EUROCS ACTIVITY towards the DIURNAL CYCLE of DEEP CONVECTION OVER LAND

Guichard[*], Petch[£], Beau[*], Chaboureau[*,#], Grandpeix[&], Grenier[*], Jakob[#], Jones[§], Lafore[*], Redelsperger[*], Royer[*], Tailleux[&] and Tomasini[*]

CNRM[*], ECMWF[#], Met Office[£], LMD[&] and SMHI[§]
(Europe, France, Sweden and UK)

EGS 26 April 2002, Nice

EUROCS : EUROpean Cloud Systems

3-year project funded by the European Union (Mar 2000 – Feb2003)

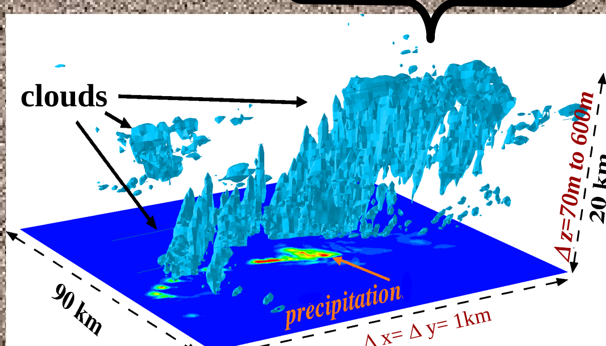
final aims: to improve the treatment of cloud systems in global and regional climate models

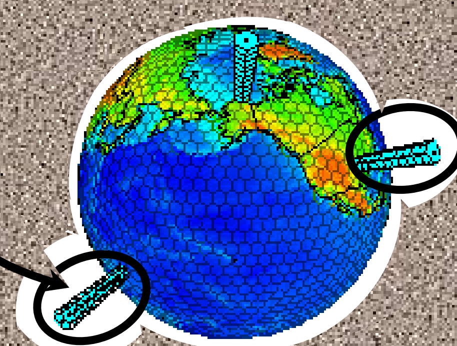
links with GCSS (GEWEX Cloud System Study)

- concentrates on 4 major well identified deficiencies of climate models:
  - ✓stratocumulus over ocean
  - ✓diurnal cycle of cumulus
  - ✓sensitivity of deep convection development on the moisture profile
  - ✓**diurnal cycle of precipitating deep convection over continents**

- bring together a community of modelers : hierarchy of scales

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





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

for more infos: www.cnrm.meteo.fr/gcss/EUROCS/EUROCS.html & J.-L. Redelsperger

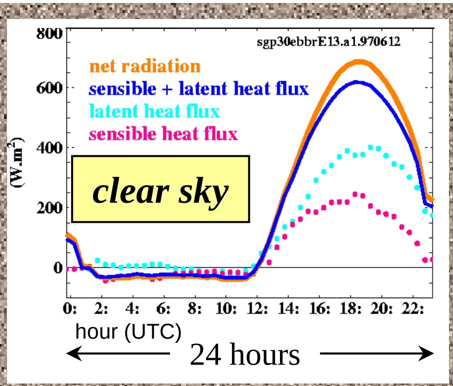
DIURNAL CYCLE OF CONVECTION: CONTEXT

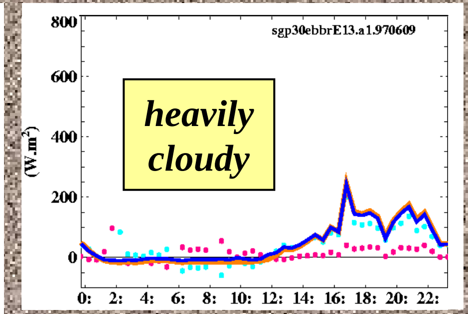
➢ *fundamental mode of variability of the climate system*

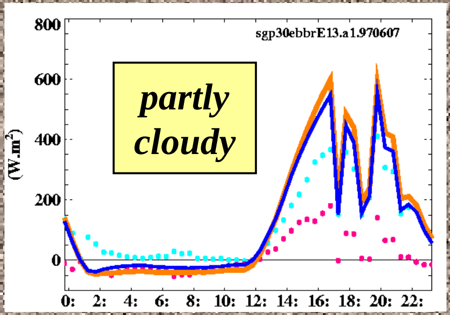
motivation: important role in the energy & water budgets

✓ radiation: contrasted day/night cloud-radiation interactions (LW/SW)

✓surface: magnitude & partition of sensible/latent heat fluxes (via cloud albedo, rainfall)







surface fluxes measurements (Bowen ratio method) ARM SGP site

what we know (dozens of articles!)

✓ stronger over land than over ocean (30-50% & 10-20 % of the total variance resp.)

✓ phase difference between land & open ocean areas

over land: afternoon-evening maximum

over ocean: early morning maximum (various theories)

✓ season dependent (stronger in summer)

✓ daytime boundary layer heating

✓ but also regional effects, orography, regimes (E/W LBA), life cycle of MCSs

✓changes in the last decades over the US

DIURNAL CYCLE OF CONVECTION: CONTEXT

modelling

- ✓ relevant & demanding test for GCMs
- ✓ assess physical parameterizations : radiation, surface exchanges, boundary layer, convective & cloud processes
- ✓ interactions surface-boundary layer-free troposphere

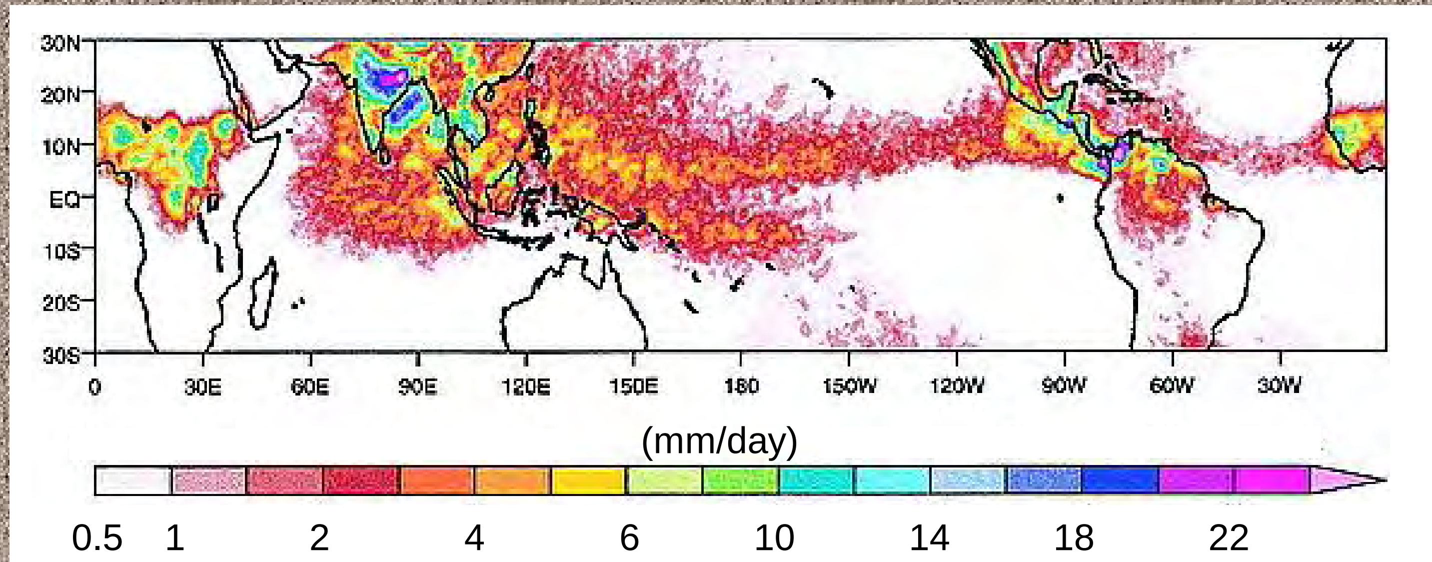
- ✓ difficult to reproduce by GCMs *(next slides)*
- ✓ monthly mean & diurnal cycle both correct at the same time quite challenging *Lin et al. (2000)*

Yang & Slingo (2001)

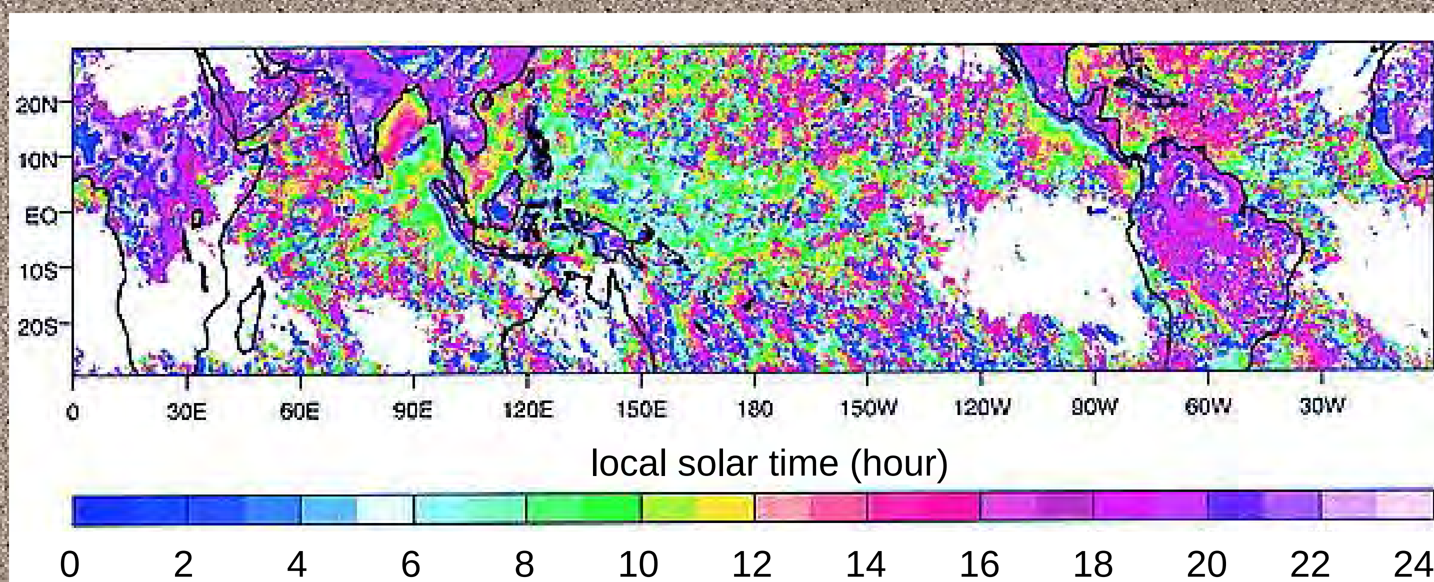
estimated precipitation (from **observations**)

satellite data, CLAUS project, summer 1985,86,87,92

amplitude of the diurnal harmonic



phase of the diurnal harmonic



Yang & Slingo (2001)

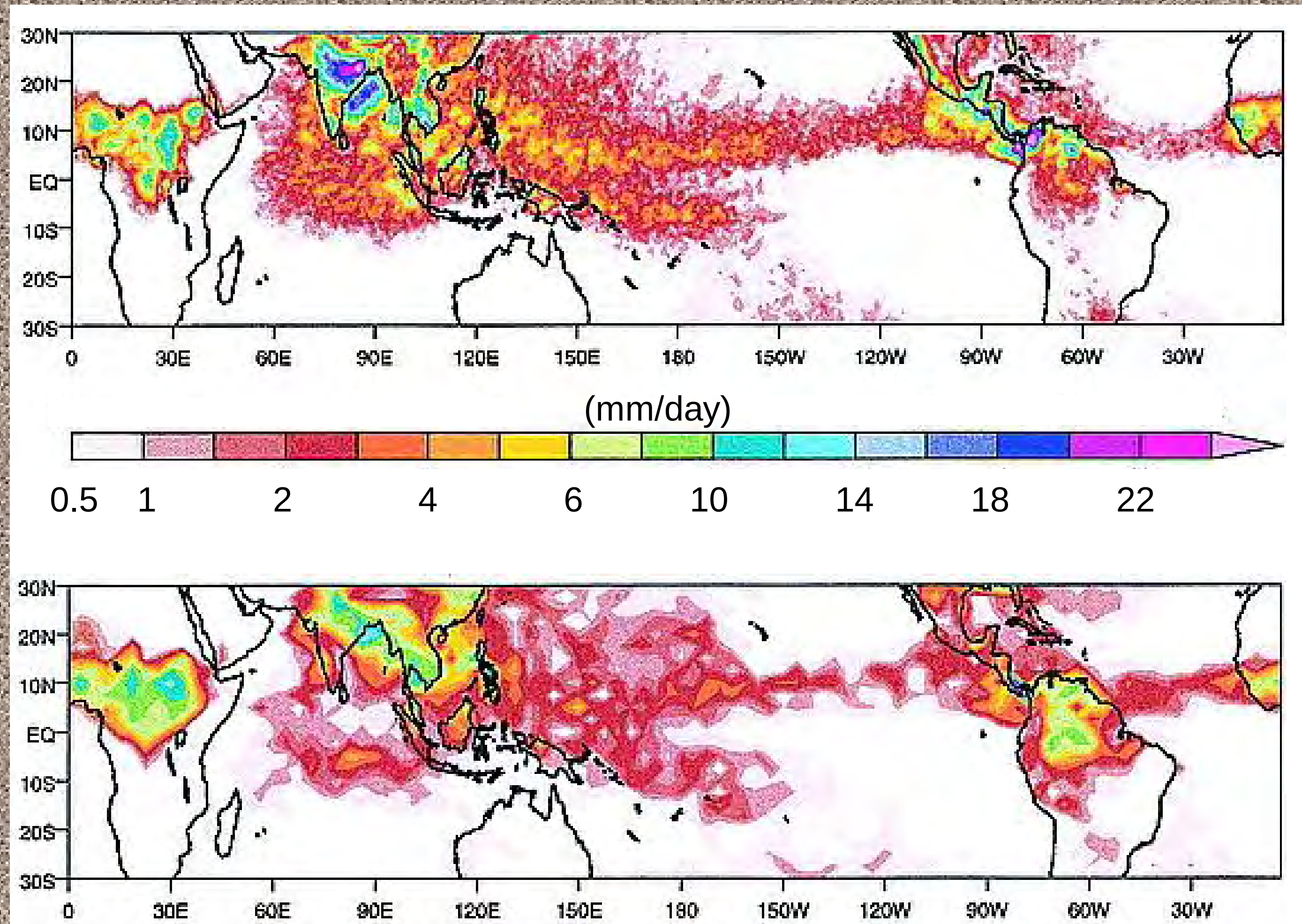
precipitation: **amplitude** of the diurnal harmonic

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)

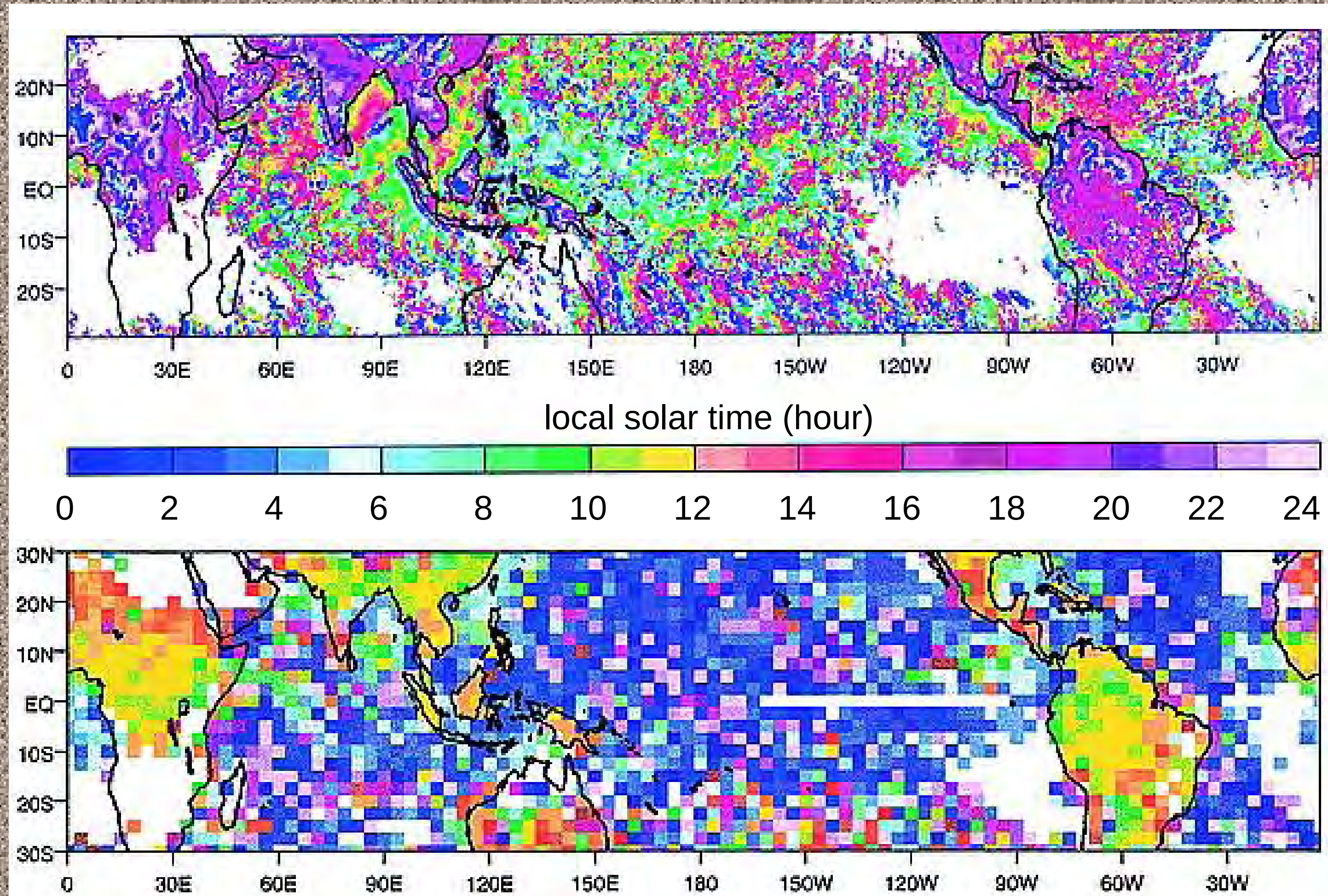
precipitation: **phase** of the diurnal harmonic

OBERVATIONS

CLAUS dataset

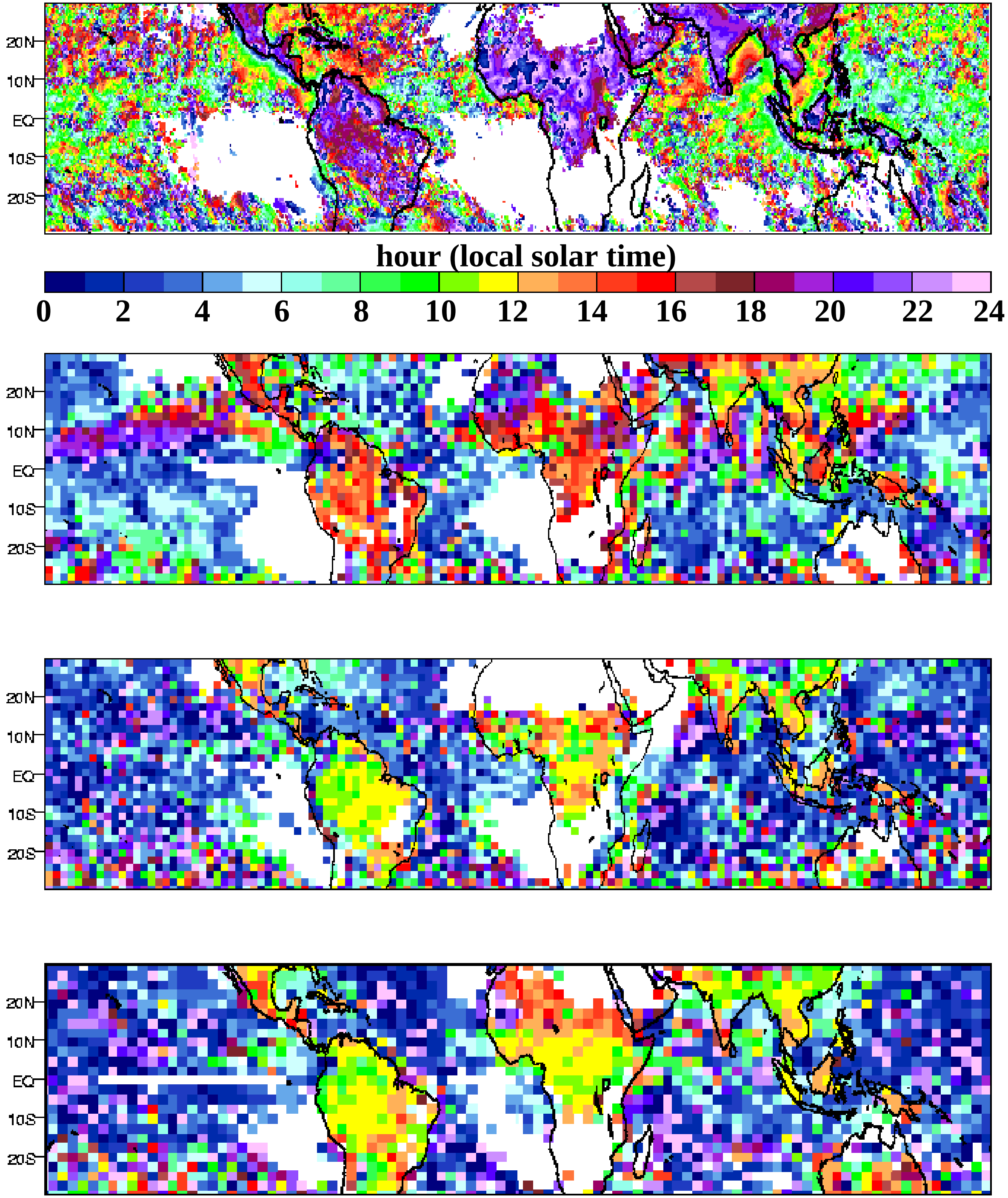
CLIMATE GCM

unified climate model



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

PHASE OF THE DIURNAL HARMONIC IN 3 GCMs
thanks to J.-M. Pirou



OBSERVATIONS
Yang & Slingo (MWR, 2001)

ARPEGE NWP model
Piriou (2002)

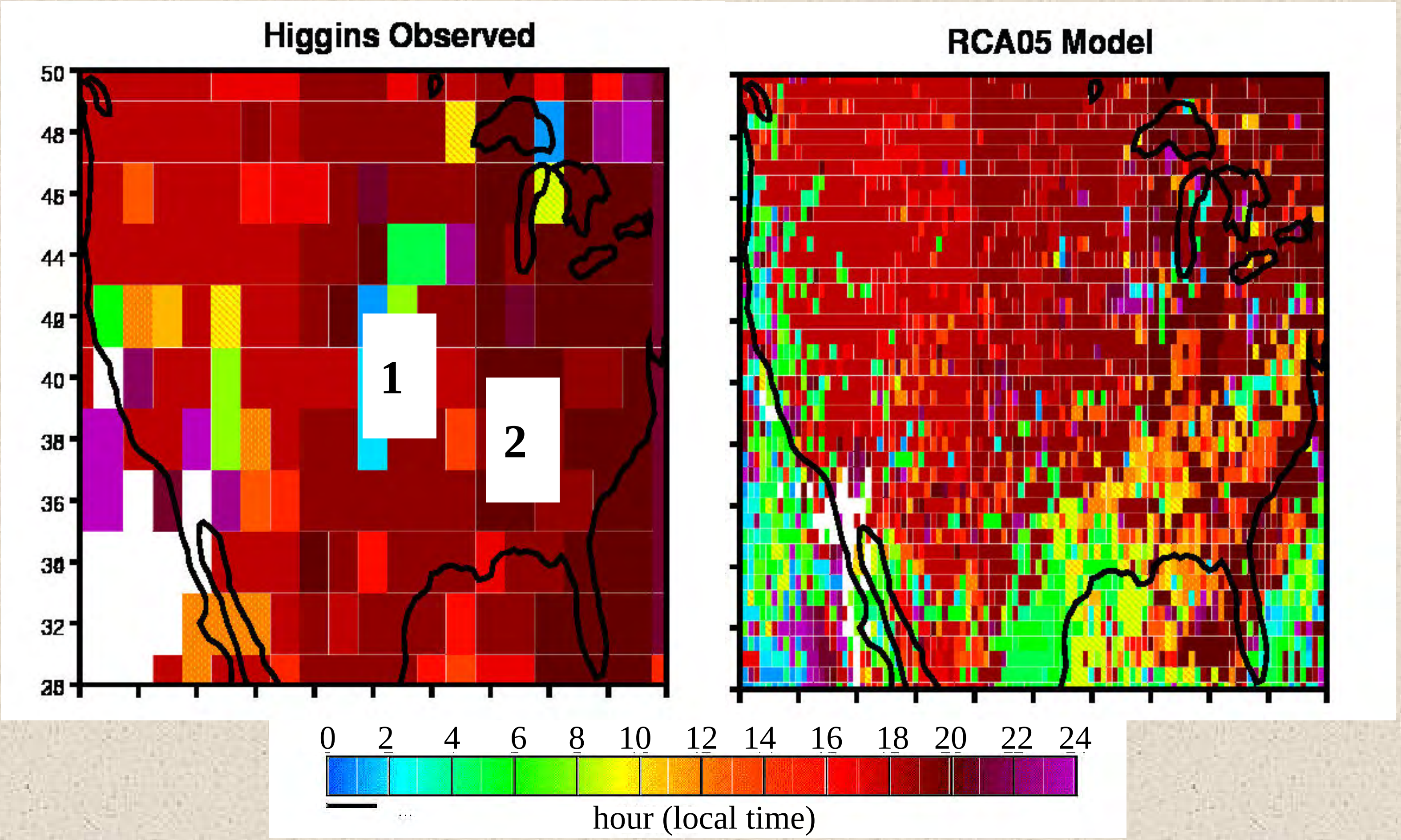
IFS NWP model
Beljaars (2002)

UNIFIED CLIMATE model
Yang & Slingo (MWR, 2001)

➢ ***GCMs wrong in the « same way »***

Regional Climate Modelling *thanks to Colin Jones*

most frequently occuring time of max precipitation in a diurnal cycle
(June 10-July 31 1993, from hourly accumulations)

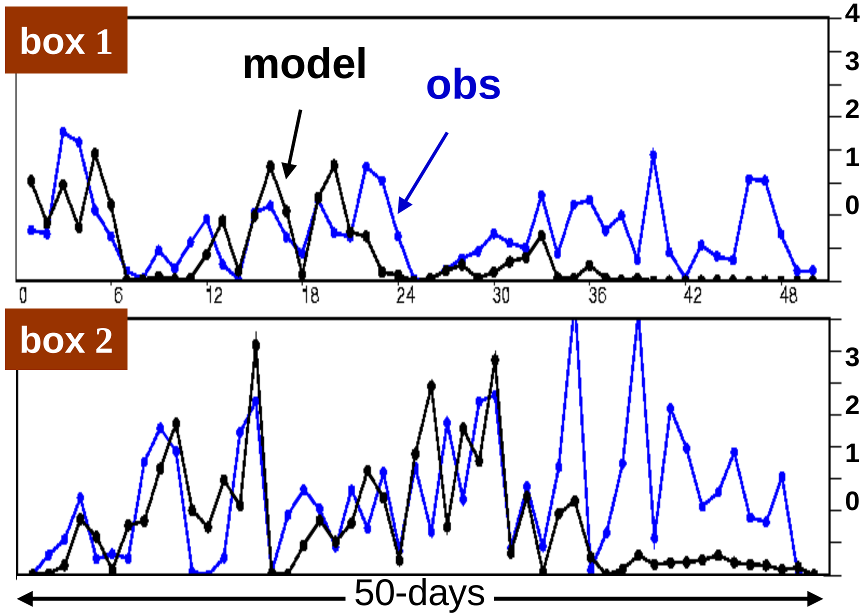


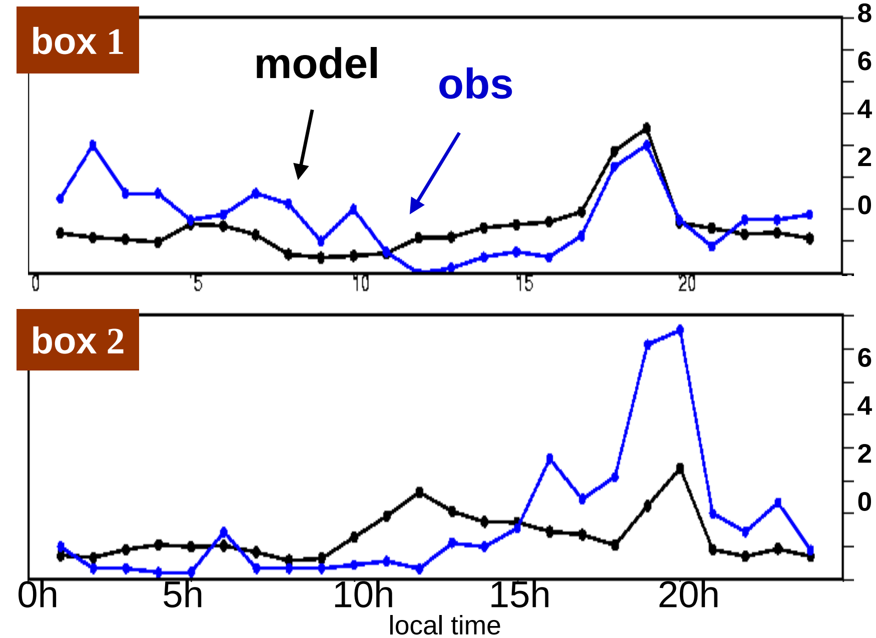
- ✓ ***the model captures the broad early-late evening max of rainfall***
- ✓ ***larger error is in the SE, could be related to its proximity to the model boundaries***

Regional Climate Modelling *thanks to Colin Jones*

daily maximum of precipitation
from 1 hour mean values

binned occurrence of max precipitation
function of local time of day





- ✓ ***first 35 days: maxima of precipitation quite reasonable***
- ✓ ***last 15 days: the model failed to produce rainfall*** ***various causes: analyses, soil moisture***
- ✓***apparently different from Dai et al. (1999)*** ***too early and too weak cycle in RCM***

COMMON CRMs/SCMs CASE STUDY

1 : an « observed case » to assess our models over land (GCSS/ARM)

Southern Great Plains

GCSS WG4 Case3a

✓4-day runs with deep convection occuring
✓large-scale advections prescribed from observations
✓fixed surface heat fluxes
✓wind nudged towards observed
✓cyclic lateral boundary conditions

case part of the GCSS intercomparaison exercise for CRMs Xu et al. (2002) & SCMs (Xie et al. 2002)

2 : building an « idealized case » to address the diurnal cycle of deep convection over land and its representation in models

ARM : Atmospheric Radiation measurement

THE SIMULATIONS : 5 SCMs & 3 CRMs

model type	lab *(model name)*	participants
SCM	CNRM *(ARPEGE Climat)*	Beau & Grenier
SCM	ECMWF *(IFS)*	Chaboureau, Jakob & Koehler
SCM	LMD *(LMDz)*	Tailleux
SCM	Met Office *(UM)*	Petch
SCM	SMHI *(close to HIRLAM)*	Jones
CRM	CNRM *(mésoNH)*	Chaboureau & Tomasini
CRM	CNRM *(comeNH)*	Guichard
CRM	Met Office *(UM)*	Petch

CRMs : Lx ~ 500 km Δx ~ 250m to 2km Δz ~ stretched 70-700m or less
mostly 2D & but a few 3D runs

SCMs : 18 to more than 60 vertical levels

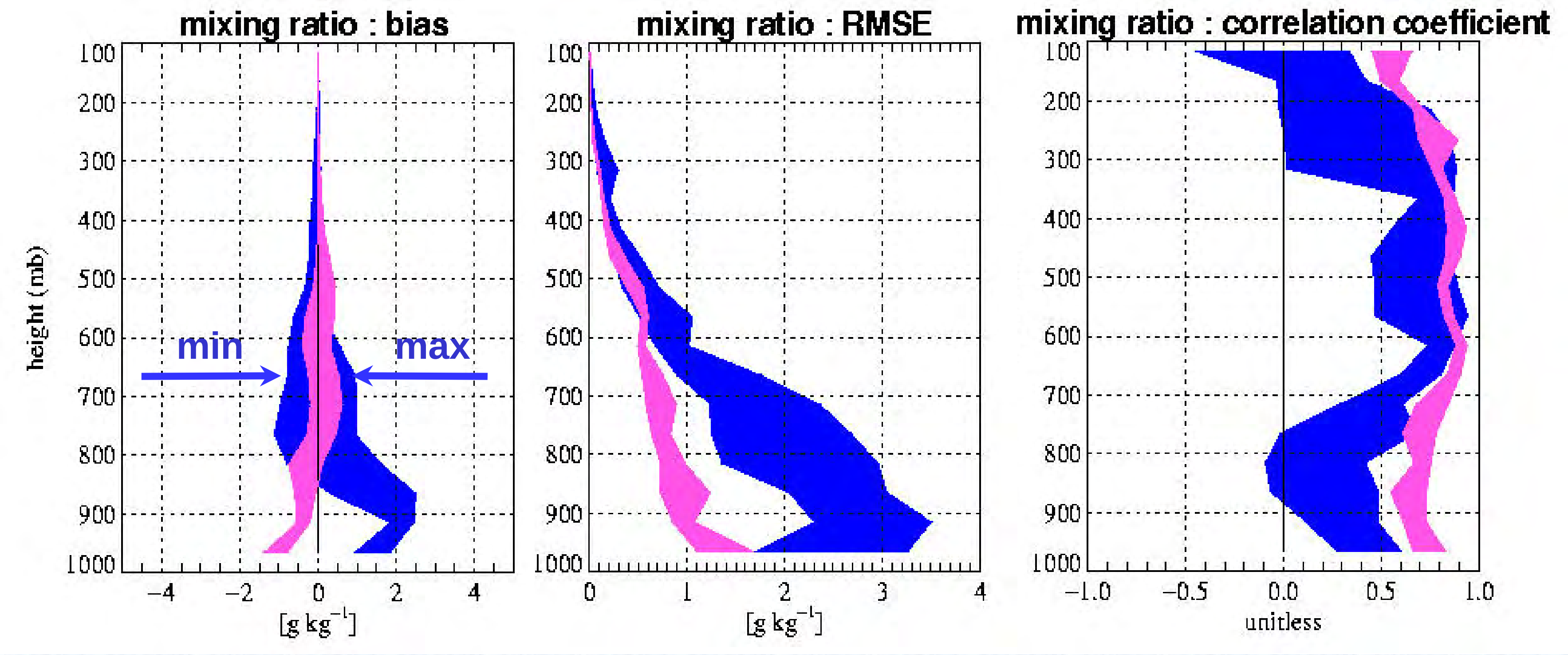
closer lab-lab collaborations, e.g. CNRM-ECMWF (Chaboureau & Koehler)

THE OBSERVED CASE : SUMMARY

✓ broad conclusions in agreement with Xu *et al.* (2002) & Xie *et al.* (2002)

new test for more than 50% of models which were not part of the exercise above
joint comparison of SCMs & SCMs

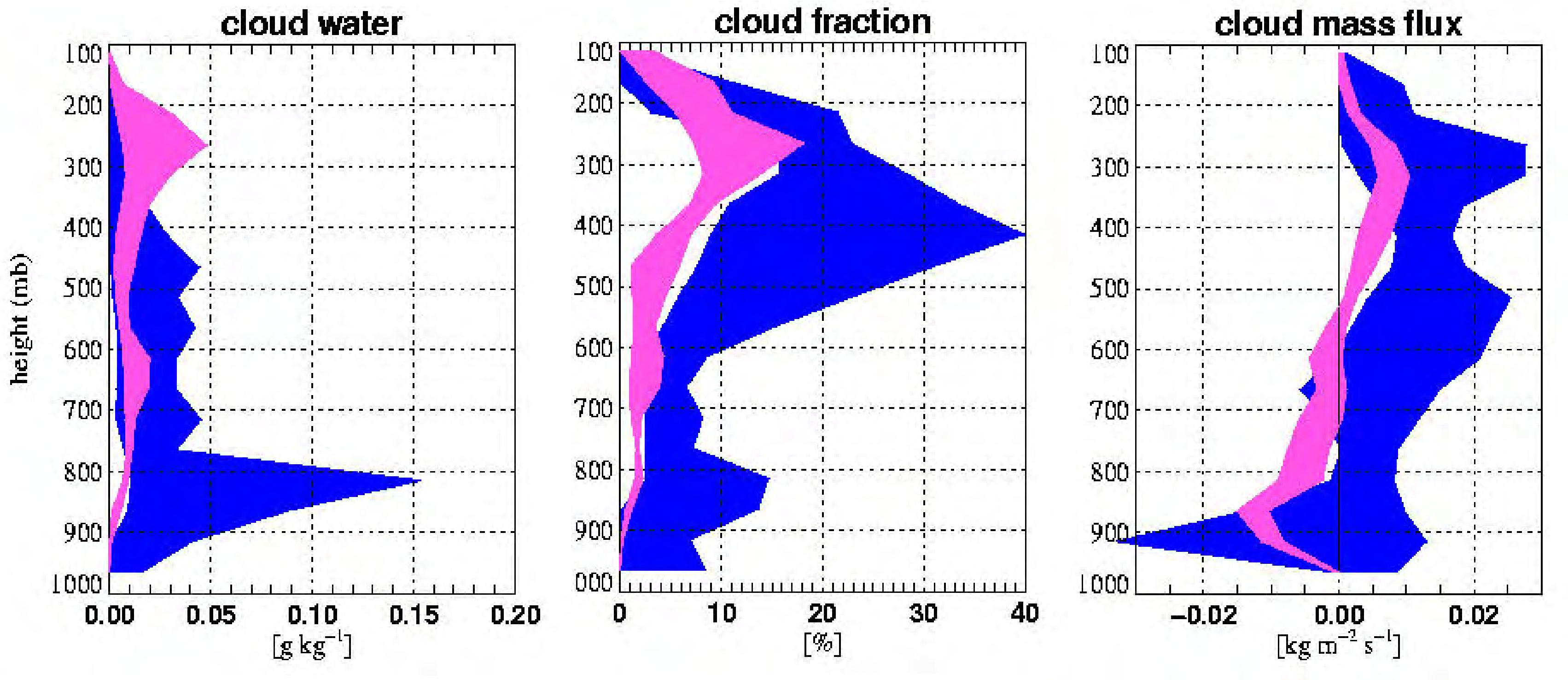
an example : comparison with obs, min-max envelope for **CRMs** & **SCMs**



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

THE OBSERVED CASE : SUMMARY

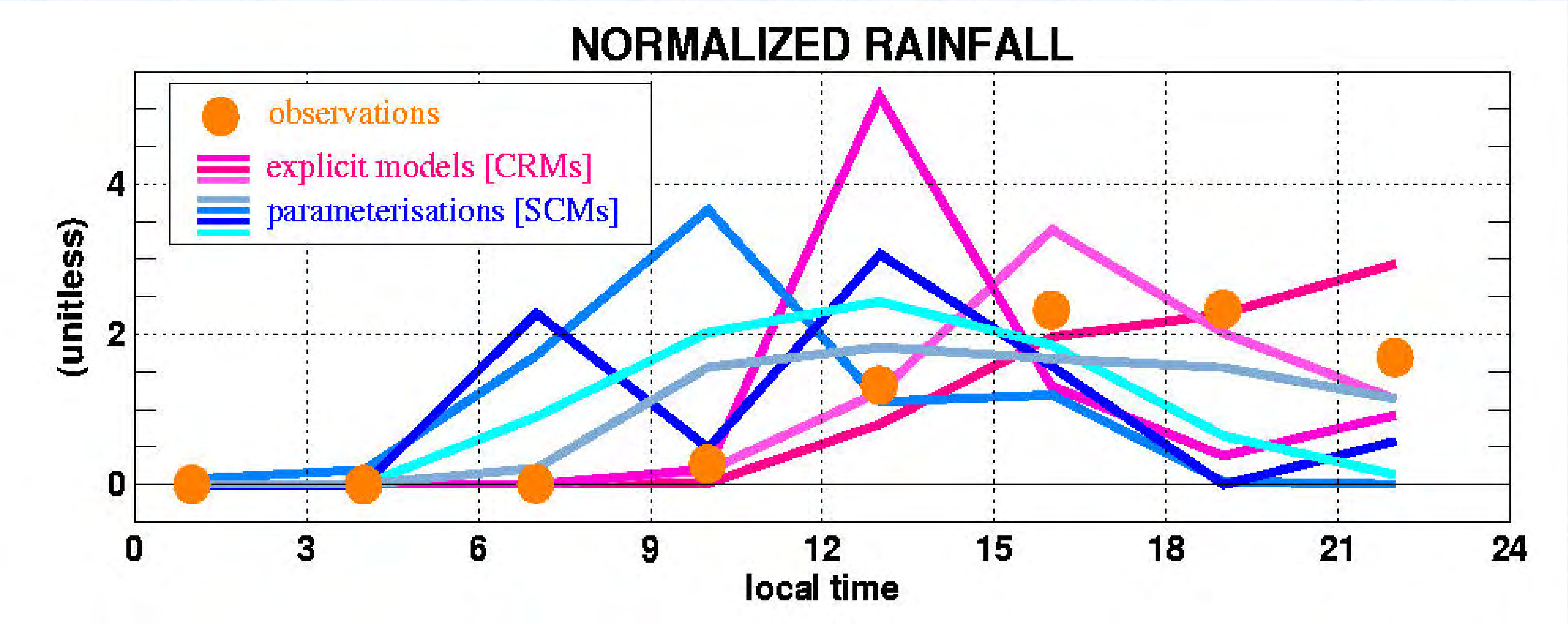
comparison CRMs & SCMs (no observations)



- *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*

THE OBSERVED CASE : SUMMARY

zoom on the 1st part of the simulation

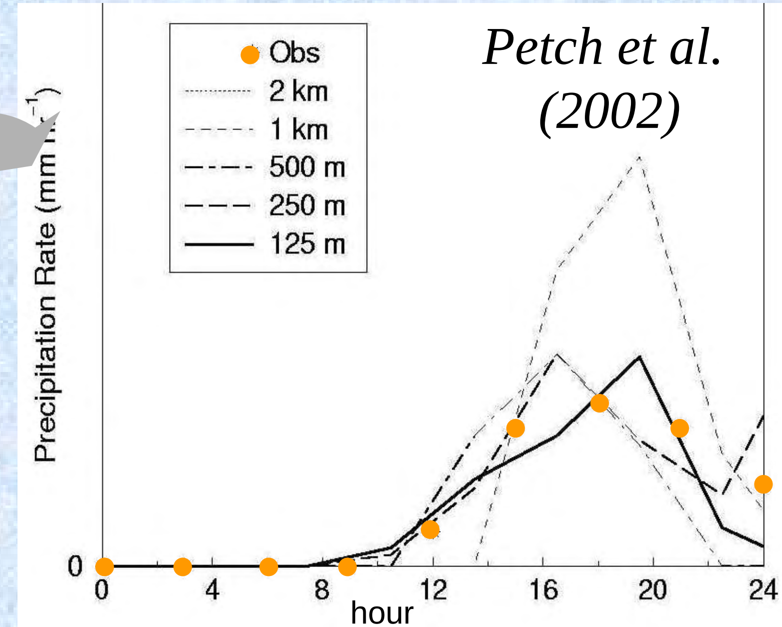


- *rainfall « in advance » for many SCMs*
- *CRMs: next slide*

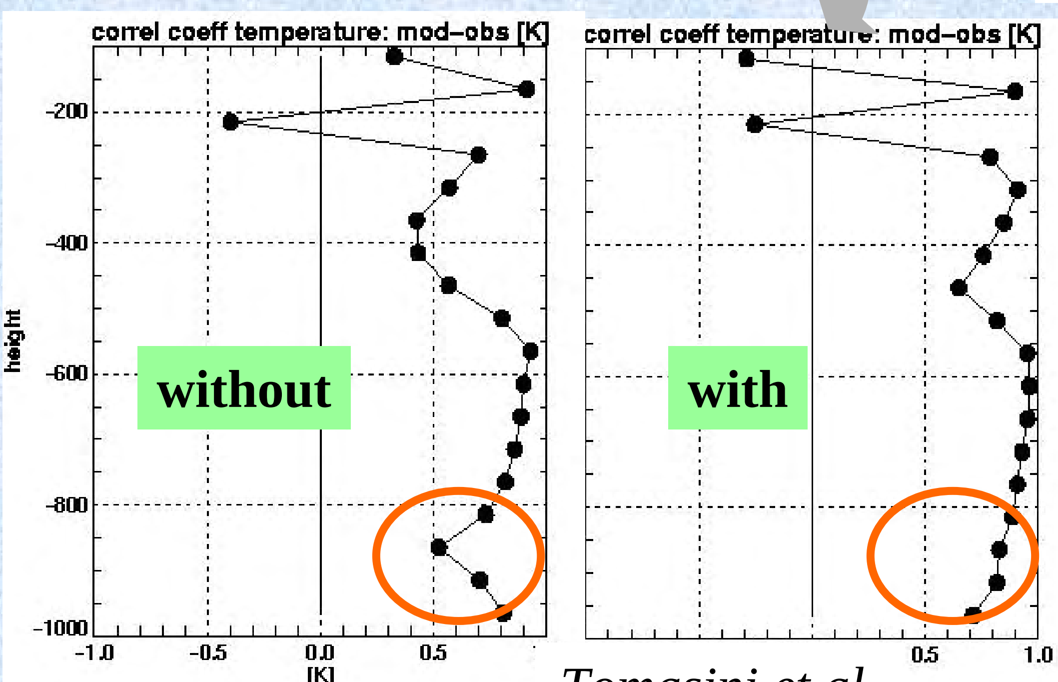
THE OBSERVED CASE : SUMMARY

CRM sensitivity studies

- importance of horizontal resolution
- importance of subgrid scale processes
  mixing length formulation
  subgrid scale microphysics



Petch et al. (2002)



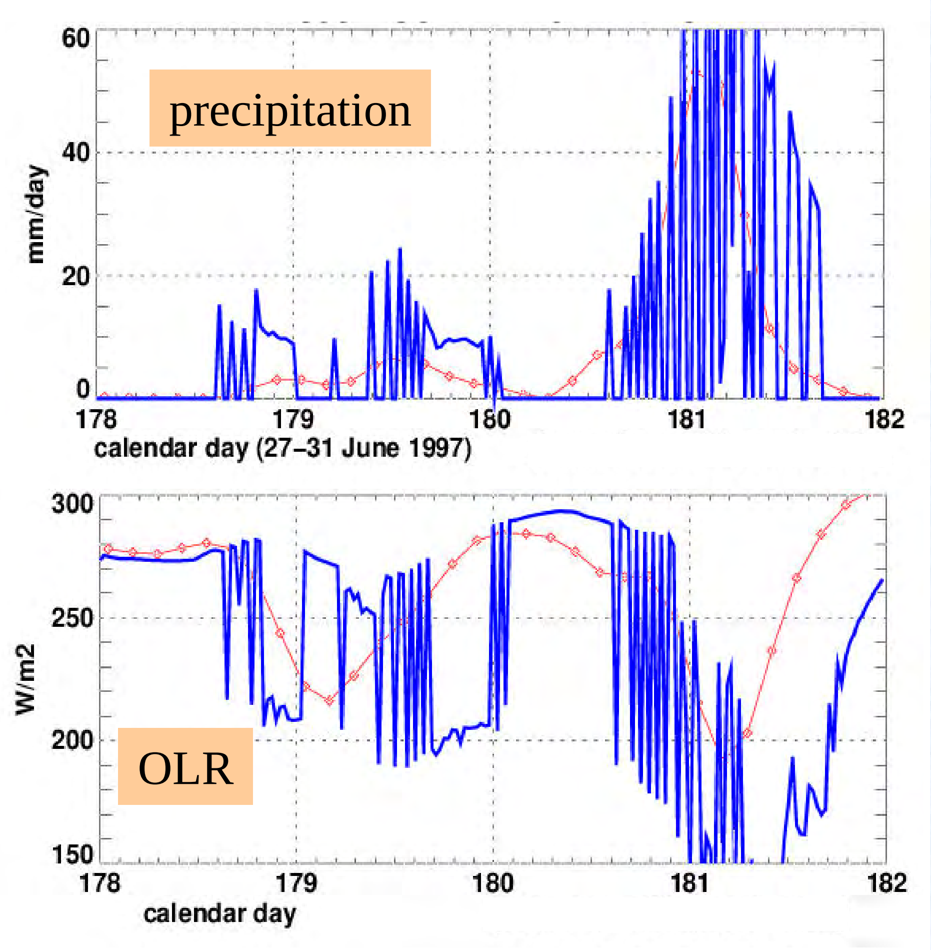
Tomasini et al.

➢ *the good representation of boundary layer processes is essential*

THE OBSERVED CASE : SUMMARY

interactions between paramaterizations, 1st problem for several SCMs:

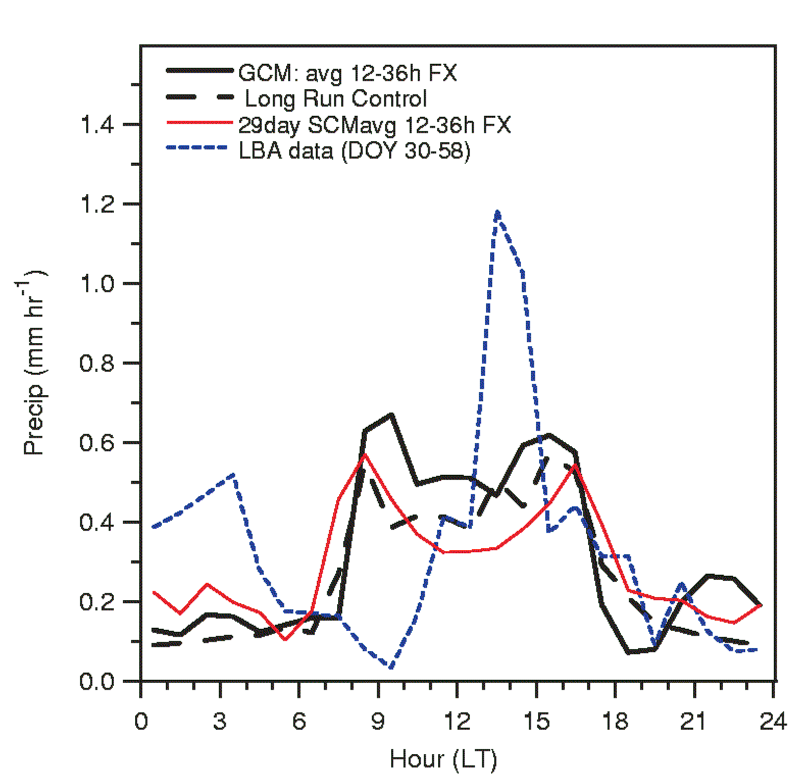
- a lot of noise in many runs : deep convection turned successively on/off (not seen from 3-h mean)
- impact on cloud properties (e.g. CWP) & radiation



THE IDEALIZED CASE

why?

- ➢ several events in the « observed case » not linked to our aims
- ➢ this GCSS/ARM case not designed for this purpose
- ➢ motivated by Betts & Jakob (2002)



29-day diurnal cycle of precipitation from short & long term forecasts and SCM runs using large-scale forcing from the 3-D model

error in the diurnal cycle of deep convection:

- ***shared by short and long- term GCM runs***
- ***reproduced in SCM runs***

(sensitivity to diurnal cycle of large-scale ascent)

➢ ***SCMs useful to investigate this very robust error!***

THE IDEALIZED CASE

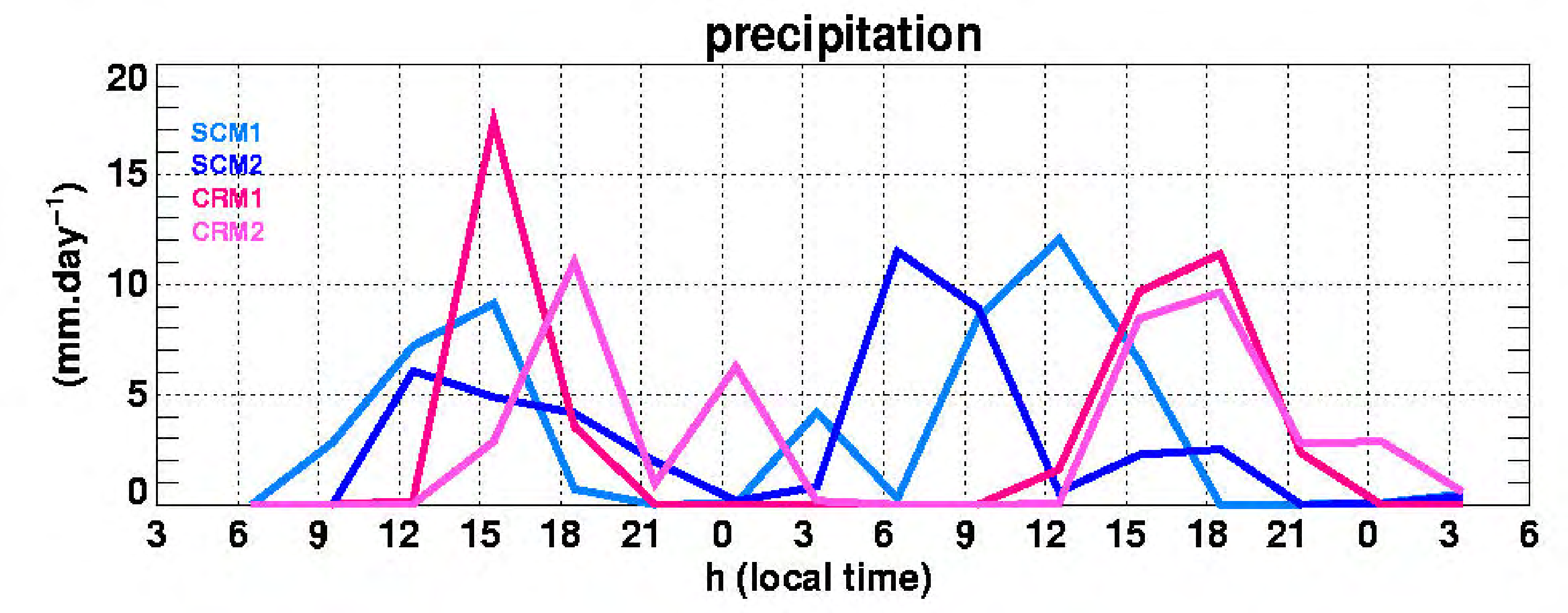
same framework of previous case except:

✓ 27 Mai 1997 of GCSS case 3 repeated twice

large-scale vert. adv. (relatively weak) & prescribed surf. fluxes

✓48 h run, begins in the morning instead of the evening

results still preliminary, work in progress



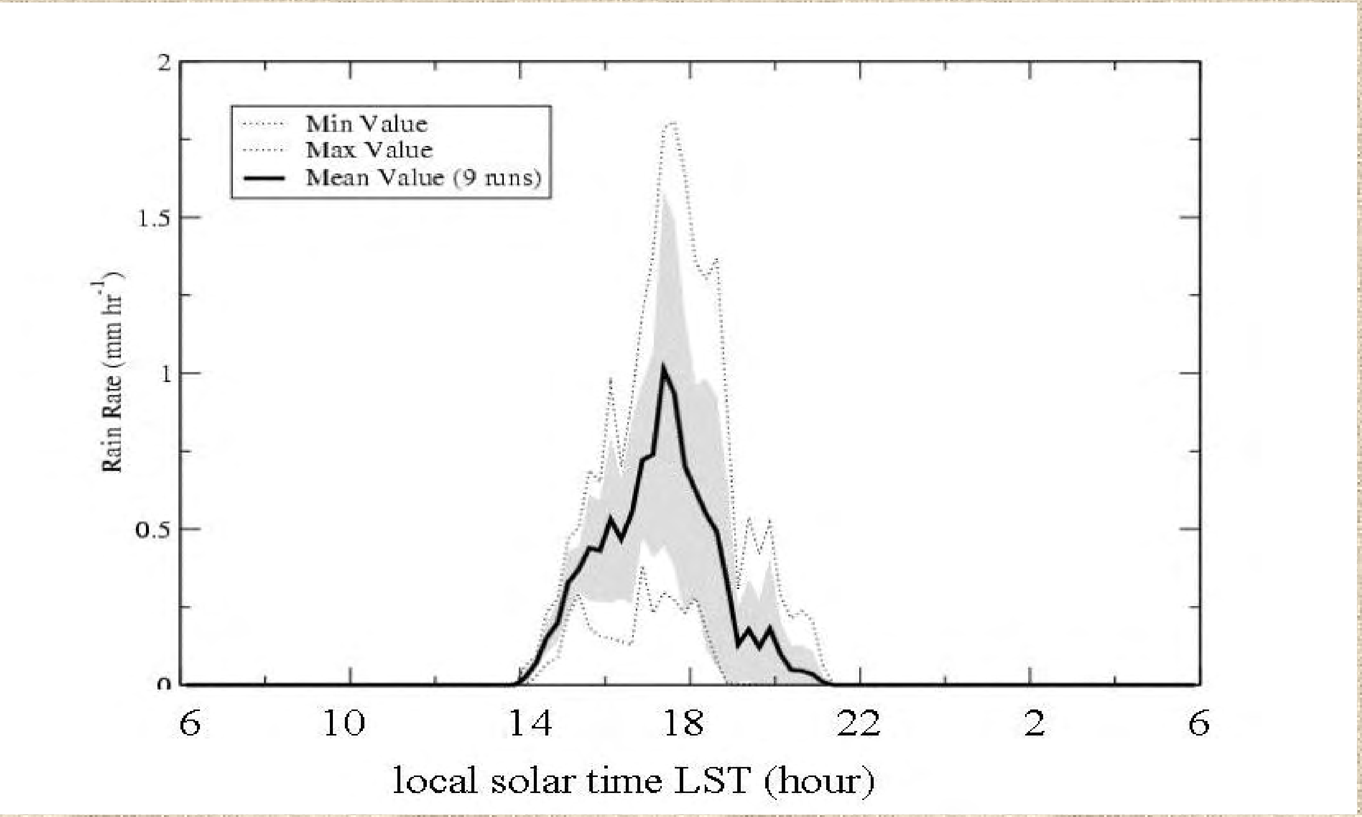
- ➢ rainfall events tend to occurs earlier in SCMs than CRMs (2 SCMs missing)
- ➢ + similar findings (e.g., noise & no or weak downdraughts)

THE IDEALIZED CASE

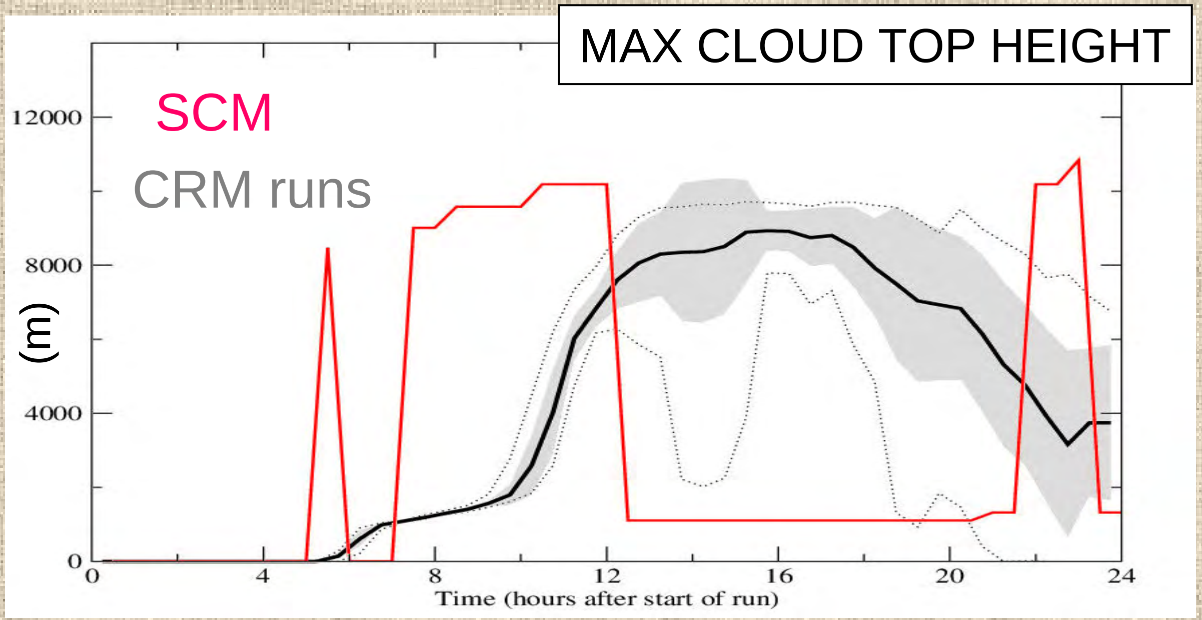
predictability issues (raised by J. Petch)

✓ different initial random noises lead to various rainfall rates
✓ timing is a more robust feature

sensitivity to the domain size?



THE IDEALIZED CASE: transition regimes

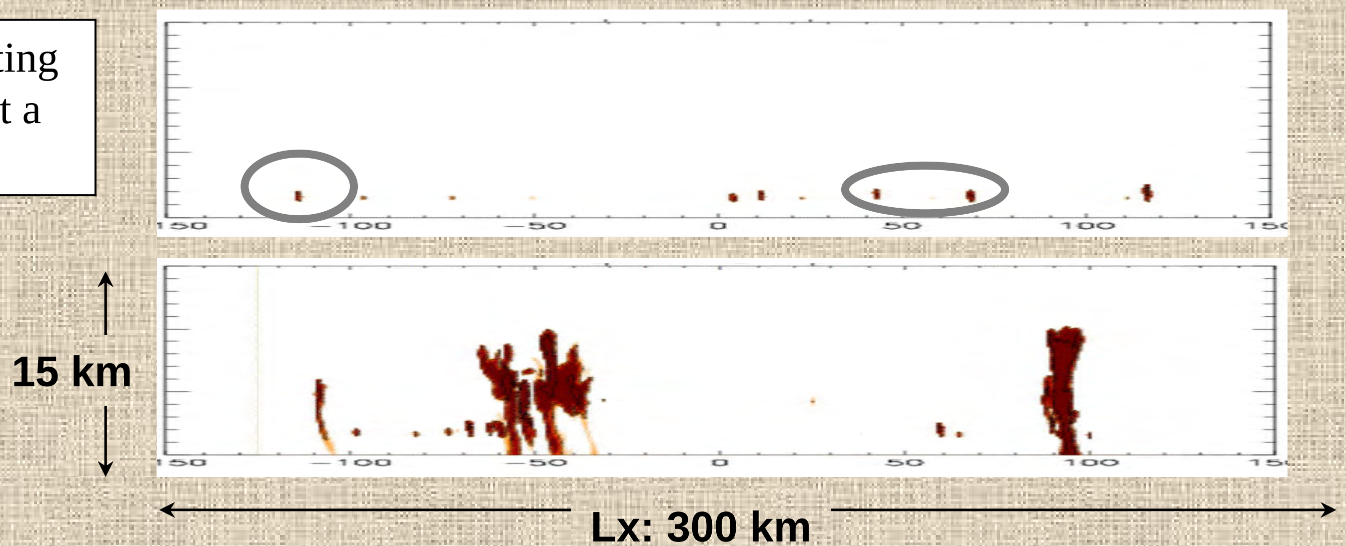


transition phase:
not represented
in several SCMs

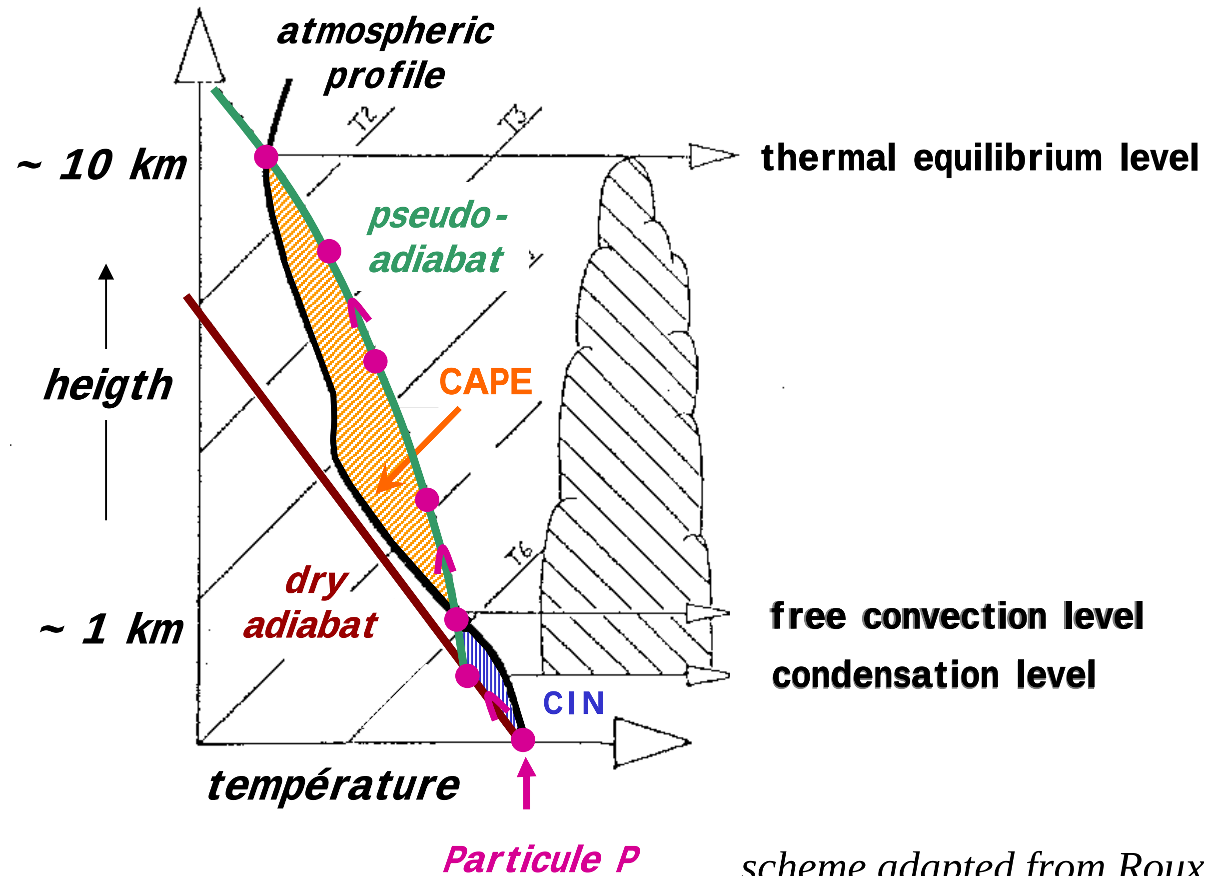
snapshots of cloud + rain water content in CRM run

a « shallow » non-precipitating transition period which last a few hours in CRMs

before the development of deep convection



CONDITIONAL INSTABILITY: CIN & CAPE



scheme adapted from Roux (1991)

CAPE : Convective Available Potential Energy
energy that could be relased by the ascent of P

CIN : Convective INhibition
energy barrier for P

➡ for an analysis of more elaborated stability parameters: Remi Tailleux

CONVECTIVE (IN)STABILITY

- ✓ ***strong diurnal variation of CAPE & CIN***
- ✓ ***large amount of CAPE***
- ✓ ***lower CIN mean values correlated with rainfall events, not CAPE***

QUESTIONS:

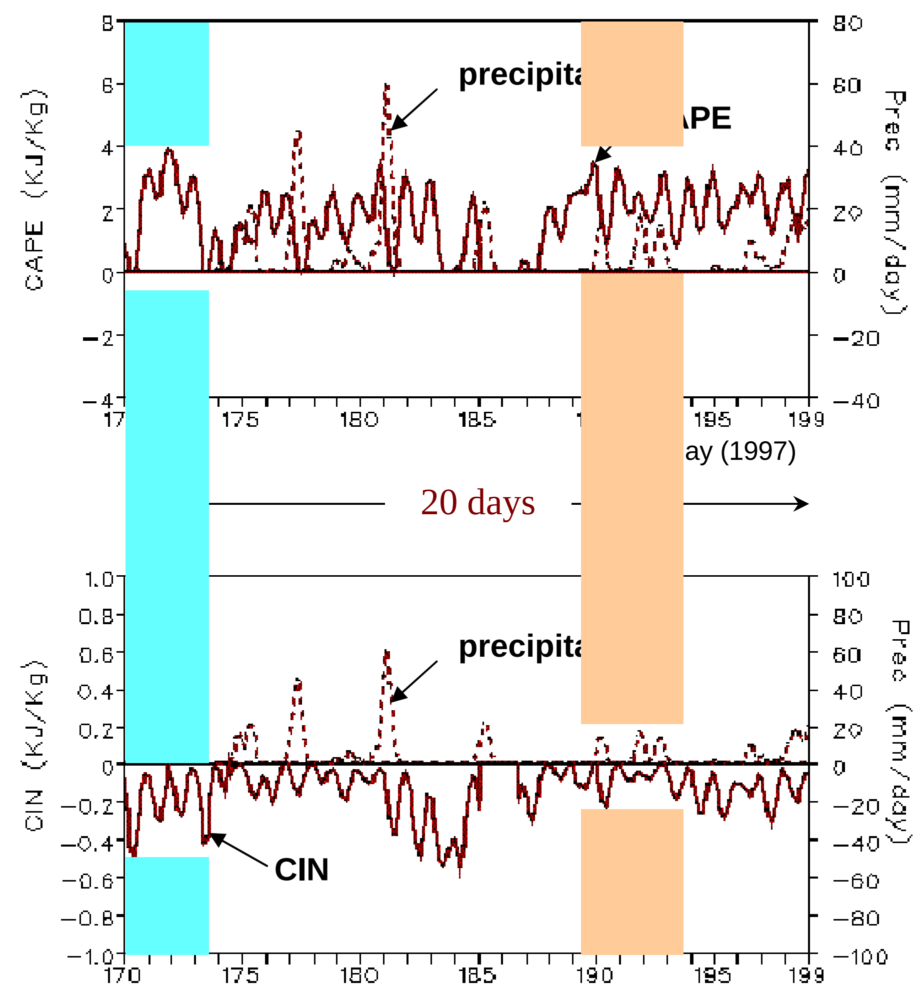
➢ performances of our models?

boundary layer θ_v, θ_e RH,

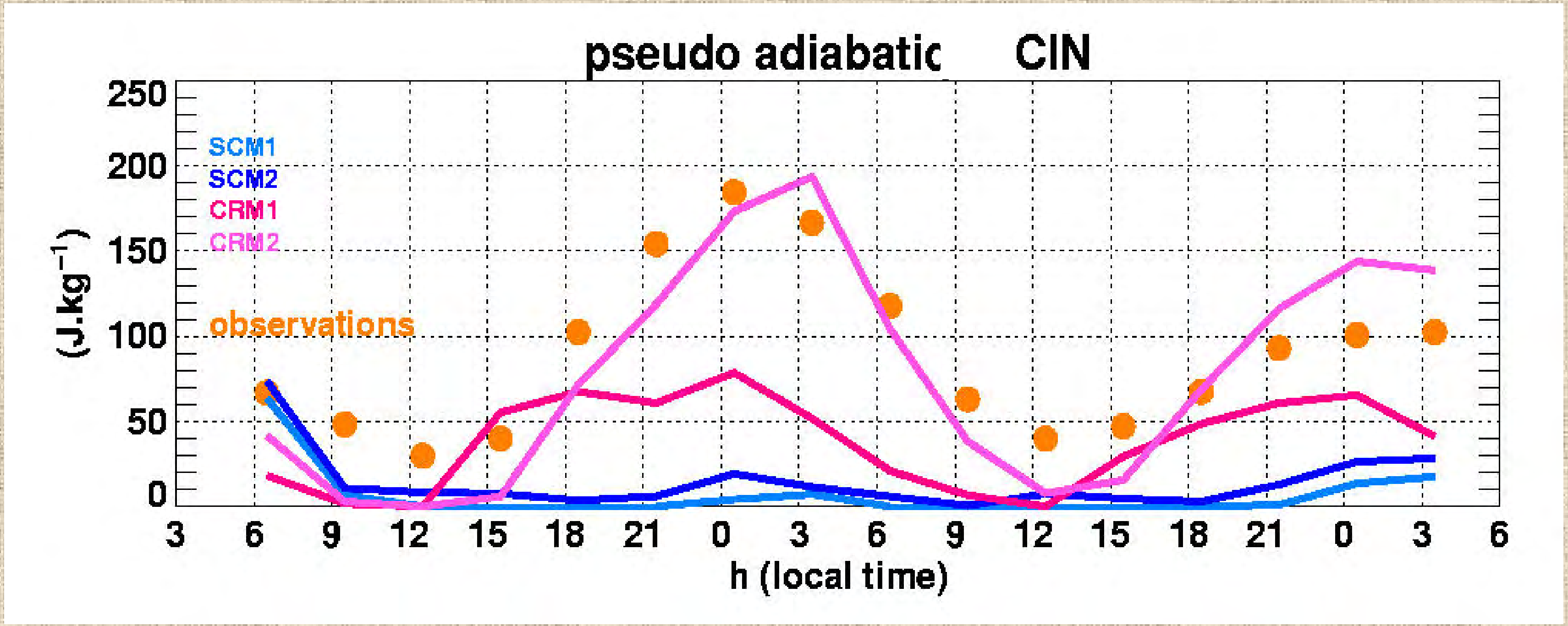
CAPE, CIN

CRMs/SCMs differences?

observations *(Xie et al. 2001)*



THE IDEALIZED CASE : CIN



- ✓ almost no CIN in SCM runs during daytime (true for at least 4 SCMs) !
- ✓apparently not simply a resolution problem

- ✓ challenging for CRMs too
- ✓ strongly modulated by convective activity
- ✓ in CRMs runs, deep convection increases the CIN
- ✓ possibly related to convective downdraughts (?)

CONCLUSION

- ✓documentation of GCMs & RCM weaknesses/diurnal cycle of deep convection

- ✓assess CRM/SCM models over land with GCSS/ARM case
- ✓design an idealized case to address the problem
- ✓better results/consistency among CRMs than SCMs
  (T & q, cloud parameters: agreement with previous GCSS work)

- ✓CRM runs : the treatment of the BL is important
  increased horizontal resolution &/or subgrid-scale processes

- ✓deep convection often occurs earlier than observed in SCMs runs too
- ✓no succession of dry-shallow-deep regimes in SCMs, dry to deep directly
- ✓complex sensitivity to triggering criteria & downdraughts formulation
- ✓no CIN during daytime & weak downdraughts (a link?)

the end, thank you

transition regime in CRMs, corresponding to the build up of convection: a feature « broadly coherent » with several previous observed studies

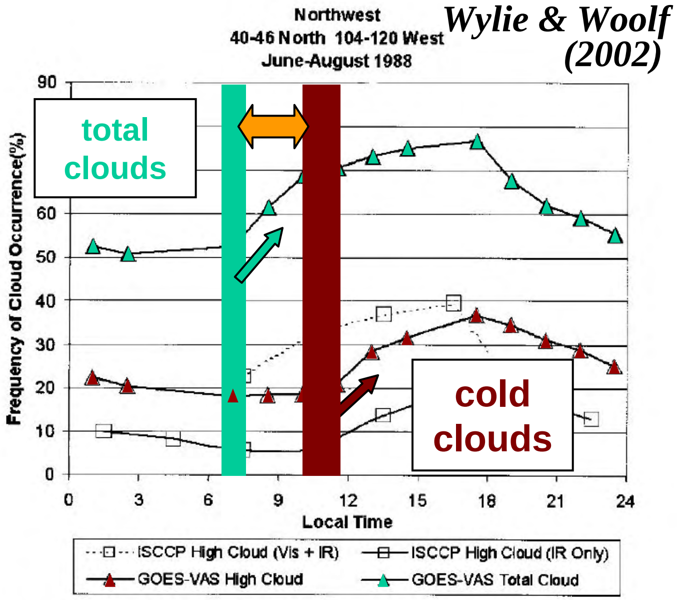


FIG. 4. The frequency of clouds in the northwestern United States during Jun–Aug 1988.

which factors control the lenght of this phase?
role of buoyancy, wind shear, moisture…

continental scale of the diurnal cycle of deep convection?

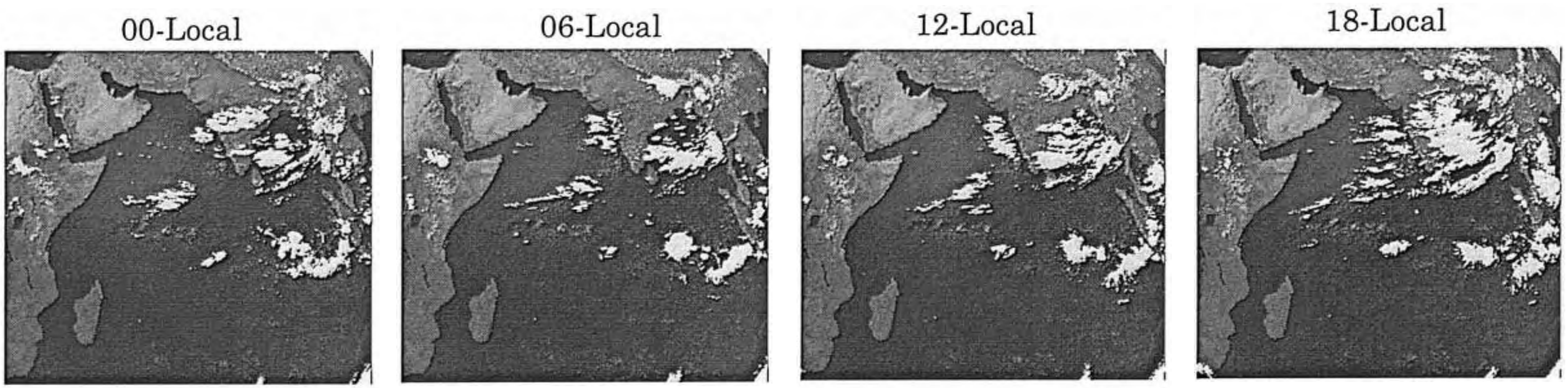


FIG. 3. Diurnal fields of OLR for deep convection (for cloud-top temperatures less than −40°C) for 27 July 1998. The four panels show OLR fields for 0000, 0600, 1200, and 1800 LT (*local time* refers to approximate local time over central India).

Krishnamurti & Kishtawal (2000)