THE DIURNAL CYCLE OF CONVECTION MODELLING ISSUES

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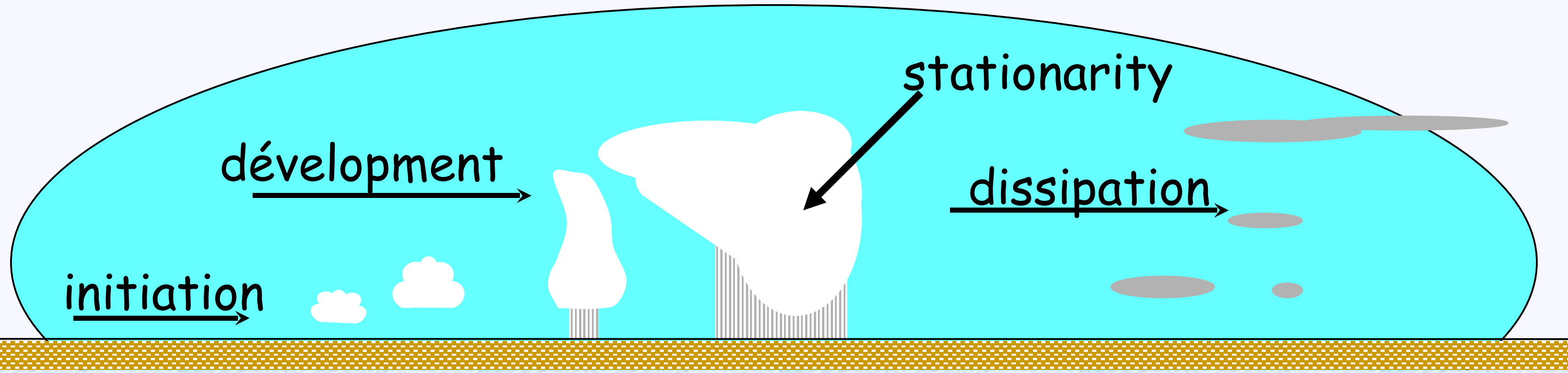
« Even today, many comprehensive GCMs use a daily mean insolation in place of the true diurnally varying insolation »
from Randall et al. (1985)

✓ relevant & demanding test for GCMs

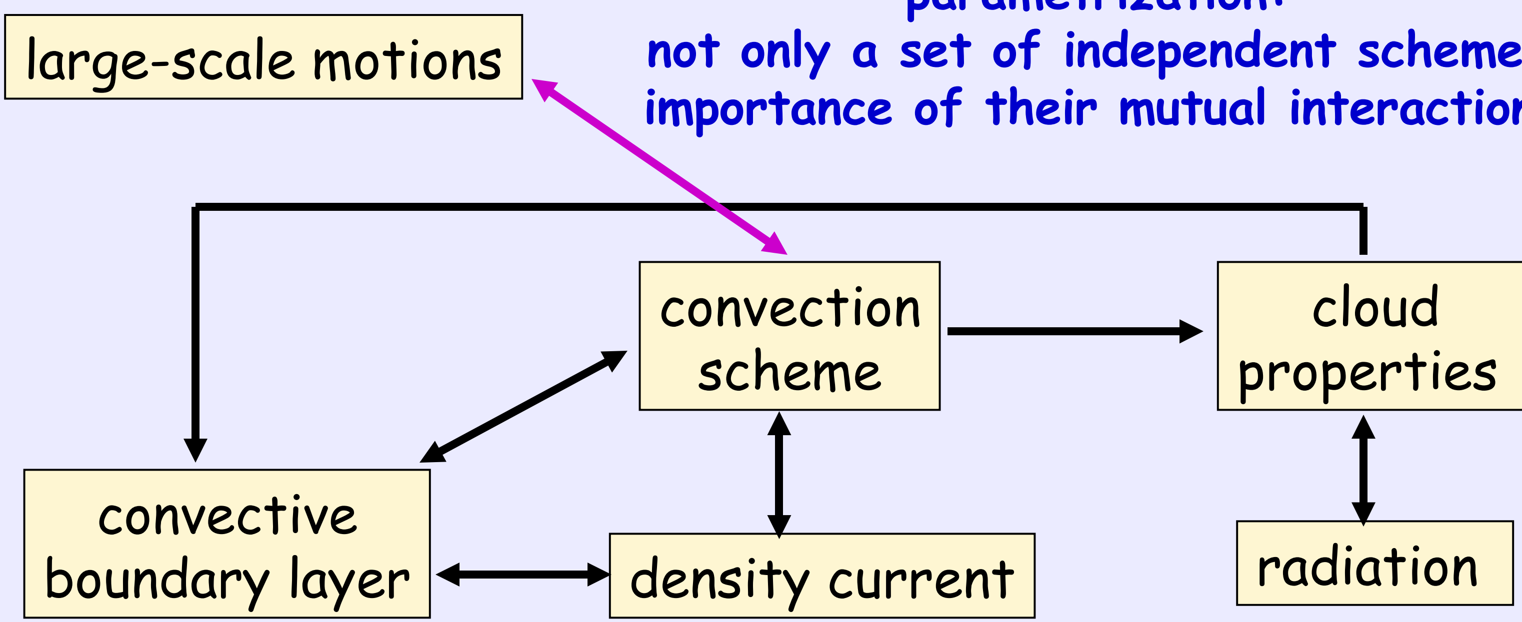
✓ assess physical parameterizations : radiation, surface exchanges, boundary layer, convective & cloud processes

diurnal cycle of convection

life de vie, transitions, régimes



parametrization:
not only a set of independent schemes
importance of their mutual interactions!



✓ difficult to reproduce by GCMs *(illustrated next slides)*

e.g. monthly mean & diurnal cycle both correct at the same time quite challenging *Lin et al. (2000)*

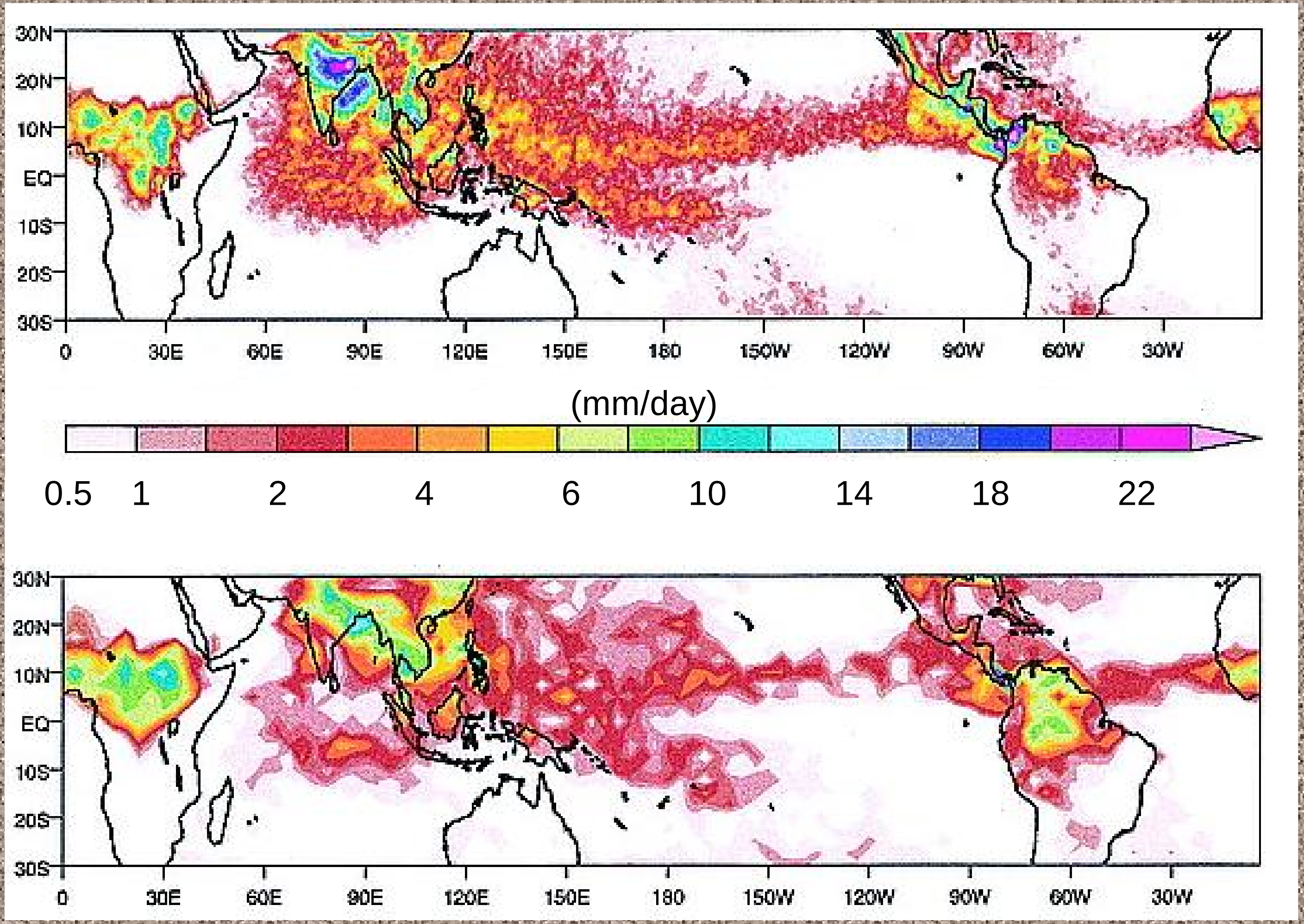
re-tuning: may be quite delicate (e.g. shift convective to stratiform dominant, radical modification of the cloud cover!)

Yang & Slingo (2001)

precipitation: **amplitude** of the diurnal harmonic

OBERVATIONS

CLAUS dataset



CLIMATE GCM

unified climate model

➢ ***quite resasonable agreement (caution: not at all the case for all GCMs!)***

frequently too weak, e.g. Royer et al. (2000), Lin et al. (2000), Dai et al. (1999)

Yang & Slingo (2001)

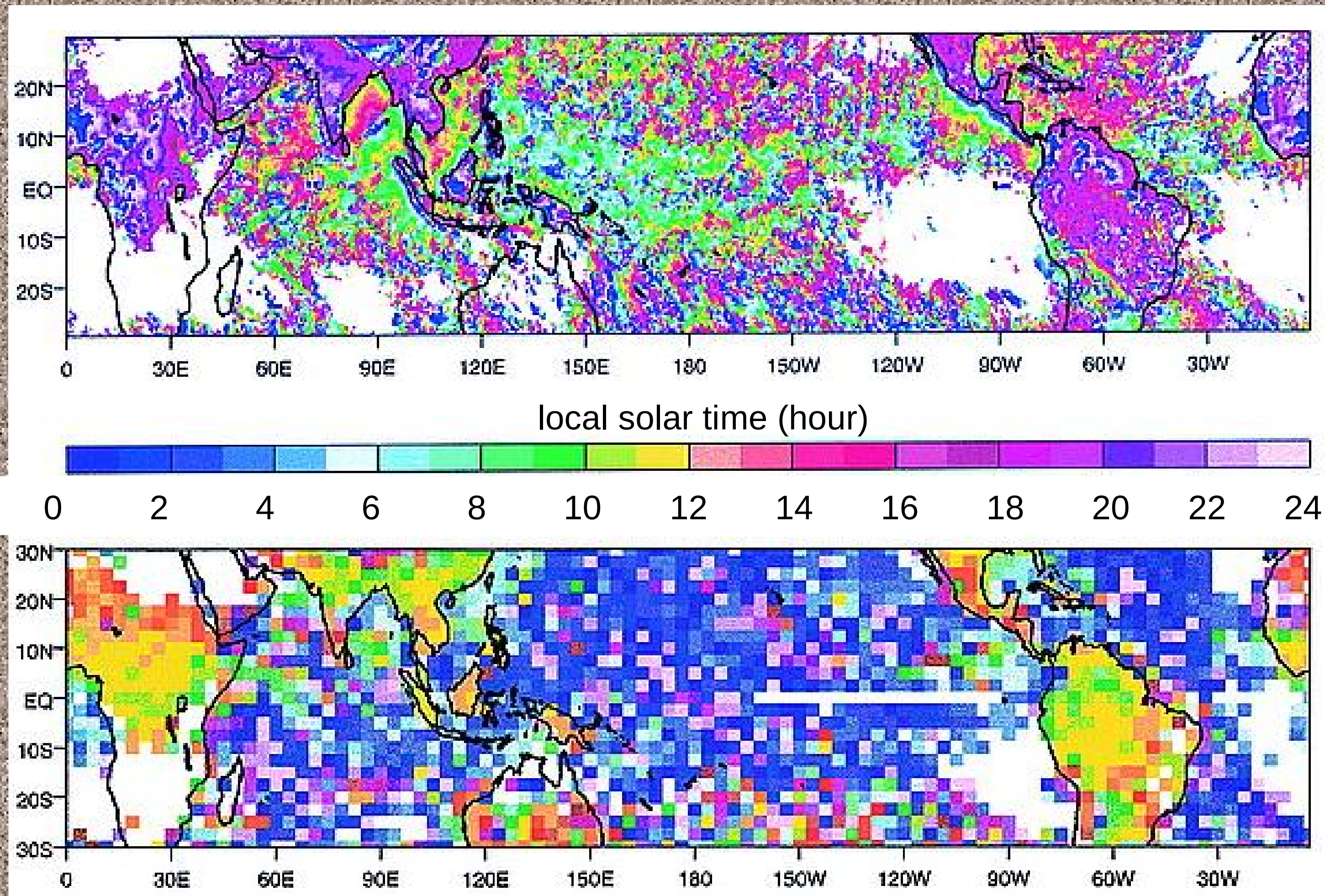
precipitation: **phase** of the diurnal harmonic

OBERVATIONS

CLAUS dataset

CLIMATE GCM

unified climate model



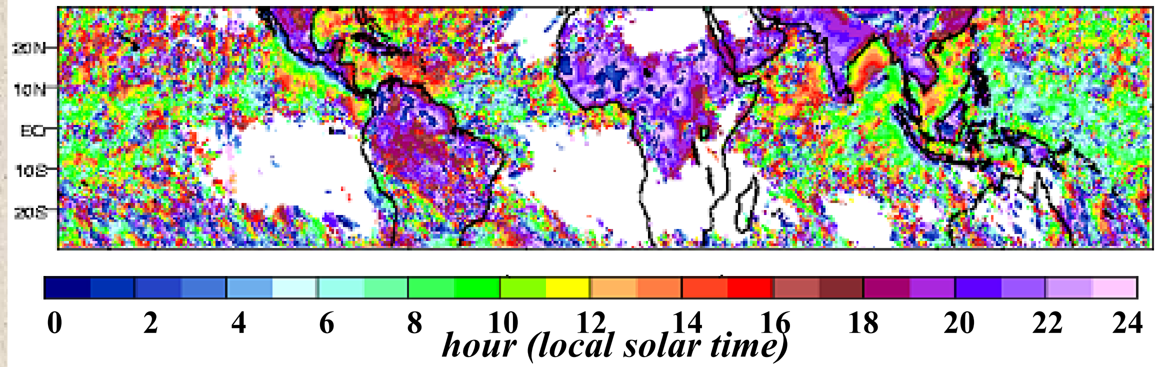
➤ ***precipitation too early by several hours compared to observations***

comparaison of the phases of the diurnal harmonic of rainfall in obs & 3 GCMs

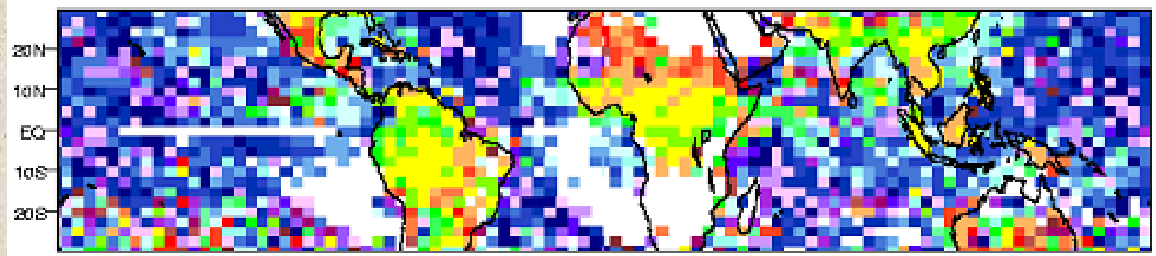
(J. M. Piriou)

Yang & Slingo (2000)

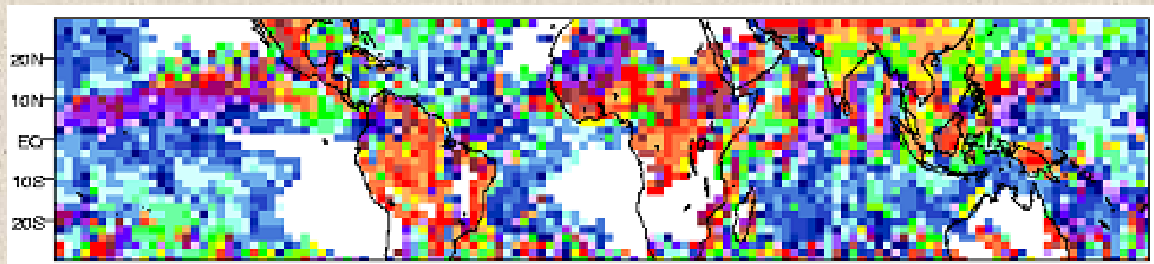
observations
satelite data CLAUS



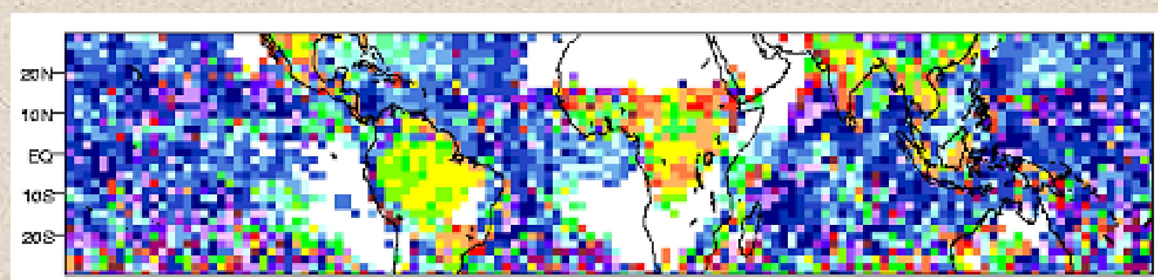
Unified Model
(Met Office)



ARPEGE NWP
(J.-M. Piriou)



ECMWF IFS
(provided by A. Beljaars)



approch to the problem

from there, how to proceed?

analysis of the interactions between parametrizations in 3D
can rapidly become a nightmare...
(complex feedback loops, compensation errors...)

it is misleading to concentrate on one *given* field, like precip.

approach developed within GCSS & EUROCS

not the final solution within 3 years for each GCM involved
but useful insights (which aspect to work on?...)

use this intercomparison frame to point to various problems which
are not model dependent

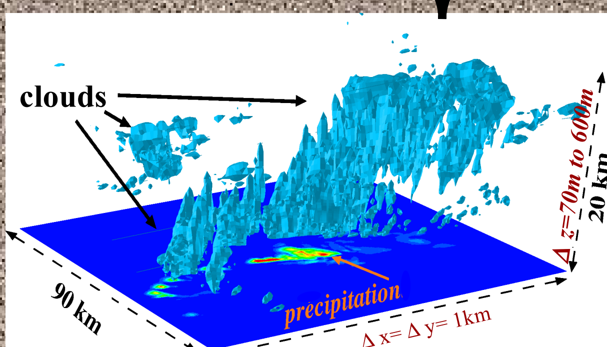
GCSS : Gewex cloud system study
EUROCS : EUROpean Cloud Systems

focus on well known GCM problems

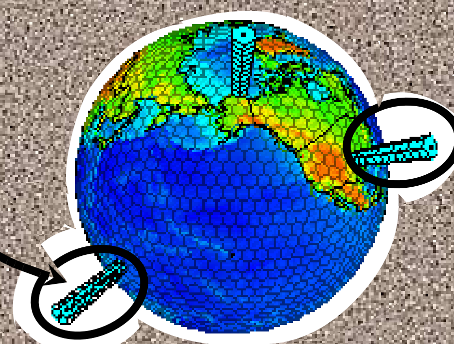
within EUROCS, diurnal cycle of:
- shallow non precipitating convection over land
- deep convection over land
- marine stratocumulus

- bring together a community of modelers : hierarchy of scales

obs ⟺ LES & CRMs --- SCMs --- RCMs & GCMs ⟺ ***obs***

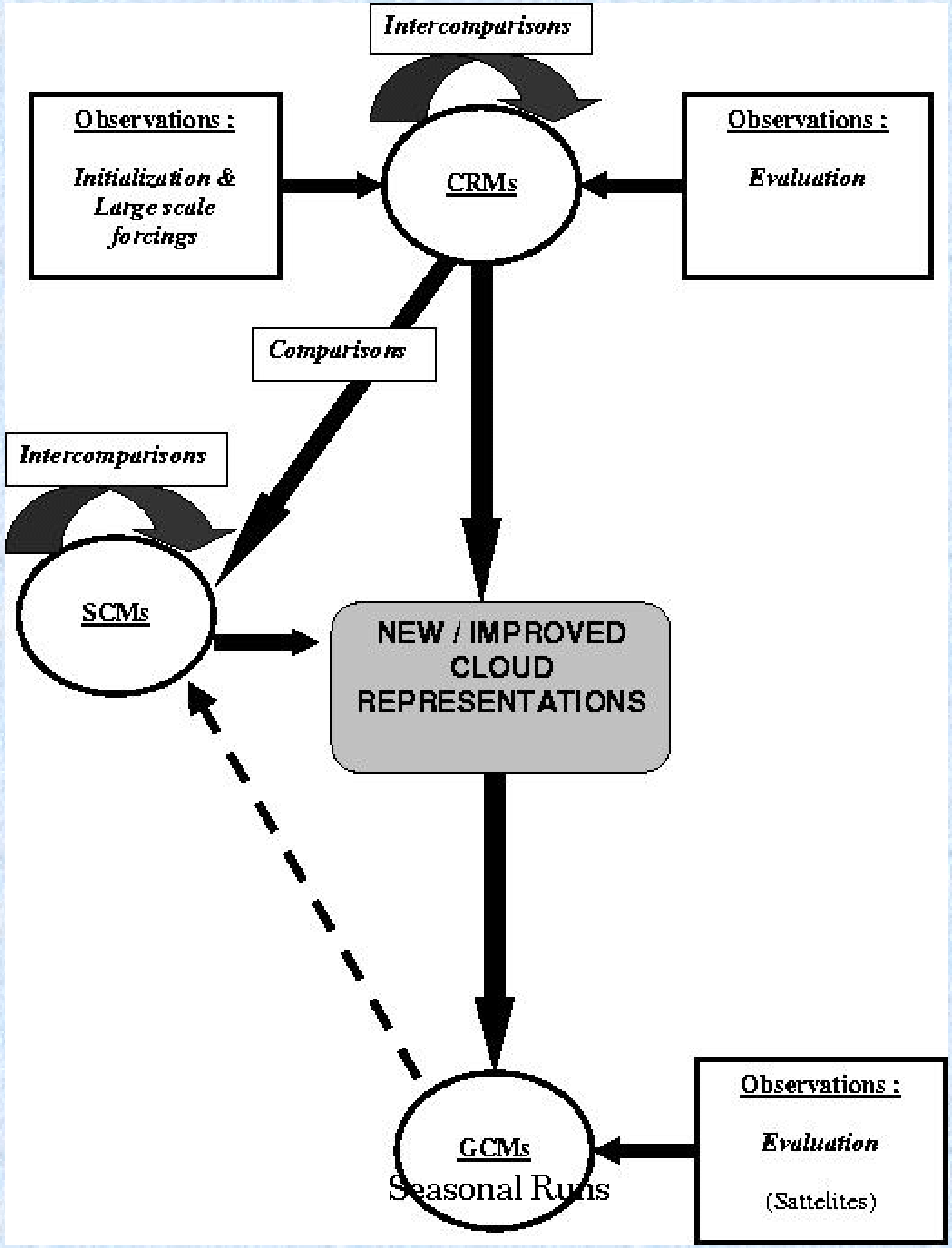


CRM-simulated convective system: illustration, from Guichard et al. (1997)



GCM picture from Colostate web page

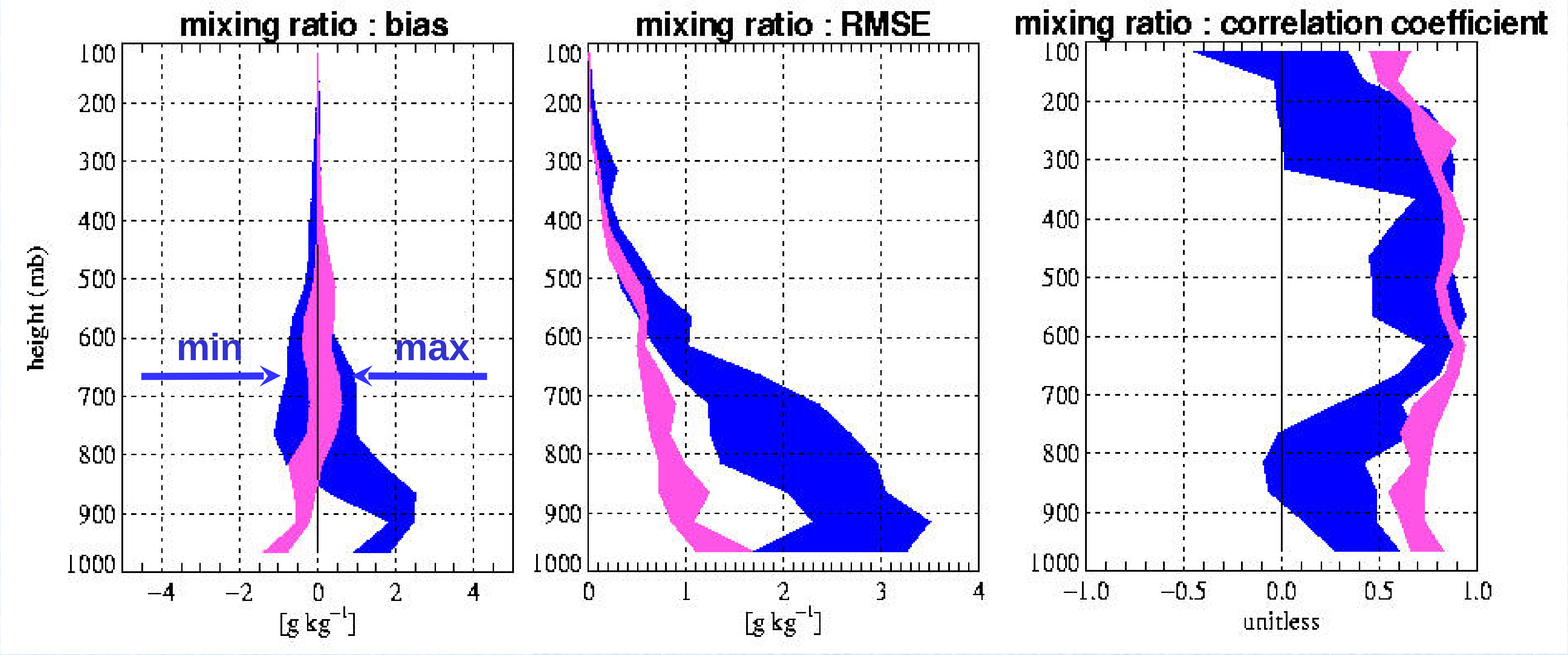
LES: Large Eddy Simulation
CRM: Cloud Resolving Model
SCM: Single Column Model
RCM: Regional Climate Model
GCM: General Circulation Model



scheme from EUROCS project description

SIMULATION OF AN OBSERVED CASE FOR VALIDATION PURPOSE

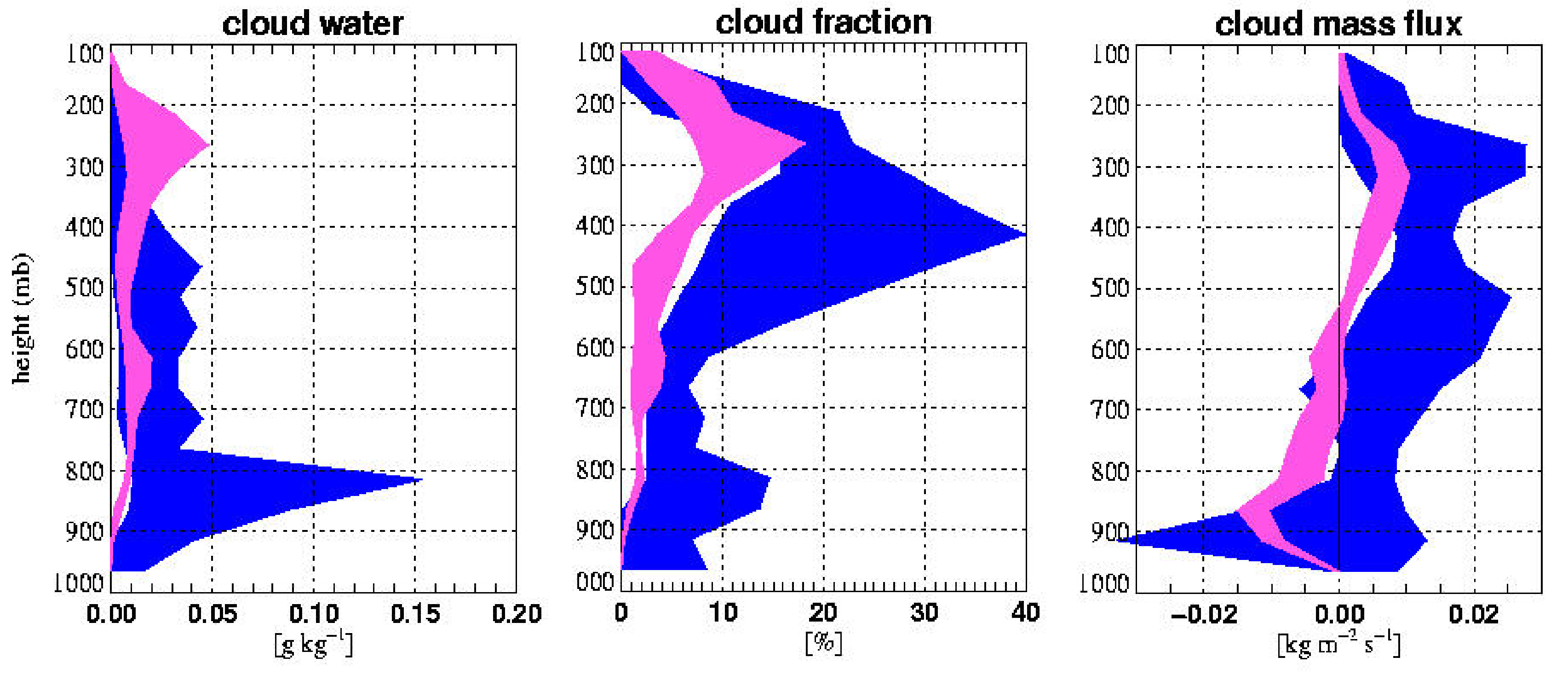
an example : comparison with obs, min-max envelope for **CRMs** & **SCMs**



➢ *better agreement & less scatter among CRM results that SCM ones*

(figures : from EUROCS report)

comparison CRMs & SCMs (no observations available)

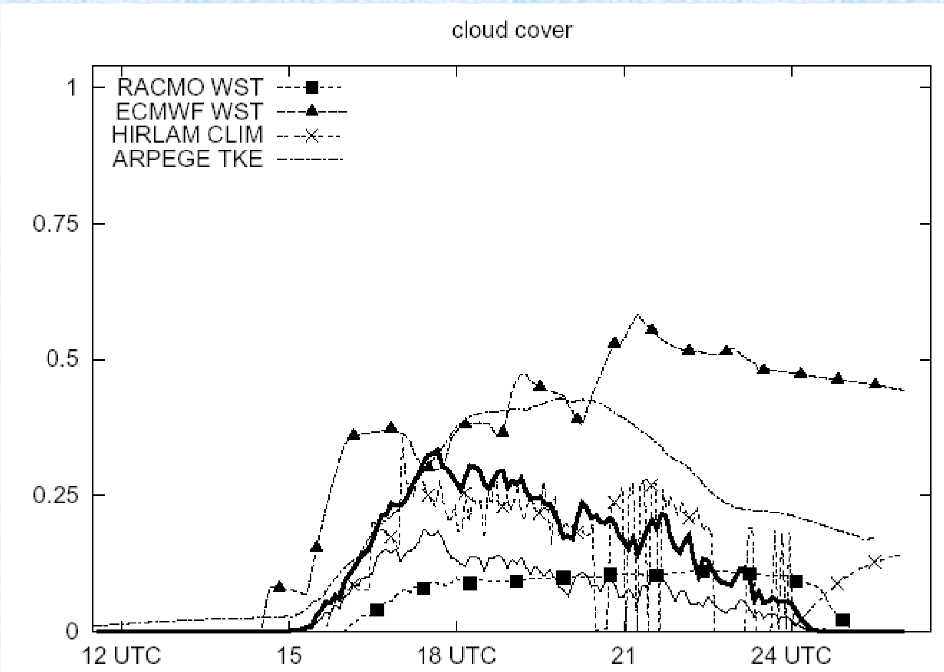


- *scatter linked to the microphysics for CRMs in the upper troposphere*
- *very weak convective downdraughts in several SCMs*
- *obviously room for CRMs improvements*
- *however much more consistency among CRMs than SCMs*

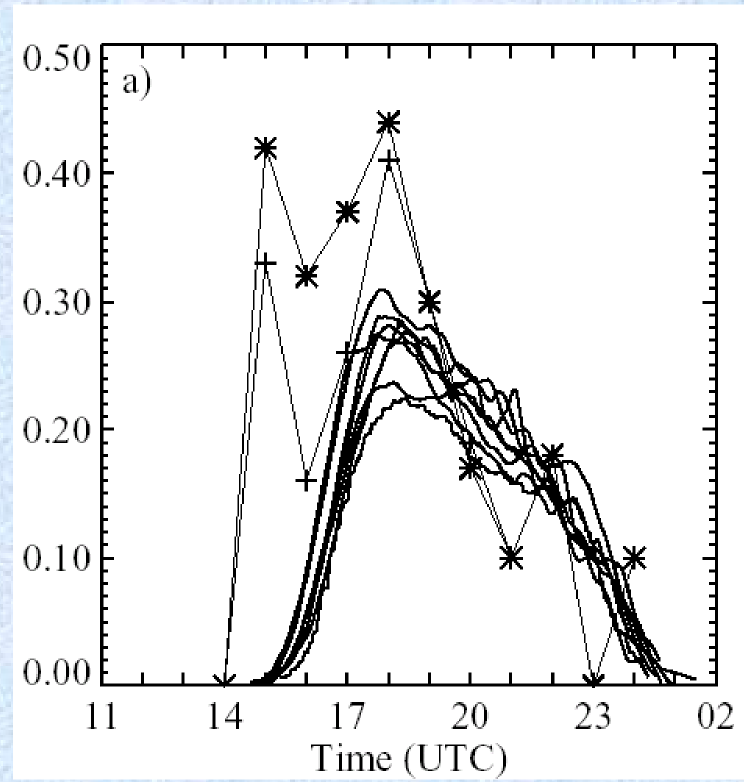
(figures : from EUROCS report)

diurnal cycle of shallow cumulus

cloud fraction

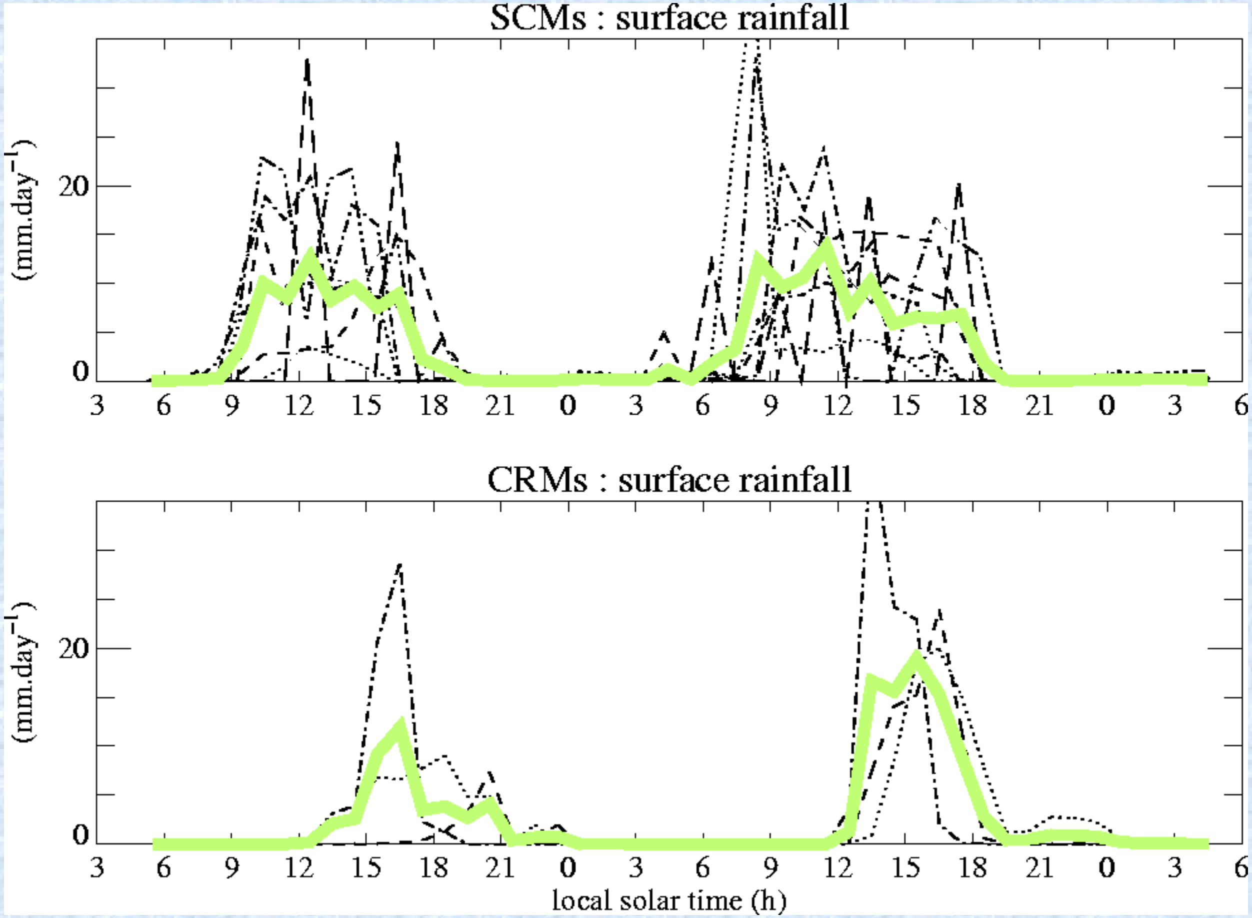


Lenderink et al.(2004)
intercomparaison SCMs
results at the end of the project



Brown et al.(2002)
intercomparaison LES

crucial role of the coupling between BL & cumulus parametrization !

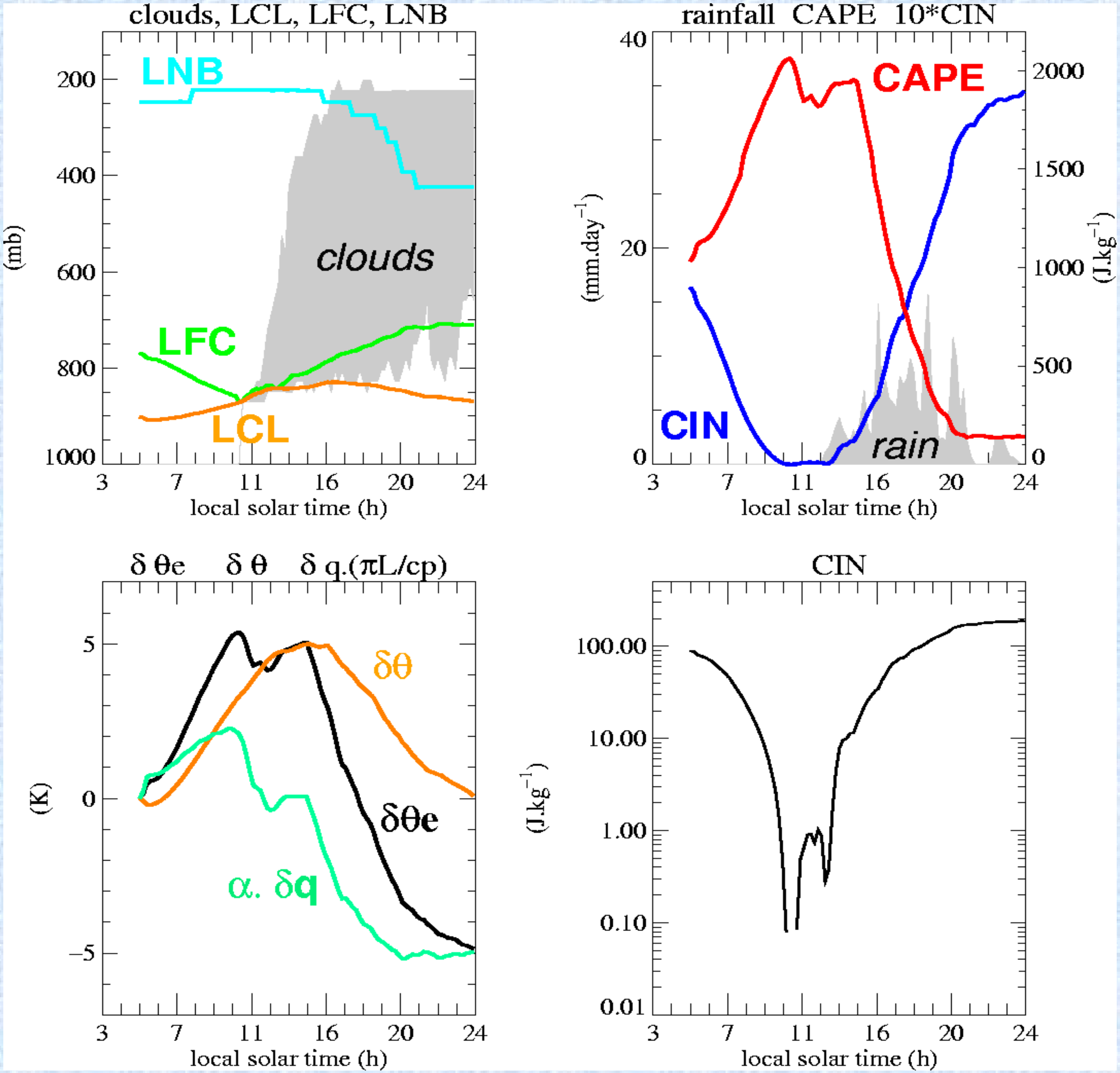


Guichard et al. (2004)

Large spread in the amount of predicted rainfall but…
the typical weakness found in GCMs is reproduced
deep convection starts later in CRMs

Why?

diurnal cycle of convection in CRMs

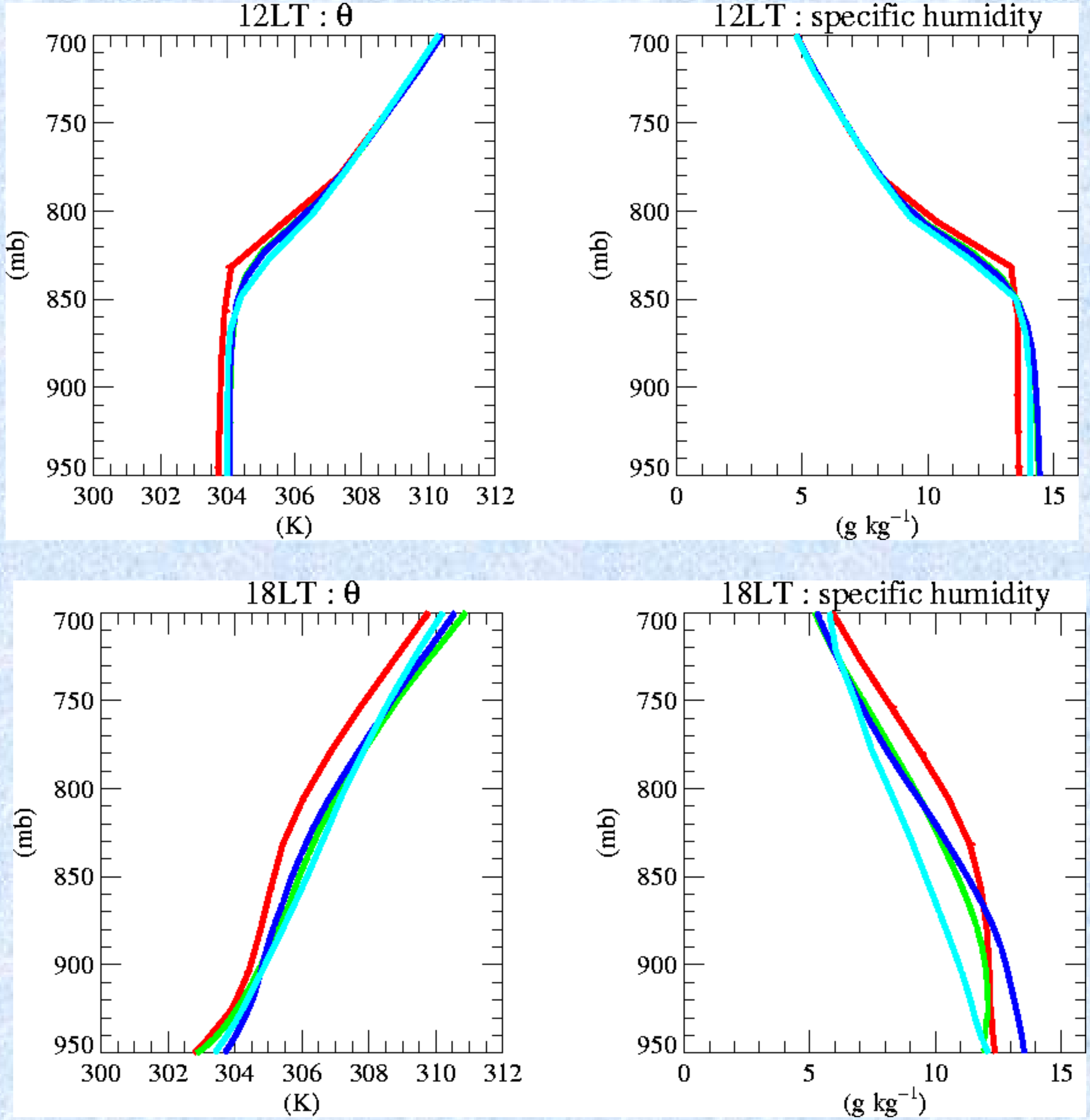


Guichard et al. (2004)

θ and q in the BL: CRMs

at noon

in the late afternoon



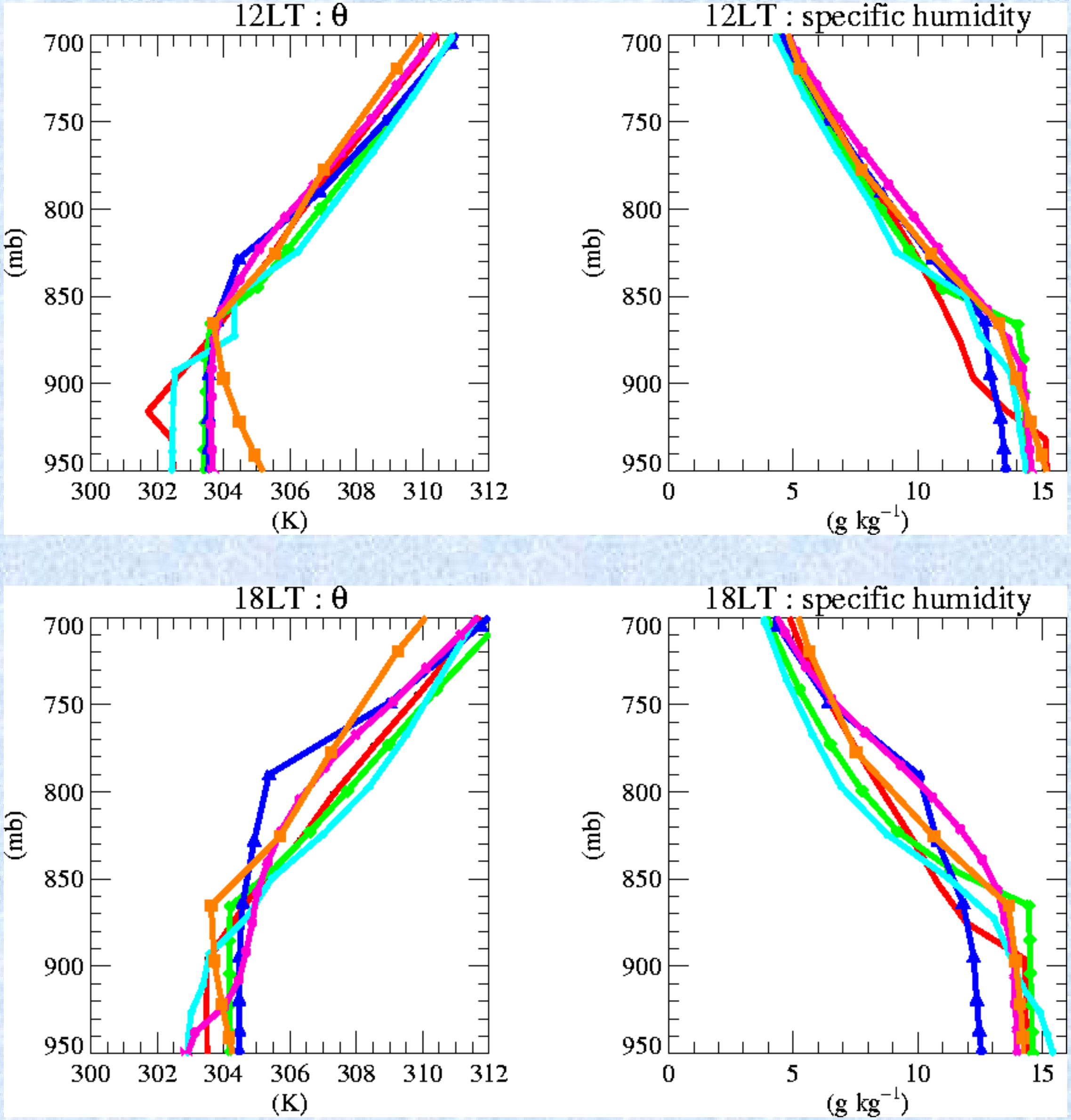
differences in BL at noon consistent with further differences in moist convection development

Guichard et al. (2004)

θ and q in the BL: SCMs

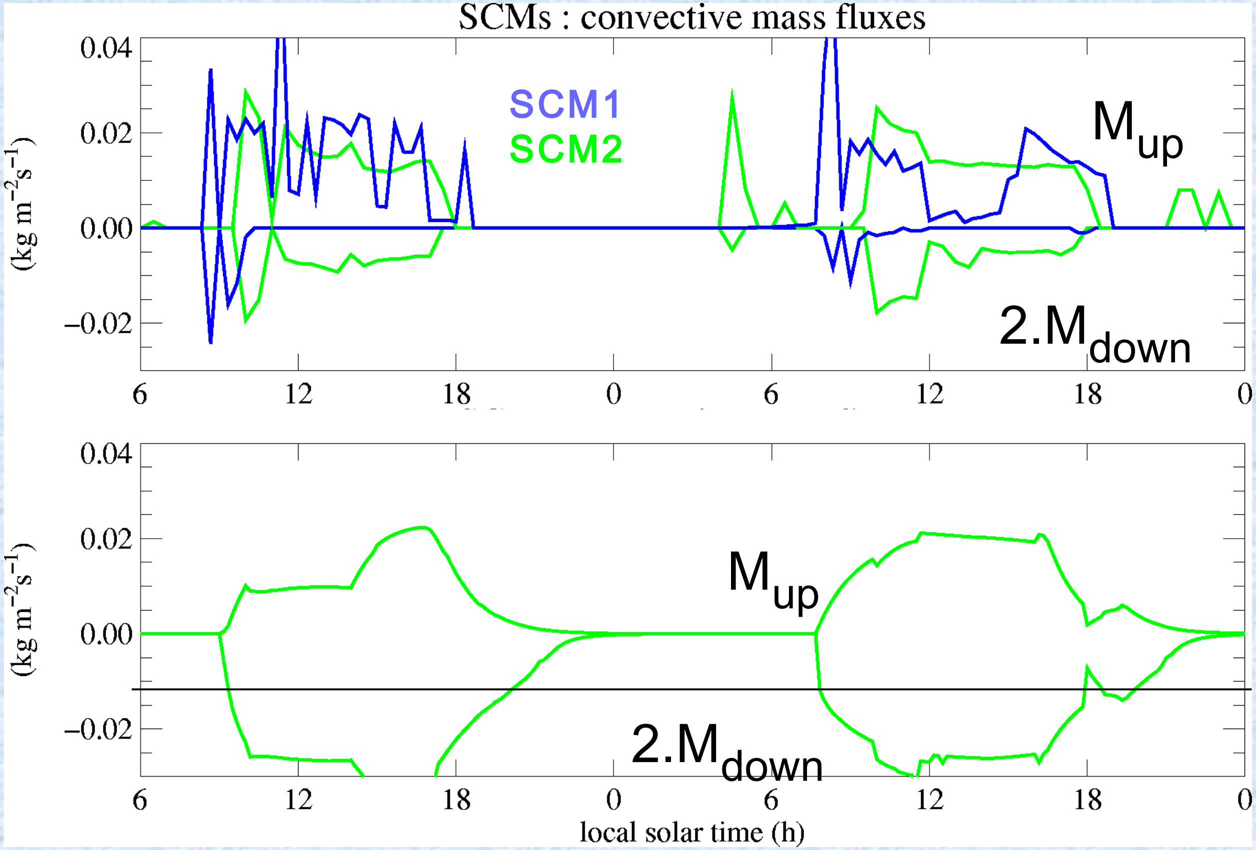
at noon

in the late afternoon



Guichard et al. (2004)

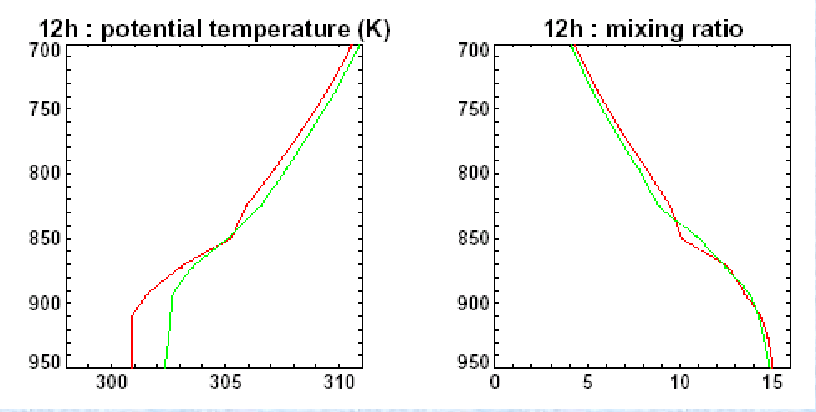
characteristics of parameterized downdrafts

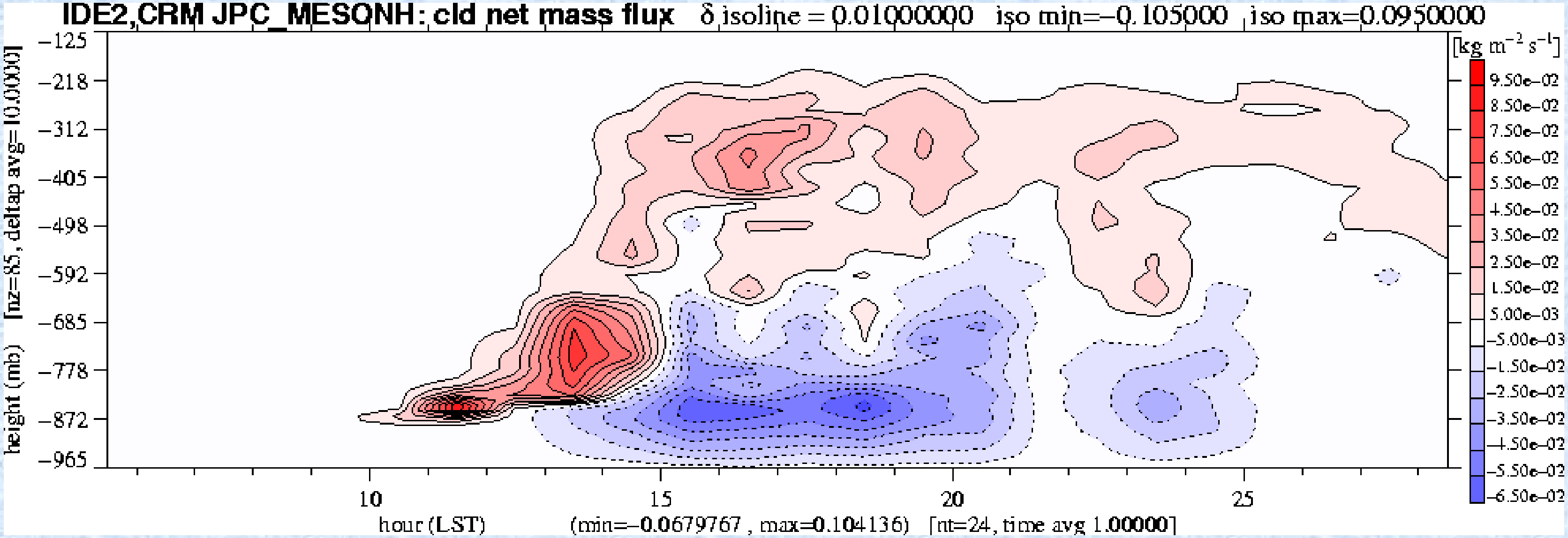


Guichard et al. (2004)

contrasted behaviours among SCMs
various relative intensities (not directly linked to their impact though)

significant impact on BL development in the morning, additional source of pb





(figure from EUROCS web page)

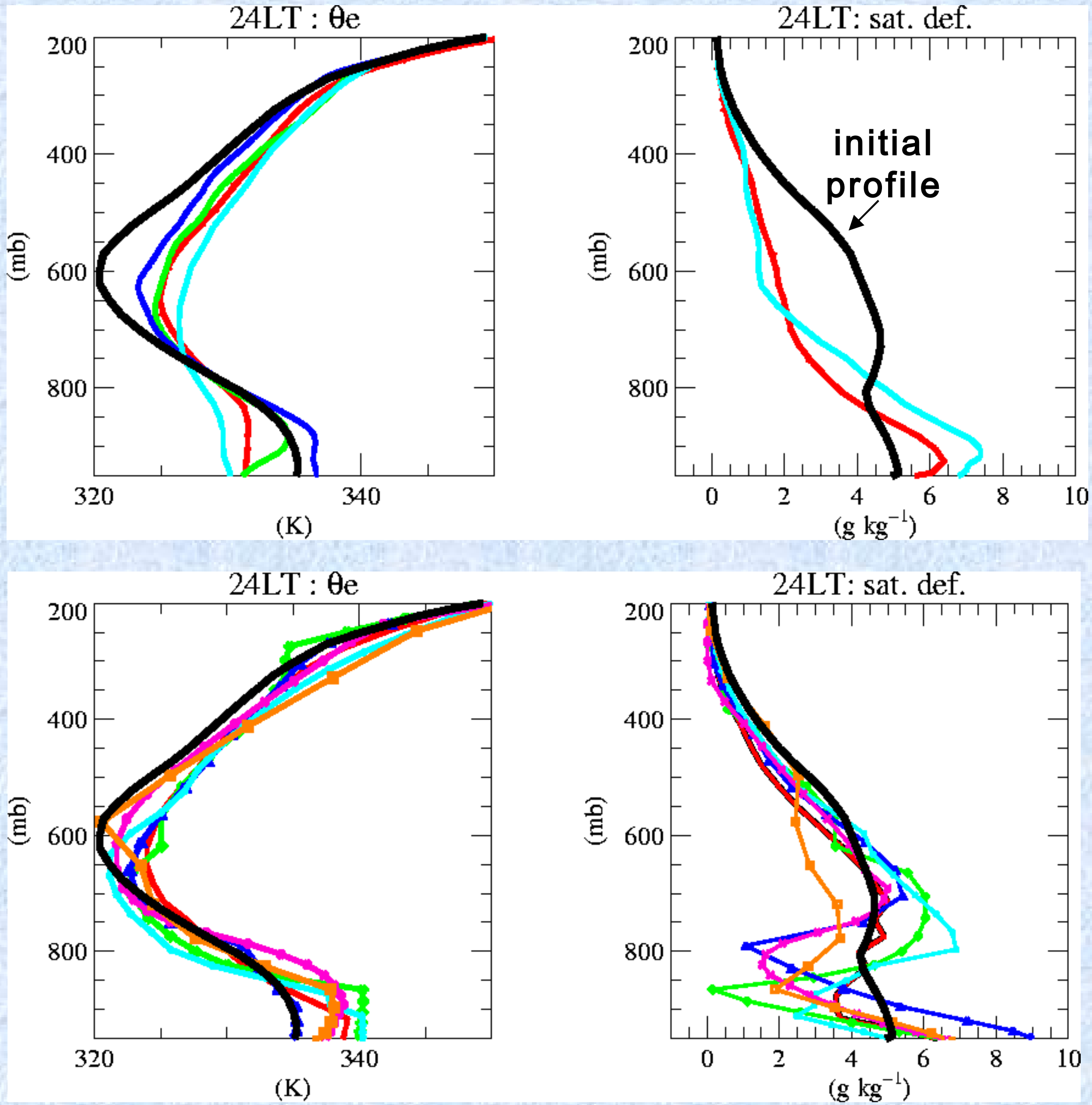
In CRMs, convective draughts are predominantly upwards at first, convective downdraughts develop later

Clearly need a dedicated effort/careful analysis
Hypothesis in SCMs? How are they supported or not by CRMs?...

θe and saturation deficit in the whole column at midnight

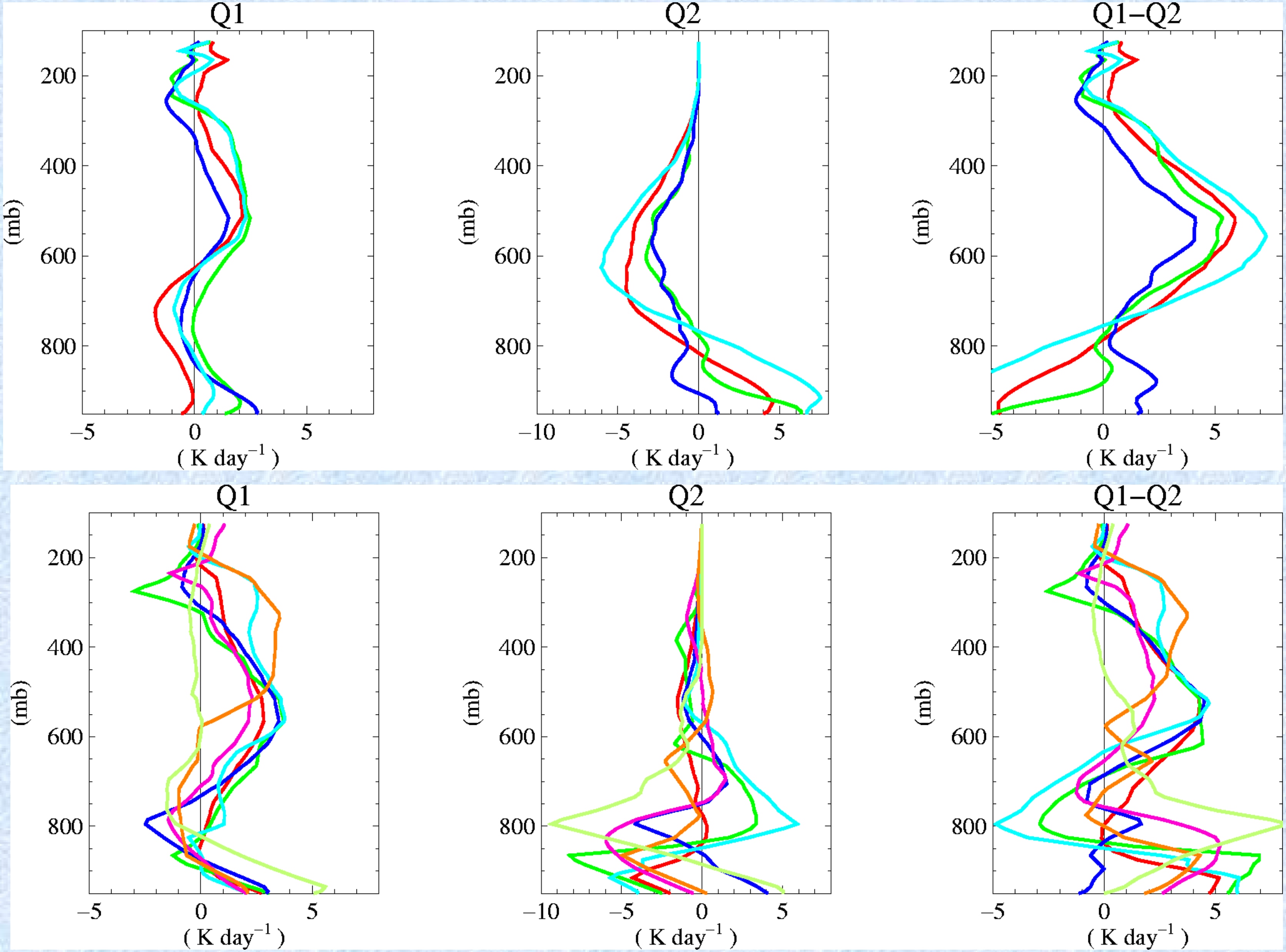
CRMs

SCMs



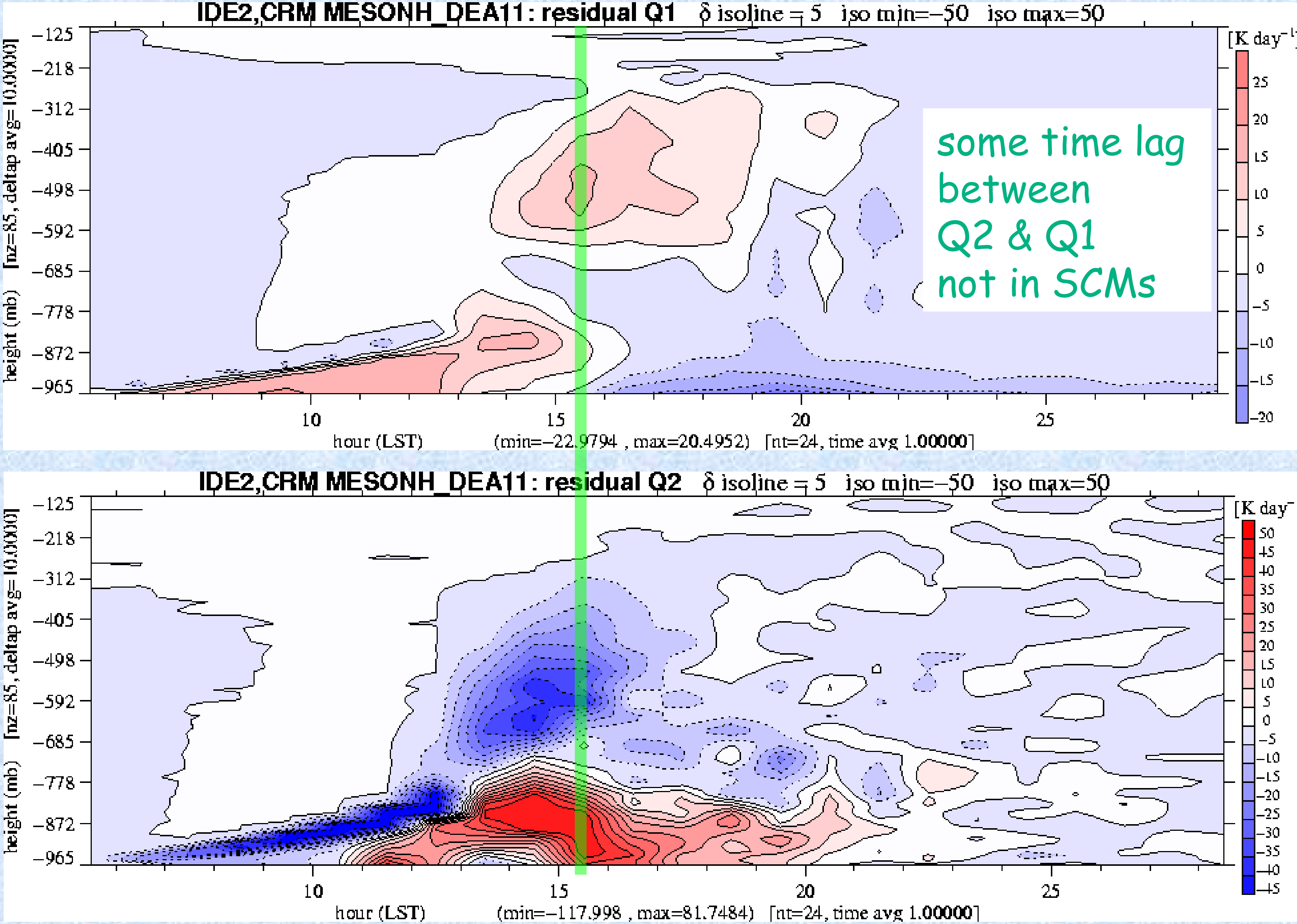
Guichard et al. (2004)

Q1/Q2: time mean profiles



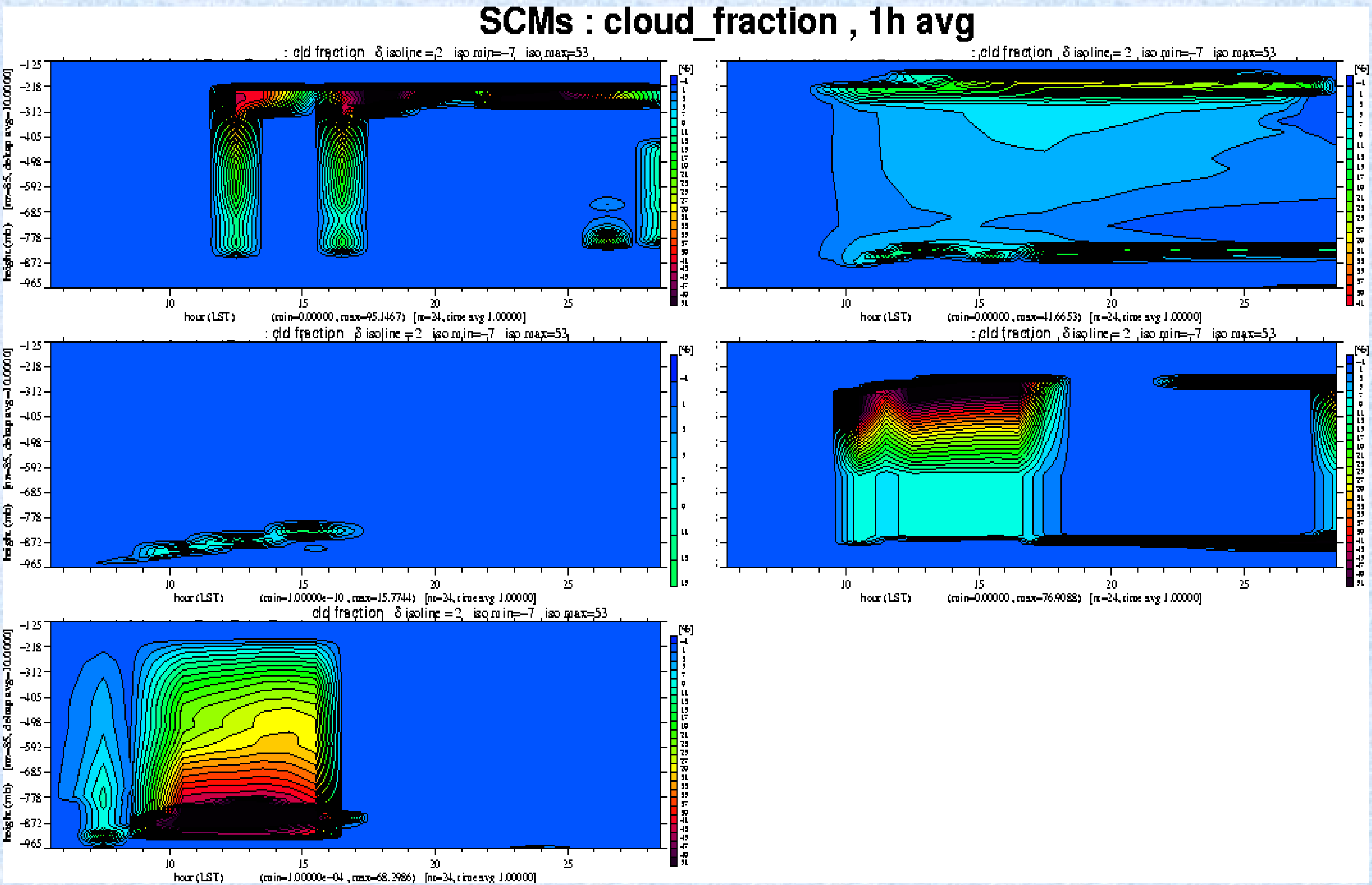
Guichard et al. (2004)

Q1/Q2: time height evolution



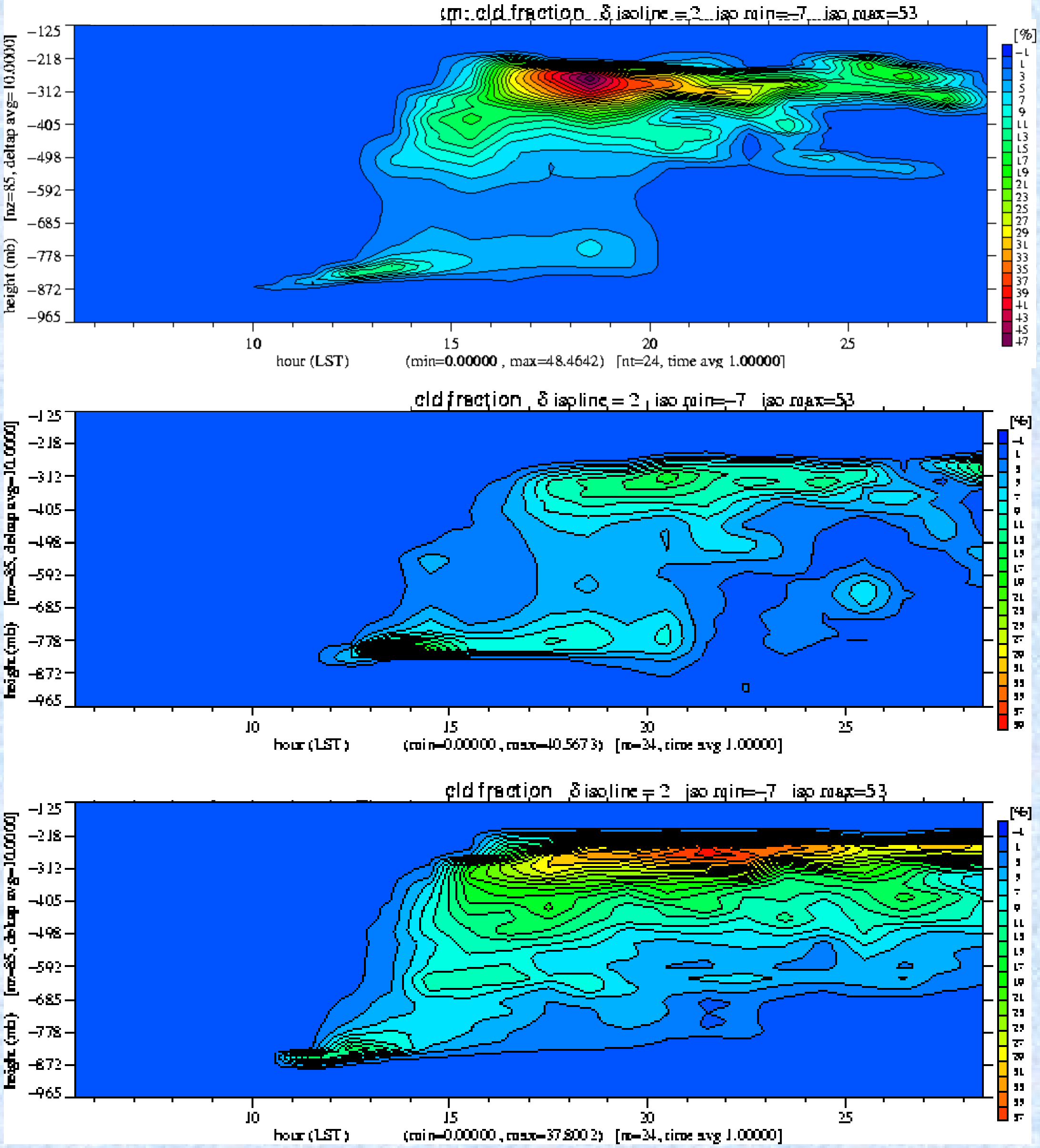
(figures from EUROCS web page)

CLOUDS



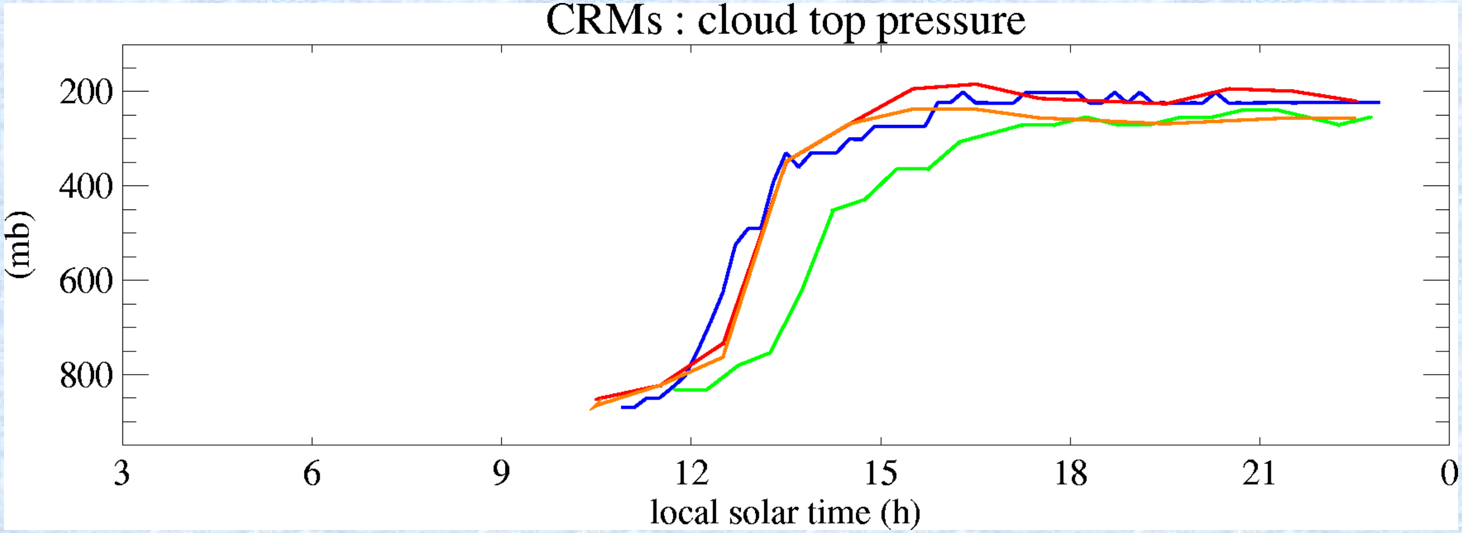
(figures from EUROCS web page)

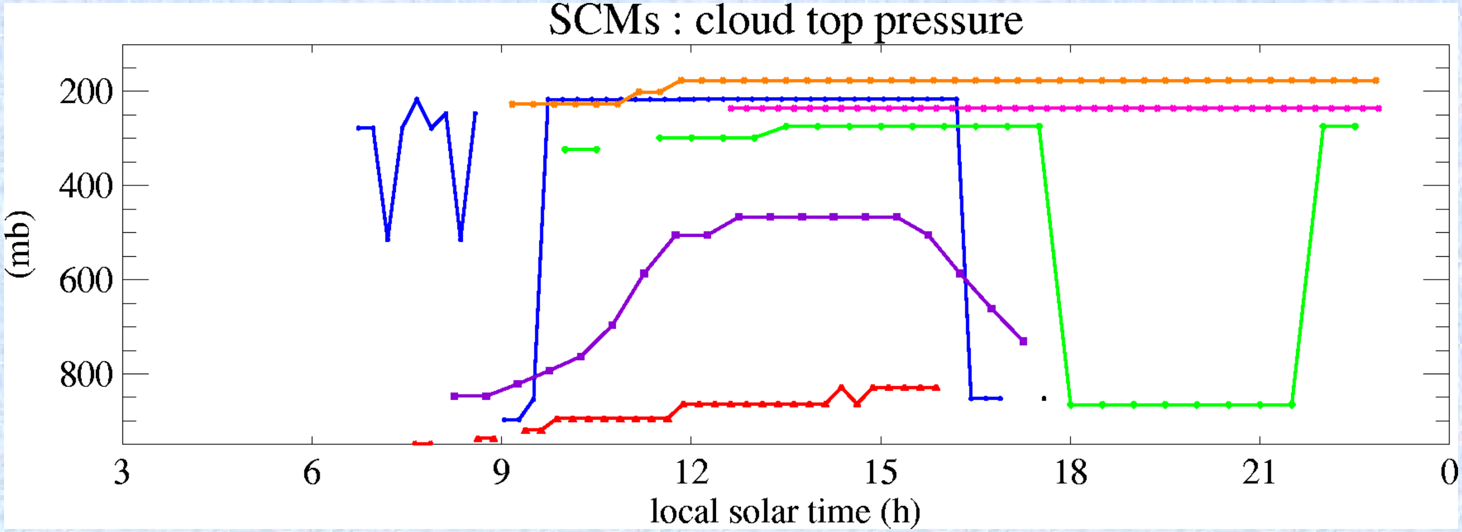
CRMs : cloud_fraction , 1h avg



(figures from EUROCS web page)

clouds





Guichard et al. (2004)

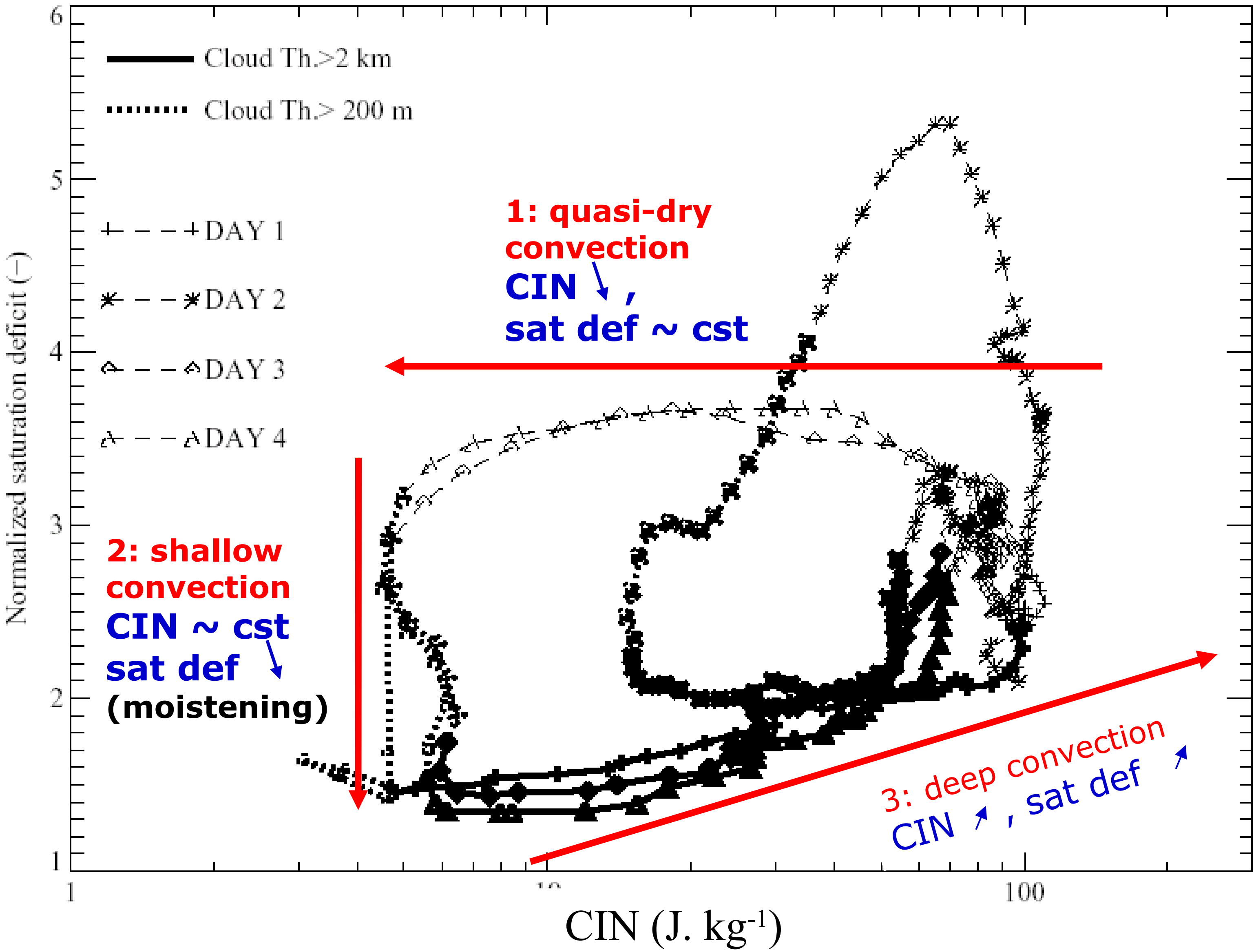
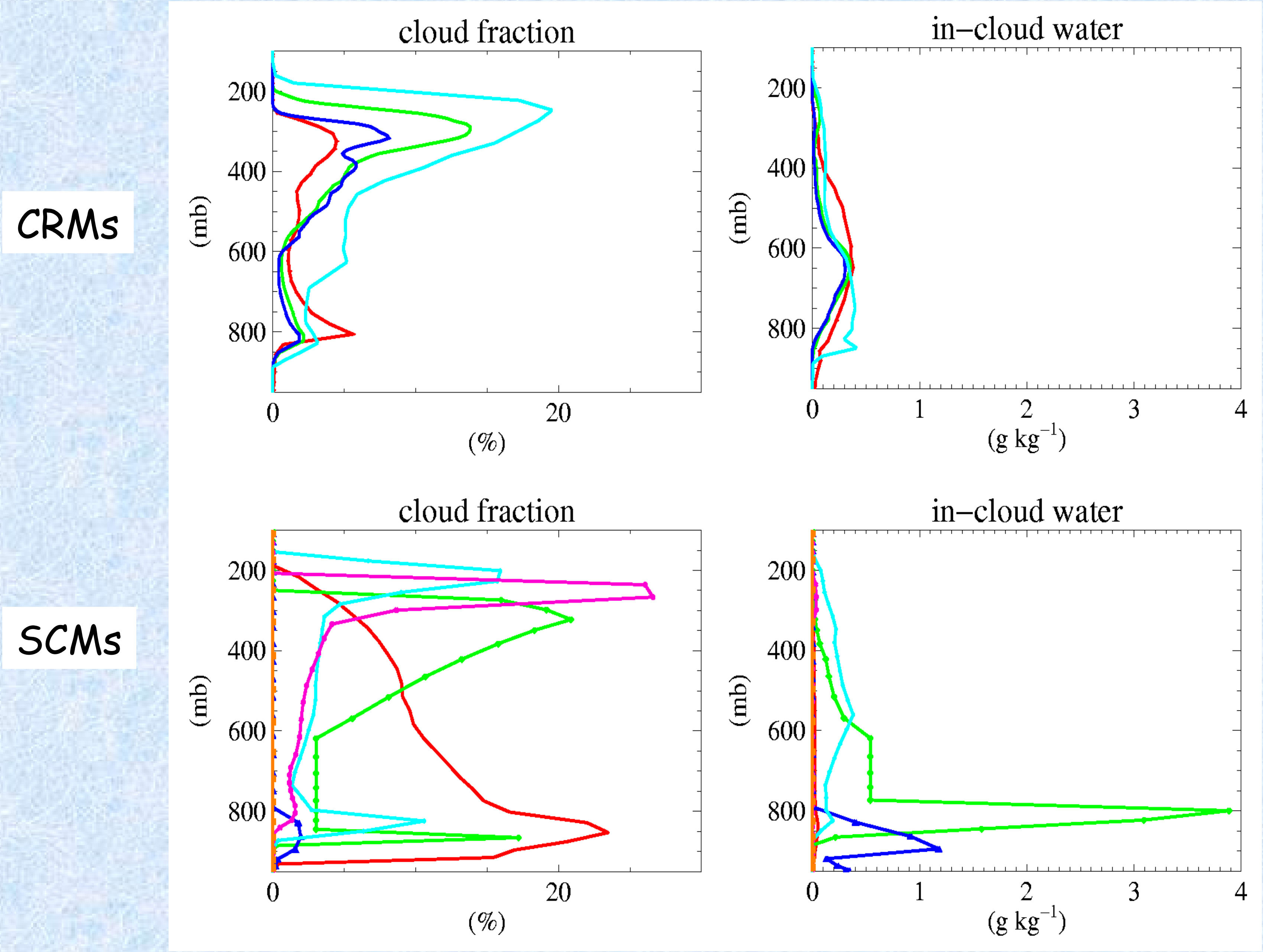


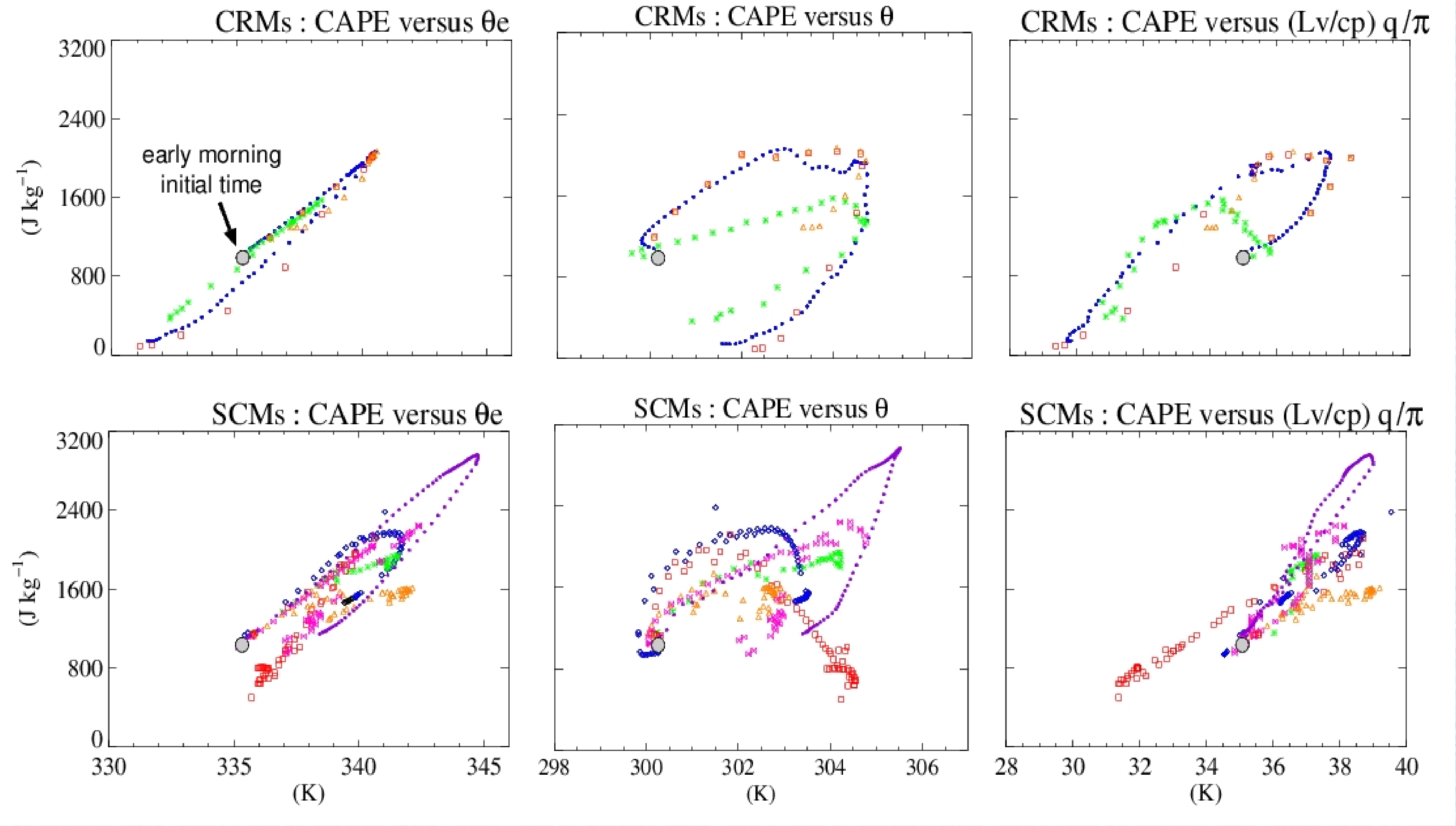
Figure 7. Normalized saturation deficit averaged between the PBL top and the LFC as function of CIN. Dotted (solid) thick line represents the periods with the cloud thickness larger than 200 m (2 km, respectively).

Chaboureau et al. (2004)

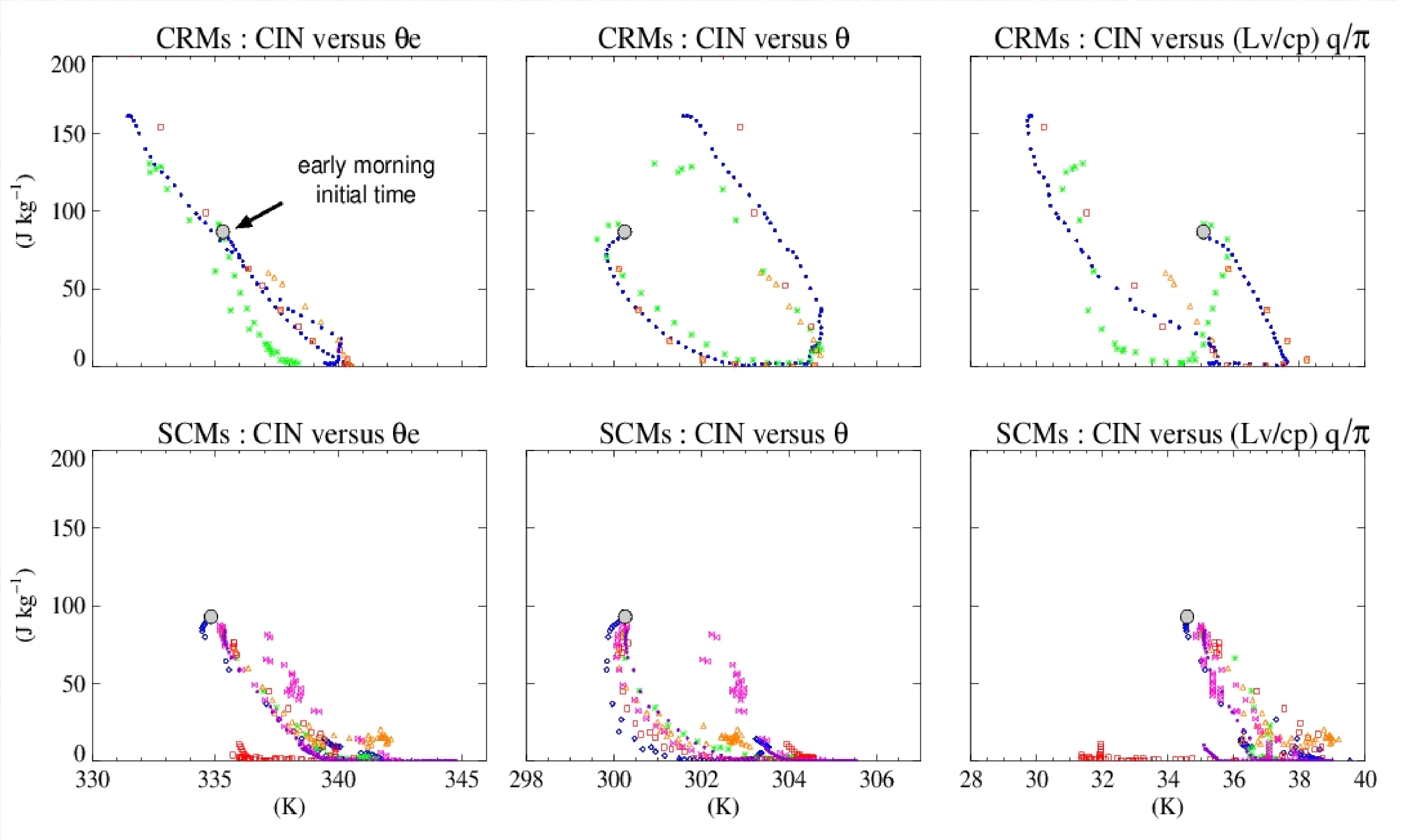


Guichard et al. (2004)

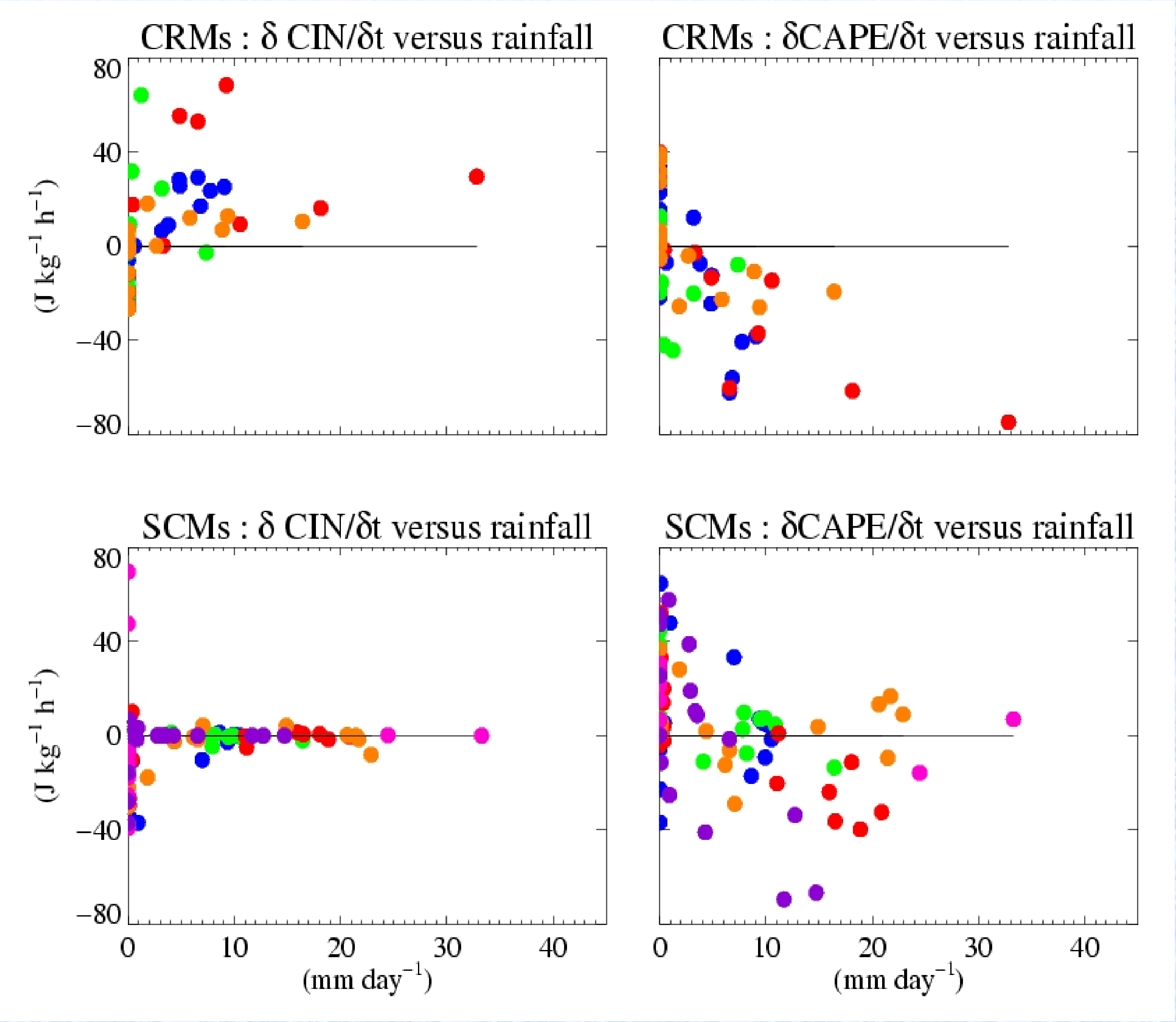
Diurnal cycle of convective stability



Guichard et al. (2004)



Guichard et al. (2004)



Guichard et al. (2004)

summary (1/2)

a simple framework (case-study) for CRMs and SCMs allows to identify weaknesses of conv. param. / type of situation

✓ CRMs: provided useful informations despite weaknesses (BL & shallow cumulus) about the succession of convective regimes

✓ most SCMs cannot handle properly such a succession of regimes

✓ difficulties with boundary layer simulation

✓ too early triggering of convection can be related to
- *their too strong link with CAPE independently of BL activity*
- *their lack of sensitivity to moisture / ≠ CRMs*

✓ additionnal problemes arise from the param. of downdraughts...

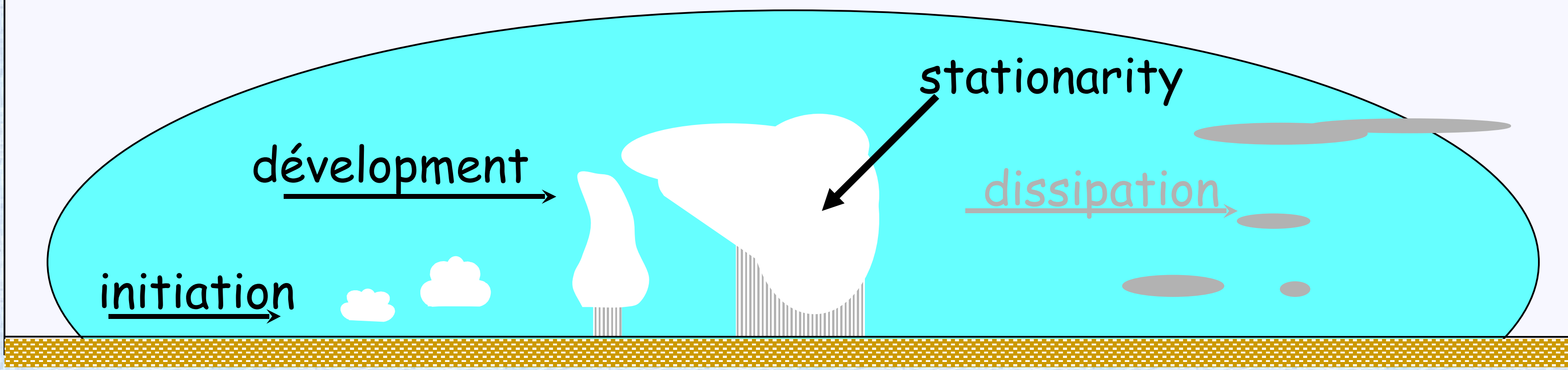
✓ strong & various impacts on the simulated clouds (each SCM a special case)

on going work, on entrainment *(methods)* ...

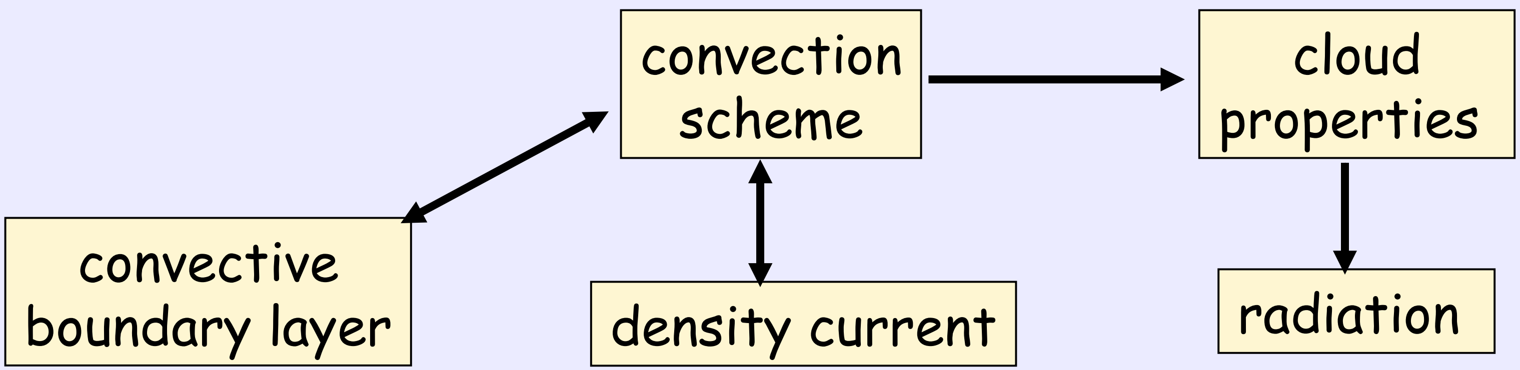
in //: analysis of data / transition phases required

SUMMARY (2/2)

life cycle, transitions, régimes



parametrization: not only a set of independent schemes their mutual interactions



not much progress can be expected without an improvement of both schemes & interactions

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