Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

MINISTÈRE DE L'ÉCOLOGIE, DU DÉVELOPPEMENT DURABLE ET DE L'ÉNERGIE

Évaluation du programme HIRLAM-B

External review of the HIRLAM-B programme

Rapport n° 010423-01
établi par

Peter LYNCH, Dominique MARBOUTY, Tiziana PACCAGNELLA

Septembre 2015

CGEDD
CONSEIL GÉNÉRAL DE L'ENVIRONNEMENT ET DU DÉVELOPPEMENT DURABLE

Résumé

Le développement des modèles de prévision météorologique est devenu une tâche très coûteuse qui n'est plus à la portée d'un pays isolé (c'est justement ce qui a conduit à la création du Centre européen pour les prévisions météorologiques à moyen terme pour la prévision à moyen terme, CEPMMT). Le développement des modèles à aire limitée pour la prévision à courte échéance en Europe est effectué dans le cadre de 3 consortiums (HIRLAM pour l'Europe du Nord, ALADIN pour la France et les pays d'Europe centrale, COSMO pour Allemagne, Suisse et Italie). HIRLAM et ALADIN ont de nombreux points communs, en particulier les deux modèles utilisent au maximum la complémentarité avec le modèle du CEPMMT et Météo-France appartient aux deux consortiums.

HIRLAM travaille par cycles de 5 ans, avec une évaluation à l'issue de chaque cycle. Le prochain cycle, HIRLAM-C, revêt un intérêt particulier car HIRLAM et ALADIN ont fixé comme objectif de fusionner les deux programmes à l'issue de ce cycle en 2020. HIRLAM-B se terminant en 2015, le Conseil du programme HIRLAM a nommé une équipe d'évaluation internationale coordonnée par un membre du CGEDD, ci-après dénommée 'la mission'.

La mission a examiné la gouvernance, les ressources et les réalisations du programme HIRLAM-B. Elle a passé en revue la mise en œuvre des recommandations faites par l'équipe d'évaluation précédente, en 2010 à la fin du programme HIRLAM-A. La coopération HIRLAM a une longue histoire et est maintenant bien organisée. En conséquence la mission n'a fait que peu de commentaires sur HIRLAM lui-même et s'est concentrée sur la coopération avec le programme ALADIN.

La mission a rencontré les prévisionnistes de la plupart des centres HIRLAM. Les gains apportés par le modèle régional à haute résolution, pour les prévisions à courte échéance et par rapport aux prévisions globales du CEPMMT, ne sont plus discutés. La mission a été impressionnée par les progrès réalisés dans l'utilisation du modèle Harmonie et par les commentaires positifs de la plupart des prévisionnistes, lesquels identifient cependant un certain nombre de faiblesses et de problèmes du modèle.

La mission a concentré son attention sur l'analyse des problèmes à régler pour réussir la fusion avec le consortium ALADIN. Elle a tout d'abord noté que la coopération entre les deux consortiums est déjà bien développée, en particulier entre les chefs de programme et dans certains domaines scientifiques. La mission a fait des recommandations concernant les domaines couverts par le consortium commun, l'organisation et la gouvernance commune, les ressources en personnel et les méthodes pour le développement du code commun, les questions de politique de données et de propriété intellectuelle, et la communication. Le détail de ces recommandations est donné page suivante. La mission insiste sur la nécessité que les directions des membres des deux consortiums s'impliquent dans leur mise en œuvre.

Liste des recommandations

Performance du modèle, retour des prévisionnistes

L'équipe d'évaluation recommande la mise en place d'un échange entre prévisionnistes des pays HIRLAM et ALADIN. Elle suggère de la faire sous la forme d'une extension de la réunion des utilisateurs du CEPMMT.

Domaines couverts par le consortium, activités de base et optionnelles

Le domaine couvert par le futur consortium commun doit être examiné, accepté par l'ensemble des membres et constituera le programme de base. La définition qui en est donnée dans la déclaration commune est un bon point de départ. Il conviendra sans doute d'y ajouter la modélisation de surface et le système de vérifications.

Des programmes optionnels (modules complémentaires du système de prévision, version climat du modèle, …) peuvent être envisagés, mais la participation à un tel programme optionnel impose d'avoir satisfait les besoins du programme de base.

Des infrastructures opérationnelles communes devraient être traitées par des accords séparés.

Organisation et gouvernance

Un plan scientifique commun devrait être développé pour les 5 années à venir par une équipe commune (et ne devrait pas être réalisé par la fusion de deux plans séparés).

Vu la taille du futur consortium commun, sa gouvernance devra être pensée avec soin. En particulier un comité scientifique indépendant doit être envisagé, les prises de décision à l'unanimité devraient être aussi limitées que possible, un comité stratégique de taille raisonnable devrait être créé pour préparer les décisions du Conseil commun.

Ressources en personnel et développement du code

Il convient de poursuivre l'effort de mettre à disposition du programme essentiellement des agents au moins à mi-temps et d'

organiser la formation au développement de code de tous les agents.

La contribution totale en personnel d'HIRLAM devrait être augmentée pour assurer une contribution équilibrée au consortium commun. L'augmentation nécessaire devrait cibler le développement et la maintenance du code.

Il y a un besoin urgent d'évolution des méthodes de développement et de phasage du code. Cela imposera des discussions avec tous les groupes. L'objectif doit être un système de phasage distribué, efficace et rapide

Le programme HIRLAM devrait contribuer au financement du poste d'architecte du code.

Politique de données et propriété industrielle

L'équipe d'évaluation recommande que la politique de données soit discutée au niveau des directeurs, sur la base de propositions innovantes préparées par un groupe d'experts.

Elle recommande également que la question de la propriété intellectuelle du code soit d'abord traitée au niveau du CEPMMT.

Dénomination du consortium et du système de prévision communs

L'équipe d'évaluation recommande qu'un même nom nouveau soit donné au consortium et au système de prévision communs, qui devra être approuvé par l'ensemble des membres des deux consortiums.

External review of the HIRLAM-B programme 2011 – 2015

Peter Lynch
Dominique Marbouty
Tiziana Paccagnella

September 2015

Table of contents

Summary

The Review Team appointed by the HIRLAM Council examined the governance, resources and achievement of the HIRLAM-B programme. It reviewed the implementation of the recommendations made by the previous review team in 2010 at the end of HIRLAM-A. The HIRLAM cooperation has a long history and is now well organised. As a result the Review Team made few comments concerning HIRLAM in isolation from the wider collaboration with ALADIN.

The review team also met forecasters in most of HIRLAM centers. Benefits of using regional high resolution model for short range forecasts, as compared to ECMWF global forecasts, is no longer questioned. The Review Team was impressed by the progress made in using Harmonie and the positive comments made by many forecasters, although there are known weaknesses and difficulties.

The Review Team focused its attention on the analysis of the issues that need to be addressed in order to successfully create a joint consortium with ALADIN. It first noted that the cooperation between the two consortia is already well developed, particularly at management level and in several scientific areas. The Review Team developed recommendations in the areas of scope and activities, organisation and governance, staff resources and code-development, data policy and code-ownership, and branding. The details of these recommendations are reproduced below (opposite page). The Review Team emphasizes that several of these recommendations require the involvement of HIRLAM and ALADIN members' directorate.

List of recommendations

Model performance, forecasters' feedback

The Review Team recommends that exchanges be organised between forecasters from the HIRLAM and ALADIN countries. A possibility would be to do this as an extension of the ECMWF Users Meeting.

Scope of the consortium, core and optional activities

The scope of the future single consortium should be reviewed jointly and agreed by the HIRLAM and ALADIN partners and constitute the core programme. The definition set in the joint declaration is a good starting point to which the addition of surface modelling and verification should be considered.

Optional programs (e.g. complementary part of the forecasting system, climate version of the model) may be developed. Joining and contributing to an optional program should be subject to meeting the requirements of the core programme.

Operational common facilities should be considered under distinct specific agreement.

Organisation and governance

A common scientific plan should be developed for the next 5-years period by a joint drafting team, and should not result from merging plans elaborated separately.

The governance of the future single Consortium should be carefully considered, given its size. In particular an independent scientific committee should be considered, unanimous decision-making cases should be as limited as possible, and a policy advisory committee with reasonable size be set up to prepare joint Council-Assembly decisions.

Staffing resources and code-development

Efforts should be pursued in providing mostly half-time persons to the programme and in organising code-development training of all staff involved.

Overall HIRLAM investment in staffing resources should be increased to ensure that HIRLAM provides proportionate resources to the enlarged consortium in the future. This increase should be concentrated on code-development and maintenance.

There is an urgent need for changes in the present practice of code phasing and evolution. This will require discussion between all groups. The aim is to develop a more distributed, optimal and faster phasing system.

HIRLAM should contribute materially to the proposed common Code Architect position.

Data policy and code ownership

The Review Team recommends that the data policy of the single consortium be discussed at directors' level, on the basis of innovative proposals prepared by experts.

The Review Team recommends that the issue of IFS becoming open source be raised at ECMWF.

Branding of the single Consortium and common system

The Review Team recommends that a new name for the single Consortium and the common forecasting system be agreed between all members of both consortia.

External Review of the HIRLAM-B programme

1. Introduction

The Memorandum of Understanding of HIRLAM-B states that an external evaluation should be carried out at least once during the HIRLAM-B period. At the HIRLAM Council meeting of July 2014, the desired scope of such an evaluation was considered. It was agreed that the focus of the assessment should be mainly forward-looking. The Terms of Reference for the review of HIRLAM were set down at the Council meeting in December 2014 (attached as annex 1).

Background to the Review

In general, the evaluation considers the achievements of the HIRLAM programme, and possible choices regarding the future scope and goals of the collaboration, the organisation of the programme, and international cooperation aspects, in particular the evolution of relations with ALADIN and ECMWF.

The Review Team was requested to consider the scientific and technical results achieved by the programme, with reference to the targets originally set for it, together with recommendations on the scope of the collaboration for the next phase of the programme (2016-2020), and the main directions for scientific and technical developments in that period. In particular, the evaluation was requested to provide:

- An assessment of the scientific and operational achievements, and their impacts and relevance, compared to the goals set for HIRLAM-B.
- An assessment of the organisation, management and effectiveness of the working practices within the programme and the collaboration with ALADIN.
- Recommendations on the desirable evolution of the organisation and its ways of working.

- Recommendations on directions to take for the long-term vision and strategy (2016-2025), both scientific and organisational, and on the scope of the HIRLAM collaboration for the next phase 2016-2020.
- Recommendations on the desirable future development of relations of the HIRLAM consortium with other relevant parties, especially the cooperation with ALADIN and ECMWF, and the form this should take in the future. Also, the expected evolution and impact of regional cooperations like MetCoOp on the consortium.

Composition of the Review Team and its organisation

The Review Team comprised Dominique Marbouty (Chairman), Tiziana Paccagnella and Peter Lynch:

- Dominique Marbouty, former Head of Operations and, later, Director General of ECMWF and currently a member of the Conseil Général de l'Environnement et du Développement Durable (CGEDD) in France, where he is also coordinating the national contribution to the European Copernicus programme.
- Peter Lynch, former Deputy Director, Met Éireann, HIRLAM project leader (1997–1999), Professor of Meteorology, University College Dublin (2004–2014), now Professor Emeritus.
- Tiziana Paccagnella, Head of Numerical Weather Prediction at ARPA SIMC, Regional Met. Service in Bologna, Italy, and Scientific Project Manager of the COSMO Consortium (2003–2007).

The Review Team was convened in January 2015 and Dominique Marbouty agreed to act as Chairman of the team.

Following some telephone conferences, the team organised a series of visits to HIRLAM member institutes. Dates were generally chosen to coincide with scientific or business meetings of the programme. The team visited DMI, FMI, Met Éireann, KNMI, Met Norway, AEMET and SMHI. They also paid a visit to co-operating HIRLAM member

Météo-France. In addition, remaining members of HIRLAM were contacted and invited to complete a simple questionnaire or otherwise provide input to the review.

During each visit, the Review Team had meetings with the management, the forecasters and the scientists involved in the modelling system development. In addition to these visits, the team attended the following meetings:

- HMG, Cordoba, 4 February, 2015
- PM, De Bilt, 5-6 March, 2015
- All-staff Meeting, Elsinore, 16 April, 2015
- HMG-CSSI, Copenhagen, 17 April, 2015
- HAC-PAC, Helsinki, 21 May, 2015
- HAC, Helsinki, 22 May, 2015
- HIRLAM Council, Darmstadt, 22 June, 2015.

Looking to the next five years, the HIRLAM-C period, it was quite clear from the outset that it was impractical to consider HIRLAM in isolation. It was essential to take into account the ongoing process to merge with ALADIN, and the consequential stronger link to be established with Météo-France. The merging of the two consortia is well underway but it raises intrinsic challenges:

- The two consortia have developed in strongly different contexts. HIRLAM is based on cooperation amongst equals, while ALADIN has always had the strong leadership role of Météo-France.
- A "cultural" dimension: this includes actual cultural perspectives and also attitudes and work practices in the two consortia. This cultural dimension impacts on many areas, such as data policy and willingness to move toward operational co-operation.
- The wide geographical spread of the participating countries, 26 in total, and the different scientific/operational priorities due to different climatic conditions and weather types.

To have a more comprehensive picture of the growing inter-consortia cooperation, and to have an appreciation of the different viewpoints, the team also met staff at Météo-France, the ALADIN Program Manager and some LACE representatives.

2. The HIRLAM programme

HIRLAM is a collaborative programme amongst ten European countries. The primary goal of the programme is to maintain and develop a world-class numerical weather prediction system for operational use in the member institutes. The main emphasis is on the prediction of extreme weather events on short and very short time ranges, and weather guidance relating to public safety. The ten regular members of HIRLAM are:

1. The Danish Meteorological Institute (DMI),
2. The Estonian Environmental Agency (ESTEA)
3. The Finnish Meteorological Institute (FMI),
4. The Icelandic Meteorological Office (IMO),
5. The Irish Meteorological Service (Met Éireann),
6. The Lithuanian Hydrological and Meteorological Service (LHMS)
7. The Royal Netherlands Meteorological Institute (KNMI),
8. The Norwegian Meteorological Institute (Met Norway),
9. The Meteorological State Agency of Spain (AEMET),
10. The Swedish Meteorological and Hydrological Institute (SMHI).

In addition to the regular members, Météo-France, has been a co-operating member since the beginning of HIRLAM.

Structure and governance of the programme

The constitution, organisation and operating principles of the HIRLAM Programme are set down in a Memorandum of Understanding (MoU) which is agreed and signed by all members. Normally, the MoU covers a period of five years.

Overall responsibility for the HIRLAM Programme rests with the HIRLAM Council. The Council is comprised of the directors of the member institutes (or their nominees). The Council normally meets twice each year and a joint meeting with the ALADIN General Assembly takes place once per year.

An advisory body, the HIRLAM Advisory Committee (HAC), reports to and advises Council on scientific, technical, administrative and financial matters relating to

HIRLAM. HAC comprises representatives from each of the member institutes. HAC regularly scrutinizes the scientific and work plans of HIRLAM, makes substantial scientific inputs and monitors progress of the programme, checking achievements against targets. HAC normally meets twice per annum, and also holds a joint meeting with the ALADIN Policy Advisory Committee (PAC) each year.

Executive responsibility for the HIRLAM Programme rests with the Programme Manager (PM). The PM reports directly to the HIRLAM Council. The specific responsibilities of the PM for HIRLAM-C are listed in the MoU (§5.1). The PM is supported by a scientific secretary (although this position has been vacant since January 2015).

The day-to-day management of the HIRLAM Programme is overseen by the HIRLAM Management Group (HMG), whose members are the PM together with the Project Leaders (one of whom acts as deputy programme manager). One of the Project Leaders has responsibility for the maintenance and development of the Reference System. Another has responsibility for operationally oriented activities. The PM assigns areas of responsibility for the other Project Leaders, which change from time to time. At the time of the final phase of HIRLAM-B (June 2015), the Programme Manager was Jeanette Onvlee (NL) and there were six Project Leaders on the HMG, with responsibility for the six key areas of research and development:

- Project Leader for Applications (Xiaohua Yang, DK)
- Project Leader for System (Ulf Andrae, SE)
- Project Leader for Physical Parameterization (Laura Rontu, FI)
- Project Leader for Model Dynamics (Mariano Hortal, ES)
- Project Leader for Probabilistic Forecasting (Inger-Lise Frogner, NO)
- Project Leader for Data Assimilation and Observations (Elena Bojarova, NO)

The total allocation to the HMG was 4.75 FTEs per annum (counting the vacant position of Scientific Secretary to the PL).

For the HIRLAM-C Programme, the following structure has been agreed:

- Programme Manager (100%)
- Project Leader for System (75%)
- Project Leader for Quality Assurance (50%)

- Project Leader for Upper-air Data Assimilation (50%)
- Project Leader for Upper-air Forecast Model (50%)
- Project Leader for Surface Analysis and Model (50%)
- Project Leader for Predictability (50%)
- Code Architect (50%)
- Scientific Secretary (25%)

The total committed resource for the managing structure is thus 5.0 FTEs.

Staffing resources.

Staffing for the project includes a core group and regular staff. Core group members work either full-time or half-time on the programme and report directly to the Programme Manager or to a Management Group member. Core group staff is assigned to high priority tasks identified by the HMG. The bulk of research and development work is carried out by regular research staff from the member institutes. They should be allocated to the programme on at least a half time basis.

The Review Team noted that, in general, member institutes are providing staff resources well in excess of the minimum agreed levels. The management of these resources has been effective. However, there is evidence of some fragmentation, with large numbers of staff contributing small amounts of time. There is the equivalent of 23 full-time staff (23 FTEs) formally committed. In 2014, 33 FTEs were made available. Even with this substantial surplus, the degree of fragmentation is a matter of concern. There are about 80 scientists in total that are active in some way in the project. This is quite inefficient and needs to be minimised, or eliminated wherever possible.

There appears to be inadequate expertise in particular areas such as software and code development. An issue of current concern is the new code environment, OOPS (Object Oriented Programming System). The development of OOPS started at ECMWF in 2010 in order to facilitate the development and testing of new data assimilation techniques. It has proven a major development, impacting all users of the IFS framework, as it requires important initial training for all developers. It seems that this is being done without sufficient attention to the implications for HIRLAM and other groups outside ECMWF.

As a result OOPS is causing major and ongoing difficulties. This issue has been recently addressed with ECMWF and some progress has been made.

Staffing resources of the programme are provided beyond the committed level, but efforts to comply with the requirement that most resources made available to the programme should be on at least half-time persons basis needs to be pursued. Training in the area of code development also needs to be pursued, in particular concerning the use of the OOPS system environment. These two points are included in the recommendations developed in part 4.

Achievements of the HIRLAM-B programme

The Review Team recognises that the decision to cease development of the synoptic-scale HIRLAM model and to concentrate on Arome-Harmonie was both necessary and courageous. It demonstrated a willingness to change the direction of research: this has enabled closer collaboration with Météo-France and ALADIN. It has also allowed the allocation of research resources to the areas of highest priority.

Some notable scientific advancements have been made during the course of the programme. Perhaps the most significant is the development of the 4DVar and 3/4D-EnVar assimilation systems. These promise to be of substantial benefit in operational applications. Good progress on the development of ensemble prediction systems (GLAMEPS and HarmonEPS) is also to be welcomed.

The parameterization of surface process is another area with notable achievements. The programme scientists have made material contributions to various SURFEX modules, specifically those treating atmospheric interactions with lakes, sea-ice and snow over vegetation.

Work on assimilation of non-conventional data has also yielded benefits in terms of forecast accuracy. The Review Team notes in particular the work on introducing radar reflectance data and Mode-S data from aircraft.

Finally, we might mention the system for verification, developed in close collaboration with ALADIN scientists. Known as HARP (HIRLAM ALADIN R-Package), this is a significant result of the pooling of resources.

Recommendations of the previous review

The recommendations from the previous review of the HIRLAM-A programme in 2010 were:

a. ***Preparation of the 2010-2020 strategy*** *- The new research programme should be strictly focused on a small set of common goals. If the proposal for the next phase of HIRLAM does not include a clear and credible plan for delivering a short-range NWP system that is second to none, there could be reduced participation. Progress in mesoscale forecasting and data assimilation should remain the number one priority for the consortium.*

b. ***Governance (i)*** *- Overlapping efforts and contributions that are more reflective of individual interests rather than overall programme priorities should be reduced. An external independent Scientific Advisory Board should become part of the governance structure to scrutinize development plans, thus helping to break the existing planning cycle that implicitly encourages such contributions.*

c. ***Governance (ii)*** *- The programme should become more user-driven. The HAC would be best placed to realize this and its terms of reference should be amended to reflect this additional role.*

d. ***Development of co-operation with ALADIN*** *- The collaboration with ALADIN should be strengthened; a common research plan should become part of the MoU; HIRLAM must aim to be a strong and highly valued partner in the ALADIN/HIRLAM collaboration.*

e. ***Access by the academic community and other collaboration*** *– Efforts to create an easy-to-use, self-contained and well documented modelling system for academia should be significantly strengthened and added to the core activities. A workshop involving the main users of the IFS/ARPEGE framework should be held to explore possible improvements to the collaborations that exist around this framework.*

f. ***Scope of co-operation within the consortium*** *- Having some shared operational activities is a natural step in the evolution of the programme. The ambition level will be determined by the consensus that can be achieved within the consortium. Such operational activities must be clearly separated from the research and development efforts and should be managed independently.*

The Review Team considered whether these recommendations had been adopted, and reached conclusions as follows:

a. **Preparation of the 2010-2020 strategy :** This recommendation has been well adopted during the past five years of activity. Although the research programme was not focused solely on a small set of common goals (see point b), it is clear that substantial resources were devoted to progress in short-range meso-scale forecasting and that developments in data assimilation have been among the strongest achievements of the consortium.

b. **Governance (i) :** Overlapping efforts and contributions that are more reflective of individual interests rather than overall programme priorities were still evident in the programme, but there is a general awareness of the need to reduce this inefficient use of resources. The advice to appoint an independent, external Scientific Advisory Board was not adopted by the HIRLAM Council.

c. **Governance (ii) :** Some progress in the direction to serve user needs more effectively. HAC may not be the appropriate body to have responsibility for this. We recommend in the report that a HIRLAM user meeting be organised as an extension of the ECMWF user meeting.

d. **Development of co-operation with ALADIN :** It is clear that a lot of progress has been made during the past five years. More will be said about this below. The research plans are not really common so far, but there is clear evidence of the will of HIRLAM to move in this direction.

e. **Access by the academic community and other collaboration :** This suggestion has not been accepted mainly due to limited staffing resources. A modelling system for academia must be easy to use (computer science resources are required) and well documented, and good user support must be available. Even though the involvement of academia could be very beneficial, the Review Team does not recommend this as a priority at this stage. We note that the availability of OpenIFS will be relevant for future decisions.

f. **Scope of co-operation within the consortium :** The development of shared operational activities is clearly ongoing, as demonstrated by GLAMEPS and, even more strongly, by MetCoop.

3. Model performance, forecasters' feedback

The operational use of the HIRLAM/Harmonie forecasts has greatly increased in recent years. In the past, forecasters were sceptical and reluctant to use them for guidance, preferring ECMWF products. This has now changed: in the majority of forecast centres, there is a very positive attitude, and Harmonie is used enthusiastically. There is no doubt that the accuracy of the forecasts has substantially improved in recent years. It clearly gives valuable guidance over and above ECMWF products.

Forecasters from HIRLAM countries generally have three operational streams available – ECMWF, HIRLAM and Harmonie – although there are differences from one institute to another. The operational use of HIRLAM is *a common factor* and in most countries the forecasters are very confident in HIRLAM products and hope to have HIRLAM available for several more years (e.g., Met Éireann, FMI). In some services, there is very good operational use of all the available models (SMHI, DMI); the only country that has moved exclusively to Harmonie is Norway.

There is general recognition of the better quality of the Arome-Harmonie model as regards the realism of the prediction of localized, intense events such as squall lines, wind gusts and showers (Figure 1). Realism means that, despite errors in location and timing, the forecaster is able to anticipate the physical characteristics of intense phenomena that are likely to occur in a specific area.

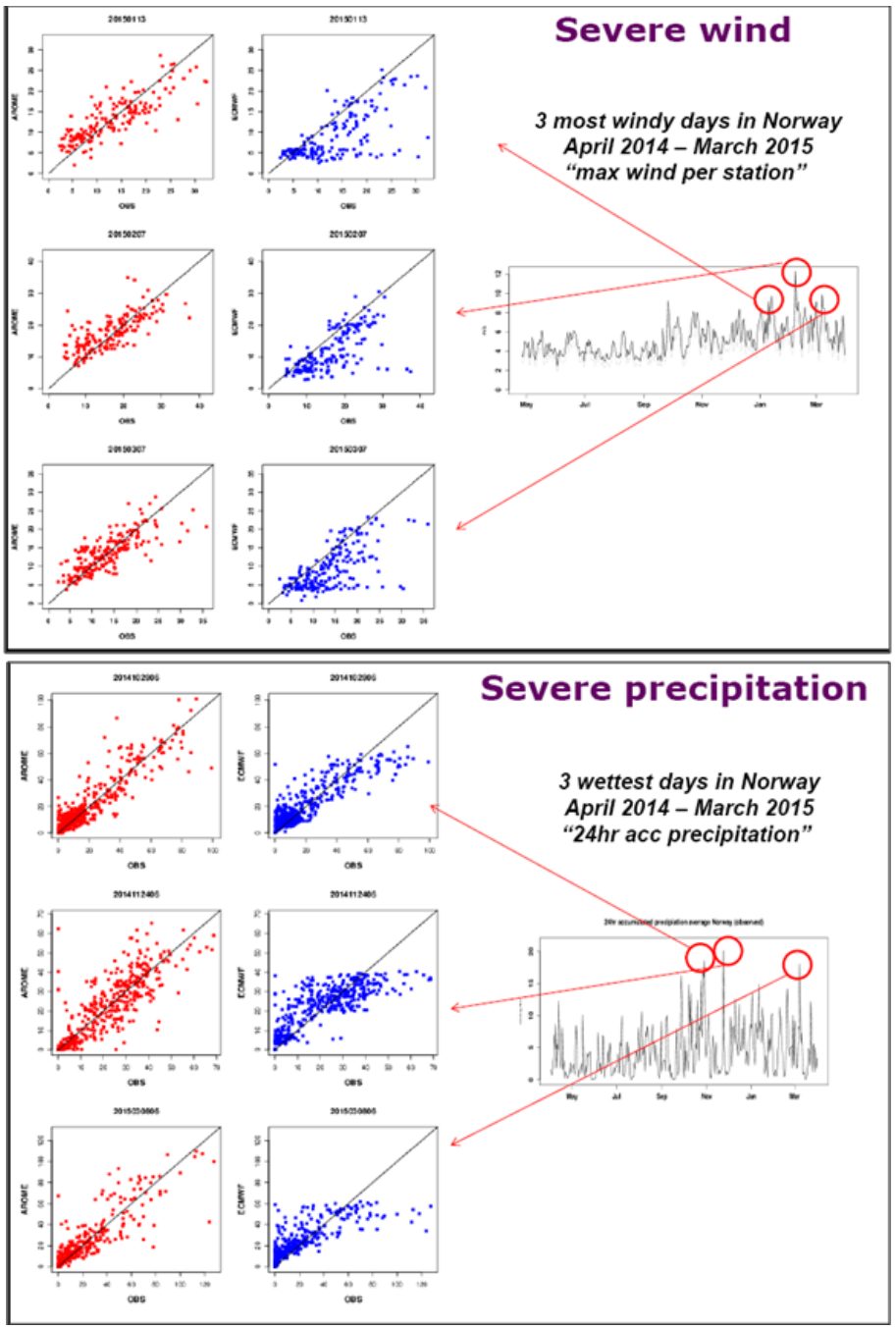

Figure 1 : Added value of Arome with respect to ECMWF
From the presentation by Morten Køltzow at the ASM 2015

In several cases forecasters also recognize the value of Arome-Harmonie in forecasting surface parameters. Figure 2 shows some statistics from AEMET.

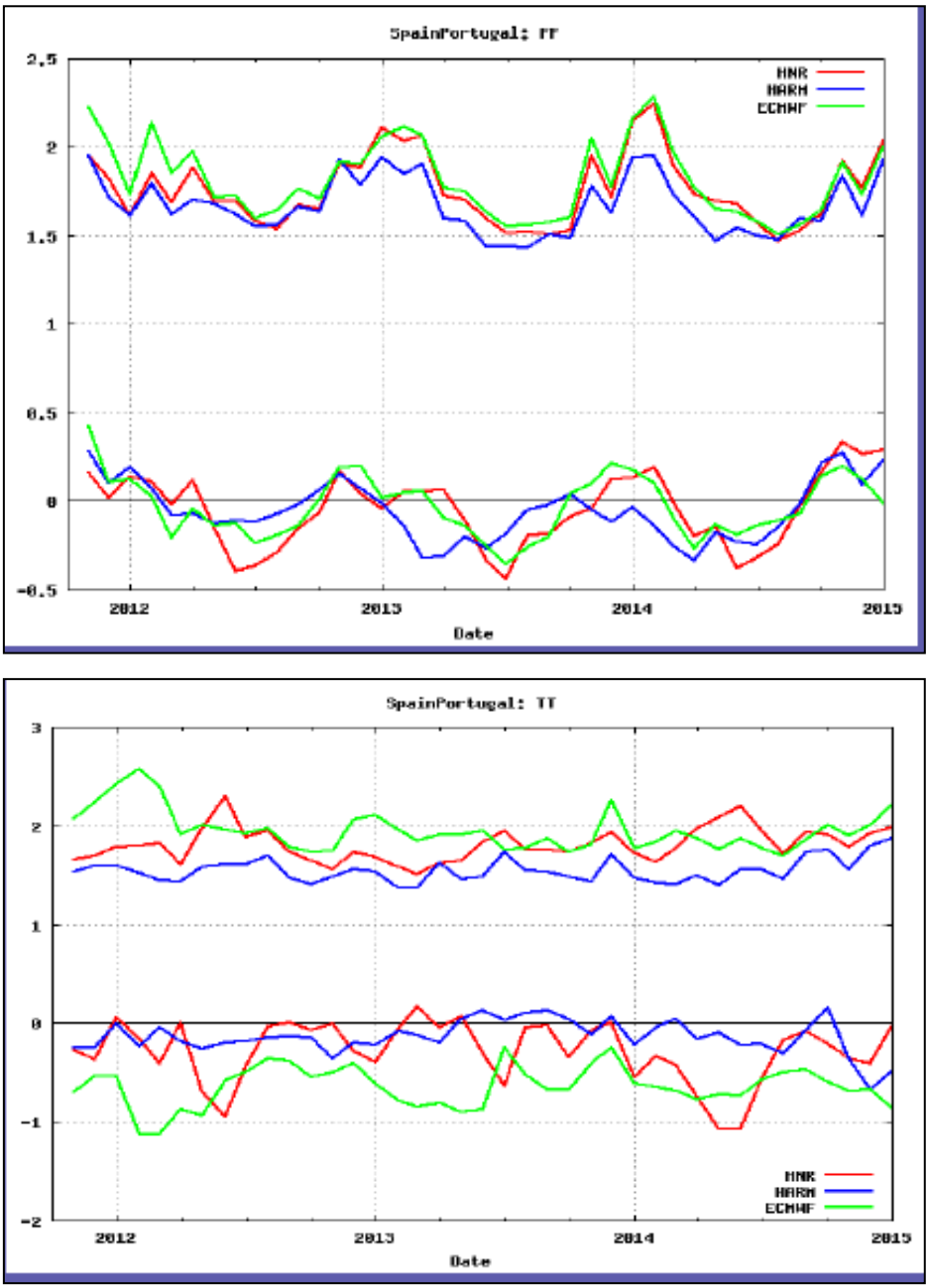

Figure 2 : AEMET long range verification: wind speed (top) T2m (bottom)
From the presentation by Javier Calvo at the ASM 2015

Arome-Harmonie model errors vary from one region to another (See Figure 3 for an example), but all the forecasters reported similar main weaknesses: the forecasting of fog, low clouds and intense precipitation due to deep convection. The forecast of fog presents problems both in the onset and dissipation phases, and the possible causes are already under investigation. Some work is ongoing to improve the situation through a better use of cloud-mask information and by further improving the turbulence transfer scheme in stable conditions.

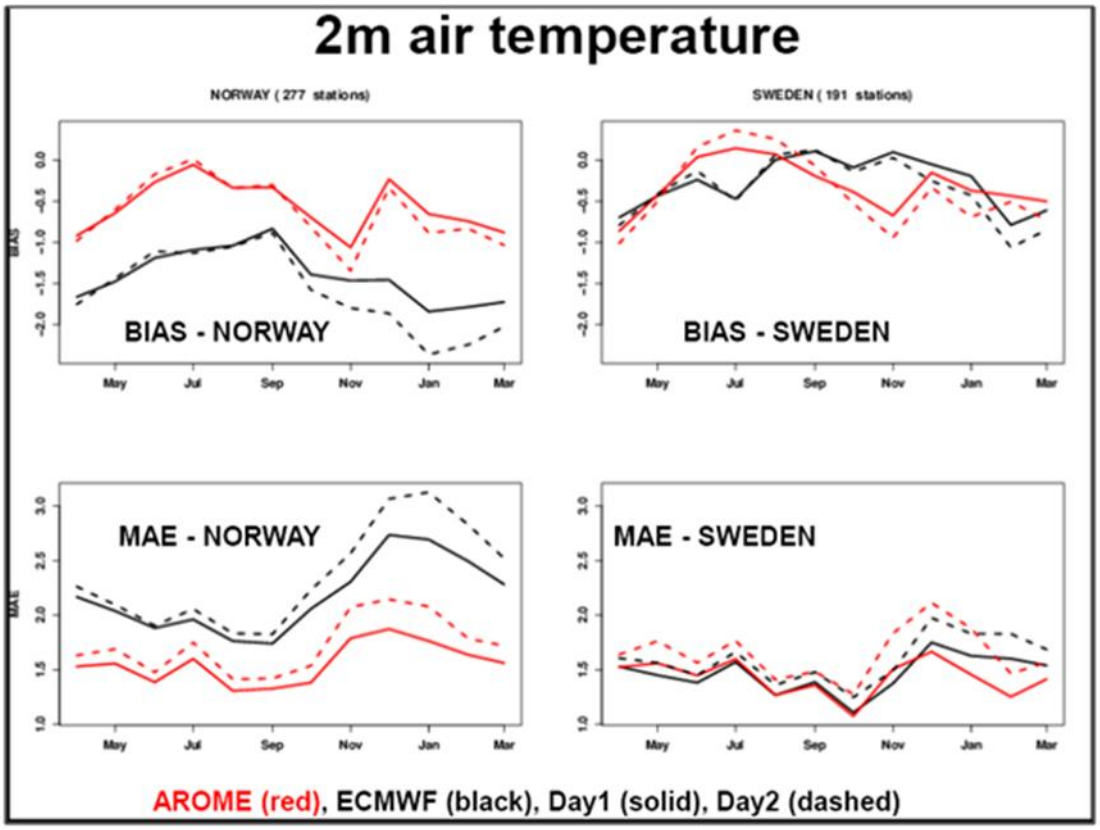

Figure 3 : Added value of Arome with respect to ECMWF in Norway and in Sweden
From the presentation by Morten Køltzow at the ASM 2015

Nowcasting products are also in demand and forecasters hope for more research on nowcasting for specific purposes such as fog for airports.

The Rapid Update Cycle (RUC) run each hour is a popular product in several centres: users clearly put great value on frequent and regular forecast updates. A survey of the operational RUC systems in member states is intended (the time-scale for this is uncertain).

The attitude toward EPS products is even more variable between different countries. Some members rely only on ECMWF EPS basic products whilst others make wide use of all available EPS guidance, and hope for higher resolution probabilistic products based on Arome-Harmonie.

To improve the use of EPS by forecasters, further guidance on its use would be very helpful. The implementation of an EPS User Forum could help. This would facilitate the exchange of knowledge and experience between forecasters and would also facilitate a better design of tailored probabilistic products.

The exchanges between forecasters and model scientists are also very different in different institutes, ranging from infrequent to weekly meetings. A better organised feedback from the forecasters to the developers would also help. In some countries there is the general belief that the HIRLAM Programme could play a more active role in fostering greater communication and interaction between modellers and forecasters.

In recent years, thanks to the improvements in NWP, there is a growing interest of users in several areas: Energy management applications, water boards, civil protection agencies, environmental and hydrological modeling, etc. Some important initiatives, already well advanced in some HIRLAM services like KNMI and AEMET, must be taken to train these user groups in the application of EPS probabilistic products and also in using high-resolution deterministic forecasts since, in view of the decreased predictability at the pixel scale, a probabilistic interpretation is somehow necessary.

There is a general feeling of the importance of exchanges between forecasters and modellers and between forecasters and users. But there is also a need for contacts between forecasters from the various HIRLAM and ALADIN countries, sharing their experience in the challenging task of using such a high-resolution non-hydrostatic model. Organising such meetings of forecasters has proven difficult so far. The Review Team suggests to use the opportunity of the Users meeting, organised annually by ECMWF (in June) to discuss a one-day extension for exchanges involving Arome-Harmonie users and developers.

Recommendation: model performance, forecasters' feedback

The Review Team recommends that exchanges be organised between forecasters from the HIRLAM and ALADIN countries. A possibility would be to do this as an extension of the ECMWF Users Meeting.

4. Towards an expanded programme

The knowledge and expertise required to develop and maintain a comprehensive, world-class NWP system are generally beyond the capacity of a single weather service, so a number of consortia are in place. With advanced non-hydrostatic models and sophisticated data assimilation systems, even a consortium of the size of HIRLAM struggles to remain at the leading edge of scientific progress. Thus, for the last ten years, HIRLAM has been working in close harmony with the ALADIN community.

HIRLAM took a strategic decision in 2005 to commence a close collaboration with ALADIN. The aim was to develop a common mesoscale limited area model code in the ECMWF IFS/AAAH framework. It was envisaged that the new system, known in the HIRLAM community as Harmonie, would supersede the HIRLAM model in all applications.

Another strategic decision, already mentioned earlier, was made in 2010 when the HIRLAM Council decided to stop developments on the HIRLAM model and to concentrate on the development of Arome-Harmonie.

Recently, the governing bodies of HIRLAM and ALADIN reached agreement to combine the efforts in the two programmes and form a united programme with a single set of plans, work schedules and goals. The terms of the unified programme have been set down in a Joint Declaration of the ALADIN General Assembly and the HIRLAM Council, on 2 December 2014 (see Annex 2). It was agreed that the ALADIN and HIRLAM consortia will work together, with the aim of forming a single consortium by the end of the 2016-2020 period.

The cooperation between HIRLAM and ALADIN has developed well on many fronts. All staff meetings have been joint meetings for many years: from our attendance at this meeting it is clear that the scientific cooperation comes naturally in some areas. As identified in the joint declaration, joint meeting of the governing bodies of both organisations are held at least once a year. There is a good and constructive interaction between the two programme managers: in particular it is important to note that they do not hide the difficulties but work on identifying and addressing them (as long as it is in

their power). However, there are still a number of areas where substantial difficulties remain to be overcome: most of them were clearly identified in the Joint Declaration.

Scope of the single consortium, core and optional activities

A main difficulty to be addressed is that HIRLAM and ALADIN have different scopes: in a nutshell, HIRLAM's scope is to develop a forecasting system that includes several operational components, whereas ALADIN is targeting the model, while operations and quality control remain the responsibility of each NMS.

The real situation is in fact more blurred: the LACE consortium, a sub-group of ALADIN is developing a forecasting system, some ALADIN countries work with HIRLAM in the development of system components such as the HARP verification system, Météo-France and HIRLAM are cooperating on the development of a 4D-VAR Arome-Harmonie data assimilation system, etc.

It seems to the Review Team that it would be important that the scope of the single consortium be discussed and agreed. The joint declaration already gives clear indications for this, defining the limited area system to be developed as "*a set of data pre-processing, data assimilation, atmospheric model and post-processing tools*" and opening the "*possibility of core and optional programs*" within the single consortium. This is important as the scope should set the list of core activities to which all members have to contribute on an agreed and balanced basis.

The scope will evolve with time as a consequence of scientific developments. Already the question of including into this scope some additional components, as compared to the definition given in the Joint Declaration should be considered:

- Verification system, as this is an important and necessary element for operational quality control of the system ;

- Surface modelling (i.e. land surface including snow and lakes, ocean surface and waves), which is a crucial component of a high resolution system: although not mentioned in the declaration, it was probably implicitly included ;
- Ensemble forecasting system, as it is now widely recognized as the necessary input, if not the central input, for most forecasts.

Therefore the Review Team recommends that the scope of the future single consortium be reviewed jointly and agreed by the HIRLAM and ALADIN partners. It seems to the Review Team that the definition set in the joint declaration is a good basis, to which surface modelling and verification should be added. EPS is more complicated and raises specific data policy issues: it could be left as an optional activity for the time being.

Many HIRLAM members are willing to work on specific activities linked to the very existence of the Arome-Harmonie model : this includes for example developing a climate version of the model, or developing an atmospheric chemistry component for the system. It could also include the development of some part of a common forecasting system, if such parts are not included in the scope. Such developments are important for most NMSs and their size is usually beyond the reach of a single NMS, thus requiring cooperation. In addition some of these developments (regional climate, atmospheric chemistry) are likely to attract support from the various research-funding agencies, either national or European (e.g. H2020 or Copernicus). Such developments should be organised as optional programs. The important point is that joining and contributing to an optional program should be subject to meeting the requirements of the core programme (i.e. the scope of the consortium).

Another type of cooperation is being developed between some HIRLAM or ALADIN members: the running of an operational common configuration of the forecasting system (e.g. MetCoop). It implies sharing a common computing facility and usually involves a limited number of members. It also implies agreeing a common data policy. Such specific activities should probably be considered within a specific cooperation agreement, outside the consortium.

Recommendation: scope of the consortium, core and optional activities

The scope of the future single consortium should be reviewed jointly and agreed by the HIRLAM and ALADIN partners and constitute the core programme. The definition set in the joint declaration is a good starting point to which the addition of surface modelling and verification should be considered.

Optional programs (e.g. complementary part of the forecasting system, climate version of the model) may be developed. Joining and contributing to an optional program should be subject to meeting the requirements of the core programme.

Operational common facilities should be considered under distinct specific agreement.

Organisation and governance

As mentioned earlier a lot of progress has been made concerning joint work between the two consortia. This will continue in the coming years and should in particular result in increasing the number of common working teams and joint working weeks. The Review Team considers that a crucial step is that a common scientific plan be developed jointly by the two groupings for the next five years (and should not result from separate developments subsequently merged). This would allow a better focus of both groupings on the same core priorities, resulting in a better use of existing resources. It would also facilitate the building of common teams. Given that plans for the next period are being developed now, this should be implemented in 2016 by setting up a common drafting team. This recommendation is strongly linked with the previous one concerning agreeing on the scope of the single consortium.

The governance of the future single consortium was not really in the remit of the Review Team. But when discussing future organisational aspects, some elements were discussed on the following points.

The single consortium will be a large one, which will be quite different from what the HIRLAM members are used to. Both current groupings tend to reach decisions on a consensual basis. However they both have in their convention the possibility to resort to voting. Quite often the very existence of such a possibility contributes to reaching a

consensus. When developing the governance rules of the single consortium, the members should take into account the experiences learned in the current consortia, but also those from organisations like ECMWF or EUMETSAT who are also experiencing an increase in membership.

There are three points concerning governance that the Review Team wishes to emphasize:

- Scientific Advisory Committee – the set-up of such a committee was proposed by the previous Review Team and rejected by the HIRLAM Council. The current Review Team considers that, given the size of the single Consortium, and the importance of scientific issues to be addressed and choices to be made, the need for an independent scientific body, able to review scientific plans and their annual implementations, will be crucial to the successful development of the forecasting system ;
- Policy Advisory Committee – an advisory committee preparing decisions of the joint Council/Assembly is important. Given the size of the future Consortium, it should include a limited and balanced number of participants (see ECMWF's PAC for example) ;
- Voting in the governing body of the single consortium – As the goal is to develop a system for operational use, it is recommended to limit the number of decisions requiring unanimity (in case of voting).

Recommendation: organisation and governance

A common scientific plan should be developed for the next 5-years period by a joint drafting team, and should not result from merging plans elaborated separately.

The governance of the future single Consortium should be carefully considered, given its size. In particular an independent scientific committee should be considered, unanimous decision-making cases should be as limited as possible, and a policy advisory committee with reasonable size be set up to prepare joint Council-Assembly decisions.

Staffing resources and code-development

The Review Team evaluated the HIRLAM contribution to common Arome-Harmonie code-developments. Each consortium keeps an account of the contributions of its members. The resulting figures for the years 2012 and 2014 are provided in the table below :

	HIRLAM	ALADIN (1)	Météo-France
2012	**33**	**47**	**38**
2014	**38**	**51**	**44**

(1) *without Météo-France*

These figures emphasize the specific role played by Météo-France (which is associated with the two consortia) and indicate a striking imbalance between the two consortia. However this imbalance must be viewed in the light of the following factors:

- the ALADIN group is bigger than HIRLAM (16 countries vs 10 and 100 million inhabitants vs 30 million). However this argument is counterbalanced by the fact that, in terms of GDP, the HIRLAM countries and the ALADIN countries (without France) are similar ($4.4 billion vs $4.1 billion) ;
- the ALADIN contributions include resources dedicated to local implementation of the model (evaluated to 15%) ;
- on the other hand the scope of HIRLAM is larger, which should result in proportionally more resources.

Overall, the imbalance remains, even when leaving Météo-France outside, given its specific role as part of the two groupings and more importantly as being the one responsible for code phasing (consistent with its long history of code-phasing with ECMWF's IFS).

This imbalance is even more pronounced when considering code development specifically. The current practice entails successive cycles in Reading, Toulouse and HIRLAM (R-cycle, T-cycle and H-cycle). The R-cycle is the IFS-ARPEGE phasing. The T-cycle is the current common phasing whilst the H-cycle is specific to HIRLAM. Most HIRLAM efforts are done remotely and concern the H-cycle. The result is that,

although much of the corresponding input ultimately finds its way into the T-cycle, this effort is currently not regarded by the ALADIN partners as contributing to the phasing. This is partly a problem of visibility and of an agreed definition of what constitutes common work. It is also a methodological issue.

It is part of the work of the HIRLAM code-development team to validate the code for all model aspects and on a range of computer architectures. Also specific developments, such as HARP or data assimilation, are offered and used by several ALADIN members. However these validation and development activities are not seen as contributions to the common code. The solution to this aspect of the problem has already been discussed in the section related to the scope of the single consortium: it is an agreed definition of what constitutes the content of the core activity.

The current code-phasing system, shaped by historical developments, is by-and-large a continuation of the system put in place at the outset of the ALADIN collaboration. It is centralised in Météo-France and is focussed on the model. Access to the repository from outside Météo-France is restricted. The Review Team considers that the centralisation of the phasing is unnecessarily restrictive and is far from optimal. It is time consuming and results in long delays in implementing new versions of the code. For example, in September 2015, the Reading IFS-ARPEGE was at cycle R42, HIRLAM at cycle H40 and the ALADIN version at cycle T38. There is an urgent need for more distributed approaches to code development and testing, thus reducing the lag between the LAM and global model codes, and improving contacts with, and influence on, scientists at ECMWF and Météo-France on the latest version of the code. This will need to be discussed and agreed between all groups.

Overall the Review Team believes that a reasonable target is that HIRLAM staff contribution should match the ALADIN contribution (without Météo-France) and that the necessary increase be concentrated on code-development. This could be achieved through the expected reduction of the staffing resources required on the ALADIN side by an evolved, more optimal phasing system, together with a reasonable increase in staff contribution from the HIRLAM side. This is consistent with the findings mentioned in section 2 that efforts should be pursued in providing mostly half-time persons to the programme and on code-development training of all staff involved. Finally it will be a

very positive step for HIRLAM to contribute to the code architect position, which both programmes have identified as a need.

Recommendation: staffing resources and code-development

Efforts should be pursued in providing mostly half-time persons to the programme and in organising code-development training of all staff involved.

Overall HIRLAM investment in staffing resources should be increased to ensure that HIRLAM provides proportionate resources to the enlarged consortium in the future. This increase should be concentrated on code-development and maintenance.

There is an urgent need for changes in the present practice of code phasing and evolution. This will require discussion between all groups. The aim is to develop a more distributed, optimal and faster phasing system.

HIRLAM should contribute materially to the proposed common Code Architect position.

Data policy and code ownership

There is clearly a data-policy issue concerning the future single consortium: most HIRLAM members are evolving toward a free and open data policy for the products generated by their Harmonie system, which is very different from the policy implemented by most ALADIN members. There is a general feeling that free and open data policy will be the norm in Europe in the future. However nobody knows how long this evolution will take (and it could well be many years).

The data policy issue could prove quite divisive for the following reasons :

- members opposed to a free and open data policy feel threatened by the possibility of unfair competition by free and open products made available in their area of interest ;
- this feeling is reinforced by the fact that several of those members contributed to the development of Arome which forms the basis of the Harmonie development ;
- there is also a feeling that HIRLAM members are richer countries that can afford free and open policy (i.e. get budgetary compensation by their government).

Different data policies are perfectly possible within a consortium (as is already the case), but difficulties arise when production domains overlap (resulting in free and non-free products simultaneously available for some areas). There are cases for which such occurrences are unavoidable:

- when building an EPS from products generated by different production centres (e.g. GLAMEPS) ;
- when preparing products requested by European calls (e.g. H2020, Copernicus).

The Review Team does not have a ready-to-use-solution to the data policy issue. Moreover it is convinced that the solution has to be developed through discussions within the single consortium. It will require inventive and clever solutions and political decisions that can only be made at the directors' level. The Review Team recommends that this discussion be organised as soon as possible: it could involve experts developing a range of options to be submitted to a working group of the consortium Council/Assembly tasked to prepare a proposal. As an initial input, the following list of basic or simplified options can be proposed:

- full free and open data policy ;
- the existing HIRLAM data policy ;
- the existing ALADIN data policy ;
- restricting open data dissemination within each national domain ;
- mandatory submission of "effective" area of production that would seriously overlap national areas of other members to the consortium governing body for agreement (such agreement would not be unreasonably denied, voting rights for such decision should be carefully considered)

Concerning the code ownership (IPR on the common codes), there does not seem to be any serious problem. There is a general agreement that there should be a common ownership of these codes, giving full right of use to all members.

An important question however is whether these codes should be open-source: some HIRLAM members are clearly in favour of this evolution. It is important because it would simply cancel the data policy issue as no constraint could be imposed upon the

use of products generated by open-source software. However the answer cannot be given independently from ECMWF as the code is developed on the basis of the IFS framework: an open-source IFS is a prerequisite to an open-source Arome-Harmonie. As this is not a simple issue the Review Team recommends that the question be raised at ECMWF level in order to clarify whether it is likely or not that IFS evolves toward open-source. If the answer is "no", then the question of an open-source Arome-Harmonie disappears.

The other question related to the ownership is whether the single consortium decides to use the level of contribution of members in order to develop some weighted voting processes or some revenue sharing system. These are important questions but they would not affect the member's right of use of the system.

Recommendation: data policy and code ownership

The Review Team recommends that the data policy of the single consortium be discussed at directors' level, on the basis of innovative proposals prepared by experts.

The Review Team recommends that the issue of IFS becoming open source be raised at ECMWF.

Branding of the single Consortium and common system

The amalgamation of HIRLAM and ALADIN into a unified programme should not be seen as a merger; this term can be problematic. What is under consideration is really the beginning of a completely new consortium, with new terms of reference, a new MoU and a new image.

The term *Harmonie*, adopted unilaterally by HIRLAM, was originally intended as a name for the research programme and the entire NWP system. The use of this name for the forecast model (essentially *Arome*) has inadvertently led to some bad feeling as it masks the substantial contributions of scientists outside the HIRLAM community. For the future consortium and the forecasting system, a new name and identity must be

found, and agreed by all partners, in order that it can be enthusiastically embraced by all participants.

Clearly, both names HIRLAM and ALADIN are over-restrictive and unlikely to be acceptable. It should then be possible to arrive at a means of branding the new venture effectively. Ideally, the name should describe both the consortium and the NWP system developed by it, and should reflect the nature and purpose of the enterprise and the balance between all partners.

The Review Team suggests that a simple competition be held, inviting all interested participants from both groupings to propose a name for the new consortium.

In the meantime, here is a suggestion for a suitable name for the new *consortium*:

SyMFONIE: Synergy in Mesoscale Forecasting for Operational NWP In Euromed.

If it is applied to a *model*, the acronym may be resolved as follows:

SyMFONIE: System for Mesoscale Forecasting for Operational NWP In Euromed.

The word *Symfonie* is here spelt as in Czech and Dutch/Flemish, reflecting the appropriate balance. The term *Euromed* ensures inclusion of the consortium members outside the continent of Europe. The appellation *Symfonie* is apposite: many different and diverse artists playing together to produce something wonderful: just like HIRLAM/ALADIN, only better! But no doubt a superior name can be found.

Recommendation: branding of the single Consortium and common system

The Review Team recommends that a new name for the single Consortium and the common forecasting system be agreed between all members of both consortia.

5. Conclusion

The Review Team has focused its attention on the issues that still need to be addressed in view of the joint ALADIN-HIRLAM consortium and made several recommendations in this report.

The report is addressed to the HIRLAM Council, and the Council will decide on its response to the recommendations. However, the Review Team wishes to emphasize that, while most of these recommendations will be implemented by the HIRLAM and ALADIN management and staff, some of them will require the direct intervention and support of the directorate of the member institutes. In particular, this is the case for :

- defining the content of the core activities of the single consortium ;
- implementing the joint ALADIN-HIRLAM governance ;
- provision of the required staff resources ;
- data policy and code-ownership ;
- agreeing a common branding for the consortium and the common forecasting system.

While the remaining tasks to be addressed before the single consortium is in place are still far from negligible, the gains that can be expected from bringing together a large part of the European regional NWP community are worth the challenge. The feeling of the Review Team is that the impetus for progress is already in evidence at all levels.

The Review Team:

Peter Lynch
Dominique Marbouty
Tiziana Paccagnella

September 2015

List of Annexes

Annex 1: Scope and Terms of Reference for HIRLAM-B External Review

Annex 2: Joint HIRLAM-ALADIN Declaration

Annex 3: List of acronyms

Annex 1

Scope and Terms of Reference for HIRLAM-B External Review

1. Scope of the Review

The Review should consider the achievements of the HIRLAM-B Programme, and evaluate the scientific and technical outcomes against the Programme's planned goals. The impact and relevance of the Programme's outcomes should also be assessed.

The Review should examine the overall effectiveness of the HIRLAM cooperation: the role and relative responsibilities of the main HIRLAM steering bodies (Council, HAC and management group), as well as the main elements of the daily HIRLAM working practices , such as the Reference System, the core group, the organisation of joint activities, and the common facilities provided on the HIRLAM server and at ECMWF.

The Review should provide guidance on the future evolution of the HIRLAM collaboration, in its scientific, technical and organisational aspects. A major consideration in this regard is the recent joint Declaration of the HIRLAM Council and ALADIN Assembly, in which both parties agreed to work towards forming one single Consortium by the end of the 2016-2020 period. The text of the joint Declaration is attached as an Annex.

More broadly, the scope and development of the HIRLAM consortium should be assessed in the context of the IFS/AAAH framework and the future of the numerical modelling of weather and climate in Europe. In this regard, the evolution of regional operational cooperation (e.g. MetCoOp) should also be considered.

2. Terms of Reference

Specifically, the Review should provide:

1. An assessment of the scientific and operational achievements made in the past years, and their impacts and relevance, as compared to the goals set for the HIRLAM-B Programme.

2. An assessment of the Programme's organisation and management, and the effectiveness of its working practices, along with recommendations for future developments.

3. Recommendations on the scientific and organisational scope of the HIRLAM collaboration for the next cycle 2016-2020, and on longer-term vision and strategy (2016-2025), taking particular account of the joint Declaration on a merger with ALADIN and how this may be facilitated during the 2016-2020 period.

4. Recommendations on the HIRLAM Consortium's relationships with other relevant parties, in the context of the IFS/AAAH framework and the expected development of regional cooperation initiatives such as MetCoOp (Meteorological Co-operation on Operational NWP between NMI and SMHI).

3. **Persons and organisations that may be consulted**

- HIRLAM Council (NMS Directors)
- HIRLAM Management Group
- Chair of HIRLAM Advisory Committee (and members, if desired)
- ALADIN Programme Manager
- ALADIN Committee for Scientific and System/maintenance Issues (CSSI)
- Heads of Research and of Operations in HIRLAM Institutes, and in HIRLAM-related scientific groups in the various member countries
- Météo-France staff dealing with HIRLAM strategic matters

Note: Separate from the Review, HIRLAM will arrange meetings / workshops early next year where legal experts will consider how issues such as IPR rights and data policy should be addressed in the context of the ongoing cooperation and expected eventual merger of HIRLAM and ALADIN. The Review Team will be kept informed of any outputs from these discussions that might impact on the overall planning of future joint HIRLAM/ALADIN activities.

4. Expected actions based on the outcomes of the Review

The HIRLAM Institutes will be requested to consider and provide their opinions on the recommendations made by the external reviewers, and these responses will be discussed by the HIRLAM Advisory Committee and Council. The report of the Review and the strategic discussions in HAC and Council will be used as input to formulate a new Memorandum of Understanding for the period 2016-2020. A revised scientific strategy will be formulated by the new HIRLAM management group, in collaboration with the ALADIN partners, at the beginning of the new MoU period.

Annex 2

Joint HIRLAM-ALADIN Declaration

Adopted on 2 December 2014

by the joint meeting of the HIRLAM Council and ALADIN General Assembly

Recognizing the capabilities and achievements of the NMHS belonging to Aladin and Hirlam consortia:

1. The NMHS present at the joint Aladin-Hirlam meeting (Dec 2, 2014) share the same objective to jointly develop and maintain the best possible skilled limited area weather forecasting system, building on the developments of the IFS/Arpege global forecast system and on the Aladin and Hirlam limited area systems. This limited area system is defined as a set of data pre-processing, data assimilation, atmospheric model and postprocessing tools for producing the best possible operational mesoscale weather forecasts.

2. Aladin and Hirlam consortia will work together with the aim of forming one single consortium by the end of the 2016-2020 MoUs. To this aim, the following issues have to be resolved:

- code ownership (software IPR) : current situation and suitable evolutions. In particular advantages vs drawbacks of open source solutions should be assessed;
- data policy (access to model outputs) ; to this aim a map of the various current operational configurations of the limited area system should be produced and scenarios for data dissemination should be assessed;
- global picture of annual contribution of countries to the various types of activities (from fundamental research to code implementation);
- identification of common activities and specific activities (possibility of core and optional programs);
- branding (including suitable evolution of the name of the system).

3. Human resources to support the work will be identified.

4. Both PM will report every six months on those issues to the consortia governing bodies.

5. Joint meeting of governing bodies of both consortia will be held at least once a year.

Annex 3

List of acronyms

Used in the report

AAAH	Arpege Arome Alaro Harmonie
ALADIN	Aire Limitée Adaptation dynamique Développement InterNational
ARPA	Agenzia regionale per la prevenzione e l´ambiente
ASM	All Staff Meeting
CGEDD	Conseil Général de l'Environnement et du Développement Durable
COSMO	COnsortium for Small scale MOdeling
CSSI	Committee for Scientific and System/maintenance Issues
ECMWF	European Centre for Medium-Range Weather Forecasts
EPS	Ensemble Prediction System
FTE	Full Time Equivalent
GDP	Gross domestic product
GLAMEPS	Grand Limited Area Ensemble Prediction System
HAC	HIRLAM Advisory Committee
HIRLAM	High Resolution Limited Area Modelling
HMG	HIRLAM Management Group
IFS	Integrated Forecasting System
IPR	Intellectual Property Rights
LACE	Limited Area modelling in Central Europe
MoU	Memorandum of Understanding
NMS	National Meteorological Service
NMHS	National Meteorological and Hydrological Service
NWP	Numerical Weather Prediction
OOPS	Object Oriented Programming System
PAC	Policy Advisory Committee
PM	Programme Manager
RUC	Rapid Update Cycle