Deep convection parameterisation in the frame of ALARO

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The aim: to underline once more

- the differences between "classical" and new convection parameterization
- the approximations/choices involved
- some technical details

▪ **Mass flux approach**

▪ **Diagnostic scheme**

▪ **Prognostic scheme**
  - draft velocity equation
  - closure assumption
  - data flow within 3MT frame
  - input/output parameters
  - free parameters

Basic equation for parameterisations

$$\frac{\partial \overline{\psi}}{\partial t} = -\overline{\mathbf{V}}\nabla\overline{\psi} - \overline{\omega}\frac{\partial \overline{\psi}}{\partial p} - \frac{\partial \overline{\omega'\psi'}}{\partial x} - \frac{\partial \overline{\omega'\psi'}}{\partial y} - \frac{\partial \overline{\omega'\psi'}}{\partial p} + S_{\psi}$$

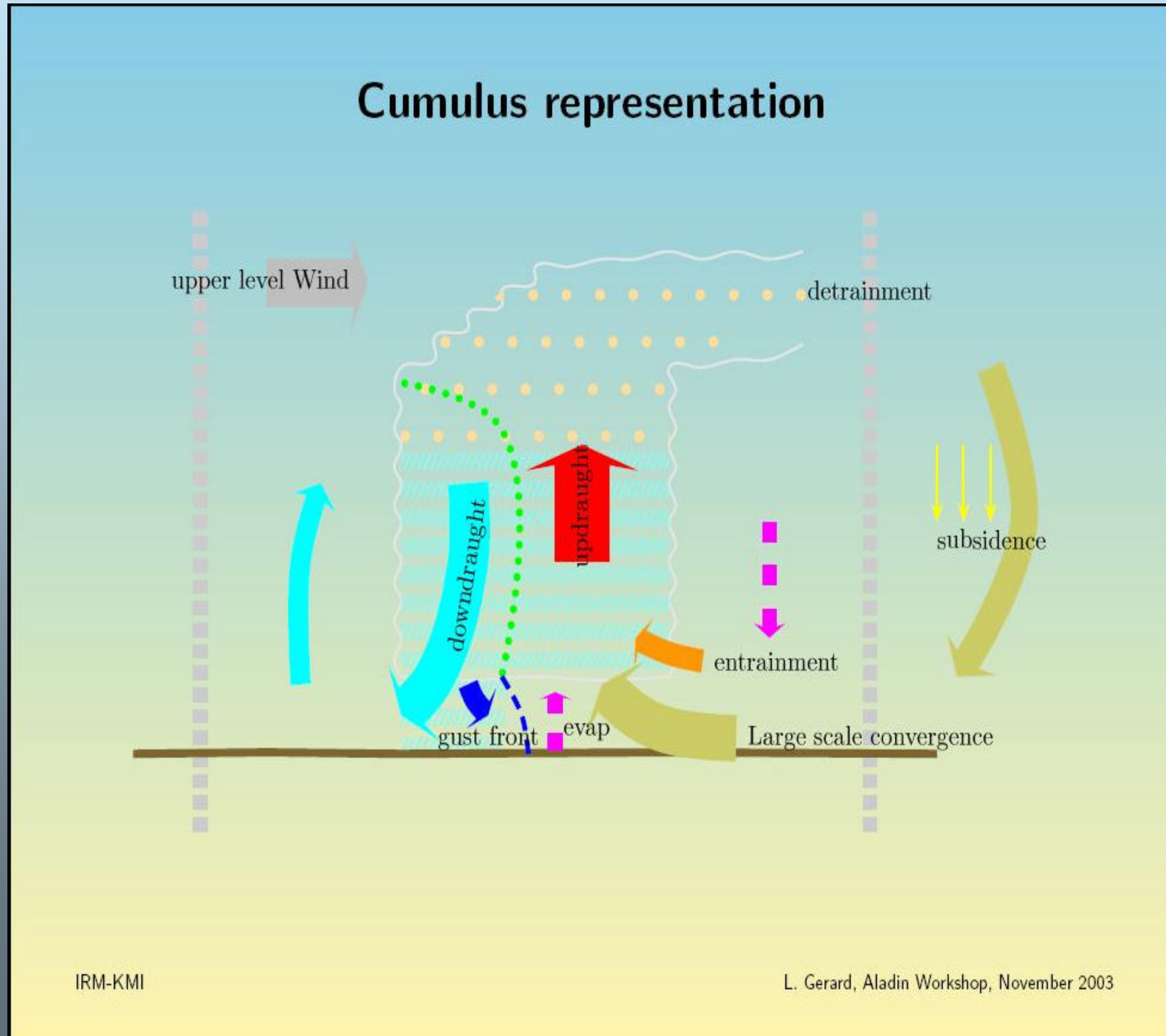
$$\left(\frac{\partial \overline{\psi}}{\partial t}\right)_{SG} = \text{source} - \frac{\partial \overline{\omega'\psi'}}{\partial p} = \left(\frac{\partial \overline{\psi}}{\partial t}\right)_{conv} + \left(\frac{\partial \overline{\psi}}{\partial t}\right)_{vert.diffusion} + \text{other}$$

$\overline{\psi}$ - mean values

ψ' - sub-grid perturbations from the mean value provided by physical parameterisations

Mass flux approach (1)

cloudy area $\Leftrightarrow$ no cloudy area



Mass flux approach (2)

updraft + downdraft +environment

$$\sigma_u \qquad \sigma_d \qquad \sigma_e$$

$$\overline{\omega'\psi'} = \sigma_u \left[\overline{\omega'\psi'}\right]_u + \sigma_d \left[\overline{\omega'\psi'}\right]_d + \sigma_e \left[\overline{\omega'\psi'}\right]_e$$

$$\overline{\psi} = \sigma_u \psi_u + \sigma_d \psi_d + (1 - \sigma_u - \sigma_e)\psi_e$$

$$\overline{\omega'\psi'} = \sigma_u(\omega_u - \omega_e)(\psi_u - \overline{\psi}) + \sigma_d(\omega_d - \omega \;)(\psi_d - \overline{\psi})$$

$$\overline{\omega'\psi'} = \sigma_u(\omega_u - \overline{\omega})(\psi_u - \psi_e) + \sigma_d(\omega_d - \overline{\omega})(\psi_d - \psi_e)$$

Relative drafts velocity in respect to the environment

$$\omega_u^* = \sigma_u \cdot (\omega_u - \omega_e) \qquad \omega_d^* = \sigma_d \cdot (\omega_d - \omega_e)$$

$$-\frac{\partial \overline{\omega'\psi'}}{\partial p} = -\frac{\partial \omega_u^* (\psi_u - \overline{\psi})}{\partial p} - \frac{\partial \omega_d^* (\psi_d - \overline{\psi})}{\partial p}$$

Mass flux approach (3)

Up and downdraft mass fluxes

$$M_u = -\sigma_u \cdot \omega_u = -\left(\omega_u^* - \sigma_u \omega_e\right) \Leftrightarrow \omega_u^* = -\left(M_u + \sigma_u \omega_e\right)$$

$$M_d = \sigma_d \cdot \omega_d = \left(\omega_d^* - \sigma_d \omega_e\right) \Leftrightarrow \omega_d^* = \left(M_d + \sigma_d \omega_e\right)$$

Mixing with environmental air

$$\frac{\partial M_u}{\partial p} = D_u - E_u + \frac{\partial \sigma_u}{\partial t} \qquad \frac{\partial M_d}{\partial p} = D_d - E_d + \frac{\partial \sigma_d}{\partial t}$$

$$\frac{\partial\left(M_u \psi_u\right)}{\partial p} = D_u \psi_u - E_u \psi_e + \frac{\partial \sigma_u \psi_u}{\partial t} + \text{source} \qquad \frac{\partial\left(M_d \psi_d\right)}{\partial p} = D_d \psi_d - E_d \psi_e + \frac{\partial \sigma_d \psi_d}{\partial t} + \text{source}$$

ψ - conservative variable of the draft (moisture, dry static energy)

$E \geq 0$ - entrainment rate

$D \leq 0$ - detrainment rate

Mass flux approach (4)

Approximations

a) $\sigma_{u/d} << 1 \qquad \omega_e \approx 0 \qquad \Rightarrow \qquad -\omega_u^* \approx M_u, \quad \omega_d^* \approx M_d \qquad \psi_e = \overline{\psi}$

b) $\dfrac{\partial \sigma_{u/d}}{\partial t} \approx 0; \quad \dfrac{\partial \psi_{u/d}}{\partial t} \approx 0$

c) The condensed water is removed as precipitation in one time step

Mass flux budget

$$\frac{\partial M_u}{\partial p} = D_u - E_u \qquad \frac{\partial M_d}{\partial p} = E_d - D_d$$

$$\frac{\partial (M_u q_u)}{\partial p} = D_u \psi_u - E_u q_e - c \qquad \frac{\partial (M_d q_d)}{\partial p} = D_d q_d - E_d \psi_e + e$$

$$\frac{\partial (M_u s_u)}{\partial p} = D_u \psi_u - E_u s_e - Lc \qquad \frac{\partial (M_d s_d)}{\partial p} = D_d s_d - E_d s_e + Le$$

$$\frac{\partial M_u \vec{V}_u}{\partial p} = D_u \vec{V}_u - E_u \overline{\vec{V}_u} \qquad \frac{\partial M_d \vec{V}_d}{\partial p} = D_d \vec{V}_d - E_d \overline{\vec{V}_d}$$

$$\left(\frac{\partial \overline{s}}{\partial t}\right)_u = Lc - \frac{\partial \overline{\omega' s'}}{\partial p} = \omega_u^* \frac{\partial \overline{s}}{\partial p} + D_u (s_u - \overline{s}) \qquad \left(\frac{\partial \overline{q}}{\partial t}\right)_u = -c - \frac{\partial \overline{\omega' q'}}{\partial p} = \omega_u^* \frac{\partial \overline{q}}{\partial p} + D_u (q_u - \overline{q})$$

Diagnostic schemes

L3MT=FALSE

- **based on the mentioned approximations, using a single equivalent updraft/downdraft**
- **in the ALARO frame used outside 3MT switch**

Bougeault (19985) | Ducrocq and Bougeault (1995)

$$\left(\frac{\partial\overline{\psi}}{\partial t}\right)_{u/d} = \underbrace{\omega^*_{u/d}\frac{\partial\overline{\psi}}{\partial p}}_{\substack{\text{pseudo}\\ \text{subsidence/ascent}}} + \underbrace{\overline{D}_{u/d}\left(\psi_{u/d}-\overline{\psi}\right)}_{\text{detrainment}} + \frac{\partial F^{diff}_{\psi}}{\partial p} \Leftrightarrow \omega^*_{u/d}\frac{\partial\overline{\psi}}{\partial p} + D_{u/d}\left(\psi_{u/d}-\overline{\psi}\right)$$

Updraft profile: moist adiabatic ascent

Updraft velocity

$$\omega^*_c = \alpha_c\rho\left(h_c - h\right)^{\frac{1}{2}}$$

Updraft closure: total moisture convergence = Rate of cloud water production= rained out water + detrained water

$$\alpha_c = \frac{F_q^{vert\_diff}(p_b) - F_q^{vert\_diff}(p_t) - \int_{p_t}^{p_b}(\vec{V}\cdot\nabla\overline{q} + \overline{\omega}\frac{\partial\overline{q}}{\partial p})\frac{dp}{g}}{\int_{p_t}^{p_b}\left[\rho(h_c - h)\right]^{1/2}\frac{\partial\overline{q}}{\partial p}\frac{dp}{g}}$$

Downdraft profile: moist adiabatic descent

Updraft velocity

$$\omega^*_d = \alpha_d\left(h_d - \overline{h}\right)^{\frac{1}{2}}F(p);\ F(p) = \left(\frac{p_s - p}{p_s - p_t}\right)^{exp}$$

Updraft closure: a fraction of the available precipitation is used to moisten the environment

$$\int_{p_t}^{p_b}\omega^*_d\frac{\partial q_d}{\partial p}\cdot\frac{\partial p}{g} = \varepsilon P$$

Conservation of moist static energy over the depth of the draft $\Longrightarrow$ $\overline{D}_{u/d}$

Second closure assumption

Prognostic schemes (1)

- ***diagnostic schemes*** (Bougealt, Bougealt and Ducrocq)

  - equilibrium between mass flux and large scale forcing (resolved humidity convergence)

  quasi equilibrium assumption: $\tau_{LS} >> \tau_D$, not always fulfilled !

  - sequence of QEs : mass flux re-diagnosed every time step from the new conditions the equilibrium is to be established in 1 time step (may be shorter than τ_D)

  $\tau_{ascent} < \tau_{LS}$ less critical

- **prognostic approach** (Gerad, 2005**)**

  relaxation of quasi equilibrium hypothesis

  $\Longrightarrow$ <u>a prognostic type closure for the mass flux</u>

  2 additional equations for
  - draft velocity: from vertical motion equation
  - draft mesh fraction (constant on the vertical): from the closure assumption

  ❖ $\tau_{ascent} < \tau_{LS} \Rightarrow$ an instantaneous diagnostic of cloud profile

  - preserve the memory -

L3MT=TRUE

Prognostic scheme (2)

Gerard, 2007

❖ part of an integrated package treating in an unified consistent mode all cloud processes

In respect with Gerard 2005:

- use of prognostic condensed water (q_l,q_i) and precipitation (q_r,q_s)
- an unified treatment of transport & microphysics (Piriou, 2007)

$$-\frac{\partial\overline{\omega'\psi'}}{\partial p} = -\frac{\partial\omega_u^*\left(\psi_u - \overline{\psi}\right)}{\partial p} - \frac{\partial\omega_d^*\left(\psi_d - \overline{\psi}\right)}{\partial p} \Leftrightarrow \textbf{convective transport and condensation}$$

Two routines called sequentially: **ACCVUD** and **ACMODO**

Draft vertical velocity

$$\frac{\partial \omega_u^*}{\partial t} + \left(\vec{V}\cdot\nabla\right)_\eta \omega_u^* + \dot{\eta}\frac{\partial \pi}{\partial \eta}\frac{\partial \omega_u^*}{\partial \pi} = \mathbf{source}(\omega_u^*)$$

prognostic variable:
relative updraft velocity

$$\left.\frac{\partial \omega_u^*}{\partial t}\right|_{dyn} + \left(\vec{V}\cdot\nabla\right)_\eta \omega_u^* + \dot{\eta}\frac{\partial \pi}{\partial \eta}\frac{\partial \omega_u^*}{\partial \pi} = 0 \longrightarrow$$ simple passive advection

$$\left.\frac{\partial \omega_u^*}{\partial t}\right|_{phys} + \left(\dot{\eta}_u - \dot{\eta}\right)\frac{\partial \pi}{\partial \eta}\frac{\partial \omega_u^*}{\partial \pi} = \mathbf{source}(\omega_u^*)$$

$\omega_e << \omega_u$ neglect all derivates of ω_e

$\omega_u \approx -\rho g w_u$

$$\left.\frac{\partial \omega_u^*}{\partial t}\right|_{phys} + (1_u - \sigma_u)\omega_u\left(\frac{\partial \omega_u^*}{\partial \pi} - \frac{\omega_u^*}{\pi} + \omega_u^*\frac{\partial \ln T_v}{\partial p}\right) = -\rho g \cdot \mathbf{source}(w_u)$$

$$\frac{\partial \omega_d}{\partial t} + \left(\vec{V}\cdot\nabla\right)_\eta \omega_d + \dot{\eta}\frac{\partial \pi}{\partial \eta}\frac{\partial \omega_d}{\partial \pi} = \mathbf{source}(\omega_d)$$

prognostic variable:
absolute downdraft velocity
ω_e independent of ω_d
- could not be neglected

$$\omega_d \approx -\rho g w_d \quad \frac{\partial \rho_d}{\partial t} \approx 0$$

$$\left.\frac{\partial \omega_d}{\partial t}\right|_{phys} + \left(\omega_d - \overline{\omega}\right)\left(\frac{\partial \omega_d}{\partial \pi} - \frac{\omega_d}{\pi} + \omega_d\frac{\partial \ln T_v}{\partial p}\right) = -\rho g \cdot \mathbf{source}(w_d)$$

Updraft velocity

$$\left.\frac{\partial \omega_u^*}{\partial t}\right|_{phys} + (1_u - \sigma_u)\omega_u \left(\frac{\partial \omega_u^*}{\partial p} - \frac{\omega_u^*}{\pi} + \omega_u^* \frac{\partial \ln \overline{T_v}}{\partial p} \right) = \underbrace{\frac{g^2}{1+\gamma} \frac{p}{R_a} \frac{T_{vu} - \overline{T_v}}{\overline{T_v} T_{vu}}}_{\text{buoyancy}} + \underbrace{\frac{\omega_u^{*2}}{p} R_a T_{vu} \left(\lambda + \frac{K_{du}}{g} \right)}_{\text{dissipation}}$$

neglected

- **buoyancy** : difference between parcel virtual temperature and environmental virtual temperature
- **dissipation** → entrainment of the environmental air – to be accelerated up to ω_u

  depends on $\omega_u - \omega_e$ $\quad -\frac{1}{\rho\rho^2 g}\lambda_u \omega_u^{*2}$

  → friction (aerodynamic braking): ~ ω_u^{*2}

  K_{du} updraft dissipation coefficient (**TUDFR**)

⇨ $\Delta\omega_u$: inbalance between buoyancy and dissipative effects

γ - updraft virtual mass parameter due to acceleration of the surrounding fluid (**TUDBU**)

Downdraft vertical velocity (1)

$$\left.\frac{\partial \omega_d}{\partial t}\right|_{phys} + \left(\omega_d - \overline{\omega}\right)\left(\frac{\partial \omega_d}{\partial p} - \underbrace{\frac{\omega_d}{\pi} + \omega_d \frac{\partial \ln T_v}{\partial \pi}}_{\text{neglected}}\right) = \underbrace{-\frac{g^2}{1+\gamma}\frac{p}{R_a}\frac{T_{vd} - T_{ve}T_{vd}}{T_{vd}T_{ve}}}_{buoyancy}$$

$$\underbrace{-\delta_{dP}\left(\left(\lambda + \frac{K_{du}}{g}\right)\frac{R_a T_{vd}}{\pi}\right)\left(\omega_d - \omega_P\right)^2}_{dissipatio\ n} - \delta_d \frac{C_{dyn\_press}}{\left(\pi - \pi_s\right)^2}\omega_d^2$$

dissipation → entrainment of the environmental air, ***main part*** ; depends on $\omega_d - \omega_e'$

immediate environment: - updraft,

- updraft environment,
- an environment moved vertically in a large scale motion

choice: downdraft linked to precipitation → depends on $\omega_d - \omega_P$

→ friction (aerodynamic braking): $\mathbf{K_{du}}$ -updraft dissipation coefficient (TDDFR) for fine tuning

braking: only if $\omega_d > \omega_P \Rightarrow \delta_{dP} = 1$, otherwise 0

γ - downdraft virtual mass parameter (TDDBU)

NB: - the transient condensate in the downdraft could be important – not estimated !

⇒ use of the mass parameter (negative value) to enhance the negative buoyancy but no link to precipitation

Downdraft vertical velocity (2)

Interaction with the surface

$$w = \frac{dz}{dt} = \left(\frac{\partial z}{\partial t}\right)_{\pi} + \vec{V}_{\pi} \cdot \nabla_{\pi} z - \frac{w}{\rho g}$$

- far from the surface: $\omega \approx -\frac{w}{\rho g}$
- near the surface: the advection term could not be neglected
  - flow bends due to the local high generated by the accumulation of the air near surface
  - the equation for dw/dt $\rightarrow$ complicated

  choice: simulation of the effect by an additional term ~ dynamical pressure $\frac{\omega_d^2}{\pi} - \frac{\partial \omega_d^2}{\partial \pi}$

$$-C_{dyn\_press} \frac{|\omega_d| \omega_d}{(\pi_{surf} - \pi)^{\beta}} = -\delta_d \frac{C_{dyn\_press}}{(\pi_{surf} - \pi)^{\beta}} \omega_d^2$$

With β=2 (actual setting) : $C_{dyn\_press} \equiv$ reference pressure thickness for the decrease of ω_d

$\Downarrow$ $\Downarrow$

GDDBETA GDDDP

Updraft prognostic closure assumption

$$\underbrace{\frac{\partial \sigma_u}{\partial t} \cdot \int_{p_t}^{p_b} \left(h_u - \overline{h}\right) \frac{\partial p}{g}}_{storage} = \underbrace{L \int_{p_t}^{p_b} \sigma_u \omega_u^* \frac{\partial \overline{q}}{\partial p} \frac{\partial p}{g}}_{consumptio\quad n} + \underbrace{L \cdot TMC}_{\substack{input \\ large\ \ scale \\ forcing}}$$

- based on Chen & Bougeault (1990)
- keeping the Kuo closure principle

the water vapour supplied by the large scale (Total Moisture Convergence):

- **converted to condensate** → precipitation
- **detrained from the updraft**
- **difference input-consumption → energy storage**
  - as moist static energy
  by increasing the updraft mesh fraction

NB. The closure assumption based on CAPE ⇒ diagnostic σ_u

Downdraft closure assumption

$$\underbrace{\frac{\partial \sigma_d}{\partial t} \cdot \int_{p_t}^{p_b} \left[(h_d - h_e) + \frac{\omega_d^2 - \omega_e^2}{2(\rho g)^2} \right] \frac{\partial p}{g}}_{storage} = \underbrace{\sigma_d \int_{p_t}^{p_b} F_b \frac{\omega_d}{\rho g} \frac{\partial p}{g}}_{-consumption} + \underbrace{\varepsilon \cdot \int_{p_t}^{p_b} -g \frac{\partial F_{hP}}{\partial p} \frac{\partial p}{g}}_{energy-input}$$

different in respect with the updraft prognostic closure
downdraft diagnostic closure

$h_{e'} \approx h_e$

T ⇔ q

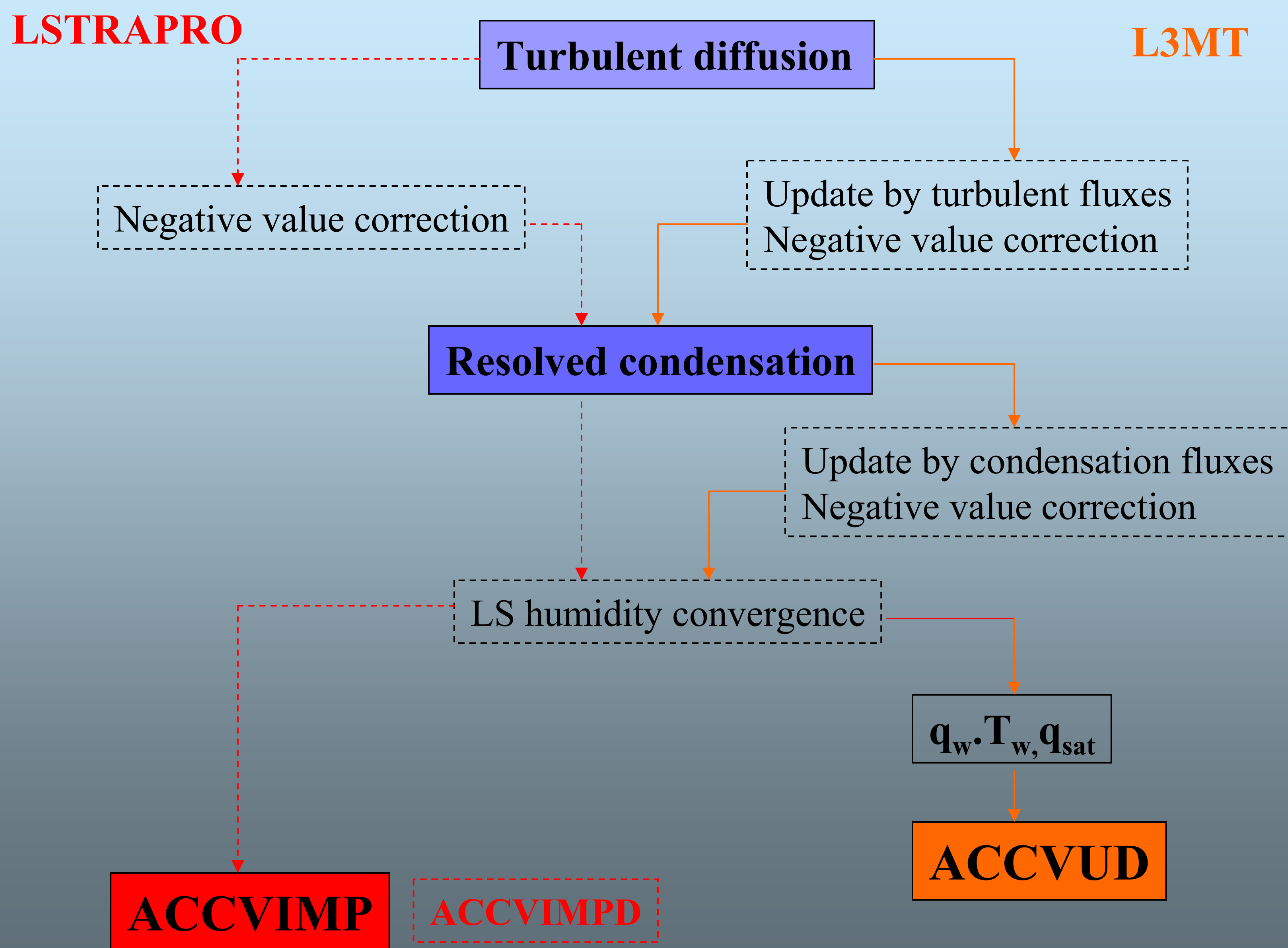
- **energy input:** cooling linked to precipitation
  - evaporation, melting, adjustment to the local temperature from the same grid box ~ fast variation
- **consumption:** cooling negative buoyancy
  downdraft "consumes" the energy linked to $T_d - T_e \rightarrow$ its own mass flux
- **difference input – consumption → energy storage**
  - moist static energy
  - kinetic energy

ε → GDDEVF

GDDEVA (diagnostic scheme)

$$\varepsilon \approx \frac{\textbf{downdraft mesh fraction}}{\textbf{precipitation mesh fraction}}$$

Call of the convective updraft parameterisation



ACCVUD

Input parameters

q_v, q_i, q_l, T → PQ, PQI, PQL, PT **-** updated in cascade: $Z\Psi^{(0+diff+LSC)}$

u, v → PU, PV **- wind components**

q_s T_s → PTS – **surface moisture and surface temperature**

q_w, T_w → PQW, PTW- **wet thermometer specific humidity and temperature**
recomputed (ACQSAT) before the call of ACCVUP

q_{sat} → PQSAT – **saturation specific humidity**

α_{SC} → PGEOSLC **slantwise convection factor**
recomputed (ACQSAT) before ACCVUP

f → PRCORI – Coriolis factor

ξ → PVORT0 **relative vorticity**

∇q_v → PCVGQ – **resolved humidity convergence**

τ_{CAPE} → PTAUX

ω_d, σ_d → PDDOM, PDDAL – **downdraft vertical velocity an mesh fraction**

ACCVUD

Output parameters

$\mathbf{F_{q_v}^{ud\_tran}, F_{q_i}^{ud\_tran}, F_{q_{li}}^{ud\_tran}, F_s^{ud\_tran}, F_u^{ud\_tran}, F_v^{ud\_tran}}$

- PDIFCQ, PDIFCQL, PDIFCQI, PDIFCS, PSTRCUD, PSTRCVD

$\mathbf{F_l^{conv\_cond}, F_i^{conv\_cond}}$ $\rightarrow$ PFCCQL, PFCCQI- convective condensation fluxes

$\mathbf{q_u, T_u, u_u, v_u}$ $\rightarrow$ PQU, PTU, PUU, PVU – **updraft,humidity, temperature and wind**

σ_D $\rightarrow$ PFRDE – **updraft detrainment area**

k_{act} $\rightarrow$ KNACT – **convective activity index** (active if 1)

k_{phys} $\rightarrow$ KNND – **zero if non physical solution** (used for convective cloudiness)

CAPE $\rightarrow$ PCAPE – **convective available potential energy**

I/O parameters

α_{SC} $\rightarrow$ PGEOSLC **slantwise convection factor**

ω_u, σ_u $\rightarrow$ PUDOM, PUDAL – **updraft vertical velocity and mesh fraction**

λ_{hist} $\rightarrow$ PENTCH – **prognostic updraft entrainment**

Updraft profile

ACCVUD

- moist pseudo-adiabatic ascent
- entrainment of the environmental air

Diagnostic mixing: quite complicated

- prescribed minimum and maximum entrainment rate
- variable on the vertical, minimum and maximum values being modulated by the integral buoyancy of an undiluted ascent
- dependency on mesh fraction
- simulation of cloud ensemble influnence on entrainment

-**Prognostic (historic) mixing : LENTCH switch ⇒ more complicated**

..one more variable **PENTCH** and additional tuning parameters

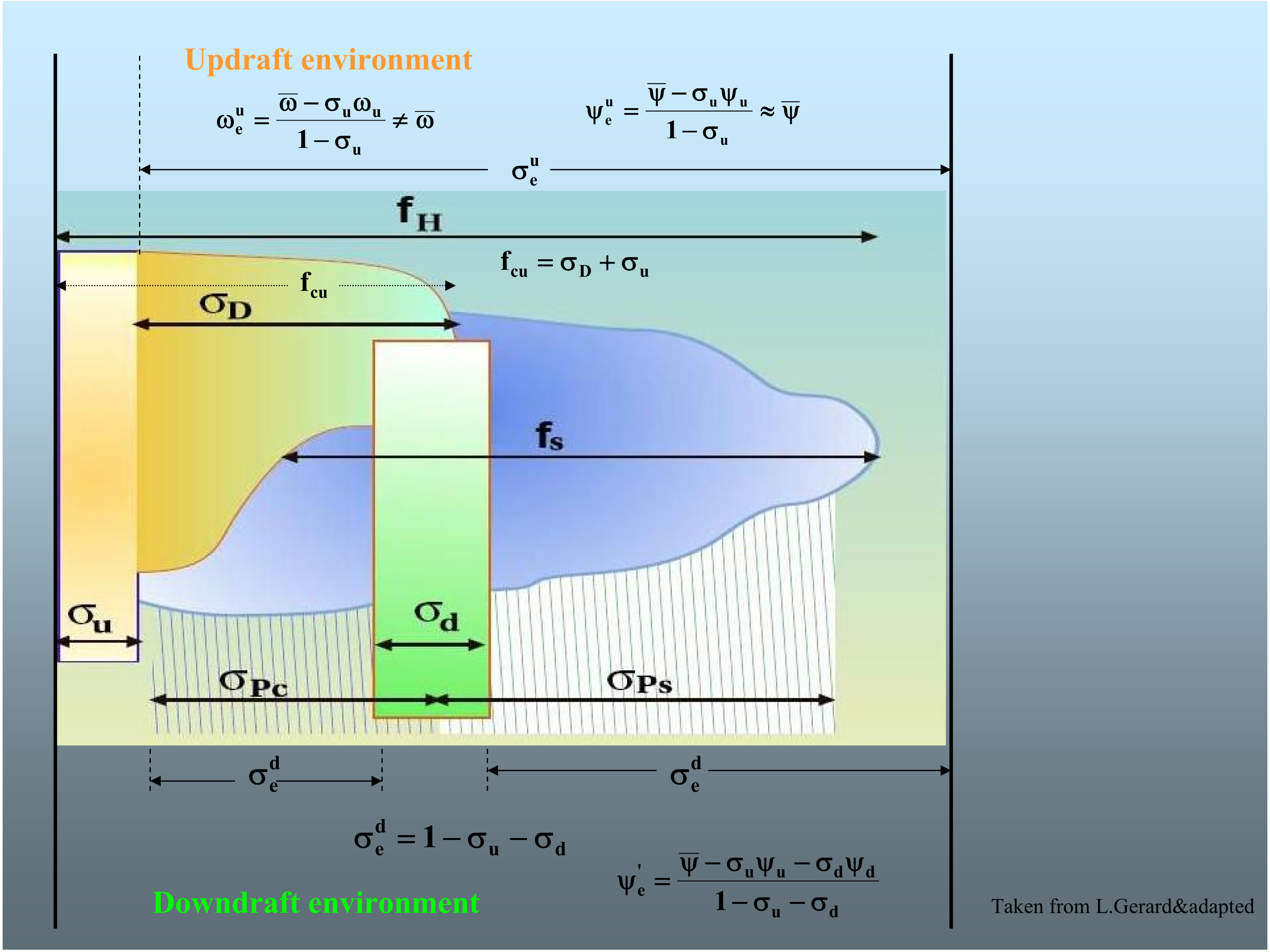
- no modulation of the prescribed minimum and maximum entrainment rate !

TENTR : convective updraft's entrainment rate.
TENTRX : maximum convective updraft's entrainment rate
GCVALFA : coefficient to compute entrainment rate from cloud buoyancy
GCVNU : entrainment rate to compute dilute plume buoyancy. .
GCVBEE : impact of acceleration on entrainment!
GCVEEX : exponent for impact of acceleration on entrainment.
GPEFDC **:** prognostic mixing parameter
GPETAU **:** prognostic mixing parameter
GPEMAX **:** prognostic mixing parameter
GPEIPHI **:** inverse of max height of cloud from the base in m2/s2

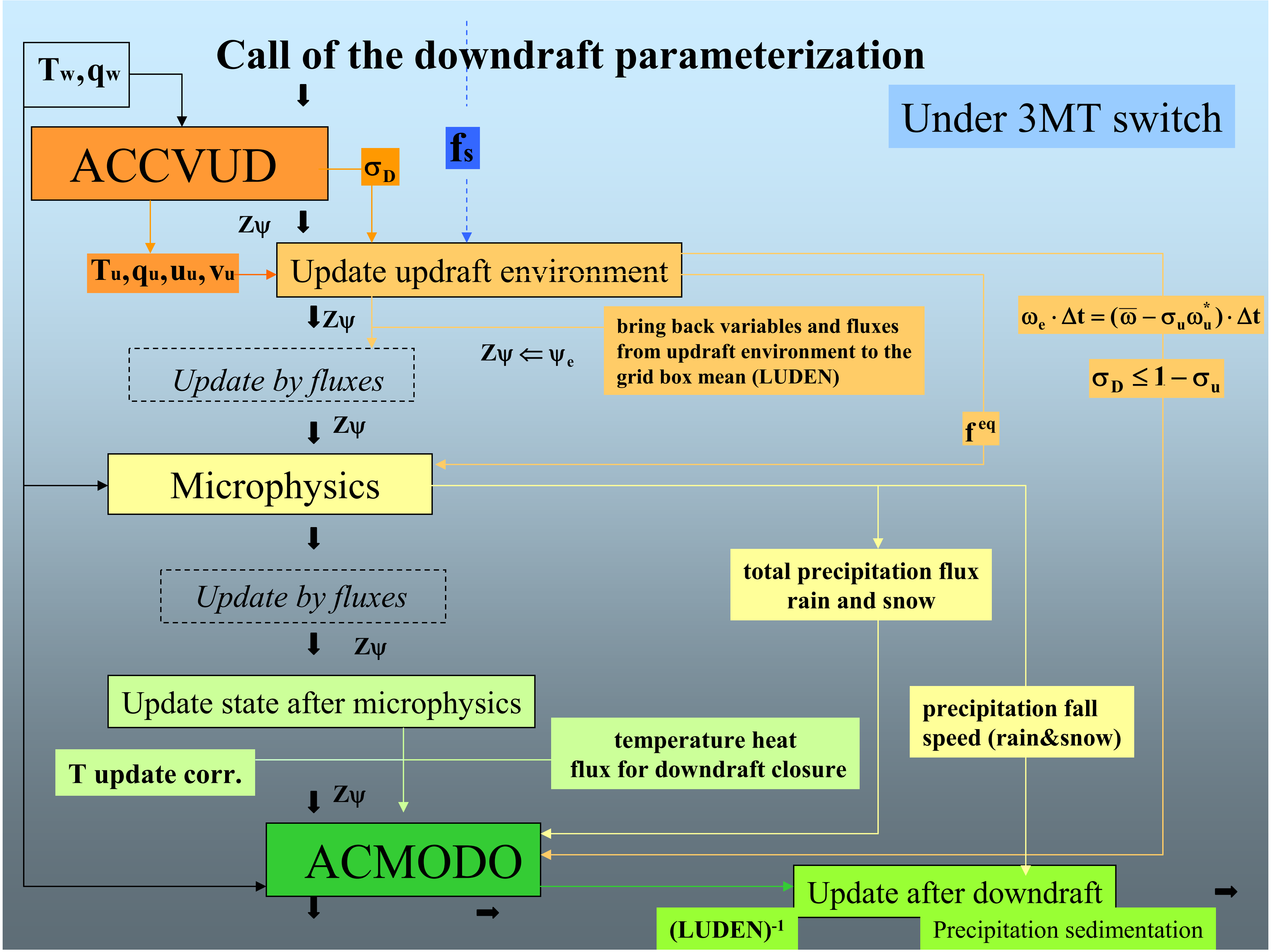
… other free parameters

ACCVUD

GCVACHI : Activity History, absolute minimum draught advected!
velocity to declare continued activity whichever be ZKUO
GCVALMX : maximum acceptable value for total mesh fraction
…….


Updraft environment
$\omega_e^u = \frac{\overline{\omega} - \sigma_u \omega_u}{1 - \sigma_u} \neq \overline{\omega}$
$\psi_e^u = \frac{\overline{\psi} - \sigma_u \psi_u}{1 - \sigma_u} \approx \overline{\psi}$
σ_e^u
f_H
$f_{cu} = \sigma_D + \sigma_u$
f_{cu}
σ_D
f_S
σ_u
σ_d
σ_{Pc}
σ_{Ps}
σ_e^d
σ_e^d
$\sigma_e^d = 1 - \sigma_u - \sigma_d$
$\psi_e' = \frac{\overline{\psi} - \sigma_u \psi_u - \sigma_d \psi_d}{1 - \sigma_u - \sigma_d}$
Downdraft environment
Taken from L.Gerard&adapted

Call of the downdraft parameterization



ACMODO

Downdraft profile

- evaporating descent including the mixing with the environment

λ_d **TENTRD – downdraft entrainment rate (constant)**

Precipitation fall speed

Downdraft velocity equation

Dissipation due to the entrainment : ~ $\omega_u - \omega_e'$

$$\omega_d - \omega_P = \omega_d - \left(\rho g w_P + \omega_e^d\right) \approx \omega_d - \left(\rho g w_P + \omega_e^u\right)$$

$$\omega_P \Delta t = \omega_e \Delta t + \underbrace{C_{wP}}_{\text{GDDWPF}} \cdot \frac{p}{R_a} g \Delta t \left[w_r \cdot \alpha_{melt} + w_s\left(1 - \alpha_{melt}\right)\right]$$

ACMODO

Input parameters

q_v q_i, q_l, T → PQ, PQI, PQL, PT - updated in cascade: $Z\Psi^{(0+diff+LSC+UPC+mphys)}$

u, v → PU, PV - **wind components**

T_s → PTS - **surface temperature**

q_w, T_w → PQW, PTW- **wet thermometer specific humidity and temperature** recomputed (ACQSAT) before the call of ACCVUP

$\omega_e \Delta t$ → POME – **updraft environment vertical velocity; resolved $\omega \Delta t$**

PZATSLC → **slantwise convection factor** recomputed (ACQSAT) before ACCVUP

F_{p_rain}, F_{p_snow} → PFPLSL, PFPLSN- **precipitation flux (rain & snow)**

F_h → PZFHP – precipitation heat flux

Output parameters

$F_{rain}^{conv\_evap}, F_{snow}^{conv\_evap}$ → PFESL, PFESN- evaporation fluxes

$F_{q_v}^{dd\_tran}, F_{q_i}^{dd\_tran}, F_{q_{li}}^{dd\_tran}, F_s^{dd\_tran}, F_u^{dd\_tran}, F_v^{dd\_tran}$

- PDIFCQD, PDIFCQLD, PDIFCQID, PDIFCSD, PSTRCUD, PSTRCVD

I/O parameters

ω_d, σ_d PDDOM, PDDAL – **downdraft vertical velocity and mesh fraction**

ACMODO

….other tuning parameters

GDDBETA : downdraught explicit detrainment coefficient
GDDFXM : limitation of flux decrement between layers
…..