# The physical parametrizations in LMDZ

LMD

Laboratoire de Météorologie Dynamique

# Atmospheric GCM equations (samples)

**Dynamic equations in Pressure coordinates**

$$
\left\{
\begin{array}{l}
\partial_t \vec{V} = -(\vec{V}.\vec{\nabla})\vec{V} - \omega \partial_p \vec{V} - \vec{\nabla}\Phi \; - f\vec{k} \text{ x } \vec{V} \; + \vec{S_V} \\
\\
\vec{\nabla}.\vec{V} + \partial_p \omega = 0 \\
\\
\partial_t q = -\vec{V}.\vec{\nabla} q - \omega \partial_p q + S_q
\end{array}
\right.
\qquad
\left\{
\begin{array}{l}
\Phi = gz \quad \text{geopotential} \\
\\
\omega = \partial_t p \quad \text{vert. velocity} \\
\\
q = \text{specific humidity}
\end{array}
\right.
\qquad (1)
$$

transport — gravity — Coriolis — Sources

$\vec{S_v}$ and $S_q$ : source terms determined by **physical parametrizations** :

- planetary boundary layer
- deep convection (big cumulus and cumulonimbus)
- clouds
- radiative processes
- orography
- soil . . . . . . .

## Basic facts about parametrizations

- Each parametrization : (1) works almost independently of the others ; (2) depends on vertical profiles of u, v, w, T, q and on some interface variables with the other parametrizations ; (3) ignores the spatial heterogeneities associated with the other processes (except with the wakes).
- The total tendency due to sub-grid processes is the sum of the tendencies due to each process :

$$
\begin{aligned}
S_T \;=\; (\partial_t T)_\varphi \;&=\; (\partial_t T)_{\mathrm{eva}} + (\partial_t T)_{\mathrm{lsc}} + (\partial_t T)_{\mathrm{diff\ turb}} + (\partial_t T)_{\mathrm{conv}} \\
&\quad + (\partial_t T)_{\mathrm{wk}} + (\partial_t T)_{\mathrm{Th}} + (\partial_t T)_{\mathrm{ajs}} + (\partial_t T)_{\mathrm{rad}} + (\partial_t T)_{\mathrm{oro}}
\end{aligned}
$$

## physiq.F structure - I

**Initialization (once)** : *phyetat0, phys_output_open*

**Beginning** *change_srf_frac, solarlong, cloud water evap.*

**Vertical diffusion (turbulent mixing)** *pbl_surface*

**Deep convection** *conflx* (Tiedtke) or *concvl* (Emanuel) or *conema3* (Emanuel old)

**Deep convection clouds** *clouds_gno*

**Density currents (wakes)** *calwake*

**Strato-cumulus** *stratocu_if*

**Thermal plumes** *calltherm* and *ajsec* (sec = dry)

**Thermal plume clouds** *clouds_gno*

**Large scale condensation** *fisrtilp*

**Diagnostic clouds for Tiedtke** *diagcld1*

**Aerosols** *readaerosol_optic*

**Stratiform clouds** *diagcld2*

**Cloud optical parameters** *newmicro* or *nuage*

**Radiative processes** *radlwsw* (bis)

In blue : subroutines and instructions modifying state variables

## physiq.F structure - II

**Orographic processes : drag** *drag_noro_strato* or *drag_noro*

**Orographic processes : lift** *lift_noro_strato* or *lift_noro*

**Orographic processes : GW breaking** *hines_gwd*

**? ? ? ?** Axial components of angular momentum and mountain torque : *aaam_bud*

**Cosp simulator** *phys_cosp*

**Tracers** *phytrac*

**Tracers off-line** *phystokenc*

**Water and energy transport** *transp* and *transp_lay*

**Outputs**

**Statistics**

**Output of final state (for restart)** *phyredem*

## Turbulent diffusion

- Turbulent diffusion or "turbulent mixing" : transport by small random movements. Similar to molecular diffusion.

$$Dq/Dt = S_q \quad \text{où} \quad S_q = \frac{\partial}{\partial z}(K_z \frac{\partial q}{\partial z})$$

- **Prandtl mixing length** : $K_z = l\,|w|$
  $l$ : characteristic length of the small movements
  $w$ : characteristic velocity
- **Turbulent kinetic energy (TKE)** : $K_z = l\,\sqrt{e}$

$$\begin{aligned} De/Dt &= f(dU/dz, d\theta/dz, e, ...) \\ Dl/Dt &= ... \end{aligned}$$

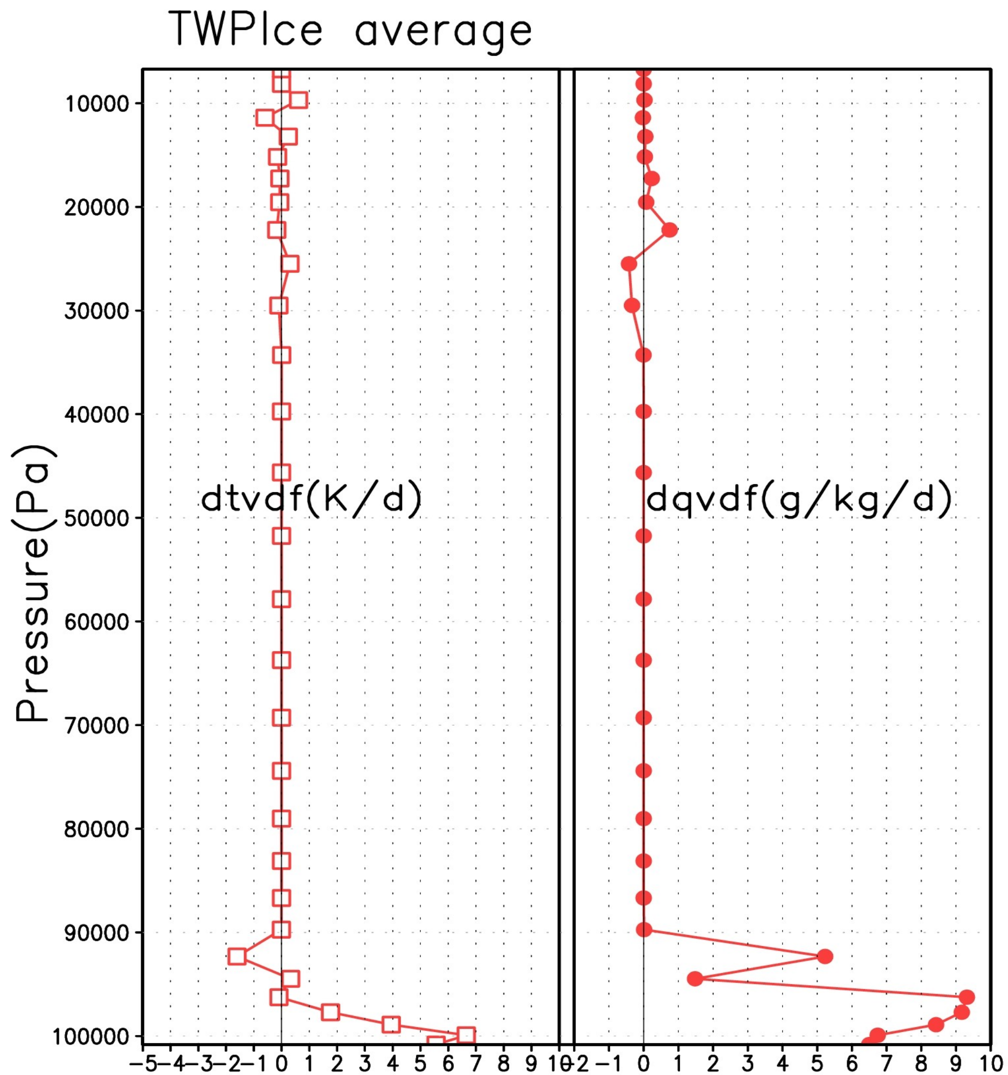
**Vertical diffusion**

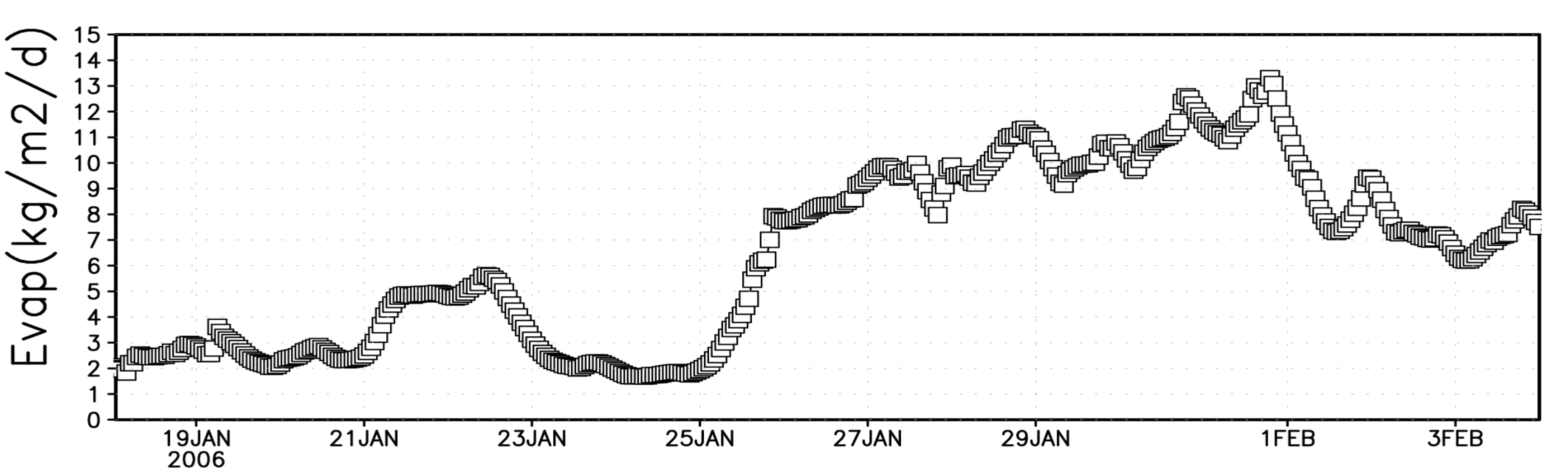
**Tendencies :**

dtvdf, dqvdf, duvdf, dvvdf

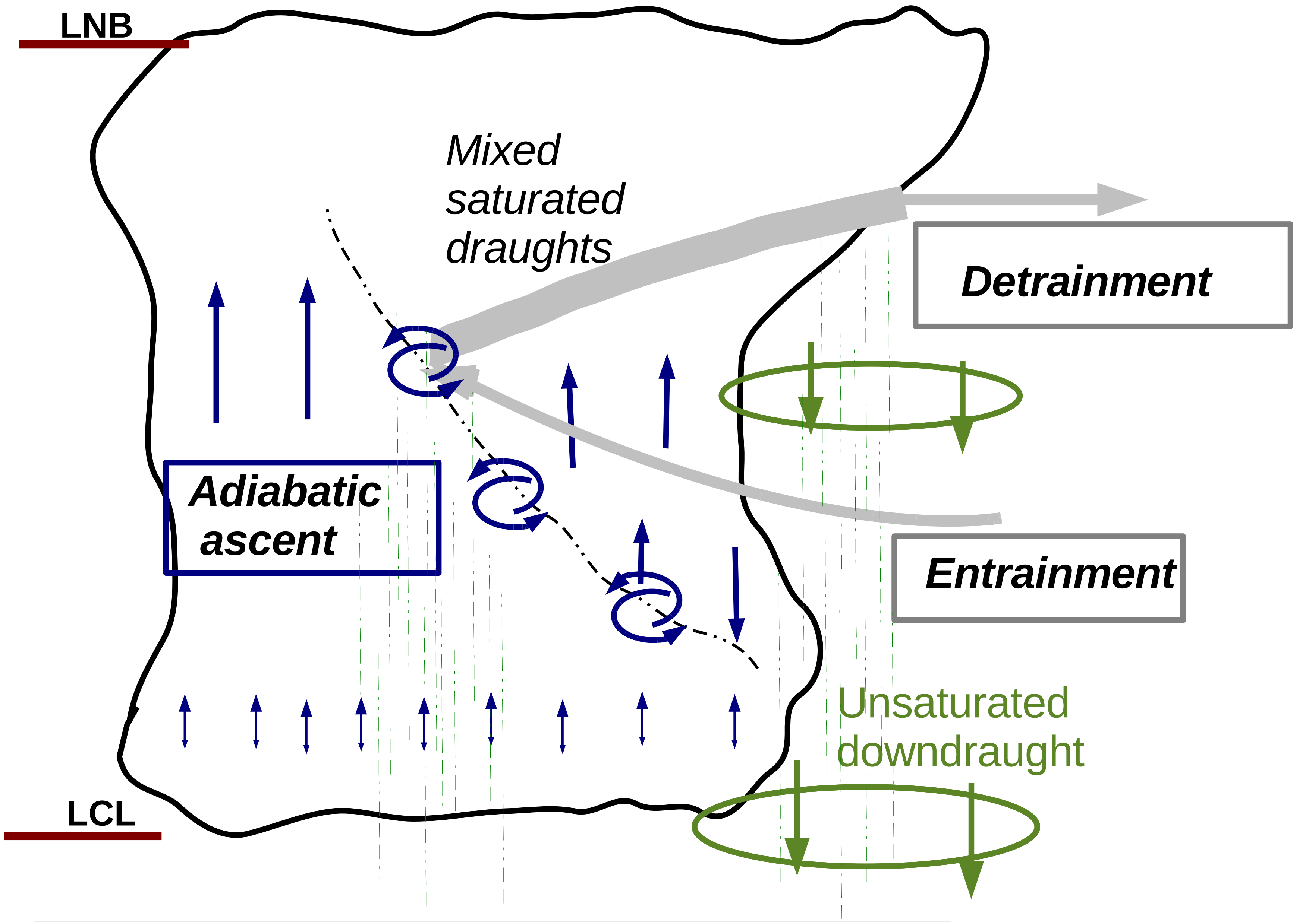
**Other variables**

- sens : sensible heat flux at the surface (positive upward)
- evap : water vapour flux at the surface (positive upward)
- flat : latent heat flux at the surface (positive downward)
- taux, tauy : wind stress at the surface



# Emanuel scheme



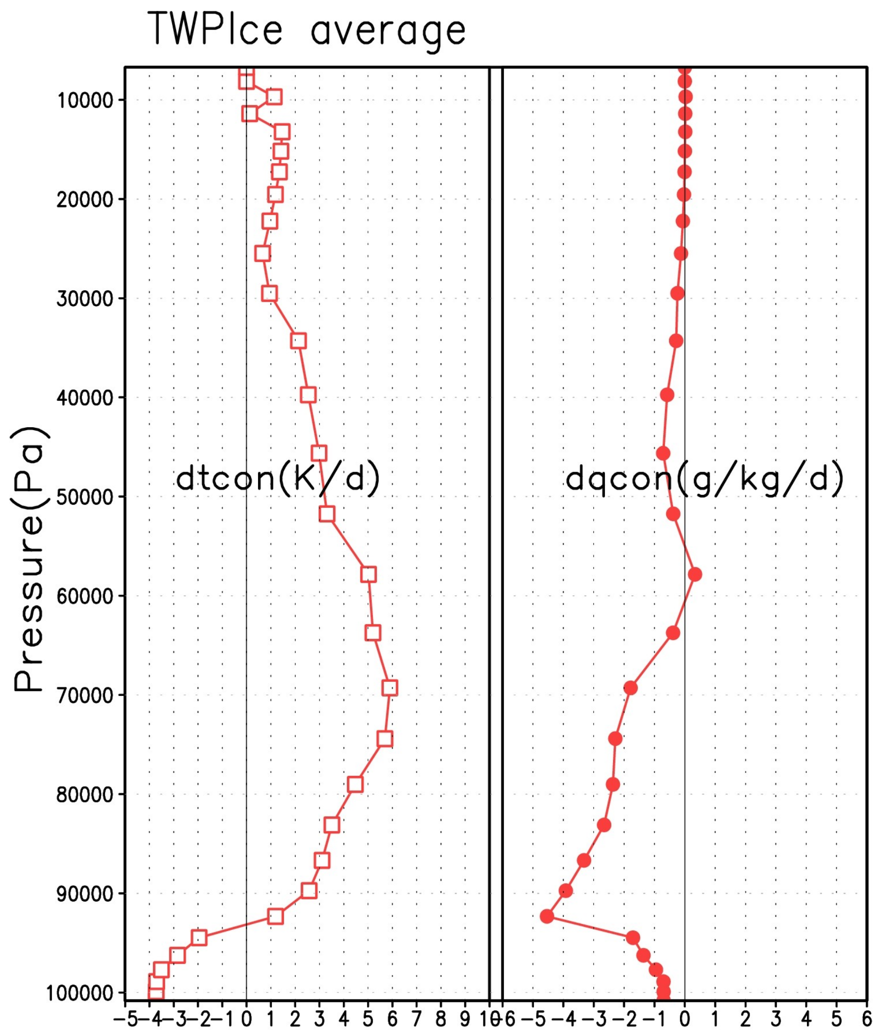
## Deep convection

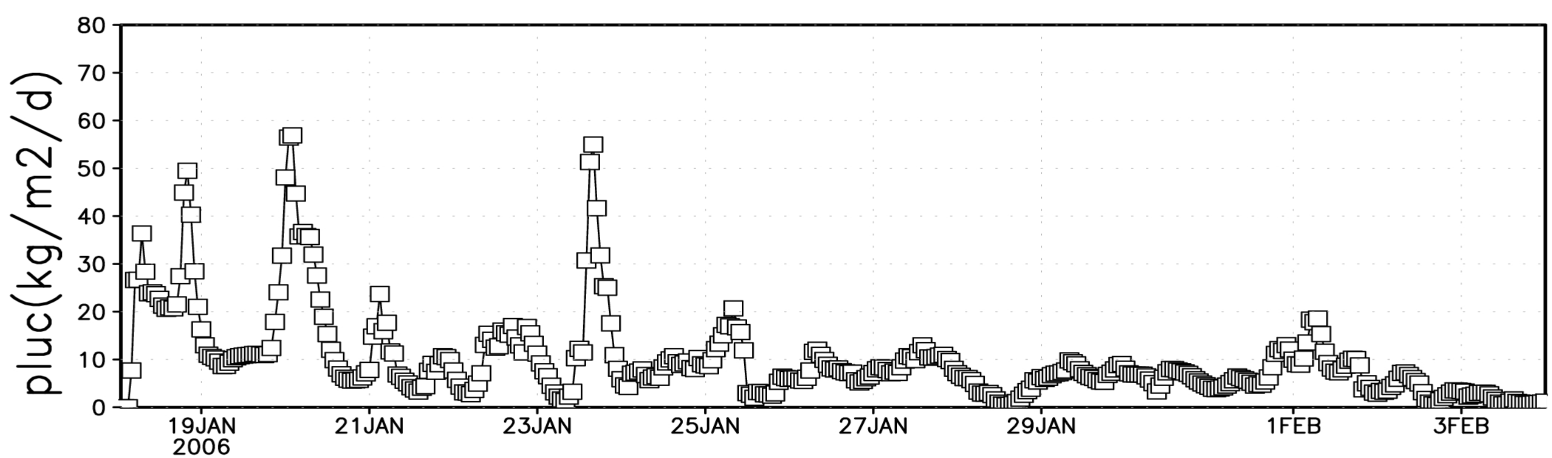
**Tendencies :**

dtcon, dqcon, ducon, dvcon

**Other variables**

- pluc : convective precipitation at the surface
- ftd : temperature tendency due to the sole unsaturated downdraughts
- fqd : moisture tendency due to the sole unsaturated downdraughts
- clwcon : condensed water of convective clouds ("in cloud" condensed water content)
- Ma : mass flux of the adiabatic ascent
- upwd : mass flux of the saturated updraughts
- dnwd : mass flux of the saturated downdraughts
- dnwd0 : mass flux of the unsaturated downdraught (precipitating downdraught)
- Vprecip : vertical profile of convective precipitation



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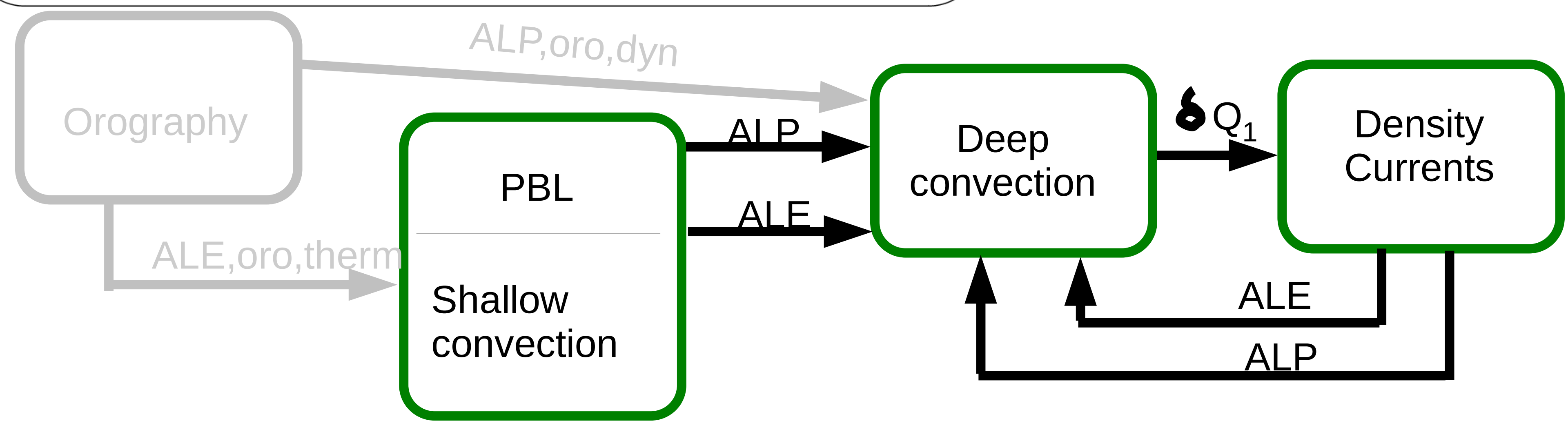
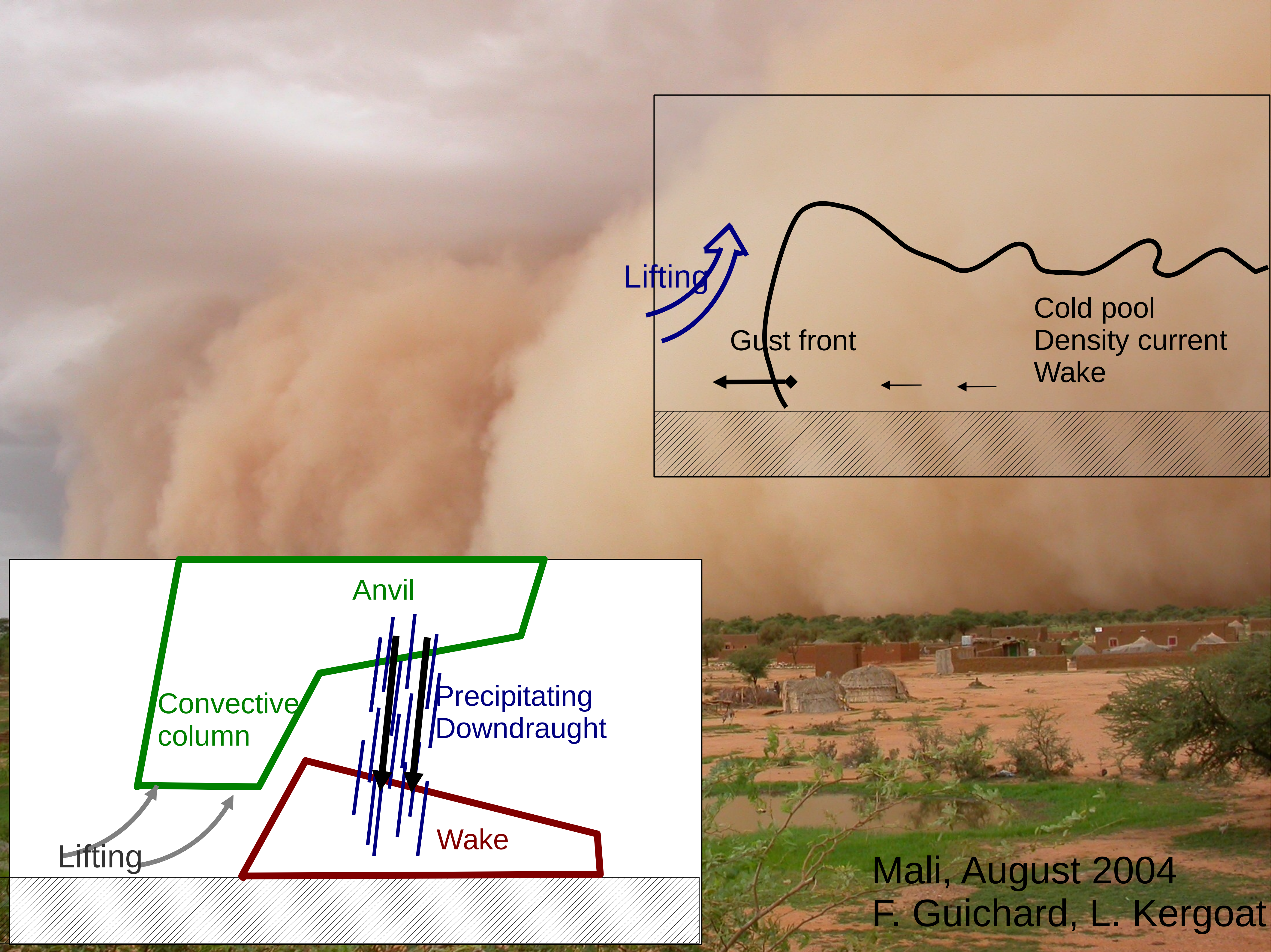
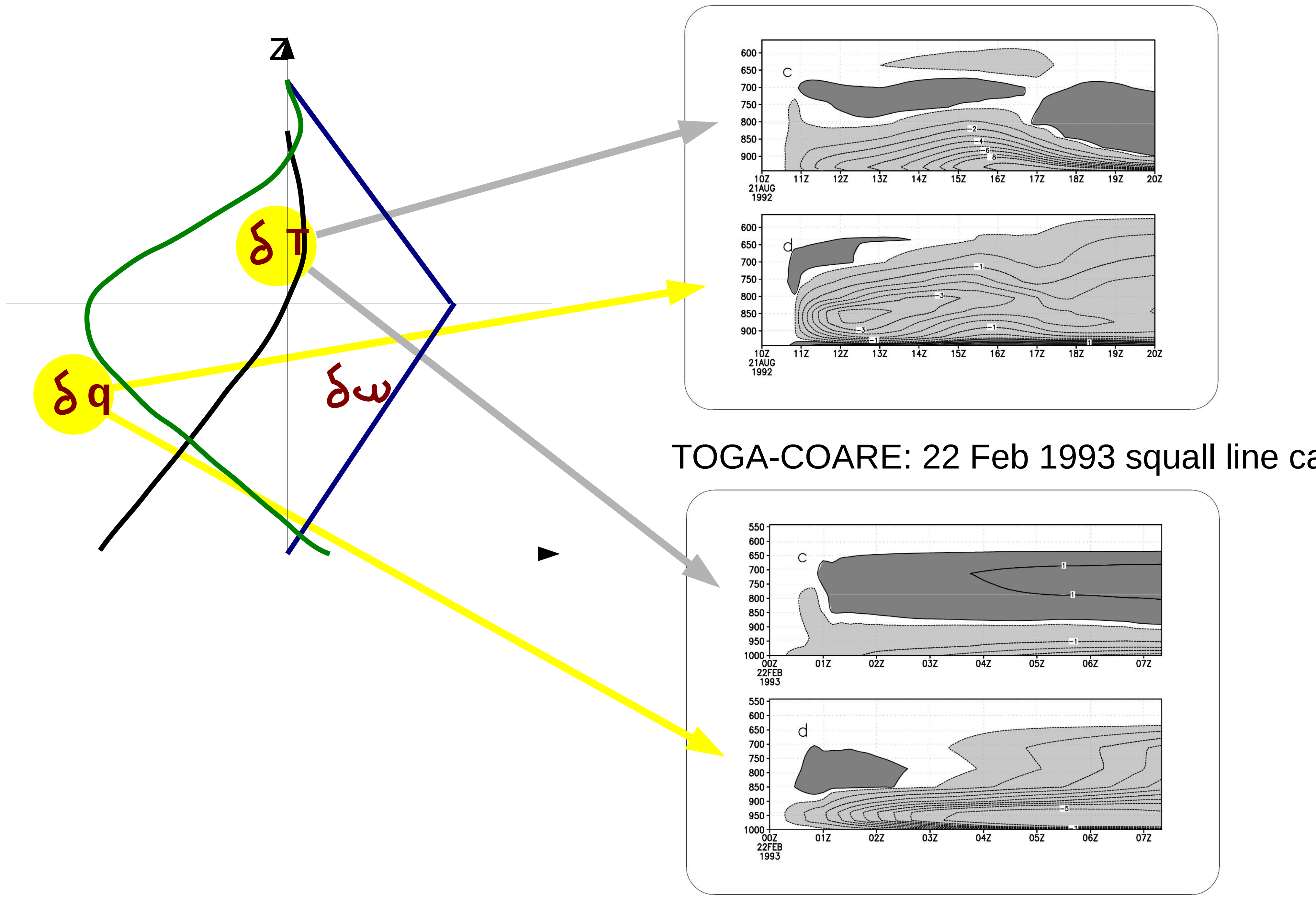



Lifting
Gust front
Cold pool
Density current
Wake
Anvil
Convective
column
Precipitating
Downdraught
Wake
Lifting
Mali, August 2004
F. Guichard, L. Kergoat

# Simulated wake properties

HAPEX92: 21 Aug 1992 squall line case



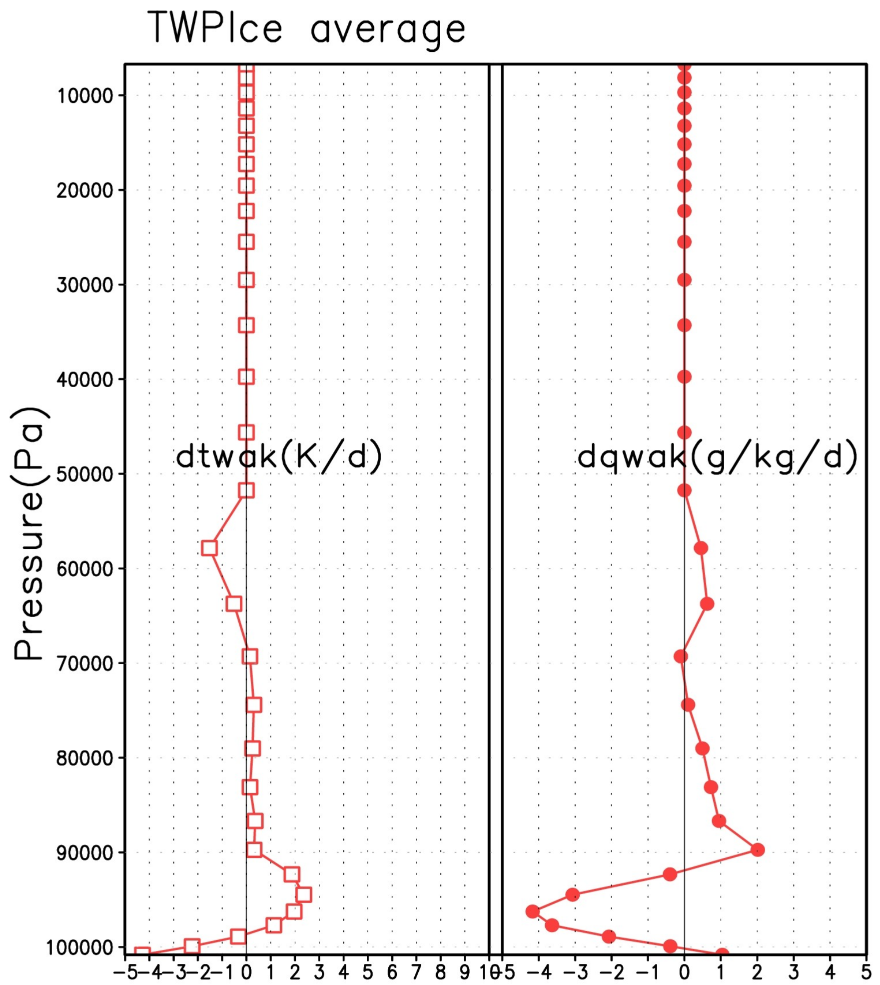
## Cold pools (wakes)

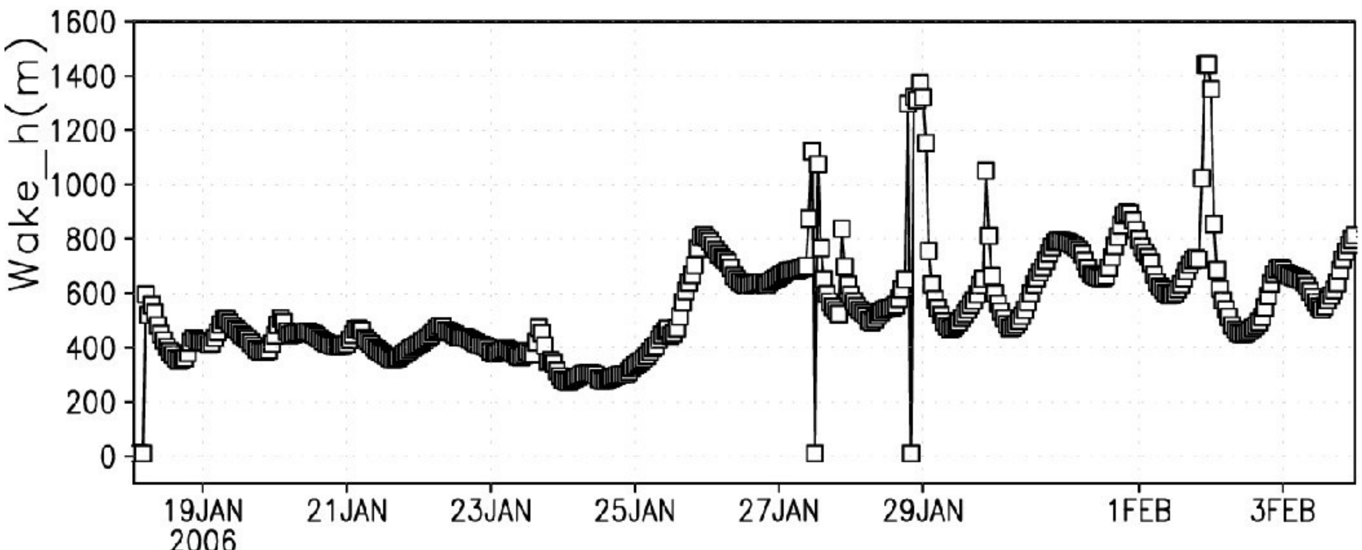
**Tendencies :**

dtwak, dqwak

**Other variables**

- Alp_wk : lifting power due to cold pools
- Ale_wk : lifting energy due to cold pools
- wake_s : fractional area of cold pools
- wake_h : cold pool height
- wape : WAke Potential Energy
- wake_deltat : vertical profile of temperature difference $T_w - T_x$
- wake_deltaq : vertical profile of humidity difference $q_w - q_x$
- wake_omg : vertical profile of vertical velocity difference $\omega_w - \omega_x$



## Orography

**Tendencies :**

dtoro, duoro, dvoro : tendencies of temperature and velocity due to the drag
dtlif, dulif, dvlif : tendencies of temperature and velocity due to the lift

Total tendencies are the sums of the drag and lift tendencies.

## Large scale condensation (evap & lsc)

**Tendencies :**

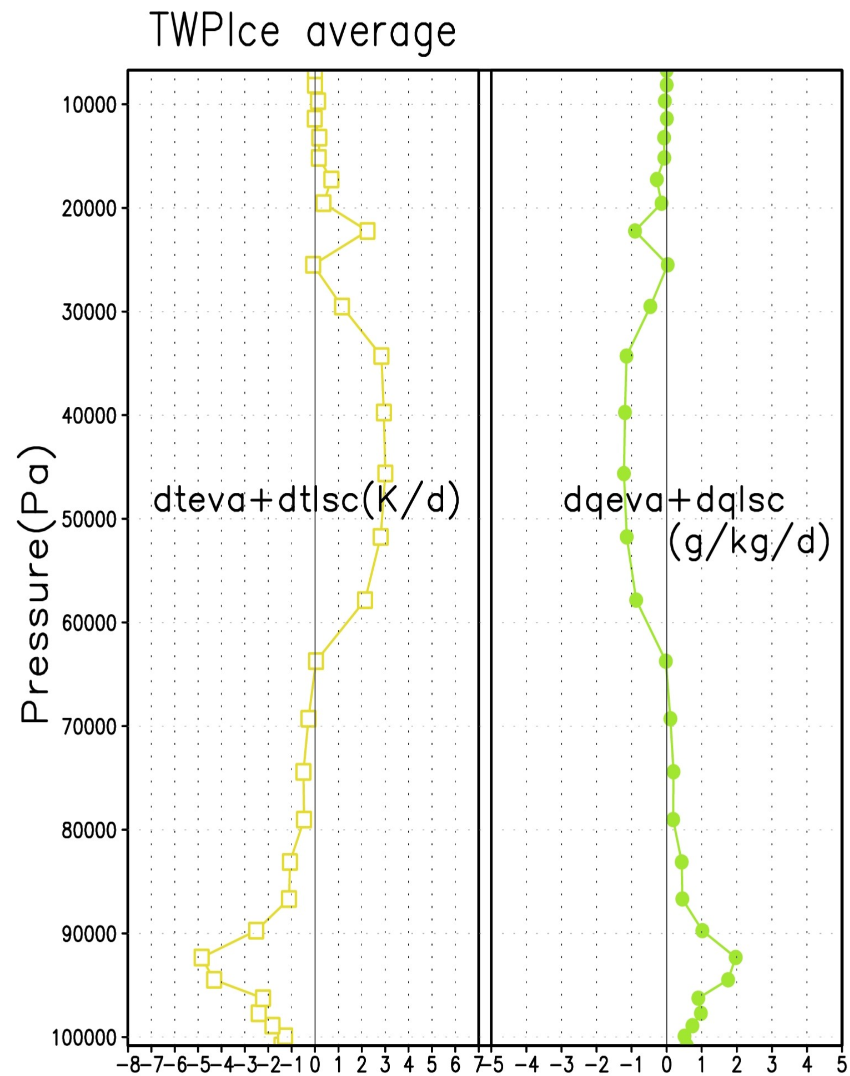
dteva, dqeva : tendencies due to cloud water evaporation

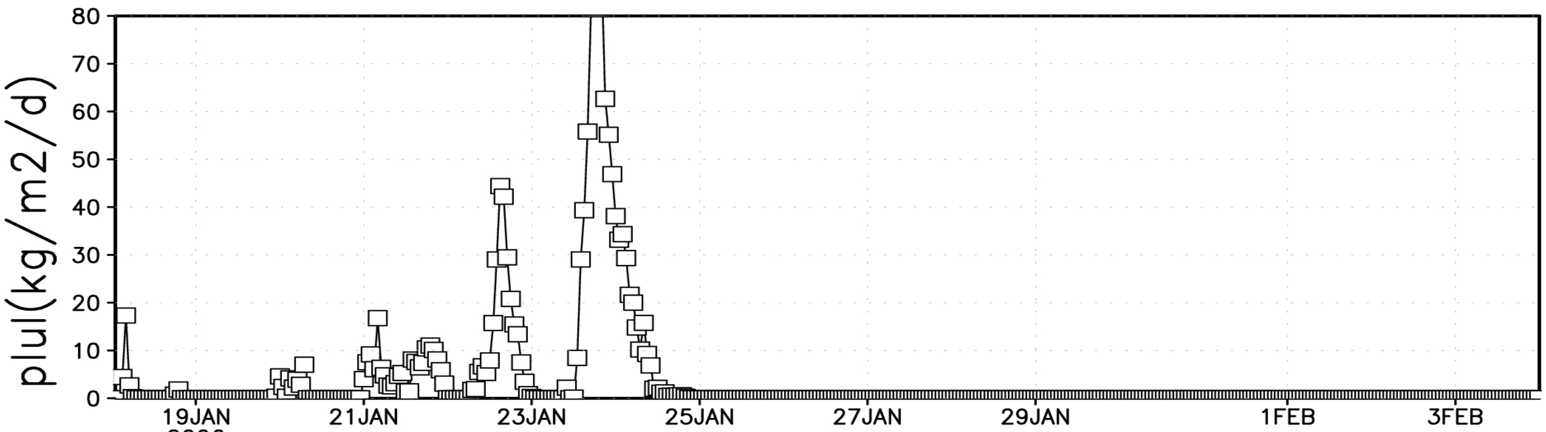
dtlsc, dqlsc : tendencies due to cloud water condensation

Total tendencies are the sums of the evaporation and condensation tendencies.

**Other variables**

- plul : so called "large scale" or "stratiform" precipitation ; encompasses both stratiform precipitation and boundary layer cumulus precipitation.
- rneb : cloud cover



## Radiation

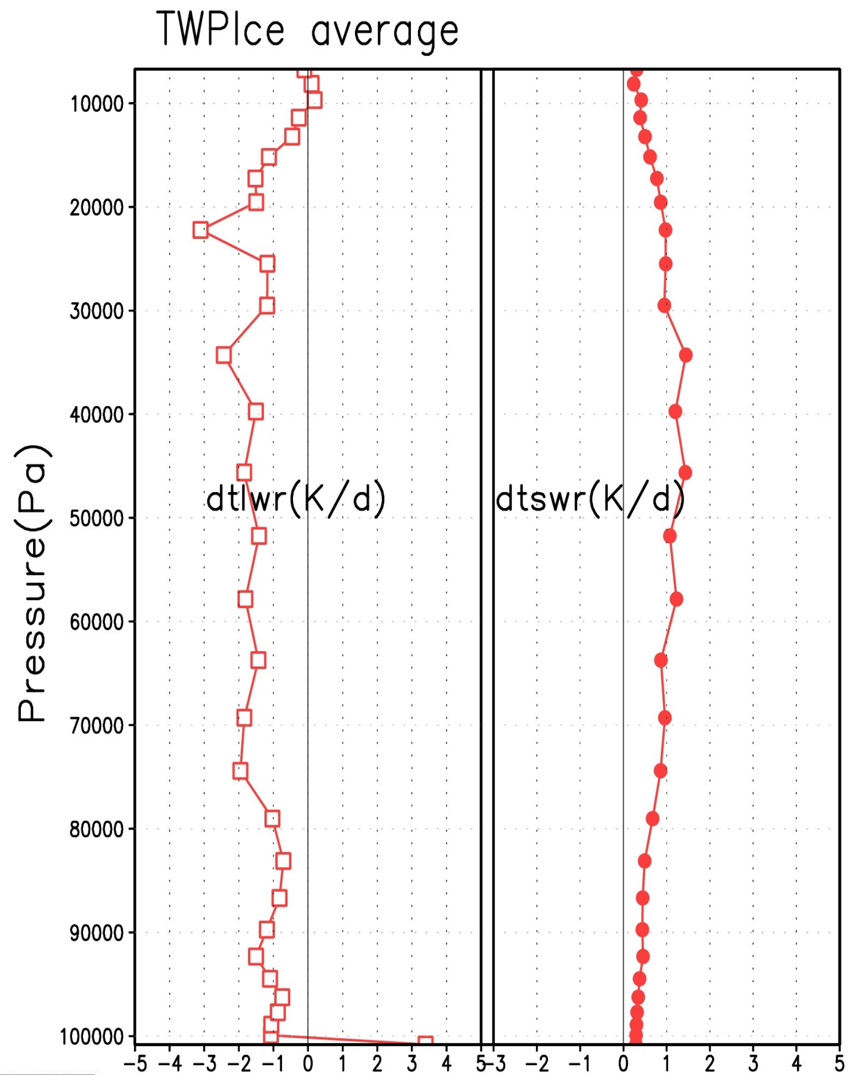
**Tendencies :**

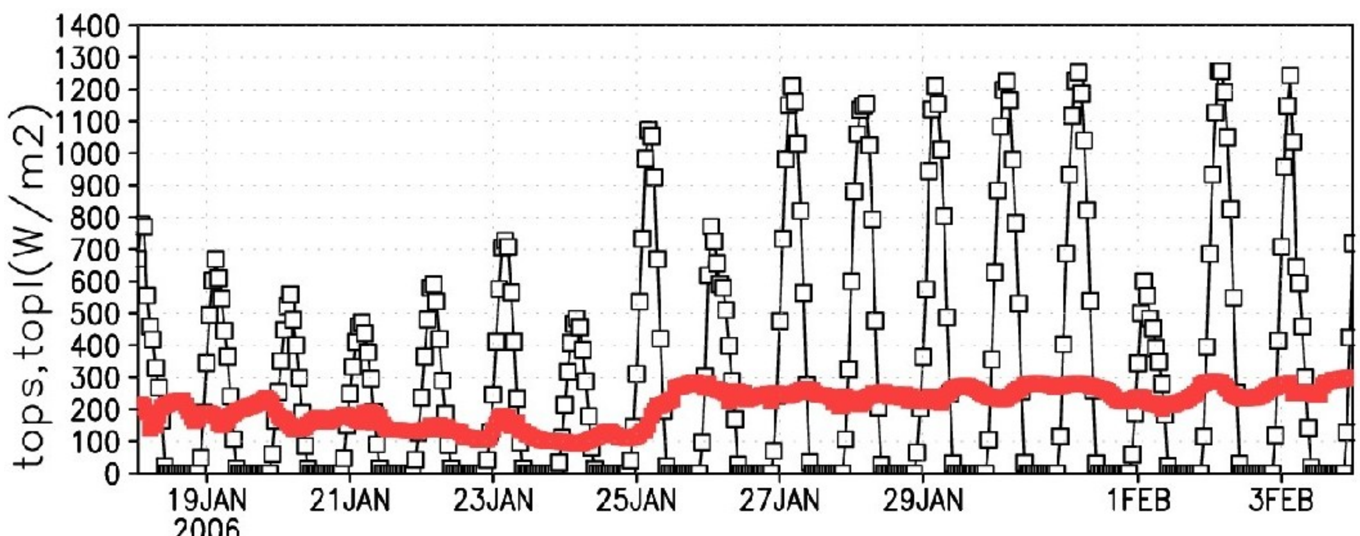
dtswr, dtlwr Temperature tendencies due to solar radiation (SW = short wave) and thermal infra-red (LW = long wave)

The total radiative tendency is the sum of the SW and LW tendencies.

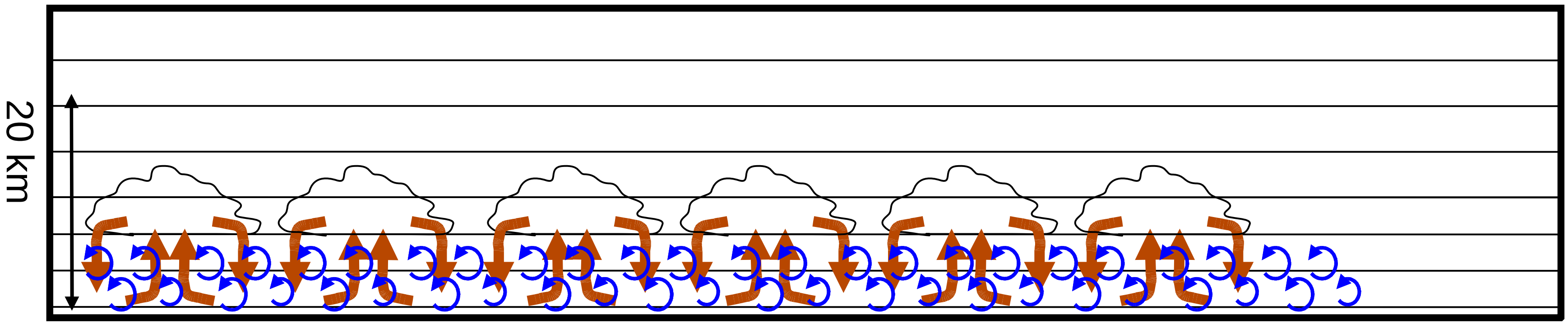
**Other variables**

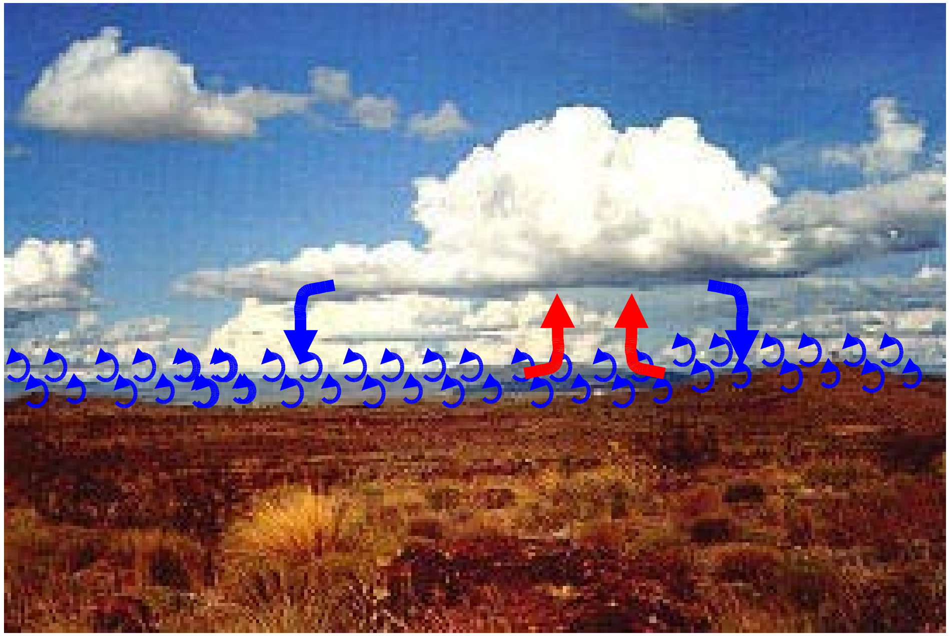
- dtsw0 : clear sky SW tendency
- dtlw0 : clear sky LW tendency
- tops : net solar radiation at top of atmosphere
- topl : net infra-red radiation at top of atmosphere
- tops0, topl0 : same for clear sky
- sols : net solar radiation at surface
- soll : net infra-red radiation at surface
- sols0, soll0 : same for clear sky



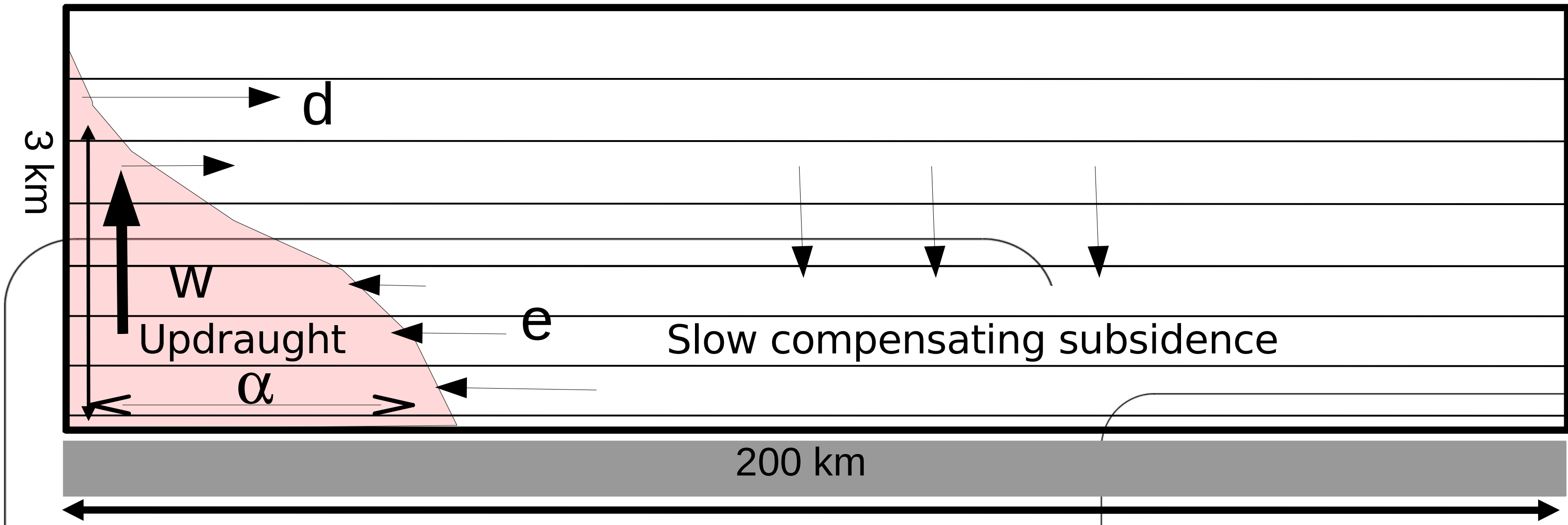
In a model column there are structures of boundary layer scale



**"The Thermal Model":**
Each column is split in two parts: Ascending air from the surface and subsiding air around it.

The model represents a mean plume (the thermal) and a mean cloud.




**Internal variables of the parametrization :**

- $w$ = mean vertical velocity of ascending plumes
- $\alpha$ = fractionnal area covered by the updraughts
- $e$ = lateral input rate of air into the plume (entrainment)
- $d$ = output rate of air from the plume (detrainment)
- $q_a$ = concentration of constituant $q$ in the updraughts

**Source term for the explicit equations :**

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

**Turbulent Diffusion**

**Transport by the thermal plume model**

- **Mass conservation**

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

- **Mass conservation of constituent $q$**

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

- **Equation of movement**

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

- **where B is the buoyancy :**

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

- **and the complex part lies in the expression of $e$ and $d$ :**

$$e = f\, max\left(0, \frac{\beta}{1+\beta}\left(a_1 \frac{B}{w^2} - b\right)\right)$$
$$d = \dots$$

Etc ...

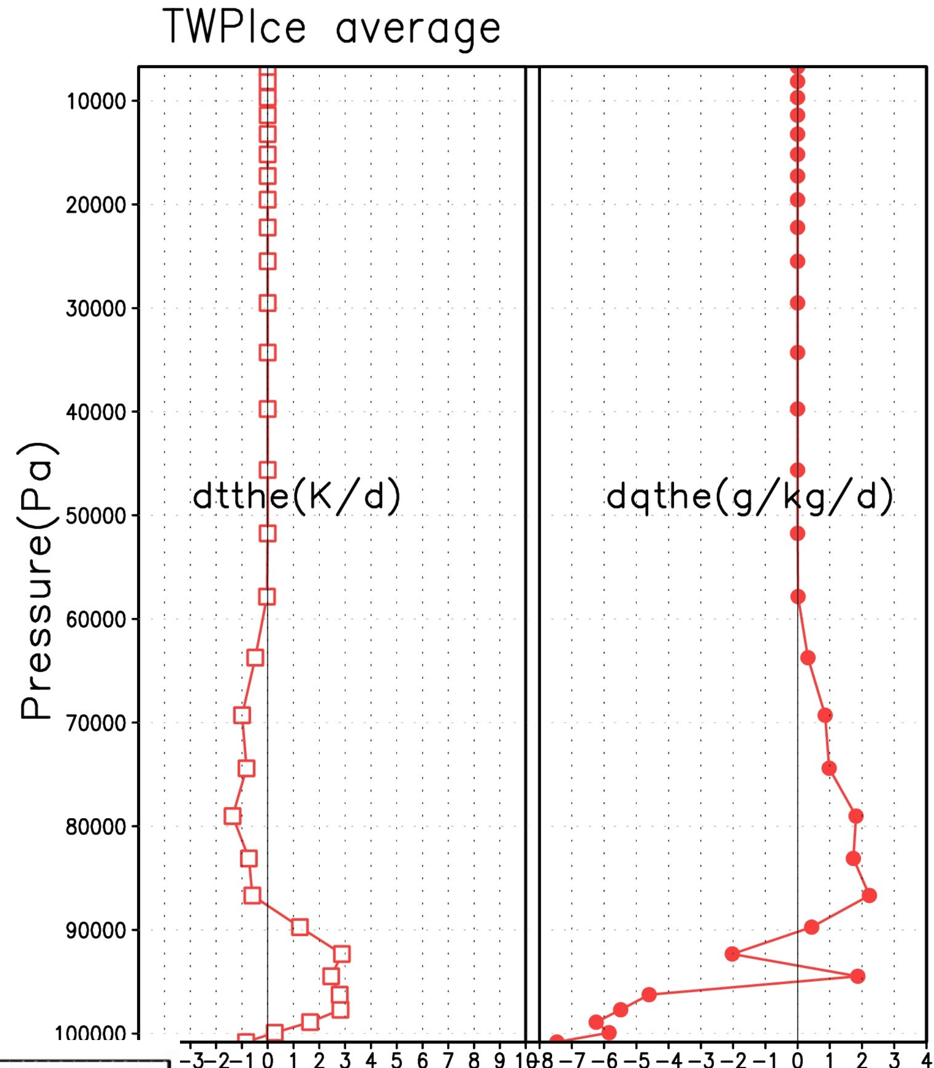
## Thermals and dry adjustment

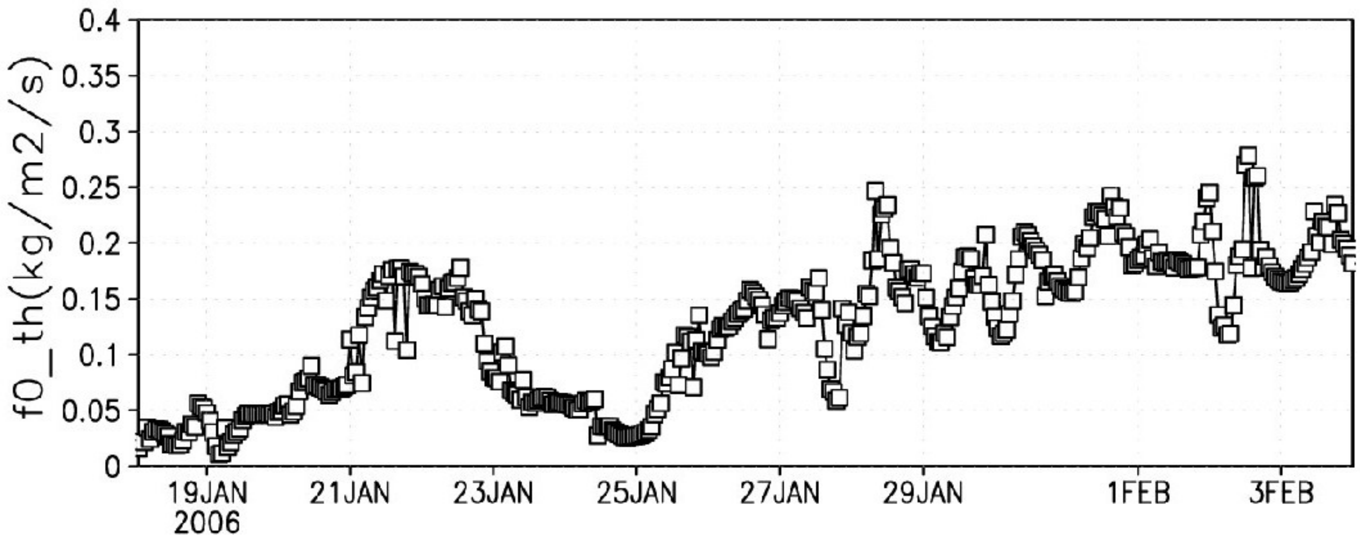
**Tendencies :**

dtthe, dqthe,duthe, dvthe

**Other variables**

– dtajs : temperature tendency due to the sole dry adjustment
– dqajs : humidity tendency due to the sole dry adjustment
– a_th : fractional area of thermal plumes
– d_th : detrainment
– e_th : entrainment
– f_th : mass flux
– w_th : vertical velocity in the thermal plume (m/s, positive upward)
– q_th : total water content in the thermal plume
– zmax_th : altitude of the top of the thermal plume (m)



| LMD | IPCC/AR4 | Nouvelle physique |
|---|---|---|
| Couche limite | Diffusion turbulente + Contre gradient (Louis/Laval) | Diffusion turbulente (Mellor et Yamada) + Schéma en flux de masse couche limite convective (modèle du thermique) |
| Convection | Schéma en flux de masse d'Emanuel. Fermeture CAPE | Schéma d'Emanuel modifié. Decl./Fermeture en ALE/ALP Couplé au modèle du thermique + poches froides |
| Surface | Modèle Sechiba à 2 couches | Modèle Sechiba à 11 couches (Patricia de Rosnay) |