Working Area Dynamics & Coupling

Progress Report

Prepared by:	Area Leader Petra Smolíková
Period:	09/2014-12/2014
Date:	25/02/2015

Progress summary

In 2014, work has been continuing on main topics in the Area of Dynamics&Coupling, as the implementation of finite elements in the vertical discretisation of NH model version and design of physical tendency of vertical velocity again for NH version, or detection method for rapid changes in the surface pressure field of LBC files. We have started several new topics as the application of ENO technique in the SL interpolations and tuning of SLHD for high resolution runs of model ALARO. This report is devoted to topics being touched from September 2014 till the end of the year 2014. Other activities done in the Area of Dynamics&Coupling in 2014 are already being summarized in the report from September 2014. The efforts invested in the area are presented for the whole year 2014 at the end of this report.

Concerning our already established collaboration with HIRLAM group of dynamics, we had the occasion to meet our Spanish colleagues during the “Dynamics working days” being held in Valencia in October 2014.

One stay has been realized during autumn 2014, David Lancz (Hu) has been working with us at CHMI in Prague on the design of physical tendency for vertical velocity in NH model version.

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: 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.

Executed efforts: JV – 3 months (1.5 month of local work, 1.5 months - LACE stay at CHMI, Prague), PS – 3.5 months (local work); total 6.5 months

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

Documentation: Petra Smolíková, « Idealized tests and real simulations with finite elements used in vertical discretization of ALADIN-NH (cy40t1) », report published on the RC LACE web pages

Status: As the most important task for the year 2014 it was identified the need to explain in details why the currently implemented version of VFE in NH model (cy40t1) works and what are its benefits. For this reason we have concentrated ourselves on the theoretical explanations and studies of the simple cases with known analytical solution to see the impact of vertical discretization method choice.

For the first test, a slightly modified version of the idealized test setup used by Skamarock and Klemp was proposed by Baldauf and Brdar: the quasi linear 2-dimensional expansion of sound and gravity waves in a channel induced by a weak warm bubble. The modification allows derivation of an exact analytical solution for the compressible, nonhydrostatic Euler equations that are the basis for ALADIN-NH model. The derived analytical solution is supposed to be used as a benchmark to assess compressible dynamical cores

Since ALADIN-NH uses a mass based vertical coordinate, the vertical velocity might be imposed to be zero at the bottom but at the top the model is open and there are not boundary conditions for the vertical velocity: atmosphere can evolve freely and can move up and down at the top. As a consequence, the evolution of the initial perturbation is a set of waves that propagate both in the horizontal and vertical directions. Trying to fix vertical velocity to zero at a given height is not an easy task, as the model itself is not prepared nor designed for such an imposition.

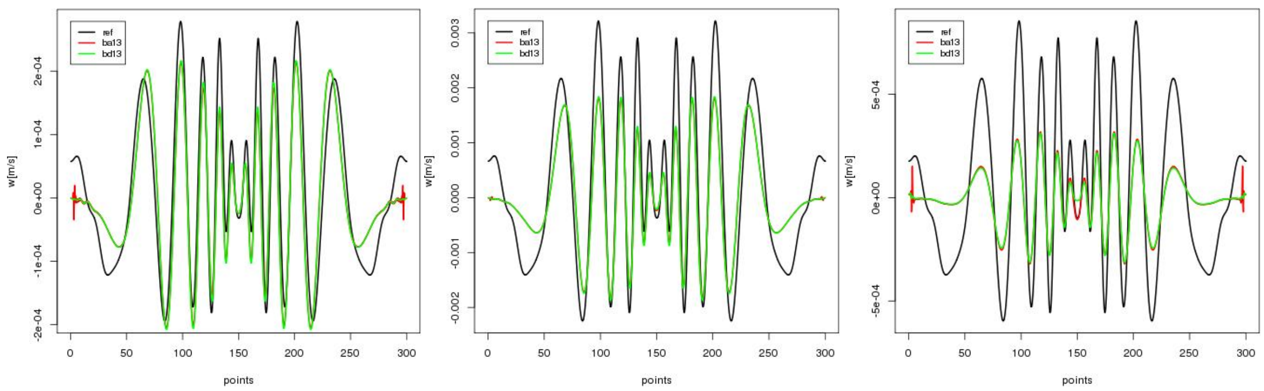

Figure 1: *Potential temperature in Baldauf-Brdar test for distinct vertical levels in 125m vertical resolution; left: 4th level in 0.5km; middle: 40th level in 5km (middle of the domain in vertical); right: 76th level in 9.5km. Analytical value is in black, VFE in red and VFD in green.*

As a consequence, the difference between the vertical velocity field of the experiment with FE used in vertical discretization and the one with FD used is order of magnitude smaller than the overall error of both experiments compared to the analytical solution. See Figure 1 for comparison of vertical velocity value in the height of 0.5km, 5km (middle of the domain) and 9.5km. In higher levels, there is an indication of the VFE method being more precise in the middle of the domain, while most of the results of the VFE and VFD discretizations are almost undistinguishable.

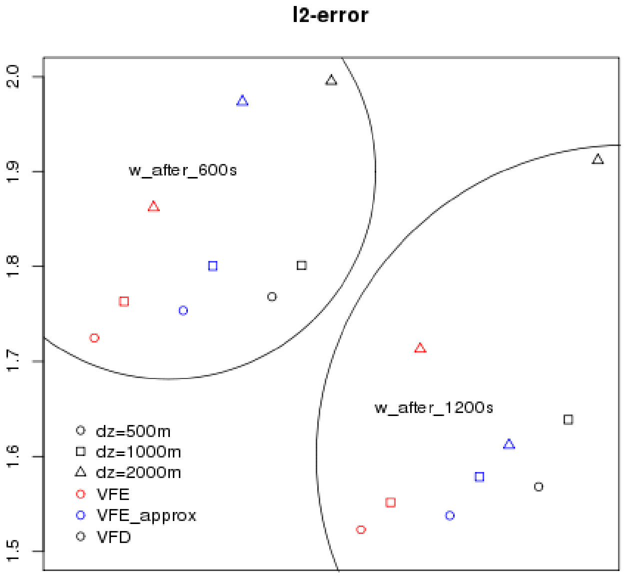

Figure 2: *Relative l2-error for vertical velocity field in distinct experiments with modified Baldauf-Brdar test after 300s and 600s.*

Following the idea of Juan Simarro to modify the initial perturbation of temperature to localize its maximum in the lower atmosphere, we have run another set of experiments for this new simple case. Here the perturbation would evolve as a set of waves propagating horizontally and vertically. Because the initial perturbation is located in the lower atmosphere, it will take some minutes to get the upper atmosphere, and meanwhile the vertical velocity at the top will be zero in the analytical solution. Unfortunately, in the numerical solution of ALDIN-NH this is not true anymore, the sink of mass through the top is unavoidable and the solution is again distorted. On the other hand, we could notice that the accuracy of the experiment with FE was enhanced compared to the one with FD in vertical discretization. And this claim holds for all three resolutions used, 500m, 1000m and 2000m, see Figure 2 for an illustration of this fact.

As conclusion, it is difficult to show benefit coming from the usage of FE in the vertical discretization.

Another important task for VFE topic was to show that FE may be as stable as FD in 3D real simulations in high horizontal resolutions. We have chosen 2 months of experiments, January 2014 and July 2014, over the domain covering the Alpine region. Consult Figure 5 for the orography used. The horizontal resolution was 1.25km and vertically we have used Czech operational setting of 87 levels. We have run one integration per day from 00UTC until +24hours. Results obtained have confirmed previous results obtained with coarser resolution of 2.2km over Czech domain. We may conclude:

1) VFE scheme used in NH with proper setting of FE parameters and proper setting of vertical levels may be as stable as FD scheme; the time step used in our experiments was 50s.

2) It is difficult to find any benefit from FE used in vertical discretization concerning objective scores.

3) The precipitation field is modified by FE in such a way that there is bigger number of grid points without rain (cumulated precipitations for 1 hour < 0.1mm) and bigger number of grid points with highest values of cumulated precipitations (>30mm/hour). Consequently, there is smaller number of grid points with modest rain between 0.1 and 30mm. We consider this trend as beneficial since the field of precipitation is more sharpened and the rain locations are more restricted. We should admit that this phenomenon is clearly present but not as intensive as to be observed easily. Our conclusion comes from the statistical analysis of results; see Figure 3 for histograms of cumulated precipitations for each hour in each forecast made for the summer period. Concerning the intensity of observed trend, we may summaries that the two experiment series (VFE and VFD) differ only in 0.3% of events when using our histogram intervals. Nevertheless, the phenomenon is observed in both, summer and winter series, and it is clearly pronounced.

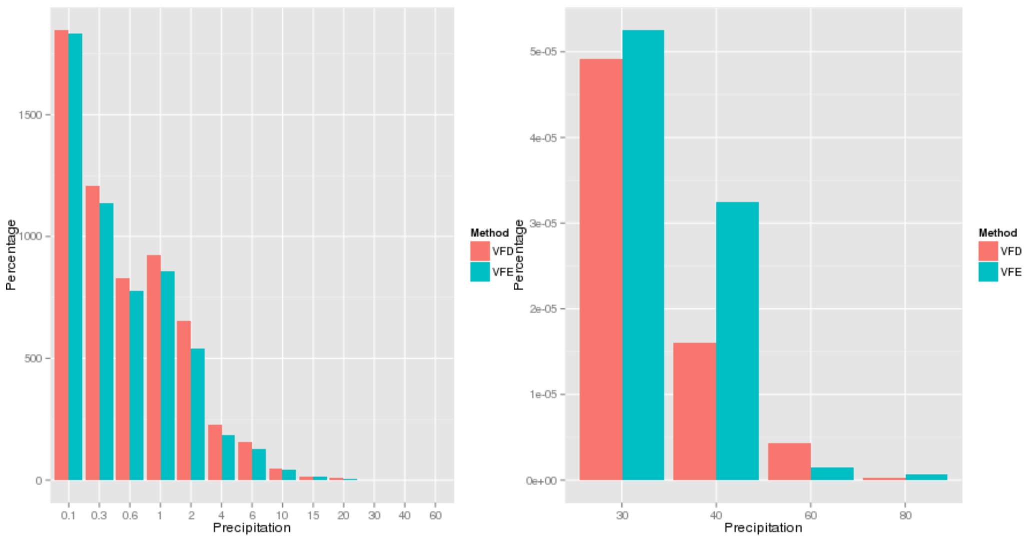

Figure 3: *Histograms for summer period of 3D simulations (July 2014). To be able to visualize the difference between FE and FD experimental series, we have rescaled the results in such a way that only 10% of common events are taken with the remaining number of events in which two series differ.*

Task 2. Physics-dynamics interface

Subject: 2.1 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.

Executed efforts: 1 month (LACE supported stay at CHMI, Prague), 0.5 month of local work (CHMI)

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

Documentation: report from stay - David Lancz, « Examination of vertical diffusion of vertical velocity in 2D experiments with ALADIN-NH », published on the RC LACE web pages

Status: This task is a continuation of work being done in 2013 during stay of David Lancz at CHMI, Prague. In 2013, modifications of the code needed for the calculation of physical tendency from vertical turbulence of vertical motion variable and its summation with other terms in the prognostic equation for vertical motion variable has been prepared. The possible choices of vertical motion variable are: modified vertical divergence d (NVDVAR=4, LGWADV=F) or vertical velocity (LGWADV=T). If it is not necessary to specify which variable was used, we speak about vertical motion variable (VMV).

The purpose of the second stay of David in Prague was to prepare 2D vertical slice simple experiments demonstrating the effect of vertical turbulence on VMV. Moreover, the influence of the resolution on the observed effect has been studied through vertical mean profiles of potential temperature and horizontal wind.

The initial conditions set for the experiments were such that the Kelvin-Helmholtz instability could be developed, strong wind shear and stratified temperature profile being the most important ingrediencies. The domain vertical extent was 1200m and a jump in the horizontal wind field was situated at the height of 520m, changing the wind-speed from 0 m/s to 5m/s. In the same height, there was a break in the potential temperature profile. A small orographic disturbance was built in to trigger eddies. Constant in time lateral boundary conditions have been applied.

The turbulent tendency of VMV is estimated during the computation of the turbulent kinetic energy in the part of the code called TOUCANS. However, if this tendency has been calculated and the whole turbulence scheme was turned on, the development of eddies has been inhibited. In case eddies have been already developed in the initial file as the result from a previous experiment, the parameterization of turbulence has eliminated them after some time. Hence the experiment was set in such a way that the turbulent fluxes for VMV have been calculated, but the whole turbulence scheme was turned off. The effect of turbulent tendency applied on VMV is demonstrated on Figure 4.

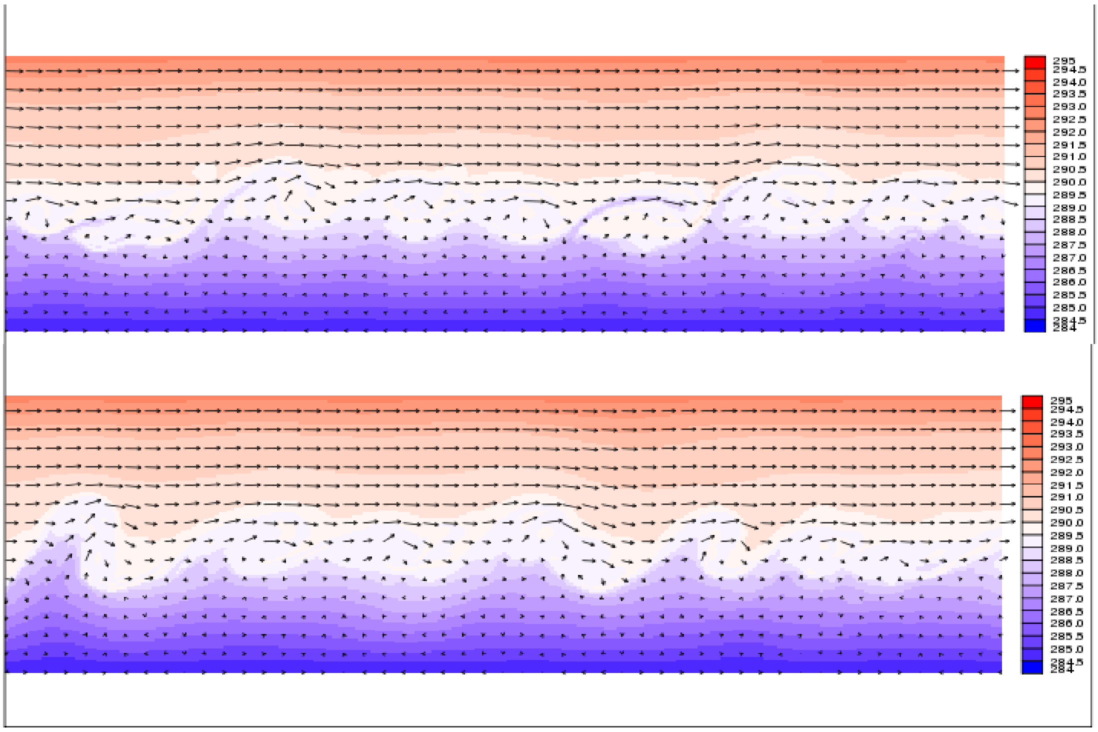

Figure 4: *The potential temperature field [K] with wind arrows in the 2000. timestep of the experiment with dx = 10 m, dz = 10, top: without VMV turbulent tendency; bottom: with VMV turbulent tendency.*

Due to the chaotic behaviour, the VMV tendency modification makes eddies develop elsewhere then without its application. It would be quite difficult to compare the vertical velocities in two fields full of eddies which are not in the very same place, because the amplitudes of the differences would be as high as the values itself, while the average values wouldn't differ so much. It was decided to compare rather the mean profiles of the potential temperature and horizontal wind. The differences of standard deviations of the vertical velocity have been also studied, see figure 9 for some results.

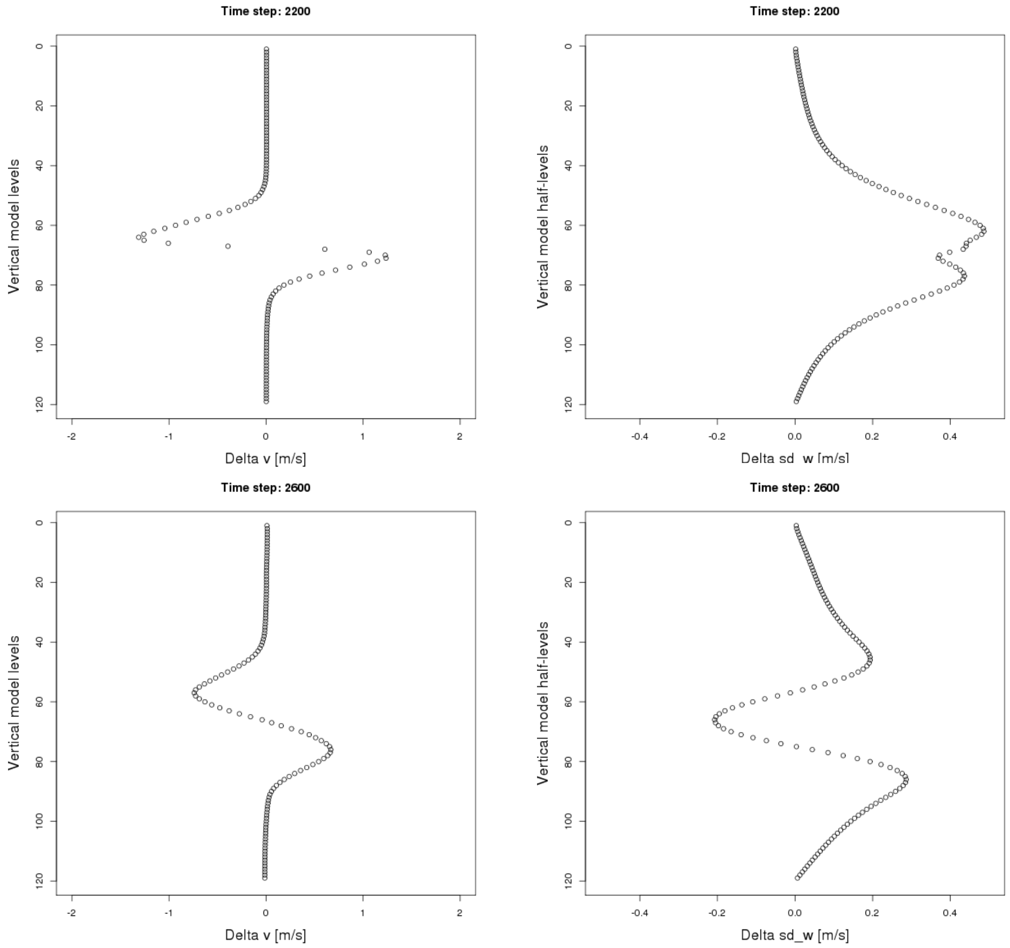

Figure 5: *Profile of differences of the mean horizontal wind (left) and profile of the standard deviation of vertical velocity w (right) between cases with and without VMV turbulent tendency calculation in experiments with dx = 100 m and dz = 10 m. Top: at the timestep 2200, bottom: at the timestep 2600.*

Experiments were prepared with various vertical and horizontal resolutions to see how turbulent tendency of VMV depends on the grid-size. We found that in the range of dx = dy between 10 and 40 m the resolution has impact on the variability in time and at lower resolutions there are lower differences. For horizontal resolution dx = 100 m the differences in all fields are better developed. The amplitude of differences in the mean potential temperature is in this case about ±0.2 K (in case of profile with ~8 K difference between the top and bottom value) and near a wind-shear, where the wind-speed jumps from 0 to 5 m/s, the mean wind-profile can differ by ±1 m/s.

As conclusion, we consider the results as consistent and qualitatively and quantitatively well corresponding to expected behaviour.

Subject: 2.2 Application of ENO techniques to semi-Lagrangian interpolations
Executed efforts: none
Status: ONGOING

Subject: 2.3 Design of the ideal share between the horizontal turbulence and numerical diffusion depending on the scale
Executed efforts: none
Status: ONGOING

Task 3. 1D2D turbulence scheme for ALARO

Subject: 3.1 Scientific validation of 1D2D turbulence
Executed efforts: none
Status: POSTPONED TO 2015
The work has not been started yet for the reason of tasks in 2D turbulence not being finished yet and due to no availability of the dedicated workforce.

Subject: 3.2 Tests in <1 km resolutions
Executed efforts: none
Status: POSTPONED TO 2015
This task is related to the realization of the previous task and may be started after the previous one is finished.

Task 4. LBC coupling strategy

Subject: 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 2012.

Executed efforts: MT - 2 months (local work)

Contributors: Martina Tudor (Cr)

Documentation: manuscript "*Methods for automatized detection of rapid changes in LBC fields for NWP LAM*" prepared for Geosci. Model Dev.

Status: An analysis was performed of the MCUF field for the LACE coupling domain for the period since 23rd January 2006 until 15th November 2014. The MCUF field being a good indicator of rapidly moving pressure disturbances (RMPD), this analysis may indicate the preferable position of the Croatian (or other region) operational ALADIN domain. Since MCUF is available only in LBC from ARPEGE and is not available in coupling files from IFS, several methods were tested to detect RMPD a posteriori from the IFS model fields:

1. by running ALADIN in low resolution on the coupling files
2. by simple computation of variations in the mean sea level pressure from three consecutive coupling files
3. by error function which is computed using tendencies estimated by running ALADIN for one time step, using coupling fields without initialization, initialized with DFI and with SSDFI.

As resolutions of both LAM models and leading global models are increasing, the question arises whether even hourly available coupling data will be sufficient in some cases. Since more accurate methods for LBC data time interpolation exist, but are computationally expensive, they should be used only when needed. Therefore there will be an increasing need of a reliable method to detect such events of severe weather conditions which missing in the forecast may cause important damages.

The core of this work has been already done in 2012 and 2013. The important step forward is now the preparation of a manuscript for further publication.

Documents and publications

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

1) Alexandra Craciun, Report from the stay at CHMI, June 2014: *Application of ENO technique to semi-Lagrangian interpolations.*

2) Jozef Vivoda, Report from the stay at CHMI, July 2014: *Consideration about vertical Laplacian operator being discretized using VFE.*

3) Petra Smolíková, 2015: *Idealized tests and real simulations with finite elements used in vertical discretization of ALADIN-NH (cy40t1)*

One manuscript was prepared for upcoming publication:

4) Martina Tudor, *Methods for automatized detection of rapid changes in LBC fields for NWP LAM*, manuscript prepared for Geosci. Model Dev.

Activities of management, coordination and communication

Activities between September 2014 and December 2014:

1) 36th EWGLAM & 21th SRNWP joint meetings, 29 September - 2 October 2014, Offenbach, Germany (participation of Petra Smolíková – presentation „Latest developments in the LACE dynamics“)

2) ALADIN/HIRLAM joint dynamics working days in Valencia, Spain, October 2014 (participation of Jozef Vivoda and Petra Smolíková).

LACE supported stays – 4 person/months in 2014

There have been three stays realized during 2014:

1) Alexandra Craciun (NMA, Romania) - 1 month in Prague (CHMI), May-June 2013

2) Jozef Vivoda (SHMI, Slovakia) – 1.5 months in Prague (CHMI), May-July 2014

3) David Lancz (OMSZ, Hungary) – 1 months in Prague (CHMI), October-November 2014.

Summary of resources/means

The total effort invested into the area of Dynamics&Coupling in frame of LACE in 2014 is 13.5 person/months, 3.5 person/months from that as scientific stays at CHMI in Prague. The plan for 2014 was 15 person/months and thus we may say that we are close to fulfil all we have planned.

Task		Subject	Resources		Stays	
			Planned	Executed	Planned	Executed
VFE NH	1.1	Design of VFE in NH model	6	6.5	1.5	1.5
Phys-dyn interface	2.1	Physical tendency of w	1.5	1.5	1	1
	2.2	Application of ENO technique in SL interpolations	1.5	1.5	1	1
	2.3	Ideal share between horizontal turbulence and numerical diffusion	2.5	2	0	0
1D2D turbulence	3.1	Scientifique validation	1	0	0	0
	3.2	Testing	0.5	0	0	0
Coupling strategy	4.1	Rapid changes in surface pressure field	2	2	0	0
Total manpower			**15**	**13.5**	**3.5**	**3.5**

Problems and opportunities

We believe that there are interesting and challenging tasks in the area of Dynamics&Coupling, even if they are not felt as urgent. Our ability to make progress in these tasks is highly dependent on the available workforce. In the past two years several young colleagues from Hungary, Romania and Spain (HIRLAM) have come to Prague for joint work in the field of dynamics and we consider that as a very important achievement of all concerned partners in RC LACE. We hope that a long living cooperation has been established in this field.