Algorithmic sequences in APLPAR, associated variables' evolutions for the two basic versions of ALARO-0

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One should distinguish here between ALARO-0-minus-3MT (called thereafter version **V-1**) and the full ALARO-0 (called thereafter version **V0**). The distinction is needed because of four facts:

- at the level of the APLPAR sequencing, the innovations in V-1 are rather of scientific nature (albeit rather conventional), while the one of V0 also have a strong algorithmic component (apart from some important original science as well of course);
- V-1 was phased first but with many preparatory steps for V0, which is still undergoing its differential phasing process;
- V-1 has been operationally validated, while V0 has yet only been scientifically checked for its capacity to preserve the nice 'grey-zone' handling properties of its 'parent' research mode version, developed by Luc Gerard;
- V-1 is not a pure subset of V0: for making it possible to run ALARO-0 while still calling ACCVIMP, several small specific features had to be implemented; they will be mentioned as **"O"** features (for overlap) in the ensuing text.

ALARO-0-minus-3MT

The system is still one of parallel physics calling, but the moisture prognostic variables are nevertheless updated to ZQx arrays at the beginning of APLPAR in order to cope for correction of negative values. The algorithm for this correction (which will be reused all along APLPAR in the V0 'cascading' case) is that water vapour is first called-in to compensate for negative condensed species (without any latent heat consequence however) and that, whenever the resulting q_v was or becomes negative, there is pumping from the level below, before the process is repeated there. Implicit surface pumping is also, like up to now in ACDIFUS alone, not associated with any latent heat effect.

The 'fluxes' (PFCQxNG), whose divergences will give the rebalanced state corresponding to the above paragraph, are only going to be defined at the beginning of APLPAR, updated after ACDIFUS (in compatibility with the former use of PFCQNG in ACDIFUS) and used in CPTEND_NEW in the V-1 case. But this already meant that one had to get rid of the computation previously used in ACDIFUS. This was done in harmonisation with the users of other APLPAR sequences and the splitting plus displacement of the correction, albeit not completely neutral, was proved a safe step for the meteorological results.

From the point of view of <u>radiation</u>, there are two modifications transparent for the APLPAR sequencing (inclusion of a simplified version of the Voigt-line-broadening effect proposed by Geleyn et al. (2005a); call by ACRANEB to AC_CLOUD_MODEL for the handling of multilayer saturation aspects of the cloud absorption and scattering). For the thermal NER computations the 'statistical' model for the interpolation coefficient (Geleyn et al., 2005b) was differentiated between the cases LRPROX=.T. (the 'exact' computations do not concern only 'cooling to space' and 'exchange with surface' but also 'exchange between adjacent layers') and LRPROX=.F.. Furthermore, since the new model calls far more complex functions of the sigma vertical coordinate, it was decided to use pre-computed eta-equivalents for the standard atmosphere (alike for critical relative humidity profiles) and to pass them to ACRANEB (PMAK & PMAN).

For preparatory computations, there are two occurrences where $q_t = q_v + q_l + q_i$ replaces q_v. First in ACNEBN for the computation of the stratiform part of the cloudiness. Second in ACCOEFK for the computation of the shallow convection's influence on the diagnostic exchange coefficients. In the latter case, this is done in the spirit of 'moist-conservative variables'. As a "O" feature the convective cloud cover part of ACNEBN is left unchanged (as a frozen rather old version).

For the implicit algorithm of vertical diffusion, one uses the so-called 'moist-conservative variables' (q_t and s_l) for computing the water and dry-static-energy fluxes (LDIFCONS=.T.), but then the return to fluxes of q_v and s is done under the assumption of zero turbulent fluxes for q_l and q_i. Trying to introduce non-zero fluxes at that point creates unexplained problems with surface pressure scores. However the code is ready for a reactivation of this possibility.

Concerning the turbulence, there is the so-called p-TKE code (Geleyn et al., 2006). A prognostic variable is activated for the turbulent kinetic energy, with all the associated mechanics. However the updating of this variable (and the output of its increment) is done within the framework of ACDIFUS where nearly all the necessary information (especially the one of the 'static' exchange coefficients previously computed by ACCOEFK) is available. From the updated TKE value, new local values for the exchange coefficients are made available to the implicit algorithms of ACDIFUS, this making the procedure quasi-transparent to the 'classical' computations. There are however two additional pieces of information that need to be passed from ACCOEFK to ACDIFUS: the neutral exchange coefficients and an amplification factor to be applied for the anti-fibrillation aspect of the solution of the TKE auto-diffusion. Currently this factor is equal to the one for the horizontal wind, but the code was prepared for a future possible different choice.

The stratiform condensation is also of prognostic character. There are four completely independent prognostic quantities for liquid and solid cloud water as well as for rain and snow falling particles. The microphysics part of the algorithm (APLMPHYS) treats the following processes: sedimentation, pseudo-graupel effects, auto-conversion, Wegener-Bergeron-Findeisen process, collection, evaporation of falling species, melting/freezing of falling species, geometry of the cloud- and precipitation sub-grid structure (under the LRNUMX=.T. maximum/random overlap assumption). The APLMPHYS code is a closed one, but soon there should be the possibility to modularise it at four levels: the basic function for the so-called statistical sedimentation process, the auto-conversion and WBF processes, the various collection aspects and the evaporation-melting/freezing part. The input requirement are limited to the values of hydrometeors and to the saturation deficit for the water vapour in the grid box, as well as to a partial cloud cover. While q_r and q_s are treated quasi transparently (for the time being) in APLPAR and APLMPHYS, the input values for cloud cover, q_l, q_i and saturation deficit are the result of an adjustment process simulation performed just before calling APLMPHYS.

The said moist stratiform adjustment process first computes, in ACPLUIE_PROG (a "O" feature in this role, since it will be split between two components [ACNEBCOND and ACCDEV, both containing also the Smith-Gerard option used to develop 3MT in research mode] after the ongoing phasing process), a cloud cover starting from the values of q_t and q_w (from ACTQSAT) as well as from a critical relative humidity. The latter depends on the mesh size of the model and is bounded by 'one' for vanishing meshes and by the ACNEBN-used value at the opposite end. The equilibrium point for cloud cover is the result on a transformed

Newton-loop crossing a Xu-Randall like function and the need for the water vapour in the clear air part of the grid box to be just at the critical relative humidity level. Condensation/evaporation rates are further obtained from the information about critical relative humidity and cloud cover. One first finds the equilibrium point for $q_c=q_l+q_i$. In case of net condensation q_l and q_i are increased proportionally to the FONICE function, in case of net evaporation, the proportionality factor is the initial proportion of q_l and q_i. ACPLUIE_PROG calls directly APLMPHYS, itself an independent routine to be called in stand-alone mode in V0.

Finally, all the ALARO-0 computations (V-1 alike V0) follow the Catry et al. (2007) system of equations for the conservative evolution of the prognostic quantities, this being encompassed in the CPTEND_NEW routine. With respect to the provisional V-1 phasing, the V0 one will encompass the $\delta_m=1$ option as well as the correct handling of p-TKE in the total energy budget.

The 3MT upgrading (V-1 => V0)

First of all, 3MT (Gerard, 2007) works under the cascading assumption, applied to all 'moist-physics' processes (i.e. everywhere except for momentum tendencies and for radiative effects). The idea of the cascading system is to still have the final upgrade of prognostic variables done in CPTEND_NEW and CPUTQY from the addition of independently computed fluxes, **but** to have a progressive updating of the local variables ZQx (and now also ZT) corresponding to the prognostic quantities and entering the routines that compute the above-mentioned fluxes.

Of course a full-scale application of this principle would requite to call CPTEND_NEW & CPUTQY several times. But the independence of the various flux computations makes such a cumbersome step unnecessary, since an approximate updating procedure will still lead to the searched effect, somewhere between parallel and sequential physics use. Hence the hypothesis is made for V0 that C_p and $L_{v/s}$ are time-independent precomputed values during the time step (but they stay of course location-dependent). From this assumption a consistent set of far simpler updating rules can be derived with little approximations.

Nevertheless, use of the cascade can reintroduce negative values for the water vapour or any condensed species, at some specific points within APLPAR. Specific applications of the negative correction algorithm have to be applied just after the updating steps. The above-mentioned (PFCQxNG) correction fluxes to be used in CPTEND_NEW are then systematically overwritten by their incremented values. In a similar spirit, functions depending on temperature have to be updated when needed.

Finally, since 3MT is essentially an introduction of prognostic convective computations, there is a specificity (within the cascading process) linked with the closure assumptions for up- and downdrafts. In order to avoid double counting, the physical tendencies linked to these closures are not part of the upgrades. This applies to the water vapour tendency of the vertical diffusion (ACDIFUS) and to the cooling effect of evaporation plus melting/freezing of falling precipitations in the microphysics (APLMPHYS).

Now the main trademark of 3MT is a treble synergic combination (Gerard et al., 2006):

- one uses the M-T approach of Piriou et al. (2007), hence separating in ACCVUD (updrafts) and ACMODO (downdrafts) the mass-flux transport terms from the condensation/evaporation ones;

- the (then well separated) microphysics is fed by the sum of the condensation/evaporation effects of both large scale (alike that of ACPLUIE_PROG and to be incorporated, under an independent switch, within ACNEBCOND and ACCDEV) and convective (computed in ACCVUD) motions;
- the downdrafts closure is resulting from the single call to APLMPHYS (after ACCVUD) and can hence be said to be triggered by precipitation of any origin, stratiform or convective.

But this poses (at least) four specific technical problems: (i) there is a need for independent communications between ACCVUD and ACMODO which is not straightforward to perform across the activation of APLMPHYS (itself necessary in any case, for instance in the absence of any convective activity); (ii) the influence of sedimentation processes on the impact of downdraft-generated evaporative cooling cannot be taken into account in APLMPHYS (unless at the price of an expensive iteration) and must be recomputed with the help of the diagnosed species' fall-speeds, output by APLMPHYS; (iii) the information output by APLMPHYS must help setting the ACMODO partition between solid and liquid phases of the above-mentioned precipitating species evaporation process; (iv) the cloud geometry necessary for the APLMPHYS input must combine information coming from the stratiform part and from the ACCVUD computation, in an unchanged mode for the former when the latter is missing.

In order to foster modularity by keeping ACCVUD, APLMPHYS and ACMODO as independent as possible of the way their input is provided, three additional routines complete the sequence of computations, each called after the main one (ACUPU, ACUPM & ACUPD).

All the above about 3MT did not yet treat the question of its prognostic character (Gerard and Geleyn, 2005). But, like for p-TKE, the latter is rather transparent to the APLPAR sequencing. Let us just state that there are four fully-fledged prognostic variables (with advection), concerning draught area fractions and internal vertical velocities in up- and downdrafts, plus one 'historical' variable for the computation of one 'prognostic updraft entrainment rate'.

What about both "O" features mentioned in the first part? First the convective cloudiness part in ACNEBN will be fed by an input value coming from the previous time-step's computation in ACCVUD. Given the way ACNEBN is arranged, this will be done by first inverting the Xu-Randall-type sequence up to the production of a condensate that would give back the input convective cloudiness, should there be no stratiform contribution. In the opposite case both condensate amounts will be added and sent to the direct computation.

There is then the question of cloudiness for condensation/evaporation and the process itself. Following the lines of development of its prototype, 3MT will be built for that part around the concept of independent routines (ACNEBCOND and ACCDEV), but within the cascading process (basically the cloudiness must be computed before ACDIFUS, to be used as input there in case one would reactivate the turbulent transport of q_l and q_i and the condensation/evaporation must be done after the ACDIFUS-bound update-correction sequence, just prior to ACCVUD which will in turn provide the second part of the condensation/evaporation tendencies).

References

Catry, B., J.-F. Geleyn, M. Tudor, P. Bénard and A. Trojakova, 2007: Flux-conservative thermodynamic equations in a mass-weighted framework. *Tellus A*, **59**, pp. 71-79.

Geleyn, J.-F., P. Bénard and R. Fournier, 2005a: A general-purpose extension of the Malkmus band-model average equivalent width to the case of the Voigt line profile. *Q. J. R. Meteorol. Soc.*, **131**, pp. 2757-2768.

Gerard, L., 2007: An integrated package for subgrid convection, clouds and precipitation compatible with the meso-gamma scales, *To appear in Q. J. R. Meteorol. Soc.*.

Gerard, L. and J.-F. Geleyn, 2005: Evolution of a subgrid deep convection parametrization in a limited-area model with increasing resolution. *Q. J. R. Meteorol. Soc.*, **131**, pp. 2293-2312.

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. *Submitted to J. Atmos. Sci.*.

Working Group on Numerical Experimentation (WGNE) Blue Book:
<http://collaboration.cmc.ec.gc.ca/science/wgne>

- Geleyn, J.-F., R. Fournier, G. Hello and N. Pristov, 2005b: A new 'bracketing' technique for a flexible and economical computation of thermal radiative fluxes, scattering effects included, on the basis the Net Exchanged Rate (NER) formalism.
- Geleyn, J.-F., F. Vana, J. Cedilnik, M. Tudor and B. Catry, 2006: An intermediate solution between diagnostic exchange coefficients and prognostic TKE methods for vertical turbulent transport.
- Gerard, L., J.-M. Piriou and J.-F. Geleyn, 2006: Advances in the integration of deep convection and microphysics for the meso-scale.