

# The physical parametrizations in LMDZ

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## Atmospheric GCM equations (samples)

### Dynamic equations in Pressure coordinates

$$\left\{ \begin{array}{l}
 \partial_t \vec{V} = \underbrace{-(\vec{V} \cdot \vec{\nabla}) \vec{V}}_{\text{transport}} - \underbrace{\omega \partial_p \vec{V}}_{\text{gravity}} - \underbrace{f \vec{k} \times \vec{V}}_{\text{Coriolis}} + \underbrace{\vec{S}_V}_{\text{Sources}} \\
 \vec{\nabla} \cdot \vec{V} + \partial_p \omega = 0 \\
 \partial_t q = -\vec{V} \cdot \vec{\nabla} q - \omega \partial_p q + \underbrace{S_q}_{\text{Sources}}
 \end{array} \right. \left\{ \begin{array}{l}
 \Phi = gz \quad \text{geopotential} \\
 \omega = \partial_t p \quad \text{vert. velocity} \\
 q = \text{specific humidity}
 \end{array} \right. \quad (1)$$

$\vec{S}_v$  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 :

$$S_T = (\partial_t T)_\varphi = (\partial_t T)_{\text{eva}} + (\partial_t T)_{\text{lsc}} + (\partial_t T)_{\text{diff turb}} + (\partial_t T)_{\text{conv}} \\ + (\partial_t T)_{\text{wk}} + (\partial_t T)_{\text{Th}} + (\partial_t T)_{\text{ajs}} + (\partial_t T)_{\text{rad}} + (\partial_t T)_{\text{oro}}$$

## 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 *concul* (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** *radlwsu* (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.

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

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

$$De/Dt = f(dU/dz, d\theta/dz, e, \dots)$$

$$Dl/Dt = \dots$$

# TWPlce average

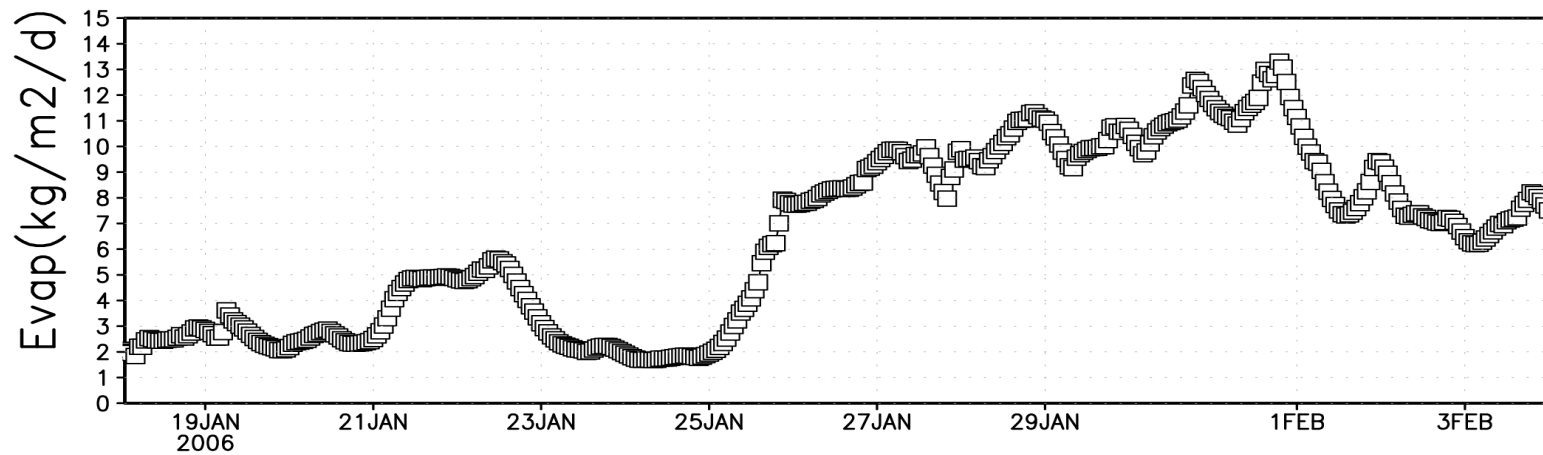
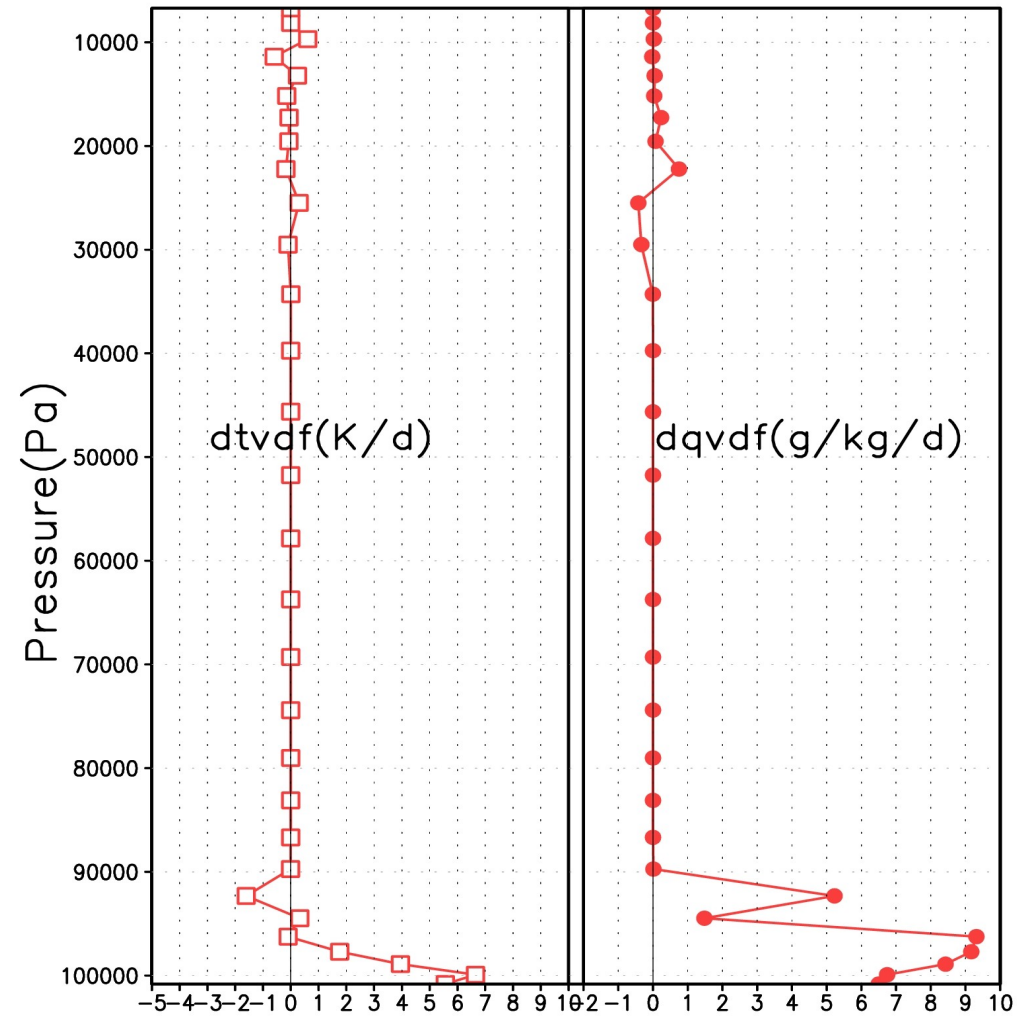
## Vertical diffusion

### Tendencies :

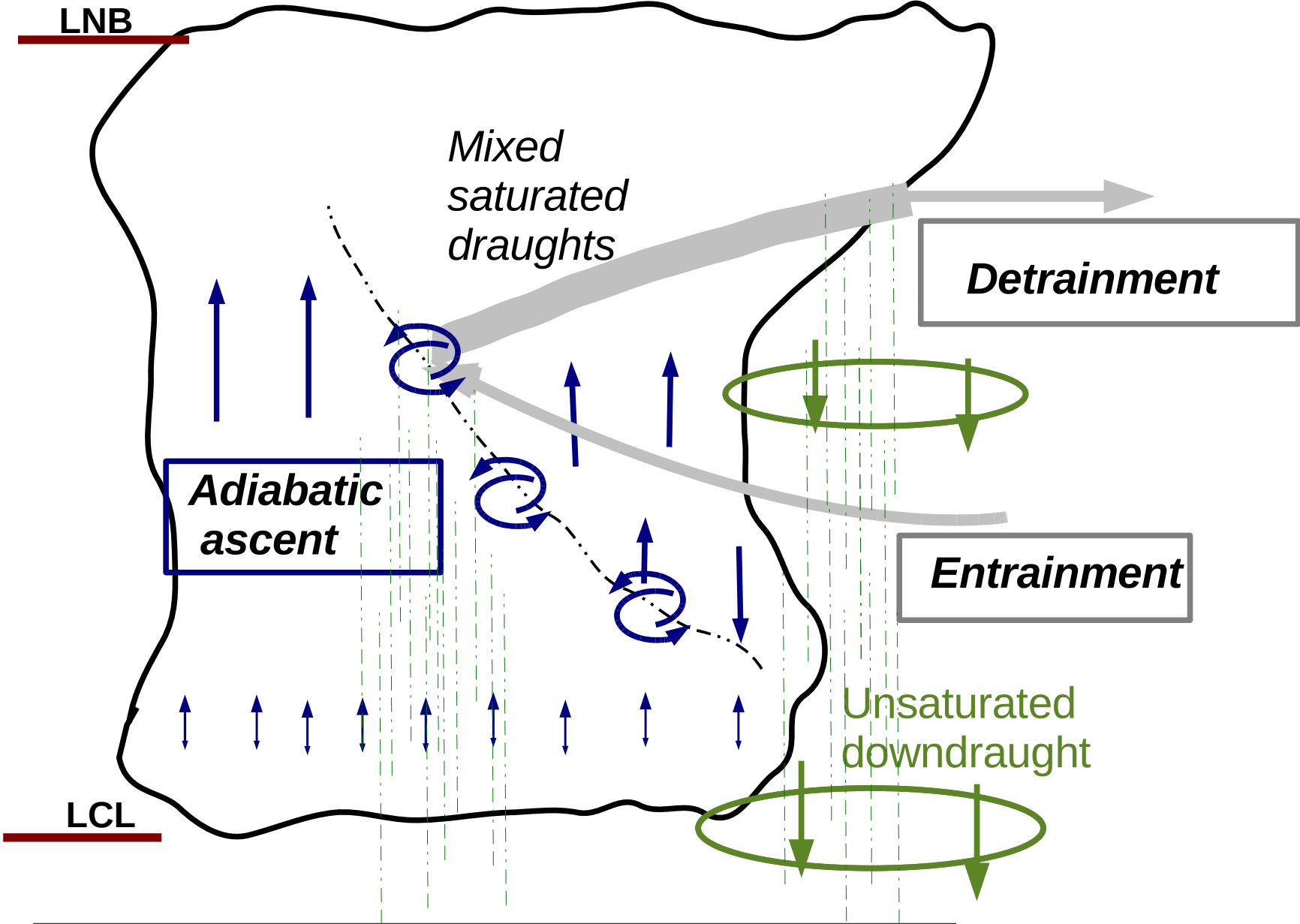
dtvdf, dqvdf, duvdf, dvvdf

### 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

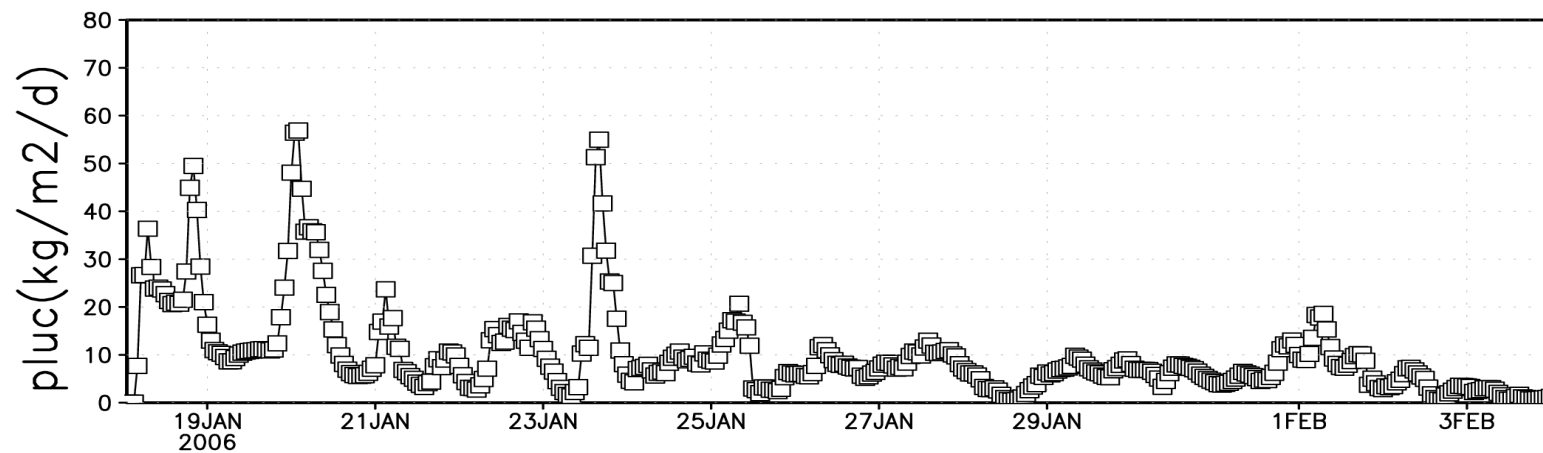
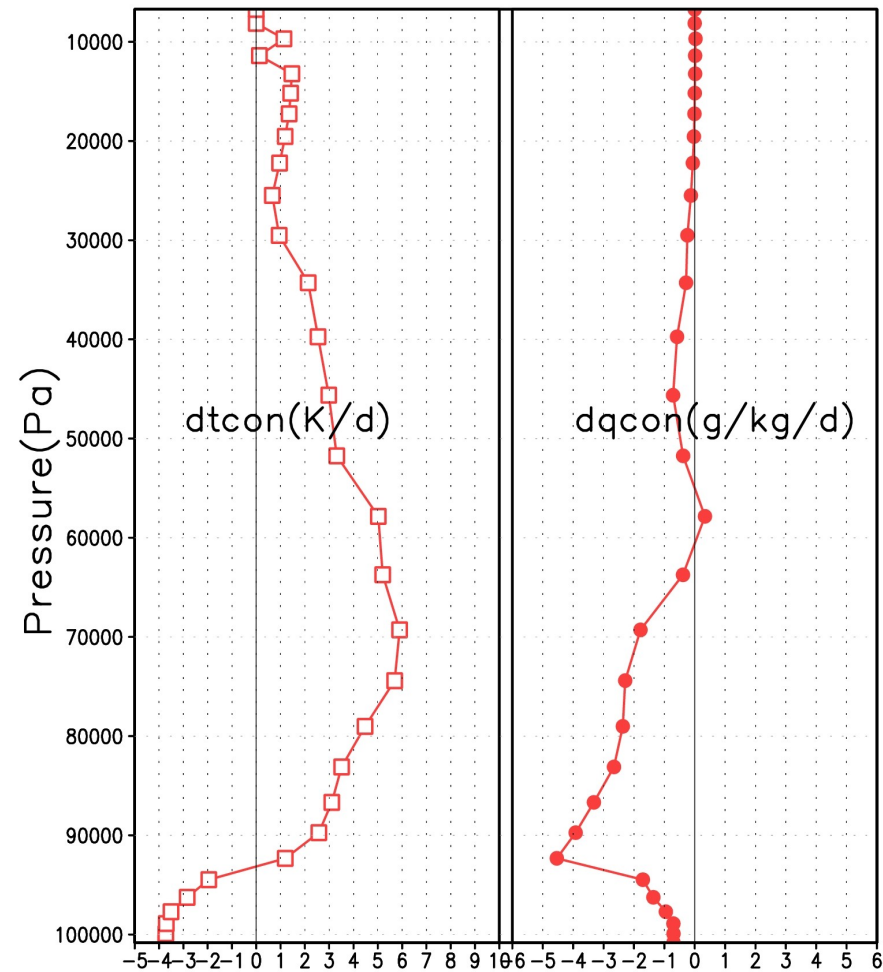
### Tendencies :

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

## TWPlce average





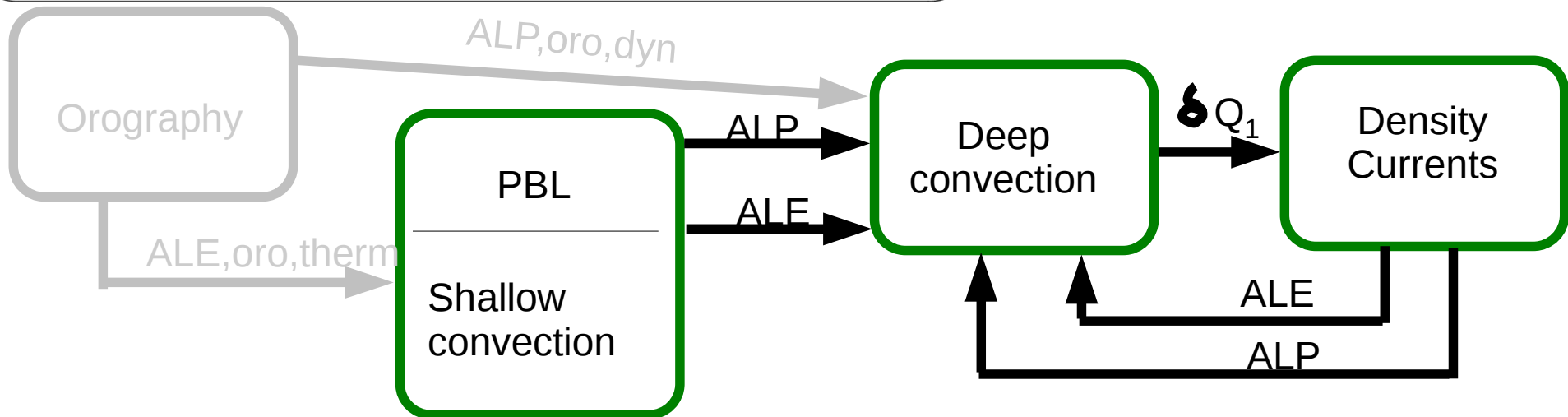
## Deep convection

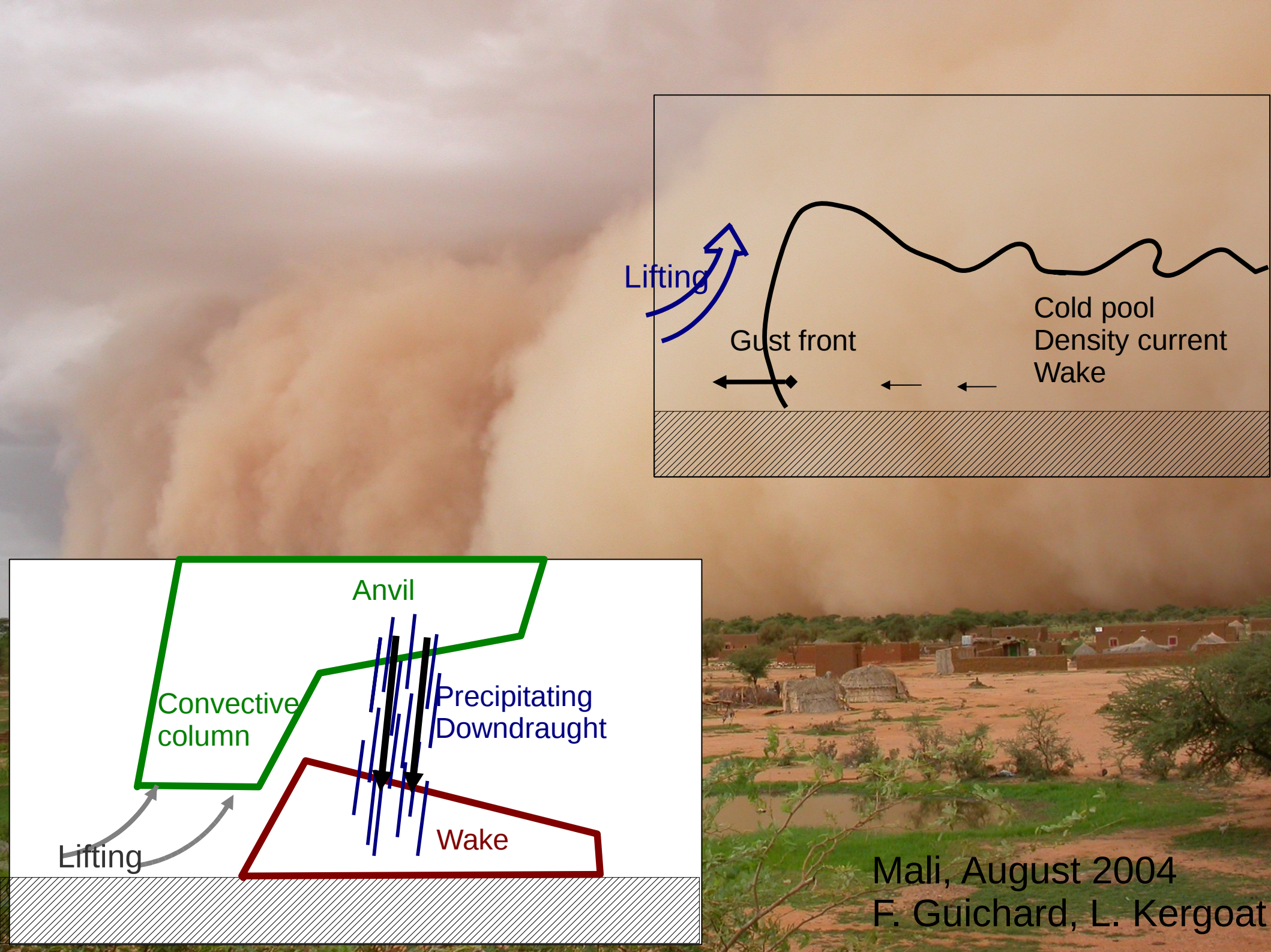
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Lifting

Gust front

Cold pool  
Density current  
Wake

Convective column

Anvil

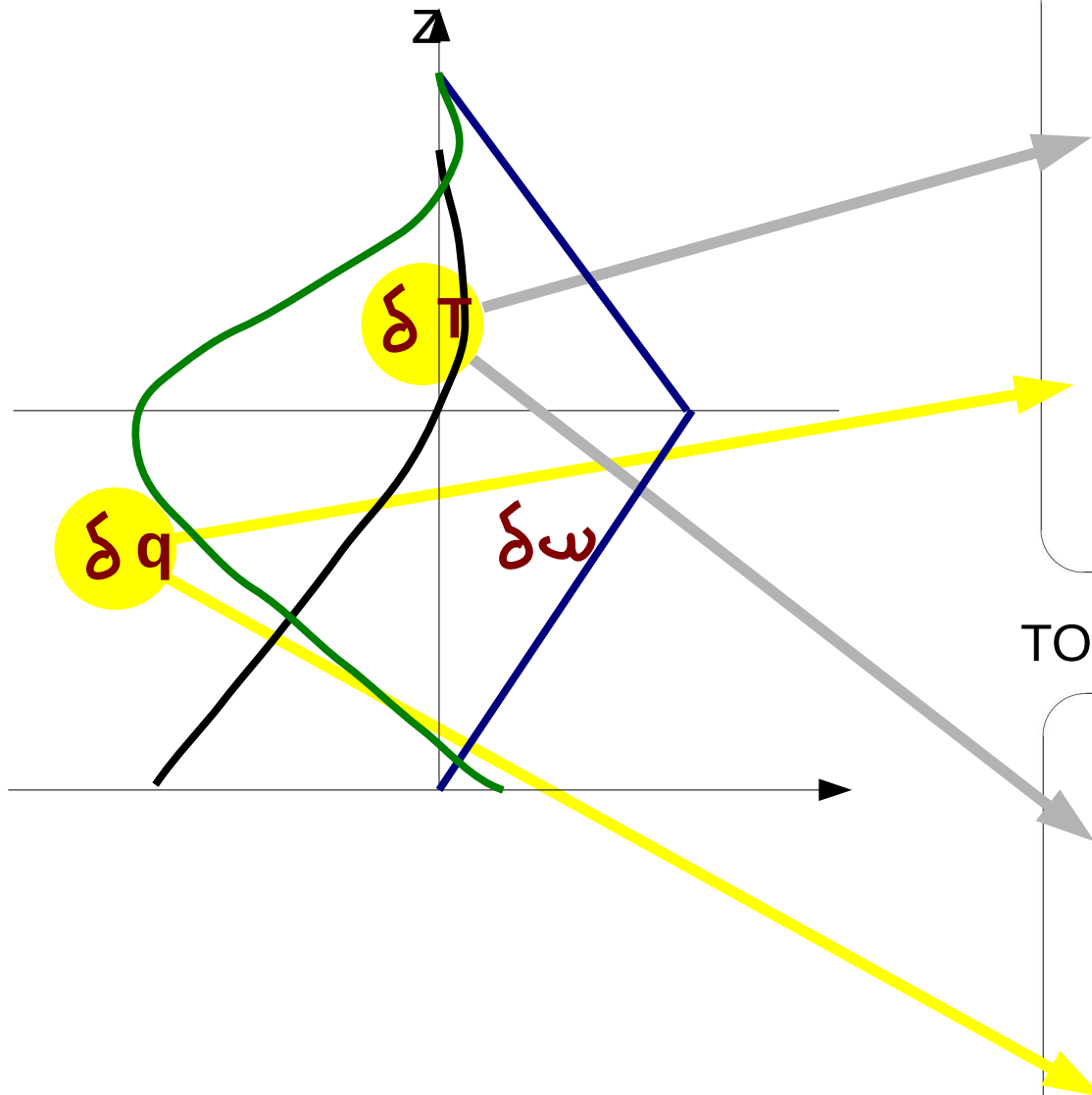
Precipitating  
Downdraught

Wake

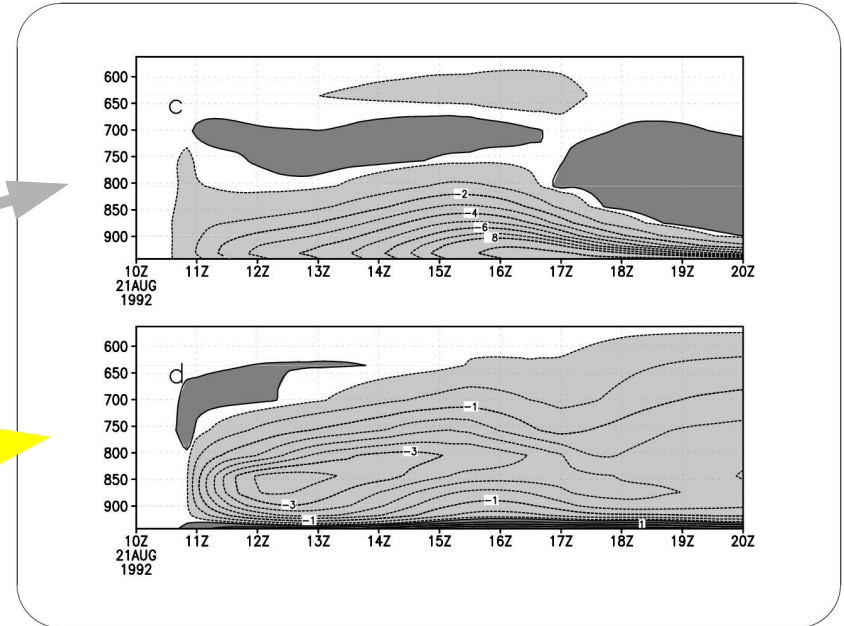
Lifting

Mali, August 2004  
F. Guichard, L. Kergoat

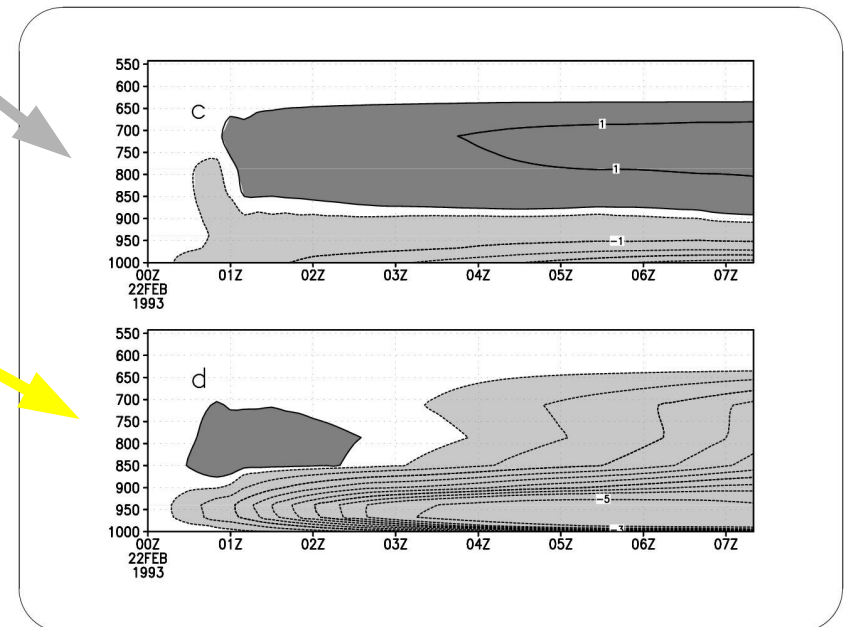
# Simulated wake properties



HAPEX92: 21 Aug 1992 squall line case



TOGA-COARE: 22 Feb 1993 squall line case



## Cold pools (wakes)

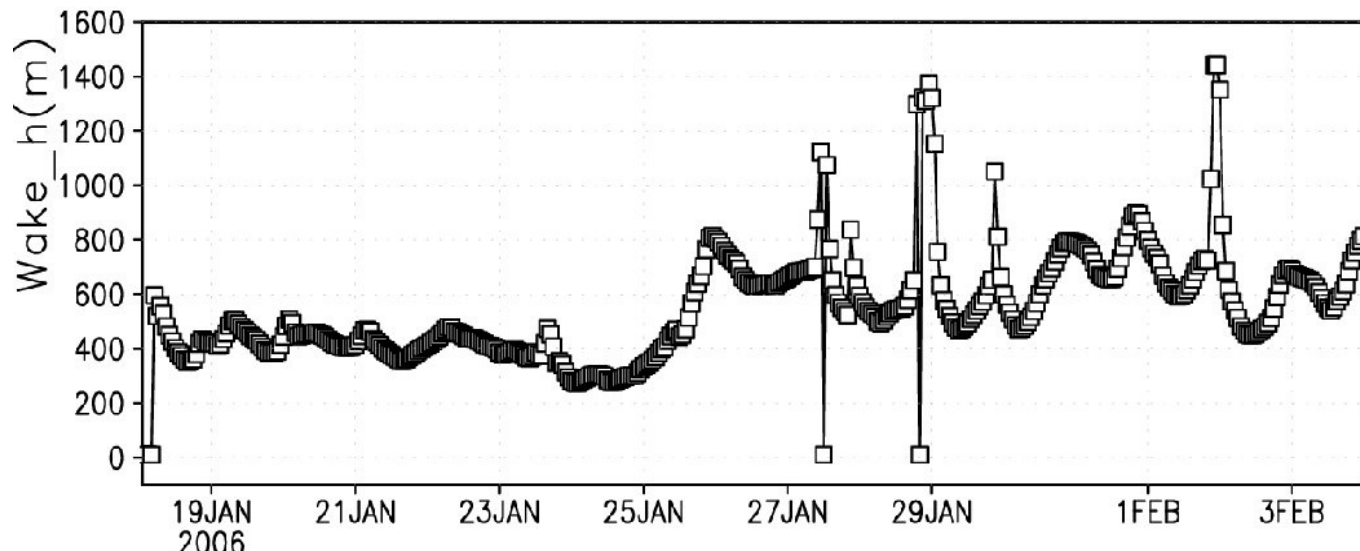
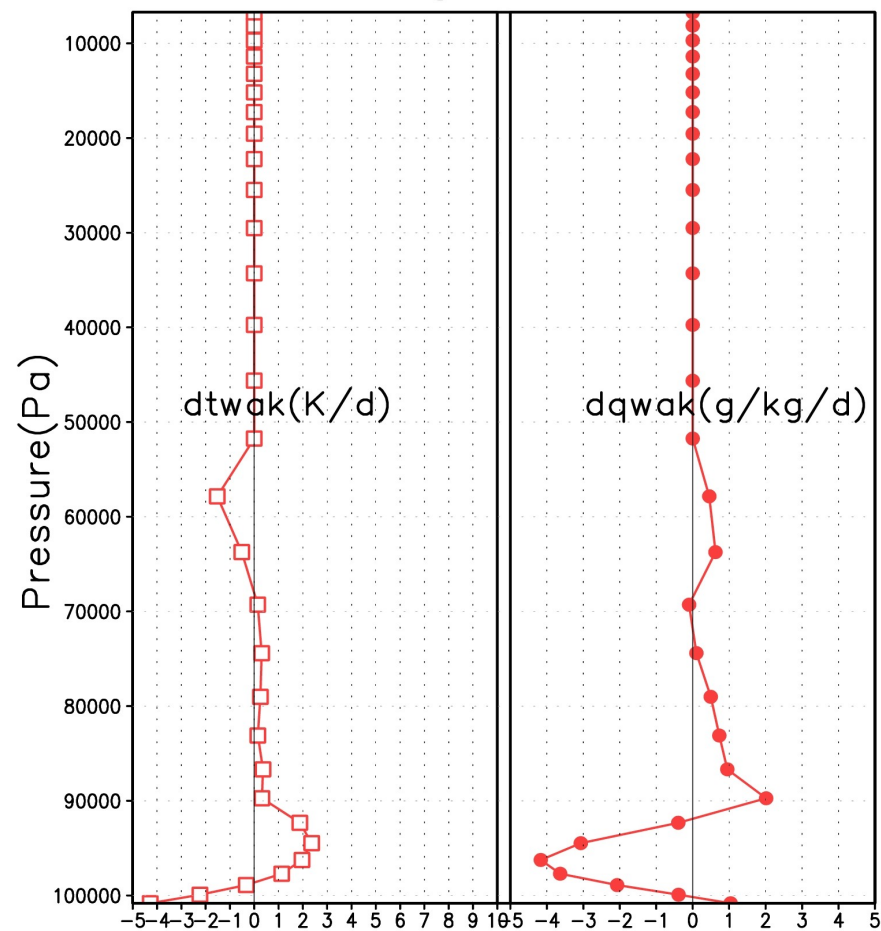
### Tendencies :

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  $\omega_w - \omega_x$

TWPIce average



## Orography

### **Tendencies :**

d<sub>toro</sub>, d<sub>uoro</sub>, d<sub>voro</sub> : tendencies of temperature and velocity due to the drag

d<sub>tlif</sub>, d<sub>ulif</sub>, d<sub>vlif</sub> : 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

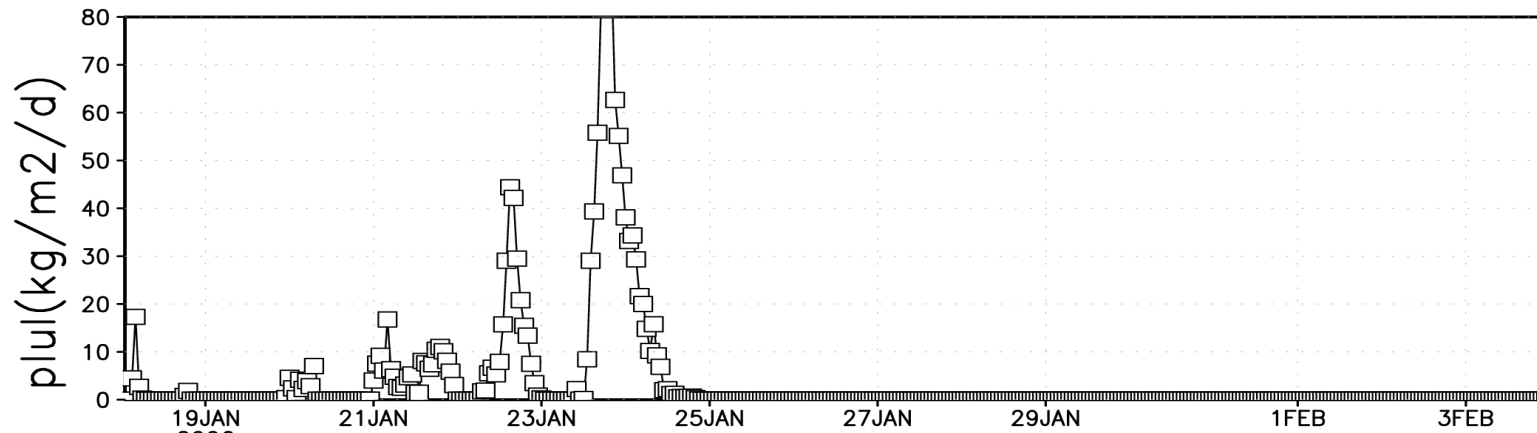
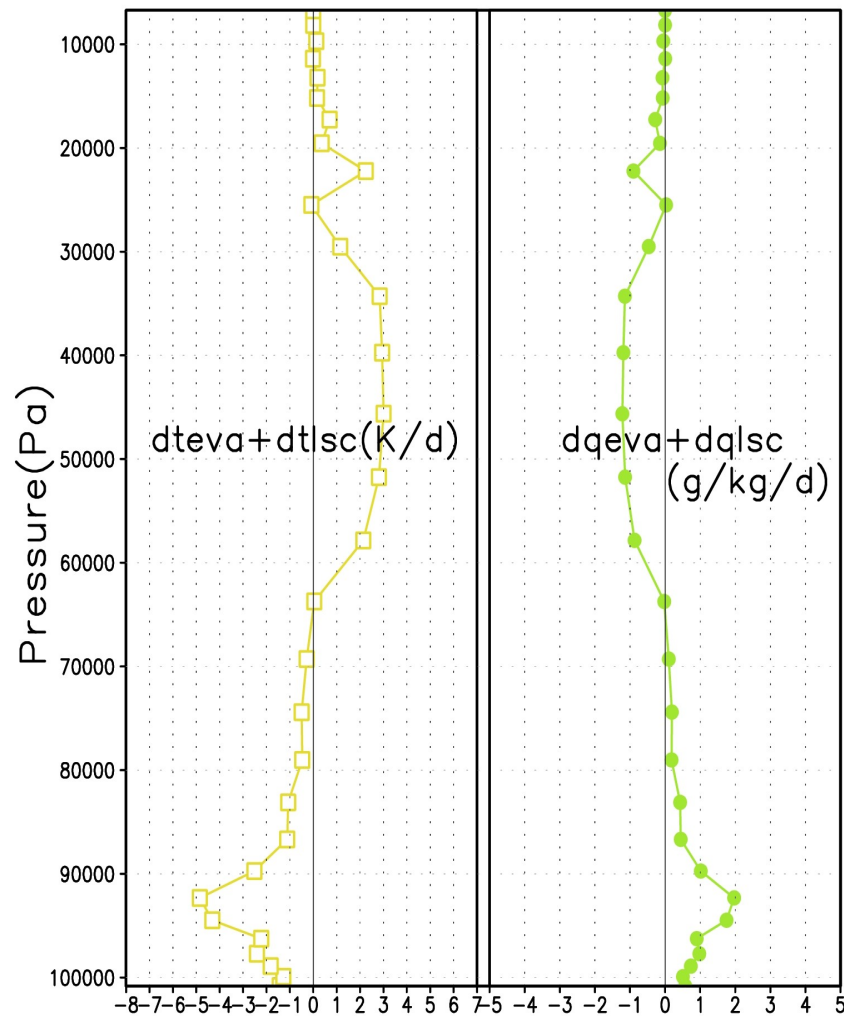
dtlsc, dqlsc : tendencies due to cloud water condensation

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

### Other variables

- plu1 : so called "large scale" or "stratiform" precipitation ; encompasses both stratiform precipitation and boundary layer cumulus precipitation.
- rneb : cloud cover

## TWPIce average



## Radiation

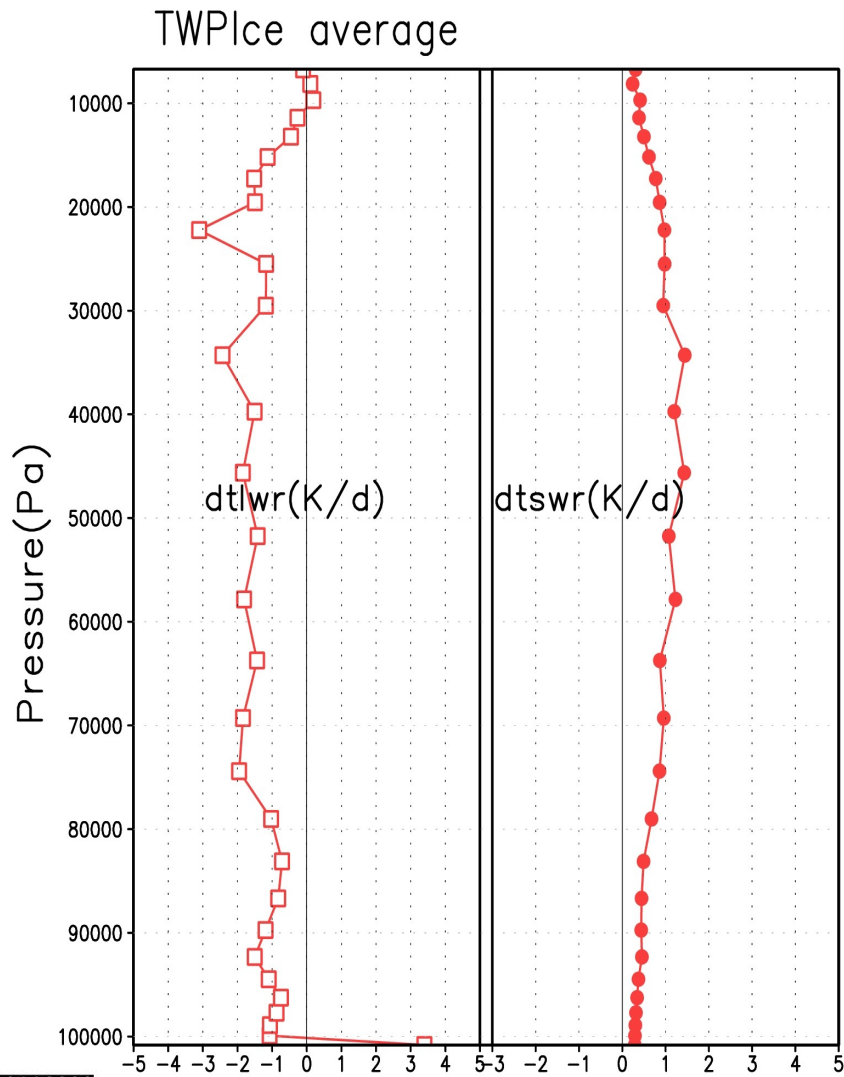
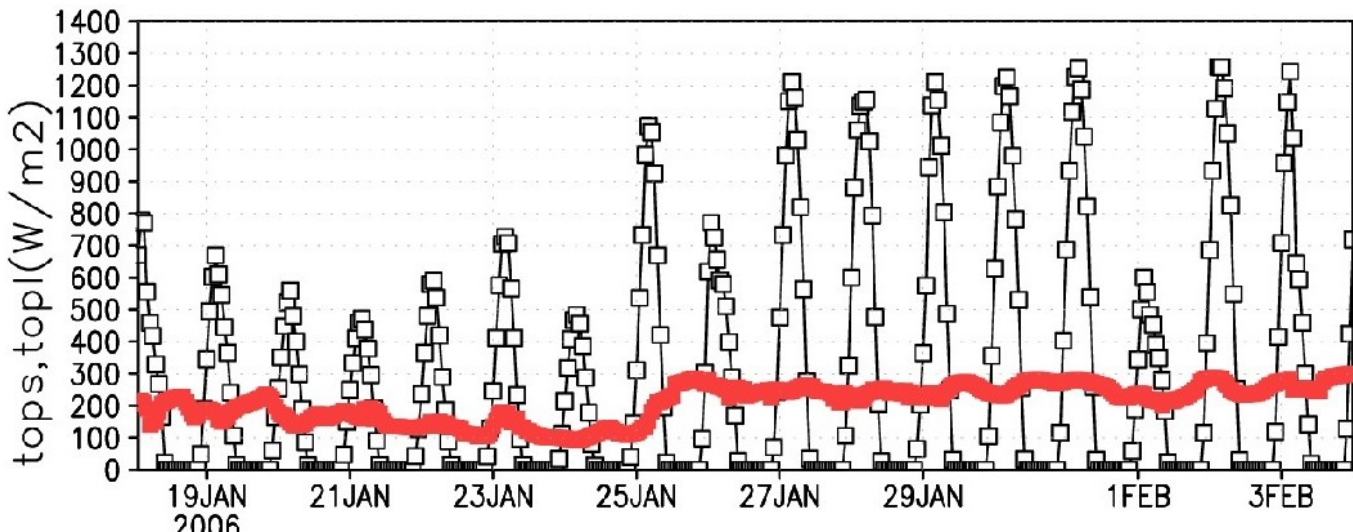
### Tendencies :

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

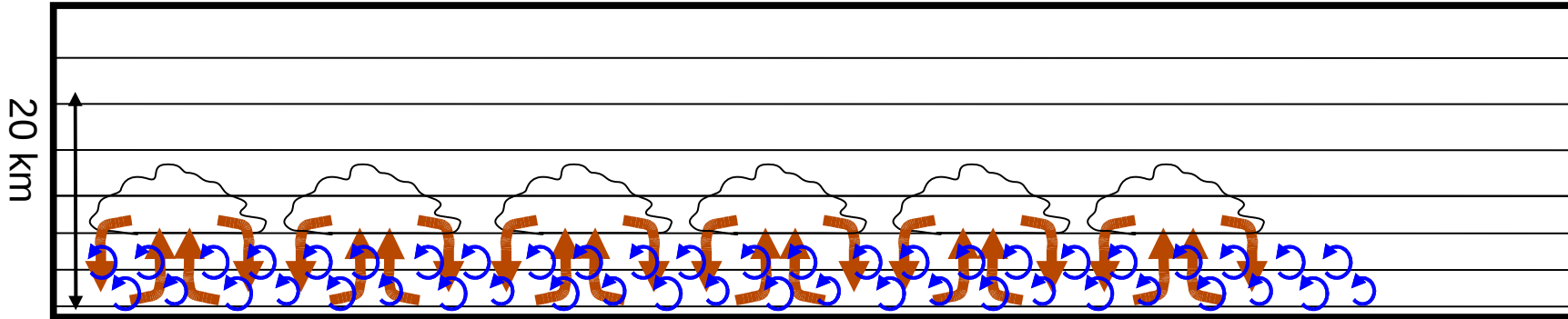
The total radiative tendency is the sum of the SW and LW tendencies.

### Other variables

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



In a model column there are structures of boundary layer scale

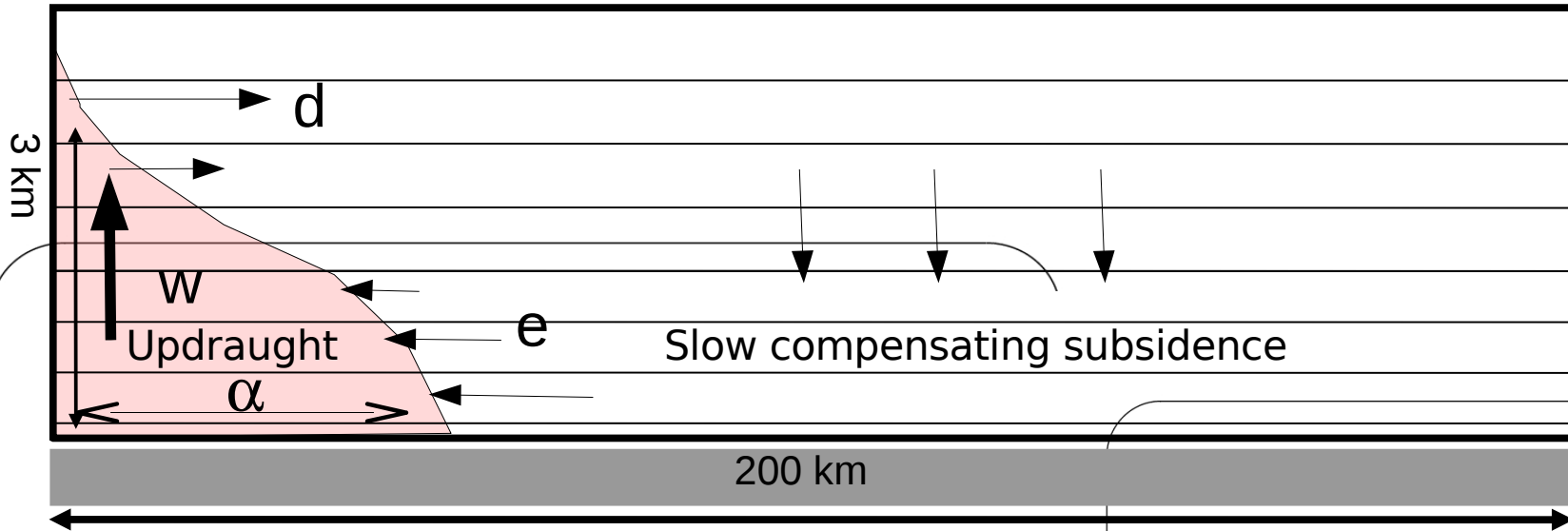


**“The Thermal Model”:**

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 constituent  $q$  in the updraughts

**Source term for the explicit equations :**

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

**Turbulent Diffusion**

**Transport by the thermal plume model**

- Mass conservation

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

- Mass conservation of constituent  $q$

$$\frac{\partial f q_a}{\partial z} = e q - d q_a$$

- Equation of movement

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

- 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  $d$  :

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

$$d = \dots$$

Etc ...

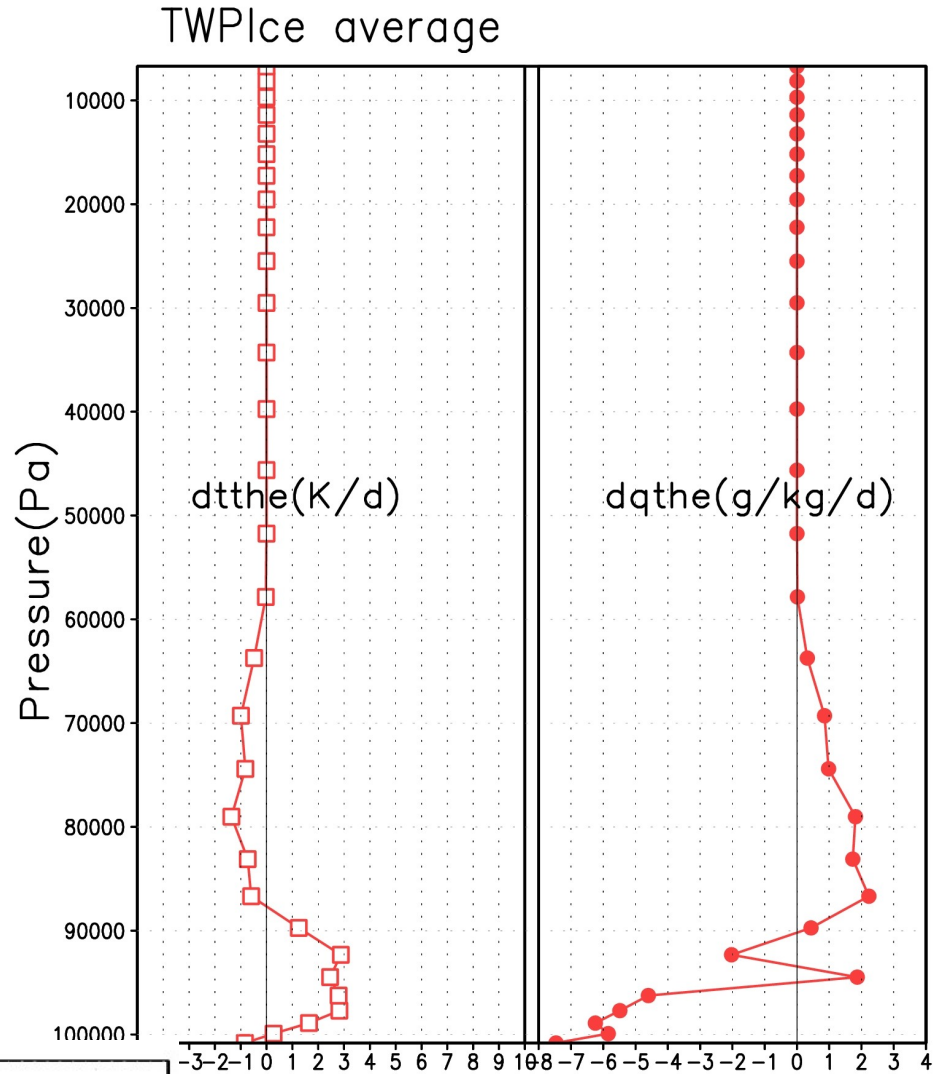
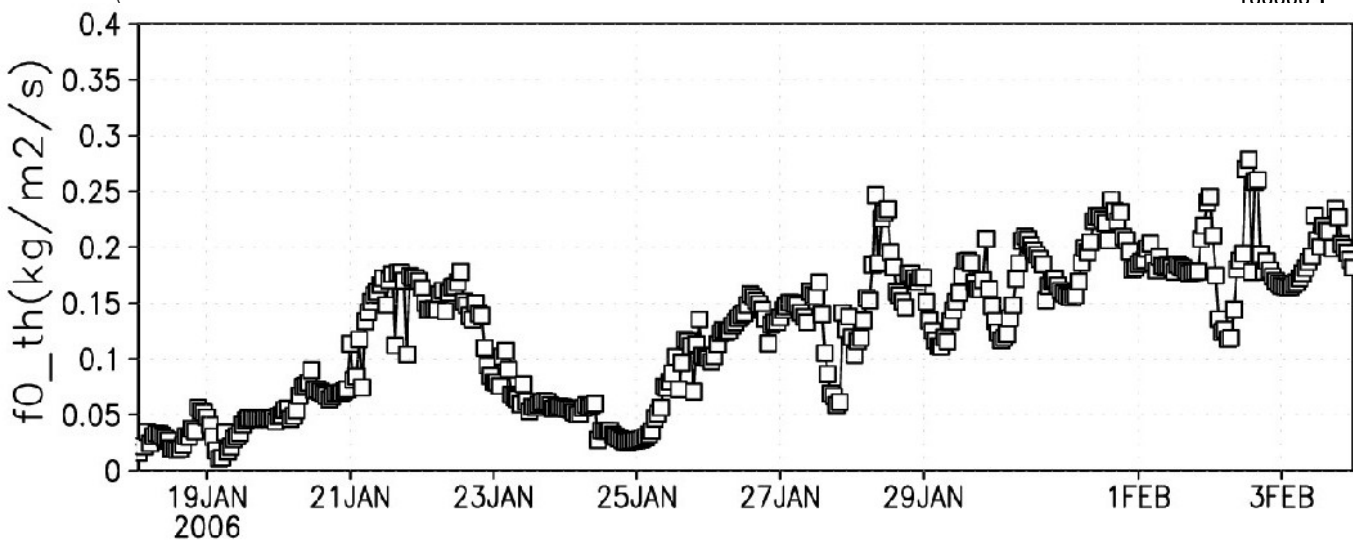
## Thermals and dry adjustment

### 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	LMDZ5A	LMDZ5B
Boundary layer	Turbulent diffusion + Counter gradient (Louis/Laval)	Turbulent diffusion (Mellor and Yamada) + Convective boundary layer Mass flux scheme (thermal model, Rio/Hourdin)
Convection	Mass flux scheme by Emanuel. CAPE closure	Modified Emanuel scheme. ALE/ALP trigger/closure coupled with the thermal model + cold pools
Surface	2 layer Sechiba model	2 layer Sechiba model