Working Group for Dynamics & Coupling:

fulfillment of 2009 plan

March 10, 2010

NOTIFICATION: This document is a supplement of the LACE project "Toward an operational implementation of the NH dynamics" proposal (hereafter referred as NH project) and the "Research plan for the year 2009". The topic descriptions and objectives are not explained once again here. In case of need they can be referred directly from the original documents. The listed topics have been restricted to just those supposed to be tackled according the NH project during 2009 and to those for which a progress was achieved.

Preface

The subject of the main focus for the research in dynamics coordinated by the LACE was the NH dynamics during this year. This is fully in an agreement with the LACE project: Toward an operational implementation of the NH dynamics.

As already announced, mainly due to delayed delivery of HPC system at CHMI, the original schedule of this project had to be revisited with expected delay of about 10-12 months. Fortunately the areas not directly related to the new computer installation at CHMI were progressing quite well. The Work Package 1 (WP1: Validation of current NH dynamics) has been completed. Quite some progress was achieved within the Work Package 2 (WP2: Additional development and validation). Thanks to originally not planned interested of ZAMG, some progress was also registered for the WP3: Comparison of the NH and hydrostatic dynamics (at targeted resolution 4-5km).

The other subjects not covered by the LACE NH project are mainly related to the following three issues, all of them of the constant interest for the RC LACE: code optimization, better lateral boundary condition (LBC) coupling and 3D turbulence scheme. The former two can directly influence operational forecast in terms of cost and quality. The latter one is the necessary precondition for safe transition toward a kilo-metric scale modelling.

The LACE manpower available for dynamics and coupling is very limited. This year only four people from LACE (not counting the validation effort at ZAMG) were dealing with the dynamics. None of them was devoting to the subject more than half a year of his/her time. The LBC coupling is suffering even more in this respect. In a way to demonstrate the constant interest to this important subject the specific coupling action attended by experts from IRM (Belgium) and Meteo-France was organized and supported by LACE at CHMI.

1 LACE project "Toward an operational implementation of the NH dynamics"

Summary of means

Task	Planned deliverable	Status	Planned means	Executed or expected means
WP 1	first half of 2009	FINISHED	1 month	1 month
WP 2	continuous	in progress	9.5 months	5 months
WP 3	late 2009, early 2010	in progress	-	0.5 month

WP1 Validation of the current NH dynamics

Thanks to the international cooperation, the validation of the current NH dynamics took part in various places. **Academic tests** benchmarking the scientific content of the dynamics were independently performed at SHMI, Meteo-France and also ECMWF. All seem to prove that the NH dynamics is capable to deliver correct result with respect to expected solution.

During the **validation** of the CY36 a bug has been detected related to the `LGWADV`=.T. option, defining the preferable NH configuration with prognostic vertical velocity in grid-point space replacing the d_4 variable used in the spectral part of the model. The fix is applied at the level of CY36 for the common code. The back-phased bugfix was distributed for CY35T1 and CY35T2 from Prague.

In order to identify problems of the full 3D model implementation and also to learn about the additional value of the NH dynamics (at the actual horizontal resolution of 9km) the **parallel test** was launched for the ALADIN/CE operational application at CHMI. The results comparing the NH and hydrostatic dynamics performance confirm following:

- NH dynamics is fully comparable to the hydrostatic one in terms of the quality. The slightly worse signal produced by the NH dynamics is related to the more complicated algorithmic leading to slightly higher numerical noise. Still the NH outperforms hydrostatic dynamics for the wind field in terms of bias (but not stde) during the dynamically less active period of day (between 00 and 12 hours of local time) bellow 500 hPa.
- More significant improvement can be obtained by the more sophisticated vertical discretization technique (`NDLNPR`=0 → `NDLNPR`=1 → VFE). The increased sophistication has to be however provided by sufficient vertical resolution.
- Further improvement can be obtained by the ICI (Iterative Centered Implicit scheme, sometimes also called Predictor-Corrector scheme). The improvement related to this method is general and it is grooving with the forecast range. The only disadvantage of the ICI scheme is its characteristics to amplify the systematic biases from physics (mainly surface scheme) through the repeating usage of diabatic tendencies at every time-step.
- In terms of scores there's no difference between the `LGWADV`=.T. option (i.e. solution chosen at ECMWF) and `LGWADV`=.F. option (i.e. Meteo-France or Arome solution).
- The possible improvements coming from the dynamics are as follows:
  - `NDLNPRT`=1 delivers better results with respect to `NDLNPRT`=0 (at no extra cost), provided the vertical resolution is sufficient;
  - NH versus hydrostatic dynamics are more or less identical for 9km of horizontal resolution (NH increases the cost by 8%, for NEC and OpenMP parallelization);

- VFE is capable further increase accuracy (at 15 % of extra cost). It doesn't exist for the NH model so far;
- ICI has potential to further improve the model (for like 33 % of extra cost for every additional iteration).

Those four are cumulative (if they are available).

Conclusion (for Δx= 9 km): *The NH dynamics is capable for the operational use. The extension from hydrostatic to NH dynamics is smooth, there is no danger to see any jump in scores once the NH is activated. However with 9 km of horizontal resolution there's no gain from the activation of the NH dynamics. It just increases the computational cost of the model. For the equivalent cost increase, more significant impact can be obtained with increased vertical resolution and/or better vertical discretization technique.*

WP2 Additional development and validation

2.2 Vertical finite element discretization for NH dynamics

After long stagnation of this subject, the work has promisingly re-started. During his stay at ZAMG JV has developed a set of general routines defining the VFE bases with respect to actual number of degrees of freedom (number of levels, order of bases and number of available boundary conditions). Using those bases (with not necessarily same parameters for every model variable) the VFE scheme similar to the current `LGWADV`=.T. code is supposed to be designed. The current development is compliant with CY35T1.
Means: 2 months of LACE stay
People involved: JV
Reference: J. Vivoda - VFE integral operator, Dec 2009, memo.

2.3 Consistent coupling of physics to fully elastic dynamics

The work is done since long. The results are ambiguous. It has been proved experimentally that the present equations are not capable to offer correct solution. The theoretical foundation to this is however still missing.
Means: 1.5 month
People involved: RB
Reference: R. Brožková - Prediction of Heat on Temperature and Pressure in Fully Compressible Case, Jan 2010.

2.7 Dealing with the problems detected during parallel test with hydrostatic dynamics - better pressure gradient term

One of the possibility to cure the observed noisy pattern in derivatives above orographic features is seen through an improved computation of the pressure gradient term. This is also a goal for the expected higher significance of slopes at kilo-metric of hexa-metric scales in the future. Although there are various methods in the literature, their à priori evaluation is not trivial. Any such method is usually closely related to the whole model discretization. The impact is then far from being straightforward. Mostly it has to be evaluated empirically. Moreover for the spectral model, any pressure gradient term can be composed only from fields having spectral derivatives. This introduces another restriction in the Aladin.

During his stay at CHMI JM has been analyzing the main contributors to the pressure gradient term error. He has been then designing the tool (based on 2D model) evaluating those errors for general computation of this term. Next step then will be to investigate various techniques known from the literature for their ability to eventually reduce this error. As the error was found to be related to the model orography, it will be also desirable in the future to check and optimize the way how the model orography is generated with this respect.
Means: 2 months (1 month on LACE stay)
People involved: JM, FV
Reference: J. Mašek - Discretization of horizontal pressure gradient force, Nov. 2009.

WP3 Comparison of the NH and hydrostatic dynamics

Various parallel tests were launched with the ALADIN/CE model (the operational application of Alaro at CHMI). Among the outcome specified above, it also has defined the methodology for the future test in 4.5 km with 87 model levels.

In parallel to this activity, ZAMG was running since summer 2009 two application of Alaro at 4.9 km with 60 vertical levels. The one of them used hydrostatic SI scheme, the other one was running NH ICI dynamics with `LGWADV`=.T.. This means the difference was caused by: i/ different vertical discretization, ii/ SI versus ICI scheme and the iii/ dynamics (NH versus hydrostatic) itself. The results were showing following tendency:

- precipitation from NH tends to be very slightly better in case of mountainous areas, especially for intensive precipitation events;
- NH version tends to produce more peaked (or small) features than the hydrostatic version for the precipitation structures;
- nearly no difference for the surface parameters.

Means: 2 months
People involved: FV (CHMI), CW (ZAMG)

2 Subjects of dynamics & LBC coupling not covered by the NH project

Summary of means

Research subject	Planned means	Executed means
3D turbulence	2 months	1 month
Boyd's extension	3 months	2 months
New interpolation for sL advection	-	1 month
TL/AD of rotated Mercator projection	-	0.25 month
Code optimization (SL, OpenMP,..)	-	1 month

Design for 3D turbulence scheme

The original plan was to deliver guidelines for the implementation of a true 3D turbulence scheme being a counterpart of the existing vertical scheme (from the physical package). After solving the last rather technical issue related to the SL data-flow (to appear in CY36T1), the model dynamics (including its data-flow) seems to be ready for an inclusion of a 3D turbulence. (By coincidence the necessary code changes in the dynamics were found also profitable for the DDH diagnostic tool when evaluating dynamics tendencies.) The remaining issues to complete the 3D turbulence scheme are then mainly of a scientific nature: i/ To derive horizontal terms compliant with the vertical diffusion and ii/ to reduce the full 3D theory in such a way to obtain acceptable results of 3D scheme in the typical NWP models where vertical resolution is about 100 times finer with respect to the horizontal one. After some literature survey it seems to be evident that the former point should be relatively easy to achieve with the QNSE theory being adapted to the Alaro TOUCANS (vertical) turbulence scheme. The second issue should be designed with respect to maximum compliance to the SLHD data-flow. Like that it is expected to deliver accurate and numerically robust results for relatively low computational cost. Only in a case this requirement is found too restrictive some extra method to reduce the resolution discrepancy will have to be adapted.
Means: 1 month
People involved: FV

Boyd's extension

The key issue to achieve any improvement of the LBC coupling is an ultimate improvement of model fields near the lateral boundaries. This is directly linked to a used technique for making the model fields periodic. One of such techniques proving in 1D tests to be superior with respect to the present spline extension implemented to the model is the one following the idea of Boyd (M.W.R., 2005). Even recognizing the importance of any LBC coupling progress, this area is systematically understaffed among (not only) LACE experts. To somehow contribute to this area, the LBC working month was organized in Prague during July 2009. Its aim was to allow Aladin coupling experts P. Termonia from Belgium and F. Voitus from France to sit together and hopefully progress in this area. The action was locally helped by FV and remotely supervised by R. ElKhatib (France). The new code has been designed allowing to run Aladin with this new periodicity technique. First results proved feasibility of this method. The research code should be however still phased into the common source to remain available for a consequent development.

Means: 2 months

People involved: PT (Be), FVo (Fr), FV

Reference: P. Termonia and F. Voitus : Periodic Fields by Boyd's Window in ALADIN, TECHNICAL REPORT, August 2009.

New interpolators for sL advection

Since CY35T1 (except for some parts of TL/AD code being available only since CY35T2) the model contains new code for the SL interpolation allowing more freedom in the advection and diffusion design. The work had been completed from the development (technical) point of view. The default option preserves the previous situation. It is however desirable to further explore the new possibilities of this model scheme in order to operationally profit from this feature.

As the first step toward the new available area the ALADIN/CE (operational model at CHMI) has been upgraded to the new SL(HD) scheme diffusing model fields through 2^{nd} order accurate interpolator (`LSLHD_OLD`=.false.). The next step was then a reduction of the diffusivity of the basic (i.e. not subjected by diffusion) SL interpolator. This was only partly successful as the reduced diffusivity of the SL interpolator had to be returned via increased horizontal and vertical diffusion. Still the results shows some increase of sharpness in small scale features resembling a higher resolution results.

Means: 1 month

People involved: FV

Reference: ALADIN/CE parallel suite results, suite "aim" and "ain".

TL/AD of rotated Mercator projection

In collaboration of the Meteo-France people the TL/AD version of the rotated tilted Mercator projection option was coded for the SL advection (displacement matrix) scheme. The relevant code is available since CY36 in the common source.

Means: 1 week

People involved: FV

Code implications: Available since CY36.

Code optimizations

Shared memory parallelization OpenMP is an attractive alternative and also extension to the fully processor-memory distributed MPI parallelization. This is then specially true for the new scalar computers with the multi-core processors sharing the same memory registers. The attractiveness of the OpenMP parallelization lies also in its ability to improve job balancing, especially when a computer is shared between several running jobs. The OpenMP parallelization is regularly maintained only for the IFS model at ECMWF. It works for the LAM geometry as well since CY29 but there were still places for further improvement (I/O of FA files, transformations,...). During this year two modsets were phased to the common source (for CY36 and CY36T1) with more OpenMP features specially optimizing the LAM code. The most important component was also fixation of long term bug preventing up to now the mixed MPI-OpenMP parallelization with LAM geometry. Specific effort has been also payed to the spectral dynamics, where the computation is very regular thus easy to be balanced. Thank to this, it can be just divided into N equal parts, with N being the amount of available threads for the parallel computation. This consequences to reduction of a fork/join scheduling cost and in the elimination of undesired dependency of OpenMP to a size of the problem.

For CY36 the vectorization of the Alaro code has been further improved, mainly by introduction of specific compiler directives.

Finally, the interpolation during the SL advection being the bottle-neck of the dynamics (if not of the whole model) evaluation is constantly monitored and improved with respect to the most frequently used platforms. This very delicate work is limited by rather specific and sometimes contradicting requirements from scalar and vector computer architectures. No surprise then that every official model release since CY35 contains slightly different version of the interpolation routines. Since CY36T1 the code of this routine has been separated to the one better suite scalar platforms (short loops, multiple hits to the same memory is beneficial) and the other one for vector platforms (one huge loop, maximum effort to reduce memory conflicts). The vector version (similar to the one before CY35) was further optimized for NEC by use of specific directives. (Those were reducing the cost of the whole model by 2%!)
Means: 1 month
People involved: FV
Code implications: Part available since CY36 the rest from CY36T1.
Reference: The CY36 and CY36T1 documentations.