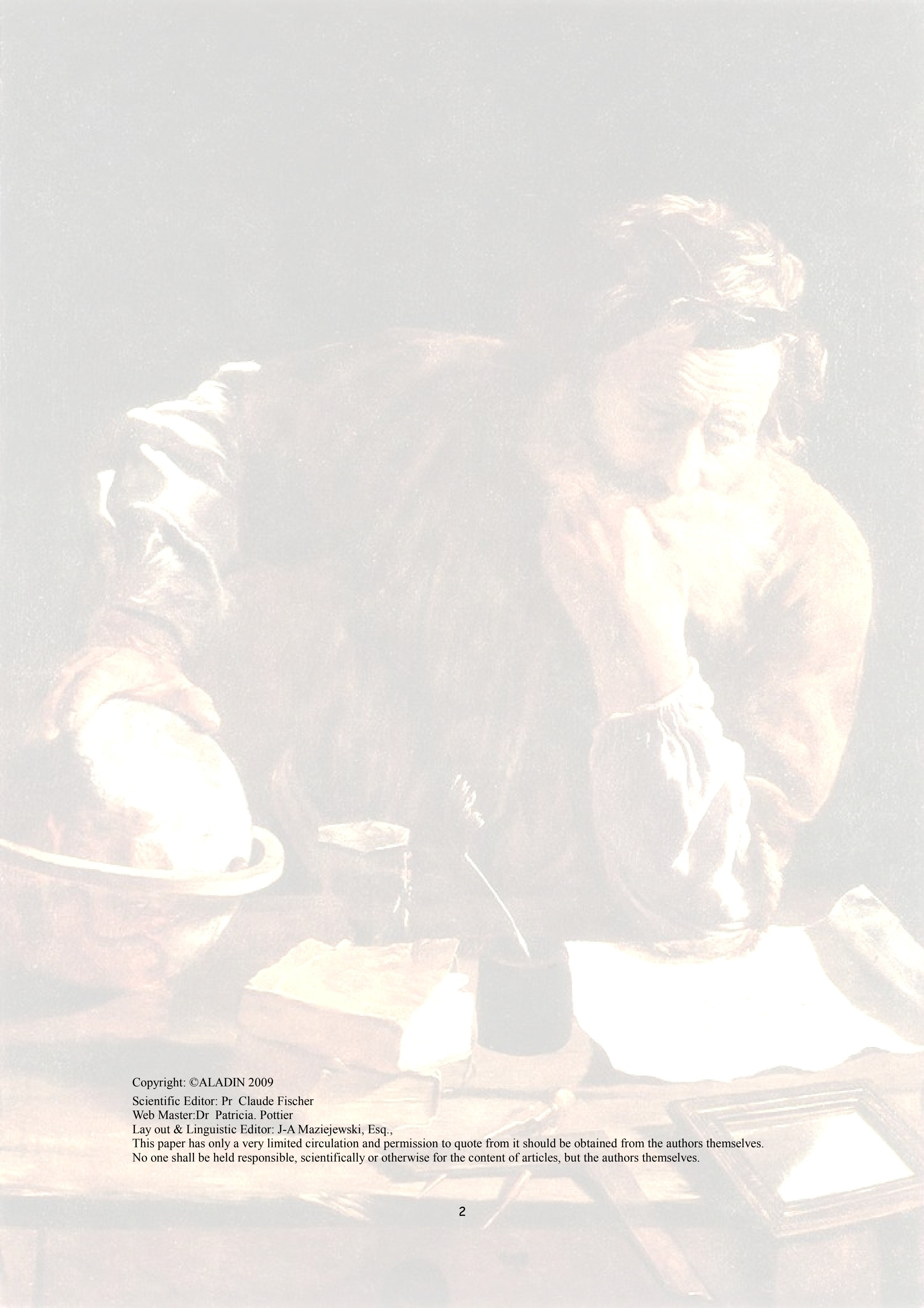
1st semester 2010

ALADIN NEWSLETTER 38



CONTENT

1. EDITORIAL

1.1. Foreword

Taking into account the continuous decrease of contributions over the last years, a reshaping of the format of the newsletter is proposed. The core idea is to move towards an e-zine format, allowing much more freedom about the content of individual articles (targeting either operations, or R&D activities, nationally or transversally to the Programme).

The "operations" and "R&D" sections, which proved to be fairly difficult to fill in, in recent past, would be replaced by a single section of "operational and R&D activities in the Programme". This Section would contain any of the above-mentioned contributions, based on a more "on-offer" logic (as opposed to an "on-demand" approach as in the past).

Teams willing to promote their work will therefore be able to continue to contribute with status notes about the evolution of their applications and/or short scientific notes - which sometimes could be understood as preparatory notes to a peer-reviewed paper.

The status about cycles and Arpège operations, as well as the Foreword text, would remain, when relevant.

The Sections about "papers" and "PHD studies" will remain; the "papers" section will specifically focus on advertising accepted papers; the "PHD" section will remain focused on on-going PHD work at any partner institute.

The Support Team will continue to regularly advertise partners to contribute to the ALADIN e-zine. However, each release will be closed at a given date, and its content at that date will constitute the corresponding version

C. Fischer & The Support Team

1.2. EVENTS

ALARO-1 Working days, Budapest, Hungary, 16 – 19 February 2010

N. Pristov

ALARO-1 Working days were organized by the ALADIN PM, the Area Leader for Physics of RC LACE and hosted by the Hungarian Meteorological Service. 25 participants from 13 countries (ALADIN, LACE, HIRLAM consortia and Russia) came together to spread the knowledge about the ALARO, to discuss and start actions for further developments.

Presentations were focused on overview of current developments: (moist) turbulence and diffusive transport, radiative and radiative-cloud issues, condensation/evaporation associated processes including also deep convection. In few additional presentations general and connected topics were presented (physical-dynamical interplay , time step organization in physics computation, DDH). Participants from eight countries already using ALARO-0 reported about their experience, local implementations and evaluation. During the two exercise sessions participants became more familiar with the process of the code developing and maintaining.

The method (named TOUCANS) how to treat moist turbulence and the associated diffusive vertical transport of enthalpy and moisture under its three phases (shallow convection) was described. Some parts are already coded, on the other hand some scientific questions are still to be solved. Enhancement of the the prognostic description of convective vertical velocity is allowing us to go on with the 3MT concept (even down to kilometric scales). It can be pointed out that this concept is also in line with the research on the European level. Implementation of more complete description of microphysics process (including prognostic graupel) has started with the extraction of 28 processes from ICE3, at the same time additional problems have been identified.

During the discussion it was stressed that the validation of ALARO-1 developments would not be easy task because all of these developments have to be tested together. For this purpose a good diagnostics environment and validation tools are essential.

More information can be found at the following address: http://www.rclace.eu/?page=128

Acknowledgments are going to HMS for hosting and RC LACE for financial support.



1.3. ANNOUNCEMENTS

PAC ALADIN: 30 November 2010, Budapest, Hungary.

GA ALADIN Partners: 14-15 December 2010, Prague, Czech Republic.

ALADIN-HIRLAM WORKSHOP: 5-8 April 2011, Norrköping, Sweden.

2. OPERATIONS

2.1. CYCLES

C. Fischer

CY36T2: this cycle has been prepared from early May through June. It has been declared on August 20, 2010.

Content:

◇ Assimilation:

o Cleaning of Neural Network routines for AIRS (V. Guidard)

o Adaptation of code to use the ECMWF bias correction for radiosonde and SYNOP at Météo-France (P. Moll)

o code cleaning including upgrade of the use of Atmospheric Motion Vectors and Scatterometer data with respect to ECMWF use, which should be easily extended to the use of other types of satellite data (information of ODB columns: gen-centre, gen_subcentre and datastream in sathdr table,...), one bug fix playing a role in a Scatterometer diagnostic and in the a-priori choice of the 2 solutions among 4 when these are available (C. Payan)

o aelous bufr decoding for ODB (C. Payan)

o Microwave radiances:

◇ Addition of emissivity parameterization using a Lambertian approximation for refractivity (F. Karbou) and compare with the specular hypothesis,

o Infrared radiances:

◇ Computation of cloud top pressures for cloudy IASI radiances (performed once during screening with a different formulation than in the IFS, V. Guidard and N. Fourrié). Same development already is operational for AIRS.

◇ Introduction of an alternative cloud detection method for AIRS and IASI (MMR code from Thomas Auligné), unless similar work planned at ECMWF (V. Guidard or N. Fourrié) – to be confirmed

o Snow analysis updated code in CANARI (F. Taillefer)

o Catch-up of code for radar reflectivity if not already in the "_bf" branch of CY36T1 (E. Wattrelot)

o Finalization of the Optimal Interpolation code within the SURFEX framework (so-called "OI_main" code); the core part of this code, which is to replace the old ISBA surface analysis code in CANARI, already is introduced in CY36T1 (F. Taillefer & J.-F. Mahfouf)

◇ Arpège/Aladin physics:

o Adaptations for using 3MT (modular multi-scale microphysics/turbulence) – J.-M. Piriou

◇ Arpège simplified physics schemes (O. Rivière):

o Modified gravity wave drag scheme (by ignoring the perturbations of some terms)

o New large scale precipitation scheme: adjustment Smith scheme (Qv => Qv*, Ql*, Qi*, cloud fraction) followed by auto-conversion and precipitation of all condensed excess (Qr*)

o Convection scheme based on a simplified Betts-Miller scheme

◇ Arome:

o Implementation of DrHook in mpa/mse/surfex/xrd (excluding the mpl part of xrd)

◇ Alaro:

o Minor portability aspects

◇ Various optimization aspects:

o 4D-VAR for NEC/SX9, based on the work in early 2010 (E. Sevault, R. El Khatib, P. Moll) o Arpège/Arome overall optimisations (vectorization, overhead reductions) (R. El Khatib)

o EDKF scheme on NEC/SX9 - if not already present in the "_bf" branch of CY36T1 (Y. Seity)

o Corrected (the present code is hard-coded for IBM thus unusable for NEC) and upgraded automatic NPROMA optimization for LAM (considering minimization of memory conflicts, optimal distribution with respect to given Open-MP threads, optimization with respect to vector lengths/size of the scalar cache,...) by F. Vana.

◇ Use of Ecoclimap-derived orography and land/sea mask in configuration 923 (via a PGD file written in FA format) (F. Taillefer, S. Riette, K. Essaouini)

◇ Use of SST/OSTIA in Arpège, Aladin and Arome (F. Taillefer)

CY37: the decision is to build this cycle from end-August through mid-October; the pre-cycle has been sent back to Reading on October 26th.

- Catch-up of some late E-suite changes in Arpège and Arome
- Blending FA file optimization (J. Mašek)
- IFS contribution CY36R4 (August sending)

CY37T1: first quarter of 2011 ? provisional content:

- Arpège/Aladin upper-air physics:

o 3D aspects for the transport of dust (M. Mokhtari and Y. Bouteloup): dry sedimentation, wet deposition, coupling with convection and radiation

- Arpège simplified physics (O. Rivière):

o Improvements for vertical diffusion and stratiform precipitations; TL/AD of convection Arome and Aladin surface scheme: version 7 of SURFEX (if ready in time, otherwise for a CY37T2 or CY38):

o Open-MP adaptations and other I/O optimizations

o Scientific content: improvements for the dust model (Mohamed Mokhtari)

- Alaro physics:

o Alaro turbulence scheme (TOUCANS) - a major update (the one originally scheduled for CY36T2)

o Bugfix for 3MT convection downdraft

o 2D horizontal extension of a vertical turbulence scheme (for the moment complying only with TOUCANS-QNSE, but the same dataflow can be used by any other vertical diffusion scheme...)

o Updated NSPLITHOI=1 option to act like a horizontal smoother to physics

o NWLAG=4, NTLAG=4 and NSVDLAG=4 options with %LPHYLIN attribute of GFL arrays allowing different interpolation of physics from the one applied to advected model quantity.

- Adaptation of configuration 901 (conversion IFS to Arpège historical files) to GRIB2 upper-air input fields (Mate Mile & Jean-Marc Audoin)

2.2. FRANCE

Stein J. (DP/PREVI/COMPAS)

The ARPEGE e-suite, tested from autumn 2009 to spring 2010, corresponds to an increase of the horizontal resolution which is equal to 10 km over France and 60 km over New-Zealand and of the vertical resolution (70 levels) mainly in the troposphere. The time step is reduced to 10 min. The uniform resolution of the analysis is 60 km and corresponds to the lowest resolution of the simulation. New weights of the observations and the first guess are used in the 4DVAR assimilation scheme, the covariances of the assimilations come from an ensemble of data assimilation and a new linearized microphysical scheme is used during the assimilation process. The density of the assimilated satellite brightness temperatures is multiplied by 3, 10 supplementary IASI channels and the AMSU-A and HIRS soundings of the satellite NOAA19 are used in ARPEGE. The TKE advection is taken into account in the temporal evolution of TKE. The diagnostic wind gustiness is deduced from 10m wind and TKE.

The objective verification of this e-suite shows an improvement in the troposphere of the scores over Europe and the extra tropical domains when the reference is given either by the radio soundings or by the ECMWF analysis. For the geopotential heights, the improvement reaches 0.5m at 500 hPa at a lead time of 48 hours et more than 1m one day after. These results are statistically significant only for the large extra tropical domains (Figure 1). The stratospheric worsening is due to the variational bias correction for the increased number of satellite observations of the e-suite.

This worsening is seen as an improvement if the reference is the analysis of the ECMWF.

The temperature improvement in the troposphere is of the order of 0.1 K in the low troposphere and the jets errors are also reduced of 0.4m/s. The comparison with the surface observations do not provide any important and significant change.

The subjective verification of forecasters leads to the same conclusions: the forecasts are improved for lead times larger than 2 days. The most important storms of 2009 and 2010 are predicted with a quality equivalent to the operational model but the the successive runs are more stable.

The ALADIN–FRANCE model also uses the new satellite data and with the same higher resolution. Its vertical resolution is the same as ARPEGE and the horizontal resolution is increased to 7.5 km over the western Europe. The same improvement as for ARPEGE is recovered for the ALADIN-FRANCE model.

The AROME model is now directly coupled to the ARPEGE model every hours, a damping toward the ARPEGE fields is applied in the levels such that Pressure<110hPa. The vertical resolution (60 levels) is stronger than the ARPEGE resolution in the troposphere but weaker in the stratosphere. AROME assimilates the same satellite data as ARPEGE and ALADIN. It also assimilate the reflectivities observed by the French radar network. Only the turbulent fluxes of conservative variables are computed in the turbulence scheme and the shallow convection scheme of the up drafts is changed. A slow sedimentation speed is included in the microphysical scheme for the fog. These modifications lead to neutral scores for the AROME forecasts. The QPF are of the same quality but the convection was not active during the e-suite validation period mainly in winter.

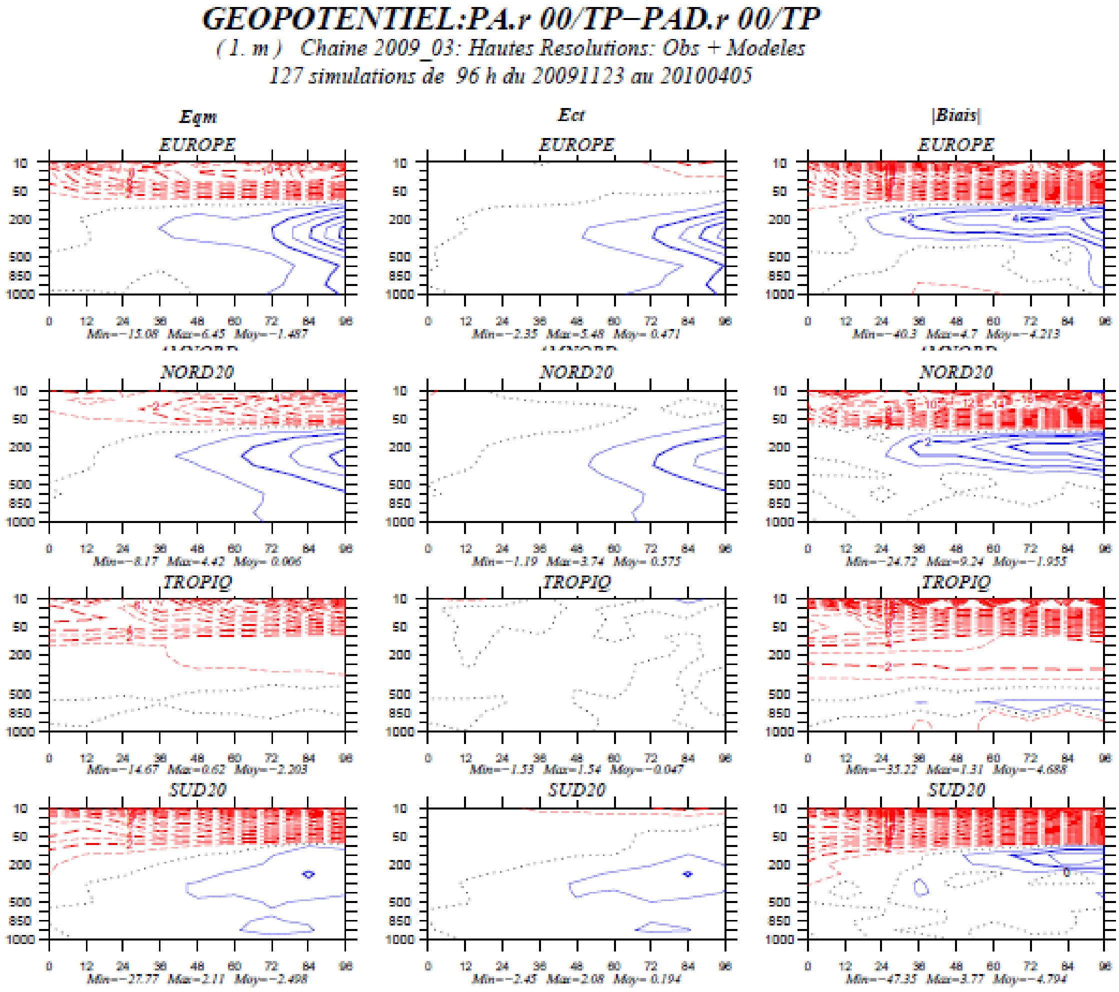
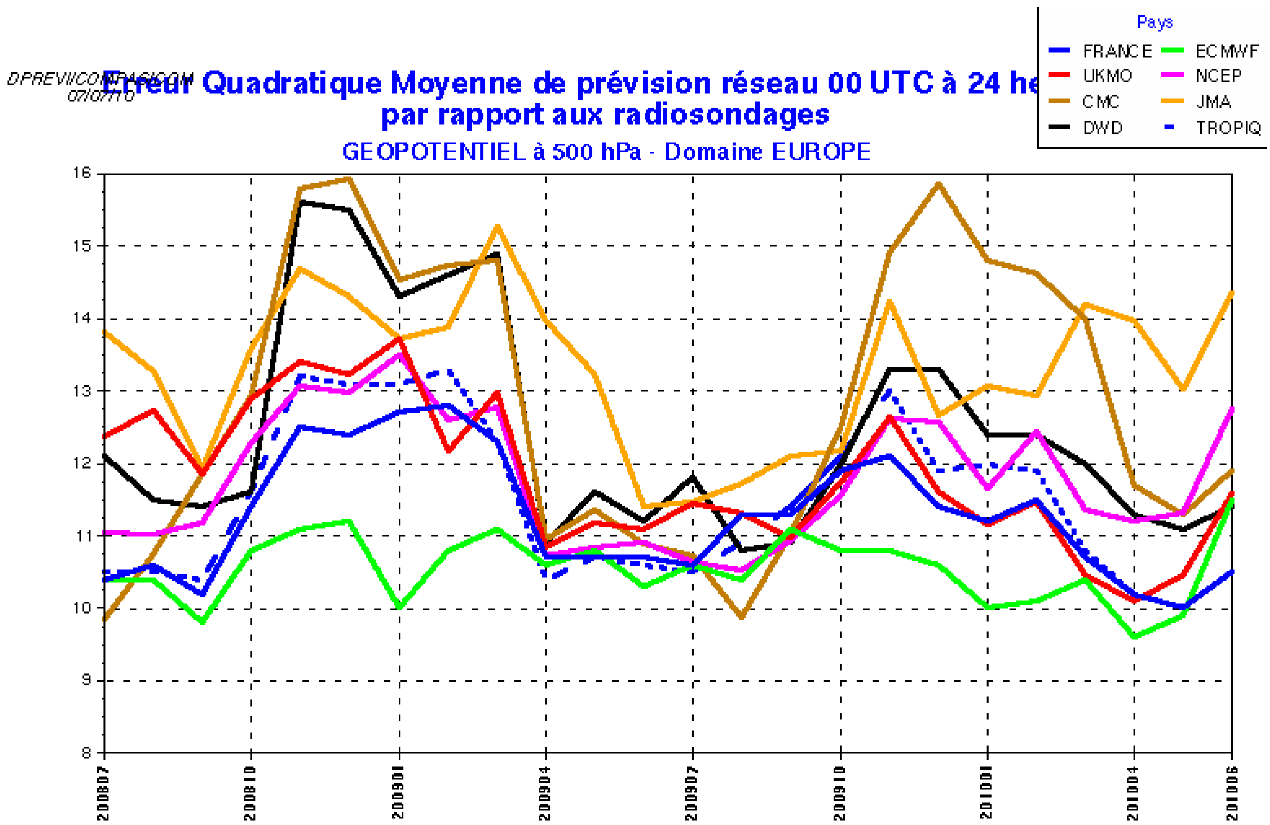


Figure 1: Difference of the scores realized by the operational version of ARPEGE and its e-suite. The reference is provided by the radio soundings measurements. The scores are computed for the geopotential heights: Bias (right), standard deviation (centre) and root mean squared error (left) for different domains: from top to bottom Europe, North 20, Tropical area, South 20. The isolines are plotted every meter and the blue ones correspond to an improvement and the red ones to a worsening.



ARPEGE tropospheric scores (Z500 at 24 h) over Europe North 20.

2.3. SLOVAKIA

E. Janikova

HARDWARE

Computer [no change]:

IBM p690 Regatta

32 CPUs of 1.7 GHz

32 GB RAM

1.5 TB disk array

Archiving facility [no change]:

IBM Total Storage 3584 Tape Library with IBM Tivoli Storage Manager current capacity of tapes around 30 TB (plus 10 TB of external tapes) used for automatic storage of ICMSH files, GRIBs and selected products

OPERATIONAL SUITE

Domain and geometry [no change]:

309 x 277 points (C + I zone)

dx = 9.0 km

quadratic truncation

37 vertical levels

Operational model version [no change]:

cy32t1 - ALARO with 3MT + bug correction by J.Masek

SLHD scheme

Integrations [no change]:

4 runs per day (00, 06 and 12 UTC up to 72 hours; 18 UTC up to 60 hours)

Pseudo assimilation cycle (upper air spectral blending):

4 runs per day (00, 06, 12 and 18 UTC up to 6 hours with long cut-off ARPEGE LBC)

assimilation guess is used to copy hydrometeors, TKE and 3MT prognostic fields; remaining 3D prognostic fields (temperature, wind, humidity) are blended with ARPEGE analysis.

surface analysis is interpolated from ARPEGE

ARPEGE LBC DOWNLOAD

Both assimilation and production LBC are downloaded 4 times per day. Primary channel is internet connection to BDPE. Backup channel is routed via ECMWF and ZAMG (sequence of RMDCN and internet). Capacity of internet lines is sufficient.

Fixing bug in xrd library causing X-pattern, J. Mašek

Bug in packing of spectral fields written to FA file was localized. It was hidden in xrd library for many years and under specific circumstances caused so called X-pattern. Fix was first prepared and validated in operational ALADIN/SHMU version based on cycle 35t1, and then it was phased into official ARPEGE/ALADIN cycle 36t1bf5. Detailed bug report can be found on RC LACE forum:
http://www.rclace.eu/forum/-> Bug and Problem Reports -> X-pattern produced by configuration ee927

Fig.: X-pattern produced by blending procedure in v-wind component on lowest model level, projected to 10m wind field.

Main operational highlights

12/09 – 02/10 Gradual transfer of operative suite to new server

12/09 – 02/10 Transfer of web-based monitoring system to new server

15/03/10 New procedure to include local orography to clim-files

08/03/10 Packing in historical files switched off (NVGRIB=0) to avoid X-pattern

08/10/09 Migration to new visualization software

15/07/09 Optimization of operative suite

17/06/09 New gribex000370 implementation into suite

2.4. SLOVENIA

N. Pristov

Computer system SGI ALTIX ICE 8200

No changes (see ALADIN Newsletters 37).

OPERATIONAL SUITE

No changes (see ALADIN Newsletters 37).

OTHER OPERATIONAL ACTIVITIES

- parallel suite aos04 (4.4 km) – no changes
- assimilation cycle (4.4 km) – aos04da running on daily basis
  - same setup as in parallel suite (4.4 km)
  - 6-h forecasts as first guess (long cut-off LBC's from ARPEGE)
  - SST analysis from ARPEGE (with BLENDSUR)
  - initialization of hydrometeors TKE and 3MT prognostic fields from 6-h forecast
  - CANARI surface analysis using surface observations (T and RH at 2 m),
  - 3DVar upper air analysis using OPLACE data and local observations (SYNOP)

- pre-operational suite aos09ecmwf, differences compared to operational suite (aos09) are:
  - four runs per day: 00, 06, 12, 18 UTC (all up to 72h)
  - initial and lateral boundary conditions from ECMWF/IFS

Some problems appeared with the daily runs of the ALADIN model coupled with ECMWF/IFS. The model integration occasionally aborted, usually because of the strange values of the orography field. It turned out that the cause was sftp transfer of ALADIN LBC files from ECMWF/IFS via internet where the use of compression causes the corruption of the files.

The setup of the assimilation cycle is tested and ready to be inserted into pre-operational daily production. This is also occasion to renew the current organization of operational and parallel suites. Migration has started in July and is planed to be completed in September.

A major problem was encountered in the assimilation cycle, where there is a bug in reading of the guess field (for surface temperature). After diagnosing that switching off grib packing is not causing abort, the bug was circumvented by modifying the code (no packing option for all surface variables).

List of important changes

04.02.2010

daily runs of ALADIN/SI model coupled with LBC data from ECMWF/IFS

24.03.2010

compression of the files during sftp transfer from ECMWF is not used any more

11.05.2010

the switch to higher resolution LBC data for LACE from ARPEGE

2.5. Application of Chapeau/Aladin in operational classroom

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[1] University of Ljubljana, Faculty of Mathematics and Physics

[2] Environmental Agency of Slovenia, Meteorological office

2.5.1. Introduction

The Department of Physics at the Faculty of Mathematics and Physics at the University of Ljubljana is carrying out the only undergraduate and graduate program in meteorology in Slovenia. A major fourth-year course is "Weather analysis and forecasting" which presently runs throughout the year including four hours of the classroom lessons, one hour of seminar and two hours of exercise per week. A special attention in the lessons has been given to the description of the Aladin model and the operational model products available via the Environmental Agency of Slovenia (ARSO) have been used in the teaching process.

In the spring term of the academic year 2009/2010 we implemented the Chapeau/Aladin model and prepared initial and lateral boundary conditions for selected weather cases for students to run the model, to analyze results and to prepare written reports. The goal of the Chapeau/Aladin lab was to learn technical aspects of NWP model implementation, to learn about post-processing of model results and to apply theoretical lessons in real case studies. Selected cases were characterized by extreme weather which allowed easier diagnosis and discussion of dominant circulation patterns and application of theoretical and conceptual models in real cases.

Below we summarize technical details of the minimal computing system used for the model implementation, organization of the student lab and provide excerpts from their reports.

2.5.2. Technical characteristics

The Chapeau/Aladin package comes with the user guide written by Daan Degrauwe. We used the version dated February 4, 2010 and it worked well. The model was installed on Intel x64 platform with Linux OS – Debian Lenny distribution.

Post-processing and visualization of the model results were performed by the open source software R. Its use with Chapeau/Aladin requires the Rfa package prepared and made available by Alex Deckmyn. We followed the installation procedure described in the document "Rfa and geogrid: R packages for analysis of ALADIN files" by Alex Deckmyn, dated 23 December, 2008. Based on difficulties experienced with the installation of the Rfa package we suggest to add to the instruction file a brief description and installation instructions for the mapNew package (additional map database) which is required by the Rfa package. Due to conversions of data structures to big endian inside the Fortran code, that is a part of Rfa, we needed to compile the Rfa/R package with the Intel compiler using the instruction ARCH=LX_ifort R CMD INSTALL Rfa_3.0.6.tar.gz. When the GNU compiler was used as ARCH=LX_gfortran R CMD INSTALL Rfa_3.0.6.tar.gz the Rfa package was not working correctly even when R was run with the environment variable export GFORTRAN_CONVERT_UNIT='big_endian:10'.

The applied sequence of installations steps which in our case provided optimal installation and correctly working software can be provided upon request.

2.5.3. Organisation of the Chapeau/Aladin lab

The first time Chapeau/Aladin lab involved nine students and it lasted little over a month with a few extra weeks allowed for the report submission. Students otherwise had a permanent access to the computer classroom and could spend any time there or work remotely.

A common class account was created under which the model was installed and all scripts stored. Each student had an own directory to copy necessary scripts to run the model and to process the outputs. A short instruction manual was prepared which described the sequence of steps needed to run the model, to run the R and to make the basic manipulation of the prognostic fields and their visualization. During this lab most of students for the first time used the Linux system, the R package and scripts. Therefore the teacher ´s presence and support is crucial. (The fact that some students keep playing games even while the teacher is talking is a topic for another kind of paper.)

In advance we prepared a model domain to be used by all students which approximately equals the operational Aladin-SI domain. Initial and boundary conditions were prepared from the ARPEGE like in the case of the operational model. Default simulations thus reproduced the operational ARSO results. Three selected weather cases included extreme bora wind and precipitation in March 2010, extreme precipitation around Christmas 2009 and convective storms in August 2009. Three groups, each involving three students, were formed to work together on a common case. Each group member had to submit own report up to 10 pages long including answers to three questions. The first question for each group was the same: to describe dominant atmospheric process in selected case and to choose, study and discuss the most relevant variables and levels. Other two questions were case dependent. For example, for the August storms we requested students to quantify how the model predicted convection and to check differences between the forecast of different lengths. In selected grid points they needed to extract profiles of model prognostic variables (pseudo-temps) and to estimate theoretically defined vertical velocity from their own calculation of the convective available potential energy. The estimates of *w* had to be compared with vertical velocities diagnosed directly in the model by Full-Pos and available in the post-processed pressure-level files. The importance here was on discussing the differences.

Such comparison is presented in Fig. 1 as performed by Matic Šavli.

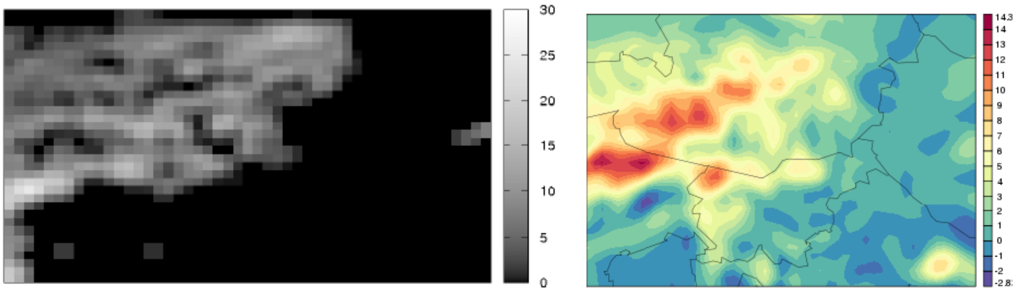

Figure 1. Left: Vertical velocity (in m/s) estimated as *sqrt(2*CAPE)* from own computation of CAPE from 1-hr forecast started on 22 August, 12 UTC. Right: vertical velocity obtained from the model post-processed (Full-Pos) ω field and transformed to *w* using the relationship $\omega=-\rho g w$. The area shown in two panels is the same. From the report by Matic Šavli.

In Fig. 2. we present a figure from a report by Blaž Šter who studied the severe bora case and compared forecasts of different length in the Vipava valley where the damage caused by storm winds was large. He wrote the following discussion of Fig. 2: "*We notice right away that maximal forecasted wind speeds during early hours of forecasts are much smaller than forecasted by earlier runs. It takes about 2-3 hrs for the forecast to "catch up" with earlier simulations. We concluded that the cause of this behaviour is in the assimilation. Each time we started a new experiment we used new initial conditions which were computed by another model which has a lower horizontal resolution and consequently more poor representation of orography. The orography is the key for the bora. Due to poorer orography, the model which produced initial conditions did not "see" the bora. When these boraless fields were applied in Aladin, it did not "see" enough strong bora during the first few hours. In addition, no wind observation from the studied bora region was used in the assimilation so that the bora influence could not come directly into initial conditions.*"

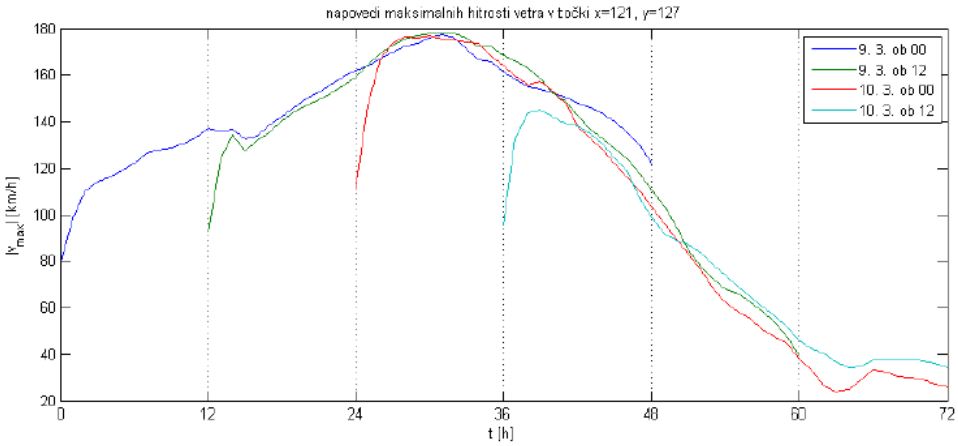

Figure 2. Maximal wind velocity of the bora wind at a grid point in the Vipava valley (southern Slovenia). Four different curves correspond to four forecasts starting on 9 March, 00 UTC (blue), 9 March, 12 UTC (green), 10 March, 00 UTC (red) and 10 March, 12 UTC (turquoise). From the report by Blaž Šter.

2.5.4. Concluding remarks

Fifteen years after the first author successfully run Chagal to visualize first "own" Aladin run on the Cray computer of Météo-France in Toulouse the development of computers and modelling allows to run Aladin on a laptop by an average undergraduate student. Global developments in NWP has made it possible for anyone knowing basic computing to download and to run mesoscale models in real time, for example using the WRF model and in real-time available initial and lateral boundary conditions from the global NCEP model. Most scripts most of time work well and beginner modellers spend most of time on producing nice plots. However, it has always been the case that a difficult part is not to get a model running but to understand it and to advance its products and use in operations.

At the undergraduate level we aim to teach students basics of the practical work carried out by modellers at NMSs who provide pleasant to eye and friendly to use plots to forecasters. Numerical lab involving operational model also makes students aware of broadness of work in NWP. Getting own hands on model outputs is a best way to refresh and memorize theoretical aspect of the model formulation and to learn practical aspects of handling the model outputs in the operational environment. Such a lab inevitably must presume students use the model as a black box. Shortage of time and numerous technical details which need to be learned make anything else impossible. Just handling the scripts and visualizing outputs require practically a permanent teacher's help. Discussion of the model results and application of lessons heard in the classroom is strongly dependent on the supervision. It is unrealistic to expect that significant feedback useful for the model development feeds back from the University to NMSs. Such feedback is however fully possible within more advanced labs, for example carefully prepared and supervised master-level projects between the NMSs and Universities which last for a couple of months and involve more independent work

3. RESEARCH & DEVELOPMENTS

3.1. SLOVAKIA

E. Janikova

During his stay in Budapest, Michal Neštiak was investigating the use of non-GTS SYNOP reports in the ALADIN/HU CANARI + 3D-VAR system.

The aim of his work was to assess the impact of non-GTS SYNOP reports from LACE countries (LSND) in data assimilation. Experimental period was from 10 to 20 May 2005. ALADIN CY30T1 was used. Scores are generally very neutral near the surface. There are some differences on higher levels. The differences can be found for temperature and humidity scores, but the impact is not relevant. For some levels and variables LSND is slightly better for some others it is worse. Scores against the ARPEGE analysis show some improvement for LSND for almost all the variables for the 00 UTC runs, but practically there are no differences. For the 12 UTC run, the impact is not clear and it seems that the quality of 42-48 hour forecast is even worse. Because it is only 10 days comparison it is not possible to draw definitive conclusions. Bigger impact of surface assimilation is expected during winter and spring, where the wrong snow coverage has big impact on ground temperature. More information can be found in the report

http://rclace.eu/File/Data_Assimilation/2009/report_MN_2009.pdf

Michal Neštiak used knowledge acquired from LACE stage in Budapest for successful none-operative tests of CANARI on cycle 35T1 in Slovakia. Results were compared against CHMI and OMSZ. Tests were done on 9km current operative resolution. Preliminary tests were done on new planed resolution and on special high resolution domain prepared for traffic service company. Currently we are preparing new par suite with CANARI.

Jozef Vivoda works on new B-spline based finite element vertical operators. The existing approach of definition of finite element (FE) operators requires introduction of additional artificial boundary conditions. New approach has been developed which overcomes this problem. The set of basis functions (splines) is defined over the set of knots (points in eta domain). The number of knots fulfills following relation

knots = model_levels + # BCs + order_of_splines.

New approach exploits all input degrees of freedom and does not require any additional artificial condition to be fulfilled. A function can be represented by different set of basis functions as its derivative or its integral.

During his stay in Prague, Ján Mašek focused on the discretization of horizontal PGF(Pressure Gradient Force) in ALADIN-NH. Well known problem of terrain following coordinate is almost complete cancellation of two big terms (pressure and geopotential gradients along sloped model levels) in computation of horizontal PGF above steep orography. Numerical evaluation of resulting PGF in discretized model is therefore connected to considerable loss of accuracy. Content of the stay was error analysis for current ALADIN-NH PGF discretization in idealized cases (2D vertical plane, sigma coordinate, resting and hydrostatically balanced isothermal or polytropic atmosphere, bell shaped mountain). It was shown that while in isothermal case PGF error is zero, in more general polytropic case it consists of two contributions – error coming from vertical discretization (vanishes in the limit of infinite number of levels) and error coming from spectral fitting of nonlinear terms (remains nonzero as the number of levels tends to infinity). Second contribution can be minimized either by using higher truncation for prognostic fields than for orography (linear grid with quadratically truncated orography gives very satisfactory results) or by suitable orography filtering.

Planned future steps are single timestep experiments with vertical plane 2D model in order to confirm semi-analytical results and testing some alternative PGF discretizations (e.g. Simmons and

Jiabin 1990 PG scheme or dirty coded finite volume approach).

The verification of text forecasts provides helpful feedback to forecasters and thereby helps to improve their work. On call of SHMI forecasting office a new, more detailed tool of text forecast verification has been developed by Milan Káčer. It is a package of several object-oriented JAVA classes that is going to replace the old FORTRAN version. In comparison to the latter one, it covers more forecasted elements, deals with more observation data and allows local regional forecasts. The present version of the package enables interactive forecast formulation inputs, database reading/writing as well as statistics of verifications for all forecasts (also 2^{nd}, 3^{rd} and 4^{th} day) globally or categorized by author, day, month…

As the demand for bigger ALADIN-LAEF domain arose, Martin Belluš is setting up a new domain and retuning the blending ratio accordingly. Demand for bigger ALADIN-LAEF domain with better topography representation arose mostly out of two reasons. One of them is inclusion of the whole Black sea (requested by Romania) and coverage of Turkey (as a new ALADIN partner) in the computational ALADIN-LAEF domain. The second reason is the request for the cooperation with GLAMEPS (Grand Limited Area Model Ensemble Prediction System). The main restriction on the other hand is the SBU limitation Austria has at ECMWF's HPC.

New blending ratio according to the higher target resolution and the whole operational breeding-blending cycle for the new ALADIN-LAEF domain is currently under testing procedure.

Additional research will be done to answer the question, whether more profit would be gained from such high resolution ensemble (Δx=10-12km) or rather from increased number of ensemble members at the new domain but necessarily with coarser horizontal resolution (currently the "old" operational setup reads 16 members at Δx = 18km).

Another activity of our group (Richard Habrovský and Ján Kaňák) is application of GII method to calculations of DTHETA2 index with use of EUMETSAT and ALADIN model data, in the framework of retrieval algorithm (Kalman filter). This index was compared with original GII indices (K-index, Lifted index and total precipitable water contant). This DTHETA2 index was used in detail study of severe windstorm over Slovakia and Hungary on 25 June 2008 (to be published).

4. PAPERS and ARTICLES

4.1. Montmerle T. and L. Berre

Use of heterogeneous background error covariance matrices at mesoscale

by Thibaut Montmerle *and Loïk Berre
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Summary

This study focuses on the feasibility of a simultaneous use of different background error covariance matrices at convective scale to make better use of observations linked to precipitation. Multivariate background error covariances have been computed separately for clear air and precipitating columns from an ensemble of AROME forecasts at 2.5 km horizontal resolution. Convection and microphysical processes, which are explicitly resolved, explain in particular the large discrepancies in correlation lengths, error variances and in the coupling between humidity, temperature and divergence errors. Theses results argue in favor of including an heterogeneous background error covariance matrix in AROME incremental 3Dvar. This can be achieved by expressing the analysis increment as the sum of two terms, one for precipitating areas and the other for non-precipitating areas, making use of a grid-point mask. This implies to double the size of the control variable and of the gradient of the cost function. The feasability of this method is shown through single observation experiments.

1 Introduction

The AROME NWP system runs operationally since December 2008 at Météo-France, providing forecast of potentially dangerous meteorological events and of lower tropospheric phenomena at convective scale. This system makes use of cycled assimilation/forecast steps based on a specific 3h Rapid Update Cycles (RUC) configuration (Brousseau *et al.*, 2008). AROME 3DVar uses a climatological multivariate background error covariance matrix (so-called **B** matrix) deduced from an ensemble-based method. As pointed out by Bannister (2008a) , **B** has a profound impact on the analysis, by i) weighting the importance of the a priori state, ii) smoothing and spreading information from observation points, iii) imposing balance between the model control variables. As a consequence, climatological covariances often produce unrealistic increment structures in regions characterized by strong gradients (precipitating fronts, top of boundary layer...), the information that is brought by observations spreading too much towards data sparse areas. Spatial localization and flow-dependency of background error covariances are thus required in order to get increments more adequately balanced and structured in regions characterized by different meteorological behaviors.
By using masks on forecast differences, section 2 presents to which extent modelled covariances can differ in clear air and in precipitating areas. The strongly different behaviors that have been found have lead us to develop an original method allowing to use different background error covariances in those regions. The theoretical aspects of such method, followed by a simple one-observation experiment, are discussed in section 3.

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2 Background error covariance matrices for clear air and precipitating areas

2.1 Computation using an AROME ensemble at mesoscale

Berre (2000) has proposed a multivariate formalism for ALADIN adapted from Parrish *et al.* (1997) and Derber and Bouttier (1999) for global Numerical Weather Prediction (NWP) systems. This formalism uses linear balance relationships between errors of different physical quantities, computed from statistical regressions, with an extra balance relation for specific humidity. The use of spectral regressions allows us to obtain scale-dependent balance relationships that are representative of the area of interest, which is well suited for assimilation purposes at the mesoscale in any domain. The statistical relations read:

$$\begin{array}{rcl} \zeta & = & \zeta \\ \eta & = & \mathcal{M}\mathcal{H}\zeta + \eta_u \\ (T, P_s) & = & \mathcal{N}\mathcal{H}\zeta + \mathcal{P}\eta_u + (T, P_s)_u \\ q & = & \mathcal{Q}\mathcal{H}\zeta + \mathcal{R}\eta_u + \mathcal{S}(T, P_s)_u + q_u \end{array} \tag{1}$$

where $(\zeta, \eta, (T, P_s), q)$ are respectively forecast errors of vorticity, divergence, temperature and surface pressure, and specific humidity, which are the model control variables that are analyzed on model vertical levels; the subscript u stands for unbalanced (total minus balanced) fields. $\mathcal{M}, \mathcal{N}, \mathcal{P}, \mathcal{Q}, \mathcal{R}$ and $\mathcal{S}$ are vertical balance operators relating the spectral vertical profiles of predictors and those of the predictands. $\mathcal{H}$ is a horizontal balance operator that transforms the spectral coefficients of vorticity ζ into those of the balanced geopotential P_b (i.e $P_b = \mathcal{H}\zeta$). Balanced geopotential is supposed to be the balanced part of P_t, which is the linearized mass variable deduced from (T, P_s) by the linearized hydrostatic relationship.

Background error covariances are computed from two 6-member ensembles built with the ALADIN and AROME models at 10 km and 2.5 km horizontal resolution respectively, in cascade from the real time ARPEGE ensemble assimilation that runs operationally at Météo-France since July 2008 (Desroziers *et al.*, 2008). Each member has been computed for 17 precipitating cases chosen from April to July 2008. The ALADIN ensemble includes a perturbed 3DVar step (with perturbed backgrounds and observations), while the AROME ensemble has been conducted in spin-up mode, using the ALADIN ensemble as initial and coupling files. The AROME RUC (Rapid Update Cycle) being based on cycled assimilation/forecast steps every 3 hours (Brousseau *et al.*, 2008), statistics on 3h forecast differences $\varepsilon_b^{kl} = x_b^k - x_b^l$ between members (k, l) have been calculated.
However in this study, contrarily to the operational background error matrix, statistics have been computed separately for precipitating and for clear air areas using forecasts valid at 21 UTC, which corresponds approximately to the maximum of convective activity for the chosen dates. For that purpose, two masks have been built in order to take into account, in each pair of forecast, only profiles whose vertically integrated mixing ratios of precipitating rain do and do not exceed 0.1 $g.kg^{-1}$ respectively. The forecast difference field ε_b^{kl} is thus decomposed in three different terms:

$$\varepsilon_b^{kl} \approx \left[G\delta_{p,p}^{kl}\right]\varepsilon_b^{kl} + \left[G\delta_{np,np}^{kl}\right]\varepsilon_b^{kl} + \left[G\delta_{p,np}^{kl}\right]\varepsilon_b^{kl}$$

where $\delta_{p,p}^{kl}$ ($\delta_{np,np}^{kl}$) is a Kronecker-like operators equal to 1 in common precipitating (non-precipitating) areas between the two compared members (k, l), and equal to 0 elsewhere. In a similar way, $\delta_{p,np}^{kl}$ is equal to 1 in non-common areas. In order to smoothen the spatial structures of these different terms, a gaussian blur G , based on a convolution with a 5x5 kernel, has been applied in addition to these operators.

2.2 Comparisons of statistics obtained for clear air and precipitating regions

2.2.1 Auto-covariances

Figure 1 shows the spectrally averaged vertical profiles of standard deviations of the forecast errors σ_b, as used in the AROME operational suite, and as deduced from the ensemble of precipitating cases. Note that standard deviations are rescaled with respect to their spatial sample size in cases where subdomains have been considered for their computation.

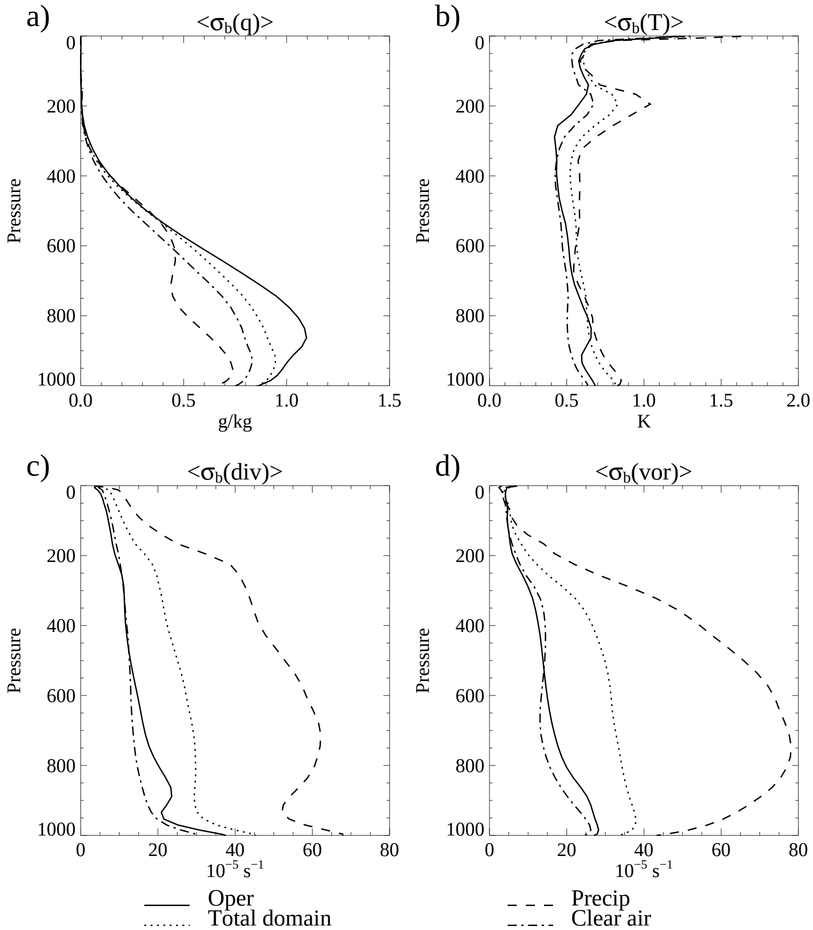


Figure 1: Vertical profiles of mean standard deviation of (a) humidity, (b) temperature and surface pressure, (c) divergence and (d) vorticity forecast errors for AROME over France for the operational version (full line), and deduced from an ensemble of precipitating cases: total domain (dotted line), precipitating (dashed line) and non-precipitating areas (dotted-dashed line).

Smaller values are displayed for q and T over rainy areas, which is explained by the fact that, in this case, only saturated profiles characterized by small dispersion of q and T have been considered in the computation. Two maxima are displayed in the boundary layer and around 600 hPa, denoting variations of the level of free convection and of the cloud top. For this subdomain, values are also much larger at all altitudes for errors of ζ and η, reflecting the important small scale dynamical circulation within precipitating clouds. Variability in the low level convergence

and in the vertical extension of the clouds are in particular shown by the η profile. Statistics obtained by considering only clear air profiles are close to what is used operationally.
To compare horizontal correlations, horizontal length-scales as defined by Daley (1991) have been computed and the results are plotted in Fig. 2. Two times smaller lengthscales (5 vs 10 km approximately) are obtained over rainy areas compare to clear air for q and T. Furthermore for these variables, quasi-invariant values are displayed all over the vertical, contrarily to what is used in AROME operationnally, where lengthscales are increasing with height. This is probably due to the "verticality"of the bi-dimentional mask which is applied at all vertical levels. For ζ and η however, very similar profiles are obtained (not shown). These results indicated that much more localized increments can be obtained in precipitating areas using specific background error covariances. This is of great interest for high density observation networks like radar data or satellite radiances, since the representative scales of the resulting analyses should become much smaller (obviously by also paying attention to correlations between observation errors) and therefore more realistic.

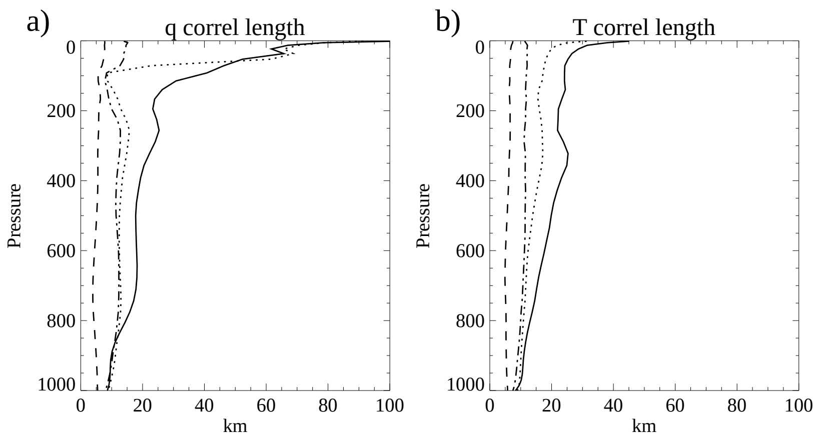


Figure 2: Vertical profiles of horizontal lengthscales (in km) of (a) humidity and (b) temperature forecast errors for AROME over France for the operational version (full line), and deduced from an ensemble of precipitating cases: total domain (dotted line), precipitating (dashed line) and non-precipitating areas (dotted-dashed line).

Signatures of vertical cloud development can be seen mainly on the mean vertical auto-correlations for q errors (and in a less extent for T and ζ) in the mid-troposphere for precipitating areas (not shown). This point denotes stronger vertical mixing within clouds performed by the explicitely resolved convection.

2.2.2 Cross-covariances

Variance ratios are used to compute the relative importance of the balanced and unbalanced terms following the multivariate approach defined in Eq. (1). They are given by the ratio of the variance of each balanced term divided by the total variance of the full field. They indicate the amount of increment for a given variable that will be balanced with increments of other variables.
Fig. 3 shows the vertical distribution of these ratios obtained over rainy and clear air areas for the specific humidity q field. The differences of behaviours between these two areas are striking: in clear air, the total explained variance of q is approximately 10% less balanced and is mainly controlled by the unbalanced mass field $(T, P_s)_u$ up to 400 hPa. On the opposite, the coupling with the unbalanced divergence η_u is much more important in rainy regions up to the

tropopause (Fig. 3.a) and for scales smaller than 100 km (not shown). For these latter regions, a maximum of variance around 800 hPa is explained mostly by η_u but also by $(T, P_s)_u$, and seems to correspond to the level of free convection with a maximum amplitude of convergence and of heating due to diabatic processes. In these precipitating regions, the coupling with balanced geopotential P_b is almost non-existent.

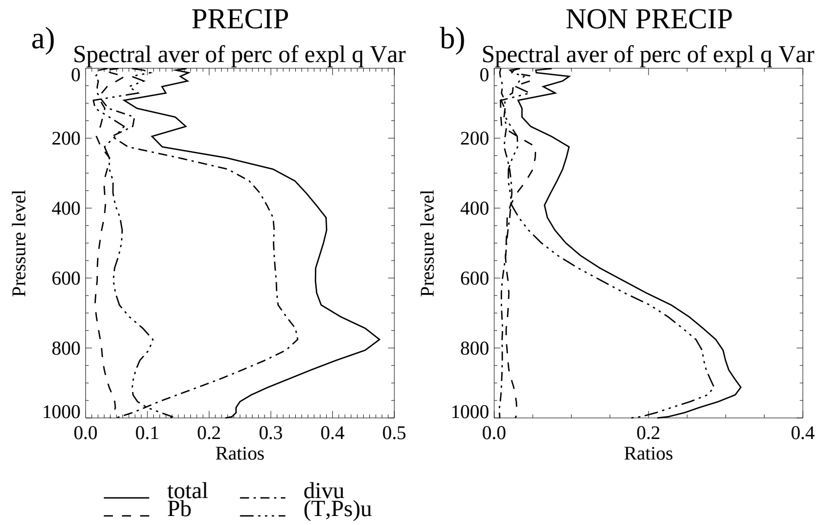


Figure 3: Spectral averages of the percentages of explained specific humidity q error variances as a function of height for AROME, computed over precipitating (left panels) and non-precipitating areas (right panels). P_b stands for the so-called balanced mass and divu for the unbalanced divergence (see text for details).

For rainy and clear air areas, the main predictors for the computation of the specific humidity forecast error covariances are thus respectively the unbalanced divergence η_u and the unbalanced temperature and surface pressure $(T, P_s)_u$. For rainy areas, spectrally averaged covariances between q and the total divergence η is coherent with the supply of humidity in convergent system: a positive increment of humidity at 800 hPa will result of a strong convergence below and divergence above (not shown). On the contrary, such a humidification has almost no impact on wind field in clear air conditions, appart from a weak local divergence. Intermediate behaviour is found for the operational background error covariances, which indicates that, in this case, increments are often balanced in a suboptimal way, either in precipitating (where the $q - \eta$ coupling is too weak) or in non-precipitating areas (where the $q - \eta$ coupling is too strong). The strongly different behaviors that have been shown in this section, which are directely linked to convection processes that are resolved explicitely in AROME, confirm the interest of using simultaneously different statistics in regions with different meteorological patterns. Such a method would indeed allow increments to be more adequately balanced and structured in those regions, and thus to make better use of observations in a data assimilation system.

3 Implementation of a heterogeneous B matrix in a 3DVAR

3.1 Theoretical aspects

Following an initial idea by Courtier *et al.* (1998) , we propose here to express the **B** matrix as a linear combination of two terms, each term characterizing non precipitating (*np* subscript) and precipitating (*p* subscript) areas respectively:

$$\mathbf{B} = \alpha^{\mathbf{1/2}} \mathbf{B_{np}} \alpha^{\mathbf{T/2}} + \beta^{\mathbf{1/2}} \mathbf{B_p} \beta^{\mathbf{T/2}} \tag{2}$$

which can also be expressed as:

$$\mathbf{B} = \mathbf{B^{1/2}}\mathbf{B^{T/2}} = \begin{pmatrix} \alpha^{1/2}\mathbf{B_{np}^{1/2}} & \beta^{1/2}\mathbf{B_{p}^{1/2}} \end{pmatrix} \begin{pmatrix} \mathbf{B_{np}^{T/2}}\alpha^{\mathbf{T/2}} \\ \mathbf{B_{p}^{T/2}}\beta^{\mathbf{T/2}} \end{pmatrix} \quad (3)$$

α and β define the areas where the non-precipitating and the precipitating statistics are applied respectively. These operators are based on 2D grid point masks that could be deduced from radar observations. The elliptic truncation used in ALADIN (Radnóti and et al., 1996), and consequently AROME, ensures a smooth transition of increment structures between areas that use different statistics, thanks to the final use of Fourier transform in these operators. Theoretically, other terms could be added to this expression, each of these additional terms being applied exclusively to another part of the domain where the analysis is performed. One can imagine for example partitioning precipitating areas into convective and stratiform parts, or clear air areas into stable and unstable parts.

AROME 3DVar uses an incremental formulation (Courtier *et al.*, 1994), where the increment δx is written as the control variable χ renormalized by $\mathbf{B^{1/2}}$:

$$\delta x = \mathbf{B^{1/2}}\chi$$

Considering eq.(3), the increment writes as a linear combination of two terms:

$$\delta x = \alpha^{1/2}\mathbf{B_{np}^{1/2}}\chi_{\mathbf{1}} + \beta^{\mathbf{1/2}}\mathbf{B_{p}^{1/2}}\chi_{\mathbf{2}} \quad (4)$$

Thus, this method implies in particular to double the size of the control vector. In the space of this renormalized control variable, the J^b cost function and its gradient become trivial:

$$J_\chi^b = \frac{1}{2}\chi^T\chi = \frac{1}{2}\begin{pmatrix} \chi_1 & \chi_2 \end{pmatrix}^T \begin{pmatrix} \chi_1 \\ \chi_2 \end{pmatrix} \quad (5)$$

$$\nabla_\chi J^b = \chi = \begin{pmatrix} \chi_1 \\ \chi_2 \end{pmatrix} \quad (6)$$

In the same space, the J^o cost function and its gradient write:

$$J_\chi^o = \frac{1}{2}\left(\mathbf{H}(\alpha^{\mathbf{1/2}}\mathbf{B_{np}^{1/2}}\chi_{\mathbf{1}} + \beta^{\mathbf{1/2}}\mathbf{B_{p}^{1/2}}\chi_{\mathbf{2}}) - \mathbf{d}\right)^T \mathbf{R^{-1}} \left(\mathbf{H}(\alpha^{\mathbf{1/2}}\mathbf{B_{np}^{1/2}}\chi_{\mathbf{1}} + \beta^{\mathbf{1/2}}\mathbf{B_{p}^{1/2}}\chi_{\mathbf{2}}) - \mathbf{d}\right) \quad (7)$$

$$\nabla_\chi J^o = \begin{pmatrix} \mathbf{B_{np}^{T/2}}\alpha^{\mathbf{T/2}} \\ \mathbf{B_{p}^{T/2}}\beta^{\mathbf{T/2}} \end{pmatrix} \mathbf{H^T R^{-1}} \left(\mathbf{H}(\alpha^{\mathbf{1/2}}\mathbf{B_{np}^{1/2}}\chi_{\mathbf{1}} + \beta^{\mathbf{1/2}}\mathbf{B_{p}^{1/2}}\chi_{\mathbf{2}}) - \mathbf{d}\right) \quad (8)$$

As for the control variable, the size of the gradient of the cost function must then also be doubled (or multiplied by the number of different $\mathbf{B}$ matrices used in eq.(3), if more than 2 matrices are used).

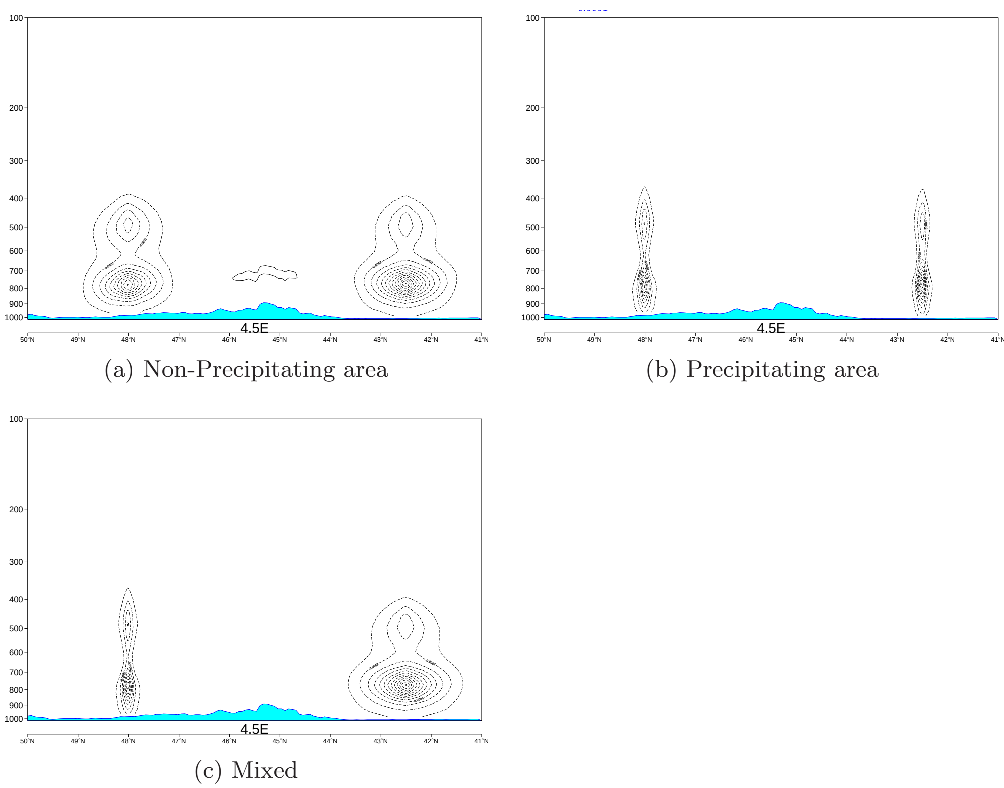
4 Results of single observation experiments

To ensure the reliability of the new formulation of the variational system described in the previous section, three different experiments have been performed:

- **CNTRL-Bnp** aims at controlling the impact on analysis of the non-precipitating $\mathbf{B}_{np}$ matrix, using the standard formulation of the variational system (e.g. considering only one **B** matrix). For that purpose, four pseudo-observations, whose localizations are 48N/4.5E and 42.5N/4.5E at 800 and 500 hPa, are assimilated. These pseudo-observations have been generated by considering -30% relative humidity innovations (e.g. observation minus background) at those locations.

- **CNTRL-Bp** is the equivalent of CNTRL-Bnp but using the precipitating $\mathbf{B}_p$ matrix.

- **Bnp-Bp** uses the hybrid formulation of eq.3 and other ingredients listed in the previous section in the variational system, considering that the northern (e.g. North of 46.5N) and the southern halfs of the domain as precipitating and non-precipitating areas respectively.



(a) Non-Precipitating area

(b) Precipitating area

(c) Mixed

Figure 4: Vertical north-south cross-sections of specific humidity increments (isocontours 0.1 g/kg) for (a) the CNTRL-Bnp, (b) the CNTRL-Bp and (c) the Bnp-Bp experiments (cf. text for details)

The large differences of correlation lengths between the two **B** matrices displayed in Fig.2 directly impact the structure of the increments, much tighter increments being obtained in CNTRL-Bp than for CNTRL-Bnp (Figs. 4.b and 4.a respectively). Some differences in the vertical structures can be identified too, especially near the boundary layer. Increments of temperature differ also quite significantly due to changes in the balances (not shown). The Bnp-Bp experiment displays what was expected: in the “rainy”northern part and in the “non-precipitating”southern part of the domain , Fig.4.c shows exactly the same increment structures as CNTRL-Bp and as CNTRL-Bnp respectively. This is a proof of concept, that increments with very different behaviours, in terms of intensities and shapes, can be obtained simultaneously using the heterogeneous **B** matrix formulation, and that different balance relationships can be used over different areas in a more adapted way.

5 Conclusion

Using ensemble information at convective scale with AROME, it has been shown that background error covariances strongly differ in clear air and in precipitating areas, and that these differences are coherent with explicit convection processes. Precipitating regions are particularly characterized by shorter correlation lengths, larger background error standard deviations for small scale dynamical variables, larger vertical correlations for the specific humidity in the mid-troposphere, very different balance relationships between the specific humidity and the unbalanced divergence. An original method has then been developped in order to use simultaneously these different backgound error covariances in VAR, allowing to make better use of observations through the better localization of increments and the more adequate balance relationships. This method is currently tested on real cases by considering radar reflectivities in AROME data assimilation system.

Acknowledgment: This work has been supported by the ANR (Agence Nationale pour la Recherche) through the ADDISA (Assimilation de Données Distribuées et Images SAtellite) project.

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5. PhD Studies

See: http://www.cnrm.meteo.fr/aladin/spip.php?article88

5.1. RADU Raluca: "Contributions to the study of the coupling problem between limited area models and large scale models." University of Bucharest, Faculty of Physics, 2d of July 2010

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Summary

Limited area models (LAM) need the information about the state of the atmosphere outside of the integration domain. This information is provided by global or largerscale models, so that an inherent LAM problem is the specification of appropriate lateral boundary conditions (LBC). Previous studies have shown that the way LBC are imposed can have a significative impact on the forecasted fields by propagation of errors inside the LAM domain (Warner et al, 1997), mainly due to the following limitations: the overspecification and the weak spatial or temporal resolution of the coupling data. This motivates the objective of this research which has been focused on an in-depth study of the coupling problem for limited area models in order to improve the LBC specification. In the vast majority of operational limited area models LBC are imposed via a pragmatic coupling scheme, named 'flow relaxation scheme' (Davies, 1983). In this scheme the prognostic variables are subjected to a forcing in the boundary zone that constraints them to relax towards the externally specified field. The Davies coupling is satisfactory if : a) transmits incoming waves from the model providing boundary information without appreciable change of phase or amplitude and b) at the outflow boundaries, reflected waves do not reenter the domain of interest with appreciable amplitude. This method has proved to be detrimental in the case of large-scale fast propagating systems as Lothar storm in Western Europe (25-26 December 1999). At that time some of the European operational models (ALADIN included) failed to forecast the cyclone even if the global models which provided the LBC (ARPEGE model for ALADIN) were able to forecast the event.

We have proposed a spectral one-way coupling method for ALADIN, in which the large scale components of the global model are combined with the small scale components of LAM using scale separation in wavenumber space, in order to minimize the differences appeared in the large scale portion of the coupled models. The spectral coupling/nudging method has been used in the past as a simple data assimilation method (Davies and Turner, 1977; Schraff, 1997), and in regional climate models as a method to avoid the deviation of large scales of the regional model from the fields provided by the global models (Kida et al, 1991; Waldron et al, 1996; von Storch et al., 2000).

The method had been applied and tested in different versions of the ALADIN limited area spectral model: forecast model (ALADIN), non-hydrostatic model (ALADIN-NH) and regional climate model (ALADIN-CLIMATE). Tests have been carried out at various spatial resolutions (10 km, 3,5 km and 50 km) in short and long-range integrations. The proposed method has also been tested in an idealized framework of the 1D shallow-water model, in selected case studies at high-resolution and in a perfect model approach (global and regional climate model results were compared at the same spatial resolution).

The potential advantages of the proposed method lie in the direct selectivity of the coupling scales, better consistency between the large scale forcing and the fields of the coupled LAM, capability to retain large-scale information independently of the location inside of the integration domain, ease of implementation in spectral models. The superiority of spectral coupling method has been demonstrated both in case studies whereby fast propagating cyclones present in the global

model are shown to be seamlessly propagated inside LAM boundaries and in a statistical sense through the computation of errors statistics versus observations when the method was applied in an operational framework (Table 1). When the method was tested at high spatial resolution (3,5 km) on a severe convection event (Movilita, 07.05.2005), the results have indicated the possibility of future application in extreme weather situations developed through scales interaction.

Another aim of the research was to prove one of the objectives of the regional climate modeling: the regional climate models are able to maintain the large scale circulation of the global model by modifying only the small scales. In this respect, the spectral nudging, a dynamical downscaling method, has been used as a suitable approach to force the regional climate model (ALADIN-CLIMATE) to adopt prescribed large scales over the entire domain, not just at the lateral boundaries, while developing realistic detailed regional features consistent with the large scales. The aim of this part of the study was to compare a global spectral climate model at high resolution (50 km) and a driven spectral regional climate model over Europe by using the so-called perfect model approach.

The spectral nudging method was applied in order to achieve a better representation of large-scale climate over a limited domain. It was proved in long-term simulations (12 and 25 years) the potential and the feasability of the proposed method seen as solution to overcome the limitations of LBC specification. The results showed that the regional model driven only at its lateral boundaries presented a summer warm bias in the middle of the domain. This bias disappeared when spectral nudging was applied. On the other hand, the smallest scales which were not driven by the spectral nudging were not significantly affected by scale interaction.

	BIAS (24h)	RMSE (24h)	BIAS (48h)	RMSE (48h)
MSLP OP/**SP**	-0,92/**-0,72**	1,43/**1,26**	-0,80/**-0,53**	1,62/**1,44**
2M T OP/**SP**	-0,37/**-0,22**	2,00/**1,95**	-0,54/**-0,40**	2,14/**2,08**

Table 1: Statistics computed for 24h and 48h for MSLP and 2m T forecasted fields with ALADIN model using Davies coupling (OP) and spectral coupling (SP, in bold).

The only detrimental impact of spectral nudging was a slight precipitation increase in the upper quantiles of precipitation, which was resolved by largescale nudging of specific humidity. It was pointed out that spectral nudging method is able to avoid the deviation of the RCM from the GCM in the spatial scales typical of the GCM (wave length of 600 km and above). This is true for the mean climate (stationary part) as well as for the day-to-day variability (transient part). As far as the smallest scales are concerned, we found very little predictability in the meteorological sense (so called butterfly effect). However, the statistical properties of these small scales (predictability in climatic sense) are not degraded by the effect of relaxation of the lower part of the spectrum.

It was studied the question whether the simulated extreme precipitation in summer and winter with the RCM spectrally nudged show similar characteristics with those simulated in the GCM. For each grid point of the analysis domain, the percentiles of daily precipitation in both seasons have been computed. We have concluded that spectral nudging improves the regional simulation by allowing more intense precipitation events.

The results from regional climate simulations using spectral nudging technique were published in *Tellus A* (Radu et al., 2008 and Colin et al., 2010).

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6. PUBLICATIONS

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