Cloud System Modeling

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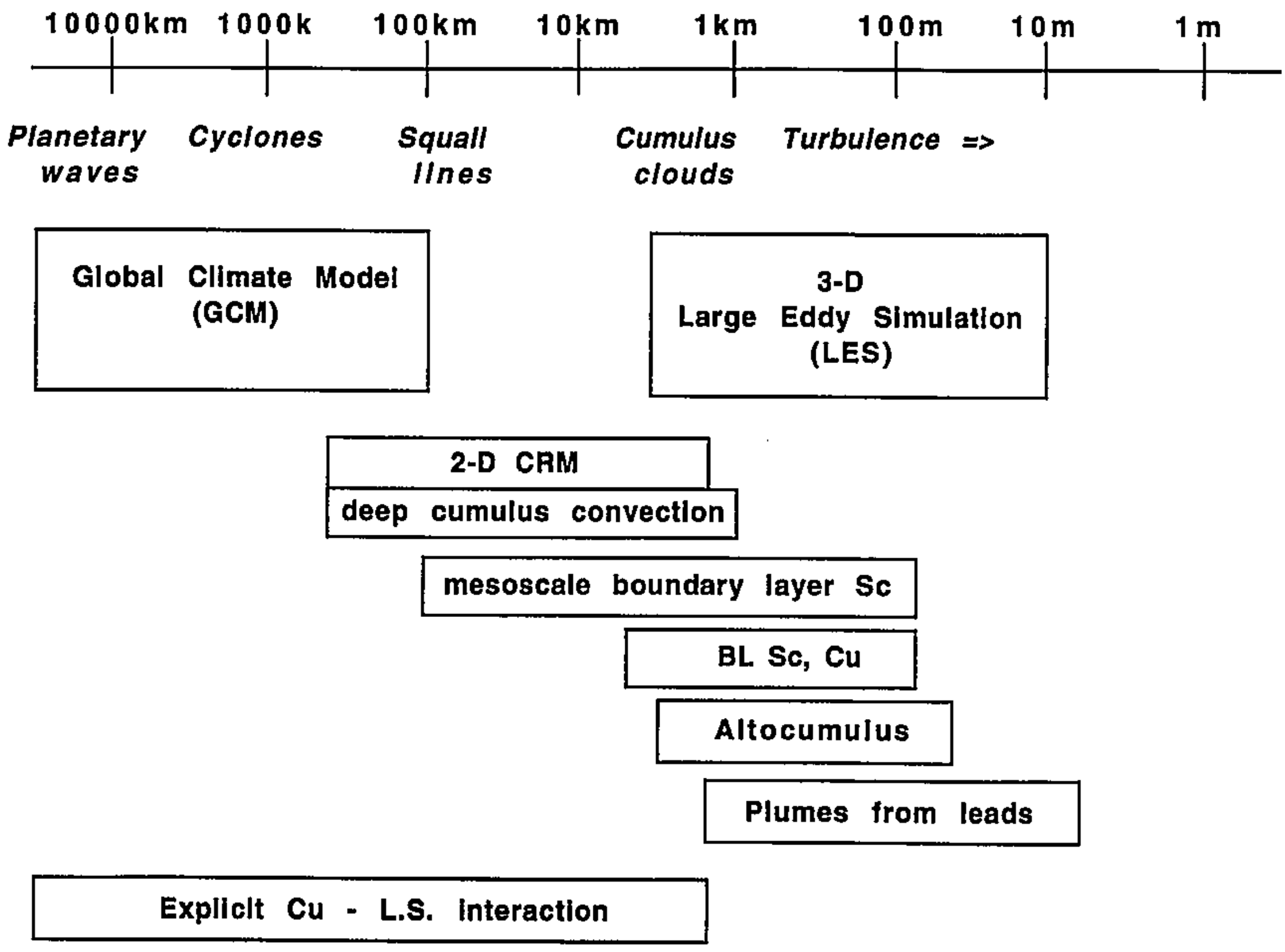


Figure 1 The scales of motion that are explicitly represented by various numerical models of the atmosphere.

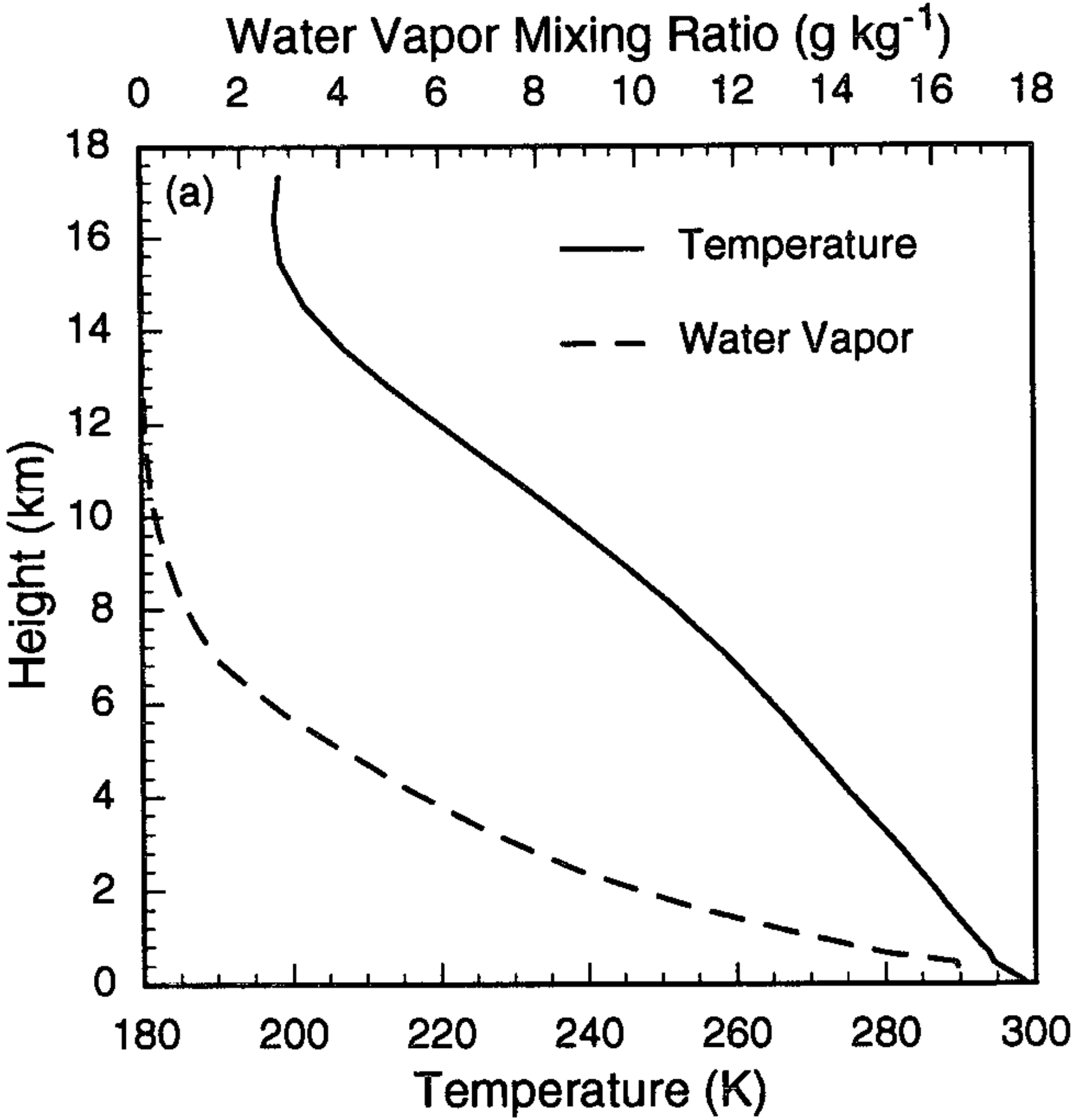
CRMs and GCMs: A Scale Comparison

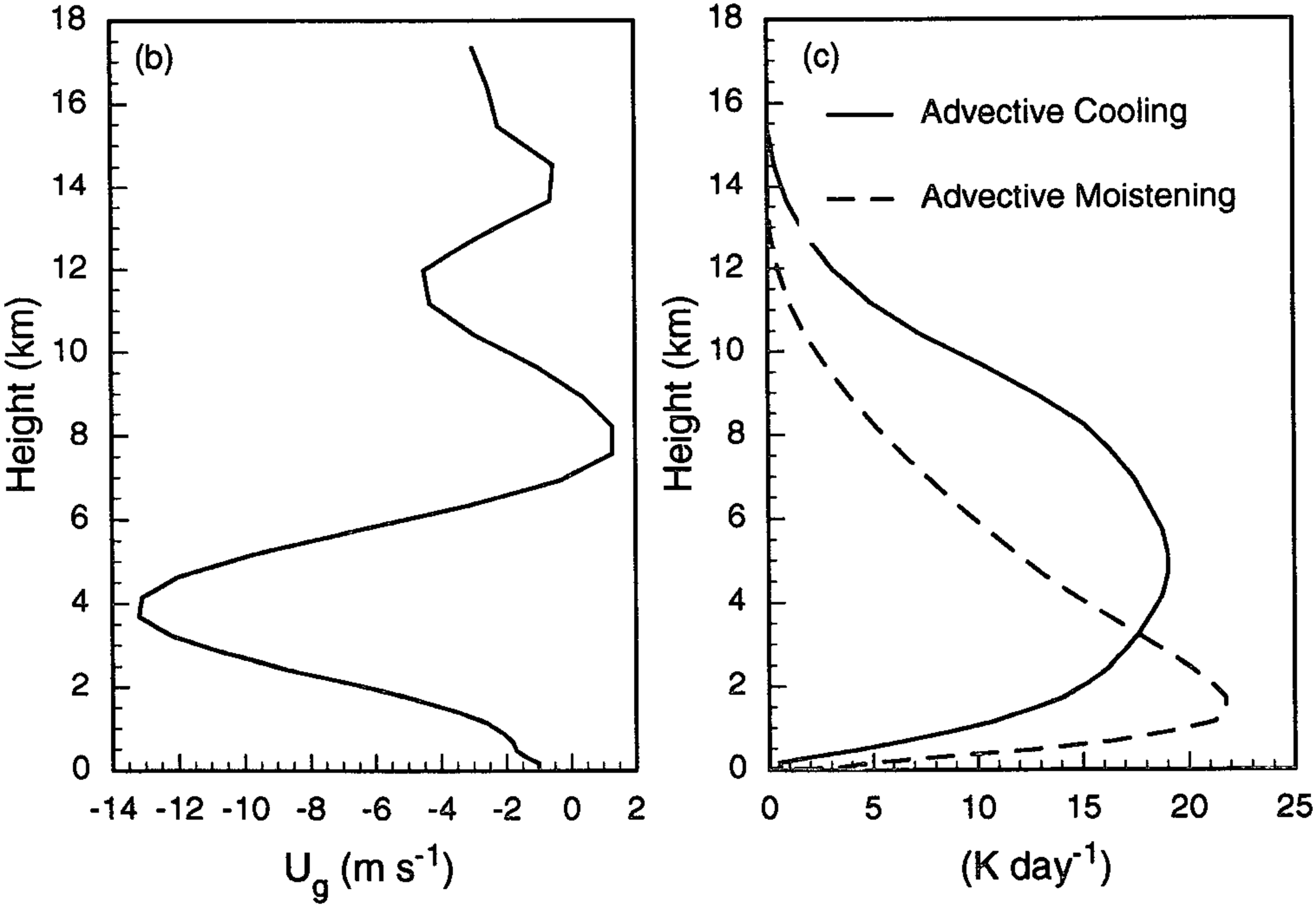
Aspect	CRM	GCM
Eddies	Cumulus clouds	Baroclinic eddies
Eddy time scale	3×10^3 sec	3×10^5 sec
Forcing time scale	3–4 days	365 days
Domain size	400 km	40,000 km
Horizontal grid size	2 km	200 km
Time step	10 sec	10^3 sec

Comparison of Convective Boundary Layer Models

	1-D Turbulence closure	2D CRM/ERM	3D LES
Explicitly represented circulations	None	Mesoscale and large convective eddies	Large turbulent eddies
Parameterized circulations	Clouds and turbulence	3-D turbulence	Small turbulent eddies
Cloud-regime-specific input required	Turbulent length scale Condensation scheme	None	None
Vertical domain	3 km	3 km	3 km
Horizontal domain	(none)	5 km	5×5 km
Grid size	50 m	50×50 m	$50 \times 50 \times 50$ m

II. INTERACTIONS BETWEEN RADIATION AND CONVECTION IN TROPICAL CLOUD CLUSTERS

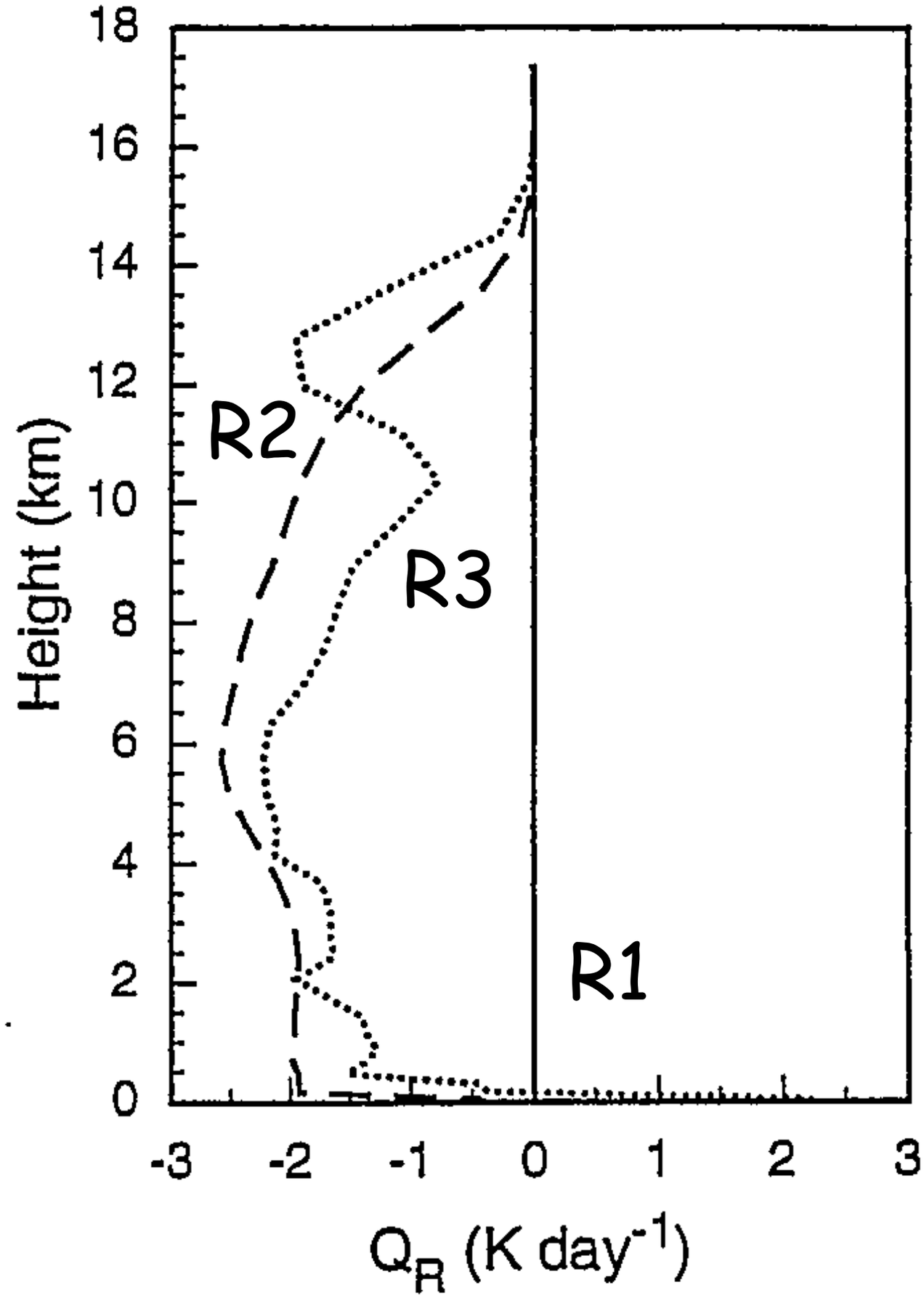

Water Vapor Mixing Ratio (g kg^{-1})
0
2
4
6
8
10
12
14
16
18
(a)
Temperature
Water Vapor
Height (km)
0
2
4
6
8
10
12
14
16
18
180
200
220
240
260
280
300
Temperature (K)


(b)
(c)
Height (km)
18
16
14
12
10
8
6
4
2
0
-14 -12 -10 -8 -6 -4 -2 0 2
U_g (m s^{-1})
Advective Cooling
Advective Moistening
0 5 10 15 20 25
(K day^{-1})

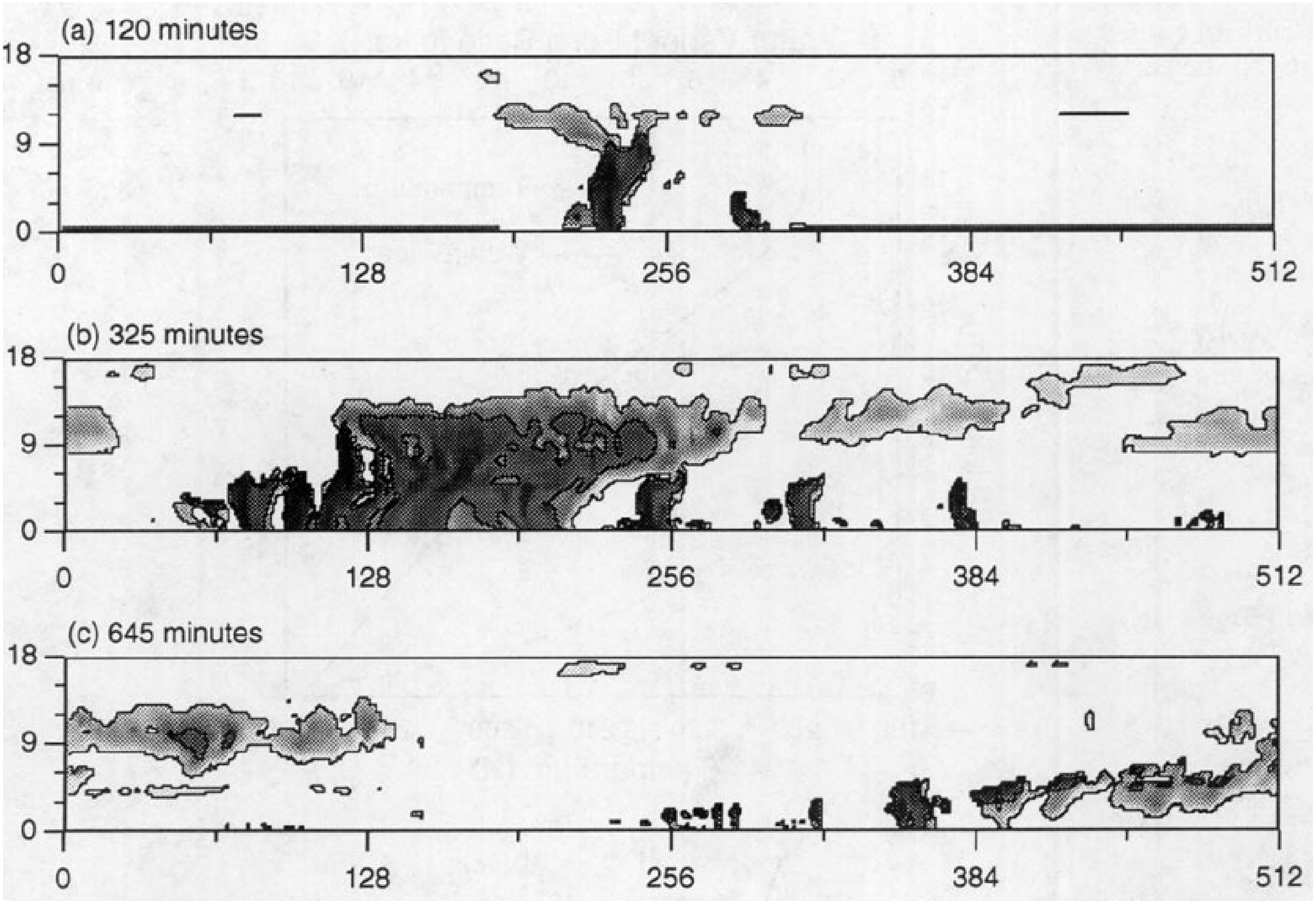
R1: No radiative cooling

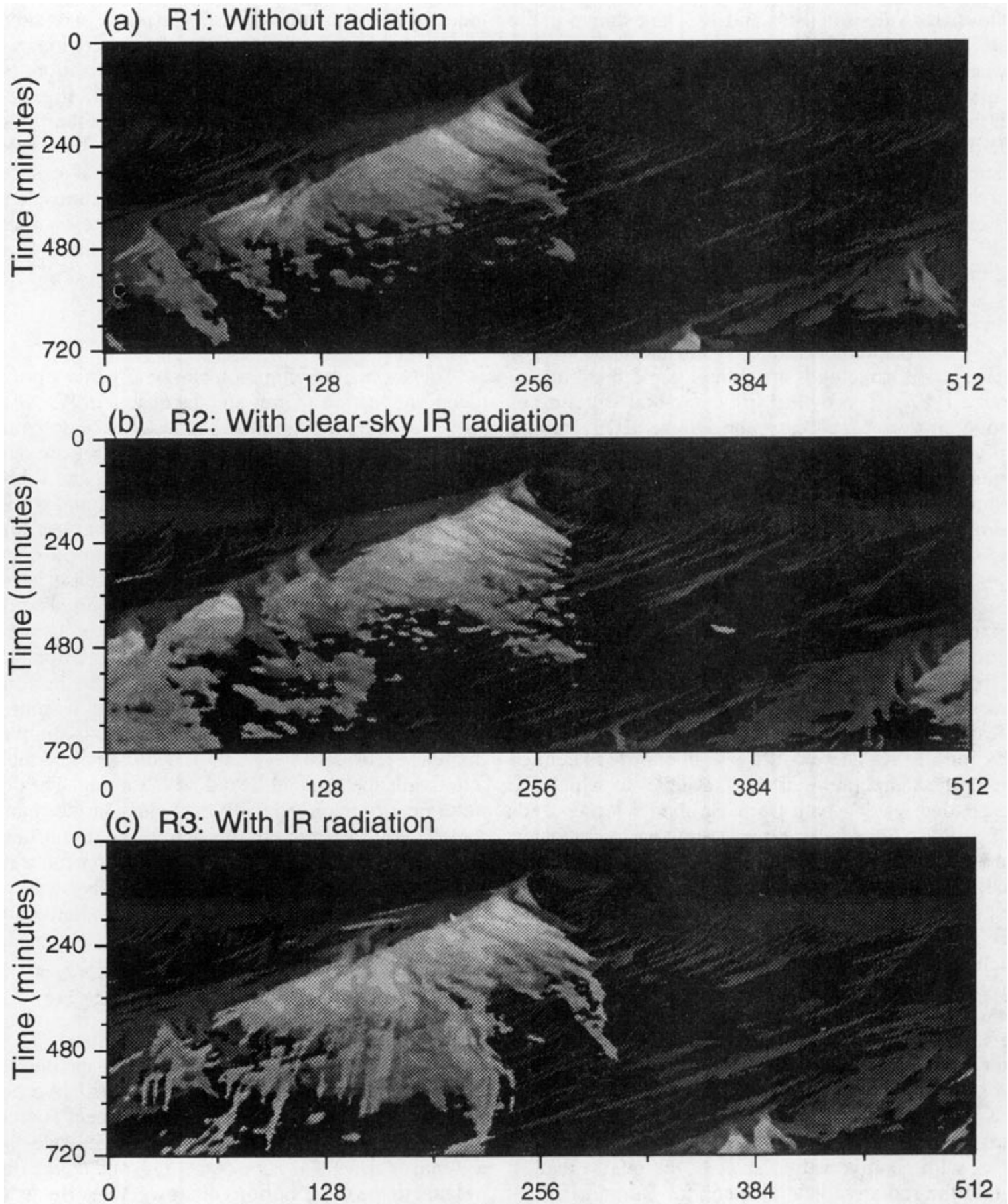
R2: clear-sky radiative cooling

R3: fully interactive radiative cooling



R3: fully interactive radiative cooling




(a) R1: Without radiation
Time (minutes)
0
240
480
720
0
128
256
384
512
(b) R2: With clear-sky IR radiation
Time (minutes)
0
240
480
720
0
128
256
384
512
(c) R3: With IR radiation
Time (minutes)
0
240
480
720
0
128
256
384
512
Distance (km)

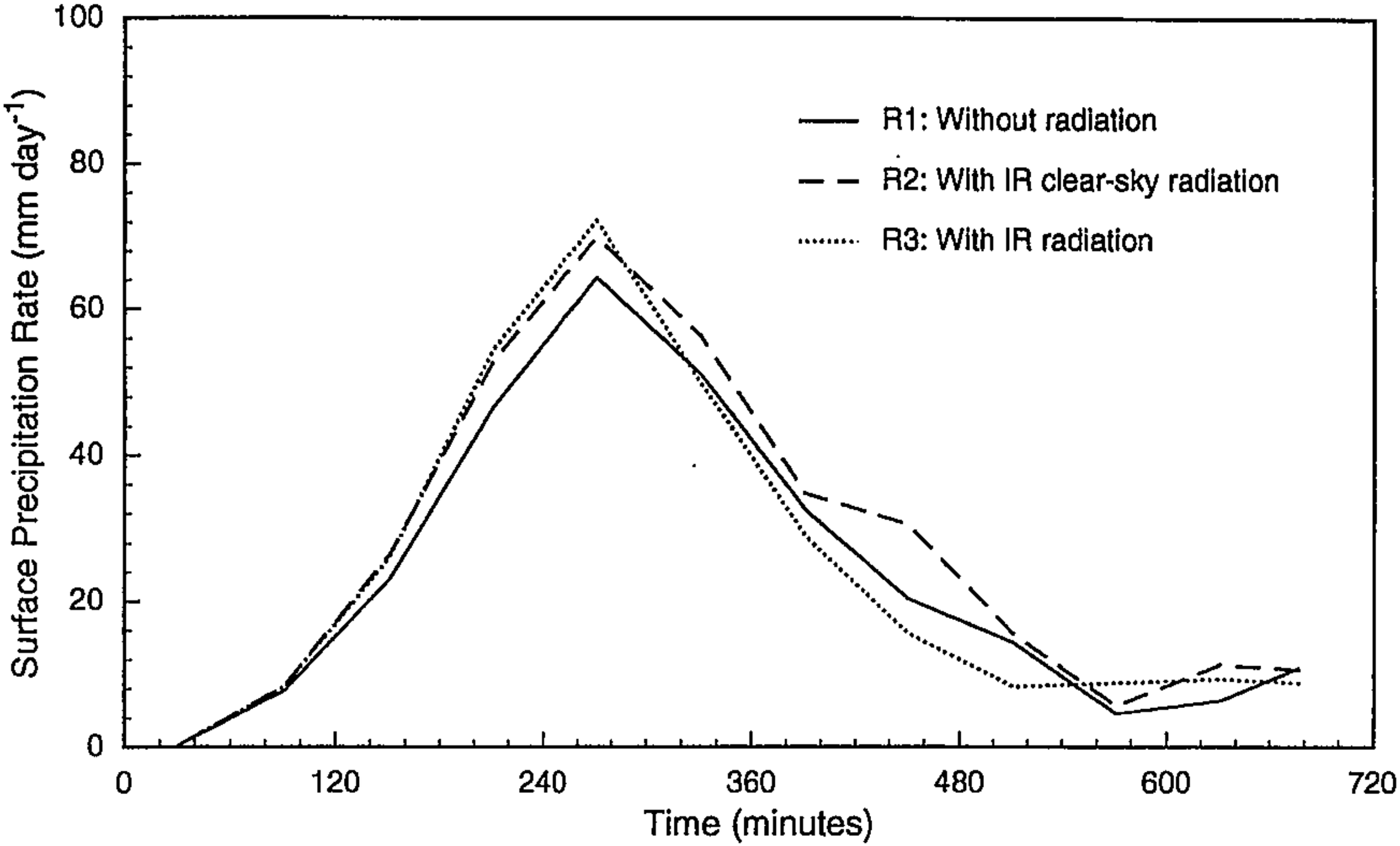
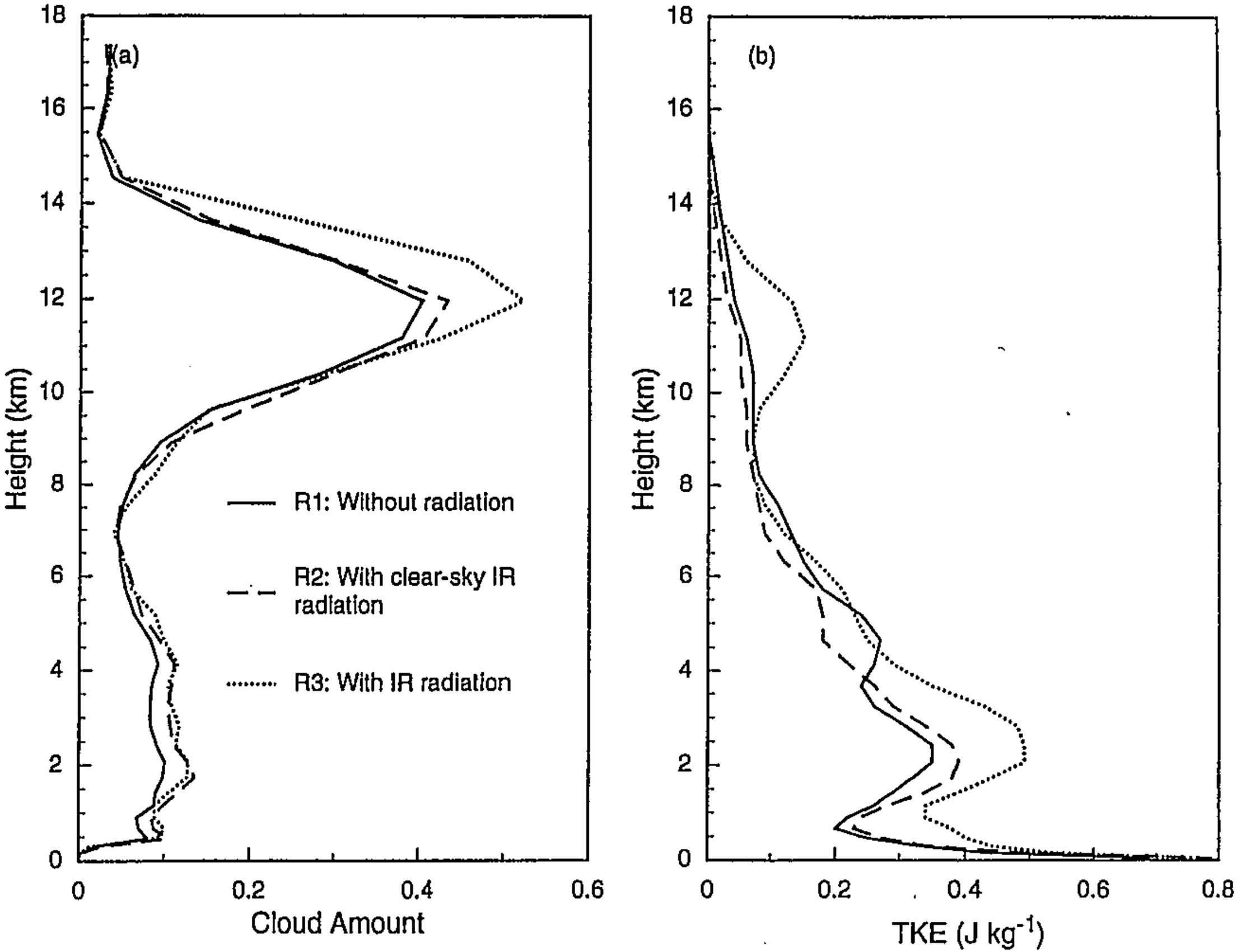
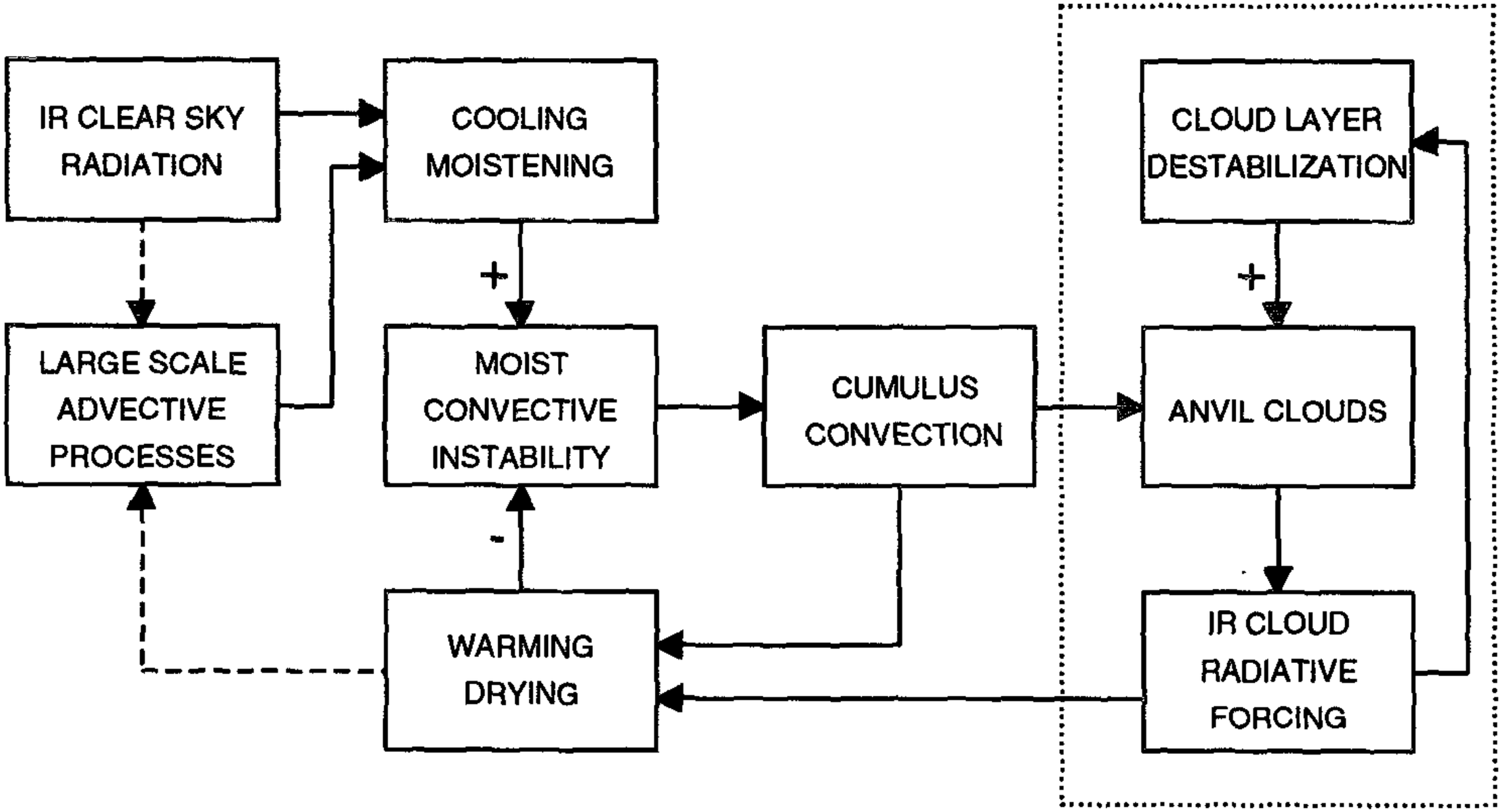


Figure 4 Time series of the surface precipitation rate for the three simulations.


(a)
(b)
Height (km)
Cloud Amount
TKE (J kg^{-1})
R1: Without radiation
R2: With clear-sky IR radiation
R3: With IR radiation
0
2
4
6
8
10
12
14
16
18
0.2
0.4
0.6
0.8


IR CLEAR SKY RADIATION
COOLING MOISTENING
LARGE SCALE ADVECTIVE PROCESSES
MOIST CONVECTIVE INSTABILITY
CUMULUS CONVECTION
CLOUD LAYER DESTABILIZATION
ANVIL CLOUDS
IR CLOUD RADIATIVE FORCING
WARMING DRYING
+
+
-

III. THIN MIDLEVEL STRATIFORM (ALTOCUMULUS) CLOUDS

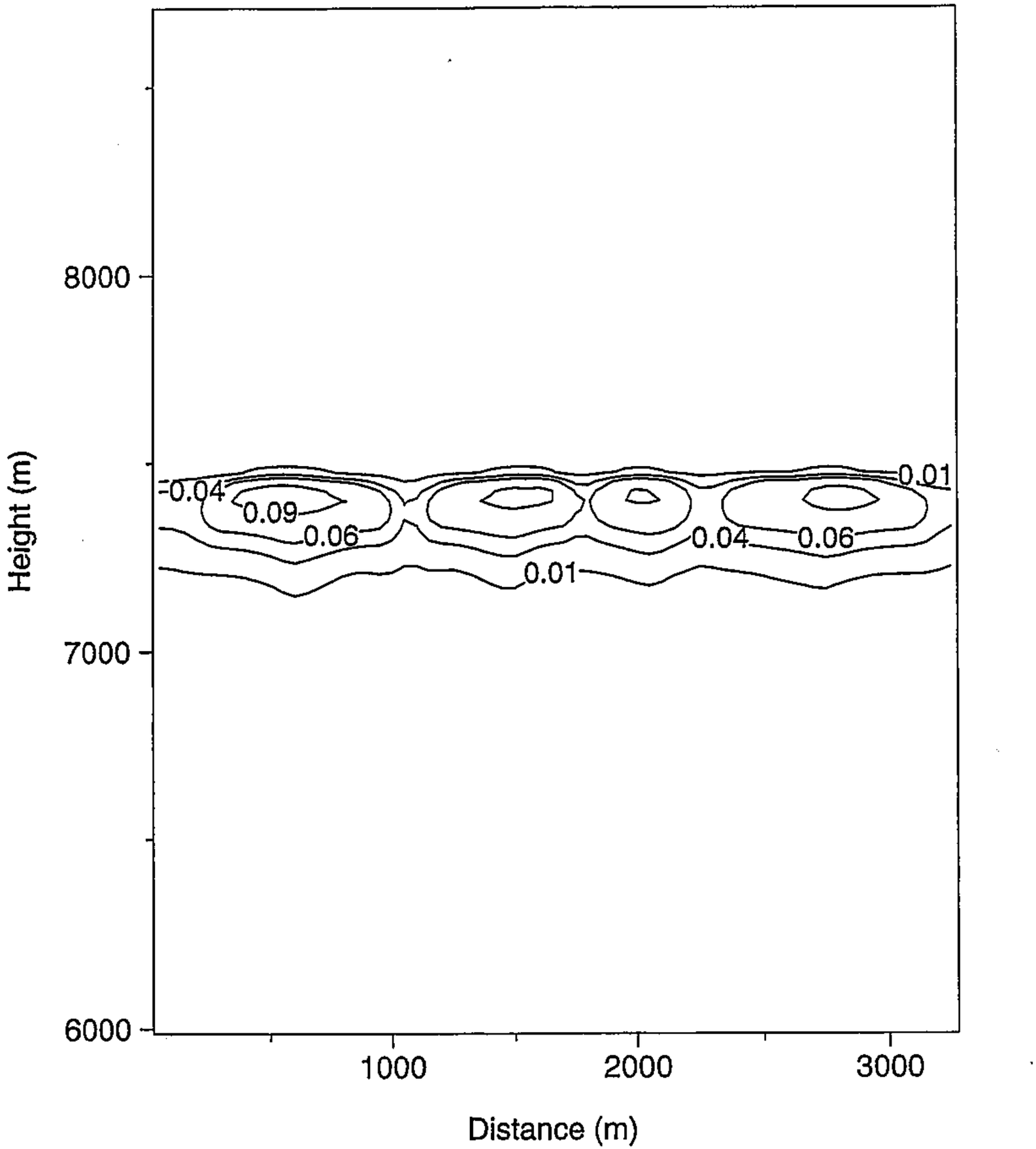


Figure 7 The liquid water mixing ratio field for the altocumulus cloud layer simulation at 2 hr.

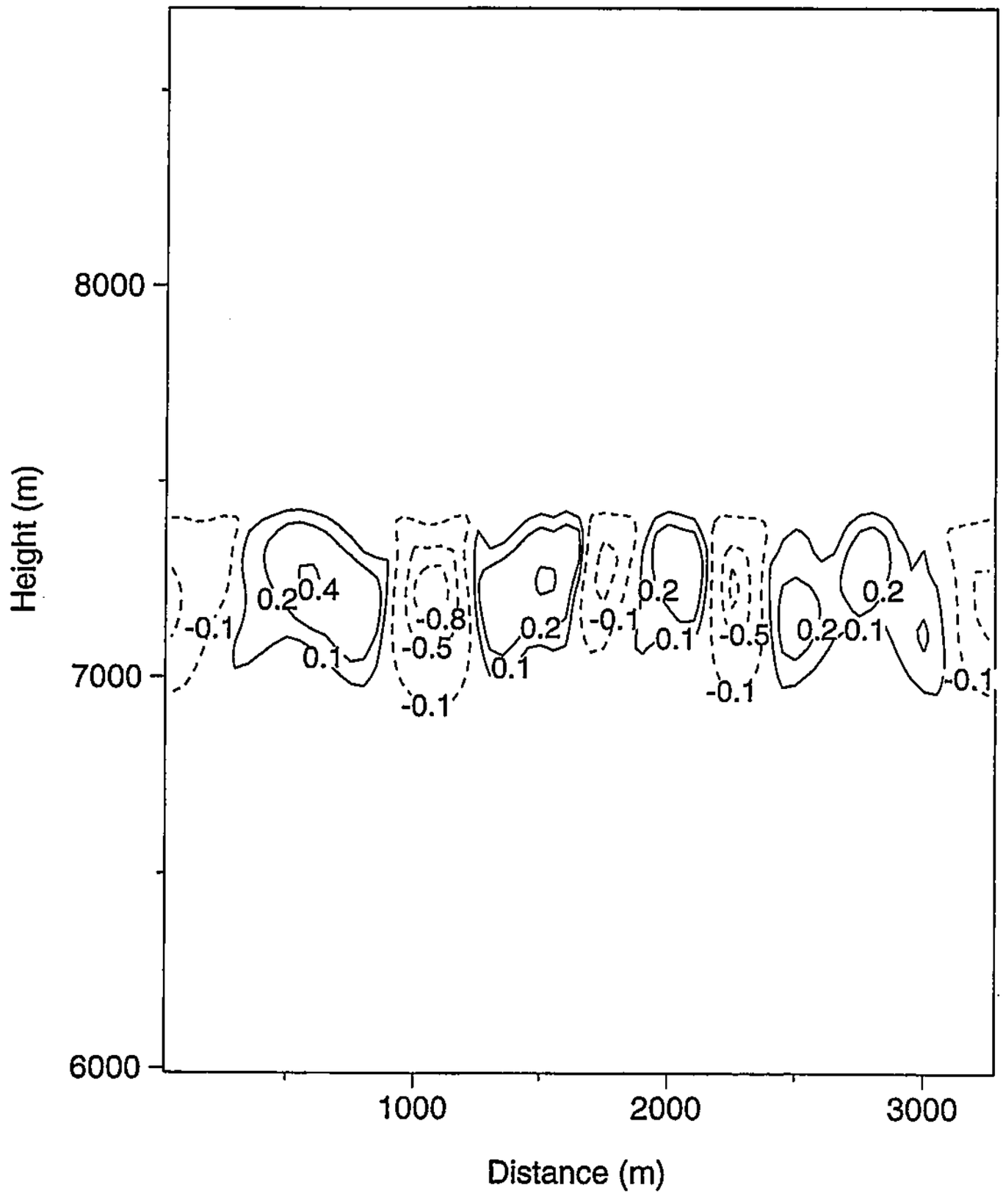
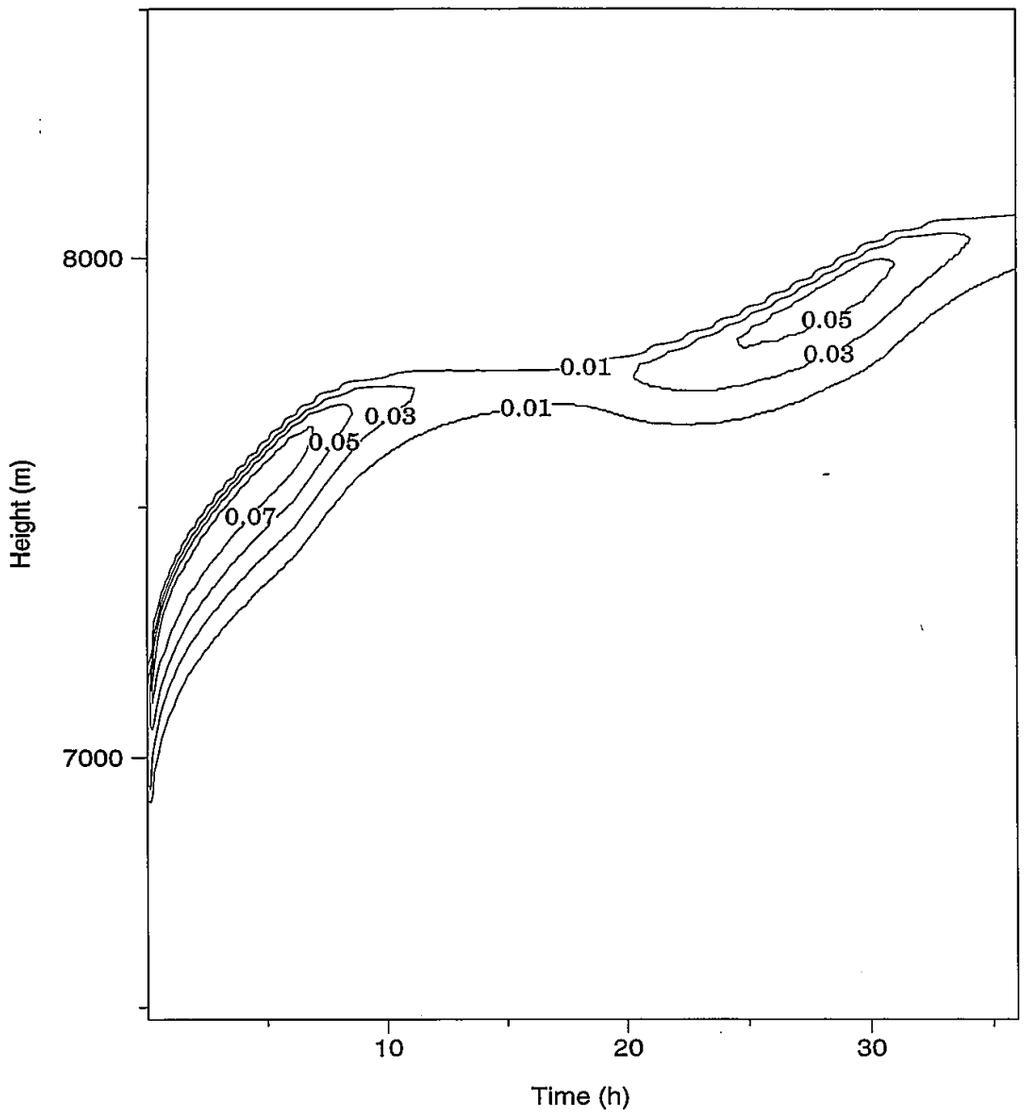
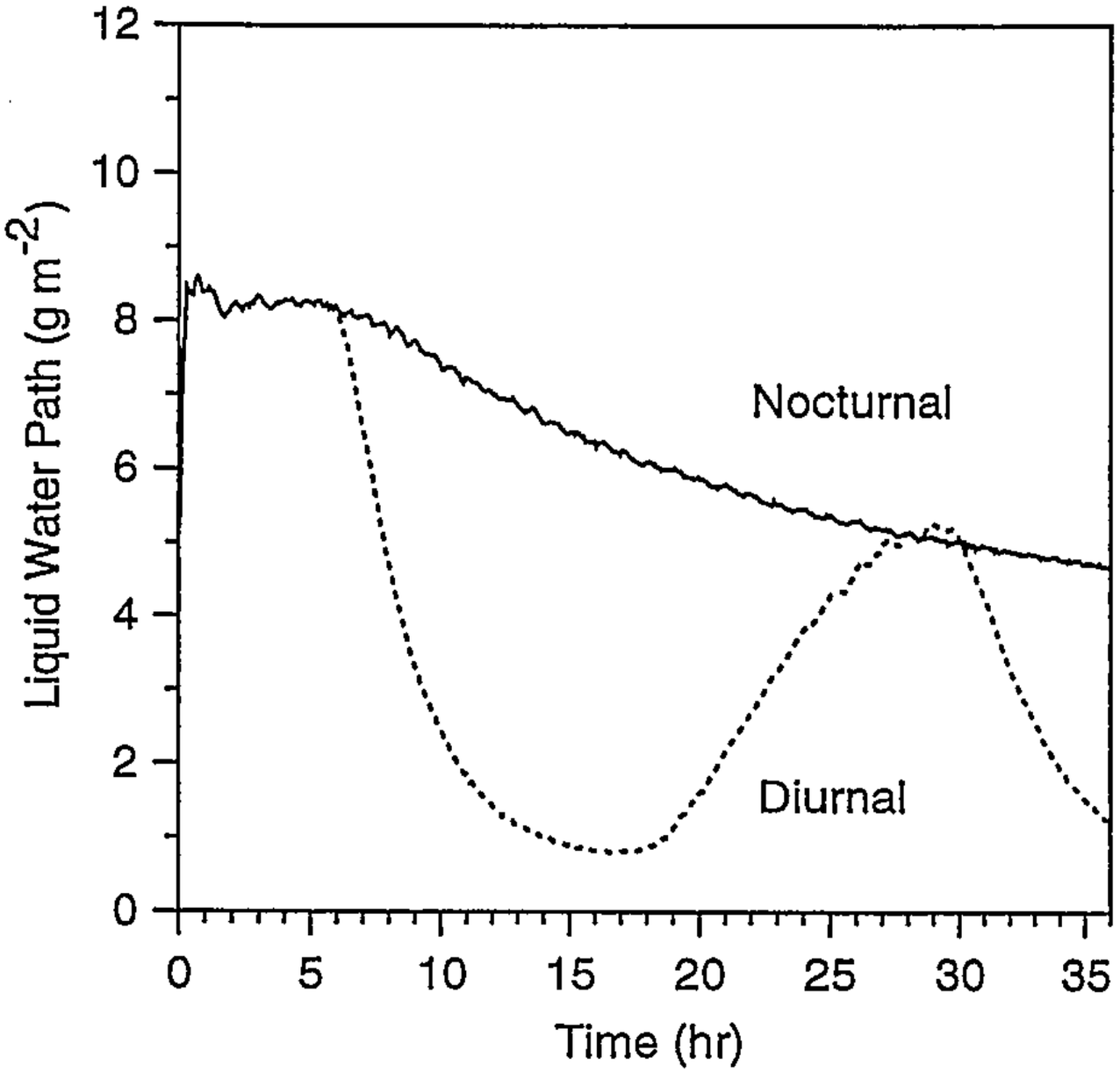


Figure 8 The vertical velocity field for the altocumulus cloud layer simulation at 2 hr.


8000
7000
Height (m)
0.01
0.03
0.05
0.07
0.01
0.03
0.05
10
20
30
Time (h)


12
10
8
6
4
2
0
Liquid Water Path (g m-2)
Nocturnal
Diurnal
0
5
10
15
20
25
30
35
Time (hr)

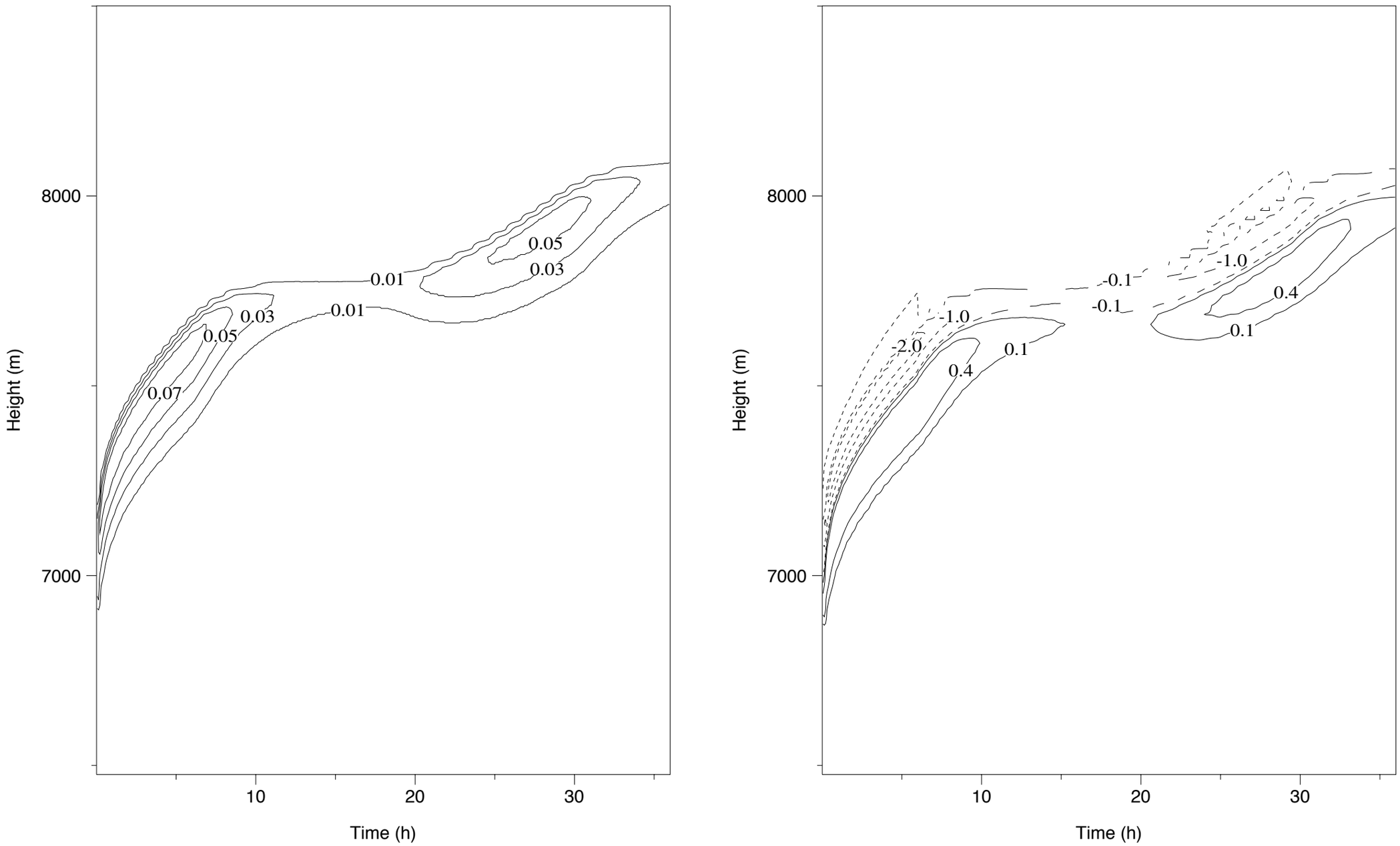
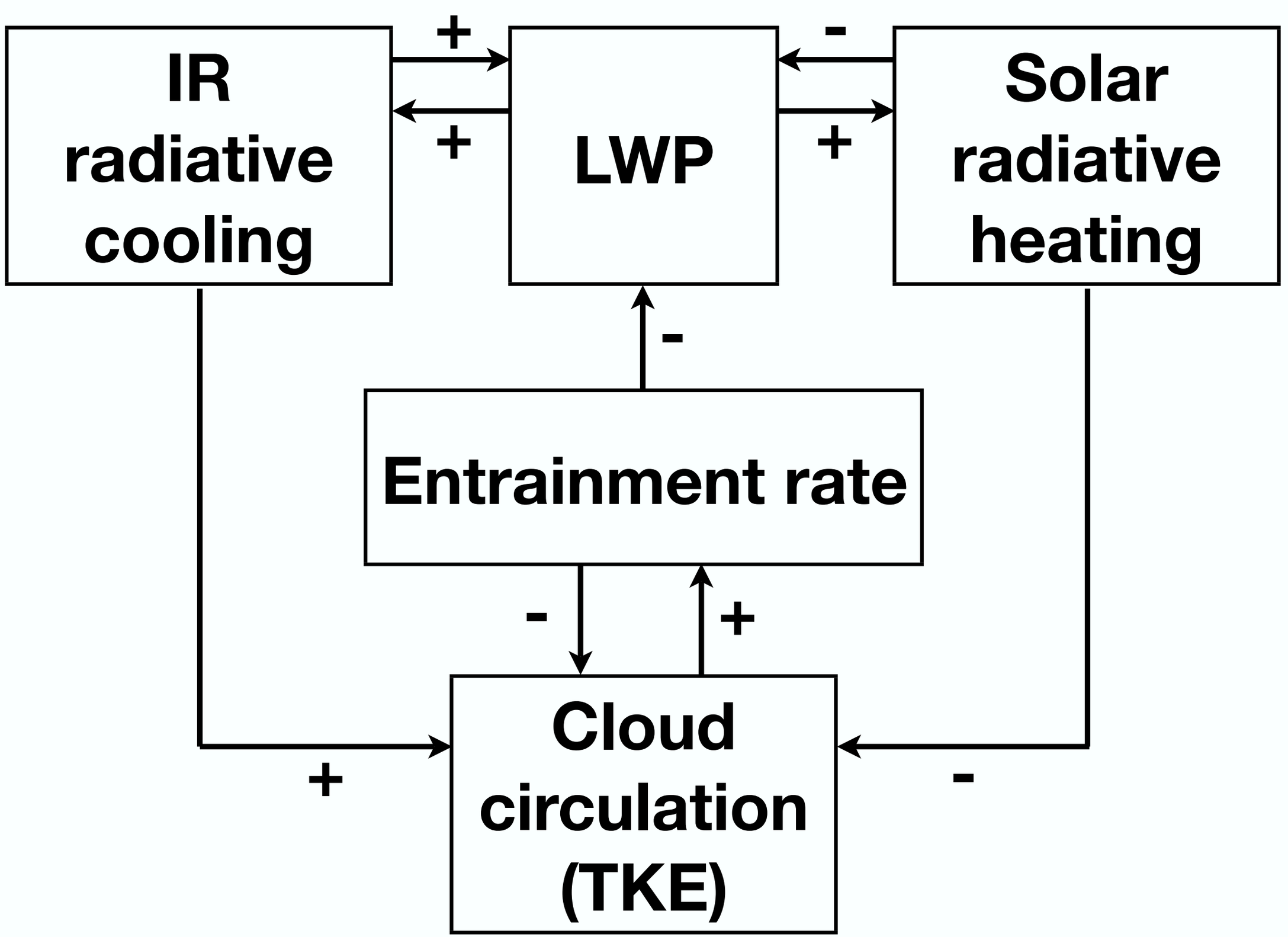
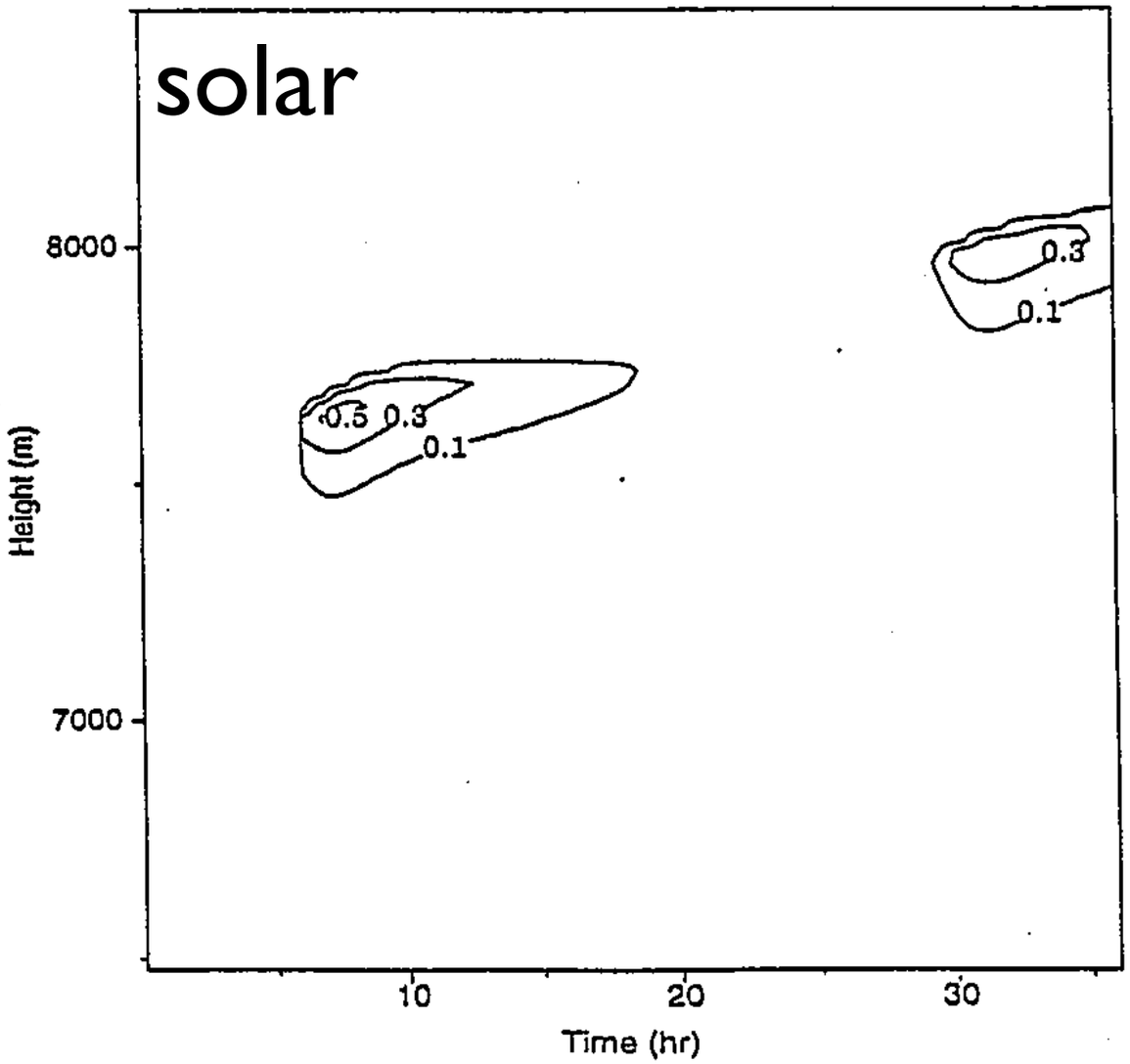
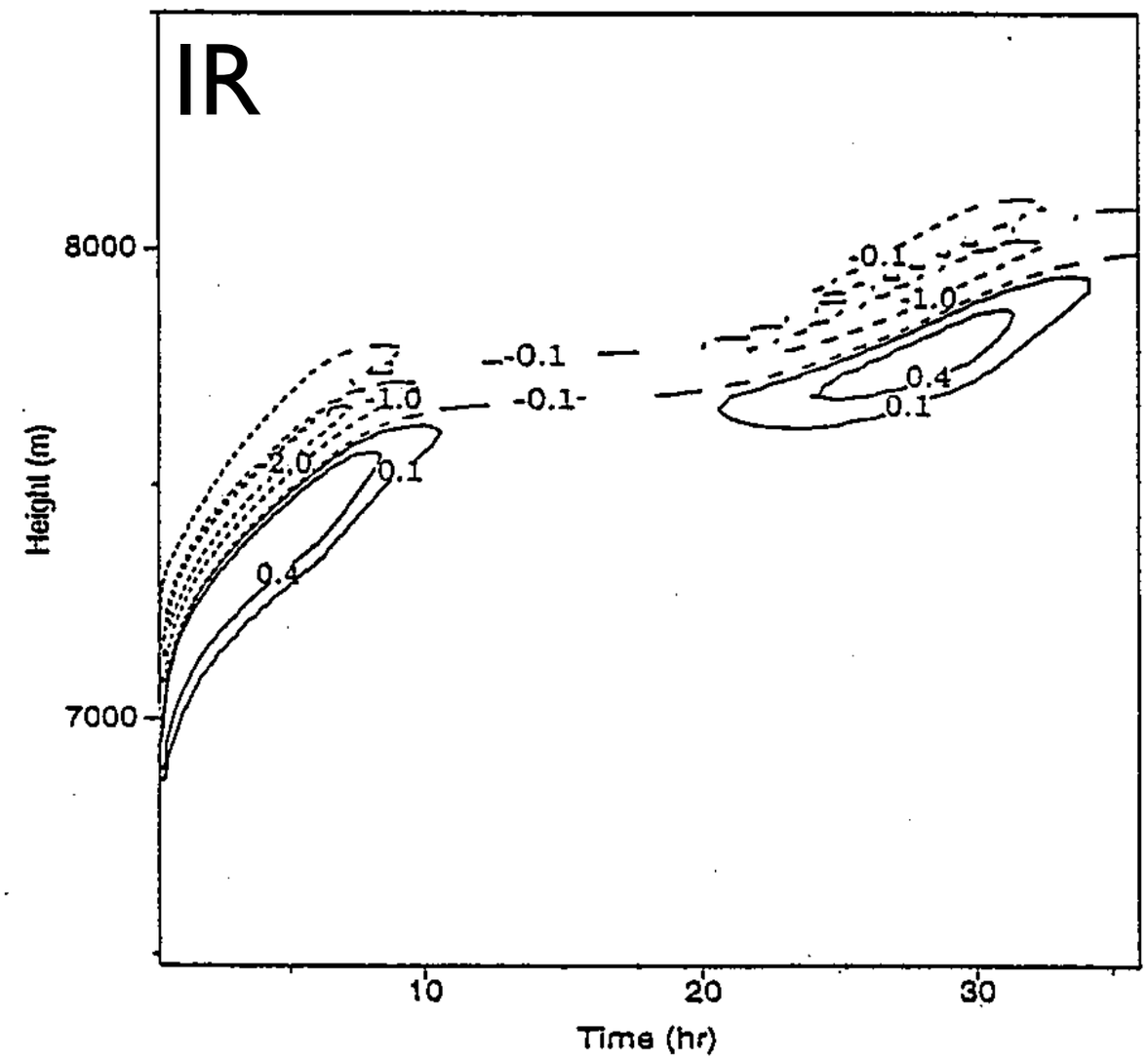


Figure 1: Liquid water mixing ratio (left, g/kg) and radiative heating rate (right, K/h) for a diurnal cycle of altocumulus.


IR radiative cooling
+
+
LWP
-
+
Solar radiative heating
-
Entrainment rate
-
+
+
Cloud circulation (TKE)
-


solar
8000
7000
Height (m)
0.3
0.1
0.5
0.3
0.1
10
20
30
Time (hr)


IR
8000
7000
Height (m)
-0.1
-0.1
-1.0
-2.0
0.1
0.4
-0.1
1.0
0.4
0.1
10
20
30
Time (hr)

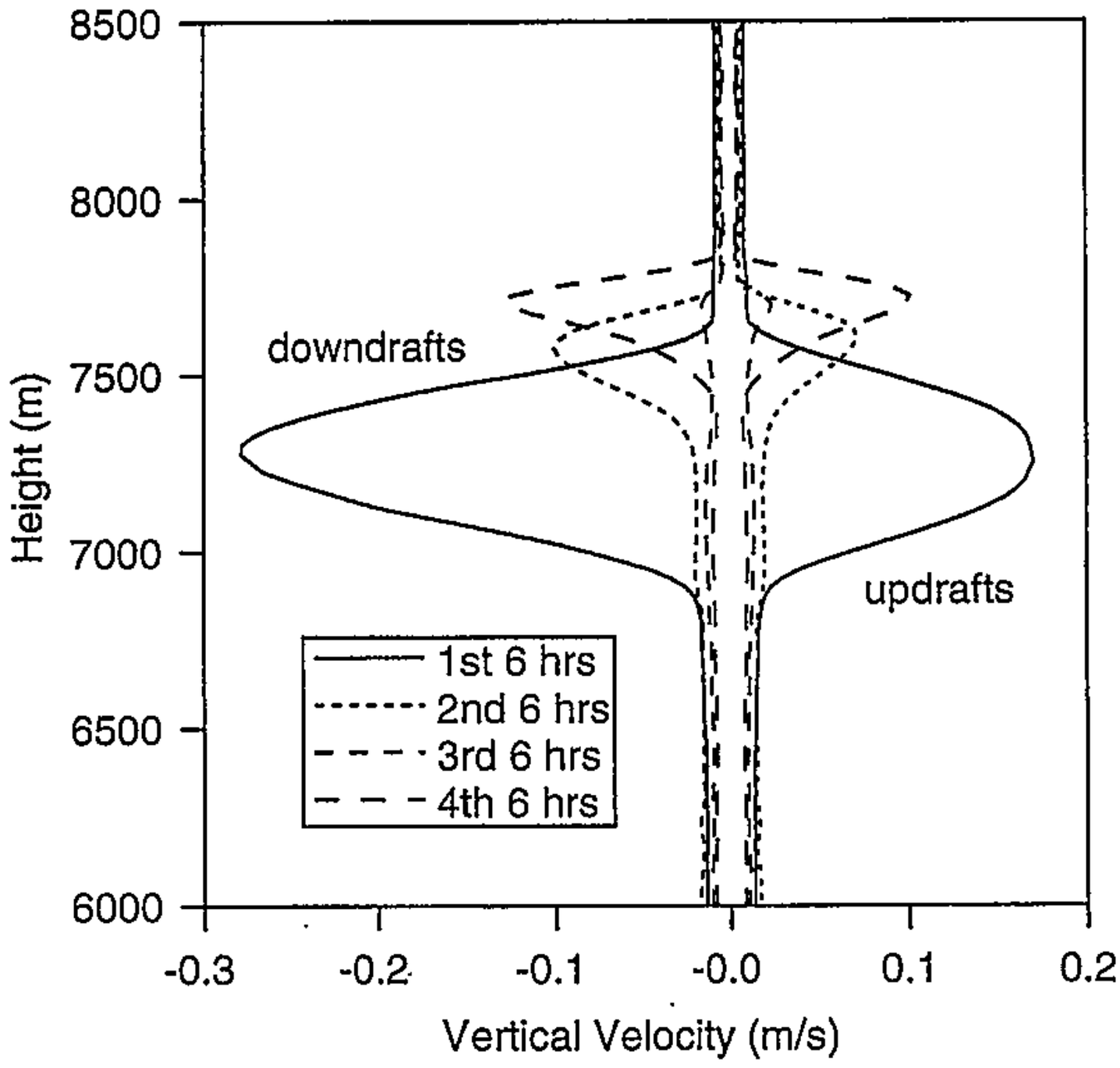


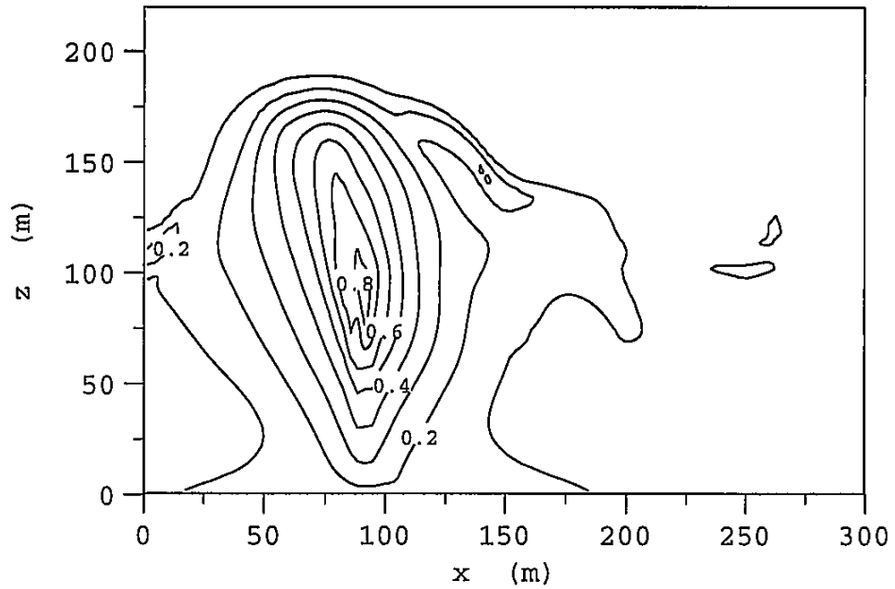
Figure 11 The profiles of the 6-hr-averaged updraft and downdraft vertical velocities for the altocumulus cloud layer simulation.

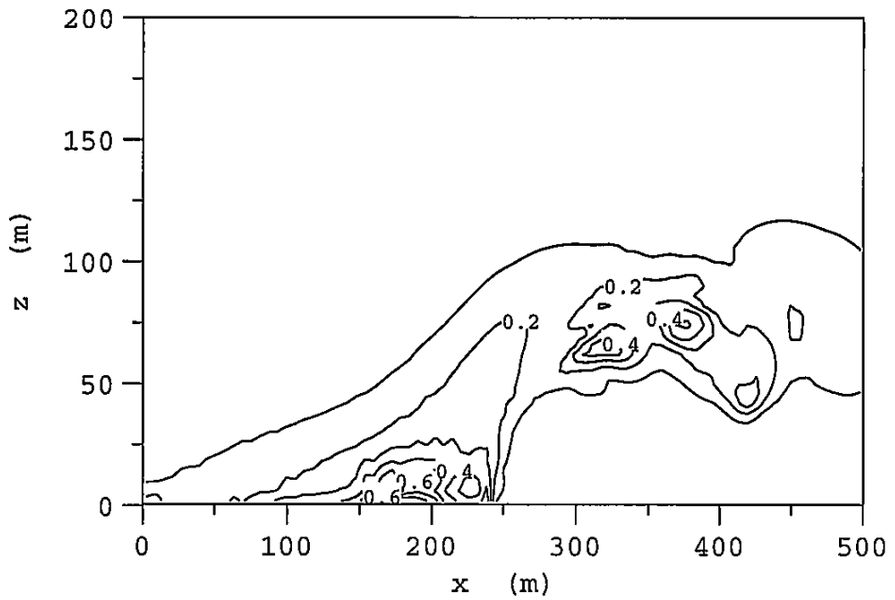
VI. PLUMES GENERATED BY ARCTIC LEADS

Lead and associated plume. Photo taken on BASE flight 16, October 12, 1994, over the Beaufort Sea.

Simulations of Arctic Leads

Case	Domain size (m)	Lead width (m)	Geostrophic wind angle (deg)	$(F_s)_{lead}$ (W m^{-2})	$(LF_q)_{lead}$ (W m^{-2})	Plume height (m)
A	768	200	0	244	73	190
B	768	200	15	246	75	115
C	2304	200	90	243	72	65
D	768	400	0	264	80	270





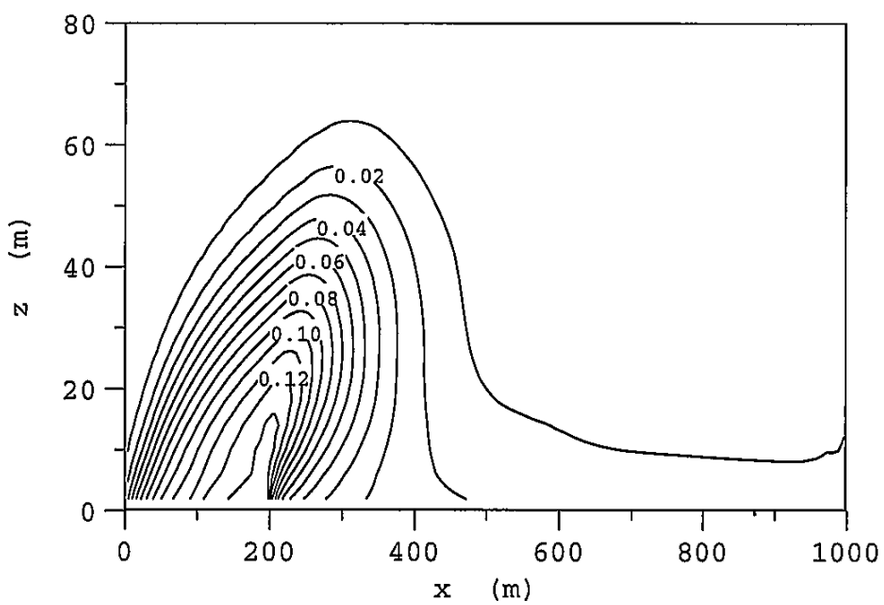


Figure 16 Mean total turbulent kinetic energy ($m^2\ s^{-2}$) for cases A (top), B (middle), and C (bottom).