the DIURNAL CYCLE of DEEP CONVECTION OVER LAND: contribution from EUROCS

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CNRM[*], ECMWF[#], Met Office[£], LMD[&] and SMHI[§]

GCSS 20-24 May 2002, Kananaskis, Alberta, Canada

EUROCS : EUROpean Cloud Systems

- ✓ 3-year project funded by the European Union (Mar 2000 – Feb2003)
- ✓ aims: improving the treatment of cloud systems in global and regional climate models
- ✓ strong links with GCSS (GEWEX Cloud System Study)

❑ concentrates on 4 major well identified deficiencies of climate models:

- ✓stratocumulus over ocean *(Duynkerke, De Rhoode & Grenier)*
- ✓diurnal cycle of cumulus *(Lenderinck & Siebesma)*

WG1

- ✓sensitivity of deep convection to the moisture profile *(Derbyshire)*
  idealized runs with RH nudged to prescribed values
- ✓diurnal cycle of deep convection over land *(Petch & Guichard)*

WG4

❑ bring together modelers dealing with a hierarchy of scales

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

www.cnrm.meteo.fr/gcss/EUROCS/EUROCS.html & J.-L. Redelsperger

OUTLINE

- context
- examples of GCM and RCM results
- work on GCSS-WG4 case 3a
- an idealized case, preliminary results
- conclusions & future work

mosaic « talk » toward our activities

CONTEXT

➢ fundamental mode of variability of the climate system

important role in the energy & water budgets

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)

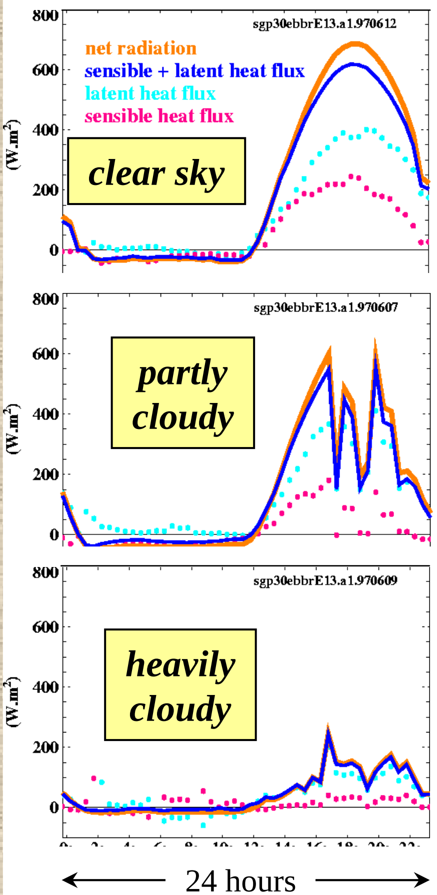
✓ season dependent (stronger in summer)

✓ daytime boundary layer heating (over land)

✓ but also coupled to regional effects, orography, regimes (E/W LBA)

✓ life cycle of MCSs

✓ changes in the last decades over the US



surface fluxes measurements
(Bowen ratio method) ARM SGP site

CONTEXT

modelling

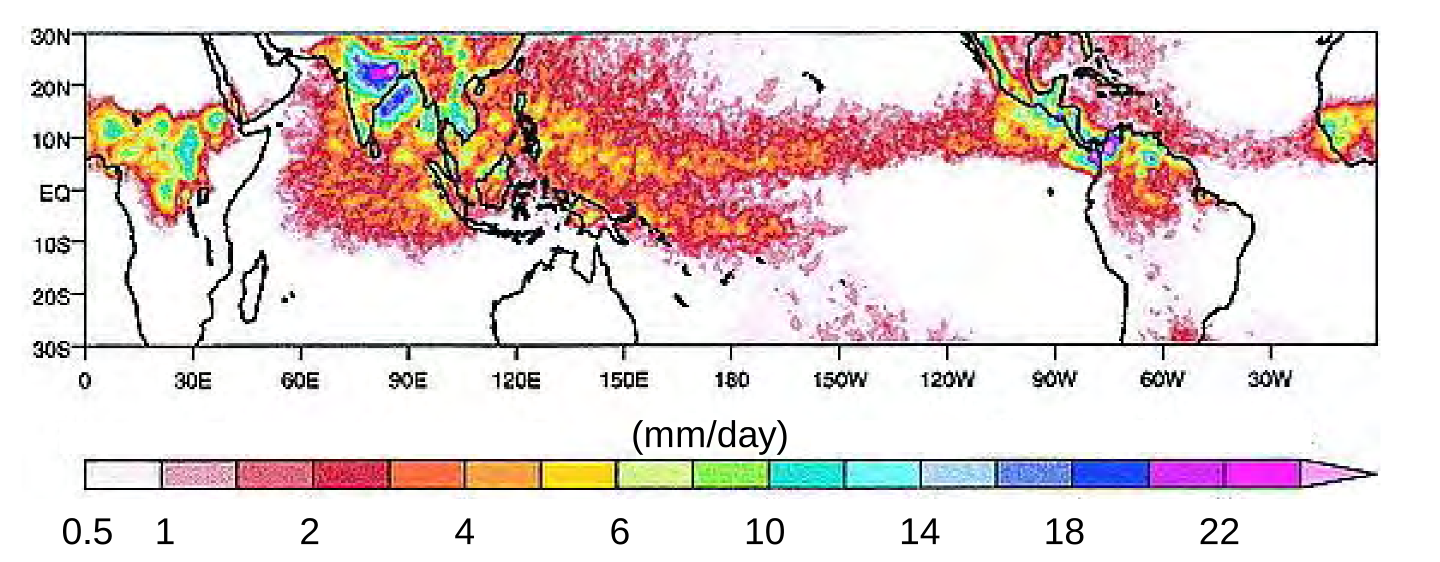
- ✓ relevant & demanding test for GCMs
- ✓ assess physical parameterizations & how they interact
- ✓ difficult to reproduce by GCMs *(next slides)*
- ✓ monthly mean & diurnal cycle both correct at the same time: quite challenging

Yang & Slingo (2001)

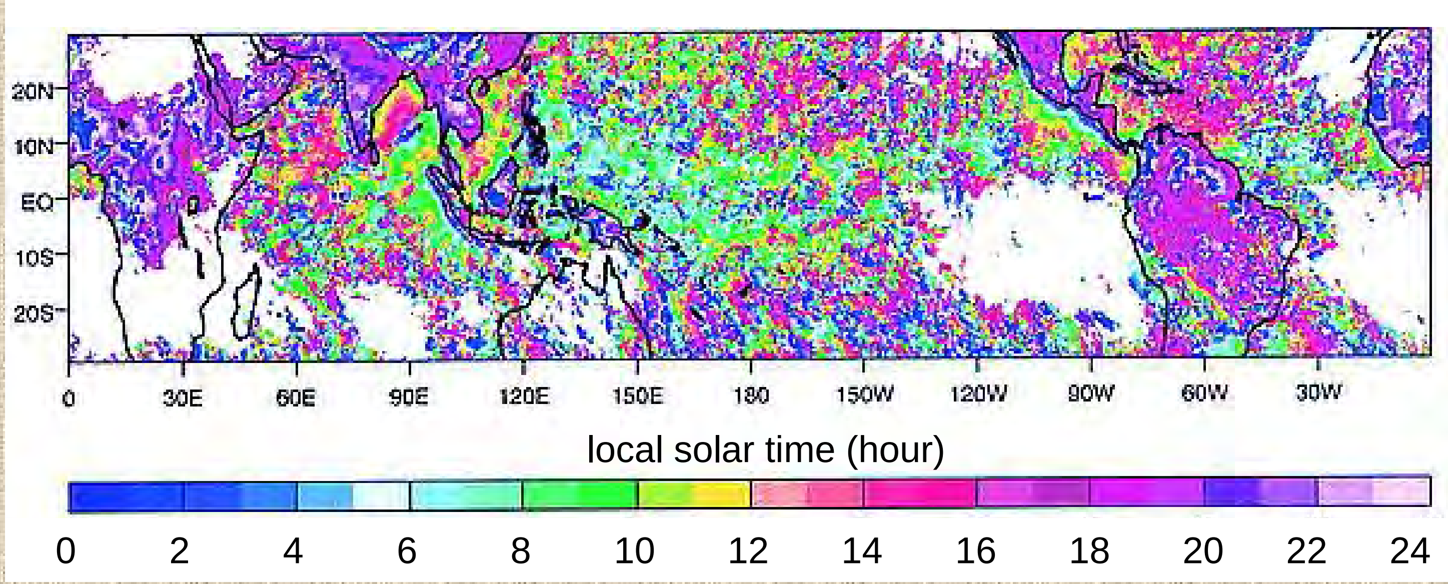
estimated precipitation

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

amplitude of the diurnal harmonic



phase of the diurnal harmonic

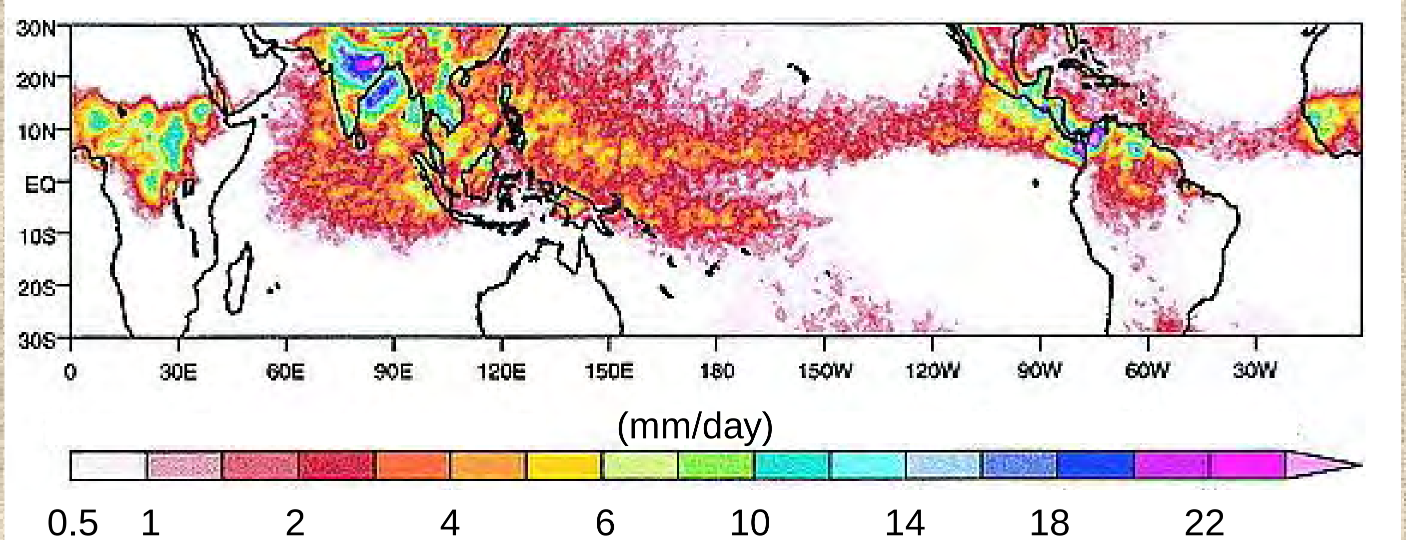


Yang & Slingo (2001)

precipitation: **amplitude** of the diurnal harmonic

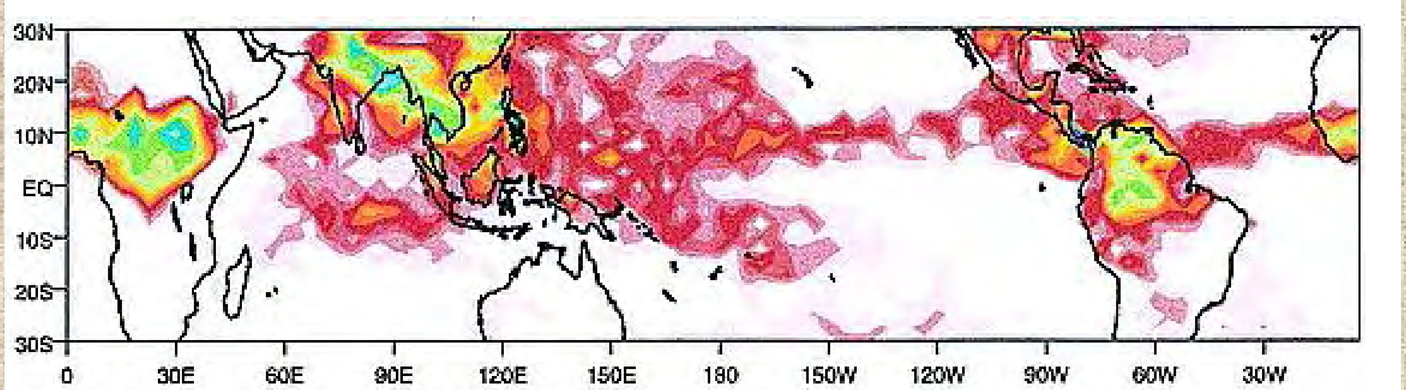
OBERVATIONS

CLAUS dataset



CLIMATE GCM

unified climate model



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

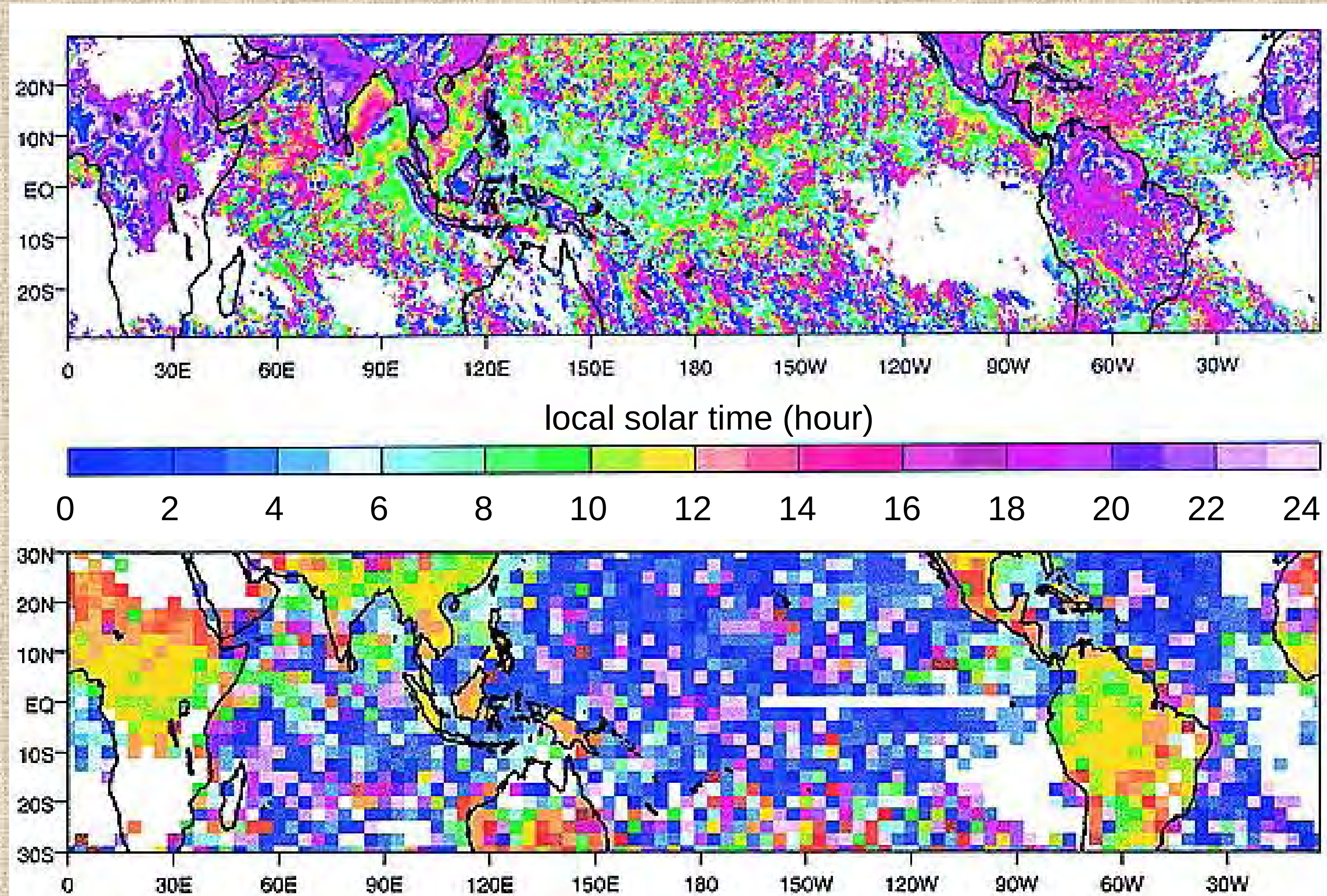
frequently too weak, e.g. Royer et al. (2000), Lin et al. (2000), Dai et al. (1999)

Yang & Slingo (2001)

precipitation: **phase** of the diurnal harmonic

OBERVATIONS

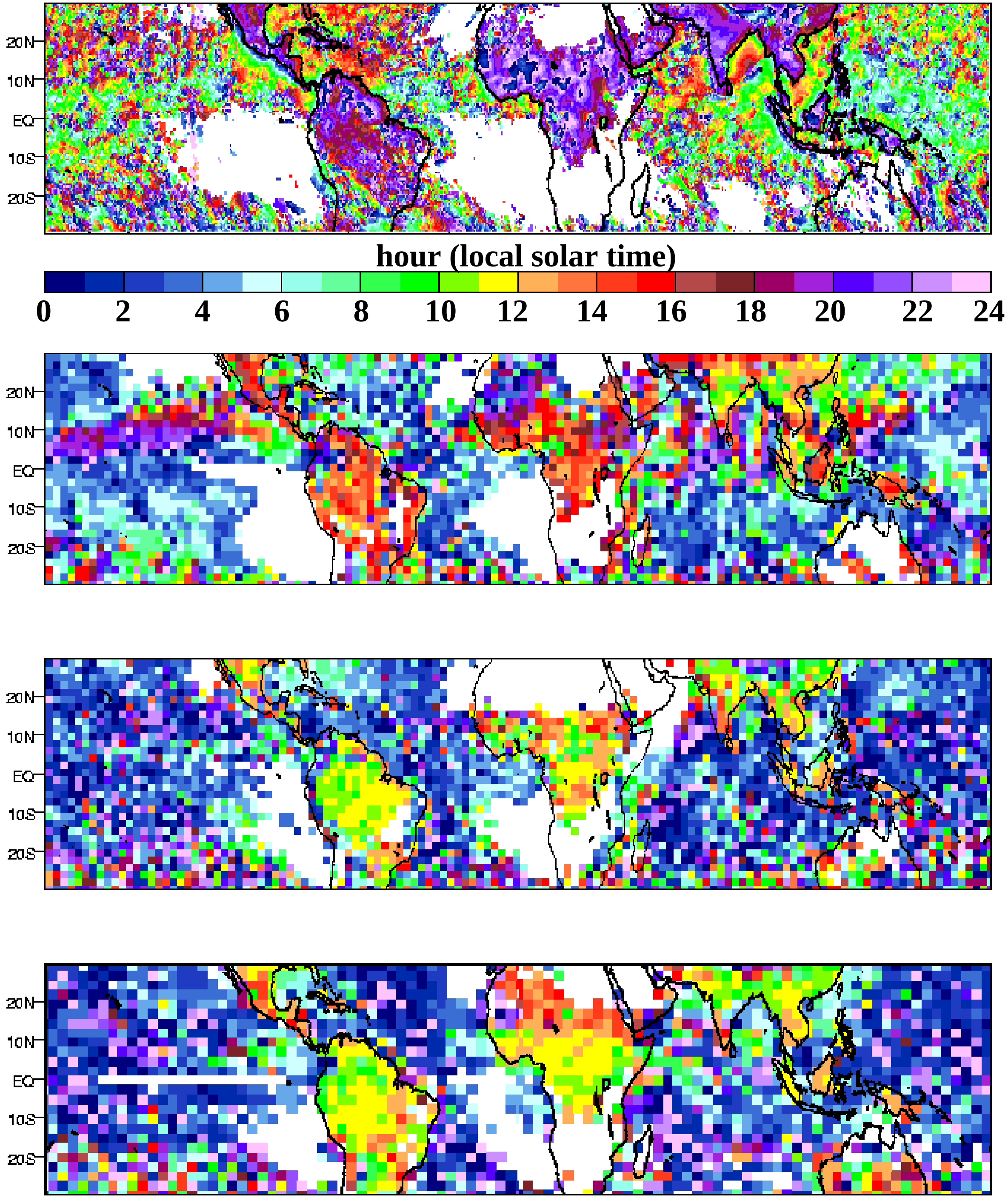
CLAUS dataset



CLIMATE GCM

unified climate model

precipitation too early by several hours compared to observations



PHASE OF THE DIURNAL HARMONIC IN 3 GCMs
J.-M. Piriou

OBSERVATIONS
Yang & Slingo (MWR, 2001)

ARPEGE NWP model
Piriou (2002)

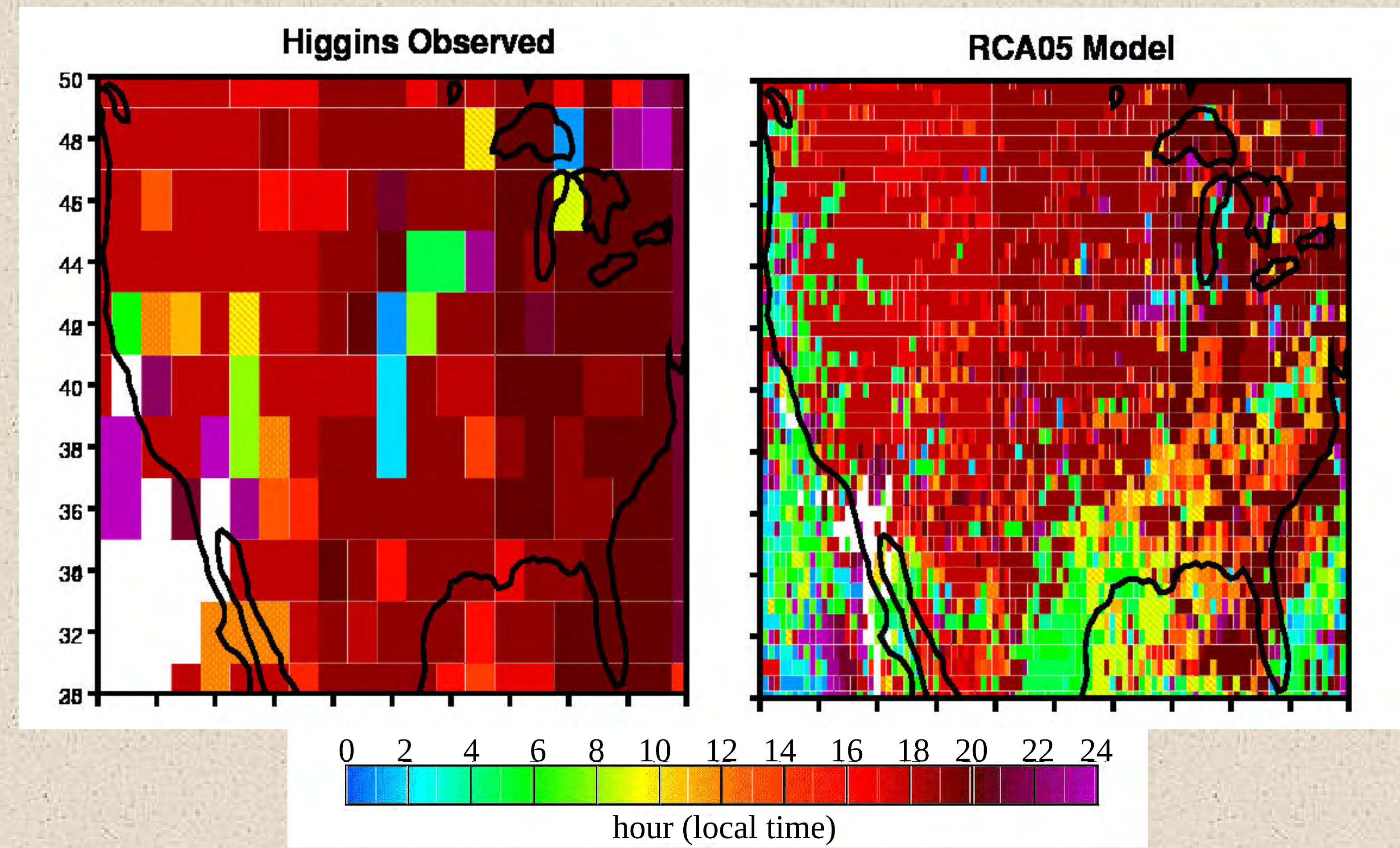
IFS NWP model
Beljaars (2002)

UNIFIED CLIMATE model
Yang & Slingo (MWR, 2001)

GCMs wrong in the « same way »

Regional Climate Modelling *Colin Jones*

an example: most frequently occuring time of max precip. in a diurnal cycle
(June 10-July 31 1993) *more information on the EUROCS web site*



the model captures the broad early-late evening max of rainfall

COMMON CRMs/SCMs CASE STUDY

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

GCSS WG4 Case3a (ARM Southern Great Plains)

✓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

THE SIMULATIONS : 5 (maybe 6?) 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 Dx ~ 250m to 2km Dz ~ stretched 70-700m or less
mostly 2D & but a few 3D runs
SCMs : Dz : 18 to more than 60 vertical levels

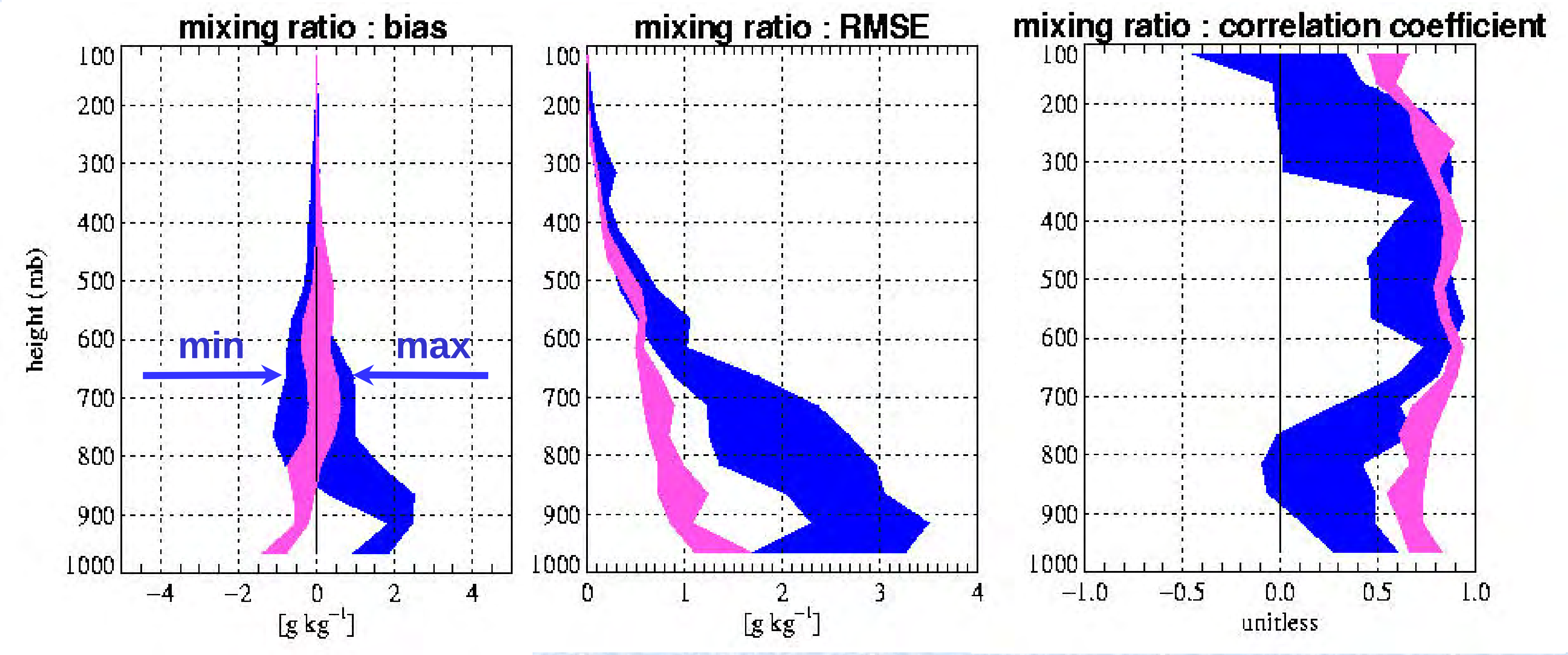
closer « cross-scales » collaborations, e.g., CNRM-ECMWF (Chaboureau & Koehler)

THE OBSERVED CASE : SUMMARY

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

new test for 50% of models not part of the exercise above

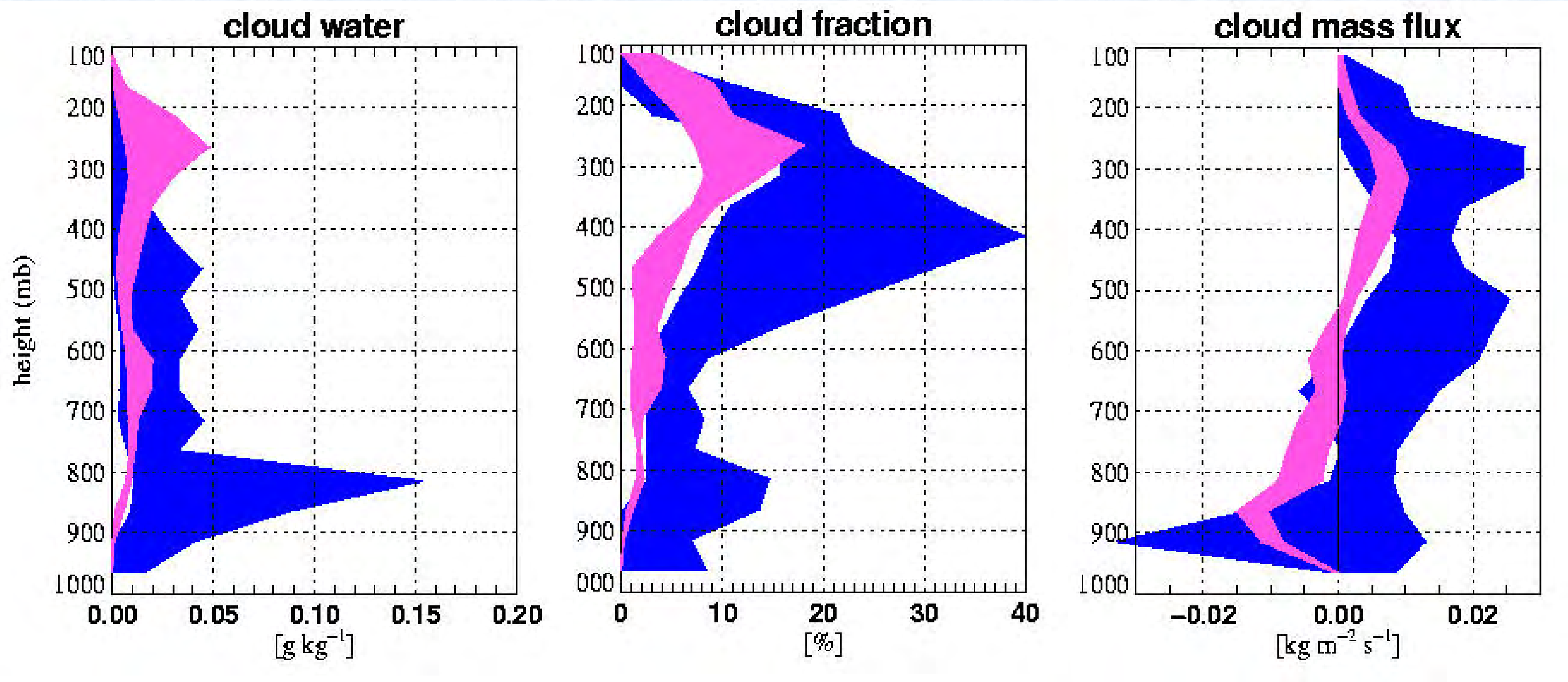
an example : comparison with obs, min-max envelope for **CRMs** & **SCMs**



better agreement & less scatter among CRM results that SCM ones

THE OBSERVED CASE : SUMMARY

comparison CRMs & SCMs (no observations)

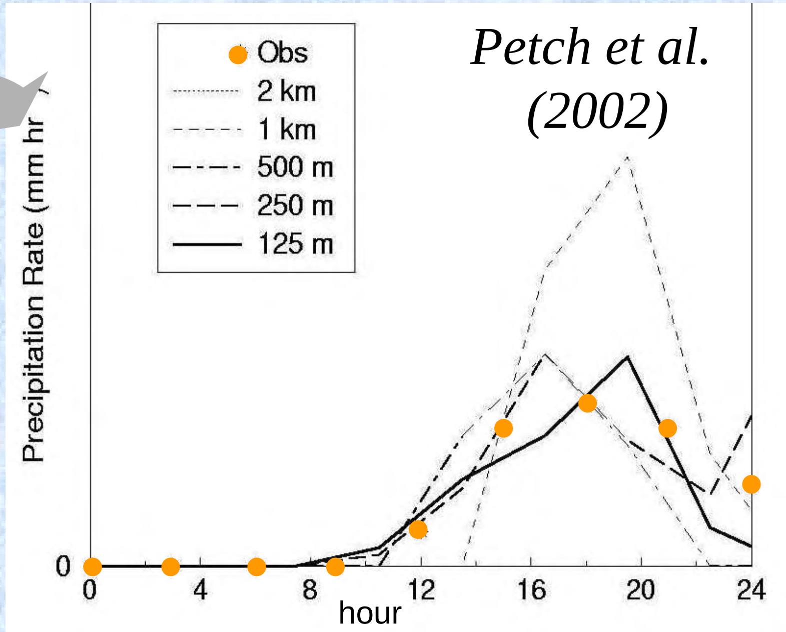


- *scatter linked to the microphysics for CRMs in the upper troposphere*
- *obviously room for CRMs improvements*
- *however much more consistency among CRMs than SCMs*
- *very weak convective downdraughts in several SCMs*

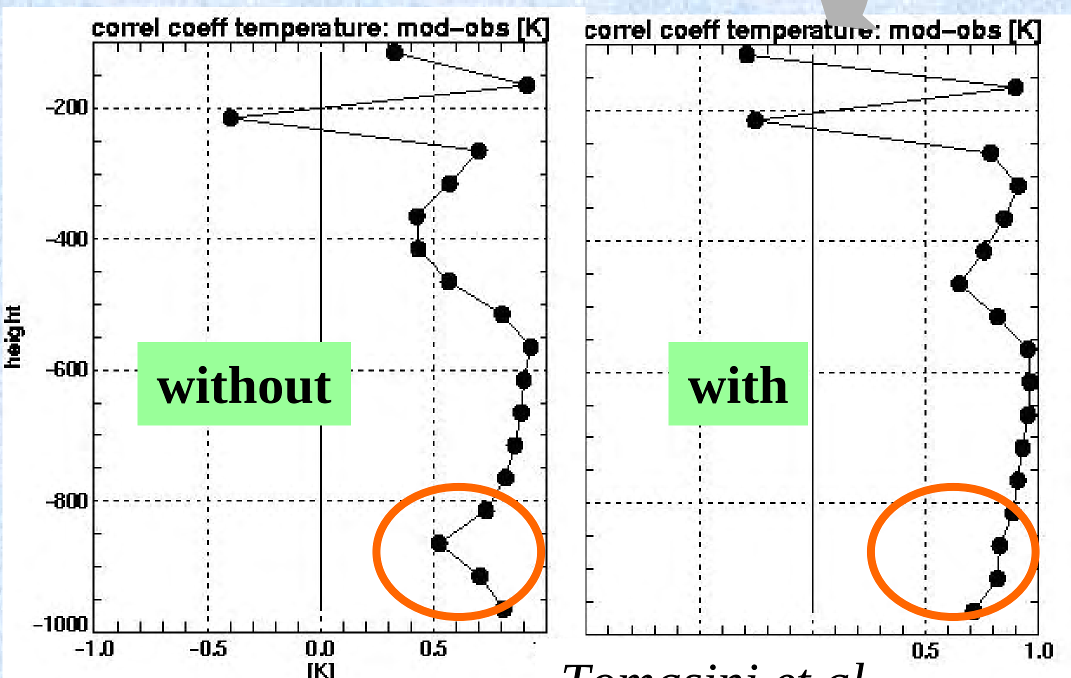
THE OBSERVED CASE : SUMMARY

CRM sensitivity studies

- ➢importance of horizontal resolution
  - *boundary layer fluxes*
- ➢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 crucial

THE OBSERVED CASE : SUMMARY

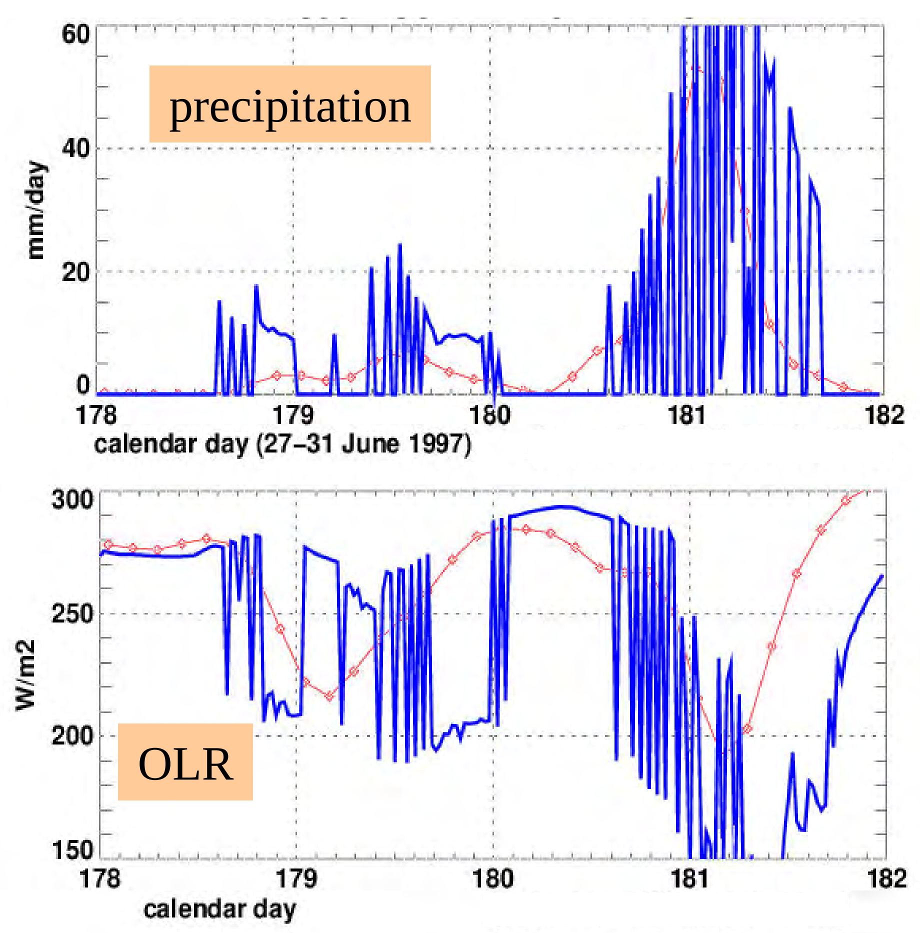
interactions between paramaterizations, 1st problem for several SCMs:

- a lot of noise in many SCM runs deep convection turned successively on/off

  (not seen from 3-h mean)

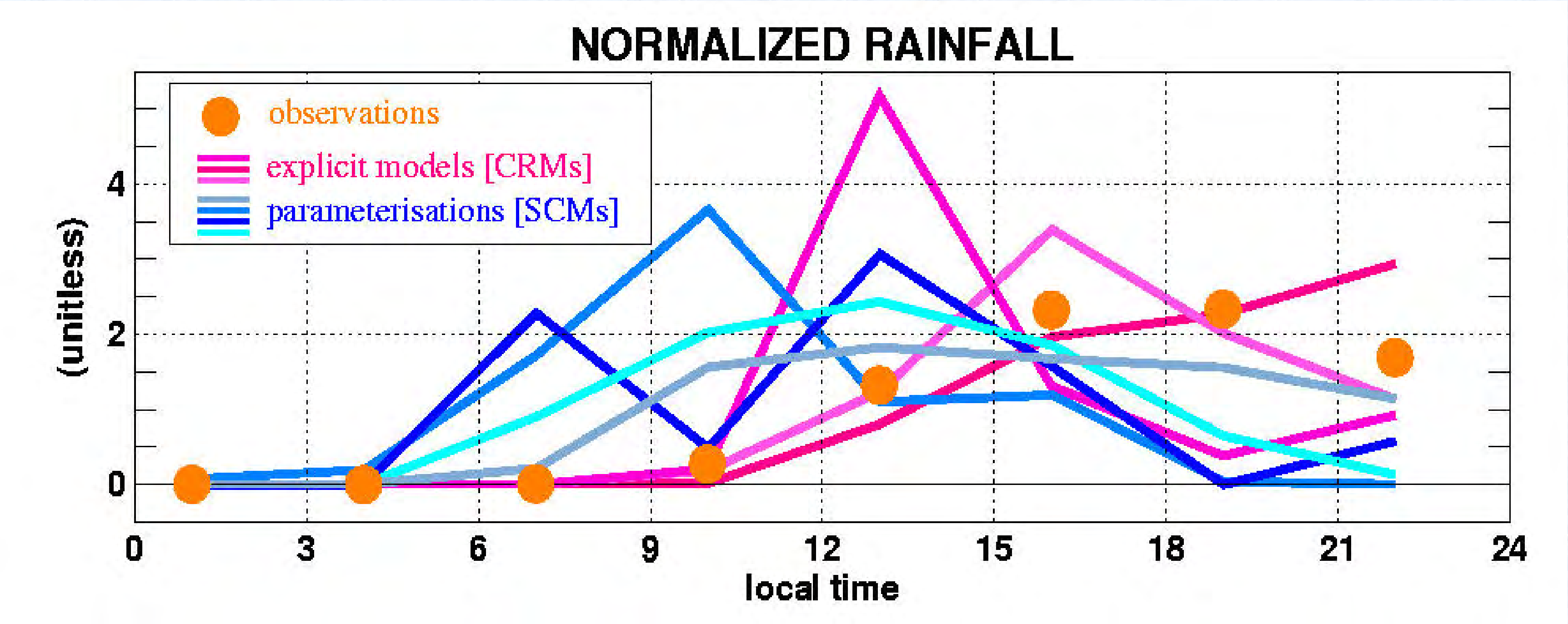
- impact on cloud properties

need to document why



THE OBSERVED CASE : SUMMARY

zoom on the 1st part of the simulation



rainfall « in advance » for many SCMs

THE IDEALIZED CASE

why?

- ➢ most deep events not linked to our aims (SGP area « particular »)
- ➢ this GCSS/ARM case not specifically designed for this purpose
- ➢ motivated by Betts & Jakob (2002): GCM problem reproduced in SCM

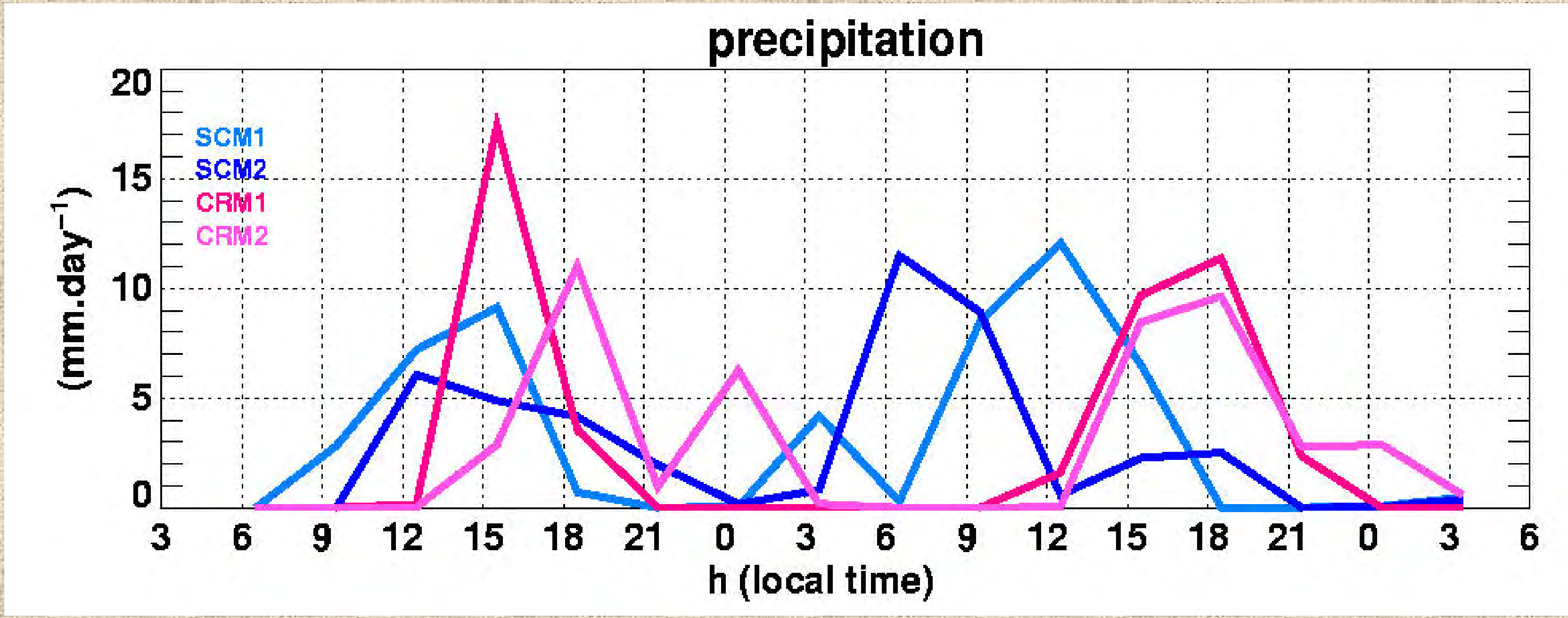
❑ same framework of previous case except:

- ✓ 27 Mai 1997 of GCSS case 3a repeated twice
  large-scale vert. adv. (relatively weak) & prescribed surf. fluxes (+new set prepared)
- ✓ 48 h run, begins in the morning instead of the evening

❑ links with WG1 (EUROCS) ARM case of shallow cumulus case

THE IDEALIZED CASE

results still preliminary, work still in progress !



- rainfall events tend to occurs earlier in SCMs than CRMs (3 SCMs at least)

- + similar findings as before (e.g., noise & no or weak downdraughts)

THE IDEALIZED CASE

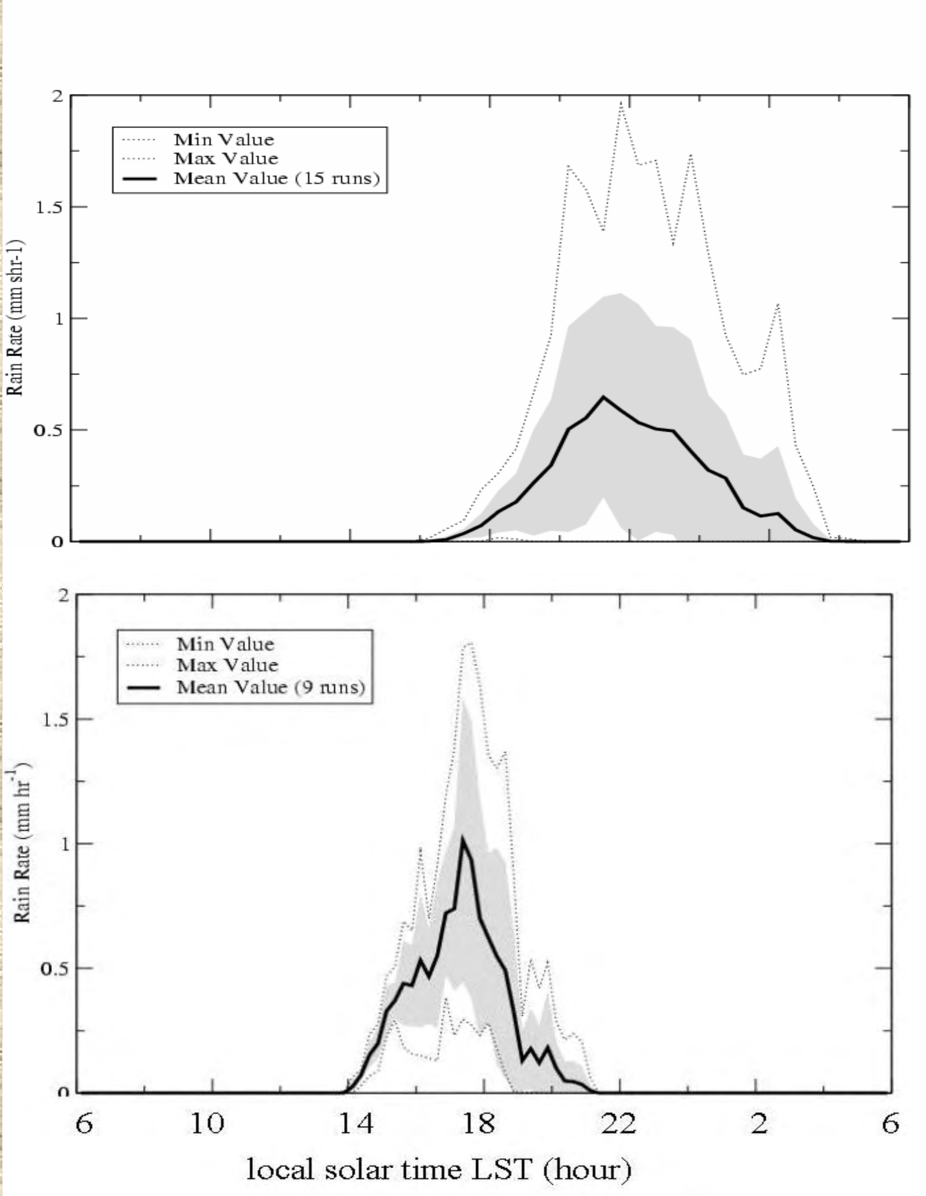
predictability issues in CRMs
(raised by J. Petch)

✓ different initial random noises lead to various rainfall rates

✓ timing is a more robust feature

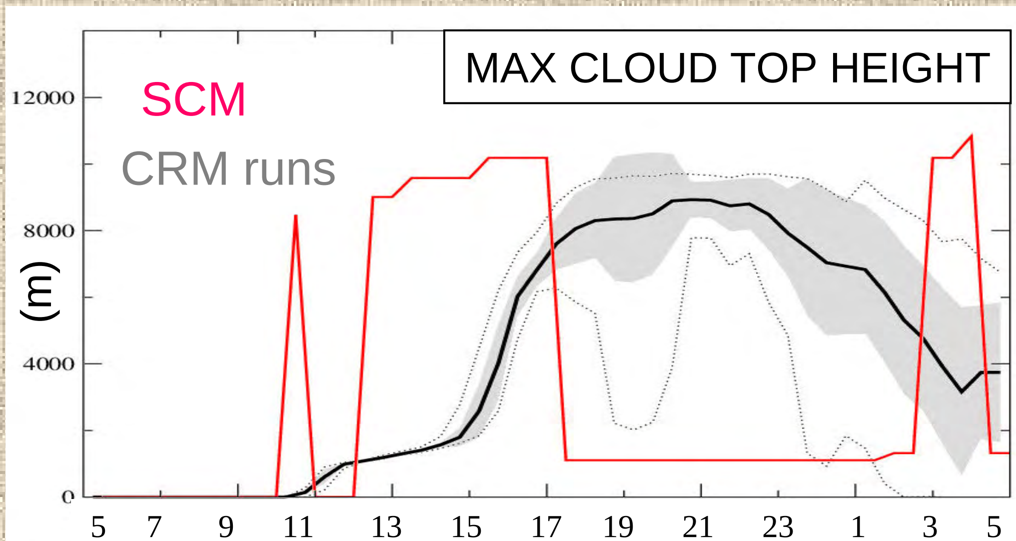
✓ weaker spread with more realistic surface heat fluxes

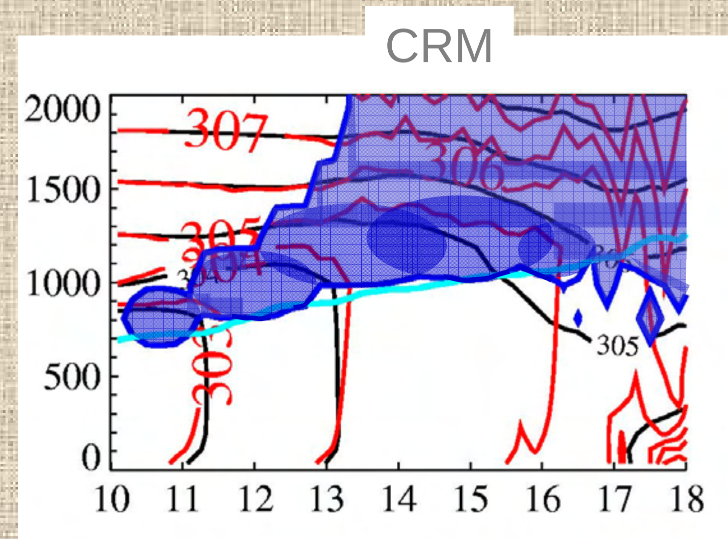
sensitivity to the domain size?



THE IDEALIZED CASE: different transition regimes in CRMs and SCMs

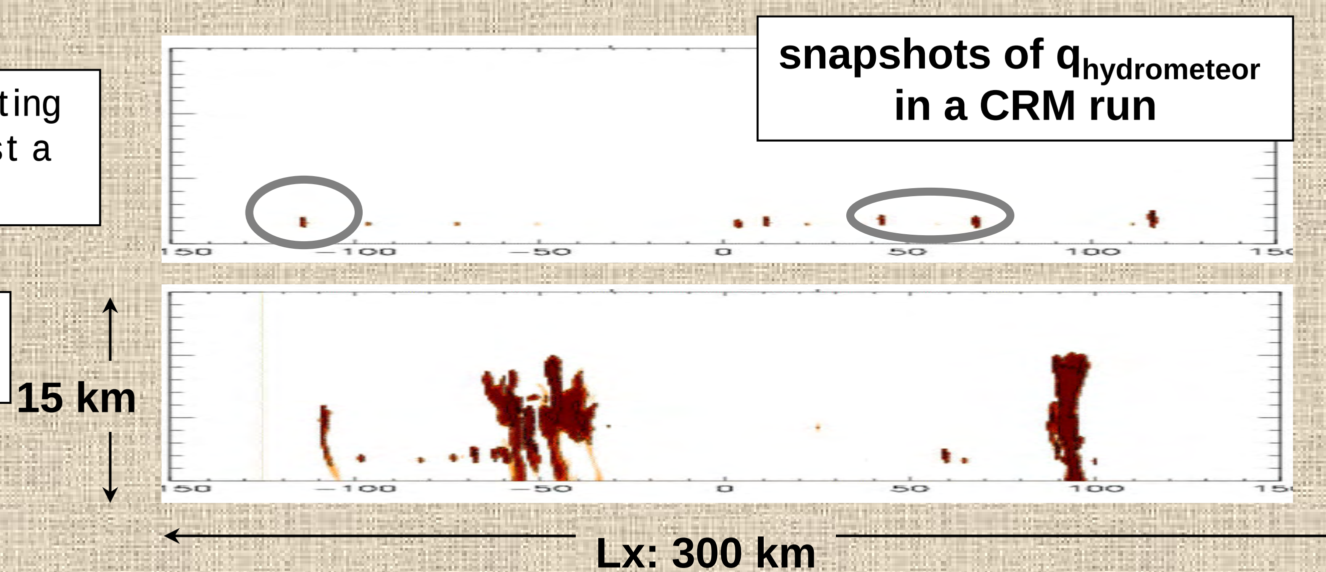
does not exist in several SCMs, CRMs apparently capture something





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

before the development of deep convection



CONVECTIVE (IN)STABILITY

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

QUESTIONS:

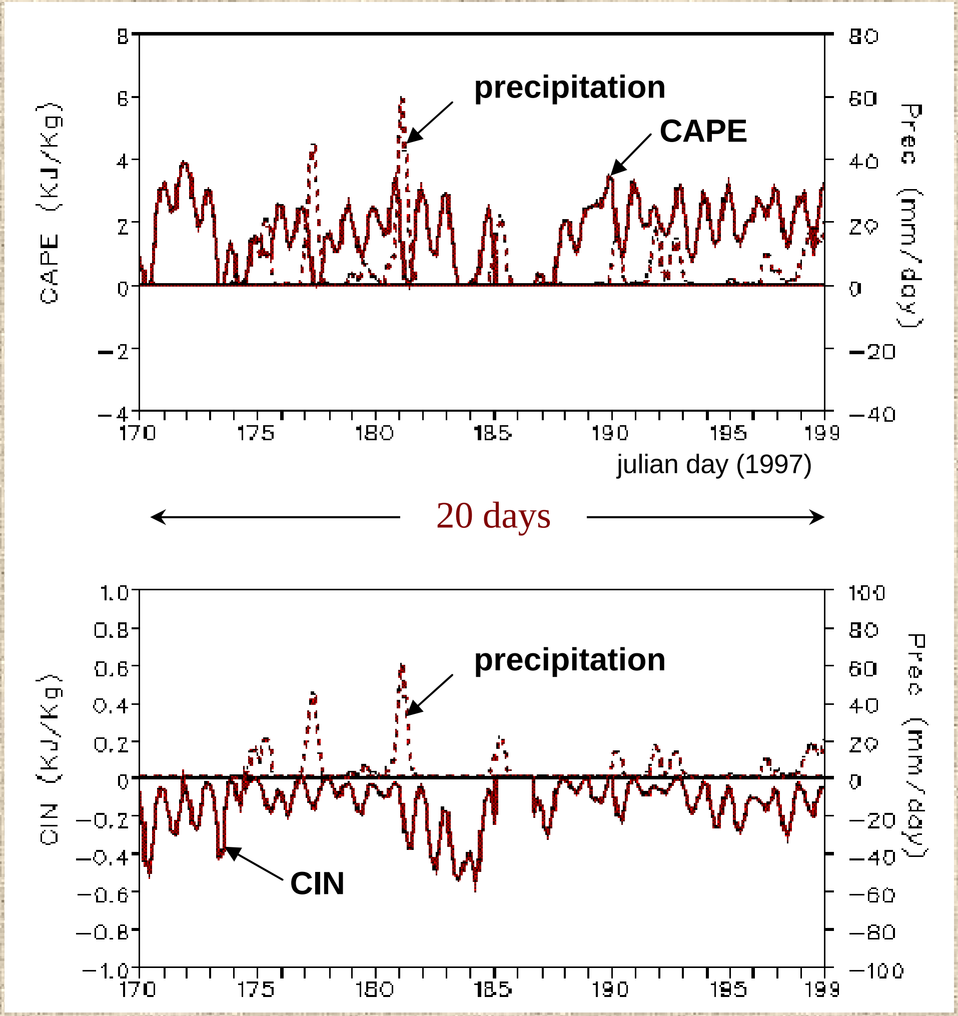
➢ performances of our models?

boundary layer θ_v, θ_e, RH

CAPE, CIN

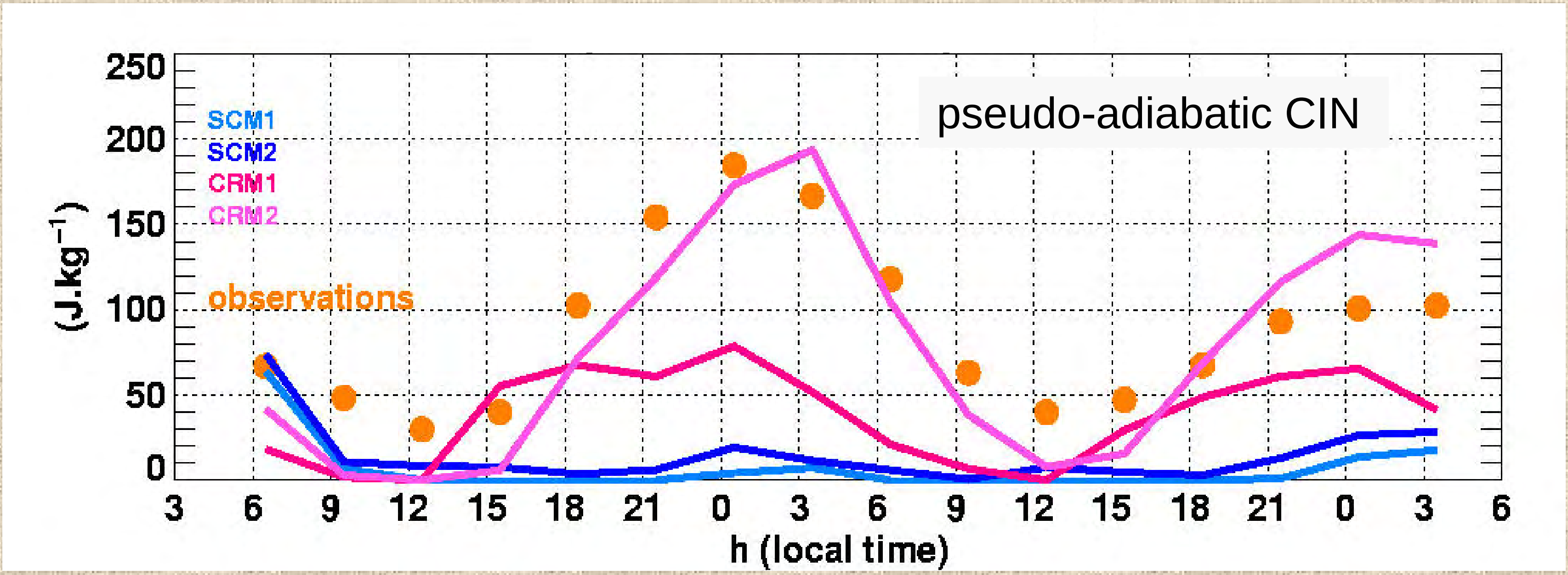
CRMs/SCMs differences?

observations (Xie et al. 2001)



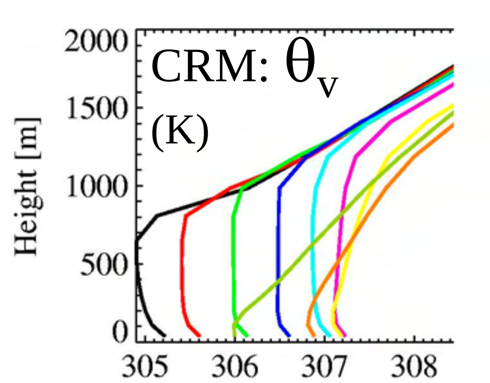
work on more sophisticated stability parameters: Remi Tailleux

THE IDEALIZED CASE : Convective INhibition



✓ almost no CIN in SCM runs during daytime (true for at least 4 SCMs) !

✓ challenging for CRMs too
✓ CIN strongly modulated by convective activity in CRMs
✓ impact of convective downdraughts



distinct links between convection & stability in CRMs & SCMs
need to investigate the « why »

CONCLUSIONS / FUTURE WORK

✓documentation of GCMs & RCM weaknesses

✓assess CRM/SCM models over land with GCSS/ARM case
✓better results/consistency among CRMs than SCMs
(agreement with GCSS work)
design an idealized « diurnal cycle case » to address the problem

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

✓deep convection often occurs earlier than observed in SCMs
✓no succession of dry-shallow-deep regimes in SCMs, dry to deep
✓complex sensitivity to triggering criteria & downdraughts formulation
✓no CIN during daytime in many SCMs

✓further analysis of CRM & SCM runs
(document, explain + sensitivity tests: trigger, downdraughts/resolution, size)
✓ test of new formulations in SCMs & then GCMs

the end, thank you