SPECIAL PROJECT INTERIM REPORT

Interim 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 2010-June 2011
Project Title:	HIRLAM-B Special Project
Computer Project Account:	SPSEHLAM
Principal Investigator(s):	J. Onvlee
Affiliation:	KNMI
Name of ECMWF scientist(s) collaborating to the project	--
Start date of the project:	January 2011
Expected end date:	31 December 2013

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)	1,000,000	1,000,000 (+ additional pool of national resources)	2,500,000	On 23 May: 1.1 MSBU
Data storage capacity	(Gbytes)	8,500 GB		8,500 GB	

Summary of project objectives

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)

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 Special Project; July 2010 – June 2011

Jeanette Onvlee, HIRLAM Programme manager, KNMI

The HIRLAM-B Programme, which has started on January 2011, is a continuation of the research cooperation of previous HIRLAM projects. The members of HIRLAM-B are: the national meteorological institutes in Denmark, Estonia, Finland, Iceland, Ireland, Lithuania, Netherlands, Norway, Spain, and Sweden.

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, which is called Harmonie, and the derivation of ensemble prediction methods suitable for the short range. The emphasis in the HIRLAM-B Special Project at ECMWF is primarily on experimentation with, and evaluation of, the Harmonie Reference System. The main results achieved in the past year in the development of Harmonie 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 grand ensemble of (targeted ECMWF, HIRLAM and ALADIN) EPS systems, called GLAMEPS. Additionally, a ensemble is being developed for the convection-permitting scale, based on the Harmonie model. Separate special project resources have been requested for these probabilistic forecast research activities (spnoglameps), so that work will be described elsewhere.

Harmonie analysis and forecast system

<u>Data assimilation and use of observations:</u>
Harmonie Cy36h1.3, which was released last December, is the first Harmonie cycle offering a complete data assimilation setup: 3D-VAR for upper air analysis, and OI/CANARI for the surface data assimilation in combination with the SURFEX forecast model, and with the option of soil wetness index scaling in the case of a cold start. By default, conventional, AMDAR and AMSU data are assimilated, although several other remote sensing observation types are available. The verification of Cy36h1.3 has shown that the surface assimilation provides a clear added value over downscaling, but the upper air assimilation does not yet do so. This is presumably partly due to the limited number of observations presently provided over those already assimilated by ECMWF (the analysis of which is blended into the Harmonie small-scale analysis), and the low default cycling time of 6h.

Recent experiments with more frequent (3h,1h and <1h) cycling have shown that the relative impact of asynoptic remote sensing data in the analysis grows at higher cycling frequencies, as expected. The most important data source for use in rapid update cycling (RUC) mode are radar reflectivity and wind data. In the past few months, top priority in Harmonie assimilation activities has been given to the ingest of radar data from HIRLAM countries into the Harmonie analysis by means of the CONRAD radar pre-processing package. This package was developed for met.no, but is being extended so that it can handle radar precipitation and radial wind data from most (presently 6-7) Hirlam countries, with different data formats, scan strategies and volume sizes. In addition to the Cartesian radar grid which is used only by Meteo-France, the radar assimilation system will be extended by the option of polar coordinates, which is the natural grid for radar data, used by all other European countries.

After having realized the ingest of radar data from Norway, Sweden, Denmark, Ireland, Spain, and hopefully Finland and the Netherlands, by the summer, the radar assimilation work will continue in two parallel streams. In the first place, starting from fall 2011 a set of observation impact experiments will be done involving 3D-VAR with 1- and 3-hourly cycling; the observations to be used include radar reflectivities and winds, and several other sources of remote sensing data (GPS ZTD, IASI, AMSU, Mode-S, …). First, single-observation radar experiments will be done (see e.g. fig.1). Then, a full observation impact experiment for months in different seasons will be performed on an area covering Denmark, and parts of Norway, Sweden, the Netherlands and Germany. The relative impact of the different data sources is to be studied, as well as spin-up effects for various model variables. A dataset is being gathered for the summer and winter periods which have been selected for the impact study. Secondly, considerable attention will need to be paid to the quality control of individual radars. Effects like beam blockage and noise originating from e.g. wifi systems or wind turbines need to be dealt with for each individual radar. This can be done by providing blacklisting maps to be used within the Harmonie data quality control. Additionally, in some countries radar clutter removal and de-aliasing procedures appear to be generally insufficient. Experiences from Meteo-France have shown that such deficiencies can have a significant detrimental impact on model scores. The OPERA programme will be informed of noted radar quality problems and will hopefully solve them in the future; but for the time being Hirlam will create its own screening solutions by applying within CONRAD some existing quality control algorithms developed within OPERA.

In the search for more flow-dependent assimilation techniques, experience is being gained with hybrid ensemble assimilation methods. The Ensemble Transform Kalman Filter (ETKF) which has been developed for the HIRLAM model, is being transferred to Harmonie. First tests have been done comparing the HIRLAM ETKF in hybrid ensemble 3D-VAR assimilation model (following ideas of Lorenc 2003), to the ensemble data assimilation approaches used by ECMWF and MeteoFrance (Berre et al. 2007). It has been shown that for all three methods the flow-dependent structures present in their forecast covariances enhance 3D-VAR performance. In terms of conventional forecast scores, these improvements are comparable to those between 4- and 3D-VAR.

The Harmonie 4D-VAR scheme has been improved in several ways (inclusion of multiple outer loops, surface analysis, more satellite data, introduction of a Jdfi term, more advanced simplified physics). It has been tested against 3D-VAR in a month-long experiment (January 2010) at 11km resolution. The performance of the two was comparable, confirming the functionality of the basic components of the 4D-VAR scheme. Further assimilation experiments at higher resolution are planned.

In high-resolution models, the assimilation system will frequently have to deal with features which are displaced in the model with respect to observations. Variational techniques are generally not very good at handling this type of (non-Gaussian) error. A new method has been implemented to deal with such phase errors: first the phase error is estimated (as a displacement field) and this is used to warp the first guess field. Then standard 3D-VAR is used to minimize the remaining error. This image warping or field alignment method deserves further study in the coming years.

The present surface assimilation in Harmonie is based on OI/CANARI. It has been shown to have added value over downscaling at 2.5 (AROME) and 5-11km (ALARO) horizontal resolution. The OSTIA SST analysis has been included. Lake surface temperatures are presently taken from monthly climatology files; plans have been made for a lake surface temperature analysis on the basis of MODIS observations. First experiments have been done with assimilation of ESA GlobSnow snow data in HIRLAM. Aspects still requiring attention before incorporating these data in Harmonie are: observation quality control, the relation used to relate snow depth and snow water equivalent,and horizontal observation error correlations.

A more advanced Extended Kalman Filter (EKF) is being implemented in Harmonie. It is almost ready for testing on conventional T2m and RH2m data, after which it will be enhanced with satellite soil moisture information. At a later stage, the control variables of the EKF scheme will be extended from soil water content to snow and lake analysis.

Forecast model:
The evaluation of Harmonie Cy36h1.3 has shown that at present the model overall shows good performance, but it has several deficiencies which need to be addressed, such as the prediction of low clouds and fog, and an underestimate of cold temperatures occurring in stable winter Nordic conditions (fig.2). Several adaptations have been made to the statistical cloud scheme and the entrainment description in the EDMF scheme, which lead to an improved description of low clouds and fog. A combination of effects may be responsible for the cold winter temperatures problem, which appears quite similar to what has been seen in HIRLAM in the past. Improvements to the surface scheme (see below), increased vertical resolution, and adaptations to the turbulence scheme are all elements which play a role. A concerted action has been started to tackle the model performance under stable conditions in a comprehensive way.

A study has been undertaken on various choices for the radiation scheme and its settings. A start has also been made with a study how the parametrization of radiation orographic effects available in HIRLAM can be transferred to Harmonie. In the context of preparing the model for use at sub-km resolutions, DMI staff have been experimenting with the concept of modelling radiation with a tilted column approach in HIRLAM. Earlier studies have shown that the tilted column approach is a simple but still quite accurate approximation of a (far more costly) fully 3-dimensional radiation parametrization, and that the cloud shadows which can be represented with it may have a significant impact on convective evolution. This approach also appears to be well translatable to Harmonie. A comparison has been made of cloud microphysical properties retrieved from the MSG and Cloudsat satellites and those of the HIRLAM and IFS/Harmonie microphysics schemes. From this validation it turned out that the IFS microphysics gave a more realistic representation of cloud ice. Apart from their usefulness for validation of microphysics parametrization, the satellite cloud information can of course also be of crucial value for a proper initialization of cloud properties. This will be studied as a next step.

Experiments have been done with cellular automata (CA) in the ALARO convection scheme, to study the role of stochasticity in convective evolution. CA are an interesting alternative to traditional stochastic physics for generating a stochastic representation of sub-grid scale variability. The CA used in this study was chosen to mimic convective organization through atmospheric gravity waves, and contained several features of interest to deep convection evolution, such as lateral communication, inherent memory and self-organization.

Nesting experiments have been done with single and double nesting of Harmonie within ECMWF and HIRLAM/ALADIN. It was shown that, in terms of standard verification scores, direct nesting of 2.5km resolution Harmonie in ECMWF was preferable to double nesting using an intermediate HIRLAM or ALADIN model. It remains to be seen if this is also the case for swiftly evolving situations of extreme weather. Tests have also been done with hourly and 3-hourly provision of boundaries. Hourly boundary information may have some benefit for upper air scores, but this needs further confirmation. Experiences in near-real-time Harmonie-AROME runs have indicated that model performance depends on domain size, in the sense that the model grid should be large enough to allow the model to develop mesoscale features internally.

For the newly developed vertical finite element (VFE) discretization for the Harmonie dynamics, it has been shown to be stable provided that the vertical coordinate is changed to a height-based hybrid one. This is being implemented and tested. The present semi-Lagrangian scheme in Harmonie is not mass-conserving. Conserving semi-Lagrangian schemes exist, but are prohibitively costly. However, tests have shown that the mass conservation properties of the present scheme can be significantly improved by simple changes in the interpolation methods used. The semi-implicit time-stepping scheme of Harmonie can introduce dispersion through the treatment of short linear gravity waves. A semi-analytical scheme which should be free of this defect has been proposed by Lynch, and this is being implemented.

In the area of surface modelling, the most important development has been the transition of the concepts of the HIRLAM snow and forest scheme to a multi-energy balance (MEB) scheme. This MEB scheme has been implemented in SURFEX and a start has been made with testing it. Some early validation results are shown in fig.3. An intercomparison has been made of surface radiative fluxes in the SURFEX Town Energy Budget (TEB) scheme and observations from a mobile platform in the streets of Helsinki for a period of about one year. The TEB scheme can provide a good description of the radiative balance and temperature in street canyons, provided that the urban characteristics provided in the physiographic database are realistic.

A Harmonie climate branch has been created. With this setup, the Rossby Center is performing long climate runs at ~6km resolution, using lateral boundaries and SST/sea ice analyses from ERA-Interim. Other interested regional climate modelling groups are more inclined towards the use of ECMWF physics; this has been provided as an option in Harmonie, but which still requires further testing.

Given the relatively high computational cost of Harmonie with respect to HIRLAM, a significant amount of attention has been paid to the optimization of the efficiency and scalability of the system on various platforms. Bottlenecks for the parallellization and scalability of the code have been and are being identified and tackled.

Studies on the modelling and impact of atmospheric chemistry on the atmosphere have been done in HIRLAM context with the HIRLAM chemistry branch, the on-line coupled ENVIRO-HIRLAM system. Enhanced chemistry parametrizations are being developed which will be incorporated and tested in an updated chemistry branch.

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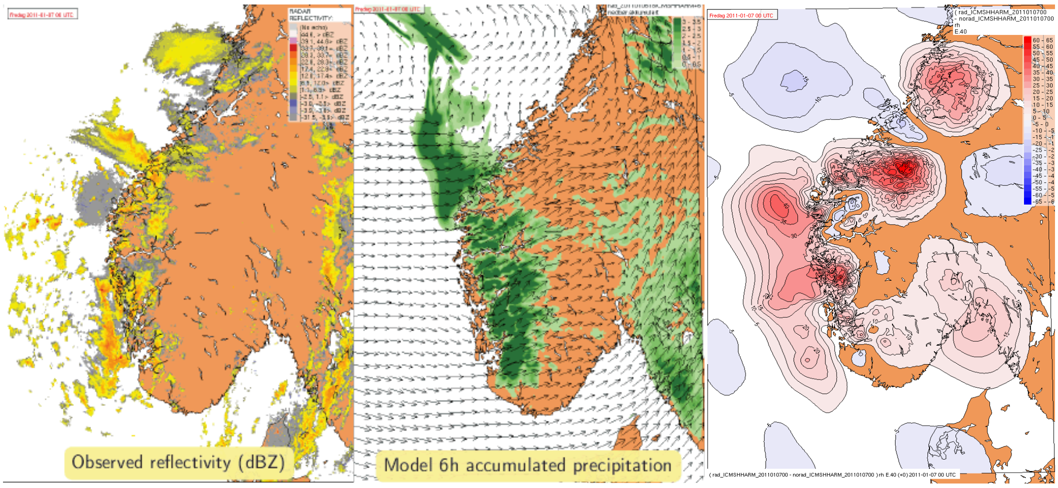

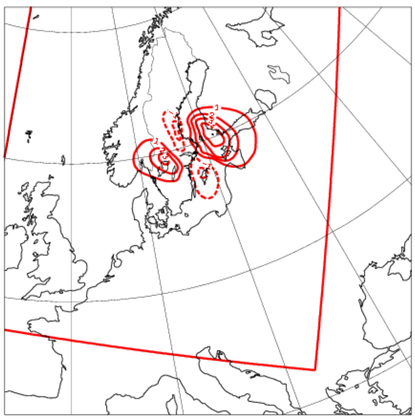

Fig.1: Two radar assimilation impact experiments. Top panel: From left to right a radar composite over Norway, the Harmonie first guess, and the difference between a Harmonie 3D-VAR analysis including radar reflectivities and the same analysis without reflectivities. The impact of assimilating radar data is clearly beneficial to a correct positioning of the rain/no rain areas. Bottom: single observation experiment using radar radial winds from the radar at Arlanda airport.

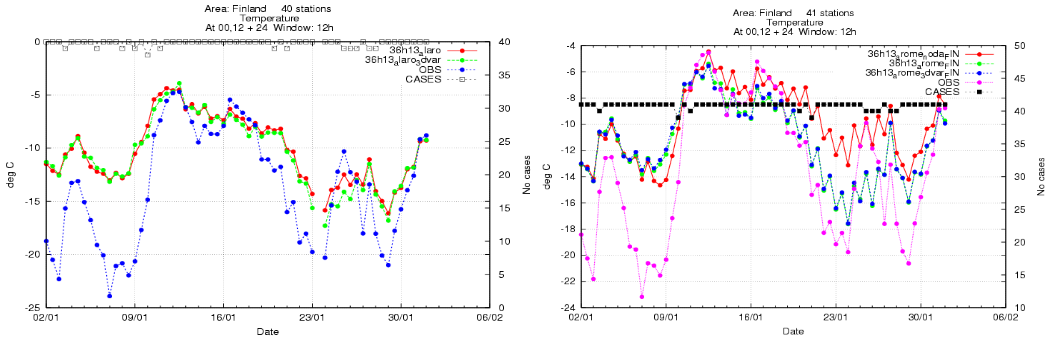

Fig.2: Time series of RMS error and bias of T2m for a winter month over Finland, showing the problems which both Harmonie/ALARO and Harmonie/AROME have with reproducing very cold stable wintertime conditions. The left panel shows results obtained with Harmonie with ALARO physics at 5km horizontal resolution. The red curve represents ALARO runs without data assimilation (but with blending in of the nesting model analysis), and the green ones runs with surface assimilation. Observations are indicated in blue. The right panel shows results obtained with three runs of Harmonie/AROME at 2.5km resolution: in downscaling mode (red curve), with surface assimilation only (green) and with surface and upper air assimilation (blue). Observations are indicated in pink. Neither model is able to account for the low temperatures observed.

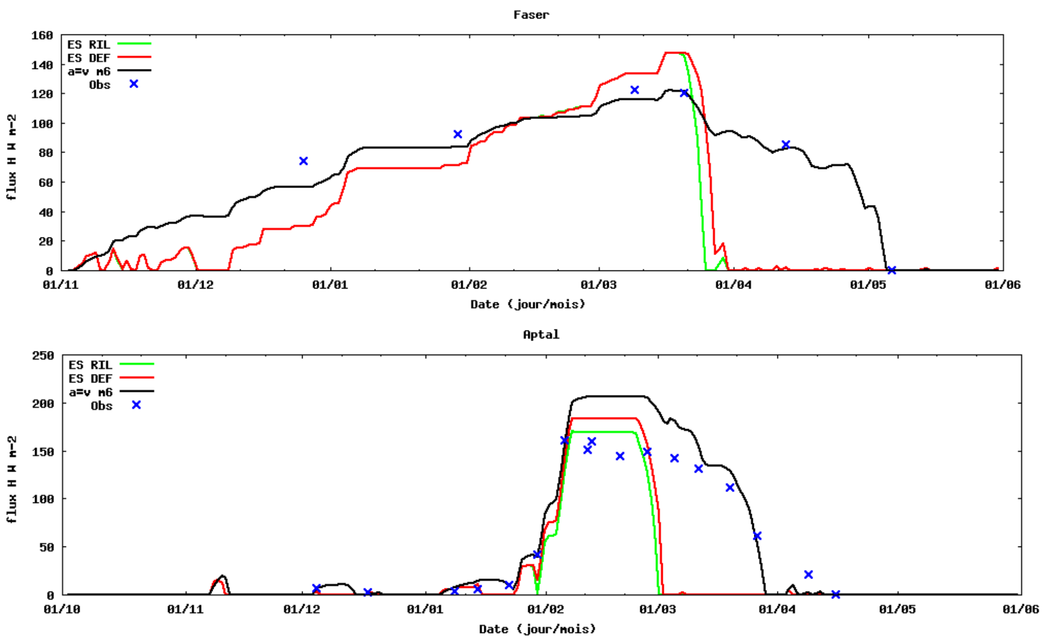

Fig.3. Experiments on the performance of the new multiple energy balance scheme (black lines) as compared to the 2- and 3-layer ISBA soil schemes presently available in SURFEX (red and green curves, respectively). The panels show the modelled snow depth at the forest floor against observations (blue

crosses) for two locations used in the Snow-MIP (model intercomparison) experiment. All surface schemes are capable to representing the time of snow advent fairly well, but the MEB scheme is best capable of reproducing the timing of snow melt.

Summary of plans for the continuation of the project

In the coming year, the main goal for Harmonie research will be the optimization of the model for operational use. The data assimilated into Harmonie are to be enhanced with more space- and ground-based observations, in particular radar data, and the impact of these data will be assessed and optimized. The performance of hybrid ensemble data assimilation will continue to be studied. 4D-VAR will be developed further and tested against a 3D-VAR/FGAT rapid update cycling approach and against hybrid ensemble assimilation. Forecast model developments will focus on improving convective behaviour and the description of low clouds, fog and stable boundary layer at present resolutions, enhancing the snow and forest aspects of the surface scheme, experimentation with different initialization strategies and inclusion of passive tracers. Research activities on the Hirlam model will largely cease, excepting studies on the impact of two-way coupling with chemistry transport. These will be gradually transferred to Harmonie.