Une nouvelle paramétrisation de la dynamique de population de poches froides dans le GCM LMDZ

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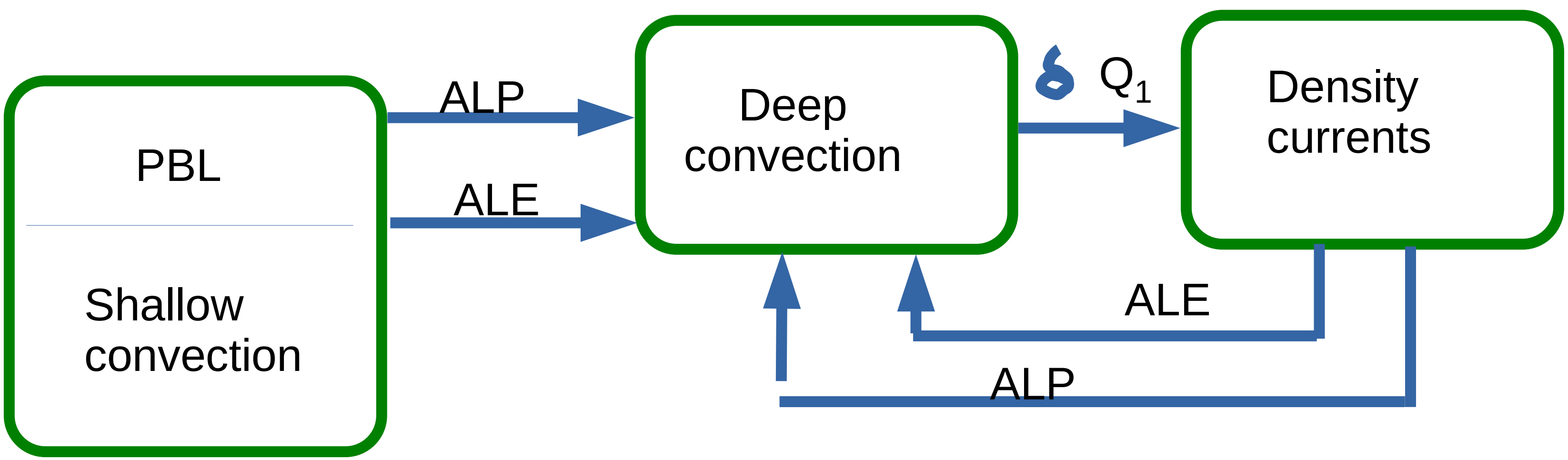
1- The ALP-ALE system: coupling boundary layer thermals, deep convection and density currents. (LMD & CNRM)

- Deep convection trigger given by the Available Lifting Energy (ALE) :

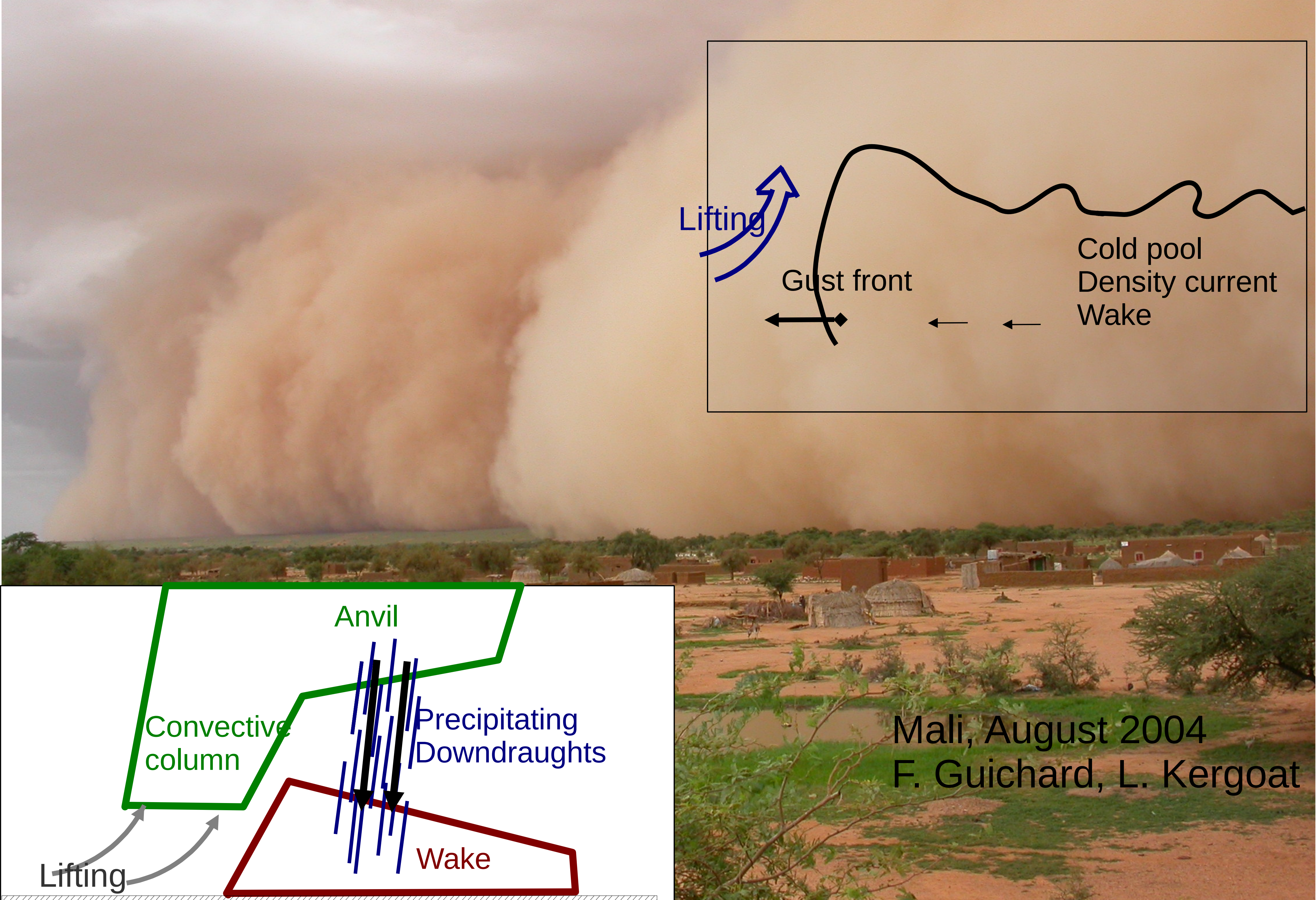
ALE > |CIN| ==> deep convection is triggered

- Closure given by the Available Lifting Power (ALP) :

$M = ALP/(2\,W_B^2 + |CIN|)$;
M = cloud base mass flux; W_B = updraught velocity at LFC



2- Cold pools: the “wake” scheme (LMD & CNRM)

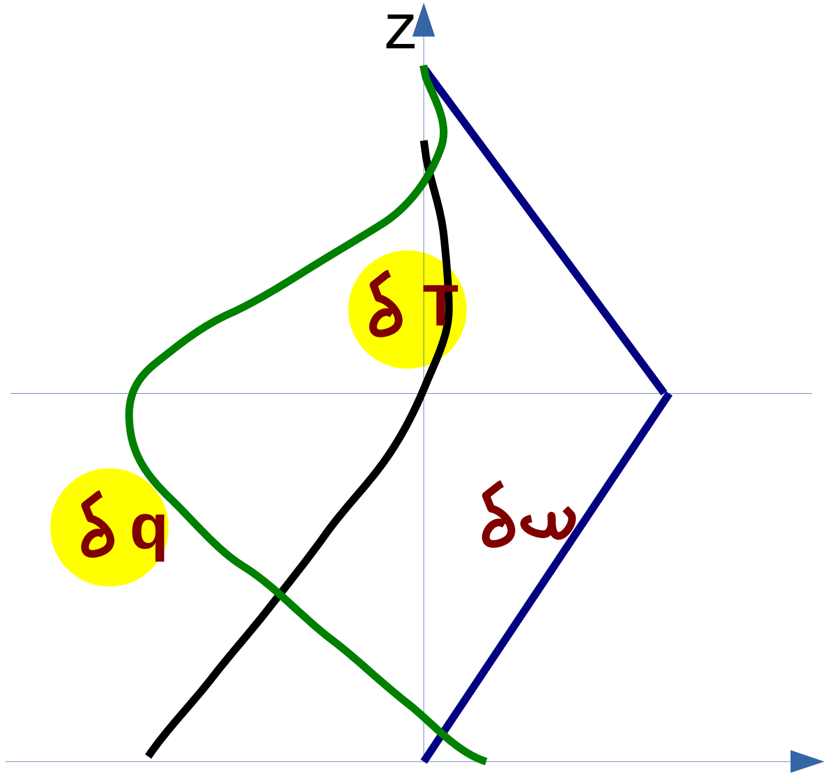


The density current (wake) parametrization

(Grandpeix and Lafore, JAS, 2010 ; Grandpeix et al., JAS 2010)

- Representation of a part of an infinite plane where identical cold pools (radius r, height h) are scattered with an homogeneous density $D_{\rm wk}$.
- State variables : (i) surface fraction covered by the wakes $\sigma_w = \frac{S_w}{S_t}$ ($\sigma_w = \pi r^2 D_{\rm wk}$), (ii) temperature and humidity differences (resp. $\delta\theta(p)$ and $\delta q(p)$) between wake and off-wake regions.
- Spreading speed : C_* such that $C_*^2 \simeq$ WAPE (WAke Potential Energy) ; $WAPE = \int_{p_{top}}^{p_{surf}} R_d \delta T_v \frac{dp}{p}$
- Evolutions of $\delta\theta$ and δq profiles are given by conservation equations of mass, energy and water taking into account vertical advection, turbulence and phase changes.
- Turbulence and phase change terms are assumed to be given by the deep convection scheme.
- $\delta\omega$ profile is linear between the surface and the wake top (no mass exchange through the wake boundary) ; it goes back to 0 linearly between the wake top and an arbitrary altitude (about 4000 m).

Wake differential profiles

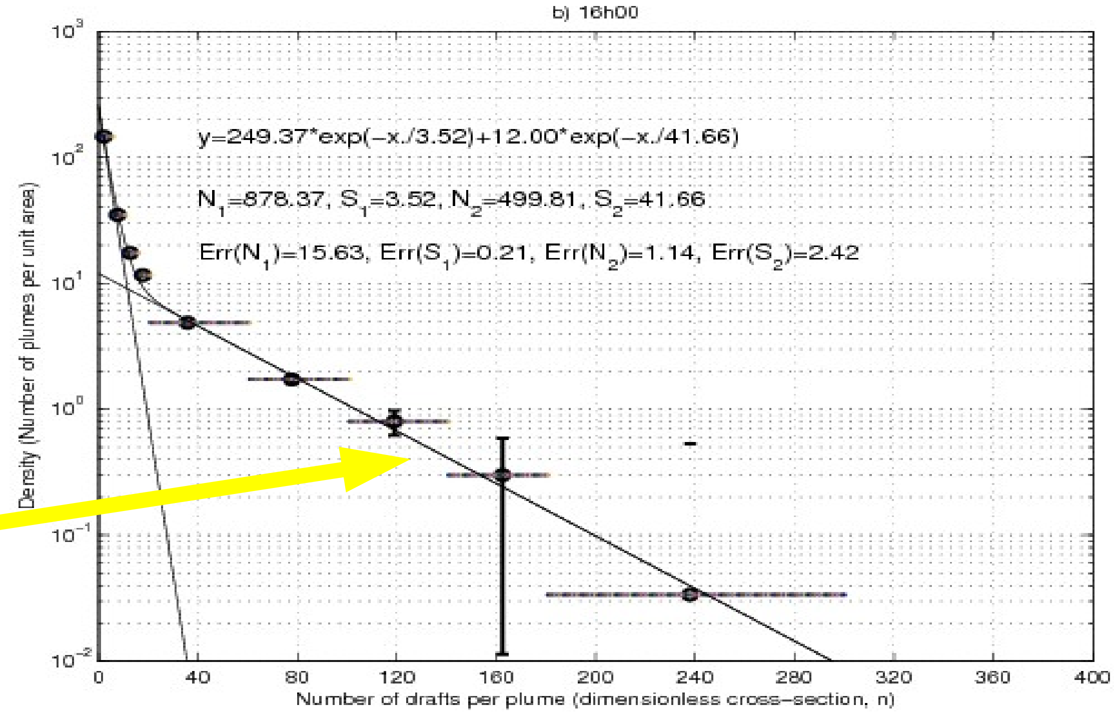


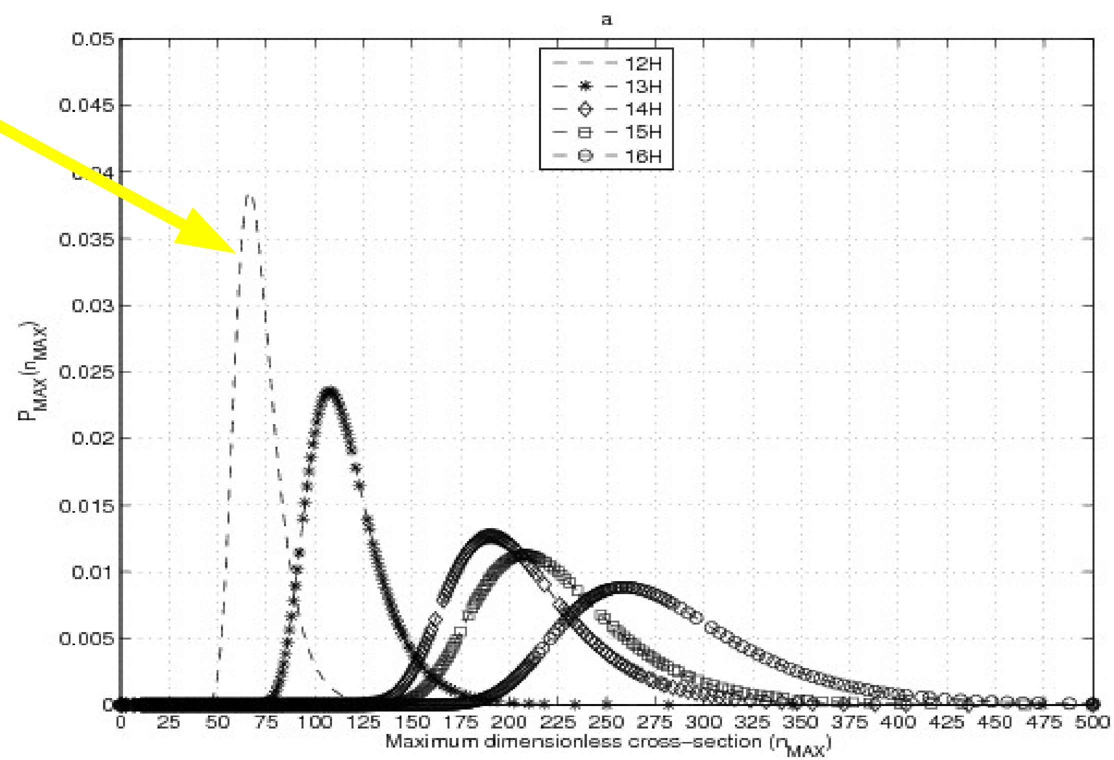
3- Stochastic physics: Deep convection triggering by boundary layer thermals

Stochastic trigger

- Analysis of LES (Large Eddy Simulation" of 10 July 2006 case over Niamey :
  1. PDF of cumulus sizes is exponential.
  2. deep convection triggers when there are large cumulus.
- Trigger = "largest cumulus size exceeds a given threshold"
- From PDF of Cu size ⟶ PDF of largest cumulus size
- From the thermal model ⟶ number of cumulus clouds per unit area
- ⟹ number of cumulo-nimbus per unit area
- ⟹ probability of triggering ; use of a random number generator to implement this probability (no trigger ⇒ ALE set to zero).

(Rochetin et al, JAS, 2014, I and II)





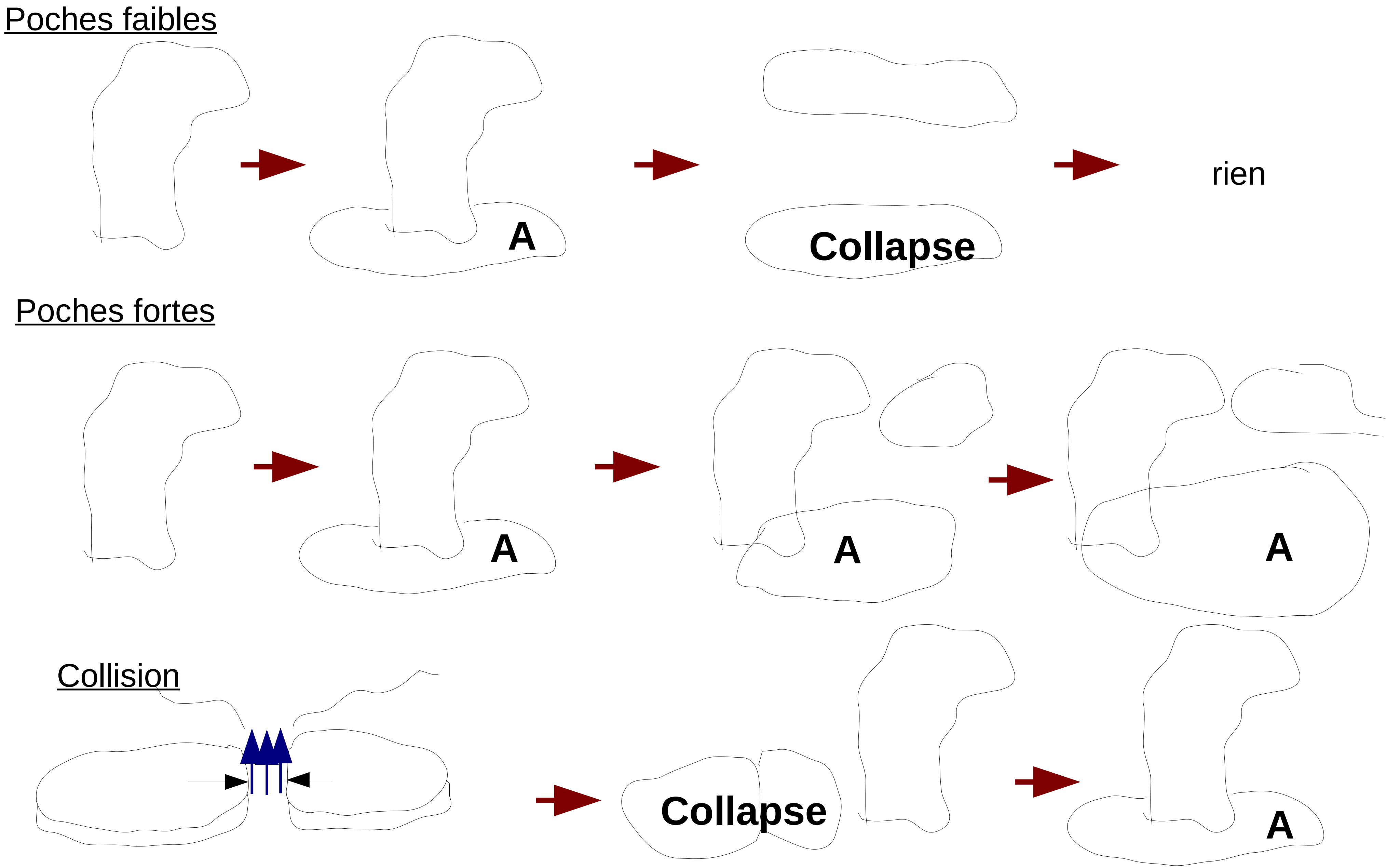
5 - The two radius scheme

Principle:

The cold pool (or wake) scheme describes a population of identical (except for the radius) circular wakes. It is supposed to represent a population of wakes of various sizes and ages, some fed by a cumulonimbus (the “active” ones), others merely collapsing. These wakes may collide or merge. The purpose of the scheme is to describe the evolution of such a diverse population while representing a population of identical wakes.

Structure:

- Two categories of wakes: active (with Cu Nimb) and inactive (collapsing). ***D*** is the number of wakes per unit area and ***A*** the number of active ones. The active wakes become inactive when their attached CBs decay. The inactive ones decay by collapsing.
- The wake radii vary by three mechanisms: (i) spread (speed C*); (ii) genesis (new cold pools are small, hence cold pool genesis induces a decrease of the mean wake area); (iii) coalescence (when colliding wakes merge, yielding a larger wake, the average size increases) and collision.
- Wake encounters: A-A and A-I encounters yield a new active wake by merging. I-I collisions yield a new small active wake while the two incoming wakes decay.


Poches faibles
A
Collapse
rien
Poches fortes
A
A
A
Collision
Collapse
A

Formulation du modèle

But : représentation pas trop compliquée d'une population de poches froides.

Départ : modèle représentant les spectres de surfaces des deux espèces de poches. Densités spectrales : $f_A(s,t)$ et $f_I(s,t)$. (s = aire des poches)

Densités spatiales des poches :

$$A(t) = \int_{s_0}^{\infty} f_A(s,t)ds \qquad I(t) = \int_{s_0}^{\infty} f_I(s,t)ds$$

Fractions surfaciques couvertes par les poches :

$$\sigma_A(t) = \int_{s_0}^{\infty} s f_A(s,t)ds \qquad \sigma_I(t) = \int_{s_0}^{\infty} s f_I(s,t)ds$$

Equations des moments du modèle specral en surfaces des poches

Équations :

$$\begin{cases} \partial_t A = B - \dfrac{A}{\tau_A} + 4\pi C_*(I^2\overline{r_I} - A^2\overline{r_A}) \\[2ex] \partial_t D = B - \dfrac{I}{\tau_I} - 4\pi\overline{r}C_* D^2 \\[2ex] \partial_t \sigma_A = Ba_0 - \dfrac{\sigma_A}{\tau'_A} + 2\pi\overline{r_A}AC_* \\ \qquad + 4\pi^2 C_*\overline{r_I^3}AI + 4\pi C_*\overline{r_I}a_0 I^2 + 4\pi C_*\overline{r_A}\sigma_I A \\[2ex] \partial_t \sigma = Ba_0 - \dfrac{\sigma_I}{\tau'_I}I + 2\pi C_* D\overline{r} \\ \qquad - 4\pi C_*\overline{r_I}I^2(\pi\dfrac{\overline{r_I^3}}{\overline{r_I}} + \pi\overline{r_I^2} - a_0) \end{cases}$$

A noter : intervention de rayons moyens, de rayons carrés moyens, de rayons cubes moyens, de temps de vie inverses moyens.

Naissances

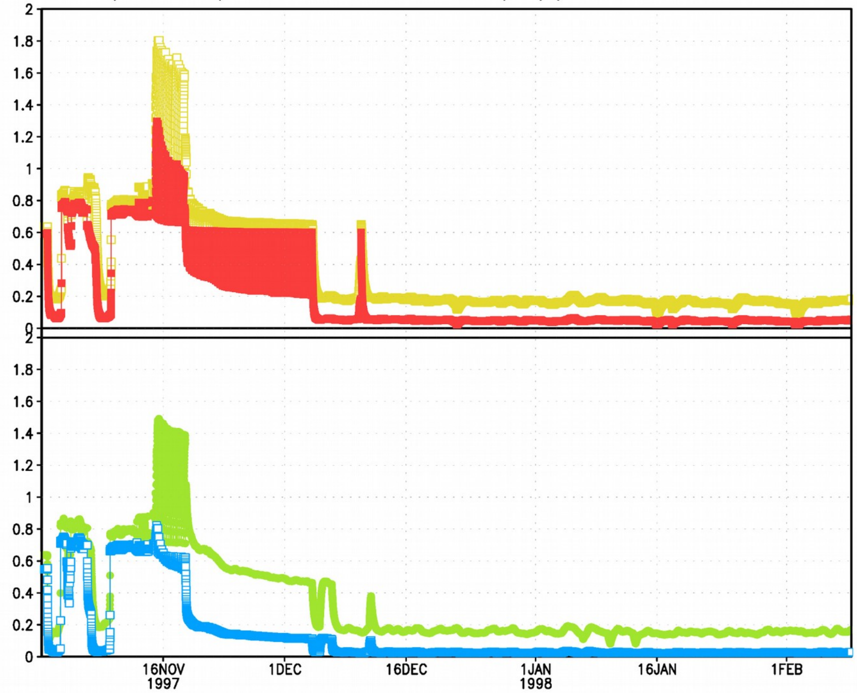
Morts

Équations simplifiées : approximations $\overline{r_I^2} \simeq \overline{r_I}^2 \ldots$

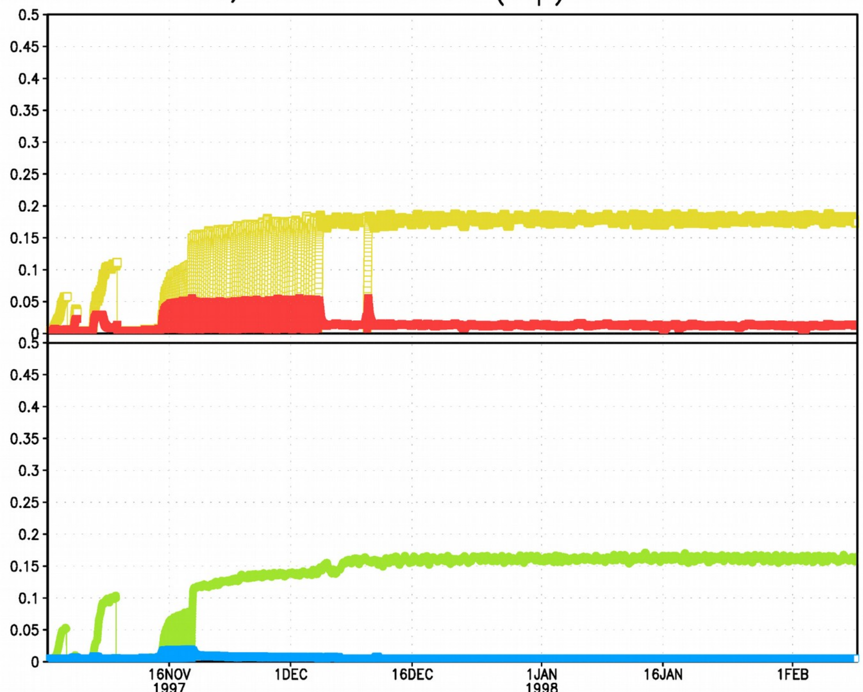
$$\left\{\begin{array}{lll}
\partial_t A & = & B - \dfrac{A}{\tau_A} + 4\pi C_*(I^2 r_I - A^2 r_A) \\[2ex]
\partial_t D & = & B - \dfrac{I}{\tau_I} - 4\pi\overline{r} C_* D^2 \\[2ex]
\partial_t \sigma_A & = & B a_0 - \dfrac{\sigma_A}{\tau_A} + 2\pi r_A C_* A \\
& & + 4\pi^2 C_* r_I^3 A I + 4\pi C_* r_I a_0 I^2 \\
& & + 4\pi C_* r_A \sigma_I A \\[2ex]
\partial_t \sigma & = & B a_0 - \dfrac{\sigma_I}{\tau_I} + 2\pi C_* D \overline{r} \\
& & - 4\pi C_* r_I I^2 (2\pi r_I^2 - a_0)
\end{array}\right.$$

Etalement

Wake densities (*1.e10); TauA = 8000s (top) and TauA = 4000s (



Wake fractionnal areas; TauA = 8000s (top) and TauA = 4000s (



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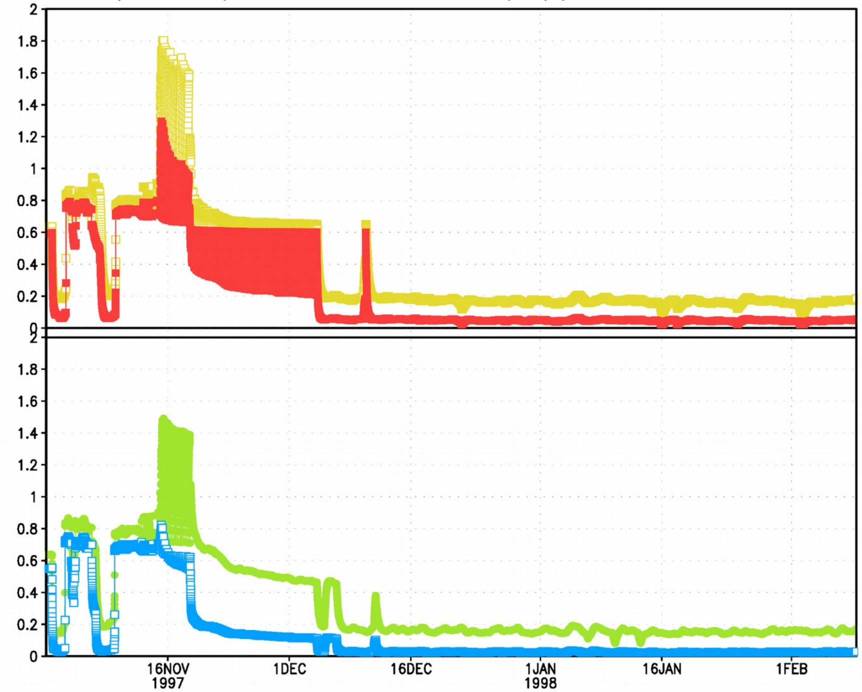

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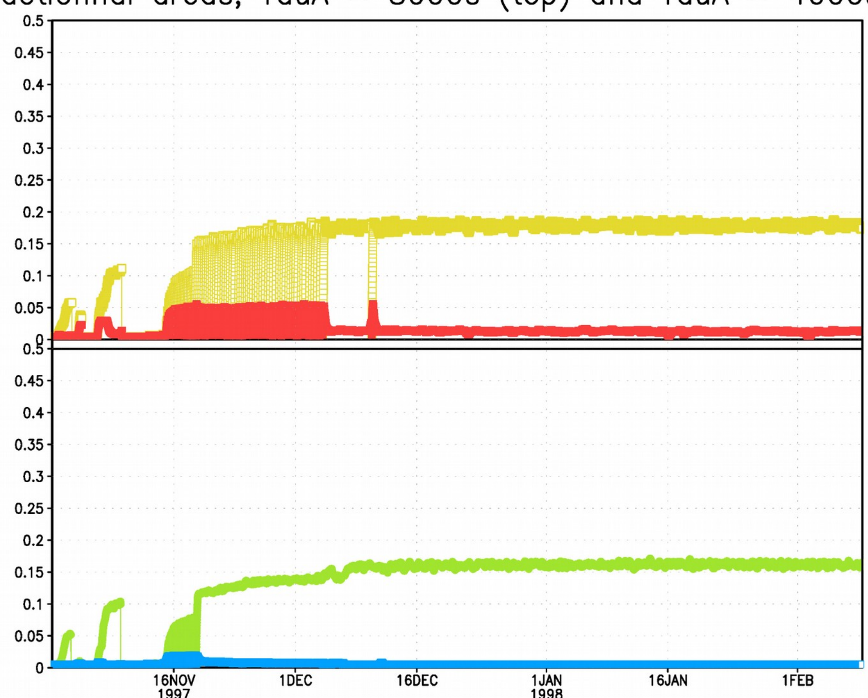
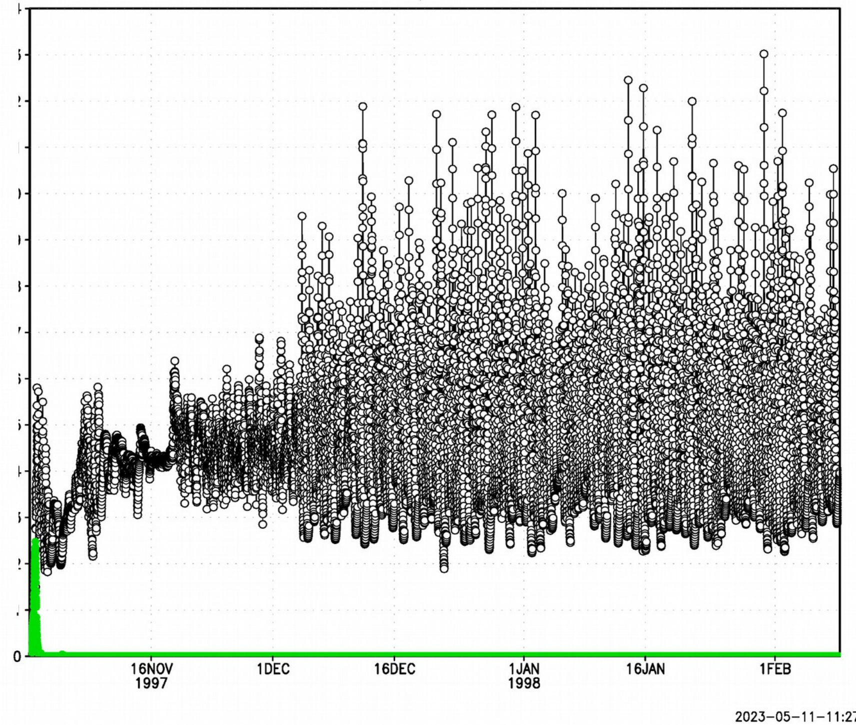
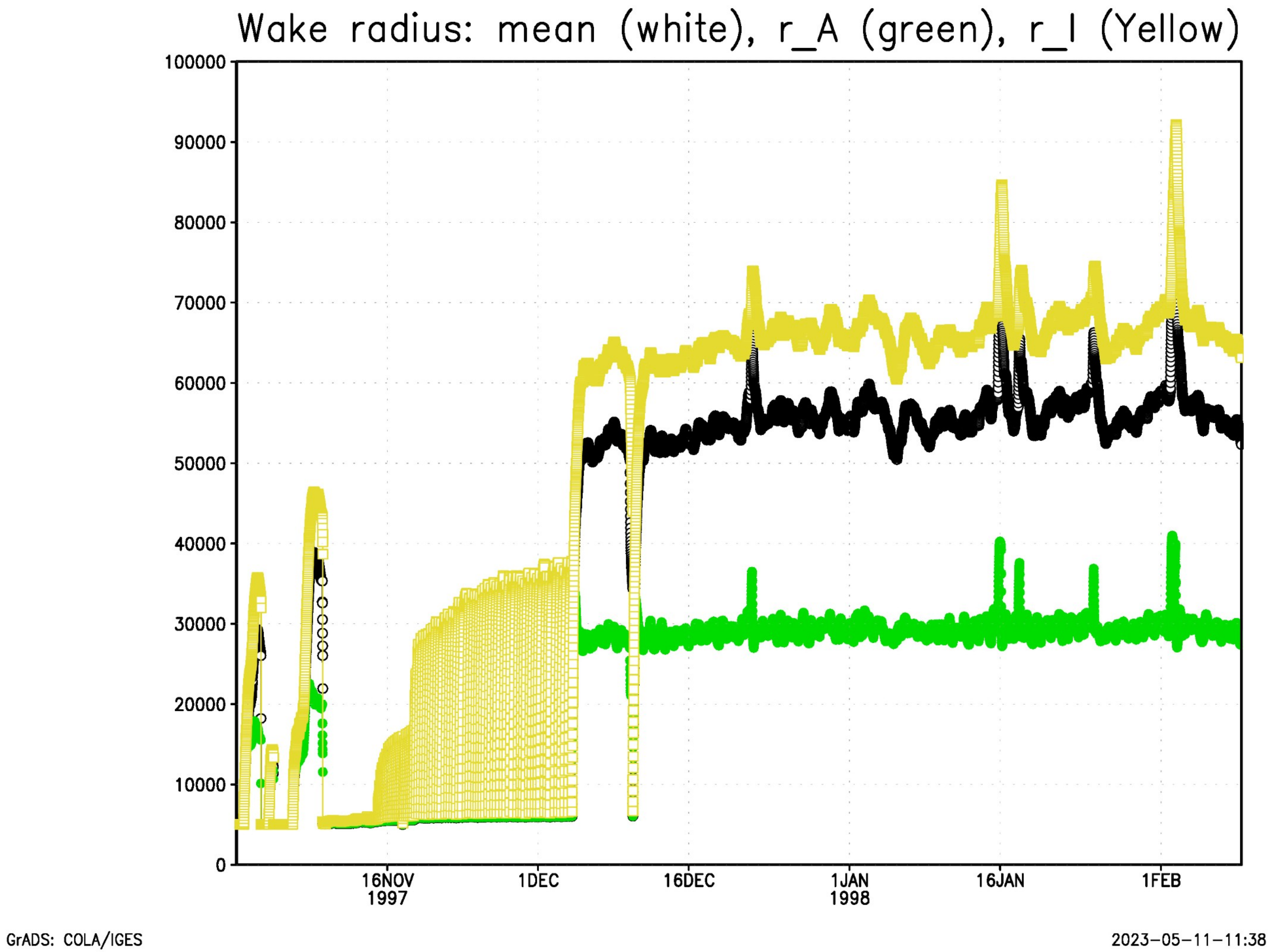


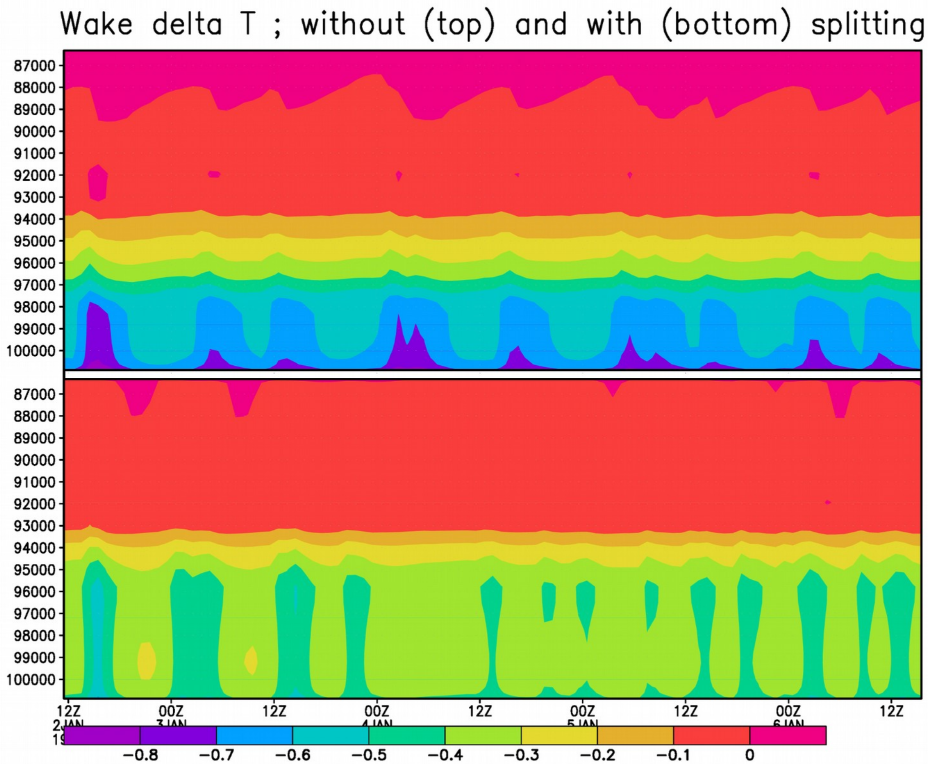
Precipitation

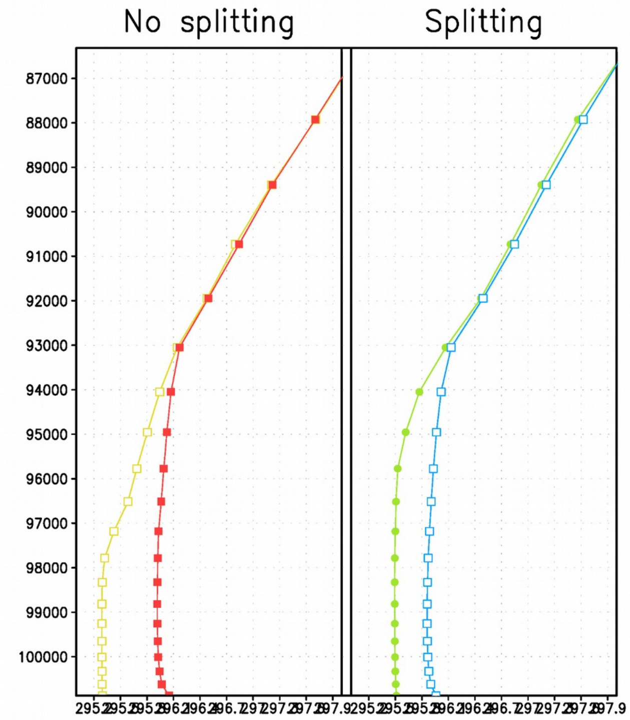




Wake radius: mean (white), r_A (green), r_I (Yellow)
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
16NOV
1997
1DEC
16DEC
1JAN
1998
16JAN
1FEB
GrADS: COLA/IGES
2023-05-11-11:38

Effet du splitting





Tw and Tx

Temperature difference Tw-Tx

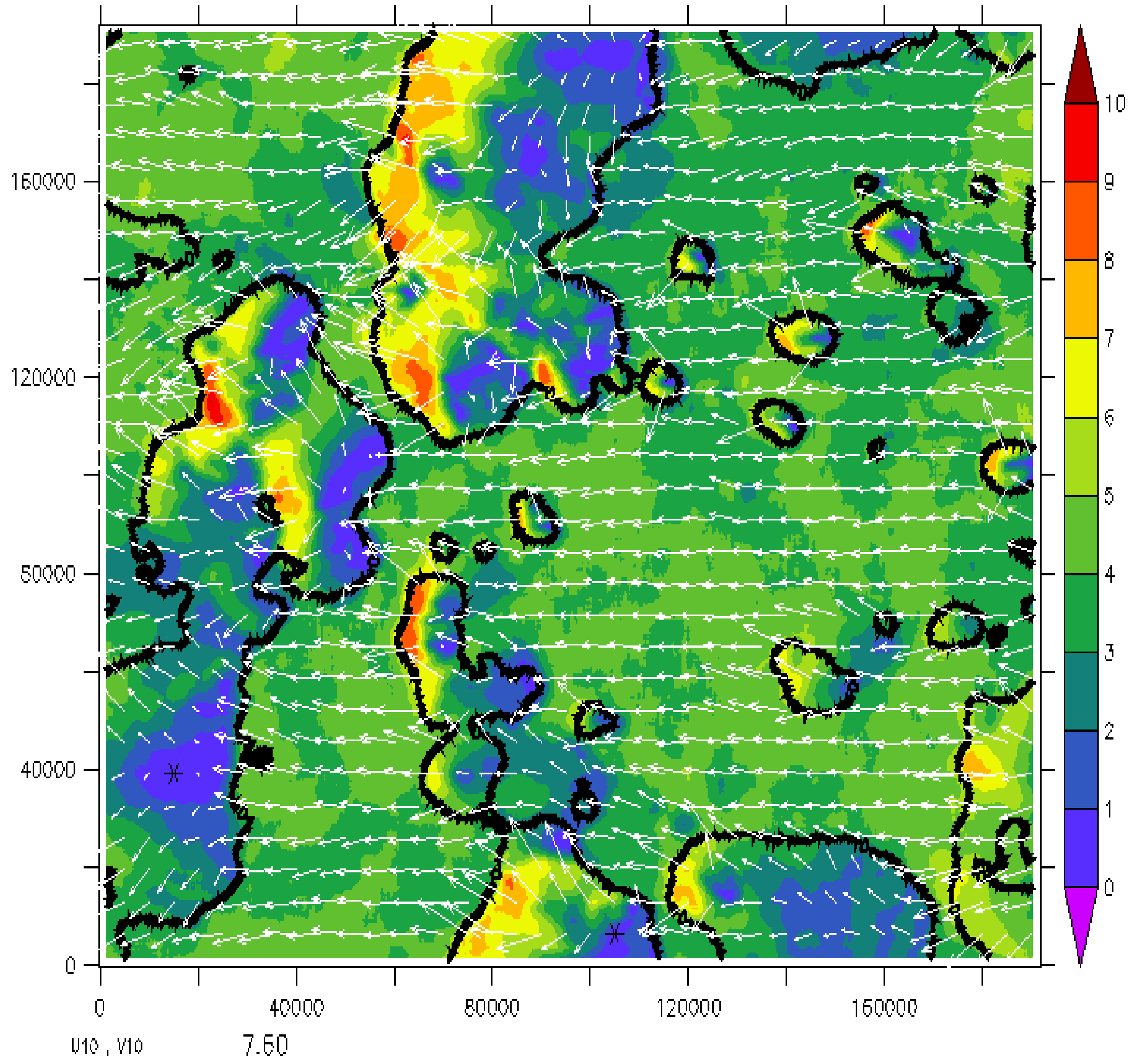
Importance de la couche bien melangee dans les poches (surtout avec splitting).
Contradiction avec les LES ?

Perspective

- Le nouveau modèle de dynamique de la population des poches froides a deux rayons semble raisonable et prometteur.

- Mais résultats très préliminaires : manquent des études de sensibilité aux divers parametres.
- Le modele converge vers un point fixe peu compatible avec ce que l'on attend.
- Le temps de vie des poches actives semble un parametre important. Necessite de coupler plus directement la dynamique de population avec le schema convectif.

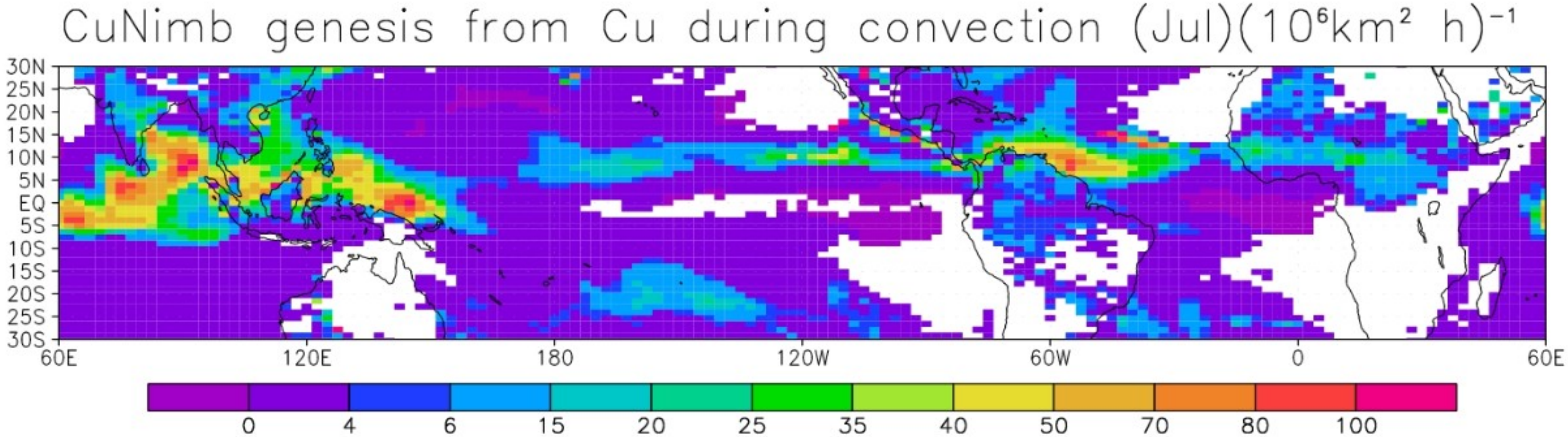
LES SAM

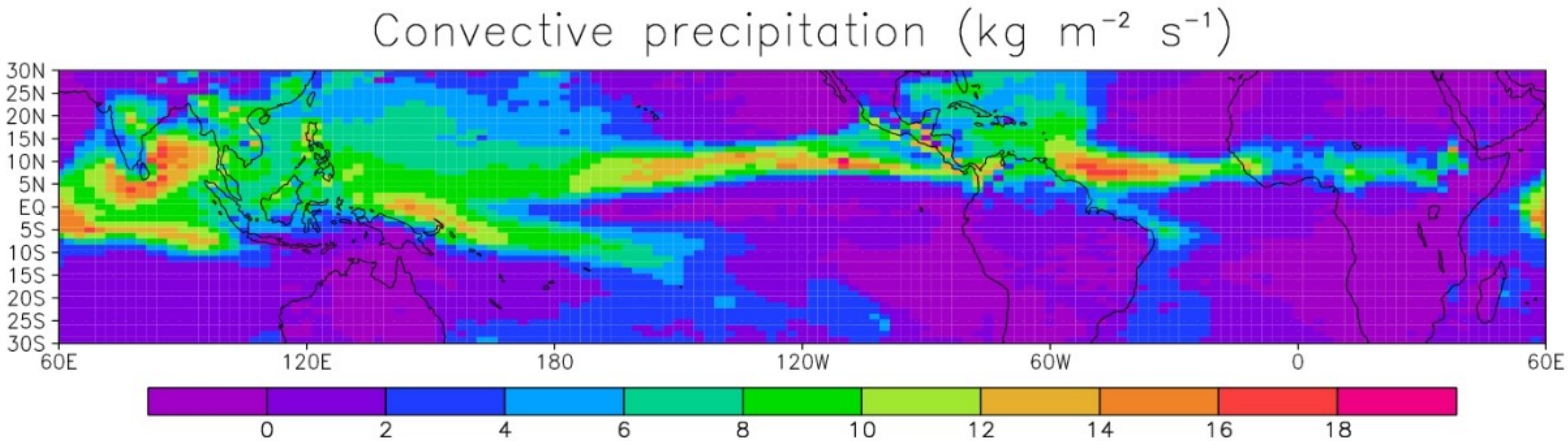


160000
120000
80000
40000
0
0
40000
80000
120000
160000
U10 , V10
7.60
10
9
8
7
6
5
4
3
2
1
0

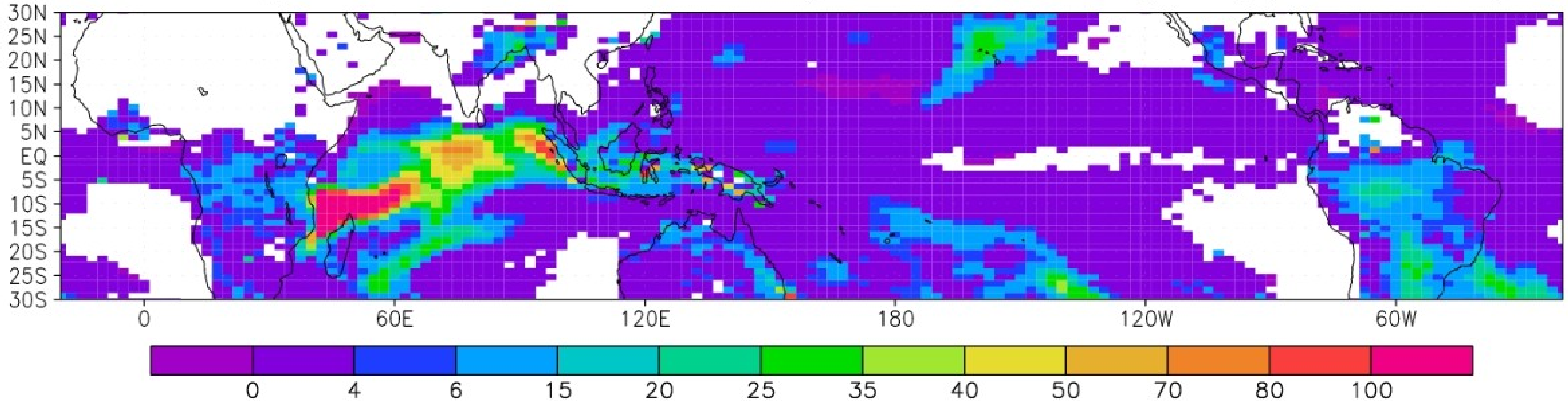
4 -Cumulonimbus & cold pool genesis

CuNimb genesis rate diagnosed from an LMDZ AMIP simulation. The order of Magnitude looks reasonable: up to a hundred per million km2 and per hour over ocean; half a dozen over Sahel in July.





CuNimb genesis from Cu during convection (Feb)$(10^6 km^2\ h)^{-1}$



Convective precipitation $(kg\ m^{-2}\ s^{-1})$