Introduction of the FASTER Project

Yangang Liu
(Brookhaven National Laboratory)

- **FASTER** = ***FA**st-physics **S**ystem **TE**stbed and **R**esearch*

- **Funded by the Earth System Modeling (ESM) program of the US DOE at ~ 3M/year for 5 years from 2009**

- **21^{+} investigators from 10 institutions (+ post docs and students)**

- **Co-managed by Atmospheric System Research (ASR) and ESM program managers**

- *Major* ESM effort to bridge with ASR and utilize ARM measurements to evaluate GCM parameterizations of fast processes, to a new level!

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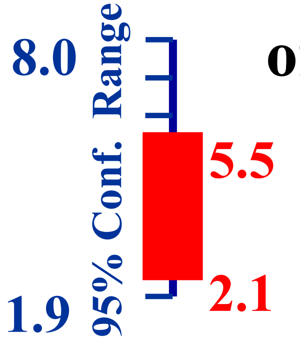
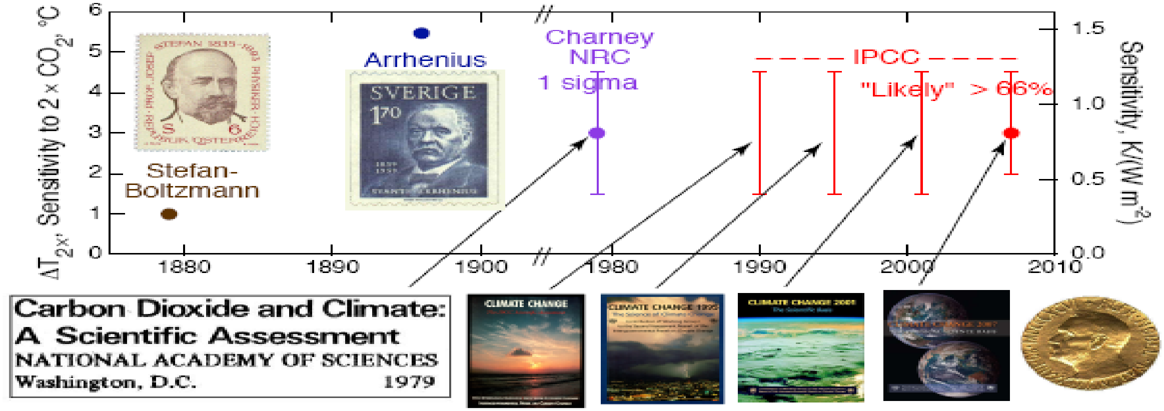
Motivation One: Modeling Side

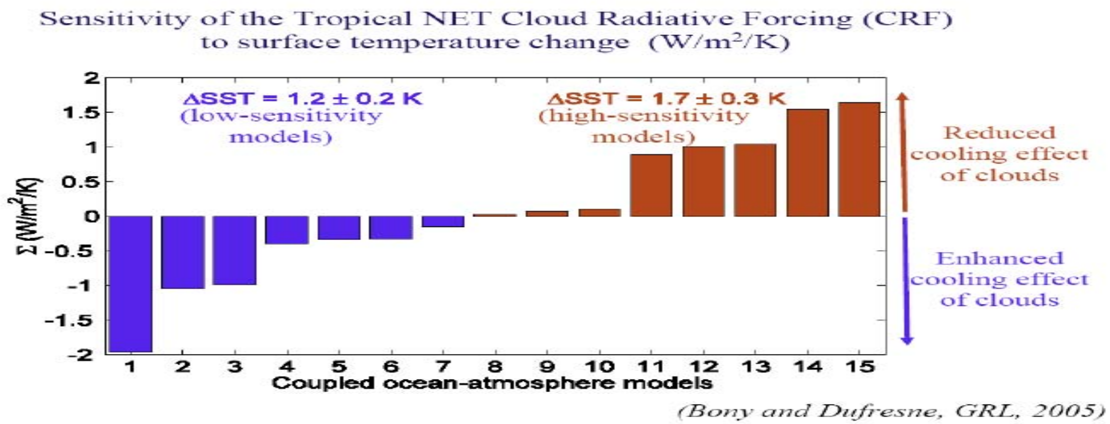
Virtually Unchanged Large Uncertainty of Model Climate Sensitivity through Ages



(Huybers, 2009)



Despite extensive research, climate sensitivity remains highly uncertain, and the source of uncertainty is likely with parameterizations of cloud-related fast processes in GCMs, e.g.:

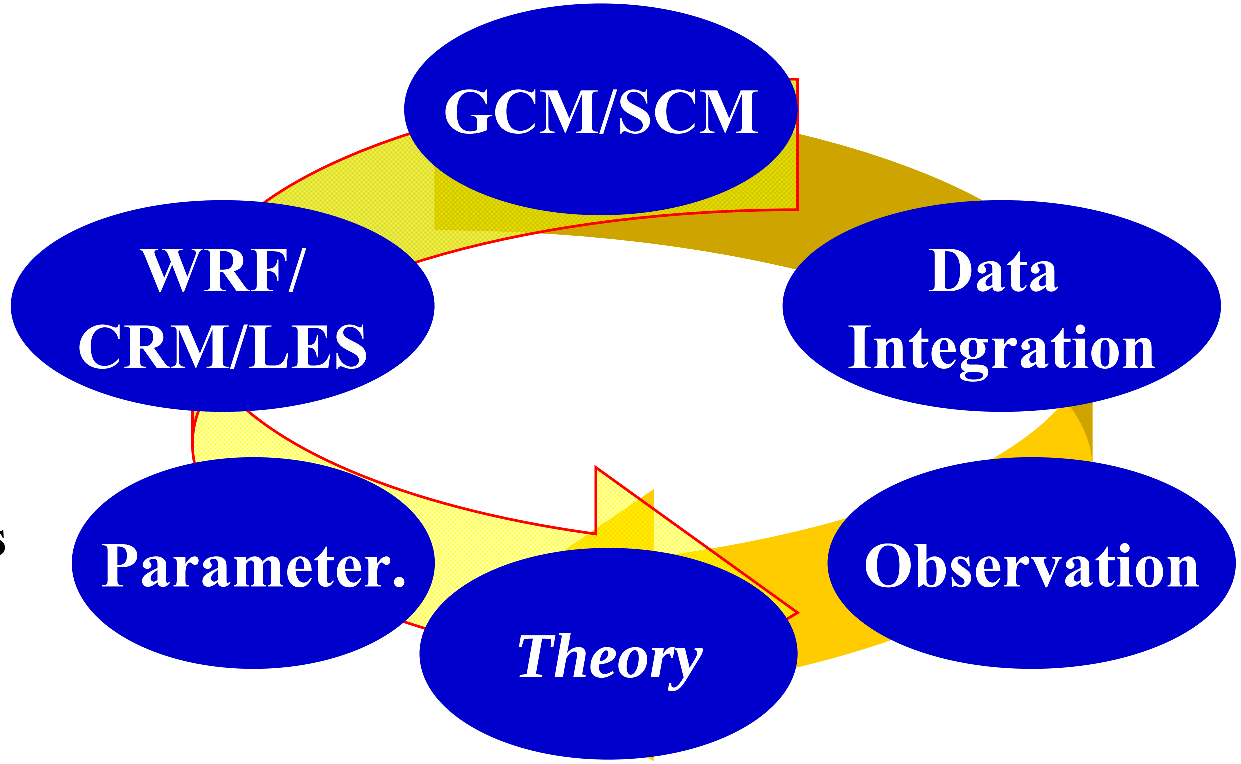


(Adapted from Schwartz 2009 and Zhang 2010)

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

Complexity:

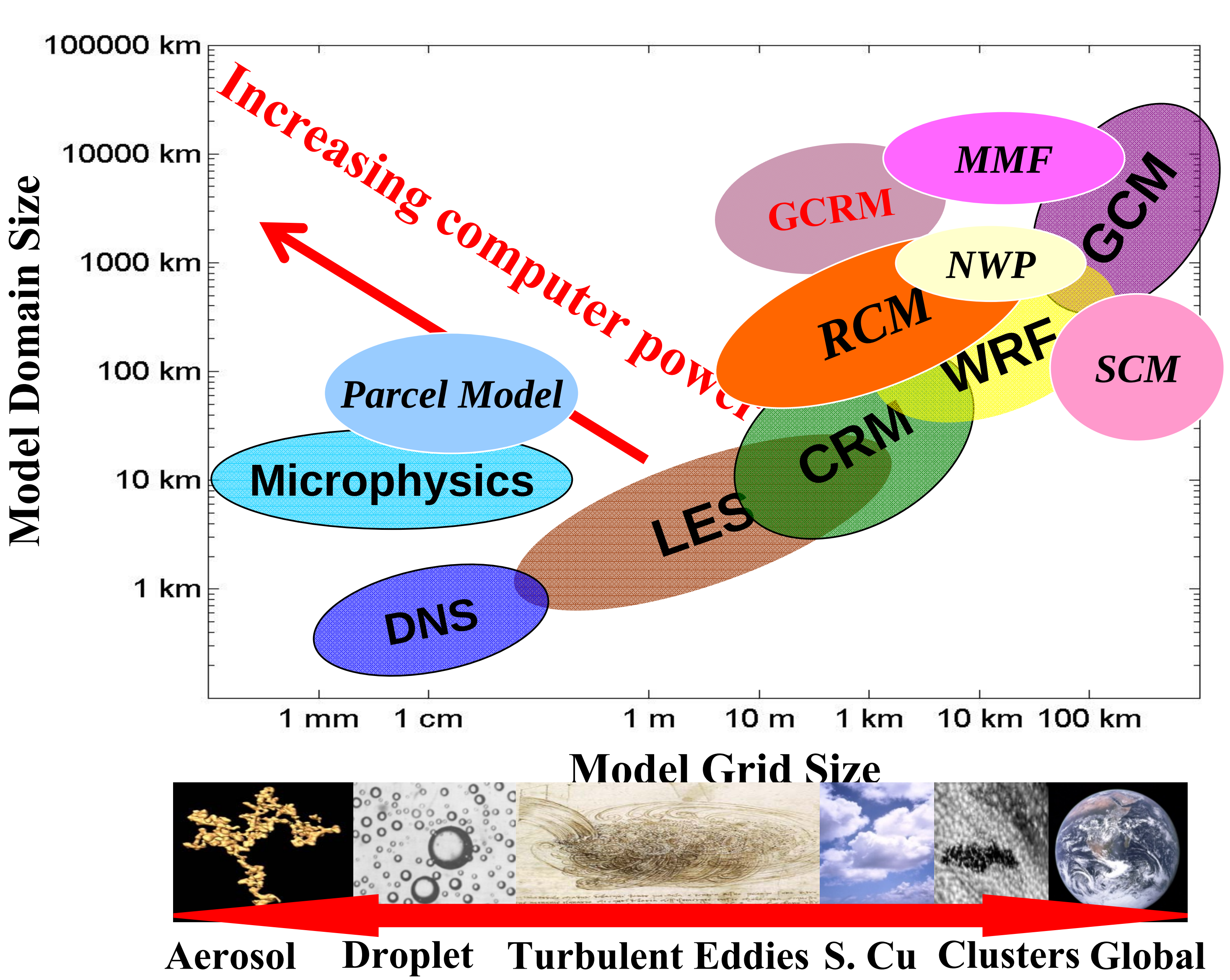
- **Scientific**
  - -- Conceptual
  - -- Numerical
  - -- Coupling
- **Engineering**
  - -- Inter-field interactions
  - -- Para. imple. in GCMs



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 consider the complexity as a *valley of death* for GCMs.

Complexity is reflected by model hierarchy



Poorly understood interactions

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

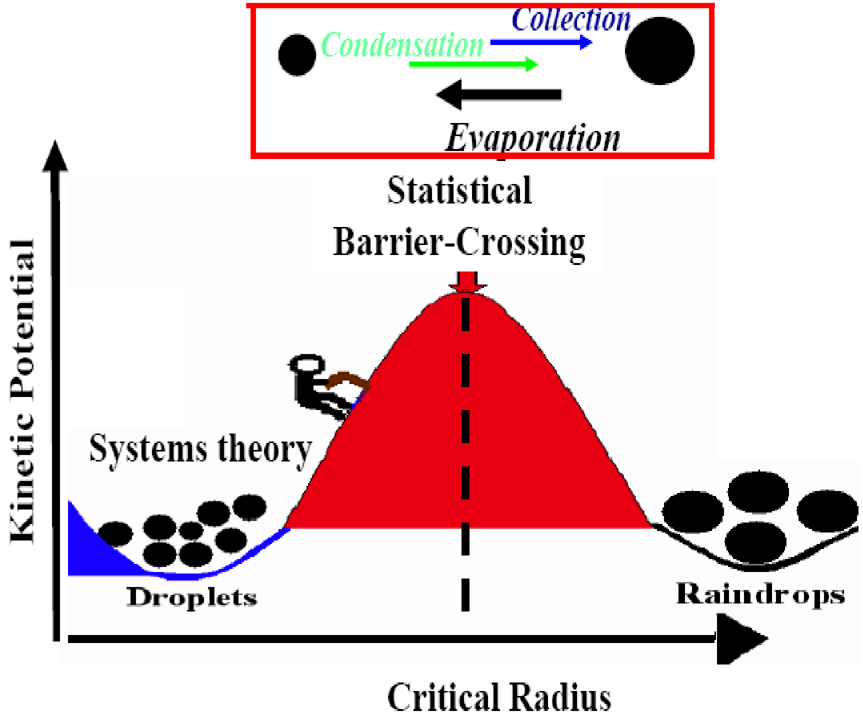
SCM = Single Column Model

"Breaking the parameterization deadlock"

An analogy with rain initiation theory:

Rain initiation is considered 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 accelerates and crosses over the barrier !</u>

Acceleration of progress and barrier-crossing demands more focused effort

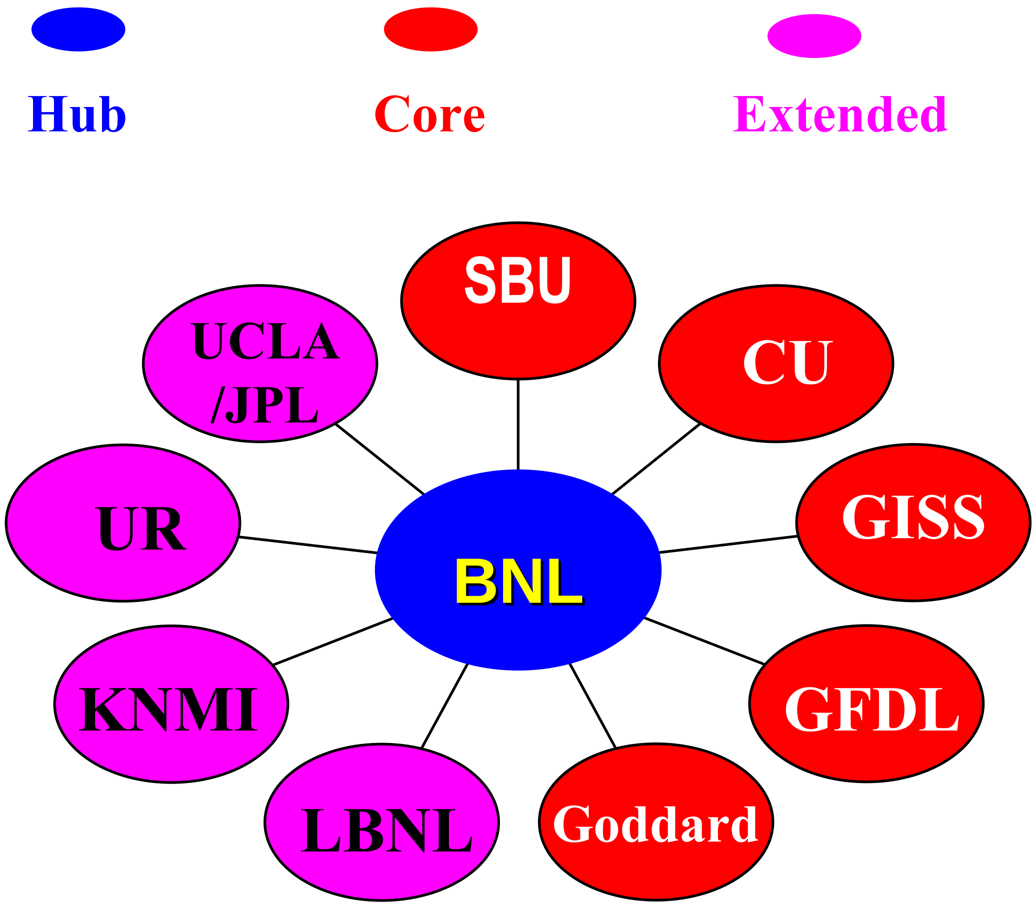
History reveals to us a process of multiple evaluation approaches and increasingly focused efforts:

- **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 <u>fill this critical need</u> <u>to build a Fast-Physics Testbed</u> by synthesizing SCM-testbed and NWP-testbed approaches and enhancing them via a suite of other activities, and <u>perform continuous model evaluation against comprehensive, long-term ASR measurements.</u>

FASTER Team: who are we?

10 institutions and 21 scientists



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 have strong theoretical background on top of other areas of expertise

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.

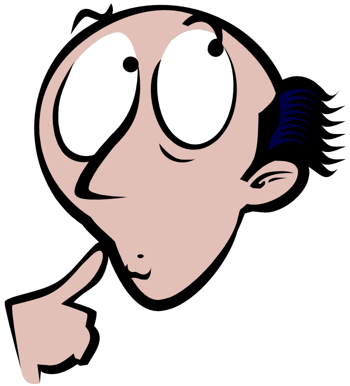
Six Objectives

- **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**

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



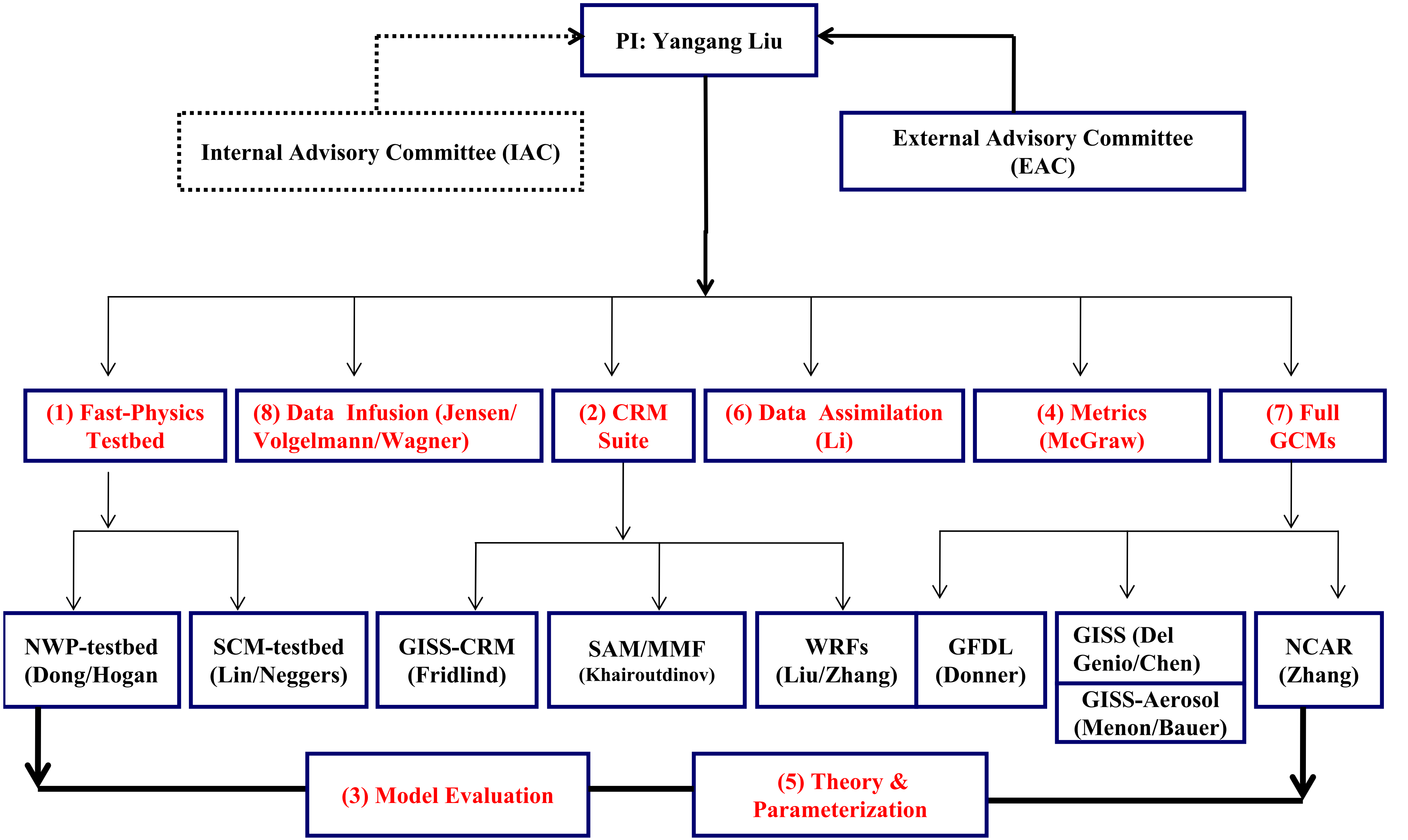
Evaluation approach

Evaluation variables

Major Fast Processes

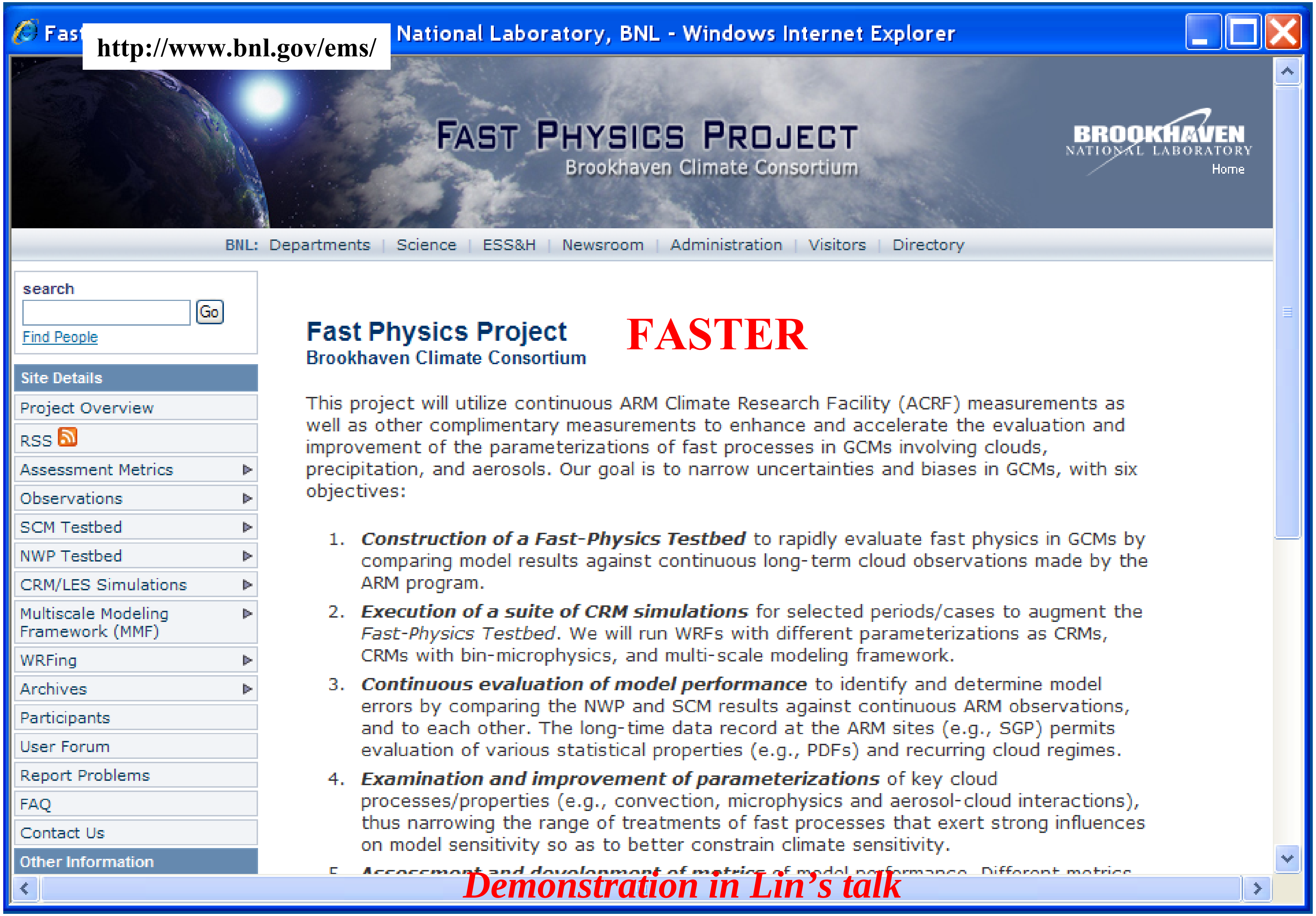
- Microphysics
  -- Warm clouds
  -- Ice clouds
  -- Mixed phase clouds
  -- Mono vs. multi-moment schemes
- Aerosol-cloud interactions
- Radiation
- Shallow convection
- Deep convection
- Entrainment/Detrainment
- Boundary processes
- Subgrid turbulence
- Cloud fraction
- Land-surface-atmosphere interaction

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.

Construction of Project Gateway – Website



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

ECMWF IFS

Integrated forecasting System (IFS) of the European Centre for Medium-range Weather Forecasts (ECMWF)

Current physics version: Cycle 36 R<something>

ERA Interim (CY31R1)

KNMI RACMO

Regional Atmospheric Climate Model (RACMO)

Consists of HIRLAM dynamics and IFS physics (currently C31R1)

*Used for * Generation of future climate scenarios for Europe / The Netherlands*

** Short-term forecasts (Initialization & domain boundaries: ECMWF analysis)*

** Testing of experimental parameterization schemes (boundary layer)*

** Provides forcings for the KNMI Parameterization Testbed (KPT)*

Two SCM versions participate in FASTER:

** CY31R1 (also known as the "ECMWF SCM")*

** CY31R1 + EDMF-DualM*

Eddy Diffusivity - Mass Flux scheme (Seibesma et al, JAS 2007)

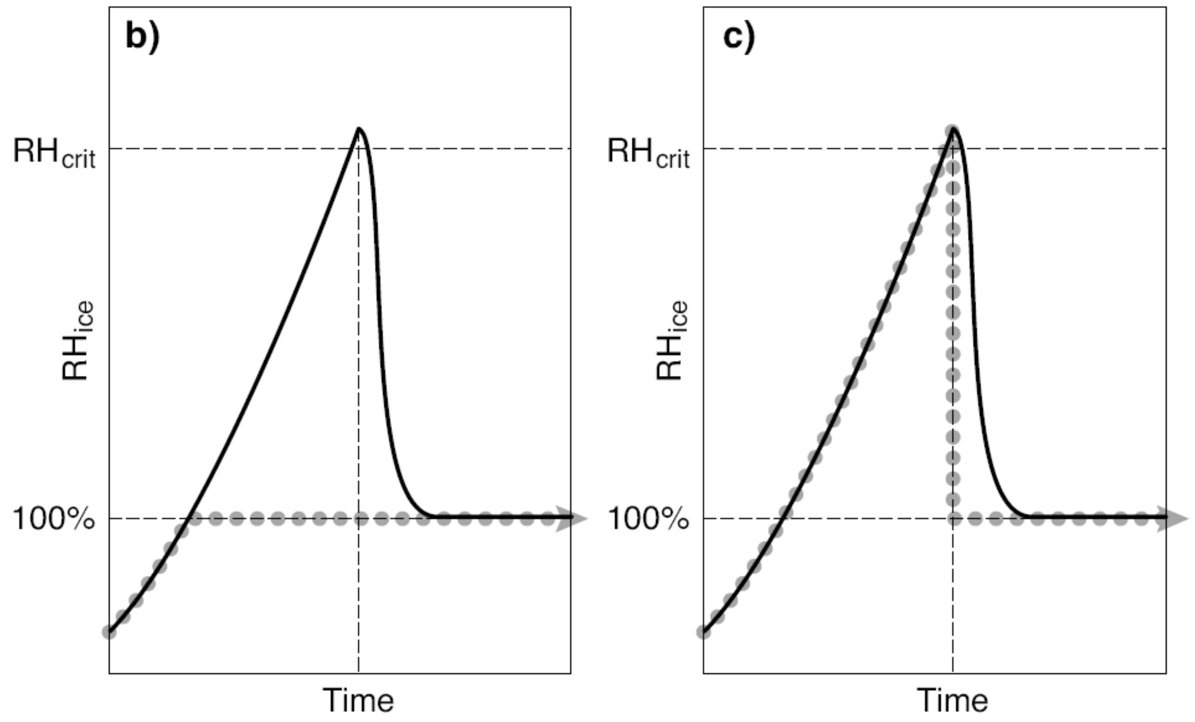
Dual Mass flux framework (Neggers et al, JAS 2009)

Topic I: Impact of the ice super-saturation function on the high cloud cover in the IFS

A (new) routine for ice super-saturation above RH=100% was introduced into the IFS in 2005:

OLD
(no super-saturation allowed)

NEW
(allowing super-saturation)



Dotted grey arrow: behavior of RH when gridbox reaches saturation

Tompkins et al., ECMWF Tech. Memo 481, 2005

IFS GCM results: SuperSat – Control (no SuperSat)
yearly mean 200009-200109

Tompkins et al., ECMWF Tech. Memo 481, 2005

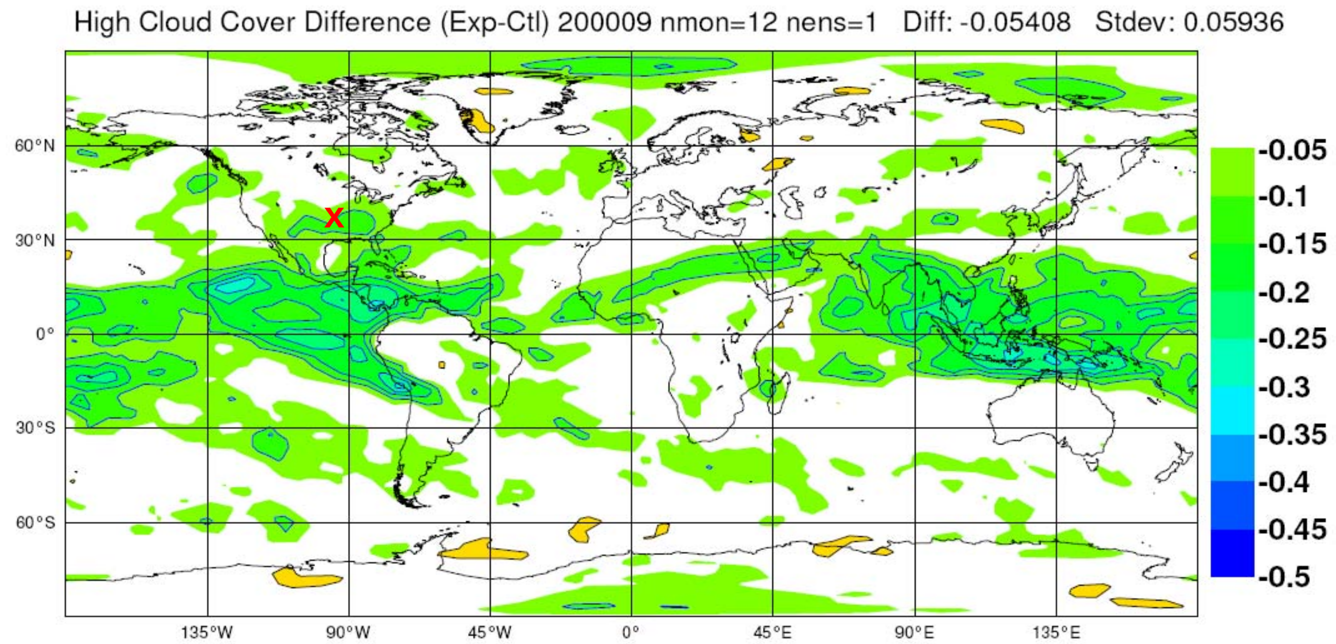


Figure 2: 12 month average difference in high cloud cover (p<450 hPa approximately) between two experiments using the new nucleation parametrisation and the control, respectively.

Q: Is this reduction of high clouds an improvement?
Can we evaluate against ARM SGP measurements using the SCM technique?

March 2000

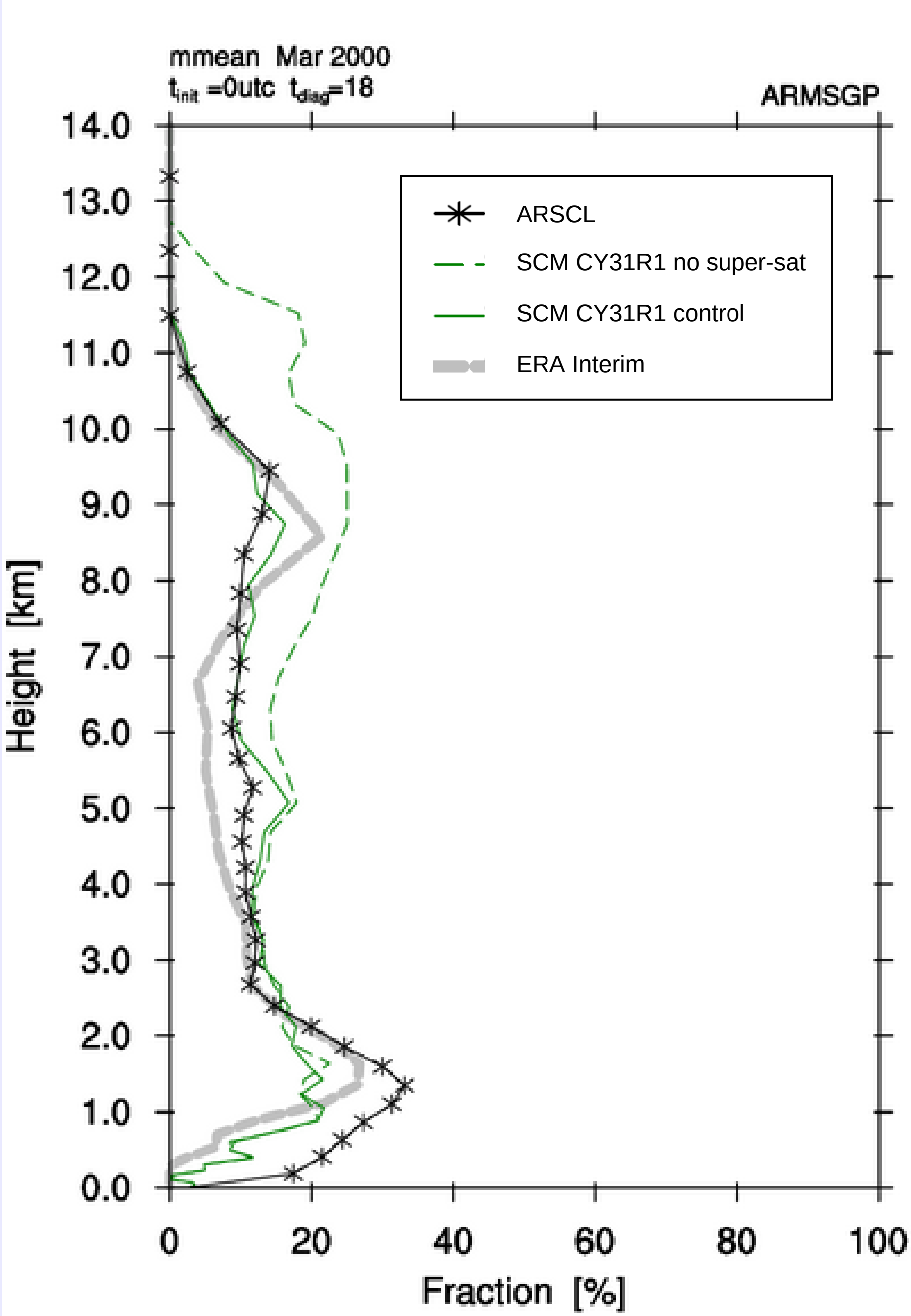
monthly mean at 18 UTC

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 reasonably well, even when driven by an independent forcings dataset



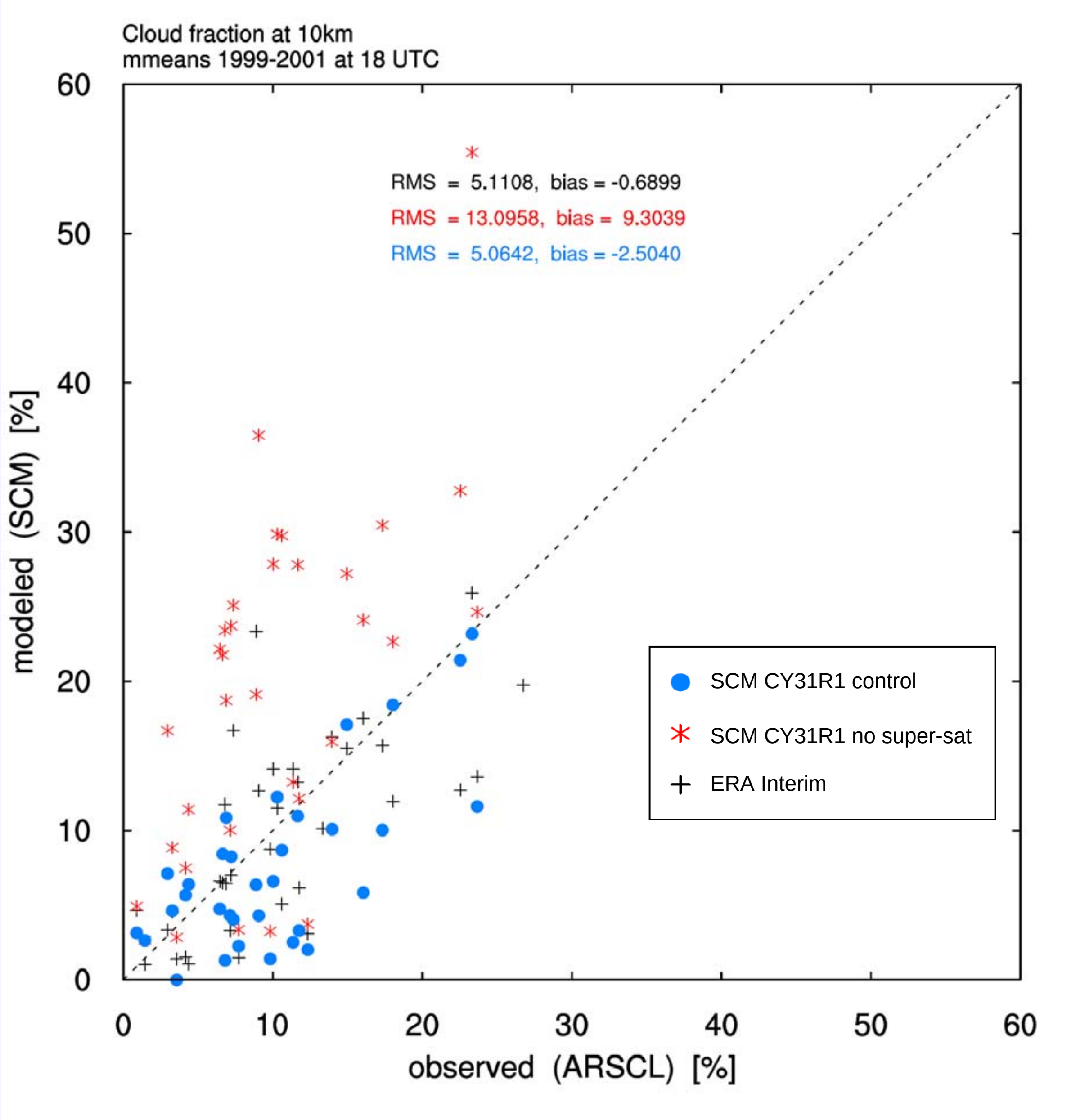
Better statistics:

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*

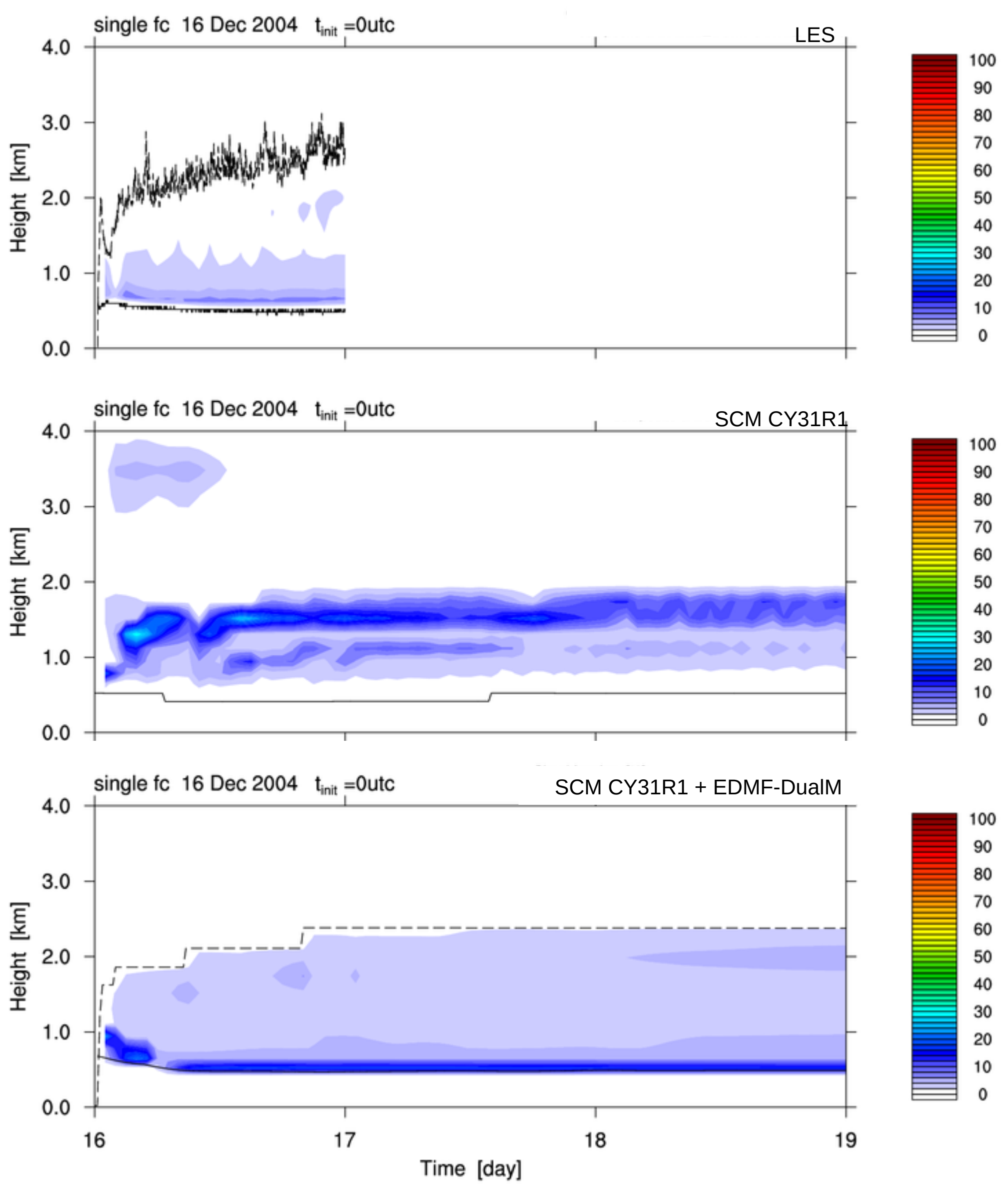
** The supersaturation function brings a statistically significant improvement*

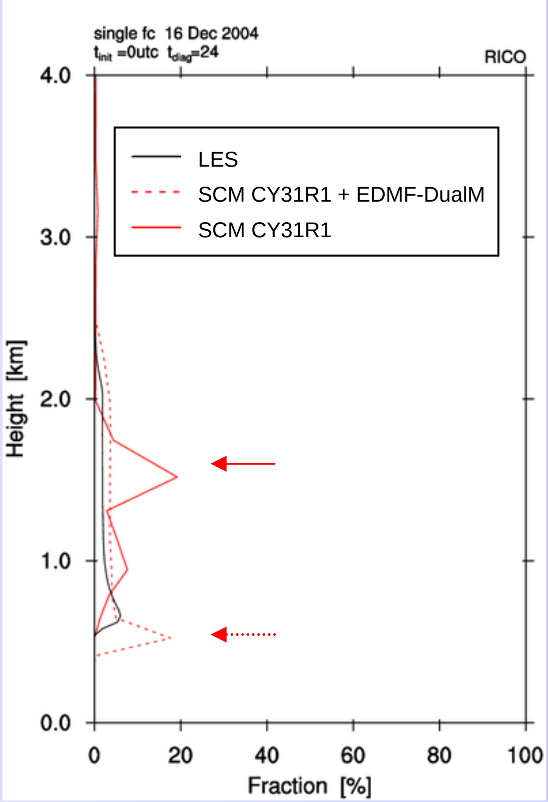
** Not accounting for super-saturation leads to too much high cloud occurrence*



Topic II: Testing a new boundary layer scheme for RACMO / IFS

Results with the EDMF-DualM framework for the Rain In Cumulus over the Ocean (RICO) case of the GCSS Boundary Layer Cloud Working Group (BLCWG) http://www.knmi.nl/samenw/rico/RICO



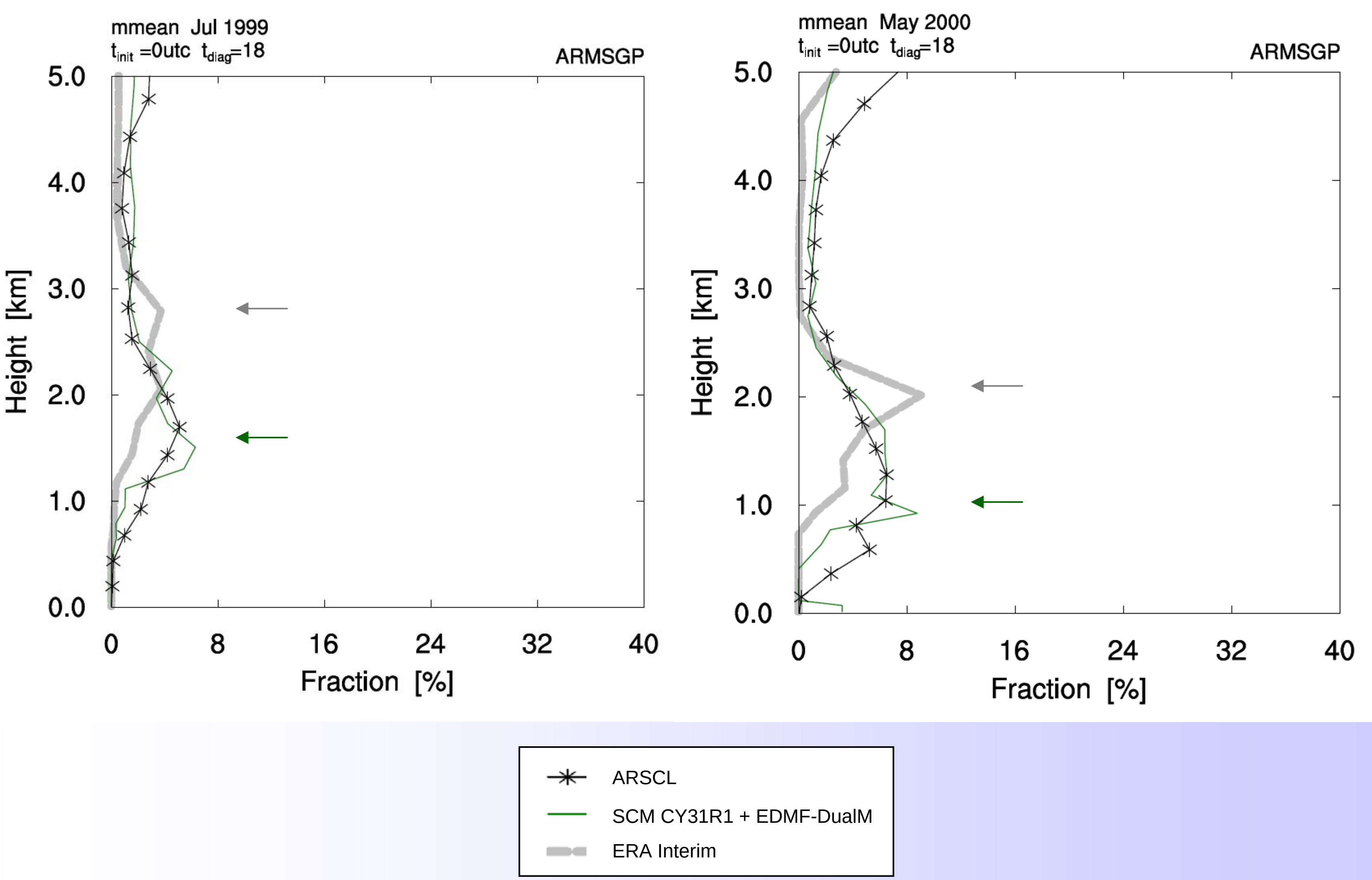


EDMF-DualM better reproduces the “bottom-heavy” profile of cloud-fraction as seen in LES

Q: This is an idealized case. Do these results carry over to the real world?

Spring/summer cloud fraction at SGP:

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

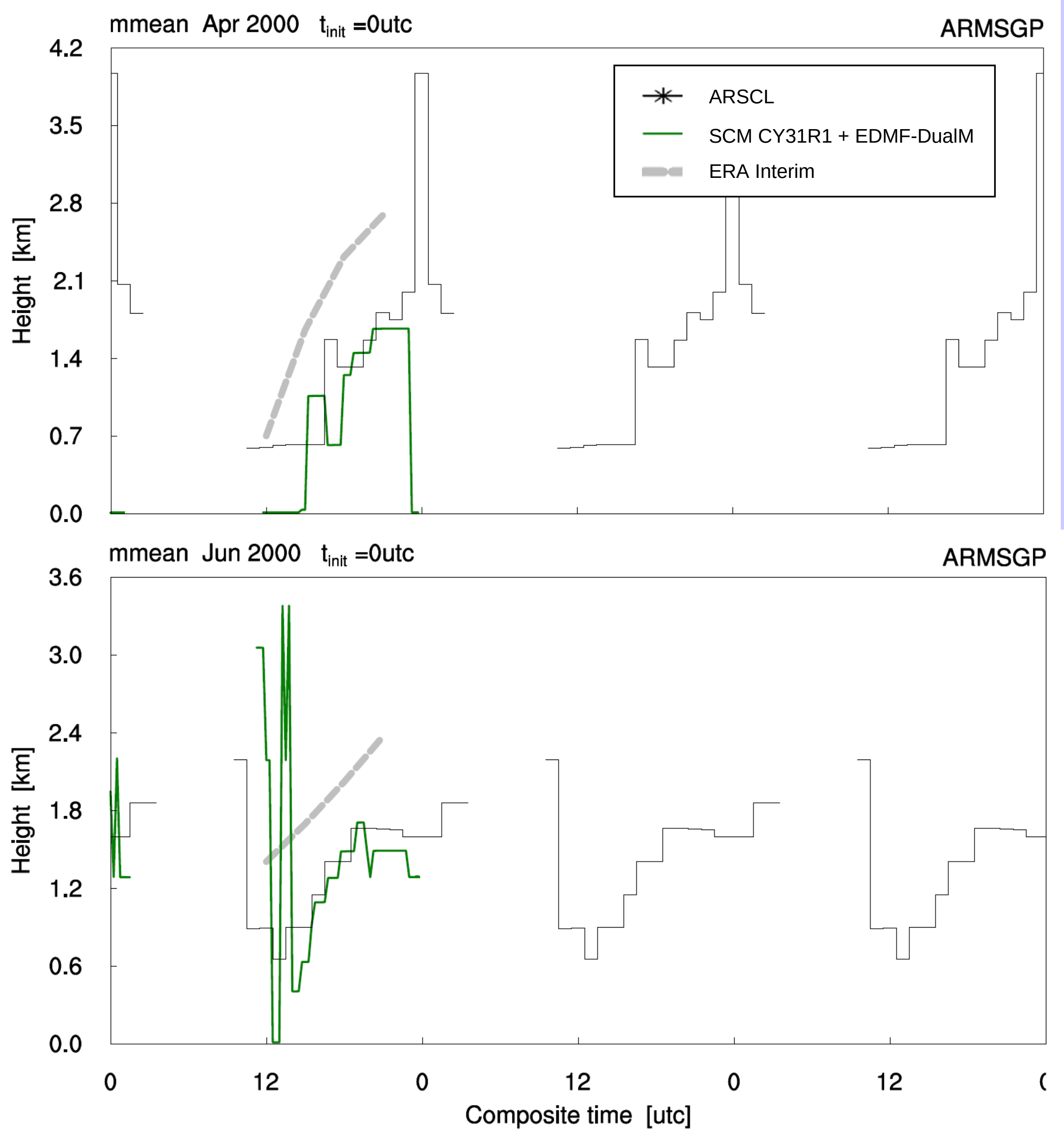


Process-level evaluation

Evaluation of the monthly mean height and time-development of the daytime maximum cloud fraction in the lowest 4km

** The typical diurnal rise of the peak in PBL cloud fraction can be distinguished*

** EDMF-DualM agrees better with ARSCL*

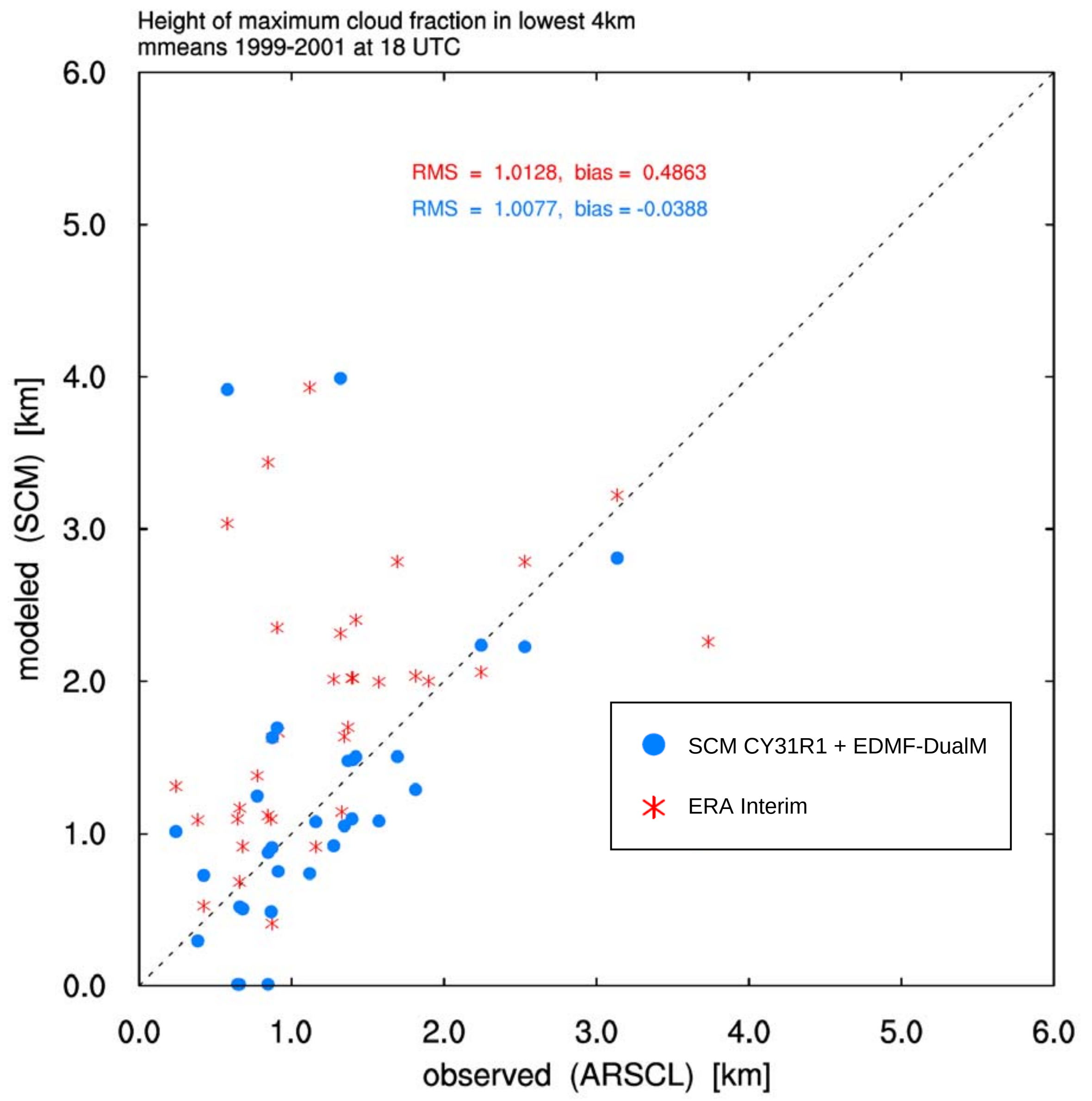


Better statistics:

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*



Summary / conclusions

Long-term SCM evaluation against ARM SGP datasets reveals that:

** The ice super-saturation routine in RACMO / IFS brings a significant improvement in high cloud occurrence*

** Typical results with EDMF-DualM on shallow cumulus cloud structure for the idealized GCSS RICO case also materialize in multi-year statistics at ARM SGP*