EVALUATION
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Evaluation of the international HIRLAM project and HIRLAM operational applications

David Burridge, Erland Källén and Claude Pastre

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1. Introduction and background

The primary goal of the HIRLAM co-operative project is to develop state-of-the-art regional numerical weather prediction systems suitable for operational use in its member institutions. Currently, weather services from eight countries make up the core of the co-operative project – Denmark, Finland, Iceland, Ireland, Norway, Spain, Sweden and The Netherlands whilst Météo France participates in the research and development but does not use a HIRLAM forecasting system for operational forecasting.

Each HIRLAM project has had a lifetime of three years and each project has had its own Memorandum of Understanding (MOU) with directives and deliverables. The current MOU is the sixth, HIRLAM-6, and runs for the years 2003 to 2005 inclusive. Although the emphasis of HIRLAM MOUs is research, the primary deliverable is the maintenance and continued development of a Numerical Weather Prediction software system, the Reference System, for regional analysis and weather forecasting.

A HIRLAM Council consisting of representatives from each member institution governs the implementation of each MOU. A Project Leader has overall responsibility for the management and implementation of the project. The Council and the Project Leader are advised regularly on all matters (plans, policy and finance) by a HIRLAM Advisory Committee (HAC). The Council and the HAC meet at least twice each year.

The science and observational basis for numerical weather prediction is expected to develop rapidly over the next 10 years and, in addition, there are possibilities of new European partnerships for HIRLAM member institutions. This, and the necessity to develop a new MOU for HIRLAM-7, prompted the HIRLAM Council to commission an evaluation of the HIRLAM project from David Burridge, Erland Källén and Claude Pastre.

The evaluation should have two main components:

- An evaluation of the recent HIRLAM projects;
- Advice on the options for achieving the HIRLAM institutions' objectives for operational short-range weather forecasting.

In developing its evaluation, the evaluation group visited each member institution and had consultations with all nine Directors, members of the HAC, the Project Leader, HIRLAM managers and most HIRLAM project scientists including local HIRLAM teams. The group also reviewed the MOU for HIRLAM-6, scientific plans and work plans, Council and HAC minutes, HIRLAM reports including the HIRLAM-5 Final report.

Our evaluation is set out in the following four sections of this report, section 5 providing a summary, recommendations for future scientific strategy, organisation and management of the project.

2. HIRLAM – a brief historical background and the present status

History and the main achievements

The HIRLAM project began in 1985 as a cooperative research and development project involving the Nordic weather services – DMI (Denmark), FMI (Finland), Met.no (Norway) SMHI (Sweden), Vedurstofa (Iceland). The initial goal was to develop a regional Numerical Weather Prediction (NWP) system suitable for operational use. Soon after its inception, the KNMI (The Netherlands) and Met Éireann (Ireland) joined the project.

Initially, a central development group was established in Copenhagen and the first HIRLAM Forecasting System (HFS) was based on the ECMWF global grid-point model and an Optimum Interpolation analysis scheme. When the first version of the HFS had been developed and tested the central group was disbanded (around 1990). Some of the project partners adopted the first HFS as their operational system whilst others continued to use older operational systems for a few years. Eventually, all HIRLAM members adopted the HFS as their main operational short-range NWP system.

After this first phase, the HIRLAM project continued and the partners, who were joined by Météo-France in 1992 and by INM (Spain) in 1994, continued to carry out joint research and development. New versions of the HFS were continually released and a Reference System was established and maintained at the ECMWF.

The first major achievement of HIRLAM was to produce a state-of-the-art, short range forecasting system that could be employed operationally at higher spatial resolutions than those in use at the ECMWF. Additionally, a number of new elements were developed and subsequently included in the Reference System:

- a semi-Lagrangian time integration scheme;
- a digital filter for initialisation;
- an efficient radiation scheme;
- a liquid-water based cloud parameterisation scheme;
- a spectral version of the HIRLAM model (used for continuous data assimilation – see below).

In recent years a number of additional new components have been included in the Reference System, notably:

- an operational 3DVAR assimilation scheme;
- an experimental 4DVAR assimilation scheme using the spectral version of the model;
- a surface parameterisation scheme and a soil moisture assimilation scheme;
- a revised cloud scheme.

Of these recent advances, the most important has been the development of an operational 3DVAR analysis scheme and an experimental 4DVAR assimilation scheme.

The horizontal and vertical resolution has also continued to increase, keeping the resolution of operational versions of the HFS finer than those used in the ECMWF global forecasting system.

Operational use of HIRLAM

With the exception of Vedurstofa (Iceland), each HIRLAM member runs their own operational system. Vedurstofa use operational HFS products from the DMI.

Typically, operational HFS configurations have the following characteristics:

- a large limited area for analyses and forecasts with time-dependent boundary conditions received from the ECMWF;

- the horizontal resolution employed for these large domains is in the range 15-25 km;

- intermittent data assimilation using 3DVAR to produce four analyses per day;

- embedded within the large area is a smaller area with a horizontal resolution of 5-10 km;

- in some applications there is an independent data assimilation for the small area, in others the initial state for the small area is interpolated from larger scale analyses.

As an example, figure 1 shows the integration areas used at the DMI. The DMI system uses the largest integration area of all HIRLAM members and, interestingly, the territory of all HIRLAM member countries is included well within the large DMI area. However, HIRLAM members from time-to-time make forecasts for non-European areas in support of national, typically defence, activities.

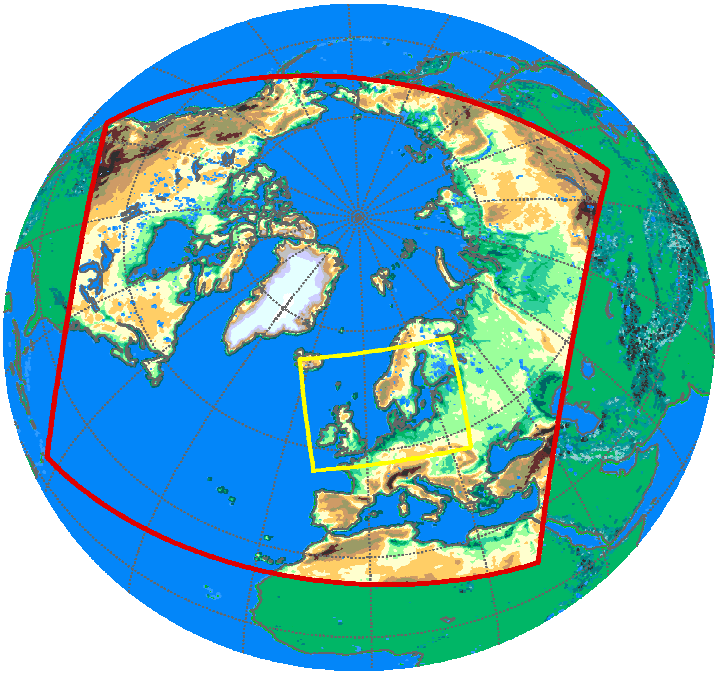
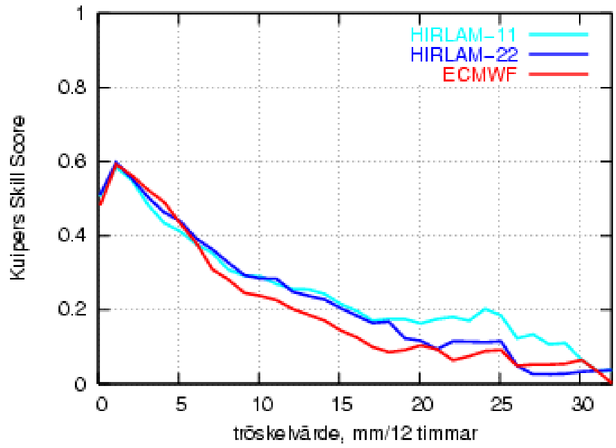


Figure 1. The areas used by the DMI in mid-2004. The large area is delineated by the red border and the small area is delineated by the yellow border.

The performance of all operational HIRLAM systems is as good as any other regional NWP system. Average forecast scores for large-scale variables are similar for all systems and it is difficult to determine objectively which system performs the best. However increases in horizontal resolution are beneficial

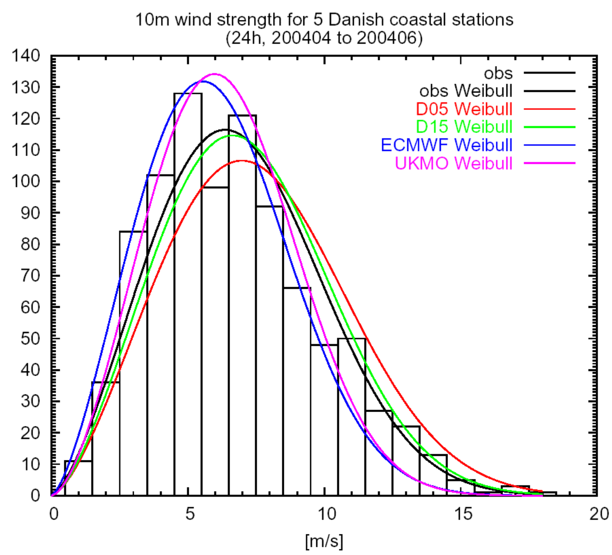
For large-scale variables, the ECMWF average forecast scores are better than those for the HIRLAM systems when comparing forecasts with the same forecast lead time. However, HIRLAM systems have advantages in real time and for the prediction of weather parameters.

In real time, the HIRLAM systems have an advantage over ECMWF because more recent observations can be used and results from the same nominal initial data time are available sooner. The main advantages of the higher resolutions employed by HIRLAM members are apparent when comparing the statistical distributions of predicted weather parameters. Figures 2 and 3 show HIRLAM performance statistics derived at the DMI and the SMHI. Intense precipitation events are clearly better predicted with the highest resolutions as are high wind events. In addition the highest resolution regional models are better at predicting high wind speed events than low resolution regional models (not shown). This result cannot be discerned from an analysis of average scores.



Curves are given for the 11 and 22 km resolution HIRLAM regional models employed at the SMHI (light and dark blue) and for the ECMWF model (red). For intense precipitation the highest resolution HIRLAM systems are best.

Figure 2 Precipitation skill score as a function of intensity (in mm/12 hours).



Observations are illustrated by the black histogram and the continuous black curve (a best fit Weibull distribution). Forecasts (24 hour lead-time) are shown for DMI HIRLAM models (green – horizontal resolution of 15 km; red – 5 km), the ECMWF (blue) and the UKMO (magenta). The HIRLAM results lie closer to the observed frequency distributions.

Figure 3 Wind speed (horizontal axis) against frequency of occurrence (vertical axis).

Despite the good performance of HIRLAM systems described above, forecast users in all member institutions experience some particular problems with the HIRLAM forecasts compared with observations or with other forecast models.

The most significant problems are:

- poor prediction of spring-time surface temperatures at high latitudes;
- poor representation of low-level clouds;
- poor direct prediction of surface temperatures in near-zero temperature conditions;
- significant inconsistency (jumpiness) between forecasts for a particular time from different initial times;
- poor representation of the wind field in mountainous regions.

These problems have been identified by the HIRLAM project team and attempts have been made to resolve the first three. To date, these attempts have not been very successful. Unfortunately, users (operational forecasters and, in some cases, senior managers) interpret this as an inability of the HIRLAM project team to respond to user feedback. Some of the problems may be resolved as a result of future developments. Increases in resolution and the adoption of non-hydrostatic meso-scale models for operational forecasting can improve the representation of winds in mountainous areas. Inconsistency between forecasts may have its resolution in the use of Ensemble Prediction Systems (EPS).

In some HIRLAM member institutes, the HFS provides all primary NWP products for short range forecasting. In others, where satisfaction levels are low, HFS products are used less than half of the time for synoptic-scale guidance. All, however, regard HFS products as a useful complement to NWP products from other Centres notably the ECMWF, the UKMO and the DWD. The primary competitor in terms of use for synoptic-scale forecast guidance is the ECMWF. Despite this partial reluctance to use the HFS fully for operational synoptic-scale guidance, all members rely heavily on the HFS for downstream applications – for example, for the prediction of air pollution, water waves, land surface hydrology and road conditions.

A formal internationally organised two-way communication between HIRLAM users (operational forecasters) and the HIRLAM project team does not exist. In some countries the communication between operational forecasters and the local HIRLAM group is good whilst in others the “distance” between forecasters and the local HIRLAM group appears to be large.

The concerns about forecast quality have been discussed at All Staff meetings, within the HAC and at Council meetings and this has led to action by the Management Group. However, it has not been clear to HIRLAM users that their feedback has been dealt with, neither through feedback from the project management nor from improvements in forecast quality. This appears to be a main reason why the project team is perceived as being unable to handle well identified long standing forecasting problems. As a consequence, this undermines user confidence in the HFS.

The HIRLAM experience

All participants in the project value membership of the HIRLAM community - membership providing a motivating factor for their work which would be absent otherwise. Workshops and other project meetings are highly appreciated as an opportunity to discuss matters of mutual interest. All teams feel that they are on an equal level; there is no team that is seen as dominant.

The participation of Météo-France in HIRLAM is different from other HIRLAM groups. Although Météo-France does not use a operational HFS it has benefited from HIRLAM development work through the implementation of HIRLAM ideas into their own operational systems. Similarly, the other HIRLAM institutes have benefited from research co-operation with the Météo-France team.

Participation in HIRLAM has enabled many HIRLAM teams to bid for EU contracts with success. The HIRLAM system has also been used for other purposes than NWP, most notably regional climate modelling (SMHI, Met.no, KNMI and Met Éireann). Many versions of the HIRLAM regional climate model exist and the climate modelling activity has benefited development work particularly in the area of parameterization. Work on satellite data has become more extensive and effective following the adoption of a 3DVAR data assimilation system.

Until recently, the Reference System had not been used very much operationally. Strengthening of resources for testing and maintenance has improved on this. Now many members base their operational HFS closely on the latest version of the Reference System. The FMI run the Reference System without any modification, however there are still some local variations in the implementation of the HIRLAM reference system at other centres, usually the local operational HIRLAM is enhanced with local development efforts.

Some HIRLAM members co-operate with other regional model development groups or participate in projects involving other regional modelling partners. The Met.no co-operates with the UKMO on the use of the Unified Model (UM), the Vedurstofa and Met. no use the MM5 for experimental meso-scale forecasting and the Met.no. and INM use versions of the HFS for ensemble prediction.

In contrast to these positive views, many participants think that more steering from HIRLAM management is desirable. The present research plan has the character of a long shopping list that cannot reasonably be accomplished with the present level of resources and there is little evidence that any prioritisation has been attempted. Progress is slow in many areas; for example in the improvement of surface and boundary layer parameterisation schemes, the formulation of lateral boundary conditions and the development of a meso-scale model.

In some areas this due to a lack of resources; in particular, the improvement of lateral boundary conditions and the development of a non-hydrostatic meso-scale model have suffered from lack of sufficient attention within the project. In other areas, particularly model parameterisation, the problems appear to be difficult and, despite substantial efforts, problems are still largely unsolved. Notably, however, the development of the variational assimilation scheme has progressed remarkably well and it is appreciated by all participants. It is clear that this project has benefited from strong inspired leadership.

3. Elements of a research and development strategy for the next 10 years

Background

All the weather services currently involved in HIRLAM will be required to provide increasingly accurate, reliable and more detailed forecasts of regional weather and to provide advice on weather-related risks to life and property. In addition, the HIRLAM weather services should continue to improve national and international decision making procedures in order to reduce the impact of severe weather.

In order to provide the necessary support, access to high-resolution synoptic-scale and meso-scale weather forecasts is essential.

The ECMWF is expected to maintain its leading position in the field of global forecasting and analysis and to achieve a significant operational capability in environmental monitoring. The shared responsibilities between ECMWF and its Member States will be such that any expansion in the activities of ECMWF will be consistent with its revised convention and ECMWF would not be allowed to supplant short-range forecasting in its Member States. Consequently, it is unlikely that ECMWF will develop an appropriate meso-scale forecasting system for use by its Member States. However, the ECMWF could provide computational resources to support Member States "real-time" research and operations.

It is envisaged that by 2015, regional NWP systems will be based on:

- High-resolution synoptic-scale numerical forecasts with a horizontal grid-spacing of ~ 10km;

- High-resolution meso-scale forecasting systems with a horizontal resolution in the range 1 to 2 km - these models will be non-hydrostatic.

Flexibility will be required to zoom-in to local areas and it should be possible to derive Nowcasting products from high resolution forecasting systems. These high-resolution systems are also required for regional climate research in order to "down-scale" global analyses and global climate simulations.

Development of meso-scale forecasting systems

The HIRLAM countries have had a requirement for a high-resolution meso-scale forecasting system for some time. The model being developed at Tartu University was not viewed as being suitable for HIRLAM purposes and, as discussed above, it has not been possible to allocate the necessary resources to develop a state-of-the-art research system within the HIRLAM community.

As a result, in order to "catch-up", HIRLAM members have imported well known meso-scale models for research use, MM5 for example, and sought international co-operation with other institutions in order to "acquire" the necessary systems and expertise. The Met.no. investment in co-operation with the UK Meteorological Office (UKMO) has resulted in the successful implementation of a quasi-operational version of the UKMO Unified Model (UM) for meso-scale forecasting.

The majority of HIRLAM institutions are keen, and have almost committed themselves, to co-operate more closely and more extensively with Météo France by contributing towards Météo France's AROME system. Météo France's main goal is to run a high-resolution AROME system operationally in 2008. However, intermediate AROME systems could be employed operationally before 2008. Since the dynamical core of the AROME system is based on the ALADIN non-hydrostatic dynamical core it is regarded as necessary to establish a formal collaboration agreement with the ALADIN group of institutions.

The road map for HIRLAM research and development

Over the next 10 years the resolution of both global and regional synoptic-scale models will be increased and by 2015 operational global numerical weather prediction systems will provide the best synoptic-scale analyses and forecasts. For a given data cut-off time, regional models are unlikely to be as realistic or as reliable.

However, for the next 5 to 10 years the HIRLAM institutions should continue to develop synoptic scale forecasting systems including its regional 3DVAR and 4DVAR systems until products from global systems can be used to fulfil operational requirements for synoptic-scale forecasts. Additionally, in order to develop data assimilation for meso-scale models more experience with regional 3/4DVAR schemes for the short synoptic scale is needed.

At the December 2004 meeting of the HIRLAM Council, the Project Leader presented a paper on future HIRLAM research and development ("Road-map for HIRLAM research, ALADIN collaboration and March towards AROME"). In addition to a detailed plan of research, the road map envisages that the HFS model's program code be merged with the ALADIN model's program code.

The first step would be to replace the HFS model's grid-point dynamics with the ALADIN spectral dynamics. The ALADIN dynamical core is essentially a non-hydrostatic version of the spectral dynamic core of the assimilating model used in the HIRLAM experimental 4DVAR system. Consequently, this should not be seen as a major scientific change in direction but a means of facilitating "full code" collaboration with Météo France and the ALADIN group on the development of meso-scale forecasting systems. It will also facilitate co-operation on the development of synoptic-scale forecasting systems.

The merge could alleviate somewhat the need for additional HIRLAM resources for meso-scale forecasting system development since the same dynamical core would be used for the current operational synoptic-scale forecasting system, 4DVAR assimilation and meso-scale forecasting. Additionally, operational improvements are likely to be achieved more quickly and more efficiently if all institutions use the Reference System for operational forecasting.

The evaluation group believe that both the UM system and the AROME system would provide state of the art meso-scale forecasting systems. The "full code" collaboration with Météo France and the ALADIN group has many added advantages - full ownership of a unified system for synoptic-scale and meso-scale forecasting and the software compatibility to enable HIRLAM members to make immediate use in research and operations of developments at the ECMWF. However, if resources permit, the HIRLAM group could continue to use the UM system and this would facilitate easy comparison of the performance of two state-of-the art meso-scale forecasting systems.

Because of the inevitable uncertainty in initial conditions and also uncertainty in the formulation of forecast models, the development of regional Ensemble Prediction Systems (EPS) will be necessary and will provide crucial input to risk forecasting systems. Within a few years the ECMWF will be delivering operational global deterministic products with a horizontal resolution of 25km and ensemble products with a resolution 50km. These global products should be complemented with regional EPS having resolutions of 10/15km. The HIRLAM institutions have the models and the variational assimilation systems necessary to do this. And, the evaluation group recommends that more effort should be put on the development of a regional EPS. This will enable HIRLAM institutions to contribute more effectively to EURORISK, which is focussed on the development of tools to enhance the mitigation of weather-related disasters, and to provide support to the THORPEX programme.

Centralisation of operations

In the past, operational collaboration was ruled out because of communication costs. However since communication costs have fallen, and will continue to fall, it would be useful to assess the desirability and to re-evaluate the costs of running forecasting systems centrally.

Since the regions used for synoptic-scale forecasting are now large, as noted above one of the DMI areas covers the whole of the HIRLAM member states, it may be feasible and cost-effective to carry out operational synoptic-scale forecasting (including ensemble prediction) for European areas at one or possibly two HIRLAM institutions and operational meso-scale forecasting at all institutions as required for local products. The resulting operational products could be exchanged using the GRID technologies currently being investigated through European Union funded projects and provide a focussed HIRLAM contribution to a European component of THORPEX.

4. Resources, organisation and management

Resources

Except for a brief period at its inception, the HIRLAM project has always relied on a distributed team of scientists and programmers for its research and development. Currently, the international HIRLAM project utilizes about 20 person-years per year spread over about 80 people from the member institutes. This distribution of human resources is both a strength and a weakness. It enables members to maintain up-to-date NWP "know-how" and keeps costs down but there may be inefficiencies because of the lack of stringent project management procedures.

Establishing a fully centralized development activity for the international HIRLAM would be expensive and difficult and may be beyond the financial resources available to members. And, it may not be desirable, considering the benefits the member institutes gain from the current distributed arrangement. However, it would be beneficial to establish, temporarily, centralised task forces for specific projects. These task forces could be established using a system of extended visits funded from the central HIRLAM budget.

A significant number of staff, about 20 person-years per year, is involved in local development and implementation of the HFS (table 1), roughly doubling the amount of human resources committed to HIRLAM-related work.

Institute	Person-years/year employed on local development and implementation	Annual expenditure on large-scale computing (K€)
DMI	4.0	1000
FMI	2.0	700
Met Éireann	1.0	350
KNMI	3.5	700
Met.no.	1	200
INM	6	1600
SMHI	3	150
Totals	20.5	4700

Table 1. Local resources employed, in addition to those which are committed to the International HIRLAM project – based on figures provided by each HIRLAM institution

The Expenditures on computing are approximate:

Amounts have been rounded to the nearest 50 K€;

in some cases, Spain for example, the annual "expenditure" depends on the length of time over which computing costs are amortized;

Costs for computer staff are included and are based on rough estimates;

For DMI 75% of its expenditure on large-scale computing has been entered since DMI's computer is also used for climate research.

The local HIRLAM systems and their adaptation to local needs constitute the actual HIRLAM product as seen by the users. Even if HIRLAM research and development could be centralized, the work performed by local staff, in direct contact with the users, would still have to be done. The total number of 40 person-years per year is commensurate with similar efforts elsewhere. It is, for instance, about the amount of staff devoted by Météo-France to NWP.

Based on estimates provided by HIRLAM members, approximately 5 M€ is spent annually by members on large-scale computing (table 1) with the INM and DMI accounting for a little more than half. Whilst significant, this expenditure is not enormous when compared with other similar operations. There seems to be however a possibility, at least, for higher efficiency that deserves to be being investigated, namely the centralization of some the HIRLAM operations. In particular, as discussed above, the desirability and financial consequences of the centralization of European-wide synoptic-scale forecasting could be assessed.

It is somewhat difficult to believe that the necessary tight "code collaboration" with the ALADIN group could be achieved, at least in the initial phase, without either additional human resources or the transfer of significant resources from current activities which would consequently have to be abandoned. Collaboration with ALADIN may perhaps alleviate the need for additional resources eventually, but ensuring the success of the initial phase and the transition to the merged system will require extra work while current activities continue to be pursued. This problem does not seem to have been addressed so far.

Organisation and management

The short duration, three years, of HIRLAM MOUs has a detrimental effect on the management of the project which, with the absence of a long-term strategy, makes any "hard" planning difficult. Consideration should be given to the establishment of a more stable institutional framework, where the attainment of the objectives could be synchronised with the contractual commitments. This could be accomplished either through an open-ended agreement with a long-term strategic plan, yearly budgets and identified intermediate milestones or, and probably more appropriately for a non-governmental arrangement, by MOUs of longer duration, five years say, specifying a multi-annual commitment.

According to the current MOU the Council has "overall authority" and "considers annually for approval the Scientific Plan, Progress Report, Budget and accounts". It is a weakness of the present MOU that there is no explicit mention of the establishment of a long-term strategy among the tasks of Council. And, since some of the Council's working practices appear rather questionable (hurried meetings with too much time devoted to a too detailed analysis of a progress report), the Council may find itself taking uninformed decisions on major strategic changes.

The function of the Project Leader is poorly presented in the current MOU. He "appears" as part of the HIRLAM Secretariat and as a member of the Management Group. The Project Leader has "overall responsibility for the management of the Project" but no executive power to discharge that responsibility. The consequences can be seen for instance in the way the annual work plan is decided. Essentially, the HIRLAM scientists contribute to the science plan the tasks they intend to perform for the coming year and this becomes the work plan. There is, for example, no possibility in such a process to establish priorities based on users' requests. The Project Leader is also burdened by secretarial tasks (general administration, minutes, publications etc) which reduces the time for available for scientific and technical management. This should be addressed in future MOUs.

The HIRLAM Core Group was established in HIRLAM-6 under the authority of the Management Group, not of the Project Leader, as means of addressing urgent tasks. This approach does not seem to have been very fruitful. This approach has been tried elsewhere, also with little success, because a small group cannot have all the necessary expertise and because such a group tends to be allocated unrewarding tasks that no one else wants to undertake. However, in one instance this approach has been useful, the core-group member working at FMI on the Reference System shows what the ingredients for success are – the full-time employment, to the exclusion of any other work for his parent institute, on a long-term task that is essential for the project. It would be of advantage to replace the notion of Core Group by that of Core Resources, in the form of a budget in the hands of the Project Leader, who could contract with member institutes or recruit people directly.

It is difficult to distinguish the role of The Management Group from the Project Leader, both as defined by the MOU and in actual practice. The Area Leaders provide strong support to the Project Leader. They act as co-ordinators of the scientists in their field and, without any official authority on these staff, they do the best possible under the circumstances. It is clear that strong scientific leadership, as was the case for instance for the development of variational data assimilation, is necessary for priority research tasks. The positions of Area Leader appear not to be very attractive for HIRLAM scientists.

The HAC appears as a rather ambiguous body, since it must advise both the Council and the Project Leader on all matters. In practice, the HAC plays a strong role in the definition of HIRLAM plans and in their implementation due to the fact that several of its members have high-level positions in their institutes where they are responsible for the human resources made available for HIRLAM. The evaluation team recommends that the role of the HAC be clarified and for it to be designated explicitly as a policy advisory committee which would be more consistent for a body comprised of representatives of the members.

The need would remain for HIRLAM, its Council and its Project Leader to obtain independent scientific advice. Without resorting to the establishment of a dedicated scientific advisory committee, this would be best achieved by external scientific reviews performed periodically, for instance twice in a five year period.

The MOU fails to recognise a requirement for any organised dialog between the HIRLAM project scientists and the end-users. The users' interests are actually taken into account but there is no feedback process which, for example, could be used to explain to users why some problems have not yet been solved despite real efforts. The requirement for the end-users to be involved in the definition of HIRLAM priorities was a strongly voiced in all HIRLAM institutes. As indicated above, it will naturally be necessary first to give the project the possibility to manage priorities. The involvement of end-users should be worked out in parallel.

5. Summary and recommendations

Over the past 20 years, the development of independent HIRLAM research and operational capabilities in short-range Limited Area NWP has clearly benefited the HIRLAM Member States.

- The HFS provides competitive, state-of-the-art regional forecasting systems and the level of applied research and development carried out is good; testing and maintenance of HFS Reference System has improved considerably, the Reference System is now more attractive to use operationally;

- The adoption of a 3DVAR system for operational data assimilation system is an exceptional achievement;

- High resolution versions of the HFS have distinct advantages over the ECMWF for intense precipitation and strong wind situations; for average scores the ECMWF has better performance for the same forecast lead times;

- Some serious operational deficiencies (prediction of surface temperatures, low-level clouds, and winds) have existed for some time and with a different managerial scheme these may have been alleviated by now;

- There are distinct advantages with the distributed working arrangements that have evolved for the project but firmer leadership is required by HIRLAM staff and would be beneficial.

The overall success of HIRLAM speaks highly for the quality and strong dedication of the scientists who designed and developed the HFS. Nevertheless the lack of a long-term strategic plan, the short-lived MOUs and the absence of clear lines of command have made it difficult for HIRLAM to address difficult priority items (e.g. mesoscale models) and to develop a transparent decision process for strategic changes (for example partnership with ALADIN). Independent scientific advice and end-user input for the definition of priorities would also be beneficial. The development of a partnership between HIRLAM and ALADIN will pose specific organisational and management problems which must be addressed this year.

The "critical mass" of the HIRLAM group has also been important for the development of the research and the operational capabilities of the ECMWF. The HIRLAM group, partly through its common interests and purpose, has helped "balance" the influence of the larger European weather services.

The review group believes that because of the scientific and operational capabilities achieved to date and the "political" weight that has been developed, that all HIRLAM countries will want to retain their membership of a HIRLAM project for the next 10 years and recommends that HIRLAM Council considers the following recommendations.

Recommended strategic directions

- Continuation of the development of synoptic forecasting systems based on a merge of the HFS and the ALADIN forecasting system and operational use of the Reference System at all institutions;

- Development of meso-scale forecasting systems in collaboration with Météo France and the ALADIN group to develop the AROME system and, provided there are sufficient resources, continued use of the UM meso-scale forecasting system;

- Development of EPS for forecasting at all time ranges but firstly for synoptic forecasting;

- Re-evaluation of the possibility of carrying out some operational forecasting centrally particularly for synoptic-scale forecasting;

- Development of a contribution towards EURORISK and a European component of THORPEX.

Recommended improvements to the organisation and management

- Establishing a more stable contractual framework

An effort should be made to link the identification of deliverables with the contractual commitment of the participating institutes. This could be achieved by the definition of clear milestones in the framework of an open-ended MOU. However, to avoid the need for difficult yearly discussions on the budget, the HIRLAM members will probably prefer using MOUs of definite duration specifying deliverables and resources. In that case the duration must be long enough to attain significant progress, for example five years.

- Identifying the role of Council and sub-committee(s)/group(s)

The MOU should define more clearly the role and responsibilities of each element in the structure. In particular the limits of authority delegated by the Council to the Project Leader or to representative bodies should be outlined. The HAC should be redefined as a Policy Advisory Committee. A process to get independent scientific advice should be established, possibly in the form of ad-hoc periodic scientific reviews synchronised with the revisions of a strategic plan. The users should be given a stronger position in the structure, preferably through the establishment of a HIRLAM Users Group.

- Defining an authoritative role for the Project Leader.

The role of the Project Leader should be defined by the MOU. The Project Leader should report to Council. He/she should receive a clear delegation of executive authority over HIRLAM resources, in particular human resources. In order to make it clear that a definite change is taking place, and to underline the long-term continuity of HIRLAM, it would be advisable to replace the title "Project Leader" by "Programme Manager". This person would naturally continue to be a recognized and experienced NWP scientist. The project management structure should be reviewed annually by the Council.

- Agreeing a long-term strategy.

A strategic plan, covering a ten-year period for example, should be prepared and should be updated every five years. The plan should be prepared by the HIRLAM Project Leader with external scientific input and using input from the end-users of the HFS.

- Improving support for the Project Leader

The Project Leader should be provided with HIRLAM budget funds to recruit scientists or contract directly with the member institutes for part of the scientific and technical work. The Project Leader would also benefit from some dedicated personal scientific and technical assistance.

- Centralization of some research effort

This could be achieved through a system of extended visits funded by the project.

Organisation/management in the context of extended international cooperation

- A clear strategic framework should be established and approved by the HIRLAM Council and the ALADIN General Assembly by the end of 2005; this will provide guidance to all parties involved in the actual work and avoid misunderstandings that could result in catastrophic failures at a later stage;

- A robust management structure on each side to ensure that commitments are honoured by both parties and that of parallel work plans are carried out in a timely manner;

- An organised working relationship between the HIRLAM and ALADIN project leaders in order to agree work programmes in very definite terms, to identify deliverables and milestones and to establish periodic discussion between the partners; the project management practices should be commensurate with the size of the project and avoid unnecessary bureaucracy.

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