A strategy for the ALADIN consortium from 2008 to 2017 (final version – 06/02/08)

0. Executive summary

The ALADIN consortium has become one of the major actors in LAM NWP, providing the participating NMSs with state-of-the-art world-class tools for short-range weather forecasting. The main challenge for the consortium in the next decade is to keep this position while improving its cost efficiency and the impact of good short-range NWP tools on downstream applications.

From the scientific point of view, the main axes are:

- development of a NWP suite at kilometric scale;
- noting that the complete replacement of current 10-km systems by the kilometric-scale system will take many years because of the induced computing resources, development of a NWP suite at intermediate scale (typically 5 km) at affordable cost for all members;
- development of a scale-relevant probabilistic forecasting system mainly based on ensemble prediction techniques.

All this should be competitive with any other system of that type in the world. Achieving this requires work in all NWP domains:

- model part: more sophisticated physics, the transition from implicit to explicit treatment of deep convection (especially important for the intermediate-scale system), advanced methodologies for Lateral and Surface Boundary Conditions (LBC and SBC);
- data assimilation part: based on the variational approach, it should become able to ingest advanced high-resolution observing systems such as radars or satellites;
- the model perturbation techniques, partly linked to the data assimilation tools, partly linked to the research on model physics, partly linked to LBC and/or SBC;
- advanced post-processing techniques;
- development of small-scale oriented verification;
- special attention to maintenance, since the common code currently gets more and more contributors and deals with more and more types of application.

On top of this pure NWP work, the interface with applicative models in fields like hydrology, air pollution, oceanography, etc. will be improved, aiming at environmental prediction. In some cases this may lead to inclusion of applicative modules in the ALADIN software.

The operational benefits are expected:

- for short range prediction (1-2 days) with special emphasis on the first 24 hours; the skill of the kilometric-scale system for nowcasting issues will be assessed, which will probably result into first operational nowcasting-oriented configurations;
- for prediction of local phenomena, such as convective precipitation (including extreme precipitation), rain/snow discrimination, fog and low clouds, sea- or mountain breeze, wind gusts, etc.

These items belong to the main priorities expressed by the NMS' users, mainly but not only in link with protection of life and property. The value to vital sectors of the economy is also undoubted e.g. to the management of large airports in foggy conditions.

Among the means for improving the consortium's efficiency, the enlarged collaboration with HIRLAM has priority. It has first mutual scientific advantages: while HIRLAM will benefit from ALADIN know-how in terms of model dynamics e.g., the reverse will exist in other domains like data assimilation. But it also has an important political impact, improving interoperability in line with SRNWP main priority, reinforcing the cooperation with ECMWF, and more generally helping structuring NWP in Europe. Additional co-operations with research institutions and other NMSs will also be sought.

1. Introduction

Numerical Weather Prediction (NWP) models have become the backbone component of modern systems for forecasting the weather. They support two main categories of applications:

- global (i.e. covering the whole earth) forecasting at relatively coarse resolution, aiming at forecasting several days ahead; only a few big centres perform such activity;
- local area forecasting at high resolution, mainly focusing on the first 1 or 2 days; in developed areas such as Europe, almost all National Meteorological Services (NMSs) run Limited Area Models (LAM); running a LAM requires Lateral Boundary Conditions (LBCs) coming either from a larger LAM or from a global model.

Created in 1991, ALADIN is a consortium of 16 (at the date of writing) NMSs[1] co-operating in LAM NWP. It is based on the following key-ideas that are shared by the participants:

- the NWP tools obtained from this co-operation are better than what any single member could develop alone, using solely its own financial or human resources;
- acquiring know-how, developing an efficient NWP model, understanding its content, its strengths and weaknesses, mastering its functioning, optimising its performances, gives significantly better end-products than just running as a black box a model developed by a third party;
- the best quality of a NWP system can only be achieved by combining forecasting and data assimilation, which itself requires adequate observing systems devoted to fine scale meteorology such as satellites and radars; mastering the whole chain from observation to forecast, as the NMSs do, makes a difference that can be crucial in high impact weather situations e.g. surface wind-storms, sharp fronts, steady precipitation systems on large areas, intense convective systems leading to flash floods, squall lines, intense lee vortices, breaking mountain waves, strong sea-breeze fronts, extreme heat or cold waves, specific situations potentially leading to important pollution events.

In other words, at a time where advanced NWP models and their LBCs can be freely downloaded from Internet and run at home by any type of institutions, the ALADIN NMSs have found a cost-effective co-operative organisation allowing to provide significantly better information to their users, in domains spanning from civil protection to economic activities, and to maintain this advantage in time. It is worth noticing that, since the consortium creation, the number of ALADIN members has always been increasing. This indicates that, until now, the benefits of the co-operation have met the expectations of the participating institutes.

The current ALADIN members all originate from the Euro-Mediterranean region. Other LAM consortia exist in Europe, such as HIRLAM or COSMO, based on the same key-ideas with some implementation differences. All of them coordinate through the framework of EUMETNET SRNWP Programme, which is currently being redesigned, aiming among others at an increased interoperability between the systems created by the consortia. Among the other consortia, HIRLAM has the closest links to ALADIN, having had for many years a research co-operation with Météo-France, while ALADIN has been, from the beginning, partly based on scientific ideas from HIRLAM. The goals and means of both consortia are very similar: although presented in a slightly different manner, the HIRLAM strategy[2] and this document have a high level of commonalities. The respective strengths and weaknesses of both consortia complement each other well. In the recent years, in the so-called "HARMONIE" dynamics, ALADIN and HIRLAM have collaborated more and more closely, giving a new impulse to the European structuring of NWP activities; this trend will certainly continue in the next decade, if not up to a full integration of both consortia, at least to a high level of interaction.

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[1] Several members are also NHMSs, or may have other missions to carry out than just meteorology.

[2] See 'http://www.hirlam.org/open/documents/strategy0615.pdf'

Almost all countries involved in the SRNWP consortia are either ECMWF members or having cooperation agreements with ECMWF, world leading centre for global medium-range NWP. But ALADIN also takes advantage from his unique position with respect to ECMWF, through the inclusion of its NWP code in the IFS-ARPEGE framework that has been jointly developed by ECMWF and Météo-France for the last 20 years.

From the scientific point of view, the main challenge for LAMs in the next decade is the progressive move from the current systems running at 10 km mesh-sizes to systems running at kilometric scale. Behind this pure generic description (10->1 km), a lot of important issues are to be solved in all domains of NWP. The objective is not just to run models at kilometric scale, it is to have these models really performing much better than the current systems, better than the global models that will in the mean time come closer to our current scale, and improving the detailed weather forecast at short range in a way that meets the users' expectations, with special attention on high impact weather conditions and more generally on highly weather sensitive social and economic activities. High-resolution probabilistic forecasting, mainly relying on LAM ensemble systems (systems performing or the same event several forecasts that slightly differ in their initial state and/or in their forecast formulation), is also one of the important issues. On top of weather forecasting, downstream applications such as pollutant dispersion forecasting, oceanic surface forecasting (waves, storm surges, etc.), hydrological forecasting, etc. should all benefit from the improved atmospheric description.

The hereafter developed 2008-1017 ALADIN strategy intends to reach these ambitious challenges in the most efficient and cost-effective way, keeping the consortium at its world-class position in its domain.

2. Goals & Benefits

2.1 Main goals

As expressed by the 3rd ALADIN Memorandum of Understanding (2006), the main goal of the ALADIN cooperation is *"to improve the value of the meteorological, hydrological and environmental [forecasts], through the operational implementation of a numerical weather prediction (NWP) system capable of resolving horizontal scales from the meso-beta to the meso-gamma scale (1-3 km mesh size) and improving the prediction of high impact weather phenomena such as heavyprecipitation, intense convection and stormy winds."*

This goal implies the research, development (R&D), and operational use of NWP software, which includes forecast models, data assimilation systems, probabilistic prediction software, nowcasting tools, and their interfaces with environmental models (e.g. air quality, pollutant dispersion or hydrology).

The cooperation aims to provide ALADIN national teams with state-of-the-art, flexible solutions for their own operational needs, as well as sufficient training for local maintenance and optimisation of their NWP operational systems.

Thus, the ALADIN consortium will support several configurations of the NWP software, in order to leave room for scientific innovation and for a diversity of operational strategies across the ALADIN partner institutes. At the same time, it is recognised that working on a unified framework (in terms of scientific strategy and software tools) can improve the efficiency of

R&D work. Thus, a balance will be sought between a diversity of approaches, and a unification of the working framework, as outlined in the 'Implementation' section.

2.2 Complementary goal

A complementary goal of the ALADIN cooperation is the development and use of regional climate models and related tools, in order to serve the needs of the ALADIN members in the field of climatology (climate research, seasonal prediction and risk assessment). This activity has recently been growing in importance, both as tool showing the intrinsic quality and versatility of the ALADIN system and as test-beds for NWP solutions. This trend should be encouraged whenever it does not endanger the progress on more directly NWP-related issues.

2.3 Link between user requirements and benefits of NWP

A 2007 survey has shown that the user priority for limited-area model products is on regional short-range forecasts of:

- precipitation (extreme, flooding, convective, hail, solid vs. liquid),
- low level temperatures (extremes, winter anticyclones, urban heat islands),
- cloudiness (low clouds and fog),
- low level wind (windstorms, gusts, sea/mountain breeze),

where the emphasis is on helping decision-making and risk-quantification. A critical aspect is the translation of NWP output into critical end user events: floods, road icing, health hazard, and traffic conditions. The probabilistic formulation of NWP output as well as the development of numerical nowcasting tools is requested by the users. The (hydro)meteorological services require the NWP systems to make good use of the computing systems and observing systems they have funded (regional networks, radars, satellites).

The strategy presented here aims for a continuing improvement of NWP tools that meets all these requirements. This will increase the value of ALADIN partner products in the fields of meteorology, hydrology, and monitoring of the environment. Particular benefits are expected in the ability to produce timely warnings of high impact weather events at the national and local scales, such as flooding, fog, heat waves, frost, downslope windstorms, coastal damage, lightning, pollutant dispersion; as well as improved monitoring of air quality, forecast of road and air traffic conditions, improved efficiency in the agricultural, manufacturing and building sectors, products for the tourism industry, assistance for military and humanitarian operations, numerical modelling infrastructure for the academic and applied research in the meteorological, space and environmental sciences. Last but not least, the local modelling know-how provides each ALADIN partner country with national expertise and the capability to adapt to new user demands.

The extent to which the requirements are met will strongly depend on the amount of resources allocated to NWP R&D staffing, local computer and telecommunications infrastructure, deployment and acquisition of observations.

3. Current status

The relative heterogeneity of the ALADIN cooperation largely determined its present state. Indeed it involves national meteorological institutes with different means and workforces, and often different educational backgrounds. This has diversified and will continue to diversify the targets and tends to make the cooperation heavier. In contrast, this has forced the cooperation to strongly rely on algorithmic to provide flexible enough solutions to suit the needs of all partners and to acquire a quite unique experience in this.

One of the strategies to achieve the common frame has been to provide sufficient reciprocal support to stimulate each partner to become as autonomous as possible. The goal here has been to create a full link between research and operations. In turn this created a background for fostering new ideas that have been capitalised on. While doing so, the ALADIN cooperation built substantial experience in optimising the use of available manpower at an international scale.

In a scientific and operational cooperation as the ALADIN one, there is a persistent threat of losing the balance between being flexible enough to incorporate emerging innovation and imposing sufficient technical constraints to guarantee a successful collaboration. Managing the joint collaboration between the partners and the software link with the IFS system, the ALADIN cooperation found a good balance in its early years, apart from weak points such as for instance a lack of documentation. However, with the increasing European demand for interoperability, keeping this balance is expected to become an important task in the near future.

Currently, the diversity between the ALADIN partners asks for a multi-scale approach to NWP, needing models that are consistent across a range of scales with varying computational efficiency. This poses a big scientific challenge. The present state within the ALARO project provides compelling evidence that the most delicate problem of all, running models at scales around 5 km of mesh-size, will be possible in the coming years. On the other hand, the first AROME results have confirmed the feasibility of an operational capability resolving explicitly convection, at mesh-sizes of 2-3 km.

Technological evolutions are creating more freedom to run models with a local-customer adapted frequency. Additionally, increasing societal demands will ask for more integrated forecasting systems (hydrology, air pollution, and oceanography), more emphasis on ensemble forecasting and nowcasting applications and high-resolution reanalysis. These lasting trends offer new opportunities for the NWP community to deliver more value to society and to broaden the spectrum of applications of its work. However, even if the related activities are closely related to NWP, they do not constitute the core of NWP modelling, and one therefore needs to control the risk of diverting limited resources in a too wide range of applications, leading to resources dispersion and loss of critical mass in members' teams.

Also, societal demands are likely to start growing beyond that scope of what the ALADIN cooperation has been coping with in the past. Overly satisfying not-so-well-defined ones may start to bring more disadvantages rather than gains. An exception to this is expected to be climate modelling in which a feedback from the climate modelling community should be expected to be beneficial to NWPmodelling.

HARMONIE (the bridge between ALADIN and HIRLAM Consortia) provides opportunities for sharing efforts but should be undertaken carefully. Indeed if both sides are just overly adopting the others' strong features, we shall overdo the convergence rather than building a true synergy. Additionally, concerning training and recruiting newcomers to the workforce there is room for extending the link with academia. This has to take into account various ownership of code elements and the related need for code protection whilst promoting more research licenses as always encouraged in the successive MoUs. Opportunities for considering new alliances and partnerships might come from the increasing demand for non-operational applications such as climate modelling, reanalysis and 'exercise-type' modelling. The latter item deserves special attention since one should find dedicated power in order both to protect the ownership rights of partner NMSs and ECMWF and to put the needed additional developments in line with the specific characteristics of the ALADIN maintenance (constrained by the IFS/ARPEGE phasing exercises).

Due to the diversity of needs and the scientific evolution, any hierarchy between up-to-date forecast systems in NWP is difficult to establish and there is no purpose in trying to identify the single *best* one. On the contrary, it is becoming more and more necessary to extend the scope of the evaluation of the cooperation to -besides standard verification scores for the model output- notions such as numerical efficiency, portability, flexibility of use and upgrading, capacity to capitalise on new ideas, as well as to the socio-economic benefits of the information provided by the various ALADIN-based NWP suites.

All of this is summarised into the SWOT (Strengths, Weaknesses, Opportunities and Threats) table below, which serves as a reference for targets, R&D planning, organisation and evaluation. The numbering after each item refers to the section(s) of the text where more information about the relevant issue can be found (apart from within the current section 3).

Strengths	**Weaknesses**
• ALADIN trademark: reliance onalgorithmics (5.1) • attention to flexibility (5.2 and 5.5) • capitalising on new ideas (5.1, 7.1 and 7.2) • each partner has a full link between R&D and operations (5.5) • experience in searching for unused manpower (5.5 and 7.1) • use of existing meteorological infrastructures at the European level (7.3 and 8.) • early ALADIN years: good example of a middle ground between total interoperability and the innovation component (5.1) • possibility of reliance on internal groupings (e.g. RC LACE) (4.1) • joining people from very differing educational backgrounds (5.5) • care for Integration of the software: link with IFS (ECMWF name for the common software platform with ARPEGE and hence with ALADIN) (5.5)	• difference between partners in workforce and in access to technology (4.3) • documentation (6.) • limits to wide access to the system (to e.g. academia) due to code protection (7.3)

Opportunities	**Threats**

• more freedom to run models with local-customer adapted frequency (4.2 and 5.5)
• external demands:
    ○ EPS for decision making (4.2.3 and 5.4)
    ○ reanalysis data (4.2.2)
    ○ integrated modelling (hydrology, air pollution, oceanography) (4.2.5)
    ○ nowcasting (4.2.2)
    ○ climate modelling (4.2.5)
• HARMONIE: synergy between ALADIN and HIRLAM (4.2, 5.3 and 7.1)
• consolidation of the transversal support to mobility in R&D (5.5)
• link to academia (5.1 and 7.2)
• across-scale consistency (5.2)
	• dispersion of human and computing resources to address too many opportunities (7.1 and 8.)
	• overly satisfying not-so-well-posed user requirements may start to bring disadvantages (4.3)
	• using an empty notion of the *best* system (8.)
	• have a construction around NWP where finally one wonders: "who is still doing the NWP?" (5.1)
	• HARMONIE: failure to capitalise efficiently on each other strengths and staying half-way between cooperation-competition and full cooperation (5.1, 5.3 and 7.1)

4. Targets

4.1 General development activity

The target is to provide, at any moment of the ten-year planning period, a state of the art mesoscale NWP capability for a broad spectrum of national resource levels. The key NWP software components are *forecast models*, *data assimilation systems*, and *ensemble prediction systems*. In the 2008-2012 period these components will focus on the representation of weather phenomena on horizontal resolutions[3] between 1km and 20km. Various versions of the components will be tuned to different resolutions in this range. In the 2013-2017 period the focus will shift towards the 500m-10km range in response to the likely increase in national computing power, and resolution of the forecast products from global modelling centres.

The activity on forecast models, data assimilation systems, and ensemble prediction systems, will focus on applied research, training, software development, and coordinated operational maintenance of the corresponding software. This *core activity* of the consortium will be complemented by *complementary activities*: academic research, R&D and maintenance of peripheral software (observation pre-processing, post-processing, verification, nowcasting application, etc.). These complementary activities will only be carried out at the ALADIN consortium level, if it is more cost-effective than national organisations (or existing sub-groupings within ALADIN, like RC LACE), or other international cooperation instruments (ALADIN-HIRLAM cooperation, SRNWP programmes, EU COST & FP projects, EUMETNET, ECMWF & EUMETSAT initiatives, etc.).

4.2 Key deliverables

The objectives of the spectrum of activities can be summarised by the following five types of deliverables.

<u>4.2.1. Model configurations:</u> The deliverable of the ALADIN cooperation is a set of four atmospheric *model configurations* that are intended for daily operational NWP. Each model configuration is optimised[4] for a specific range of horizontal resolutions:

- resolutions of 10km and above, which are affordable by all ALADIN partners throughout the strategic planning period, with an emphasis on wide-area modelling of synoptic phenomena, on low numerical cost for use by the smallest ALADIN computing centres, and use as climate models;
- resolutions between 4 and 9km, which are the best affordable resolutions for NWP at country scale[5] in most ALADIN institutes in the 2008-2012 timeframe;
- resolutions between 1 and 3km, which are affordable at country scale in the most powerful ALADIN computing centres during most of the strategic planning period, as well as in other centres for regional NWP or in the longer term;

[3] For the sake of brevity, the horizontal resolution scales here refer to the horizontal collocation mesh size, although the actual size of modelled weather features is somewhat larger than that.

[4] At the time of writing, the active *model configurations* are named ALADIN, ALARO-0 and AROME; this terminology being subject to semantic evolution, it is not used in this document. The guideline is that a well-tuned *model configuration* should be available for each operational resolution. Although any particular model configuration could be run operationally at a resolution for which it was not designed, the ALADIN R&D will focus on improving each configuration at its own target resolution, as opposed to fuelling competition between the model configurations.

[5] "country scale" means NWP products that cover the mainland national territory of a national institute.

•resolutions better than 1km, which shall be studied in the 2008-2012 timeframe and will become necessary for local NWP shortly afterwards.

4.2.2. Data assimilation tools: The deliverable of the ALADIN cooperation is a set of data assimilation tools (see part 5.3 for more details) that improve the short-range forecasts using regional in situ observing networks, satellites, and radars. These tools will support all model types listed above, as well as nowcasting applications by real-time diagnostic analyses of the atmosphere. A secondary goal will be their adaptation to reanalysis activities, especially for high-resolution reanalysis opportunities, whenever they may concretise.

4.2.3. Probabilistic forecasting systems: The deliverable of the ALADIN cooperation will be a set of decision-making tools for use with the NWP models of the ALADIN partners. In the 2008-2012 timeframe, the priority will be to develop ensemble prediction systems for all models developed and operationally used by the consortium. The user emphasis on short range, regional forecasts suggests that the uncertainty in the data assimilation and (lateral and lower) boundary conditions shall be explicitly modelled. In the 2013-2017 timeframe, a broader approach will be needed to account for the multi-model nature of the forecaster work, to provide a probabilistic formulation of automated forecast products, and to implement an interdisciplinary approach to the production of high-impact weather event warnings (including related events such as flooding). In preparation for this objective, academic research will be needed, as well as participation in relevant international activities (e.g. THORPEX, GLAMEPS, and SRNWP's EurEPS).

4.2.4. NWP software coordination: The deliverable of the ALADIN cooperation will be a sustained activity on using and improving a common NWP software repository that implements the above deliverables. This software repository shall be the main tool for research, for operations, and for hands-on training by all partners. The reliance on a common software repository is a traditional cornerstone of the ALADIN cooperation, and arguably its greatest asset. The software basis will be, in the 2008-2012 timeframe, the IFS/ARPEGE software, developed in cooperation with ECMWF and the HIRLAM consortium. Whatever future strategic decisions by these partners may be (and noting that the ALADIN consortium should take its full place in the discussions leading to those), and noting a possible extension to a broader European software cooperation, the backbone of the ALADIN cooperation will remain the use of common software.

4.2.5. Ancillary software and support to complementary goals: extra deliverables of the ALADIN cooperation will be initiatives to support non-strictly NWP activities, to the extent that it is cost-effective to handle them at consortium level. This includes software for observation processing, monitoring, verification, NWP post-processing, use of the joint software as a climate model or reanalysis tool, interfaces to coupled models (air quality, dispersion, hydrology, oceans, etc.). These ancillary activities will be taken onboard, only so far as they do not endanger the main objectives of the ALADIN cooperation. In the 2008-2012 period, the emphasis will be on facilitating the access of smaller ALADIN institutes to key ALADIN system components they cannot yet use because of insufficient local staffing (the data assimilation, climate and nowcasting tools in particular). In the 2013-2017 period, it is expected that the pan-European NWP cooperation (e.g. SRNWP) will have matured to the extent that these activities will be coordinated at a higher level than the ALADIN consortium.

4.3 Operational strategy

The definition of an operational evolution scenario for the ALADIN consortium is complicated by the large heterogeneity of human and computing resources between the partners. The wish to work in a unified framework will inevitably be vexed by permanent conflicts of priorities between the most expensive and the cheapest operational choices. Although nature is continuous, no single numerical modelling choice has proven able to satisfy all user needs at all scales. Consequently, the ALADIN consortium cannot have one single operational strategy, but typically three simultaneous modelling strands: a basic configuration, an intermediate configuration, and an advanced configuration. As computing power increases, the cheapest configuration becomes obsolescent (superseded by global models), the so-called "advanced" one becomes second to a newer, more cutting-edge configuration. This vision is very obvious in the field of model physics, it also exists in data assimilation (no data assimilation vs. blending vs. 3D-Var), and it certainly will occur soon in probabilistic forecasting and other emerging aspects of NWP. It should however be stressed here that encountering unexpected difficulties or witnessing some breakthroughs in the domain of nesting characteristics and strategies might require a mitigation or a revisit of what follows. This is especially true since the EUMETNET effort on 'Interoperability' will offer new ways of combining assets with those of other Consortia. Furthermore, the above-mentioned heterogeneity of the Consortium will probably induce various ways to look at this issue from one partner to the other.

During the 2008-2010 period, several options will be available for operational use:

•model configurations: the ALADIN model (already available), ALARO-0 (available around 2008) and AROME (available around 2008);

•model initialisation techniques: dynamical adaptation, blending and 3D-Var data assimilation;

•probabilistic forecasting: ensemble forecasting using ensembles of lateral boundary conditions, optionally with perturbation of the initial state by an ETKF, or by singular vectors;

•NWP software will continue to be based on the IFS/ARPEGE framework, with most software management done in Toulouse, and some model variations handled by the LACE group. The HIRLAM options will be rather innocuous add-ons at this stage;

•the main ancillary software will be ALADIN-climate, and two 3D diagnostic analysis options (Canari-Diagpack, and Varpack).

In the 2011-2014 timeframe, novel features will progressively become available; their actual use by the ALADIN partners will vary greatly from country to country, due to differences in funding level and NWP national strategies, including maybe coupling to IFS LBCs:

•in models, the distinction between ALADIN, ALARO and AROME will evolve towards unification of most physical parameterisations at scales from 1 to 10km. As regards deterministic NWP, modelling at scales larger than 10km will stop being a consortium activity, as many global models will start resolving them. New model options will emerge as part of the development sub-kilometric model configurations, scientific innovation, and the insertion of external code (from HIRLAM at least) into the ALADIN software. Assuming stability in the scientific staffing, about three operational model configurations will be actively supported by the ALADIN consortium;

•as regional observing systems develop, data assimilation will become the main factor in the short range forecast performance of NWP institutes: most partners will run their own 3D-Var data assimilation, use a neighbouring country's assimilation, or face increasing challenges about their national NWP activity. The use of regional data assimilation means a growing interdependence between NWP and regional observing system deployment & processing. The bigger NWP centres will start using simplified versions of 4D-Var and ensemble data assimilation;

•a sound LAM ensemble forecasting system configuration, including all major sources of uncertainty, and with demonstrable operational benefit, will reach pre-operational maturity around 2010. The high computing cost of ensemble forecasts probably means that neighbouring NWP centres will share their computing resources to run large regional ensemble systems. As model interoperability develops, ARPEGE will cease to be the only provider of boundary conditions to ALADIN partners, and the use of IFS EPS and MOGREPS boundary conditions will spread. All the bigger NWP centres will participate in the pan-European multi-model ensemble projects (EurEPS);

•NWP software management may change a lot due to decisions at ECMWF, HIRLAM and other consortia about the use of the IFS/ARPEGE software. It is expected that the HIRLAM software will become thoroughly merged with the ALADIN software, and that the central role of Toulouse as phasing centre will be partly superseded by a more diffuse network of software maintainers that interact through videoconferencing;

•Ancillary software will develop considerably. One reason is the need for normalisation of peripheral activities such as observation processing, EPS product generation, model couplers, which are too labour intensive to be handled by most NWP centres. Interoperable software will start to be developed and used, in the spirit of the "Vision for NWP in Europe", and its maintenance will become an important new activity (tools for interoperability, verification, EurEPS). The relevant workforce can only be found by mutualisation of the R&D between several consortia, starting with HIRLAM. Regional climate simulations will use various configurations of the software. Surface (re)analysis, currently neglected, will be shared with other consortia and developed to use modern satellite products and assimilation algorithms. The diagnostic analysis will be interfaced to radar networks and nowcasting workstations in real time, although it is unclear how much staff will be allocated to these activities.

In the longer term (beyond 2014), deep changes to the European Meteorological Infrastructure may be expected, and the nature of the ALADIN activities may need redefinition, in a spirit of maximum possible continuity. The boundaries between ALADIN and HIRLAM are likely to disappear, as we will use the same NWP systems.

4.4. Operational roadmap

4.4.1. Deterministic forecast model

Operational implementations are more concerned with forecast quality and computational efficiency than the detailed physical content of the numerical model. The latter is a matter of national preference that cannot be controlled at consortium level. Thus, it is impossible to foretell which scales will eventually be run using the ALADIN, ALARO or AROME, or other configurations. For the sake of conciseness, the operational implementation plan will focus on the easiest to understand model characteristic, which is the horizontal grid resolution (the '5km' and '2km' numbers only represent ordersof magnitude).

2008-2010: 5-km model system available to all partners: The required computer resources for this 5-km system are about 10 times more than ALADIN-10km; this corresponds to approximately 5 years of computer evolution (assuming Moore's law); running the 5-km system in 2008 isn't more expensive than running ALADIN-10km in 2003, which all partners did, most of them even much before. One shall keep in mind, though, that computer changes are not done continuously, but step by step every 3-5 years on average, which can easily lead to a lag of one or two year in the actual availability of a given computation power with respect to the theoretical calculation. Anyhow, in this particular context, this doesn't change the general result that the 5-km system is affordable to most partners.
If verification results show that the 5-km system performs significantly better than ALADIN-10km, then most partners are expected to replace the current ALADIN-10km ones. This is expected to happen, for most partners, in the 2008-2010 period.

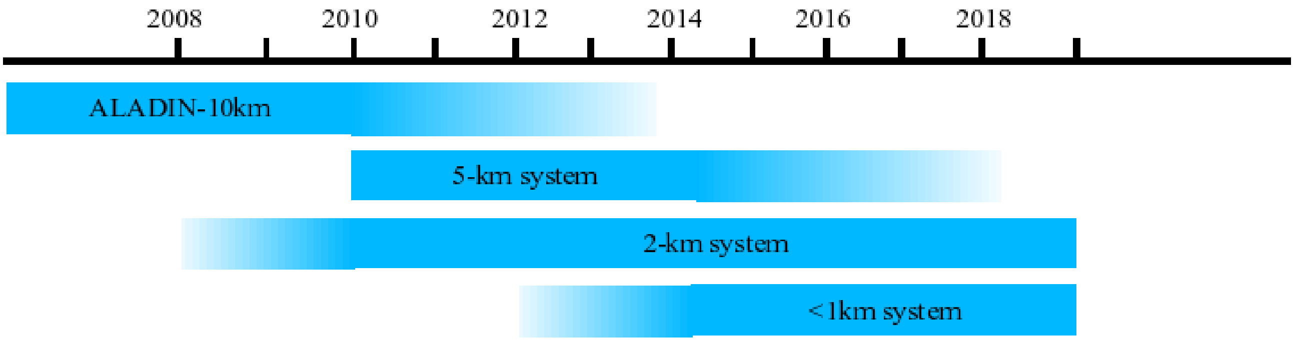
2008-2017: progressive implementation of the 2-km system: the 2-km system will become affordable[6] approximately 8 years after ALADIN-10km. The date of implementation of the 2-

[6] Timings of AROME vs. ALADIN in 2007 indicate a twofold overhead in per-gridpoint computing cost. Factoring in a tenfold decrease of the forecast model area for the 2km vs 10km system, the 2km forecast system

km system depends on several factors: budget of the NMS, size of the country, number of ALADIN applications to be replaced. But the consequences of the differences between big NMSs and small NMSs should not be overestimated. It is clear that Météo-France will be among the first NMS to have an operational 2-km system covering its country in 2008, but the variety of its ALADIN applications (overseas territories, military assistance, commercial support to other NMS out of the ALADIN consortium, etc.) and the geographical size of the corresponding domains makes a full replacement unlikely until 2012-2015. The first versions of the 2-km system will not have as much geographical coverage and forecast range as the lower-resolution systems. Therefore, for all partners at this first stage, the 2-km system should be seen as an additional application, rather than a replacement of either ALADIN-10km or the 5-km system, especially because most partners cannot rely on the coupling model to provide user-tailored products.

2009-2017: progressive phasing out of the ALADIN-10km system; however the envisioned introduction of operational LAM-EPS versions, and the existence of model versions on very large geographical domains (such as NORAF), imply that even at the very end of the 10-year period, the 5-km system may still be operational for some specific applications. But the large majority of applications will have switched the 2-km system. By then, some partners will have started using models at a better than 1km resolution, on top of the 2-km and 5-km systems.

The life cycles of these various operational configurations are sketched in the diagram below.



4.4.2. *Data assimilation, probabilistic system and nowcasting*

Although being key factors contributing to make the difference with Internet black-boxes, data assimilation, predictability systems etc. are regarded as less important in most NMSs. Thus, they will often be used as adjustment variables with respect to the local staff and computing resources, which will generate large discrepancies between the ALADIN partner centres. The only hope to mitigate this trend is by organising joint operational production of this part the NWP systems, in regional groups of ALADIN countries.

Implementation scenario for data assimilation:

•2008-2010: implementation of 3D-Var data assimilation systems, at full deterministic model resolution, in all centres that will be organised to afford it. Use of a lower-resolution regional data assimilation system (or, one run by another NWP centre) in the others.

•2011-2017: consolidation of data exchange practices across European countries and increasing interest in data assimilation in all centres, which will likely foster stronger cooperation inside regional groups of ALADIN countries that perform joint data assimilation. Rise of more advanced data assimilation algorithm such as 4D-Var in some NMSs.

costs 4x4x7x2/10=22 times as much as the 10km system, which represents 8 years of computer power evolution assuming Moore's law (a doubling every 18 months).

Implementation scenario for probabilistic forecasting:

•2008-2009: R&D and exploitation of experimental regional ensemble forecasting systems in a few ALADIN centres.

•2010-2013: implementation of more ambitious ensemble forecasting systems that provide demonstrable forecast value, either in the larger ALADIN centres, or in groups of smaller ALADIN centres.

•2014-2017: development of multi-model probabilistic forecasting systems with the other consortia, leading to externally imposed constraints on the ALADIN ensemble operational configurations, and better decision-making tools for high impact weather, not limited to the use of ensembles.

Implementation scenario for nowcasting:

•2008-2009: R&D and experimentation of rudimentary numerical nowcasting systems, the bulk of operational nowcasting applications being provided by non-NWP (e.g. imagery-based) traditional nowcasting techniques.

•2010-2017: development and deployment of a common NWP platform that can be interfaced to each institute's diverse nowcasting environments, using simplified, cheap data assimilation systems.

5. R&D choices for implementation of the strategy

The implementation of the strategic goals is done via coordinated R&D actions. There shall be high-level projects, which shall be completed by smaller, more focused ones. While the applications might be optimised for some horizontal scale ranges, the upstream research should account for the continuity of scales, which occurs in nature.

5.1 Scientific working arrangements

The coordination of R&D actions is given by the ALADIN governance (with progressively also more and more HIRLAM involvement), although currently still in a learning mode. Programme Manager, CSSI and LTMs shall prepare a prospective plan for medium term and more detailed work plan for a year. This sets up the necessary references and guidelines. However the decision making on new developments ought to be a compromise between already agreed orientations and innovation via confrontations of scientific ideas. As demonstrated by experience, the overall supervision by the steering bodies should not preclude the launching of scientifically new ideas, which have to be challenged and evaluated in scientific meetings (workshops, seminars, conferences, etc.) which also provide ideal occasions to spot new ideas, to check the level of our system in comparison with other European consortia and also world-wide. Confrontation with larger scientific community, either NWP or academic, is a very valuable practice to encourage in the whole ALADIN community. Therefore the planning process shall look for the equilibrium between keeping the focus on the planned targets and allowing for innovation: it shall allow a room for concurrence of ideas and trials of new things.

Another important strategic point is to take care for the algorithmic and numerical aspects. Indeed, the latter emphasis on such issues is making the key difference between the world of academic research and what is perceived in general as 'operational' weather modelling. It is a science, which is sometimes wrongly confused with purely technical coding aspects. It is all about stability, precision and effectiveness of the modelling schemes, an art on how to model in the simplest way complex physical processes. Therefore this care for scientific numerical aspects is a crucial strategic point for the ALADIN programme and its success, especially given the large stretch in computing power across the consortium.

5.2 R&D on the model part (dynamical core, physical parameterisations)

Advanced work on dynamical and algorithmic aspects of the model has been a trademark of the ALADIN scientific community, so that one expects substantial future activity in this area.
A sound basis of any modelling work is always to have a set of *governing equations*. These have to be appropriate for the smallest scales to be modelled, while keeping more approximated sets as switchable subsets. In the timeframe 2008-2012 one will aim at using as basis the Euler Equations for shallow atmosphere (with Hydrostatic Primitive Equations as a subset) together with energy-conserving barycentric equations for the thermodynamics. In the timeframe 2013-2017, a higher physical accuracy of the equations will be sought, e.g. by abandoning the shallow atmosphere approximation and by attempting to go to more and more complete sets of thermodynamical equations.

The basic set of model equations determines in any case the data flow architecture in the model and the interfacing rules between the atmospheric physics, the dynamics and the surface scheme. These rules are of vital importance to keep consistency in the common software. To develop in compliance with sound interfacing rules is indeed an important strategic choice, which enables modularity, generality and flexibility principles to be applied in a single framework. In other words the code architecture will allow the co-existence of several scientific options in the model, which is a natural way of cross-fertilisation of scientific ideas and at the same time a protection against obsolescence of basic concepts. For collaboration of so many countries around the same code, the governing equations and interfacing rules are essential and this principle should be the first one guiding any link between a strategic plan and its implementation.

The main foreseeable avenues of work in the purely dynamical part of the code will be (i) the continuation of the work on a compatible solution between the ALADIN-NH compressible dynamical core and the Vertical-Finite-Elements (VFE) discretisation scheme implemented at ECMWF and (ii) the search for a lateral coupling able to replace the Davies-type LBC relaxation-type application in a buffer zone, in the spirit of so-called 'open boundary conditions'. In the first case (NH-VFE), the successful link between both issues is of interest to the IFS, ARPEGE, ALADIN and HIRLAM community. It should thus receive increased attention, both for a first concretisation and, later, for a consistent transversal monitoring in order to avoid as much as possible divergences of use of the unifying tool one is currently aiming at. In the second case, all previous efforts pointed out to the difficulty of getting a compact spectral open boundary condition system. The accent is now put on the idea to use a splitting technique (a finite difference treatment of the differential terms linked to the coupling, within a still spectral general framework) in order to offer better chances of success to the yet long-term goal of a scheme combining all advantages of its 'spectral' and 'new-LBC' components. The present successful solution for the non-linear lateral diffusion (with the so-called SLHD development) provides good reasons to be optimistic on the capacity to progress along this avenue.

The physical parameterisations will be upgraded to (a) increase the realism of processes already modelled, (b) introduce the representation of extra processes, because of new user requirements and/or because of their interaction with the weather, (c) improve the physical, numerical and software compatibility between physical parameterisations (as suggested in subsection 5.1). The last item is of particular importance in order to avoid a dispersion of the R&D community into work on uncoordinated, competing parameterisations; the aim of the consortium is to keep a sufficient critical mass of workforce on each model component, which will limit the number of implemented safe and stable options. When parameterisation diversity is not warranted by clear physical or numerical reasons (e.g. justified by historical reason or coding taste only), intercomparisons should be performed using clean scientific experimentation (see the evaluation criteria in section 7) and open debate, in order to determine the best approaches for achieving the consortium objectives. Parallel physical developments will be allowed if they address different problems, or if they help to import valuable new science and expertise from new R&D partners.

The identified physical parameterisation priorities in the 2008-2017 period include:

- improvement of the representation of clouds, precipitation and the low level atmosphere at all horizontal resolutions, since they are key user requirements;

- improvement of numerical and physical components necessary to improve deterministic and probabilistic storm forecasts, which is another key user requirement;

- the representation of convection in the 3-9km resolution range, which is a key item for the 5-km model configuration, and a strategic item for future global model resolution increases;

- a reduction of redundancies between the ALADIN, ALARO, AROME and HIRLAM physics wherever they exist, by seeking software solutions to accommodate all requirements;

- introduction of the representation of new key processes, and of their interaction with dedicated models: dust, aerosols, chemistry, hail, lakes, ice, ocean waves, marine boundary layer, surface radiative properties, simplified physics for ensemble forecasting and 4D-Var, processes for modelling at sub kilometric resolutions (fine-scale turbulence, 3D radiation, slope effects).

5.3 R&D on data assimilation part

The staffing on data assimilation will be a difficult issue in many ALADIN members (meteorological services as well as academic institutions in the countries). Among other reasons it stems from technical hurdles in observation pre-processing and installation of observation software. This makes it difficult to install operational applications of the existing data assimilation system in ALADIN. It also has a non-negligible impact on the organisation of R&D as a network of many services. In long term it could become quite a penalising problem for the program. In this respect it is an important strategic choice to alleviate the above-mentioned technical hurdles by standardisation and/or sharing of data pre-processing tools whenever possible. Coordination of existing efforts on ODB could be a first and determining step in this direction.

Since the manpower constraint in general will exist in any case, the development strategy has to rely on the basis already offered by the global IFS-ARPEGE tools and to concentrate on the areas specific to high-resolution modelling and existence of lateral boundary conditions. There are enough challenges anyway: use of high-resolution data, use of observation-operators and their link to the algorithmic part of the system, whether and how to include moist physics aspects to the system.

Although a 4D data assimilation (4D-Var) is at this moment computationally out of the reach to be implemented operationally at resolutions less than 10 km, strategically it should be included in the research plans. It also has a lot to do with the question of the incorporation of moist physics considerations. Currently there is not enough knowledge to decide either to abandon completely investment in this area or on the contrary to focus there an important part of the research forces. In the short term it is important to at least maintain the tools like tangent linear and adjoint ALADIN model for the “dry” part. In the medium and longer term the question of water cycle should be addressed. This issue is linked as well to the design of observation operators as to the prognostic character of moist physics. The important strategic thing in the short term is not to close the door to future possible enhancement of the tools, for example observation operators and also their link to the chosen algorithmic solution.

The perspective to run ensembles of data assimilations (which is a simplified form of Kalman Filter) is going to be important for data assimilation itself, probabilistic forecasting and nowcasting. It raises cost and physics issues that are similar to 4D-Var. Algorithmic simplifications to 4D-Var and ensemble data assimilation should be invented and applied specifically for 2- and 5-km time-critical operational applications. The presence of physical non-linearities in key phenomena at these scales (e.g. fog, convection, cloudiness, precipitation) may severely limit the usefulness of tangent linear models, so some regularisation approaches (e.g. based on clever variables choices, probabilistic and object-oriented approaches) should be studied.

An important part, which is currently under developed in the ALADIN system, is the surface analysis. While the atmospheric circulation gets quickly dominated by the lateral boundary conditions, the surface initial conditions and scheme substantially influence the forecast quality of screen level parameters all along the forecast. For example, a robustly applicable snow cover analysis is still missing in the system and contributes to large forecasting errors in winter. It is planned to join with HIRLAM to develop state of the art regional analysis schemes for all critical surface fields which are not yet satisfactorily provided by global analyses: soil moisture and humidity (using variational methods), snow on ground, sea ice, and downscaling in mountainous and coastal areas.

The development of data assimilation seeks to be a superset of the ARPEGE-IFS system, less the stratospheric aspects (which are better left to global systems due to their large horizontal scale and complexity), plus extra ingredients for adding value at mesoscales (i.e. analyses at 1 to 10km resolution, analysis of boundary layer structure, humidity fields and convective cells). The main vehicle will be the use of high density, high frequency datasets e.g. surface automatic stations, radars, lidars, satellites, and any new relevant observing systems. The emphasis on short range forecasting and nowcasting calls for specific work on the physical initialisation of the models. The emphasis on high impact weather calls for new, specific approaches to the assimilation of weather objects, e.g. bogus data derived from pattern recognition. Major drivers in the coming years will be the growing exchange and modernisation of European and Mediterranean radar data, the upgrade to satellite platforms (Metop, NPOESS, Meteosat, ADM-Aeolus, ground-based and RO GPS, precipitation missions), breakthroughs in the use of microwave radiances over land, and European field experiments (e.g. COPS and Medex/Hymex) that will help investigations in observation targeting strategies. Mesoscale Observing System Experiments shall be carried out in connection with the community in order to help observation network planning. Due to its high expertise in data assimilation, a strong cooperation with HIRLAM on these issues is anticipated. What is then likely to become a strong association between two Consortia could be turned into some science-policy force in order to be more proactive at the level of the European coordination on NWP issues (if indeed the started trend of EUMETNET and SRNWP concretises further). The main aim should then be to alleviate the partly blocking issues mentioned in the first paragraph of this subsection, for starting some virtuous cycle.

5.4 R&D on probabilistic forecasting

The high-resolution probabilistic forecast is getting more and more attention; a lot of activities are witnessed. In the short term our forces should focus on the success of the GLAMEPS project. A weight should be put however on a rigorous approach rather than to promote heuristic methods to generate members of ensemble forecasts. The short-term priorities are the development of sensible perturbation methods for the LAM initial condition (taking into account not just singular vectors, but also analysis errors e.g. using analysis ensembles or the ETKF algorithm), and of sound ensemble calibration and validation procedures. This requires running experimental ensembles on long periods, which will be computationally expensive and requires an interface between the reanalysis archives and the ALADIN models (in order to sample high impact weather events adequately). A key, urgent question is the determination of an optimal trade-off between ensemble number of members, model domain size, and model resolution.

A longer-term research goal is to address the possibility of using the model errors covariance (so called B-matrix of the data assimilation system) as the input for ensemble members' generation. Also, some effort should be invested into the elaboration of sensible post-processing of ensembles and deterministic runs, in terms of probabilistic estimates for the major end user parameters (low level wind and temperature, precipitation amount and type). In summary, at least a half of the workforce on probabilistic forecasting should focus on solving the basic scientific issues.

5.5 Implementation of software cooperation

The larger number of configurations to maintain, the operational constraints on software efficiency, and the diversity of developers, will be a challenge. A long-term view of the software maintenance and structural evolution will be essential in order to ensure a continued computational efficiency despite its growing complexity. It will involve a substantial part of the consortium's manpower and training effort, in connection with all the institutes that cooperate on the software. The degree of code commonality may vary from one area to the other (e.g. physics, dynamics, I/O, assimilation...), but the working guidelines will be:

•*Integration:* The source code should follow consistent writing norms and technical interfacing rules. This consistency shall extend as much as possible to the scientific sphere, i.e. to lower-level subroutines, basic physical hypotheses, etc. This goal is not strictly enforceable everywhere, nevertheless it will be an ongoing objective in order to avoid splitting the software into inconsistent modules. Likewise, all ALADIN centres will strive to use a common, up to date software version, by frequently upgrading their operational system and by merging their own developments into the common software repository.

•*Flexibility, modularity, generality:* When two similar features are coded in different parts of the source code, an effort will be made to merge them into a single, more general module, with configuration options to satisfy the foreseeable user requirements. This rule is of course not only meant to reduce the code's volume, it has also a structuring virtue: it allows clean comparison of scientific options while reducing the impact of their use on the code structure to the necessary minimum.

•*Solidarity:* The ALADIN community has access to the NWP software under licensing conditions defined by the ALADIN Memorandum of Understanding. All R&D teams are encouraged to contribute to the common ALADIN software. The consortium will endeavour to accept and support useful additions to the software library, including reasonable support for research and non-NWP purposes. Conversely, software contributors shall ensure that they do not break other users' configurations, nor unreasonably complicate subsequent software maintenance and evolution.

•*Joint maintenance:* ALADIN teams and other cooperating partners are expected to contribute to the common software maintenance effort[7], in order to enforce the above principles, which are essential for the consortium's sustainability. In the short term, the ALADIN joint maintenance will be performed in one single merging institute, which holds the software reference repository, and is responsible for satisfying the merging needs of all partners. In the longer term, if desired, a second merging institute may be established, possibly involving external institutes (e.g. ECMWF or HIRLAM), assuming that appropriate working practices can be established. The use of teleconferencing and work over the internet will be developed as a complement to physical travel, which will remain important for training and scientific cooperation.

•*Training:* In the spirit of the past successful efforts of two 'Réseaux Formation-Recherche' and of the EU-funded ALATNET project, the Consortium will endeavour to search a harmonious balance between basic tuition, link with Universities and Research Institutes and on-the-job training in NWP. This cannot be done without additional funding or search for partnership with people more introduced in the world of training. Efforts shall thus be renewed to find such sources or foster such associations, either alone, or in collaboration with HIRLAM, or even at the full European level.

6. Verification and evaluation

The primary deliverable of the ALADIN consortium being operational NWP systems, a serious evaluation of the NWP performance and usefulness of these NWP systems is crucial. It should be improved over what has been done in the past, a process that should be helped by the expected development of the 'verification' activity at SRNWP level.

The evaluation strategy should be at least two-fold:

•on one hand the objective scores must be produced, using advanced verification methods, particularly suited for the spatial and temporal scale of the mesoscale modelling system in question. This poses a strong constraint on a working plan to direct a significant amount of efforts into the area of verification;

•on the other hand, the societal and economic benefits of using the modelling system can without doubt be sensibly evaluated and possibly quantified, provided that the relevant information is extracted from the users' feedback. These benefits should be expressed in terms of estimated lives saved, estimated damage avoided, estimated profit made in case of business firms, or similar. Development of this approach to model evaluation and its implementation can best be stimulated by a general inflexion of the Consortium's strategy, linking for instance more closely with the relevant THORPEX projects.

The strategic plan regarding the modelling system evaluation is the following:

•research, develop and implement mesoscale verification methods for DMO (direct model output) or statistically adapted DMO parameters. This is an ongoing task and it should be closely monitored for progress;

•develop tight and strictly focused connections between the modelling community and the end users, especially emergency management agencies, energy production and distribution companies, business firms, etc. A well thought selection of the mentioned users should be

[7] This mainly consists of the so-called "phasing", i.e. the merging of source code contributions from several partners, which produces official software releases.

made, and training of the relevant contact persons at the users' side must be organised and maintained. This could be done by 2009;

•research and develop mechanisms for defining and extracting necessary information from users' feedback. This process should run simultaneously with the previous one;

•produce a set of objective scores for evaluating social and economic benefits of the modelling systems, and perform regular evaluation. First reliable results should be available in time for reviewing the 10-year strategy, i.e. in 2011.

This work should be carried out in connection with the SRNWP and HIRLAM activities on verification.

Most of the ALADIN consortium resources go towards R&D, not all of which materialises in operational NWP deliverables in an obvious way. Also, a big part of the consortium's credibility is the outside perception of its scientific seriousness, which is a prerequisite for setting up valuable co-operations with the research community, for convincing users of the value of the NWP products, and for attracting outside funding from e.g. the EU, the space agencies and many national funding bodies. Thus, part of the evaluation of the ALADIN consortium activity should measure:

•participation in international conferences and cooperative studies (e.g. field experiments);

•publications of ALADIN work in international peer-reviewed journals;

•the quality and accessibility of the technical and scientific documentation of the NWP system (a current clearly recognised rather weak aspect of the Consortium's activity and that should be improved over the ten years period);

•number of innovative ideas (both internal within ALADIN and external) that have found their way into the model code as a way to test the modularity and the flexibility.

Some aspects of the consortium evaluation may be best tackled via an external audit, following the examples of HIRLAM and RC LACE.

7. Best practices and optimum use of resources

7.1 Balancing innovation and operational focus

The natural tendency of scientists is to propose new ideas. The governing bodies and committees have to fulfil their responsibility to decide which approaches are selected to implement the agreed strategy, and which are not. But this type of selection must represent a reasonable balance. On the one hand it must take into account the relevance with respect to the consortium's objectives and the feasibility, in particular with respect to the available resources. On the other hand the practical validity of the proposals, as well as their scientific scope and long-term potential impact deserve special attention, in order not to miss any hard to recognise critical step.

Each partner institute is anyhow free to pursue its own R&D initiatives beside its consortium activities. Also, it is quite possible for the consortium to endorse optional activities, which do not clearly fit in the operational implementation strategy, as part of its exploratory scientific activities. However, this is with the understanding that each member should contribute sufficient workforce and a significant fraction of its resources to the core activities implementing the priorities agreed by the ALADIN consortium.

Also, software maintenance shall strike a balance between enforcing a common working framework, and allowing controlled software inconsistencies so as not to stifle scientific and technical innovation. This is already the practice for cooperation with ECMWF, and it is likely to extend to HIRLAM. The main constraint here is the consistency between the amount of code cleaning activities, and the amount of new options that are being allowed into the code. Teams who add new complexity to the code (either by adding new modules, or by demanding that previously separate modules be merged in a complex way within the general code) will take responsibility for maintaining the relevant code parts. The strain that is put on ECMWF staff by ALADIN/HIRLAM developments is a major issue that may have strategic consequences: it shall be closely monitored, and additional staff might need to be funded in the future in order to sustain the software cooperation. Conversely, if happening, this should be considered as an investment leading ECMWF to consider more and more the ALADIN and HIRLAM consortia as privileged interlocutors for its own policy making.

7.2 Scientific supervision

The scientific strategy shall focus on raising our reputation in the community, by concentrating on a few science topics where a level of excellence can be obtained in terms of publication, NWP system performance, and expertise of the involved staff. This is only possible if the management of national (hydro)meteorological services maintain long-term applied scientific activity in their NWP teams, coupled with a tighter scientific supervision and far better reporting procedures. The supervision aspect should ideally involve high-level scientists from Academia, while not being left solely in their hands. Indeed, such an increase in the already existing strong links with outside institutions (for most ALADIN countries) should aim at better scientific reputation (an important factor in staff motivation, better justification of NWP performance improvements and access to external funding from e.g. the EU FP or the space agencies) without leading to a decoupling between basic science and NWP applicative R&D. NWP is something with too complex imbrications between physics, numerics and operational aspects to be driven by the sole justification of making a profit on upstream scientific investments. In other words one should aim at replacing the current a-posteriori scientific control by a more on-going one, but not by an a-priori one.

7.3 Dedicating resources to technical infrastructure

The provision of a suitable technical infrastructure remains of each partner's responsibility, and is not part as such of the consortium strategy. However a few indications can still be given on this topic.

The implementation of the strategy assumes a consistent funding of the NWP infrastructure. Beside the R&D staffing itself (which should be well over two full-time staff per institute without data assimilation, and well over five of them with data assimilation, in order to achieve an acceptable critical mass), all ALADIN centres will need to maintain modern local computer systems and telecommunications, with good system support and utility software such as observation databases and NWP product generation. Ideally, smaller centres should consider joining forces with neighbouring institutes (e.g. universities, scientific institutes, met services from other countries) when dealing with issues which neither endanger their basic interests nor question their past investments.

While the computing requirement evolution has been generally well taken into account, other aspects such as telecommunications should receive more attention. Regional capacities such as RMDCN (which, since 2002, is no longer restricted to WMO RA-VI members) can provide efficient and reliable means.

Fine scale NWP becoming more and more important for very short range forecasting, NWP applications become more and more operationally critical. The need for back-up solutions will increase for each component of the technical infrastructure (telecommunications for LBC dissemination and observation collection, supercomputer, databases, product generation); mutual backup between members can be envisaged.

8. International positioning and co-operations

The co-operation with HIRLAM is the main vehicle for improving ALADIN efficiency as well as international visibility. Apart from it, the strategy of external policy of the consortium is difficult to anticipate, since it will mostly depend on external factors i.e. future cooperation policies at EU, ESA, and of course of other SRNWP consortia (COSMO and UK Met Office); at EUMETNET, ECMWF and EUMETSAT this type of uncertainty is tempered by the relative weight of the ALADIN+HIRLAM community in these institutions. It will also depend on individual strategic decisions by the ALADIN national (hydro)meteorological services. One can just say that the force of the ALADIN consortium mainly lies in its leadership on software cooperation with ECMWF, which shall be preserved and even actively enhanced as much as possible, and its expertise on a few specialised areas (mainly model numerics and data assimilation).

At the same time, the ALADIN consortium is vulnerable because of its dependency on ECMWF software, and its rather small number of full time scientists, which explains our weaknesses in a number of areas (lack of scientific recognition, low participation in many international bodies, field experiments and EU projects, lag in ensemble forecasting, very fine scale modelling and mutual fertilisation with the research community). One strategic aim should of course be to alleviate the weaknesses that can be fixed internally, which is reflected in sections 3 and 4 above; due to limited resources, another goal should be to seek support outside the consortium. The main action for this shall be to strengthen the link with HIRLAM as much as feasible, in a sense of reciprocal help to further improvement.

The other action shall be to participate in European projects that will reinforce ALADIN -or ALADIN+HIRLAM- role and visibility as a key player in a future pan-European NWP cooperation structure, such as the SRNWP/EUMETNET programmes. The involvement of the ALADIN community in the post-processing part of the interoperability programme and in verification initiatives should indeed be seen as an opportunity, which goes far beyond the sole objective of allowing inter-comparison of results' quality. All this helps qualifying strengths and weaknesses of the ALADIN systems performance, and so orienting development activities to correct the latter, and using the former to promote the operational use of ALADIN products. Taking also advantage of the co-operation framework with ECMWF, this offers opportunities of enlarged contributions to strategic European initiatives such as SESAR and GMES, in a positive and proactive way.

In all these steps, care should be taken not to alleviate the opportunity that the sharing of European meteorological infrastructures (e.g. IFS code structure) already represents for the Consortium and rather to search opportunities of going even more in this direction, be it by trying to systematically attract more attention from ECMWF for ALADIN-born initiatives, alike what is now happening with the extension of the ALADIN-NH dynamical core to the global framework. Given the size of the ALADIN+HIRLAM community, it might be useful to study the possibility of transforming the joint NWP development in Europe in a EIG EUMETNET optional programme, under the condition of finding an appropriate articulation with the already existing less tight co-ordination of the Consortia carried out in SRNWP.

In terms of membership, until now the ALADIN consortium is entirely made of NMSs from the Euro-Mediterranean area. It was originally a condition for entering the club, but it is not anymore the case (c.f. Article 2 of the 2005 MoU). However, noting that:

- there are still a few NMSs in Europe that are not member of any SRNWP consortium,
- the link with ECMWF is one of the main strengths of the consortium and would be weakened if too many of its members were out of ECMWF Membership or cooperating state status,
- the total number of ALADIN members is already large, and enlarging it too much would make good governance even more difficult,

the consortium does not have a strategic objective of geographical expansion out of the Euro-Mediterranean area. This would only happen as resulting from specific opportunities. However, the ALADIN consortium must strengthen its interaction with research institutes and find the way to initiate co-operations with other NMSs, in line with the EIG EUMETNET strategy as well as the WMO RA-VI one.

9. References

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10. List of acronyms

ADM	Atmospheric Dynamics Mission
ALADIN	Aire Limitée Adaptation dynamique Développement INternational
ALARO	ALAdin-AROme intermediate configuration *Sub-programme of the ALADIN consortium*
ALATNET	ALAdin Training NETwork *EU-financed specific ALADIN effort (2000-2004)*
AROME	Application of Research to Operations at MesoscalE *Sub-programme of the ALADIN consortium*
ARPEGE	Action de Recherche Petite Echelle Grande Echelle *Météo-France global model, part of the IFS-ARPEGE common code*
COPS	Convective and Orographically-induced Precipitation Study *International research campaign*
COSMO	COnsortium for Small-scale Modelling *One of the other SRNWP consortia*
COST	(European) CO-operation in the field of Scientific and Technical research
CSSI	Committee for Scientific and System/maintenance Issues *Part of the ALADIN structure*
DMO	Direct Model Output
ECMWF	European Centre for Medium-range Weather Forecast
EIG	Economic Interest Group *From 2009 onwards, EUMETNET should be an EIG*
EPS	Ensemble Prediction System
ESA	European Space Agency
ETKF	Ensemble Transform Kalman Filter *A method for creating perturbations for an NWP ensemble system*
EU	European Union
EUMETNET	The Network of the European Meteorological Services
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EurEPS	Proposal of operational LAM Ensemble Prediction System in the framework of EUMETNET/SRNWP
FP	Framework Programme (from EU)
GLAMEPS	Grand LAM Ensemble Prediction System *Research project aiming at combining various HIRLAM+ALADIN configurations for creating a LAM ensemble*
GMES	Global Monitoring for Environment and Security
HARMONIE	HIRLAM ALADIN Research towards Mesoscale Operational NWP In Euromed *The bridge between ALADIN and HIRLAM consortia*
HIRLAM	HIgh Resolution LAM *Among the other SRNWP consortia the one with which ALADIN has the closest collaboration*
IFS	Integrated Forecasting System *ECMWF model, part of the IFS-ARPEGE common code*
I/O	Input/Output

LAM	Limited Area Model
LBC	Lateral Boundary Conditions
LTM	Local Team Manager *In the ALADIN structure*
MOGREPS	(UK) Met Office Global and Regional Ensemble Prediction System
MoU	Memorandum of Understanding
NH	Non-Hydrostatic
NMS	National Meteorological Service (NHMS: National HydroMeteorological Services)
NORAF	NORth AFrica *One special integration domain of ALADIN (application in Casablanca for the benefit of the domain-included countries)*
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NWP	Numerical Weather Prediction
R&D	Research and Development
RA	Regional Association (of WMO). RA-VI: Europe (with a large acception)
RC LACE	Regional Collaboration on Limited Area modelling in Central Europe
RMDCN	Regional Meteorological Data Communication Network
RO GPS	Radio-Occultation from Global Positioning System satellites
SBC	Surface Boundary Conditions
SESAR	Single European Sky ATM Research (ATM: Air Traffic Management)
SLHD	Semi-Lagrangian Horizontal Diffusion
SRNWP	Short-Range NWP (a EUMETNET Programme)
THORPEX	WMO Research Programme aiming at improving the 1->14-day forecasts
VFE	Vertical Finite Elements
WMO	World Meteorological Organisation