Possibility of testing «3MT» in AROME, ALADIN-MF, ARPEGE

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The «possibility» studied in this document is mainly that of combining the most specific characteristics of «3MT» with the science and/or the algorithmic used in the operational (or quasi-operational) applications ARPEGE/ALADIN-MF and AROME.

1) What is «3MT»?

The «3MT» acronym (Modular Multiscale Microphysics and Transport) stands for an ensemble of elements (parameterisations, algorithmic) developed by the ALARO team and aiming at the representation of sub-grid convection for a wide range of horizontal resolutions, including those scales where deep convection progressively becomes resolved by the model's dynamics (so-called «grey zone»).

The «3MT» ensemble consists in several elements, the most prominent of which are:

- **a prognostic updraft scheme** providing condensation and transport terms linked to sub-grid convection on the basis of the findings of J.-M. Piriou and of L. Gerard (important prognostic aspect, «M-T» equation system, non-vanishing fraction of the convective updraft within the mesh-box, …)

- **a joint handling of sub-grid «convective» and «turbulent-resolved» condensation sources by a unique microphysics scheme**

- **a geometric approach** for the representation of cloudy and precipitation-covered sub-grid mesh fractions, as well as their vertical overlap (sub-grid microphysics)

- **a water-budget-type cascade**, corresponding to a sequential call of 'moist parameterisations' (updating temperature and all water phase's specific contents after each physical process)

- **the computation of a convective cloud-cover** on the basis of simple physical principles born from the prognostic (or historic) potential of «3MT», as well as the use of this convective cloud-cover at the next time-step within the handling of the «turbulent-resolved» thermodynamic adjustment

- **A prognostic downdraft scheme** providing a transport contribution and one term corresponding to evaporation within the «draft», term which adds to the already computed microphysical-type evaporation.

Several aspects equivalent to those of «3MT» already exist in AROME since the condensation rates associated to turbulence and to shallow convection are indeed handled by a single microphysics scheme and since microphysical processes are treated in a sequential way. Besides, contrary to a common belief, there are precipitations created by sub-grid convection in AROME.

2) Potential and weaknesses of «3MT»

The «3MT» development represents a non-negligible amount of work from the ALARO team. The potential benefits of «3MT» are as follows:

- **«3MT» encompasses a prognostic parameterisation of sub-grid convection that might replace the «ACCVIMP» parameterisation operationally used in ARPEGE, ALADIN-MF. An important weakness in the development of «3MT» is however the non-accounting of parameterisations of shallow convection («KFB», «EDKF») as present in AROME, ALADIN-MF and ARPEGE; the compatibility of both types of developments is therefore not secured**. Today the joint use of the «KFB», «EDKF» and «3MT» parameterisations is a thrust undertaken only by CNRM, while it could have been a joint target with the ALARO team, target from which the extension of «3MT» towards shallow convection would have been considered together. The advanced counter-argument of a better consistency within a unique convection scheme is scientifically disputable, owing to the deeply differing characteristics ofPBL-type and deep precipitating convection occurrences.

- **«3MT» relies on a complex algorithmic, named here «APLMPHYS», for the sub-grid microphysics handling. This issue is nevertheless the cause of many interrogations at CNRM** because on the one hand the microphysical parameterisation schemes used in AROME, ALADIN-MF and ARPEGE cannot easily be made compatible with this algorithmic and on the other hand the generality- and benefit aspects of «APLMPHYS» are far from obvious, owing to its environment of development (simple microphysics) and to the associated hypothesis (thermodynamic characteristics of the cloudy and precipitation-covered areas forgotten from one time-step to the next, temperature of precipitating species assumed identical to that of the environment, …).

- **On the basis of the developments concretised within «3MT» one may hope to get a better representation of convection at the «grey zone» resolutions.** It is indeed likely that «3MT» works better from this point of view than the «ACCVIMP» convection scheme used in ARPEGE, ALADIN-MF. The potential of «3MT» at the horizontal resolutions corresponding to AROME shall be studied with care, since this is a priori not an obvious issue.

3) Interoperability at the level of physical processes

The ALARO partners are proposing the use of several algorithmic frameworks: «3MT» for convection, «APLMPHYS» for microphysics and «p-TKE» for turbulence. **The underlying idea would be to displace the interoperability problem of the physical parameterisation schemes to the level of the physical process and not to leave it any more at the level of an ensemble of physical processes**. The fact to impose a strong algorithmic constraint to physical parameterisation schemes represents a deep change with respect to the interfacing now realised in numerical models and would mean that the convection, turbulence and microphysics schemes used in Meso-NH, AROME and ARPEGE, as well as those imported from other models (IFS, LMD, HIRLAM, …) should be adapted and/or recoded in the proposed algorithmic in order to be used. **This is a strong constraint which rather amounts to a weakening of interoperability and which implies two important risks.** The first risk is to loose reproducibility between the original parameterisation scheme and its adapted and/or recoded version in the imposed algorithmic, since the order of calling the physical processes within a parameterisation scheme might be crucial for long time steps. The second risk is that some parameterisation schemes or scientific ideas may well be incompatible with the imposed algorithmic (use of cloudy so-called «moist-conservative variables», use of an integral formulation for auto-conversion, microphysical process depending on the origin of the condensation process (resolved vs. sub-grid), …).

4) <u>Possibilities of integration of «3MT» within AROME, ALADIN-MF or ARPEGE</u>

The topics to study in view of an integration of «3MT» within AROME, ALADIN-MF or ARPEGE are similar owing to the convergence of PBL parameterisation schemes (turbulence and shallow convection) between AROME and ARPEGE/ALADIN-MF. These topics are various since the developments realised in «3MT» are not directly compatible with the parameterisations for microphysics and for shallow convection used in AROME, ALADIN-MF and ARPEGE.

The problems potentially important for the use of «3MT» are as follows:

1. **The cloud treatment in «3MT».**

Will the clouds represented in the parameterisation schemes for turbulence «CBR» and for shallow convection «KFB» or «EDKF» be correctly accounted for in «3MT»? (microphysical adjustment, diagnostic of a convective cloud-cover, etc.).

2. **The use of mass-flux-type shallow convection schemes «KFB» or «EDKF» jointly with «3MT».**

The interaction of two mass-flux schemes should be studied with care. One should not be forced to give up the important improvements of the PBL simulation brought in by the schemes «CBR» and «KFB», «EDKF».

3. **The microphysics interfacing within «3MT».**

The sole currently proposed alternative is a recoding of the microphysics parameterisations used in ARPEGE/ALADIN-MF and in AROME in the framework of the «APLMPHYS» framework but without warranty about the reproducibility of results.

This task has been done by the ALARO team for the ARPEGE/ALADIN-MF microphysics and the first results show that reproducibility cannot be obtained (document of Y. Bouteloup).

The necessary development for recoding-adapting the AROME microphysics to «APLMPHYS» shall be more complex than in the case of the ARPEGE/ALADIN-MF microphysics, owing to the increased number of processes to be represented. The ALARO team does not dispute the fact that some evolution of the «APLMPHYS» algorithmic will be needed.

The interest of an integration of the AROME microphysics within «APLMPHYS» is disputable owing to the complexity of the associated work, to the choices made at the time of development of this algorithmic and to the fact that a sub-grid microphysics may not be a compulsory ingredient at the AROME scales (hypothesis already used in AROME). **Assuming**

homogeneity of the precipitation process within the mesh would allow using directly the microphysical parameterisationof AROME within «3MT».

The use of a sub-grid microphysics appears more interesting for ARPEGE/ALADIN-MF. This must however be verified and, in such a case, the use of the ARPEGE/ALADIN-MF microphysics recoded in «APLMPHYS» would probably be the best solution, provided one would understand and evaluate the impact of the associated algorithmic change.