Technical Documentation

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Contents

1 Introduction

I worked on two topics in Toulouse. The first one was in the framework of physics dynamics interface. The goal is to modify the APLPAR routine (this is the routine which calls all the physics schemes) in that way that in the future more sophysticated microphysics or other schemes can be easily implemented. My work was to implement two new schemes (cloudiness and large scale (LS) precipitation scheme) and to tune it to the results got by the currently operational model (cycle 25t1). With the use of these new schemes the calling sequence of the schemes which deal with condensation (large scale, convective precipitation and cloudiness) can be changed. As a part of my work I started to do this modification. The advantage is that with the new sequence the cloudiness takes into account the convective precipitation of the current time step and not the previous one as it was in the original code. Further advantage is that with the new calling sequence the convective downdraft can have the total precipitation as input which is more realistic.

The other part of my work was to implement a new soil vegetation scheme to the ALADIN code. Its implementation into the ARPEGE code was already done by Martin Bellus, so this part of my work was not too challenging. However we discovered some bug in the code. We corrected it but it seems that other bugs also remained. Further study is needed to implement it correctly.

2 Physics-dynamics interface

a) Two schemes, the LS precipitation and the cloudiness scheme has been modified, and my work was to tune it to the result of the presently used schemes.

b) In the framework of physics-dynamics interface my job was to modify the calling order of the routines connected to condensation (cloudiness + precipitation).

2.1 Tuning the new cloudiness- and large-scale precipitation scheme

In the original code the routine ACNEBN deals with cloudiness and ACPLUIE describes the large-scale precipitation. Here I describe breafly how these were working in the original cycle in order to be easier to understand the changes.

The cloudiness is calculated from the condensed water content. This can be determined by a simple formula, which is the function of the excess water vapour in the grid-box. In the case of stratiform condensed water the excess water vapour is determined by: $\Delta q_{ex} = q - RH_c q_{sat}(T,p)$. (If we want to take into account the effect of sub-inversion -shallow convection-, we do a more complicated calculation for Δq_{ex} i.e. we calculate a weighted integral of $q - RH_c q_{sat}(T,p)$ for different levels, where the weights depend on the difference of the dry static energy between the levels. The idea is that the saturation function does not only depend on the current level, but also from lower ones.)

In case of convection the excess water vapour is determined from the convective precipitation flux difference between model levels, i.e. $\Delta q_{ex} = g\frac{\partial P}{\partial p}\Delta t$. The condensed water in both cases (large-scale, convective) can than be calculated as:

$$q_c = q_{max}\left(1 - e^{-\alpha_s \Delta q_{ex}/q_{max}}\right), \tag{1}$$

where q_{max} (the maximum sustainable water content) and α_s are constant parameters.

The total cloudiness is then calculated from the total water amount, $q_c^{tot} = q_c^{LS} + q_c^{conv}$ by the semi-empirical formula suggested by Xu and Randall[1]:

$$N = \left(\frac{q}{q_{sat}}\right)^r \left(1 - e^{-\frac{\alpha q_c^{tot}}{(q_{sat}-q)^\delta}}\right), \tag{2}$$

where α, δ and r are parameters.

The large scale precipitation is calculated in ACPLUIE routine. It assumes that all condensed water is falling out immediately, i.e. the precipitation flux at the bottom of a model level is:

$$P_b = \max\left(0, P_h + (q - q_{sat})\frac{dp}{g\Delta t}\right), \tag{3}$$

so if there is condensation ($\Delta q = q - q_{sat} > 0$), the precipitation flux grows by the amount $\Delta q\frac{dp}{g\Delta t}$. The scheme also takes into account evaporation of precipitation into unsaturated air by the Kessler formula[2], which we do not mention here.

In the following two subsections the two new scheme written by Jean-Francois Geleyn will be briefly presented. In sec 2.1.3 my modifications on them will be described. The results shows that the present stage of these schemes is not yet giving back the operational results, so further modifications are needed.

2.1.1 ACNXRM (cloudiness) routine

The new routine is built on Xu-Randall's scheme. The following important modifications with respect to the operational version have been done.

- Condensed specific humidity, q_c, is depending on the cloudiness, i.e. in Eq. (2) we will have an implicit formula for the cloudiness which has to be determined by a Newton algorithm. In the new routine (ACNXRM) we do not only make the formula implicit but after the idea of Jean-Francois Geleyn also the expression has been changed.

$$N = \left[\frac{q_v}{q_w}\right]^r \frac{\alpha q_c}{\alpha q_c + (q_w - q_v)^\delta} \tag{4}$$

$$q_v = q_w\left[RH_c(1-N) + N\right] \tag{5}$$

$$q_c = q - q_v \tag{6}$$

where the parameters α=QXRAL, r=QXRR, δ=QXRDEL are the same as in the original formulation, and q_v is water vapour, q_w = PQW is the wet-bulb specific humidity, N is the cloudiness and RH_c = PHUC is the critical relative humidity.

[1]K. Xu, D. A. Randall; 1996: A Semiempirical Cloudiness Parametrization for Use in Climate Models, *Journal of theAtmospheric Science*, **53**, pp. 3084-3102

[2]E. Kessler; 1969: On the distribution and continuity of water substanceon athmospheric sirculation. *Meteorol. Monogr.* **10** (32), pp 84

Eq.(4) can be rewritten as:

$$x = N(1 - RH_c) + \frac{A(1-N)^\delta N}{\beta^r - N}\ , \tag{7}$$

where $\beta = [RH_c(1-N) + N]$, $A = [q_w(1-RH_c)]^\delta/(\alpha q_w)$, and $x = q/q_w - RH_c$. Starting from an initial N value (close to zero) we do the iteration until the final point ($x_0 = q/q_w - RH_c$) is reached. (In the Newton loop the variable $s = 1/(1-N)$ is used instead of N.)

One remark is that the new routine does not uses the subroutine ACNEBXRS (as it is the case in cycle cy25t1), but the above presented calculation is done inside of ACNXRM.

- Not all the condensed water is precipitating out by LS precipitation. There is a remaining part (q_c^F=PQCF), which depends on the stratiform part of the final condensed water amount (q_c) and a limiting water amount (q_c^{lim}=ZQCLIM). They are determined as:

$$\text{ZQCLIM} \equiv q_c^{lim} \ = \ q_l^{lim} - f(T)(q_i^{lim} - q_l^{lim}) + \Delta q_c^{sc} \tag{8}$$

$$\text{PQCF} \equiv q_c^F \ = \ \frac{q_c\ (Nq_c^{lim})}{\left[{q_c}^{1/\gamma}\ + (Nq_c^{lim})^{1/\gamma}\right]^\gamma}, \tag{9}$$

  where Δq_c^{sc}=ZDQCVPP is the shallow convection contribution, $f(T)$=ZPLS is the fraction of ice, q_i^{lim}=QILIM, q_l^{lim}=QLLIM and γ=NEXPC are parameters.

- The total cloudiness is calculated differently as the stratiform part, without the use of the Newton loop. Since for the stratiform part q_c is determined, the total condensed specific humidity can be calculated as: $q_c^{tot} = q_c + \Delta q^{dc}$, where Δq^{dc}=ZDQCVP is the contribution from deep convection. The value of the vapour amount can also be calculated through $q_v = q - q_c^{tot}$, i.e. Eq.(4) will be an explicit formula.

2.1.2 ACPLUIE (large scale precipitation) routine

- The new ACPLUIE routine has three new input values from ACNXRM routine:
  PQCF≡ q_c^F: remaining water amount (earlier: PQCF=0)
  PNEBST≡ N^{LS}: stratiform cloudiness (earlier: N = 1 if $q > q_w$ and N = 0 otherwise)
  PHUCS≡ $RH_c^{LS} = RH_c - \Delta q_c^{sc}/q_w$: stratiform critical relative humidity (earlier: $RH_c = 1$)

- The routine distinguishes between cloud-free and cloudy part of the grid-box, so the routine calculates $\mathcal{P}_b^{free}$=ZFPTB and $\mathcal{P}_b^{cloud}$=ZFPTBN and the final precipitation flux will be:
  $\mathcal{P}_b = \mathcal{P}_b^{free} + N(\mathcal{P}_b^{free} - \mathcal{P}_b^{cloud})$.
  In the cloud-free case:

$$0 < \Delta q = \begin{cases} q_w(1-RH_c) & q/q_w > RH_c \\ q_w - q & q/q_w < RH_c \end{cases} \tag{10}$$

  While in the cloudy case:

$$0 > \Delta q_n = \begin{cases} \dfrac{q_c^F - \left[q - q_w(N^{LS} + (1-N^{LS})RH_c)\right]}{N^{LS}} & q/q_w > RH_c \\ \dfrac{q_c^F + N^{LS}(q_w - q)}{N^{LS}} & q/q_w < RH_c \end{cases} \tag{11}$$

  which means that if there is over-saturation only the amount $q_c - q_c^F$ is taken to account, not the total amount of condensed specific humidity, as was done earlier.

2.1.3 Modifications and results

To tune the new schemes one can modify the following parameters: LPCONT, LPNUMX, QXRAL, QXRR, QXRDEL, QILIM, QLLIM, NEXPC, HUTIL, HUCOE, NPLCO1, NPCLO2.

parameter	**explanation**
LPCONT	switch-on the new ACPLUIE calculation
LPNUMX	maximum overlap calculations in ACPLUIE
QXRAL, QXRR, QXRAL	parameters of the cloudiness formula, see Eq.(4-6)
QLLIM, QILIM	limiting water amount (water,ice), see Eq.(8)
NEXPC	power used to calculate PQCF, see Eq.(9)
HUTIL, HUCOE, NPCLO1, NPCLO2	parameters to calculate the critical relative humidity

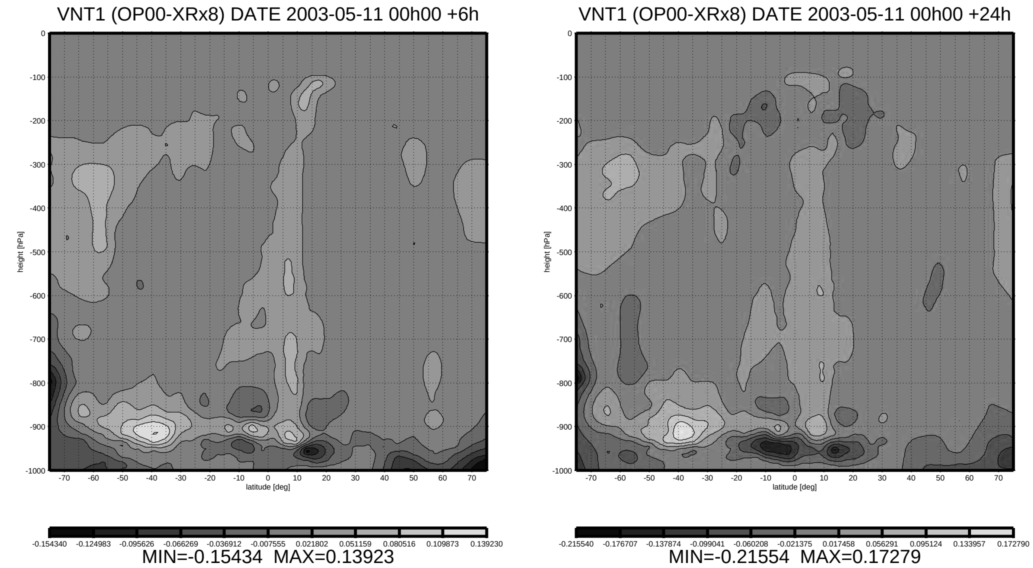

Figure 1: Difference in cloudiness (zonal DDH) between the new scheme (XRx8) and the reference(OP00) for 6h and for 24h forecast. The reference we used was cy25t1.

The best set of parameter was:

QXRAL	QXRR	QXRDEL	HUTIL	HUCOE	QLLIM	QILIM	NEXPC
200	0.25	0.5	0.0	0.3	7.10^{-2}	5.10^{-3}	2

The change of HUTIL from the operational value (HUTIL=1.8) was required because the experiments showed that there is less cloud in the upper levels in case of the new schemes. Lowering HUTIL means that we lower the critical relative humidity at the upper levels, which will allow more cloud. Also QILIM, QLLIM had to be changed from the operational value, because the originally proposed values, QILIM=QLLIM=7.10^{-5}, were too small, which means that the resulting value of PQCF is also small, i.e. the produced cloud precipitates out.

From Fig 1 one can see that it is quite far from operational, so instead of just changing the parameters we tried the following modifications in the code. Unfortunately all the modifications had only small effect on the result.

1. Maximum overlap of the cloudy part of adjacent levels in the ACPLUIE routine (LPNUMX logical key).
   - At the end of the vertical loop of level $l-1$ store the cloudiness and the precipitation flux values:

ZNEBSH $= N_{l-1} =$ ZNEBS$_{l-1}$
ZFPTH $= \mathcal{P}^{free}_{h,l-1} =$ ZFPTB$_{l-1}$ (cloud-free case)
ZFPTHN $= \mathrm{P}^{cloud}_{h,l-1} =$ ZFPTBN$_{l-1}$ (cloudy case).

- At the beginning of the vertical loop of the l-th level the values of the incoming flux ZFPTH(N) are calculated from the stored values of the $l-1$-th level :

$$\mathrm{ZFPTH} \quad = \quad \mathcal{P}^{free}_{h,l} = \frac{\mathrm{MAX}(0, N_{l-1} - N_l)\mathcal{P}^{cloud}_{h,l-1} + \mathrm{MIN}(1 - N_l, 1 - N_{l-1})\mathcal{P}^{free}_{h,l-1}}{\mathrm{MAX}(\varepsilon, 1 - N_l)} \tag{12}$$

$$\mathrm{ZFPTHN} \quad = \quad \mathcal{P}^{cloud}_{h,l} = \frac{\mathrm{MIN}(N_l, N_{l-1})\mathcal{P}^{cloud}_{h,l-1} + \mathrm{MAX}(0, N_l - N_{l-1})\mathcal{P}^{free}_{h,l-1}}{\mathrm{MAX}(\varepsilon, N_l)} \tag{13}$$

This modification was used for all experiments which will be presented here.

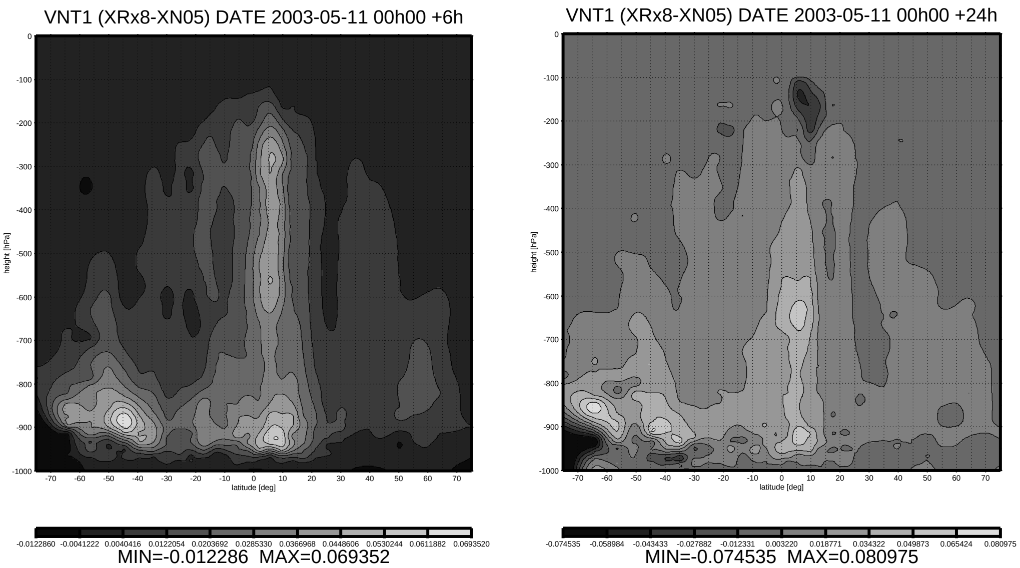

Figure 2: Effect of step 2: calculating total cloudiness also with Newton loop. The figure shows the difference in cloudiness (zonal DDH) for the original version of the new scheme (XRx8) and with the modification of step 2 (XN05).

2. Calculating total cloudiness also with iterative method

- In the original case only the stratiform cloudiness is determined with the Newton loop but the total cloudiness is calculated as written in the last point of Sec 2.1.1 This is however misleading since in this case the total condensation amount ZQC $= q_c^{tot}$ and the vapour amount ZQV $= q_v^{tot}$ will be the function of the stratiform cloudiness (PNEBST $= N^{\mathrm{strat}}$) and not the total cloudiness, i.e. we will solve the equation system (4)-(6) for $N = N^{tot}$ in Eq.(4) while $N = N^{\mathrm{strat}}$ in Eq.(5).

  The suggested change is that one should redo the whole Newton loop to calculate the total cloudiness. The difference between the original version and of this modification is shown in Fig 2.

3. Instead of modifying RH_c modify x_0

- To take into account the shallow convection we calculate the ZDQCVPP $= \Delta q_c^{sc}$ for each level and modify the critical humidity by $RH_c^{\mathrm{strat}} = RH_c - \Delta q_c^{sc}/q_w$. We use this modified relative humidity value in Eq.(7). In this case the condensed specific humidity will be:

$$q_c = q + (1-N)\Delta q^{sc} - q_w[N + (1-N)RH_c] \tag{14}$$

To avoid to have the factor $1-N$ before Δq^{sc} we do not subtract ZDQCVPP from RH_c but instead we modify the value $x_0 = q/q_w - RH_c$ by $x_0 = q/q_w + \Delta q^{sc}/q_w - RH_c$. This change affect mainly the lower atmosphere in the tropics. See Fig 3. The result shows that there will be less cloudiness at very low level, which is closer to the operational result.

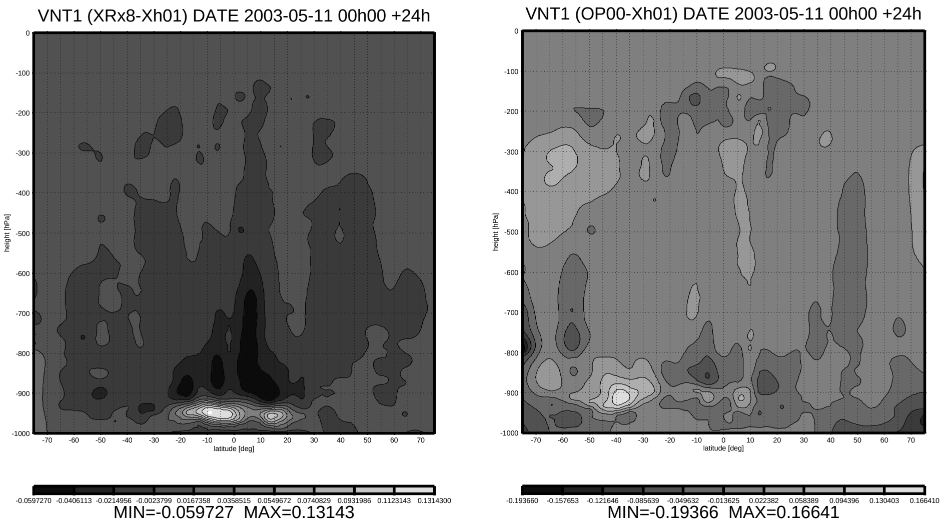

Figure 3: The effect of step 3: how to take into account the contribution of shallow convection. Difference in cloudiness (zonal DDH) after 24 hours between a) the original version (XRx8), and the modification due to step 3 (Xh01) /left figure/, and b) operational (OP00) and modification due to step 3 (Xh01).

4. Let the limiting condensation amount (ZQCLIM) depend on cloudiness.

The experiments showed that in some cases there is an overshooting in cloudiness calculation. That means that enlarging the cloudiness (e.g. reducing RH_c) also enlarges the condensed specific humidity, which will cause too much precipitation and the cloud will disappear. The problem is that for small cloudiness values the remaining water amount, PQCF, has too low value. I used different modifications

a) The simplest way is to divide the ZQCLIM $= q_c^{lim}$ term in Eq.(9). This means that small cloudiness values will not lower even more the amount of remaining water, PQCF. (We used the same calculation for ZQCL.)

b) Modify only the solid part of ZQCLIM, i.e. one should divide only $q_i^{lim} =$ QILIM in Eq.(8), but not touch q_c^{lim} in Eq.(9). (For convenience we did in the other way around: we multiplied each term by N^{strat} in Eq.(8) except of q_i^{lim}, and did not multiply ZQCLIM in Eq.(9)).

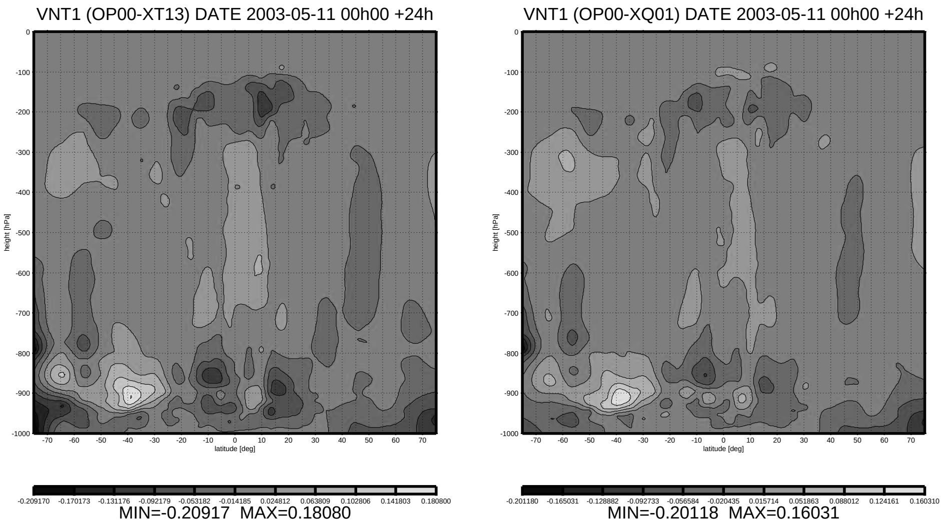

Figure 4: The effect of step 4: ZQCLIM depending on the cloud amount. Difference in cloudiness (zonal DDH) after 24 hours between a) operational (OP00), and the modification due to step 2+3+4/a) (XT13) /left figure/, and b) operational (OP00) and modification due to step 3+4/b) (XQ01).

2.2 Modification of the calling sequence of the precipitation and the cloudiness routines

The old and the new order of the routines in APLPAR which deal with condensation can be seen in Fig. 5. The routines describe the following physical processes:
ACNEBN: cloudiness (old routine)
ACNXRM: cloudiness (new routine, see Sec. 2.1.1)
ACPLUIE: large-scale precipitation
ACCVIMP: convective updraft and precipitation calculation
ACCVIMPD: convective downdraft and precipitation evaporation
ACRANEB: radiation scheme. (It is in brackets because it does not deal with condensation however it should be taken into account by the change of calling order, because it has an input from the cloudiness routine.)

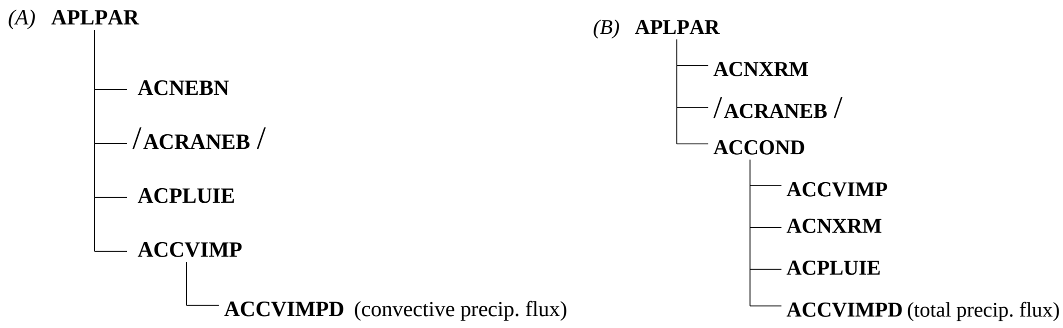

Figure 5: Calling sequence of the "condensation" routines in APLPAR. *(A)* the original sequence used in cy25t1, *(B)* the modified sequence.

To create the modification some technical changes had to be done (introduction of new variables, putting the definition of some variables to the module in order to be able to read from namelist, etc.)

which is out of the scope of this document. Only the important changes and the advantages which come with these changes are described.

- ACCOND is a new interface routine, all routines (ACCVIMP, ACCVIMPD, ACNXRM, ACPLUIE) are called from it. In the original version as can be seen from Fig. 5 the downdraft (ACCVIMPD) was called from inside the updraft routine (ACCVIMP). Now both are called directly from ACCOND.
- Since LSRCONT is not used any more, the deep convection calculation (ACCVIMP) can be put before the cloudiness calculation (ACNXRM). The aim of this change is to add to the cloudiness routine the convective precipitation flux (ZFPLC) of the *same* time step. Earlier the precipitation flux had to be stored in a pseudo-historical array at the end of the time step, and this array entered the cloudiness routine (ACNEBN) in the next time step.
- The total cloudiness (PNEB) and total remaining water (ZQCL) amount is passed from ACNXRM to ACPLUIE routine. That means that in contrast what is written in Sec. 2.1.2 the remaining water depends not only on the stratiform part but on the total amount of the condensed water.
- The radiation scheme (ACRANEB) has the input (PNEB, PQLI, PQICE) from the cloudiness scheme, but the latter is called after ACRANEB, so for the time being we solved this problem by calling 2 times the ACNXRM routine. Later this could be solved by creating a pseudo-historical array where the cloudiness values can be stored.
- We add the total amount of precipitation (stratiform + convective) to the downdraft routine (ACCVIMPD), since it is unrealistic that downdraft only evaporates the convective precipitation flux. The following changes should have been made for this modification:
  - calculate the total amount of precipitation flux, separately for liquid and for ice:

    $$\mathcal{P}_{liq}^{tot} = \mathcal{P}_{liq}^{LS} + \mathcal{P}_{liq}^{Conv} \qquad \mathcal{P}_{ice}^{tot} = \mathcal{P}_{ice}^{LS} + \mathcal{P}_{ice}^{Conv}.$$

  - At the end of the calculation we want to have separately the convective and stratiform precipitation fluxes, so before passing the sum to ACCVIMPD we have to store their proportion.

    $$r_{liq} = \frac{\mathcal{P}_{liq}^{Conv}}{\mathcal{P}_{liq}^{tot}} \quad \text{and} \quad r_{ice} = \frac{\mathcal{P}_{ice}^{Conv}}{\mathcal{P}_{ice}^{tot}}$$

    We assume that in the downdraft the two precipitation are evaporating in the same way (same amount), i.e. at the end the proportion of the separate fluxes remain the same. So at the end of ACCVIMPD the new value of e.g. convective precipitation flux will be $\mathcal{P}_{ice}^{Conv} = r_{ice}\mathcal{P}_{ice}^{tot}$.
  - since the fraction of solid precipitation is calculated differently in ACCVIMP and in ACPLUIE, we recalculate it and pass the new fraction to ACCVIMPD:

    $$z_{snow} = \frac{\mathcal{P}_{ice}^{tot}}{\mathcal{P}_{ice}^{tot} + \mathcal{P}_{liq}^{tot}}$$

    This is important since in ACCVIMPD routine there is a test (ZFCORQ1) whether the evaporation flux is negative. The test considers only the sum of the precipitation fluxes (liquid + ice), and makes the correction in case of negative evaporation flux due to the ice proportion.
- The problem is that in the original version the convective precipitation could evaporate in 2 ways: a) like LS precipitation evaporation b) by the downdraft. From now on the total amount (Conv + LS) is evaporating by the downdraft, but the LS kind evaporation term of convective precipitation (RCVEVAP) remained in ACCVIMP routine. One should think about how to solve this problem.

3 External vegetation scheme

Martin Bellus added to cycle cy26_bf the externalization of soil vegetation scheme. My work was to merge his modification to cycle CY26T1, and compile it for the ALADIN model. Below some tests are presented which was made with the implemented code.

Comparing the two experiments, a) original surface scheme (LSVEXT=F) and b) externalization (LSVEXT=T) shows large difference e.g. in surface temperature, even after the first time-step: Fig 6/(ARS0-ARS1). It turned out that there was a bug in the calculation of surface albedo, in ls_acsurf.F90 routine (part of the external surface scheme): it did not take into account the calculation in case of LVGSN=T. After the correction of this bug the range of the temperature difference did not change dramatically, however at some places it disappeared: Fig 6/(AAu0-AAu1).

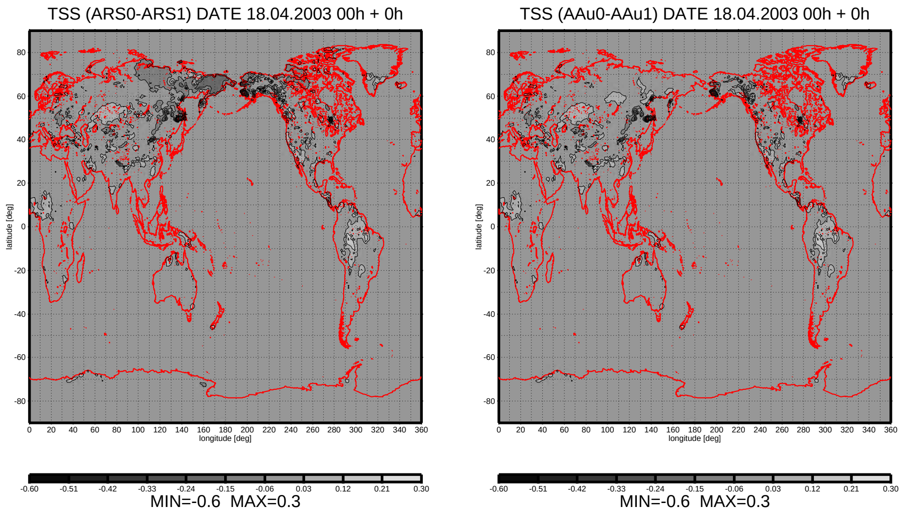

Figure 6: Surface temperature difference after the first time-step between a) REF: the original scheme, LSVEXT=F (xxx0) and b) EXP: externalisation, LSVEXT=T (xxx1). The left picture (ARS0-ARS1) shows the result for original source. The right (AAu0-AAu1) is the corrected (for LVGSN) version. (Note that the range of the different figures are the same, this is by purpose in order to be able to compare the different results.)

The remaining difference can be a) either the theoretical difference of the calculation (instead of dry static energy it uses the potential temperature θ) b) or some instability of the model (also observed for other cases, e.g. in the operational run) which increases the small difference occurring at the beginning of the integration. To check this last possibility we tried to switch-off all physics except of vertical diffusion Fig. 7/(ABu0-ABu1). (We did this experiment because Eric Bazile studied the instability and he observed that the small perturbation at the first time step does not increase when he switches off the different physics schemes.) The resulting difference is still significant (also for bigger forecast time e.g. 3h, not shown) which means that the effect is not only caused by the instability. We also tried to switch-off the anti-fibrillation scheme used in vertical diffusion: Fig. 7/(ACu0-ACu1), but the result shows that even in this case the difference remains.

Finally we looked the difference for the roughness length after the first time step (Fig 8). Surprisingly there is a difference in z_{0M} (roughness length for momentum) over see after one time step. It is perhaps the cause that also the 2m temperature differs, however it is calculated at the beginning of APLPAR by ACHMT (LSVEXT=F case) or ACHMTLS (LSVEXT=T case), and it should not be affected by the externalization. So the final conclusion is that there is still some bug in the new soil vegetation scheme.

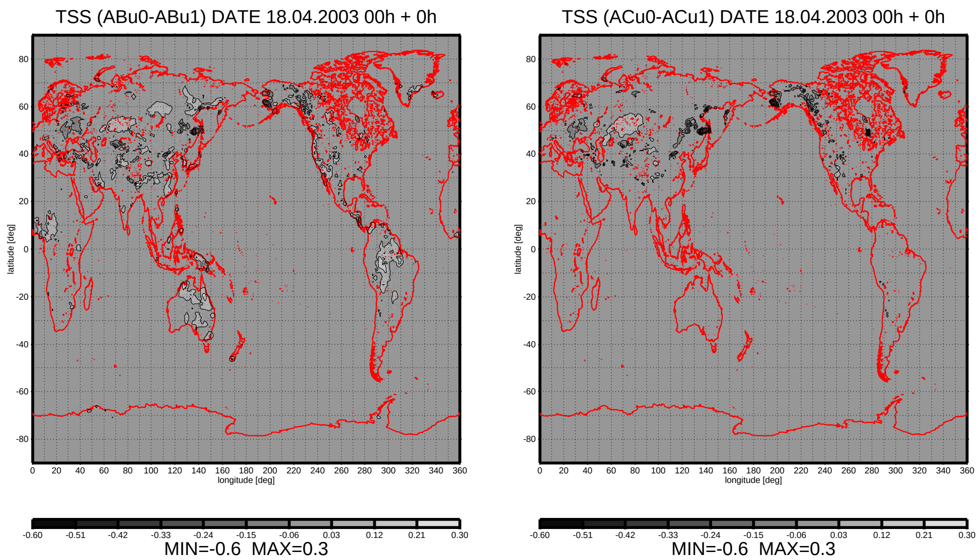

Figure 7: Surface temperature difference after the first time-step between a) REF: the original scheme, LSVEXT=F (xxx0) and b) EXP: externalisation, LSVEXT=T (xxx1). The left picture (ABu0-ABu1) corresponds to the case when all the physics schemes were switched-off except vertical diffusion. The right (ACu0-ACu1) is the case without anti-fibrillation scheme.

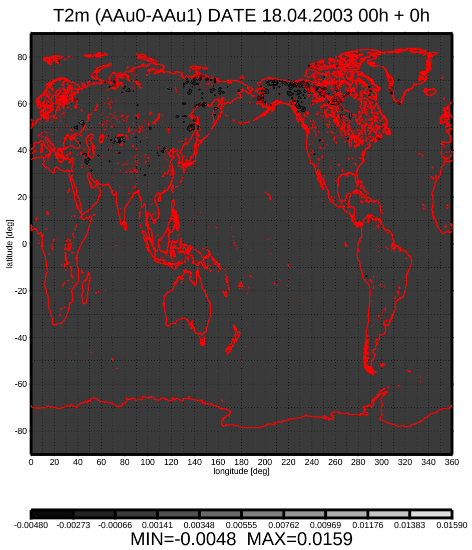

Figure 8: Difference for T2m after 1 time-step between (AAu0: LSVEXT=F) and (AAu1: LSVEXT=T). Both experiment uses the corrected (LVGSN) version.