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# "Convection: New Topics & Open Questions"

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***Please note: These are preliminary notes intended for internal distribution only.***

# Short lecture Notes for the lecture "Convection: New Topics and Open questions"

JF Geleyn

Since most of the basic material necessary for understanding what follows is included in the two previous lecture Notes

"Parameterization of Convection"

"Problems of convective Parametrization"

and since this last lecture of the serial is mainly prospective (i.e. a lot of text on transparents and little of equations or diagrams) this first page will only refer to the organisation of the lecture.

- 3 level of transparencies
  - basic concepts ("shopping lists" and "philosophical ~~essay~~ debate")
  - detailed problematic
  - illustrated examples (not always)
- organisation by increasing order of complexity
  - single problems
  - correlation between them
  - overall view of all problems

# CONVECTION : NEW TOPICS AND OPEN QUESTIONS

I) A LIST OF SUCH TOPICS AND ASSOCIATED QUESTIONS

+ some ideas about research directions

II) ARE THE PREVIOUS TOPICS AND QUESTIONS INDEPENDENT ?

+ some Further ideas ...

III) CAN THERE BE SOME COMMUN GUIDELINES FOR THE WHOLE PROBLEM!

FIRST "SHOPING LIST" (still arbitrarily limited)

## I) TIME- AND SPACE SCALES IN NATURE VS. THOSE OF PARAMETERIZATION SCHEMES.

Continuous spectrum vs. necessity of
- a cut-off space scale
- an imposed adaptation time

} ?

Duality of resolved/unresolved moist processes.
is it unavoidable!

## II) DOWNDRAFTS

Origin : cloud water?
rain water?
both?

Maintenance and dissipation mechanisms?
comparison with updrafts

Behaviour near the surface?

## III] SHALLOW CONVECTION

Can it be parametrized together with deep convection or not?

## IV] SLANTWISE "CONVECTION"

Does it exists?

What is the driving mechanism?

Is it trying to adjust: the mass Field?
the wind Field?
both simultaneously?

## V] "CONVECTIVE" MOMENTUM BUDGET

The non-hydrostatic problem: what about sub-grid scale energy conversion?
$u, v$ or $\xi, D$?

What controls the budget:
large scale dynamical constraints?
local Features via cloud geometry?
both?

# I] Time- and space scales in nature vs. those of parameterization schemes

Experimental evidence

- no natural spectrum cut-off

  Hadley cell

  Walker circulation

  Clusters

  Cbs - Frontal circulations

  Cus

  St-Cus

- For individual strong convective events characteristic time ≃ 30 min

Modelling evidence

- the separation between resolved and unresolved processes is not well-handled (especially when initial- or LB-conditions generate imbalances)

- the instantaneous "diagnostic" application of closure assumptions can lead to a strong aliasing (→ grid point storms!)

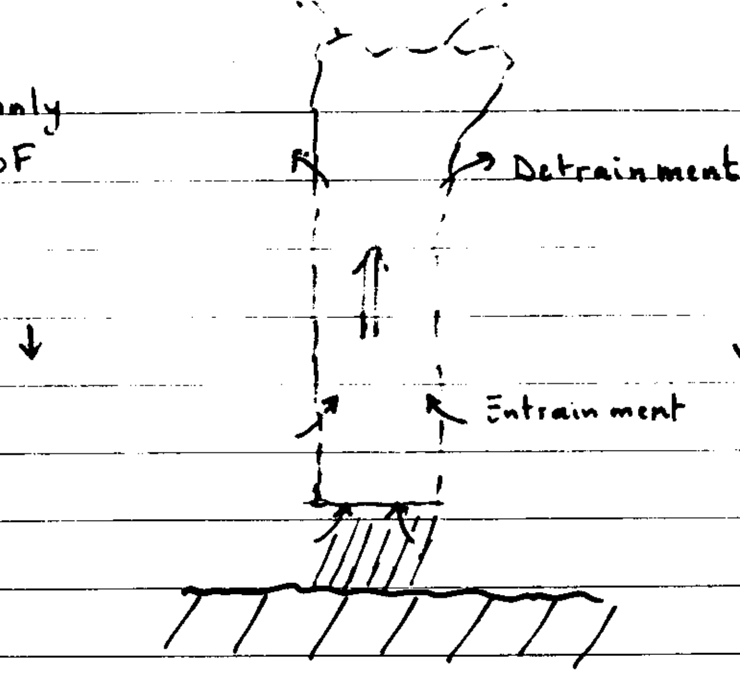
Research areas

- Nothing forbids to merge (technically speaking) the parameterization of resolved and unresolved precipitations.

- Necessary introduction of the time dependency in the parameterization problem:
  * prognostic l.w.c. ?
  * prognostic mass flux ?

- The two above mentioned avenues should help a lot reducing the space scale unwanted dependency; but still a lot to be done here.

Updrafts only
For the sake of simplicity




"Compensating" subsidence

$M_c$ = vertical velocity of compensating subsid.

## Hypothesis

- steady cloud
- neglegible area of updraft
  $\tilde{\Psi} = \bar{\Psi}$ — $\sim$ "environment"; $-$ "large-scale"
- all detrained liquid water evaporates
- no subcloud evaporation of rainfall

## Equations

$$\frac{\partial \bar{\Psi}}{\partial t} = -\frac{\partial}{\partial p}\left[M_c(\bar{\Psi} - \Psi_c)\right]$$

$$\frac{\partial \bar{q}}{\partial t} = -\frac{\partial}{\partial p}\left[M_c(\bar{q} - (q_c + l_c))\right] - g\frac{\partial P_r}{\partial p}$$

$$\frac{\partial M_c}{\partial p} = D - E$$

$$M_c \frac{\partial \Psi_c}{\partial p} = E(\Psi_c - \bar{\Psi})$$

Choice of $q_c, l_c = f(\Psi_c, p, \phi)$ Fixes $P_r$

$$M_c \frac{\partial (q_c + l_c)}{\partial p} = E((q_c + l_c) - \bar{q}) + g\frac{\partial P_r}{\partial p}$$

$\Psi$ = any thermodynamical moist conserved variable ($h$, for example)

$$\frac{\partial}{\partial t}\left[(1-a)\tilde{\psi}\right] = -\frac{\partial}{\partial p}\left[(M_c + a\bar{\omega})\tilde{\psi}\right] + D\,\psi_c - E\,\tilde{\psi} + \frac{\partial}{\partial p}\left(a\bar{\omega}\,\psi_c\right)$$

$$\frac{\partial}{\partial t}\left[(1-a)\tilde{q}\right] = \dots\dots$$

$$\frac{\partial M_c}{\partial p} = D - E + \frac{\partial a}{\partial t}$$

$a =$ "ascent" cloudiness

etc....

2 hypothesis

* $\frac{\partial \psi_c}{\partial t} = \frac{\partial q_c}{\partial t} = \frac{\partial l_c}{\partial t} = 0$

stationarity of the cloud's characteristics
(<u>not</u> its size)

$\frac{\partial a}{\partial t} \neq 0$ allowed

* $\tilde{\omega} = 0$ (not as an absolute statement but as a mean to simplify the equations)

$\Downarrow$

$\left( + \frac{\partial P_r}{\partial p}\text{"resolved"} \right)$

$$\frac{\quad}{1-a} + \frac{\partial a}{\partial t}$$

$$\frac{\quad}{1-a}$$

$$\frac{\quad}{1-a}$$

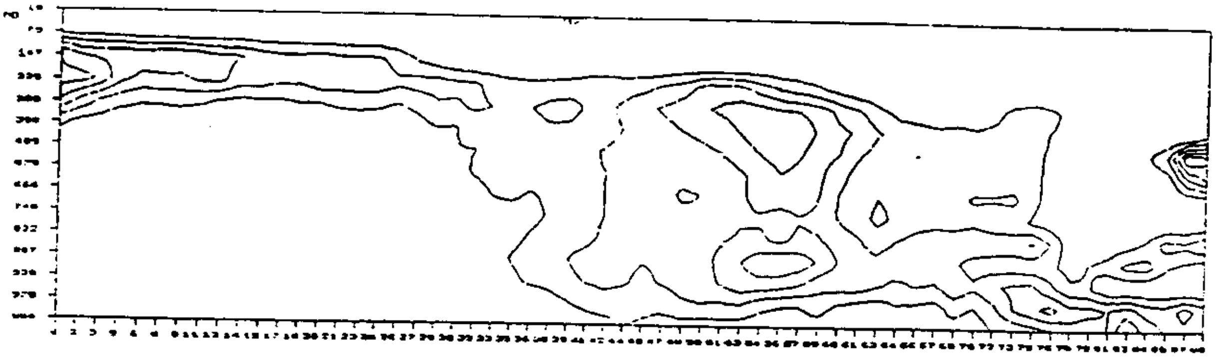
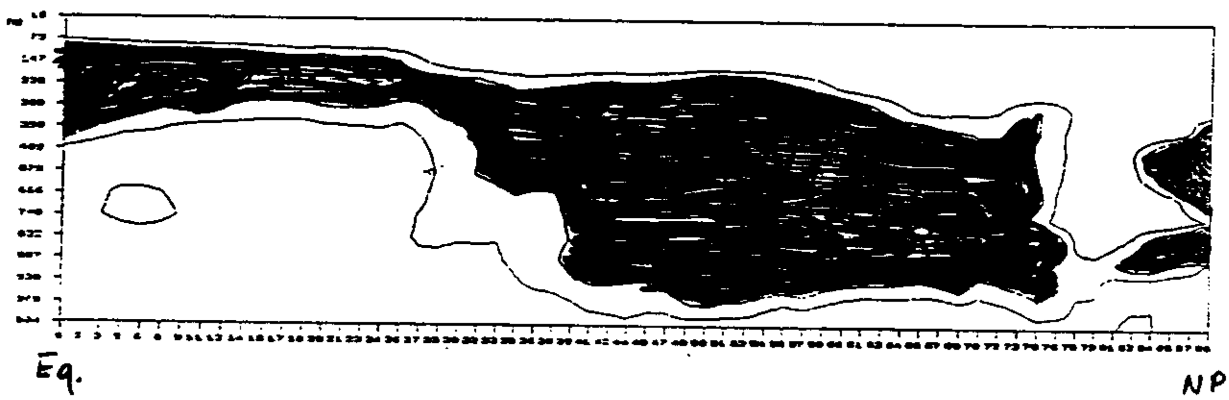


FIGURE 1 : Moyenne zonale et temporelle d'occurence de pluies stratiformes .

RAYONNEMENT




SCHEMA CONVECTIF AVEC NEBULOSITE

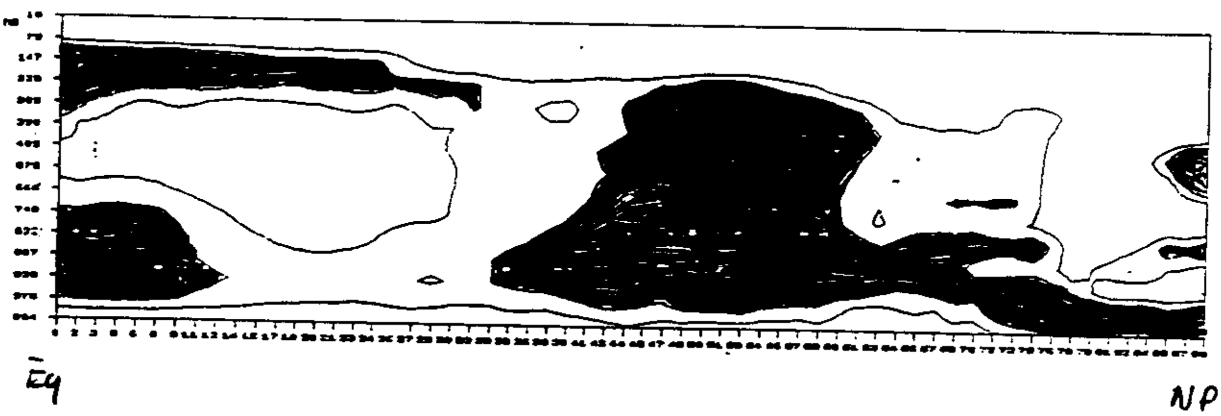


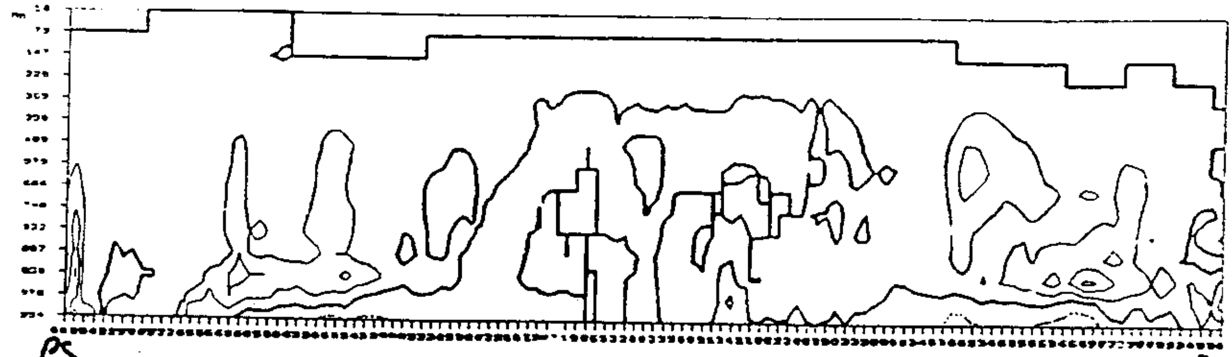

FIGURE 2 : Moyenne zonale et temporelle de la nébulosité partielle .

- Réchauffement de 3°/JOUR
- Refroidissement de 1°/JOUR

MOYENNE ZONALE ET TEMPORELLE DE LA TENDANCE DE TEMPERATURE

REFERENCE

PLGE (EMERAUDE)



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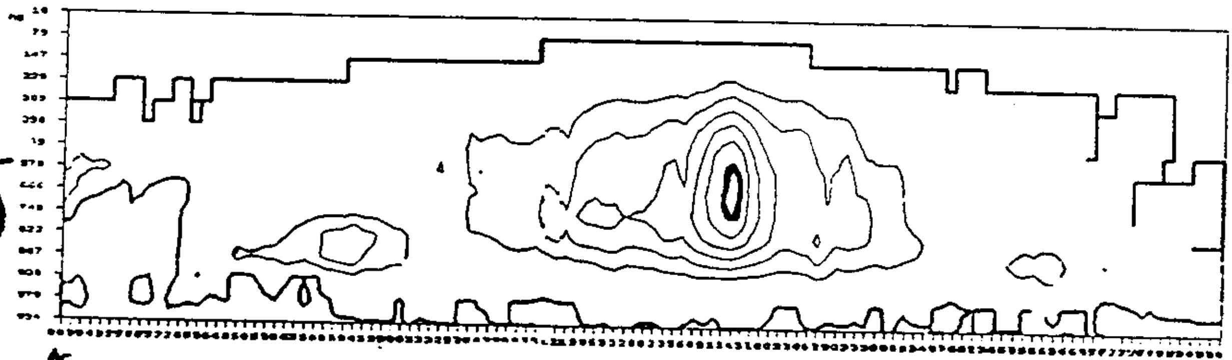

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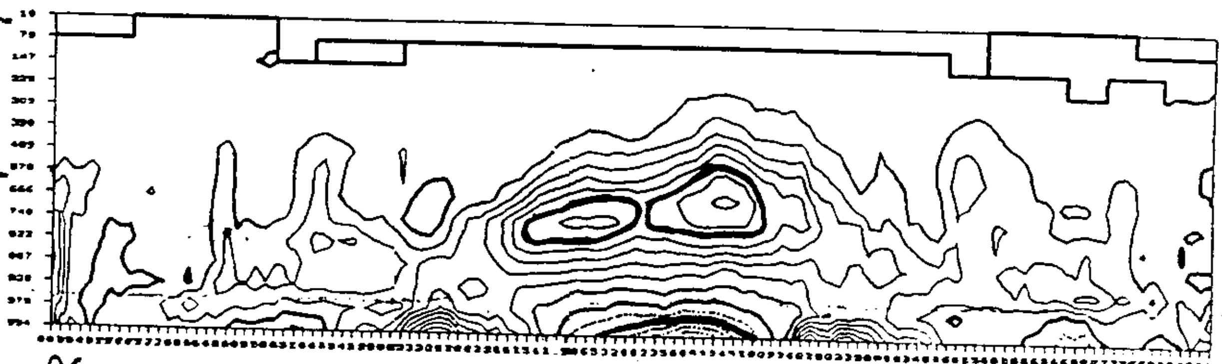
SCHEMA UNIFIE

PLGE+PLCV 579MB



PS PN

# WHAT IS A CLOSURE ASSUMPTION ?

a) What should it do ?

Maintain a quasi-equilibrium balance between large scale Forcing and convective "response" (or the reverse !) => counter-weight idea again

b) How should it do it ?

Through the computation of $M_c$ and $E$.

~~In fact the results are hardly sensitive to the few~~ degrees of freedom we have for choosing a reasonable E. Basically the choice of $M_c$ is the crucial part

Static example (relevant to this case)

~~Bougeault (MWR 1985) Kuo closure for a mass-flux-type~~ scheme

$$M_c = \alpha \sqrt{h_c - \bar{h}}$$

$$\int_{p_t}^{p_b} M_c \frac{dq}{dp} = \int_{p_t}^{p_b} CVGW$$

CVGW humidity convergence

Quasi equilibrium → non zero time scale (observations ~1/2 ...)

Prognostic evolution

$$M_c = -\alpha^* \omega_c^*$$

$\alpha^*$ "updraft" scale (horizontal

$\omega_c^*$ "updraft" vert. velocity

$$\frac{\partial \omega_c^*}{\partial t} = C_F \, \omega_c^{*2} - \beta' \frac{h_c - \bar{h}}{c_p}$$

$$\frac{\partial \alpha^*}{\partial t} \left[ \int_{p_t}^{p_b} (h_c - \bar{h}) \frac{dp}{g} \right] = L \cdot \int_{p_t}^{p_b} \alpha^* \omega_c^* \frac{\partial \bar{q}}{\partial p} \frac{dp}{g} + L \cdot \int_{p_t}^{p_b} CVGU \frac{dp}{g}$$

# A Prognostic Approach to Deep Convection Parameterization for Numerical Weather Prediction

Chen De Hui and Philippe Bougeault
(Centre National de Recherche Météorologique, 31057 Toulouse, France)

August 14, 1990

**Abstract**

In this work, the problem of dependency of the parameterized convective rainfall upon the grid-size in meso-scale numerical weather prediction models is adressed. We argue that this problem is due to the violation of the quasi-equilibrium assumption, which is underlying most existing convection parameterization schemes, and states that the convective activity may be considered in instantaneous equilibrium with the larger-scale forcing. On the contrary, meso-beta and meso-alpha scale models, *i.e.* models with horizontal grid-size ranging from 10 to $100km$, have a capacity to resolve motions with characteristic scales close to the ones of the convective motions. We hypothesize that a possible way to eliminate this problem is to take a prognostic approach to the parameterization of deep convection, whereby the quantities that describe the activity of convection are no longer diagnosed from the instantaneous value of the large-scale forcing, but predicted by time-dependent equations, that integrate the large-scale forcing over time. We propose an implementation of this idea in the frame of one existing scheme, already tested and used for a long time at the French Weather Service. We test the prognostic formulation through one-dimensional experiments with the GATE Phase III data, and shortly report on its implementation in the three-dimensional model. The results demonstrate the feasibility of the proposed approach. Some sensitivity experiments establish the relative merits of several variants of the formulation.

Submitted to Monthly Weather Review

Fig.4

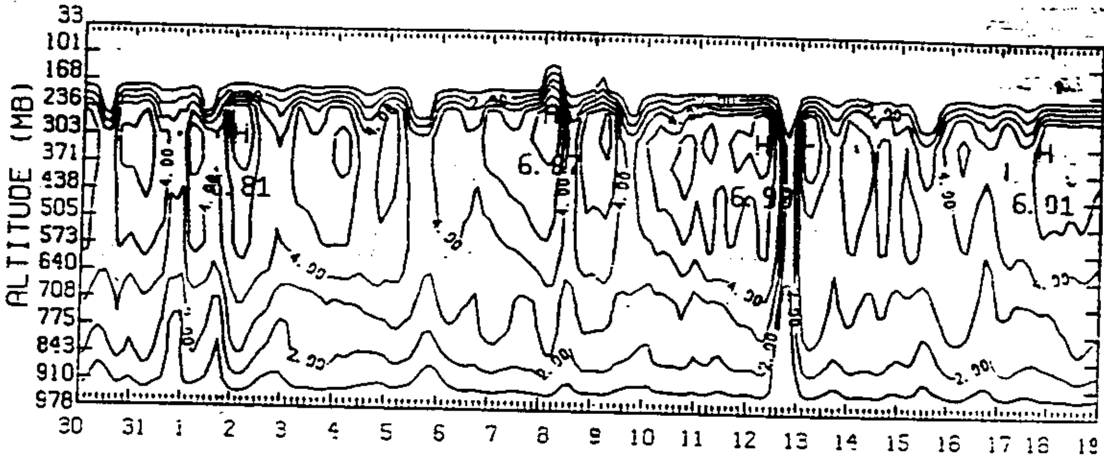

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Fig.5

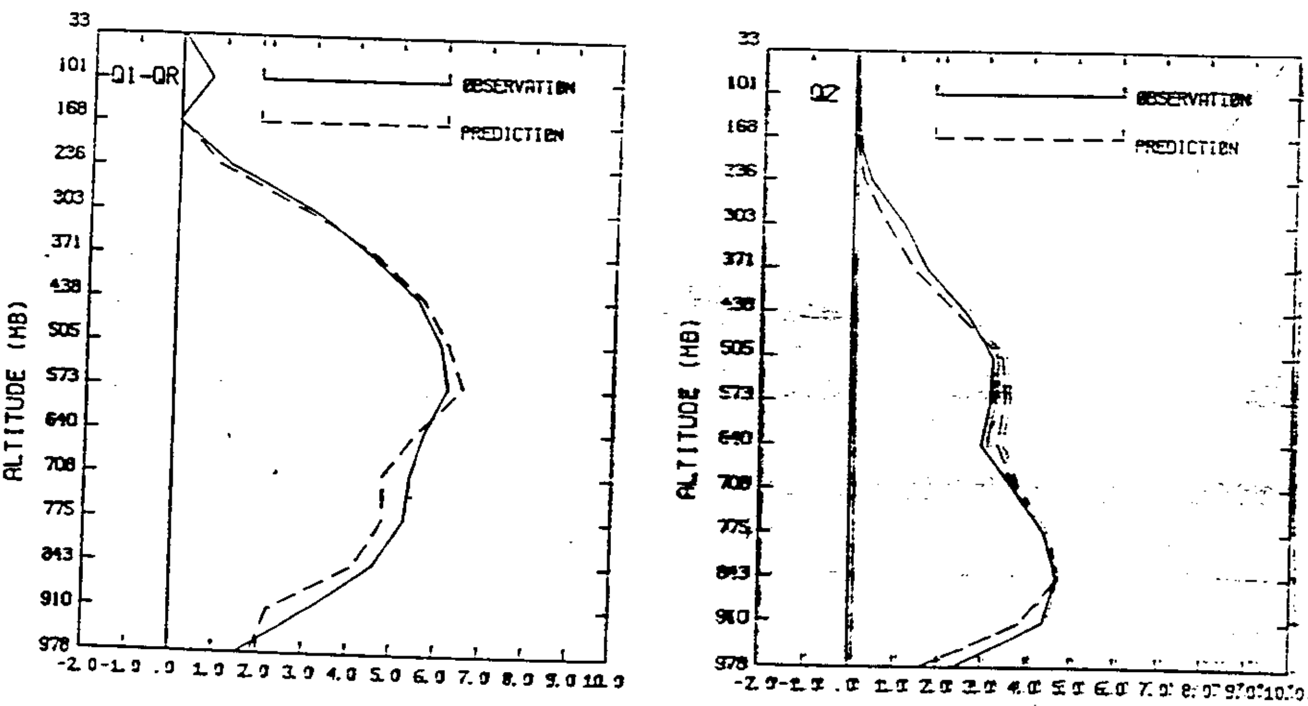
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Fig.8

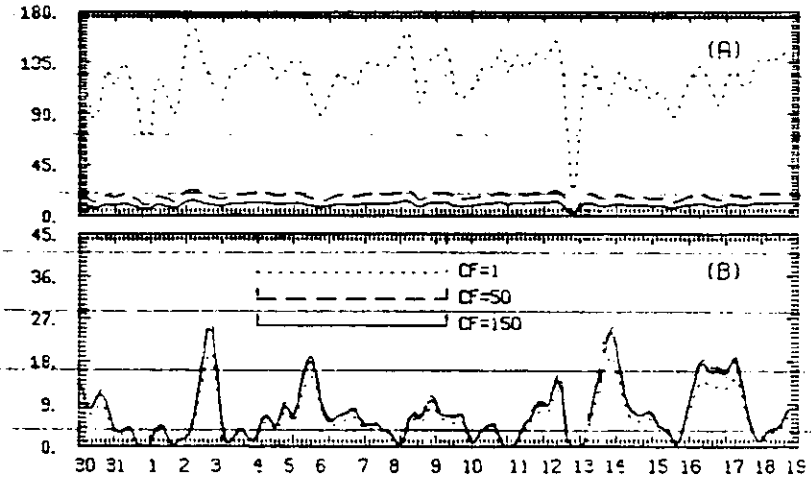
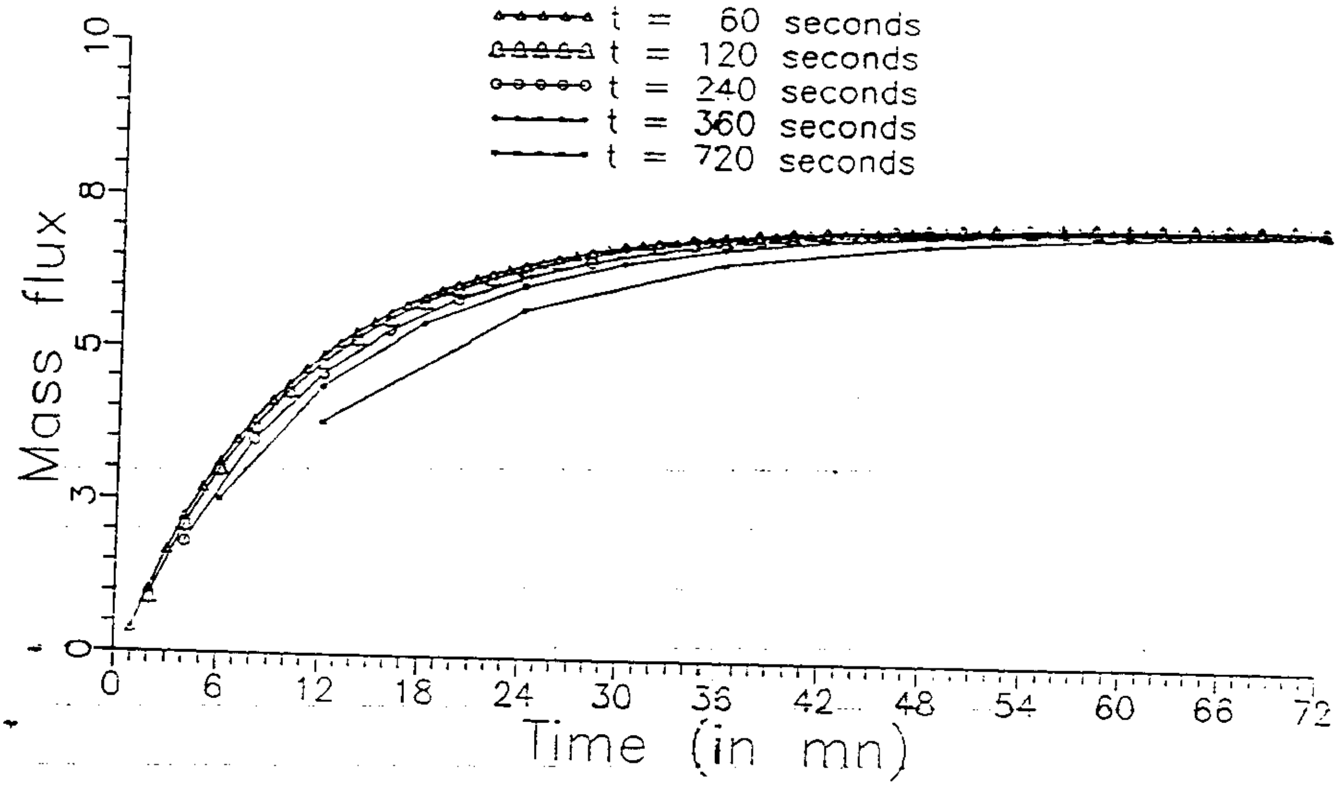


Fig.6


t = 60 seconds
t = 120 seconds
t = 240 seconds
t = 360 seconds
t = 720 seconds
Mass flux
Time (in mn)
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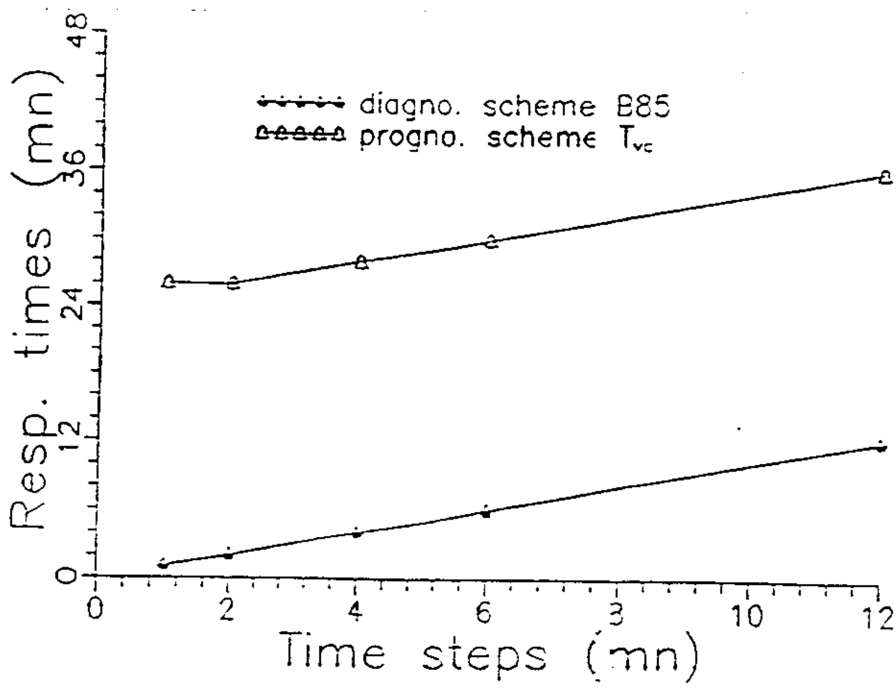
72

Fig.7


diagno. scheme B85
progno. scheme $T_{vc}$
Resp. times (mn)
Time steps (mn)
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# II] Downdrafts

## Experimental evidence

- "top entrainment" exists in some (even deep) convective forms : indirect proof that cloud water can also generate downdrafts
- "rain-water downdrafts" are essential in organizing and maintaining some forms of organized convection (squall-lines)
- the cloud geometry is a controlling parameter of downdraft intensity ; but is it the basic one?

## Modelling evidence

- "parameterizing" downdrafts (technically easy, except for the closure) has a strong mainly beneficial impact in case studies and, perhaps, NWP

[illegible]

- [illegible]

# III Shallow convection

## Experimental evidence

- in its several manifestations this top of PBL type convection is driven by:
  - bottom moisture feeding
  - top entrainment
- quasi non-precipitating

## Modelling evidence

- its parameterization is crucial for the maintenance of the tropical circulation
- can be parametrized as a diffusive process (with some precautions)
- attempts to combine it with deep convective parameterization still rather ad-hoc and not always successful

## Research areas

- mechanistic model
- better function for the diffusive approach
- problem of the transition precipitating - non precipitating convection.

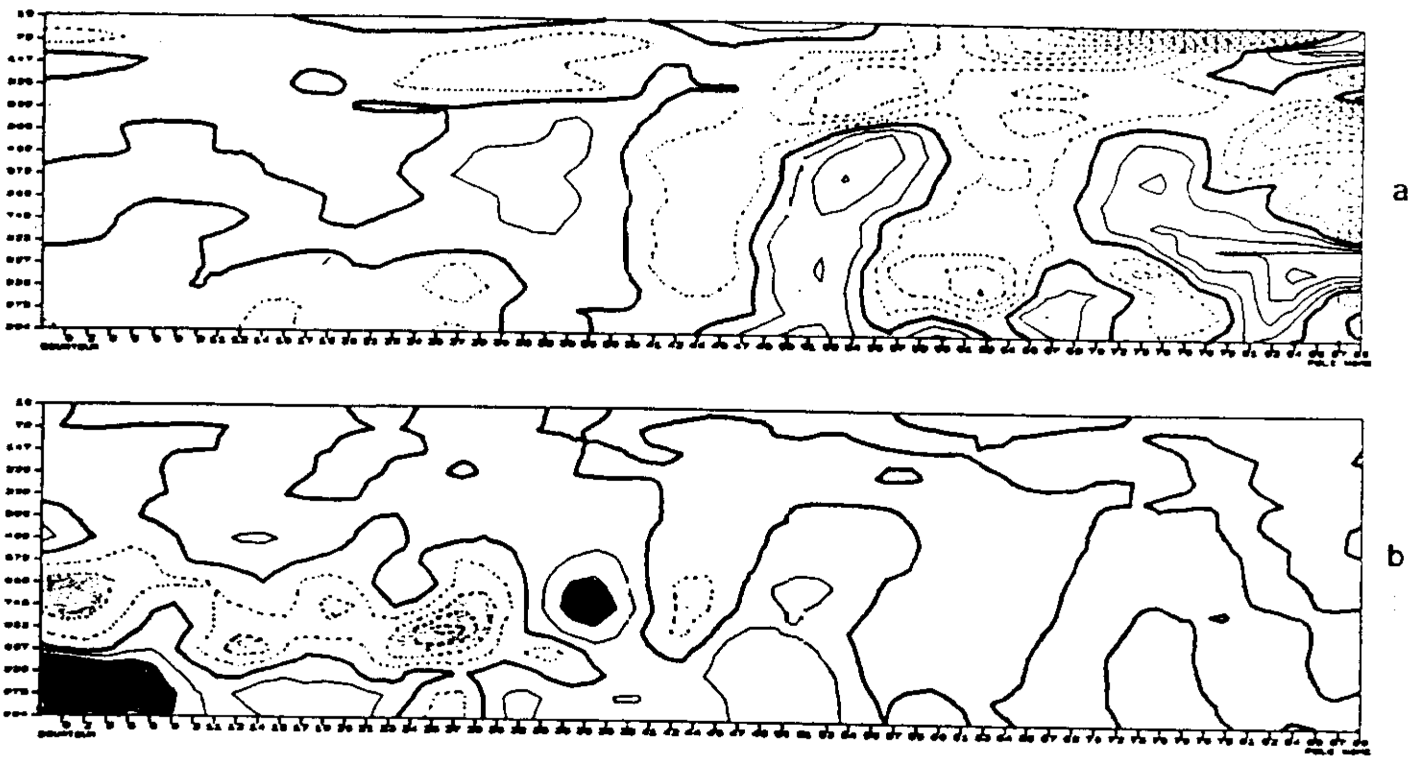



Fig 1 a-b

Zonal means of temperature tendencies (a) and of specific humidity tendencies (b) between 24 h and 48 h during the model integration from 10-01-1986 at 00Z (—— 0 line, —— positive values, ---- negative values, contour intervals are: .5°K/day (a) and .2g.kg⁻¹/day (b) ); case without shallow convection parameterization.

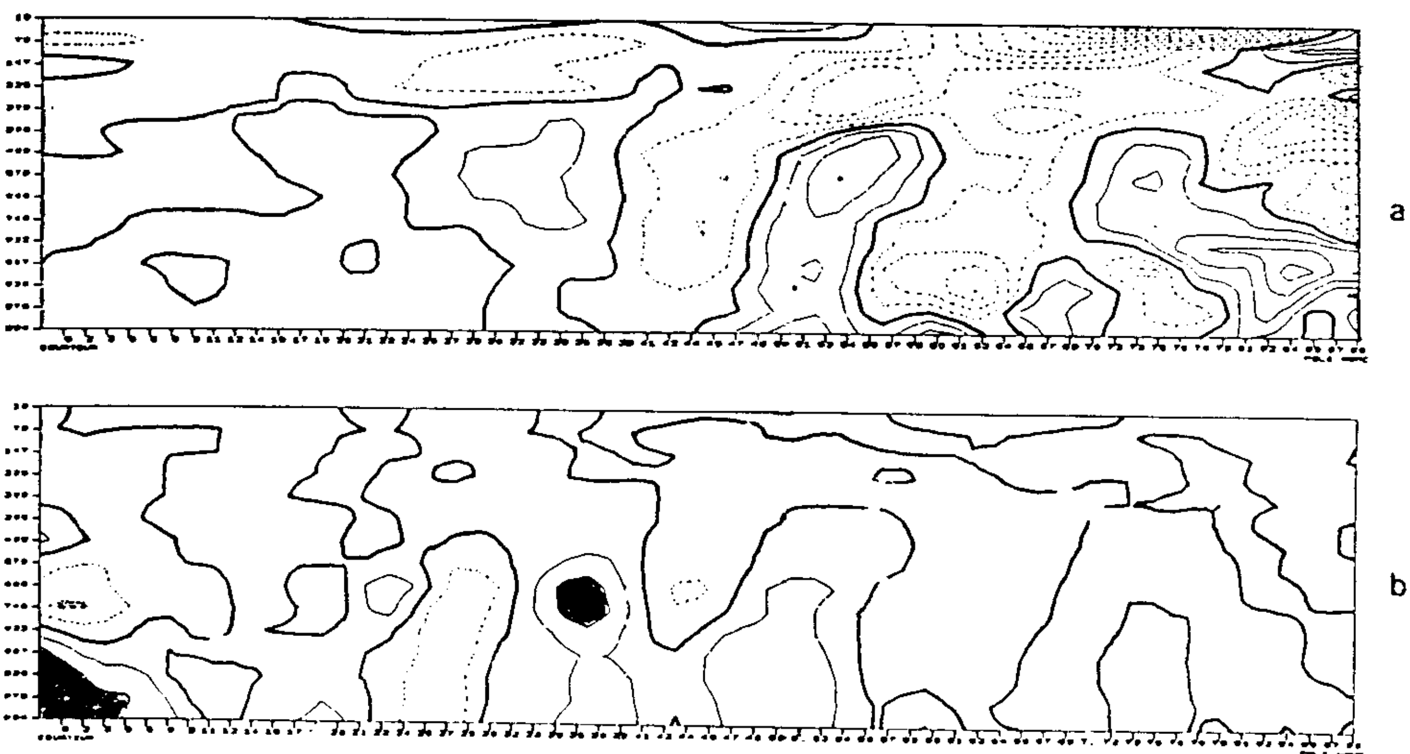


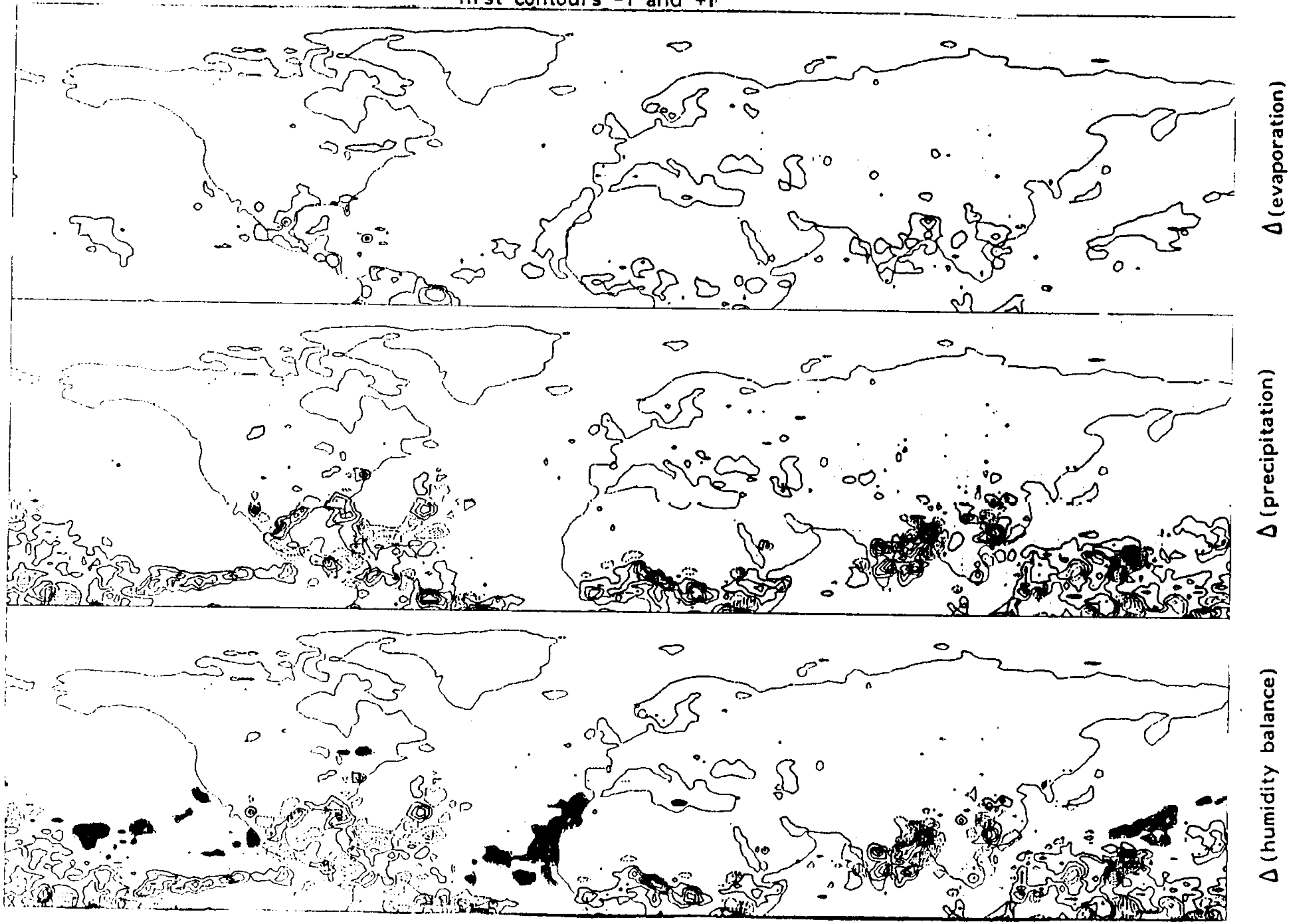

Fig 3 a-b

As Fig. 1 a-b except for: case with the proposed selfregulated shallow convection scheme.

Changes in the humidity budget (with shallow convection minus without)

mm/day contour interval 2 negative values dotted

first contours -1 and +1



# II) Slantwise convection

## Experimental evidence

- in regions of latent heat release with slanted ascents M- and $\theta_e$ surfaces tend to become parallel
- this is sometimes associated with closed circulations

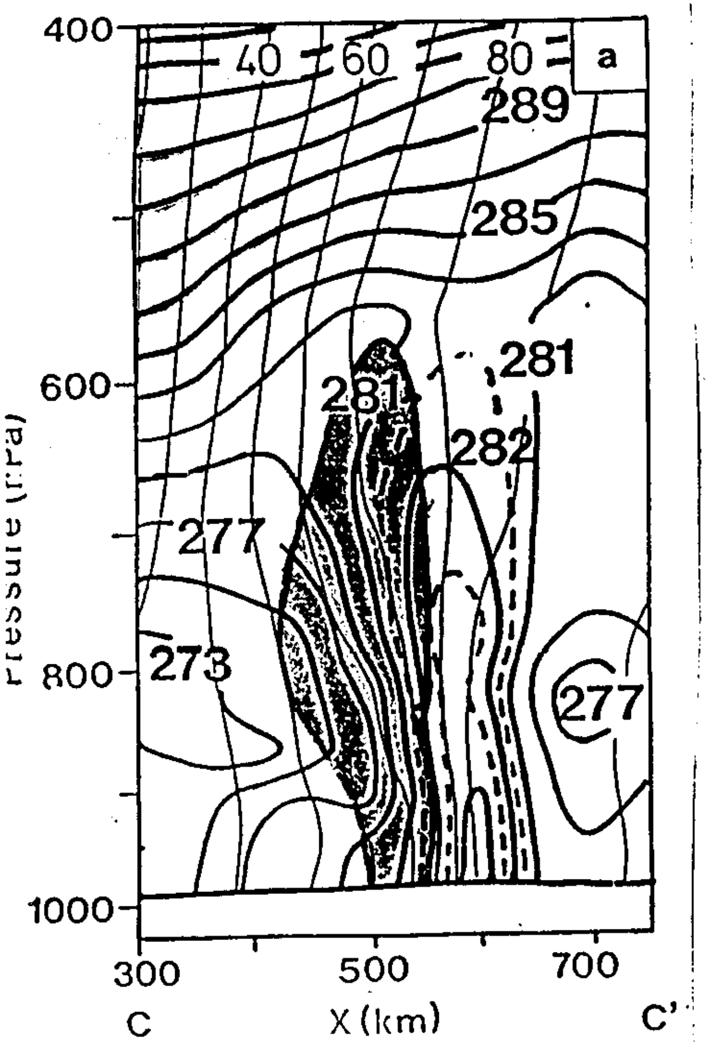
## Modelling evidence

- parameterization of this type of effect with a variation of a deep convection scheme can sometimes have a strong local impact
- there is not much "SCAPE" around (but CAPE?) in models
- symetric instability might not be the real driving mechanism

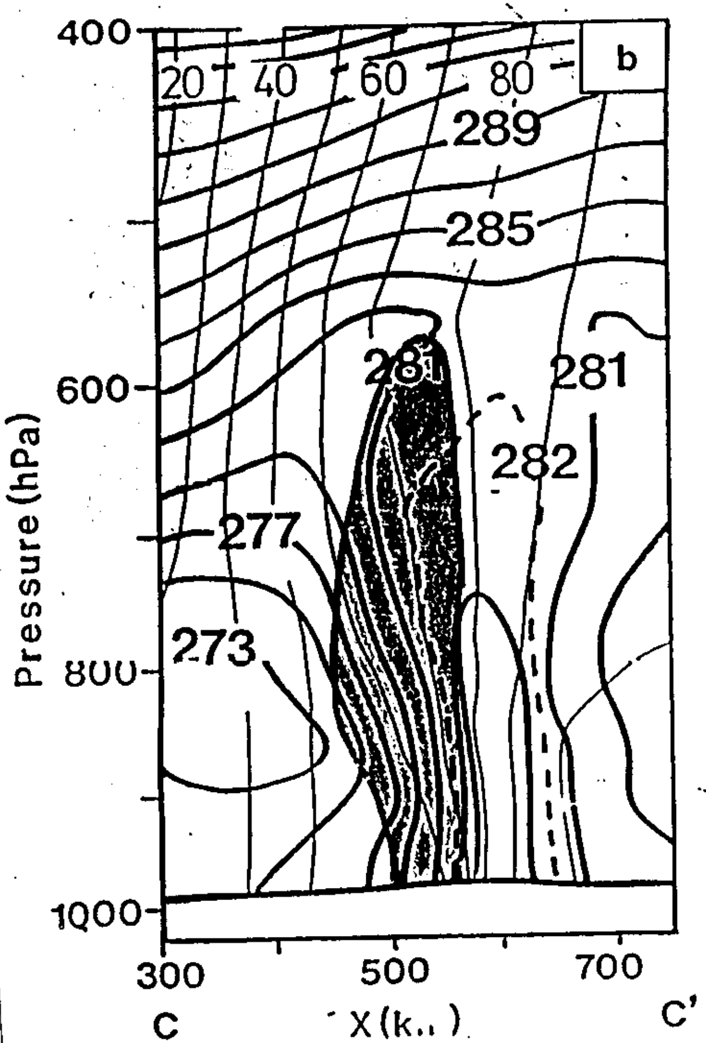
## Research areas

- what is the type of mixing (or what is the exact slope of the ascent: M, $\theta_e$, both)
- problems of horizontal vs vertical resolution (to separate [illegible] from [illegible])
- generalized approach to the [illegible] instability theorem

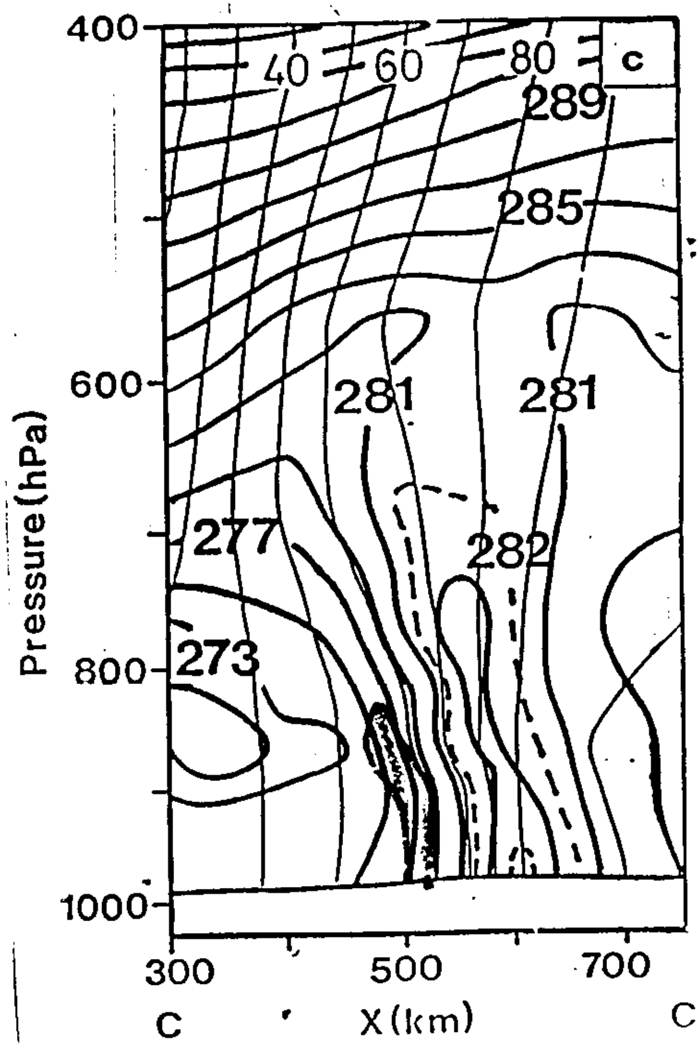
NORDENG (8?)




Pas de schéma convectif




Convection "verticale"




Convection "en pente"

# V) "Convective" momentum budget

Experimental evidence

- very limited ?!

Modelling evidence

- high resolution non-hydrostatic simulations tend to favour vorticity budgets
- budget diagnostics of the Schneider-Lindzen's approach at ECMWF are inconclusive

Research area(s)

- open territory !

# SECOND "SHOPING LIST" (cross correlations between subjects of list I)

| | downdrafts | shallow cv. | slantwise cv. | mom. budget |
|---|---|---|---|---|
| $\Delta x$ $\Delta t$ | A | / | B | / |
| downdrafts | | C | D | E |
| shallow cv. | | | / | / |
| slantwise cv. | | | | F |

A) Size of downdraft area ; time lag behind updrafts ?

B) Can sl. cv. be explicitely resolved ?

C) Can top-entrainment be parametrized in the cloud-water downdraft framework ?

D) Tilt and l.s. type evaporation of precipitation ; can it be parameterized as a downdraft, if needed ?

E) Both highly dependent on the tilting of clouds ; is there a link ?

F) Is the M redistribution a key for understanding the general momentum budget problem ?

# Mixed bag of research topics

A] [illegible] the transition [illegible] [illegible] [illegible] [illegible] for evaporation from [illegible] (because of singular microphysics)? Can the prognostic approaches be extended to the downdraft case or will it be only considered as a "correction" to the updraft parameterization

B] Provided a correct ratio exists between vert. and horiz. resolutions explicit resolution of sl. cv. is probably possible and relatively harmless (little overshooting evidence). But, if one goes for a more "soft-transition" approach for upright convection, since the slantwise extension is cheap, isn't it wishable to do it (for consistency reasons)? Many "if's"

C] Very recent evidence from Emanuel indicate the potential of "cloud water downdraft induced top entrainment" for parameterizing shallow convection. Needs further work!

D] The "downdraft part" of the slantwise circulation should not be too problematic (known area coverage & not simple microphysics) but it has yet to be shown ....

E] The amount by which cloud tilting controls (or is controlled by ?) both efficiency of downdrafts and modifications to the S.L. momentum equation has to be assessed with the possibility that the two are interrelated. Totally untouched topic.

F] Since the [illegible] instability offers a convenient theoretical link between all kinds of convective circulations, its clearest manifestation (s.l. or M redistribution) could be a good touchstone for other ideas about momentum budget. Totally untouched again.

G] (For the record). Link of all the above-mentioned with the other parameterizations

- cloud / radiative problem
- g.w.d. generated by convective momentum divergence sources
- link PBL / Convection in practical schemes

.........

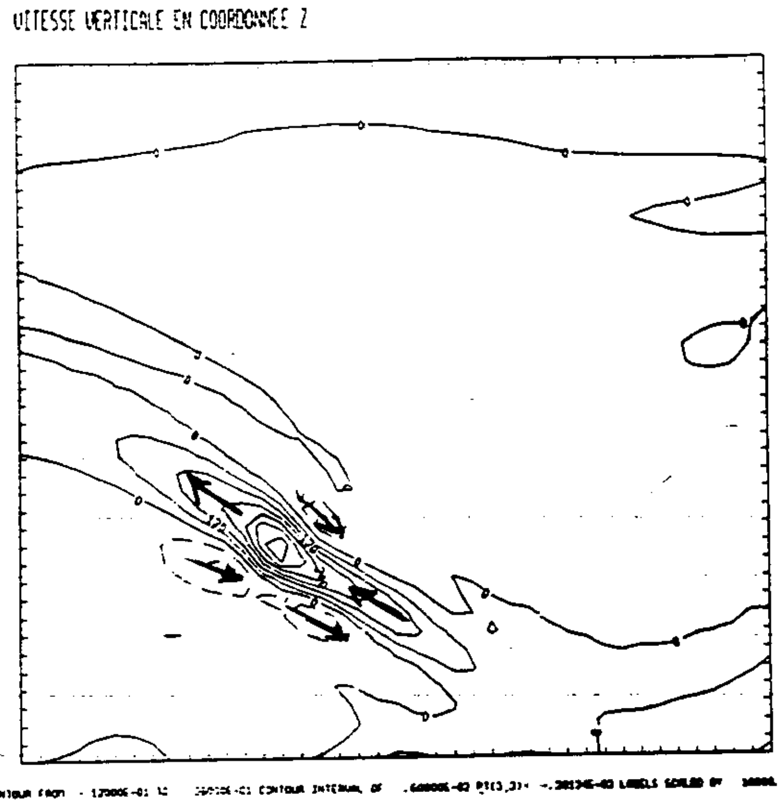
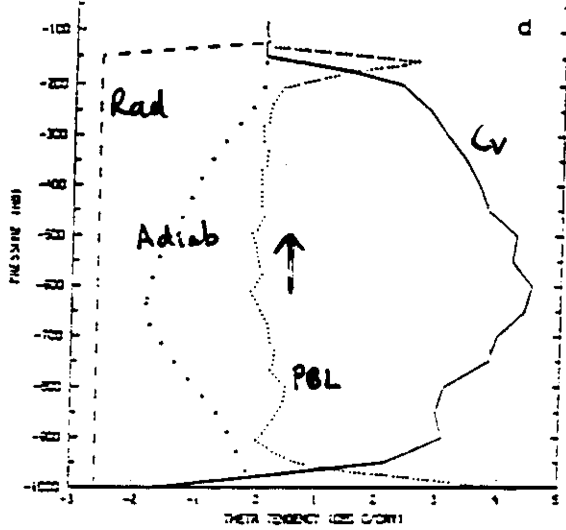


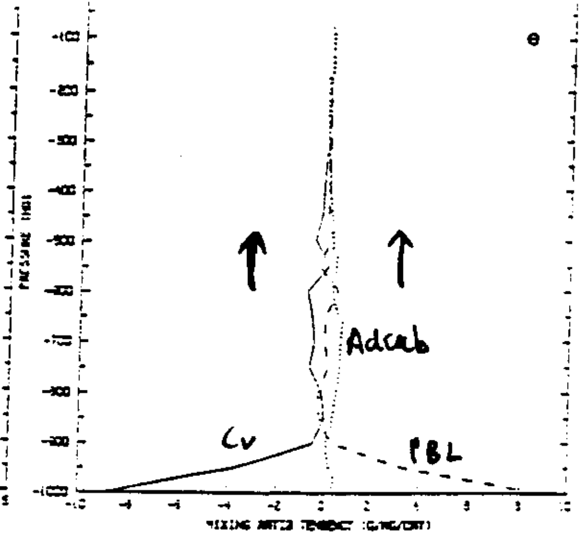

Figure III/23

Vitesses verticales après 12 heures d'intégration de la situation frontale 1.

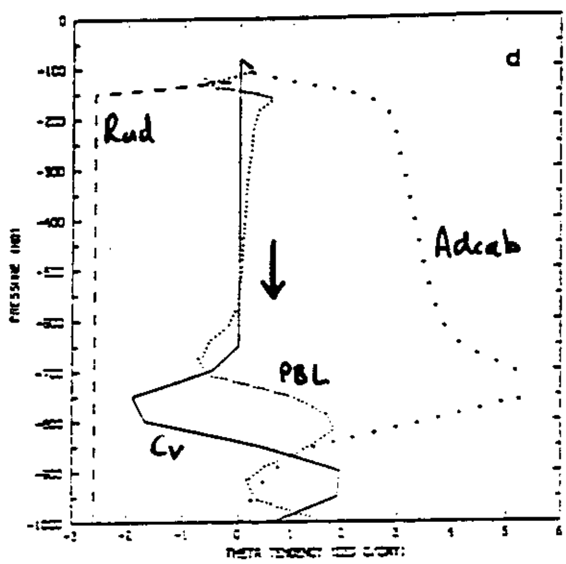
Perturbation initiale à 105 %.

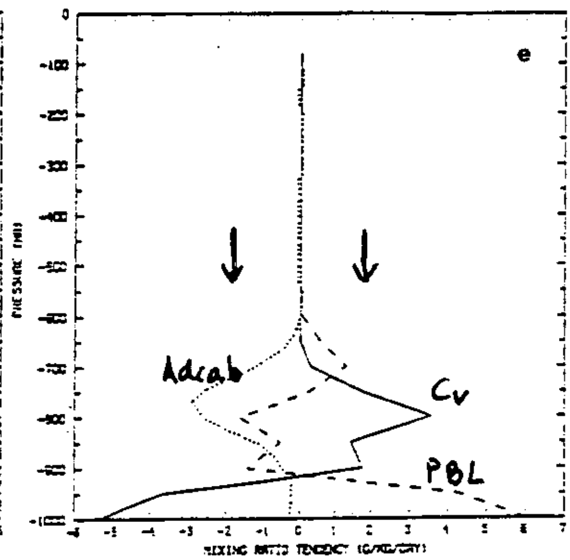
Troposphère saturée.



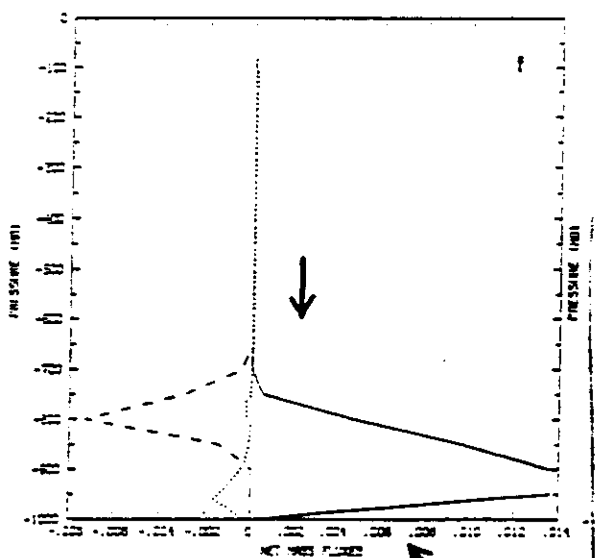



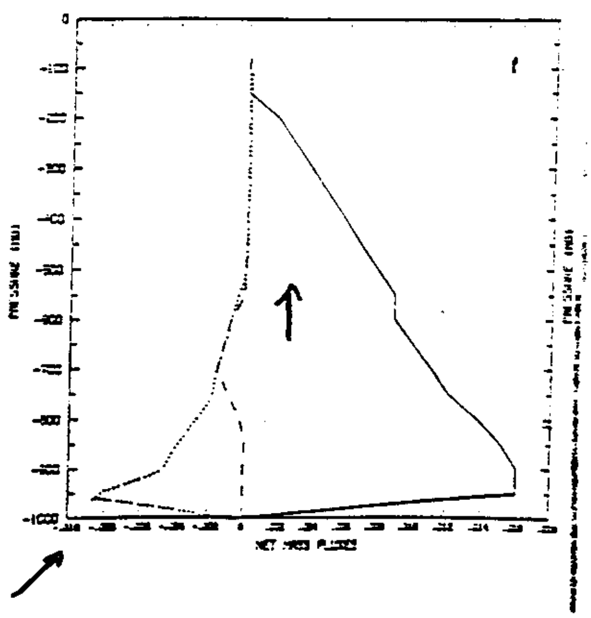

$\frac{\partial T}{\partial t}$




$\frac{\partial q}{\partial t}$




Mass Fluxes

## "PHILOSOPHICAL" DEBATE

The complexity and the multiform character of the problem generates two opposite attitudes

- this is so complex that only a piecewise, selective and process-oriented approach will have any chance of leading to sustained progress

- the complexity is only there because we separate diverse manifestations of the same basic "lift and counterweight" problem and the solution is to first unify the parameterization schemes at macro-scale before going to a detailed microphysics research for further improvement

As you would have guessed I favour the second approach but have no proof to offer you that I am right in doing so.

Conclusion : A subject for those afraid of monotony in work.