Working Group for Dynamics & Coupling:

summary of 2010 work

September 14, 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). 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 2010 and to those for which a progress was achieved.

Preface

The primary issue of the first half of 2010 was the transition of operational application (Alaro) into the targeted resolution between 4-5km of vertical mesh with sufficient increase of vertical resolution. This important step is seen to be the necessary pre-requisite to start an evaluation of NH dynamics. Soon after the successful transition of operational application to the new computer environment at CHMI (which is planned to be the main validation place for the NH project) the parallel test with nearly duplicated resolution (from 9km and 43 model levels to 4.7km and 87 model levels) has been launched. After some initial perturbation the present version of the test (initiated at 23/08/2010 and further slightly modified at 7/9/2010) seems to outperform the reference operational version in nearly every extent. This important result, among justification of an operational switch to higher resolution at CHMI, gives a reliable reference to start the evaluation of the NH dynamics for the targeted resolution of the NH project. The similar tests to what has been done for 9km should start soon.

Among the ongoing evaluation of the NH dynamics for operational use at 4-5km there are indeed some research activities. As most of the available staff for dynamics is presently located at CHMI, those people were primarily devoted to the migration to new computing system during the first half of 2010. Since September there are at least 3 people at CHMI available to dynamics, so a substantial progress in dynamics research is anticipated before the end of the year.

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

Summary of means

Task	Planned deliverable	Status	Executed means	Expected means
WP 1	first half of 2009	FINISHED		
WP 2	continuous	in progress	3.5 months	3 months
WP 3	late 2010	nothing so far for this year	-	1.5 months
WP 4	late 2010	apparently no need	-	-
WP 5	early 2011	nothing so far	-	-

WP2 Additional development and validation

2.1 Time step organization - improved coupling of physics to dynamics
PS has just started to deal with this subject. As she is fully devoted to this subject only, there is a hope to have some first outcome of this work for the late 2010 or early 2011.
Means: 1 month (expected)
People involved: PS

2.2 Vertical finite element discretization for NH dynamics
After long stagnation of this subject, the work has re-started. JV has spent 2 month stay at ZAMG by porting his development to CY36T1. The work seems to continue without reaching the final target to deliver stable VFE discretization for the operational use with NH dynamics.
Means: 2 months (stay on LACE support)
People involved: JV

2.3 Consistent coupling of physics to fully elastic dynamics
After the theoretical work done early in 2010 the work is stagnating. Hopefully there will be some re-start of this important subject before the end of 2010.
Means: 0.5 month + (0.5 month anticipated)
People involved: RB, (JM)

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 might be an improved computation of the pressure gradient term - a term of increasing importance for high resolution modelling. Although there are various methods available in literature, their a-prior evaluation is not trivial. Any such method is usually closely related to the whole model discretization. The impact is then far from being straightforward and has to be evaluated empirically. Additionally 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 last year JM coded a tool in the 2D academic environment to evaluate the error from various formulation of the pressure gradient term. There is a good hope to continue soon with this work, to be able to deliver before the end of 2010 some practical outcome.
  Means: 2 months expected
  People involved: JM
- **"Granularity pattern" in the precipitation field**
  When moving to higher resolution (from 9km with 43 levels to 4.7km with 87 levels) the already observed phenomena of strange regular granularity in the precipitation field proportional to horizontal resolution (hereafter denoted as granularity problem) has become more frequent. This phenomena has been found to be linked to a specific kind of weather (usually when the local weather dominates over the large scale one), typically in the regions with weak deep convection activity. Its regular quasi organized character tends to call dynamics to be a primary victim for it. Hence the following series of experiments aiming to explain this phenomena has been performed:
  - **orography filtering** (FV, JM - 2 weeks)
    Special tool (off the model) to smooth the model orography by a general two parametric diffusive filter has been designed. With this tool several sets of model climate files were generated (using both linear or quadratic truncation) to test a model sensitivity to the level of orography smoothing. The results however indicate that even very dramatic reduction of short waves in the model orography has nearly no impact to the studied "granularity" phenomena of precipitation field.
    ⇒ *The filter giving much more freedom for designing the model orography can be later on phased into e923 to be available to everyone.*
  - **alternative approaches of moisture convergence computation** (FV - 2 weeks)
    The convection scheme of Alaro physics (similar to the design of Arpege physics) uses the moisture convergence as a closure. There are various ways to compute the moisture convergence (which is basically the advection term of the water vapor) in the model. The standard

way for it is through the Eulerian formulation using spectral derivatives of moisture multiplied by the components of wind field. This is also the reason why the specific humidity is treated as a spectral field.

One of the frequent claims against the spectral technique concerns its inability to treat properly highly irregular fields like for example moist prognostic quantities. The spectral representation of any such field especially in high resolution model with very detailed orography description should be then affected by Gibbs effect. Like that the derivatives of such field are spoiled by the inability of spectral techniques to fit model fields by adequately smooth way. The Eulerian treatment of the advective term (especially in linearly truncated model) can further lead to an aliasing effect, again spoiling the short scale information in the model. To diagnose whether those two phenomenas can be responsible for the mentioned "granularity" problem, two alternative ways of the moisture computation were explored:

First: to check mainly the aliasing problem, the option NCOMP_CVGQ=2 was activated computing the moisture convergence by 3D Lagrangian way. The quantity used for the moisture convergence computation can be further subject of additional smoothing by SLHD. With both techniques the moisture convergence field triggering the convection can be made very smooth. Although the results of this option shows different precipitation pattern compared to the reference (which is not surprising given the way of moisture computation is very different), the granular character of precipitation seems to be still present also with this option.

Second way to deal mainly with the effects of spectral representation was to compute the moisture convergence in grid-point space. For this the new option NCOMP_CVGQ=3 were designed (as experimental model branch only) computing the horizontal part of moist convergence by 4th order accurate formula using pseudo-staggering. As this formulation requires 5 times 5 points stencil, it is generally also very well dealing with local field oscillations (for the price of either increased communication of the model or extra memory requirements when multiplicating the model fields). Indeed the use of this option NCOMP_CVGQ=3 allows to represent moisture as grid-point quantity only. Similarly to option NCOMP_CVGQ=2 also this way of computation of moisture convergence shows great dependency to a model resolution. Both alternative ways of NCOMP_CVGQ=2 and 3 also tend to increase convective activity when going to higher resolution. This seems to be the consequence of their diffusivity which is reversibly proportional to model resolution. This effect by the way is not seen with the reference spectral way of moist convergence computation. There the convective areas are very consistent between different model resolution runs. While the NCOMP_CVGQ=2 is always offering different results from the reference, the NCOMP_CVGQ=3 option nicely converge at 4.7 km of horizontal mesh to the results of the reference (NCOMP_CVGQ=0). This indicates that the granularity phenomena is unaffected when the spectral convective closure is replaced by grid-point one. So the spectral technique is apparently not responsible for it.

⇒ *Based on the previous it can be concluded that the spectral technique and aliasing is not the primary source of the investigated problem. Another side effect of this study is the proof of the spectral technique superiority over the Lagrangian and 4th order GP methods of computation moisture convergence for resolution up to 4.7 km of horizontal mesh, i.e. the resolution typically used for operational Alaro applications. The existence of the options NCOMP_CVGQ=2 and NCOMP_CVGQ=3 code gives also a freedom to verify the adequacy to use the spectral technique in the future with eventually increased horizontal resolution.*

– **coupling of physics to dynamics** (FV - 2 weeks)

By increasing the model resolution there is a chance to better describe local diabatic effects. This among ability to bring more realistic behavior to the model has a great potential to destabilize the model through the highly non-linear character of model physics adequate to the scales represented by a model. The usual compromise to treat physical processes along vertical column independently to neighboring points consequences by sometimes very inhomogeneous tendencies for the prognostic variables.

While it is for long known that the (tri)linear interpolation of adiabatic tendencies to the origin point of SL trajectory is the most stable option for dynamics, diabatic tendencies are exclusively treated by the high order interpolator. To see the potential impact of homogenization of diabatic tendencies, two new options of the model were implemented. The first one

activated globally through the key NSPLTHOI=1 (split high order interpolation) allows to apply diffusive interpolator of 2nd order accuracy supported eventually by Laplacian smoother to diabatic tendencies along horizontal. (The vertical interpolation is unchanged in this case.) The second option acting locally through appropriate N[x]LAG=4 parameter for GMV fields and through the LPHYLIN=.T. attribute of GFL quantities then treat physical tendencies by 3D linear interpolation, similar to the best known treatment of adiabatic tendencies.
The effect of especially the latter one was found very profitable to the model results, mainly through avoiding local excessive maxims in precipitation fields. It however in general was again not answering the explanation of the granularity problem.
⇒ *It is highly recommended to use the N[x]LAG=4 and LPHYLIN=.T. options (if the slightly increased cost for LPHYLIN=.T. is not an crucial issue) in the model. There will be certainly more sensitive studies performed with both: N[x]LAG=4, LPHYLIN=.T. and NSPLITHOI=1 options to better understand the potential they can bring to the model. It however doesn't once again explain where the granularity problem comes from. Note that this issue has been also coded to allow a clean inclusion of 3D turbulence to the model. Like that this code is of double importance and should appear in the common source at the level of CY37T1.*

- **effect of physical parametrization** (FV, IBD, RB)
  After all previous studies targeted to dynamics, it seems the highest sensitivity for the mentioned problem comes from the physical parametrization. It has been found the convection scheme (3MT) has some potential to influence the granularity (in both directions). Also by activating the new TOUCANS turbulence scheme of Alaro the granularity problem can be greatly suppressed for most of the cases. Further investigation detected the description of shallow convection as the most sensitive component of TOUCANS to this issue. The new shallow convection acting through the moist θ_{s1} doesn't need the (moist) anti-fibrillation stabilization. The possibility to switch off this numerical technique seems to have the most positive impact out of all explored ways.
  ⇒ *This demonstrates very tight relation between physics and dynamics. A problem looking like a problem of dynamics (or physics-dynamic interface) appeared to be mainly originating in physical parametrization. This also demonstrates that especially in higher resolution modelling the problematics of physic and dynamics becomes increasingly related. Like that to split the model into separated physics and dynamical core realms is no longer possible.*

Means: 1.5 months
People involved: FV, JM, RB, IBD

WP3 Comparison of the NH and hydrostatic dynamics

The reference hydrostatic Alaro application running with 4.7 km and 87 model levels seems to reach satisfactory state (by offering better results with respect to 9 km and 43 level operational). The intensive evaluation of NH dynamics against this reference is scheduled to early October 2010.

In parallel to this activity, ZAMG is running since summer 2009 the NH application of Alaro at 4.9 km with 60 vertical levels. The results are continuously evaluated.
Means: expected 1.5 months
People involved: FV (with help of CHMI team) and CW (ZAMG)

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

Summary of means

Task	Executed means	Expected means
3D turbulence	1.25 months	0.5 month ?
Optimal model setup of NPROMA	-	0.5 month ?

3D turbulence scheme

Since summer 2010 the TOUCANS/QNSE vertical diffusion scheme can be consistently extended by horizontal components to 1D+2D turbulence scheme (rather than 3D turbulence scheme which resembles a scheme designed for isotropic resolutions like LES). The new code based to CY36T1 contains for all GMV model variables Ψ new term $-K_{m/h,H}\nabla^2\Psi$ where the momentum or scalar exchange coefficient are obtained from the QNSE horizontal fits with horizontal mixing lengths. The horizontal extension of GFL variables can be activated on demand by activating appropriate attribute LHORTURB=.T.. Thanks to use of the existing SL(HD) data-flow, the extra cost related to this extension is only 1.8% of extra CPU. On the other hand in terms of memory the activation of the horizontal extension of vertical turbulence scheme requires additional 14.8% (at least for NEC SX9). So it is rather memory demanding extension than the question of the model cost.

The changes done in the code were:

- Horizontal QNSE fits consistent to the vertical diffusion (Ri, L,...) computed inside the physical parametrization code.
- Extension of SL buffers by exchange coefficients $K_{m,H}$ and $K_{h,H}$ being passed from the grid-point space to the SL space.
- Extension of SL weights by those affected by $K_{m/h,H}$ coefficients in addition to existing sets.
- Introducing the GFL attribute LHORTURB to activate 2D extension to appropriate model variables.
- Splitting the interpolation of physics from the field itself to be able to apply horizontal turbulence correctly. This again is made fully controllable via model namelist (GFL attribute LPHYLIN and GMV namelist parameter N[x]LAG).
- In case of NH dynamics (so far only LGWADV=.F.) the shear production term of prognostic TKE equation is enriched by all so far neglected components to become fully 3D.

The new code seems to be stable. However with the tests done so far with the 4.7 km resolution it is difficult to consider it as fully validated. More tests are thus planned with domain at 1 km resolution and for academic tests targeted to 3D turbulence such as GABLS. Moreover the work has to be phased with the ongoing research of TOUCANS turbulence scheme which needs to be consolidated prior to any full 3D experimentation. The new code will enter the common cycle at the level of CY37T1.
Means: 1.25 month, possibly still 0.5 month before the end of year
People involved: FV, IBD (for the physical part)

Optimal model setup of NPROMA

The present automatic setup for NPROMA parameter (the main model tunable to influence the platform dependent computing efficiency) is hard coded. So far this is bypassed by forcing the NPROMA to a given value. To compute an optimal value of this parameter for vector machines (with values of NPROMA exceeding 2000-3000) using openMP parallelization is strongly domain and number of parallel threads dependent. Thus it is desirable to let the model to compute the optimal value by itself.
Means: expected at maximum 0.5 month
People involved: FV