

Documentation of the KFB Shallow Convection scheme used in the CLIMATE version 5.0 of ARPEGE (based on the cycle 32t0_op1v2_13 + CNRM/GMGEC modset).

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from the GPCP documentation (in French) of Meso-NH (MASDEV4_6)
and Arome (CY30T1) versions of the Bechtold Shallow Convection
scheme (documentation made by Sylvie Malardel, CNRM/GMME).

1 Part A : Motivations

1.1 A1 : Objectives - Motivations

The turbulent part of the vertical diffusion, acting in both the dry air and the cloudy moist PBL, is parameterized by a 1.5 order exchange coefficient scheme, based on a prognostic TKE equation, described in the TKE-CBR documentation.

This moist turbulent scheme is able to represent the vertical diffusion within the moist PBL, but it is not able to represent accurately the vertical exchanges realized by the non-precipitating shallow convection, when the cloud start to extend out of the PBL, leading to above Strato-Cumulus or small Cumulus.

On the other hand, the precipitating Cumulus or Cumulo-Nimbus clouds can be parameterized by mass flux schemes, like the one described in the documentation of the Deep-Convection scheme of Bougeault, Gerard and Bazile.

As a consequence, in addition to the existing moist turbulent and Deep Convection mass-flux schemes, the Shallow Convection will be parameterized by another scheme. It is the Shallow Convection mass-flux scheme of Bechtold et al. (2001), written following the ideas of Kain and Fritsch (1990). It will be denoted as KFB_shal in the following

This scheme has been used in the old SCM version of ARPEGE, for instance during the EUROCS 2000-2003 program and in particular for the ARM-Cumulus case described in Lenderink et al. (2004).

This scheme is presently used in MésoNH (MASDEV4_6), also in the AROME model (since the cycle 30T1). The same KFB_shal scheme is used jointly by the NWP and the

CLIMATE teams, both in the NWP and the GCM versions of ARPEGE, in particular since the cycle 32t2 for the tests of the “GAME” physics.

1.2 A2 : The Physical Processes

The Shallow Convection scheme KFB_shal is used to represent the convective vertical mixing made by the moist thermals located in the non-precipitating clouds.

To do so,

- this scheme is activated only if a triggering condition is satisfied, based on an existing condensation level with some other criterias verified for the updraft (in particular with minimum and maximum depth for the computed cloud), as described in the section 1.3.1 ;
- this scheme corresponds to a vertical mixing of the conservative variables and to reversible microphysics processes (with no precipitations).

As a consequence of these hypotheses, the sub-cloud thermal processes cannot be parameterized by the KFB_shal scheme, and the moderate precipitating Cumulus cannot be represented accurately by this scheme, either.

1.3 A3 : The theory : equations and hypotheses

The KFB_shal scheme corresponds to the classical “mass-flux” approach for describing the subgrid vertical mixing. This “mass-flux” approach leads to a simple formalism when the vertical mixing concerns conservative variables, like the Betts (1973) variables θ_l and r_{np} defined as

$$\theta_l = \theta \left(1 - \frac{L_v r_c + L_s r_i}{C_{ph} T} \right), \quad (1)$$

$$r_{np} = r_v + r_c + r_i, \quad (2)$$

where r_{np} is the non-precipitating total water (vapor plus cloud liquid water plus ice).

The Betts potential temperature θ_l is often replaced in the numerical computations by the “moist static energy”, denoted by h_l and often called “moist enthalpy” (though it is not at all the moist enthalpy)

$$h_l = C_{ph} T - L_v r_c - L_s r_i + (1 + r_w) g z, \quad (3)$$

where $r_w = r_c + r_i$ is the total condensed cloud water.

The mass-flux approach corresponds to a separation of the grid-cells into 3 sub-columns, each of the sub-columns being associated with 3 mass-fluxes, represented by M^u for the updraft, M^d for the dowdraft and M^{env} for the environmental part of the grid-cell.

The associated formulation for the convective vertical mixing of any conservative variable denoted by ϕ is

$$\bar{\rho} \left. \frac{\partial \bar{\phi}}{\partial t} \right|_{\text{conv}} = - \frac{\partial \rho \overline{w' \phi'}}{\partial z} \simeq - \frac{\partial \left[M^u (\phi^u - \bar{\phi}) + M^d (\phi^d - \bar{\phi}) + M^{env} (\phi^{env} - \bar{\phi}) \right]}{\partial z}. \quad (4)$$

The overbar variables represent the mean values over the grid-cell. The part covered by each subcolumn has a fractional area denoted by s^1 for the updrafts, s^2 for the downdrafts and s^3 for the environment. Similarly, the specific volume and the vertical velocity are denoted by ρ^i and w^i , respectively, for $i = 1, 2, 3$. Using these notations, the 3 mass-fluxes are defined as $M^i = \rho^i w^i s^i$.

The mass-flux approach represented in the KFB_shal Shallow Convection scheme corresponds to the following hypotheses

- the impact of the downdrafts can be neglected ;
- the impact of the updraft is not so important and the difference between the environmental and the mean variables can be neglected too, i.e. $(\phi^{env} - \bar{\phi})$ in (4).

As a consequence, the vertical flux associated with the Shallow Convection KFB_shal reduces to

$$\rho \overline{w'\phi'} \simeq M^u(\phi^u - \bar{\phi}), \quad (5)$$

where $M^u = \rho w^u s^u$ is the mass-flux associated to the updrafts.

So, the main objective of the KFB_shal scheme will be to compute the properties of updraft, i.e. M^u , h_l^u et r_{np}^u . When the properties of the updraft are known, it is then easy to compute the vertical fluxes of the conservative variables $\rho \overline{w'\phi'}$, also the divergence of these vertical fluxes $\partial(\rho \overline{w'\phi'})/\partial z$, to get from (4) the final convective tendencies of the conservative variables $(\partial \bar{\phi}/\partial t)_{conv}$.

Like in most of the mass-flux convection scheme, the updraft is computed level by level, with the hypothesis that the changes in the properties of the updraft are determined by the lateral mixing with the environment. The entrainment of the environment air into the updraft is represented by the entrainment rate ε^u , whereas the detrainment of the (updraft) cloud air into the environment air is represented by detrainment rate δ^u .

The two equations verified by the updraft are

$$\frac{\partial}{\partial z}(M^u) = \varepsilon^u - \delta^u, \quad (6)$$

$$\frac{\partial}{\partial z}(M^u \phi^u) = \varepsilon^u \bar{\phi} - \delta^u \phi^u. \quad (7)$$

In the the KFB_shal scheme the entrainment rate ε^u and the detrainment rate δ^u are computed following Kain and Fricht (1990), see the section 1.3.2.

Before the computations of the true properties of the updraft, a first guess is derived, based on a (very) simplified version of the cloud, in order to easily determine if the triggering properties are fulfilled (see the section 1.3.1).

If this simplified triggering property is valid, the condensation level computed for this simplified version of the cloud will be retained for the updraft properties of the KFB_shal scheme (see the section 1.3.2).

After the computations of the updraft properties, the ‘‘closure’’ computations are made in the section 1.3.3, in order to determined the intensity of the convection, starting from the available amount of CAPE.

1.3.1 The triggering of the scheme

The question to know if the cloud exist (or not) corresponds to what is called the “triggering property”. This property is determined via the computation of a first guess, based on a simplified version of the cloud.

If this triggering property is valid, the properties of this simplified updraft computed at the condensation level will be retained for defining the properties at the base of the true updraft, used in the section 1.3.2) to compute the vertical profile of the updraft.

The simplified version of the cloud is defined with the following hypotheses :

- A “mean parcel” is built with the properties representing the mean state close to the surface, computed by averaging the input vertical profile (by definition the environment) over the first 40 hPa layer above the ground (this value is set in the subroutine `ini_convpar_shal.mnh` located in `/mpa/conv/internals/`, see the variable `XZPBL = 40.E+2 Pa`, corresponding to a depth of about 500 m or so) ;
- The flotability of this “mean parcel” is enhanced by adding a temperature perturbation equal to `XDTPERT = 0.30 K` or so (this value is available in the NAMELIST called `NAMCVMNH`, described in the section 4.2) ;
- The Bolton’s formulas are used to determine the temperature and the pressure at the condensation level (LCL, for Lifting Condensation Level) of this perturbed “mean parcel”, with the hypothesis of a protected ascending, i.e. without entrainment nor detrainment with the environment.
- The height of the top of the cloud is then estimated by the height of the level reached by this perturbed “mean parcel”, i.e. by the level when the CAPE starts to be lower than a given value (for instance 10 % of the initial CAPE).

The triggering condition is said to be fulfilled if the depth of the computed cloud is greater than `XCDEPTH = 500 m` and lower than `XCDEPTH_D = 4000 m`, two values available in `NAMCVMNH` (see the section 4.2).

1.3.2 The updraft computations

The properties of the cloudy updraft, i.e. the mass-flux M^u , the moist static energy h_t^u and the total water content r_t^u are determined starting from the LCL and going upward, up to the top height of the cloud (see the previous section 1.3.1).

The first key parameter used to built the updraft is the computation of the mass-flux at the LCL, denoted by M_{LCL}^u . In the `KFB_shal` scheme, an arbitrary value of $M_{LCL}^u = 10^{-3} \text{ kg.m}^{-2}.\text{s}^{-1}$ is used, but this value is then modified by the CAPE algorithm (see the section 1.3.3).

The mass-flux varies from a vertical level to another only because the updraft can be modified by the entrainment and the detrainment processes, by an exchange of mass with the environmental surrounding dry air. The mass-flux equation is

$$(M^u)_{k+1} - (M^u)_k = \varepsilon^u - \delta^u . \quad (8)$$

At the LCL and in the cloudy part of the grid-cell, the entrainment and detrainment rates ε^u and δ^u are determined from Kain and Fritch (1990, hereafter KF90), via some

empirical vision of the exchange of cloudy moist air and environmental dry air occurring at the lateral boundary of the cloud.

Let us focus on a parcel of air in the “exchange region”, where the updraft and the environment exchange some amount of air.

The first important formulae concerns the (net) total rate of exchange of air entering this “exchange region”, denoted by δM_t and equal to

$$\delta M_t = \delta M_e + \delta M_u = M^u (c_{\text{entr}} \Delta z / R_0) .$$

It is the sum of the air coming from the environment δM_e and the one coming from the cloud region δM_u .

This formula is based on laboratory experiments (Simpson, 1983). It is assumed that the amount of air contained in the “exchange region” is inversely proportional to the radius of the updraft column and proportional to the total mass-flux of the updrafts.

The radius of the updraft is not tunable in NAMCVMNH. It is set to XCRAD= 50 m in ini_convpar_shal.mnh (it could be put in NAMCVMNH, or ini_convpar_shal.mnh can be recompiled, if needed).

The mixing constant c_{entr} depends on XENTR = 0.015 m/Pa in NAMCVMNH (see the section 4.2), leading to a value of 0.15 for c_{entr} and for the hydrostatic conditions close to the surface (10 Pa/m).

The entrainment corresponds to the air located in the “exchange region” and coming from the environment (δM_e), creating some buoyant and “unstable” parcels in the mixed air.

The detrainment corresponds to the air located in the “exchange region” and coming from the updraft (δM_u), creating some unbuoyant and “stable” parcels in the mixed air.

Let us denote by χ the fraction of environmental air located inside a parcel of the “exchange region”. For pure cloud air $\chi = 0$ and for pure environmental air $\chi = 1$.

Let us assume that there exists a critical value χ_c for which the parcels of the “exchange region” with $\chi < \chi_c$ are all buoyant and “unstable” parcels (and on the opposite all the parcels with $\chi > \chi_c$ are unbuoyant and “stable” ones).

Let us assume that the distribution of these mix parcels in the “exchange region” could be approximated by the Gaussian distribution $f(\chi)$, centered around $\chi = 0.5$ and leading to the following formulas for δM_e and δM_u expressed in terms of δM_t :

$$\delta M_e = \delta M_t \left[\int_0^1 \chi f(\chi) d\chi \right] ,$$

$$\delta M_u = \delta M_t \left[\int_0^1 (1 - \chi) f(\chi) d\chi \right] .$$

The entrainment rate is thus equal to the environmental air entering the buoyant and “unstable” parcels ($\chi < \chi_c$) and verifying

$$\varepsilon^u = \delta M_t \left[\int_0^{\chi_c} \chi f(\chi) d\chi \right] . \tag{9}$$

On the opposite, the detrainment rate is equal to the cloudy air entering the unbuoyant and “stable” parcels ($\chi > \chi_c$) and verifying

$$\delta^u = \delta M_t \left[\int_{\chi_c}^1 (1 - \chi) f(\chi) d\chi \right]. \quad (10)$$

The entrainment and detrainment rates are computed for each levels by using the equations 9 and 10, starting from the LCL and going upward.

Similarly, the updraft properties are computed starting from the LCL and going upward, by using the equation 8 for the mass-flux M^u and verifying

$$\Delta(M^u h_l^u) = \varepsilon^u \bar{h}_l - \delta^u h_l^u, \quad (11)$$

$$\Delta(M^u r_{np}^u) = \varepsilon^u \bar{r}_{np} - \delta^u r_{np}^u, \quad (12)$$

for the updraft values for the moist static energy h_l^u and the non-precipitating water r_{np}^u .

The Equilibrium Temperature Level (ETL) is defined as the level where the updraft start to get a negative buoyancy. Above this ETL it is assumed that the entrainment cancels out ($\varepsilon^u = 0$) and the updraft can only detrain toward the environment dry air.

The top of cloud (CTL) is defined by the first level verifying one of the two criterias

- the mass-flux cancels out ;
- the vertical velocity of the updraft (w^u) cancels out, if w^u is determined by

$$\Delta [(w^u)^2] = \frac{2g}{1 + \gamma} \left[\frac{\theta_v^{um} - \bar{\theta}_v^m}{\bar{\theta}_v^m} \right] \Delta z - 2 \frac{\varepsilon^u}{M^u} (w^u)^2. \quad (13)$$

The mass-flux in the upper part of the updraft, located between the ETL and the CTL, is set to a smooth linear decreasing profile.

Below the LCL, the mass-flux is set to some simple linear profiles :

- it increases linearly from 0 to the LCL mass-flux value (going from the ground to the top of the mixed PBL) ;
- it is then equal to the top of the mixed PBL constant value (going from the top of the mixed PBL to the LCL).

1.3.3 The closure of the scheme

As already explained in the section 1.3.2, the updraft computed in KFB_shal is initiated with a prescribed cloud mass flux M_{LCL}^u at the condensation level. It is then necessary to compute and verify some “closure criteria”, in order to tune the intensity of the shallow convection scheme KFB_shal.

The “closure method” used in KFB_shal is based on the hypotheses that the updraft can be tuned so that the CAPE available from the input profile can be destroyed in a given adjustment time interval τ_{adj} .

If LSETTADJ is set to .TRUE. (available in the NAMELIST), this adjustment time interval τ_{adj} is computed at each time step and for each column with an iterative method, starting from a prescribed value OTADJS set by the user and available in the NAMELIST.

Note that the scheme KFB_shal is highly dependent on this prescribed value for τ_{adj} .

The iterative process is used to determine a final state for the mean thermodynamic parameters, corresponding to a decrease of the CAPE to a value equal to 90% of the initial CAPE.

The same equation than the one for the mass-flux (4) is applied to the non-conservative variables $\bar{\theta}$, \bar{r}_v , \bar{r}_c and \bar{r}_i .

A new mean state ($n + 1$) is computed at each iteration, by using the initial (0) and the current state (n) vertical profiles, following

$$\bar{\phi}^{(n+1)} = \bar{\phi}^{(0)} + (\tau_{adj}/\bar{\rho}) \left[-\frac{\Delta}{\Delta z} (M^{u(n)}\bar{\phi}^{(0)}) - \varepsilon^{u(n)}\bar{\phi}^{(0)} + \delta^{u(n)}\phi^{u(n)} \right].$$

The new $CAPE^{(n+1)}$ is then computed, corresponding to this new ($n + 1$) vertical profile for the mean thermodynamic variables.

A test is made to check that the final updraft is strong enough to destroy the initial $CAPE^{(0)}$ within the time interval τ_{adj} . If the initial value $CAPE^{(0)}$ cannot be destroyed, the updraft variables are multiplied by the adjustment factor :

$$F_{adj}^{(n+1)} = F_{adj}^{(n)} \frac{CAPE^{(0)}}{CAPE^{(0)} - CAPE^{(n+1)}},$$

where $CAPE^{(0)}$ is the initial value for the CAPE and $F_{adj}^{(0)} = 1$. Note that if the first iteration lead to a sufficient updraft, the first adjustment factor is set to 1/2.

The iterative process continues until the values of $CAPE^{(n)}$ corresponding to the vertical profiles of $\bar{\theta}^{(n)}$, $\bar{r}_v^{(n)}$, $\bar{r}_c^{(n)}$ and $\bar{r}_i^{(n)}$ is less than 10% of the initial value $CAPE^{(0)}$.

When this threshold of 10% of $CAPE^{(0)}$ is reached, the convective tendencies are computed following

$$\left. \frac{\partial \bar{\phi}}{\partial t} \right|_{\text{conv}} = \left(\bar{\phi}^{(n)} - \bar{\phi}^{(0)} \right) / \tau_{adj}.$$

It is important to note that $\bar{\phi}^{(n)}$ is not the mean state variable at time $t + dt$. It is rather an theoretical value of $\bar{\phi}$, corresponding to a possible stationary updraft which would have the same mass flux $M^{u(n-1)}$, entrainment $\varepsilon^{u(n-1)}$ and detrainment $\delta^{u(n)}$ during the whole adjustment interval τ_{adj} .

1.4 A4 : Results and limitations

1.4.1 A4-a : Validations with SCM cases

The two 1D-SCM cases usually used for the validation of the non-precipitating shallow convection are the BOMEX and the Eurocs/ARM Cumulus.

For these two SCM cases, the KFB_shal scheme appears to be very sensitive to the value of the adjustment time τ_{adj} . If the default value of 3 hours seems to be relevant for the quasi-stationary case BOMEX, a value of 30 mn or so leads to better results for the convective fluxes simulated with the Eurocs/ARM Cumulus case.

So, the closure assumption implemented in the KFB_shal and using the CAPE method does not seem to be relevant for all kinds of shallow convection.

It is worth to note that, however, the vertical shape for the fluxes of the conservative variables are correct, even if the intensity of these fluxes are not properly determined by the present closure assumption, using the CAPE.

1.4.2 A4-b : Validation in 3D mode (GCM and PNT)

The validations in 3D mode have mostly been done with AROME, also with Meso-NH, for the period of June 2005. Except the problem of the unrealistic feature for the CAPE method, already mentioned for the BOMEX and Eurocs/ARM Cumulus SCM cases, another problem is observed which concerns the triggering part of the KFB_shal scheme.

Indeed, when the cloudiness is small (5 to 25 %), the KFB_shal scheme can remain inactive. In AROME and Meso-NH, the turbulent scheme is not active enough, it does not mix enough the variables in the convective updraft regions.

As a consequence, the dynamics and the resolved micro-physics scheme are more active than what they should be, because they must do the job of the KFB_shal scheme in these regions. Doing so, unrealistic rolls appear, with some δx long on the horizontal, associated with some “streets of 100% cloud cover”, also corresponding to strong vertical velocities \bar{w} , the clear manifestation of unrealistic “grid-point” shallow convection.

1.5 A5 : Next modifications and possible improvements

1.5.1 Closure method using w^* ?

When the first SCM tests have put forward the problems of the too high sensitivity with the adjustment time τ_{adj} , some other solutions have been tested for the closure part of the scheme, as a replacement of the CAPE one.

As a test, a convective vertical velocity w^* can be computed, in order to characterize the mean convective activity within the PBL. The vertical velocity w^* is computed in the turbulent scheme (TKE-CBR), depending also on the surface fluxes. The aim is to compute the mass-flux at the base of the cloud. The cloud fraction is set to a prescribed value of 4 or 5 %, from which are deduced the convective fluxes of the conservative variables. These convective fluxes are close to the one obtained with the LES for the Bomex and the Eurocs/ARM Cumulus cases.

1.5.2 The Updraft of KF90 defined as the “shallow convective part” of a non-precipitating generalized updraft ?

In spite of the existing problems in the triggering and the CAPE-closure part of the KFB_shal scheme, the SCM results obtained with the closure in w^* show that the cloudy updraft computed by the KFB_shal scheme is relevant for the shallow convection. As a result, the triggering and the closure part of the scheme must be revisited.

As an example, the work undergone by F. Couvreur corresponds to an adaptation of the ideas of Bretheton et al (2004) for the triggering and the closure hypotheses, with an application to the computation of the updraft part of the KFB_shal scheme.

2 Part B : Interactions

2.1 B1 : Interactions with other parameterizations

The true KFB_shal scheme has no input value coming from other subroutines, or other physical parameterizations.

For the modified version and for the the closure using w^* , the input value for w^* comes from the turbulent scheme.

As for the output of the KFB_shal scheme, the properties for the cloudy updraft can serve to diagnose a cloud fraction and a mixing ratio, both associated with the convective scheme (see the section 2.2). These diagnostic cloud properties can, then, interact with the radiation scheme.

2.2 B2 : Interactions with the data flow

Even if the KFB_shal scheme corresponds to a vertical mixing in terms of the conservative variables, the original scheme using the CAPE closure gives as output tendencies for the non-conservative variables $\bar{\theta}$, \bar{r}_v , \bar{r}_c and \bar{r}_i (see 1.3.3).

But, in Meso-NH and AROME, the tendencies for \bar{r}_c and \bar{r}_i are not used to compute directly the value of r_c and r_i for the next time step, also for the radiative and the dynamics.

Indeed, the tendencies computed by the KFB_shal scheme are cancelled by the “adjustment to the saturation” processes. Therefore, in Meso-NH and AROME, the value of \bar{r}_c and \bar{r}_i could disagree with the cloud information, even if the KFB_shal scheme is active.

In ARPEGE, the cloud cover and the mixing ratio are computed in ACNEBN, just like for the deep convection, from the flux of condensation given as input of the KFB_shal scheme and transmitted as a provisional value as input to the next time step.

2.3 B3 : Interactions with the dynamics

The final impact of the KFB_shal scheme is a vertical mixing of the conservative variables. But the dynamics acts on the non-conservative variables and the impact of the shallow convection can then correspond to some artificial tendencies for the condensed water, with possible underlying condensation/evaporation processes.

3 Part C : Algorithmics - Informatic

3.1 C1 : Algorithmic choices - Strong Constraints

- the computation are made for each vertical column, independently on each others (1D column);
- the computations of the updraft and the closure criteria are only made for the convective columns, those for which the triggering properties are verified;
- the mass-flux formulation directly gives the convective tendencies of the variables, not the convective fluxes.

3.2 C2 : Algorithmic choices - Weak Constraints

The KFB_shal scheme has been coded initially in Meso-NH. As a consequence, the DOCTOR norm of Meso-NH has been used to write this sub-routine.

For ARPEGE, the Meso-NH subroutine is called via an interface, with some transformation of the variables (the variables are put upside-down, ...);

Note that, in the Meso-NH code, the KFB_shal subroutine do not need to be called at every time step. In this case, the convective tendencies are set to constant values in between two calls to the full convective subroutine.

4 Part D : Informatic

The Fortran 90 code must be compiled with the double-precision options.

4.1 D1 : The architecture - list of subroutines

The monitor of the ARPEGE physics is **APLPAR**. If LCVPPKF=.TRUE., the ARPEGE KFB_shal scheme is called by the main subroutine **ACVPPKF**, a subroutine written with the DOCTOR norm of ARPEGE.

The first list of subroutines is

APLPAR : the general monitor of the ARPEGE physics

- > **ACVPPKF** : main call to the ARPEGE KFB_shal code
- > **convection_shal.mnh** : the interface to the Meso_NH KFB_shal code
- > **CPHFLUX** : compute the flux of water vapor from the tendencies
- > **CPHFLUX2** : compute the flux of static energy from the tendencies
- > **CPFHPFS** : compute the sensible heat, enthalpy and total precipitation fluxes from the condensation and precipitation processes

The subroutines ACVPPKF,CPHFLUX and CPHFLUX2 are located below the ARPEGE physics directory (/arp/phys_dmn/), whereas the subroutines CPFHPFS is located

below the “adiabatic” part of ARPEGE (/arp/adiab/). The **convection_shal.mnh** is located below the AROME and Meso_NH directory (/mpa/conv/).

The subroutine **convection_shal.mnh** is the true interface to call the Meso_NH external KFB_shal code, written by P. Bechtold. In this interface, the input arrays are first flipped upside-down, with the specific humidities (for ARPEGE) transformed into the mixing ratios (for Meso_NH). The KFB_shal code is then called, via the call to **shallow_convection.mnh**.

As outputs, the Meso_NH shallow convection tendencies arrays are reflip upside-down, but the tendencies of mixing ratios are set equal to the tendencies of specific humidities (except for the updraft, where the back transformation is applied).

Here is the second list of true Meso_NH subroutines, all located below the directory /mpa/conv/ and called by **convection_shal.mnh**.

- > **convection_shal.mnh** : the interface to the Meso_NH KFB_shal code
 - > **shallow_convection.mnh** : monitor routine, compute the shallow convection
 - > **convect_trigger_shal.mnh** : compute the environmental enthalpy, the total water, the environmental saturation theta_e (triggering)
 - > **convect_satmixratio.mnh**
 - > **convect_updraft_shal.mnh** : compute the updraft properties
 - > **convect_condens.mnh**
 - > **convect_mixing_funct.mnh**
 - > **convect_closure_shal.mnh** : compute the downdraft properties (closure)
 - > **convect_closure_thrvlcl.mnh**
 - > **convect_satmixratio.mnh**
 - > **convect_closure_adjust_shal.mnh**
 - > (*convect_chem_transport.mnh*) : only if OCH1CONV=.TRUE.

4.2 D2 : The architecture - list of NAMELIST options

The main NAMELIST variables used in the version of ARPEGE are

&NAMPHY

LCVPPKF=.TRUE., : the main switch to call the KFB_shal scheme (APLPAR)

&NAMPHY0

RTKFBCVPP=200., : for the computations of ”qc” (kin ACVPPKF)

&NAMCVMNH

LSETTADJ=.TRUE., : to switch-on the computation of the adjustment time...

OTADJS=10800., : ... with this user defined shal. adjustment time (in s)

XENTR=0.015, : the lateral entrainment rate

XDTPERT=0.30, : a triggering perturbation of temperature (in K)

XCDEPTH=500., : the minimum depth for the shallow cloud (in m)

XCDEPTH_D=4000., : the maximum depth for the shallow cloud (in m)

5 Part D : References.

Bechtold, P., Bazile, E., Guichard, F., Mascart, P. and Richard, E., 2001 : A mass-flux convection scheme for regional and global models. *Quart. J. R. Met. Soc.*, 127, p.869-886.

Betts, A.K., 1973 : Non-precipitation cumulus convection and its parameterization. *Quart. J. R. Met. Soc.*, 99, p.178-196.

Kain, J. S., and J.M. Fritsch, 1990 : A one-dimensional entraining/detraining plume model and its application in convective parameterization. *J. Atmos. Sci.*, 47, p.2784-2802.

Lenderink, G., Siebesma, A. P., Cheinet, S., Irons, S., Jones, C. J., Marquet, P., Müller, F., Olmeda, D., Sanchez, E. and Soares, P., 2004 : The diurnal cycle of shallow cumulus clouds over land : A single-column model intercomparison study. *Quart. J. R. Met. Soc.*, 130, p.3339 - 3364.

Simpson, J., 1983 : Cumulus clouds : Interactions between laboratory experiments and observations as foundations for models. *Mesoscale Meteorology*. D.K. Lilly and T. Gal-Chen, Eds., Reidel, p.399-412.