New Insights in parameterizations of precipitation and ice-microphysics

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with contributions of :
Stephan de Roode, Erik van Meijgaard, Gerd-Jan Zadelhof, Geert Lenderink, Margreet van Zanten and Louise Nuyens (KNMI)

- ✓ ~~Turbulent mixing~~
- ✓ Precipitation
- ✓ ~~Cloud Inhomogenity and radiation~~
- ✓ Ice-cloud Microphysics

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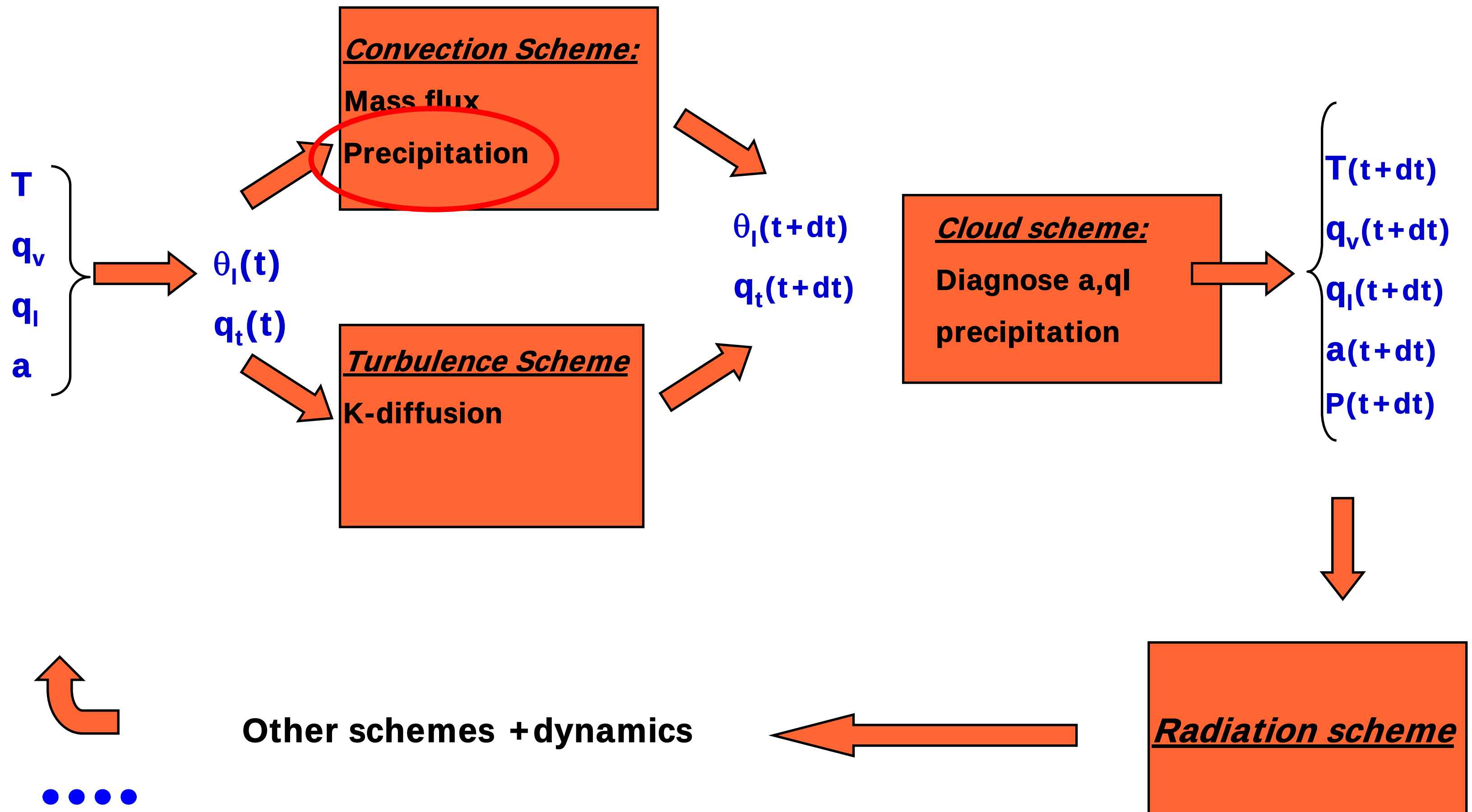
....The various parameterization building blocks connected to clouds are usually organized as:



Precipitation over the Rhine catchment

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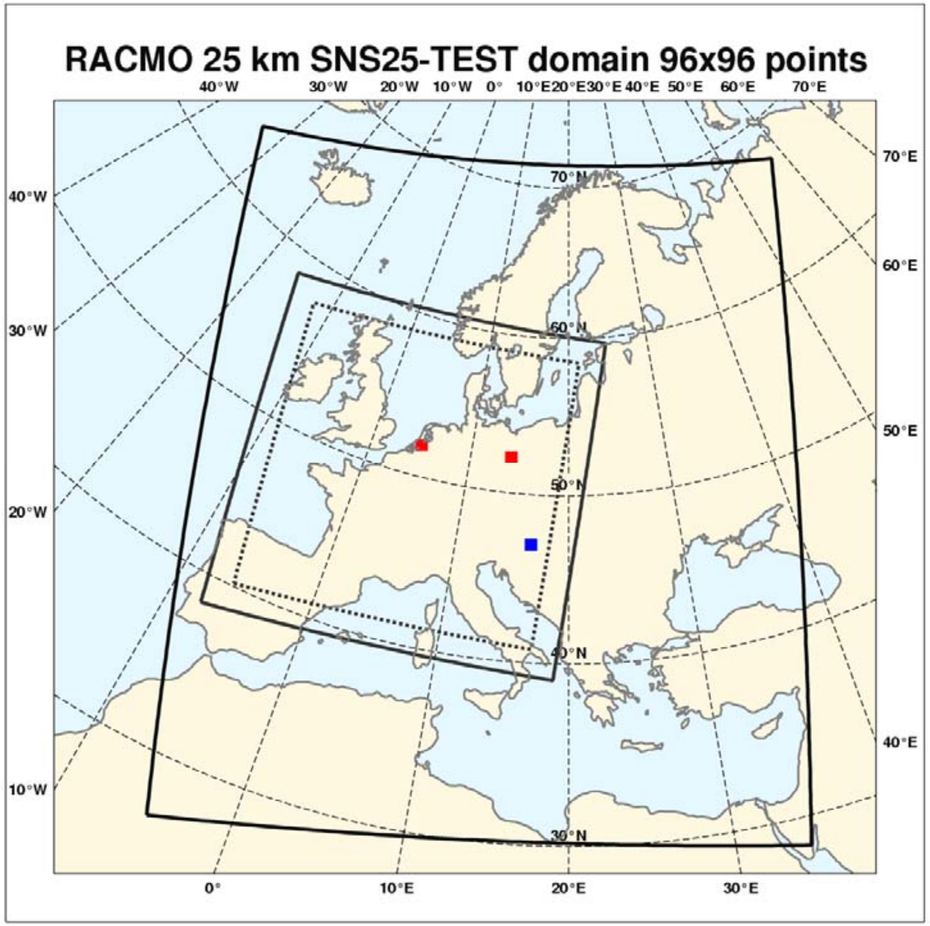

- 5 year integration
- Boundaries: ERA40
- RACMO-CTL : “23r4”
- RACMO-NEW : “25r4”

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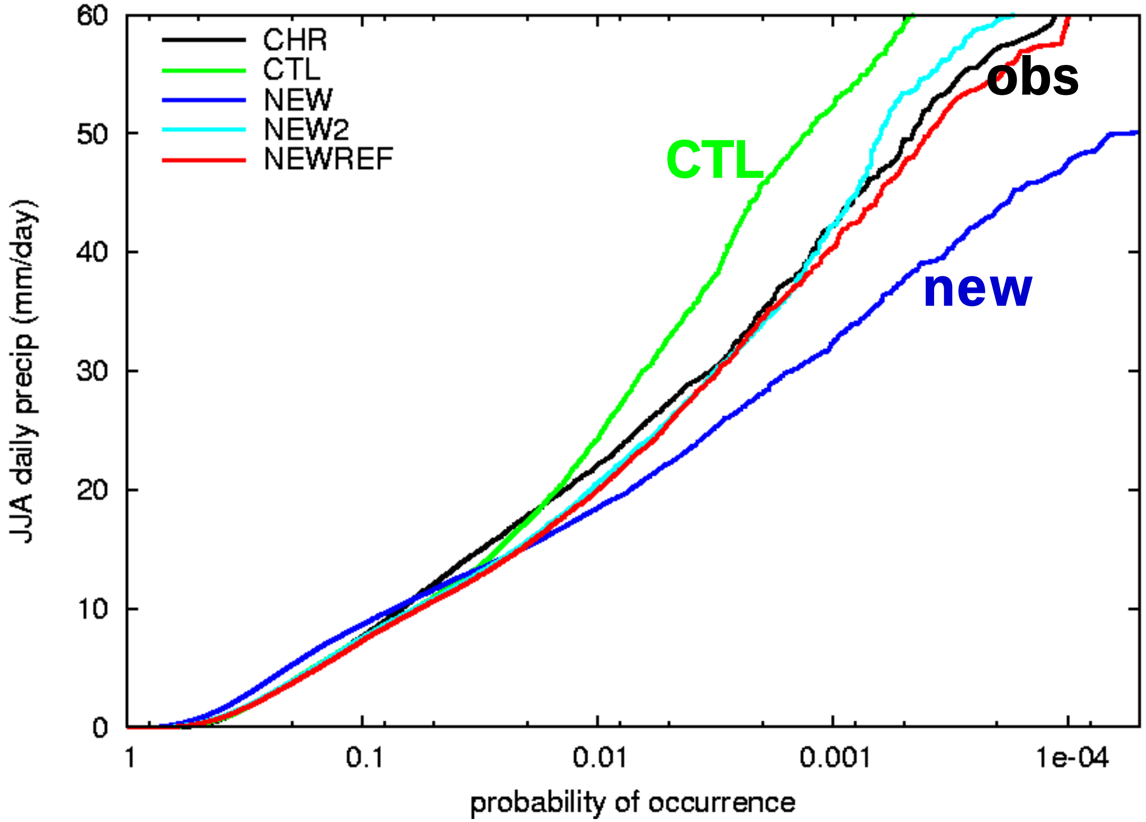
Precipitation Histogram of JJA for 1991-1995 for the Rhine catchment area



Ctl (23r4) :

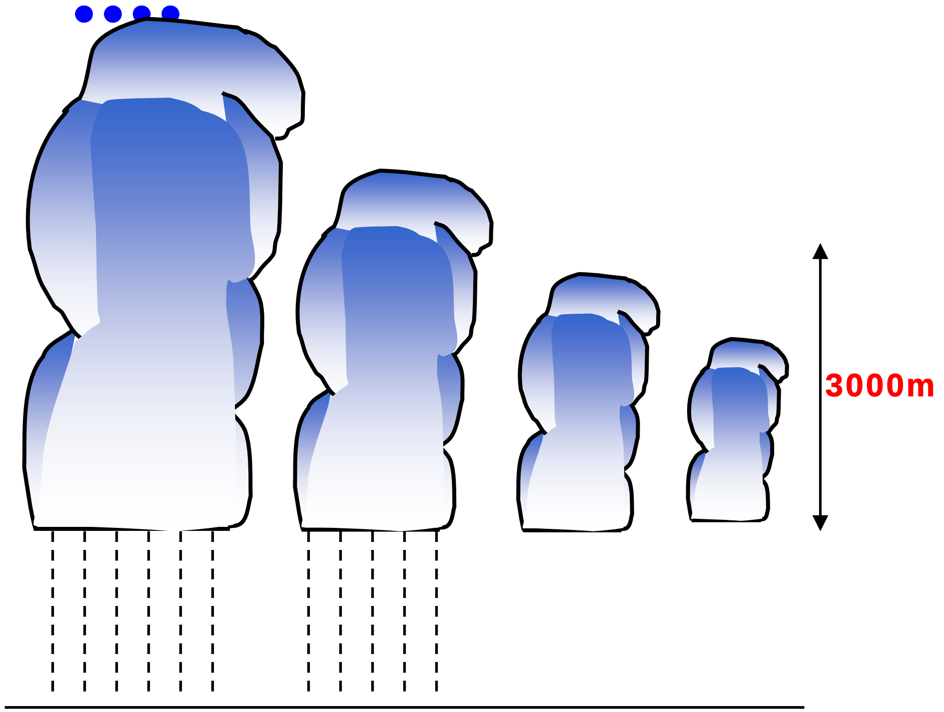
- **Too few low precipitation rate events.**
- **Too many high precipitation rate events**

Ctl (25r4) :

- **Too many low precipitation rate events.**
- **Too few high precipitation rate events**
- **Lower extreme events!!**

Howcome?

Almost exclusively due to a one line code change......



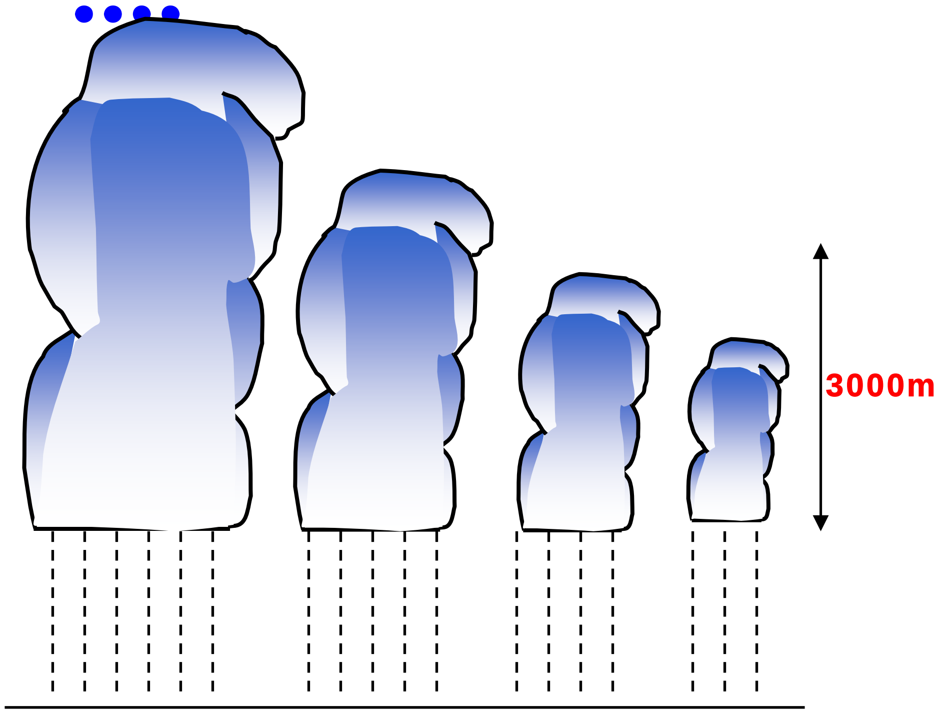
Control (23r4) :

clouds shallower than 3000m are not allowed to precipitate:

- **Obviously reduces the "moderate rain intensity events"**
- **Allows more extreme rain events to build up.**

As opposed to..........

Almost exclusively due to a one line code change……



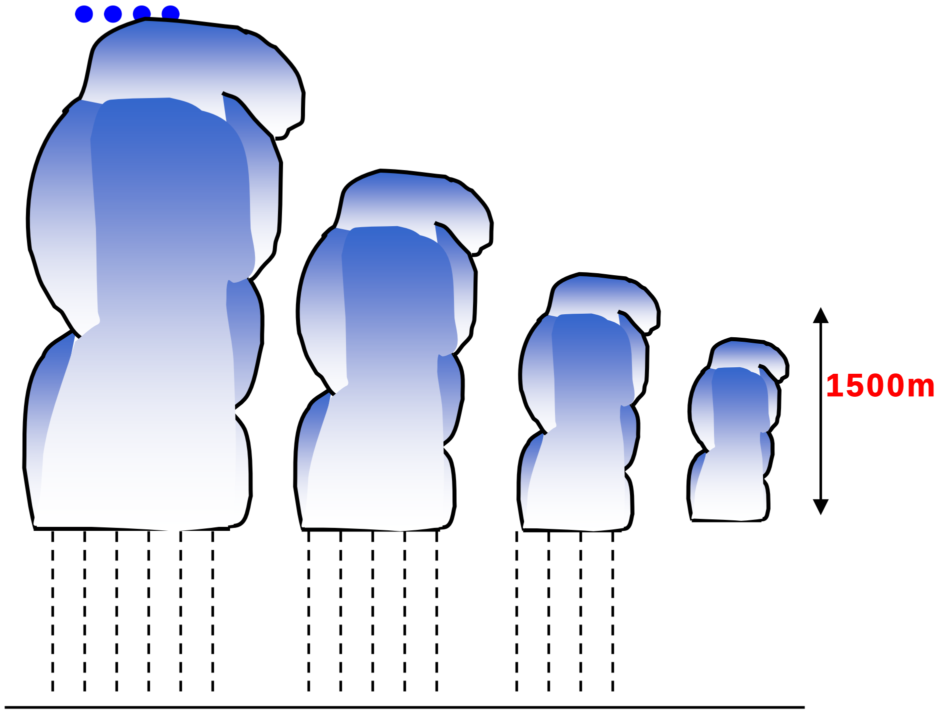
New (25r4) :

In which all clouds are allowed to precipitate (if enough ql):

- **Obviously encourages the "moderate rain intensity events"**
- **Prohibits more extreme rain events to build up.**

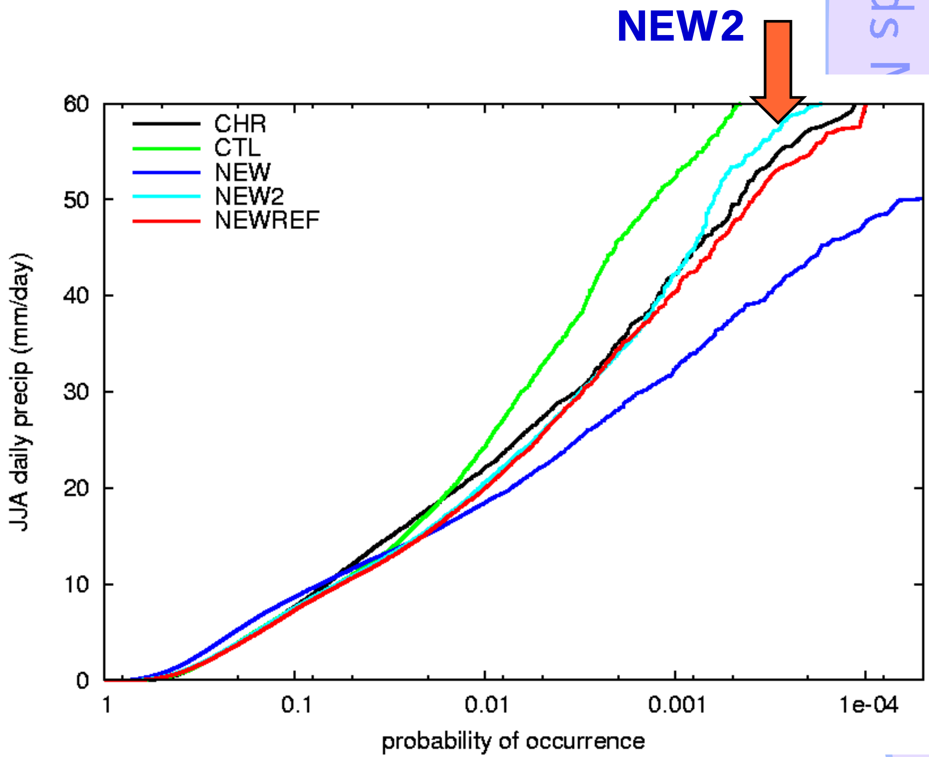
So as a (temporary) fix:

.....On can prohibit clouds of 1500m to precipitate



•This merely shows the sensivity of the overall precipation statistics to the precipitation efficiency of shallow clouds!!

•••• and luckily......



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Latest GCSS Boundary Layer Clouds Working Group (GCSS-BLCWG) Intercomparison case is based on Precipitating shallow cumulus such as observed during

RICO

Rain In Cumulus over the Ocean

"To understand shallow cumulus and processes involved at all relevant scales, with special attention to precipitation "

Information: **www.knmi.nl/samenw/rico**

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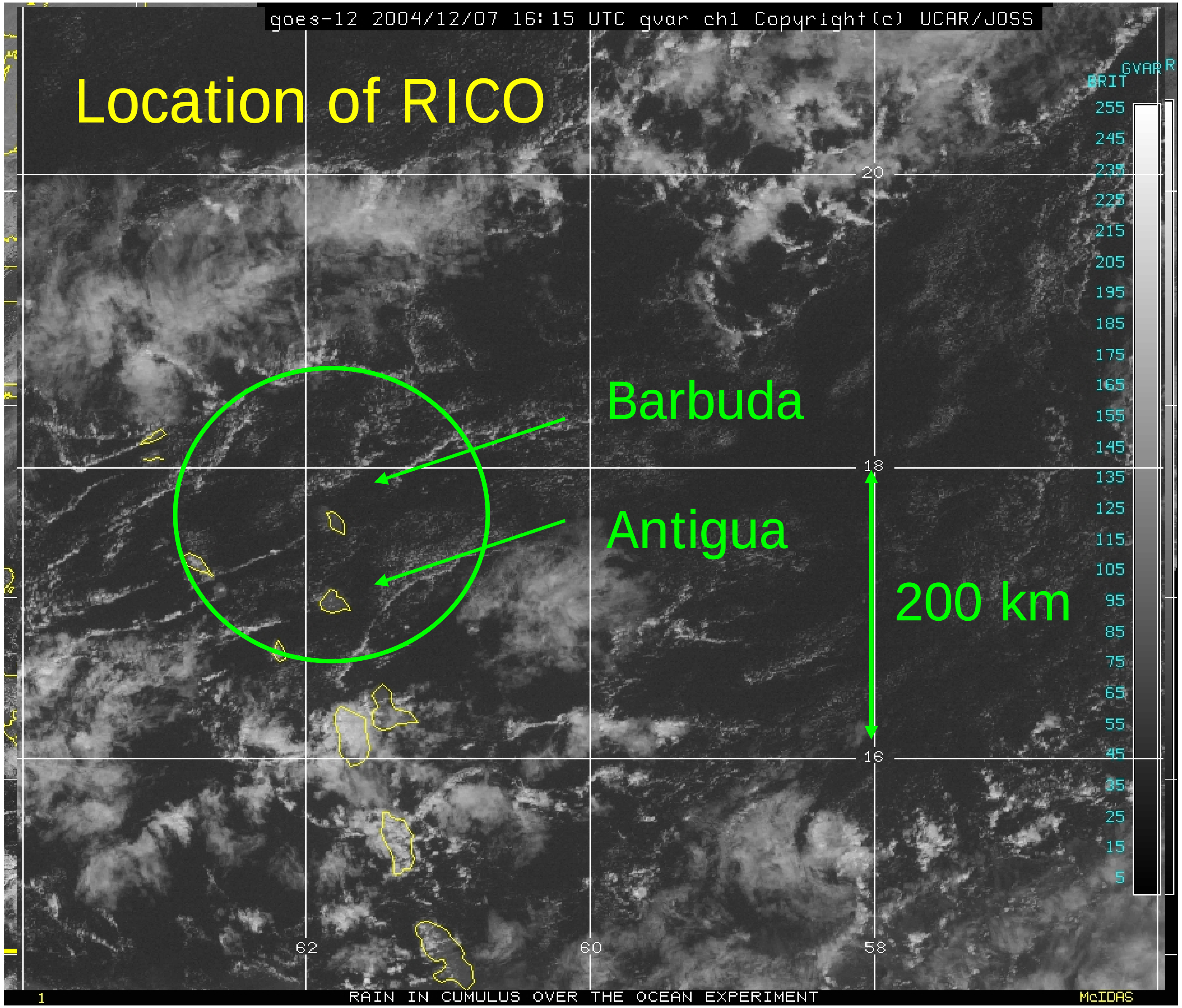
The RICO field study (B. Rauber, L. di Girolamo, H. Gerber, L. Nuijens, B. Stevens



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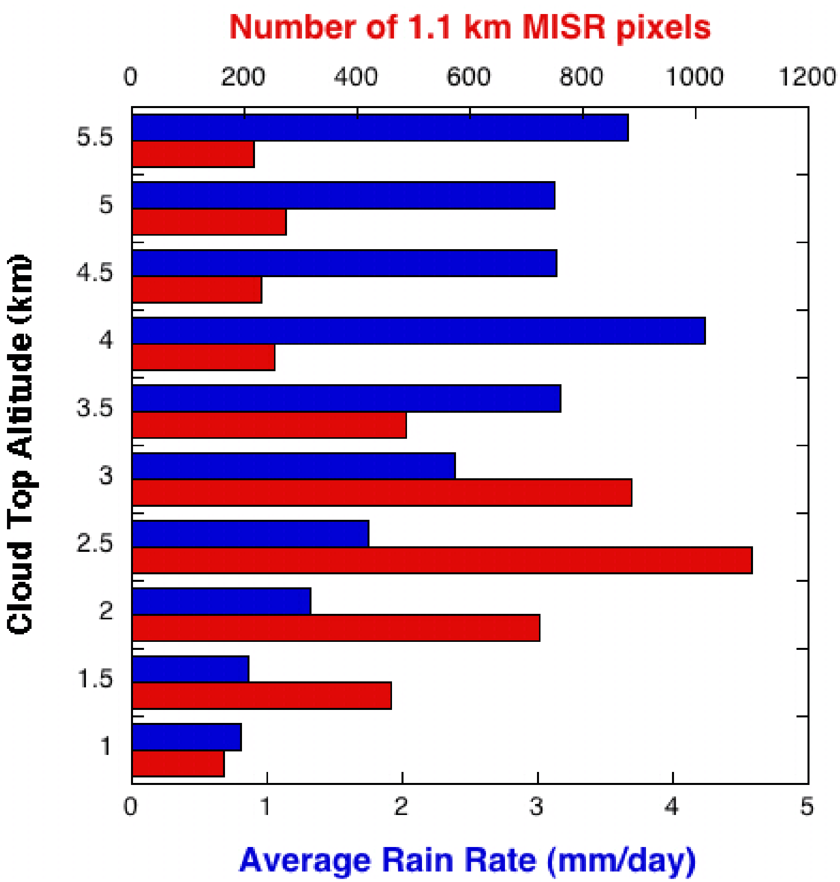
•••• By co-locating rainradar data with MISR it is been possible to obtain a relation between cloud depth and precipitation rate:



- **Clouds as shallow as 500m do precipitate**
- **"linear" relationship cloud depth versus precipitation rate**

Courtesy: Larry Di Girolamo (U. of Utah

Intercomparison Modelling Strategy:

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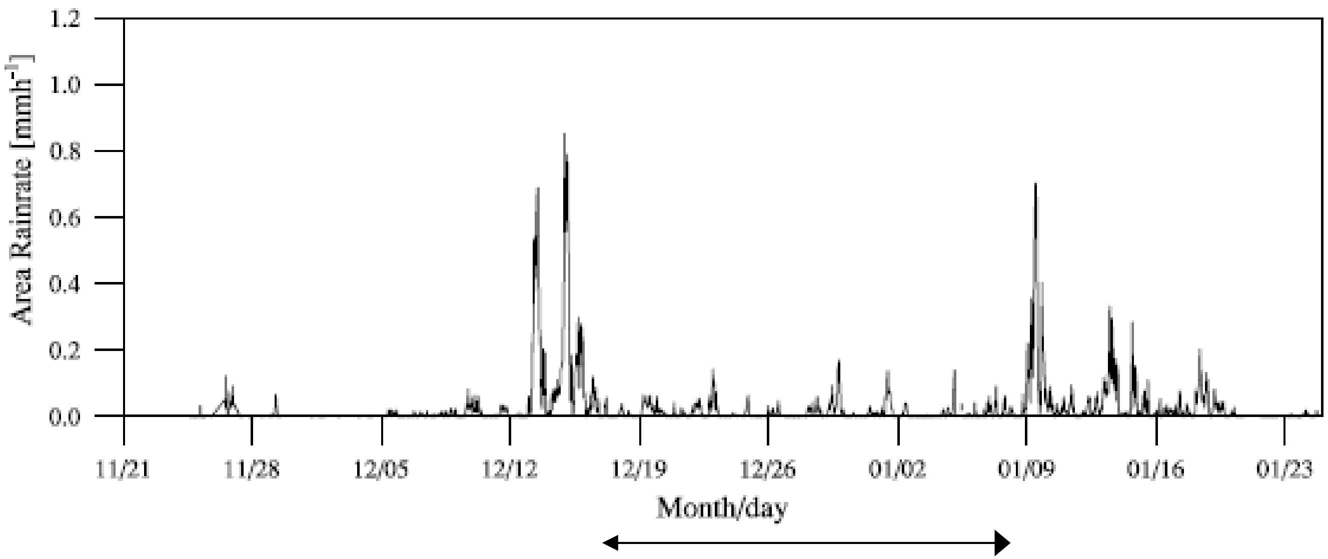
Construct a composite based on a suppressed period

from 16/12/04 till 08/01/05



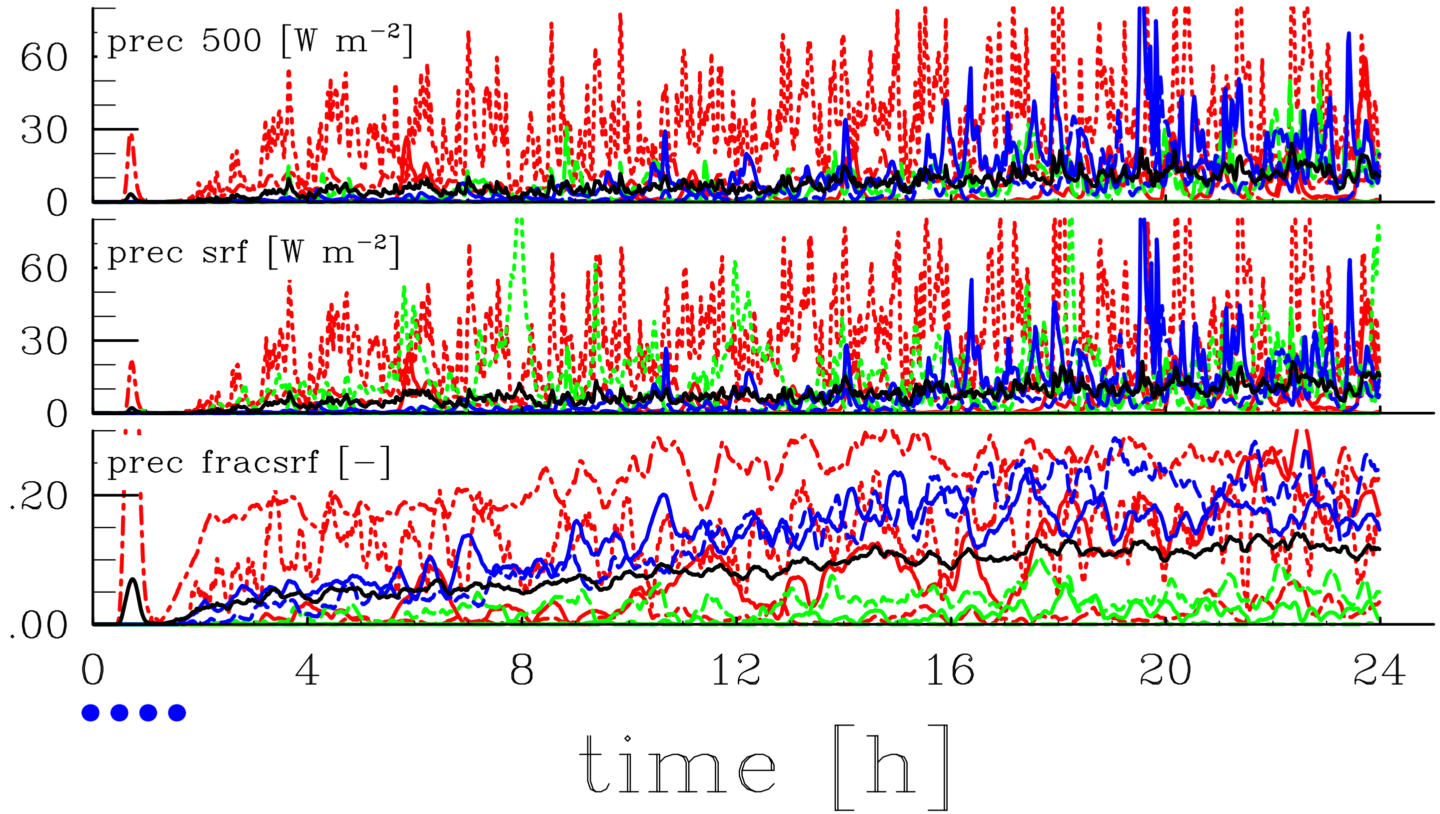
Average observed precip in this period: 0.4~0.8 mm/day

(SPOL-Radar results, Thanks to Louise Nuyens)

Precipitation of 12 LES models based on a composite case of the suppressed period

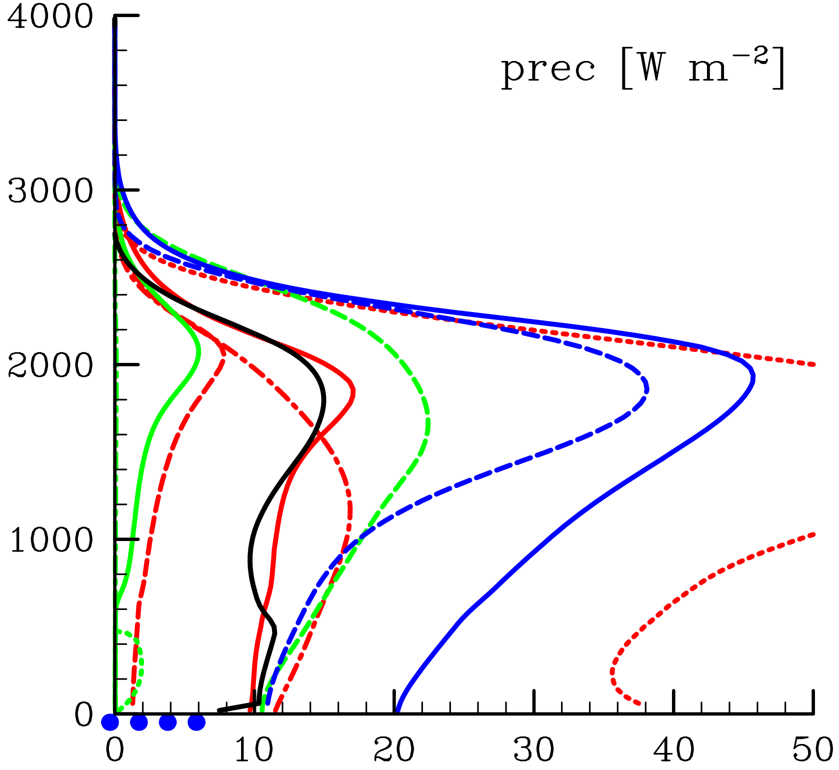
LES Model ensemble : ~0.5mm/day (about right)

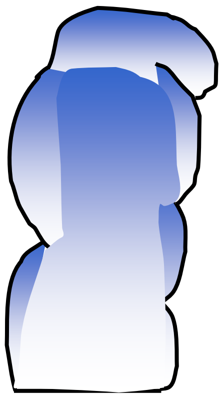
However: large spread from model to model



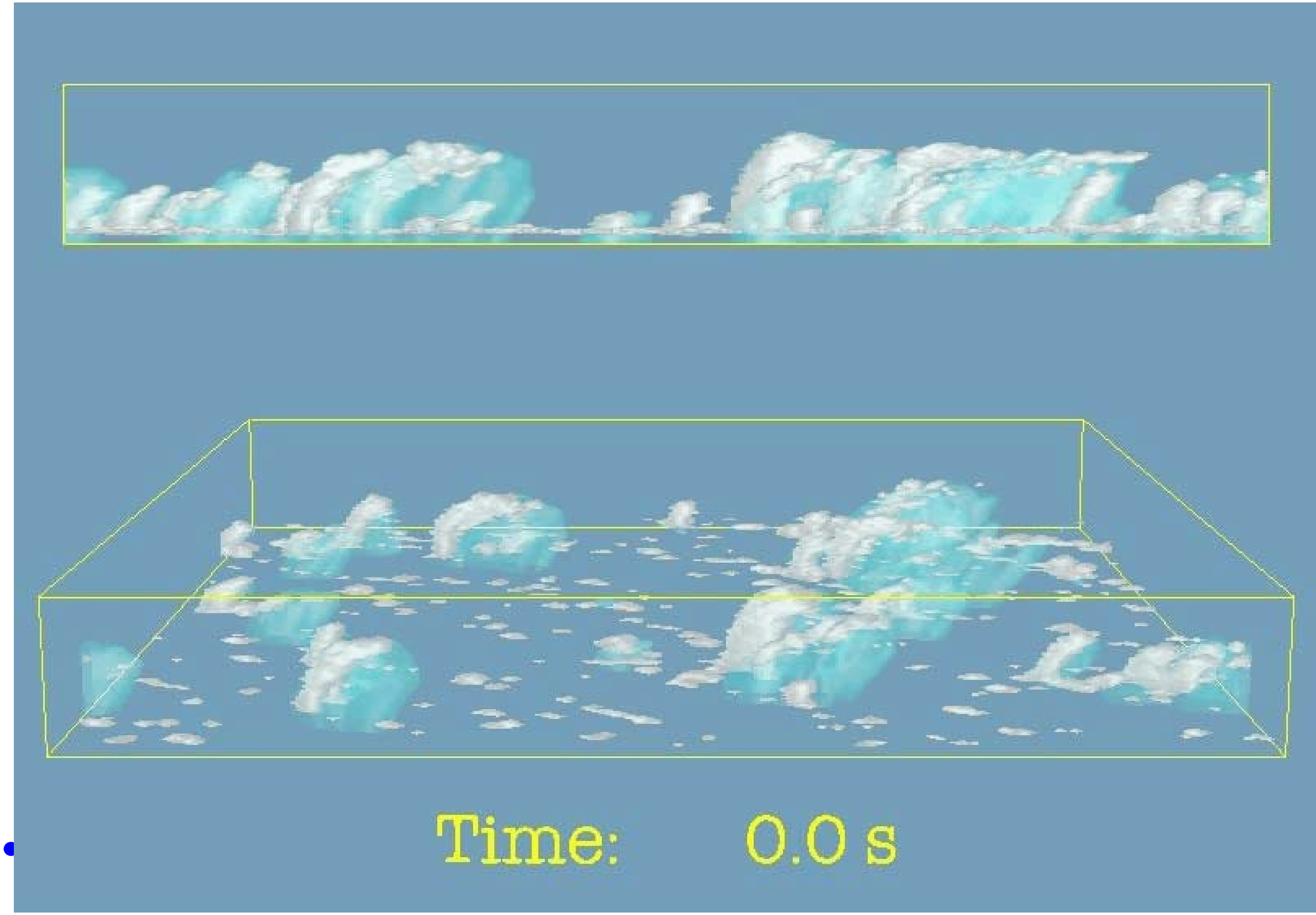
LES results (cont)

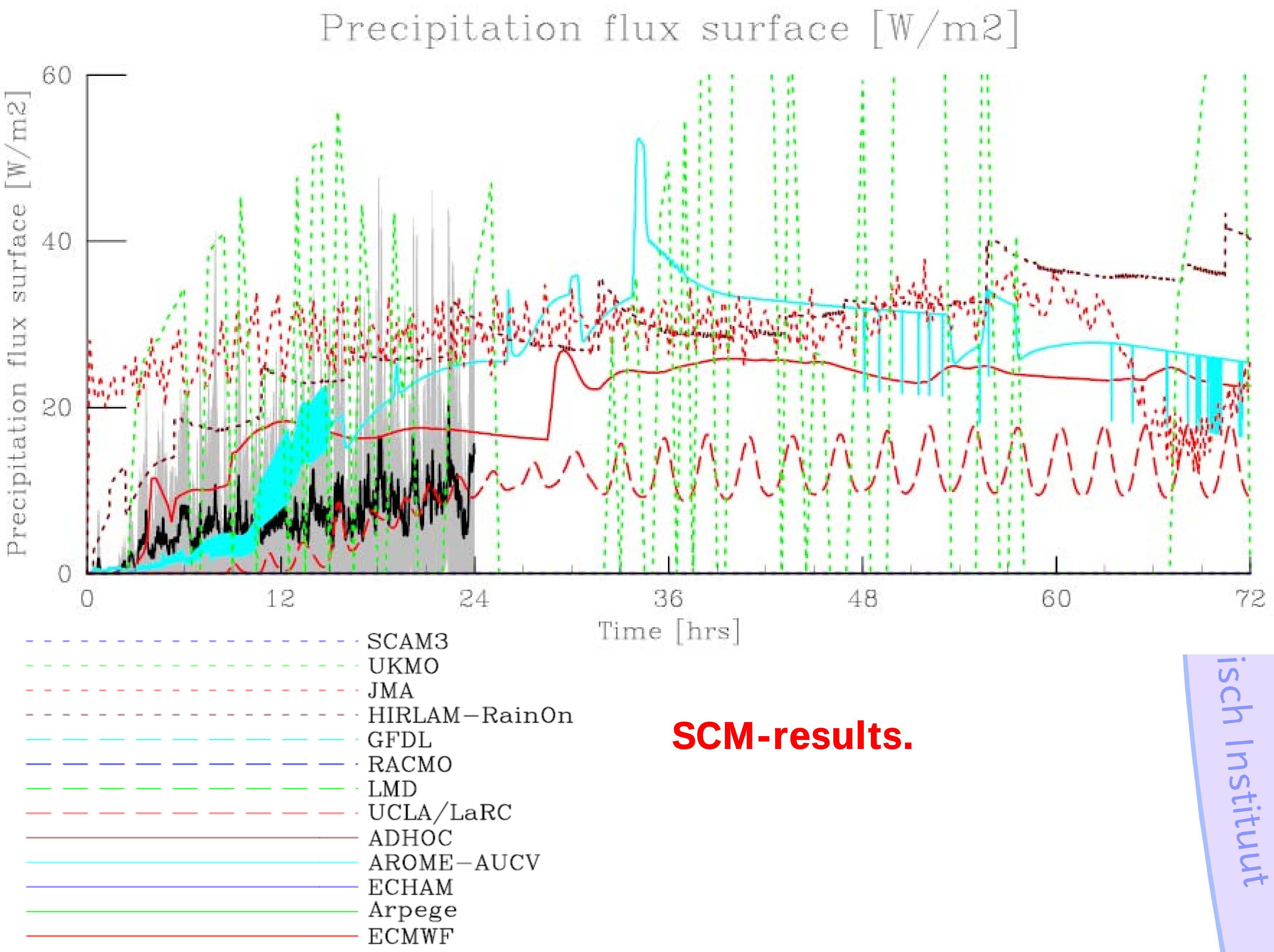
- Precipitation rate peaks high in the cloud layer
- Apparently evaporation of rain plays an important role
- Significant amount of rain falls out of the clouds way above cloud base.





3D View on the LES RICO Clouds (40x40km) (courtesy : Steve Abel: MetOffice)





SCM-results.

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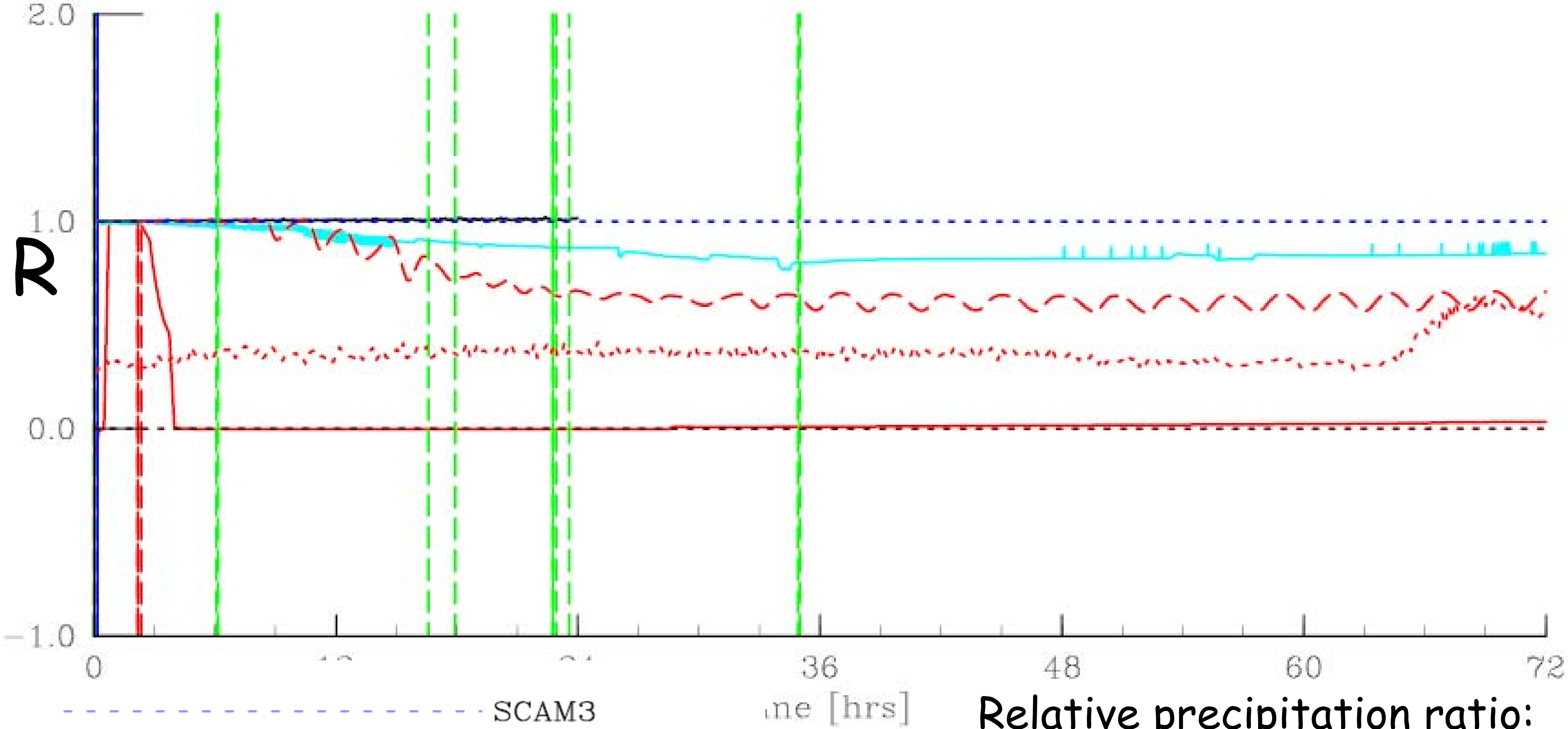
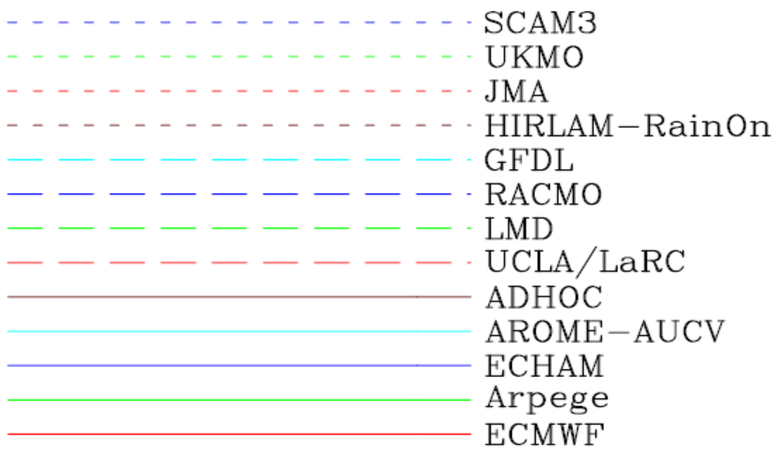
Evaporation of Rain of the participating SCM's

R





Relative precipitation ratio:

$$R = \frac{P_{500} - P_{srf}}{P_{500}}$$

ECMWF does not evaporate rain if RH>80% !!

Conclusions

- Precipitation of shallow clouds do affect the precipitation statistics significantly.
- Clouds as small as 500m do precipitate (obs)
- Strong relation between cloud height and precipitation rate (obs).
- Microphysically -> large spread among LES-models:
  - Amount of rain water differs factor 3 to 4
  - Huge spread in precipitation amounts
  - Differences not yet tied to choice of microphysical scheme
- The LES-model ensemble mean precip in reasonable agreement with obs. (But is it for all the right reasons?)
- Evaporation of rain seems to be an important mechanism
- Large scale models show a huge scatter in precipitation evaporation efficiency.

….The various parameterization building blocks connected to clouds

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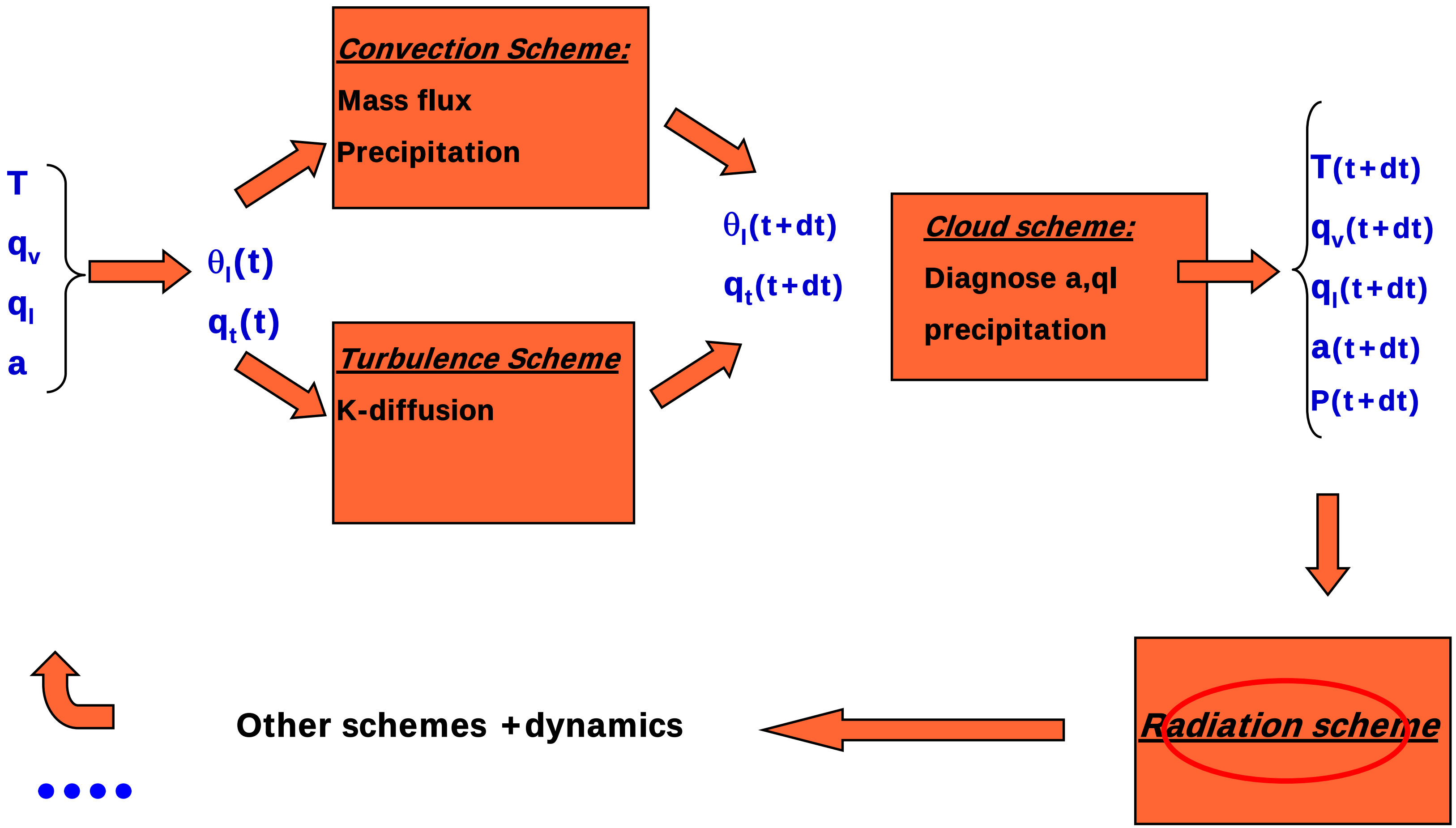

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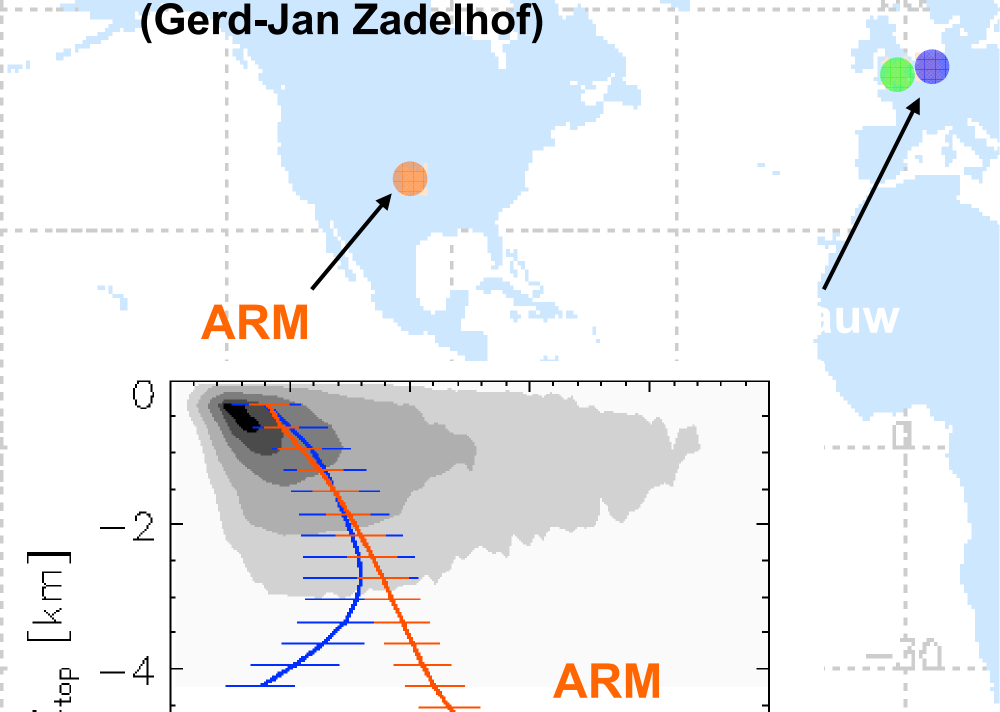
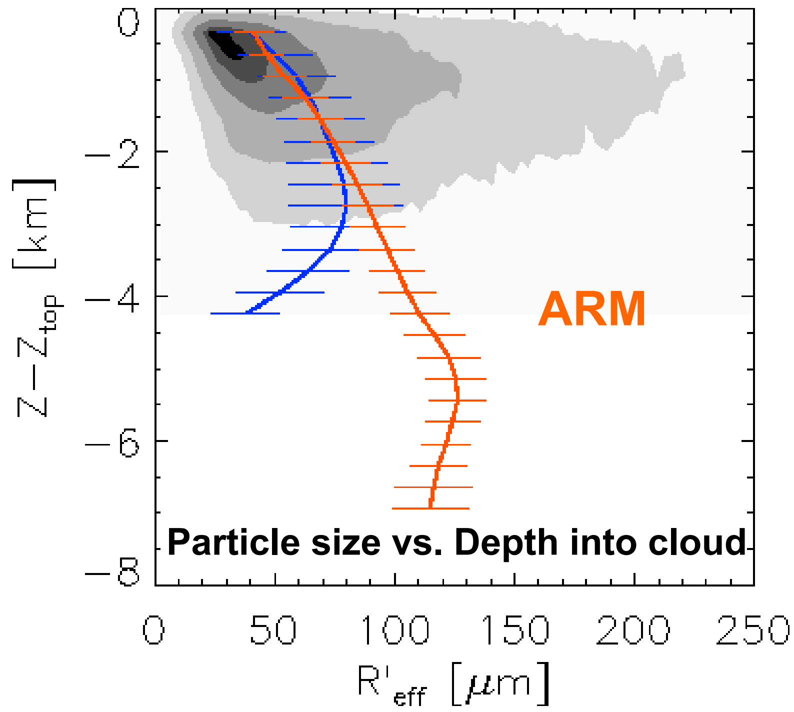
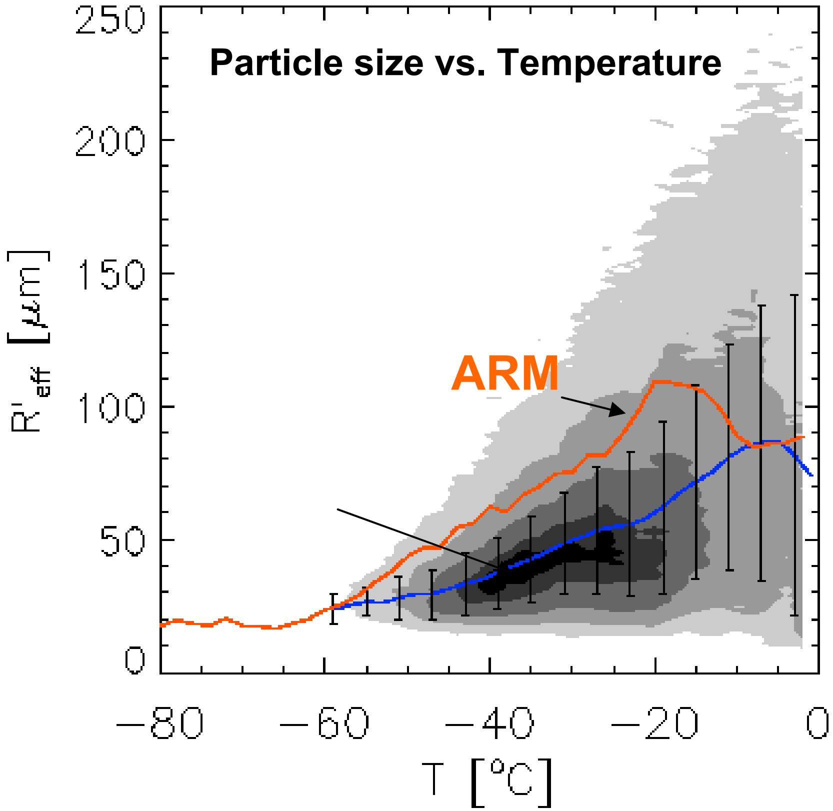
Comparing microphysical ice cloud properties

Comparison of results obtained over coastal Europe and Central U.S.

(Gerd-Jan Zadelhof)







Size-vs-temperature relationship different for ARM-SGP and Cabauw !

(Chilbolton and Cabauw similar)

Description of the parameterization

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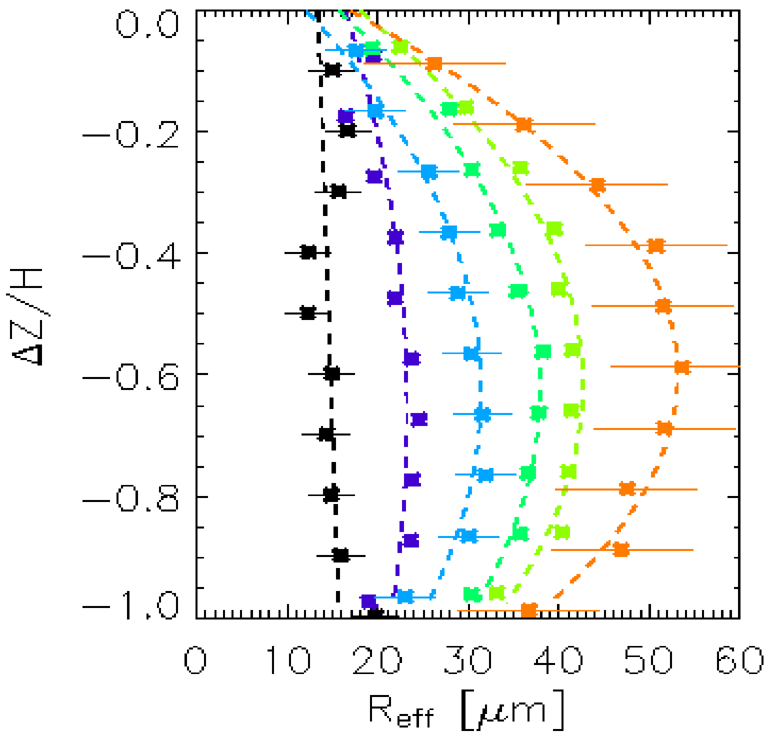
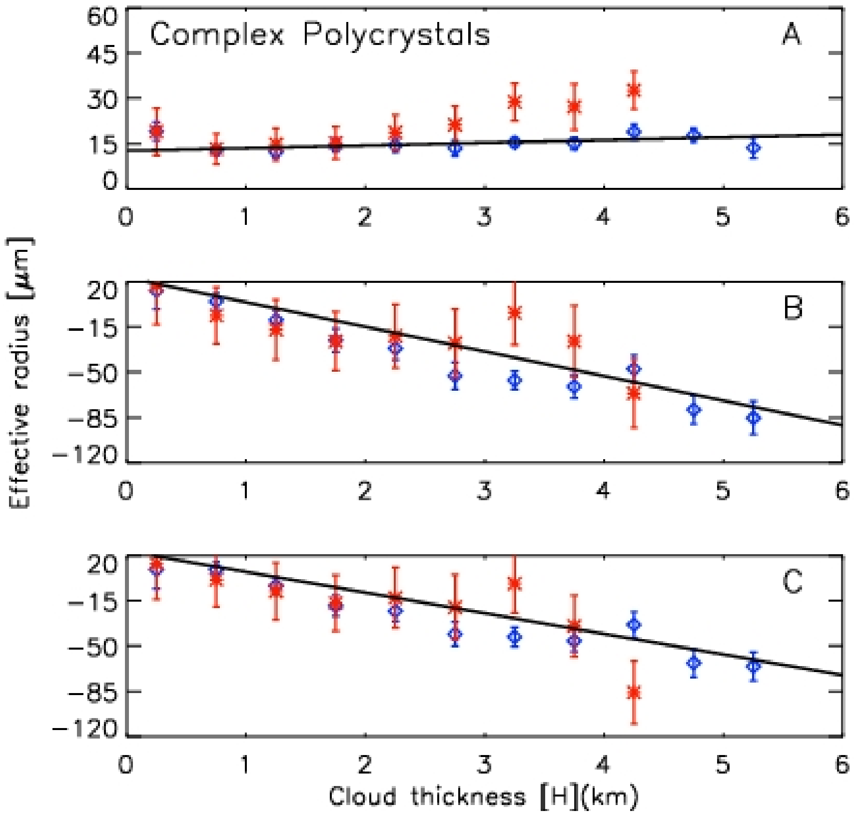
H=[0.5,1.25,1.75,2.25,2.75,4.75]





$$R_{eff}(Z,H)=A + B\ (Z/H) + C\ (Z/H)^2$$

Z is the depth into cloud from cloud top

H is the total cloud thickness

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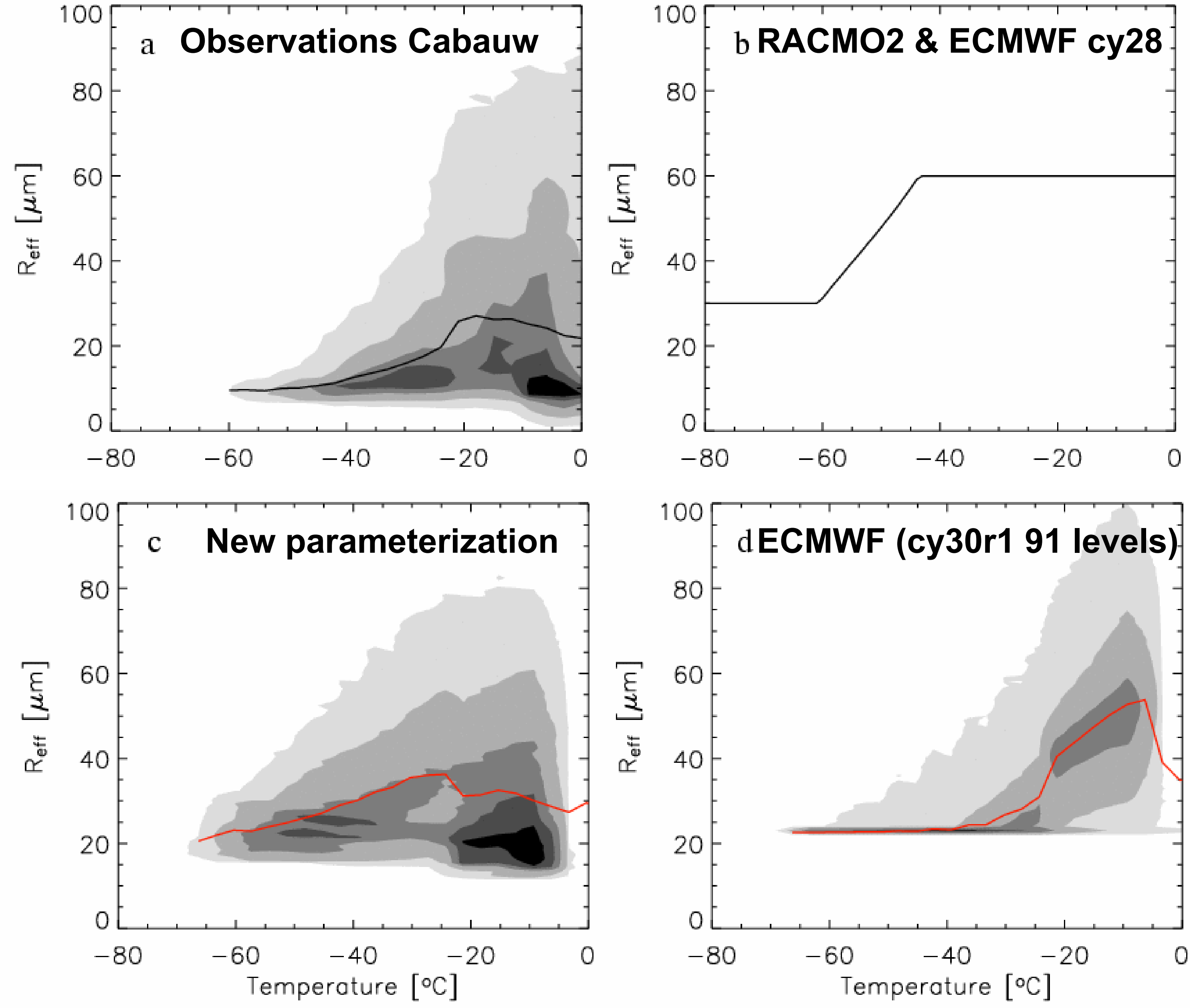
Including R_{eff} in a regional climate model



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Regional results:

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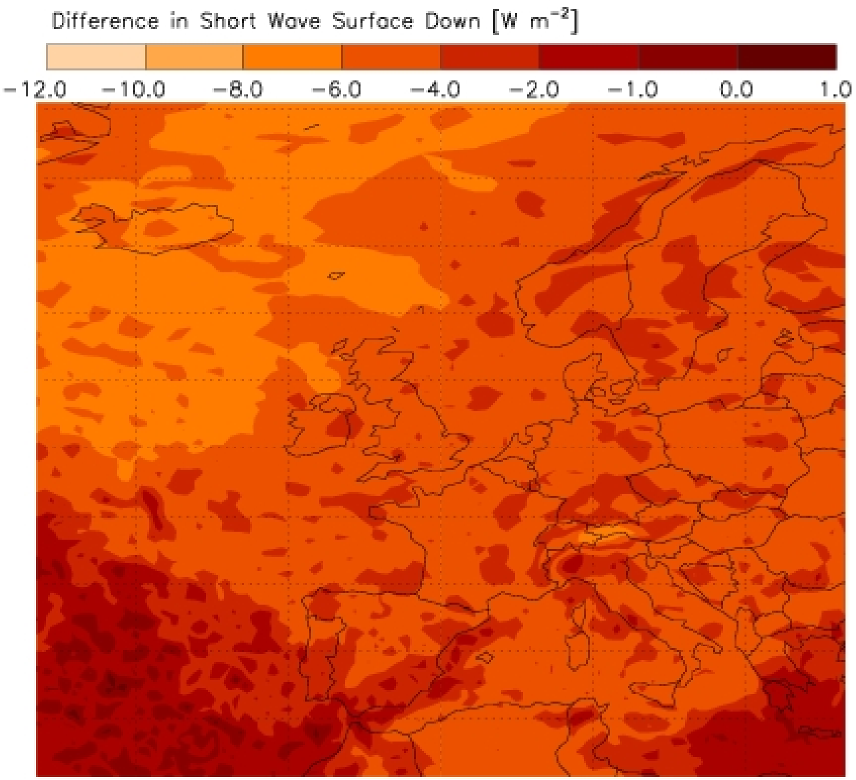
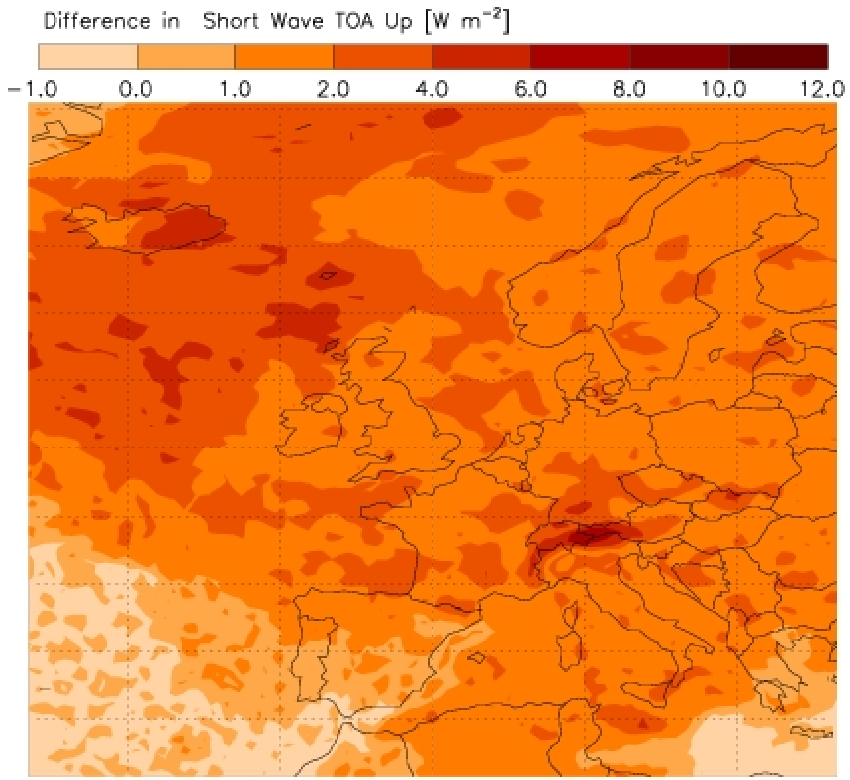
Difference in W/m2 (Experimental-Control)





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Further plans (LES+Obs)

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- Case set up will be revised (even simpler without scrutinizing the obs)
- All models run with and without precip
- Pdf's of precip
- Precip as a function of cloud size
- Precip as a function of cloud types .
- Further individual experiments with: interactive radiation, larger domains, mesoscale structures.

GCSS/WGNE Pacific Cross-section Intercomparison (GPCI)

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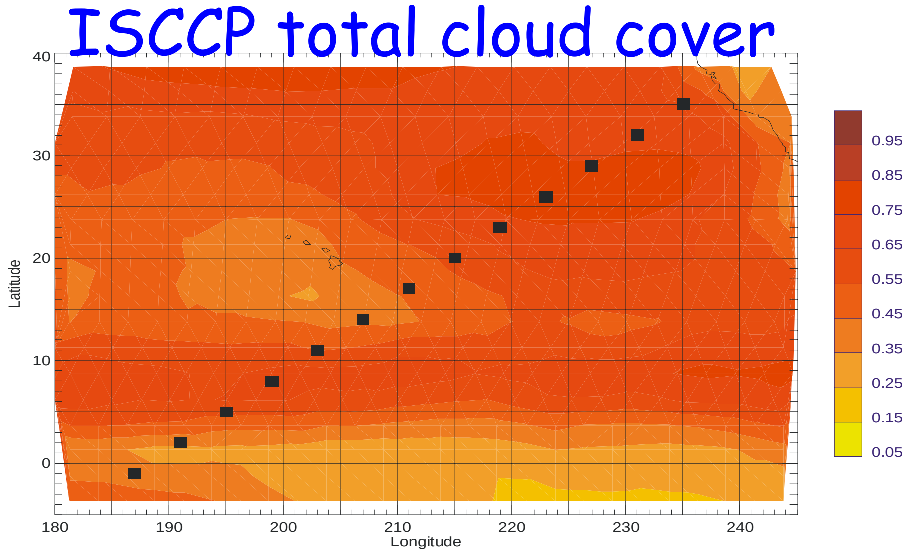

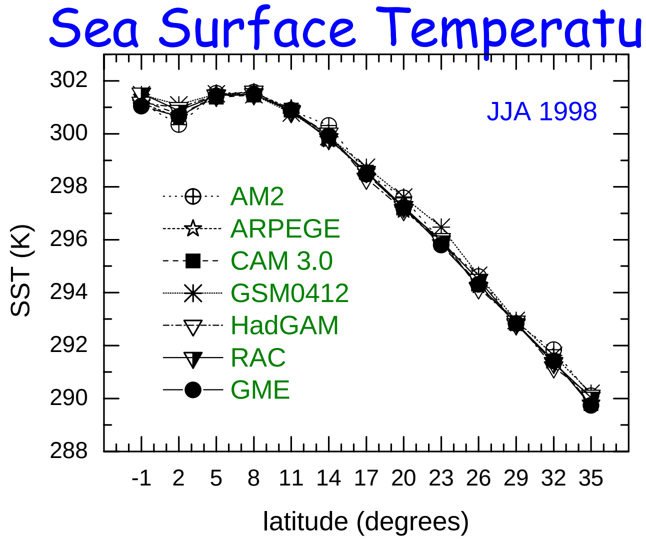

GPCI is a working group of the GEWEX Cloud System Study (GCSS)

Models and data are analyzed along a Pacific Crossection from Stratocumulus, to Cumulus and to deep convection

Models: GFDL, NCAR, UKMO, JMA, MF, KNMI, DWD, NCEP, ECMWF, BMRC, NASA/GISS, UCSD, UQM, LMD, CMC, CSU, GKSS

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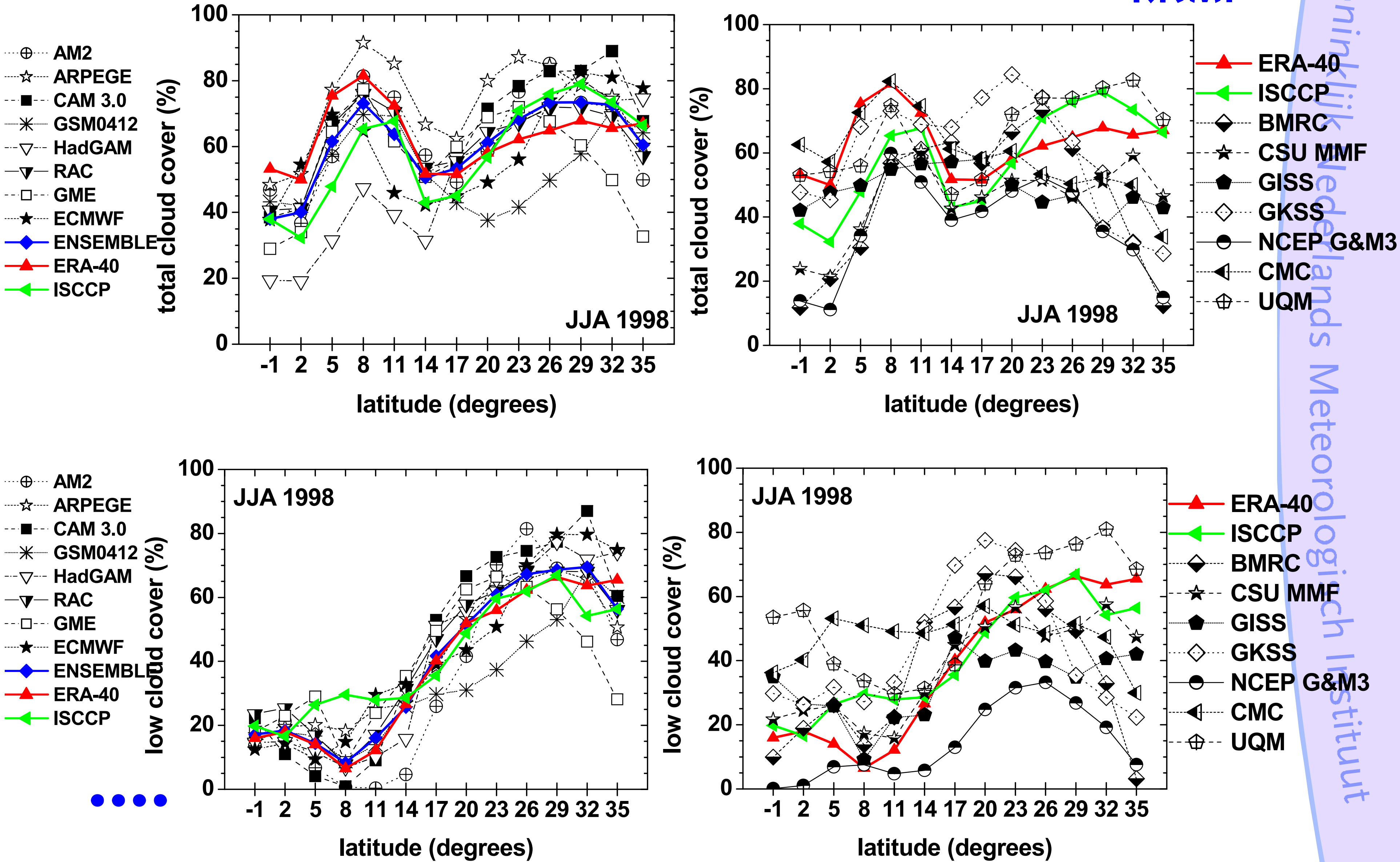
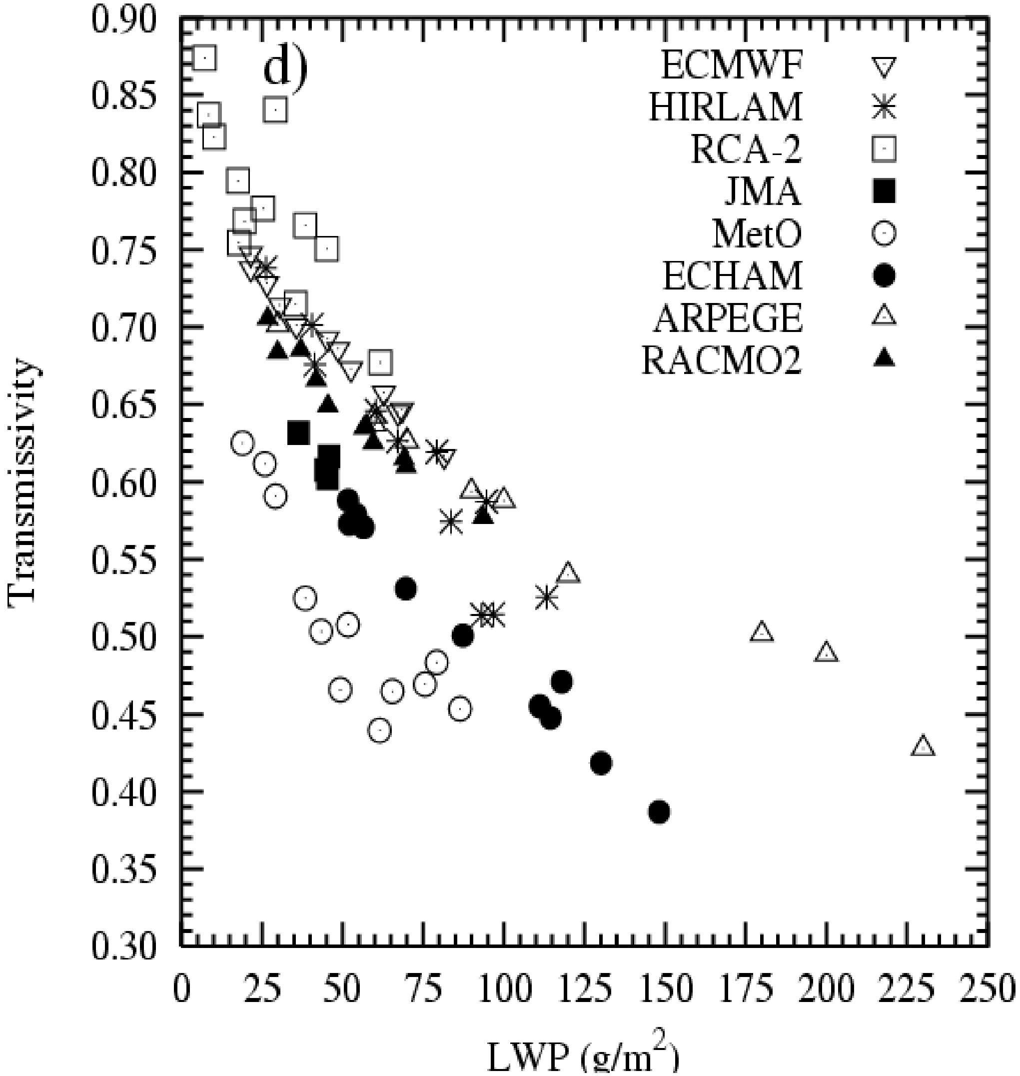
Total and low cloud cover (JJA98)



Scatter plot: LWP versus Transmissivity.



$$T = \frac{\left\langle F_{rad,sw,down,srf} \right\rangle}{\left\langle F_{rad,sw,down,toa} \right\rangle}$$

With:

<..> = monthly time averages over [9hr,15hr] local time

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MetO, ECHAM, JMA : low transmissivity, high albedo

ECMWF, RACMO, Arpege: high transmissivity, low albedo

Possible Reason: Cloud inhomogeneity !!

MetO, ECHAM JMA: treat clouds as plane parallel

ECMWF, RACMO : include the magic 0.7 factor in order to take cloud inhomogeneity into account.

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Conclusions (SCM)

Some models behave remarkably well

- ECMWF, HIRLAM, AROME, ARPEGE
- These models worked actively on shallow cumulus (but did not tune their parameterization on the present case)
- It seems that there are 3 crucial ingredients:

1. Good estimate of cloud base mass flux : M~ac w*
2. Good estimate of entrainment and detrainment
3. Good estimate of the variance of q_t and θ_l in the cloud layer in order to have a good estimate of cloud cover and liquid water.

Further Plans (SCM)

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- Pursuit further the long runs (15 days with variable forcings
- Bring in other RCM's (Colin Jones)
  - To have more LS-focings for the SCM's
  - To adress the parameterizations in a 3d context
  - To drag in even more mesoscale NWP

Further Plans (GENERAL BLCGW))

- Controlled Microphysics (Jon Petch?)
- Wrap up the drizzling DYCOMs case
- Redo previous cases and put them in a database (including 3d LES data (DIME)

Average Soundings for this period

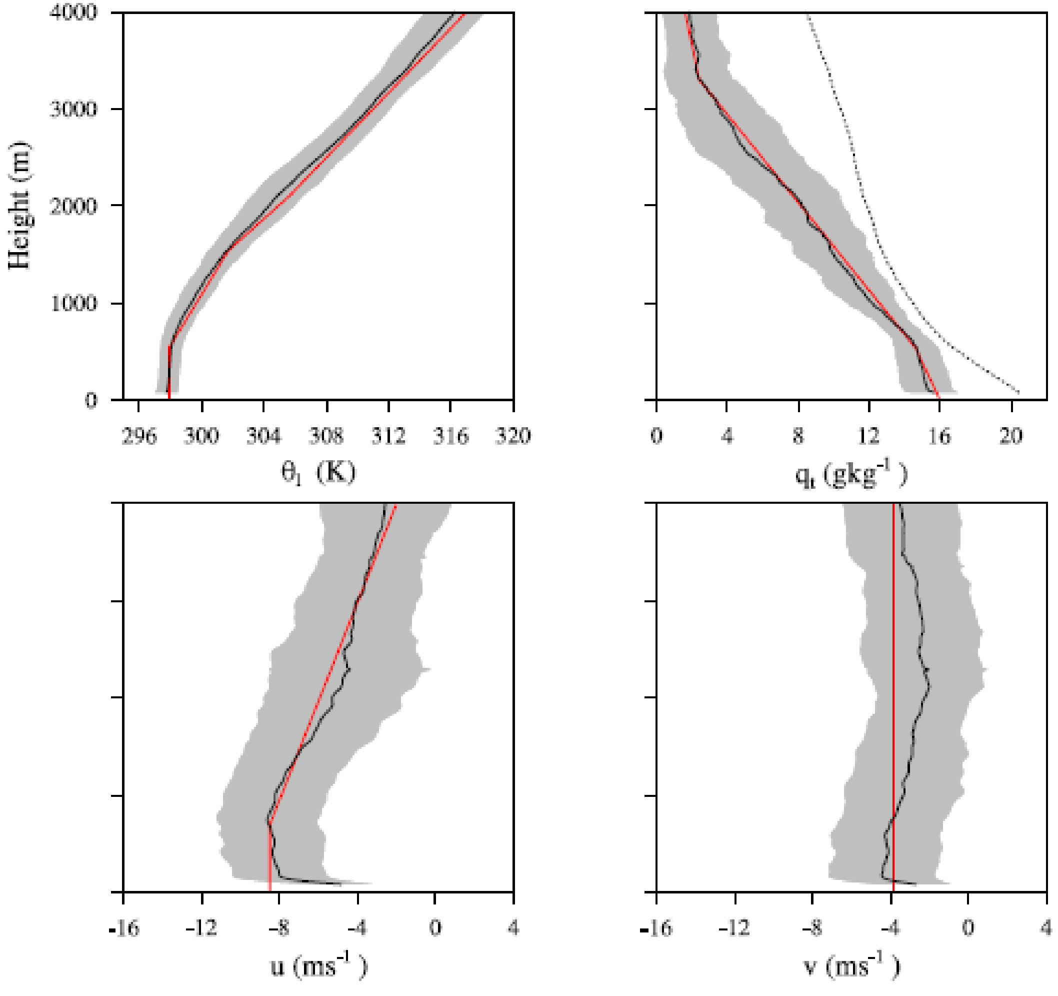

Figure 3.1: Vertical profiles are shown of (a) the potential temperature (K), (b) the specific humidity (gkg^{-1}), (c) the zonal wind (m/s) and (d) the meridional wind (m/s). As solid black lines the mean profiles of the composite period are shown with in grey $\pm\sigma$. In blue the mean profiles are shown for January 11. The dotted lines represent the saturation specific humidity (gkg^{-1}). In red the profiles as constructed for LES are shown.

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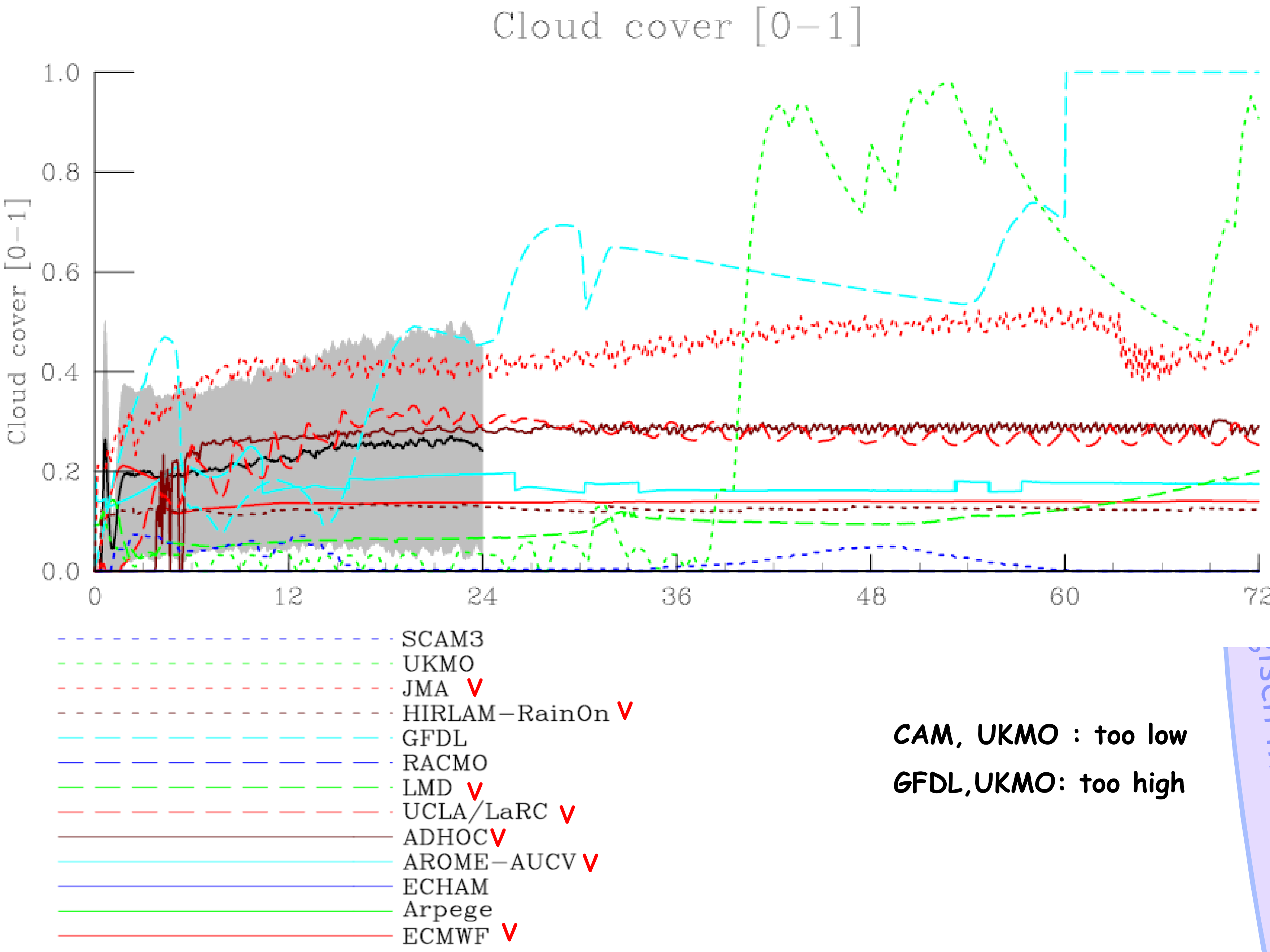

CAM, UKMO : too low

GFDL,UKMO: too high

Turbulent Mixing in Scu

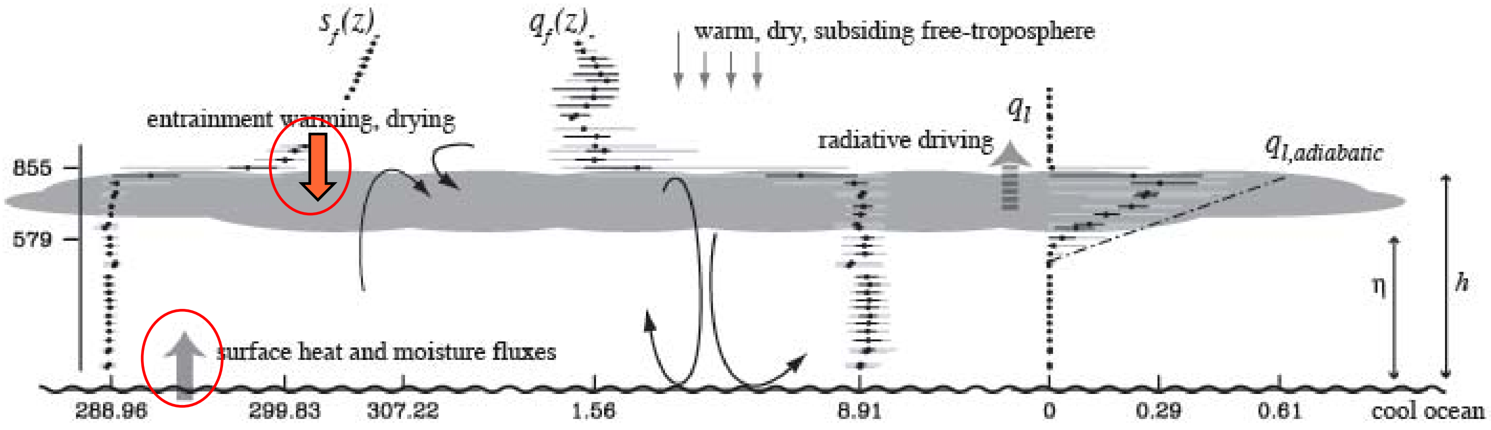

Fig. 1 Structure of the stratocumulus topped boundary layer as observed during DYCOMS-II.

- **Well mixed layer : constant profiles of moist conserved variables: q_t , θ_l**
- **liquid water q_l: (near) adiabatic**

- **The dogma: Getting the surface flux and the entrainment flux right solves the problem.**
- **Is this really true?**

LES results of the GCSS/EUROCS FIRE Scu Case

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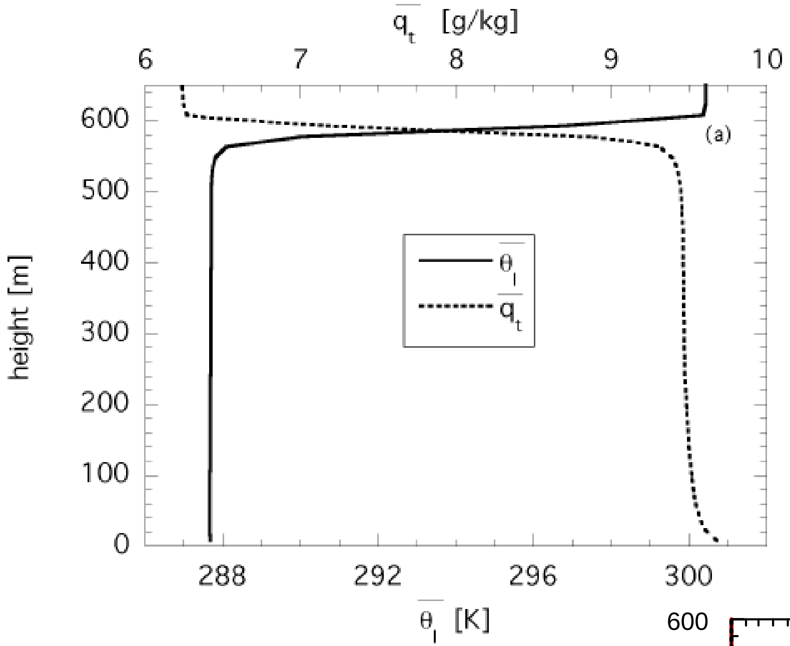
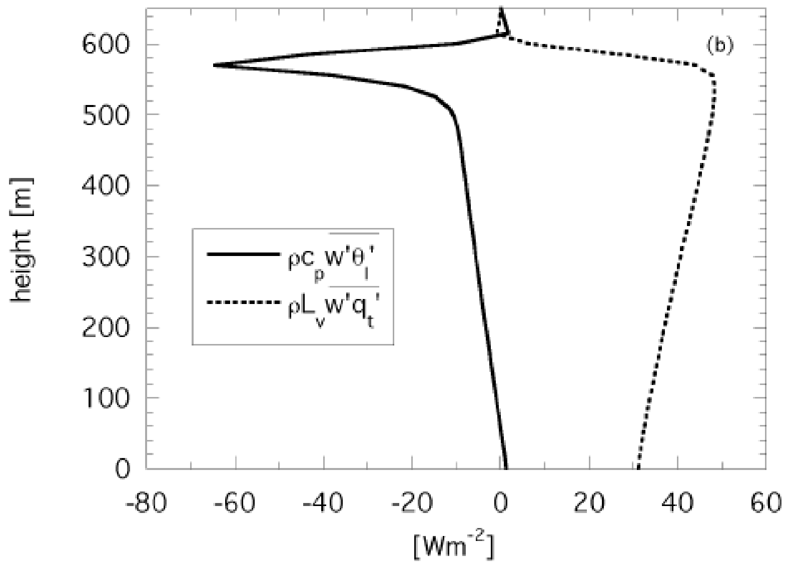
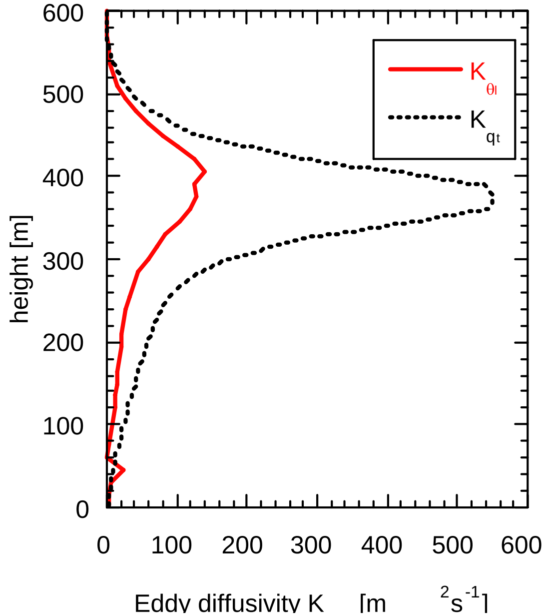




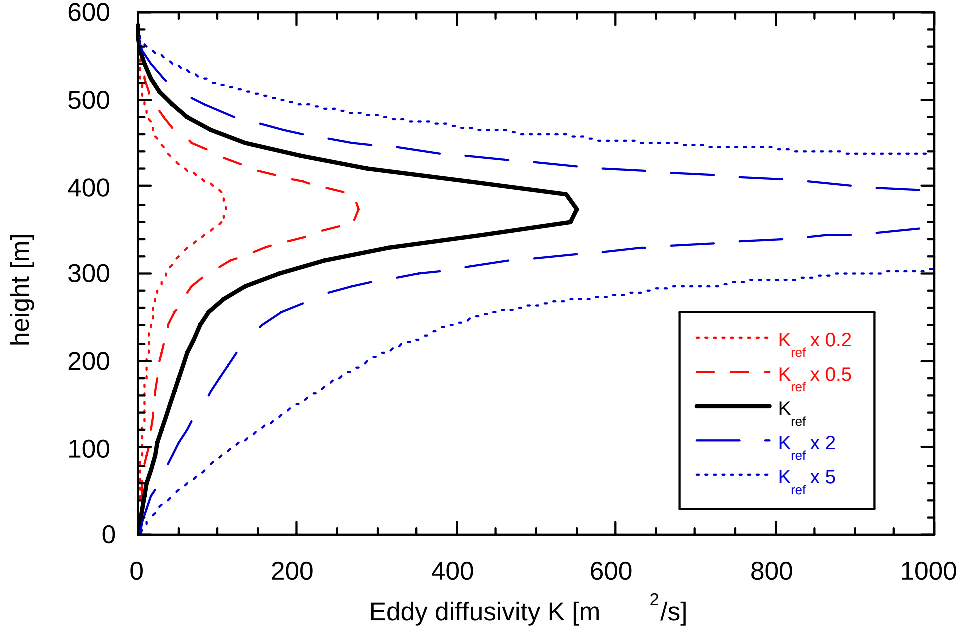
Diagnose the eddy diffusivity profile:

$$\overline{w'\psi'} = -K_{\psi} \frac{\partial \overline{\psi}}{\partial z}$$



- **K_{qt} and $K_{\theta l}$ differ**
- **K-values much larger than used in parameterizations**

Vary eddy diffusivity profiles with a constant factor c



- K_{ref} **is identical to** K_{qt} **from LES**
- **Multiply** K_{ref} **times constant factor c**

Calculate quasi-steady state solutions for $\psi = \{q_t, \theta_l\}$ **:**

$$\overline{\psi}(z) = \psi_0 - \int_{z'=0}^{z'=z} \frac{\overline{w'\psi'}(z')}{K_\psi(z')} dz'$$

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Quasi-steady state solutions

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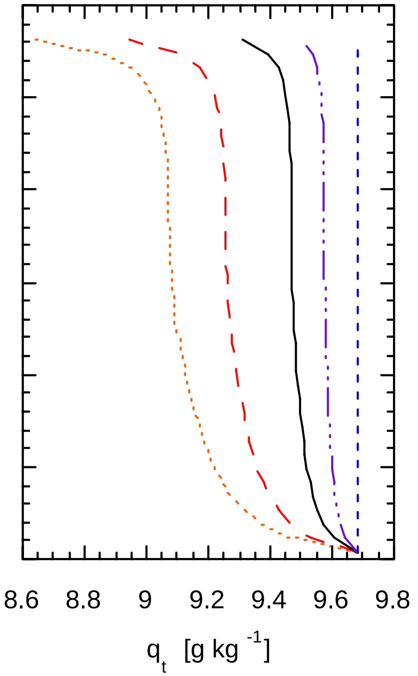
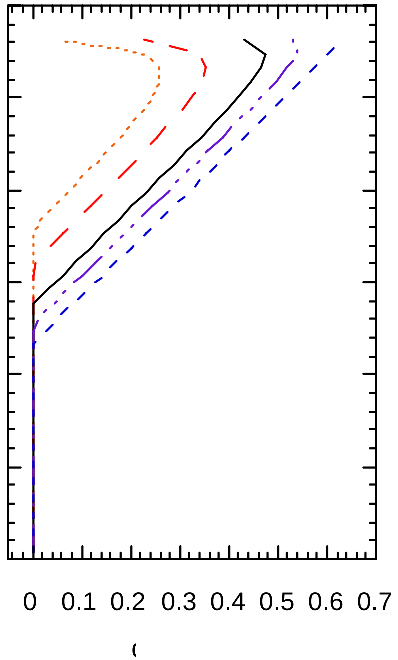
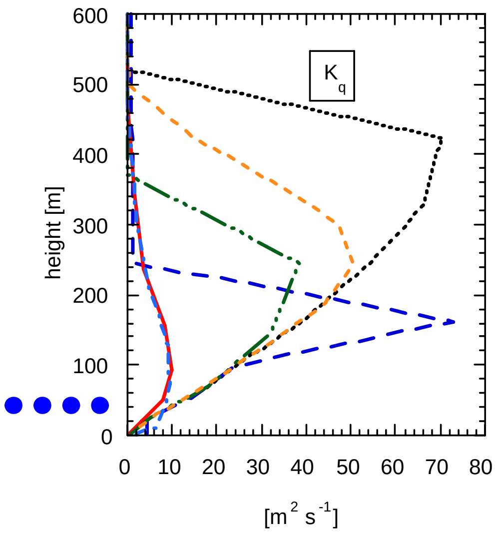


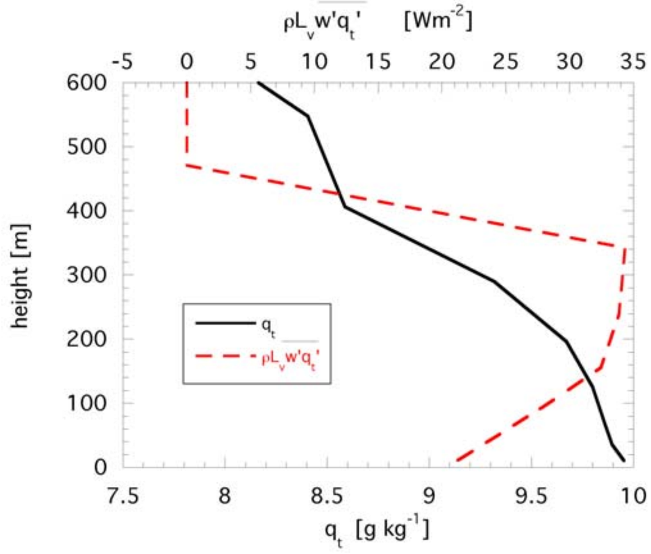


- **Adiabatic liquid water depends critically on K, even with fixed entrainment and surface fluxes.**

- **23R4 (ERA40) version of ECMWF had too low values of K resulting in less well mixed boundary layer and hence underestimating cloud liquid water.**

  - **Partly resolved by new EDMF scheme (see presentation Kohler / Neggers?).**





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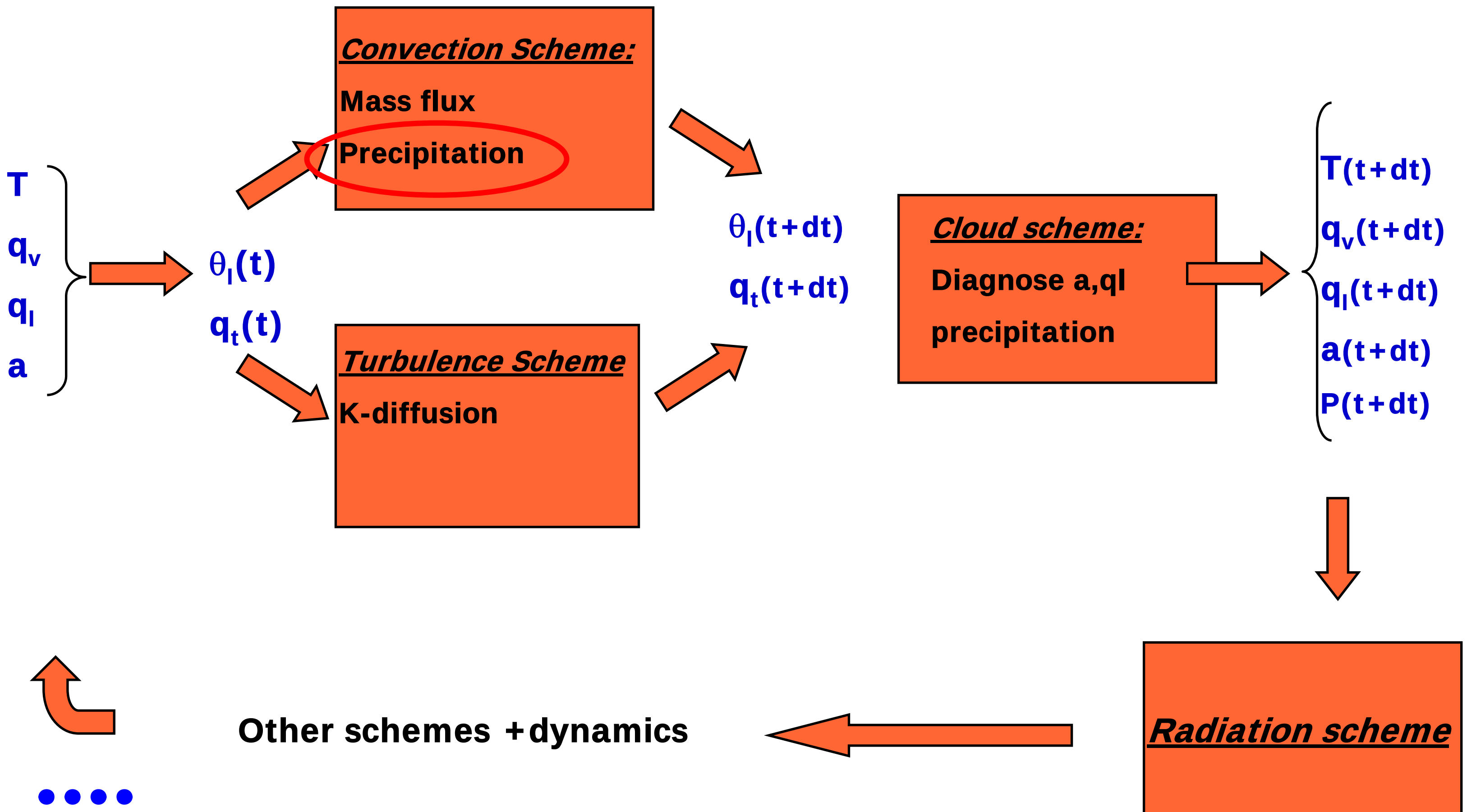
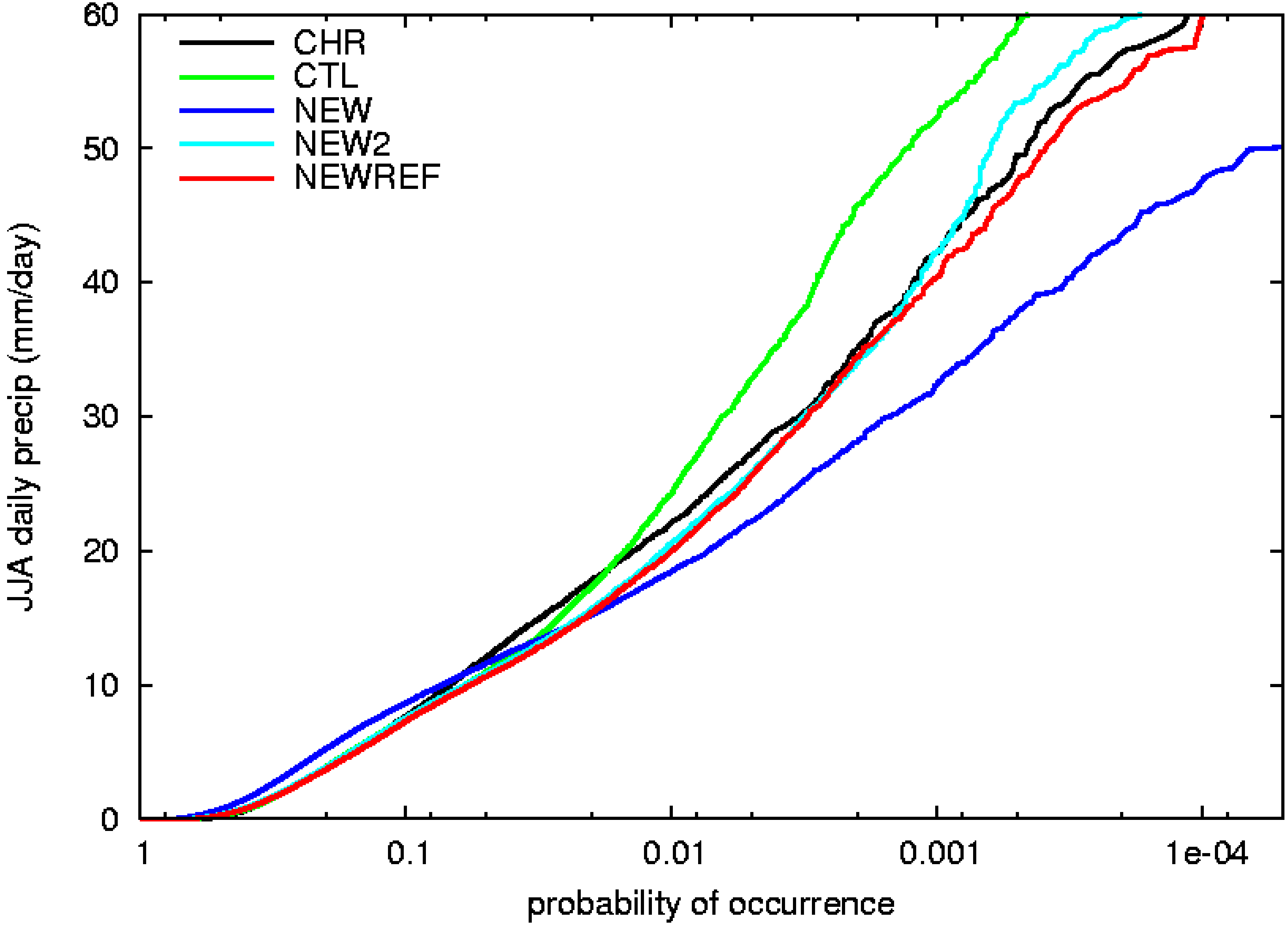
The various parameterization building blocks connected to clouds





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Conclusions (LES)

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- All LES's show in general similar (thermo-) dynamic mean state
- Cloud cover in agreement with obs
- Steady state is not reached after 24 hours simulation
- Different mean state than in BOMEX (no inversion)
- Different transport characteristics than in BOMEX
- Cloud cover, and liquid water profile 1st order problem, microphysics is a 2nd order problem (but it does affect the mean state considerably!!)

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