Working Area Dynamics & Coupling

Progress Report

Prepared by:	Area Leader Petra Smolíková
Period:	01/2015-09/2015
Date:	18/09/2015

Progress summary

We have achieved the big progress in several subjects. Among them ENO based cubic interpolations for SL scheme have been implemented in the code of the model and tested in 2D framework. Further 1D2D turbulence scheme has been proven to be working well in the cycle CY38t1_op3 and it has been tested in 2D model and on a real case. We continue the work on finite element method in vertical discretization of NH version of the model ALADIN. Big progress has been achieved on monitoring rapid changes in surface pressure field in the coupling files provided to the LAM application; a paper has been prepared and accepted on this topic.

Three stays have been realized during 2015, Alexandra Craciun (Ro) has been working with us at CHMI in Prague on the design of ENO technique for SL interpolations and Jozef Vivoda (Slo) has been continuing his work in Prague on finite element method used in the vertical discretization of the NH model. Ivan Bašták-Ďurán (Cz) spent one month in Ljubljana working on 1D2D turbulence scheme. One more stay of David Lancz (Hu) is planned for the end of the year.

Scientific and technical main activities and achievements, major events

Let us mention the biggest achievements in the planned topics and illustrate them by several figures.

Task 1. VFE NH

Subject: 1.1 Design of vertical finite elements scheme for NH version of the model

Description and objectives: The main objective of this task is to have a stable and robust vertical finite elements (VFE) discretization to be used in high resolution real simulations with orography with the expected benefit being the enhanced accuracy for the same vertical resolution when comparing with vertical finite differences (VFD) method. We want to stick as much as possible to the existing choices in the design of dynamical kernel (SI time scheme, mass based vertical coordinate) and to stay close to the design of VFE in hydrostatic model version (according to Untch and Hortal).

Contributors: Jozef Vivoda (Sk), Petra Smolíková (Cz)

Executed efforts: 4 months in total; 2.75 months of local work, 1.25 month – RC LACE stay

Documentation: contribution to the ALADIN-HIRLAM Newsletter No.5, August 2015: Petra Smolíková, Jozef Vivoda and Juan Simarro, *Testing accuracy of finite element scheme used in vertical discretization of ALADIN-NH.*

Status: We have been thoroughly testing the existing implementation in the cycle CY40T1 in very high resolution (1.25km) over the Alpine region for two month series (January 2014 and July 2014), integration once per day from +00UTC for 24 hours. The important conclusion from these tests is that the stability of FE scheme is comparable with the stability of FD scheme. We could use 50s time step for our experiments without any apparent signs of numerical instability. This is in contradiction to the results obtained in 1.3km version of AROME in Météo France (Karim Yessad, personal communication) where the stability of FE scheme is much worse than the stability of FD scheme. Our tests with vertical levels distribution of AROME (90levels) have confirmed these results. The change of vertical level distribution from AROME 90 levels to Czech operational application 87 levels enables to restore the stability of FE scheme. We prepared a mixed vertical levels distribution with 90 AROME levels plus 4 top levels of Czech operational application distribution. This configuration again enables stable runs. We may conclude that FE scheme used in the vertical discretization of the NH model is even more sensitive to the vertical levels distribution, particularly in the upper atmosphere.

As the most important task for the year 2015 we considered the need to explain in details why the currently implemented version of VFE in NH model (cy40t1) works and to explain clearly the choices made during its design. From this detailed analysis we were brought to improvements of the code which may lead to better stability of the scheme. We have concentrated on boundary conditions of defined vertical operators. There were several possible choices in the definition of boundary conditions of a finite element vertical operator. At input we may use two different methods:

1) Explicit definition: the data vector is enlarged by (possibly several) boundary conditions which are built directly into the projection matrix from the grid point space to the finite element space. Hence stiff and mass matrices are ovedimensioned with respect to the number of vertical levels.

2) Implicit definition: a special set of basis function is chosen satisfying the given set of boundary conditions. These conditions have to be constant in horizontal direction and in time, we use only two kinds of them: all basis functions are 0 on the given boundary or the derivative of all basis functions is 0 on the given boundary.

It was found that these two methods are not equivalent. Hence the full set of operators with implicit treatment of BC was implemented under the key LVFE_DER_IMPL_BC (for derivative) and LVFE_INT_IMPL_BC (for integral). At output of the operator application, the boundary conditions have to be applied implicitly by a proper choice of the set of basis functions.

On each place in the discretized model equations where the vertical derivative or integral is used one has to choose an operator with physically justifiable set of boundary conditions.

Hence there is an enormous number of degrees of freedom in the design of the whole method. The boundary condition has been properly set on several places compared to the previous version.

On the other hand, according to Occam's law, the simplest theory should be chosen among the available ones. Hence we wanted to simplify the choices of operators as much as possible while not omitting any important detail.

We have ensured the compatibility of the new code version with the previous one described in the ALADIN/HIRLAM Newsletter (2013) by introducing the key LVFE_COMPATIBLE.

The stability analysis was incorporated in the code under the key LVFE_ANALYSIS. The key LVFE_INTB has been replaced with NINTB=1 or 0.

Several new operators have been defined under the names RDERBH01, RDERBF10, RDDERBF11 and their application on proper places of the equation set has been tested. The code has been cleaned from obsolete options and its consistency was carefully checked.

After all the modifications will be finished, we plan to test the new code in terms of stability and accuracy and compare it with the previous version.

As an important task we see the need to prepare a paper for publication. A work has been done for this aim. We will continue in the last part of the year.

Task 2. SL scheme

Subject: 2.1 Application of ENO techniques to semi-Lagrangian interpolations

Description and objectives: High order semi-Lagrangian interpolations, in 1D typically represented by cubic Lagrange polynomial on 4-point stencil, are not monotonic and produce spurious overshoots in the vicinity of discontinuities or sharp gradients. Their quasi monotonic version exists, but simple cut off procedure reduces accuracy dramatically. However, if interpolation stencil was extended to 6-points, 3rd order ENO (Essentially Non-Oscillatory) interpolation could be applied. It is able to reduce spurious oscillations/ overshoots while keeping high order of accuracy uniformly. Aim of the work is to implement ENO interpolation technique in ALADIN and evaluate its performance/cost. A first study of the problem has been already done in 1D – linear advection toy model, and for quadratic interpolators in full model code and 2D vertical plane model. Quadratic interpolators have been found too smoothing, but 1D experiments show promising results for cubic interpolator, or WENO technique in which two quadratic interpolators are combined depending on the advected field. We continue in the already started work.

Contributors: Alexandra Craciun (Ro), Petra Smolíková (Cz)

Executed efforts: 3 months in total; 2 months of local work, 1 month - LACE stay

Documentation: progress report published on the LACE web page

Status: The short description of the proposed third order (cubic) ENO technique for interpolations may be this: For cubic interpolation one needs 4 values of the interpolated field in the neighborhood of the point to which one interpolates. Having 6 values of the interpolated function f in $x_1<x_2<x_3<x_4<x_5<x_6$ and looking for the interpolated value in x_0, $x_3<x_0<x_4$, one may interpolate using 3 different sets of values, or three stencils: the left hand one with $f(x_1),f(x_2),f(x_3),f(x_4)$, the central one with $f(x_2),f(x_3),f(x_4),f(x_5)$, or the right hand one with $f(x_3),f(x_4),f(x_5),f(x_6)$. The ENO technique consists in calculation of all three interpolated values and in the choice of one of them according to the smoothness of the interpolated function f.

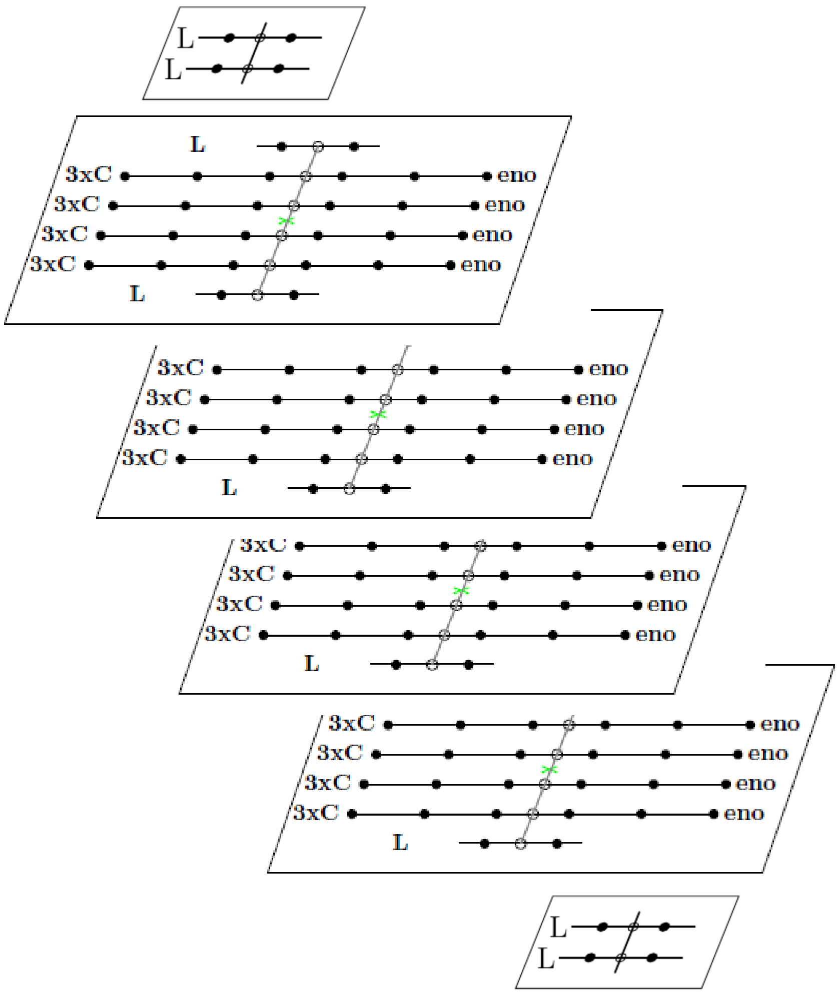


Figure 1: The stencil for the 3-dimensional cubic ENO interpolation, the number of grid-points used is 120.

The third order (cubic) ENO interpolation technique has been implemented in the code of the cycle CY40. For this purpose the interpolation grid has to be extended from 4 to 6 points in each direction. The data flow for this extension is in the cycle CY40 already prepared under the key NSTENCILWIDE=3 (the standard grid is under NSTENCILWIDE=2). The code modification consists in calculation of SL weights for three 4-points stencils in each of the

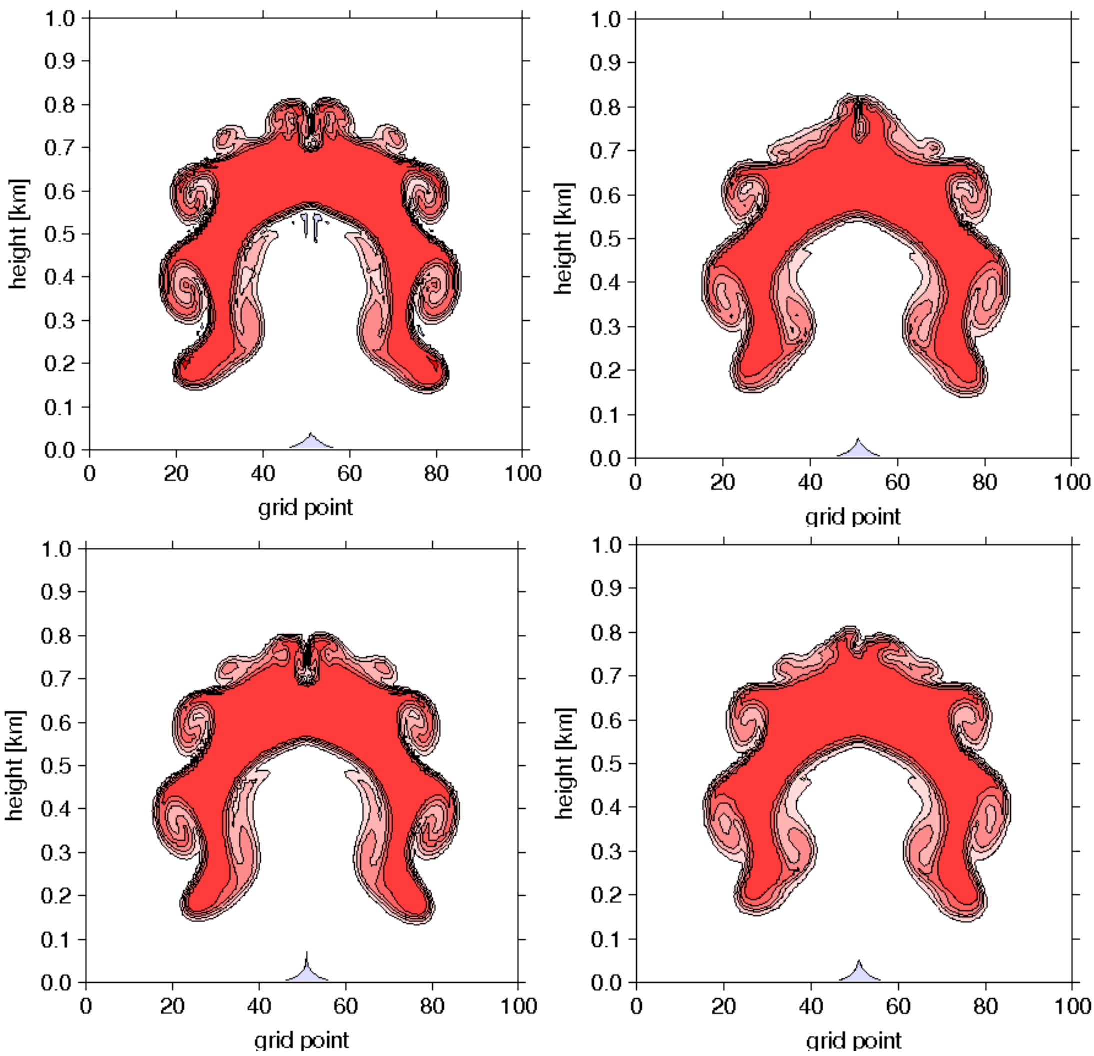


Figure 2: Warm bubble after 80 time steps. Left : Lagrange cubic interpolation; right: ENO cubic interpolation. Top: standard solution; bottom: quasi-monotonic adjustment.

horizontal direction and in the vertical, in calculation of interpolated values from these weights for each stencil and in each direction and in the choice of the best interpolated value among them according to the smoothness of the interpolated field. It also requires recalculation of pointers to SL buffers needed in interpolations.

The number of 1-dimensional cubic interpolations is increased from 7 in standard 32-points SL interpolation to 63 in one 3D ENO interpolation which involves 120 grid points. Hence there is an increase in the computer time needed as well. The real increase in adiabatic 2D

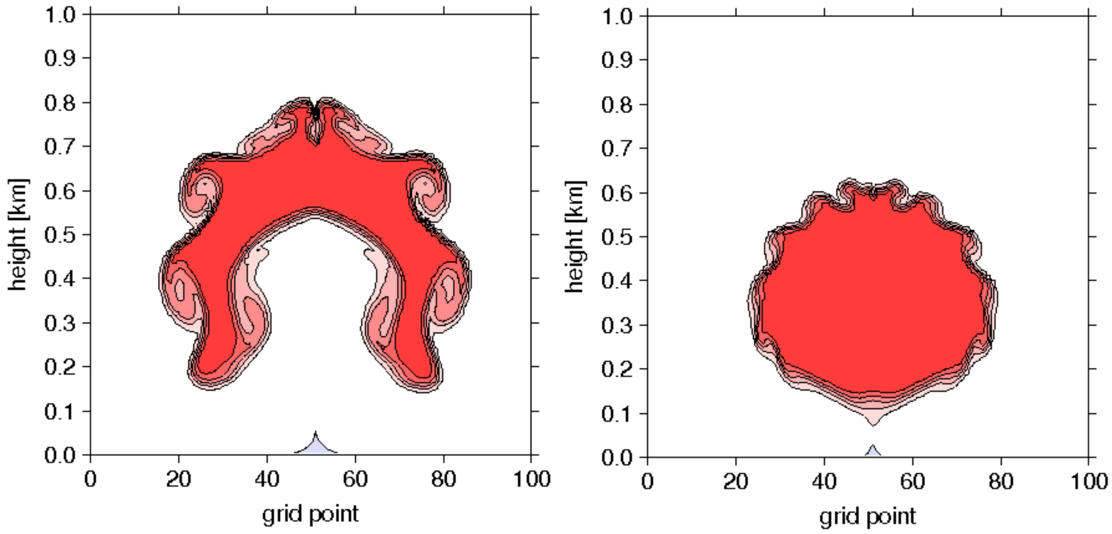


Figure 3: Left: Warm bubble after 80 time steps, the preferred stencil is the central one with the preference factor of 2, QM ENO interpolation. Right: Warm bubble after 40 time steps with cubic Lagrange interpolation to be compared with Figure 4.

experiment was about 100% (the experiment was two times slower than the reference one). What would be the increase in 3D experiment with full physics may be hardly estimated.

The new code modification has been tested in 2D model (1 horizontal and 1 vertical direction) on the evolution of warm bubble without and with advection. The result for the sharp warm bubble without advection may be seen on Figure 2.

We use cubic Lagrange interpolation as the reference and run both, the reference and ENO with and without the quasi-monotonic (QM) adjustment. One can see that the influence of QM adjustment on the bubble with ENO applied is much weaker than with cubic Lagrange interpolation (comparison top to bottom in Fig.2.) which shows that the overshooting is much less frequent and weaker with ENO than with reference interpolation. Unfortunately, cubic ENO is still too much smoothing. Since for quadratic interpolations, much better results have been obtained with WENO (Weighted ENO); see RC LACE Progress Report for the Working Area Dynamics&Coupling for 2014; we plan to implement WENO technique to the existing ENO implementation and test it thoroughly.

For the evolution of warm bubble without advection we were considering an interesting question which stencil is being chosen in each point of the domain. We would expect that both outer stencils will be used close to the bubble boundary where the gradients are biggest and it would be better to keep one stencil in parts with moderate gradients. Unfortunately, when having look on stencils chosen for quasi-monotonic ENO interpolation of the temperature field in the horizontal direction we found that it is not the case. Even in parts with moderate gradients, the stencil chosen was varying very quickly; see the left picture of Fig.2.

The reason for this behavior may be seen in the smoothness in these regions being very similar for all the stencils and hence the stencil used being chosen almost randomly. To correct this problem, we have introduced a preference factor PF=2 which makes the central stencil to be preferred. We choose the central stencil unless the smoothness in one of the outer stencils is PF times bigger. After this modification, we may see the chosen stencil on the right of Fig.2. We may see that the outer stencils are chosen only close the bubble boundaries and above bubble. The corresponding potential temperature field is depicted on Fig.3 (right) and the potential temperature field after 80 time steps on Fig.3 (right). We may see that the bubble after 80 time steps is much more symmetric and especially close its upper boundary better developed than without preference (PF=1). There is a question of the

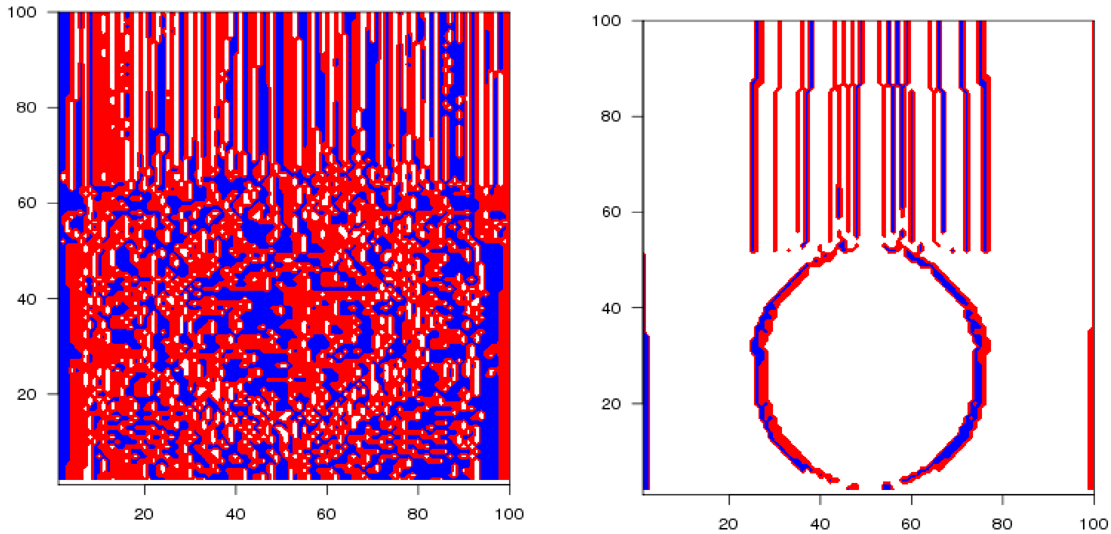


Figure 4: Stencils used for the horizontal interpolation of the temperature field in the 40th step of integration of the evolution of warm bubble without advection; the left stencil is depicted in blue, the central stencil in white and the right stencil in red. Left: the standard definition of ENO interpolations used as it was described (PF=1); right: the central stencil is being preferred by factor 2 (PF=2).

choice of the value of PF. For bigger values of PF ENO technique is applied only for sharper gradients, for values of PF close to 1, ENO is applied on wider domain. This aspect has to be investigated and PF remains a tunable parameter of the implemented method.

Subject: 2.2 COMAD weights for SL interpolations

Description and objectives: The COMAD weights have been designed at ECMWF (Sylvie Malardel). The linear and cubic semi-Lagrangian weights are modified to take into account the deformation of air parcels along each direction, with deformation factor defined with the respect to the local velocity in the given direction and the time step used. The proposed modification had a positive impact on the objective scores of the IFS runs and on the AROME 1.3km runs. We would like to know if we may get some benefit from this modification for the local model ALARO.

Contributors: Petra Smolíková (Cz)

Estimated efforts: 0.5 month (local work, CHMI)

Executed efforts: none

Documentation: none

Status: Planned for the end of the year.

Task 3. Physics-dynamics interface

Subject: 3.1 Feasibility study to add the physical tendency of vertical velocity to the adequate prognostic (NH) variable

Description and objectives: For parameterization schemes used in HPE systems, the horizontal momentum 'feels' the sub-grid effects of mountain drag, turbulence and convection. The impact of these processes on the vertical momentum in the case of NH dynamics has to be reconsidered.

Contributors: David Lancz (Hu), Petra Smolíková (Cz)

Executed efforts: none

Documentation: none

Status: Planned for the end of the year.

Subject: 3.2 Design of the ideal share between the horizontal turbulence and numerical diffusion depending on the scale

Contributors: Radmila Brožková , Ján Mašek, Petra Smolíková (Cz)

Executed efforts: none

Status: Postponed to the next year.

Task 4. 1D2D turbulence scheme for ALARO

Subject: 4.1 Scientific validation

Description and objectives: Scientifically correct behaviour of the whole 1D2D system is a necessary condition needed to be satisfied to be able to fulfil further tasks. The vertical part has been prepared in the scheme TOUCANS, while the horizontal part has to be redesigned and modified to get consistent system on the latest model cycle. It follows that the compliance of the whole 1D2D turbulence scheme behaviour with the laws for transport of energy from bigger to smaller scales has to be carefully examined. Energy spectrum study is foreseen as an instrument for such validation. Preparation of a testing environment is considered as a part of the issue.

Contributors: Ivan Bašták-Ďurán (Cz)

Executed efforts: 0.5month (LACE stay at Ljubljana)

Documentation: progress report published on the LACE web page

Status: The 1D2D turbulence scheme was tested in the cycle CY38t1_op3 which contains ALARO physical package version ALARO1. It was checked that both the components, the horizontal and the vertical, are available and the code is up to date. Then 2D (1 horizontal and 1 vertical direction) experiments were prepared with idealized initialization involving a

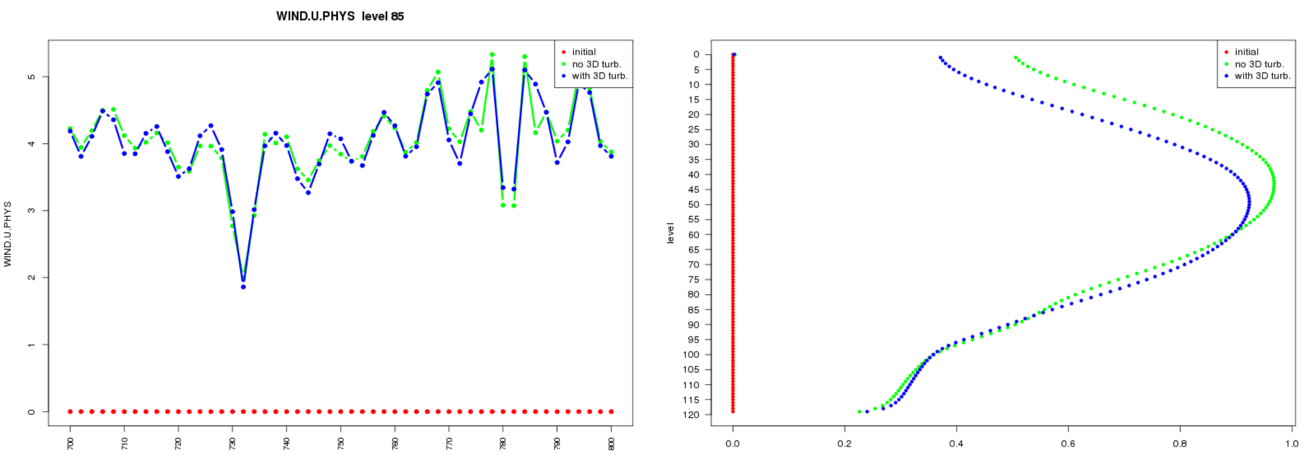


Figure 5: Results of 2D model runs. Left: Wind u-component at 85th model level (from 120); right: standard deviation of wind u-component for each vertical level. In blue 1D2D turbulence is switched on, in green it is switched off, in red is the initial state.

turbulence stimulating wind shear. The field of temperature was a superposition of a horizontally uniform field with vertical profile and a horizontally periodic perturbation with amplitude decreasing with height. The results after 10 hours of integration show that the 1D2D turbulence parametrization decreases the horizontal variability of the diffused fields and that its influence is significant only where the horizontal gradients are steep enough. It means that 1D2D turbulence parametrization may smooth such gradients only if the model horizontal resolution is sufficiently high.

Subject: 4.2 Tests in <1 km resolutions

Description and objectives: As soon as the previous task is successfully finished, academic tests with the full model may be targeted to further study scheme behaviour and its interconnection with other model parts. Very fine horizontal resolutions (subkilometric) are needed for such tests.

Contributors: Ivan Bašták-Ďurán (Cz)

Executed efforts: 0. 5month (LACE stay at Ljubljana)

Documentation: progress report published on teh LACE web page

Status: Following the results of the previous subject, a real case study was prepared for the Alpine region in 1.25km horizontal resolution, with 87 vertical levels, integration from 1.7.2014 at 00 UTC. The results show that 1D2D turbulence has a significant impact on model forecast of diffused variables in regions with steep horizontal gradients. Moreover, the 1D2D turbulence parametrization show sensitivity to both, the choice of stability functions and the choice of the length scale. It is left for the future work to analyse the spectrum of the model fields to see where the 1D2D turbulence is most active in order to determine the horizontal resolution at which the scheme is worth to be switched on.

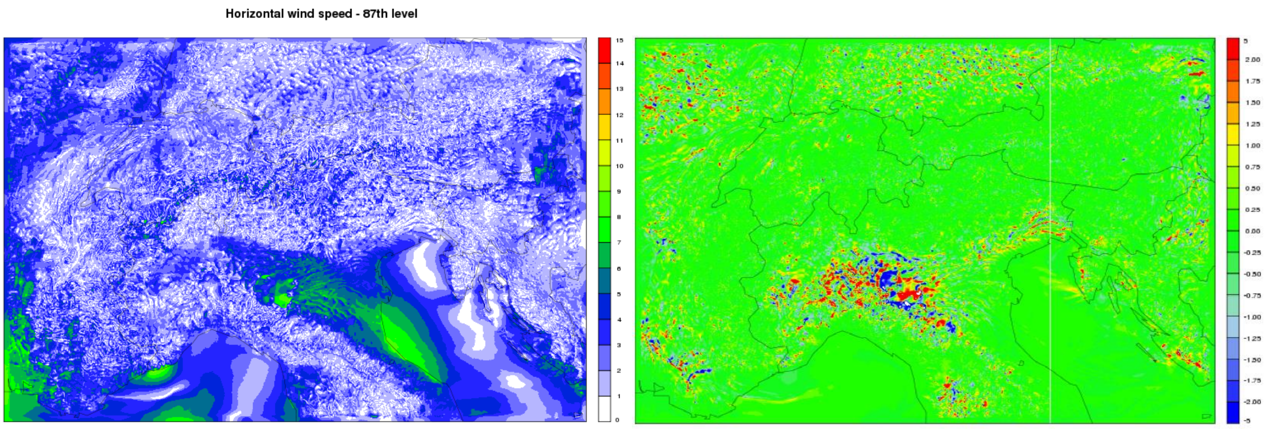


Figure 6: Horizontal wind speed for the real case study, the bottom most level. Left: Field after 14 hours of integration, right: the difference between run with and without 1D2D

Further, since SLHD partly supersedes horizontal turbulent diffusion, the optimal mixture of these two schemes has to be found again in dependence on the horizontal model resolution.

Task 5. Evaluation of the model dynamical core in very high resolutions

Subject: 5.1 Clear comparison of SETTLS and ICI time schemes

Description and objectives: On workshops, during meetings with our colleagues from ALADIN, HIRLAM and ECMWF, in email exchanges, we are facing the complaints on the speed, affordable timestep, computational time requirements and stability properties of the centred iterative time schemes (called PC scheme) developed under the RC LACE auspices. In 2011, a study of Filip Váňa has shown problems which may be faced when using alternative non-iterative 2-time-level scheme called SETTLS. From our case studies we believe that iterative schemes offer better stability properties that SETTLS without danger of creating spurious oscillations. We would like to compare the two alternative kinds of time schemes available in the code of ALADIN/ALARO/AROME model and show benefits and drawbacks of them in a clear and convincing way.

Contributors: Petra Smolíková (Cz), Jozef Vivoda (Sk)

Executed efforts: 1 month of local work

Status : Postponed to the next year.

Subject: 5.2 Upper boundary conditions

Description and objectives: Mariano Hortal (HIRLAM, Spain) has introduced upper boundary nesting based on Davies relaxation similar as it is used on lateral boundaries. He has shown that this relaxation helps to get rid of upper level explosions observed in real cases for SETTLS time scheme. We would like to understand better the behaviour on the upper boundary and its interaction with PC time scheme used in most operational applications.

Contributors: Petra Smolíková (Cz)

Executed efforts: 1 month of local work

Status : Postponed to the next year.

Task 6. LBC coupling strategy

Subject: 6.1.Rapid changes in surface pressure field

Description and objectives: Interpolation in time applied on LBC data of the large scale model to get the data on lateral boundaries for each timestep of a LAM distorts the model fields and can lead to LAM forecast failures in case of fast propagating storms. The analysis of the MCUF (Monitoring the Coupling-Update Frequency) field from ARPEGE coupling files for the common LACE coupling domain may help to monitor the occurrence of such storms to draw conclusions on coupling zone positioning etc. Distinct warning index could be designed to capture high precipitation events again with consequences on LACE domain boundaries. It is a continuation of work from 2014.

Contributors: Martina Tudor (Cr)

Executed efforts: MT - 3 month (local work)

Documentation: published paper

Tudor M., *Methods for automatized detection of rapid changes in lateral boundary condition fileds for NWP limited area models*, Geosci. Model Dev.,8, 2627-2643, 2015.

Status: One easy cure when a fast cyclone enters the domain too quickly would be to restart the forecast again from the forecast file containing LBCs at the hour when the cyclone is already inside the domain. But this is not possible to be done in an assimilation cycle. Hence

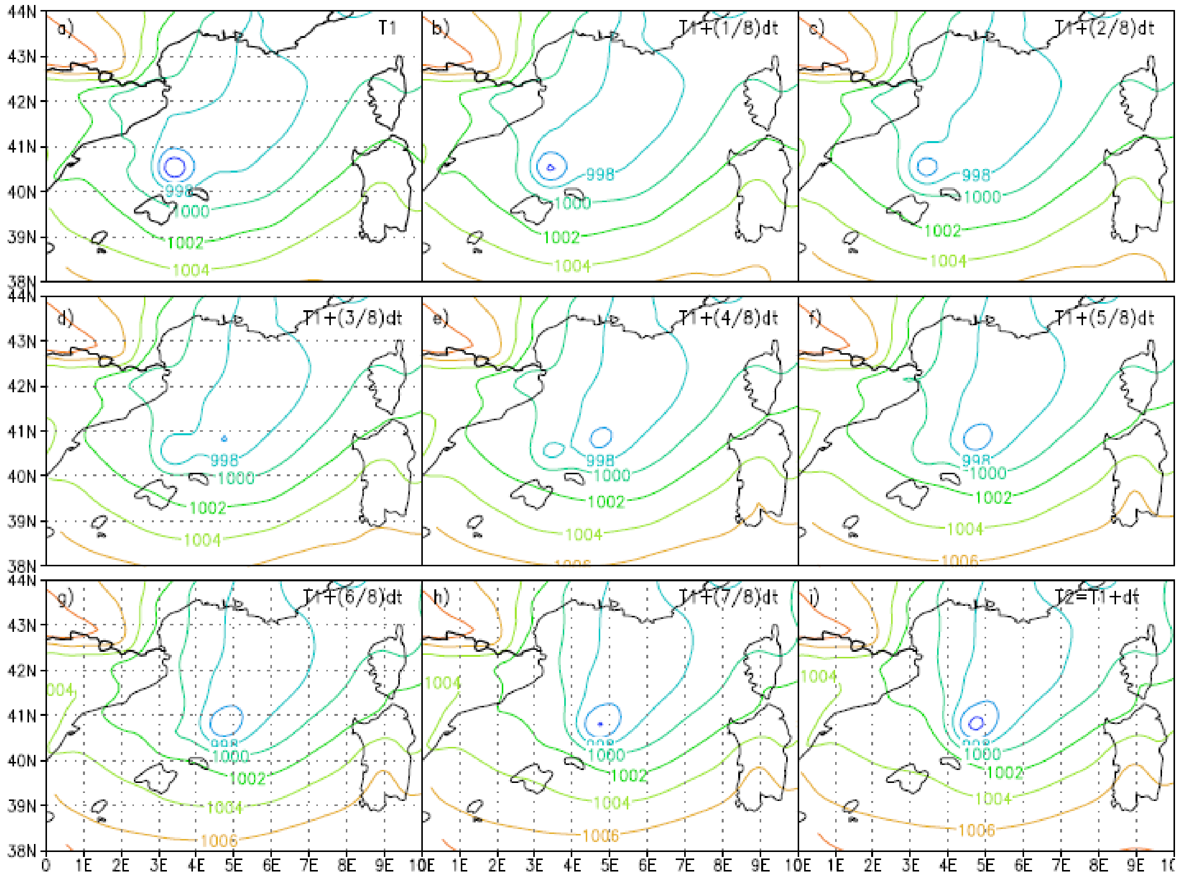


Figure 7: An illustration of the effect of the linear interpolation of coupling files: in place of moving storm, we see a dual cyclone structure in the interpolated coupling files between two consecutive LBCs (a) and i)).

the subsequent run (after restart) should be initialized with dynamical adaptation. Then the advantage of having the cyclone in the domain may be supressed with the disadvantage of quitting the assimilation cycle. Or, well-tuned initialization procedure has to be chosen to give satisfying results.

The MCUF field, as a good indicator of rapidly moving pressure disturbances (RMPD), is being provided operationally in the ARPEGE coupling files, but this is not the case for IFS coupling files. Several methods were tested that detect RMPD a posteriori from the IFS model fields provided in the coupling files:

1) Computing MCUF field from IFS coupling files by running ALADIN on the LACE domain with resolution and time step of the original coupling files (Δx=15.4km, Δt=600s) for 78 hours. Several cyclones have been detected with this method, but much less than with ARPEGE MCUF field and the values of MCUF provided with this method are suspiciously low over the western Mediterranean suggesting that the method suffers from the same problem it was designed to detect – fast cyclones entering the LBC domain too quickly. To check the proposed method, the same method was applied on the ARPEGE coupling files with 450s time step and ARPEGE resolution of 10.61km and the field MCUF has been obtained which is in good agreement with the same field provided in the ARPEGE coupling files.

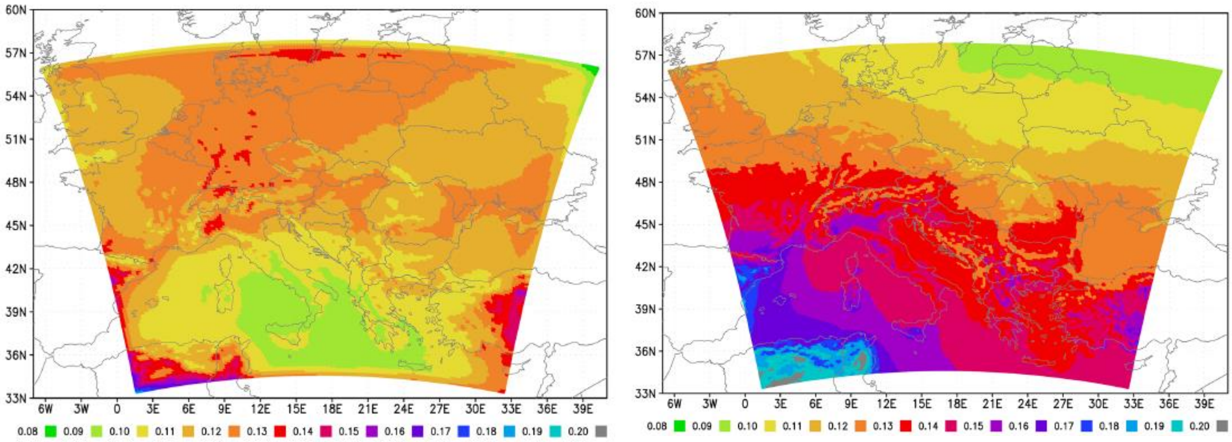


Figure 8: The average MCUF field calculated from IFS coupling files (top) and provided in ARPEGE coupling files for the period from 1.11.2010 until 15.11.2014.

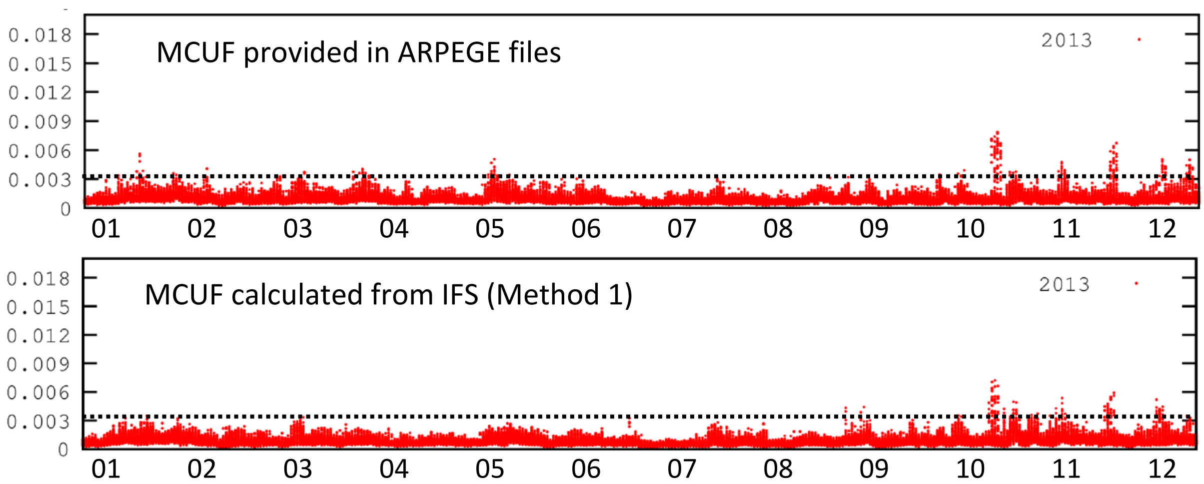
2) Computing an error function from the surface pressure field according to Termonia (2003) and considering its maximum over the model domain as the indicator of RMPD. The method requires running ALADIN for one time step for each coupling file and computing tendencies of surface pressure and mean sea level pressure either without any filtering, using DFI or using scale selective DFI. All three possibilities have been considered and discussed. When running ALADIN without filtering a rather high level of noise was detected and the threshold value for the MCUF field should be

increased in order to avoid false alarms. When DFI was applied for fields initialization the noise has been reduced, but also the signal of RMPD. Moreover, this method suffers from being influenced with orography to create false peaks. When using scale selective DFI for fields initialization the level of noise and the intensity of the signal of approaching RMPD were similar to those computed with DFI.

Both filtering methods require running ALADIN adiabatically backwards for a number of time steps and then diabatically forward for the same number of time steps for each of the coupling files which makes them computationally expensive.

3) Computing the amplitude A of oscillations in mean sea level pressure from its values in three consecutive coupling files. This method is simple and does not require running ALADIN at all. Unfortunately, A could miss the evolution of mean sea level pressure on timescales smaller than the coupling update frequency (3h). The amplitude maxima achieve large values even during periods without RMPD, but the amplitude is much larger in cases with RMPD ensuring that the signal may be easily distinguished with properly chosen threshold used. There were cases when A reached values above the threshold in grid points close to the coupling domain boundaries while there was no indication of higher values of MCUF calculated by the first method from the IFS coupling files. In these cases the cyclone entered the domain too quickly to be detected by the first method.

It was concluded that the error function computed without initialization and the amplitude of mean sea level pressure variations are good indicators of RMPD which may be calculated by cheap methods. The results of two other methods (MCUF calculation and the error calculation with initialization) do not justify their extra computational cost and were not recommended to be used. An alternative to the proposed methods is to compute MCUF field operationally and provide it in the IFS coupling files. But this is in hands of ECMWF.



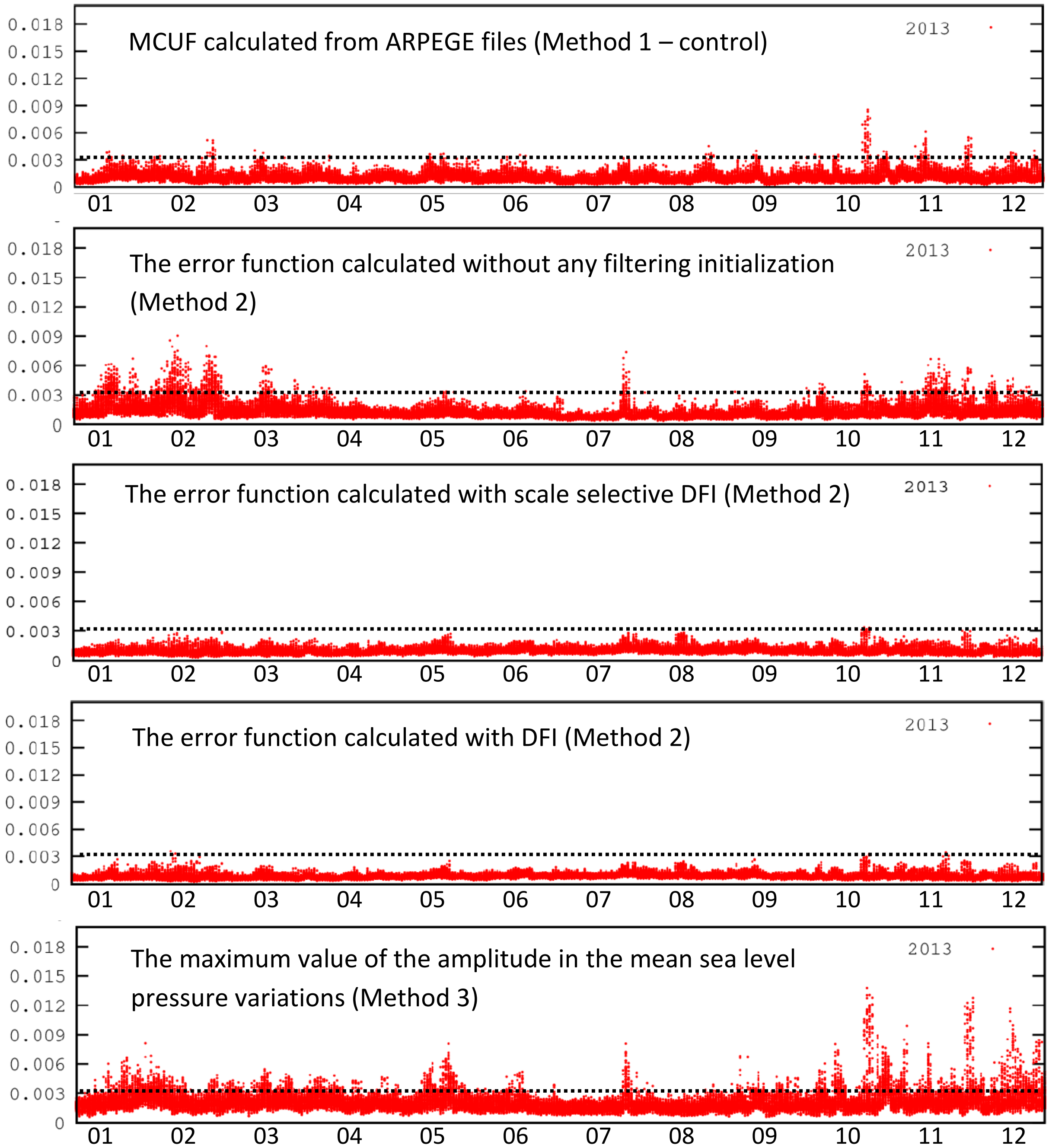


Figure 9: Time series of the distinct characteristics indicating the RMPDs for the year 2013. The usually used threshold value 0.003 is indicated on the plots.

Documents and publications

Three reports have been published on the RC LACE web page:

1) Ivan Bašták-Ďurán, Report from stay in Ljubljana: 18th May – 12th June 2015

2) Alexandra Craciun, Report from the stay at CHMI, June 2015: *Application of ENO technique to semi-Lagrangian interpolations.*

3) Jozef Vivoda, Report from the stay at CHMI, July 2015: *???*

Two manuscripts were prepared for publication and published:

1) Petra Smolíková, Jozef Vivoda and Juan Simarro, *Testing accuracy of finite element scheme used in vertical discretization of ALADIN-NH,* ALADIN-HIRLAM Newsletter No.5, August 2015

2) Tudor M., *Methods for automatized detection of rapid changes in lateral boundary condition fileds for NWP limited area models*, Geosci. Model Dev.,8, 2627-2643, 2015.

Activities of management, coordination and communication

Activities between January 2015 and September 2015:

1) Joint 25th ALADIN Workshop & HIRLAM All Staff Meeting 13-17/4/2015, Helsingor, Denmark, presentation – P. Smolíková: LACE - News in dynamics

LACE supported stays

There have been three stays realized during 2015:

1) Ivan Bašták-Ďurán (CHMI, Czech Republic) – 1 month in Ljubljana, May 2015

2) Alexandra Craciun (NMA, Romania) - 1 month in Prague (CHMI), May-June 2015

3) Jozef Vivoda (SHMI, Slovakia) – 1.25 months in Prague (CHMI), May-June 2015

Summary of resources/means

The total effort invested into the area of Dynamics&Coupling in frame of LACE in 2015 is 11 person/months, 3.25 person/months from that as scientific stays in Prague and in Ljubljana. The plan for 2015 was 14 person/months. Since there are still 3 month left till the end of 2015 and we expect one more stay (1 month) to be executed in Prague, we may expect to fulfil plan in terms of total manpower. Concerning topic solved, there has been a shift from less urgent topics to more urgent ones or to topics whose solution has shown to require more time than expected.

Task	Subject		Resources		Stays	
			Planned	Executed	Planned	Executed
VFE NH	1.1	Design of VFE in NH model	4	4	1	1.25
SL scheme	2.1	Application of ENO technique in SL interpolations	1.5	3	1	1
	2.2	COMAD weights for SL interpolations	0.5	0	0	0
Phys-dyn interface	3.1	Physical tendency of w	1.5	0	1	0
	3.2	Ideal share between horizontal turbulence and numerical diffusion	2.5	0	0	0
1D2D turbulence	4.1	Scientifique validation	0.5	0.5	0.5	0.5
	4.2	Test in <1km resolutions	0.5	0.5	0.5	0.5
Evaluation of the dynamical core in very high resolutions	5.1	Clear comparison of SETTLS and ICI time schemes	1	0	0	0
	5.2	Upper boundary conditions	1	0	0	0
Coupling strategy	6.1	Rapid changes in surface pressure field	1	3	0	0
Total manpower			**14**	**11**	**4**	**3.25**

Problems and opportunities

We are happy to see young colleagues from Romania and Hungary to join us in the area of Dynamics and we hope to find more candidates to work on the planned topics in this area.