Climate modelling needs for upper-air data

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Contents

A report of Working Group I of the
Intergovernmental Panel on Climate Change

Summary for Policymakers

Human and Natural Drivers of Climate Change

[…]

- Anthropogenic contributions to aerosols (primarily sulphate, organic carbon, black carbon, nitrate and dust) together produce a cooling effect, with a total direct radiative forcing of –0.5 [–0.9 to –0.1] W m^{-2} and an indirect cloud albedo forcing of –0.7 [–1.8 to –0.3] W m^{-2}. These forcings are now better understood than at the time of the TAR due to improved *in situ*, satellite and ground-based measurements and more comprehensive modelling, but remain the dominant uncertainty in radiative forcing. Aerosols also influence cloud lifetime and precipitation. {2.4, 2.9, 7.5} […]

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Understanding and Attributing Climate Change

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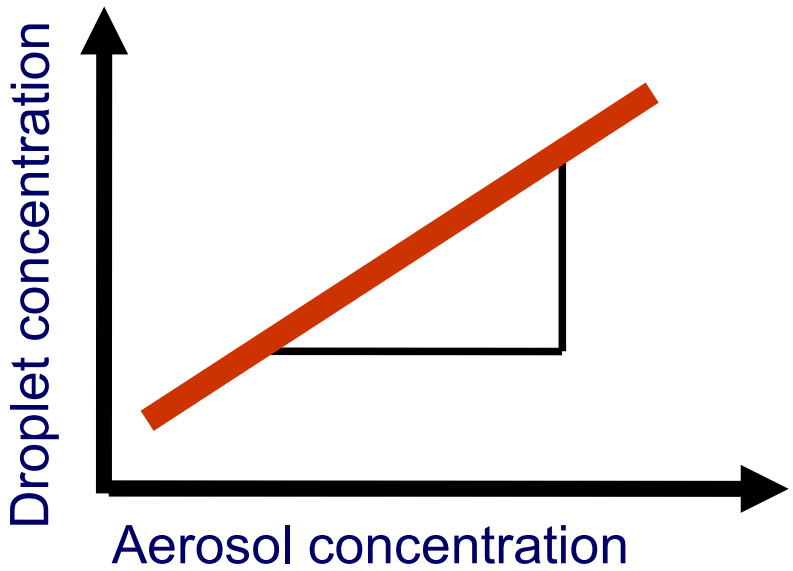
Climate model process evaluation

- A main science task: development of pertinent **observable metrics**

Aerosol-cloud interactions

- A main science task: development of pertinent **observable metrics**

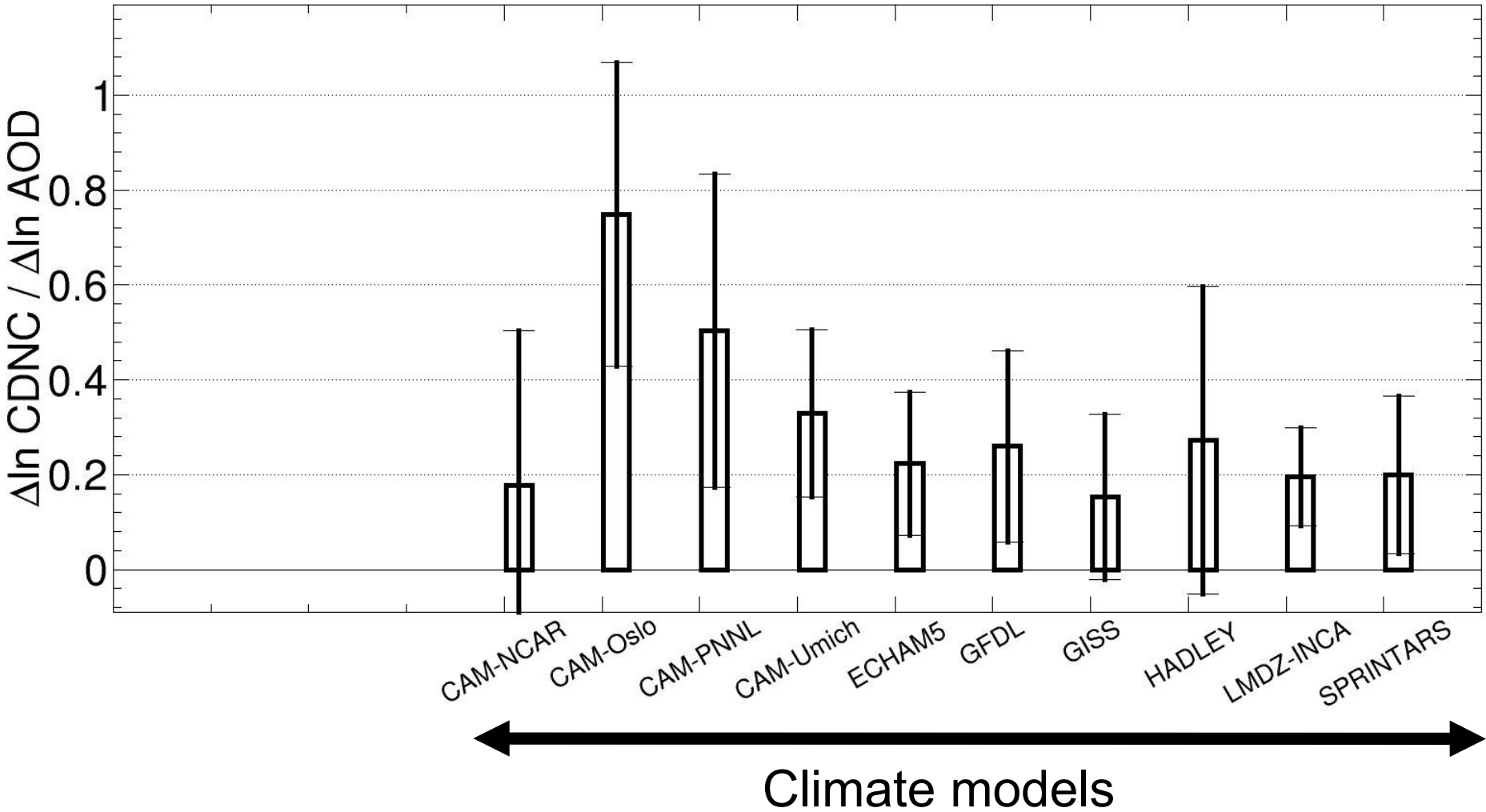


$$\text{Slope} = \frac{\Delta \ln \text{CDNC}}{\Delta \ln \text{AOD}}$$

CDNC – cloud droplet number concentration [cm^{-3}]
AOD – Aerosol optical depth

Feingold et al., Geophys. Res. Lett., 2003

AEROCOM: **Model evaluation of aerosol-cloud interactions**



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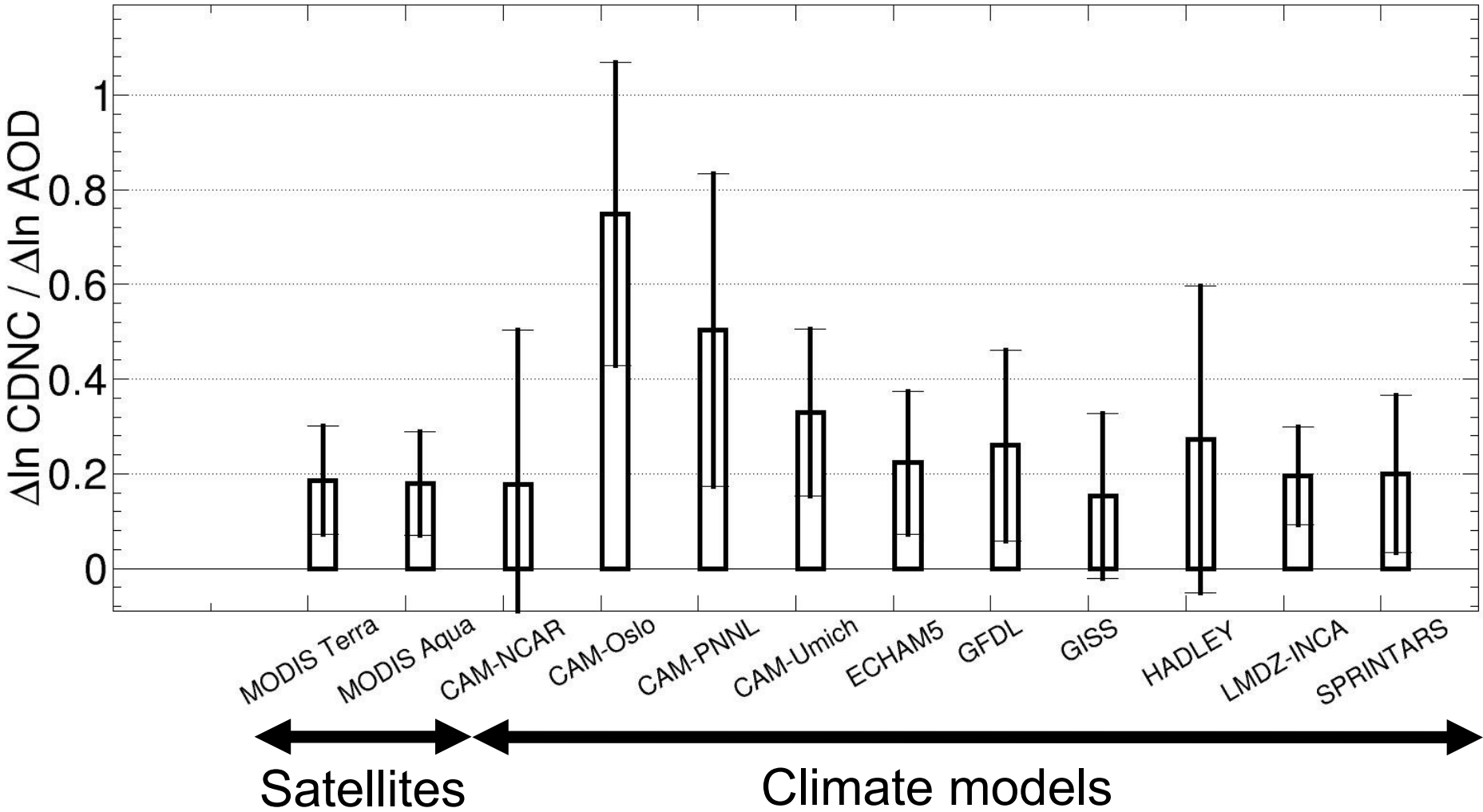

Quaas et al., Atmos. Chem. Phys., 2009

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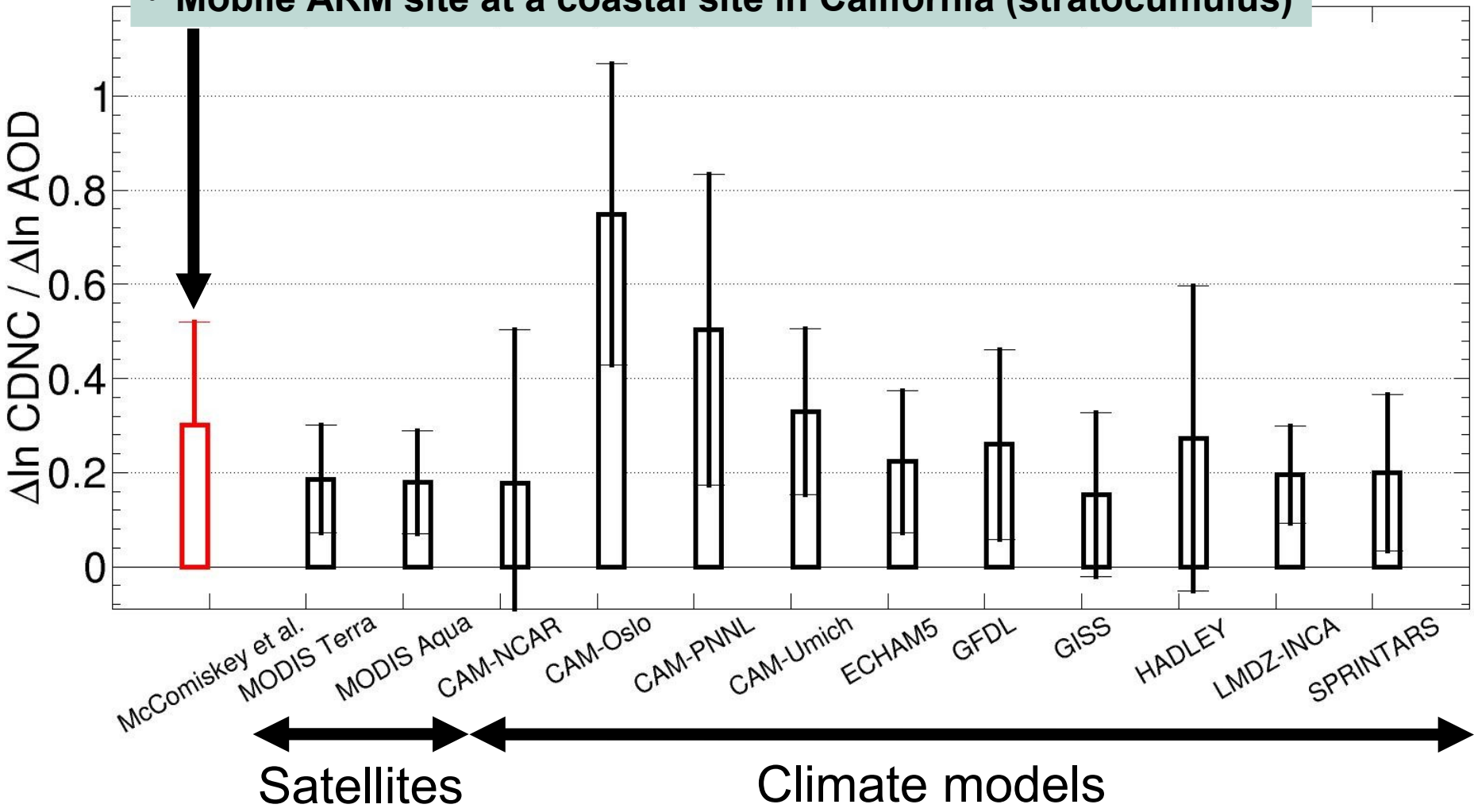

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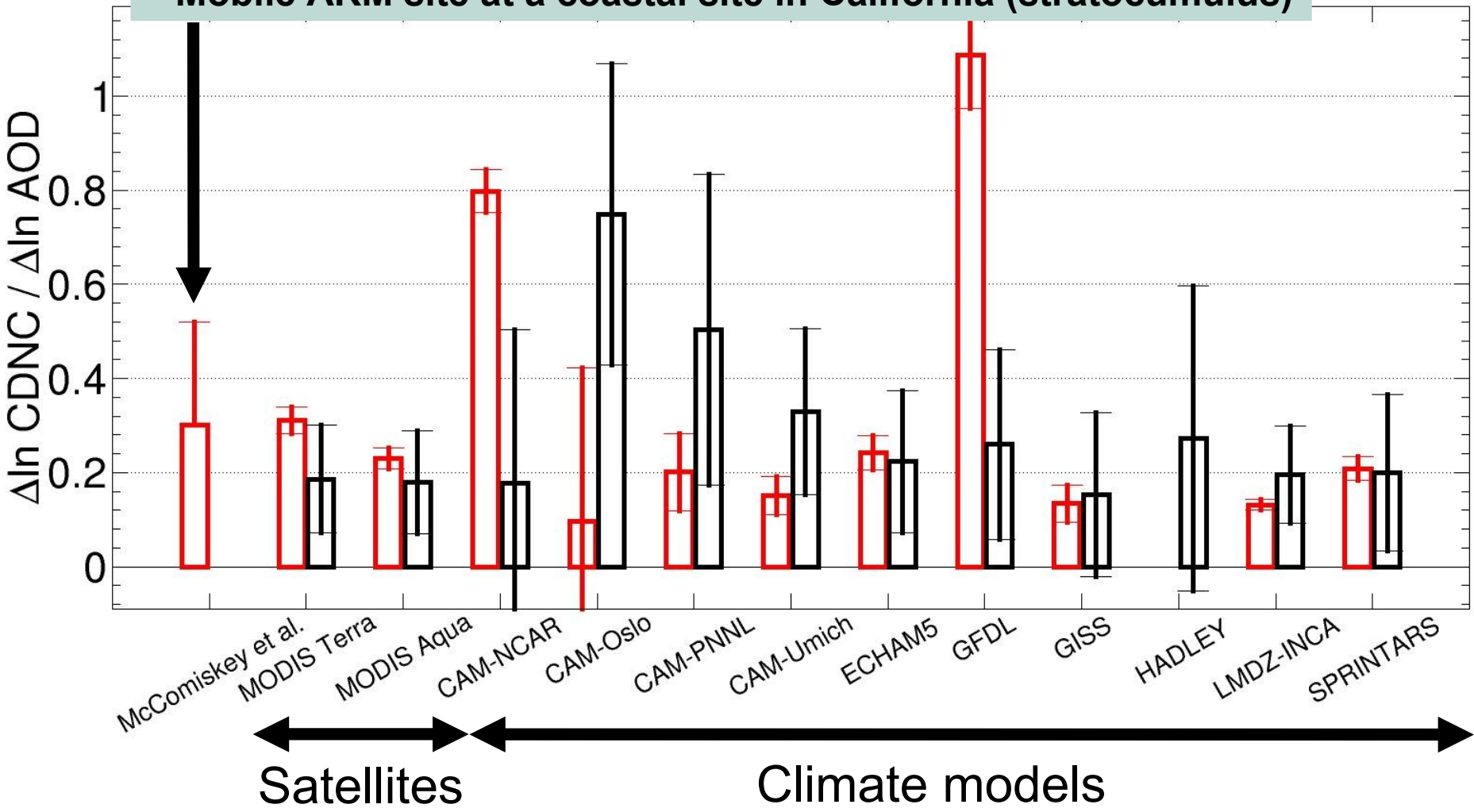

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ω	Vertical wind speed	–10 to 10 m s^{-1}	Environ-ment
RH	Relative humidity	20%–100% (up to 170% w.r.t. ice)	
TKE	Turbulent kinetic energy	0–10 m^2 s^{-2}	
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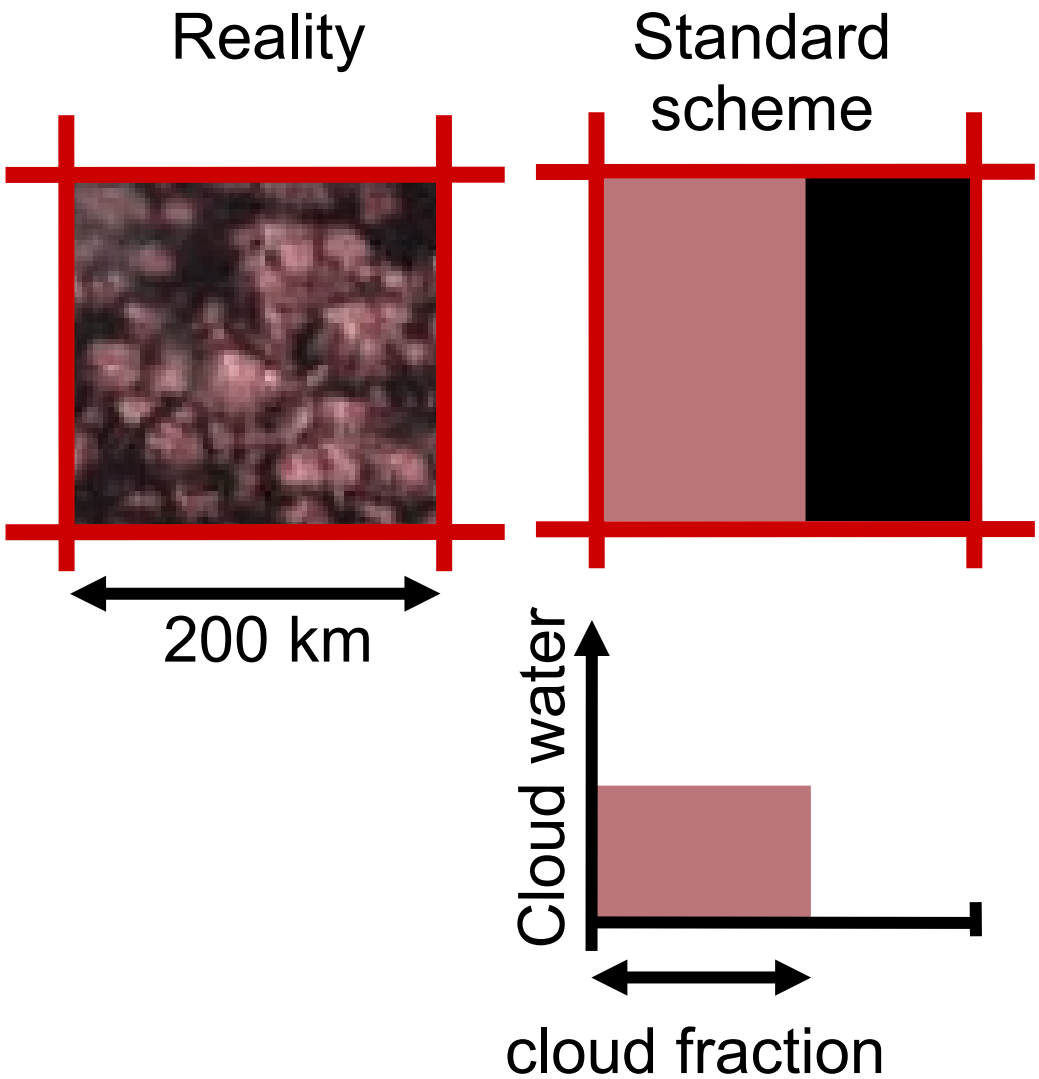
Statistical cloud scheme



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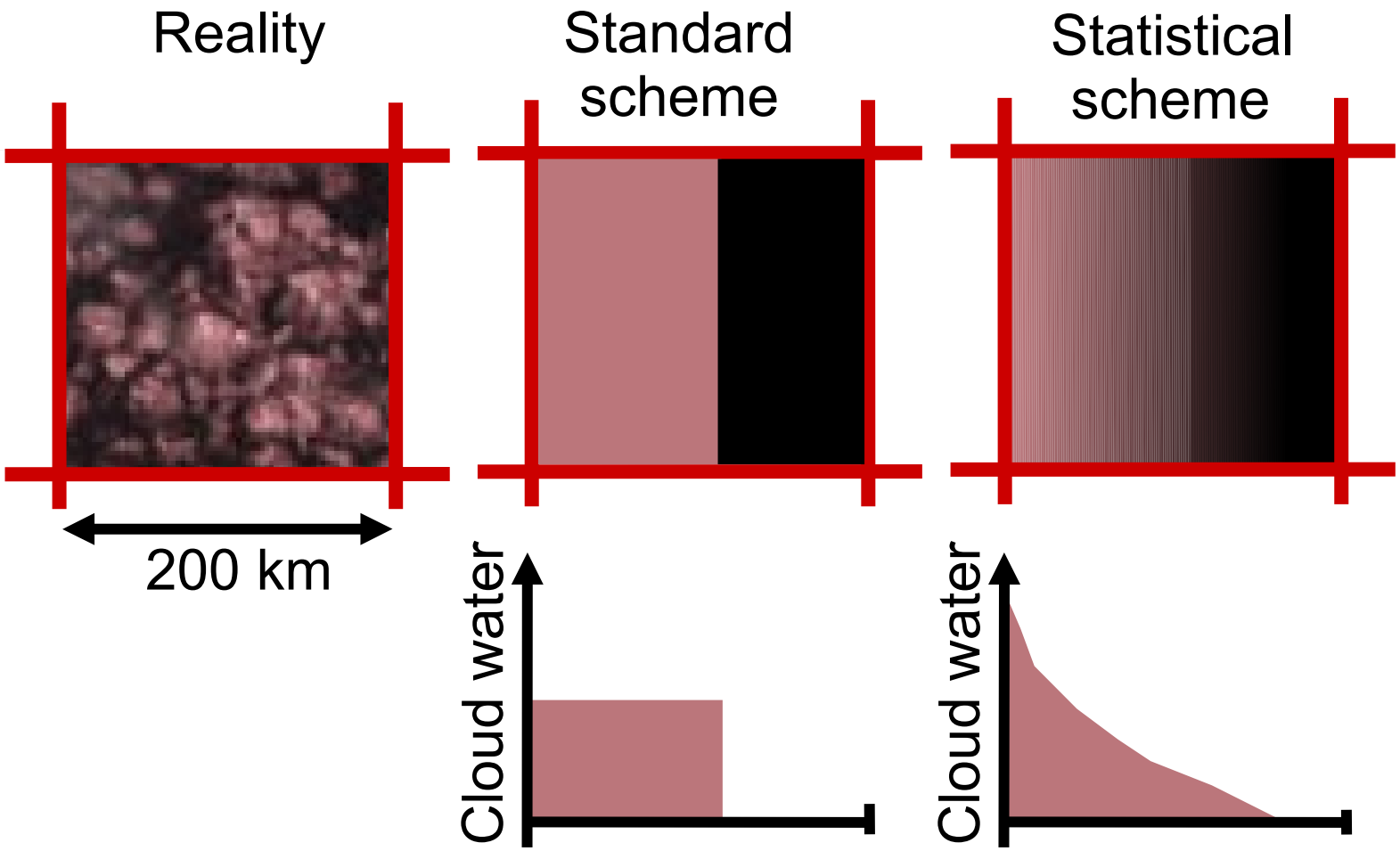
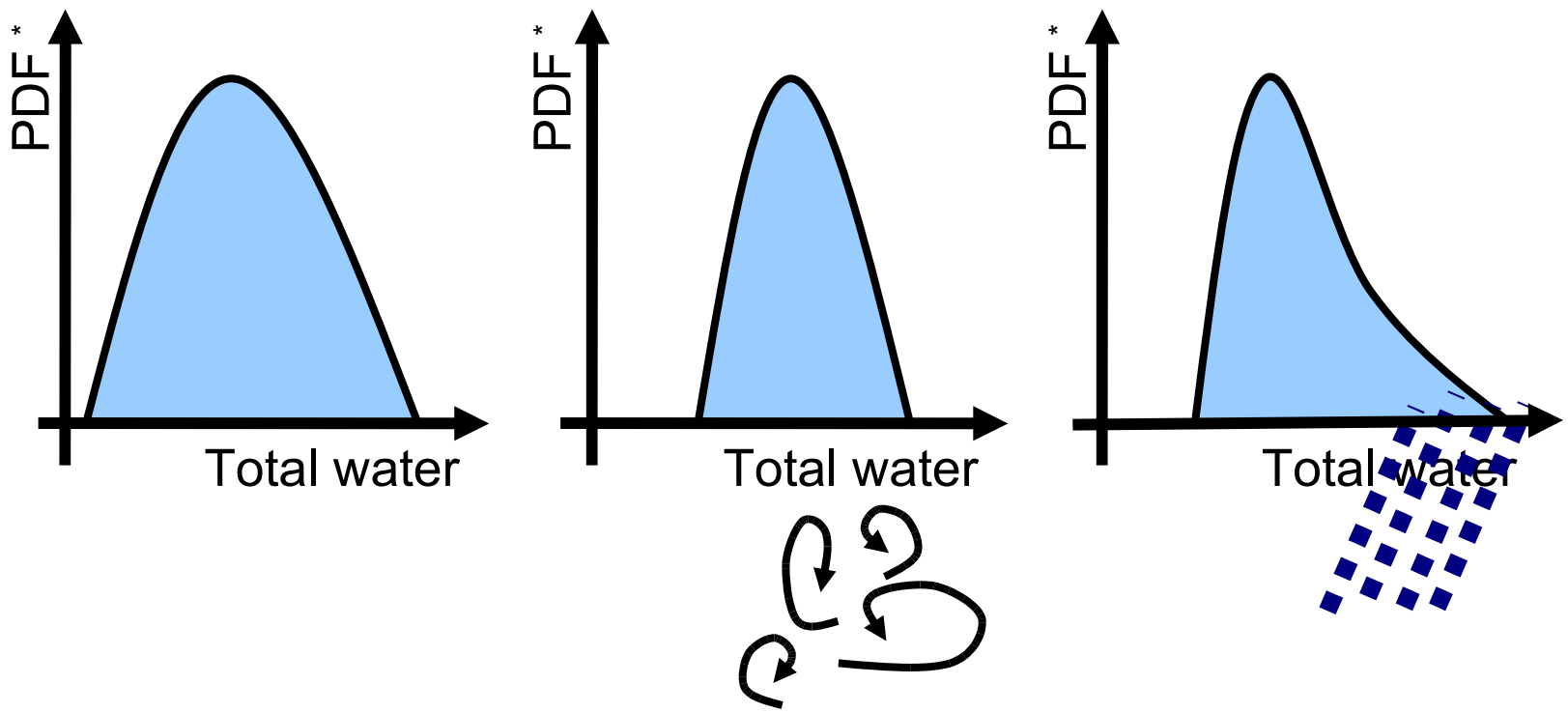


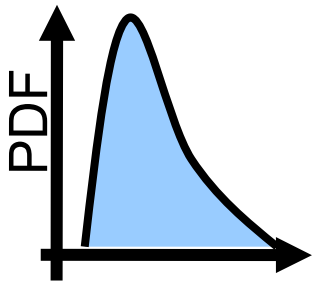
Statistical cloud scheme: simulation of higher moments



Turbulence dissipates variance

Precipitation reduces skewness

Tompkins, J. Atmos. Sci. 2002

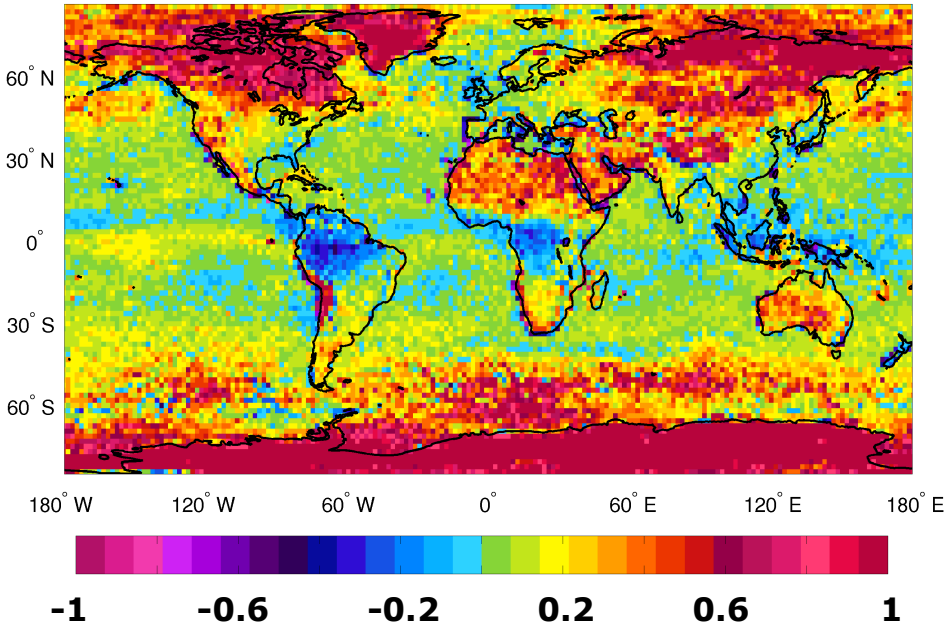


Statistical cloud scheme

MODIS satellite Data

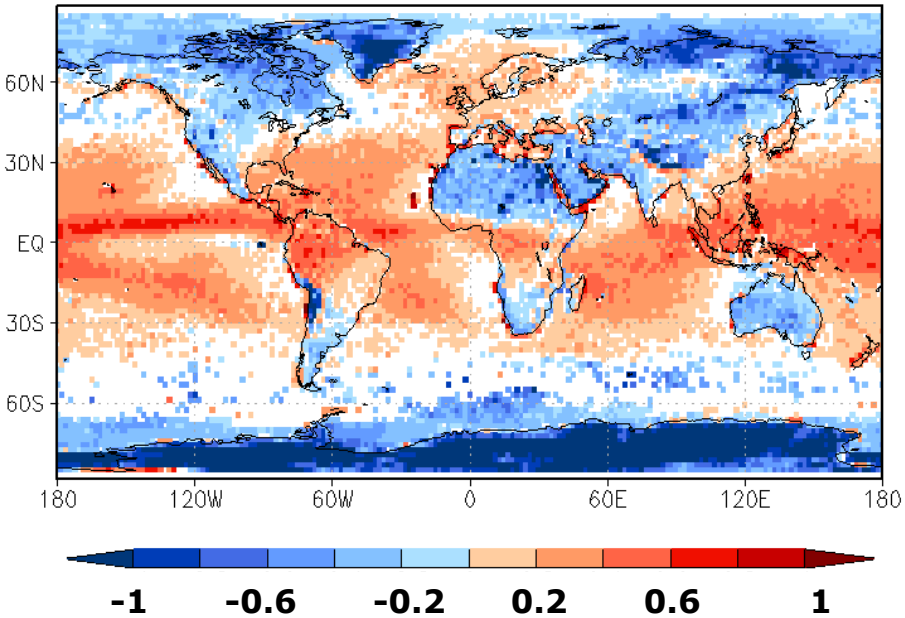
Model – Satellite Data

Skewness



Deviation skewness

global mean bias -8.46%

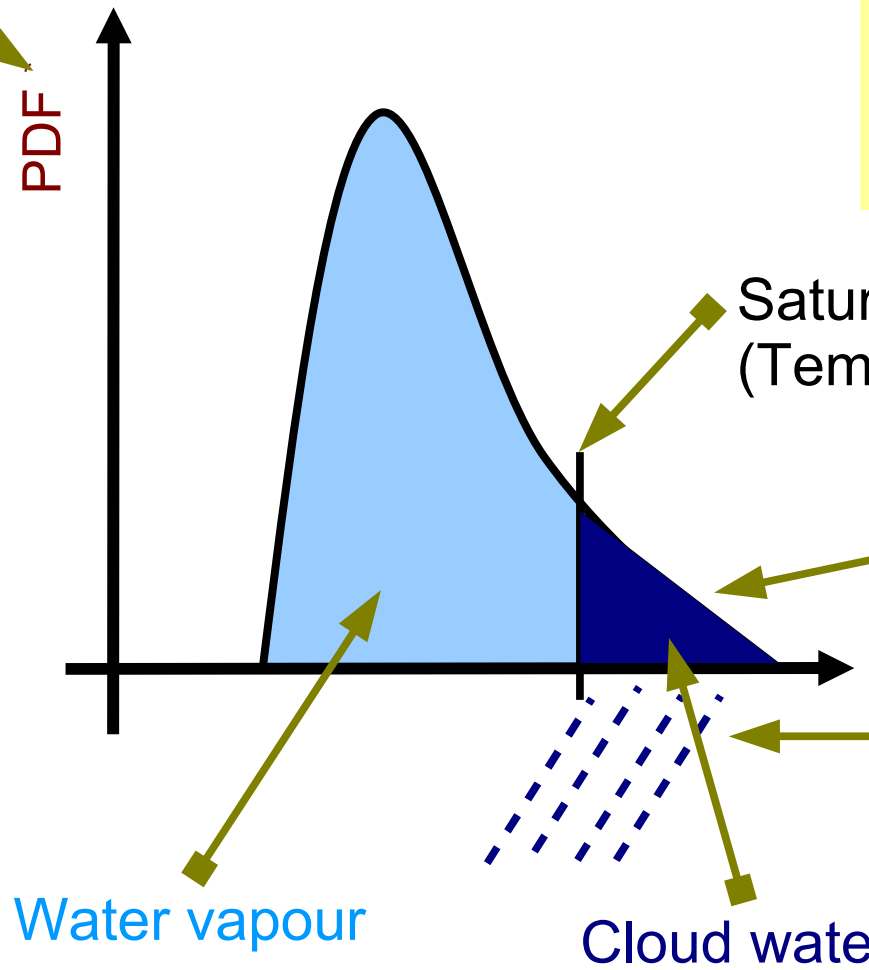


Statistical cloud scheme

Turbulence
Convection
Microphysics

Scales

temporal: 3-30 min
horizontal: 2-200 km
vertical: 50-500 m



KNMI parameterization testbed

- Aim: evaluation and improvement of GCM **parameterizations**
- Exploitation of **time-series** of super-site observations
- GCMs in **single-column-mode** (SCM)
- **Sensitivity studies**, evaluation, test of new parameterizations

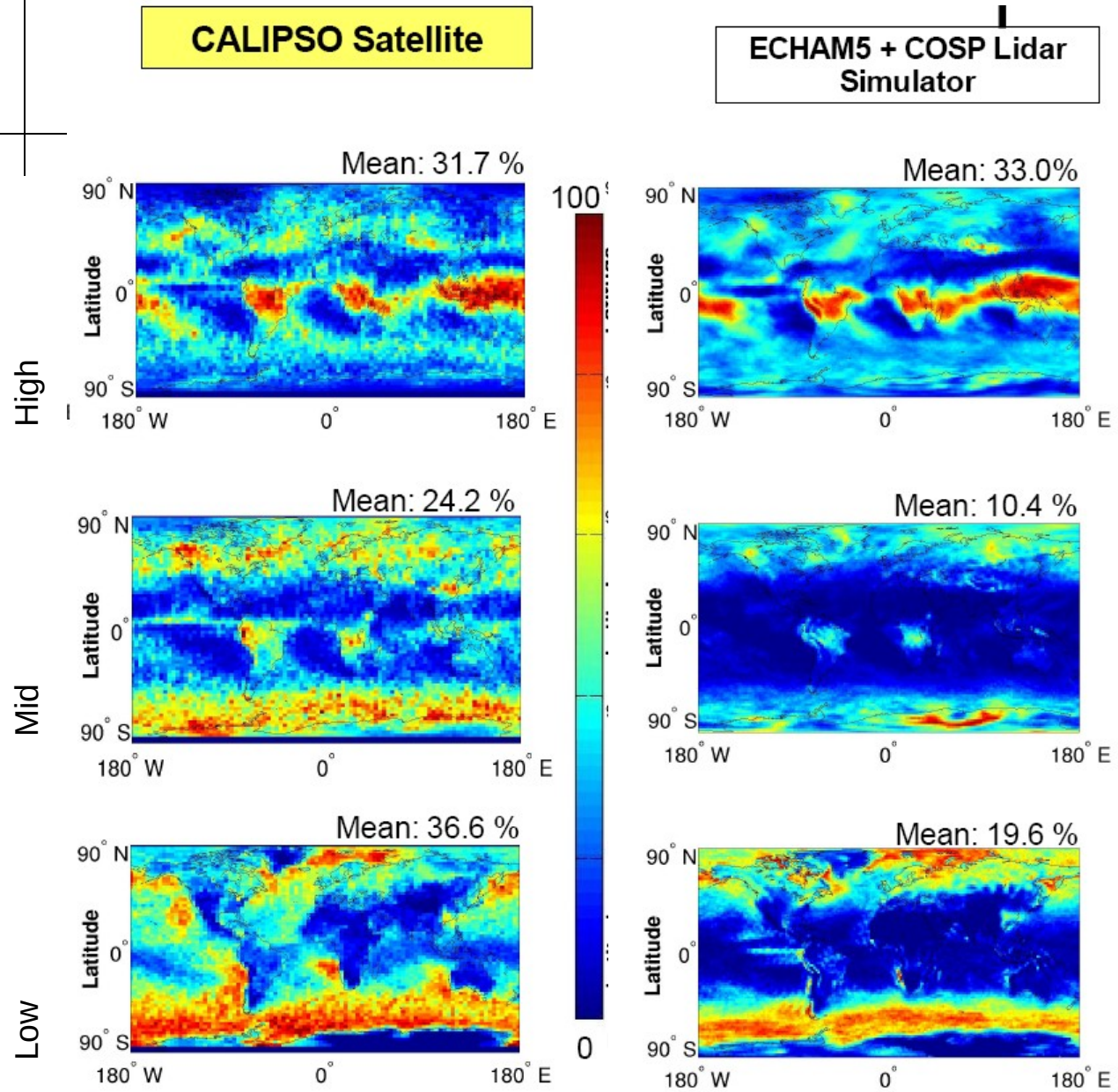
Courtesy Roel Neggers, KNMI

Step I: COSP evaluation of clouds in ECHAM5

Figure courtesy of Christine Nam, MPI Hamburg

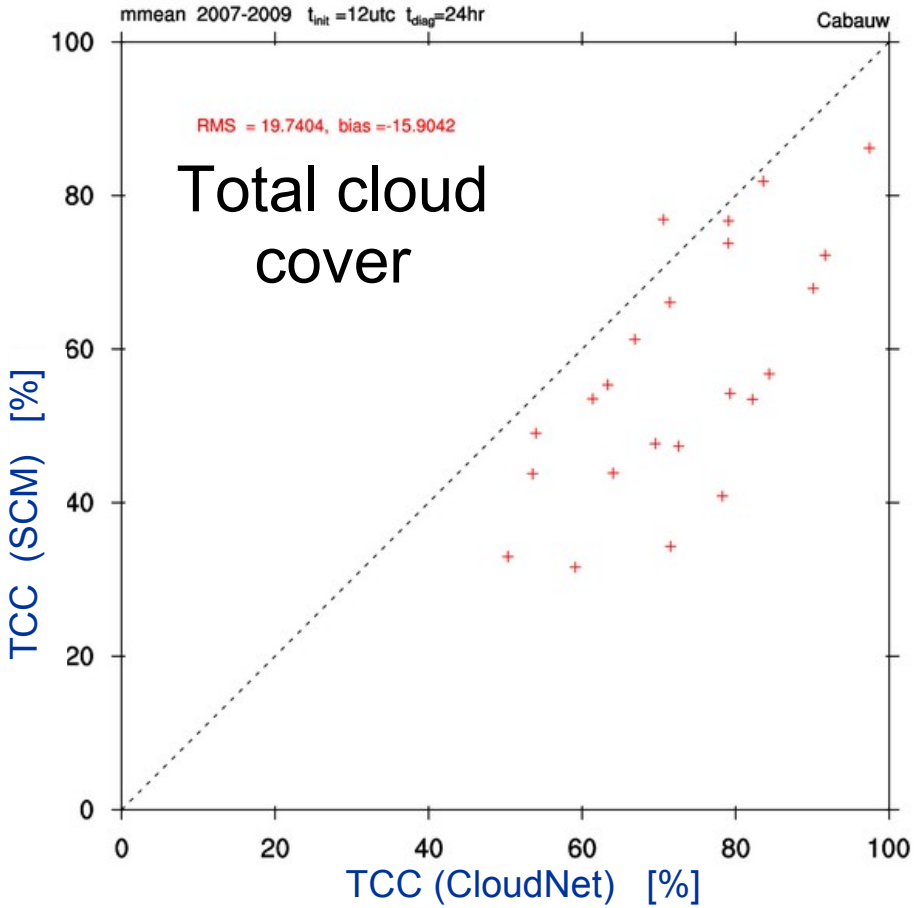
JFM 2007 Cloud cover

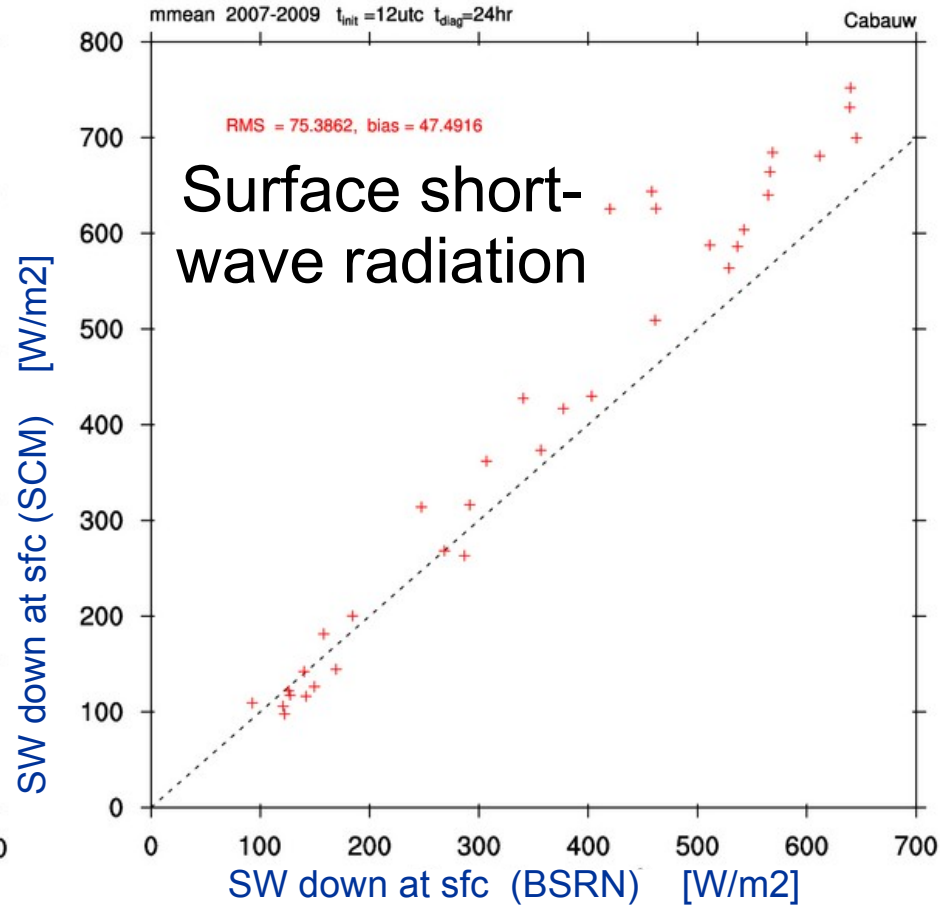
ECHAM5 significantly lacks low and midlevel clouds



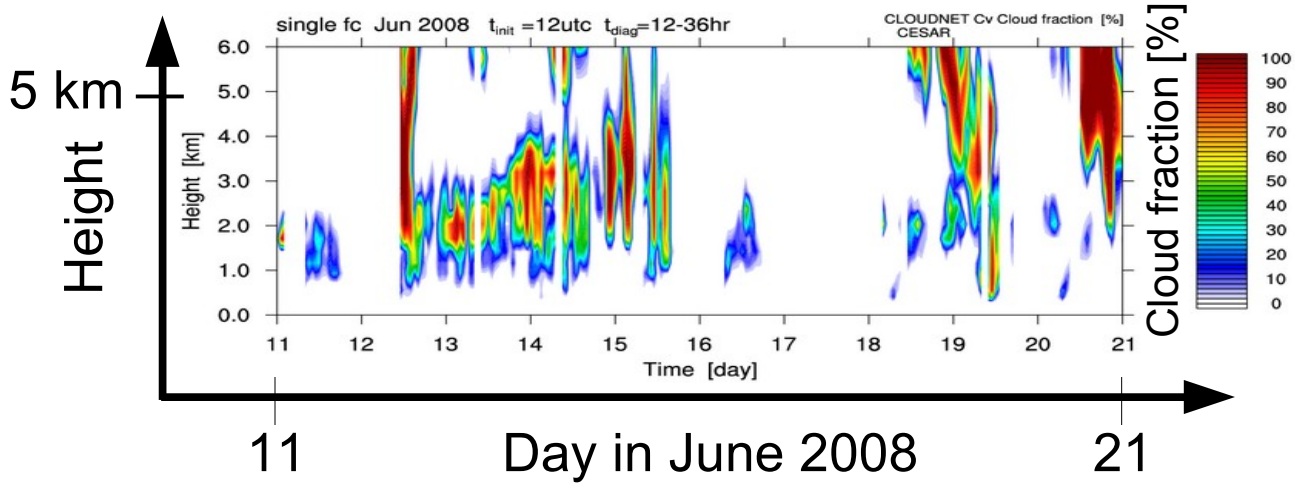
Step II: Does the SCM reproduce the GCM behavior?

Observed (x) versus SCM (y) monthly means at 12 UTC for 2007-2009 at Cabauw





Neggers et al., in preparation for Bull. Am. Meteorol. Soc.



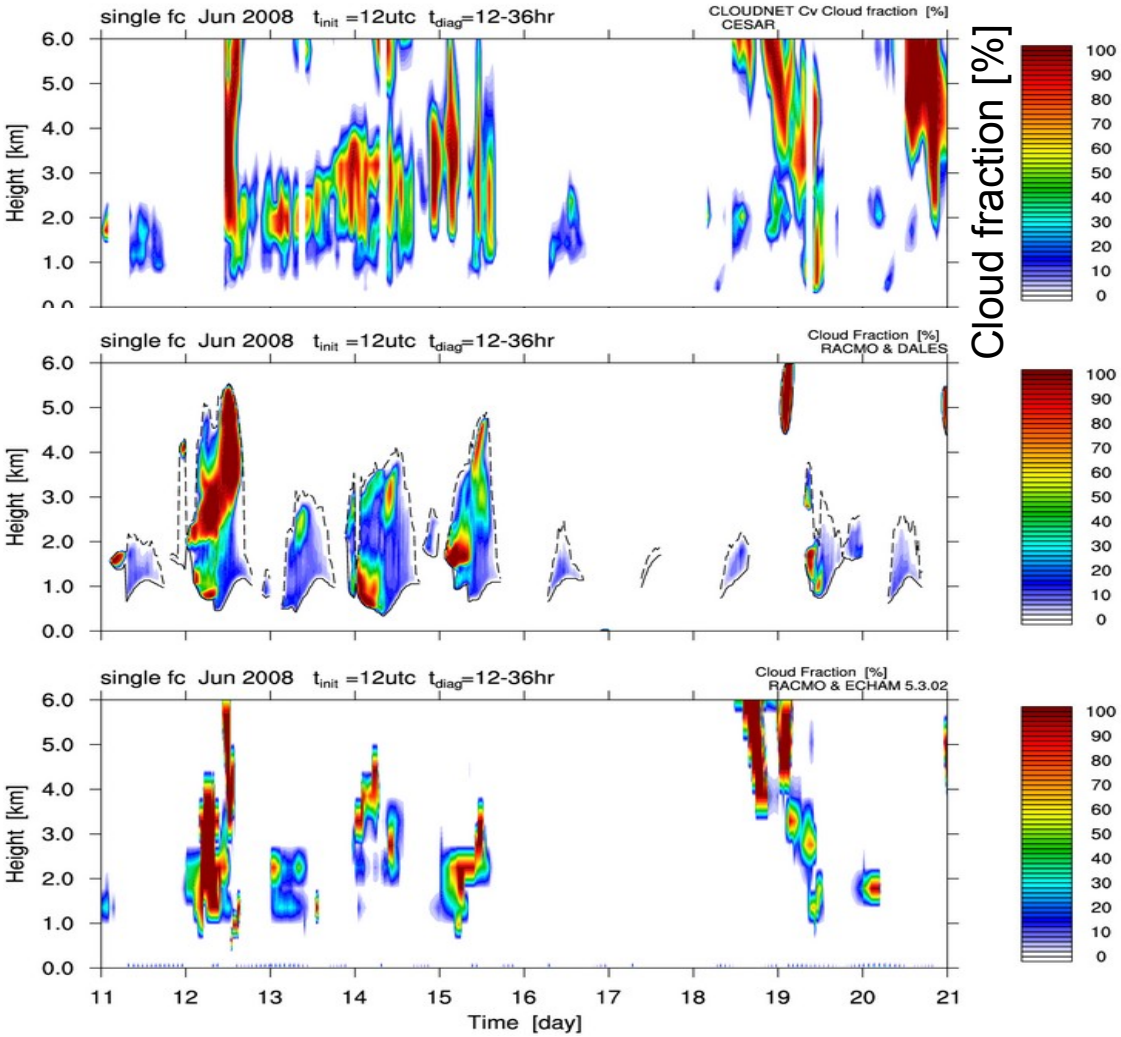
Cloudnet product
from Radar-/Lidar observations

Courtesy Roel Neggers, KNMI

Cloudnet

Large-eddy simulation

Single-column model



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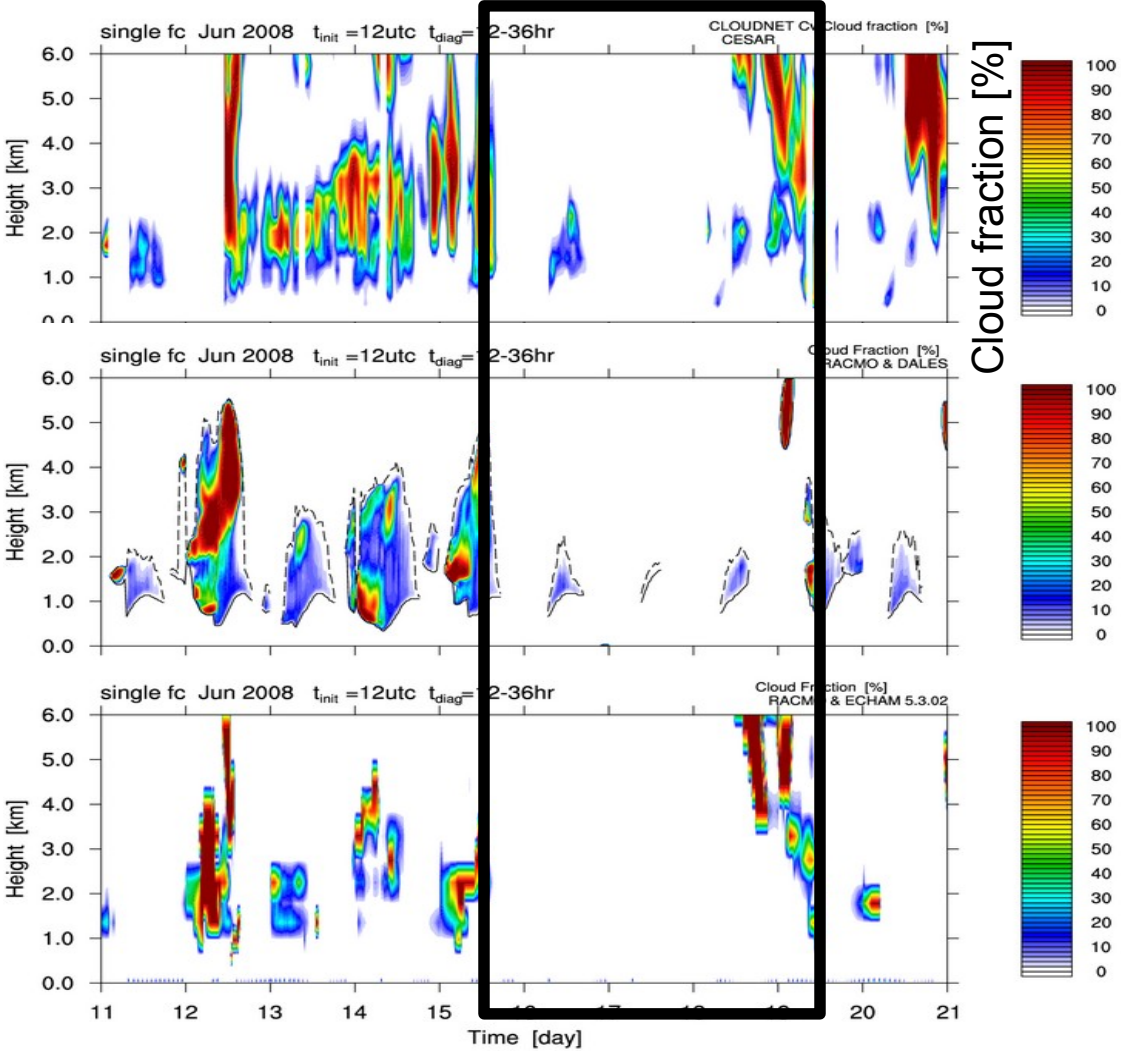

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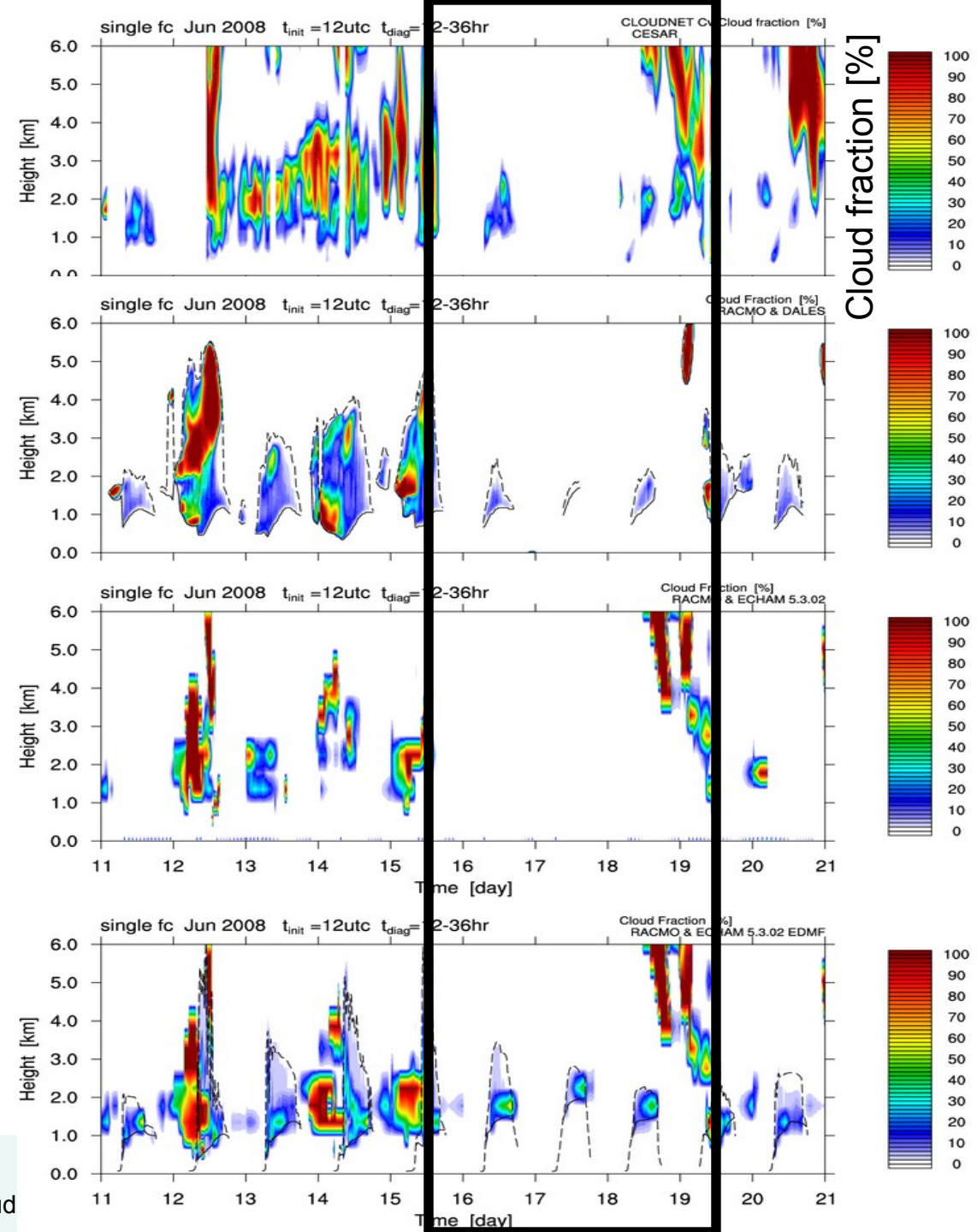
New para-meterization



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Priorities for GCM modelling

- Large **parameter set** crucial for process-oriented evaluations
- Specific and relative **humidity** priorities
  (satellites: only coarse resolution)
- Sound statistics essential
  Frequent sampling, long time-series, global network
- Uncertainty quantification highly welcomed
  Data assimilation, satellite data assessment
- Easy access would be welcomed
  Netcdf format, web dissemination

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Acknowledgements

The **AEROCOM** team
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C. **Nam**, T. **Weber**,
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Lohmann, Quaas, Feichter, Kinne, Bull. Am. Meteorol. Soc. 2007

Data requirements – a “wish list”

Table 2. Attribution of the parameters listed in Table 1 to the evaluation of the different aerosol indirect effect mechanisms, including the required data resolution.

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Cloud lifetime effect	—	N_d SD_d, LWC, AU, CC	TKE	1 km, 100 m, 1 h
Semi-direct effect	N_a, SSA, BC(z)	LWC, CC	RH	10 km, 1 km, 6 h
Aerosol effects on mixed-phased and ice clouds	N_a, SD_a, SF_a, AT	N_i, SD_i, IWC, CC	w, RH, T	1 km, 100 m, 1 h

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Semi-direct aerosol effect

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Aerosol effects on mixed-phase and ice clouds

Data requirements – a “wish list”

Statistical cloud scheme	
Physical quantity	**Desired resolution**
Water vapour mixing ratio [kg kg^{-1}]	1 km x 100 m x 1 min
Cloud water mixing ratio [kg kg^{-1}]	
Temperature [K]	
Convective mass-flux [m s^{-1}]	
Turbulence kinetic energy [m^2 s^{-2}]	
Autoconversion rate [kg kg^{-1} s^{-1}]	