CRCP IN CLOUDS-IN-CLIMATE PROBLEM

Wojciech W. Grabowski

Mesoscale and Microscale Meteorology Division

NCAR

- Moisture-convection feedback in the tropics and Intraseasonal Oscillations

- from CRCP to super-parameterization ("CRCP as a physics coupler")

boundary layer and shallow convection: diurnal cycle over land

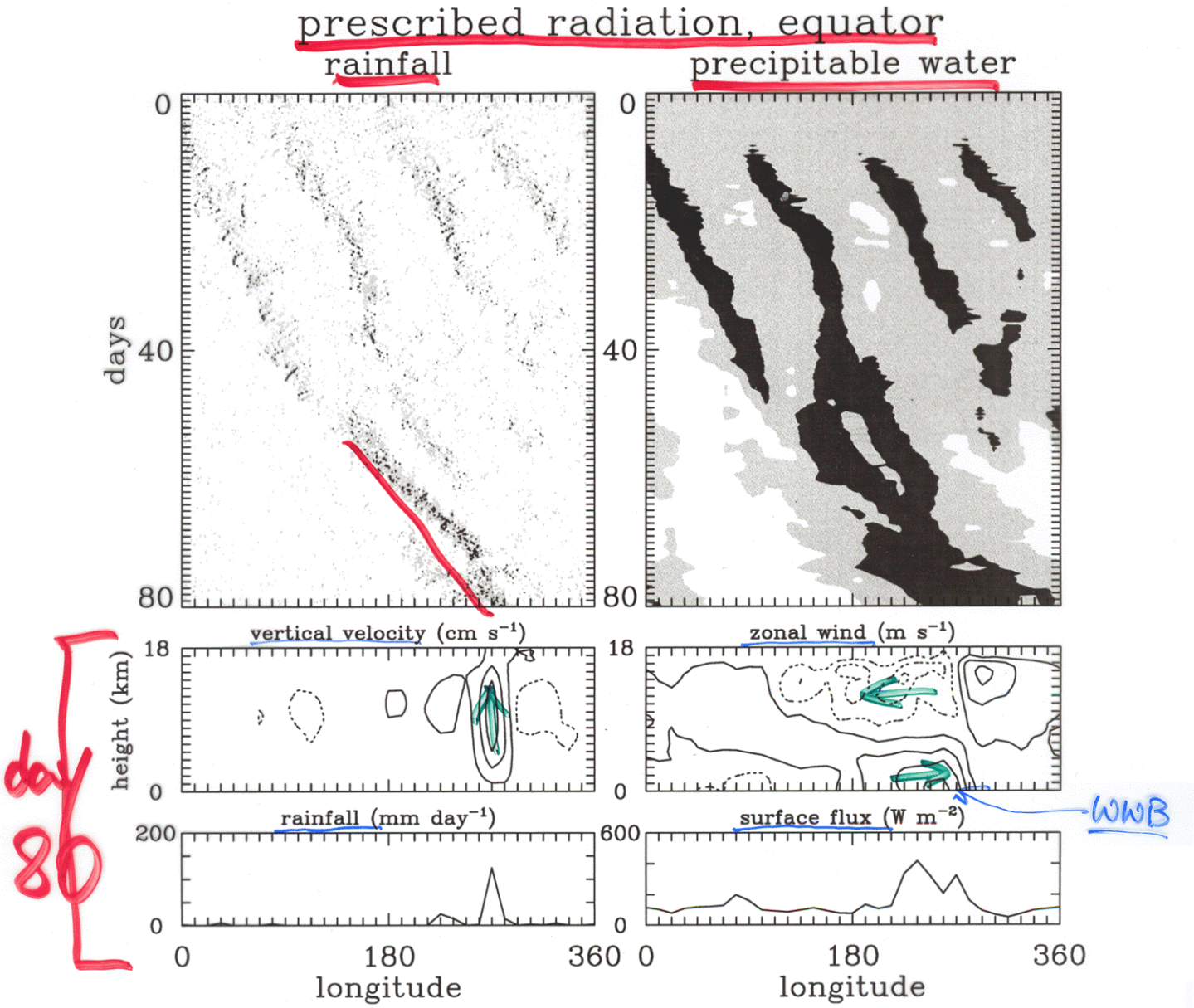
$\longrightarrow$ *Hamlet's dilemma: "2D or not 2D, this is the question..."*

- CRCP in CAM over tropical western Pacific

MJO-like coherent structures on a rotating Earth-size constant-SST aquaplanet

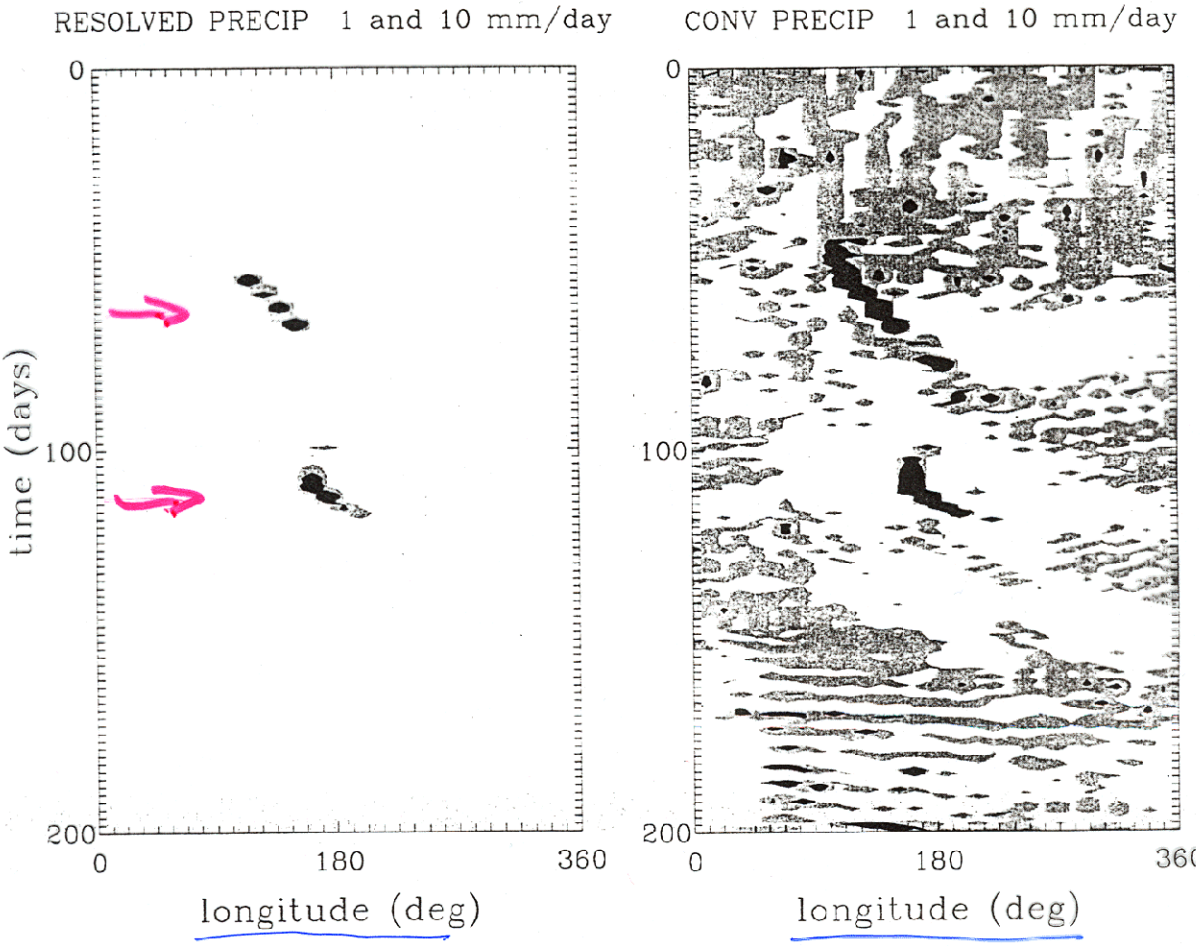
impact of free-tropospheric moisture and moisture-convection feedback on large-scale convection organization in the tropics

Grabowski, JAS 2003


prescribed radiation, equator
rainfall
precipitable water
days
0
40
80
vertical velocity (cm s^{-1})
zonal wind (m s^{-1})
height (km)
18
0
rainfall (mm day^{-1})
surface flux (W m^{-2})
200
600
0
180
360
longitude
WWB
day 80

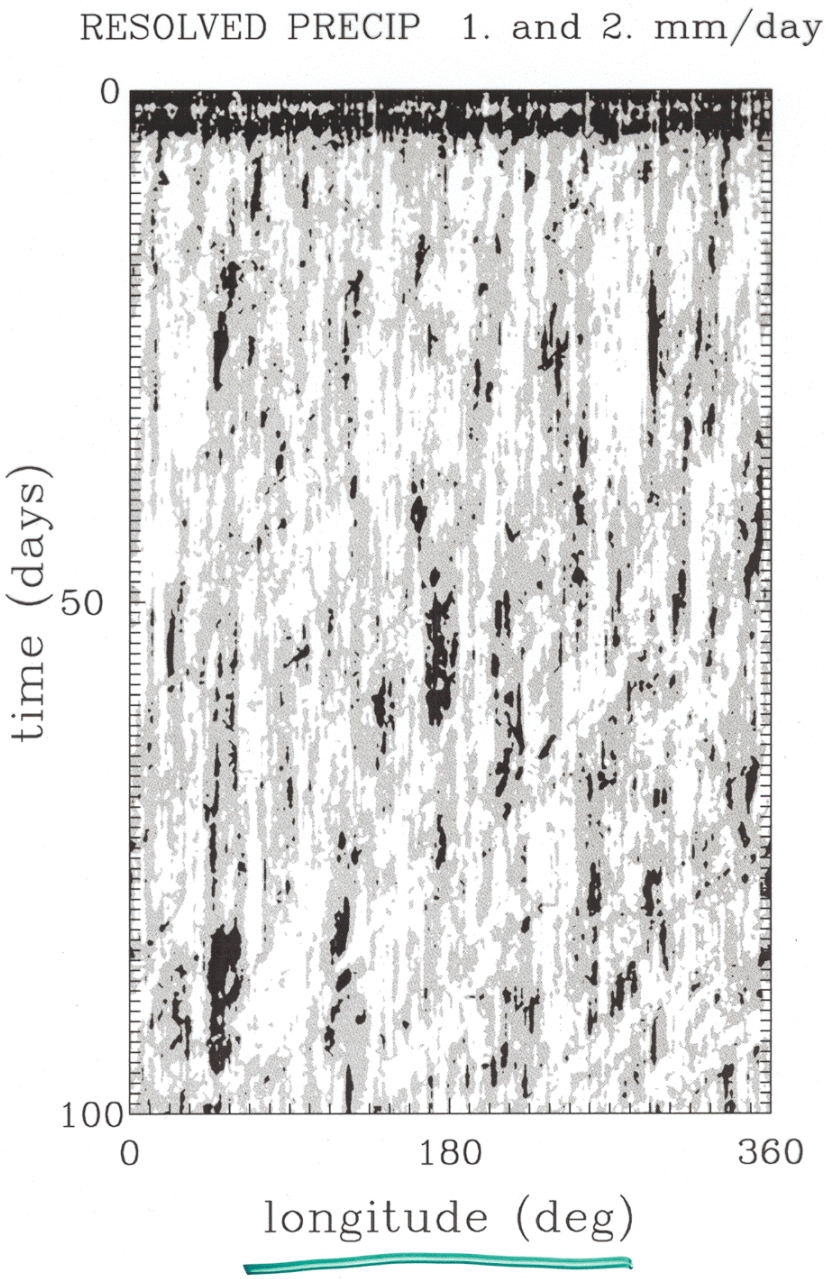
32 × 16
Zonal meridional

EQUATOR



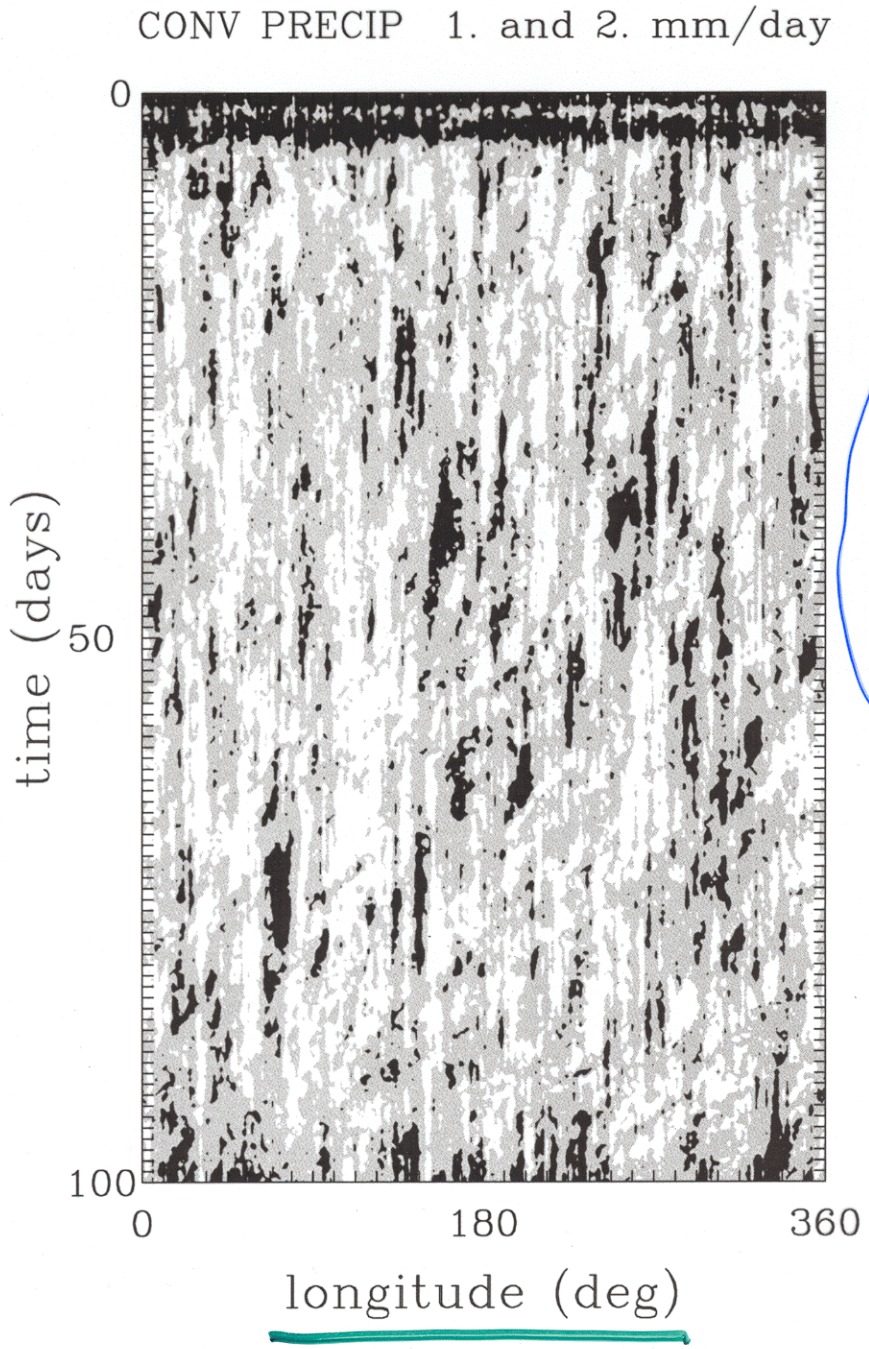
CRCP replaced by traditional convective parameterization (Emanuel scheme)

200 x 100



zonal distribution of precip (20°S ; 20°N)

200 x 100



NO MJO !

zonal distribution of precip (20°S ; 20°N)

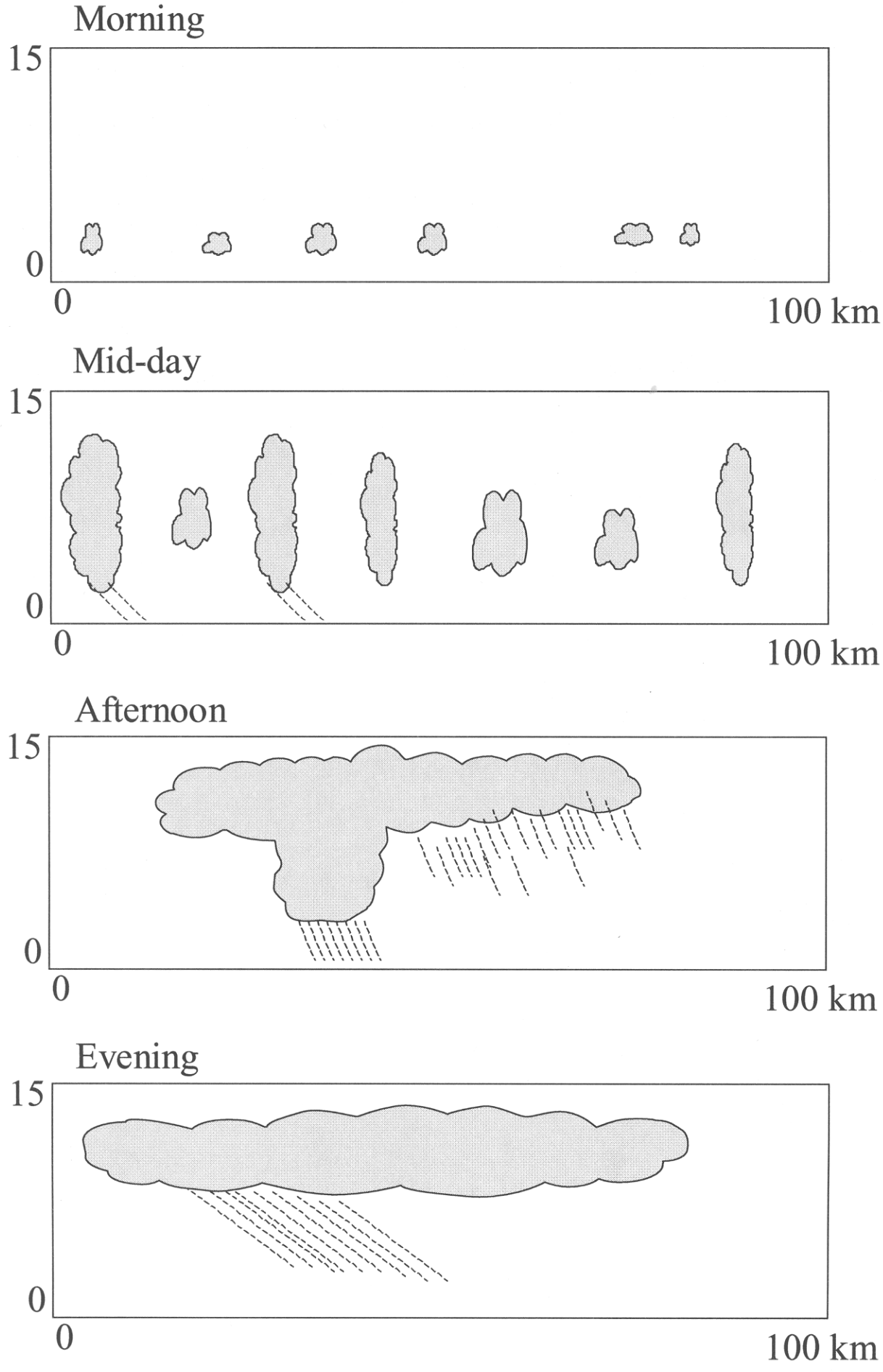
CRCP over land

representation of diurnal cycle of convection over land (shallow convection and transition from shallow to deep convection)

can a 2D cloud-resolving model
with horizontal/vertical resolution of ∼1 km/∼0.1 km
capture these processes?

$\longrightarrow$ diurnal cycle of shallow convection over land: GCSS WG1 case based on ARM observations

$\longrightarrow$ shallow to deep convection transition over land: GCSS WG4 case based on TRMM/LBA observations


Morning
15
0
0
100 km
Mid-day
15
0
0
100 km
Afternoon
15
0
0
100 km
Evening
15
0
0
100 km

Q. J. R. Meteorol. Soc. (2002), **128**, pp. 1075–1093

Large-eddy simulation of the diurnal cycle of shallow cumulus convection over land

By A. R. BROWN[1]*, R. T. CEDERWALL[2], A. CHLOND[3], P. G. DUYNKERKE[4], J.-C. GOLAZ[5], M. KHAIROUTDINOV[5], D. C. LEWELLEN[6], A. P. LOCK[1], M. K. MACVEAN[1], C.-H. MOENG[7], R. A. J. NEGGERS[8], A. P. SIEBESMA[8] and B. STEVENS[9]

[1]*Met Office, UK*
[2]*Lawrence Livermore National Laboratory, USA*
[3]*Max-Planck-Institut für Meteorologie, Germany*
[4]*Utrecht University, The Netherlands*
[5]*Colorado State University, USA*
[6]*West Virginia University, USA*
[7]*National Center for Atmospheric Research, USA*
[8]*Royal Netherlands Meteorological Institute, The Netherlands*
[9]*University of California Los Angeles, USA*

(Received 23 July 2001; revised 7 December 2001)

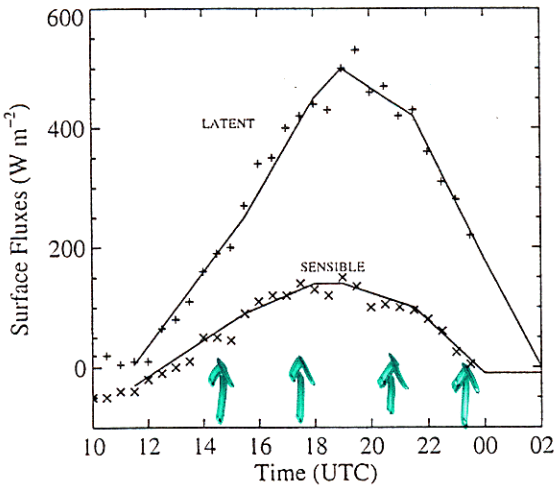


Figure 3. Observed surface sensible-heat and latent-heat fluxes at the central facility (symbols) and the values imposed in the models (solid lines).

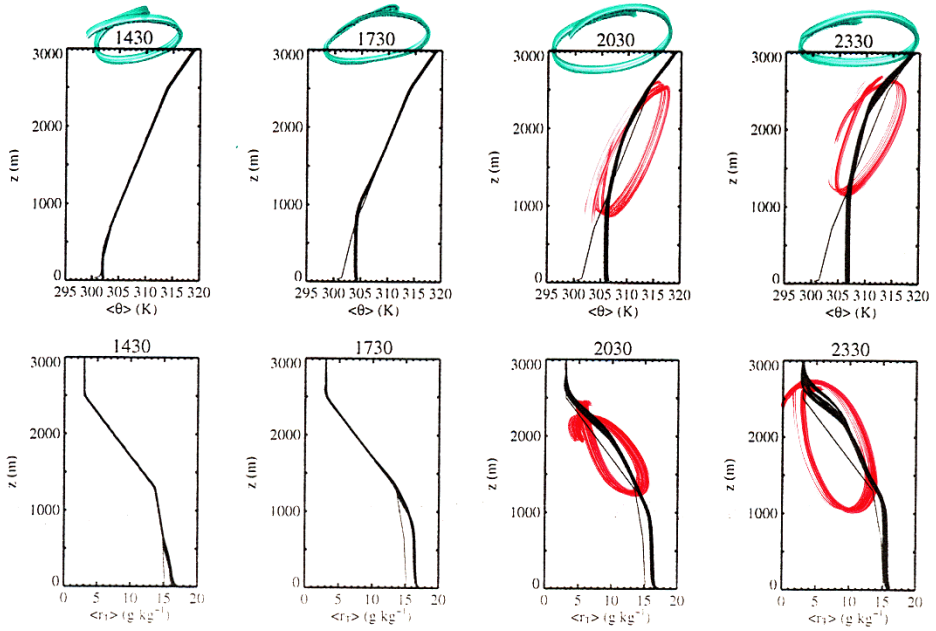


Figure 4. Profiles of potential temperature $\langle\theta\rangle$ and total-water mixing ratio $\langle r_T\rangle$ at various times UTC from the eight different models. In almost all panels the lines from the different models are sufficiently close together that they overlap, and so we actually see the range of LES results rather than individual solutions. The light lines in each panel show the initial profiles.

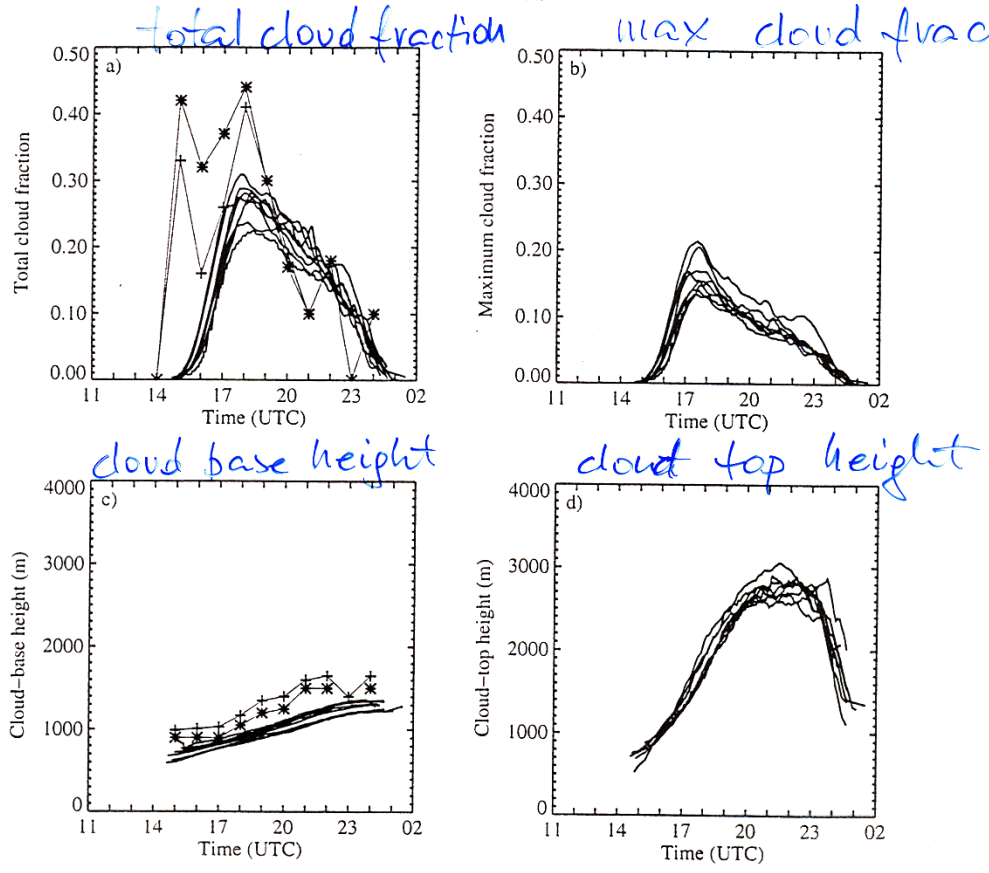


Figure 5. Time series (smoothed over one hour) from the eight simulations. (a) Total cloud fraction, (b) maximum cloud fraction at any one level, (c) cloud-base height and (d) cloud-top height. In (a) and (c) the stars are the observations of the micro-pulse lidar, while the crosses are the observations of the Belfort Ceilometer at the central facility.

diurnal cycle of shallow convection over land: GCSS WG1 case based on ARM observations

3D LES (*benchmark*)

$96 \times 96 \times 111$; 66.7m horizontal, 40 m vertical

2D "LES-type"

192×111; 66.7m horizontal, 40 m vertical

$\longrightarrow$ aligned E-W (along geostrophic wind)

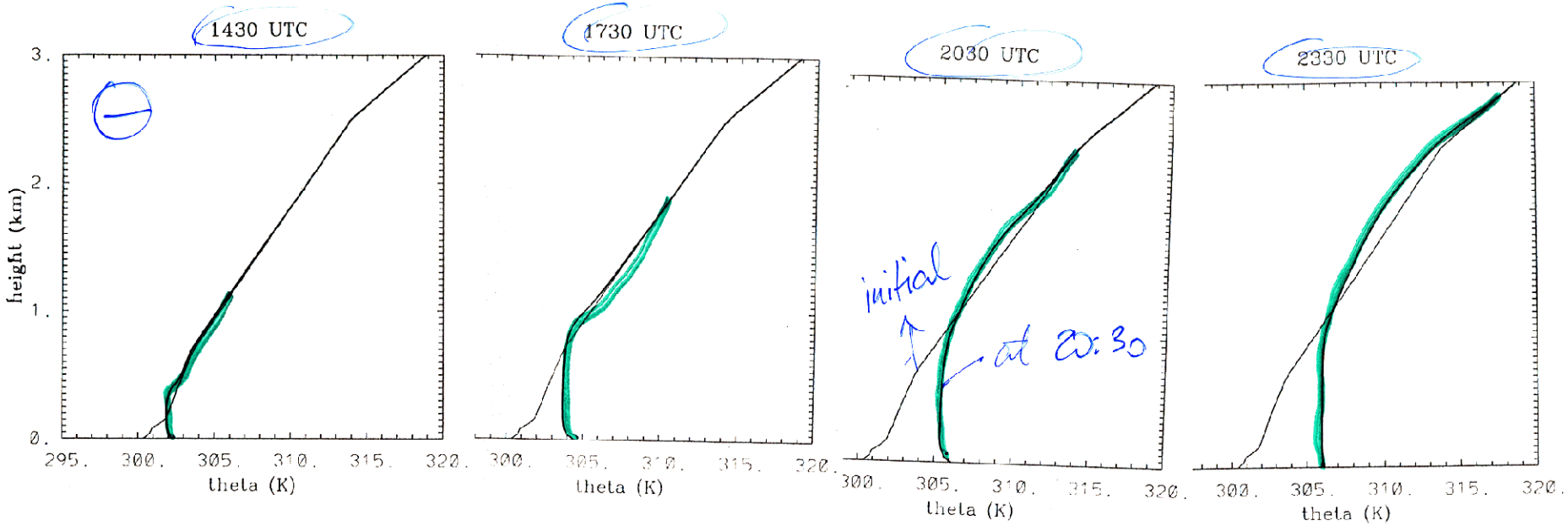
$\longrightarrow$ aligned N-S (perpendicular to geostrophic wind)

CRCP, along lowest 2 km winds

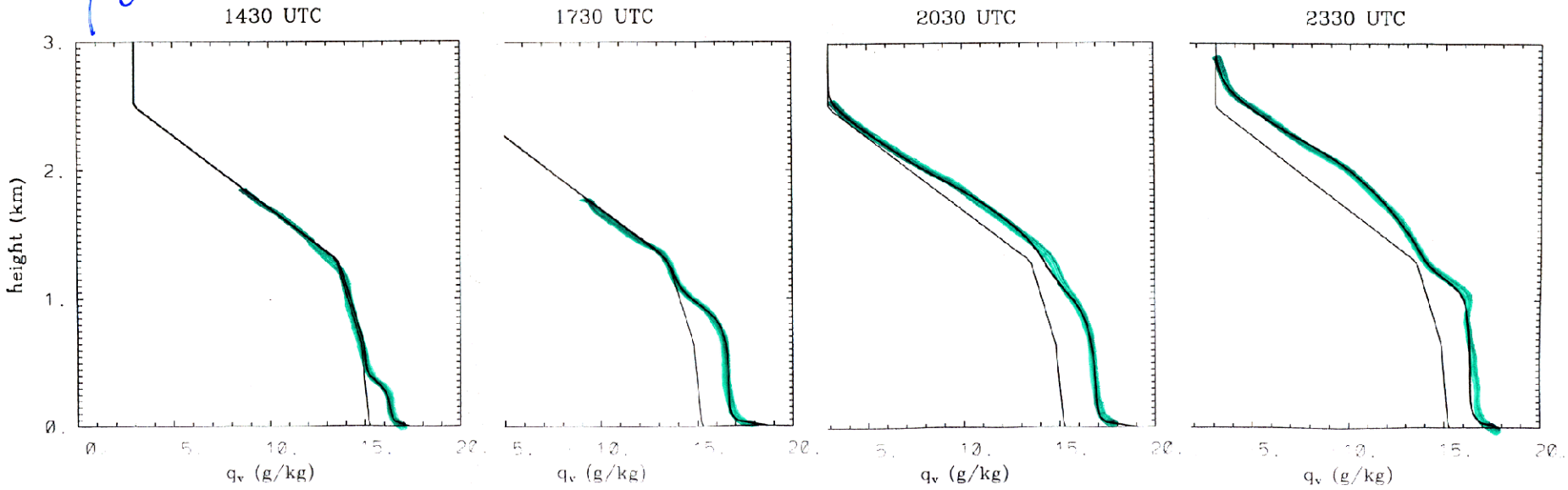
101×23; 1 km horizontal, stretched in vertical

(0, 90, 220, 390, 570, 760 m...)

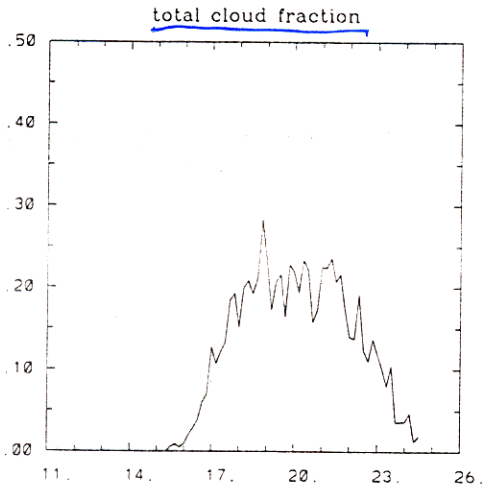
$\longrightarrow$ nonlocal 1D mixing scheme to represent boundary layer transports (Troen and Mahrt 1986)

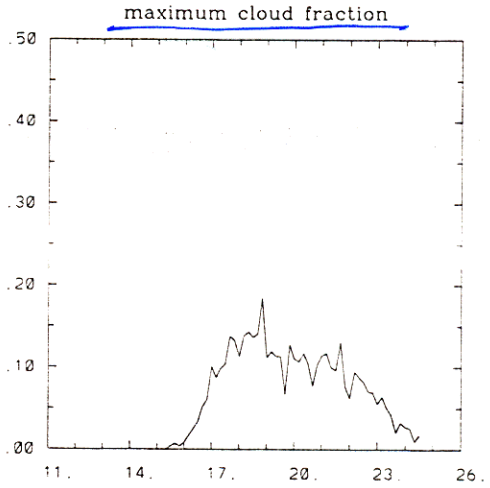

1430 UTC
1730 UTC
2030 UTC
2330 UTC
θ
initial
at 20:30
height (km)
theta (K)
0.
1.
2.
3.
295.
300.
305.
310.
315.
320.

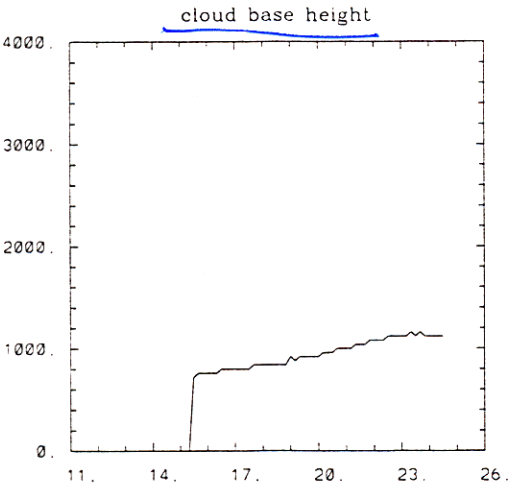
3D LES

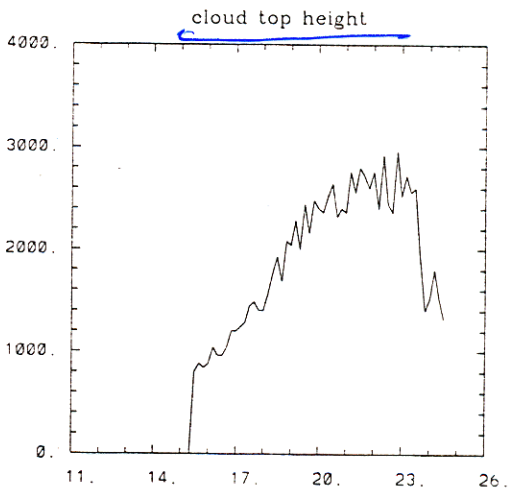

qv
1430 UTC
1730 UTC
2030 UTC
2330 UTC
height (km)
qv (g/kg)
0.
1.
2.
3.
0.
5.
10.
15.
20.

3D LES


total cloud fraction
.50
.40
.30
.20
.10
.00
11.
14.
17.
20.
23.
26.


maximum cloud fraction
.50
.40
.30
.20
.10
.00
11.
14.
17.
20.
23.
26.


cloud base height
4000.
3000.
2000.
1000.
0.
11.
14.
17.
20.
23.
26.


cloud top height
4000.
3000.
2000.
1000.
0.
11.
14.
17.
20.
23.
26.

diurnal cycle of shallow convection over land:

GCSS WG1 case based on ARM observations

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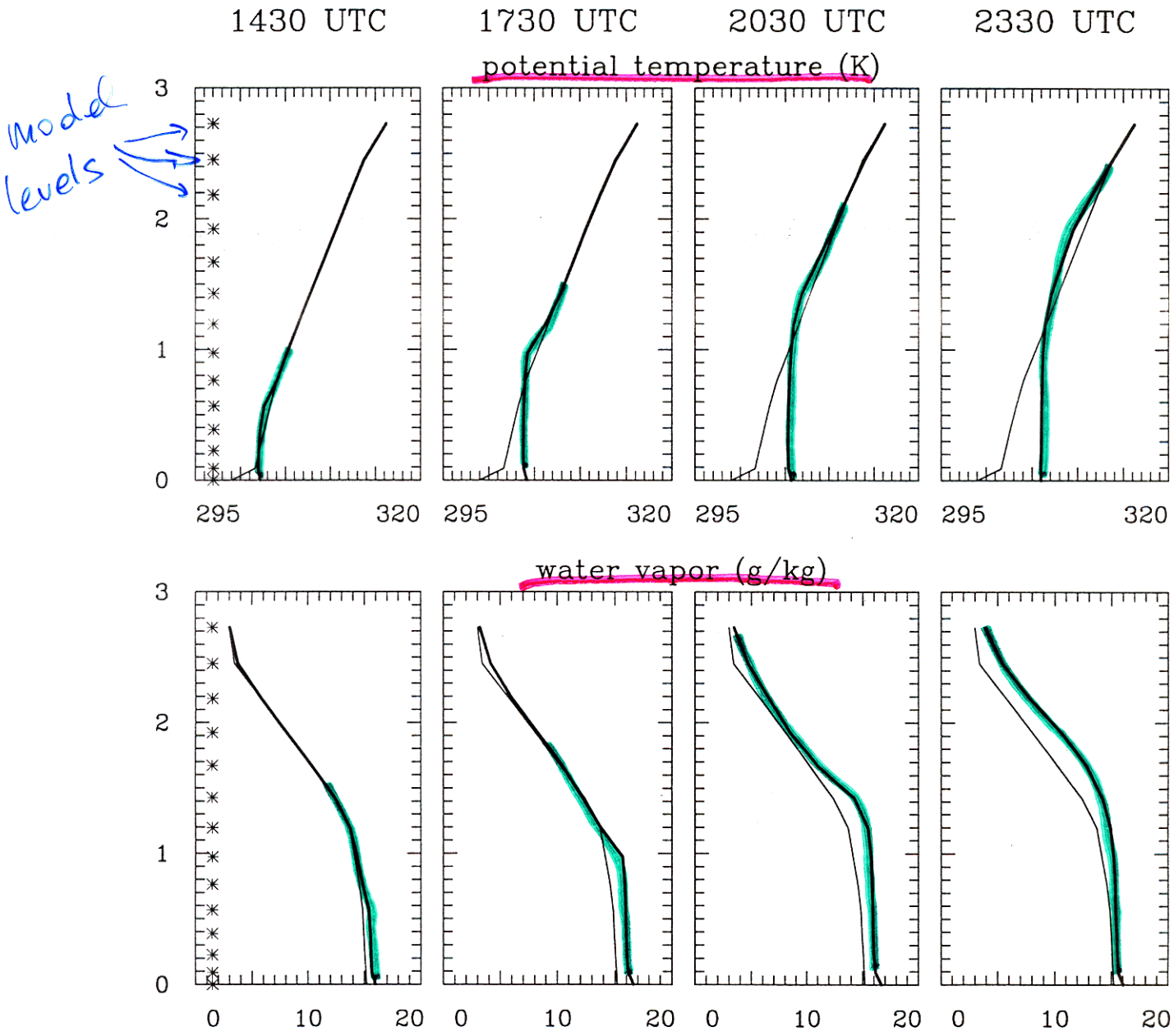
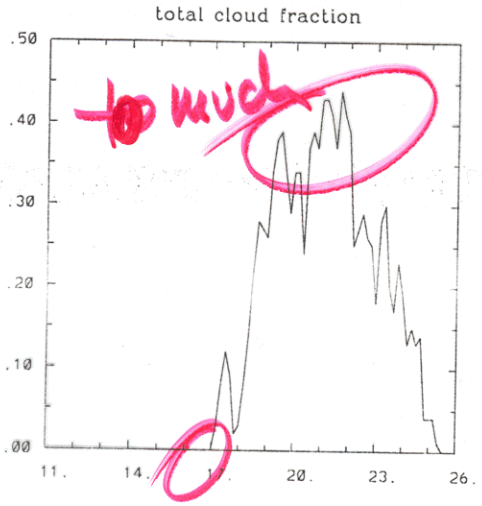
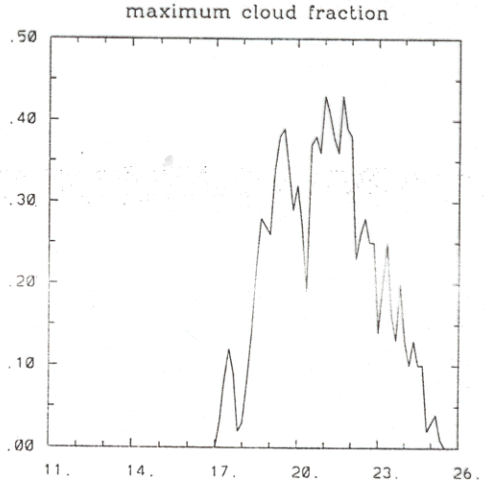
$\longrightarrow$ nonlocal 1D mixing scheme to represent boundary layer transports (Troen and Mahrt 1986)

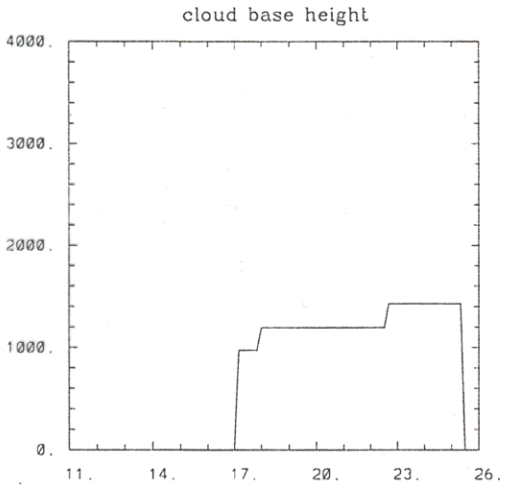
CRCP

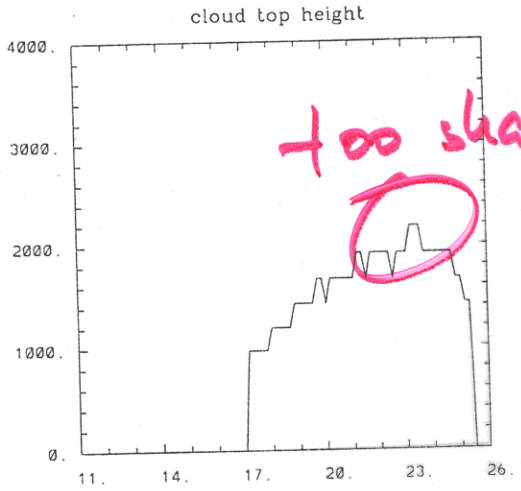

1430 UTC
1730 UTC
2030 UTC
2330 UTC
potential temperature (K)
model levels
3
2
1
0
295
320
water vapor (g/kg)
0
10
20

CRCP

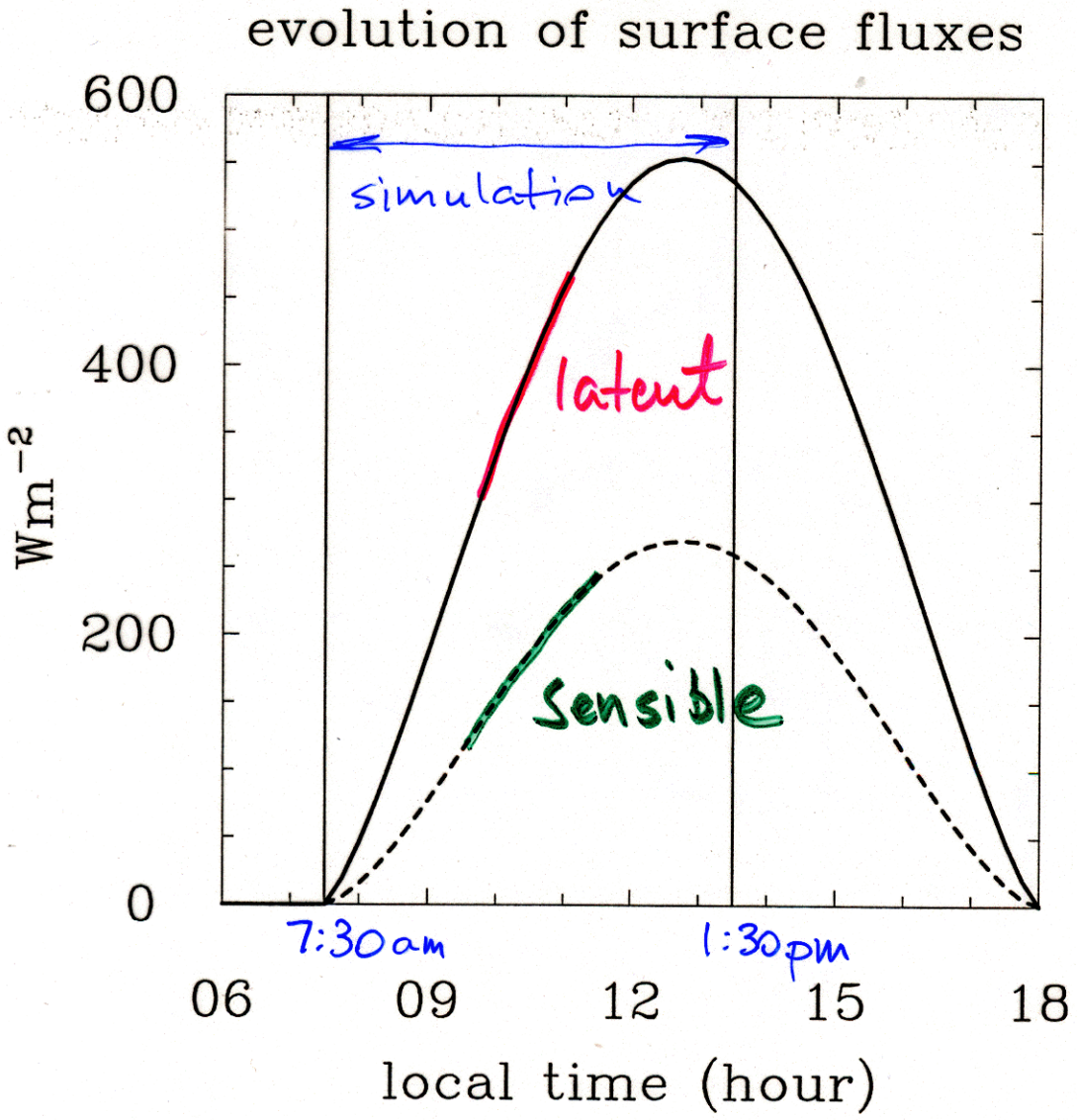

total cloud fraction
too much
too late
.50
.40
.30
.20
.10
.00
11.
14.
17.
20.
23.
26.

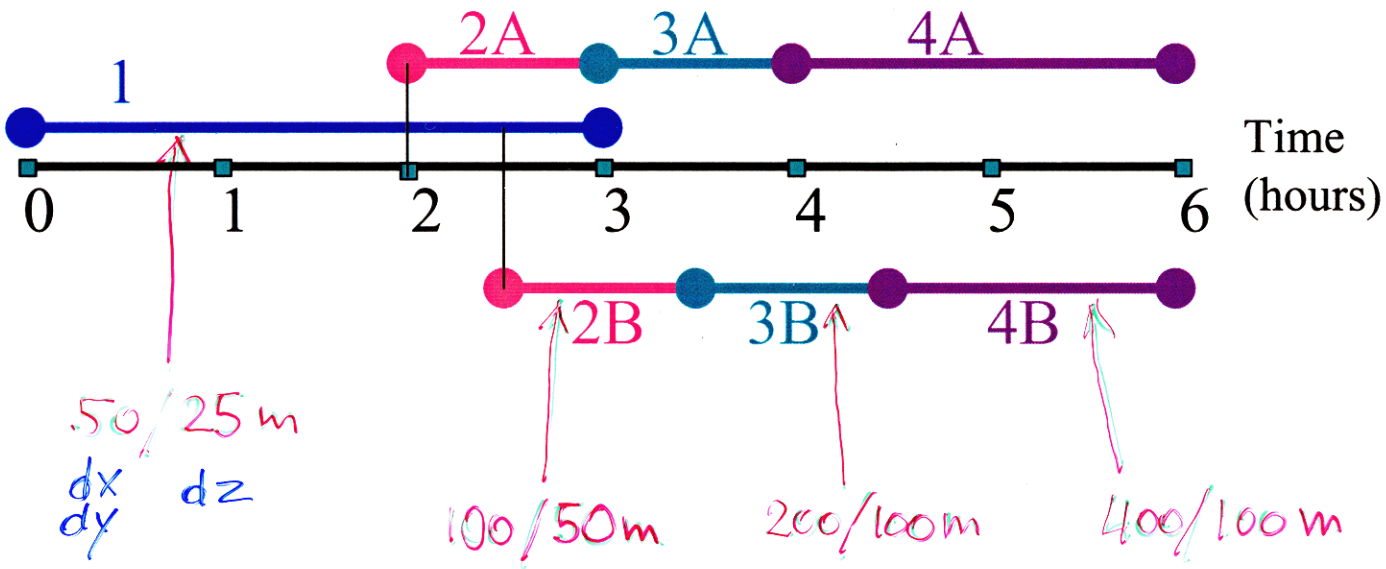

maximum cloud fraction
.50
.40
.30
.20
.10
.00
11.
14.
17.
20.
23.
26.

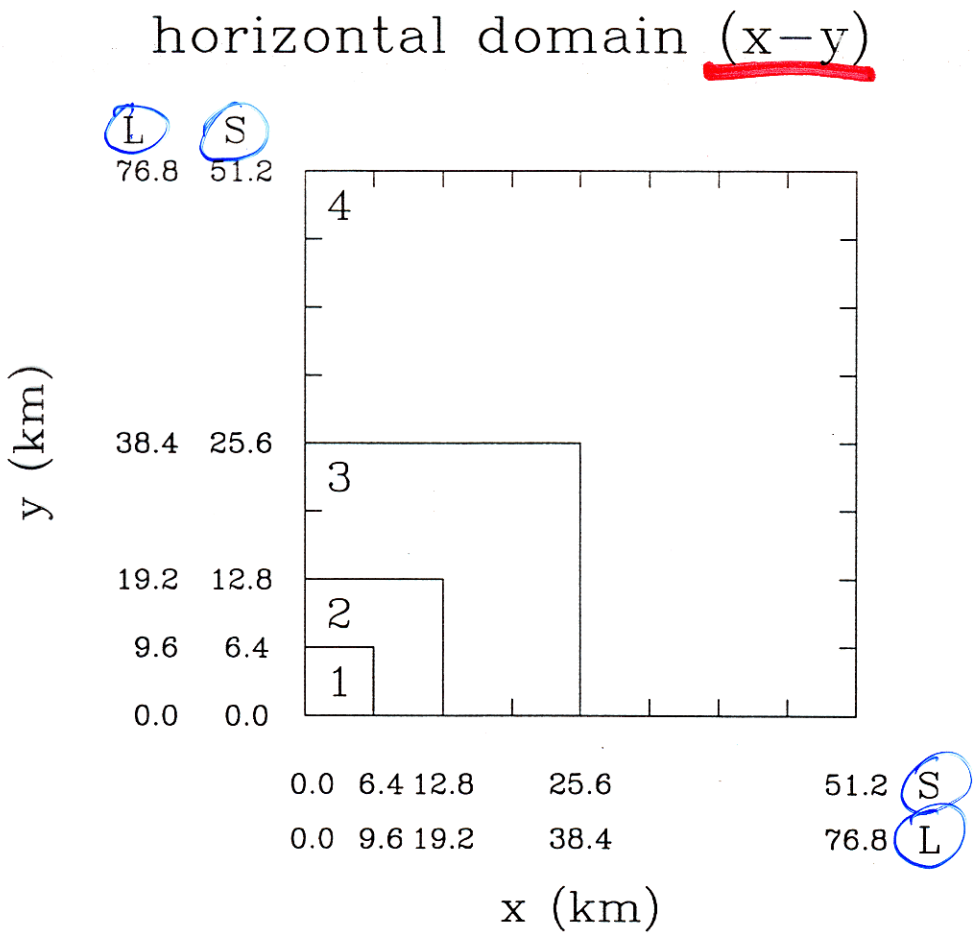

cloud base height
4000.
3000.
2000.
1000.
0.
11.
14.
17.
20.
23.
26.


cloud top height
too shallow
4000.
3000.
2000.
1000.
0.
11.
14.
17.
20.
23.
26.

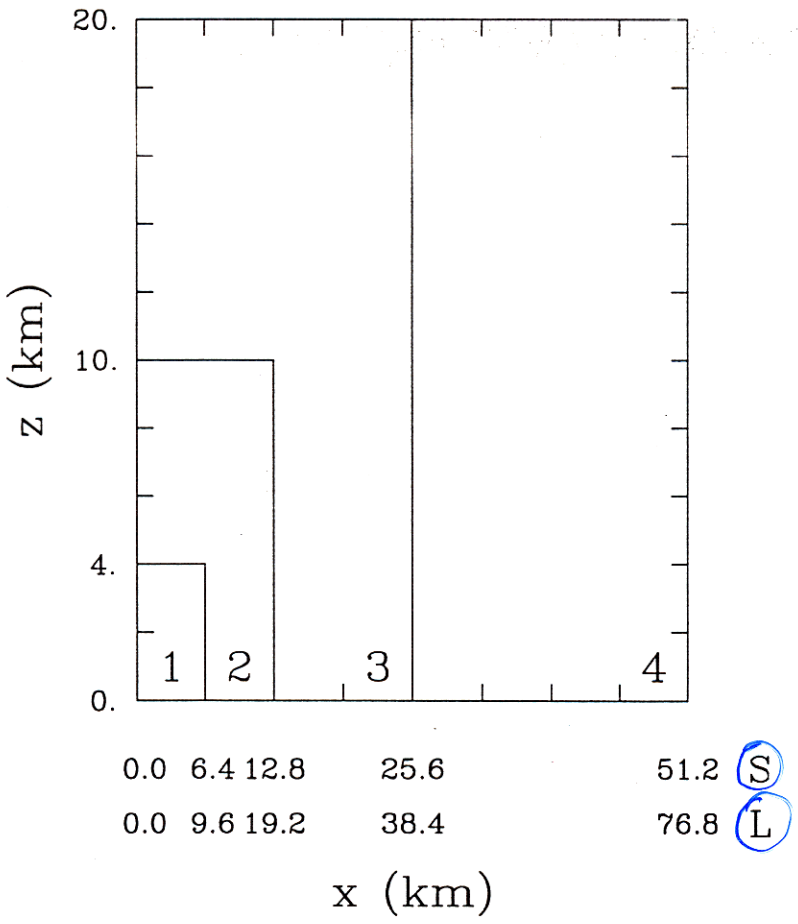
LBA


evolution of surface fluxes
600
400
200
0
Wm^{-2}
simulation
latent
Sensible
7:30am
1:30pm
06
09
12
15
18
local time (hour)


1
2A
3A
4A
0
1
2
3
4
5
6
Time
(hours)
2B
3B
4B
50/25 m
dx
dy
dz
100/50m
200/100m
400/100m


horizontal domain (x−y)
L
S
76.8
51.2
4
38.4
25.6
3
19.2
12.8
2
9.6
6.4
1
0.0
0.0
y (km)
0.0
6.4
12.8
25.6
51.2
S
0.0
9.6
19.2
38.4
76.8
L
x (km)

vertical domain (x−z)



shallow to deep convection transition over land:

GCSS WG4 case based on TRMM/LBA observations

ensemble of 3D simulations (*benchmark*)

2 sets: $128 \times 128 \times 201$, $192 \times 192 \times 201$

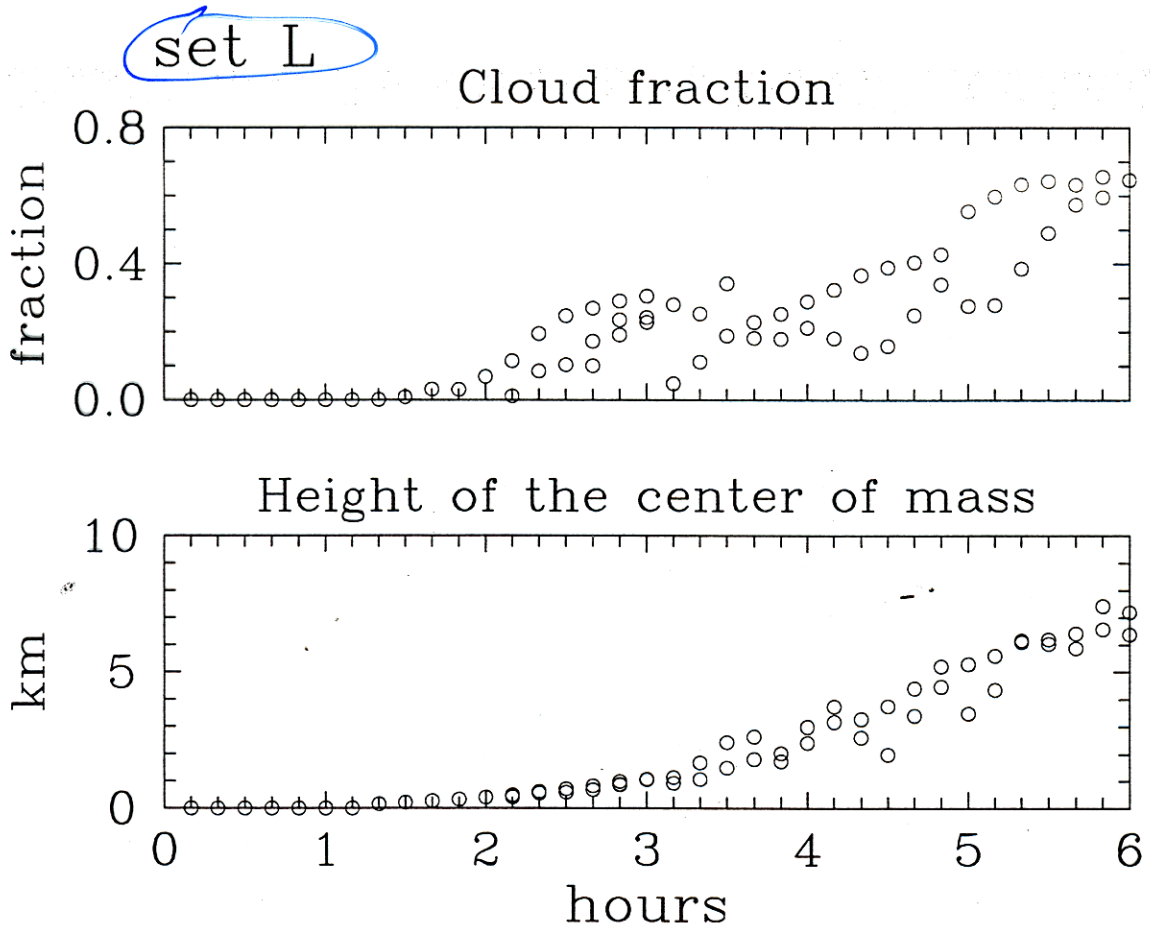
$(\Delta x, \Delta z)$: (50,25) $\rightarrow$ (100,50) $\rightarrow$ (200,100) $\rightarrow$ (400,100)

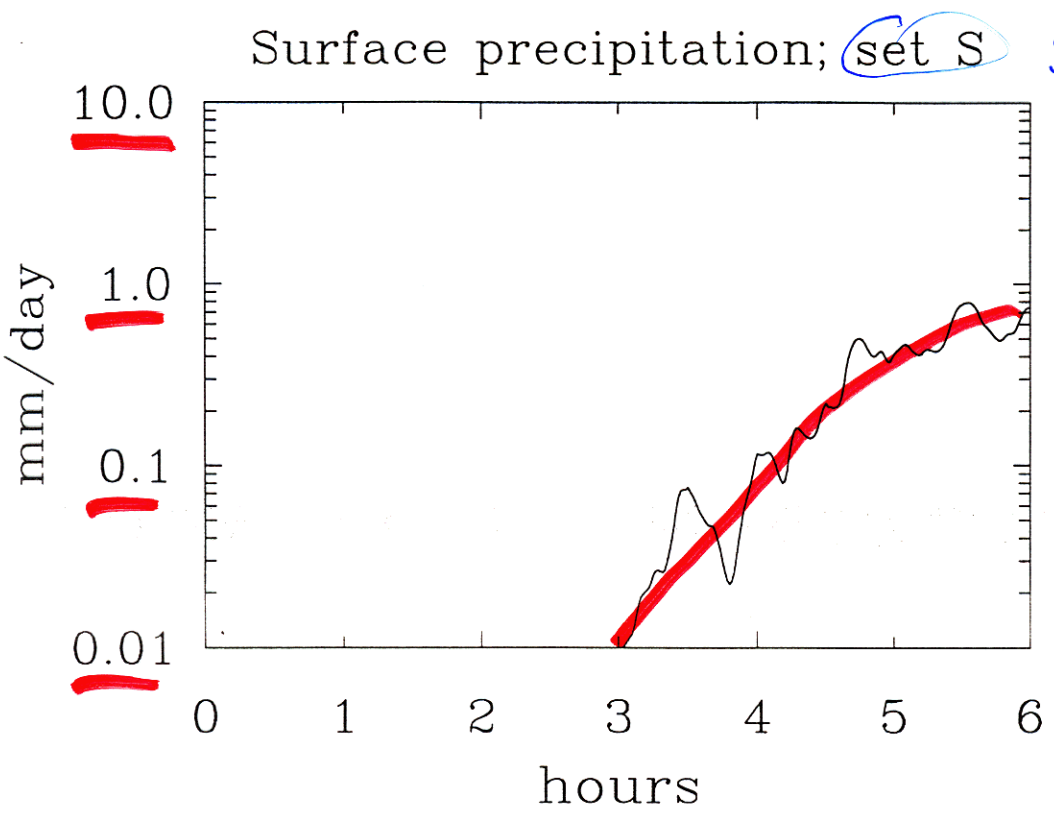
CRCP, along lowest 2 km winds

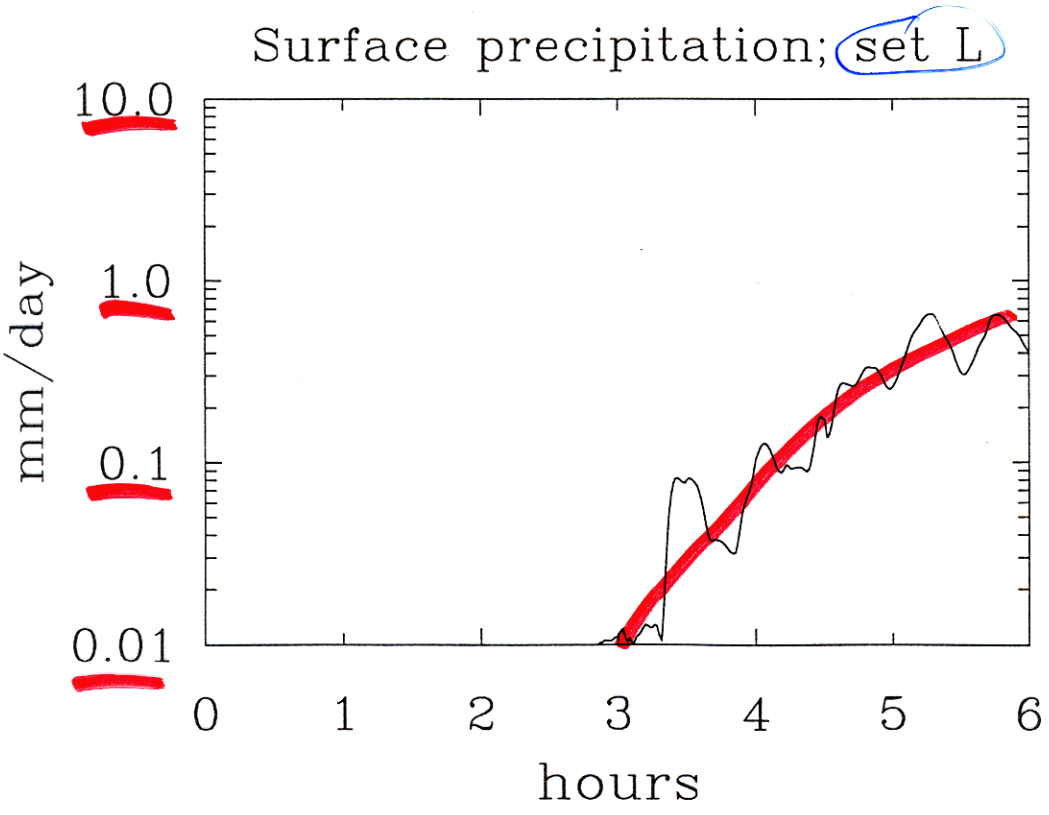
101×61; 1 km horizontal, stretched in vertical

(0, 100, 260, 440, 650, 870 m...)

$\longrightarrow$ nonlocal 1D mixing scheme to represent boundary layer transports (Troen and Mahrt 1986)


set L
Cloud fraction
fraction
0.8
0.4
0.0
Height of the center of mass
km
10
5
0
0
1
2
3
4
5
6
hours


Surface precipitation; set S
ensemble average
10.0
1.0
0.1
0.01
mm/day
0
1
2
3
4
5
6
hours


Surface precipitation; set L
10.0
1.0
0.1
0.01
mm/day
0
1
2
3
4
5
6
hours

shallow to deep convection transition over land:

GCSS WG4 case based on TRMM/LBA observations

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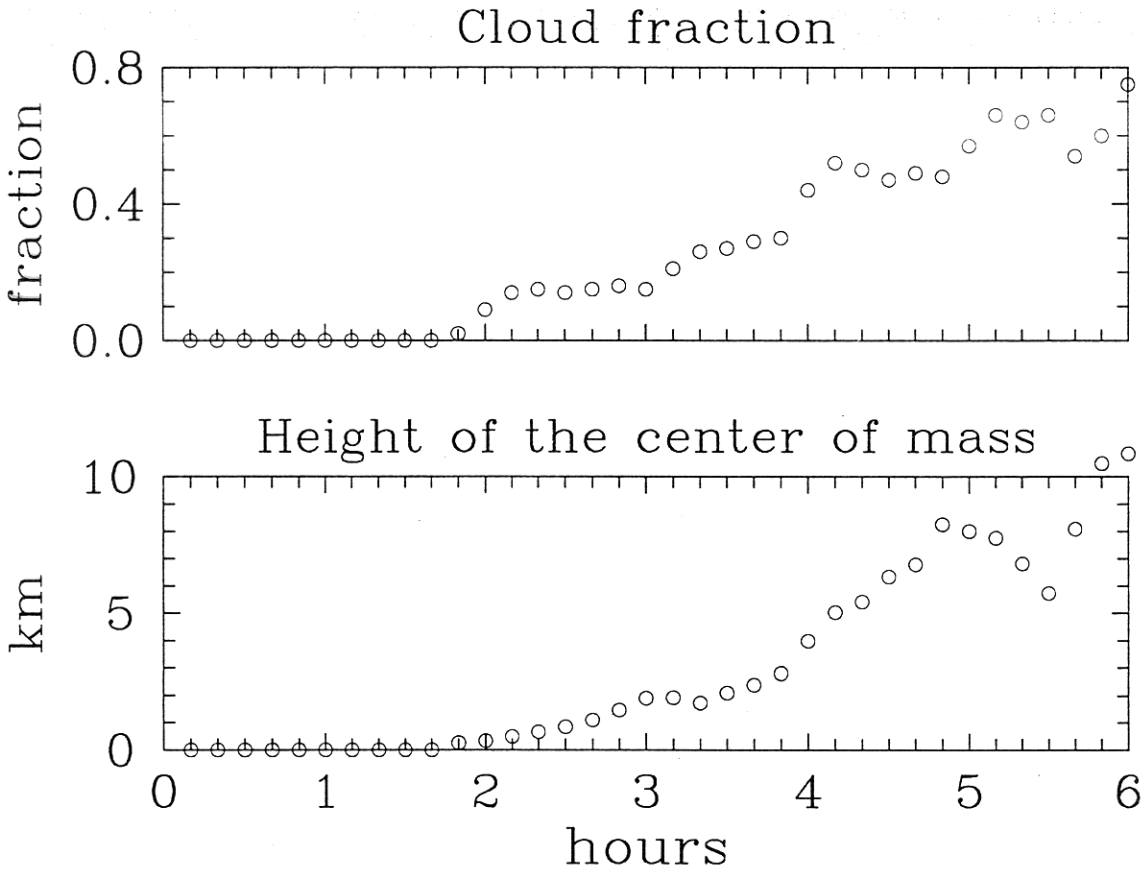
CRCP


Cloud fraction
fraction
0.8
0.4
0.0
Height of the center of mass
km
10
5
0
0
1
2
3
4
5
6
hours

Super-parameterization in CAM over TWP

Michał Ziemianski

systematic evaluation of the impact of CRCP on cloud-radiation interactions over the tropical western Pacific (TWP):

$\longrightarrow$ 1. applying CAM large-scale forcing from a set of 56 columns over TWP (150E to 170E and 10S to 10N) to 56 CRMs (i.e., no feedback to CAM)

$\longrightarrow$ 2. replacing deep convection parameterization in CAM over this area with CRMs (i.e., feedback included)

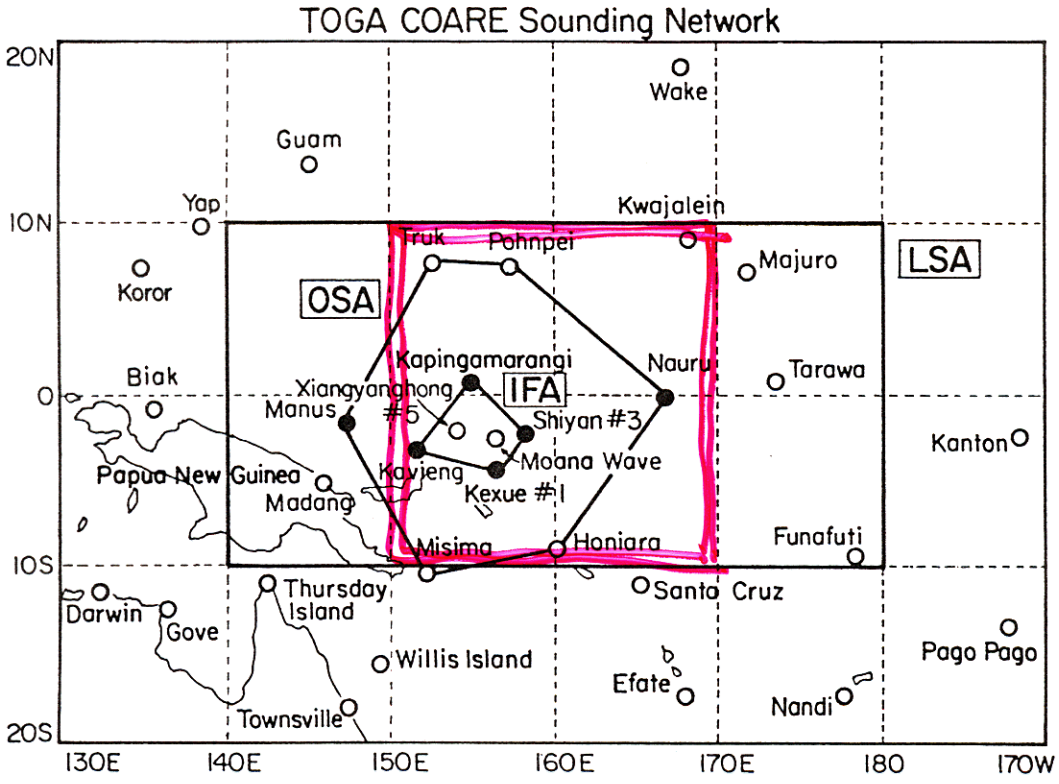
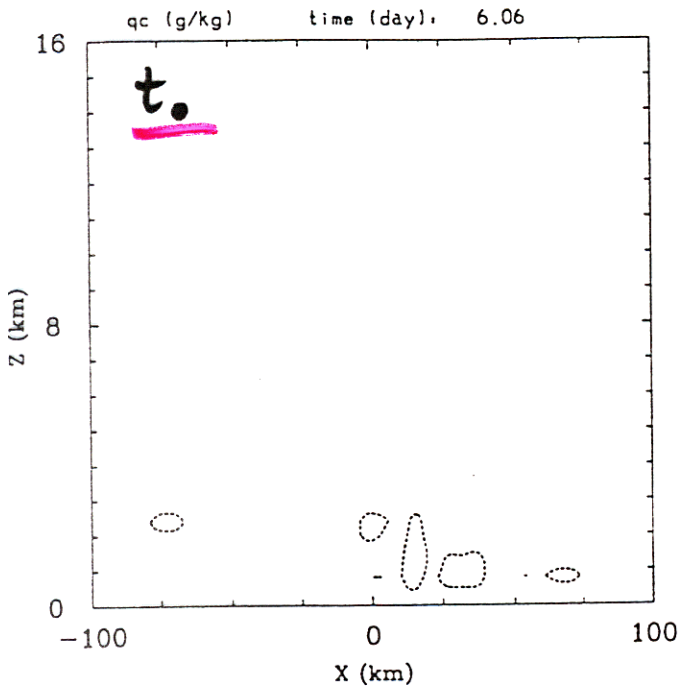
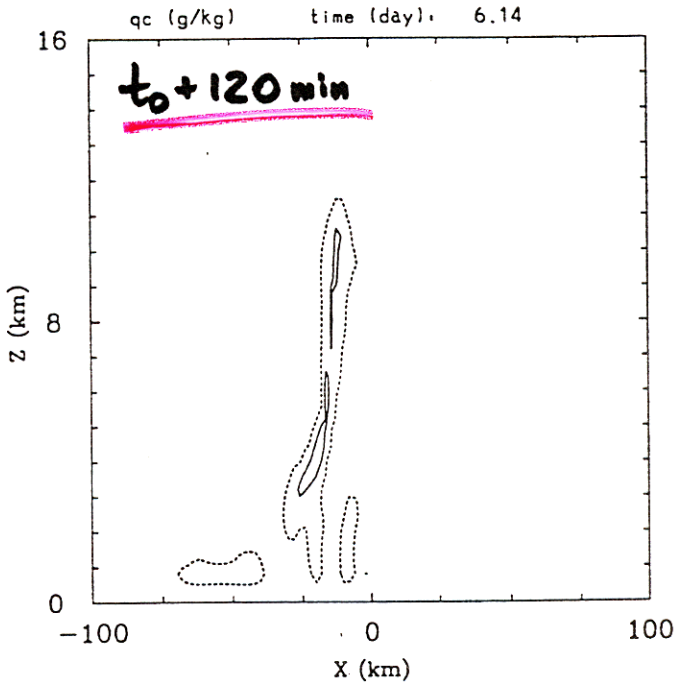
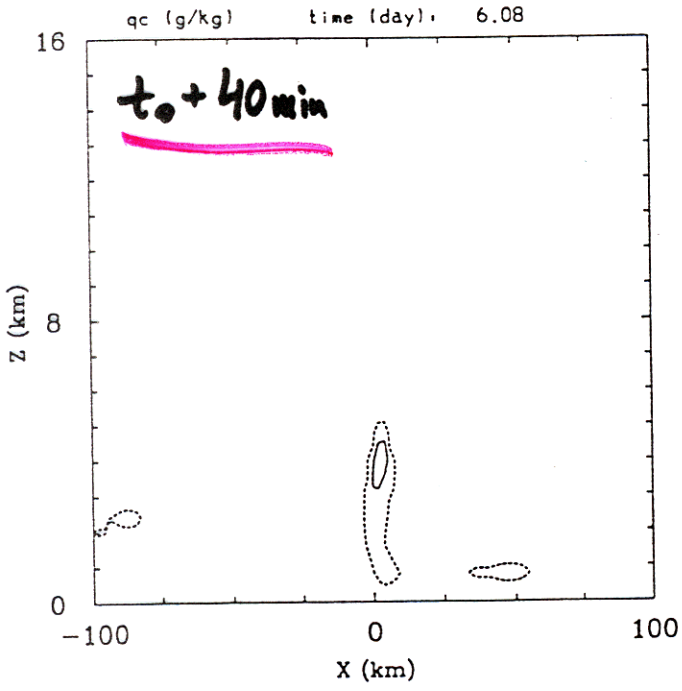


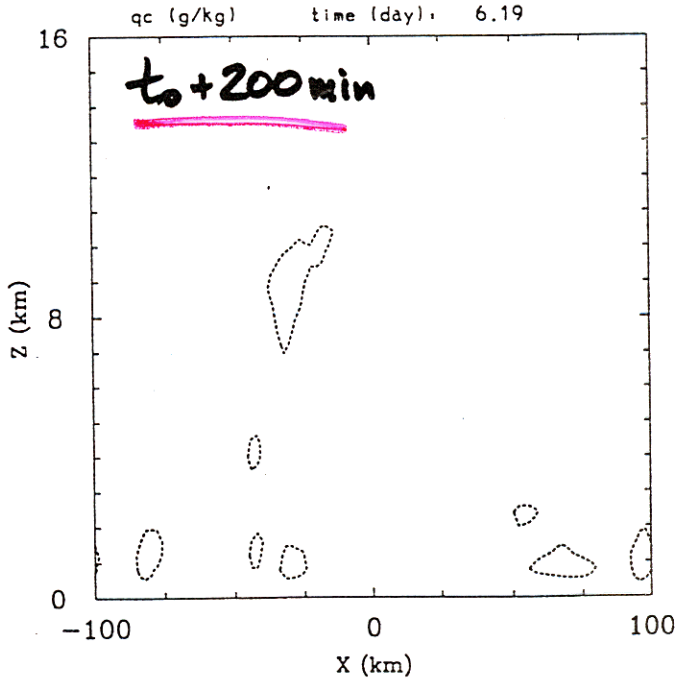
FIG. 1. The TOGA COARE sounding network. The solid circles indicate ISS stations, and the open circles represent other sounding stations.

cloud condensate (cloud water, cloud ice)









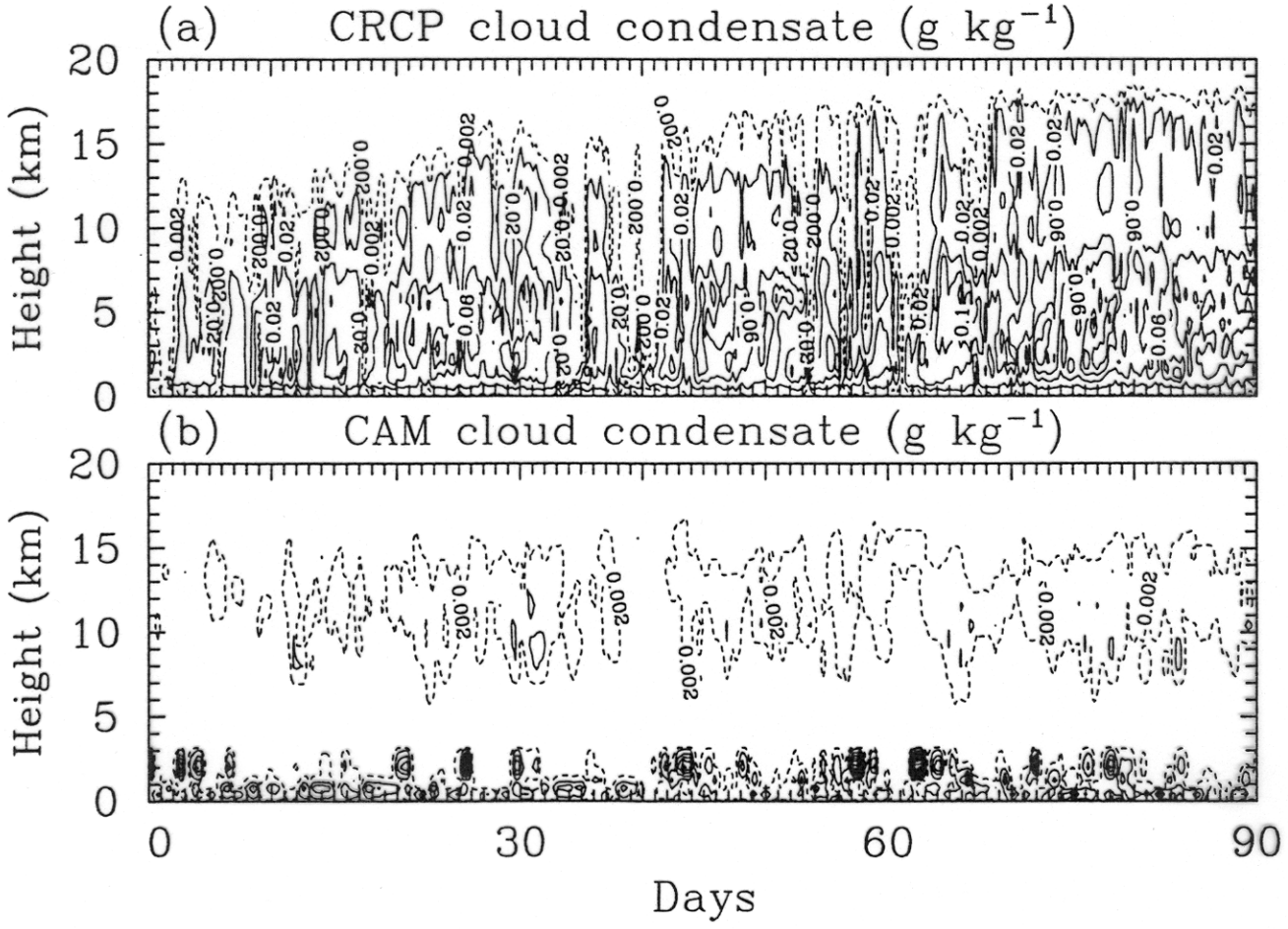
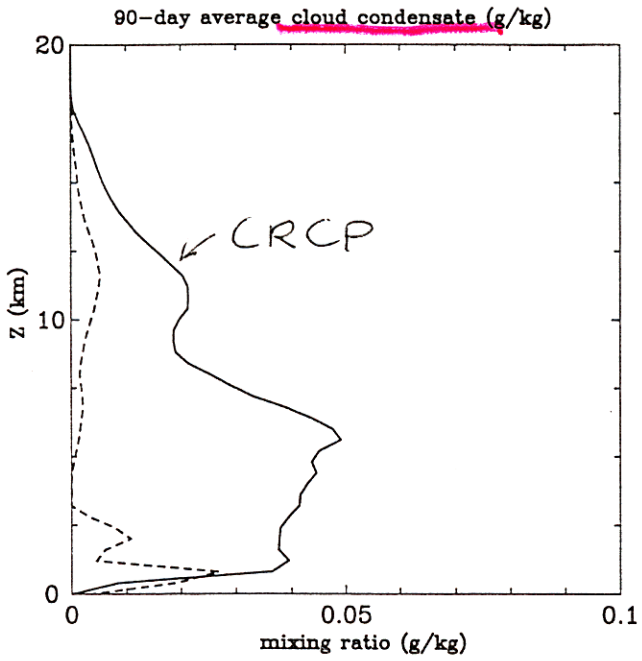

(a) CRCP cloud condensate (g kg^{-1})
(b) CAM cloud condensate (g kg^{-1})
Height (km)
20
15
10
5
0
0
30
60
90
Days

Fig. 3.


90-day average cloud condensate (g/kg)
20
10
0
z (km)
CRCP
0
0.05
0.1
mixing ratio (g/kg)

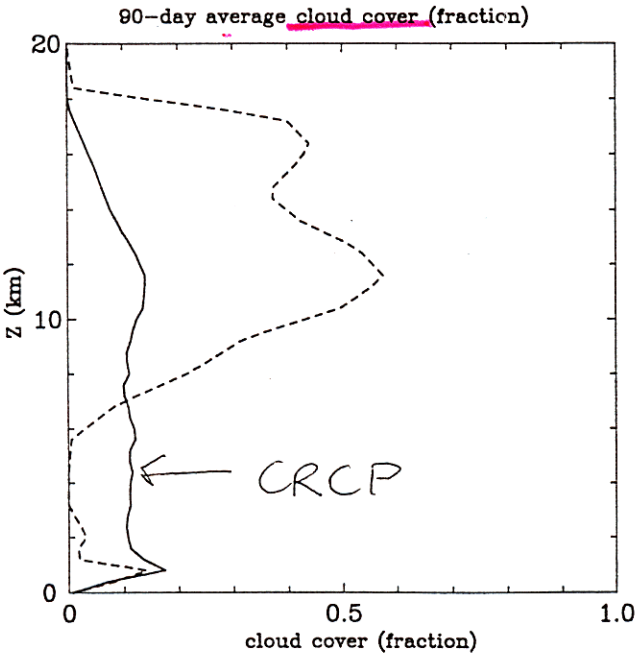

90-day average cloud cover (fraction)
20
10
0
z (km)
CRCP
0
0.5
1.0
cloud cover (fraction)

Table 1: Cloud radiative forcing on the top of the atmosphere (TOA) and surface (SRF) and its standard deviation (in square brackets), resulting from CRCP and CAM convection parameterization for the whole experiment area and integration period; also WM01 results for their CRM and SCM simulations are shown for comparison (in parentheses).

Cloud radiative forcing ($W\ m^{-2}$)	CRCP (CRM)	CAM (SCM)
TOA shortwave	-132.0 [21.6]	-57.6 [7.3]
WM01	(-119.3)	(-78.2)
SRF shortwave	-134.4 [22.8]	-59.6 [7.6]
WM01	(-124.9)	(-79.9)
TOA longwave	69.2 [15.6]	55.8 [11.0]
WM01	(81.4)	(80.7)
SRF longwave	17.8 [0.9]	16.2 [1.0]
WM01	(22.6)	(23.8)

WM01 - Wu & Moncrieff 2001

CRM & SCM forced by TOGA COARE observations

CONCLUSIONS AND OUTLOOK, I

• Intraseasonal Oscillations •

CRCP and a traditional convective parameterization scheme (Emanuel's scheme) give very different solutions as far as MJO-like coherent structures on a constant-SST aquaplanet are concerned. Why?

This is consistent with improved (over-improved?) MJO in CAM with CRCP (Marat)

$\longrightarrow$ organized convection? (next talk)

$\longrightarrow$ moisture-convection feedback? (impact of environmental humidity on deep convection)

CONCLUSIONS AND OUTLOOK, II

• from CRCP to super-parameterization •

diurnal cycle of convection over land:

$\longrightarrow$ CRCP with 2D computational domain aligned along low-level winds, using 1 km horizontal grid spacing and stretched grid in the vertical (100 m near the surface), and applying nonlocal boundary layer scheme captures daytime convective development over land associated with diurnal cycle of surface forcing

$\longrightarrow$ further improvements likely possible when subgrid schemes included (turbulence, condensation, etc), but these will increase cost of CRCP

topographic forcing and land-surface processes are next...

CONCLUSIONS AND OUTLOOK, III

• cloud-radiation interactions over TWP •

CRCP and traditional deep convection parameterization give different picture of clouds over TWP (condensate mixing ratio, cloud fraction, cloud radiative forcing, etc)

results are consistent with a similar study where CRM and CAM SCM were driven by observed large-scale conditions from TOGA COARE (Wu and Moncrieff 2001)