SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year Jan-June 2016……………………………………

Project Title: HIRLAM-C 1st phase (2016-2018) Special Project

Computer Project Account: SPSEHLAM………………………………………………

Principal Investigator(s): J. Onvlee…………………………………………………

Affiliation: KNMI……………………………………………………

Name of ECMWF scientist(s) collaborating to the project (if applicable) ---

Start date of the project: 1 January 2016…………………………………………

Expected end date: 31 December 2018……………………………………

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	6500000	6000000 (+ part of an additional pool of national resources)	10000000	53.300 by mid-May (+ part of an additional pool of national resources)
Data storage capacity	(Gbytes)	20000	20000	20000	20000

Summary of project objectives

(10 lines max)

To develop and improve the Harmonie analysis and forecast system, with a view to the operational needs of the HIRLAM member institutes. Experimentation with, and implementation of, new developments in the Harmonie Reference system are mainly carried out at ECMWF, using the Special Project resources plus a pool of national resources.

Summary of problems encountered (if any)

(20 lines max)

The main problems encountered are:

- permanent disk space is limited compared to what is available at the HIRLAM institutes.
- the varying environment with work load spread over various hosts (for e.g. compilation vs. execution), which makes the HIRLAM and Harmonie working environments at ECMWF rather different from the ones at the HIRLAM institutes.

ECMWF user support deserves a compliment for their help and responsiveness to users encountering difficulties.

Summary of results of the current year (from Jan to June of current year, for the second half of 2015, see the final report for the Special Project HIRLAM-B second phase (2014-2015)

The HIRLAM-C First phase (2016-2018) Special Project; Jan – June 2016

Jeanette Onvlee, HIRLAM Programme manager, KNMI

The HIRLAM-C Programme, which has started on January 2016, is a continuation of the research cooperation of previous HIRLAM projects. The full members of HIRLAM-C are: the national meteorological institutes in Denmark, Estonia, Finland, Iceland, Ireland, Lithuania, Netherlands, Norway, Spain, and Sweden. Meteo-France is an associate member of HIRLAM-C.

Within HIRLAM, research is focussed on the development and improvement of a convection-permitting non-hydrostatic analysis and forecast system within the IFS coding environment, called Harmonie, and the derivation of ensemble prediction methods suitable for the short range. The Harmonie system is developed jointly with Meteo-France and the ALADIN consortium. The emphasis in the HIRLAM-C Special Project at ECMWF is on experimentation with, and evaluation of, the Harmonie model. The main results achieved in the development of Harmonie since the start of HIRLAM-C are outlined below. Much of this research has been done on ECMWF platforms.

In the field of probabilistic forecasting, the goal is to achieve a reliable high-resolution production system for short-range ensemble forecasts, with an emphasis on severe weather. Existing and new ensemble generation techniques are being combined into a multi-model ensemble of HIRLAM and ALADIN members of ~8km resolution, called GLAMEPS, and in an ensemble for the convection-permitting scale, based on the Harmonie model, called HarmonEPS. Separate special project resources have been requested for these probabilistic forecast research activities (spnoglameps), so that work will be described elsewhere.

<u>Data assimilation and use of observations:</u>

The bulk of the data assimilation R&D efforts in the past years have been devoted to make, assess their impact in real-time suites, and optimize their impact through enhanced quality control, bias correction procedures and tuning of structure functions. The main focus in the past months has been on preparing for the operational introduction of a range of high-resolution atmospheric observations in the Harmonie data assimilation system and local operational suites: radar reflectivities, GNSS zenith total delays, Mode-S aircraft data, ATOVS, ATMS and IASI radiances, scatterometer winds, SEVIRI water vapour observations and atmospheric motion vectors (AMV's).

For radar data, stricter quality control procedures have been introduced. A pre-processing system has been made by DMI for radar data from the OPERA data hub, called PREP-OPERA. Work is ongoing to improve corrections for beam blocking in mountainous areas. Radar reflectivity data have been introduced in pre-operational suites in MetCoop, AEMET, DMI and KNMI. For radar wind data, alternatives for the Baltrad de-aliasing procedure are being investigated, such as the He et al (2012) algorithm.

GNSS zenith total delays and ATOVS/ATMS radiances have shown positive impact after variational bias correction and careful observation statistics tuning, and these too have been or are being prepared for operational inclusion in DMI, MetCoop, AEMET, KNMI and IMO. DMI will also introduce GPS radio occultation data in its new suite. An observation operator has been developed for the assimilation of GNSS slant delays, and single observation experiments with these data have started.

Mode-S EHS aircraft observations have proven to be a powerful new source of dense high-quality wind data. Work is ongoing in several HIRLAM institutes to obtain similar data from other aviation authorities and assess them. Scatterometer wind data were shown to have a significantly positive impact over sea in hourly cycling, as compared to 3-hourly runs. An alternative observation operator, in which the fact has been taken into account that scatterometer observations are not point observations but have a spatial footprint, has been introduced and proven to be beneficial (fig.1). SEVIRI clear-sky water vapour data have been seen to have positive impact on various moisture-related parameters in 3D-Var, but results with 4D-Var have been more ambiguous. Studies are ongoing as to the best way all-sky assimilation can be performed on SEVIRI data. Atmospheric motion vector (AMV) winds are being included in the operational suites of MetCoop, AEMET, DMI and IMO. To permit use of AMV winds from various sources (polar and/or MSG, locally processed with NWC SAF software or obtained from Eumetcast) simultaneously, a more flexible handling of AMV data has been developed.

The system for routine monitoring of observations and their error statistics and impact has been extended with various scores (e.g. FSO and MTEN norms).

On the algorithmic side, past studies have clearly shown the severe limitations of 3D-Var in handling adequately the assimilation of high-density data such as radar, even in RUC mode. The focus has been on the further development of two more advanced, flow-dependent algorithms 4D-Var and a hybrid 3D-Var/ETKF scheme. Ultimately, it is intended to combine these two approaches into an integrated 4DEnVar ensemble assimilation scheme.

In the past years, a 4D-Var data assimilation system has been developed for Harmonie. Various changes have been introduced recently which have made this setup more efficient and robust. In the real-time 4D-Var system run at KNMI, the costs of a 4D-Var analysis presently equal those of an 8h forecast, which brings 4D-Var within operational reach, and ways are foreseen in which this can be reduced further significantly. Impact studies with 4D-Var using conventional data, Mode-S observations and radar reflectivities are ongoing. The functionality of 4D-Var is being extended further, e.g. through the introduction and intercomparison of different ways of initialization and treatment of the large scales, the implementation of (multiple) outer loops and alternative cost terms, and the introduction of more high-resolution observation types.

For ensemble assimilation, a hybrid 3D-Var/ LETKF assimilation scheme has been developed, which, after tuning of length scales for horizontal and vertical localization and investigating the choices for multiplicative or additive inflation, has shown an encouraging improvement over 3D-Var. The LETKF scheme is presently being upgraded to the latest model cycle, and it is being considered how to best apply it in connection to the HarmonEPS system.

Two methods which have proven their capabilities to enhance a variational analysis (and forecasts in the nowcasting range) are cloud initialisation by means of MSG data, and a hybrid 3D-Var/field alignment (FA) system. In the past months, a more flexible and robust pre-processing for the MSG data used in the cloud initialization has been developed, and will likely be included in the Harmonie Reference model later this year. In Spain, the hybrid 3D-Var/FA method using radar wind information has been streamlined, parallellized and documented; verification has shown a positive impact in the first ~6h of the forecast on average. Work has started to study how the technique could best be used in combination with 4D-Var.

In the context of the ECMWF projects OOPS and COPE, the IFS data assimilation and observations pre-processing code is being completely overhauled. A possible option to make the present OOPS C++ design more flexible is to use a matrix-free linear algebra approach developed by Met Norway staff, and this will be explored further this year in collaboration with ECMWF and Meteo-France. Additionally, it is aimed to gain knowledge of, and experience with, the new data assimilation testing tools which have been developed within OOPS for the global model by ECMWF and Meteo-France, and to see how these can best be used and/or adapted to LAM models, to enable a more effective validation process for LAM data assimilation in the future.

Forecast model:

Several systematic weaknesses of the model until recently were: over-active convection in weakly forced situations, the overestimation of low clouds, too spotty precipitation and cloud behavior, biases in boundary layer winds and short-wave downward radiation, and the under-prediction of snow from shallow convective clouds in cold conditions. In the past months, a collection of changes in the turbulence treatment, microphysics and radiation schemes, developed to improve model performance in these aspects, has been tested successfully and introduced together in Harmonie Cy40h1 (fig.2).

An inter-comparison has started of the various available long-wave radiation schemes. Advanced aerosol direct effect parametrizations for short-wave radiation have been shown to be significant and beneficial in specific situations, provided that observed aerosol values are used. It is aimed to introduce MACC aerosol analyses into the research radiation branch for the initialization of aerosol. This will be followed by a study of the behaviour of aerosol indirect effects.

At Meteo-France, the second moment microphysics scheme LIMA is being validated against HYMEX data and being implemented in AROME. When available, it will be considered how best to tie in the aerosol parametrizations in the LIMA framework. Various microphysics adjustments in the ICE3 microphysics scheme are being evaluated with the aim to further improve the treatment of supercooled and freezing rain.

To improve accuracy, a non-hydrostatic vertical finite element discretization with a mass-based vertical coordinate has been developed in a close cooperation between ALADIN and HIRLAM. The work on this is now close to completion. Studies of the scheme with various settings of the vertical model levels show satisfactory behavior, although only marginally improved verification scores.

Experiments have been done with alternatives to the default linear spectral grid. The option of using a cubic spectral grid (which truncates waves at 4Dx vs 2Dx for the linear grid) has been investigated, as well as a quadratic and a so-called superlinear grid developed by Vignes (met.no), which use truncations between those of the linear and cubic grids. The use of the non-linear grids provides greater stability and enables the use of larger time steps than the linear grid. The reduction of computational costs achieved this way is of particular interest to the introduction of HarmonEPS ensembles, which are becoming operational this year in several HIRLAM countries. However, the greater spectral smoothing of the non-linear grids leads to small but significant deteriorations in wind and temperature scores, and is particularly damaging in mountainous areas. Also the kinetic energy spectra show some strange features, and the settings of e.g. horizontal diffusion for these schemes may need to be reviewed. More study is required to resolve this issue.

The so-called COMAD option introduced by Meteo-France (Malardel and Ricard 2011) is believed to obtain more realistic interpolation weights for the semi-Lagrangian advection. An assessment of the potential benefits of COMAD for Harmonie is ongoing.

The HARP probabilistic verification system was developed for the routine monitoring and quality assessment of probabilistic forecasts, including conditional verification and neighbourhood verification. This year, the HARP system will be extended with routine spatial verification (e.g. SAL, upscaling) for both deterministic models and ensemble systems. Tools for ingesting in real-time the required radar composite and MSG cloud fields and gridding them on a common grid with the model data already exist. These need to be integrated with the tools for the calculation of spatial scores (mostly already available) and the HARP visualization interface.

Surface:

The surface analysis system presently is far less sophisticated than either the atmospheric data assimilation or the surface model; it is limited to the CANARI horizontal spatialization and OI assimilation in the vertical of in-situ surface observations for screen level parameters, snow, lakes and sea ice. Thus, it is considered a high priority for the coming years to enhance the surface analysis system through the introduction of a wider range of satellite surface observations of the soil, sea surface and inland waters, and snow- and ice-covered surfaces, in combination with more advanced assimilation methods. Both are needed to allow a proper initialization of the advanced new modules of the surface model Surfex-v8.

It is aimed to upgrade the surface assimilation from OI to the Surfex Offline Data Assimilation (SODA) system of extended Kalman Filters (EKF’s). EKF’s have been and are being developed for soil, snow and lakes. Studies have been made of the suitability and impact of various types of surface satellite data (e.g. Globcover snow, MODIS lake surface temperature, sea ice cover) in combination with these EKF’s, e.g. in the context of COST action ES1402. For soil and snow, more sophisticated soil and snow forecast modules have become available in Surfex-v8 which may require significant adaptations to these EKF’s.

Surfex-v8 contains new modules for soil, snow, snow-over-vegetation, lakes and sea ice, which will be assessed for operational NWP use, as well as for regional climate modelling purposes. Work has started to assess the new Extended Snow (ES) and Mass Energy Balance (MEB) snow-over-vegetation schemes in combination with both the default ISBA force-restore and the more advanced ISBA-DIFF diffusion soil scheme, and in combination with soil and snow assimilation. Over the MetCoop area, experiments with Cy38h1.2 have shown excessive latent heat flux due to snow cover over open land. This problem can be tackled by introducing multiple patches in the land surface tile. Turning off the CANOPY surface boundary layer scheme (Masson and Seity 2009) over land generally leads to better scores for all near-surface variables, in particular for u10. These tests will be extended to more domains and to Cy40h1.1, in combination with the new HARATU turbulence scheme.

The evaluation of ISBA-DIFF which has recently started is not only of great interest to the regional climate modelling community, but also important to NWP, as this scheme is believed to be much more realistic in representing the drying of the soil in summer than ISBA-FR. A critical issue to be tackled there is the need for a more sophisticated soil data assimilation setup to initialize ISBA-DIFF with.

The combination of the FLAKE lake model with the updated lake depth and climate databases GLDB-v3 will be tested in Cy40h1. A start has been made with the development of a higher resolution (~250m) lake database.

A simple sea ice model SICE has been introduced in Cy40h1. The next step will be to achieve a more sophisticated treatment of snow on the sea ice and to introduce a dynamic evolution of ice thickness. Work on this has begun. Also, it is being considered how to optimize the initialization of SICE by e.g. the use of sea ice thickness from sea ice mass balance (SIMBA) measuring buoys in the Arctic ocean.

In urban studies, non-standard options of the Town Energy Budget (TEB) scheme are being explored, such as the inclusion of an alternative building energy model (BEM). The need for more extensive local data from high-resolution GIS databases, or alternatively extending ECOCLIMAP with a wider range of urban cover descriptions is being investigated.

A new higher-resolution (250m) orographic database, GMTED2010, has been introduced by Meteo-France, and has now been included in Cy40h1 as well. Changes have been introduced in the ECOCLIMAP physiographic data over Iceland and Greenland on the basis of available higher-resolution local datasets and more recent satellite data. These adaptations have resulted in an improved behavior of albedo, the evapotranspiration of various vegetation types and the representation of permanent snow on glaciers, and have led to a significant improvement in all surface scores of Harmonie-Iceland (Palmasson et al. 2016, fig.3). A similar evaluation of ECOCLIMAP over the Netherlands pointed towards problems in the existing model climatologies for evapotranspiration and LAI for several vegetation types, which may be the cause of serious T2m errors in summer. This needs to be studied more in-depth.

Climate modelling

A growing number of regional climate modelling (RCM) groups in Hirlam member states has begun to explore the use of Harmonie for climate modelling purposes. A climate branch has been developed for Harmonie based on Cy37, and this is being upgraded now to include atmospheric and surface model improvements introduced in Cy40h1 and Surfex-v8, respectively. This has nearly been completed. Assessment of the model in both free climate and hindcast mode is ongoing.

Computational aspects

In the externally funded ESCAPE project, LAM partners are contributing to the introduction and testing of new dynamics and multi-grid options, and the preparation of the code to work on computer architectures involving accelerators. Among others, a study is ongoing to optimize the radiation schemes for efficiency and scalability at DMI. Also, efforts are spent on profiling and accelerating Harmonie in massively parallel CPU and mixed CPU-GPU architectures, together with several external partners.

Figures:

– Accounting for observation footprint in model space – “supermoding”

u/v (m^2s^{-2})	variance (o-b)	variance (o–<b>$\vert_{footprint}$)
ASCAT	2.75/3.31	2.46/2.99
OSCAT	1.93/2.86	1.51/2.31

averaging in model domain improves (o-b) statistics substantially (10-20%)

Recommendation: HARMONIE observation operator to take into account observations footprint

Fig. 1. Until recently, scatterometer data were essentially treated as point observations in the Harmonie 3D-Var assimilation. In fact, they have a spatial footprint, and this can be taken into account in the observation error characteristics by averaging over this footprint in the model domain. When this so-called “supermoding” is applied, the observation error statistics improve substantially, in average by 10-20%, as can be seen for the variances (o-b) for ASCAT and OSCAT u and v winds in the table above.

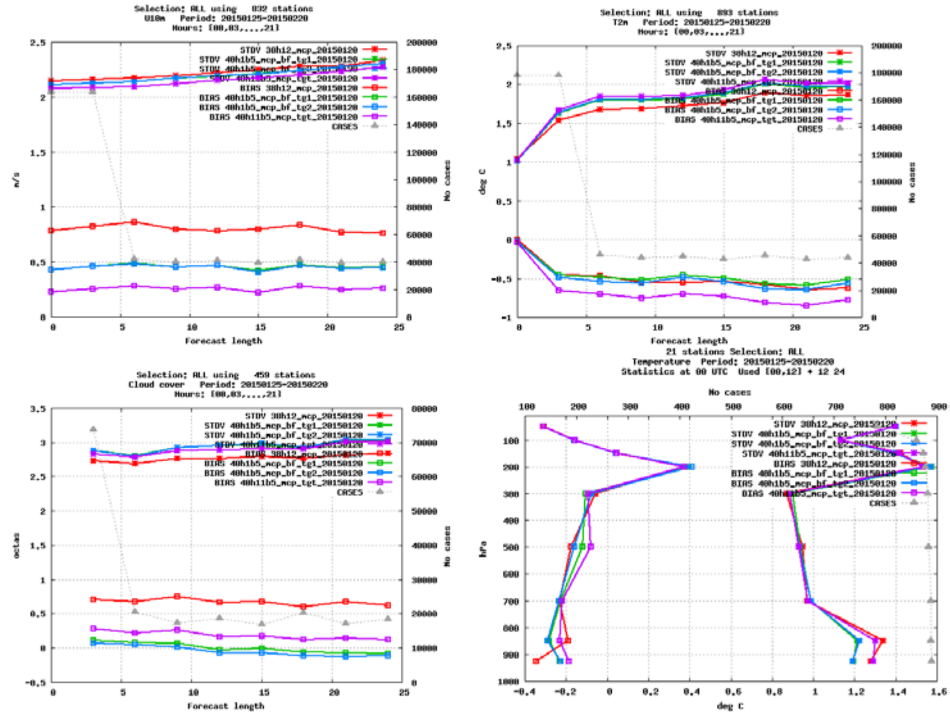

Fig 2: Impact of the change to a new turbulence scheme with enhanced mixing (called HARATU) on verification scores. The four panels show standard deviation and bias scores for u10, T2m, cloud cover and temperature profiles for the MetCoop domain for a winter period. Red colours indicate the results for Cy38h1.2, green the final Cy40h1 configuration, and the blue and purple two preliminary versions of Cy40h1, with a slightly different tuning of HARATU. The final Cy40h1 performance is significantly better than Cy38h1.2 for most scores. The biases in (low) cloud cover and u10 are strongly reduced, and cloud properties, profiles in the lower troposphere and diurnal cycles for most parameters are improved. A slight degradation can be seen for T2m in winter. Similar results are seen for other periods and for most other Harmonie domains. This meteorological impact is overwhelmingly caused by the introduction of a new turbulence scheme (HARATU), with small additional impacts provided by changes in the microphysics and radiation schemes.

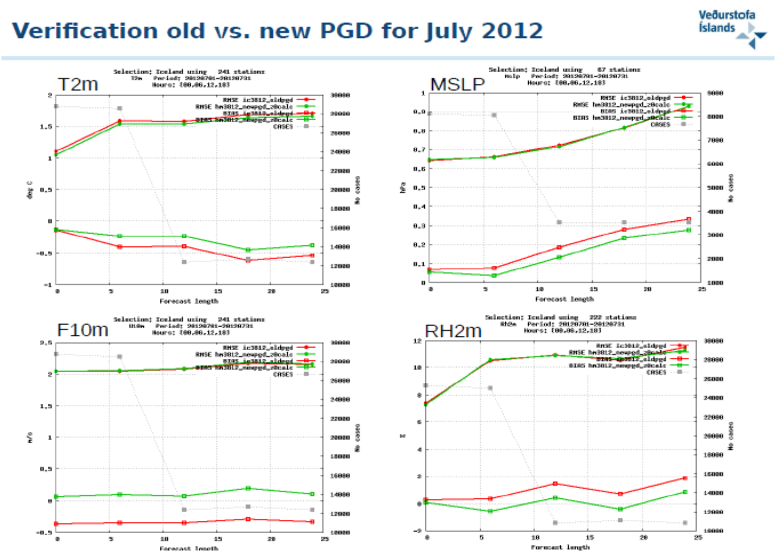

Fig. 3: Impact of updating the ECOCLIMAP-II physiographic data for Iceland. ECOCLIMAP fields have been improved over the Iceland area on the basis of more recent satellite data (Corine 2006) and high-resolution soil and vegetation maps from the Agricultural University of Iceland. Rms errors and biases are shown for the near-surface parameters T2m, pmsl, u10 and RH2m) obtained with the old (red curves) and new (green) physiography. With the updated physiography, model performance (bias) is improved significantly for all near-surface parameters.

List of publications/reports from the project with complete references

Bengtsson, L. and Körnich, H. ,2016. “Impact of a stochastic parametrization of cumulus convection, using cellular automata, in a mesoscale ensemble prediction system”. Q.J.R. Meteorol. Soc., 142: 1150–1159. doi: 10.1002/qj.2720

Campins, J. and Navascués, B. , 2016. “Impact of targeted observations on HIRLAM forecasts during HyMeX-SOP1”. Q.J.R. Meteorol. Soc.. doi: 10.1002/qj.2737

Dahlgren, P., Landelius, T., Kållberg, P., Gollvik, S., 2016. “A high resolution regional reanalysis for Europe Part 1: 3-dimensional reanalysis with the regional HIgh Resolution Limited Area Model (HIRLAM)”. Q.J.R. Meteorol. Soc. 477-870X. http://dx.doi.org/10.1002/qj.2807

Fortelius, C., Hamalainen, K., Kangas, M., Kurzeneva, E., Rontu, L., Sokka, N., 2016. “Highlights of NWP activities at FMI in 2015”. ALADIN-HIRLAM Newsletter 6, p69-71, http://www.cnrm.meteo.fr/aladin/IMG/pdf/nl6.pdf

Gleeson, E., Toll, V., Nielsen, K. P., Rontu, L., and Mašek, J., 2016. “Effects of aerosols on clear-sky solar radiation in the ALADIN-HIRLAM NWP system”, Atmos. Chem. Phys., 16, 5933-5948, doi:10.5194/acp-16-5933-2016.

Kangas M, Rontu L, Fortelius C, Aurela M, Poikonen A., 2016. “Weather model verification using Sodankylä mast measurements”. Geosci. Instrum. Method. Data Syst., 5, 75?84, doi:10.5194/gi-5-75-2016. www.geosci-instrum-method-data-syst.net/5/75/2016/

Landelius, T., Dahlgren, P., Gollvik, S., Jansson, A., Olsson, E., 2016. “A high resolution regional reanalysis for Europe Part 2: 2D analysis of surface temperature, precipitation and wind”. Q.J.R. Meteorol. Soc. 1477-870X. http://dx.doi.org/10.1002/qj.2813

Lorenz, E., Kühnert, J., Heinemann, D., Nielsen, K.P., Remund, J., Müller, S.C., 2016. "Comparison of global horizontal irradiance forecasts based on Numerical Weather Prediction models with different spatio-temporal resolutions". Progress in Photovoltaics (resubmitted)

Olsson, J., Pers, C., Bengtsson, L., Berg, P., Pechlivanidis, I., and Körnich, H., 2016. “High-resolution hydro-meteorological ensemble forecasting: a case study in Malmö, Sweden”. Journal of Hydrology. Under revision.

Palmasson, B., Thorsteinsson, S., Nawri, N., Petersen, G.N., Bjornsson, H., 2016. “HARMONIE activities at IMO in 2015”. ALADIN-HIRLAM Newsletter 6, p72-75, http://www.cnrm.meteo.fr/aladin/IMG/pdf/nl6.pdf

Rontu L, Wastl C, Niemelä S, 2016. “Influence of the details of topography on weather forecast: Evaluation of HARMONIE experiments in the Sochi Olympics domain over the Caucasian mountains”. Frontiers in Earth Science, 4, Feb 2016, 16 pp. http://dx.doi.org/10.3389/feart.2016.00013.

Soci, C., Bazile, E., Besson, F., & Landelius, T. ,2016. ”High-resolution precipitation re-analysis system for climatological purposes”. Tellus A, 68. doi:http://dx.doi.org/10.3402/tellusa.v68.29879

Toll, V., Gleeson, E., Nielsen, K.P., Männik, A., Mašek, J., Rontu, L., Post, P., 2016.”Impacts of the direct radiative effect of aerosols in numerical weather prediction over Europe using the ALADIN-HIRLAM NWP system”. Atmospheric Research, vol. 172–173, p. 163–173. doi:10.1016/j.atmosres.2016.01.003

Whelan, E., Gleeson, E., Gallagher, S., McGrath, R., 2016. “MetEireann NWP highlights in 2015”. ALADIN-HIRLAM Newsletter 6, p76-78, http://www.cnrm.meteo.fr/aladin/IMG/pdf/nl6.pdf

Summary of plans for the continuation of the project

The present project is for the first three years of the Hirlam-C programme. The main areas of attention will be:

- introduction and optimization of flow-dependent assimilation techniques (4D-Var and hybrid 3/4DEnVar)
- increasing the range of remote sensing data to be assimilated (esp. all-sky radiances, surface observations)
- the introduction of field alignment and cloud initialization methods.
- a more sophisticated and consistent description of the radiation-cloud-microphysics-aerosol interaction, winter stable boundary layer conditions, and surface modelling.
- experimentation on increasing the operational horizontal and vertical model resolution to ~90 layers, 0.5-1km),
- and research on (forecast model) developments required to run the model at hectometric resolutions.