RC LACE Technical Note

ALARO 1 Configuration with ACRANEB2 and TOUCANS Schemes – Version A

Radmila Brožková

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Introduction

This technical note describes the first operational configuration of ALARO 1 with new radiation scheme ACRANEB2 and turbulence scheme TOUCANS. This is a starting point of using these two schemes together, however in future we still expect improvements (solar scattering saturation in radiation, new version of shallow convection and length scale in TOUCANS, prognostic graupel in microphysics to mention some of them). At the same time we introduced further enhancements to the microphysics, concluding two developments engaged in the past in collaboration with IRM, Belgium. Future versions of ALARO 1 will also include validated developments in moist deep convection.

Library content and namelist

The development is now ready on the basis of the cycle CY38T1.bf3, which was dispatched as the export version. Main pieces are as follows:

ACRANEB2

New radiation scheme is coded including the system of single intermittency in solar band and of double intermittency in the thermal band, allowing cloud-radiation interaction computation at every time-step of the model, while more expensive gaseous transmissions terms are divided to one or two categories requiring more or less frequent refreshment to keep the sufficient precision of the whole scheme. Gaseous transmission functions have now much better fit, and also cloud optical properties are handled more precisely and are retuned. Therefore with ACRANEB2 we cannot emulate the previous ACRANEB scheme; we are getting new features and higher quality.

In addition to the first ACRANEB2 version available in winter 2013/2014 there are several novelties available:

- Parameterization of gas-cloud short wave overlap;
- Optical properties of ice and water clouds were re-fitted using more recent references;
- New parameterization of short wave cloud optical saturation with better vertical dependency; as a part of the exercise parameter *REXP_NEB* became 1 and in the new procedure AC_CLOUD_MODEL2 (associated with ACRANEB2) is unused, see below.
- Intermittency of solar band transmission computation; typically to be used with one hour interval.

The modified routines are:

adiab/

cpg.F90 (intermittency mechanism)

module/

yomphy.F90 (basic switches), yomphy0.F90 (parameters), yomphy3.F90 (gaseous transmission constants, Rayleigh scattering parameters and cloud optical properties), yomtrc.F90 (global transmission coefficients storage)

namelist/

namphy.h, namphy0.h, namphy3.h

phys_dmn/

ac_cloud_model.F90, ac_cloud_model2.F90, acraneb.F90, acraneb2.F90, acraneb_coefs.F90, acraneb_coeft.F90, acraneb_solvs.F90, acraneb_solvt.F90, acraneb_solvt3.F90, acraneb_transs.F90, acraneb_transt.F90, aplpar.F90, mf_phys.F90, suparar.F90, suphy0.F90, suphy3.F90

phys_radi/

suecrad.F90

setup/

su0phy.F90, sudyn.F90, susc2b.F90

utility/

dealsc2.F90

Namelist changes with respect to the scheme ACRANEB at the level of CY38T1 in NAMPHY

Switch	New value	Old value	Default value	remark
NRAY	2	none	1	New scheme is on when NRAY=2, previous scheme is on when NRAY=1. What follows is valid for new scheme.
LREWS	removed	TRUE	FALSE	Considered as if TRUE
LRMIX	removed	TRUE	FALSE	Considered as if TRUE
LRTDL	removed	TRUE	FALSE	Considered as if TRUE
LRSTAB	removed	TRUE	FALSE	Considered as if TRUE
LRPROX	FALSE	TRUE	FALSE	Exact computation of NER exchanges between adjacent levels only, foreseen for the use at every time-step, suited for previous ACRANEB.
LRAUTOEV	removed	FALSE	FALSE	Exact evaluation of all pairs of NER exchanges (thermal band); very expensive.
NTHRAYFR	-1	none	1	Intermittency of thermal band gaseous transmission computation in hours (negative value; in time-steps if positive value).
NSORAYFR	-1	none	1	Intermittency of solar band gaseous transmission computation in hours (negative value; in time-steps if positive value).
NRAUTOEV	3	none	0	Instead of LRAUTOEV, frequency of exact NER computation set to NRAUTOEV * NTHRAYFR; i.e. in this example set to 3 hours.

and in NAMPHY3:

Parameter	New value	Old value	Default value	remark
REXP_NEB	unused	8.	8.	Exponent defining effective cloud optical depth in case of non-trivial cloud geometry (solar band only).
FCM_NU_DI	0.	none	0.1972	Scattering saturation parameter for ice clouds
FCM_NU_DL	0.	none	0.4286	Scattering saturation parameter for liquid clouds
RLAMB_SOLID	0.6	none	0.	Proportion of Lambertian reflection for solid surfaces (zero is old solution).

New radiation scheme ACRANEB2 is quite a compact piece of code. Most of parameters, like gaseous transmission coefficients are fitted and set by default. From the user point of view the parameters to be eventually tuned are the intermittency frequencies *NRAUTOEV*, *NSORAYFR* and *NTHRAYFR*; however the setup recommended above is a good compromise of computational cost and precision.

Introduction of the scheme removes weaknesses of the previous one; however, since the model physics was tuned with the previous scheme, retuning is necessary. Since we have a completely new turbulence scheme TOUCANS nearly at the same time on the table, it becomes desirable to make the tuning in one go, namely due to natural interactions between radiation and turbulence. The ensuing recommended setup is described below.

TOUCANS

The library contains the basis of the scheme and also some pieces of the code as preparation for further enhancements. Therefore not all the routines are used in the active path of the first operational setup. There are now five new GFL fields coded, which required to modify all necessary routines in the setup and post-processing parts of the model. Here is the overview of the modified routines:

canari/

caclsi.F90

fullpos/

fpachmt.F90

module/

yom_ygfl.F90, yomafn.F90, yomfa.F90, yomlouis.F90, yomphy.F90, yomphy0.F90, yomqnse.F90

namelist/

namfa.h, namgfl.h, namphy.h, namphy0.h

phys_dmn/

acdifv2.F90, acdifv3.F90, achmt.F90, acmixelen.F90, acmrip.F90, acmris.F90, acmriss.F90, acptke.F90, acptkes.F90, actkecoefk.F90, actkehmt.F90, actkehmtls.F90, actkezot.F90, actkezotls.F90, actkecls.F90, aplpar.F90, arp_ground_param.F90, mf_phys.F90, suphy0.F90 setup/

su0phy.F90, su_surf_flds.F90, suafn1.F90, suafn2.F90, suafn3.F90, suctrl_gflattr.F90, sudefo_gflattr.F90, sufa.F90, sugfl1.F90, sugfl2.F90, sugfl3.F90

Among five new GFL fields, four of them carry the memory of the scheme and are not advected, nor cycled within the data assimilation yet. The fifth one, which is total turbulent energy TTE, is advected and cycled, since it is the counterpart of turbulent kinetic energy TKE and both energies need the same consistent treatment. The NAMGFL namelist setup is as follows:

GFL	Attributes	remark
YEFB1	LGP=.T., LADV=.F., NREQIN=0, LREQOUT=.F.	YEFB1 carries the memory of shear term – source term of energy equations
YEFB2	LGP=.T., LADV=.F., NREQIN=0, LREQOUT=.F.	YEFB2 carries the memory of total water turbulent flux – source term of energy equation instead of K-gradient term
YEFB3	LGP=.T., LADV=.F., NREQIN=0, LREQOUT=.F.	YEFB3 carries the memory of heat turbulent flux – source term of energy equation instead of K-gradient term
YMXL	Not activated yet in this setup	YMXL carries the memory of length scale
YTTE	LGP=.T., LADV=.T., NREQIN=1, LREQOUT=.T. in cycling	New prognostic variable of the scheme: total turbulent energy. It should be treated in the same way like TKE. It is recommended to cycle it within the data assimilation and/or blending.

Proposed setup of TOUCANS is in some way conservative, we do not yet profit from all the potential, but there are already important novelties put in place with respect to pTKE scheme. We use a new type of stability functions (so-called tuned model II, see Bašták et al., 2014), parameterization of moist third order moments, turbulent diffusion of cloud condensates and use of fluxes to compute source terms. The most revolutionary is the use of total turbulent energy TTE. On the other hand we still rely on the same type of length scale computation as in pTKE, and the first version of the shallow convection also emulates the previous one. Here is the setup of the switches in NAMPHY:

Switch	New value	Old value	Default value	Remark
LCOEFKTKE	TRUE	none	FALSE	Main TOUCANS switch. It uses TKE solver, thus LPTKE=.TRUE. as well.
CGTURS	'MD2'	none	'MD2'	Model II of turbulence
CGMIXLEN	'EL0'	'AY'	'Z'	Type of length scale. The choice of 'EL0' is equal to 'AY' (Ayotte type)

LPTKE	TRUE	TRUE	FALSE	Since some parts of computations are common to p-TKE scheme, this switch must be kept TRUE.
LCOEFK_F1	TRUE	none	TRUE	At the surface f(Ri)= min(1.,f(Ri))
LCOEFK_FLX	TRUE	none	FALSE	Flux-form of source terms for TKE and TTE. Mandatory when prognostic TTE is used.
LCOEFKSURF	TRUE	none	FALSE	Call to ACTKEHMT surface routine and modified interpolation ACTKECLS for screen level param.
LCOEFK_PTTE	TRUE	none	FALSE	Use of total turbulent energy TTE
LCOEFK_SCQ	TRUE	none	FALSE	Influence of skewness in moist Brunt-Vaisalla Frequency computation.
LCOEFK_TOMS	TRUE	none	FALSE	Use of Third Order Moments parameterization.
LCOEFK_RIS	TRUE	none	TRUE	Shallow convection cloudiness based on Ri* or Ri**. Currently mandatory.
LDIFCONS	TRUE	none	FALSE	Activation of Betts transform.
NDIFFNEB	1	0	0	Cloudiness choice for turbulent diffusion of condensates (if LDIFCONS=T). Shallow convection cloudiness is used with influence of skewness (if value 1).

It should be noted that TOUCANS scheme contains several options in its subparts, however not all combinations are correct to be used together. Some of the most incorrect choices are abort-handled in the setup, but not all. Therefore one has to consult the specific TOUCANS technical documentation to learn more. There is also a specific treatment of the exchange with surface by ACTKEHMT, having the same arguments as the standard ACHMT surface routine, in order to handle consistently computations needed in surface analysis and in Full-Pos. It should be noted that the screen-level-interpolation routine ACTKECLS (called by ACTKEHMT) is derived from the original ACNTCLS procedure but it is combined with the proposal of László Kullman as a function of intensity of the exchange with surface. Warning: coupling of TOUCANS with SURFEX is still under development. The proposed setup of parameters in NAMPHY0 (table below) reflects the above choices of the scheme switches:

Parameter	New value	Old value	Default value	remark
C_EPSILON	0.871	none	0.871	Turbulence model dependent
C3TKEFREE	1.183	none	1.184	Turbulence model dependent
ETKE_BETA_EPS	0.05	none	0.02	Security
ETKE_CG01	1.	none	1.	TOMS related coefficient
ETKE_CG02	1.	none	1.	TOMS related coefficient
ETKE_CG03	1.	none	1.	TOMS related coefficient

ETKE_GAMMA_EPS	0.03	none	0.03	Security
ETKE_OLAM	0.29	none	2./3.	Turbulence model dependent
ETKE_LAM0	0.29	none	2./3.	Turbulence model dependent
ETKE_RIFC_MAF	0.5	none	0.5	Parameter of moist anti-fibrillation scheme (unused with LCOEFK_THS1= .FALSE., which is default)
NUPTKE	0.5265	0.52	0.52	Turbulence model dependent
TKEMULT	1.	unused	1.	Multiplier of TKE in length scale computation. It is unused in case of 'EL0' option.
XDAMP (NAMPHY2)	1.	1.	0.	We keep the same setup for the moist anti-fibrillation as in pTKE.

As already mentioned above, some parts of the scheme emulate the pTKE setup used in ALARO-0 (length scale, shallow convection closure). For validation purposes, one can also emulate Louis stability functions in upper air and at surface; hence TOUCANS under the specific settings may yield results close to pTKE. Tests with other turbulence models (QNSE, EFB) were also made; their results are quite reasonable but are slightly less good than the 'tuned Model II' choice. Each novelty added meant slight improvement; the most remarkable impact was reached by introducing the Total Turbulent Energy.

Next expected improvement to come is a new version of shallow convection. The use of another type of length scale would be the following step to study.

MICROPHYSICS

The library contains two developments, which were pending by some time but finally reached the mature stage, plus some smaller modifications. The first one is the enhancement of vertical geometry of cloudiness and falling precipitation. Till now we used the maximum-random hypothesis of the vertical overlap. The code also contained a local switch *LLRNUMX* for the choice of vertical overlap. It was put to *.TRUE.* by hard coding, i.e. we had the maximum-random overlap choice. We know from the tests that switching it off to get the pure random overlap leads to quite exaggerated enhanced evaporation of precipitation. More realistic description of the cloud scene is given in the paper by Shonk et al., 2010. To parameterize it, we introduce a bit of randomness to the maximum-random overlap. Degree of additional randomness is computed for each level as a function of its pressure thickness normalized by a reference thickness (parameter of the scheme). The resulting dimensionless coefficients ε_l may vary between zero (random overlap) and one (maximum-random overlap):

$$\varepsilon_l = e^{-\frac{\Delta p_l}{RDECRD}}$$

Where *RDECRD* is the above mentioned parameter of reference pressure thickness; setting it to a very big value will push ε_l closer to one, so to say to the original solution of the maximum-random overlap.

The second development follows the proposal of Abel and Boutle (2012) on the improvement of rain drop size distribution. In short, there is according to measurements higher number of smaller drops than given by the classical Marshall-Palmer formula. Their complex proposal is made for liquid phase only (rain), since the case of solid phase is much more delicate (various subtypes of solid precipitation with quite differing shapes and sizes …). Higher amount of small drops lead to their easier evaporation. It helps to diminish amount of light rain knowingly exaggerated by the model. The change of drop-size distribution required modifications of all formulas for rain. In addition to their scientific content one was mathematically optimised to reduce computing cost. Therefore even when the switch of the novelty *LAB12* is set to *.FALSE.*, the numerical results are not exactly the same as before. Nevertheless the meteorological ascending compatibility was verified, confirmed by only a small change of spectral norms. The formulas for graupel and snow were modified too, albeit in a lesser extent. The coding of solid phase processes was also revisited on the basis of original data (without now any compatibility constraint with the liquid phase aspects) and accordingly cleaned. This was done in a way preserving the existing links between graupel and snow, as much as feasible.

Besides there are some small novelties introduced to the library, like the possibility to have different evaporation rate for snow than for rain and dependency of solid phase evaporation rate on temperature via parameter *REVAPN*. Till now hard coded parameter *ZGELSFON* (for freezing and melting) was also moved to the namelist as *RGELSFON*.

In order to keep the same meanings regarding the basic parameters of the non-auto-conversion microphysics (*FSPRAIN*, *EFFCOLL*, *EVAP*, *REVAPN*, *FONT*, *RGELSFON*), all changes were hard coded inside the routines (the *LAB12* switch takes care of everything). The only “trick” is that *REVAPN* has to be used inside *APLMPHYS* (to handle the influence of graupel there) while it should in principle be (like *RGELSFON*) purely a parameter of *ACEVMEL*. Because of this slight approximation, it is preferable not to modify *REVAPN* too far away from its default value “one”.

Namelist switches (NAMPHY):

Switch	New value	Old value	Default value	Remark
LAB12	TRUE	None	FALSE	It activates improved rain drop size distribution after Abel & Boutle 2012. When FALSE, ascending compatibility still holds, spectral norms change a little.

Parameters (NAMPHY0):

Parameter	New value	Old value	Default value	Remark
RDECRD	20000.	None	20000.	Reference pressure thickness for automatic setup of the overlap coefficient. Big value would push the overlap coefficient closer to 1.
REVAPN	1.	None	1.	Ratio of snow evaporation rate with respect to the case of rain. Value "1." means potential evaporation rates for snow and rain are equal.
RGELSFON	0.0125	ZGELSFON = 0.0125	0.0125	Move of hard coded parameter to namelist.

There are two more small modifications of the library linked to moist processes, more precisely in the adjustment. Within the tuning exercise a distinction between the parameter α (QXRAL) used to compute the cloudiness for radiation and cloudiness of the adjustment process was made – parameter QXRAL_ADJ was introduced. Later tests have shown a very small impact of varying QXRAL_ADJ, hence the recommendation is to keep it equal to QXRAL. Another distinction was made for the parameter of time relaxation decay of deep convective cloudiness GCVTAUDE. This parameter was used also for a relaxation type of computation in the adjustment, which was not a proper solution. New parameter ADJTAU was introduced with default value of 900s.

ADDITIONAL TUNINGS

As mentioned above, introduction of new better schemes usually breaks down compensation errors mechanism, where deficiencies of a scheme are overcome by tunings. It is not a surprise to have to retune some parameters.

In addition the automatic setting of convective closure modulation is activated by the namelist parameter *RMULACVG* set to a negative value:

$$\mu = min\left(|RMULACVG|, max\left(1., \left(\frac{\Delta x}{1200.}\right)^2\right)\right)$$

The absolute value of *RMULACVG* gives the upper limit of the modulation coefficient μ; a reasonable value is 25. Its lower limit (μ=1.) is reached for mesh size of 1200m and smaller. Use of this automatic setting ensures a proper variation of the coefficient μ with the map factor as well. Activation of this option can be done independently on new radiation, turbulence and modified microphysics.

The computation of cloud water content of the stratiform part of radiative cloudiness was modified. Stratiform clouds become less opaque with height. For that, existing tuning parameter QSSUSV (unchanged value 250.) is modulated by a linear function of the vertical coordinate. At the bottom (η=1.) QSSUSV keeps its namelist value, while at the top (η=0.) it becomes QSMODC-times bigger. QSMODC is a new parameter, default value is zero (no modulation), and recommended value is 4.

In case of the combination of ACRANEB2, proposed version of TOUCANS and enhancements in microphysics, the following parameters were changed:

Parameter	New value	Old value	Default value	remark
SLHDEPSV	0.	0.016	0.	Coefficient of vertical Laplacian smoothing strength, used with SLHD scheme. Removal helps to restore sharp gradients namely close to tropopause.
QSMODC	4.	none	1.	Modulation of stratiform radiative cloudiness opacity (Xu-Randall scheme) with height.
QXRAL	150.	130.	130.	Xu-Randall scheme parameter for radiative cloudiness – amount is enhanced.
QXRAL_ADJ	150.	130.	130.	Xu-Randall type of the scheme for resolved cloudiness. Value kept equal to QXRAL.
RAUTEFR	0.5E-03	1.E-03	1.E-03	Inverse of auto-conversion characteristic time for rain – twice slower.
RAUTEFS	2.E-03	1.E-03	1.E-03	Inverse of auto-conversion characteristic time for snow – twice faster.
RMULACVG	-25.	15.	25.	Automatic set of deep convection closure modulation with variable horizontal mesh (independent from using new radiation and turbulence). The previous value 15 was the initial tuning for 4,7km resolution.
RCTVEG(3)	1.1E-05	1.4E-05	0.8E-05	Inverse coefficient of thermal resistance of low vegetation – resistance is a bit enhanced.