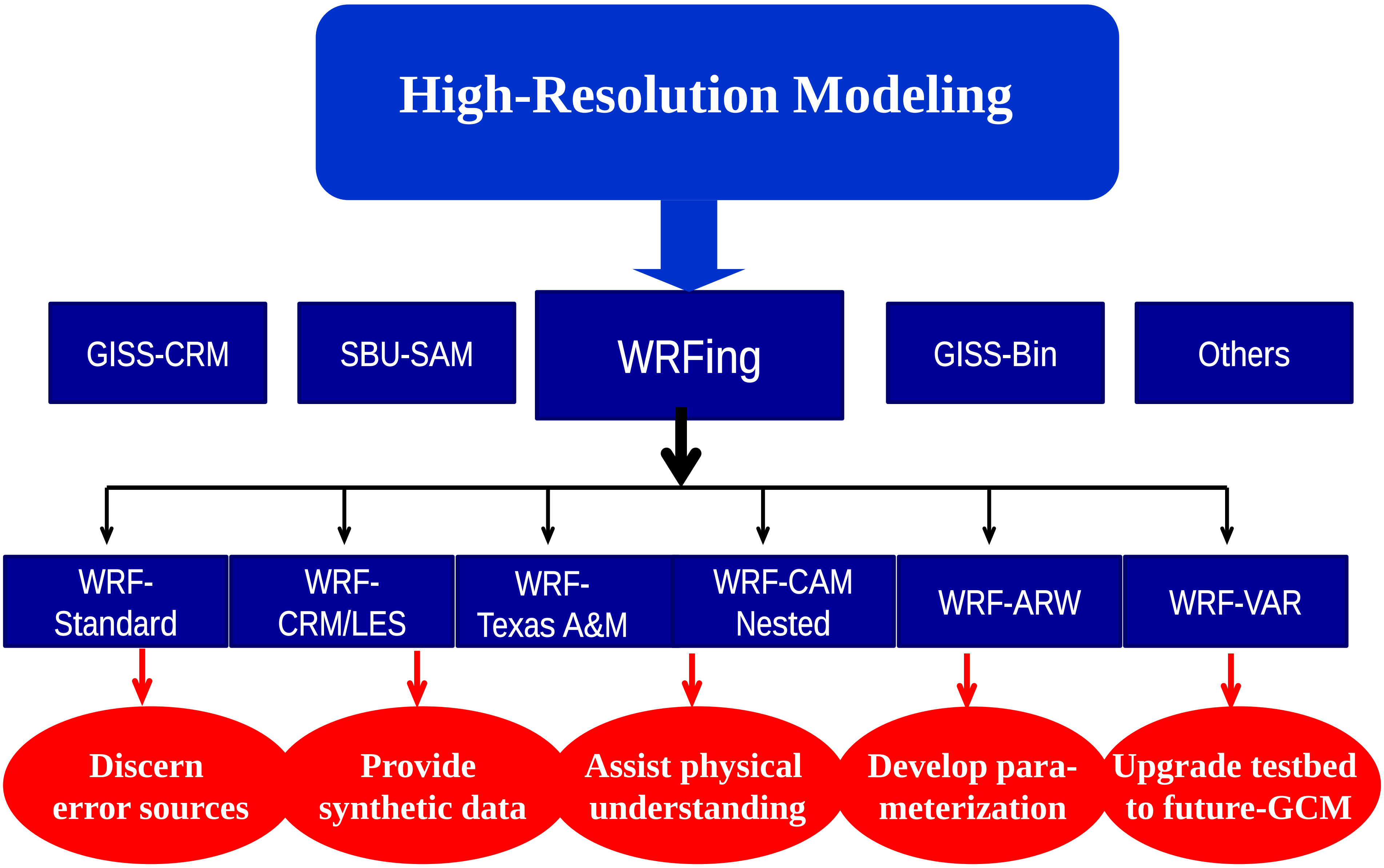

| Investigator | Institution |
|---|---|
| Yangang Liu | BNL |
| Stephen Schwartz | BNL |
| Warren Wiscombe | BNL/Goddard |
| Robert McGraw | BNL |
| Wuyin Lin | BNL |
| Andrew Vogelmann | BNL |
| Michael Jensen | BNL |
| Richard Wagener | BNL |
| Dong Huang | BNL |
| Wei Wu | BNL |
| Surabi Menon | LBNL |
| Susanna Bauer | CU |
| Minghua Zhang | SBU |
| Marat Khairoutdinov | SBU |
| Anthony Del Genio | GISS |
| Ann Fridlind | GISS |
| Yonghua Chen | CU |
| Leo Donner | GFDL |
| Zhijin Li | UCLA/JPL |
| Robin Hogan | UR |
| Roel Neggers | KNMI |

**Core institutions are adjacent to BNL and operate three major US GCMs; many team members participate in ASR or related research, and has strong theoretical background on top of other areas of expertise essential for success**

# Concept of Fast-Physics Testbed



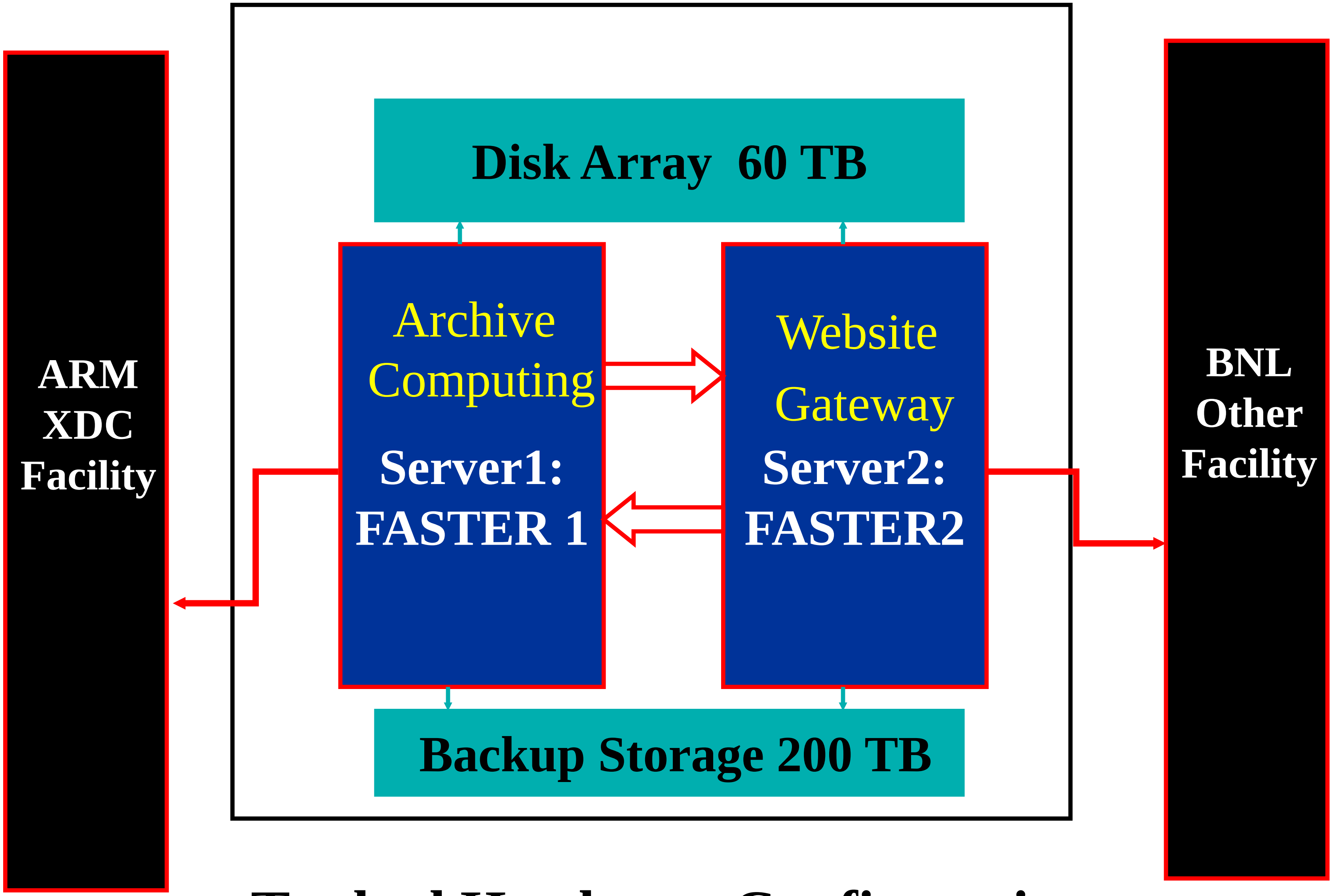
# High-Resolution Modeling Activities



# Near-Term Plan

- Digesting the results and writing papers
- Continue current activities
- Summarize warm-up and decide next focused SGP IOP (ROCORO)
- Integrate SCM-testbed and NWP-testbed
- Meeting at GISS next Wed, 10 Nov 2010.
- Fast-physics section at AGU (over 50 abstracts, growing and exciting)

# Project Hardware




Testbed Hardware Configuration

# Relationship between Cloud Albedo and Cloud Fraction in Observations and GCMs

- **Three year (1999-2001) hourly data**

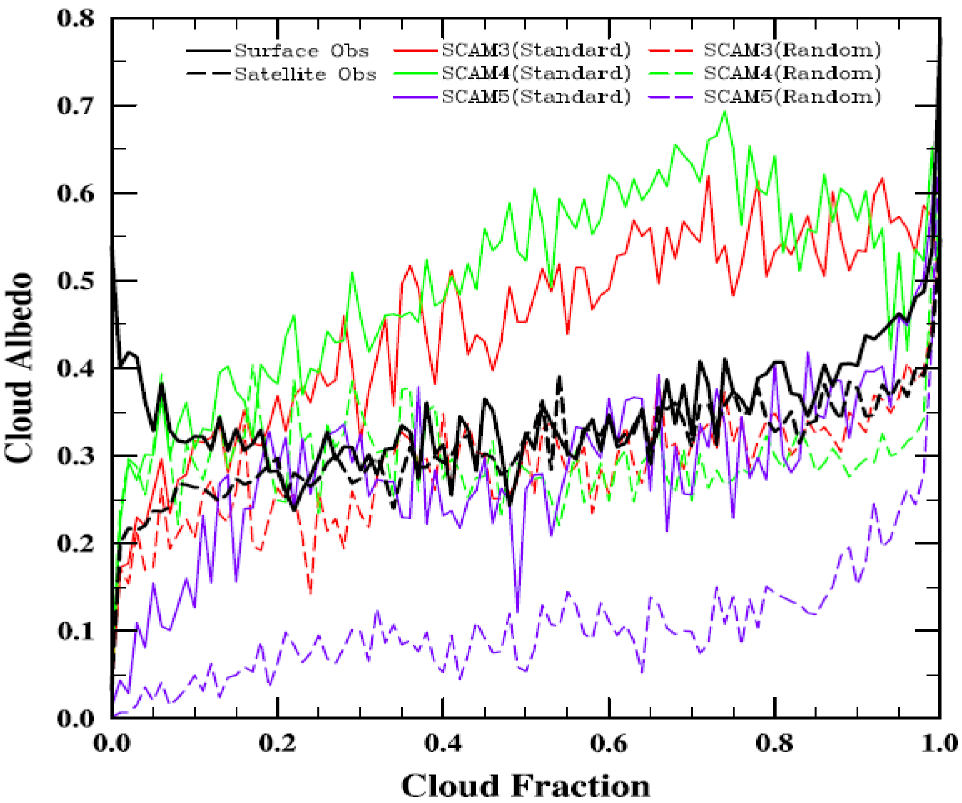
- **Cloud albedo and cloud fraction are clearly related to each other**

- **Observational difference is much less than inter-model difference**

- **Model results can be improved by**

  **-- changing parameterizations of specific fast processes (solid lines ); or by**

  **-- using different assumptions of vertical cloud overlap (dashed lines)**




**-- Underlying physics for albedo-fraction relation ?**
**-- Underlying parameterizations for model difference ?**
**-- Self-consistency of individual parameterizations and relationships to cloud overlap assumptions?**

# Four Levels of Model Evaluation

**Subgrid Processes**

**Offline Evaluation**

**Direct no process interactions**

**SCM Evaluation**

**With process interactions but no column interactions**

**Full GCM Evaluation**

**Full interactions but propagation of parameterization errors**

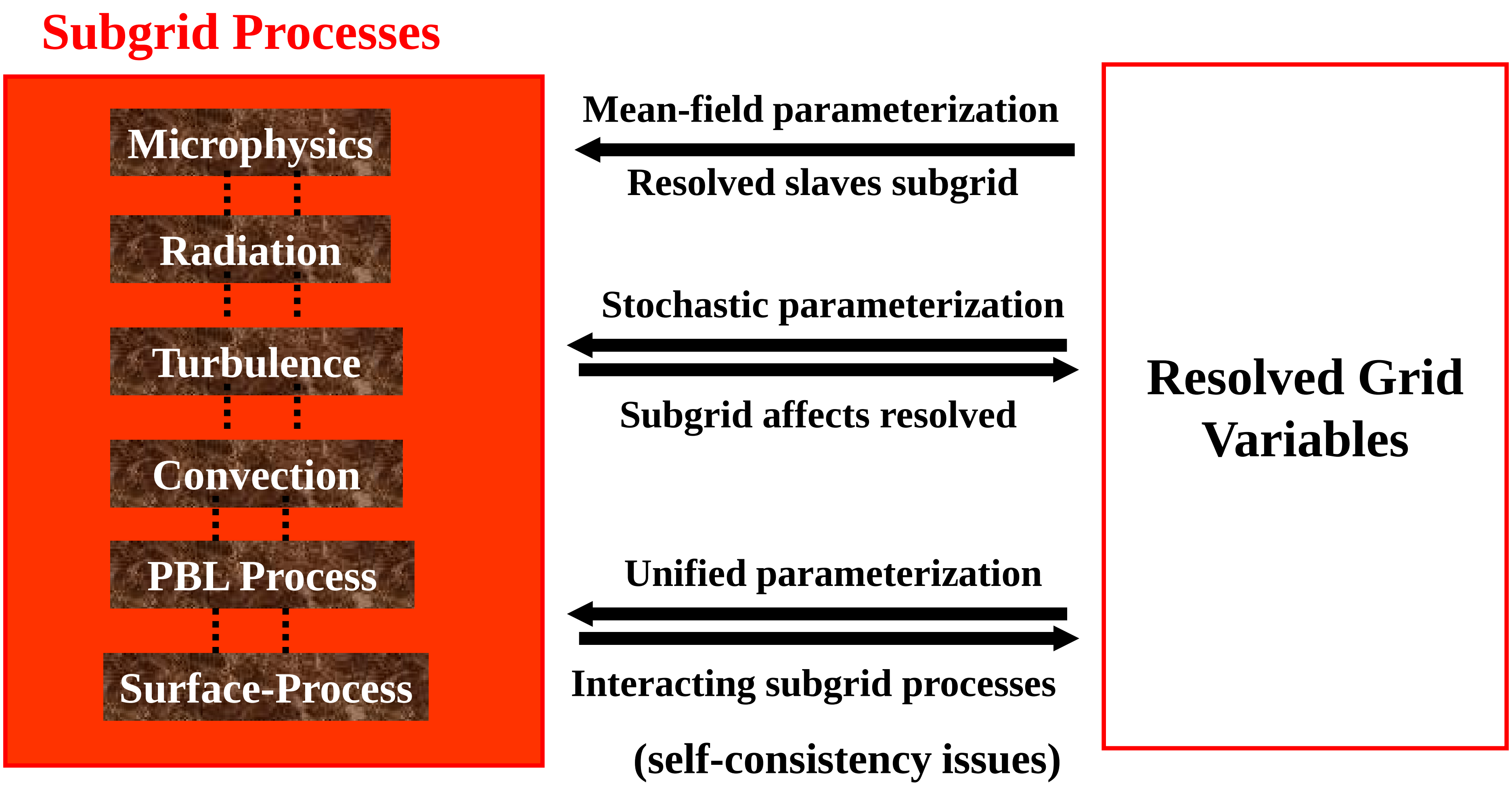
**NWP Evaluation**

**Better Resolution**

**HRM Evaluation**

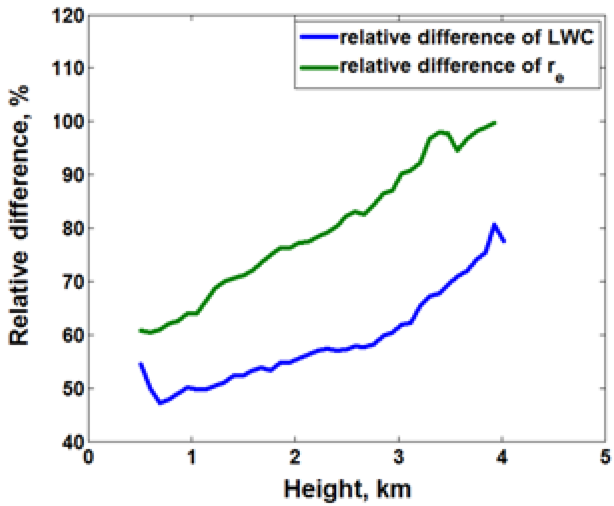
**Best Resolution & Subgrid variability**

# Three Levels of Parameterizations




*Parameterization is not just a practical necessity, but a deep theoretical underpinning of scale-interactions within the multiscale system in question.*

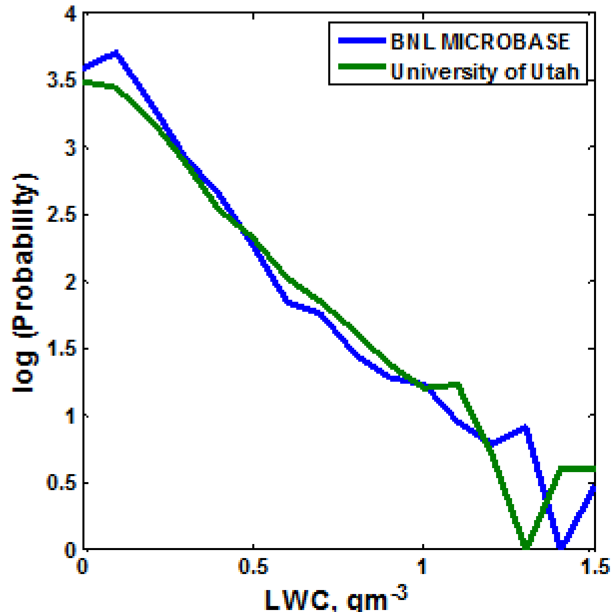
# Large uncertainty in cloud microphysical retrievals

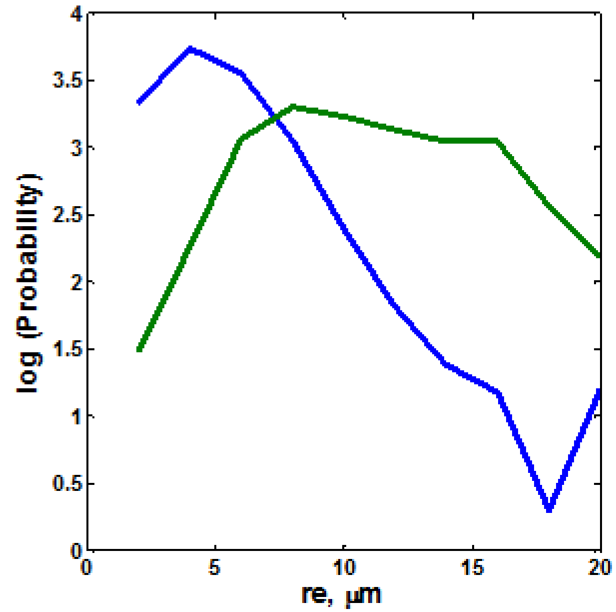



Large difference found between the seven year averages of the University of Utah and MICROBASE retrievals

PDFs of LWC look (both constrained by microwave radiometer)

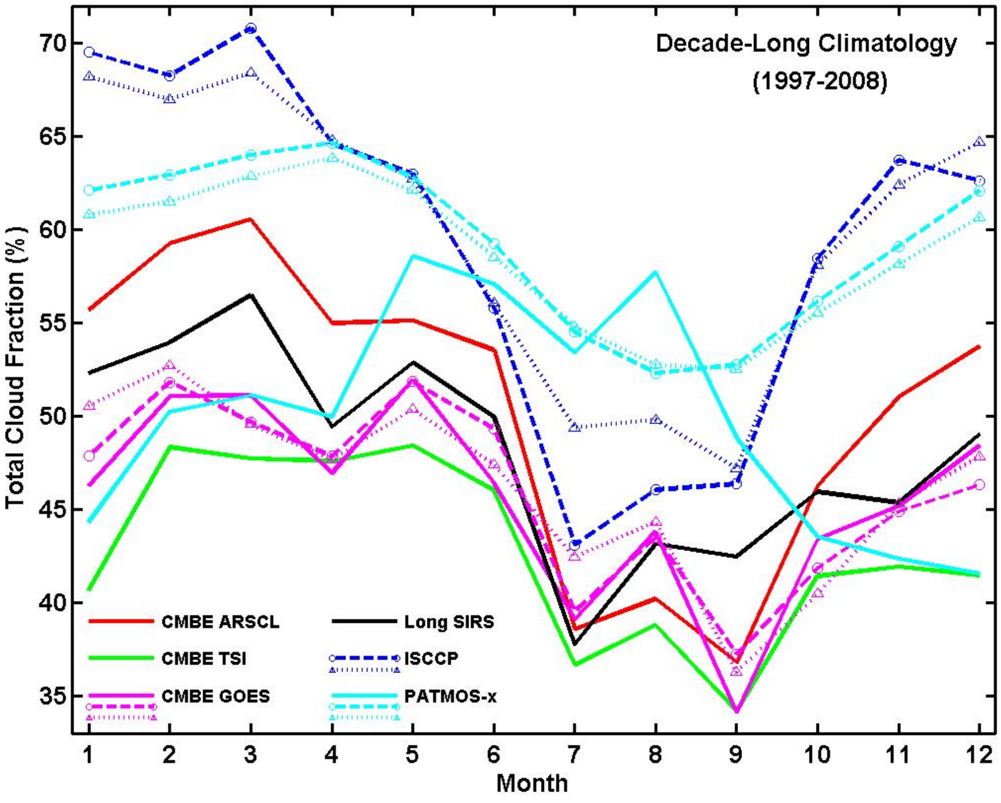
Very different PDFs of effective radius




**(D. Huang)**

# Large Spread in Cloud Fraction Observations



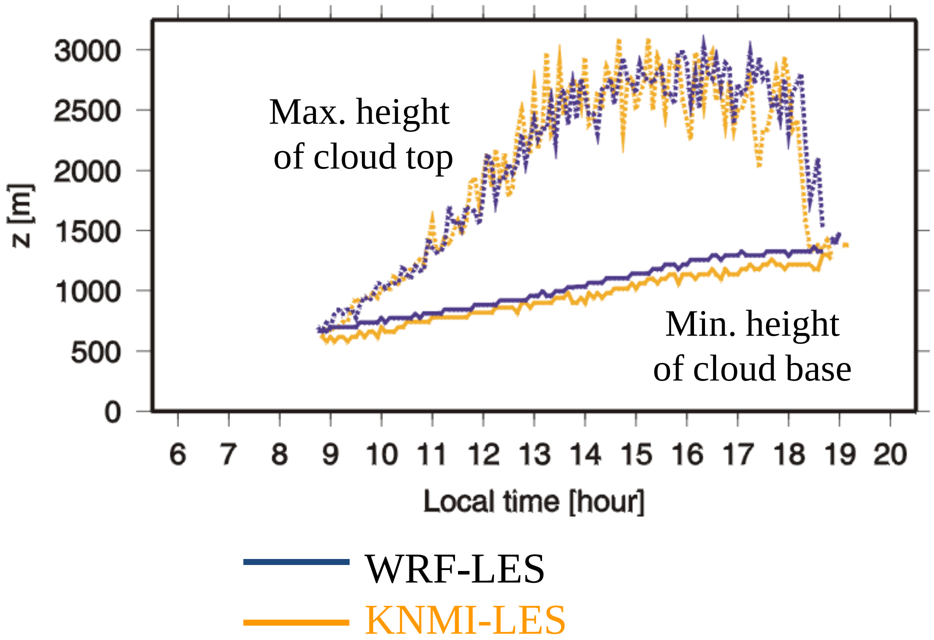

**Lines: monthly climatology**
**solid: surface or 0.5º satellite**
**dashed: 2.5º satellite**
**dotted: the entire SGP domain**

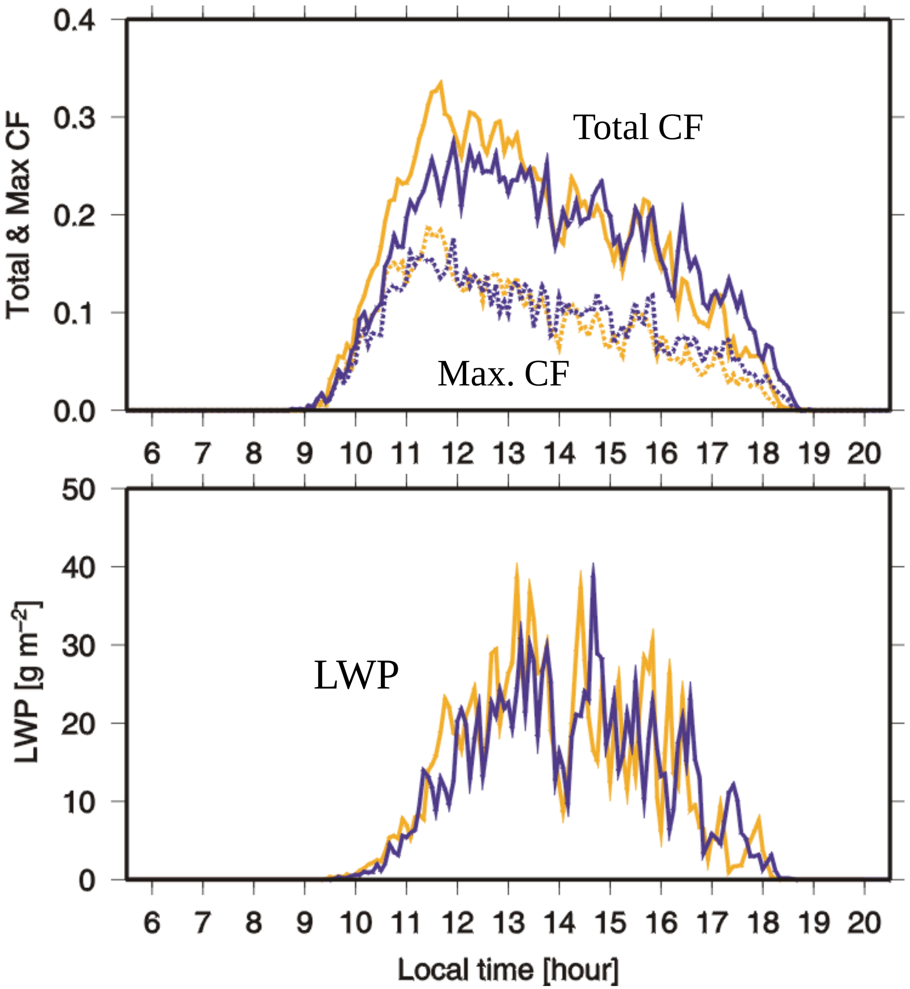
**Characteristics:**

- **Difference: largest in Winter and Spring, smallest in Summer**
- **Surface measurements smaller than satellite measurements (except GOES)**
- **Not much sensitivity to spatial scale change (except 0.5º PATMOS-x with a phase problem)**

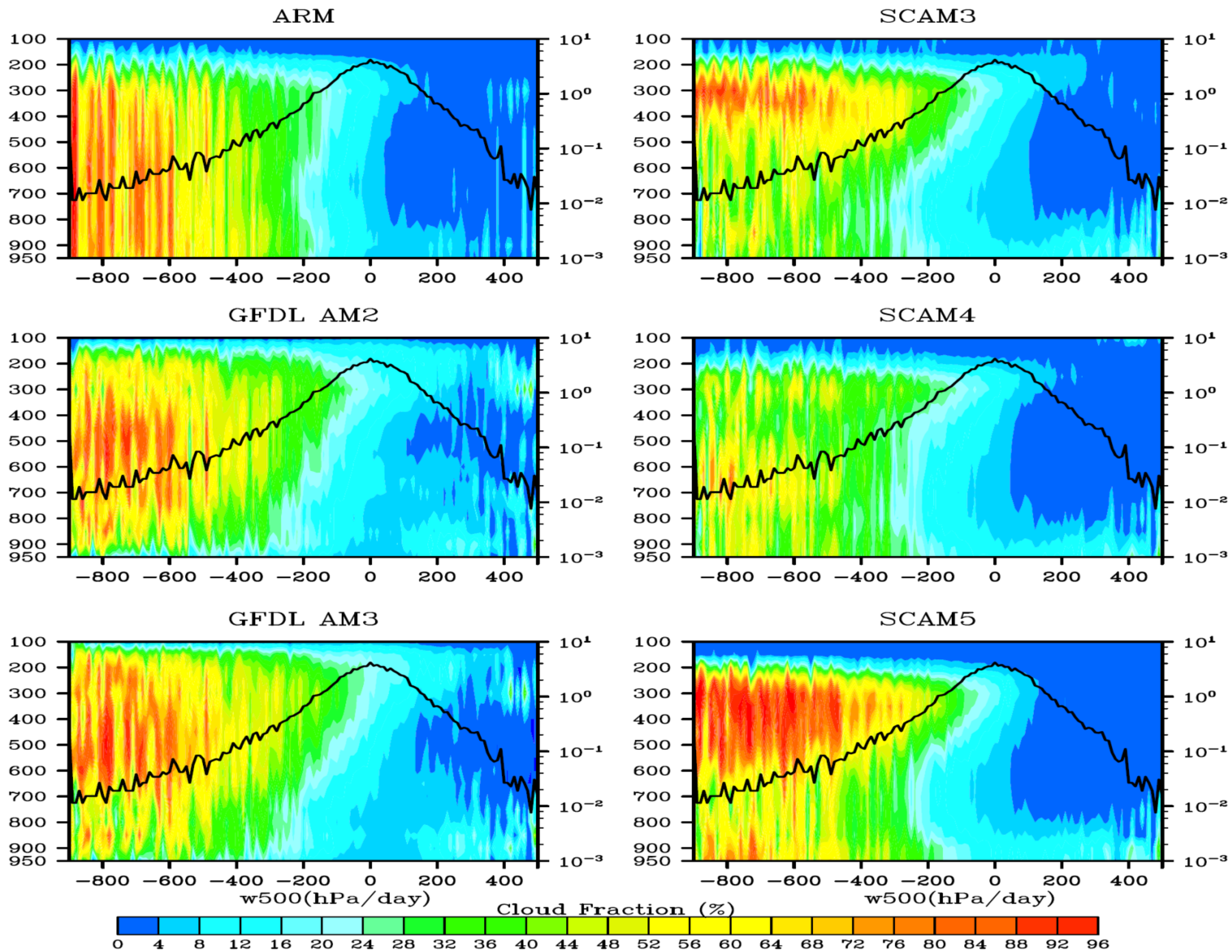
**(W. Wu)**

# Comparison of Forcing-WRF with KNMI-LES



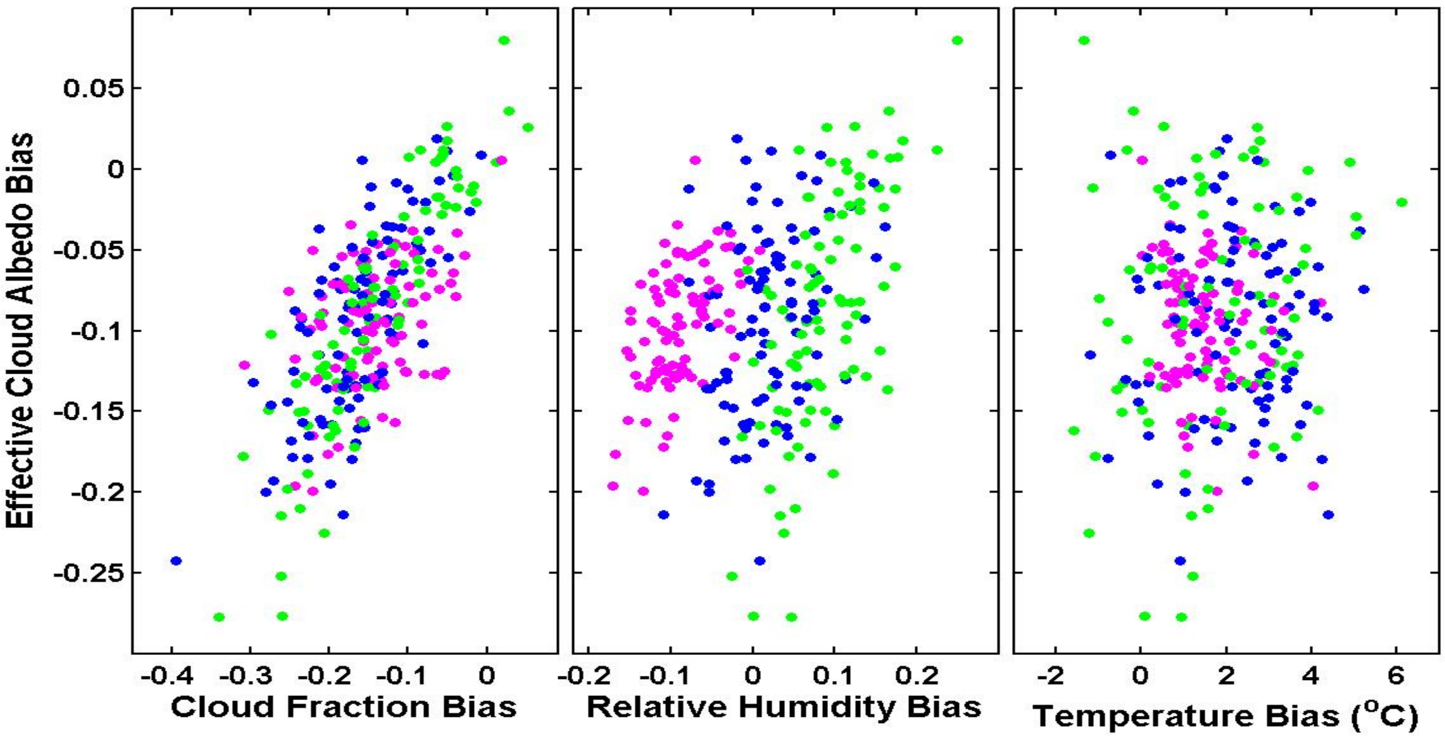



# Three Years (1999-2001) SCM Runs at SGP



# NWP Highlight: Relationship between Biases

**Monthly Data**

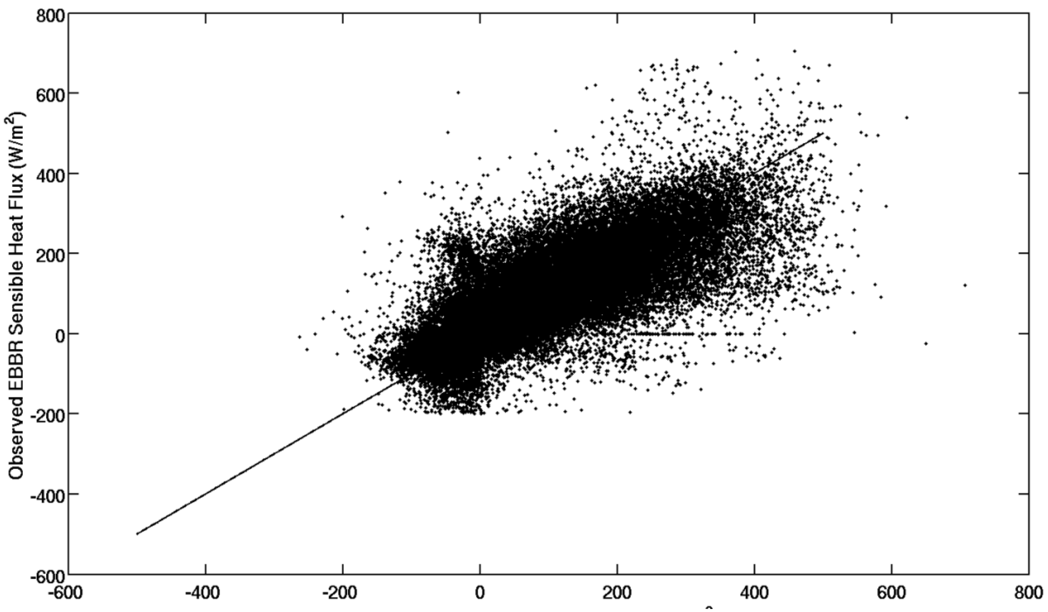


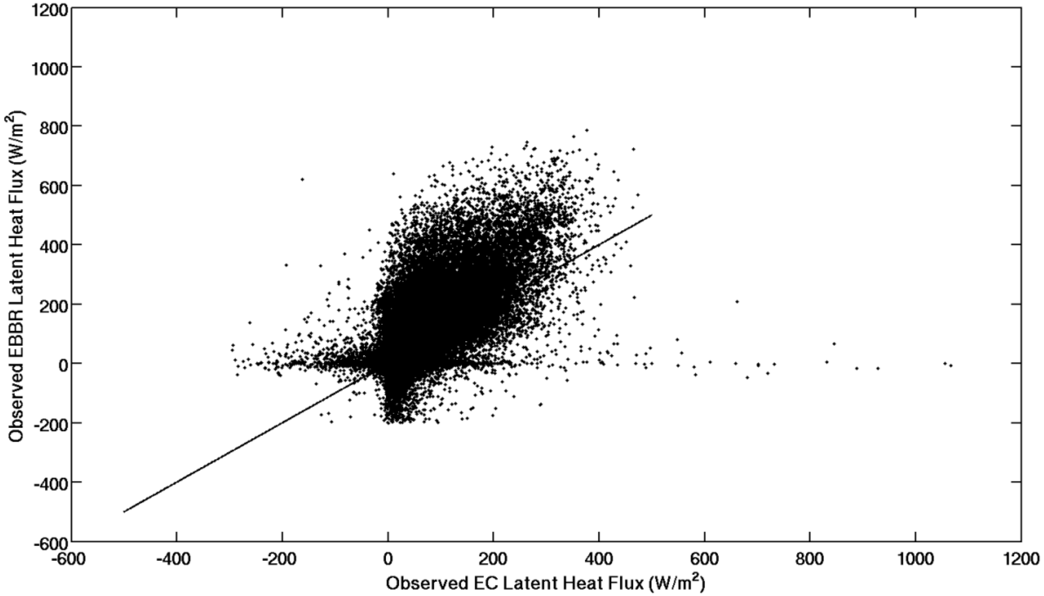

**NCEP/NCAR Reanalysis, NCEP/DOE Reanalysis, ERA-Interim**

***Hypothesis: Error propagation from RH to cloud fraction to effective cloud albedo via parameterizations and couplings***

**(W. Wu)**

# Surface Fluxes



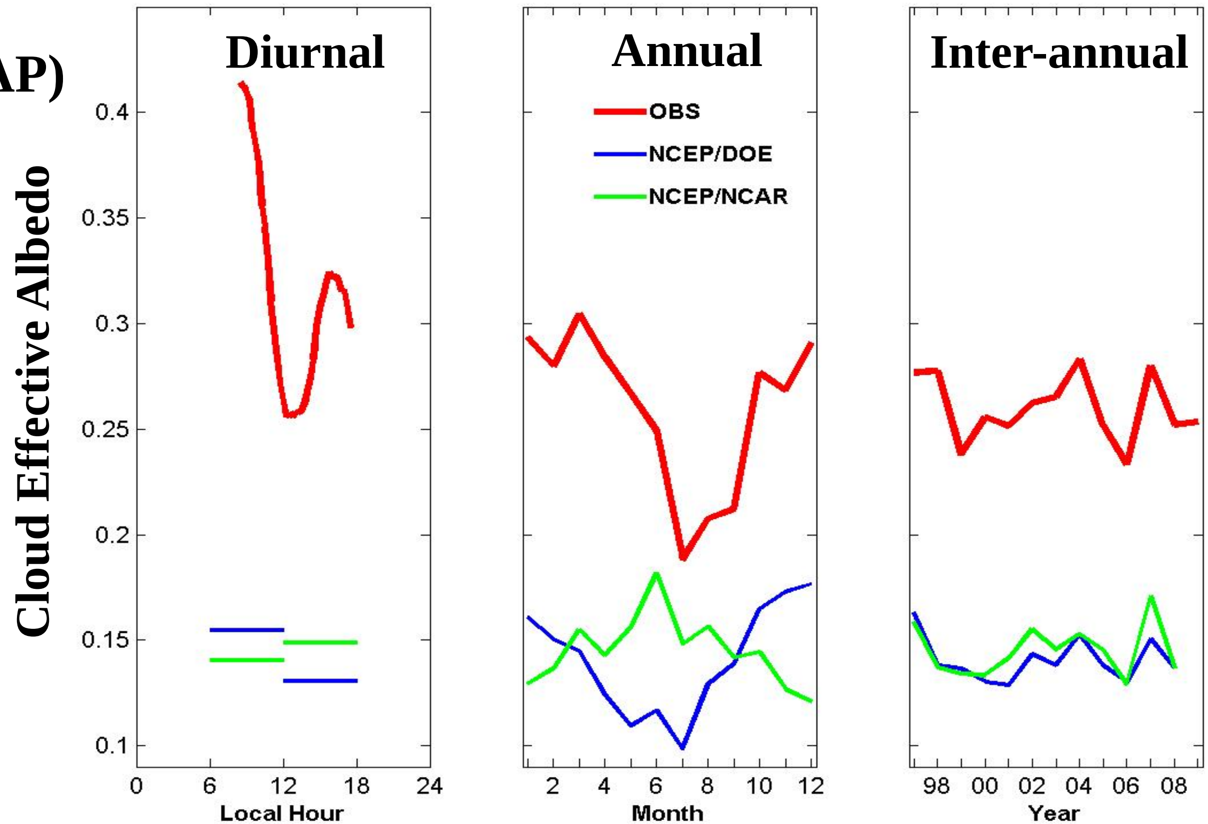



# SGP Effective Cloud Albedo and Observation-Reanalysis Comparison

- **Long-term radiation measurement (Long's VAP)**
- **Minimizing non-cloud effects**
- **Effective cloud albedo (Betts, 2009):**

$$\alpha_e = \frac{F_{clear} - F_{all}}{F_{clear}}$$

- **Derived long-term cloud effective albedo data since 1997**




***This diagram compares diurnal, annual, and inter-annual variations of effective albedo derived from radiation measurements (red), NCEP/DOE reanalysis (blue), and NCEP/NCAR reanalysis (green). Both reanalyses capture the inter-annual pattern well, but strongly underestimate. NCEP/DOE catches the annual variation better than NCEP/NCAR. → cloud fraction, albedo, and NWP usefulness***

# Version 1.0 Web-Based FASTER Testbed

**http://www.bnl.gov/ems/**





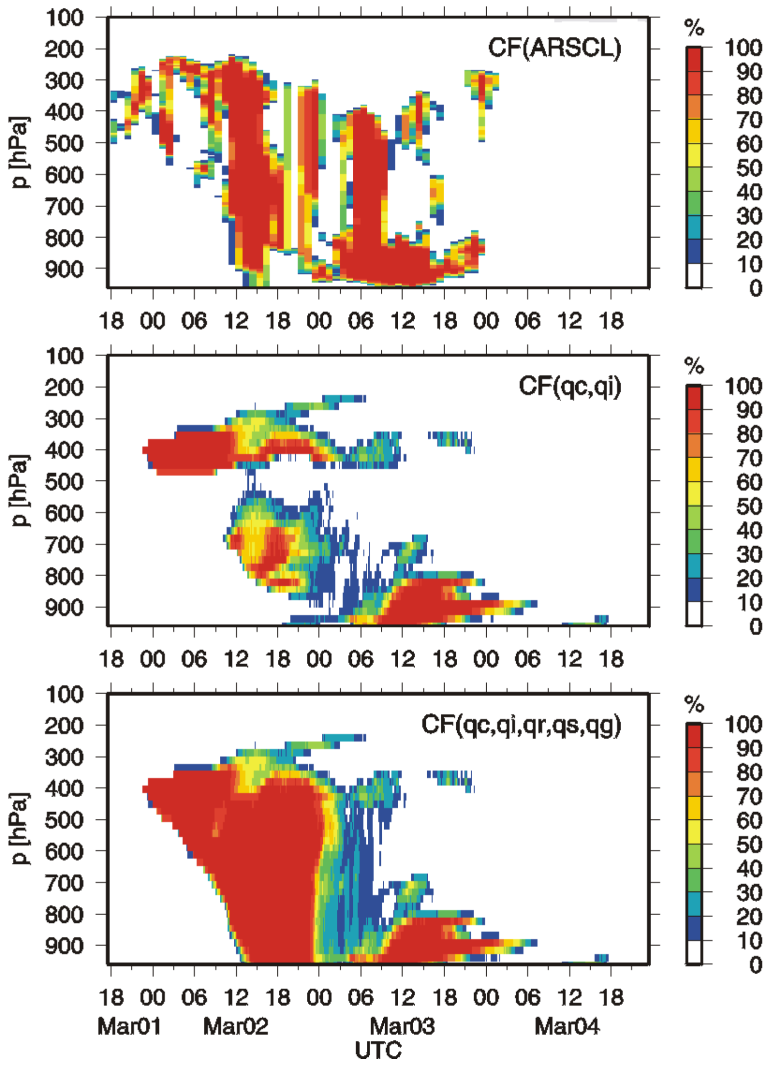

## FASTER (FAST-PHYSICS SYSTEM TESTBED AND RESEARCH) Project

Brookhaven Climate Consortium

The FASTER project arises from the proposal "Continuous Evaluation of Fast Processes in Climate Models Using ARM Measurements" funded by the Department of Energy's Earth System Modeling (ESM) program. The overarching goal of this project is to narrow uncertainty and biases in GCMs by utilizing continuous ARM measurements to enhance and accelerate evaluation and improvement of parameterizations of fast processes in GCMs involving clouds, precipitation, and aerosols, with six primary objectives:

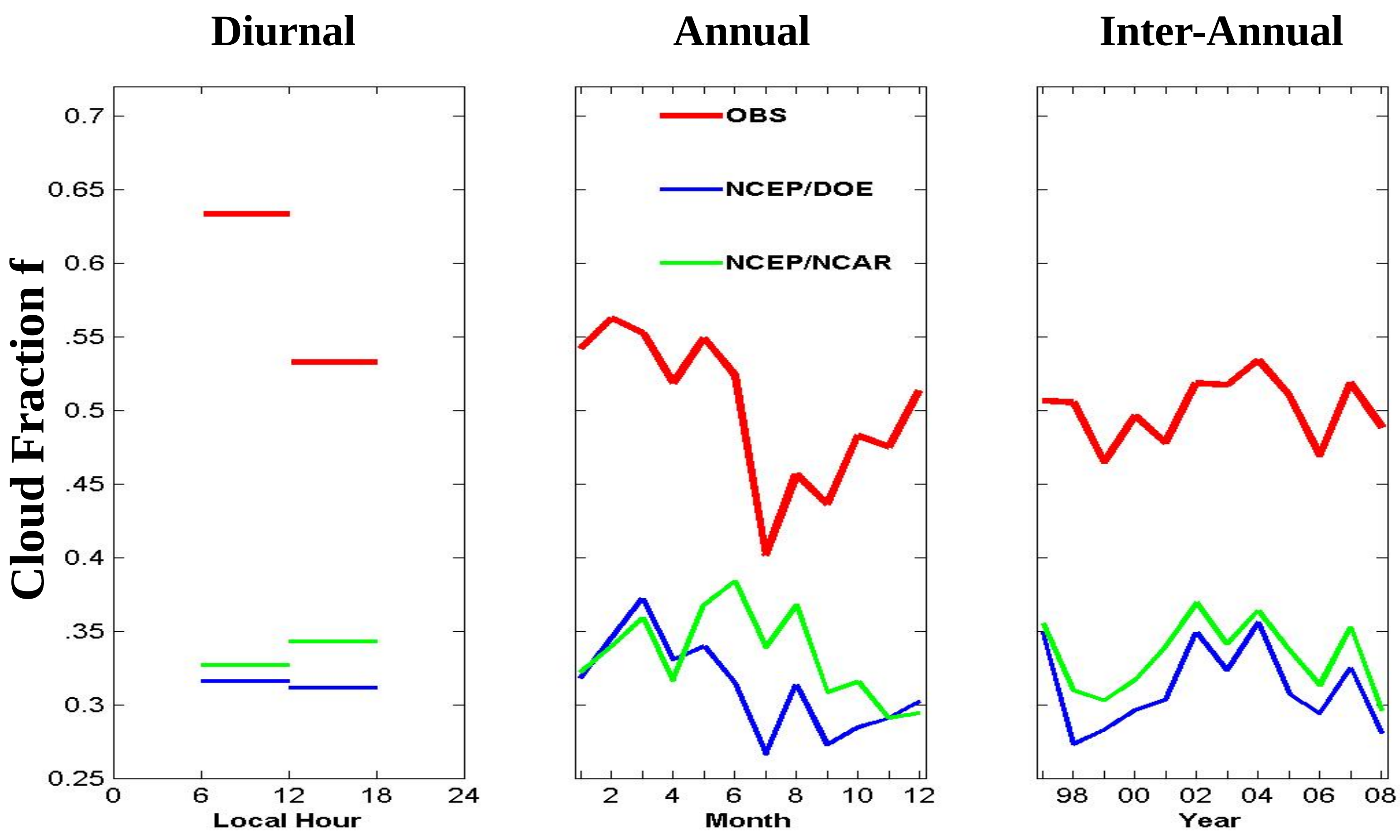
1. ***Construction of a Fast-Physics Testbed*** to rapidly evaluate fast physics in GCMs by comparing model results against continuous long-term cloud observations made by the ARM program.
2. ***Execution of a suite of CRM simulations*** for selected periods/cases to augment the Fast-Physics Testbed. We will run WRFs with different parameterizations as CRMs, CRMs with bin-microphysics, and multi-scale modeling framework.
3. ***Continuous evaluation of model performance*** to identify and determine model errors by comparing the NWP and SCM results against continuous ARM observations, and to each other. The long-time data record at the ARM sites (e.g., SGP) permits evaluation of various statistical properties (e.g., PDFs) and recurring cloud regimes.
4. ***Examination and improvement of parameterizations*** of key cloud processes/properties (e.g., convection, microphysics and aerosol-cloud interactions), thus narrowing the range of treatments of fast processes that exert strong influences on model sensitivity so as to better constrain climate sensitivity.
5. ***Assessment and development of metrics*** of model performance. Different metrics will be applied and tested in the evaluation, and new metrics will be explored. Special care will be taken to address the issue of scale-mismatch between observations and models.
6. ***Incorporation of newly acquired knowledge on parameterizations*** into the full participating GCMs to evaluate the impact of the refined parameterizations on GCM and ascertain the improvement in the representation of fast physics in the GCMs.

# Configuration of WRF as a CRM




Cloud Fraction in Period A

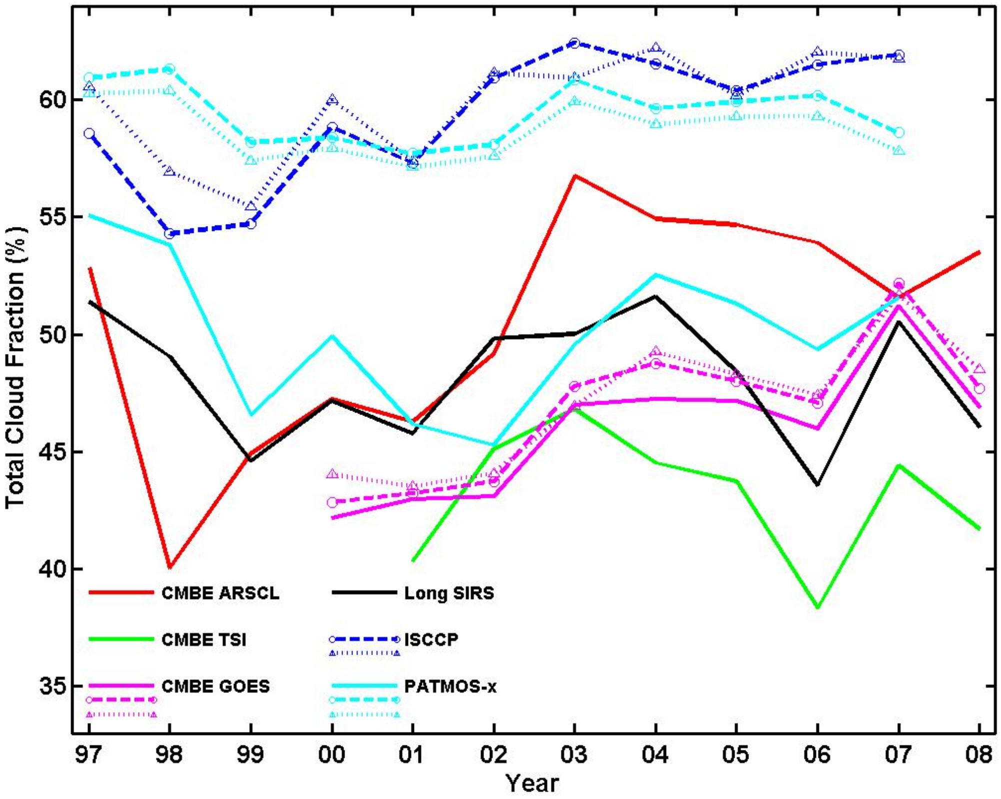
# Cloud Fraction and Observation-Reanalysis Comparison at SGP




*This diagram shows variations of cloud fraction are similar effective cloud albedo. Both reanalyses capture the inter-annual pattern well, but strongly underestimate. NCEP/DOE catches the annual variation better than NCEP/NCAR. >> cloud albedo*

**(Wei Wu)**

# Inter-Annual Variations of SGP Cloud Fraction Observations




**Lines: inter-annual variations**
**solid: surface or 0.5º satellite**
**dashed: 2.5º satellite**
**dotted: the entire SGP domain**

**Characteristics:**

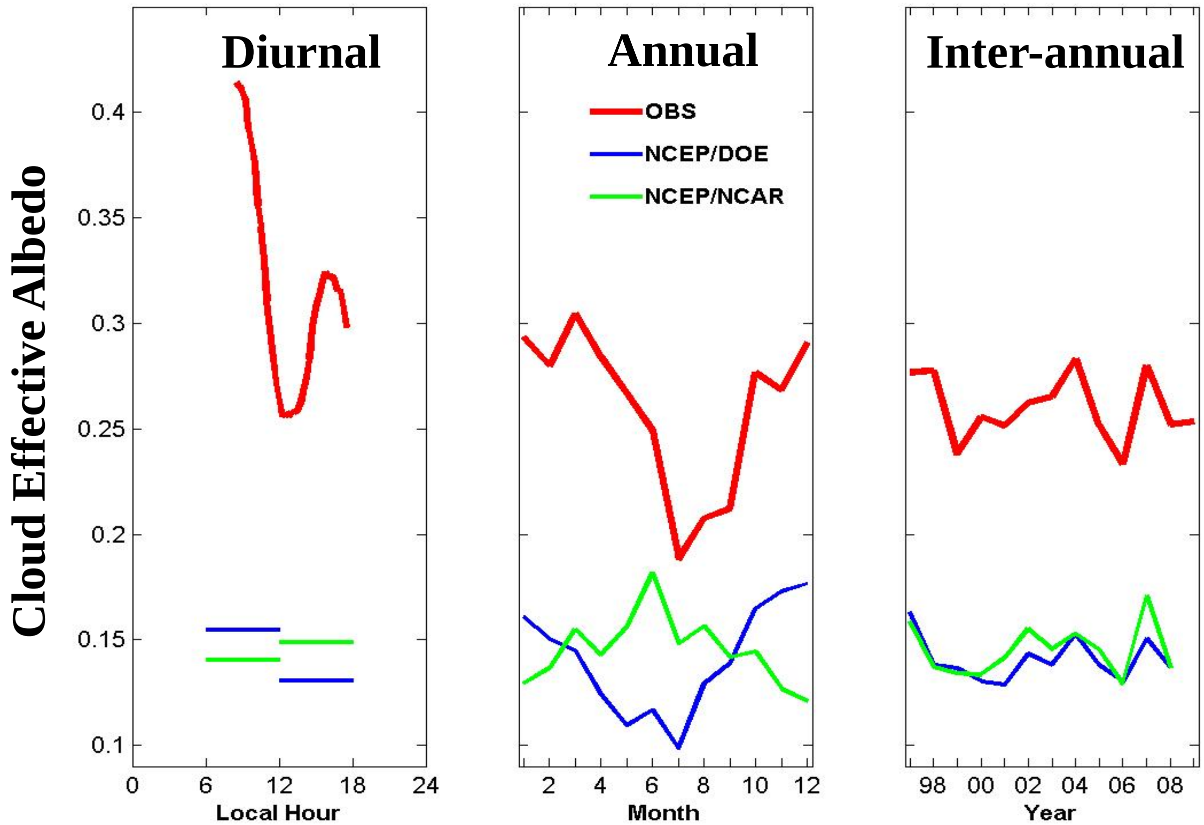
- **Magnitude: significant difference**
- **Phase: similar (including 0.5º PATMOS-x with an annual-cycle phase problem)**

# Effective Cloud Albedo and Observation-Reanalysis Comparison at SGP

- Long-term radiation measurement
- Minimizing non-cloud effects
- Effective cloud albedo (Betts, 2009):

$$\alpha_e = \frac{F_{clear} - F_{all}}{F_{clear}}$$

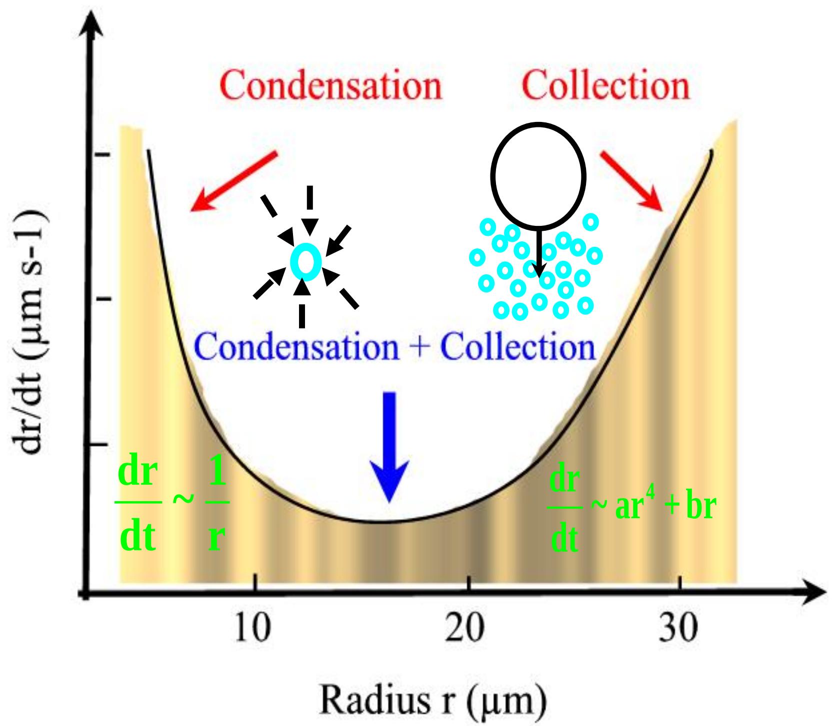
- Long-term cloud effective albedo data since 1997 (Wei Wu)




*This diagram compares diurnal, annual, and inter-annual variations of effective albedo derived from radiation measurements (red), NCEP/DOE reanalysis (blue), and NCEP/NCAR reanalysis (green). Both reanalyses capture the inter-annual pattern well, but strongly underestimate. NCEP/DOE catches the annual variation better than NCEP/NCAR.* → *cloud fraction, albedo, and NWP usefulness*

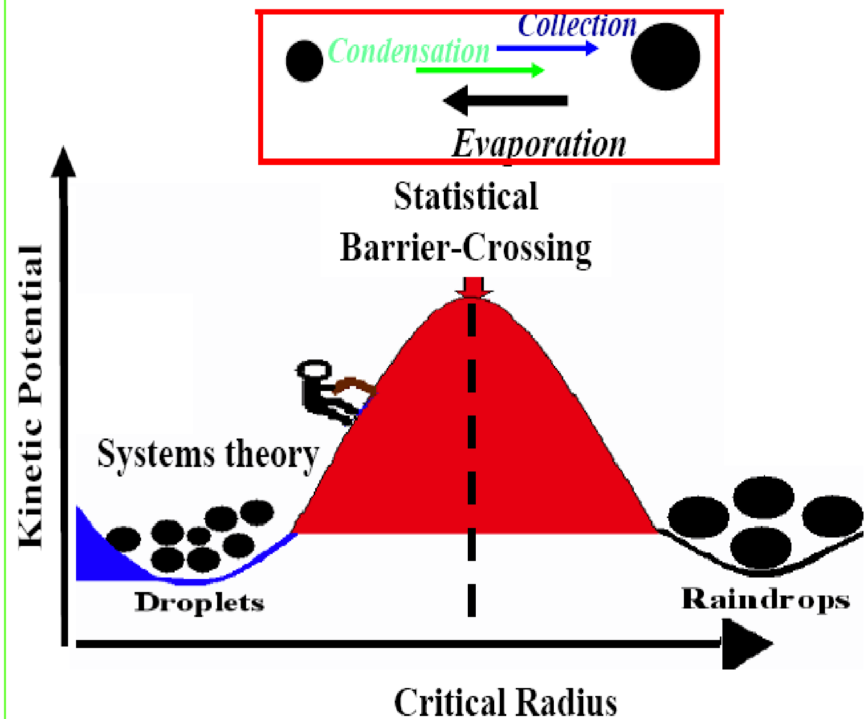
# Valley of Death or Mountain of Life

## Valley of Death




**Rain initiation has been an outstanding puzzle with two fundamental problems of spectral broadening & formation of embryonic raindrop**

## Mountain of Life




**The new theory considers rain initiation as a statistical barrier crossing process. Only those "RARE SEED" drops crossing over the barrier grow into raindrops.**

***Parameterization problem in GCMs is similar:***

***Issues well recognized, efforts made, & progress realized;***

***<u>now is the time to for us to be a SEED that accelerate and crosses over the barrier !</u>***

# Acceleration of progress and barrier-crossing demands more focused effort

**History reveals to us a process of multiple evaluation approaches and increasingly focused efforts:**

- **Brute force full-GCM (slow) -- Focused by IPCC**
- **GCM in forecast mode (faster than IPCC) -- Focused by CAPT**
- **SCM enhanced with CRM/LES modeling (fast and easily rerun) -- Used in ARM/GEWEX; Focused by KNMI SCM-testbed**
- **Available NWP forecast, analysis and reanalysis (NWP-testbed; fast but not easy to rerun) – Focused by European Cloudnet project**

***There are less focused efforts in SCM-testbed and NWP-testbed in US, and FASTER is to fill this critical need to build a Fast-Physics Testbed by synthesizing SCM-testbed and NWP-testbed approaches and enhancing them via a suite of other activities, and perform continuous model evaluation against comprehensive, long-term ASR measurements.***

# Goal and Objectives

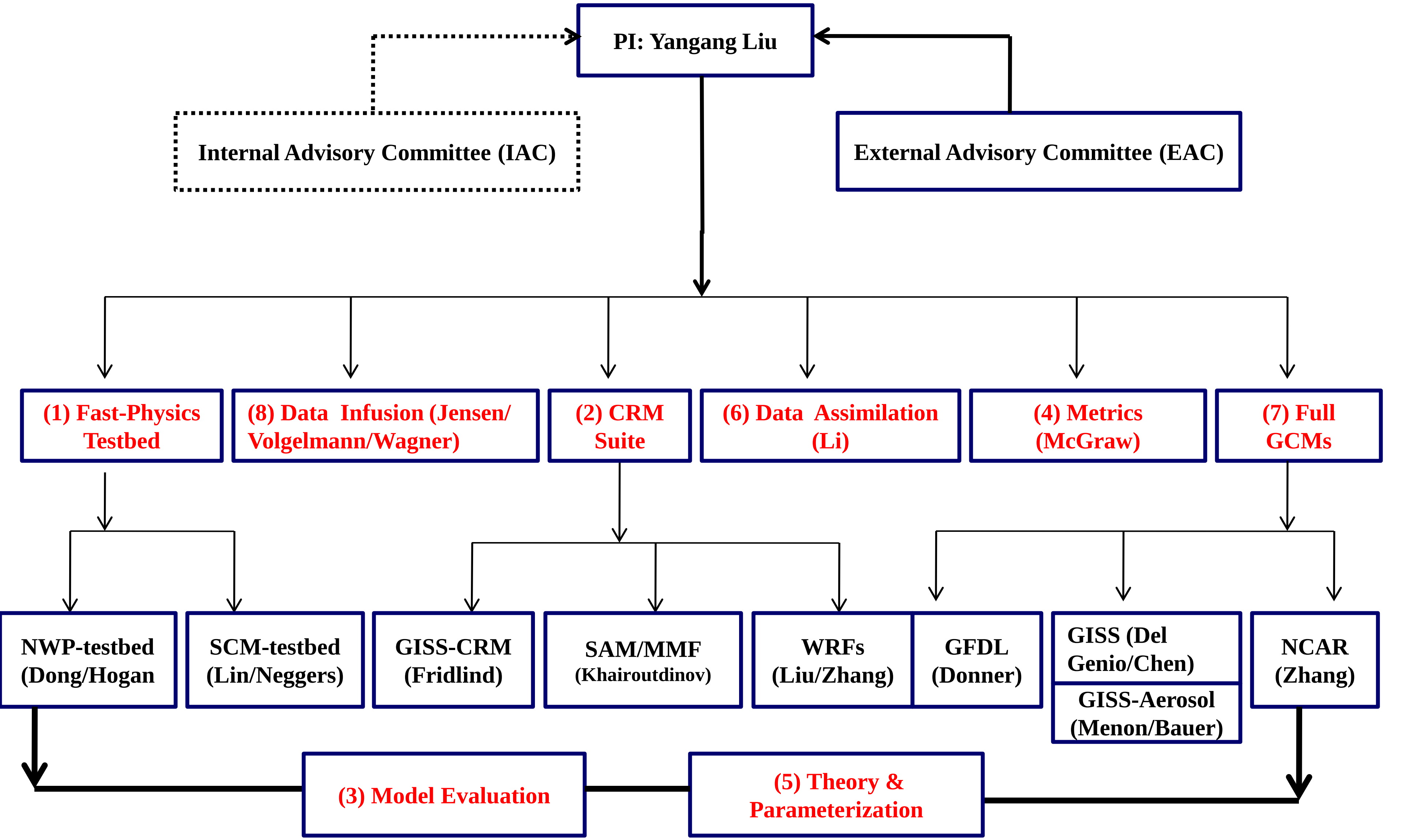
## One Goal

**Fully utilize continuous long-term ARM measurements to enhance/accelerate evaluation and improvement of parameterizations of cloud-related fast processes and narrow GCM uncertainties and biases.**

## Six Objectives

- **Construction of a fast-physics testbed**
- **Execution of a suite of CRM/LES simulations**
- **Evaluation of model performance**
- **Examination and improvement of parameterizations**
- **Assessment and development of evaluation metrics**
- **Incorporation of acquired knowledge into the full GCMs**

# Scientific Management




**Note that the flow chart is for illustrative purpose; all scientists work closely together, with focused areas identified. All scientists participate in (3) and (5), focusing on different processes/aspects.**

# Thanks again and Happy Thanksgiving!

# FASTER has one overarching goal and eight major tasks.

**Goal: Use continuous long-term ARM measurements to enhance/accelerate evaluation/improvement of parameterizations of cloud-related fast processes in GCMs. FASTER will be also valuable to NWP, WRF and CRM evaluation and development.**

Testbed Research

**Eight Interconnected Major Tasks**

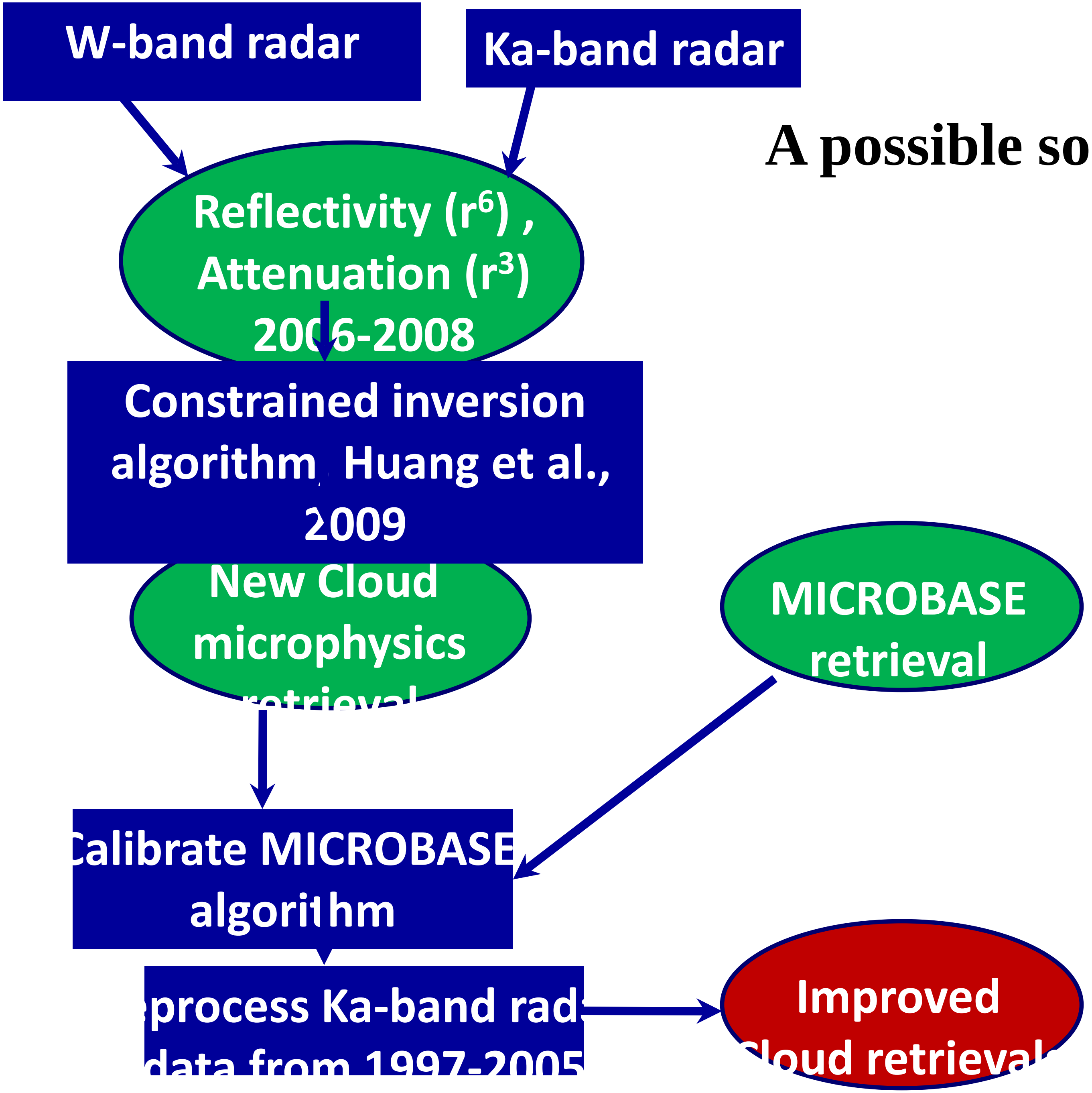
- **Construction of fast-physics testbed by integrating SCM-testbed, NWP-testbed, and a WRF (see posters by Lin et al. and Wu et al.)**
- **Execution of a suite of WRF/CRM/LES simulations**
- **Integration of various data (see poster by Jensen et al)**
- **Construction of a multiscale data assimilation system**
- **Evaluation of model performance**
- **Examination and improvement of parameterizations**
- **Assessment and development of evaluation metrics**
- **Incorporation of acquired knowledge into the full GCMs**

# Progress Report

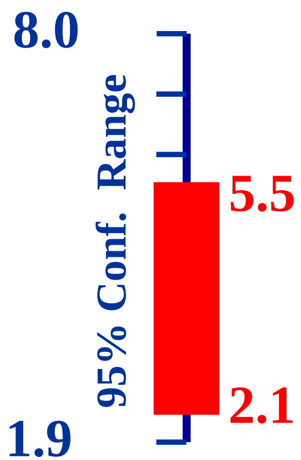
- **Some timelines**
  - -- 11/10/08, knew the proposal solicitation & charged to lead
  - -- 2/9/09, proposal submitted
  - -- 5/1/09, notified of the good news of proposal being funded
  - -- 6/09, DOE labs received $; able to use in July at BNL
  - -- 9/09, University received $
- **New team members since proposal being funded**
  - -- Wuyin Lin at BNL
  - -- Satoshi Endo at BNL
  - -- Tami Toto at BNL
  - -- Gijs de Boer at LBL
  - -- Catherine Rio at GISS-CU
  - -- Ewan O'Connor at UR-BNL


- **Fast-physics testbed and web setup at BNL**
- **Examination of SGP radiation and cloud observations**
- **Model preparation and tune-up**
- **We are progressing from preparation stage to "warm-up" stage**

# A possible solution



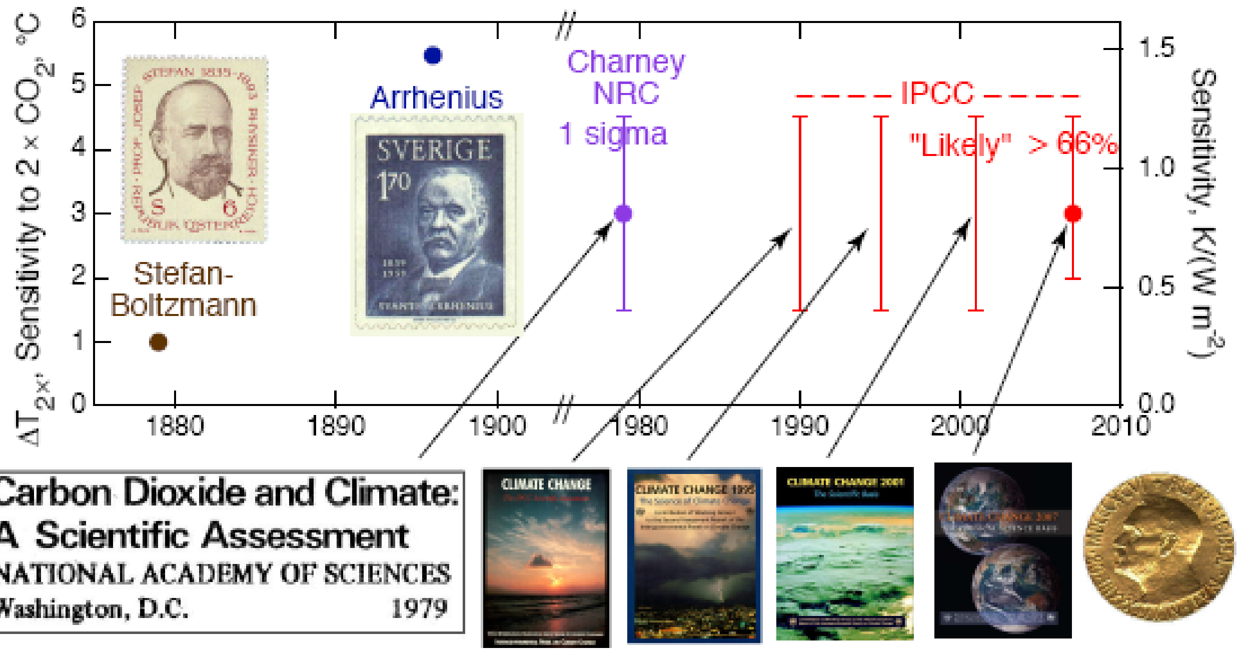
# Research has progressed, but the pace has been frustratingly slow!




(Huybers, 2009)

## Virtually Unchanged Large Uncertainty of Model Climate Sensitivity through Ages

**(Adapted from Schwartz 2009)**

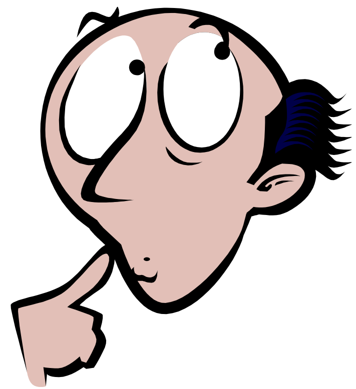



*Wide spread are likely related to parameterizations of cloud-related fast (subgrid) processes.*

# Eight Tasks and Major Fast Processes

## Eight Tasks

- Fast-physics testbed (NWP-testbed & SCM-testbed)
- A suite of high-resolution model simulations
- Model evaluation against measurements
  -- Model errors
  -- Error sources
- Evaluation metrics
  -- Statistical measures
  -- Forecast skill
- Theory and parameterization
- Data assimilation
- Full GCM assessment
- Data integration



Evaluation approach

Evaluation variables

## Major Fast Processes

- Microphysics
  -- Warm clouds
  -- Ice clouds
  -- Mixed phase clouds
  -- Mono vs. multi-moment schemes
- Aerosol-cloud interactions
- Radiation
- Shallow convection
- Deep convection
- Entrainment/Detrainment
- Boundary processes
- Subgrid turbulence
- Cloud fraction
- Land-surface-atmosphere interaction