RC LACE Evaluation Report

LACE
nwp central europe

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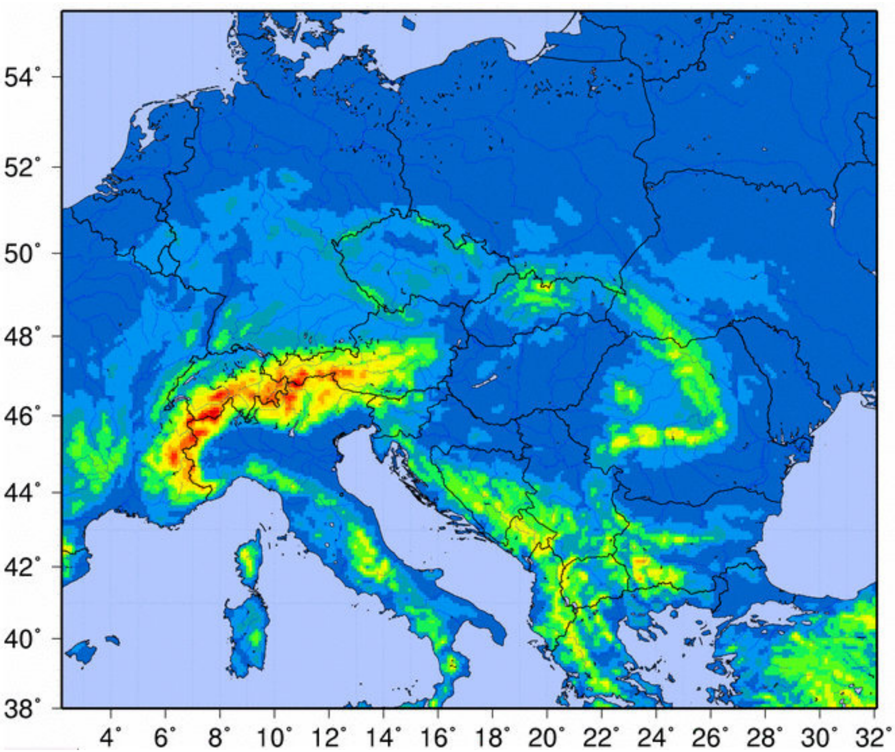

Executive Summary

Considering the rapidly-changing circumstances in operational meteorology in Europe, the RC LACE Council decided recently that an evaluation of the RC LACE Project should be undertaken. This report summarises the results of that evaluation.

RC LACE has a tradition of good cooperation and an excellent record of scientific collaboration. The achievements of the project over its lifetime are formidable. There is a strong wish, shared by all participants, to continue the cooperation. This background places LACE in an ideal position for development over the coming decade in a rapidly changing environment. However, significant changes will be required to guarantee the future success of the LACE Project.

After a review of the history of the LACE collaboration, we examine the strengths and weaknesses of the current project. A detailed consideration of options and opportunities for sharing of tasks during the coming decade is presented. Following this, we present a collection of recommendations for the future structure of the project and for organization of the management and scientific work. The key recommendations are indicated below.

- The most crucial requirement is to enhance the efficiency and effectiveness of the collaboration. To achieve this, the LACE partners should increasingly *share specific tasks,* with *Lead Centres* coordinating work in each key area. This should be done on a voluntary basis. We propose that each LACE Lead Centre assume responsibility for one or more key areas which correspond best with their local expertise and interest. We are convinced that a *balanced distribution* of responsibilities is achievable.

- An example of a possible configuration of Lead Centres is given in §6 below, but we stress that this is only a suggestion; the determination of the areas of responsibility of the Lead Centres, and the precise definition of their duties, will require further detailed analysis and planning. Considering the scarce manpower available, task sharing will enable all LACE centres to provide their customers with competitive NWP products based on state-of-the-art modelling, including high-resolution data assimilation making use of local observations.

- We advice the Council to adopt a general *10-year strategy of RC LACE,* which should be updated every five years. Based on this general strategy, the LSC should formulate a more detailed 2-year plan, updated annually, which describes concrete goals, itemizes specific outcomes and includes work-packages and implementation schedules of a small number of priority projects.

- The current management structure is appropriate and is working well. However, we make some recommendations in order to improve the overall efficiency of the LACE management bodies.

- Internal and external communications should be improved. This can be done without undue difficulty. The visibility of RC LACE should be enhanced by adopting a uniform format for conventional and web-based publications and by more active promotion of the aims and achievements of the project.

- Communications with other NWP Consortia in Europe should be increased to ensure that LACE benefits to the maximum extend from advances elsewhere.

1 Introduction

Guidance from numerical weather prediction models is an essential component of operational weather forecasting in all modern National Meteorological Services. The design, implementation, maintenance and development of NWP systems is a formidable task, beyond the individual capacity of most small and medium sized National Services. Thus, there is a compelling incentive for such organizations to co-operate, to share the burden of developing NWP systems and to benefit directly from each other's experience and expertise.

The subject of this report is RC LACE (Regional Co-operation for Limited Area modelling in Central Europe) a collaborative project with six participating National Meteorological Services in Central Europe. Considering the rapidly-changing circumstances in operational meteorology in Europe, and especially the changes expected in numerical weather prediction over the next ten years, the LACE Council decided that an evaluation of the RC LACE Project should be undertaken. The primary purpose is to assist the Council and the project management to plan most effectively for the coming decade. Terms of Reference for the evaluation may be found in Annex I.

In the course of our investigations, we sent out a questionnaire to the members of the LACE Steering Committee and visited all six RC LACE institutes, where we had discussions with the Directors, the local NWP teams, technical and forecasting staff and internal NWP users. We also participated in meetings of the LACE Council, the LACE Steering Committee, met with the Management Group and attended a Vision Meeting on the future of NWP in Europe at ECMWF. A schedule of visits of the Evaluation Team is given in Annex II. Brief details of the Team members are given in Annex IV.

In §2, we review the history of the LACE collaboration. In §3, the current status is considered, with particular attention on the changing European context and on the strengths and weaknesses of the current project. The options for development over the coming decade are discussed in §4. This is followed in §5 by a detailed consideration of options and opportunities for sharing of tasks during the coming years. Finally, in §6 we present a collection of recommendations for the future structure of the project and for organization of the management and scientific work.

2 Short history of RC LACE

The profound political changes in Europe in the late 1980s opened up new communication channels and brought great opportunities for co-operation in the Central European area. These opportunities were recognized at an early stage and eagerly seized upon by several visionary groups. In 1990, a meeting was convened in Vienna to explore the possibility of establishing a Regional Centre for limited-area high-resolution modelling of the atmosphere, for application to operational forecasting. This was the embryo of RC LACE (Regional Centre for Limited Area modelling in Central Europe; later, RC became 'Regional Co-operation'). The LACE Project was established within a year, the participants being the National Meteorological Services of Austria, Croatia, Czech Republic, Hungary, Slovakia and Slovenia.

The French Government, also quickly spotting the opportunities for co-operation in Central Europe, provided substantial financial support to foster closer links. With this backing, Météo-France proposed a limited-area version of its global ARPEGE model for future operational application in the countries newly embarking on numerical weather prediction. This proposal included strong training and research components. The LAM-ARPEGE Project started in Toulouse in September 1991. Shortly afterwards it was renamed ALADIN (Aire Limitée Adaptation dynamique Développement InterNational). The major aims of ALADIN were (and are)

- To develop and maintain an NWP system for use in limited geographical domains, requiring only moderate computational power whilst allowing a mesh refinement with respect to the coupling model ARPEGE.
- To permit integration with high spatial resolution on small domains, allowing dynamical adaptation to the detailed characteristics of the Earth's surface.
- To develop, *ab initio*, a state-of-the-art NWP system, enabling all partners to play an active role in the model development, with the result that the benefits of the common effort would be available to all participants.

The LACE group evaluated the French proposal and concluded that the ALADIN model would be an ideal basis for the project. Quickly, several scientists from the LACE countries joined the developments in Toulouse, along with other ALADIN participants. By September 1991 there were 17 scientists from seven countries working on ALADIN. Toulouse was the centre of modelling activity for the following several years. An official co-operation framework agreement between RC LACE and Météo-France was signed in November, 1994. [For a history of the ALADIN Project, see http://www.cnrm.meteo.fr/aladin/history/history.html].

In Spring 1996 the RC LACE management Group was established, under the leadership of Miroslav Ondráš (Slovakia). Their task was to construct an ALADIN/LACE system to provide a daily dissemination of NWP products to the LACE member institutes. The ALADIN/LACE model was expected to be the first operational application of ALADIN. At that time, RC LACE and Météo-France reached agreement to use the CRAY-J916/12 computer in Toulouse for pre-operational running of ALADIN/LACE, and to host the LACE Management Group in Toulouse. This was to provide a transition to an operational Regional Centre, originally planned to be in Vienna. However, later political changes in Austria presented difficulties with the establishment of the Regional Centre there.

The Prague Centre

In early 1997, the Czech Hydrometeorological Institute (CHMI) issued an ITT for a computer platform capable of running the ALADIN/LACE system operationally. Later that year, an NEC computer was chosen and the model software was ported and implemented on that system. The following March, the first RC LACE Memorandum of Understanding was signed by the six participating institutes, formally agreeing the establishment of the Regional Centre in Prague (the MoU was later extended to December, 2002). The leader of the project for this 'centralized phase' was Radmila Brozkova (Czech Republic).

The ALADIN/LACE operations were transferred from Toulouse to Prague in June, 1998. The Regional Centre was the centre of NWP operations and also the focus of NWP research for the following four and a half years, until December, 2002. Scientists from all the participating institutes spent extended periods working at CHMI in Prague. Boundary conditions for ALADIN/LACE, derived from the global ARPEGE model run in Toulouse, were dispatched to Prague on a regular basis. Vienna acted as the telecommunications and archival centre during this period. The Prague Centre also acted as the back-up centre for the reference ALADIN system software, thereby providing a valuable service to the ALADIN Community.

While the primary RC LACE operations were in Prague, the ALADIN system was also run in operational mode in the other centres: Slovenia (1997), Hungary (1998), Austria (1999), Slovakia (1999) and Croatia (2000). The horizontal model resolution was typically 9 km, and each centre configured the model to local requirements. A variety of computer platforms were used to run the system. Thus, by the end of the 'Prague Phase', each centre was using a combination of NWP guidance from the Prague Centre and that produced by local ALADIN implementations.

The centralized organization had many attractions but also gave rise to significant tensions. The concentrated research effort was very effective, with a large group of dedicated scientists forming a critical mass. Also, a common operational system could be maintained and developed with considerable efficiency. However, it became increasingly difficult to ensure that the NWP requirements of all the participants were fulfilled. For various reasons, scientists were gradually more reluctant to spend long periods away from their home institutes. And, finally, with the large budget required to support the Centre, the transfer of substantial financial resources away from the national institutes became unsustainable. A re-configuration of the Project was indicated.

The Current LACE Project

A new, decentralized, phase of the co-operation began in January, 2003. This followed the signing of the second RC LACE Memorandum of Understanding the previous October. RC LACE now became Regional Co-operation LACE. As the MoU has been extended until the end of 2007, this is the current configuration of the collaboration. Each RC LACE Member is responsible for its own operational NWP system, but scientific research and development is co-ordinated within the project.

The policy of the project is determined by the Council, comprising the Directors of the member institutes. The LACE Steering Committee (LSC) is the advisory body for the project. LSC representatives are nominated by the Members of RC LACE, and Météo-France also provides a (non-voting) representative. The Committee meets twice each year, with participation by the Management Group, and reports to the Council. Observers from (non-LACE) ALADIN and HIRLAM also attend the LSC.

The Project Leader is Dijana Klarić (Croatia). The Management Group (MG) comprises the Project Leader (PL), the ALADIN-LACE System Co-ordinator (ASC), the Data Manager (DM) and three Working Group Leaders (WGLs). The three Working Groups established by the MoU were for dynamics and coupling, physical parameterization and data assimilation. Later (2006) a fourth Working Group, for EPS and Predictability, was formed. Appointments to the Management Group are reviewed on an annual basis.

RC LACE continues its close affiliation with the ALADIN Project and with Météo-France. In January, 2004, RC LACE was the first group to officially join the ALADIN-2 Project. Since then, there have been intensive discussions on the roadmap for ALADIN-2 and the relationship to the AROME Project. AROME is a non-hydrostatic mesoscale NWP model with advanced physical parametrization. The AROME project was started in 2000 at Météo-France with the goal of developing a high resolution limited area model for nowcasting and very short range forecasting purposes. It is based on the dynamical kernel of the non-hydrostatic version of ALADIN and the physical parametrization package of the Meso-NH research model, and is designed to run at a resolution of around 2 km. There is great interest within RC LACE (and in the wider ALADIN community) to move towards operational application of AROME. A framework for the transition, called ALARO, has been developed, based on the ALADIN model with a refined formulation of the physical parameterizations.

Another recent development, of great significance to RC LACE, is the collaboration between the ALADIN group and HIRLAM (High Resolution Limited Area Model). This collaboration, called HARMONIE (Hirlam ALADIN Research on Meso-scale Operational NWP in Euromed) has resulted in the coming together of an unprecedented number of European atmospheric scientists to develop the AROME model. There is now an excellent opportunity for LACE scientists to collaborate with HIRLAM staff, particularly in areas such as data assimilation and surface analysis, where HIRLAM is at the forefront of research. A number of RC LACE scientists are already actively engaged in this work.

Finally, an indication of the vibrancy of RC LACE is the interest shown by other centres. Recently, the Romanian National Meteorological Administration applied to join the project, and this application was accepted by the Council.

3 Current situation

We consider the changing European context within which RC LACE operates, and then enumerate what we perceive to be the main strengths and weaknesses of the project as it is currently configured.

3.1 European context

For a very long time, primary responsibility for meteorological matters has rested with the European National Meteorological Services (NMS). They have developed rapidly to serve users' needs, and Europe maintains a world leading position in operational meteorology. All RC LACE Members, with the exception of Slovakia, are members of ECMWF; all, with the exception of Croatia, are members of the EU. It is expected that neither of these exceptions will persist for long. To date, the EU has paid scant attention to meteorology in Europe, excepting aviation meteorology. However, this situation may not continue for long. Recently, there has been some concern that a move towards centralization of meteorological operations (perhaps initiated by the European Commission) might remove some control from the NMSs. While no concrete plans in this direction have been advanced, it is recognized by the NMS's that closer collaboration is essential, and unnecessary duplication of effort must be eliminated as a matter of urgency.

EUMETNET, a network of 21 European NMS's, provides a framework for organizing co-operative programmes between the Members in various fields of basic meteorological activities such as observing systems, data processing, basic forecasting products, research and development, and training. Two of the RC LACE participants, Austria and Hungary, are Members of EUMETNET. A key goal of EUMETNET is to ensure efficient management of collective resources, so that all European users obtain the best available quality of meteorological information. The EUMETNET SRNWP (Short-Range NWP) programme has played a co-ordinating role in European NWP. Following from discussions at a recent 'Vision Meeting' in Reading, UK, it is likely that the SRNWP Programme will be re-tasked and given greater resources. This may provide significant opportunities for RC LACE to enhance its profile and play a pivotal role in defining future NWP policy.

In September, 2004, 28 European Weather Services (25 members of EU, Iceland, Norway and Switzerland) formed a new informal group, EUMET. The members are the Directors of the national weather services. Croatia has observer status; thus, all LACE countries have a presence in EUMET. The main function of the group is to co-ordinate the relationship between the European Weather Services and the European Commission. The current Chairman of EUMET is W. Kusch (Deutscher Wetterdienst), and the Vice-Chairman is I. Obrusník (Czech Hydrometeorological Institute).

The European Centre (ECMWF) increased the resolution of its models in February, 2006. The global deterministic forecast model now has a spatial resolution of 25 km. The strategy of ECMWF envisages further increases in resolution, by a factor of 1.6 in 2010 and by a similar factor in 2015. This would equate to a horizontal resolution of about 10 km in 2015. Thus, if NMS's are to provide substantial additional NWP guidance from their local systems, they must consider non-hydrostatic models with resolutions of the order of 2 km. The AROME model framework, which is the main focus of current research activity within the ALADIN-2 Project, and more specifically, within RC LACE, is in this category.

The HIRLAM Group recognized recently that they did not have the resources necessary to develop a complete non-hydrostatic modelling system, so they have joined with ALADIN in the HARMONIE Project. This gives RC LACE access to the most extensive grouping of NWP experts yet seen in Europe.

3.2 Strengths

Proven modelling expertise

By far the most important asset of RC-LACE is the scientific knowledge and ability of the LACE staff. The range of expertise covers all the principal areas of numerical weather prediction. The capabilities of LACE scientists have been demonstrated in a concrete way by the many contributions they have made in recent years. For example the dynamical kernel of the non-hydrostatic ALADIN model has been chosen as the core of AROME. It is also under serious consideration for use in the global IFS/ARPEGE system at ECMWF. The 3D-VAR system developed in LACE has also become a part of AROME. We may also mention the 'blending by DFI' technique and the SLHD scheme (semi-Lagrangian horizontal diffusion). A more complete list of the scientific achievements of LACE is presented in Annex III.

Recently, a major effort has been directed to the development of the ALARO framework; it is estimated that some 60% of the work in this area can be attributed to LACE scientists, and this work is of the highest scientific quality. The ALARO-0 physics, under current development, confirms the ability of RC-LACE to contribute to crucial research areas. There have been measurable improvements of the operations as a result of using DFI blending and the first components of the ALARO-0 physics. The contributions of LACE scientists to ALADIN have been vital to the success of the ALADIN Project.

RC LACE and the ALADIN Community

Participation by LACE Members in the wider ALADIN Project has many advantages. ALADIN is more loosely coupled than LACE and has quite limited financial resources. The higher level of co-operation in the 'tightly-coupled' LACE Project, with its more intensive management structure and formalized budgetary arrangements, justifies the popular description of LACE as 'the backbone of ALADIN'. ALADIN provides the framework for the scientific development of the NWP system. The regular meetings, workshops and training courses organized within the project facilitate the co-ordination of research, and ALADIN publications provide a valuable communication channel.

More that 40% of the scientists of ALADIN come from LACE. An analysis of the scientific achievements and the budgetary contributions to ALADIN, shows clearly that LACE is "punching above its weight" in the larger project. LACE also makes a substantial contribution, in terms of both scientists and financing, to the *mobility* of ALADIN. Clearly, the ALADIN Project derives significant benefit from the LACE co-operation, but the relationship is symbiotic, with advantages for both groups. We are convinced that the ongoing success of LACE is crucial for the continued well-being of the wider ALADIN Project.

RC LACE and Météo-France

The close association between RC LACE and Météo-France has been, and continues to be, of inestimable value for the project. Météo-France has a large team of scientists, expert in all major areas of numerical weather prediction, and resources far greater than are available to any of the Members of LACE. Through this association, LACE benefits directly from progress made at Météo-France, and LACE scientists have early access to scientific and technical advances made across the entire spectrum of NWP. Of course, the advantages flow both ways: Météo-France also derives substantial benefits from the work of LACE.

The training provided by Météo-France has greatly facilitated the development of local modelling expertise in the LACE institutes. The acquisition of such expertise on a purely commercial basis would have been economically prohibitive, perhaps even impossible to achieve. It is a clear illustration of the substantial material benefits to be obtained from open co-operation. Météo-France also provides the boundary fields required to drive local implementations of the ALADIN system. These data are disseminated on a regular operational cycle, with a high level of reliability. While it may be scientifically advisable to investigate alternative sources of boundary data, the value of the service provided by Météo-France should not be under-estimated.

Local operational ALADIN systems

While the centralized phase of RC LACE had several advantages, it became clear that a local ALADIN implementation in each member institute would provide substantial benefits not available through the centralized structure. As a result, ALADIN is now run operationally in all member institutes (see Table 1 below). Local autonomy means that the numerical weather prediction systems can be configured to suit specific operational requirements in the national institutes. Resolution, geographical coverage and schedules of model runs are all under local control. Systems can be designed for optimal exploitation of available computational resources.

Table 1. Local ALADIN systems at LACE centres

Country	Grid spacing (km)	Number of Grid points	Centre of domain
Austria	9.64	259x289	46.26°N, 17.00°E
Croatia	12.18 8.00 8.00	205x229 149x169 205x229	46.24°N, 17.00°E 44.60°N, 13.00°E 46.00°N, 15.00°E
Czech Republic	9.00 9.53	277x309 189x245	46.24°N, 17.00°E 38.77°N. 9.00°E
Hungary	7.96	309x349	46.10°N, 17.00°E
Slovakia	9.00	277x309	46.24°N, 17.00°E
Slovenia	9.50	244x258	45.44°N, 14.86°E

Local NWP knowledge

It is widely recognized that operational centres using NWP guidance need to have direct access to scientists with expertise in numerical data assimilation and modelling. The decentralized structure of RC LACE ensures that NWP expertise is available in each institute, so that modellers and forecasters can interact constructively. We found that the level of contact between these groups varied from institute to institute but was, in most instances, quite effective.

Local applications

The range of applications of numerical weather prediction products throughout the LACE community (see Table 2 below) is surprisingly diverse, and key applications vary widely across the member institutes. Most centres drive dispersion models and hydrological models using ALADIN outputs. Several run models to predict road conditions, ozone levels and energy demand. There are a number of applications specific to one institute. The current decentralized organization of the co-operation provides for a free choice of local NWP implementations to serve local needs.

Table 2. Main applications of NWP output

Country	MOS/Kalman	Dispersion	Hydrology	Others
Austria	ECMWF MOS ECMWF PPM	yes	yes	ozone, INCA
Croatia	-	yes	-	media(TriVis), forest fire, road
Czech Republic	MOS	yes	yes	road, nowcast-ing, ocean (6 FP EU)
Hungary	MOS	yes	yes	energy, avia-tion, road
Slovakia	-	yes	yes	stratospheric ozone, energy
Slovenia	Kalman	yes	yes	energy, road

Budgetary control

It is clear that the transfer of substantial financial resources away from the national institutes to maintain the operational centre in Prague was a source of continuing difficulties for a number of RC LACE participants. While we detected no intimation of any lack of 'value for money' during the centralized phase, this organizational structure did reduce the level of control of the limited funds available to the national institutes and diminished the local discretion with respect to the NWP budgets. The current structure returns full budgetary control to the member institutes.

Flexibility

RC LACE has demonstrated considerable resilience to changing internal and external circumstances. This is important in view of the rapidly changing meteorological landscape in Europe. Inevitably, a group like RC LACE must respond to alterations in circumstances both within the LACE community and in the wider European context. We have been positively impressed by the ability of the RC LACE Project to 're-invent itself' more than once, and we are confident that this flexibility and ability to adapt will continue to ensure the viability of the collaboration.

3.3 Weaknesses

Manpower in NWP

A superficial count of the manpower in RC LACE (see Table 3 below) might suggest that there are more than adequate resources to cover the entire gamut of NWP. However, on closer analysis, it becomes clear that many of the scientists nominally assigned to NWP research and development have a diversity of additional responsibilities besides their NWP work. The most significant drain on resources is the requirement to maintain and develop the local ALADIN implementations as well as downstream applications (post processing tools).

Table 3. Scientists (in PY) devoted to regional NWP in the LACE centres
(Bold figures: Equivalent PY; Parentheses: Total personnel)

Country	Operational	Research	Total
Austria	**1.50** (3 persons)	**3.00** (7 persons)	**4.50** (7 persons)
Croatia	**1.00** (2 persons)	**3.50** (9 persons)	**4.50** (9 persons)
Czech Republic	**1.25** (5 persons)	**2.50** (5/7 persons)	**3.75** (5/7 persons) **6.25** (incl. visitors)
Hungary	**1.00** (3 persons)	**4.00** (7 persons)	**5.00** (7 persons)
Slovakia	**1.50** (7 persons)	**2.50** (9 persons)	**4.00** (10 persons)
Slovenia	**1.50** (2 persons)	**2.00** (2 persons)	**3.50** (4 persons)

We should remark that the boundaries between research and local operations are not always sharply defined. The same is true for the boundary between pure NWP and downstream applications work. Thus, the figures provided by different centres (on which Table 3 is based) are not always directly comparable. Figures extracted from the ALADIN data-base in Toulouse indicate (the equivalent of) one person per country for maintenance of operations, with little fluctuation about this value.

Duplication of implementation, operations and maintenance
It is indisputable that the decentralized organization of the project leads to substantial duplication of effort. This is particularly the case in regard to the implementation and maintenance of local ALADIN systems. Virtually identical work packages must be executed in each of the institutes, and this seriously reduces the scientific resources available for actual research and development. While the attractions of the current organization may make this worthwhile, we feel it is essential to find means of reducing duplication, so as to use available resources more effectively.

Lack of strong identity, lack of clear visibility
The RC LACE Project suffers from a failure to define itself clearly and present a strong image to the outside world. As a result, even experienced and knowledgeable meteorologists elsewhere cannot get a clear understanding of the project, and frequently confuse it with the ALADIN Project. Admittedly, the close relationship between LACE and ALADIN makes a clear distinction difficult. However, we believe that a stronger identity is important for RC LACE if it is to establish its place as a formidable NWP Group within Europe and to gain appropriate recognition of its efforts and achievements. This can be done without undue difficulty.

Internal communication
It is fair to say that the messages we got about communications within RC LACE were conflicting. In general, there appears to be good and timely exchange of information within the Management Group, and between management and scientists. But

we found a few cases where scientists in different institutes were working along similar lines, apparently unaware of each others' efforts. Moreover, instances were cited where the flow of information between managers and scientists or vice-versa followed a circuitous route, via Toulouse or elsewhere, rather than directly. Generally, communications between NWP scientists and forecasters were excellent, but this was not universally the case.

Complexity of the scientific planning process

The close association between RC LACE and the wider ALADIN Project has the consequence that scientific planning for LACE is inextricably entwined with that of ALADIN. With the evolving HARMONIE collaboration, the planning is becoming even more complex, as the HIRLAM group will wish to steer scientific work in directions which it considers to be of highest priority. There is a risk that the research programme may be driven from outside the LACE community. When the objectives of LACE and the other the groupings are compatible, this may be acceptable. But LACE must continue to be pro-active in defining its own objectives and in drawing up its plans accordingly. LACE needs to ensure that plans are consistent with its objectives. A more structured approach to scientific planning would put RC LACE in more control of its destiny.

Need to cover all NWP

The aspiration of LACE (as clearly reflected in responses to our questionnaire) is to cover all the principal areas of NWP. Experience has shown that LACE cannot rely on outside expertise to rectify shortcomings of local importance. Two recent examples are the treatment of low stratus and the near-surface moisture bias. These problems had to be addressed by LACE scientists, as no-one else was prepared to undertake this task. Thus, LACE must maintain expertise in all areas important for NWP operations. With limited staff resources, this poses a significant challenge.

Coordination of plans

Each of the LACE Working Groups produces a detailed scientific plan of work. However, we found clear evidence of some lack of co-ordination of the scientific work. This does not arise from any lack of willingness, but simply from a lack of a clearly defined overall strategy for the project. The scientific plans of the Working Groups should be more clearly tied to the objectives of LACE. This can only happen if these objectives are explicitly elucidated. We believe that it is not an unreasonable aspiration to try to include all major areas of NWP in the co-operation, but emphasis on different areas must be determined in accordance with clearly defined priorities.

Management Structure

The success of RC LACE depends critically on firm management, with excellent co-ordination of activities across the range of research projects. The current policy of reviewing management positions each year appears to us to bring an unnecessary degree of uncertainty. Most of the research targets require several years to come to fruition. A longer time-scale for management appointments would appear to be more appropriate. The overall structure of the MG is sound, but we do not believe that a half-time basis for the Project Leader is adequate. There is some lack of clarity in the specification of responsibilities of the MG. This is especially the case for the positions of the Data Manager (DM) and ALADIN-LACE System Co-ordinator (ASC). These positions should be defined separately and the allocation of responsibilities more clearly assigned.

Quality of current ALADIN Operational Systems

While the operational implementations of ALADIN in the member institutes generate valuable guidance, they also suffer from some consistent deficiencies. The primary shortcoming is the lack of data assimilation at model resolution (with the exception of Hungary). Typical problems of ALADIN guidance, as reported by forecasters and by other users, include:

- Incorrect distribution of precipitation in mountainous regions (too much on up-wind side, too little in the lee of mountains).
- Incorrect precipitation phase (for rain and for snow) during the winter period.
- Winter time inversions and low stratus layers too often missing (or dissolved too early) with corresponding temperature errors.
- Cloud and humidity forecasts not reliable enough for aviation forecasts in summer.
- Over-prediction of minimum temperature and under-prediction of maximum temperature in certain conditions.
- Requirement for temperature forecasts for applications (e.g. road conditions) to be corrected manually.

The lack of Model Output Statistics to remove systematic errors, especially for temperature and wind, from the direct model output of ALADIN is also a significant limitation on the usefulness of the NWP systems in some LACE services.

4 Options for development up to 2015

4.1 External factors

The future development of NWP at the LACE centres is closely linked to

- Plans at major European NWP centres
- Changing user demands
- Role of private service providers
- NWP in universities
- Government regulations
- Developments in IT and communication.

These external factors have to be taken into account when discussing options for NWP and the role of LACE in the future.

Plans at major European NWP centres

A constant threat and challenge to regional NWP is the ever-increasing resolution of global models. For example, at the European Centre for Medium-Range Weather Forecasts (ECMWF), which is the leading global modelling centre worldwide, the horizontal grid spacing of the main deterministic forecast model was reduced from 200 km in 1981 to 90 km in 1991, 40 km in 2000 and 25 km in 2006. To justify their existence, deterministic regional NWP models in Europe must use higher resolution information, and typically have a grid spacing between 5 and 10 km.

By 2010, the grid spacing of global models at the major European NWP centres will be reduced to 16–25 km and, according to the "ECMWF Strategy 2006–2015", a grid size of order 10 km will be introduced in 2015. Moreover, two centres in Europe are already running regional models for the whole of Europe at resolutions of order 10 km: the NAE at UK Met Office (UKMO), Exeter (12 km) and the LME at DWD, Offenbach (7 km). The UKMO plans to reduce the grid spacing of the NAE model from 12 to 8 km in 2009. The NAE and LME systems include complete data assimilation suites and provide forecasts four times per day.

User demands in the LACE countries

The principal users of the LACE centre products are the general public, governmental institutions (e.g. military, aviation authorities, hydrological and environmental as well as civil protection agencies) and some commercial customers (e.g. media, energy, the agro-meteorological sector). Analyses and forecasts of the ALADIN model form the basis of final user products, but downstream applications like MOS, trajectory and dispersion modelling are also included in the complex production chain.

Most LACE centres expect an increased user demand for meso-gamma scale (convection-scale) localised forecasts, especially in case of high impact weather, covering nowcasting and very short range periods (0 to 24 hour). The generation and distribution of specially tailored products will become increasingly automated, which requires an excellent quality and reliability of the whole forecasting process in general and the NWP system in particular. There is a clear need to provide users not only with detailed deterministic products but also with predictability estimates, especially for risk assessment in cases of extreme weather.

Role of private service providers

Private companies offering meteorological services and products are becoming more and more common in many countries in Europe. Currently, they are concentrating on the lucrative media business (especially TV), but sooner or later they will try to take over other commercial customers, such as the energy and insurance sectors, from the national meteorological services (NMS). Since the meteorological market will presumably not grow very rapidly over the next decade, the LACE centres will face increasing competition, which could lead to lower margins and a decrease of income from commercial activities.

To survive in the market, the LACE centres have to offer better quality, reliability and specially tailored products. Private service providers may use NWP products from other modelling centres (e.g. the global GFS forecasts from NOAA-NCEP (USA) or regional forecasts from NWP systems like LME or NAE) as the basic input to their downstream developments. Thus, the LACE centres have to ensure that their regional NWP models offer at least as high quality as these NWP systems, at a higher resolution in space and time. To provide a wide range of tailored products in the future requires a flexible and mostly automated production system, with a range of downstream developments for key customers.

NWP at universities

Many universities and research institutes in the LACE countries, and elsewhere in Central Europe, offer courses in NWP and are therefore natural partners of the NWP research teams at the weather services. But universities usually cannot perform research on high resolution data assimilation because they do not have access to local observations like surface or radar data. The LACE centres should improve the co-operation with their local university institutes, because the interaction with academia will stimulate NWP research and help in the development of innovative products. Thus the LACE centres should grant local universities access to their NWP systems for research purposes and the training of students. If LACE scientists can provide some assistance to local universities in implementing the ALADIN system, they may encourage them to undertake relevant research, thereby paving the way for fruitful co-operation between academia and operational NWP centres.

On the other hand, some universities (e.g. University of Basel, Switzerland; see http://pages.unibas.ch/ geo/mcr/3d/meteo/dt/) run public domain models such as ETA, MM5 or NMM in a quasi-operational mode for European domains at rather high horizontal resolutions. Although these models usually run without high resolution data assimilation, in dynamical adaptation mode only, they may offer an attractive alternative to forecasters and the public because of the extensive range of forecast products and elaborate and appealing graphical presentations. To compete with these NWP systems, LACE has to offer higher reliability and better forecast quality, through operational high resolution data assimilation based on GTS data and on local data not generally distributed outside the originating national meteorological institute.

Government regulations

Most LACE centres have faced severe budgetary pressures, and even staff cuts, in the recent past, and the downsizing process will probably continue at a somewhat slower pace as long as “lean government” and the need to narrow the fiscal budget deficit remain high on the political agenda in Europe. Therefore, the LACE centres should concentrate on core activities of NMS, such as national security, public safety, issuing extreme weather warnings and environmental protection. The co-operation between the LACE centres helps the services to deliver the mission-critical NWP tasks and downstream developments very efficiently.

Developments in IT and communication

Moore’s Law, which predicts a doubling of the computing power of processor chips every 18 months, will probably remain valid for another decade, although progress may be somewhat slower in the future. While high performance computers (HPC) were, in the past, based on special proprietary processors, many supercomputer vendors are now moving over to systems based on commodity scalar processors. Thus, Linux PC clusters offer a viable alternative to traditional HPC systems with respect to price and performance, so that most LACE centres will be able to improve their computing capacity by a factor of between 15 and 30 over the next decade, and at a reasonable price.

According to "Gilder's Law" (named after technologist George Gilder, who says that the bandwidth of optical fibres doubles every six months) we expect that, over the same period, the bandwidth of the main communication links, i.e. the public internet and RMDCN between the NMS in Europe, will increase by two orders of magnitude or more, allowing for fast transfer of large data volumes, such as forecast files of high resolution models. Emerging technologies like GRID computing will facilitate distributed computing and enable easy access to data stored elsewhere. These developments will have a major impact on the distributed collaborative work performed in the research teams of the LACE centres.

4.2 Strategic goals of NWP

The NWP strategy of LACE is obviously closely tied to the general goals of the ALADIN Consortium in the field of high resolution short range weather forecast, as laid down in the 3rd ALADIN MoU (signed on 21 Oct. 2005):

“A joint research and development plan aimed at maintaining the current ALADIN meso-beta model at state-of-the-art level and developing, with contributions of the Parties to the common code libraries involved:

- a meso-gamma capability (called AROME), and
- less computationally expensive, intermediate models compatible with the range of resources affordable to the Parties.”

These goals correspond well to the user demands and other external and internal factors.

Meso-gamma scale (convection-scale) NWP

All LACE centres expect to have enough computer power available within the next three to five years, to run AROME, a computationally quite demanding model (about 30 to 100 times more expensive than ALADIN), at the meso-gamma scale with a grid spacing between 2 and 3 km. However, due to limited computer resources the actual model domain may generally be confined to a geographical region just surrounding the national territory of each LACE centre or even only part of the country.

All LACE centres plan to take part in the scientific and technical development tasks of AROME. The main aim of AROME is to resolve deep convection explicitly, allowing for the simulation of the life cycle of convective clouds and their organisation into clusters and squall lines. Current meso-beta scale models like ALADIN have to parameterise these cloud structures, because the grid spacing of 8 to 10 km is too coarse to resolve the convective motions explicitly. The convective parameterisation schemes which are used are notorious for their inability to describe the intricate interactions between the meso-gamma and larger scales which lead to organised deep convection. Research models like MM5 and WRF, which resolve deep convection explicitly, have demonstrated their capability to simulate this organisation realistically.

Since many severe weather events in Central Europe are caused by organised deep convection, the successful development and operational implementation of AROME will improve the forecasting capabilities of the LACE centres considerably. However, the proper description of the initial state, especially the humidity field, plays a crucial role for the quality of AROME. Therefore, observations with high resolution in both space and time have to be exploited in a meso-gamma data assimilation scheme.

An important research topic is the effective exploitation of the information content of radar data like the 2D precipitation scan or the 3D volume scan. The goal is to initialise convective cells in the meso-gamma scale model at the correct place and with the right intensity. To obtain full benefit from AROME, a precipitation radar network covering the model domain must be operated. The preparation of a data composite, including quality flags, of all operational precipitation radars of the LACE countries will be a first and very important step towards a proper assimilation of the data.

Intermediate NWP (grid spacing 5 to 6 km) including data assimilation

The development of an intermediate NWP model framework (called ALARO), with a grid spacing of 5 or 6 km, serves two purposes:

- It will replace the current operational ALADIN models of the LACE centres by a state-of-the-art model in the near future (about 2008);

- It will provide lateral boundary conditions for AROME.

Besides non-hydrostatic dynamics and a refined TKE scheme, ALARO features an improved description of the hydrological cycle, including full prognostic treatment of water vapour, cloud water, cloud ice, rain and snow. The prognostic treatment of the precipitation phases, including their horizontal and vertical advection, will help to improve the spatial distribution of precipitation, especially in mountainous regions. ALADIN tends to overpredict precipitation on the windward side of mountains and severely underestimate it on the leeward side. For hydrological purposes, where the mountain crests usually mark the watersheds between separate river catchments, the improved precipitation distribution will be rather beneficial. This is a critical factor for forecasting of floods.

In order to compete with forecasts of the global ECMWF and other regional NWP models like LME or NAE in terms of quality and reliability, the operational implementation, within the next few years, of a high resolution data assimilation scheme for ALARO, including a detailed analysis of surface and soil parameters, is strongly recommended.

Lateral boundary conditions

The forecast quality of regional NWP models depends to a large extent on the quality of the driving (global) model, especially later in the forecast range. Currently, all LACE centres use forecasts of the French model ARPEGE as lateral boundary conditions (LBC data) for ALADIN.

To quantify the impact of the LBC data on ALADIN's quality, a systematic comparison between two ALADIN suites, one driven by ARPEGE, the other driven by the ECMWF model, is highly recommended. To avoid any additional complexity due to different soil models in ALADIN and the ECMWF model, the study should deal with an ALADIN in data assimilation mode where the LBC data are needed only for the atmospheric fields. The verification of the two ALADIN suites should concentrate on the error growth of near-surface weather parameters during the 72-h forecast for observing stations in the inner model domain.

Regional Ensemble Prediction System

With the recent appointment of a WG Leader on predictability, the LACE Council demonstrated its interest in this rapidly evolving research field. For risk assessment, many users need not just single deterministic high resolution forecasts, but also information about their reliability. Besides statistical post processing (e.g. MOS), a properly calibrated short range regional ensemble prediction system (SREPS) aims at describing the probability density function of important forecast variables. Other approaches currently being explored in Europe are the SRNWP-PEPS (Poor man's EPS) of the DWD, the multi-model, multi-analyses, multi-lateral boundary conditions

INM-SREPS developed at the Spanish Meteorological Service, and the COSMO-SREPS which is closest to the LACE approach in its design.

Increased automation of the forecasting process

In the LACE countries, there will be a rapidly growing demand for localised, specially tailored forecast products, typically involving hourly values of a dozen or more weather parameters, with a high level of quality and reliability. These forecasts cannot be produced manually, but must be generated by an automated forecasting process, based on a high resolution NWP system supplemented by intelligent downstream applications (post-processing tools). Thus, the role of the human forecaster is gradually changing from that of a forecast producer to a supervisor of the automated production process and advisor of key customers on the definition, properties and characteristics of specially tailored products.

The preparation, formatting and rapid distribution of the forecasts by electronic media like the internet and text messages for mobile phones will play an important role in the future. Thus the LACE centres should consider setting up separate units for downstream applications and distribution of forecast products, so as to be able to respond quickly to new user requirements and to allow the research team to concentrate on the further development of the NWP system.

Scientific scope of program

With its four working groups (WG) on data assimilation, dynamics, physics and predictability, LACE tries to cover all aspects of NWP. However, due to the limited manpower available, an optimal mixture between short term development and longer term research tasks is difficult to achieve. Most LACE scientists have to devote a substantial fraction of their time to operational and post processing tasks, so that concentrated research work is often realised only during research stays at Météo France or at another LACE centre. Returning to the home institute, this research work is quite often interrupted and only resumed many months later. This inefficient use of manpower is also reflected in the inability of the WG Leaders to do proper planning of inter-dependent tasks.

To improve the situation, we recommend that the LACE centres

- Concentrate research on a few selected topics in each of the four areas represented by the WGs; optimally, topics most relevant to important forecasting problems in Central Europe should be chosen, such as the proper analysis of near-surface variables in continental, mountainous areas, detailed modelling of snow processes, stable and cloud topped ABL, the modification of the flow by orography, and air – sea interaction,
- Co-operate more closely with local universities to involve diploma and PhD students in research related to NWP,

- Increase the sharing of mission-critical tasks (see §5) including downstream applications (post processing tools) for key customers,
- Explore the implementation of a “Core Group” under the control of the PL. This would comprise a small number of scientists devoted mainly (say 80%) to longer term research tasks, without interruption due to operational duties.

Interaction with other NWP Consortia

NWP research and development at operational NMS in Europe take place mainly in four consortia each concerned with its own modelling system. While there is a lot of collaboration of scientists within each consortium, interaction of e.g. LACE/ALADIN scientists with COSMO, UKMO or HIRLAM scientists has been very limited until recently.

The emerging HIRLAM – ALADIN co-operation, HARMONIE, provides a unique opportunity to LACE scientists to exchange information and co-operate on joint research projects in fields central to the LACE mission, such as high resolution surface analysis. COSMO Members like Germany and Switzerland on the other hand have been the first ones to implement non-hydrostatic models operationally, and will be among the first centres in Europe to run meso-gamma scale models including the assimilation of radar data.

SREPS will be another research task which should be open to co-operation between the consortia. Joint workshops organised by LACE Members, open to scientists of all four consortia, could be a first but important step towards a more organised form of co-operation in the future. The EPS Workshop in autumn 2006, organized by the WG for EPS and Predictability, is a good move into this direction.

5 Options for increased task-sharing within RC LACE

The NWP teams currently consist of between 4 and 10 scientists in each LACE centre, with (the equivalent of) 2 to 4 people for research at each centre, and 1 to 1.5 for operations and downstream applications of NWP products such as air pollution and road condition modelling. For a more detailed breakdown, see Table 3 in §3.3.

To avoid inefficient duplication of effort in the development (R&D) and operational implementation of important components of a state-of-the-art NWP system, the LACE partners should increasingly *share specific tasks,* with *Lead Centres* coordinating work in each key area. Besides the efficient use of the scarce manpower available, this *task sharing* offers the following advantages to the LACE centres:

- Specialisation of the NWP teams, which helps in building local expertise and accumulation of critical mass for participation in international scientific development.
- Better synchronisation and co-ordination of scientific developments and operational implementations at all LACE centres.
- Ability of smaller NWP groups to provide their centres with a complete NWP system, including data assimilation, post processing and applications of NWP data.

Task sharing between the LACE Members should be done on a *voluntary basis*, with each Lead Centre taking responsibility for one or more tasks which correspond best with their local expertise and interest. A *task* typically includes the scientific development, technical implementation and centralised operational execution of a specific NWP component or downstream application, as well as the distribution of the products generated to all LACE centres. Moreover, support during the implementation of the corresponding software should be given if another LACE centre plans to execute the task locally.

Task sharing should not involve transfer of money from the receiving centres to the producing ones since, on balance, each LACE Lead Centre will both provide services to other LACE centres and receive, from other centres, NWP products critical for its own mission, thus ensuring an equitable overall distribution of responsibilities and resources. This mutual inter-dependence will strengthen the cohesion and identity of LACE and the profile of each individual centre.

In deciding on the configuration of the Lead Centres, it is important to ensure that a *balanced distribution* of responsibilities is achieved. We propose that each LACE Lead Centre assume responsibility for one or more key areas. An example of a possible configuration of Lead Centres is given in §6 below, but we stress that this is only a suggestion: the final distribution of tasks requires further consideration and planning. In some of the Lead Centres, activities are confined to research; in others, operational tasks will also be performed. In the latter case, a second Lead Centre, acting as a back-up should be nominated, to guarantee resilience of the operational NWP systems.

The first six tasks (5.1 to 5.6) proposed below should be running within two or three years to provide all LACE centres with an operational data assimilation suite on the meso-beta scale (i.e. with a grid spacing of 5 to 6 km). The following three tasks (5.7 to 5.9) pave the way for convection-scale modelling (AROME) and ensemble prediction. Finally, the provision of standardised key post processing tools (5.10) will help to satisfy the needs of important end users.

All tasks related to the Observation Data Base (ODB) should be open to scientific co-operation with other NWP consortia in Europe (like HIRLAM, COSMO or UKMO) which also plan to use the ODB. Of course, *this does not imply that the observational data in the common LACE ODB will be shared* with the other consortia.

Since additional tasks suitable for task sharing, not yet anticipated, may emerge during the next decade, the Council and LSC should closely monitor the situation.

5.1 Common ODB including all local (non-GTS) data

The Observation Data Base (ODB) is a database software system developed at ECMWF to manage large volumes of observational data in the 4D-VAR data assimilation system. The ODB is able to handle the growing number of observations (like satellite or radar data) used in the data assimilation. It is designed to allow easier management of the data, with quicker access and more flexible organisation.

While the implementation of the ODB software (mainly written in C) on a computer is fairly straightforward, considerable manpower is needed to fill the ODB with all types of observations like SYNOP, METAR, TEMP, BUOY, AMDAR, and radar and satellite data. Special software has to be developed to convert observations from external codes such as BUFR to the internal ODB format. Moreover, some local observations may not conform to standard data formats like BUFR and may require special treatment. Since there are constant changes in the observation system, like the launching of new satellites or the introduction of new observing systems such as profilers, the maintenance of the ODB requires ongoing attention.

To implement and maintain the ODB in all six LACE centres separately would be very inefficient. Thus we propose a *common centralised operational ODB for all LACE centres*. Since this ODB is mission-critical for the operational NWP at all LACE centres, it should be maintained at two different centres which will work as mutual backup. The LACE centre and its backup, which are responsible for the maintenance of the common ODB, should store all GTS and local data from all LACE centres (e.g. hourly SYNOP data, high-resolution precipitation data and radar data) in the ODB.

All other LACE centres will be able to retrieve the observations from the common ODB and use these data files for their local data assimilation or verification systems as required.

To guarantee the security of the local observations, which are of high commercial value, against any use not intended by the LACE centres, strict protection measures will have to be implemented at the responsible centres running the common ODB, as well as in all LACE centres retrieving observations from the ODB.

5.2 Monitoring of all observational data based on ODB

Based on the common ODB, a monitoring system of all observations has to be set up to support the data assimilation schemes and to maintain the quality in the largely automated networks of the LACE services. Typical monitoring products include

- Total counts of all observation types for each analysis cycle.
- Observation distribution maps for each analysis cycle.
- Rejected observation distribution maps for each analysis cycle.
- Vertical profiles of observation fit to first guess, uninitialised analysis and initialised analysis for each analysis cycle.
- Monthly maps of radiosonde - first guess biases.
- Vertical profiles of monthly mean and standard deviation of radiosonde biases, for bias-corrected areas.
- Monthly maps of mean and root-mean-square errors of drifting buoys.

The use of observations and the exclusion of undesirable data during the data assimilation have to be controlled by means of “dynamic blacklists", which are based on the monitoring products. The centre responsible for observation monitoring should update the blacklists regularly, and produce a monitoring report on a quarterly basis.

5.3 Flexible verification tool based on ODB

Based on the common ODB which contains all local data plus quality bits assigned to them from the data assimilation and monitoring systems, a flexible verification tool for the NWP models of the LACE centres and for selected regional models of other consortia (UKMO, COSMO), as well as the global ECMWF model, has to be developed. All models should be verified against the same local observations available in the common ODB. The common verification scheme designed and coded in Slovenia may serve as the nucleus of the new tool based on the ODB. A comparison of the quality of the models at the LACE centres and selected high-resolution models of other centres (e.g. NAE of UKMO or LME of DWD) helps to highlight strengths and weaknesses of the local NWP systems and is an important input to any planning of further research and development needs. The baseline verification must also include a comparison of the quality of the regional LACE models against the global ECMWF products.

Besides standard verification scores (e.g. bias, root-mean-square error, hit rate, false alarm rate, thread score) new verification methods which avoid the double penalty problem for mesoscale models should be explored. The centre responsible for verification should produce a verification report on a quarterly basis.

5.4 Data assimilation(s) for intermediate NWP model

Hungary is currently the only LACE centre running a 3D-Var data assimilation for its regional model operationally. This improves the quality of their forecasts (especially for temperature, clouds and precipitation) during the first 6 to 12 hours, when compared to the simple dynamical adaptation (or blending) of the large scale ARPEGE analysis which is done at all other LACE centres.

For the next decade, the LACE centres will need a common regional model with a grid spacing of 5 to 6 km (the ALARO framework) which will provide the lateral boundary conditions of their meso-gamma scale AROME model. We suggest that the data assimilation for this intermediate NWP model, which will cover all the AROME domains, should be performed in one LACE centre (with backup at another). The analysis should then be distributed to all LACE centres to serve as initial state for forecasts with the intermediate NWP model, which could be performed in all LACE centres separately. This will reduce the amount of forecast data to be transferred, and also permit local variations in model configuration.

Since the common ODB contains not only GTS data but also local data of all LACE countries not distributed to non-LACE centres, the analysis of the intermediate NWP model may be expected to have higher quality than the regional analyses of other centres, such as UKMO or DWD.

5.5 Detailed analysis of surface/soil parameters

For continental and mountainous areas like Central Europe, a detailed high-resolution analysis of surface and soil parameters (e.g. snow, soil moisture, and vegetation) is of great importance for the overall quality of the forecast, especially for near surface weather conditions. On the other hand, a proper simulation of land/sea breeze circulations and other coastal flows requires a detailed high-resolution analysis of the sea surface temperature (SST).

The current practise in all LACE centres, to rely on the interpolated ARPEGE analysis for the surface and soil fields, is not adequate. In winter and early spring, the detailed distribution of snow has an important impact on local weather conditions, and in the warm season the availability of soil water determines (via the Bowen ratio, i.e. the ratio of the sensible and latent heat fluxes) the maximum temperature, boundary layer structure and, to a large extent, cloud distribution. Therefore, LACE should develop its own capability to operationally perform a high-resolution analysis of surface and soil parameters (including the SST, at the grid spacing of 5 to 6 km of the intermediate NWP model). The expertise of the HIRLAM consortium should be taken into account in setting up such a scheme.

The development of the surface analysis will initially be a research task, which could be the responsibility of a single Lead Centre. Later, when the analysis is ready for operational use, one (operational) LACE centre, with another as backup, should implement and run this analysis scheme, including the distribution of the analysis fields to all the other LACE centres running the intermediate model.

5.6 Development and integration of intermediate NWP model

If communication links between the LACE centres improve considerably in the future (e.g. transmission speeds > 256 MBit/s) at affordable costs, a *centralised integration of the intermediate NWP* model with a grid spacing of 5 to 6 km will be possible. This model will provide the lateral boundary data (coupling files) for all LACE centres running the convection-scale AROME model locally. Of course, this intermediate model must include a complete data assimilation suite for atmospheric and surface variables using all local LACE data stored in the common ODB.

The intermediate model may be driven by lateral boundary data from the global models ARPEGE (Météo France) or IFS (ECMWF). The choice of coupling model (ARPEGE or IFS) should depend on the quality of the forecast of the intermediate NWP model determined by systematic verification for a period of at least one year.

5.7 Preparation of a radar data composite

The convection-scale model AROME will assimilate radar data in order to initialise convective cells at the right place and the correct intensity. Although the AROME domains of the different LACE centres cover initially only the country plus neighbouring areas, it will be necessary to include radar data of other LACE countries in the local data assimilation. Thus, the *centralised operational production of a composite of all operational precipitation radar data* of the LACE countries including quality control is an important task.

In the next few years, many scientific and technical problems will have to be solved which include the co-ordination of radar scans across the borders, ground clutter removal, bright band detection and elimination of gross errors. The expertise of other NWP consortia (HIRLAM, COSMO, UKMO) using radar data in their data assimilation schemes should be used, too.

5.8 Nowcasting system based on ALARO/AROME and INCA

The Austrian nowcasting system INCA is currently based on a first guess of the ALADIN-Austria. In the short term, INCA should be interfaced to the common ODB which includes all local LACE data and be based on forecasts of the intermediate model (the ALARO framework) with a grid spacing of 5 to 6 km.

A *centralised INCA run* with a model domain covering all LACE countries will improve the operational forecasts in the nowcasting range (< 2 to 3 h) and will help to provide a seamless prediction from the nowcasting to the very short range scale.

For those LACE countries running the convection-scale model AROME, a local version of INCA based on AROME forecasts should be developed.

5.9 Ensemble Prediction System (EPS)

The combined computer power available at the LACE centres should be used to develop, implement and run an *ensemble prediction system with distributed (decentralized) computation of the EPS members and centralized evaluation/product generation*.

In the next few years there are still several scientific problems to be solved which include the proper prescription of the uncertainty of the initial state, lateral boundary conditions and model formulation. The expertise of other NWP consortia (HIRLAM, COSMO, UKMO) running regional EPS should be used, too.

5.10 Standardized key post processing (downstream developments) tools

Currently the scientists of the NWP groups at the LACE centres are asked to work not only on the NWP model itself but on many downstream developments like weather interpretation, Kalman Filter, MOS, parameters for air pollution models or road condition.

To avoid inefficient duplication of efforts, *standardised and portable key post processing tools* should be developed at one (or more) LACE centres and provided to the other centres on request free of charge. Since many tools like Kalman Filter or MOS require observational data, the common ODB data base should be used as interface to observations.

6 Summary and recommendations

6.1 Tasks for the near future

To remain competitive in the field of numerical weather prediction in comparison with the global ECMWF model or the European regional NWP systems NAE (UKMO) and LME (DWD), we strongly recommend that RC LACE concentrates a substantial proportion of its resources upon the following *priority projects* during the next three years. Task sharing, as outlined in §5 above, will enable LACE to implement the necessary components rather efficiently.

Common verification

As outlined in §5.3 above, a common verification scheme of all LACE applications and of the ECMWF, NAE and LME models should be implemented. This scheme will quantify the quality of the LACE products and provide a stimulus and benchmark for further development.

Data assimilation

The steps necessary for an operational high resolution data assimilation scheme for RC LACE have been described in §5.4 and §5.5 above. Without data assimilation including local data, the quality of ALADIN/ALARO forecasts will probably be inferior to the quality of NAE and LME, especially for the first 6 to 12 hours of the forecasts.

ECMWF forecasts as LBC data

The impact of ECMWF forecasts as lateral boundary conditions on the quality of ALADIN/ALARO forecasts has to be quantified as soon as possible. If it is found to be beneficial, a participation of the RC LACE institutes in the "Optional Boundary Project" of ECMWF should be seriously considered.

Downstream developments (post processing)

To reduce systematic errors of final forecast products like near surface temperature, humidity and 10-m wind at selected stations, a statistical post processing tool (Model Output Statistics, MOS) of the raw NWP forecasts is advisable. A human forecaster is hardly able to improve upon the products generated by a well-calibrated MOS.

Role of other NWP systems at LACE centres

Besides ALADIN, some LACE centres are running other public NWP models like MM5, NMM or COAMPS quasi-operationally. In view of the scarce manpower available, we strongly recommend for the future to focus on ALADIN, ALARO and AROME only, and to abandon other systems for operational applications and downstream developments. However, for scientific case studies, the comparison of ALADIN with these other models will offer additional insight and may be a valuable tool.

6.2 Lead Centres

We propose that *Lead Centres* be established, with each centre assuming responsibility for one or more key areas. We note that some evolution towards the idea of Lead Centres has already taken place, albeit on an informal basis, and that it appears to be working well. Clearly, specialized expertise in each centre should be a critical factor in deciding on the allocation of Lead Centres. The Lead Centres will fall into two categories: centres responsible for *research and development* of methods and systems, and centres which also have responsibility for running components of the NWP suite on an *operational* basis. For each Lead Centre having operational responsibilities, a second, *Back-up Centre*, should be nominated. In deciding on the configuration of the Lead Centres, it is important to ensure that a *balanced distribution* of responsibilities is achieved. Task sharing between the Lead Centres should be on a *voluntary basis*.

Table 4. Sketch of a possible configuration of Lead Centres

1	**Common ODB / Data Assimilation**	**Ops + Res**
2	**Nowcasting system / EPS**	**Ops + Res**
3	**Dynamics / Intermediate NWP model**	**Ops + Res**
4	**Post processing / Surface Analysis**	**Research**
5	**Radar data composite**	**Research**
6	**Monitoring / Verification**	**Research**

The determination of the areas of responsibility of the Lead Centres, and the precise definition of their duties, will require detailed planning. However, we are convinced that it is possible to achieve a balanced allocation of responsibilities between the LACE Members. To illustrate this, in Table 4 above we list the key topics in six groups. Responsibility for each area could be assigned to one of the LACE Members. Three of these Lead Centres would have operational duties as well as a research function. The other three would be primarily concerned with research. One possibility would be for the larger Members of LACE (Austria, Czech Republic and Hungary) to assume responsibility for the Lead Centres concerned with operations, while the research centres would be based in the institutes of the smaller LACE Members (Croatia, Slovakia and Slovenia). However, we must stress that the configuration in Table 4 is *for guidance only*. The final configuration will depend on deeper analysis and more extensive discussions.

Finally, the role of Romania in the future programme of LACE research has not been explicitly considered in this evaluation. The possibility that the Romanian National Meteorological Administration should take on the function of a Lead Centre will depend upon the qualifications of the scientists, and their particular expertise in NWP.

6.3 Strategy and planning

To improve the strategic planning process, LACE must formalise a clear and consistent procedure which takes into account the local users' needs, as well as all other external and internal factors and developments. A survey of user requirements, with respect to forecasting products in general and NWP data in particular, should be conducted on a regular basis in meetings with key customers at all LACE centres. Members of the LACE Steering Committee (LSC) should inform the users during these meetings about the strategy of NWP-related research and development, and should discuss possible downstream developments with them. LSC should co-ordinate and harmonize the individual user requirements, translate them into NWP development tasks and take into consideration all the other external and internal factors which have an influence on the final NWP strategy.

We advice the Council to adopt a general *10-year strategy of RC LACE,* which should be updated every five years. This should include the establishment of a common Observations Data Base (ODB) and the other major collaborative projects detailed in §5. Based on this general strategy, the LSC should formulate a more detailed 2-year plan, updated annually, which describes concrete goals, itemizes specific outcomes and includes work-packages and implementation schedules of a small number of priority projects.

Such an approach will help RC LACE to derive an NWP strategy which reflects its own interests to the best possible extent. Being the best-organised group in the ALADIN community, RC LACE will have much more influence on the overall ALADIN strategy in the end.

6.4 Management structure

All LACE centres feel that the current management structure (Council, LACE Steering Committee (LSC), Project Leader (PL), Management Group (MG) and Working Groups (WG)) is appropriate and is working well. However, we give some recommendations in order to improve the overall efficiency of the LACE bodies.

Council

The twice-yearly Council meetings offer a unique opportunity for the PL of LACE to inform the directors concisely about the status and progress of NWP and research and development at the member services. The volume of papers for the meeting should be reduced considerably, and should highlight the most important aspects of the project. The material must be dispatched in timely fashion, so as to be available to the participants at least two weeks before each Council meeting. The PL should prepare short management summaries for the presentations.

The Council lacks a clear policy and formalism with respect to the appointment of new management staff. Clear procedures, including formal written applications, selection criteria, interviews, etc., should be implemented.

LACE Steering Committee (LSC)

LSC serves as the main advisory body of RC LACE. To fulfil its role, LSC should

- Receive the extensive material to be studied, at least two weeks before the meeting.
- Reduce the time spend on technical issues, and increase the time for strategic issues related to the work packages.
- Highlight training needs and co-ordinate the training offered at LACE centres and elsewhere.

For each agenda item, the main issues should be highlighted in an introductory remark by the PL.

Management of a dispersed project such as LACE presents real challenges. The LSC can greatly assist and support the Management Group by ensuring that scientists in their institutes undertake the tasks as defined in Work Plans and keep to agreed schedules. However, this can be effective only if LSC members are at a sufficiently senior position. We recommend that LACE Members nominate to the LSC staff at senior level, typically at the level of Director of Research.

Project Leader (PL)

The PL position, currently a half-time position, should be raised to a full-time position (or at least to an 80% position; 4 days per week). This is considered to be essential, in view of the range of duties and responsibilities of the Project Leader.

One main concern of the PL must be to improve the international visibility of RC LACE. Since RC LACE frequently appears to be responding to and adapting to external influences, rather than to be steering developments, the PL should be more pro-active in putting RC LACE objectives on the international agenda. The PL should encourage RC LACE workshops open to other NWP consortia in Europe. He/she should participate as RC LACE representative at important meetings and conferences, and he/she should be “the FACE of LACE”.

Management Group (MG)

The MG consists of PL, ALADIN-LACE System Co-ordinator (ASC), Data Manager (DM) and the four Working Group Leaders (WGL).

The current policy of reviewing management positions each year introduces an unnecessary degree of uncertainty. The major research areas require several years for substantial progress to be achieved. A longer time-scale for management appointments, at least three years, would be more appropriate.

We recommend that the ASC and DM functions should each be a half-time position. The Terms of Reference for ASC and DM have to be completely reformulated and separated to highlight their different responsibilities.

The WG Leaders need to have more formal control of the scientists working in their group, otherwise a proper planning and management of tasks is almost impossible. The flow of information between the scientists, especially those in different WGs, has to be improved considerably.

The current scientific plans of the four Working Groups vary in quality and detail, with some of them looking more like shopping lists than firm plans. Clear priorities and firm schedules are not always included in the plans. There seems to be inadequate co-ordination between the different WGs, so that certain research tasks result in work packages in two or more WGs.

Core Group

Since many RC LACE scientists are working mainly on operations and downstream developments, the time spend on longer term research is actually rather limited. Although there is some progress visible in certain areas, there is a clear need to have more scientists in RC LACE who devote more than 50% of their time to research tasks. The installation of a "Core Group" of four to six scientists devoted almost entirely (say, 80% of full-time) to longer term research tasks should be examined.

6.5 Improved internal and external communications

A recurring theme in our discussions was the lack of recognition of RC LACE outside the ALADIN Community. We feel that this is largely due to a failure of the Project to promote itself more actively and to exploit opportunities to improve its image. We also feel that this is a problem that is easily resolved. The recommendations below address this issue.

WWW as repository for documentation

For a project like RC LACE, excellent communications are vital. All managers and scientists need to have comprehensive and timely information about current and planned activities, and research accomplishments must be publicised quickly. The current level of exploitation of the internet is far below an optimal level. The state of the RC LACE website is *quite unsatisfactory*. We understand that steps are under way to rectify this. We recommend that a well-designed and easy-to-use website is established as a matter of urgency. The ongoing maintenance of the site requires modest but continuing staff resources. However, the benefits for both internal and external communications fully justify such an investment. Management reports, scientific plans and model documentation should be easily accessible directly on the site or via easily-found links. Responsibility for maintenance of the site should be clearly assigned, but the generation of content is the responsibility of all RC LACE managers and scientists.

Visual Image of RC LACE

All successful commercial companies know the importance of a strong visual image. RC LACE can easily enhance its image by the simple expedient of adopting a uniform symbol which should be prominent on the website, on all documents and reports and on communications with other bodies and groups. We welcome the move to design a logo for RC LACE. This is another area where a small effort can have a major pay-off.

It is also desirable that all planning and scientific documents have a uniform and agreed design format. This is particularly the case for documents which are circulated outside the project, but it is a simple matter to apply the design as a universal format, which will help to consolidate the image and profile of the project.

Communications with other NWP Consortia in Europe

With strongly overlapping interests, all the European NWP consortia stand to gain enormously from close co-operation. We have mentioned the close collaboration between HIRLAM and ALADIN above. RC LACE should actively identify areas and topics where co-operation with other groups could be of obvious benefit. These may be areas of current strength, in which the RC LACE scientists can offer immediate and substantial contributions; but also areas where RC LACE is currently lagging, and needs to make rapid progress.

The RC LACE Management Group should explicitly consider possibilities for collaboration with other groups when defining the scientific plans for RC LACE.

Acknowledgement: The authors of this report should like to express their appreciation of the strong support and willing co-operation they received from all the LACE participants during the execution of this evaluation.

Annex I: Terms of Reference for the RC LACE Evaluation

Short introduction about the history of LACE and Description of the past (last 10 years) and present (last 3 years) of the LACE structure

Review of the general objective of the LACE project

The present objective can be described as *co-ordination and research* as opposed to *operations and research* under the previous MoU.

Issues to evaluate:

- considering the weight of the member institutions, is the structure appropriate
  - decentralized separate operations
  - decentralized research
  - are the human resources used optimally
  - are the technical resources used optimally
- considering the weight of the member institutions, is the working plan appropriate
  - are the human resources used optimally in the present scheme
  - is the recent NWP development optimally incorporated
  - is it possible for a structure as LACE to remain general (not specialized)
  - could a specialized character of LACE bring improvements for all members
- considering the ties with ALADIN, are the present LACE strategic goals appropriate? (ALADIN strategy, LACE strategy and MS strategies)
- in the present structure, could the customer needs be satisfied better
  - could new customer needs be identified

Advices sought:

- what would be the best long-term objectives for a group as the LACE
- should the end-user needs be treated commonly as LACE or in each member service independently; how does this depend on common vs. decentralized operations
- In light of probable changes in short range NWP in Europe:
  - is the present structure of LACE appropriate to remain an important player in the short range NWP in Europe
  - is LACE a subject or an object in the future integrations within the NWP community in Europe

Definitions about the details of work

- LACE Project Leader and reviewers team prepare the list of visits to MS's
- Reviewers propose the time-table and list of the experts they would like to interview (deadline: 1st of February, 2006)
- Hosts of the visits: the visits are hosted by the Directors of the MS's
- The reviewers team prepares an intermediate report (15th of May, 2006)
- The final document shall be available on 1st of August 2006

Annex II: Schedule of Evaluation

Date	Type of Meeting	Place	Evaluation Team
09/01/06	Planning of evaluation	Offenbach	P. Lynch, D. Majewski
16-17/02/06	Lace Steering Committee	Budapest	P. Lynch, D. Majewski
14/03/06	Council	Rust	D. Majewski
15-16/03/06	Vision Meeting	Reading	P. Lynch
20/03/06	Evaluation at LACE centre	Prag	P. Lynch, D. Majewski
21/03/06	Evaluation at LACE centre	Bratislava	P. Lynch, D. Majewski
22/03/06	Evaluation at LACE centre	Budapest	P. Lynch, D. Majewski
27/03/06	Evaluation at LACE centre	Zagreb	P. Lynch, D. Majewski
28-29/03/06	Evaluation at LACE centre	Ljubljana	P. Lynch, D. Majewski
30/03/06	Evaluation at LACE centre	Vienna	P. Lynch, D. Majewski
31/03/06	Management Group	Vienna	P. Lynch, D. Majewski
13/07/06	Discussion of the intermediate Evaluation Report	Vienna	P. Lynch, D. Majewski

Annex III: Scientific Achievements of LACE

This Annex contains a list of LACE-related developments which have been implemented in the IFS/ARPEGE/ALADIN library or have become reference tools for use in this context. We have endeavoured to prepare a comprehensive description; however, the list is not necessarily exhaustive. [We are grateful to Jean-François Geleyn, ALADIN Project Manager, for provision of the bulk of the information in this Annex].

'Data processing' tools or actions:

- Model configurations ensuring change of geometry and domain (ARPEGE to ARPEGE and ARPEGE to ALADIN) to produce the initial conditions (for global model and LAM) and lateral boundary conditions for ALADIN;
- Use of high resolution orographic data in the 'climate fields set-up' LAM configuration;
- CHAGAL: the CHArming Graphics for ALadin (visualisation tool);
- ODB (LAM adaptation, operational handling and documentation of the ECMWF tool);
- Basic tools for LAM variational data assimilation (TL & AD codes, A+B-C state computations, …);
- High resolution dynamical adaptation for forecasting wind;
- DDH (Diagnostics par Domaines Horizontaux) diagnostics for AROME;
- Algorithmic tool for the anticipated discovery of potentially stiff behaviours of physical schemes (in time or along the vertical);
- Several tools for downscaling (regional climate applications);
- 2D vertical plane model as an academic tool for dynamics;
- 3D SCANIA and ALPIA academic environment for dynamics and physics;
- The COMPARE-PYREX inter-comparison;
- The MAP real time ALADIN application;
- The MAP precipitation forecasting inter-comparison;
- Downscaling of MAP IOP ECMWF Re-analysis database;
- SURFEX developments for A/A/A/A;
- LAM-EPS basic tools' development.

Dynamics:

- Semi-Lagrangian advection scheme for ALADIN, both 3TL and 2TL;
- Spline SL interpolators;
- Major contribution to the development of non-hydrostatic ALADIN kernel (basic Eulerian 3TL version, PC scheme for the semi-Lagrangian extension, introduction of new prognostic variables, bottom boundary condition, interface to physics, 'w'-advection scheme, non-isothermal SI background, link with ECMWF VFE scheme, etc.);
- Advection of absolute horizontal wind option in ALADIN;
- Analytical Coriolis term computation when advecting absolute horizontal wind;
- Tuning of linear horizontal diffusion scheme;
- Semi-Lagrangian Horizontal Diffusion (SLHD) scheme;
- Biperiodicisation algorithm;
- Quadratic (in time) coupling;
- Tuning of the shape of the Davies-type relaxation coefficients;
- New technique for the interaction between Davies-type coupling and SI treatment of the fast waves.

Physics:

- Time and space dependent 'anti-fibrillation' scheme;
- New (slantwise) method for the determination of the PBL height;
- Contributions to the so-called 'CYCORA' packages (downdraft parameterisation, saturated adiabat more precise computation, enhanced detrainment terms, vertical profile of the turbulent exchange coefficients, …);
- Improvement of Xu-Randall cloudiness scheme, specific treatment of low-level clouds;
- Moist gustiness term development and tuning;
- Gravity wave drag/lift parameterisation;
- Radiation scheme improvements (cloud overlap, NER statistical method) and tunings;
- New formulation of thermal roughness term over sea and tuning;
- Dynamic/physics interfacing scheme;
- Development of ALARO-0 components (pseudo prognostic TKE scheme, parts of radiation scheme, new method for the sedimentation computation in complex microphysics, technical code phasing for the prognostic convection scheme called 3MT).

Data Assimilation:

- Blending algorithm (DFI-type for upper air and A+B-C-type for surface);
- Meso-scale 'lagged' structure functions;
- Application of the three-dimensional data assimilation scheme (3D-Var) in ALADIN, with LACE scientists being constantly in the forefront on this action;
- Developments for the Hollingsworth-Lönnberg statistics;
- Background error statistic with ensemble technique;
- "BlendVar" cycling scheme;
- Development of the radar obs-operator for AROME;
- Linear physical package for 4D-Var;
- Development of 3D-FGAT system;
- AVARC tool (4D-VAR assimilation of synoptic trajectory corrections);
- Nonconventional observations (ATOVS, AMDAR, wind-profilers, MSG/AMV);
- Smoothing of Soil Wetness Index;
- Latent heat nudging.

Regional Ensemble Prediction System:

- Optimization of ARPEGE SV perturbations for LAM-EPS;
- Initialization of ALADIN/EPS with ECMWF EPS products;
- Breeding method perturbations for LAM-EPS.

Annex IV: Brief details of the Evaluation Team members

Peter Lynch

19/06/1947	Born in Dun Laoghaire, Ireland
1968	B.Sc. in Mathematical Sciences, UCD
1969	M.Sc. in Mathematics, UCD
1971	Joined the Irish Meteorological Service, now Met Éireann
1982	Ph.D. in Dynamic Meteorology, Trinity College, Dublin
1994-2004	Assistant Director, Met Éireann
1991-1998	Member of Scientific Advisory Committee, ECMWF. (Chairman of Committee, 1997-1998)
1997-1999	Project Leader of HiRLAM Project.
2000-date	Member of HiRLAM Advisory Committee
2004-date	Professor of Meteorology, UCD
	Fellowships: FRMetS, FRAS, FInstP, FIMA. Member AMS, EGU.
	Publications: about 40 (refereed) in NWP and dynamic meteorology.

Detlev Majewski

07/03/1955	Born in Duisburg, Germany
1979	Diploma in Meteorology, Meteorological Institute of the University of Bonn
1979-date	Scientist at the Research and Development Division of the Deutscher Wetterdienst (DWD) in Offenbach, Germany
1981-1990	Member of the development team of the regional Europa-Modell
1991-1995	Head of the development team of the high-resolution Deutschland-Modell (international team with the Swiss Meteorological Institute)
1996-1999	Head of the development team of the global icosahedral-hexagonal gridpoint model GME (international team with J. Baumgardner, USA)
1996-date	Head of the Section Numerical Models (16 scientists, 2 programmers)
2002-date	Member of the CAS/JSC Working Group on Numerical Experimentation
2003-date	Head of ICON (Icosahedral nonhydrostatic global model) DWD team; joint development of DWD and Max-Planck-Institute for Meteorology, Hamburg (German Climate Research Centre).