Proposals on «interfacing of physical parameterisations»

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The aim of the present document is to describe the interfacing of physical parameterisations in the numerical models used at Météo-France and to make some proposals to improve the corresponding interfaces. This corresponds to the framework of the **«interface d'appel» action** decided within an internal CNRM meeting for the monitoring of the «convergence» actions, which was held on 12/12/07.

The issue about physical parameterisations' interoperability and more specifically the use of «3MT» within ARPEGE and AROME (CPPN request expressed in April 2008) will be treated in a separate document.

1) Introduction

The role of physical parameterisations is to represent the average effect of sub-grid physical processes (radiation, microphysics, transport, interactions with the surface) upon the evolution of the model's prognostic variables. **The important points concerning the interfacing of any given physical parameterisationare as follows:**

1. **the characteristics of the parameterisation** (definition of input/output variables, discretisation, described physical processes, algorithmic, …). All this is handled either upstream at the time of development of physical parameterisations or a-posteriori within the physical interface ($\Rightarrow$ Section 2).

2. **the handling of interactions between physical parameterisations** (sequential physics, parallel physics, pseudo-historic variables, …). These issues are handled at the level of the physical interface which ensures the preparation, the calling sequence and the interactions between physical parameterisations ($\Rightarrow$ Section 2).

3. **the accounting of physical terms in the dynamical equations**, handled in the physics/dynamics interface ($\Rightarrow$ Section 3).

4. **the link with physical diagnostics** which must all be consistent with the physical processes represented in the parameterisations, with the terms computed in the physics/dynamics interface and with the host model's dynamics. This issue is not treated in depth in the present document owing to the ongoing **«DDH» action**, which target is to develop a diagnostic software with maximum possible interoperability between ARPEGE/ALADIN, AROME/Meso-NH and ALARO-0.

The problematic of physical parameterisations' interfacing is thus relatively complex and touches issues of scientific nature as well as equally important technical aspects (computing efficiency, readability, potential of evolution, etc.).

2) Physical interface

2.1) Physical interface used in ARPEGE and ALARO: «APLPAR»

The physical interface «APLPAR» contains the calling sequences of the operational physical parameterisations, the equivalent for older physical parameterisations (ascending compatibility) and for physical parameterisations under development within the models ARPEGE (NWP and Climate) and ALARO. **The complexity of this interface grew substantially within the last years** with the introduction of new developments concerning the surface model «SURFEX», the common «NWP/Climate» physics and the ALARO physics, the latter introducing in particular many statements for the microphysical cascade of «3MT». Currently encompassing 3400 lines of code and 240 input/output arguments, this interface is relatively cumbersome to make evolve.

2.2) Physical interface used in AROME: «APL_AROME»

The necessity to create a specific physical interface «APL_AROME» encompassing the calling sequence of the physical parameterisations of the AROME model became rapidly clear owing to the complexity of «APLPAR» and to the existing differences between Meso-NH and ARPEGE parameterisations, this resulting from distinct choices made at the birth of both models. The main differences are: 1) the use of differing variables in input of physical parameterisations (specific humidity / mixing ratio, dry static energy / potential temperature, …), 2) an opposite convention for describing the vertical dimension, 3) the description of the horizontal dimension by 1D arrays in ARPEGE and 2D arrays in Meso-NH in order to keep a geographical meaning (longitude, latitude) of the arrays involved in the development of 3D physical parameterisations (notably turbulence), 4) very differing physics/dynamics interfaces. Differences (1), (2), (3) are currently treated by conversions performed at each time step within the «APL_AROME» physical interface, something that hampers the readability and the efficiency of the code.

The HIRLAM partners did the same analysis as for AROME when introducing their own physical parameterisations under the hat of a «HL_APLPAR» physical interface.

ECMWF also uses its own physical interface named «CALLPAR».

Accounting for LMD's physics in the framework of the «common physics» with ARPEGE-Climate also led to the same choice within the previous (1D) ARPEGE Single Column Model (SCM). The analysis should be redone, in view of including the call to the LMD physics within the new 1D version of the ARPEGE, AROME, ALARO, HIRLAM models (so-called «MUSC» SCM).

2.3) Proposals about the physical interfaces «APLPAR» and «APL_AROME»

Little effort was devoted in the last years to the improvement of our physical interfaces «APLPAR» and «APL_AROME», priority being rather given to the improvement of physical parameterisations. Please find below several proposals aiming at cleaner, simpler and more modern versions of the current physical interfaces. **The benefit of merging both physical interfaces «APLPAR» and «APL_AROME» could only be meaningfully studied once these actions would have been concretised.**

The proposals for improving the physical interfaces are as follows:

1. **Cleaning of the physical interfaces «APLPAR» and «APL_AROME»** by forbidding physical computations in these routines and by removing obsolete parameterisations. The physical interfaces should contain only the initialisation of variables, the calls of «preparatory» routines (computation of variables necessary to the physical parameterisations) and the calls to physical parameterisations themselves. Study of the overhead associated to the conversions currently performed in «APL_AROME» («reshaping», inversion of the vertical levels). Study of the possible suppression of these conversions, in particular along the lines of F. Vana's proposal. The extra cost associated to the modifications to be realised as well as the complexity of the said realisation will determine the degree of priority given to the suppression of these conversions.

2. **For the particular case of radiative computations, development of a general interface** within which would be called the radiative parameterisations currently used in IFS, ARPEGE, ALADIN, ALARO, AROME and HIRLAM. The HIRLAM partners indicated their willingness to get involved in such an action.

3. **Analysis of the possibility to use a common code for the correction of negative moisture values within the ARPEGE, ALARO and AROME physics.**

4. **Feasibility study concerning the use of FORTRAN «structures» in order to substantially reduce the number of input/output arguments of the physical interfaces.** This action should be performed in close links with the action on improving the architecture of the «DDH» diagnostics, since the latter's 'consumption' of output arguments is quite heavy.

5. **Feasibility study concerning an increased flexibility of the physical interface** for handling the sequence of calls to physical parameterisations, the pseudo-historic variables and the choice between sequential («microphysics cascade» for instance) and parallel calls to physical parameterisations.

3) Physics/dynamics interface

3.1) Physics/dynamics interface used in ARPEGE and ALARO

Given the complexity of the issue and owing to the absence of any major problem, **choices made in common for NWP and Climate at the beginning of the ARPEGE project concerning the physics/dynamics interface are still used today for the ARPEGE and ALARO physics**. Physical parameterisations are called at the beginning of the time-step before the dynamics, in a parallel mode and from the unique physical interface «APLPAR». They provide fluxes of momentum, enthalpy and water phases which are used in the physics/dynamics interface «CPTEND / CPUTQY» as well as in the «DDH, XFU, CFU» diagnostic computations. Precipitation fluxes and pseudo-fluxes linked to the phase changes of water are used in the physics/dynamics interface in order to consistently compute the associated enthalpy tendency. This interface was initially developed in the framework of purely diagnostic schemes for clouds and precipitations, where only the water vapour phase had a prognostic representation. **A first evolution of the physics/dynamics interface «CPTEND / CPUTQY» took place in 1994 with the introduction of two additional prognostic variables (liquid and solid cloud condensates)**, but without operational application. The prognostic treatment of precipitations started in ARPEGE with the PhD work of P. Lopez in 1999. The first use of a prognostic microphysics in ARPEGE (June 2006) was performed by using in the physics/dynamics interface enthalpy fluxes linked to the water phase changes computed directly in the microphysics parameterisation, i.e. through a small arm twisting of the previous logic of the physics/dynamics interface. **A second evolution of the physics/dynamics interface was proposed (Catry et al., 2007)** and coded by the ALADIN partners for the prognostic treatment of clouds and precipitations with 4 hydrometeors in a manner compatible with a barycentric compressible hydrostatic equation system. The use of this new physics/dynamics interface «CPTEND_NEW / CPUTQY» became relatively easy for ARPEGE and ALARO physics, given its continuity with the previous «CPTEND / CPUTQY» interface. A contrario, using the new physics/dynamics interface did not become easier than in the previous case for the AROME physics.

3.2) Physics/dynamics interface used in AROME

The physical parameterisations used in Meso-NH and AROME directly provide the tendencies of the prognostic variables of the model. Using the same physics/dynamics interface as in ARPEGE and ALARO on the basis of fluxes and pseudo-fluxes unavailable in output of the AROME physical parameterisations was not possible in a simple manner. The physics/dynamics interfacing of AROME was performed by summing the tendencies of all physical parameterisations within the hyper-simple «CPUTQY_AROME» routine, without going through «CPTEND» (later becoming «CPTEND_NEW»). It should be noted that the same strategy was used to interface the LMD model in the 1D SCM and the HIRLAM physics within the IFS/ARPEGE code **It is not the difference «fluxes» vs. «tendencies» which matters between AROME and ARPEGE/ALARO for the physics/dynamics interface, but rather the evolution of enthalpy which is handled in two very different ways.** This handling is performed within the AROME physical parameterisations which directly provide temperature

tendencies while the evolution of enthalpy due to the storage or release of latent heat or due to the fall of precipitations is computed in the physics/dynamics interface for ARPEGE/ALARO.

The physics/dynamics interfacing currently performed in AROME suffers from the following deficiencies: a) the conservation of enthalpy is not warranted; b) some options are not easily available («δm=1», projection on the pressure variable of the diabatic terms in the compressible case).

3.3) Limitations of the physics/dynamics interface «Catry et al.»

The (Catry et al., 2007) physics/dynamics interface used in ARPEGE and in ALARO shows some weaknesses, with a bigger impact in the case of the AROME physics.

The non-accounting of graupel and the fact to assume zero sedimentation speeds for cloudy solid and liquid phases (a problem in case of fog) appear as weaknesses of the said interface for its application in AROME. Although an extension of this interface for handling both these weaknesses is perfectly feasible, such a development is still unavailable in the current physics/dynamics interface «CPTEND_NEW / CPUTQY».

The said interface relies on the use of 6 pseudo-fluxes to describe the local diabatic exchanges between water vapour and the 4 hydrometeors. The use of pseudo-fluxes is a bit misleading from the physical point of views since intra-layer exchanges without inter-layer aspects are here at stake. This issue is of relatively minor importance even if it leads to unnecessary computations with tendencies to fluxes conversions in the microphysics and fluxes to tendencies conversions at the level of the physics/dynamics interface.

The major hurdle lies in the use of 6 exchange terms between water vapour and the 4 hydrometeors, a correct mathematical representation for what concerns thermodynamic computations, but quite remote from the physical processes taking place. The projection of all physical processes on the 6 pseudo-fluxes becomes a development with some complexity and little practical justification in the framework of a sophisticated microphysics alike the AROME one. The situation is differing for the ARPEGE and ALARO less complex microphysics for which the representation with 6 pseudo-fluxes is not far away from the handled microphysical processes, except for the process of snowmelt.

3.4) Use of the «Catry et al.» physics/dynamics interface in AROME

Despite the more or less dimensioning weaknesses of the «Catry et al.» physics/dynamics interface, it would be technically possible to compute the 6 pseudo-fluxes and the 2 precipitation fluxes from the AROME microphysics in order to use the interface.

This was first envisaged within the framework of the «DDH» diagnostics action, starting from the extraction of all physical processes described in the AROME microphysics. The necessary work for this became complex, owing to the important amount of AROME microphysical processes and to the computing cost consequences for the physics/dynamics interface.

The MAPFI proposal was then formulated by the partners in order to separate the physics/dynamics interfacing problematic from the one of the diagnostics in AROME. The main idea is to compute the pseudo-fluxes starting from a far lesser number of terms coming from the AROME physics (the precipitation fluxes, the auto-conversion rates, the divergence of radiative fluxes, the total tendencies due to microphysics for temperature, water vapour and the hydrometeors). This proposal would allow to test in a far simpler way the use of the «CPTEND_NEW / CPUTQY» physics/dynamics interface in AROME even if the difficulty to extract auto-conversion terms and the controversial reliance on pseudo-fluxes are persisting issues.

3.5) Proposals about physics/dynamics interfacing

An evolution of the «Catry et al.» physics/dynamics is proposed for a generalisation to the physics used in ARPEGE, ALARO and AROME. The main idea is to replace the 6 pseudo-fluxes by the tendencies of the hydrometeors computed in the microphysics. The present use of the 6 pseudo-fluxes indeed represents a compromise in order to get identical terms in the physics/dynamics interface and in the diagnostics, but at the price of a little justified projection on pseudo-fluxes and for a rather limited benefit at the level of diagnostics. The use of 6 terms is at the same time redundant for the physics/dynamics interface (4 would be sufficient, hence the non-unicity of the projection) and insufficient in order to precisely describe at the level of diagnostics the physical processes simulated in a sophisticated microphysics package. In fact it is not so appropriate to have the same number of terms in the physics/dynamics interface and in the diagnostics, owing to opposite constraints, namely to get a general and simple physics/dynamics interface and detailed physical diagnostics.

The proposals concerning the physics/dynamics interface are as follows:

1. **Evolution of the «Catry et al.» physics/dynamics interface for a generalisation to the physics used in ARPEGE, ALARO and AROME.** Use of the tendencies for hydrometeors computed in the microphysics in replacement of the pseudo-fluxes used in the current «CPTEND_NEW / CPUTQY» physics/dynamics interface. This solution is mathematically consistent with the equations of Catry et al. (2007). It avoids the arbitrary projection of the microphysical terms onto the pseudo-fluxes. It could be used by the AROME, ALARO and ARPEGE physics and would correct the current deficiencies of the AROME physics/dynamics interfacing. The introduction of new hydrometeors would be eased since the issue of defining new pseudo-fluxes would disappear. This proposal should be studied with the minimum constraint of adding graupel and hail and of considering non-zero fall speeds for all hydrometeors. A document precising the degree of feasibility of this proposal is currently being prepared [*NDLR at time of translation: unfortunately the said document will not yet be available on 24-25/9/08*].

2. **Writing of a unique general routine «CPUTQY» for ARPEGE, ALARO and AROME**, this furthermore allowing to avoid multiple calls from the routine «MF_PHYS» depending on the options chosen for the advection of prognostic variables.