PHYSICAL PARAMETERISATIONS IN ARPEGE AND ALADIN
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Generalities

The last widely published documentation of the whole package described below is eight years old (Geleyn et al., 1994). It is still valid in a few aspects, especially those concerning the interfacing rules and/or thermodynamic constraints, the radiative calculations once the clouds are diagnosed, the stratiform precipitation scheme and the purely gravity wave part of the mountain drag. This however does not give a complete picture.

Thus, pending an updated general paper, the interested reader is referred for details to the on-line documentation prepared and maintained by Luc Gérard (*). The description below will be a rather homogeneous introduction (with references whenever available but without details) to the current situation with a few words about unused options and planned upgrades.

Radiation computations

The basic scheme is adapted from Geleyn and Hollingsworth (1979) and Ritter and Geleyn (1992) and simplified enough for being able to describe the interactions soil-radiation and clouds-radiation at each time step. The three main 'compromise' hypotheses for speeding-up the calculations are the following:

- only one spectral interval in the solar as well as in the thermal range, but consideration of all active gases as well as of the separation between liquid- and ice-cloud components;
- grey body assumption (i.e. linear monochromatic behaviour) for all effects except gaseous absorption (but multiple scattering is treated without approximation, even in the thermal domain, thanks to a delta-two-stream computation with a choice between random and maximum-random (unused) overlap hypothesis for cloud geometry);
- the interaction between line absorption of gases and two-stream 'adding' method as well as the saturation effects of the former are treated via the diagnostic estimation of a 'minimum' gaseous optical depth for all remaining effects, once (i) absorption of parallel solar radiation in the solar domain and (ii) so-called 'cooling to space' and 'exchange with surface' terms in the thermal domain have been treated exactly.

The diagnostic schemes for the 'radiative' clouds link the cloudiness to the production of stratiform and convective precipitations, and to the existence of inversions. The scheme is based on the following principles:

- cloudiness functionally depends (with different parameters for the stratiform and convective contributions to a single amount) on the diagnosed liquid- ore ice-water-content; the functional dependency is one of those proposed by Xu and Randall (1996);
- the contribution is obtained from the rate of generation of convective precipitation at the previous time step in one case;
- in the other case, one estimates the instantaneous super-saturation of the air properties averaged along a certain delta-theta thickness below, with respect to the local saturation state multiplied by a 'critical relative humidity' vertical profile (tuned with two parameters only);
- the partition between ice and liquid state depends only on temperature with a progressive transition below 0°C.

One is currently considering a new structure for the radiative computations in which the clear sky gaseous computations, the cloud/aerosol sub-model and the delta-two-stream solver would be considered as three independent parts, this allowing more flexibility and a different view of the 'radiative time stepping problem'.

Turbulent vertical diffusion and PBL

The common scheme for the surface and upper-air exchanges is designed according to Louis (1979) and Louis et al. (1981), with the shallow convection incorporated according to Geleyn (1987) and recently modified to cure a tendency to an on/off behaviour in time and along the vertical. For the past four years a big effort (still on-going) has been made to improve the coefficients' dependency on the Richardson number in case of stable situations. Two (positive) critical Richardson numbers (each with a potentially modulated vertical profile) have been introduced. The first one deals with the enhancing effect on fluxes of sub-grid inhomogeneities and the second one with the difference in the effect of such inhomogeneities between the thermal and momentum parts of the calculation.

A retuning of the 'mixing length' vertical profile was applied during this work and it is intended to make it dependent at some stage on the time- and space-dependent height of tropopause and PBL depth, the latter computed according to Ayotte et al. (1996).

The residual gusts when the wind is weak near the sea surface and the situation is unstable are treated via a stability-dependent enhancement of the result of the basic Charnock formula, in the spirit of the Miller et al. (1992) work. An enhancement to the moist convective case, inspired by the ideas of Redelsperger et al. (2000) is currently considered as well as the possibility to distinguish between roughness lengths for momentum and for heat over sea (as it is already the case over land). The 'anti-fibrillation' scheme of Bénard et al. (2000) is activated. Extending the idea of Girard and Delage (1990), it introduces an over-implicit treatment only when and where the linear local full stability analysis estimates it necessary in order to get a pre-chosen degree of 'smoothness' of the solution. In order to avoid getting 'space-sliced' patterns in place of time oscillations, a constraint of vertical monotonicity was recently imposed on the resulting over-implicit factor. Since this scheme, by construction, cannot handle the type of shallow convection parameterisation via turbulent exchange coefficients' enhancement used in the package, the above-mentioned modification of the shallow convection scheme had to be introduced to harmonise the whole treatment.

Specific diagnostics for the boundary layer are (in a broad sense):

- interpolated values in the SBL (generally towards the measurement heights) according to Geleyn (1988);
- PBL height (up to now computed with a Richardson number offset, soon to be replaced by the above-mentioned adaptation of Ayotte's method);
- maximum gust wind speed, either through a link with the dynamical roughness and the surface friction velocity or as the wind at the top of the PBL;
- CAPE and moisture convergence (several algorithmic options for each of them) computations for the instantaneous diagnostic of convective risk, especially in diagnostic mode with a frequent near-surface-analysis update.

Mountain drag scheme

It describes in a broad sense the influence of unresolved orography on the higher levels of the atmosphere in a way adapted from Boer et al. (1984) for the linear 'gravity wave drag' part (with full use of the Lindzen (1981) saturation criterion for applying the Eliassen-Palm theorem) and from Lott and Miller (1997) for the 'form drag' low level part. An optional (yet unused) parameterisation of the sub-grid scale so-called 'lift' effect exists, following Lott (1999). Some additional effects are taken into account for the following aspects:

- influence of the anisotropy of the sub-grid orography on the direction and intensity of the stress, according to Phillips (1984);
- use of averaged wind and stability low level conditions (and smooth return to the true profiles above the averaging depth) in order to get a surface stress as independent as possible of the model's vertical discretisation;
- amplifying or destructive resonance effects parameterised according to the work of Peltier and Clark (1986), as well as dispersion effects in case of upper-air neutrality;
- the linear and non-linear potential instabilities of this complex scheme are preventively eliminated at the time of computation of the integrated effects (except for the 'lift' case that is currently an independent piece of parameterisation put in the scheme's code only for convenience).

The whole scheme is currently under review with the aim to abandon the associated envelope orography and to replace its volume effect by a better tuned form drag and by the use of a revised version of the lift effect (that would then cease to be independent of the scheme's backbone).

Deep convection

This parameterisation is surely the one that has received most attention in the evolution of the considered physics package. Contrary to the general tendency in other NWP groups, most of the attention has been paid to the formulation of the entrainment and to its consequences and not to the closure assumption, still of the Kuo-type, even if its practical implementation has also gone more complex than in the 80's.

The original scheme is the mass-flux-type one from Bougeault (1985), modified for the numerical stability according to the Appendix of Geleyn et al. (1982). In its current version it encompasses the following refinements:

- the Kuo-type closure has been made dependent on the horizontal resolution according to the ideas of Bougeault and Geleyn (1989) since the dynamical part of the moisture convergence is here modulated by a factor depending on the mesh size and that goes to zero for a vanishing one;
- a very simple microphysics to avoid 'deep convection' from too shallow clouds; this follows the proposal formulated in the Appendix of Arakawa and Schubert (1974);
- it is forbidden to have deep convection when absolute dry convection is active;
- a comprehensive treatment of the vertical transport of horizontal momentum that includes the recirculation by the mass-flux in the Schneider and Lindzen (1976) sense, the effect of lateral entrainment and the effects of pressure difference between the cloud and its environment following the proposal of Gregory et al. (1997); the 'non-hydrostatic' part of the moist adiabat ascent/descent computations are treated in conformity with Gregory's underlying hypotheses;

- a provision for cancelling the computations when the potential for convective rain at the surface makes it unlikely for the ascent to reach the lifting condensation level;
- a vertically varying detrainment rate with a constant component plus a dependency on the buoyancy decrease in the upper part of the cloud;
- an entrainment rate that (i) varies from higher values at the bottom to lower ones at the top alike the proposal of Gregory and Rowntree (1990), (ii) is dependent on a first estimate of the integrated buoyancy and (iii) encompasses the 'ensembling entrainment' concept (i.e. the clouds inside a grid-box that survive at a given height have a higher buoyancy than the averaged one below, because they entrained less in their lower part) in its consequences on the profiles;
- parameterisation of downdrafts via quasi-symmetric computations for the ascending and descending motions (Ducrocq and Bougeault, 1995); the additional differences are a geometric modulation of the mass flux to avoid its convergence in the sole lowest model level and constant entrainment/detrainment rates along the vertical, contrary to the description in the last two bullets, valid only for updrafts;
- in the closure assumption for the downdraft part, precipitation fluxes' creation replaces moisture convergence but Bougeault's main closure coefficient (ratio of mass flux to buoyancy) has been constrained to remain smaller for downdrafts than for updrafts in order to avoid a runaway feedback when a shallow moist unstable layer caps a deep dry and well-mixed PBL; to alleviate the consequences of this 'security' in terms of surface fluxes a compensating 'unorganised' sub-cloud evaporation term is incorporated following the relaxation method of Geleyn (1985).

Stratiform precipitation scheme

There is neither storage of the liquid and solid phases in the clouds, nor consideration of partial cloudiness, but a revised Kessler (1969) method is used for computing precipitation evaporation, melting and freezing. A ratio of the falling speed for the two types of precipitation allows distinguishing two aspects in the liquid/ice partition:

- formation that follows the same partition as the one used in the radiative diagnostic cloud scheme;
- evolution for the falling parts that takes into account the past 'history' of the falling fluxes, even if those are diagnosed under a (time-step by time-step updated) stationarity assumption.

Quite sophisticated parameterisations of the soil processes

This is based on the ISBA scheme described by Noilhan and Planton (1989) and by Giard and Bazile (2000). Some modifications have been added to the scheme for taking into account the freezing-melting effects of the soil water at different levels. The research version of the same scheme is well known through the participation to the various international inter-comparisons (PILPS, SNOWMIP, …).

Website for the on-line documentation: http://www.cnrm.meteo.fr/aladin/MODELES/EXT/Physics/index.html

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