Test d'advection d'un pic Gaussien

Distribution initiale

Solution exacte (translation)

U constant, nombre de Courant U dt/dx = 0,2

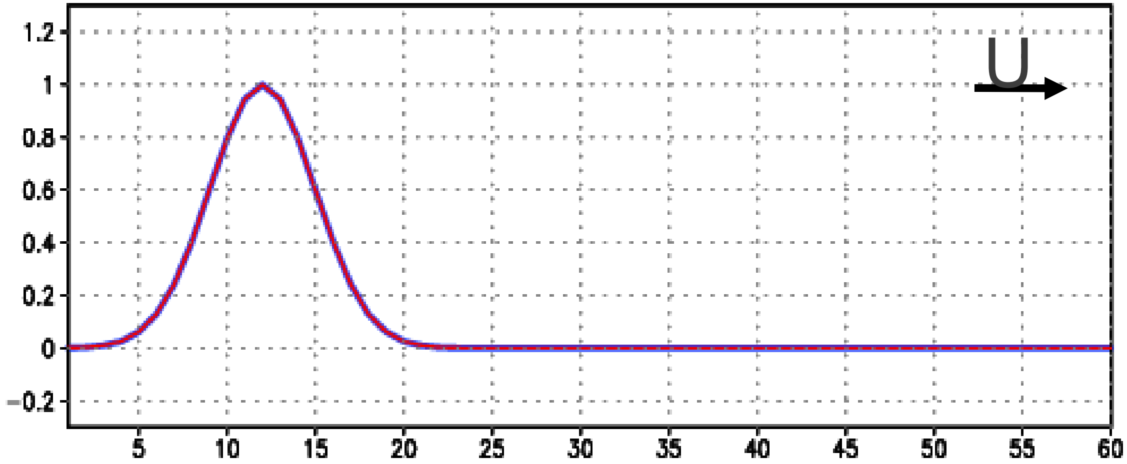
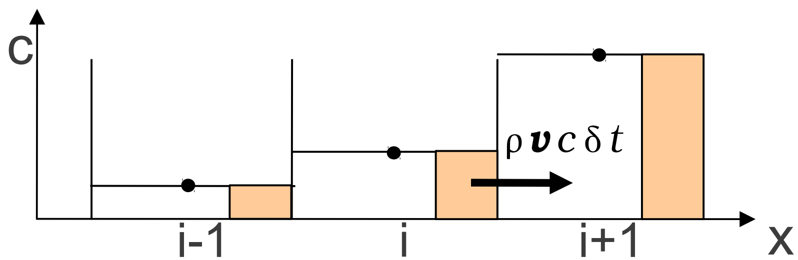


Schéma amont (Godunov, 1952)




Test d'advection d'un pic Gaussien

Distribution initiale

Solution exacte (translation)

Calcul avec schéma d'advection

U constant, nombre de Courant U dt/dx = 0,2

Advection avec le schéma amont ou semi-lagrangien d'ordre 1

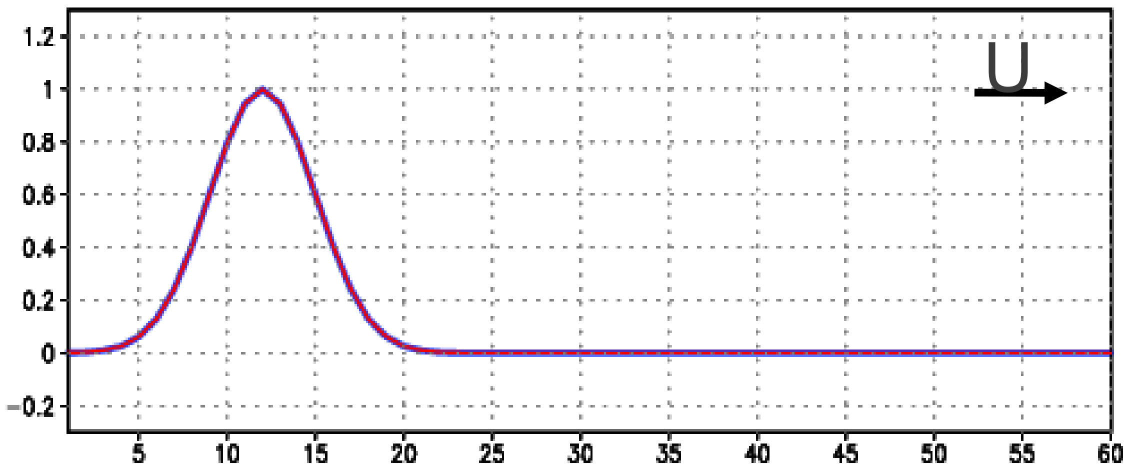
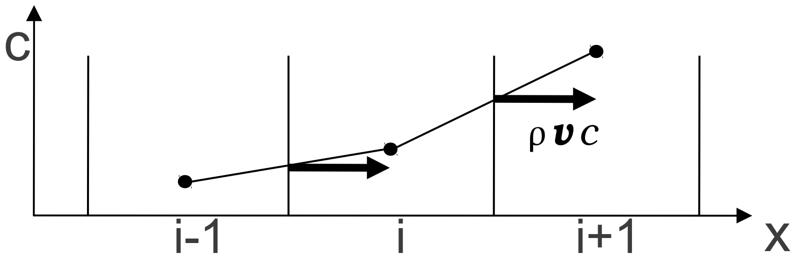



Schéma diffusif et peu précis

Différences finies centrées (second ordre)




Test d'advection d'un pic Gaussien
Distribution initiale
Solution exacte (translation)
Calcul avec schéma d'advection
U constant, nombre de Courant U dt/dx = 0,2

Advection avec le schéma en différences finies centré d'ordre 2

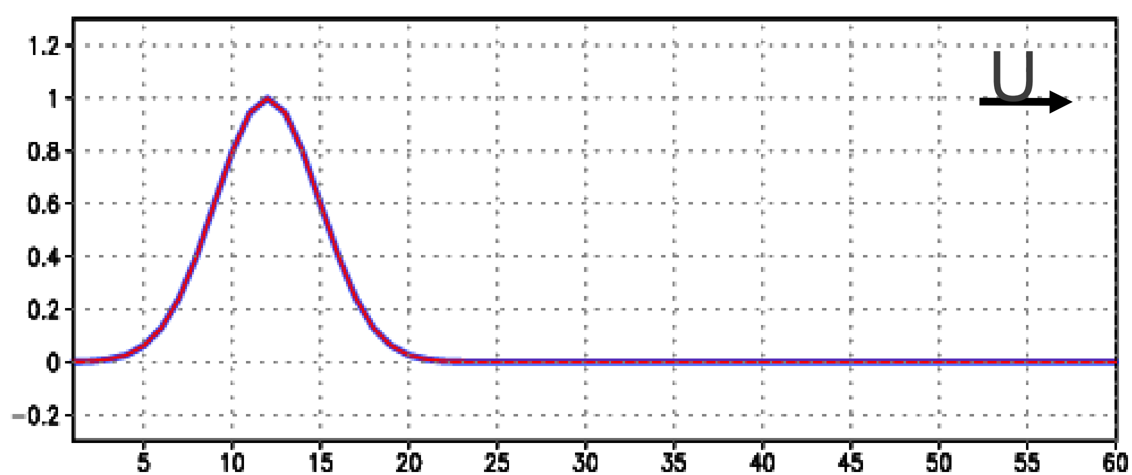
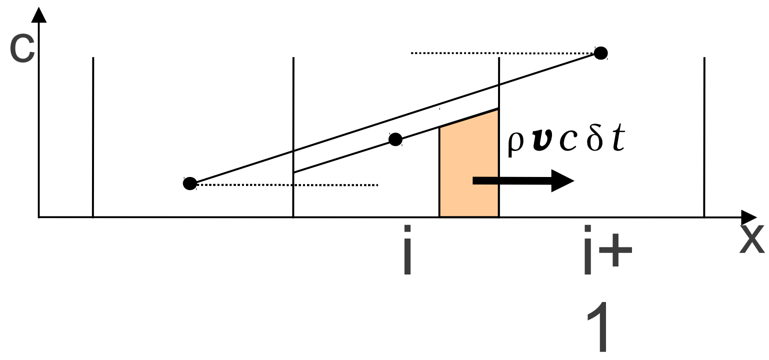



Schéma précis mais création de valeur négative et instabilité

Schéma I de Van Leer (1977)




Test d'advection d'un pic Gaussien

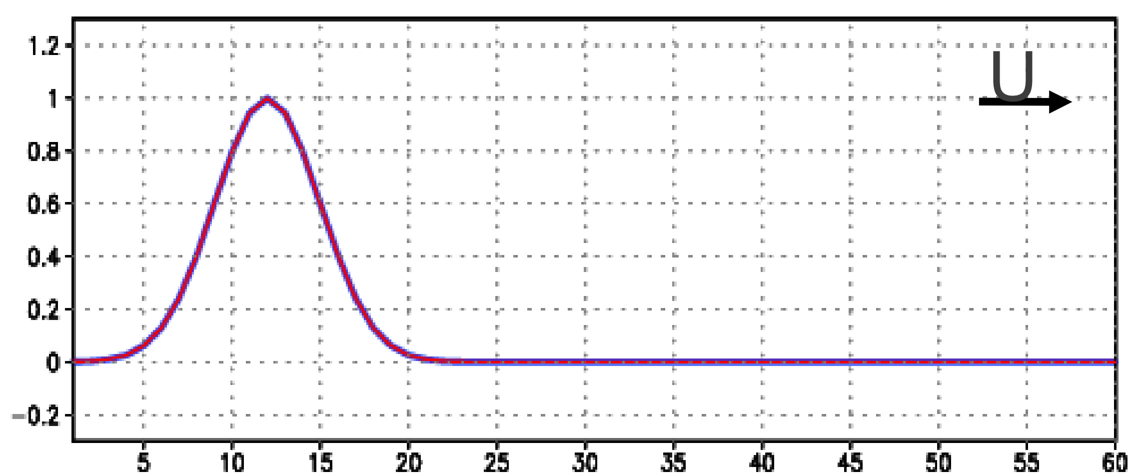
Distribution initiale

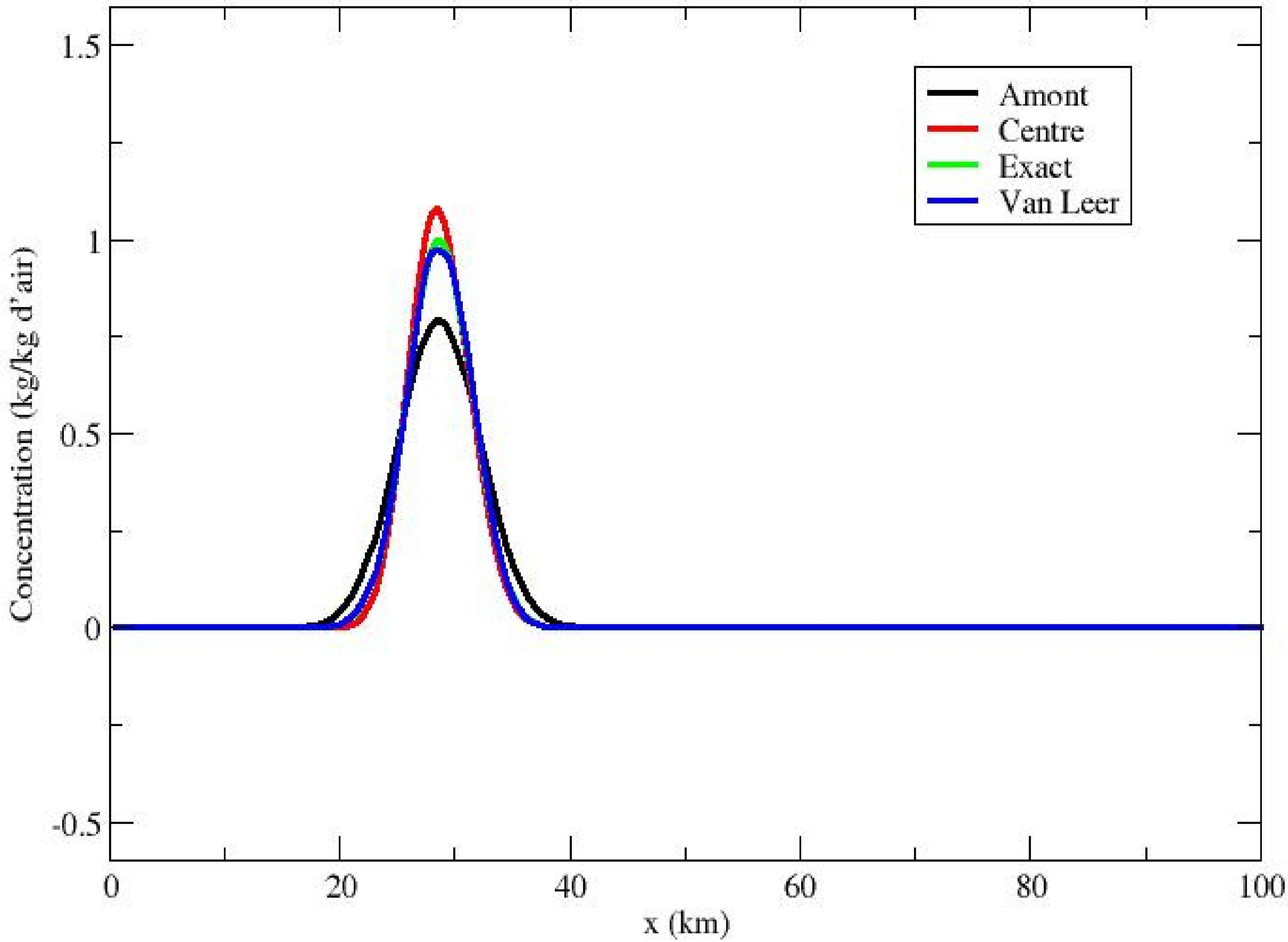
Solution exacte (translation)

Calcul avec schéma d'advection

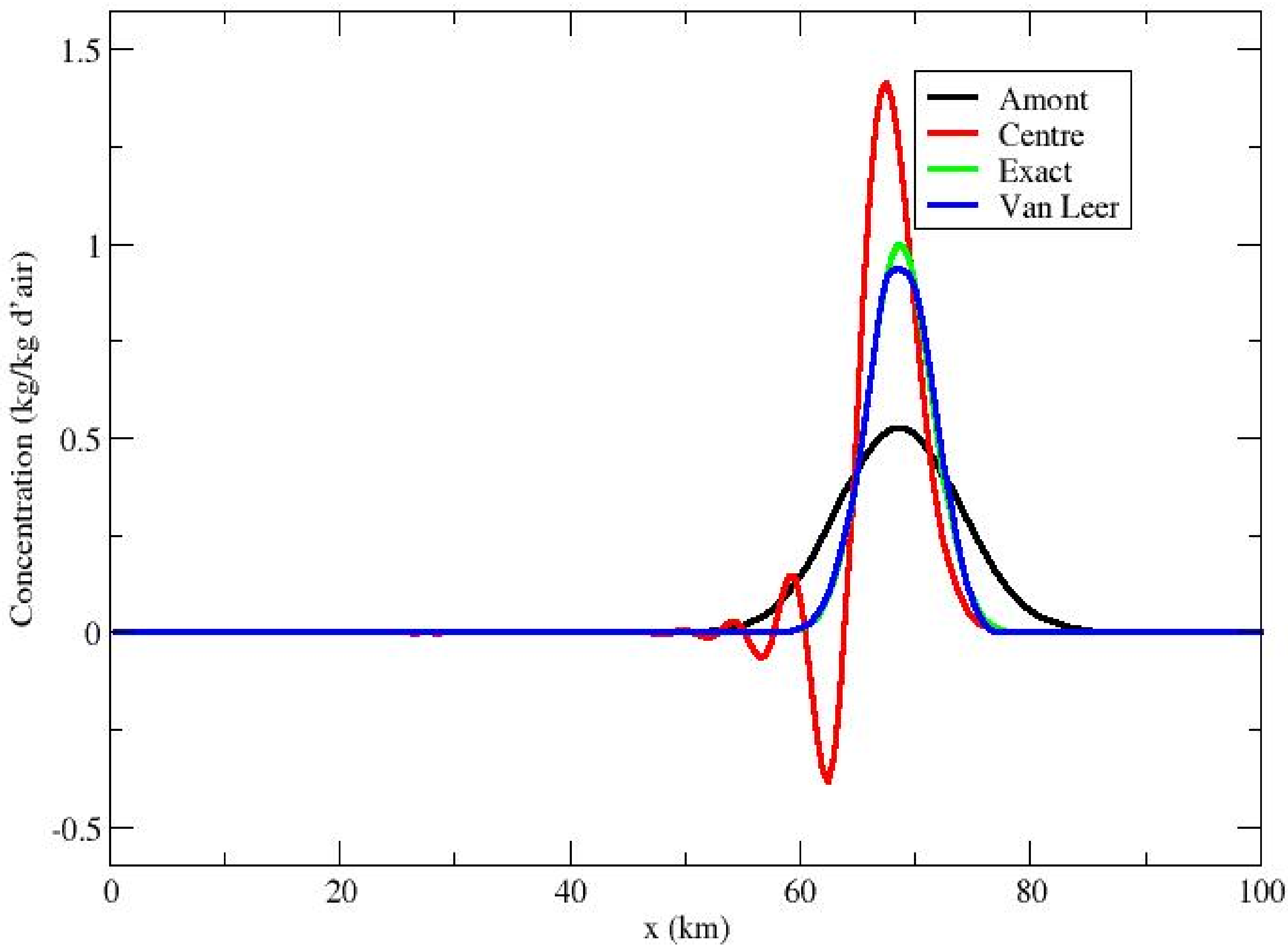
U constant, nombre de Courant U dt/dx = 0,2

Advection avec le schéma volumes finis d'ordre 2 de Van Leer

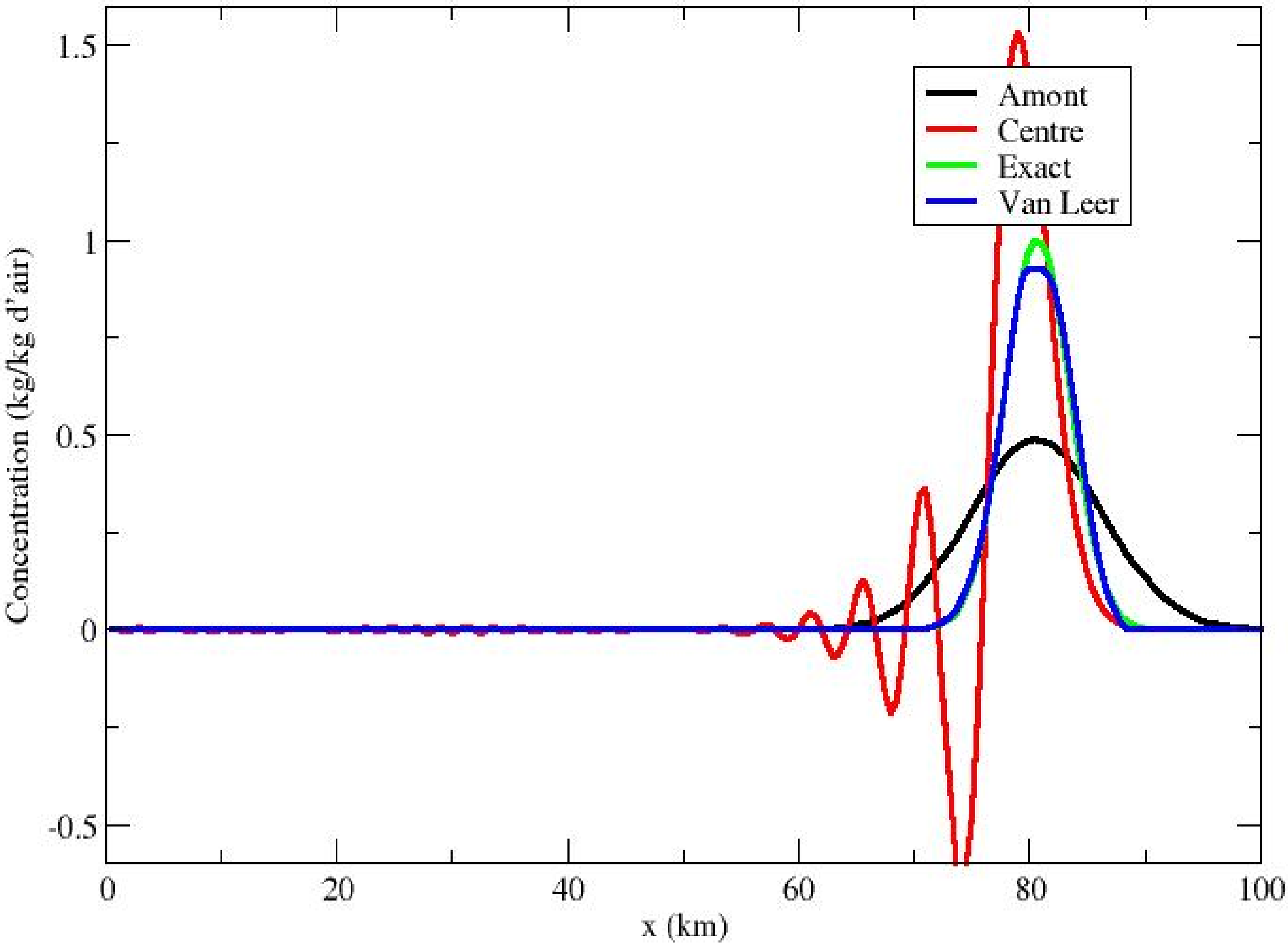




Amont
Centre
Exact
Van Leer
Concentration (kg/kg d'air)
x (km)
1.5
1
0.5
0
-0.5
0
20
40
60
80
100



Amont
Centre
Exact
Van Leer
1.5
1
0.5
0
-0.5
Concentration (kg/kg d'air)
0
20
40
60
80
100
x (km)


Amont
Centre
Exact
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Concentration (kg/kg d'air)
x (km)
1.5
1
0.5
0
-0.5
0
20
40
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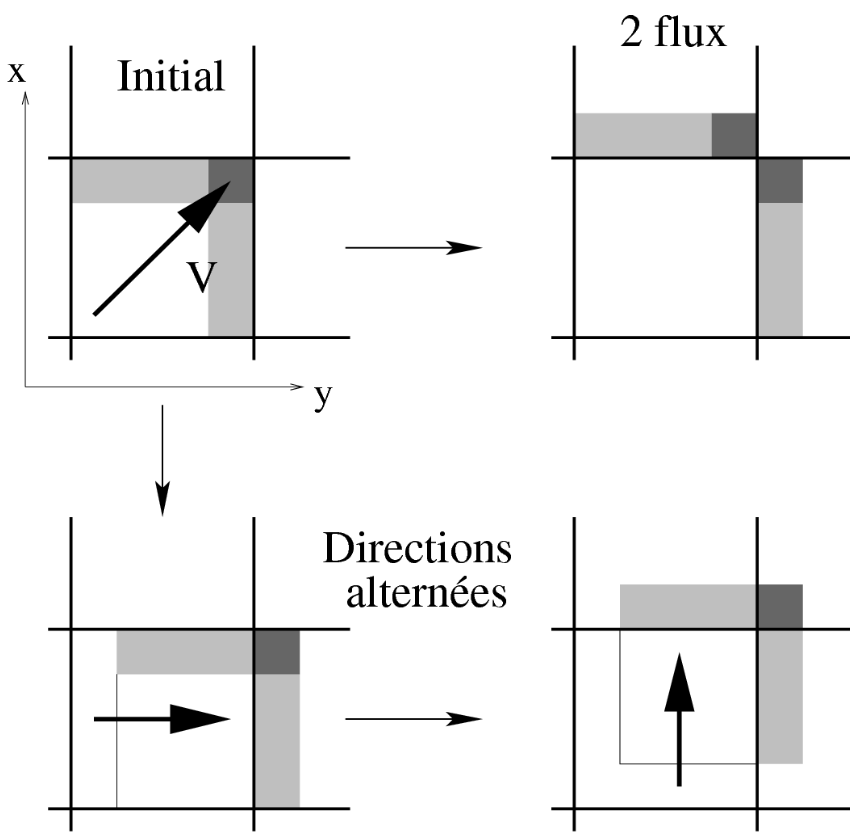
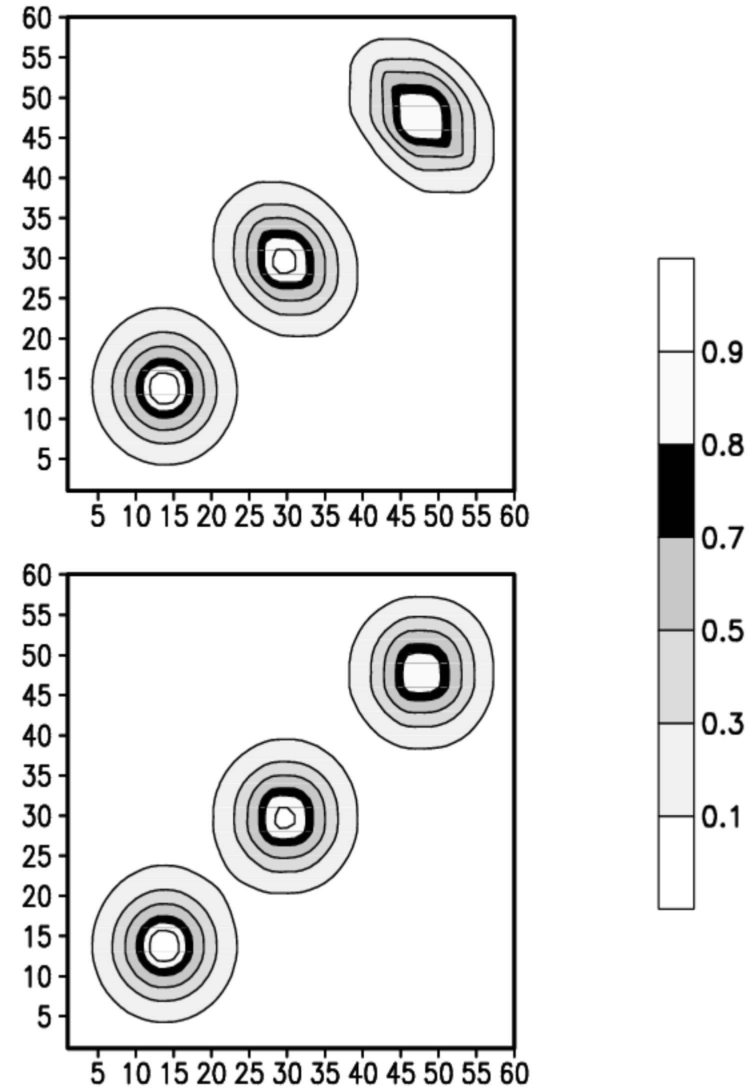
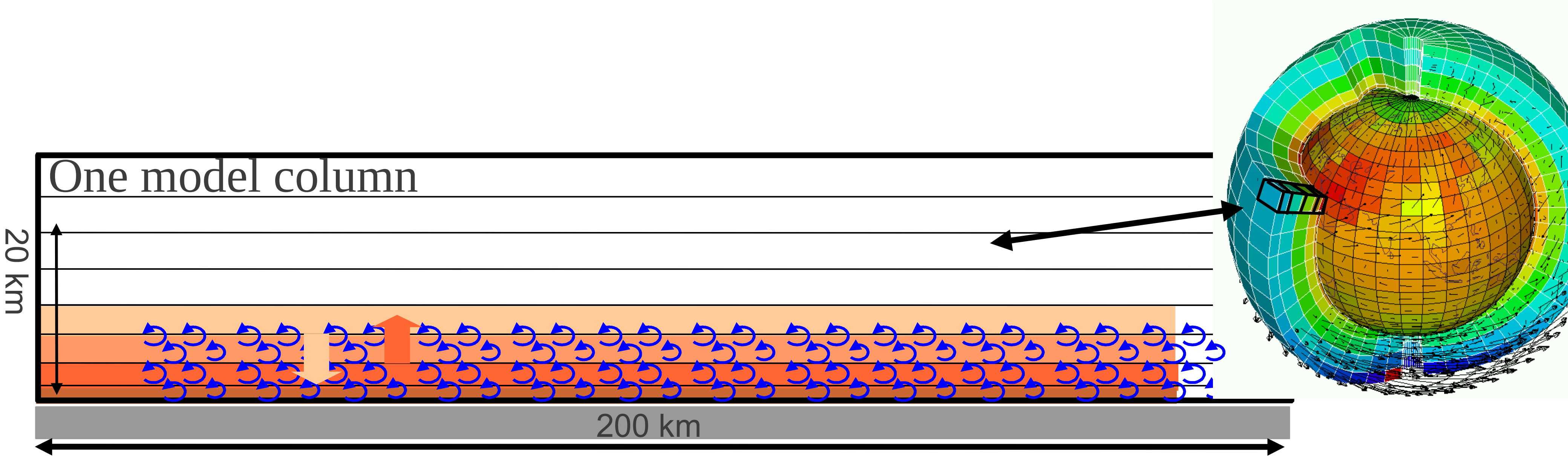
100


Initial
2 flux
x
y
V
Directions
alternées


60
55
50
45
40
35
30
25
20
15
10
5
5 10 15 20 25 30 35 40 45 50 55 60
60
55
50
45
40
35
30
25
20
15
10
5
5 10 15 20 25 30 35 40 45 50 55 60
0.9
0.8
0.7
0.5
0.3
0.1

## II.1 Thermal plumes and clouds




**Classical approach :**

→ **« Turbulent mixing » or diffusion**
Mixing by small scale random motion
Analogous to molecular diffusion

$Dq/Dt = Sq$ avec $Sq = \frac{\partial}{\partial z}\left( K_z \frac{\partial q}{\partial z} \right)$

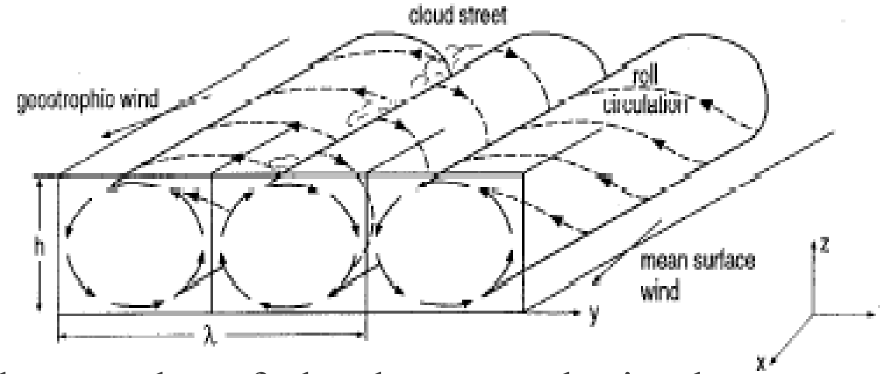
→ Computation of Kz : a field of research

*Kz = f (dU/dz, dθ/dz,e,...)*

*New equations, new parameters ...*

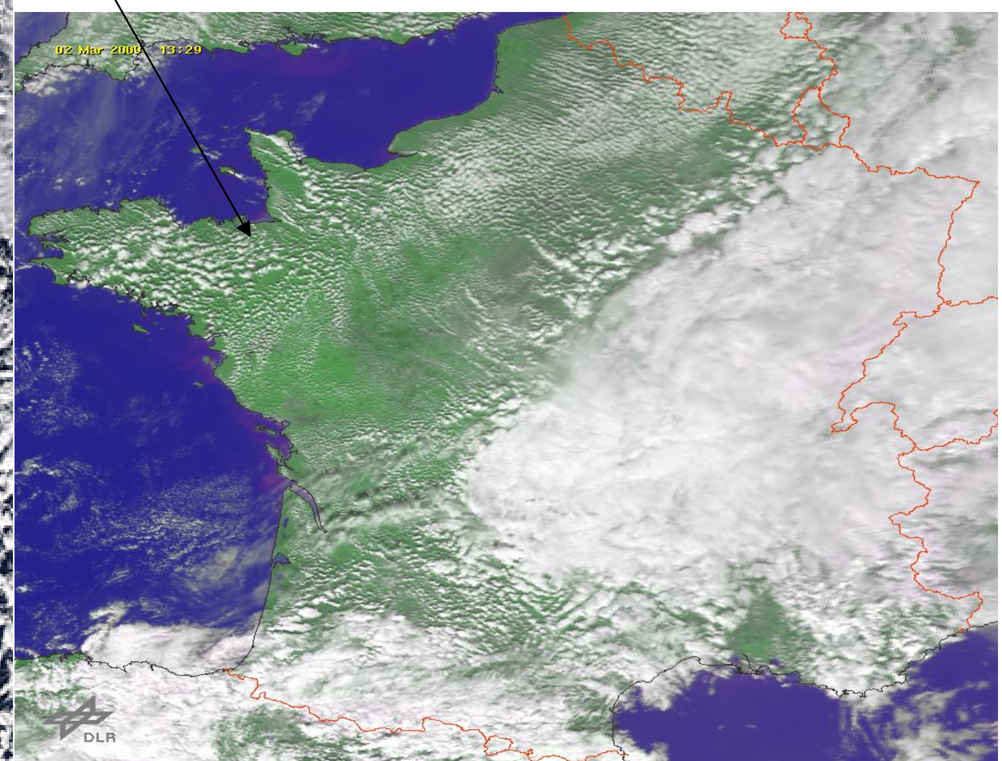
# Importance of organized structures
# Visualized by cloud streets

Atkinson & al., 1996)




Classical exemples of cloud streets obtained at the top of thermal rolls

- Polar air arriving on warm air masses
- Entry of maritime air on a warmer continent

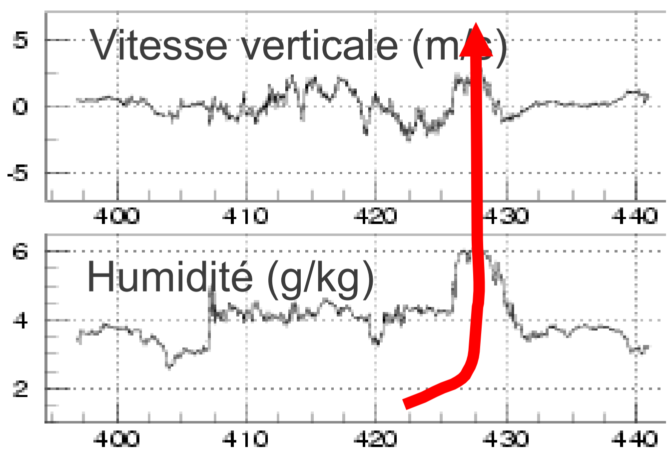


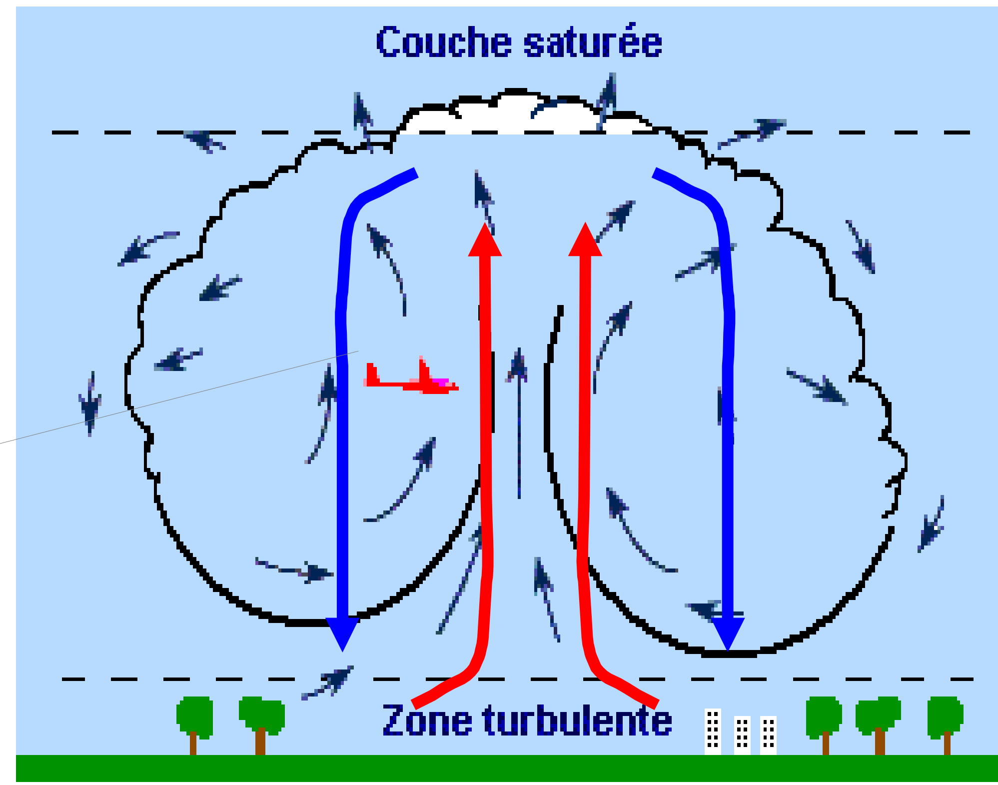
## III. Illustration de la méthodologie de développement et d'évaluation sur des développements en cours

Turbulence isotrope de petite échelle → mélange turbulent

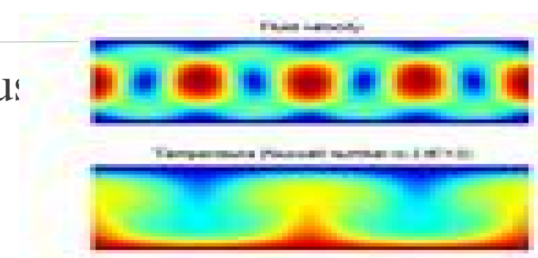
**Turbulence atmosphérique :**
**“méso-échelle”, organisée et anistrope**

Exemples de mesures avion en palier
(région parisienne, conditions estivales, cumulus)

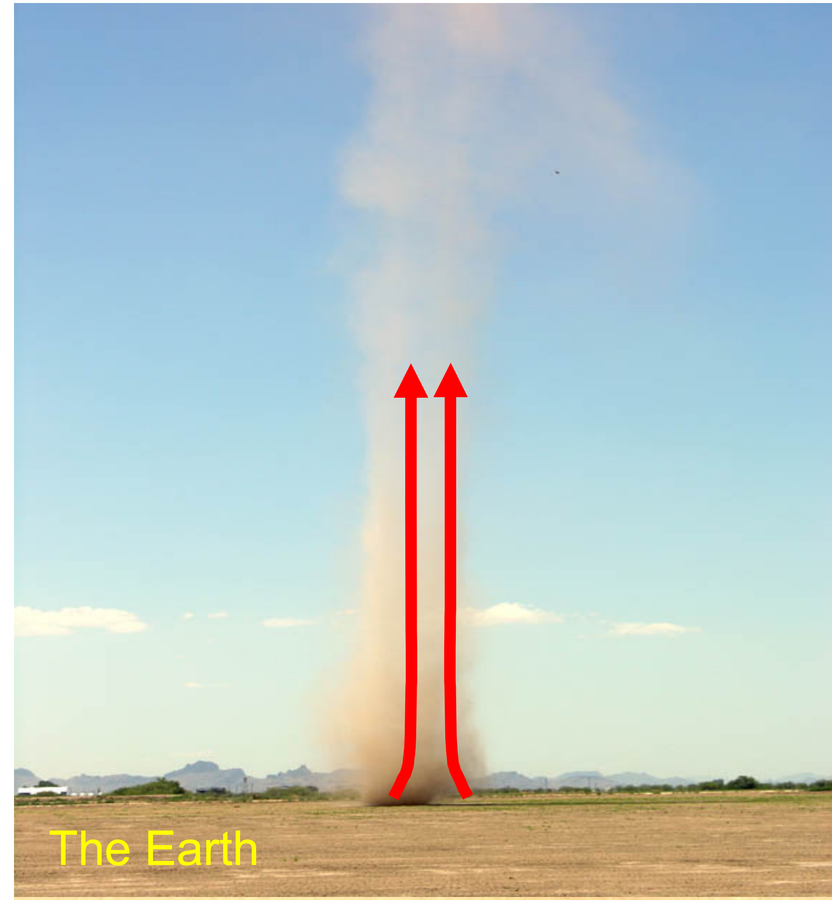


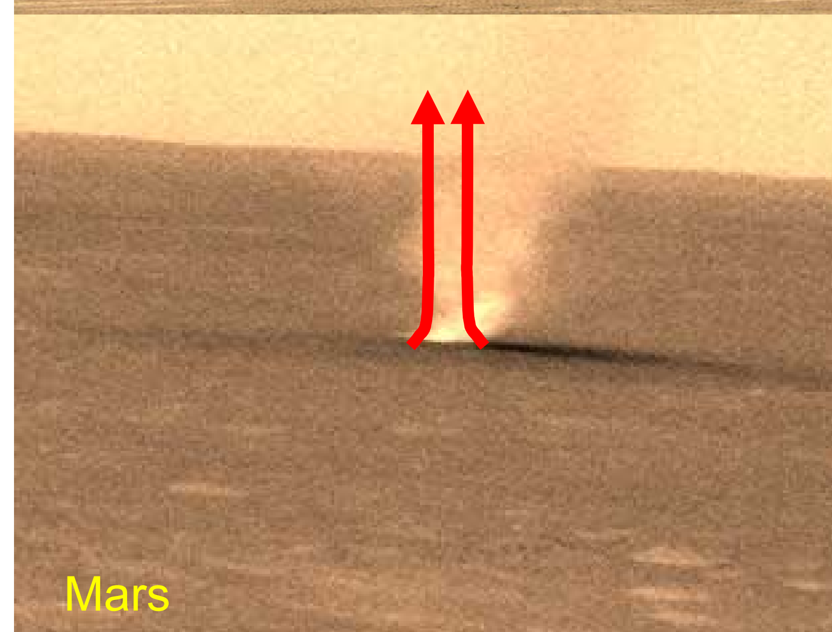




- L'air chaud (léger) et humide monte de la surface sous l'effet des forces d'Archimède.
- Analogue à la convection de Rayleigh-Benard
- En montant cet air se refroidit (détente adiabatique) et ne peut plus contenir autant de vapeur d'eau.
- Si saturation : apparition de cumulus en haut du panache .



# II.1 Thermal plumes and clouds




## Genesis of the thermal plume approach

**Mass flux schemes**

→ mass flux schemes already used but essentially for clouds and deep convection

→ dry convective boundary layer were given a weaker priority

**Origin of the LMD thermal plume model (2002) :**

→ motivated by the Martian climate : Mars is a global desert with very strong and frequent dry convection

→ Inspired by air plane observations during the Trac campaign (Paris area)

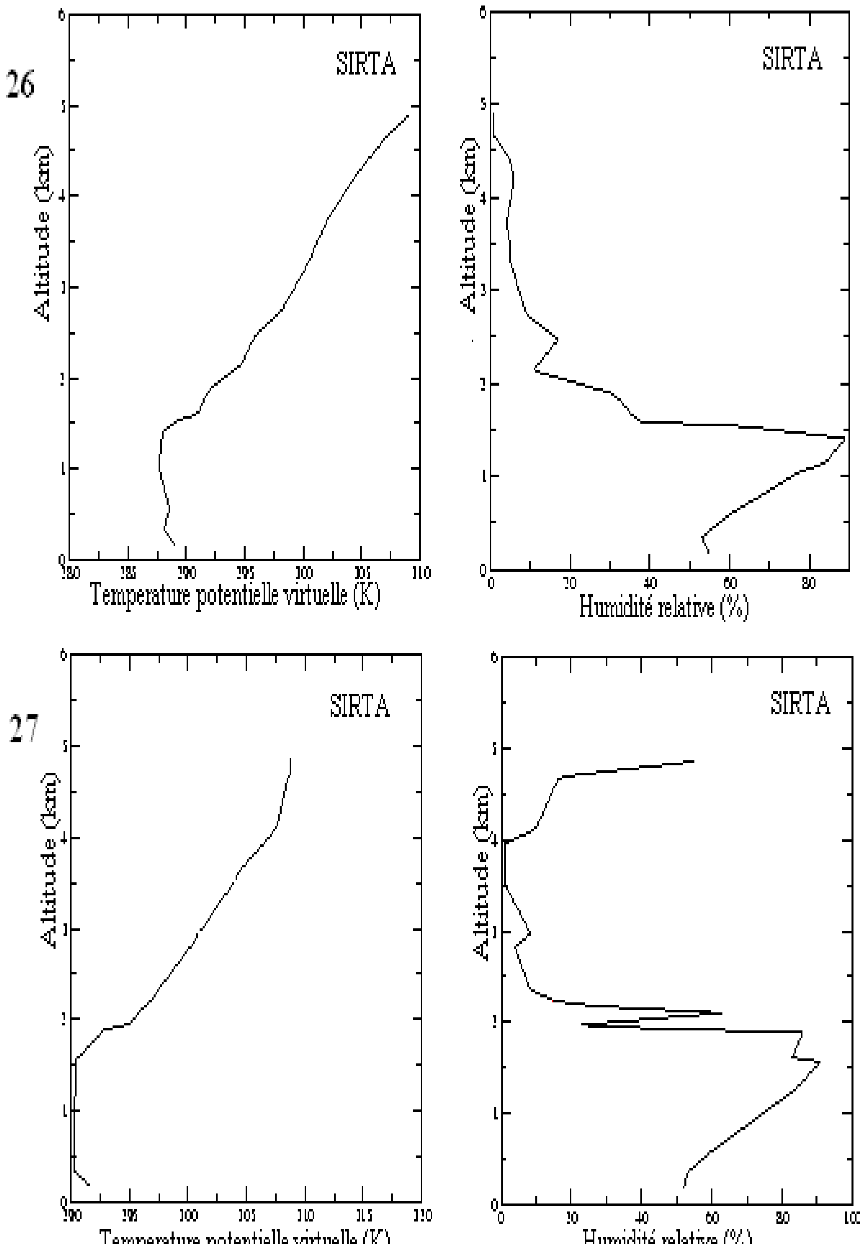
**Other origins :**

→ First paper proposing the combination of a diffusive approach and mass flux scheme for the convective boundary layer (Chatfield, 1985)

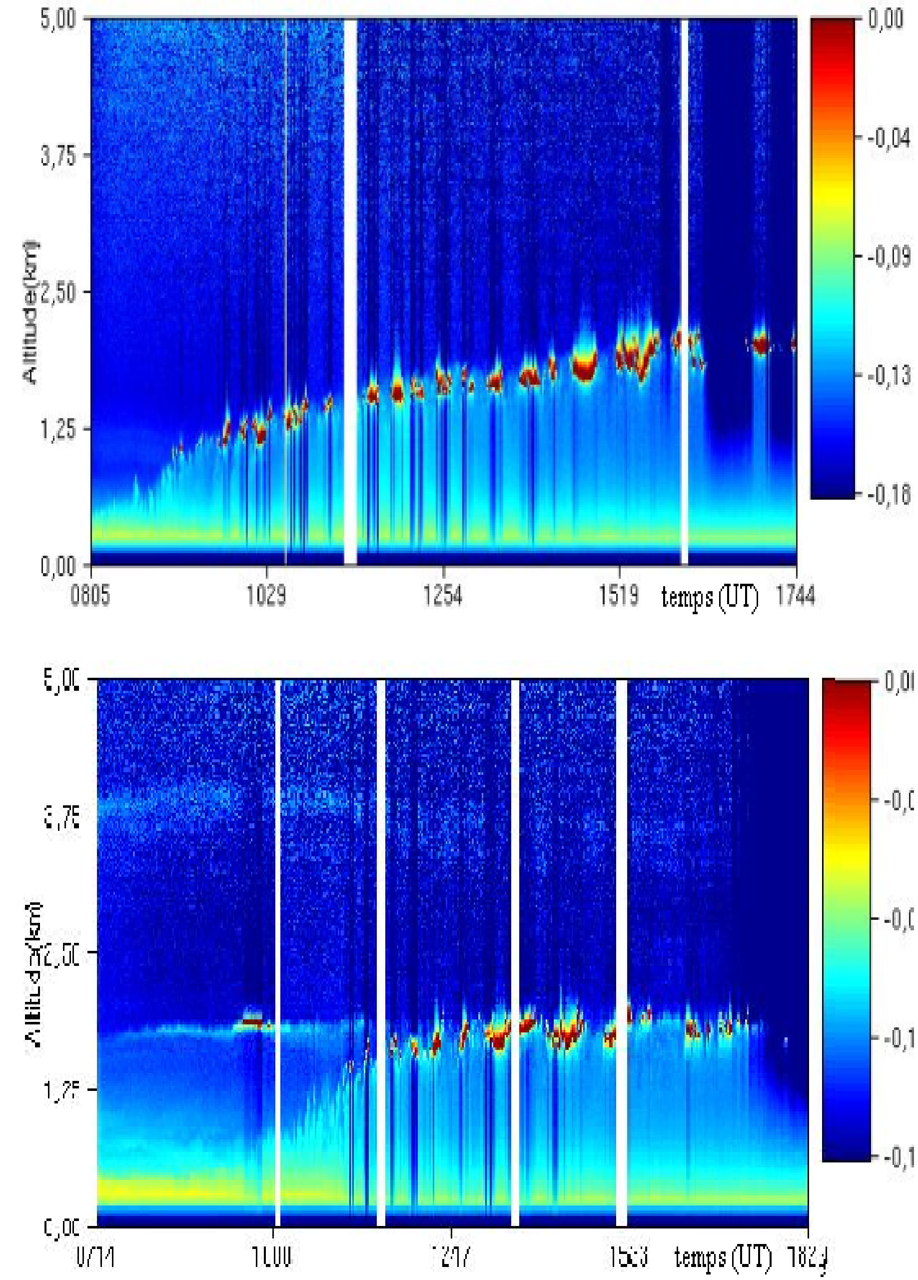
→ Independent parameterization issued from the GCSS and eurocs community (Siebesma and collaborators, 2004)

Exemple d'observations de la couche limite en région parisienne

Sondages de Trappes (Paris)

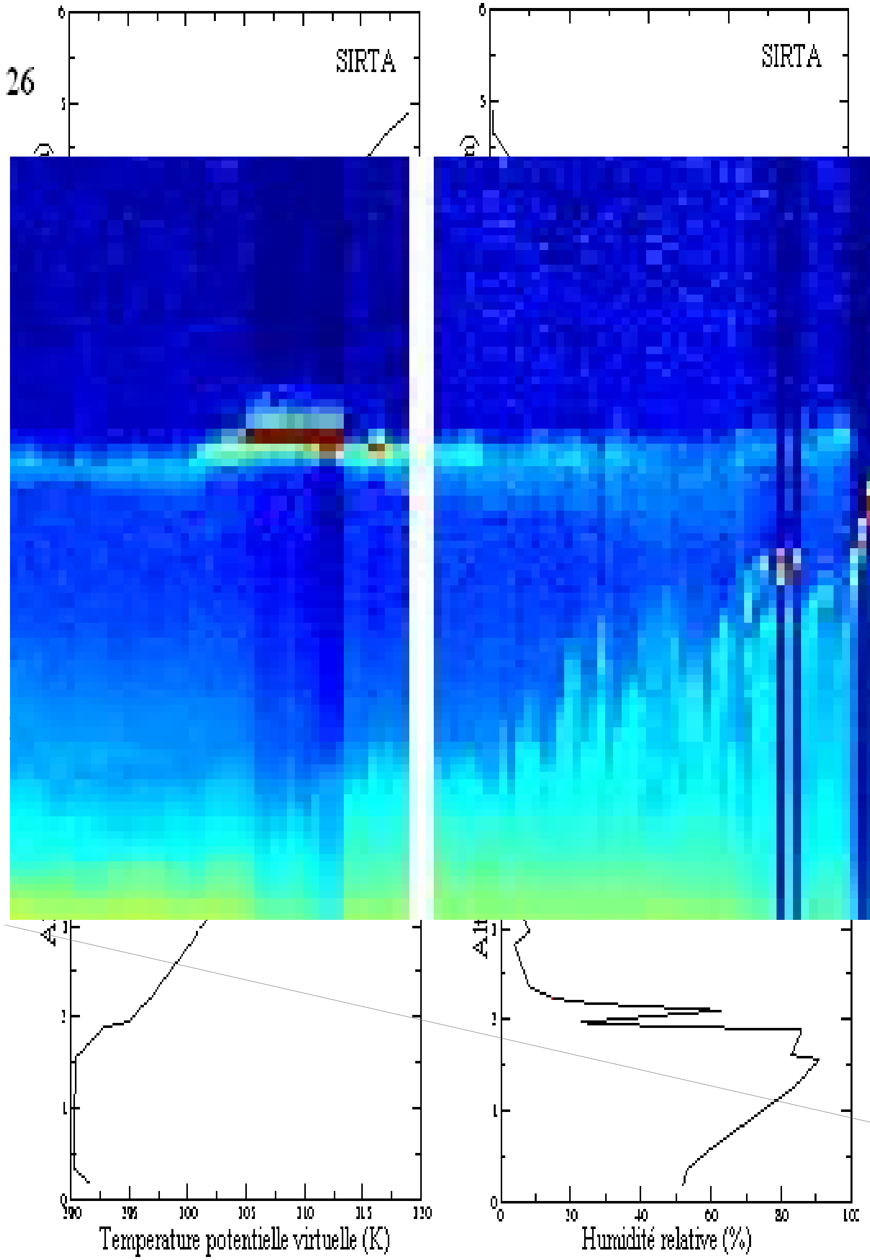



Observations Lidar

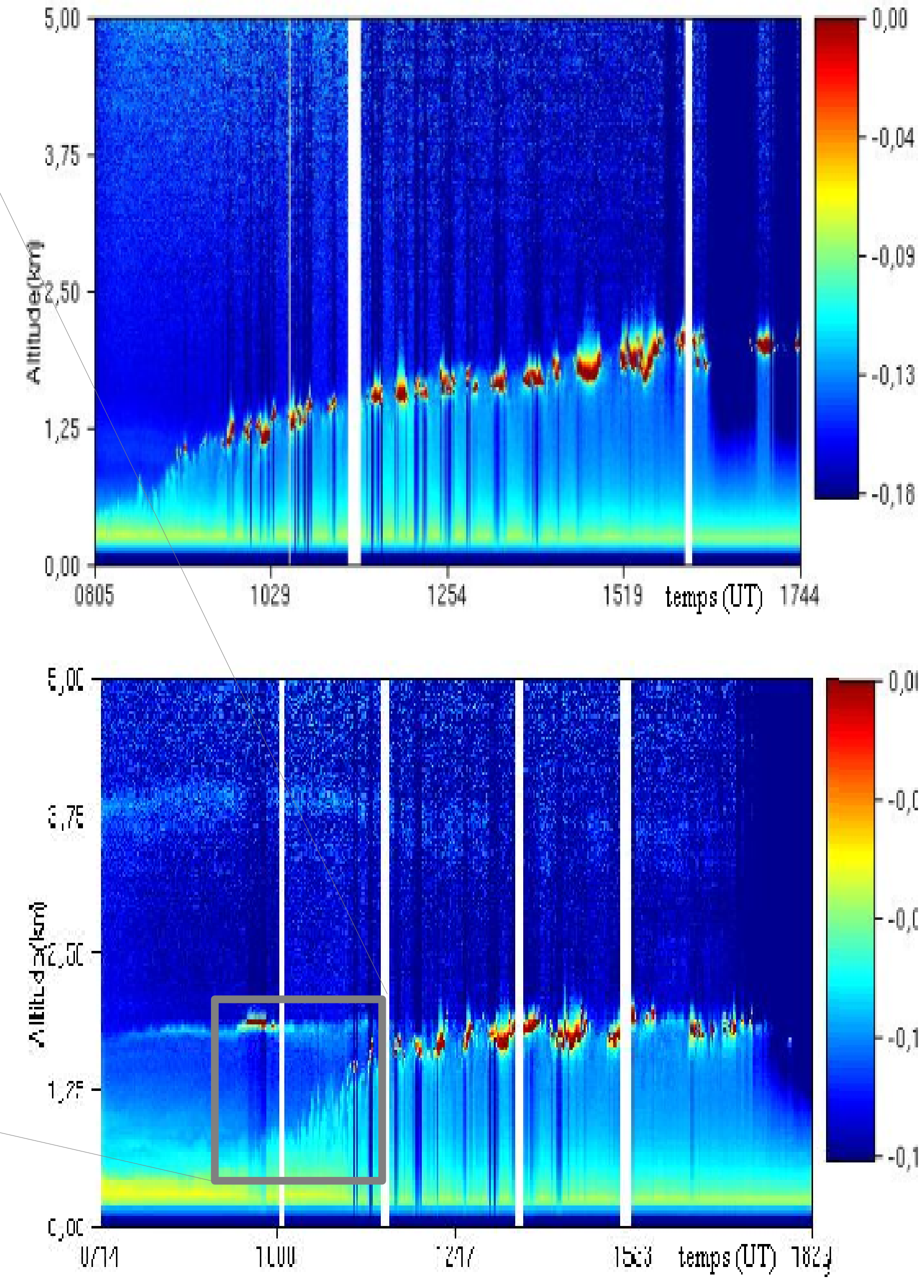


# Exemple d'observations de la couche limite en région parisienne

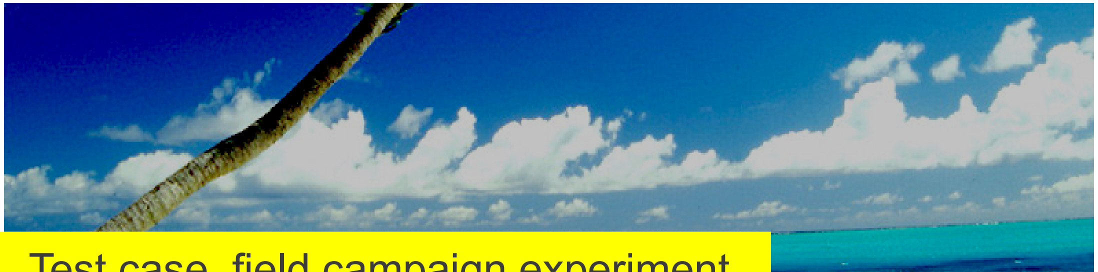
## Sondages de Trappes (Paris)




## Observations Lidar



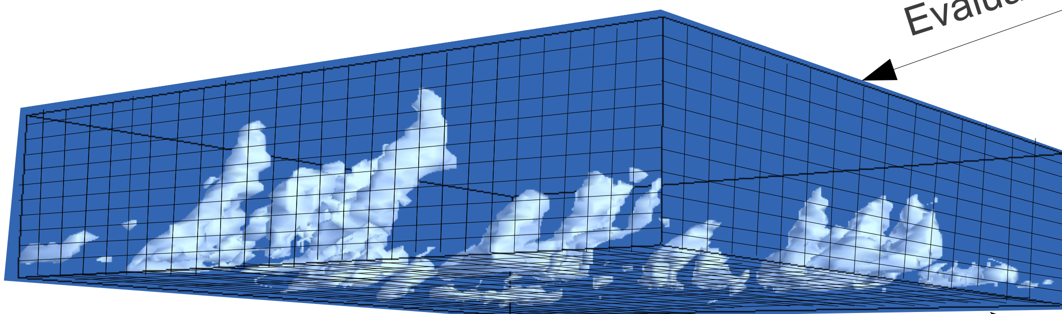
# I.2 Cloud process studies and the use of high resolution explicit models0



Test case, field campaign experiment

Observation

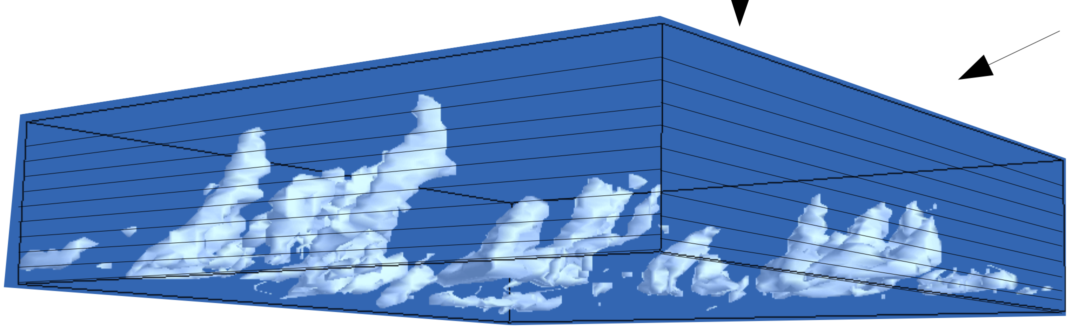
Evaluation

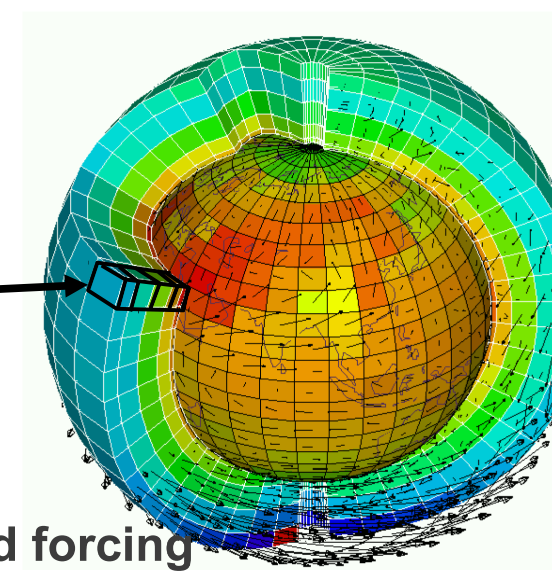


Explicit simulations, Grid cell, 20-100 m

Evaluation

« Large scale » conditions imposed



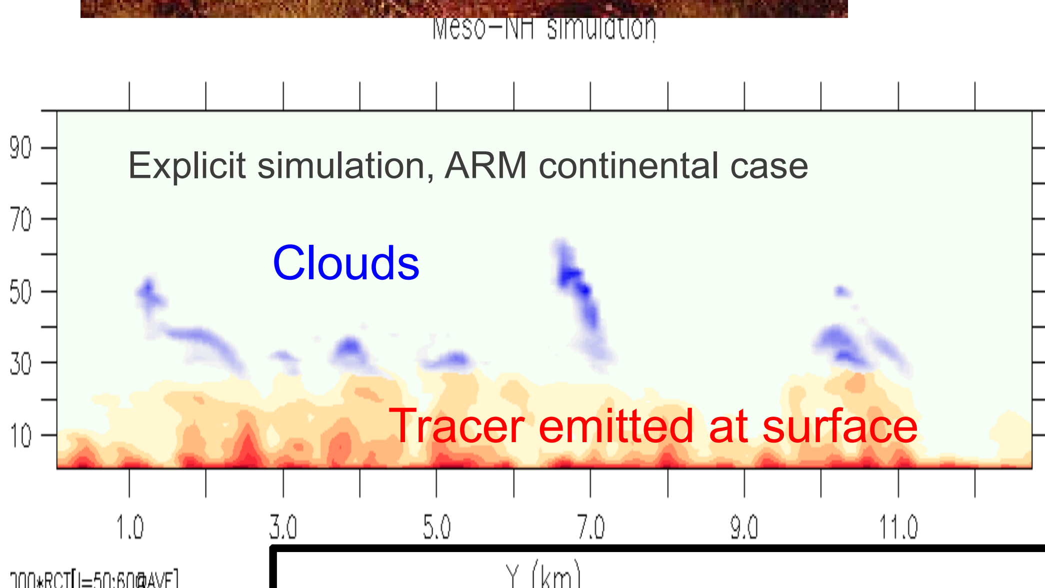


Climate model, parameterizations, « single-column » mode

→ **Parameterizations are evaluated against other models**

→ **Can be done for realistic test cases but also with more idealized forcing (check the response of the parameterization to perturbations)**

## II.1 Thermal plumes and clouds



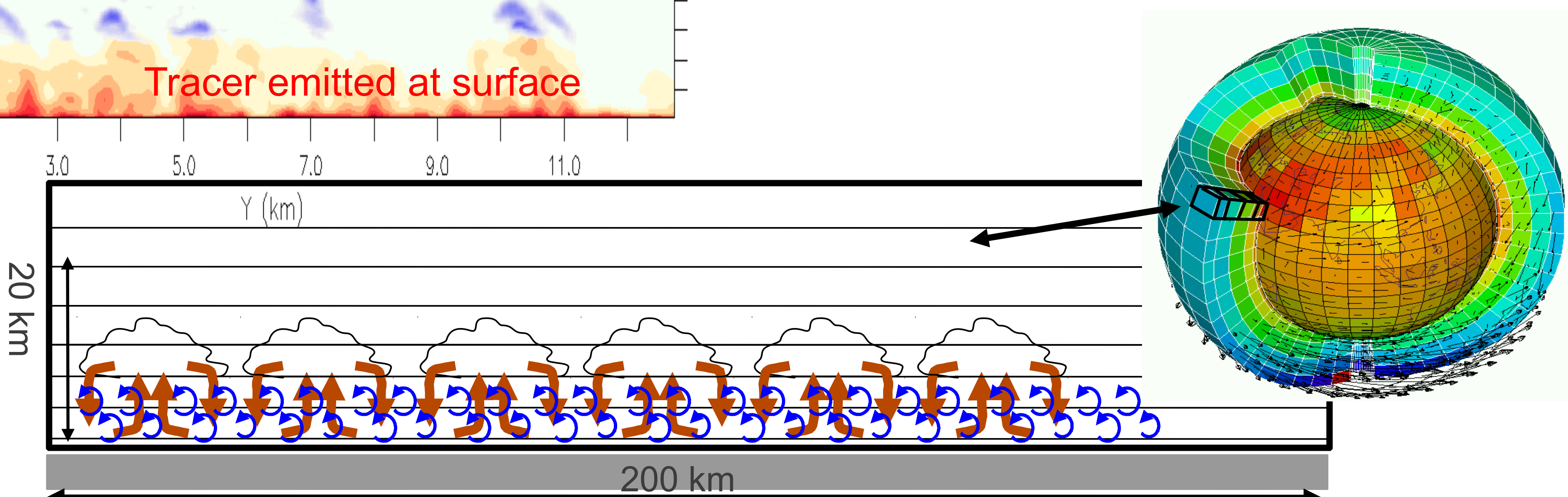

Turbulent diffusion :
for isotropic small scale turbulence
**Atmospheric turbulence :**
**"meso-scale", organized and anistrop**

**→ « Thermal plume model »**

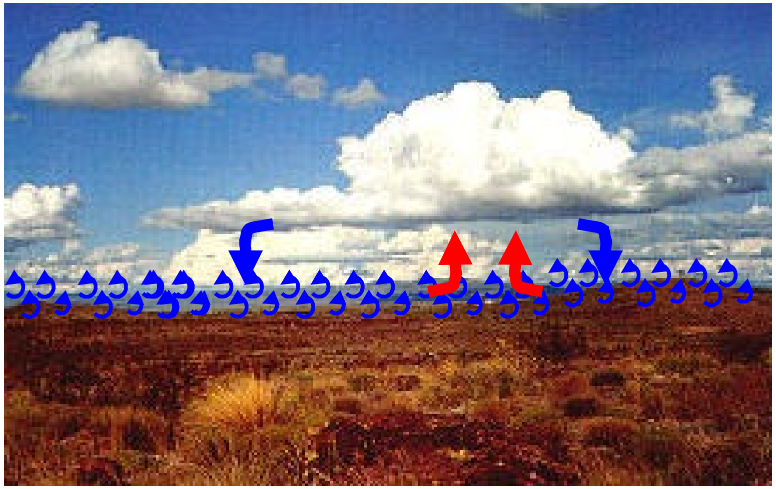
Each atmospheric column is divided in 2 :

- plume of air rising from the surface
- air subsiding around the plume

A « mean plume » is represented, at the top of which a « mean cumulus » can appear.



## II.1 Thermal plumes and clouds



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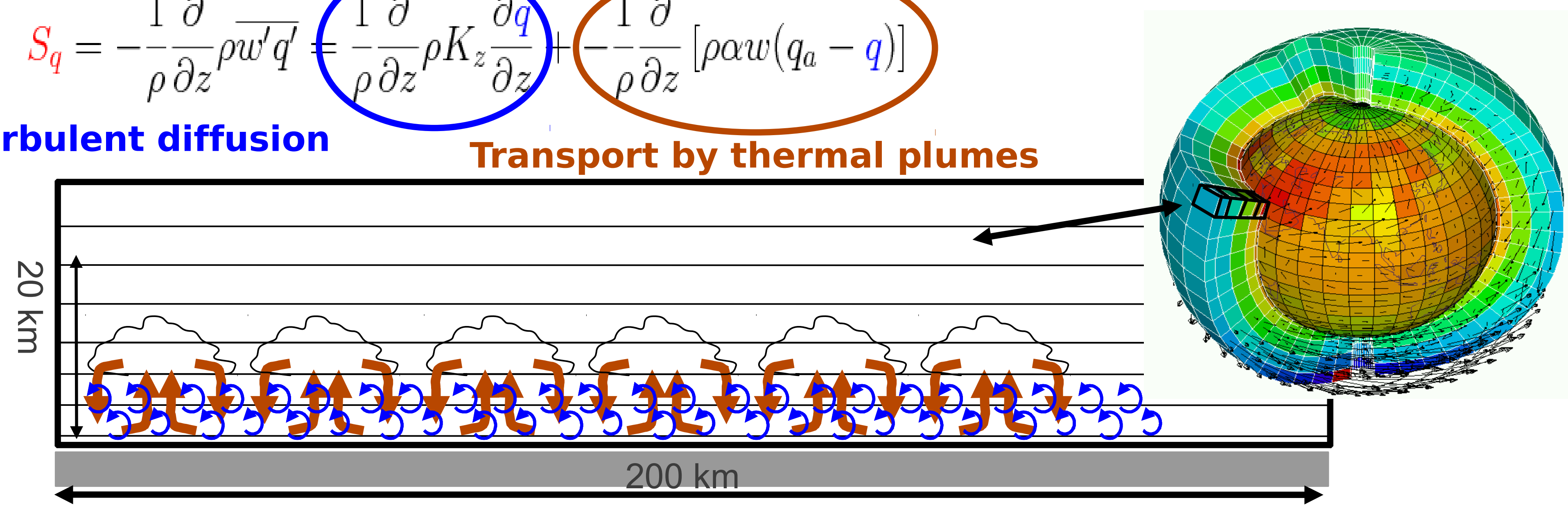
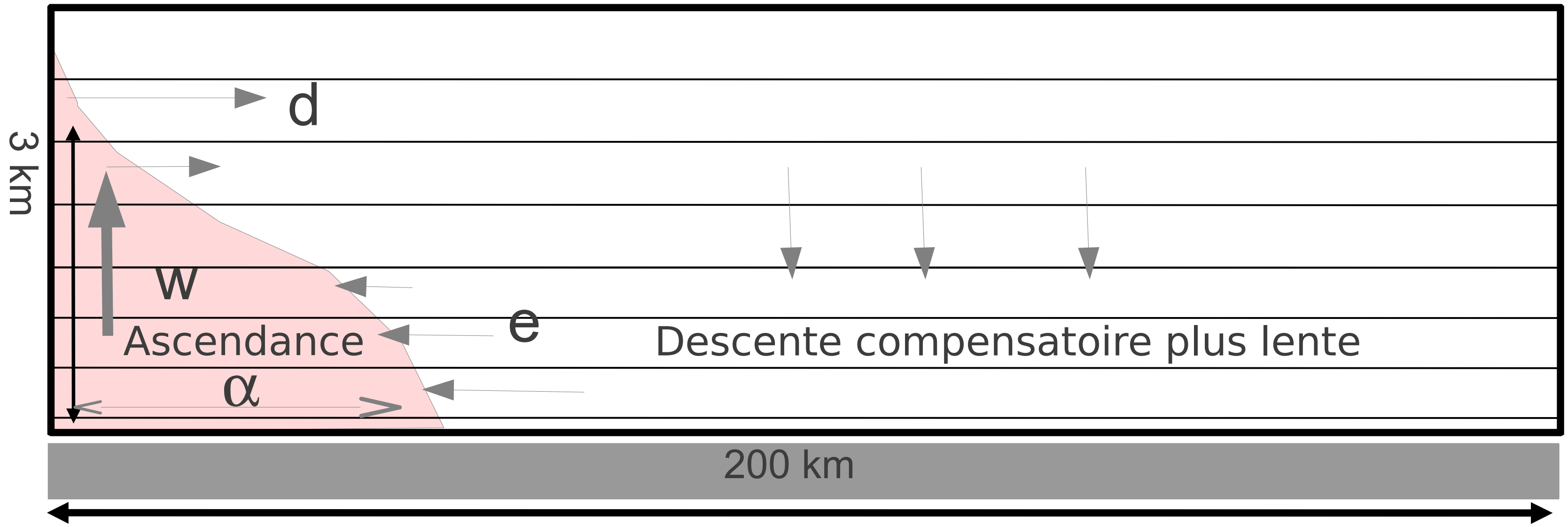
$$S_q = -\frac{1}{\rho}\frac{\partial}{\partial z}\rho\overline{w'q'} = -\frac{1}{\rho}\frac{\partial}{\partial z}\rho K_z\frac{\partial q}{\partial z} + -\frac{1}{\rho}\frac{\partial}{\partial z}\left[\rho\alpha w(q_a - q)\right]$$

**Turbulent diffusion**

**Transport by thermal plumes**



# III. Développement récent : le modèle du thermique




**Variables internes de la paramétrisation** :

$w$ : vitesse moyenne des panaches ascendants

$\alpha$ : fraction de la surface couverte par les ascendances

$e$ : taux d'entrée latérale d'air dans le panache (entrainement)

$d$ : sorties d'air depuis le panache (détrainement)

$q_a$ : concentration du composant q dans l'ascendance

**Terme source pour les équations explicites**

$$S_q = -\frac{1}{\rho}\frac{\partial}{\partial z}\rho\overline{w'q'} = \frac{1}{\rho}\frac{\partial}{\partial z}\rho K_z\frac{\partial q}{\partial z} + -\frac{1}{\rho}\frac{\partial}{\partial z}\left[\rho\alpha w(q_a - q)\right]$$

**Diffusion turbulente**

**Transport par le modèle de panache**

**Conservation de la masse :**

$$\frac{\partial f}{\partial z} = e - d \qquad \text{avec} \quad f = \alpha\rho w$$

**Conservation de la masse du composant** $q$

$$\frac{\partial f q_a}{\partial z} = eq - dq_a$$

**Equation du mouvement**

$$\frac{\partial f w}{\partial z} = -dw + \alpha\rho B$$

$B$ **étant la poussée d'Archimède**

$$B = g\frac{\theta_{va} - \theta_v}{\theta_v}$$

$$e = f\max(0, \frac{\beta_1}{1+\beta_1}(a_1\frac{B}{w^2} - b))$$

$$d = f\max(0, -\frac{a_1\beta_1}{1+\beta_1}\frac{B}{w^2} + c(\frac{(q_a-q)/q_a}{w^2})^d)$$

Etc ...

**4 Paramètres libres :**

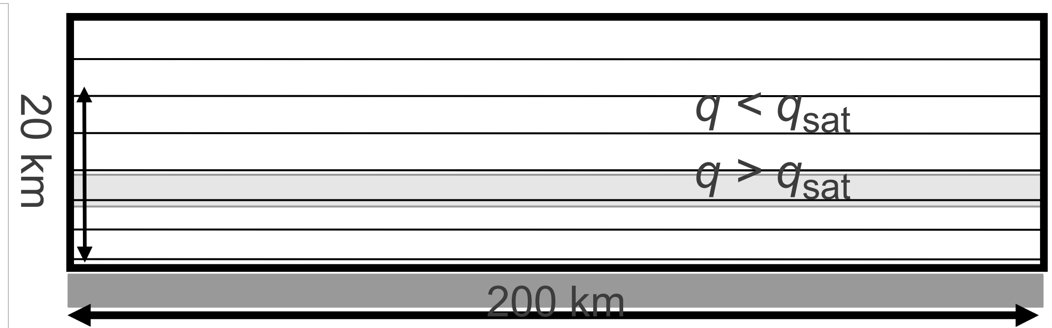
$$a_1 = \frac{2}{3},\ \beta_1 = 0.9,\ b = 0.002,\ c = 0.012m^{-1},\ d = 0.5$$

# Représentation des nuages

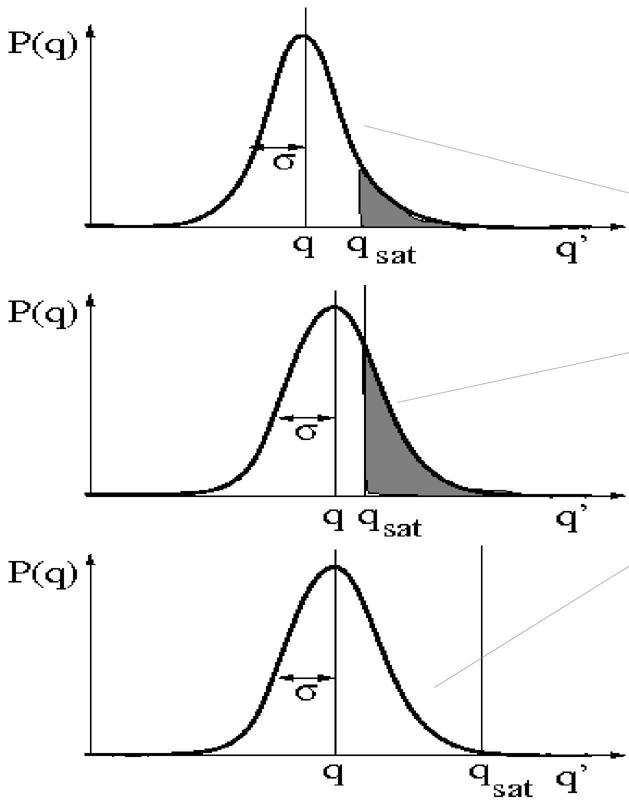
$q$ : concentration en vapeur d'eau
$q_{sat}$ : concentration maximum à saturation
Si $q > q_{sat}$ :
→ la vapeur d'eau condense = nuage

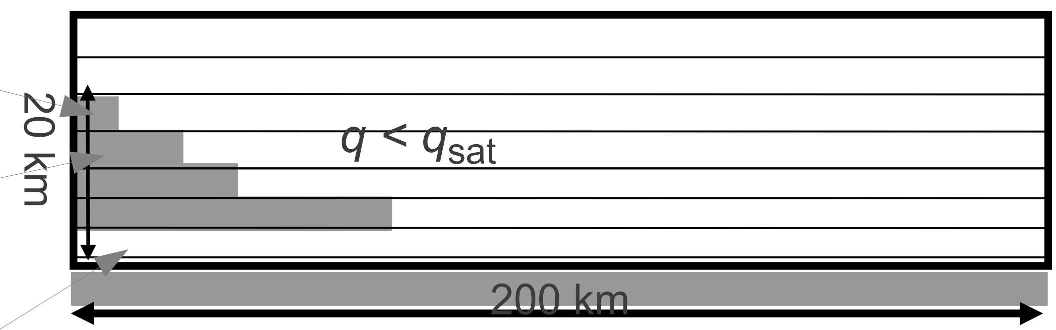
On connait $q$ et $q_{sat}$ à l'échelle de la maille
→ Fraction de la maille couverte de nuages ?

**Modèle « tout ou rien » :**
Si $q > q_{sat}$ maille nuageuse, sinon ciel clair.




**Modèle « statistique » :**
On suppose une distribution statistique de $q'$ dans la maille autour de $q$



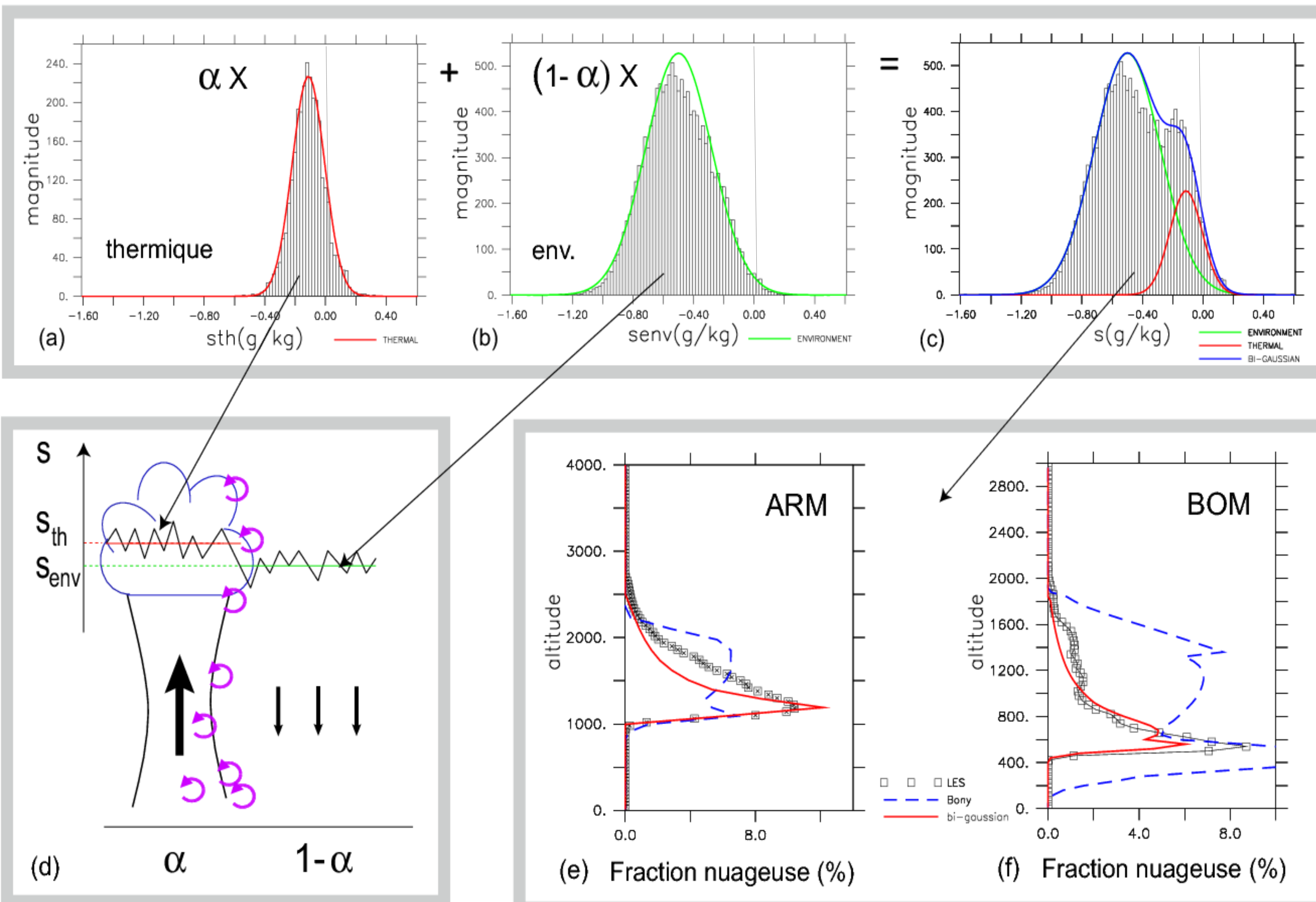




Intervient dans ***Q***
→ condensation
→ prise en compte des nuages dans le code radia

Paramétrisation simple : gaussienne $\sigma / q$ = 20%

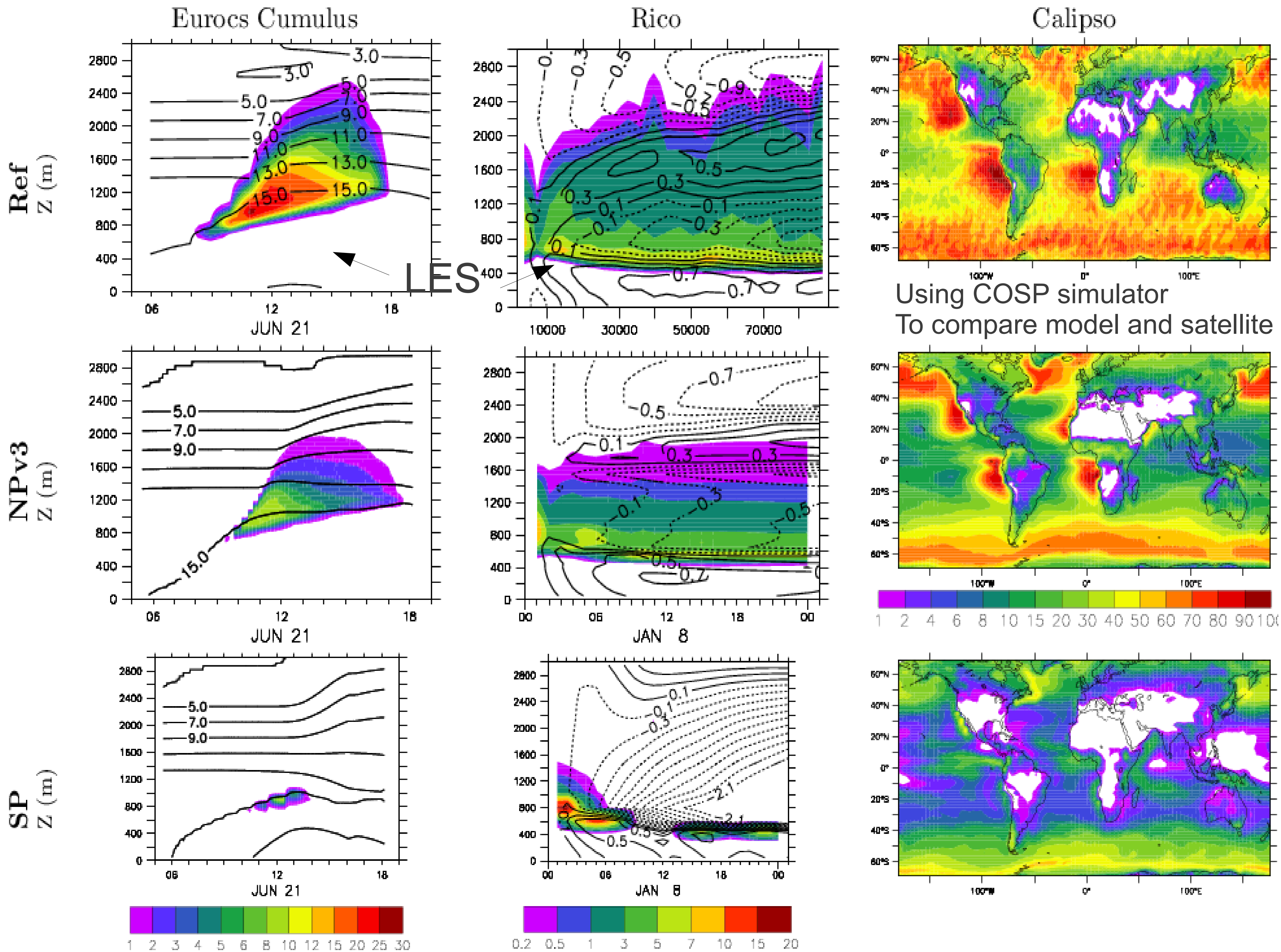
# III. Développement récent : le modèle du thermique

**Nouvelle paramétrisation de nuages couplée aux thermiques :**
Utilisation d'une PDF bi-gaussienne pour la distribution d'eau totale sous nuageuse
Une gaussienne pour les panaches thermiques et une pour l'environnement
Comparaison des distributions prédites par ce schéma avec les distributions des LES

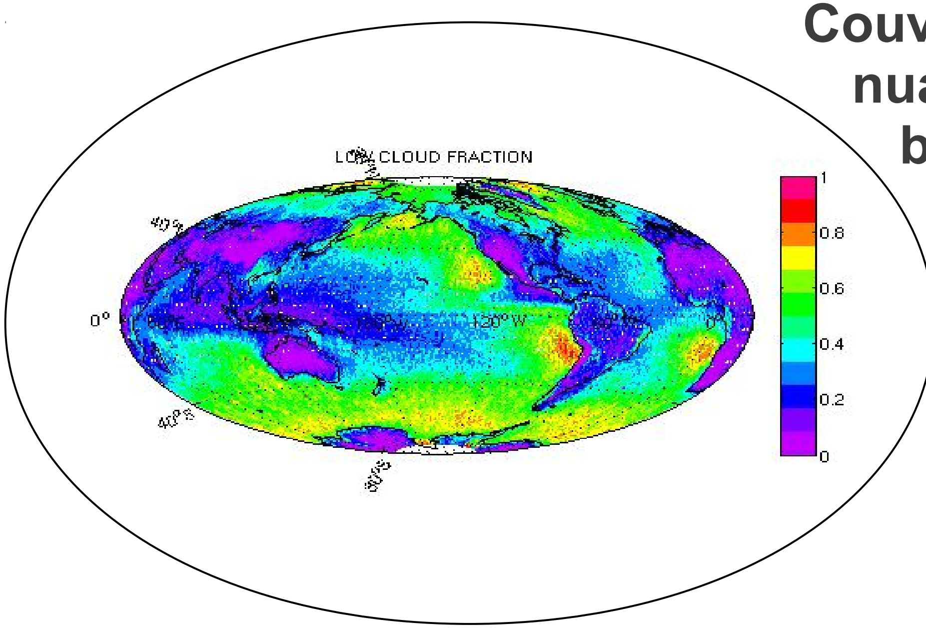


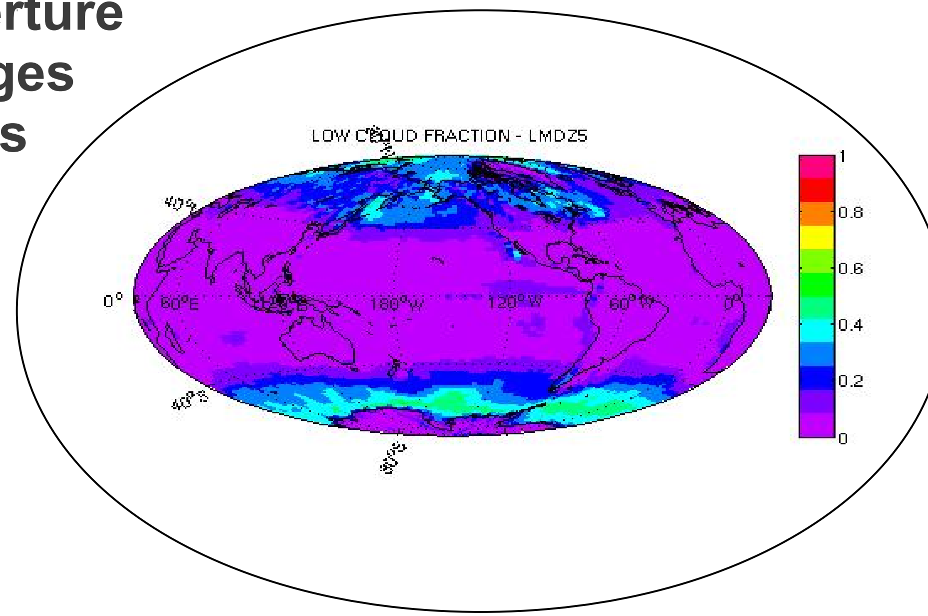
# 1D test cases

# 3D simulations

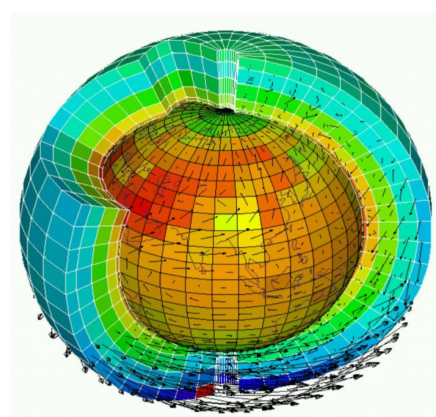



Couverture nuages bas



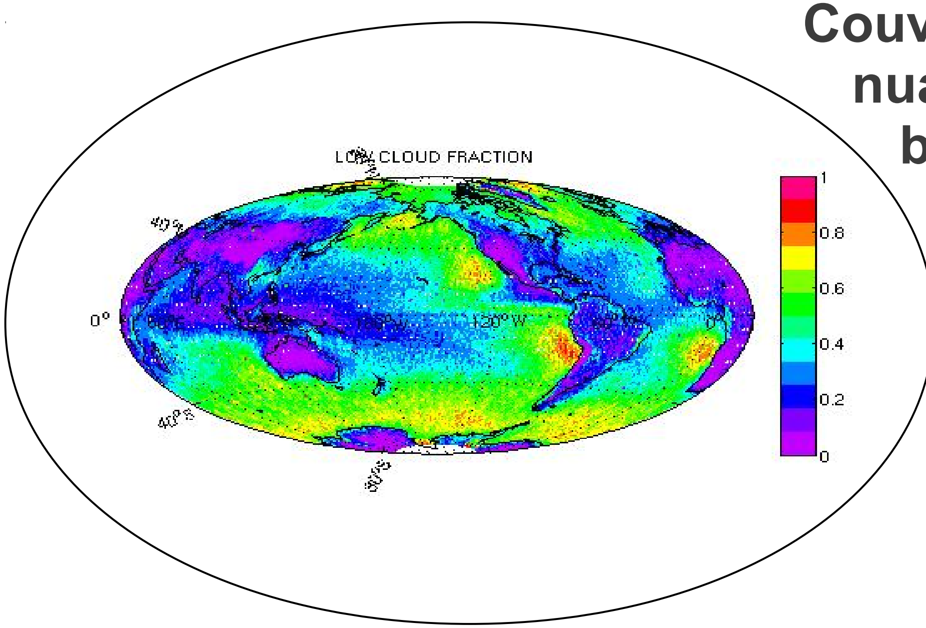



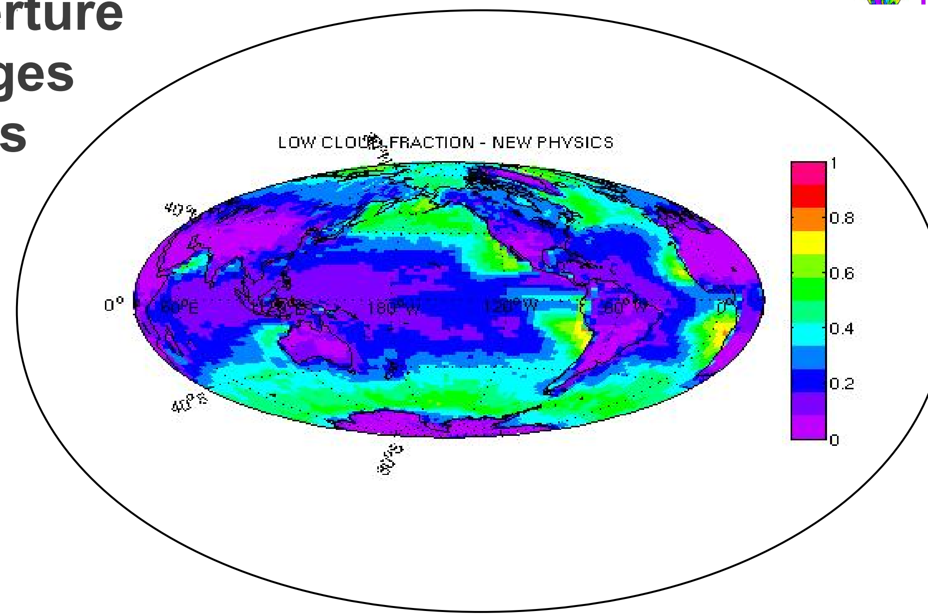

Observations calipso grille LMDZ



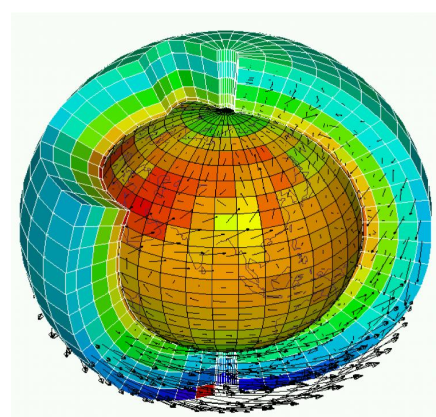
LMDZ « physique standard » + simulateur calipso


**Couverture nuages bas**




**Observations calipso grille LMDZ**



**LMDZ « nouvelle physique » + simulateur calipso**

## III Illustration with the LMDZ climate model : Climate change projections