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SMR/475-9

WORKSHOP ON ATMOSPHERIC LIMITED AREA MODELLING
15 October - 3 November 1990

"Problems of Parameterization of Convection"

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

Short Lecture Notes for the Lecture "Problems in Parameterization of Convection"

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Warnings a) Since most of the material presented in the transparencies is merely another angle of view for problems that we treated at a slightly more basic level in the lecture of October the 19th – for which extensive Notes are available – only precisions about new themes (verification, momentum budget) will be given here.

b) Albeit present in the title transparency shallow convection and slantwise convection had to be postponed to the next lecture for lack of time at the end of this one.

* Verification of convection schemes

* very difficult because of the strong link with dynamics; 3D tests with full interactivity are nearly untractable and 1D tests cannot work without an experimental knowledge of the forcing (semi prognostic mode) => basically all tests come back to the GATE data set

* Prediction of Q1 and Q2 (apparent heat source and apparent moisture sink, or rather Q1 - QR and Q2 (QR radiative forcing)

Getting Q1 right is "easy" given the constraints on the large scale vertical velocity, Q2 is a bit more tricky but still rather constrained while the real test would be relative humidity at the balanced state, something one hardly sees reported!

* another example of the "lack of information content" of thermodynamic budgets for convection is the fact that very similar Q1 budgets in a LAM

can still lead to totally contradictory behaviours of the vertical structure for kinetic energy dissipation (because the two figures don't refer to the same content but the conclusion still holds.

* Momentum budget

Since many modifications of the momentum budget can and indeed do take place inside the complex structures of convective clouds (as soon as they are not purely axisymmetric) and since we have yet no way of understanding or parameterizing them, one is tempted to put to "zero" the budget terms for large scale variables $\bar{u}$ and $\bar{v}$.

This is probably wrong since it amounts not to take into account the so-called "compensating subsidence" effect, or rather to admit a transport by large scale ascent that never took place in reality. It appears far better to use the so-called Schneider Lindzen's approach (cf equation of mass flux scheme with $\Psi = u, v$) so that the two terms $\omega \frac{\partial \vec{u}}{\partial p}$ and $-M_c \frac{\partial \vec{u}}{\partial p}$ nearly cancel and leave two smaller order terms $-(\omega + M_c) \frac{\partial \vec{u}}{\partial p}$ and $D(\vec{u}_c - \vec{u})$.

PARAMETERIZATION OF CONVECTION = A LOT OF INTERCONNECTED PROBLEMS

Special rôle of convection in models
→ technical difficulties

Cloud "model"

Equations

Closure assumption

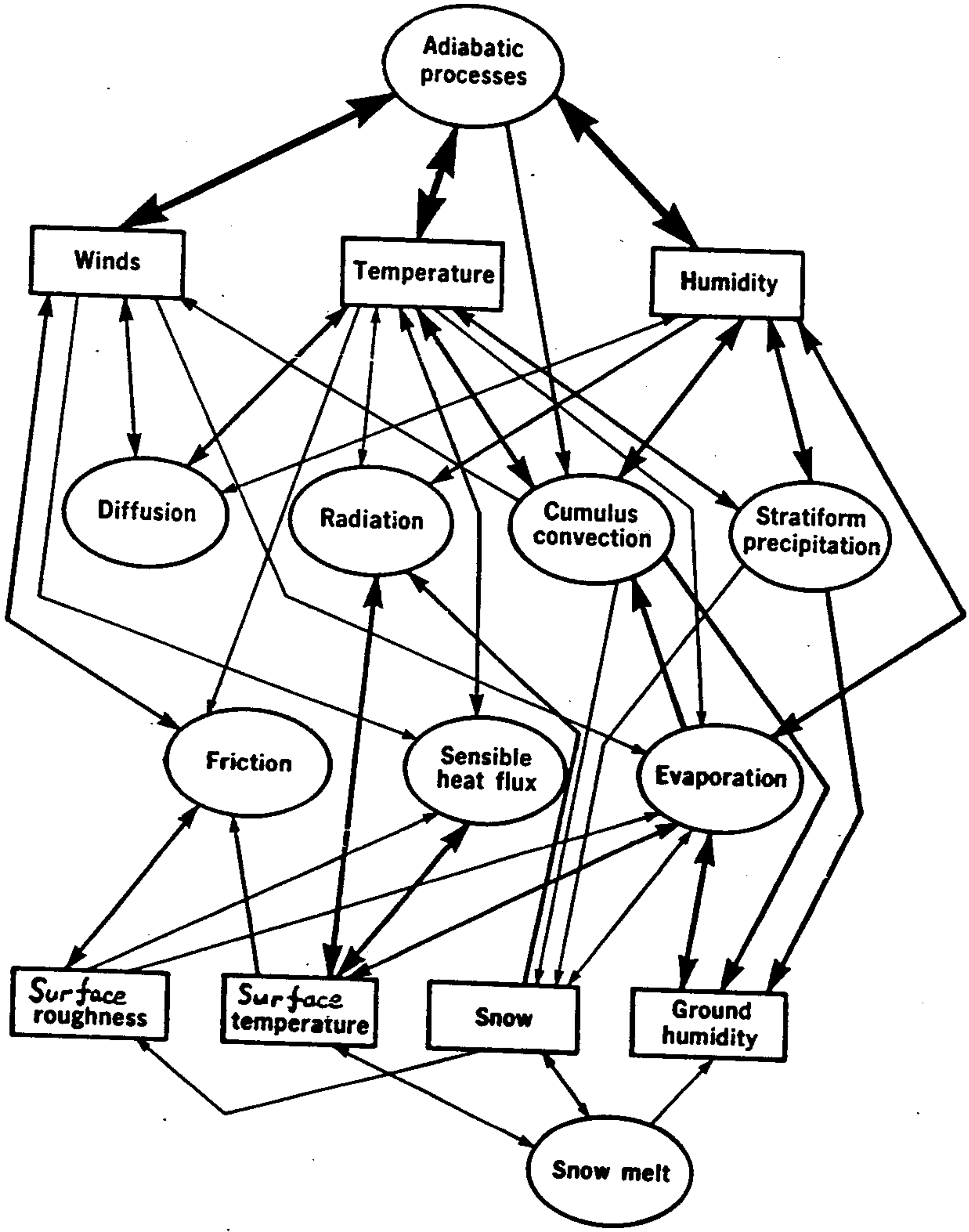
Verification of convection scheme

As $\Delta x \to 0$ - separation of resolved/unresolved features
- reevaporation

Momentum convective budget

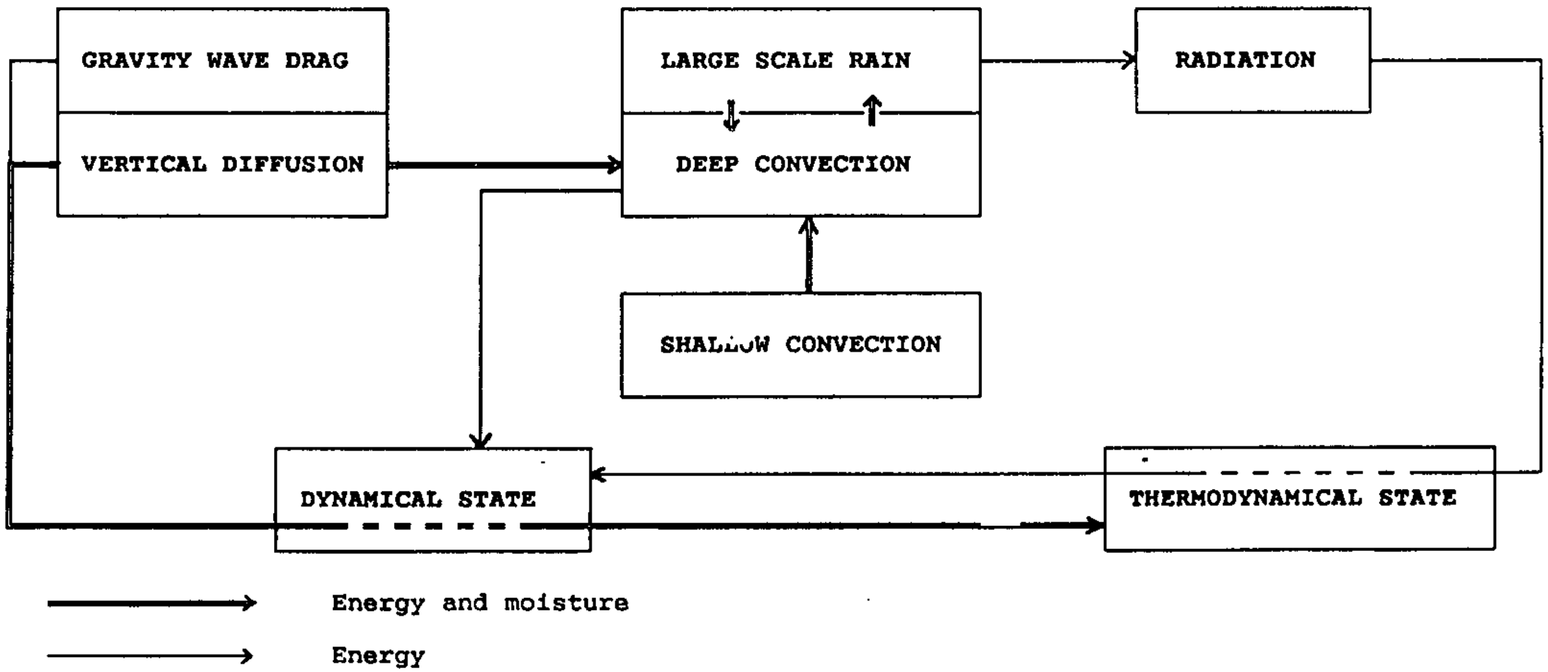
Shallow convection

Slantwise convection



Adiabatic processes
Winds
Temperature
Humidity
Diffusion
Radiation
Cumulus convection
Stratiform precipitation
Friction
Sensible heat flux
Evaporation
Surface roughness
Surface temperature
Snow
Ground humidity
Snow melt

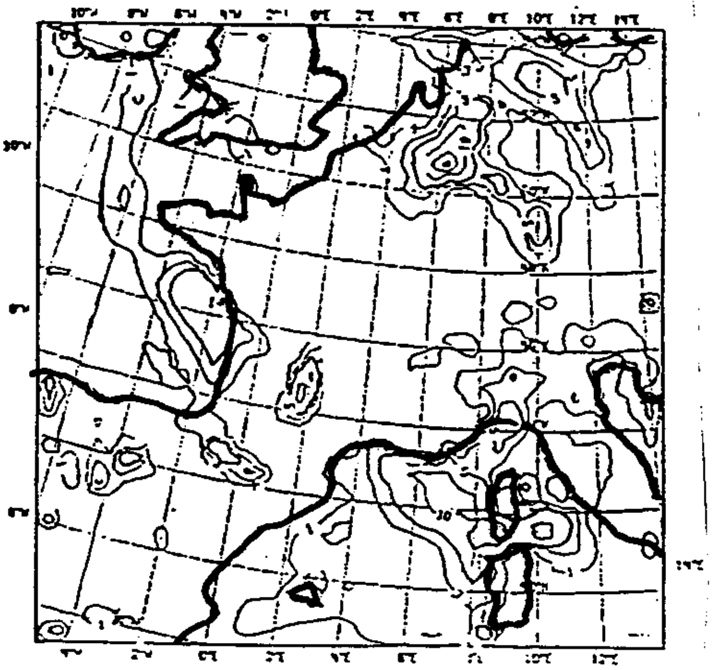
MAIN CHARACTERISTICS OF THE INTERDEPENDENCIES BETWEEN INDIVIDUAL DIABATIC FORCINGS



24 hour Forecasts From 84/6/4 12Z

6 hour accumulated precipitation

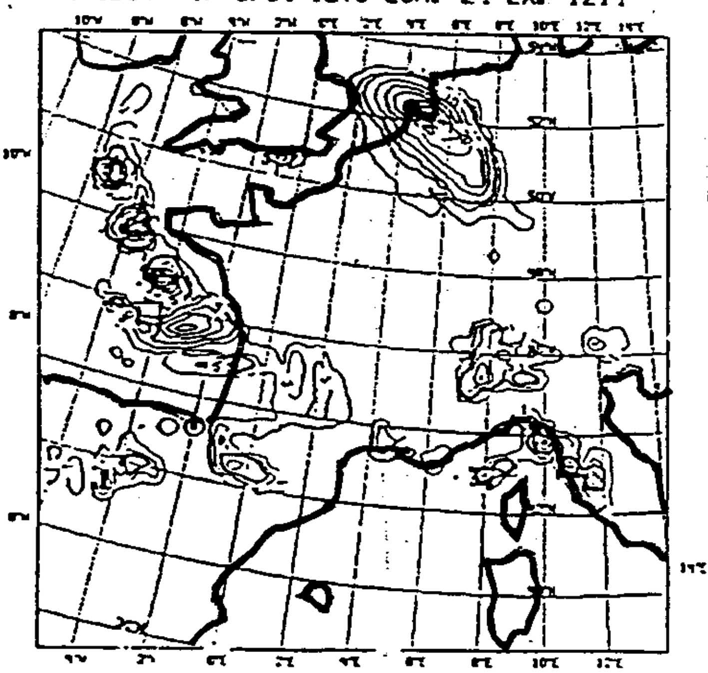
PERIDOT 4/ 6/84 12TU ECH. 24 EX. 1222



PLUIE TOTALE (MM)

parametrised convection

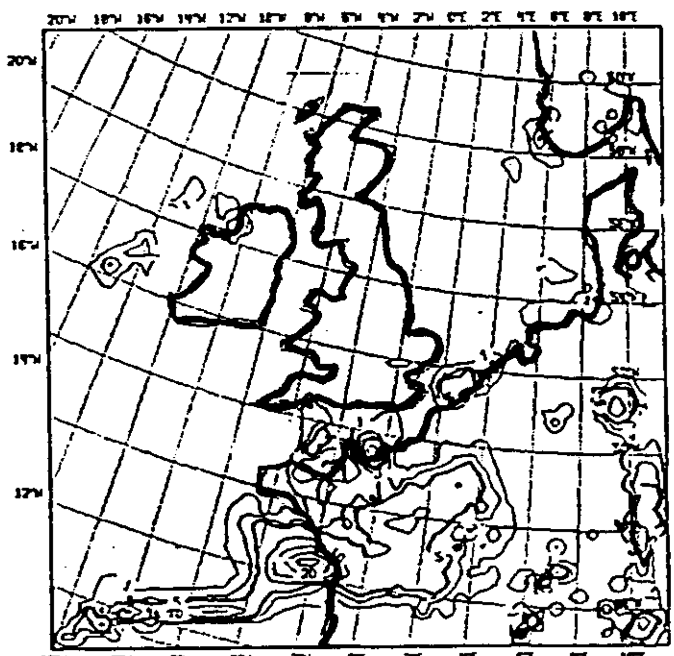
PERIDOT 4/ 6/84 12TU ECH. 24 EX. 1214



PLUIE TOTALE (MM)

"explicit" representation of convection

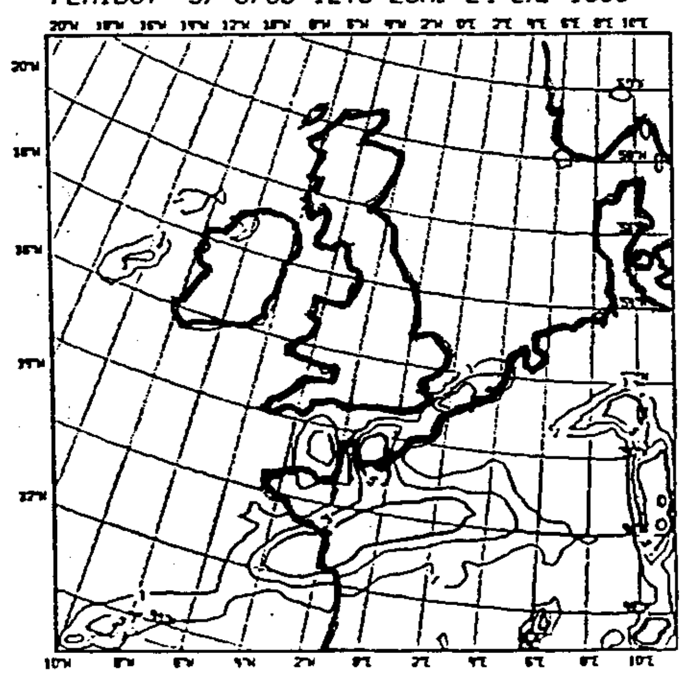
unsmoothed input to the kuo closure assumption



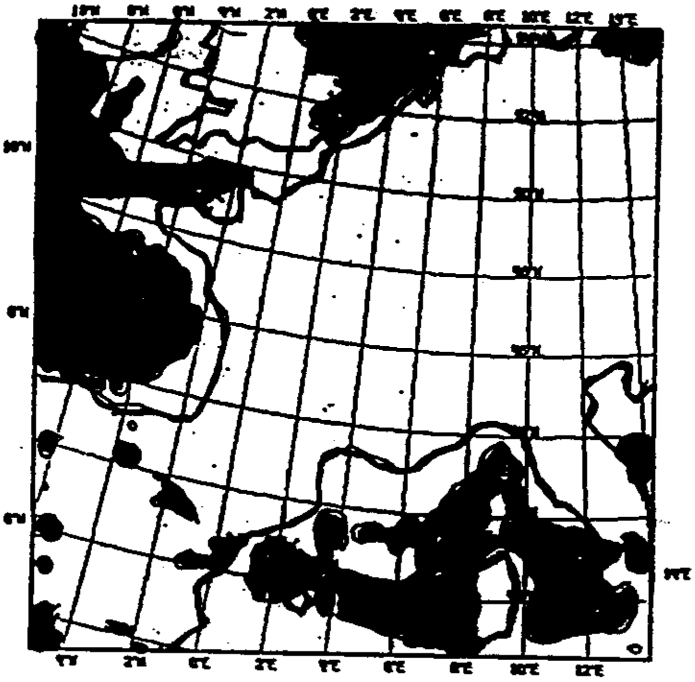
24 hour Forecasts From 83/6/5

dynamically smoothed - - - - -

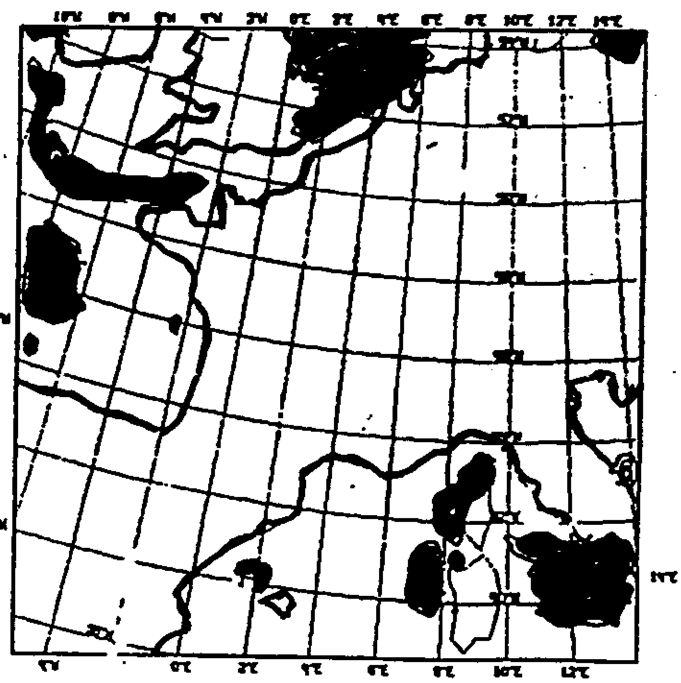
6 hour accumulated precipitation



24h rainfall Forecast (6h accumulated)



"dry" convective cloud profile.



"water storing" convective cloud profile

SPLIT OF CONVECTIVE SCHEME'S COMPONENTS

- cloud model
  - particle theory
  - used for either
    - equilibrium value
    - relaxation target
    - energy budget closure

- closure assumption
  - ensures quasi-equilibrium with "L.S." forcing
  - used diagnostically
    - explicitely
    - implicitely
  - prognostically ?

- Equations for "L.S" tendencies
  - budget equations with conservation constraints
  - 4 types : model in model (meso-scale K.F. F.C. F.S.)
    - Kuo
    - Adjustment
    - Mass-Flux (popularised (?) by Ar. Sch.)

Cloud model (1)

Simple at first glance : particle theory

but ....

- one "average" cloud or several (spectrum with different entrainment rates) cloud ascents?
- degree of entrainment of environmental air ?
- liquid water loading ?
- computation of vertical velocity or not ?
- accurate and fast algorithm !

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!) => counterweight 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

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

$$\int_{p_t}^{p_b} M_c \frac{\partial q}{\partial p} = \int_{p_t}^{p_b} CVGU$$

CVGU
humidity convergence

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

Prognostic ~~...~~ evolution

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

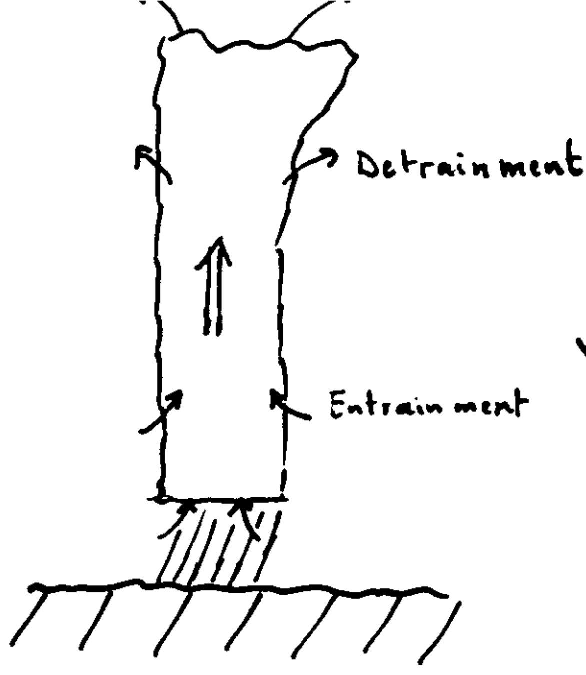
α^* "updraft" scale (horizontal)
ω_c^* "updraft" vert. velocity

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

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

Updrafts only
For the sake of simplicity

↓



↓ "Compensating" subsidence

M_c = vertical velocity of compensating subsid.

<u>Hypothesis</u>

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

<u>Equations</u>

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

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

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

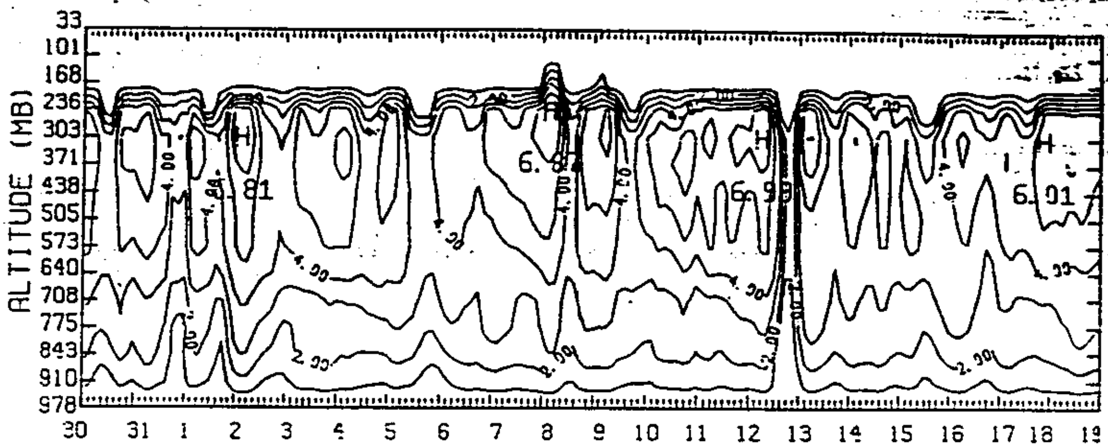
$$M_c \frac{\partial \Psi_c}{\partial p} = E(\Psi_c - \bar{\Psi})$$

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

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

Ψ = any thermodynamical moist conserved variable (h, for example)

Fig.4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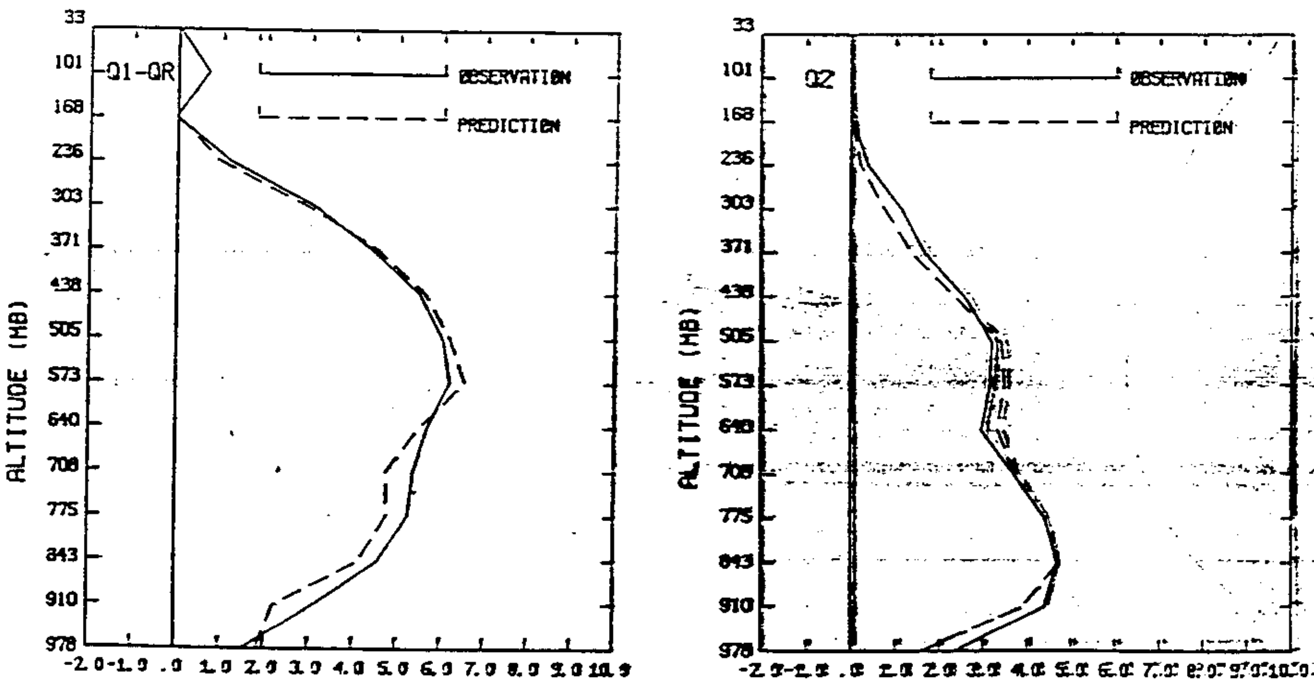
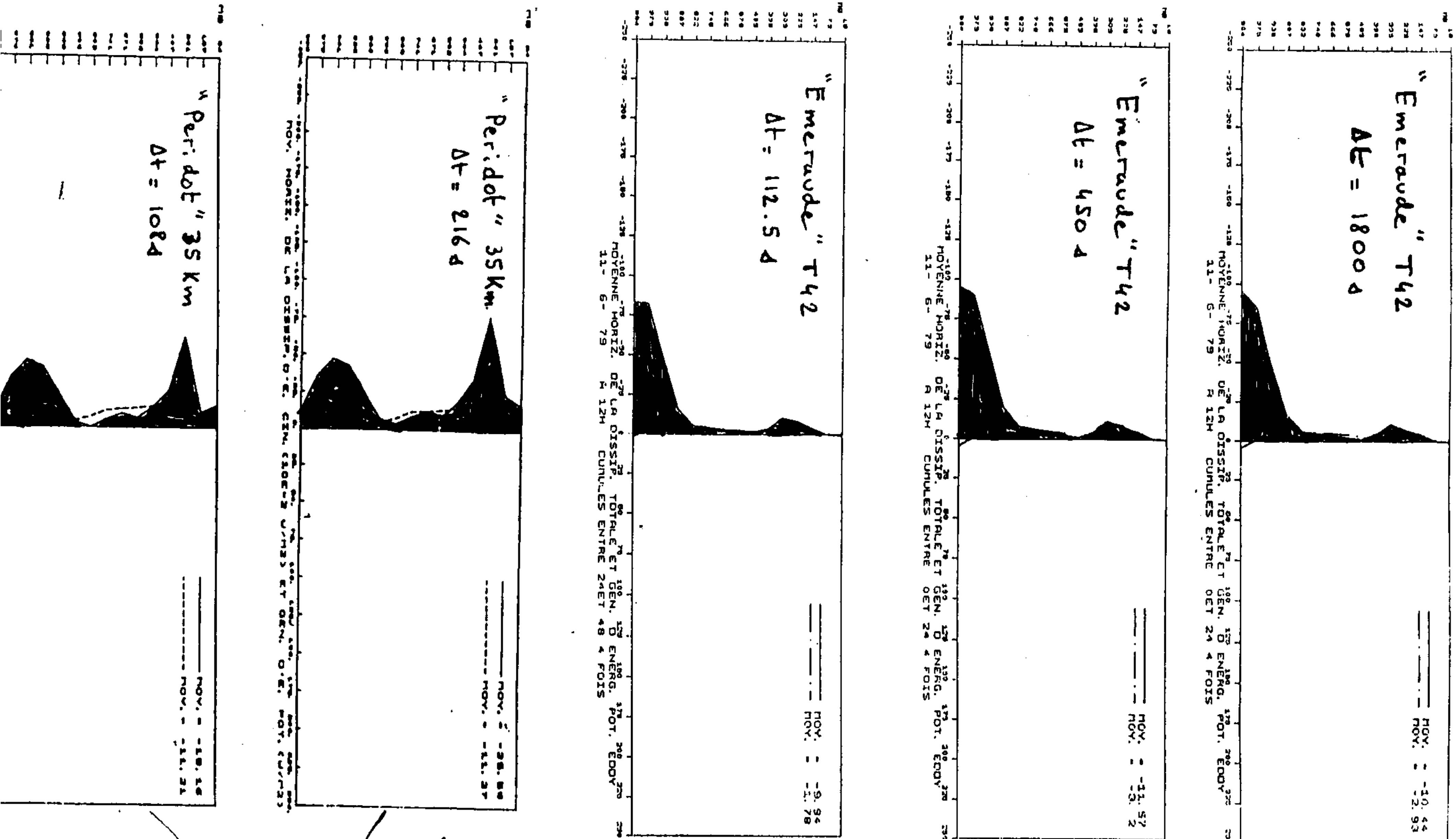
33 101 168 236 303 371 438 505 573 640 708 775 843 910 978
30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Fig.5


Q1-QR
OBSERVATION
PREDICTION
ALTITUDE (MB)
33 101 168 236 303 371 438 505 573 640 708 775 843 910 978
QZ
OBSERVATION
PREDICTION
ALTITUDE (MB)

DIABATIC DISSIPATION OF KINETIC ENERGY



Fine mesh. Lowest levels 19 m. 94 m. 144 m. } ~

Large scale. Lowest levels 42 m. 210 m. 550 m. } ~

Figure II-G1

BILANS DANS PERIDOT

22-04-1981 A 00H. CUMULE ENTRE 00H. ET 36H.

DOMAINE LIMITE PAR { I1=16 I2=28 . DIRECTION NORD-SUD ; J1=19 J2=39 DIRECTION OUEST-EST }

——— TENDANCE GLOBALE

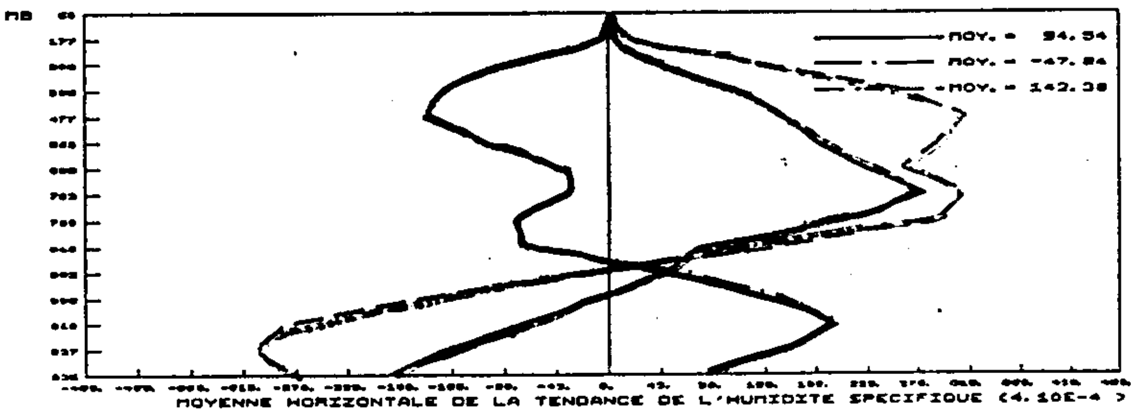
—·— PHYSIQUE

– – – ADIABATIQUE

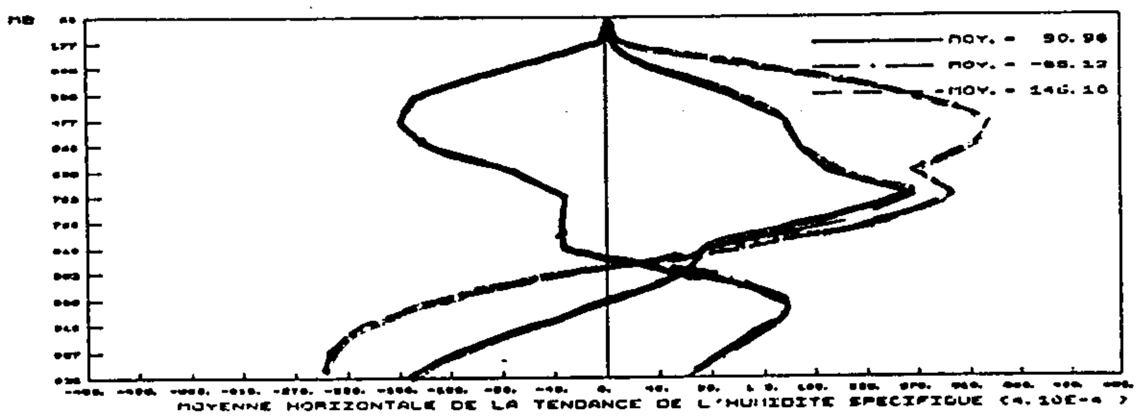
EXPERIENCE SUR LES USA. MAILLE 160 KM.

ADVECTION VERTICALE EXPLICITE.

Vertical dq/dt profile — diabatic — adiabatic — total



SCHEMA DE KUO.

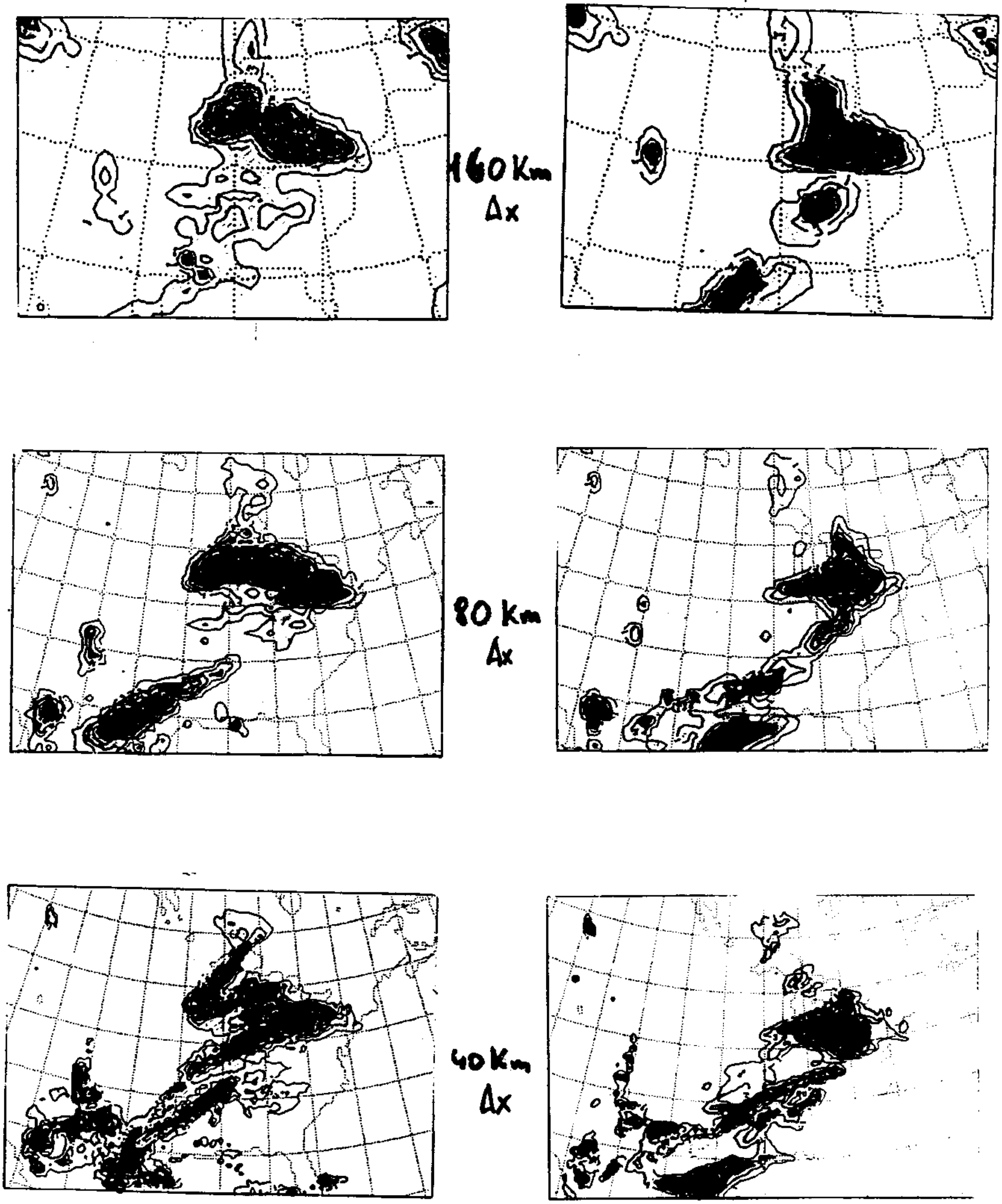


SCHEMA DE BOUGEAULT.

Source: Diagnostics développés par
MM. Jean-François MAHFOUF et Ryad EL KHATIB.

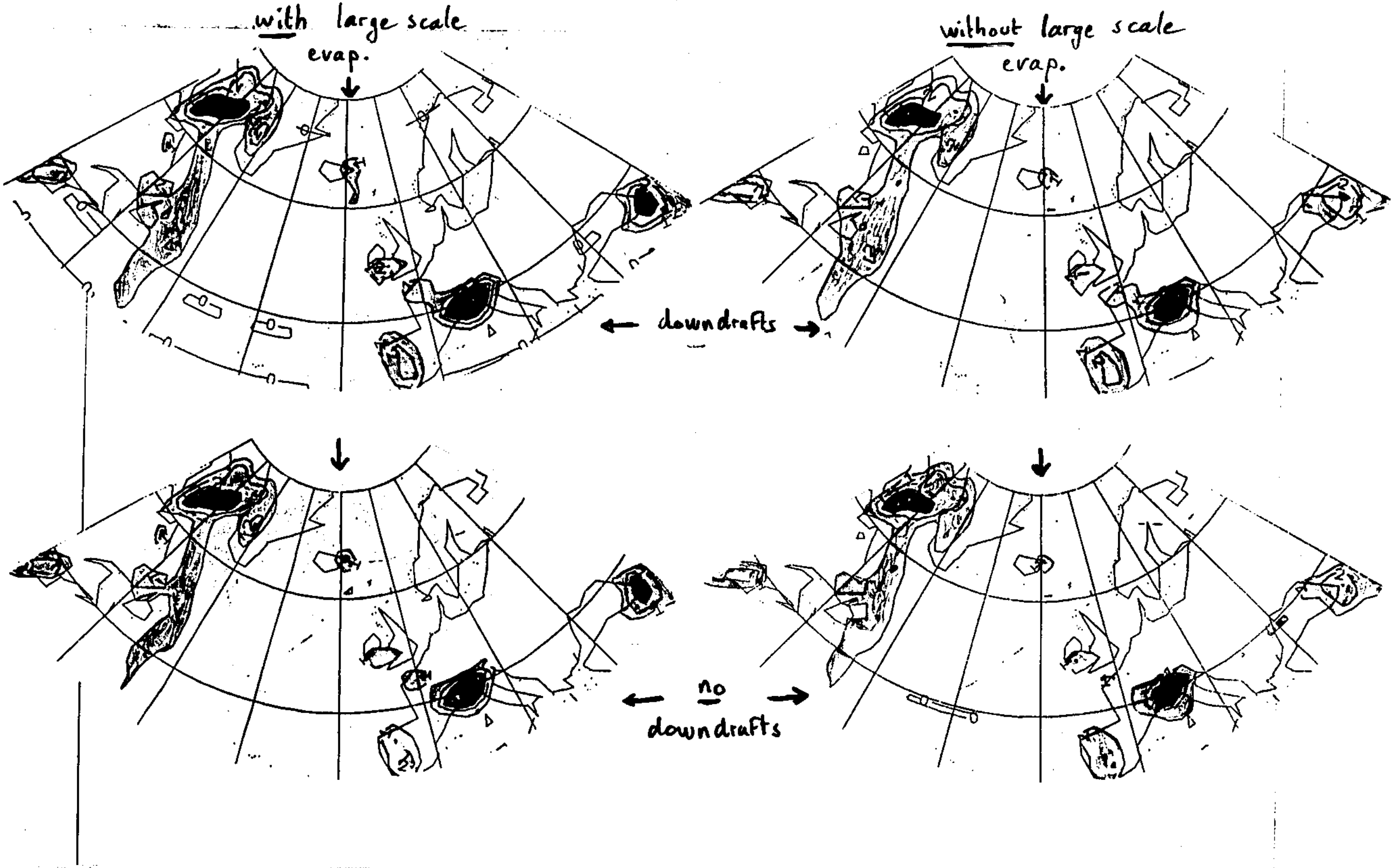
BOUGEAULT KUO

DEEP CONVECTION PARAM.

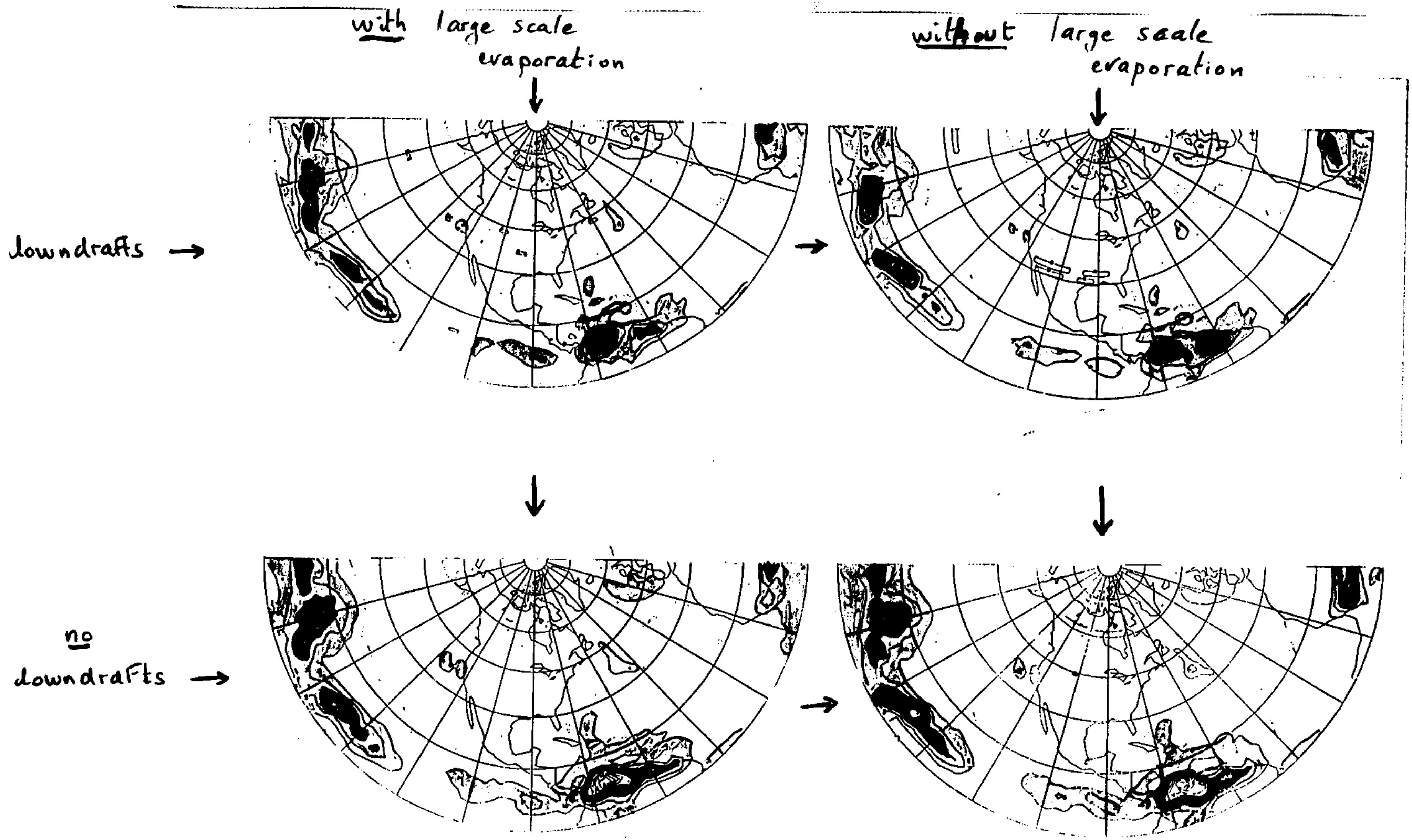


48 hour rainFall Forecast (12h accumulated)

48h → 72h Large Scale Precipitations

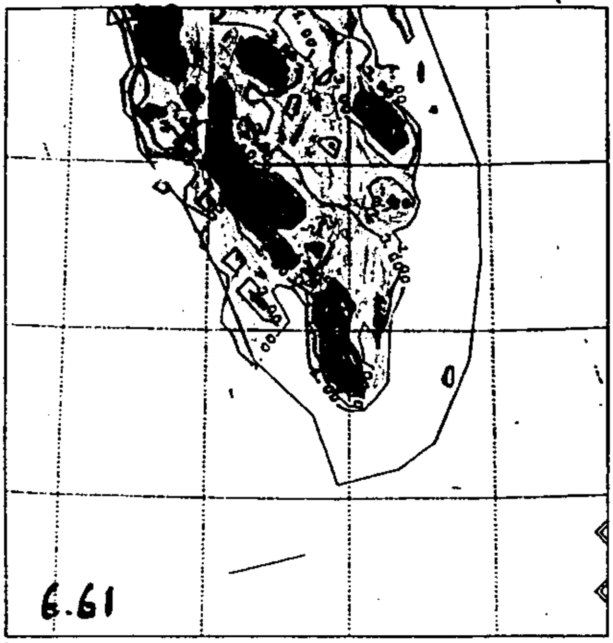


48 h -> 72 h Convective Precipitations



$\Delta x = 10$ Km. (Ph. Bougeault)

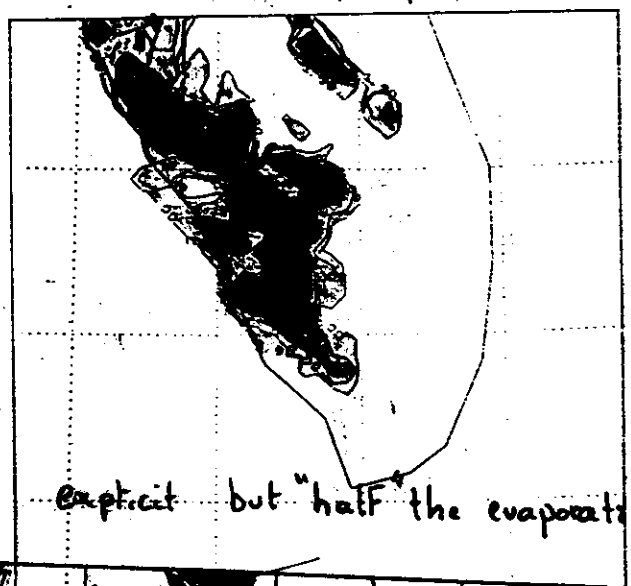
9h → 12h Total rainFall (18 local)



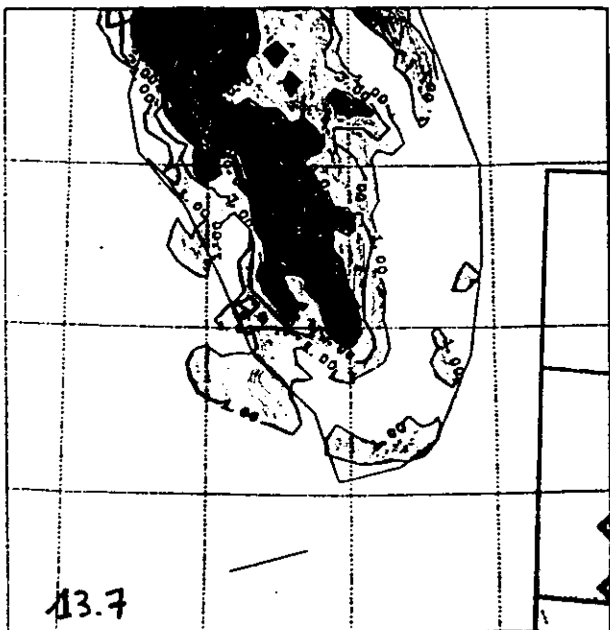
BASE 30/ 7/73 A 11HTU ECH.12 EX 2023 PTC

with downdrafts

"explicit"

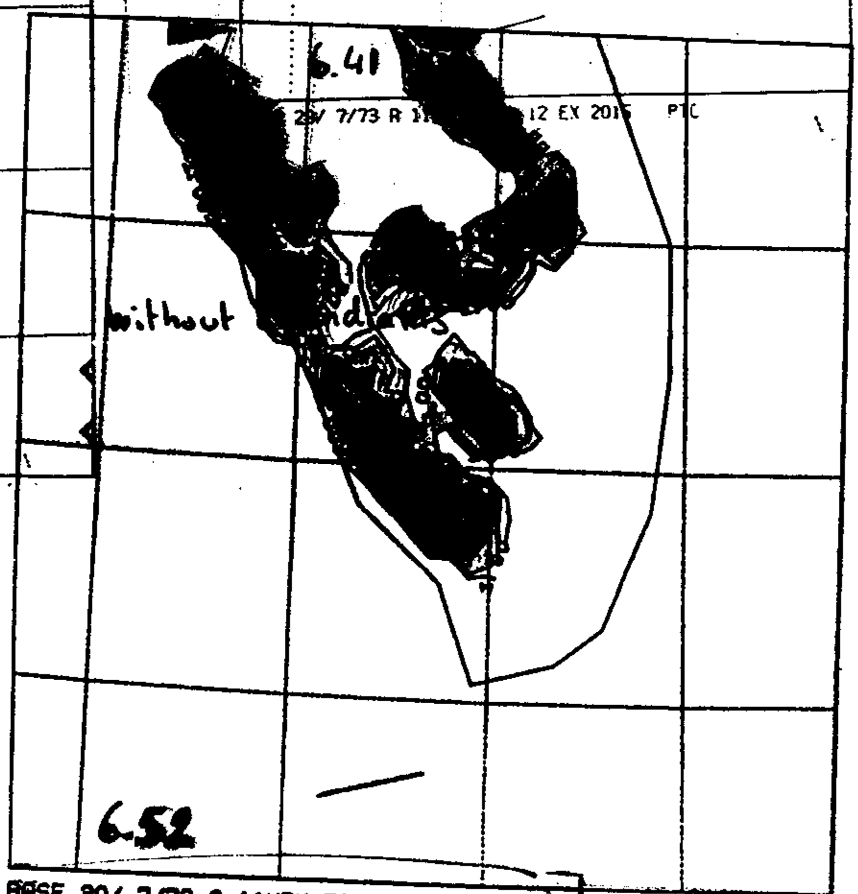


explicit but "half" the evaporation



BASE 30/ 7/73 A 11HTU ECH.12 EX 2022 PTC

without [illegible]



BASE 30/ 7/73 A 11HTU ECH.12 EX 2024 PTC

MOMENTUM FLUX PROBLEM

- We know little if anything
- A vertical axisymetric cloud can only redistribute momentum

$$\frac{\partial \bar{u}}{\partial t} = \frac{\partial}{\partial p}\left(M_c\,(u_c - \bar{u})\right)$$

$$M_c \frac{\partial u_c}{\partial p} = E\,(u_c - \bar{u})$$

"Schneider - Lindzen" approach

- Even if it only a part of the total effect
  a) it exists
  b) it is clearly a part of the "counterweight" effect

$$\frac{\partial \bar{u}}{\partial t} = -\overset{①}{\omega \frac{\partial \bar{u}}{\partial p}} - \overset{②}{M_c \frac{\partial \bar{u}}{\partial p}} + D\,(u_c - \bar{u}) + \cdots$$

$$= -\tilde{\omega}\frac{\partial \bar{u}}{\partial p} + D\,(u_c - \bar{u})$$

↑ small term as compensation between two big ones ① ②

- To go further the slantwise experience might be useful as well as Model-Diagnostic budgets --->