Documentation on the moist downdrafts in the frame of ALARO-0

- Doina Banciu -

1. Basic equations

The model variables are computed as mean values for individual grid boxes

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

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

where: $\overline{\psi}$ - mean values , ψ' - sub-grid perturbations from the mean value provided by physical parameterisations

2. Cumulus representation in parameterisation schemes

2.1. Mass flux approach

Within the mass flux approach the average of sub-grid fluxes ($\overline{\omega'\psi'}$) is performed on the convectively active ("cloudy") and convectively inactive ("no cloudy") areas.

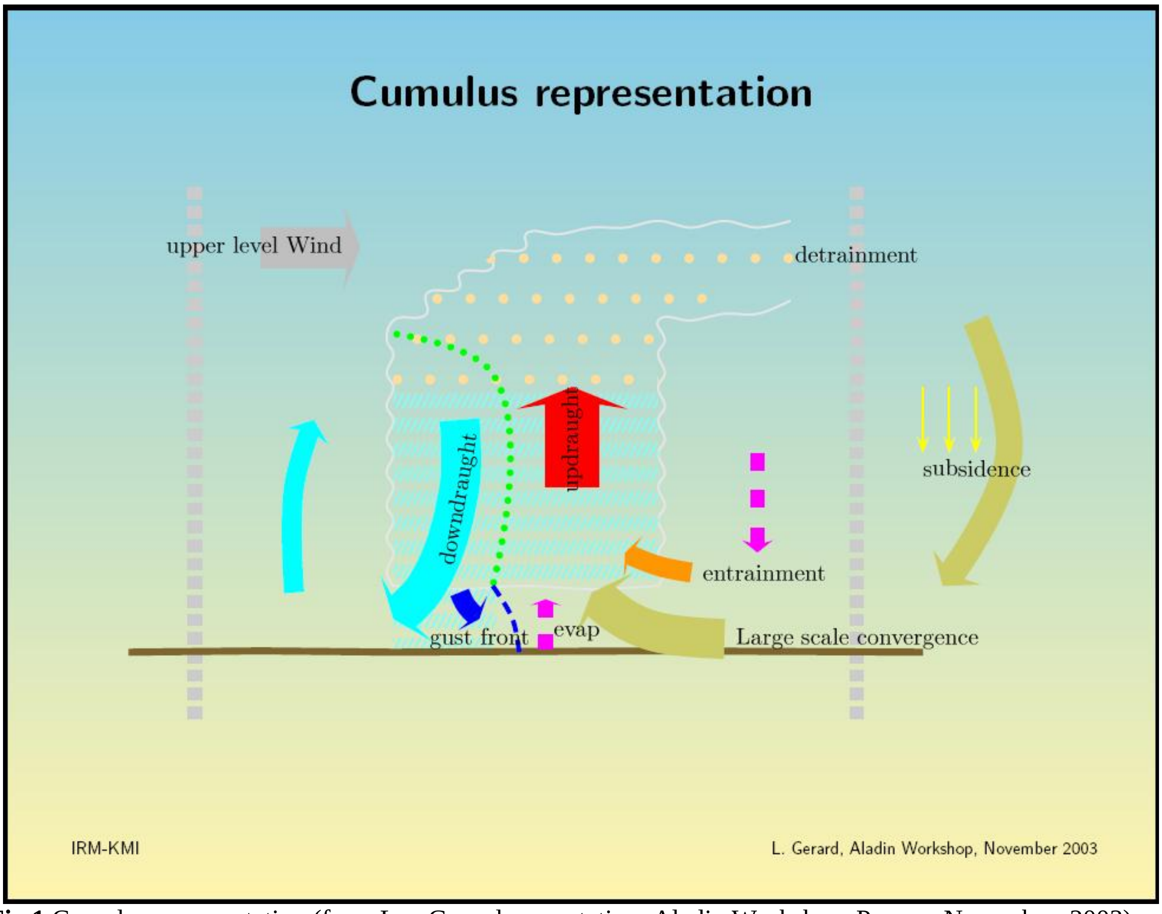

Fig.1 Cumulus representation (from Luc Gerard presentation, Aladin Workshop, Prague, November, 2003)

Considering the specific contributions of updrafts (subscript $_u$) and downdrafts (subscript $_d$) the sub-grid flux can be written as:

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

where: σ represent fractional areas

subscript "$_e$" stands for the " no cloudy" area (environment)

such as : $1 = \sigma_u + \sigma_d + \sigma_e$

Writing the mean values as:

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

we have:

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

The relative up and downdraft mass fluxes with respect to the environment are:

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

and the sub-grid contribution due to convection is:

$$\left(\frac{\partial \overline{\psi}}{\partial t}\right)_{SG} = source - \frac{\partial \overline{\omega'\psi'}}{\partial p} = -source - \frac{\partial \omega_u^* (\psi_u - \overline{\psi})}{\partial p} - \frac{\partial \omega_d^* (\psi_d - \overline{\psi})}{\partial p}$$

The absolute up and downdraft mass fluxes can be written as:

$$M_u = -\sigma_u \cdot \omega_u = -(\omega_u^* - \sigma_u \omega_e) \Leftrightarrow \omega_u^* = -(M_u + \sigma_u \omega_e)$$
$$M_d = \sigma_d \cdot \omega_d = (\omega_d^* - \sigma_d \omega_e) \Leftrightarrow \omega_d^* = (M_d + \sigma_d \omega_e)$$

Taking into account the mixing of the cloud air with the environment (through an entrainment rate $E \geq 0$ and a detrainment rate $D \leq 0$) one can write the cloud scale budgets:

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

where ψ stands for the conservative variables of the cloud.

<u>Approximations</u>:

1) $\sigma_{u/d} << 1$ or $\omega_e \approx 0 \Rightarrow$ the relative mass fluxes with respect to the environment are equal to the absolute fluxes:

$$-\omega_u^* \approx M_u \text{ and } \omega_d^* \approx M_d$$

2) $\psi_e = \overline{\psi}$ and $\frac{\partial \sigma_{u/d}\psi_{u/d}}{\partial t} = 0$ (stationary cloud properties over a time step)

the cloud scale budgets become:

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

$$\frac{\partial M_u s_u}{\partial p} = D_u s_u - E_u \overline{s}_u - Lc \qquad \frac{\partial M_d s_d}{\partial p} = E_d s_d - D_d \overline{s}_d - Le$$

$$\frac{\partial M_u q_u}{\partial p} = D_u q_u - E_u \overline{q}_u + c \qquad \frac{\partial M_u q_u}{\partial p} = E_u q_u - D_u \overline{q}_u + c$$

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

where q stands for water vapour, $\vec{V}$ for the horizontal wind, s for dry static energy, c for the condensation rate, e for evaporation rate.

NB. While the convective diagnostic scheme used in the frame of ARPEGE/ALADIN models does not have prognostic equations for the condensed water, these were omitted in the above set of equations.

Thus the sub-grid convective contribution to the dry static energy and water vapour tendencies can be expressed as:

$$\left(\frac{\partial \overline{s}}{\partial t}\right)_u = Lc - \frac{\partial \overline{\omega' s'}}{\partial p} = \omega_u^* \frac{\partial \overline{s}}{\partial p} + D_u\left(s_u - \overline{s}\right); \left(\frac{\partial \overline{s}}{\partial t}\right)_d = -Le - \frac{\partial \overline{\omega' s'}}{\partial p} = \omega_d^* \frac{\partial \overline{s}}{\partial p} + D_d\left(s_d - \overline{s}\right)$$

$$\left(\frac{\partial \overline{q}}{\partial t}\right)_u = -c - \frac{\partial \overline{\omega' q'}}{\partial p} = \omega_u^* \frac{\partial \overline{q}}{\partial p} + D_u\left(q_u - \overline{q}\right); \left(\frac{\partial \overline{q}}{\partial t}\right)_d = -c - \frac{\partial \overline{\omega' q'}}{\partial p} = \omega_d^* \frac{\partial \overline{q}}{\partial p} + D_d\left(q_d - \overline{q}\right)$$

3. Downdraft parameterisation

3.1. Diagnostic scheme (Ducrocq and Bougeault, 1995)

In the frame of ALARO-0 the diagnostic downdraft parameterisation can be used outside of the 3MT (Multi-modular, Multi-scale ,Microphysics&Transport) switch.

Based on the Ducrocq and Bougeault (1985) scheme, the downdraft parameterisation scheme (ACCVIMPD) is very similar to the diagnostic updraft parameterisation scheme (Bougeault,1985) the diagnostic downdraft scheme (Ducrocq and Bougeault,1985). It assumes a quasi-equilibrium between the convection activity and large scale processes and incorporates the redistribution of heat, moisture and momentum by vertical diffusion (computed by a separate scheme). Thus the equations for the moisture and dry static energy can be written in the form:

$$\left(\frac{\partial \overline{\psi}}{\partial t}\right)_d = \underbrace{\omega_d^* \frac{\partial \overline{\psi}}{\partial p}}_{pseudo-ascent} + \underbrace{\overline{D}_d\left(\psi_d - \overline{\psi}\right) + \frac{\partial F_\psi^{diff}}{\partial p}}_{\det rainment} \Leftrightarrow \omega_d^* \frac{\partial \overline{\psi}}{\partial p} + D_d\left(\psi_d - \overline{\psi}\right)$$

where the first term on the right side of the equation is linked to a pseudo-ascent and the second term is a relaxation term of the type used in Kuo scheme (1965). $\overline{D}_d$ is a positive constant with the meaning of an averaged detrainment rate ($\frac{\partial M_d}{\partial p} \neq D_d - E_d$).

The downdraft mass flux is computed in a diagnostic way, considering a single "single equivalent downdraft" (with a negligible mesh fraction) , its structure being determined by the local negative buoyancy expressed in terms of moist static energy, modulated by shape function (to treat the discontinuity when the downdraft reaches the ground).

$$\omega_d^* = \alpha_d \left(h_d - \overline{h}\right)^{\frac{1}{2}} F(p)$$

$$F(p) = \left(\frac{p_s - p}{p_s - p_t}\right)^{exp}$$

The α_d coefficient is obtained form the closure assumption, which states that a fraction ε of the available precipitation is used to moisten the environment trough a pseudo-descent:

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

The resulting net precipitation is therefore (1-ε)P, and the evaporation rate ε represents a tuneable parameter of the scheme (**GDDEVA**); the second one is the exponent of the shape function, **GDDSE.**

The downdraft follows the moist adiabatic descent, of the coldest point of the environment (with respect to moist static energy) modified by the entrainment of the environmental air, with a prescribed entrainment rate. Assuming that the convective process is producing only a vertical reorganization of moisture, energy and momentum it is possible to write the integral budget over the vertical. The budget of thermo-dynamical variables yields a relation between the mean detrainment coefficient and the downdraft mass flux.

$$K_d = \frac{\int_{p_t}^{p_b} -\omega_d^* \frac{\partial h}{\partial p} \frac{dp}{g} + F_h^{vert\_diff}(p_b) - F_h^{vert\_diff}(p_t)}{\int_{p_t}^{p_b} (h_d - h) \frac{\partial p}{g}}$$

The downdraft activity is directly linked to those of the convective updraft; it exists only in the presence of the updraft.

3.2. Downdraft prognostic scheme (Gerard, 2001, 2005, 2007)

The Bougeault scheme assumes that the convective mass flux is in equilibrium with the forcing (resolved moisture convergence and local vertical turbulent flux convergence as well). But the characteristic time of this forcing is unlikely to be compatible with the quasi equilibrium assumption (the adjustment time of the convective processes -τ_D must be significantly smaller than the characteristic time of large scale forcing τ_{LS}). This adds to the fact that when going to high resolutions the model is able to simulate phenomena with shorter characteristic time step, so also for the advection terms the quasi-equilibrium assumption becomes questionable.

If τ_{LS} >> τ_D, it is possible to assume that the cumulus ensemble follows a sequence of quasi-equilibriums with the large scale forcing and to use the large scale variables to diagnose the properties of convection. Otherwise it is necessary to apply a prognostic type closure for the mass flux. The assumption that the ascent time, τ_{as} is smaller than τ_{LS} may be held, allowing an instantaneous diagnostic of the cloud profiles and avoiding to keep them in memory.

The prognostic convection parameterisation has a multi-scale character by introducing the prognostic convective ascent and descent and their associated mesh fractions (relaxation of the cloudy stationarity assumption). In both cases (diagnostic and prognostic) the closure needs the estimation of the mass flux which is obtained as a product of the mesh fraction and the up/downdraft velocities. Practically the prognostic scheme involves two additionally prognostic variables: the draft velocity, obtained from a vertical motion equation, and draft mesh fraction, obtained by the closure assumption, variables that can be three-dimensionally advected or not.

The use, in the initial version of the scheme, of a constant mesh fraction over the vertical and a prescribed entrainment impacted on the coherence of the local mass budget (in the diagnostic scheme this is not required). This budget should link, at each level, the entrainment, detrainment, mass flux and the mesh fraction tendency. The performances of the initial scheme were limited by the absence of resolved cloud condensate and by the presence of two different precipitation schemes (for resolved and sub-grid precipitation) concurrently working.

The actual version of the prognostic (updraft and downdraft) scheme (Gerard, 2007) is part of an integrated package treating in a unified consistent mode all cloud processes.

In respect with to the initial scheme, the present version of the prognostic scheme involves:

- The use prognostic variable for condensed water (liquid - q_l, ice - q_i) and precipitation (rain - q_r, snow - q_s)
- The use of the Microphysics-Transport concept developed by Jean-Marcel Piriou (during the preparation of his PhD thesis, 2004). In the MT concept, the microphysics is explicitly computed where the condensation/evaporation occurs along of a convective ascent/descent being decoupled from the closure assumption and favourable to a modular treatment opposite to the situation of the diagnostic convection scheme where the computations of fluxes and tendencies are interdependent. In such a way only the prescribing of entrainment rate is necessary; there is no need anymore of detrainments rate computation. The feed – back will maintain the large-scale equilibrium rather than he opposite.

  Schematically the MT concept could be represented in the following form:

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

- The introduction of the memory of the entrainment rate.
- A new formulation of the closure.

Basis of the actual downdraft parameterisation

The downdrafts occur in the precipitation area. They are generated by the local cooling induced by both resolved and unresolved precipitation (by adjustment to the local temperature, evaporation, melting).

- Downdraft profile

  The downdraft profile follows a saturated pseudo-adiabat, modified by the mixing with the environment. It is worth to mention that the effect of the entrainment on the downdraft velocity is opposite to that on the updraft velocity: while mixing always works against the updraft , it has a vital role for the downdraft. For the convective updraft, the entrainment rate has a vertical variation and depends on the local integral buoyancy; for the downdraft descent it is supposed (for the time being) to be constant. Its value is a free parameter **TENTRD** (namphy0). When there is no available precipitation to be evaporated the downdraft follows a dry adiabat.

  In principle no condensate resides in the downdraft, but temporarily it may exist. For the virtual temperature computation it is supposed that the downdraft condensate is equal to those of the environment.

  Similar to the diagnostic scheme, the downdraft activity implies the existence of the negative buoyancy ($Tv_d < Tv_e$) and downdraft temperature to be smaller than the wet bulb t temperature of the environment. In the prognostic case the downdraft can occur also when downward downdraft velocity is advected from the previous time step or when there is positive downdraft velocity in the layer above.

- Downdraft velocity

  The tendency of the downdraft vertical velocity, ω_d , is given by (like for updrafts) a balance between the buoyancy forces and dissipation. mainly through the entrainment of the environmental air.

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

$$-\underbrace{\delta_{dP} \cdot \left[\left(\lambda_d + \frac{K_{dd}}{g}\right)\frac{R_a T_{vd}}{p}\right](\omega_d - \omega_P)}_{\text{dissipation–term}} - \underbrace{\delta_d \frac{C_{dyn-press}}{(p-p_s)^2}\omega_d^2}_{\text{int eraction with the surface}} \qquad (3.2.1)$$

  a) *Buoyancy term*

     As in the updraft vertical velocity equation the terms containing virtual temperature logarithm are neglected. As well the buoyancy term is expressed in terms of downdraft and environment virtual temperatures. The transient condensate in the downdraft is not estimated despite of the fact that it could be important. Instead, a virtual mass parameter $\gamma_{d,}$ is used to enhance the negative buoyancy of the downdraft, not being link to the precipitation. This is a tuneable parameter, **TDDBU** (namphy0).

b) Dissipation term

The main part of the dissipation term is represented by the entrainment of the environmental parcels and depends on the vertical velocity difference between the downdraft and its environment. It is difficult to know the vertical velocity of the entrained parcels since immediate environment of the downdraft could be the updraft, the updraft environment or an environment moved vertically in a large scale motion. The choice in the present scheme is to consider that the downdraft occurs in the precipitation flux, such as the dissipation term is proportional with ω_d - ω_P (ω_P = precipitation flux velocity).

$$\omega_d - \omega_P = \omega_d - \left(\rho g w_P + \omega_e^{'}\right) \approx \omega_d - \left(\rho g w_P + \omega_e\right) \qquad (3.2.2)$$

with:

$\omega_e^{'}$ - the downdraft environment velocity

ω_e - the updraft environment velocity

The precipitation flux velocity is computed by using constant fall speed for snow and rain, values that are set up in the namelist namphy0: **TFVS** and **TFVR**

This formulation leads to excessive downdraft velocities: a free parameter **GDDWPF** allows the variation of the ω_P from ω_e to the full expression 3.2.2

The entrainment rate, λ_d, is considered constant along the evaporating descent, those value is set up via namelist (**TENTRD**).

The second part of the dissipation term represents the aerodynamic friction. The downdraft dissipation coefficient K_{dd} is a free parameter (**TDDFR**); it could be used for finer tuning.

The braking occurs only when $\omega_d > \omega_P$ (δ_P=1), otherwise δ_P=0.

c) Interaction with the surface

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

- Far from the surface :

$$\omega \approx -\frac{w}{\rho g}$$

- Near the surface the advection term can not be neglected. The flow bends due to the local high generated by the accumulation of the air near surface and the vertical velocity equation becomes very complicated. The choice made in the scheme is to simulate this effect by an additional term similar to the dynamical pressure:

$$\frac{\omega_d^2}{p} - \frac{\partial \omega_d^2}{\partial p}$$

The proposed form involves a gradual increase by approaching the surface:

$$-C_{dyn\_press}\frac{|\omega_d|\omega_d}{\left(p_{surf}-p\right)^{\beta}}=-\delta_d\frac{C_{dyn\_press}}{\left(p_{surf}-p\right)^{\beta}}\omega_d^2$$

with δ_d =1 if ω_d >0, otherwise is 0.

β is a free parameter (**GDDBETA**) actually set to 2.such as C_{dyn_press} represents the reference pressure thickness (~100 hPa) for the decrease of the downdraft velocity, as well a free parameter (**GDDDP**).

- Downdraft closure

The downdraft closure states that a fraction of the microphysical heat sink is either "consumed" by the downdraft either stored in the downdraft by an increase of. the downdraft mesh fraction, which means a significant difference in respect with the diagnostic downdraft closure and as well with the prognostic updraft one. The closure is represented by a prognostic equation for the downdraft mesh fraction, assumed to be constant over the vertical:

$$\underbrace{\frac{\partial\sigma_d}{\partial t}\cdot\int_{p_t}^{p_b}\left[\left(h_d-h_e\right)+\left(k_d-k_e\right)\right]\frac{\partial p}{g}}_{storage}=\underbrace{\sigma_d\int_{p_t}^{p_b}F_b\frac{\omega_d}{\rho g}\frac{\partial p}{g}}_{-consumption}+\underbrace{\varepsilon\cdot\int_{p_t}^{p_b}-g\frac{\partial F_{hP}}{\partial p}\frac{\partial p}{g}}_{energy-input} \qquad (3.2.3)$$

where k_d , k_e are the downdraft and environment kinetic energies.

a) Energy input

The energy input is given by the cooling due to the total (unlike the diagnostic scheme where only the convective precipitation is taken into account) precipitation evaporation and melting and to the adjustment to the local temperature. Opposite to the prognostic updraft, the driving force is not linked to the large scale forcing. The heat sink is computed as the divergence of the corresponding heat flux. But only a fraction, ε, of this flux contributes to the downdraft activity considering that the area of the downdraft is smaller than those of precipitation :

$$\boldsymbol{\varepsilon\approx\frac{\sigma_d}{\sigma_P}}$$

There is an associated free parameter, **GDDEVF** (similar to **GDDEVA** of the diagnostic scheme).

b) Consumption

The cooling associated to the precipitation induces a negative buoyancy. The consumption of the energy is represented by the work of the buoyancy force, done to generate the downdraft mass flux.

c) Storage

The difference of the energy input and consumption is stored as moist static energy and as well as kinetic energy since the air entrained in the increased area of the downdraft has to be accelerated.

$$k_d - k_e = \frac{\omega_d^2 - \omega_e^2}{2(\rho g)^2}$$

3.3. The prognostic downdraft scheme within 3MT framework (Gerard, 2007)

The practical implementation of the 3MT (Modular, Multi-scale, Microphysics-Transport) framework involved a reorganization of the time step, imposing a sequential calling of the parameterisation routines rather than a parallel one. In the cascade approach the microphysics is treating in a unitary way the resolved and convective condensation. It is called only once after the updraft, the downdraft being fed in such way by the total precipitation.

The prognostic downdraft parameterisation is made within the “ACMODO” routine called by APLPAR in a specific sequence (schematically described in figure 2) under the **L3MT** and **LCDDPRO** switches.

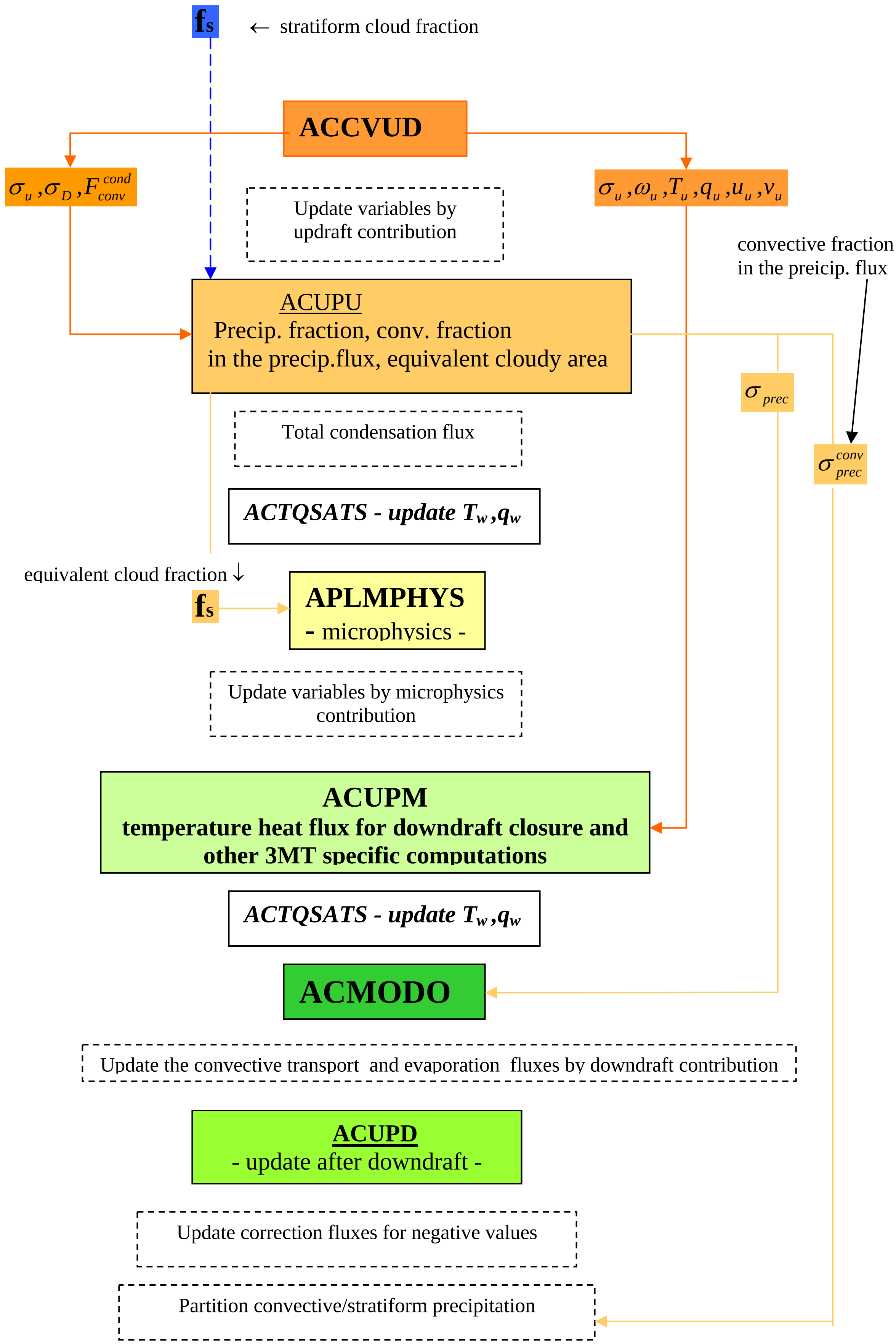

Fig. 2: Prognostic downdraft call tree within 3MT frame

The downdraft environment

The downdrafts occur in the precipitation area, the last being itself outside of the updraft mesh fraction, in the updraft environment, covering the fraction $\sigma_e^u = 1-\sigma_u$. Thus the characteristics of the updraft environment are defined by:

$$\psi_e^u = \frac{\overline{\psi} - \sigma_u \psi_u}{1-\sigma_u} \approx \overline{\psi}\,; \qquad \omega_e^u = \frac{\varpi - \sigma_u \omega_u}{1-\sigma_u} \neq \varpi\,;$$

In the presence of the downdraft, the environment is defined over an area $\sigma_e^d = 1-\sigma_u - \sigma_d$ and its characteristics are given by: $\psi_e^{'} = \dfrac{\overline{\psi} - \sigma_u \psi_u - \sigma_d \psi_d}{1-\sigma_u - \sigma_d}$.

The figure 3 represents diagrammatically the geometry the areas occupied by updrafts, downdrafts, convective and resolved condensation, convective and resolved precipitation.

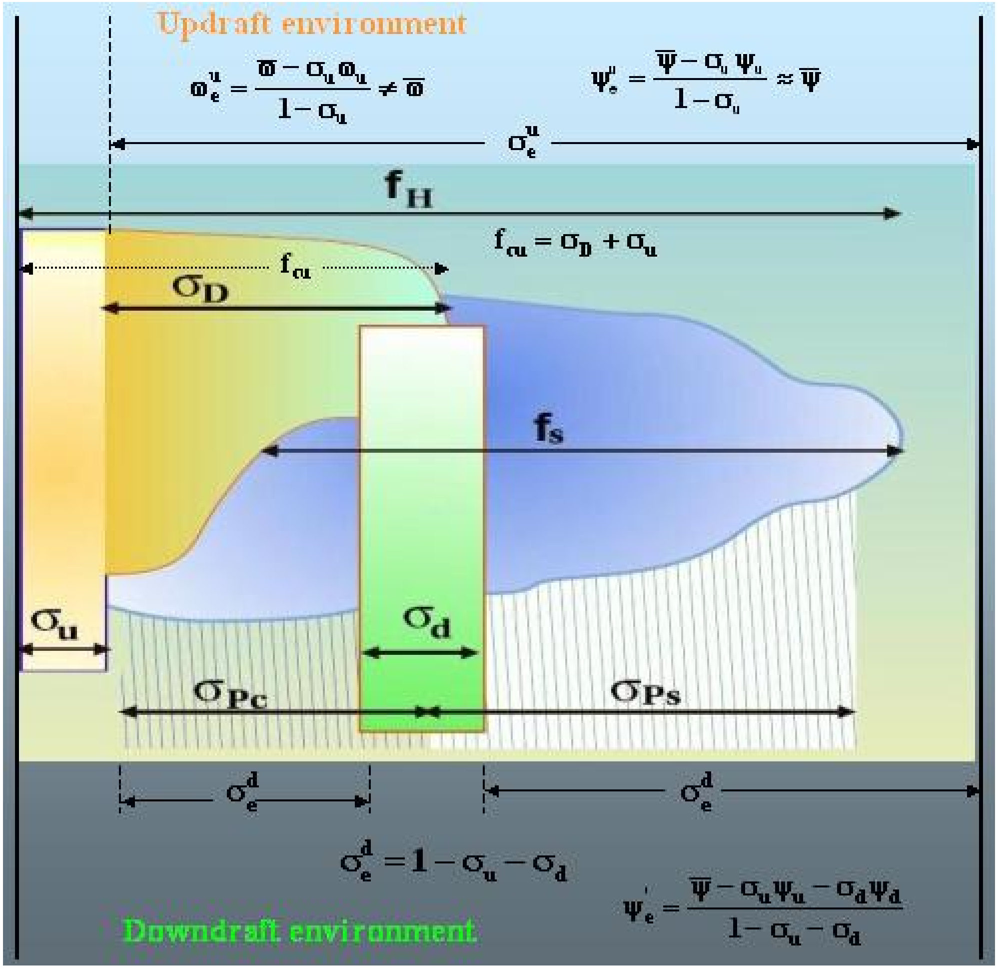

Fig.3 Geometry of the grid box considering single equivalent updraft and downdraft (taken from the presentation of Luc Gerard at the 13th ALADIN workshop and adapted)

σ_D is the updraft detrainment area, (ACCVUD output); $\sigma_D \leq 1-\sigma_u$

f_{cu}: convective cloudiness fraction; $f_{cu} = \sigma_D + \sigma_u$

f_S: large scale condensation area fraction ("stratiform cloudiness), computed by the large scale condensation scheme (ACNEBCON)

σ_{P_C} :convective precipitation area fraction: σ_{P_C}

σ_{P_S} :resolved precipitation area fraction : σ_{P_S}

ACUPU

Using the output (updraft and detrainment mesh fraction, convective condensation fluxes) of the prognostic updraft routine, ACCVUD, the ACUPU routine computes:

- the precipitation area fraction, used in ACMODO;
- the convective fraction in the precipitation fluxes, used for the partition of total precipitation in stratiform and convective parts;
- the equivalent cloud fraction, used further in the microphysics parameterisation;

  The equivalent cloudy area is defined as the equivalent cloud fraction which would occur if the condensate density was the same in all clouds of the grid box:

  $$f^{eq} = f_{cu}\, f_s - f_s\, f_{cu}$$

- the pseudo-historic convective cloud fraction (used for the computation of the total cloudiness in the next time step)

Within the routine there is only one free parameter **GRRMINA** (namphy0) with the meaning of minimum realistic precipitating mesh fraction, which is used for the computation of equivalent area fraction

ACUPM

The routine computes:

- *The values of the atmospheric parameters of the downdraft environment*

  Two types of approximation are possible:

  a) the values of the atmospheric parameters (T, q, u and v - already updated with the contributions of the updraft and microphysics) of the downdraft environment are equal with the mean box values. An exception is made for the vertical velocity of the environment, computed as:

  $$\omega_e^u = \frac{\varpi - \sigma_u \omega_u}{1-\sigma_u} \neq \varpi$$

  where the updraft mesh fraction is limited to a maximum acceptable value given by the **GCVALMX** free parameter (namphy)

  b) the environment of the downdraft is the updraft environment, under the **LUDEN** switch:

  $$\psi_e^u = \frac{\overline{\psi} - \sigma_u \psi_u}{1-\sigma_u}$$

  NB1. Under the **LCDDEVPRO** (namphy) switch it is possible to modulate the precipitation cooling effect on temperature. If the latent heat flux associated to precipitation is bigger in the layer above, a residual cooling is considered in the current layer.

  NB2. The update of the temperature and humidity saturated values is done in a separate routine (ACTQSATS), call just before the downdraft parameterisation

- *The latent heat flux associated to precipitation used in the computation of the heat sink for the downdraft closure* (F_{hP} from eq.3.2.3)

ACMODO

Input parameters

- T, T_w, q_v, q_w, q_i, q_l, q_i – updated by the contribution of turbulent diffusion, convective updraft and microphysics contributions, including the correction for the negative values of water species
- u,v

Obs. Under LUDEN switch T, q_v, u, v represent are the environment values

- $\varpi, \omega_e, \omega_d, \alpha_d$ - advected values from the previous time step
- the latent heat flux associated to precipitation
- precipitation fluxes (liquid and solid)

Output parameters

- ω_d, α_d - updated values
- downdraft fluxes of enthalpy, water vapour, liquid water, ice and momentum
- evaporation flux

Immediately after the downdraft parameterisation, the convective transport and evaporation fluxes are updated by downdraft contribution.

ACUPD

The routine has two functions :

- to update the internal state after the downdraft by re-setting the values of T, q_v, u, v to the mean grid box values
- to apply a posteriori sedimentation

The 3MT cascade is ending by an update of the correction fluxes for negative values and the classical partition of precipitation fluxes in stratiform and convective parts.

REFERENCES

- **Gerard, L.**, 2007: An integrated package for subgrid convection, clouds and precipitation compatible with the meso-gamma scales, *accepted in Q.J.R.Meteorol.Soc*
- **Piriou, J-M., J.-L. Redelsperger, J.-F. Geleyn, J.-P. Lafore and F. Guichard**, 2007: An approach for convective parameterization with memory, in separating microphysics and transport in grid-scale equations, *accepted in J. Atmos. Sci*.

- **Gerard, L.; Geleyn, J.F**., 2005: Evolution of a subgrid deep convection parametrization in a limited-area model with increasing resolution -Source: *Quarterly Journal of the Royal Meteorological Society, Number 610, July 2005 Part B, pp. 2293-2312(20)*
- **Gerard, L.,** 2001: Physical Parameterisations for a high resolution operational Numerical Prediction Model, *PhD Thèse, Université libre de Bruxelles*
- **Gerard, L**., 2007: personal documentation on updraught, *www.rclace.eu*
- **Gerard, L.,** 2007: personal documentation on downdraught, *www.rclace.eu*
- **Gerard, L.,J.-M. Piriou, J.-F. Geleyn**, 2006: Advances in the integration of deep convection and microphysics for the meso-scale, *WGNE Blue book*
- **Brožková, R., D. Banciu and J.-F. Geleyn**, 2006: Short explanatory document on the cascade and negative humidity corrections aspects of ALARO-0, *www.rclace.eu*
- **Gerard, L.,** 2005: New approaches to deep convection parameterisation and its binding to a microphysical scheme, *the 15th Aladin Workshop, Bratislava, Slovakia*