ALATNET developments during the first half of 2002 in the ALATNET centres

1. In Toulouse

The work of the five ALATNET PhD students in Toulouse, Gianpaolo Balsamo, Margarida Belo Pereira, André Simon, Cornel Soci and Malgorzata Szczech, is described in separate reports, as well as other PhD reports. The summary hereafter corresponds to the joint efforts of the other visitors and the permanent staff.

1. <u>Theoretical aspects of non-hydrostatism (NH)</u>

a) Stability of the semi-implicit semi-Lagrangian scheme

Petra Smolikova started coding the newly defined prognostic variable called *d4* in the 3d model. This work was pursued in Prague and is documented in the corresponding report.

b) Upper boundary condition

An analysis of a recursive-filter based non-reflecting upper boundary condition (RUBC) for gravity and acoustic waves interaction with the semi-implicit temporal scheme was carried on by Martin Janousek. The main concern was the influence of the modification of phase speed of waves caused by a semi-implicit scheme on the radiative performance of RUBC. It was suggested that RUBC should be kept in an explicit form in order to properly handle wave radiation. More conclusions can be expected from 2d and idealized 3d experiments which will be carried on in the next year.

3. <u>Noise control in high-resolution dynamics</u>

a) Evaluation of dynamics at high resolution

Jean-François Geleyn resumed the experiments of Alena Trojakova with the ALPIA quasi-academic framework, to investigate in details the properties of ALADIN dynamics at very high resolution : hydrostatic versus non-hydrostatic, explicit versus semi-implicit, Eulerian versus semi-Lagrangian, ... This work is described in a separate paper.

Besides, a comparison between ALADIN, HIRLAM and Meso-NH non-hydrostatic dynamics, on a "trapped lee-wave" 2d academic case, has been performed. The solutions were found to be close to each other, at least when the CFL number is not significantly larger than one. Let us recall that the other two models are gridpoint ones.

b) Predictor-corrector approach

A mini-workshop was organized in Toulouse in March to harmonize the different approaches and prepare the next developments. The report is available in this Newsletter and on the ALADIN *web* site. A base version has been coded by Jozef Vivoda and introduced in an official code release.

A theoretical analysis of the behaviour of an iterative time-scheme in the presence of orography was performed by Pierre Bénard and confirmed the previous choices concerning decentering or the use of new variables.

c) Smoothing of orography

A new method was proposed to smooth orography at high resolution, which was proved necessary (to avoid spurious small-scale noise, especially when using "linear" spectral truncations). An additional spectral term is added to the cost function used to compute and optimize the spectral orography, which acts at damping the smallest scales. This should provide smoother spectra than the present method (importing the "quadratic" spectral orography when using a "linear" truncation), which abruptly sets to zero the contribution from the smallest scales (the last third of the spectrum), and will be far more flexible. However the first tests interfered with problems in the minimization library, and the present formulation is to be reconsidered.

6. Specific coupling problems

a) Blending

The positive impact of dfi-blending was confirmed through a detailed case study, on a MAP situation, performed by Vincent Guidard with help from Claude Fischer and described in a separate article. The porting to operations for ALADIN-France is now under progress, with retunings for the new geometry (increased horizontal and vertical resolutions, linear spectral truncation) and refinements in the script.

b) Tendency coupling for surface pressure

The porting of the corresponding modifications to the latest official release of the source code was finalized by Jean-Marc Audoin and 3d tests successfully performed with ALADIN-France. The impact remains to be evaluated, maybe with a more problematic domain (i.e. with more differences between ARPEGE and ALADIN orographies along the lateral boundaries, here mainly on sea).

7. Reformulation of the physics-dynamics interface

a) Study of the interactions between non-hydrostatic features and physical parameterisations

The problem of the introduction of diabatic forcing within the predictor-corrector approach was addressed during the dedicated mini-workshop. Safety locks to preserve the presently used alternatives will be introduced. A more thorough investigation is delayed, waiting for a stable dynamical core and more impact studies.

b) Sensitivity of the physics/dynamics interface to vertical resolution

The large vertical oscillations exhibited by Martina Tudor last autumn while trying to diagnose the PBL height (see the previous Newsletters, Toulouse ALADIN report), and problems noticed when increasing the operational vertical resolution, led to reconsider the anti-fibrillation scheme. First, it is now obvious that a retuning is required for each change in resolution. Second, the vertical variations of the coefficient controlling the anti-fibrillation scheme (β) are limited, with a maximum equal to the value at the lowest level, in order to avoid the vertical slicing.

c) Sensitivity of physics to time-stepping

Eric Bazile used the single-column model to study the impact of the length of the time-step on the behaviour of physical parameterizations. The response of the vertical diffusion scheme was very regular, but for the parameterisation of convection very steep jumps were observed. This is due to the fact that the triggering of convection depends on the tendencies issued from vertical diffusion at two adjacent vertical levels, and the scheme is very noisy on the vertical. A correction was proposed and the first 1d tests performed.

8. Adaptation of physics to higher resolution & 9. Design of new physical parameterisations

a) Parameterisation of convection and implementation of a new microphysics parameterisation

Beside the correction of many problems recently discovered in the convection schemes, described in the ALADIN report, new actions were undertaken. The parameterization of deep convection was improved to take into account the vertical wind-shear, which allowed to solve some operational problems. This work is described in a dedicated paper and in the Prague report, since part of the tests were performed by the LACE team. New strategies were proposed along the several meetings on this topic, aiming at writing a more consistent parameterization set, including an improved microphysics and better handling changes in resolution. They are described in the working-group reports available in these Newsletters. Hence, new convection schemes were tested within ARPEGE/ALADIN and the adaptation of an available microphysics, the Lopez scheme, started in the framework of the PhD thesis of Karim Bergaoui. The "Functional Boxes" approach, a framework for the handling of liquid water and ice as prognostic variables, is nearly ready.

b) Improved representation of boundary layer, new parameterisation of turbulence

The main action was the organization of a mini-workshop in Toulouse to coordinate the work related to the parameterization of turbulent kinetic energy, between Bruxelles (Martin Gera) and Toulouse (Jean-Marcel Piriou and Pascal Marquet). The situation looks safer now.

Besides the behaviours of the vertical diffusion and anti-fibrillation schemes were carefully studied, in connection with operational problems.

c) Improved representation of orographic effects

No developments were performed, but the discussions during the dedicated mini-workshop allowed a better definition of objectives.

d) Improved representation of land surface, including the impact of vegetation and snow

A new database for soil and vegetation characteristics was tested in close cooperation with the Belgian team (Olivier Latinne). It is more recent than the previous ones, and of higher resolution (horizontally as well as considering the number of vegetation classes), but results were quite deceiving.

e) Refinements in the parameterisations of radiation and cloudiness

The work on radiation restarted with the arrival of Yves Bouteloup. The first step was the improvement of ozone profiles, with the introduction of a geographical and seasonal variability.

The investigation of the problem of the underestimation of low cloudiness together with deficiencies in the shallow-convection scheme, was pursued. Jean-Marcel Piriou coded a new parameterization of cloudiness, based on the Xu and Randall proposal, and tested it in 1d and 3d cases, in the framework of the EUROCS intercomparison experiment.

10. <u>Use of new observations</u>

The work related to the use of observations in ALADIN is described in the ALADIN report. No significant step forward was performed, just some more diagnostic or interface tools for limited-area models and the use of pseudo-profiles of humidity (derived from satellite data) in 3d-var assimilation.

11. <u>3D-Var analysis and variational applications</u>

a) Definition of new background error statistics

Loïk Berre formalized the various "NMC derived" methods to compute background error statistics for limited-area models, taking into account the respective parts of lateral boundary conditions, changes of resolution and initialization. This provides an a posteriori validation of the retained solution. He presented this results, together with an overview of the work around variational assimilation within the ALADIN partnership, at the HIRLAM workshop held in January. The corresponding paper is available in HIRLAM Newsletter 40, and on the ALADIN *web* site.

b) Scientific validation of 3d-var

Vincent Guidard and Claude Fischer tested various combinations of 3d-var, blending and external initialization on a well-documented convective situation. This work is detailed in a separate paper.

Claude Fischer computed background error statistics for the most recent version of the ALADIN-France model, to run and improve 3d-var assimilation starting from more recent situations.

12. 4d-var assimilation

The main progress comes from the PhD work of Cornel Soci, who proposed changes in simplified physics for ALADIN.

2. In Bruxelles

5. Coupling and high resolution modes & 6. Specific coupling problems

a) Blending experiments on ALADIN -Belgium (Alex Deckmyn)

We have run several tests of spectral blending for ALADIN-Belgium. The objective scores (bias, root-mean-square error) are mostly in line with expectancies. For one specific month, December 2001, we found that blending had a strong negative effect on surface temperatures.

In blending, we assume that the high-frequency part of a 6h forecast is an improvement on the analysis. In some cases this hypothesis fails. In December 2001 there were periods with low clouds which were not well predicted by ALADIN and as a result the 18h+6h forecasts in the blending cycle were much too cold. The midday runs were hardly affected.

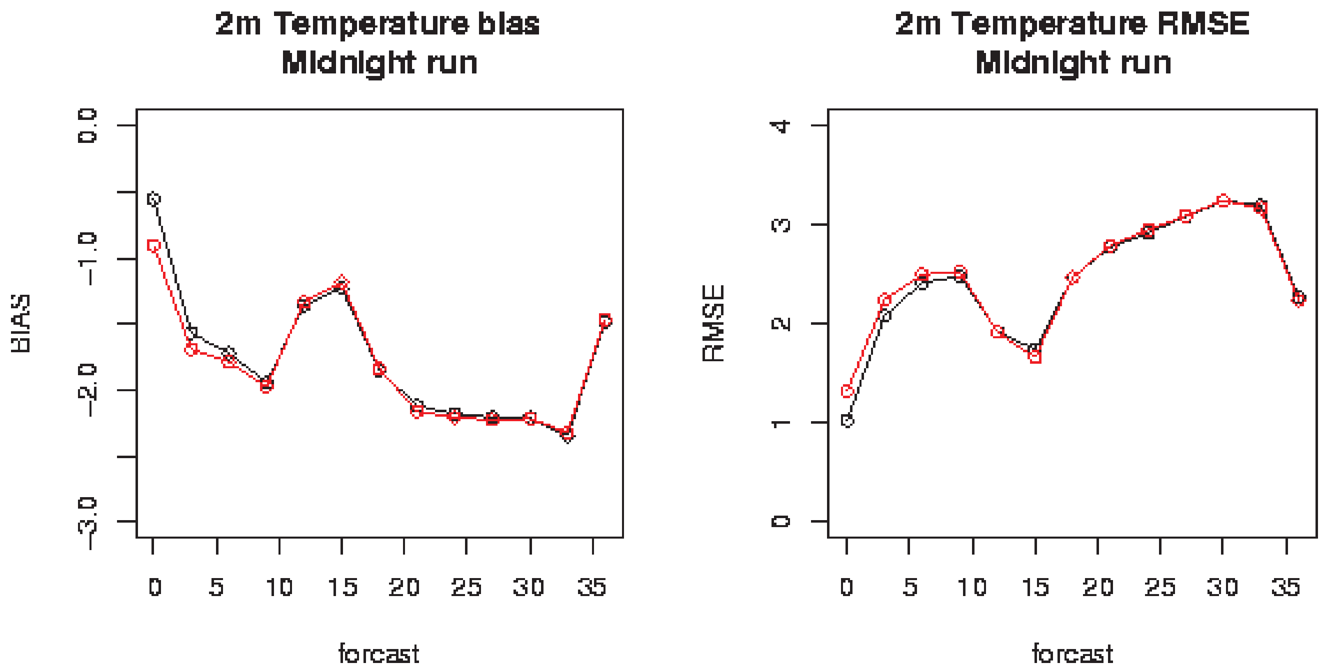

Figure 1: Forecast scores for December 2001, midnight run

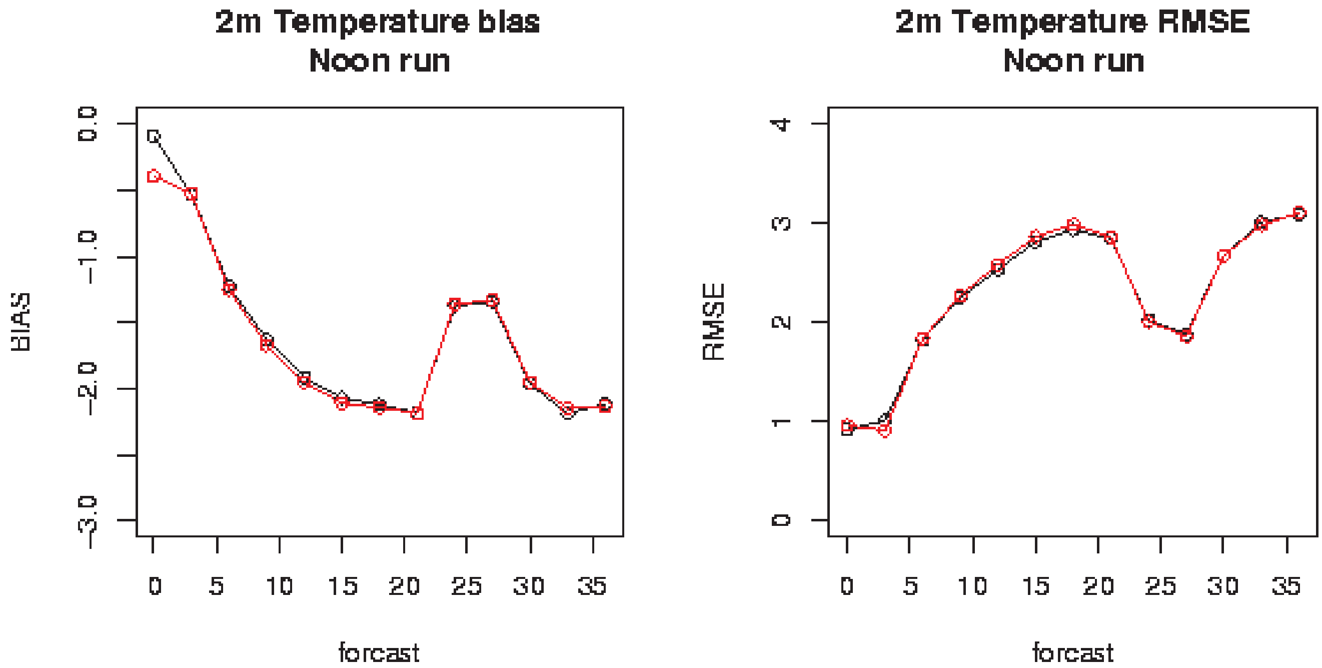

Figure 2: Forecast scores for December 2001, midday run

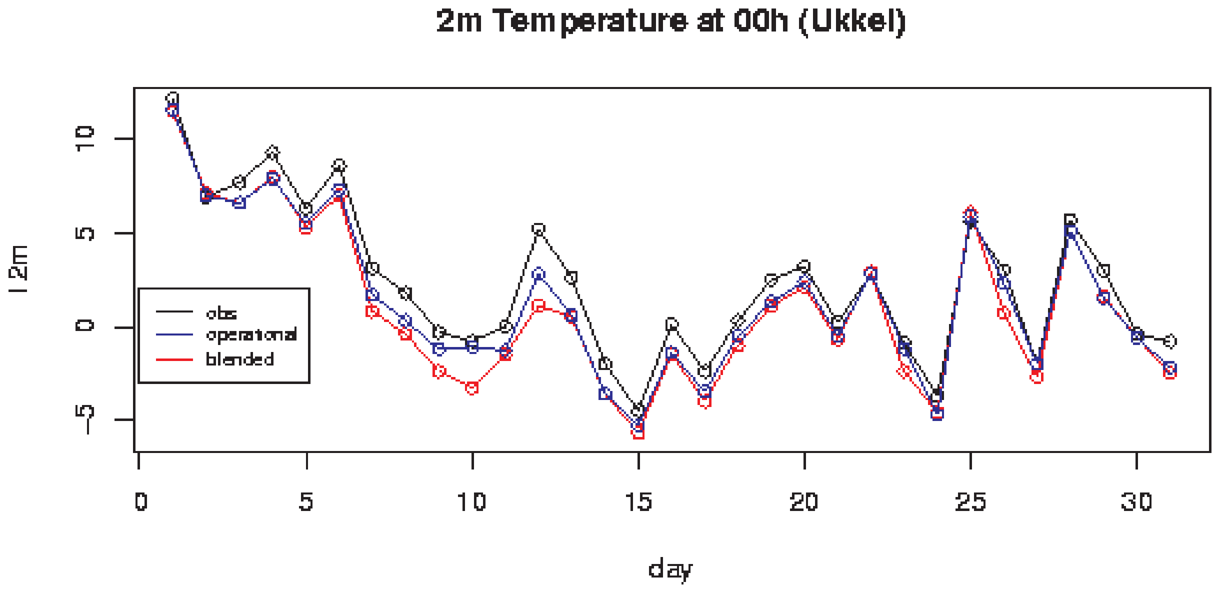

Figure 3: Surface Temperature of initial file

b) Time-interpolation of coupling data (Piet Termonia)

The previous definition of a "linear accelerated" scheme was used to define a "truncation error" indicating when linear interpolation with the present coupling frequency is likely to fail, e.g. because of rapidly propagating storms. A test covering December 1999 demonstrated the efficiency of this warning index : only one sharp increase over the period, corresponding to the Christmas' storm missed by several ALADIN models.

New coupling methods are now under investigation, in close cooperation with the Hungarian team.

7. <u>Reformulation of the physics-dynamics interface</u>

See the report from Ilian Gospodinov (ALATNET Post-Doc student).

8. Adaptation of physics to higher resolution & 9. Design of new physical parameterisations

a) Introduction of prognostic cloud water in a refined convection scheme (Luc Gerard)

The work is described in a joint paper. Cooperation with other ALATNET or ALADIN teams was reinforced through more frequent mail exchanges and a few meetings.

b) Improved representation of boundary layer, based on a parameterization of Turbulent Kinetic energy (Martin Gera)

The work is described in the ALATNET reports from Young Researchers. A few days of discussions in Toulouse allowed to clarify the distribution of work between involved researchers.

c) Improved representation of orographic effects (Bart Catry)

The topic of the PhD thesis was refined along the mini-workshop organized in March in Toulouse. It focuses on a precise diagnosis of the behaviour of the various parameterizations at small scale, including aggregation problems, using real or idealised situations.

d) More precise description of soil and vegetation characteristics (Olivier Latinne)

Experiments to evaluate the impact of newly proposed, more detailed, databases for vegetation and soil (with resolutions 1 km and 5' respectively) were pursued over two summer months and evaluated in cooperation with the Toulouse team. Results are quite deceiving.

11. 3D-Var analysis and variational applications

Alex Deckmyn started to investigate the potential of a new approach, based on wavelet theory, to represent forecast error statistics. The first results are described in a joint paper.

3. In Prague

1 Theoretical aspects of non-hydrostatism

1a) Top and bottom boundary conditions *(C. Smith)*

The reason why the semi-Lagrangian advection treatment creates a spurious standing wave above the top of the mountain was understood. In the original scheme there are two problems. The first problem was mentioned already in the previous report (from second half of 2001) : the semi-Lagrangian vertical advection on the vertical derivative of a quantity (vertical divergence) instead on the quantity itself (vertical velocity) is unstable. This instability is usually weak and it manifests itself by a noise. However for stronger vertical velocities it may lead to a blow up of the model for a given time-step. The existing instability can be nicely shown on the idealised experiment with the solid body advection in the *x*-*z* plane. The second problem was the treatment of the bottom boundary condition. This condition is in practice linked to the surface vertical acceleration diagnosed from the cinematic rule. Thus at each grid point we have a diagnostic relationship where the surface vertical acceleration is given by the surface horizontal wind acceleration and the orographic slope. It was proven that this diagnostic approach should be retained in the semi-Lagrangian advection instead of trying to advect the surface vertical velocity. A kind of an implicit scheme for the surface vertical velocity was formulated: the diagnostic relationship uses the horizontal wind at the future time-level. In order to solve the two above mentioned problems at the same time, a scheme based on the vertical velocity *w* was developed instead on the pseudo-vertical divergence. However, the pseudo-vertical divergence is retained as a spectral and semi-implicit variable. The switch to *w* is made before solving the semi-Lagrangian solution of the equation. Like that, the equation of the vertical momentum is much simpler than in the case of the pseudo-divergence form. The cross-term of the scalar product between the horizontal gradient of *w* and the vertical gradient of the horizontal wind V disappears as well as other four small terms from the source term on the right hand side. Once the future time-level field of *w* is computed at the arrival points including the implicit diagnostic treatment of the surface vertical wind, the pseudo-divergence is restored. The big difficulty with the *w* scheme is that we have to advect a half-level quantity due to the vertical staggering of variables. A rather satisfactory solution was found even for this issue. The academic tests made with the new scheme show that the "chimneys" are removed from the solution. In addition, the *w* scheme is more stable and holds for longer time-steps than the pseudo-divergence scheme. Of course, further improvements of the scheme are still necessary. The most difficult point is how to marry the w scheme with the other kind of vertical divergence variables.

1b) Predictor-Corrector scheme *(J. Vivoda)*

The work on the predictor-corrector (PC) scheme was devoted mainly to the code maintenance. The PC ALADIN NH scheme was almost harmonised with the ECMWF PC hydrostatic scheme at the level of the cycle CY25T1. The harmonisation is done at the level of the data flow and of the most important logical switches driving the iterative steps. Beside the maintenance work an analysis of the anelastic approach in ALADIN was done. It was found that the anelastic approximation is not practically applicable using the Laprise coordinate in a spectral semi-implicit model.

1c) Test of new prognostic variables *(J. Masek)*

As shown by the linear analysis results, more stable scheme can be reached by a change of prognostic variables. The change modifies the linear residuals and in some equations these residuals completely vanish. As a crucial change is the one of the pseudo-vertical divergence, influencing the residuals in the compressible continuity equation. In total, five possible variables of the pseudo-vertical divergence were examined, denoted from *d0* to *d5*. The variable *d0* is the one from the original scheme, where the partial derivative of *w* with respect to the vertical coordinate η is scaled by the time and horizontal constants of the basic state. This one leaves the largest residuum in the compressible continuity equation and is the less stable choice. The variable *d3* is a true vertical divergence (the basic state constants are replaced by variables) and leaves in the continuity equation only the cross-term of the scalar product of the horizontal gradient of orography with the vertical derivative of the horizontal wind *V*. The variables *d1* and *d2* are the intermediate steps to go from *d0* to *d3*. Then, there are variables *d4* and *d5* , which try to combine the remaining terms with the variable *d3* or respectively with *d5* so that the residual in the continuity equation completely vanishes for the adiabatic case. For these choices of prognostic variables the stability and precision were tested in the simplified environment of the idealised mountain flow tests. The tests had an increasing difficulty: the first examined regime was the linear hydrostatic one with a very mild mountain. In the following tests the level of nonlinearity was increasing and the last test was the nonlinear non-hydrostatic regime. As the most promising choice of variable is the variable *d3* and possibly *d4* . The variable *d5* produced a strange looking pattern nearby the top of the model.

1d) Clean introduction of the prognostic variable d4 *(P. Smolikova)*

In connection to what was said above, the variable *d4* is one of the most perspective ones. The use of this variable corresponds to the construction of the Canadian MC2 model. However its clean introduction requires a coding of a new pseudo-prognostic spectral variable (the very first tests in the vertical plane model were made with a provisional code changes), which is technically more difficult. The coding started in Toulouse in spring and was completed in Prague at the end of June. The code is now running and a careful validation of the coded pieces has started.

2. Case studies : CFL versus Lipschitz criteria *(A. Trojakova, R. Brozkova)*

The first part of the study based on the ALPIA type of experiment was completed. The pseudo-academic experiment to compare Eulerian and semi-Lagrangian stability criteria was done for four nested domains, each time increasing twice the horizontal resolution and with a square-root-of-two factor the vertical resolution. The starting domain had 10km horizontal resolution and 867m zequidistant vertical resolution through 26km deep atmosphere. The last examined domain had 1250m horizontal resolution and 306m vertical resolution, keeping the same depth. The experiments were done with 3TL Eulerian and 3TL semi-Lagrangian NH schemes. As outcome, there is now a robust result that the 3TL semi-Lagrangian scheme can be used still with at least double of the Eulerian time-step without meeting Lipschitz criterion. At the same time other shortcomings could have been noticed, especially those related to the ALATNET topic on the formulation of bottom and top boundary conditions. Thanks to this work there are now tools to run such an experiment: to create the academic file, to make the nesting of the domains (academic coupling procedure including the horizontal and vertical interpolators) and to make a post-processing. The ALPIA setup is now being used to make the comparison of ALADIN NH with Meso-NH models. It shall be further used for other tests, for example for the horizontal diffusion scheme.

3. Observations : Evaluation of the impact of balloon drift in sounding measurements *(M. Benko, R. Brozkova)*

The monitoring of the sounding reports taking into account the horizontal drift of the balloons continued. The strange results obtained last time were clarified: there were several bugs in the use of these data. Step by step these mistakes were eliminated, starting from the simple vertical split of the TEMP reports and ending by the use of only raw measured data to exclude any mistake caused by approximations. This strategy paid off and at the end a better quality of the data including the correct position of the balloon was proven as expected. To reach this result it was necessary to use the complete report from the sounding. We had at disposal such reports from the sounding stations Praha-Libus and Poprad-Ganovce. When trying to recompute the balloon drift from the data available at the standard TEMP bulletin as internationally exchanged, the approximation is too crude and leads to mistakes (unless a bug is still found there). In any case the use of the correct balloon position would require that this data enter the international code. Hence, it is not in the near future perspective to use the improved TEMP messages within the data assimilation scheme.

4. New parameterisation of exchanges at sea and lake surface : Gustiness (*M. Bellus, J.F. Geleyn)*

Even if the motivation is a bit less relevant for a quasi-continental domain as ours, the idea was to see how to enhance surface fluxes of heat, moisture and momentum over the sea by low mean wind speed but conditions of strong fluctuations of the actual surface wind owing to moist convection. A formulation of that type (via the sea roughness length) already exists for dry convection and the idea was to see (i) whether the two effects can be harmoniously combined and (ii) whether the moist part can be extended to the land areas and to the whole vertical (something that brings it back to our local preoccupations). Both answers were positive. Furthermore a most simpler (and more robust) formulation than the one anticipated by previous studies was found for problem "(i)", a result that made the "(ii)" extension absolutely straightforward. It remains now to go back to TOGA-COARE measurements for verifying that these several changes did not alter the validity of the original idea. Then further tests, probably in combination with the previous idea concerning the time smoothing of the shallow convection, will have to be performed in a complete ARPEGE framework.

4. In Budapest

Most of the research and development topics were concentrated around the ALATNET scientific plan and described briefly hereafter.

Steluta Alexandru continued her first ALATNET stay in Budapest, and after solving several technical problems the first interesting results were obtained and documented (see her short report about the main conclusions of her first stay elsewhere in this Newsletter). She will continue her work in Budapest in autumn.

Concerning the Hungarian lagged Jb for 3d-var background error statistics a few further investigations were made. To explore the impact of coupling ratio (difference in resolution and domain size between the model and its driving model) in the context of lagged-NMC background error statistics the total energy of ARPEGE-ALADIN/LACE and ALADIN/LACE-ALADIN/HU 6 hour forecast differences were computed for a 30 day period. It's turned out that the energy of ALADIN/LACE-ALADIN/HU differences is indeed smaller on all scales which supports again the earlier idea that with a small coupling ratio we loose too much variance using the lagged-NMC constant coupling strategy. The tuning of the `REDNMC` parameter giving bigger weight to observations (with the increase of standard deviation of background forecast errors leading to smaller weight to the background term) seems to be promising to treat the too small variances following some recently done experiments: even with a strong increase of observation weights the level of noise in the analysed fields is still acceptable.

Important steps were achieved for the local processing of ATOVS data giving a hope that real experiments can be tried in the second part of the year. The following practical problems were solved until now in that topic : An up-to-date observational (CMA) file is required to run the assimilation scheme in operational regime. Up to now, we created the CMA files from an ASCII file using the Mandalay program. This year we adapted the pre-processing packages (*Oulan* and *Bator*) used at Météo-France to create the CMA file from our local observational files (in NetCDF format) for the variational assimilation. In addition to the SYNOP and the radiosonde (TEMP) data, satellite data (ATOVS) received from our HRPT antenna were added to the observational file. We perform a direct read-out of the ATOVS data (level 1-C HIRS and AMSU-A) pre-processed by *AAPP* (ATOVS and AVHRR Pre-processing Package). ODB files are created using a chain of procedures as follows: *Oulan*, *Bator* and *cma2odb*. At the moment we are implementing the *batodb* package (that creates the ODB file from the output of the *Oulan* program) as well as the programs for the computation of the bias coefficient for the satellite data.

We participated in the 3rd ALATNET seminar in Kranjska-Gora : one teacher and one student were representing the Hungarian Meteorological Service at this important event of the ALATNET project.

The paper about the sensitivity of soil texture to the ALADIN forecast was completed and it will appear in the journal *Idojaras* very soon.

Hungarian Meteorological Service has initiated a two month research stay to be realised in Budapest. Piet Termonia was selected as the best candidate and will work together with Gabor Radnoti and with a university student on coupling problems (details are anticipated in the next Newsletter).

5. In Ljubljana

ALATNET student Raluca Radu continued her stay in Ljubljana dealing mainly with the problematic of spectral coupling.

A lot of efforts were put to the organization of 3rd ALATNET Seminar "on Numerical Methods and NWP applications", held in Kranjska Gora, Slovenia, between May 27 and June 1, 2002.