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	July 2016 - June 2017……………………………………
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)	10000000	10000000 (+ part of an additional pool of national resources)	11000000	0 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:

The HIRLAM-C First phase (2016-2018) Special Project; July 2016 –June 2017

Jeanette Onvlee, HIRLAM Programme manager, KNMI

The HIRLAM-C Programme (2016-2020), 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 operational or pre-operational introduction of non-conventional data (radar, GNSS, Mode-S, satellite radiances (AMSU-A/B, MHS, IASI), SEVIRI, scatterometer, and atmospheric motion vectors (AMV's)) keeps progressing, including the use of VarBC for radiances, GNSS and aircraft data. The amount of GNSS data assimilated in Norway, Sweden and Finland has increased a lot through the use of the NGAA processing center, and this has proven beneficial in the model analysis over this domain. In many suites, also the number of radars from which data are ingested from the OPERA hub is being extended gradually. Met Norway has started to investigate the capabilities of the PRORAD radar quality control algorithms, as alternative to the Baltrad quality control package, for both reflectivities and radial winds. For AMV's, it is being studied to what extent accounting explicitly for the spatial footprint of these data may be beneficial. The ingest code has been adapted to be able to handle both geostationary and polar AMV data. The range of ATOVS channels included in the assimilation is being extended. Alternative predictor sets are being considered to achieve an improved bias correction of GNSS ZTD data and clear-sky radiances from ATOVS and IASI. The impact of GNSS slant delays in the assimilation system is currently being tested; initial results show a positive impact, but the bias correction of these data still needs to be improved. Experiments with the assimilation of cloudy radiances from ATOVS, SSMI/S and SEVIRI have continued. Studies of the potential usefulness of E-AMDAR humidity data are beginning in several centers.

In the observation monitoring package OBSMON, new tools have been included for radiance monitoring and for the diagnostics for the relative impact of various observation types on analysis and forecast quality (FSO, MTEN).

On the algorithmic side, efforts have continued to assess and improve various aspects of the performance of 3D-Var. The main aims are to increase and prolong the impact of observations, and to improve performance in the nowcasting range, e.g. by the use of alternative structure functions, experiments with ensemble data assimilation, different thinning strategies and alternative balance formulations. For nowcasting purposes several methods are being tested which should give greater weight to observations: e.g. the rapid refresh approach, different initialization methods, and the cloud initialization and field alignment techniques. Promising results were obtained with both rapid refresh and rapid (1h) cycling techniques as compared to the standard 3h-cycling. An extensive study by FMI of the cloud initialization method has shown that in its present implementation the method produces too few low and too many high clouds. This can be improved by making a more sophisticated use of e.g. NWC SAF cloud type information and cloud mask.

In the past years, a 4D-Var data assimilation system has been developed for Harmonie. To enhance computational efficiency, the option of using multiple outer loops has been introduced. 4D-Var can now be used for both conventional and an increasingly wide range of non-conventional data (incl. satellite radiances, radar, GNSS, and SEVIRI). Impact studies for these new non-conventional data types are ongoing. The convergence behaviour of 4D-Var in Cy40h1 remains problematic in several aspects. Studies comparing different methods of initialization (e.g. a Jdfi cost term) are ongoing, and experiments with several ways of accounting for the large scale and different control variables are being carried out.

In the context of the ECMWF projects OOPS and COPE, the IFS data assimilation and observations pre-processing code is being completely overhauled. HIRLAM has contributed with work on various aspects of the new OOPS data assimilation design: to incorporate and explore the usefulness of so-called matrix-free linear algebra to make the OOPS design more flexible for the LAM models in the IFS/Arpege framework, and to help realize variational bias correction in OOPS. Efforts to consider the unit tests for data assimilation which have been developed in the global OOPS framework and study how to adapt them for the LAM models are expected to start in the second half of 2017. Within COPE, the development of an hdf5 reader for radar data into ODB has started. ECMWF has been working on a Scalable Acquisition and Pre-Processing (SAPP) system for processing GTS data. SAPP seems to be a flexible modern tool, and MetEireann is therefore evaluating it as a possible future alternative for the current LAM observation pre-processing.

Forecast model:

Activities on clouds and turbulence have focused on introducing and testing several features aiming to achieve better performance particularly over the Iberian domain in winter. Through advection of falling precipitation and adaptations in the generation of sub-grid precipitation, forecasts of precipitation from relatively shallow cumulus under cold conditions have been improved. Several small changes, introduced to harmonize formulations between the microphysics, cloud and radiation schemes, have also led to slightly better model scores.

For the study of boundary layer clouds and turbulence, a common 1D MUSC testing environment has been realized, in which the whole variety of convection and turbulence schemes and options for Arome-France and Harmonie-Arome can be tested with different global and surface forcings against supersite observations and large eddy simulation models. Also the number of relevant cases to run this system on has been increased significantly. It is aimed to use this powerful validation environment not only for parametrization development, but also systematically as sanity check in the preparation of new cycles.

Both the direct short-wave and long-wave radiative aerosol effects and the indirect cloud microphysics effects are being studied. Experiments are being carried out with cloud-aerosol interaction parametrizations, using prescribed daily aerosols. The benefits of an improved aerosol climatology on radiation and clouds have been confirmed in a 35-year Harmonie-Arome climate run over Ireland. Work has been done on ensuring a consistent use of cloud particle properties information across the radiation, cloud and microphysics schemes. At end 2017, experiments are expected to start with the more advanced second-moment LIMA microphysics scheme, in combination with parametrizations for different aerosol types (e.g. desert dust) and aerosol initialization from CAMS.

Several HIRLAM teams are experimenting with Harmonie-Arome at resolutions of 1km and finer; an example of DMI studies with a 750m model over Greenland is shown in fig.1. To coordinate these efforts, a working group will be established later this year, with the aim to prepare the model for use at higher operational resolution, and also assess the model performance on hectometric scales in research mode. It is aimed to achieve ~1km operational Harmonie-Arome ensembles by end 2020. All relevant model aspects will be considered: dynamics and parametrizations of shallow convection and turbulence, but also surface characterization, data assimilation and computational performance. Initially, efforts will concentrate on deterministic test setups only, on two domains (presumably to be set up at ECMWF): a “continental” one, in which urban aspects will receive special attention, and a “maritime” one (with a focus on data assimilation aspects, aerosols and steep orography) over the Canary Islands.

Surface:

The surface analysis system presently is far less sophisticated than either the atmospheric data assimilation or the surface model. It is a high priority 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 data assimilation methods. In Cy43h, the surface assimilation will be upgraded from OI to the Surfex Offline Data Assimilation (SODA) system of extended Kalman Filters (EKF’s) for the various soil types, initially for in-situ observations only and in combination with the force-restore soil and explicit snow (ES) snow schemes. At a later stage, satellite observations of the soil, sea surface and inland waters, and snow- and ice-covered surfaces will be added progressively to the surface assimilation. Studies on the impact of EKF vs. OI and of assimilating e.g. ASCAT soil moisture and satellite snow data are already being done, with promising results (fig.2).

Extensive testing has been done of the so-called 2-patch option in Cy40h1.2 (distinguishing between forest and open land in the calculation of surface vegetation fluxes). This 2-patch adaptation has proven beneficial more in general for significantly reducing 2m temperature and humidity biases in winter and spring, although also slight deteriorations have been seen in u10 in some (coastal) areas and seasons.

A beginning has been made with the testing of the new, more sophisticated Surfex-v8 modules: a 14-layer diffusion soil scheme, a more advanced snow scheme, snow-over-vegetation and lakes. These studies will be intensified and done in conjunction also with the new EKF assimilation schemes for soil, snow and lakes. The Flake lake model has been made available in Cy40h1.2, and experiments over Nordic domains have confirmed its beneficial impact (fig.3). The present simple sea ice model SICE is being extended in order to achieve a more sophisticated treatment of snow on the sea ice and to introduce a dynamic evolution of ice thickness. Verification of the modified ice scheme versus sea ice mass balance measuring buoys in the Arctic ocean shows promising results. Work has started to develop a more physically-based glacier model and to test new options in the urban model, such as the use of an alternative building energy model (BEM).

Several problems with near-surface biases in wind and temperature in various HIRLAM countries have been related to issues in the ECOCLIMAP-2 surface physiography data. These are being addressed.

Verification:

The HARP (Hirlam Aladin R Package) probabilistic verification system was initially developed for the routine monitoring and quality assessment of probabilistic forecasts by GLAMEPS and HarmonEPS. A new version of HARP is being prepared for release in June 2017, increasing the flexibility and modularity of EPS verification and extending the package with new spatial/conditional verification and visualization tools for satellite imagery, NWC-SAF and radar data. The new spatial verification options will enable a much enhanced monitoring of model cloud and precipitation behaviour.

Computational aspects

In the H2020 ESCAPE project led by ECMWF, LAM partners are contributing to the definition and optimization of computationally intensive blocks of code (so-called dwarfs), to be benchmarked on various computer architectures, and the introduction and testing of new dynamics and multi-grid options. Computational scientists from DMI have confirmed that the ESCAPE strategy of targeting computationally intensive, limited and isolatable blocks of code is a very effective way to spend the limited staff resources available for optimization work. In particular, reducing the large memory footprint of the model showed great promise to considerably improve both time-to-solution and energy-to-solution of the code.

Climate modelling

Increasingly, Harmonie-Arome is being used in long re-analysis and/or climate runs. An example from the recent 35-year MetEireann re-analysis (called MERA) over Ireland is shown in fig.4.

Figures:

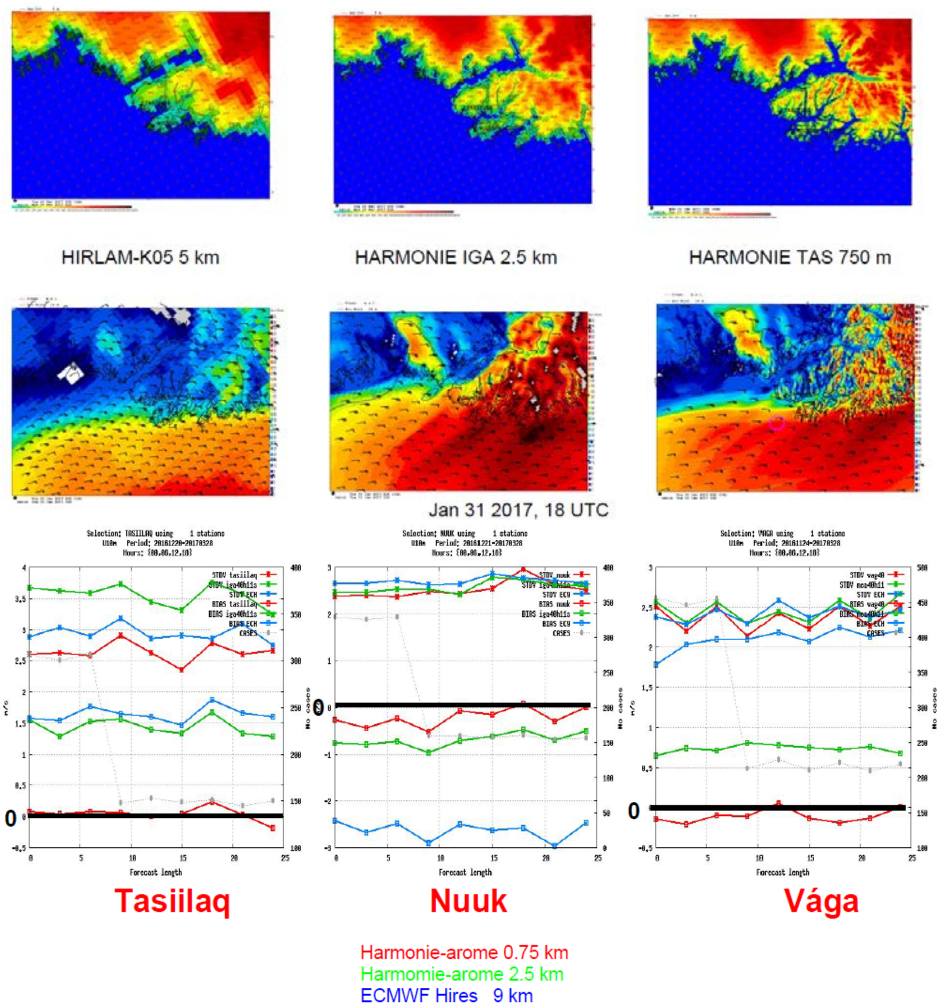

Fig. 1: Results from a 750m resolution run over the Greenland Tassilaq area. The top panel represents the local orography as seen in the HIRLAM 5km model (left), the Harmonie 2.5km run (middle) and the 750m resolution run (right). The middle section represents wind fields for these models. Actual winds are heavily affected by local orography, and the 750m model is able to represent these local variations realistically. The bottom panel gives verification results for u10 for three different locations, for the ECMWF 9km model (blue), the Harmonie 2.5km model (green) and the 750m model (red), showing the added value of the high-resolution model.

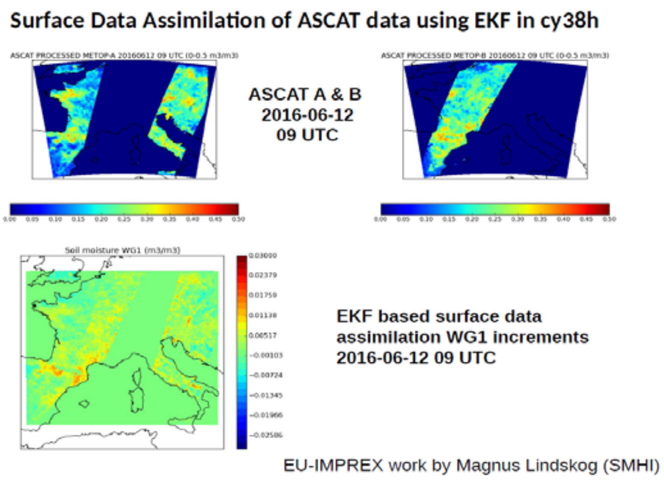

Fig.2: Results for an experiment with assimilation of Metop-A and Metop-B ASCAT soil moisture observations. The top panel shows the scatterometer tracks from Metop-A and –B.
The lower panel presents the increments obtained from assimilating these data for the topmost surface soil moisture layer WG1.

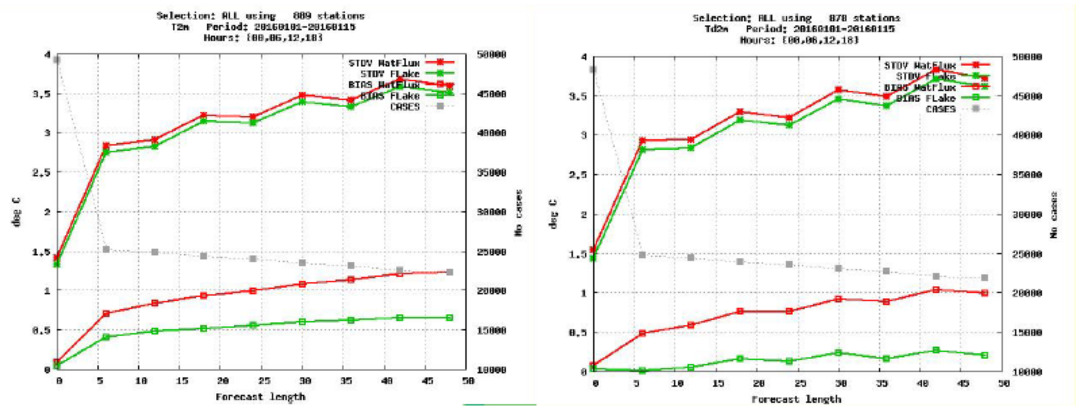

Fig. 3. Verification results showing the positive impact of the Flake model over the MetCoop domain on T2m (left panel) and Td2m (red panel). Red curves represent the default model without Flake, green curves are for the model including Flake.

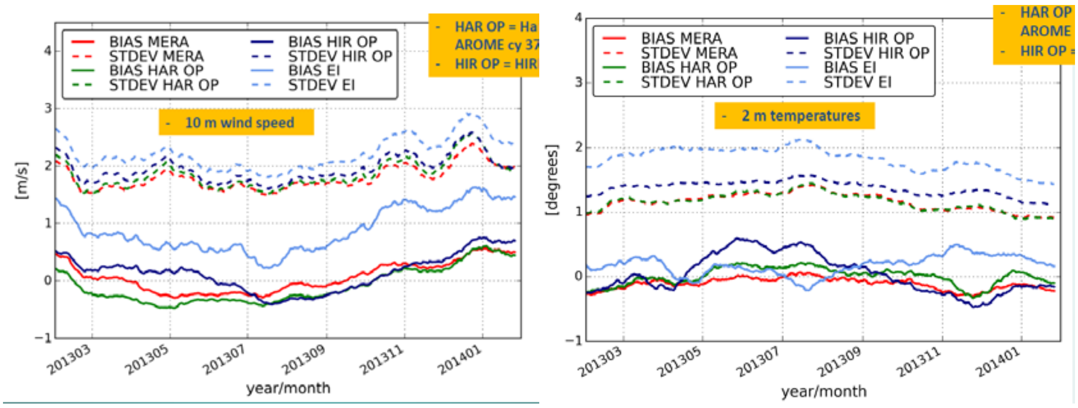

Fig. 4: Harmonie is used more and more in re-analysis activities. The figure shows the performance of the recently completed MetEireann 35-year Harmonie re-analysis (MERA) over Ireland, based on conventional observations only. Shown are the verification results for standard deviation and bias in u10 (left panel) and T2m (right panel), for a 1-year period for MERA (red), the operational MetEireann Harmonie model (green) and Hirlam model (dark blue), and ERA-Interim (light blue), which provided the boundaries for the MERA runs. The quality of the MERA runs is very comparable to the operational Harmonie runs and better than those of HIRLAM and ERA-Interim (indicating the added value of having such a high resolution re-analysis over a global one).

List of publications/reports from the project with complete references

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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 are:

- introduction and optimization of flow-dependent assimilation techniques (4D-Var and ensemble assimilation)
- development and introduction of data assimilation techniques more suitable for the nowcasting range
- increasing the range of remote sensing data to be assimilated (esp. all-sky radiances and satellite surface observations)
- a more sophisticated and consistent description of the radiation-cloud-microphysics-aerosol interaction, winter stable boundary layer conditions, and surface modelling.
- Preparations to increase the operational horizontal and vertical model (ensemble) resolution to ~90 layers, 1km, and research on (forecast model) developments required to run the model at hectometric resolutions.