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 2011-June 2012……………………………………
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 (if applicable)	---
Start date of the project:	1 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)	2500000	2500000 (+ an additional pool of national resources)	3750000	3750000 (+ part of an additional pool of national resources)
Data storage capacity	(Gbytes)	8500	8500	10000	10000

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 July of previous year to June of current year)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

The HIRLAM Special Project; July 2011 – June 2012

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 full members of HIRLAM-B 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-B.

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 in close cooperation with Meteo-France and the ALADIN consortium. 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.

Data assimilation and use of observations:

For upper air observations, priority has been given to the inclusion of radar, GNSS ZTD and IASI observations, and observation impact studies with these data. Diagnostic studies by Meteo-France on the impact of observation types on the AROME-France analysis have confirmed the importance of especially

radar and GNSS observations for an accurate description of fine-scale features in the analysis, for moisture in particular (fig.1).
The work in this area has focused on three issues: (1) observation quality control and selection, (2) the setup of real-time observation data streams, including activities focussing on achieving international real-time data exchange, and (3) preliminary impact studies for radar, GNSS and IASI observations individually, and preparations for a set of comprehensive observation impact studies involving all these three observation types on a summer period for a domain centered on Denmark containing radars from 6 countries.

Making radar data accessible for Harmonie data assimilation has been a major effort in the past year. With the CONRAD conversion tool radar reflectivity and radial wind data in both local and OPERA BUFR and HDF5 formats, and using different scan strategies, can be ingested into the assimilation system. The observation pre-processing software within Harmonie has been adapted to handle polar coordinates, and different scan strategies, volume sizes and thinning for different radars.
A first assessment of the quality control applied to individual radars revealed great differences from country to country, confirming the need for adopting a common radar quality control procedure. In the future Odyssey data hub, the Baltrad toolbox will be adopted for this purpose. In order to test whether these quality control algorithms are adequate for NWP assimilation purposes, the Baltrad algorithms have been implemented in the Harmonie Reference system. An assessment will be made of how well they work and which deficiencies remain to be tackled, and this will be reported back to Baltrad and OPERA.

In preliminary impact studies, GNSS ZTD data were shown to suffer from significant biases, confirming the need to apply variational bias correction to them. A varBC algorithm developed by ECMWF has been implemented for this purpose. For IASI, channel selection algorithms have been re-assessed with a view to permitting more channels closer to the ground.

National rapid update cycling (RUC) studies have been done to explore optimal setups and limitations of the RUC approach for individual data sources. With HIRLAM, rapid update cycling experiments have been done and documented at 3-hourly, hourly and sub-hourly intervals, involving GNSS ZTD, ModeS and radar radial winds, and selected wind profilers. The added high-resolution wind and moisture data in the frequently updated runs showed less spinup and a better reproduction of extreme precipitation in very-short-range forecasts (0-6h).
Rapid update cycling (RUC) experiments done with Harmonie using 3-hourly assimilation cycles have shown some added value over 6-hourly cycling, using the default observation data sources (not yet including radar data). Observation impact studies have been done at several services for radar, GNSS and IASI instruments separately. Radar impact studies using hourly cycling showed instabilities in moist parameters, presumably due to spin-up effects. On the basis of this, it was decided to perform the joint radar-GNSS-IASI impact experiments for the Danish domain using 3-hourly cycling. Background error statistics were derived for this area. To ease interpretation of the outcome of the impact studies, Harmonie monitoring tools have been extended with several diagnostics to assess spinup effects and the relative importance of different data types. The control experiment, using conventional observations and ATOVS, has started. Experiments including radar, GNSS ZTD and IASI data on top of this are expected to begin in September, after the various new quality control mechanisms have been implemented in the Reference System (Cy 37h1.2) in the summer and tested.
In parallel, national rapid update cycling (RUC) studies will be continued with other new data sources (e.g. Mode-S, ASCAT). Also, studies will be done with the aim to improve the impact of assimilation of already available observation types such as AMDAR and ATOVS (alternative bias correction procedures), surface observations (improved blacklisting), and SEVIRI (varBC).

The initialization of clouds on the basis of MSG information is considered to be an important next step. First experiments have been made in 2011 with a simple MSG cloud initialization approach for a HIRLAM-11km RUC setup, with very encouraging results. This initialization algorithm has been implemented in Harmonie, and is presently undergoing testing at KNMI. Also, a real-time retrieval of MSG physical cloud properties has been obtained for Europe and validated by DMI. This retrieval algorithm still requires improvements in some respects.

Several ways to refine the generation of structure functions required for mesoscales have been explored. An investigation was made of the seasonal and diurnal climatological variability of structure functions. These showed a beneficial impact of using seasonally dependent structure functions. The variability of structure functions with regard to weather regimes and boundary layer stability has also been studied, but as of yet not with conclusive results. Something to be tested in Harmonie next year is the introduction of slicing of the B matrix. This technique introduced by Meteo-France, distinguishing rainy and non-rainy areas, has proven very important for getting greater benefit out of radar assimilation.

Research on the development of more flow-dependent assimilation techniques has also progressed. The hybrid ensemble assimilation approach originally developed for HIRLAM (ETKF and EDA) has been transferred to Harmonie, and testing and tuning of this is ongoing. The optimization of the two schemes for use in the Harmonie data assimilation and in the HarmonEPS ensemble is expected to last throughout 2012.

A two-month test of a (still rather rudimentary) 4D-VAR system versus 3D-VARshowed marginally better scores for 4D-VAR. This is considered encouraging considering the relatively limited number of non-conventional data involved in the test (AMSU-A,B). The Harmonie 4D-VAR system originally has been set up for use at relatively coarse scales, i.e. in combination with ALADIN and ALARO upper air and ISBA surface physics. It is now being adapted for use together with AROME and SURFEX.

Experimentation with a new assimilation technique designed to handle displacement errors, called field alignment, is giving encouraging results, and will be continued. This method is considered to be of interest because variational methods are generally not good in handling this type of (non-additive) error.

Experiences with Harmonie have shown the critical dependence of forecast quality on a proper characterisation of the surface; efforts on surface assimilation have therefore concentrated first on ensuring that a proper initialization can be achieved for all surface aspects relevant to NWP, with an emphasis on snow and lakes.
An OI snow analysis has been set up for Harmonie, in analogy with the HIRLAM snow analysis, and this has been validated over Norway. This snow analysis is producing good results when representative snow observations are available. An extended Kalman filter (EKF) for soil has been tested on conventional T2m and RH2m data, and found to perform well. Preparations are underway to include as a next step satellite soil moisture and LAI information from ASCAT and SMOS, and to test the relative quality of these data sources. Work to introduce and test similar EKF assimilation schemes for snow and lake properties is ongoing. Lake surface temperatures are presently taken from monthly climatology files; the EKF analyses will be made on the basis of in-situ and MODIS observations. Extensive testing with these data has shown a positive impact of lake data assimilation, but also the need for preprocessing and quality control of the data. Sea SST and ice fraction are presently assimilated using OI. It is being investigated to what extent this approach can be improved by combining satellite ice extent data with information on sea ice thickness and evolution from the HIGHTSI sea ice model.

<u>Forecast model:</u>
Several sensitivity studies have been done to assess in detail the model performance under weather situations in which the model has shown weaknesses: the prediction of low clouds and fog, and an inability to reproduce the very cold temperatures occurring in stable winter Nordic conditions.

The AEMET team has looked into the sensitivity of the model for fog and low clouds for Barajas airport. KNMI staff are involved in studies to optimize the modelling of low clouds through modifications in EDMF-m convection and the turbulence schemes, using among others the ASTEX case for diagnostics; inclusion of top entrainment in the turbulence scheme appears to be beneficial for the over-forecasting of fog which is occasionally observed. A more accurate cloud initialization would of course be highly beneficial for the description of fog and low clouds. A simple cloud initialization algorithm has been developed and implemented in Harmonie. Testing of its impact on model cloud behaviour is ongoing. More advanced methods for the initialization of cloud optical properties are under consideration.

AEMET staff have extensively validated the model behaviour under conditions of severe convection for several cases of extreme precipitation which took place in the past winter (e.g. fig.2). The Harmonie precipitation forecasts were actually very good, both in location and intensity. Experiments with self-organization of deep convection using cellular automata (CA) in the ALARO convection scheme have continued. CA are an interesting alternative to traditional stochastic physics for introducing stochasticity in the representation of sub-grid scale variability. An example of a squall line with severe associated turbulence being represented more accurately with the CA-generated self-organization is given in fig. 4..

During the past winter, problems were seen in Harmonie T2m forecasts, which were unable to reproduce the very low temperatures which were observed. It was shown that a large part of this error was due to a bug in the scaling of soil moisture between ECMWF and Harmonie caused by a different interpretation of soil ice. Remaining failed forecasts occurred mostly under highly stable low-wind conditions. 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. Possible contributing factors to this poor model behaviour which are presently under study, are: the need for a more realistic description of the energy balance in the surface and canopy for snow and forest (the MEB scheme), a better initialization of the surface for snow and lakes, a higher vertical resolution in the boundary layer, and alternative formulations of the turbulence scheme. Work is ongoing to test improvements to the model in all of these aspects. In the context of GABLS, HIRLAM staff are involved in the development of a case study (GABLS-4) for stable conditions for the Antarctic, which will be used in these studies. A stable boundary layer workshop is planned for end 2012 to consider all of them in conjunction and determine the most promising ways forward.

A beginning has been made with a study over various choices for the radiation scheme with different levels of complexity. A more consistent treatment between the radiation and microphysics parametrizations is sought, in which the radiation scheme can make use of relevant microphysics information from the cloud scheme. A parametrization for the aerosol direct effect on radiation has been adopted from ENVIRO-HIRLAM and is being ported to Harmonie for further testing. Also orographic parametrizations for radiation and momentum have been introduced in the hlradia radiation scheme in Harmonie. These schemes are being compared to the RRTM radiation scheme which is used by default, in order to study the relative importance of a greater realism in aerosol and orographic representations and more frequent running of a relatively cheap radiation scheme as compared to the high spectral detail offered by RRTM.

Several groups (Spain, Ireland, Netherlands) have started experimenting at sub-km resolutions. An example is shown in figure 3, demonstrating the impact of using very detailed local orographic data on a 500m resolution Harmonie model over Gran Canaria. In the context of preparation for sub-km scale modelling, DMI staff are experimenting with the concept of modelling radiation with a tilted column approach in HIRLAM, as a simple but still quite accurate approximation of a (far more costly) fully 3-dimensional radiation parametrization. This approach appears to be well translatable to Harmonie, and it is being considered how to do this.

In the area of surface modelling, the most important development is 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 is undergoing extensive testing against field experiments. For sea ice, both the HIGHTSI scheme and a simpler sea ice scheme used in HIRLAM have been implemented in Surfex. These will be compared against the Gelato scheme, to be implemented by Meteo-France in the autumn. An improved description of snow over ice has also been introduced in the Flake lake model. This is being tested. The lake depth and lake climatology databases have been upgraded. Effects of orographic shielding on radiation have been included, and will be tested.

At several institutes (e.g. FMI, KNMI) SURFEX, and in particular the SURFEX Town Energy Budget (TEB) scheme, has been validated in offline mode against local observations. The Helsinki validation experiments have shown the need for a closer integration between the TEB scheme and the snow modelling in SURFEX.

In the dynamics, work to implement and test a Vertical Finite Elements (VFE) discretization is ongoing. The consequences of changing the vertical coordinate to a height-based hybrid one, which appears to be required to permit a stable non-hydrostatic vertical finite element discretization, are being assessed. The present semi-Lagrangian scheme in Harmonie is not mass-conserving. However it has been possible to significantly improve mass conservation properties by simple changes in the interpolation methods used.

An aspect which will be studied more intensively in the coming year, will be to what degree the present elements of the dynamical core are still functioning properly at very high (sub-km) resolutions or not. HIRLAM staff will test the spectral formulation at very high (O 100m) resolutions using very detailed data over Gran Canaria.

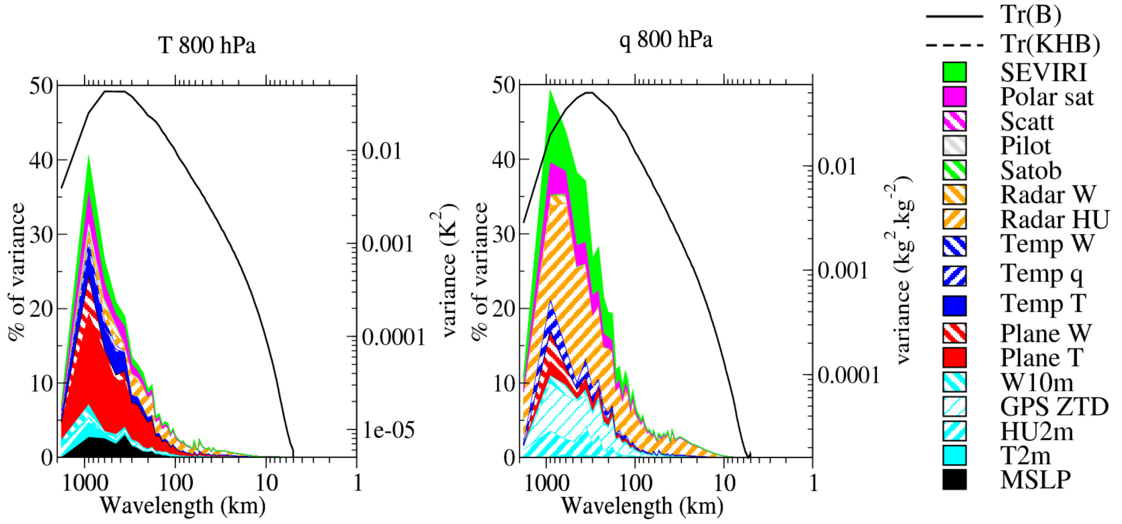

Fig.1: Spectral decomposition of the variance spectrum of Arome-France. The colours indicate the relative impact of various observation types (see colour scheme on the right) on the analysis for different spatial scales. For humidity, radar observations (orange) and GPS ZTD (light blue) are of major importance on all length scales. For scales less than 100km, radar data and, to a lesser extent GPS for humidity, provide the main contribution to variance reduction.

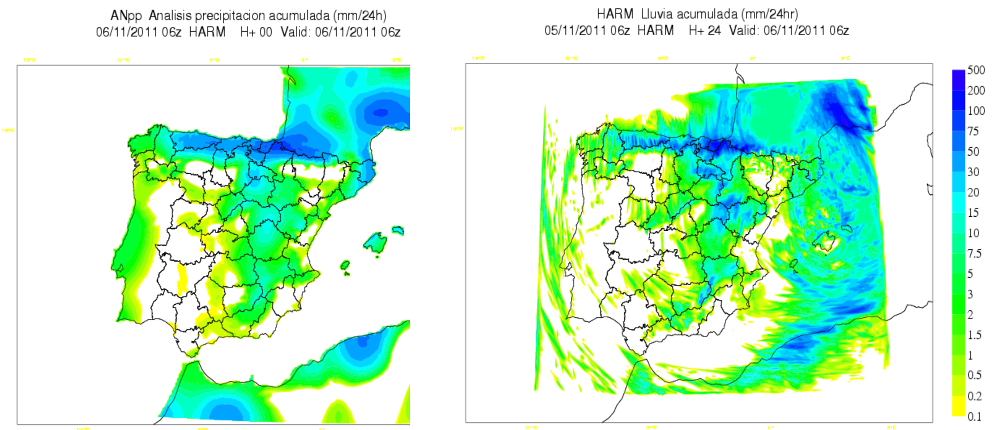

Fig.2: Example of Harmonie performance under severe weather conditions (Spain, 6 November 2011). Left: observed 24h accumulated precipitation from a network of ground stations. Right: +24h Harmonie 24h accumulated precipitation. Both location and intensity of the precipitation (173 mm observed in the Basque region) have been captured very well.

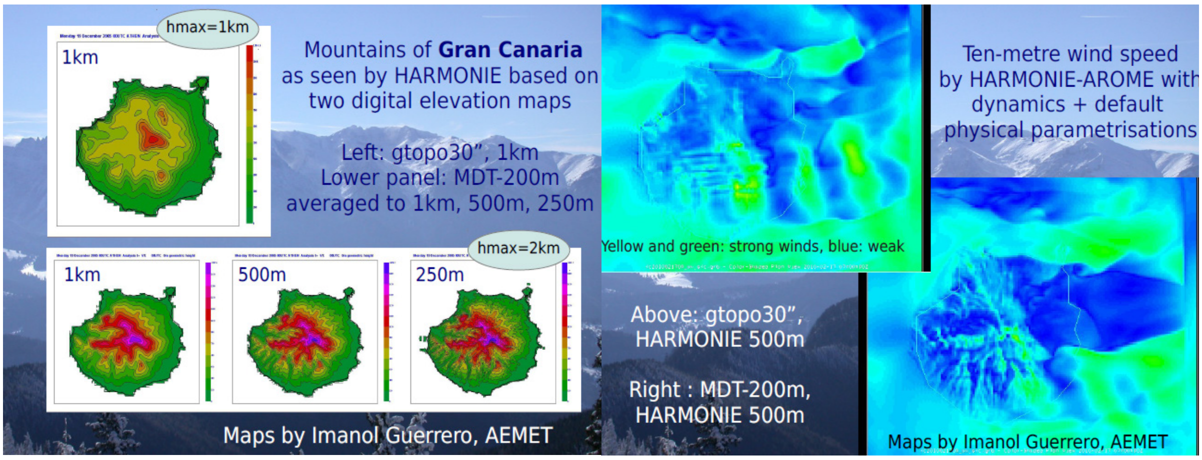

Fig.3: Sub-km resolution Harmonie experiments for Gran Canaria.
Left panel: topography as available in Harmonie (upper figure, gtopo30 1km resolution maps) and higher resolution topographic data.
Right panel: behaviour of u10 as modelled by a 500m resolution Harmonie model, using the gtopo30 toptographic information (upper left) and the higher resolution local topographic data (lower right). The wind fields from the latter experiment look more realistic.

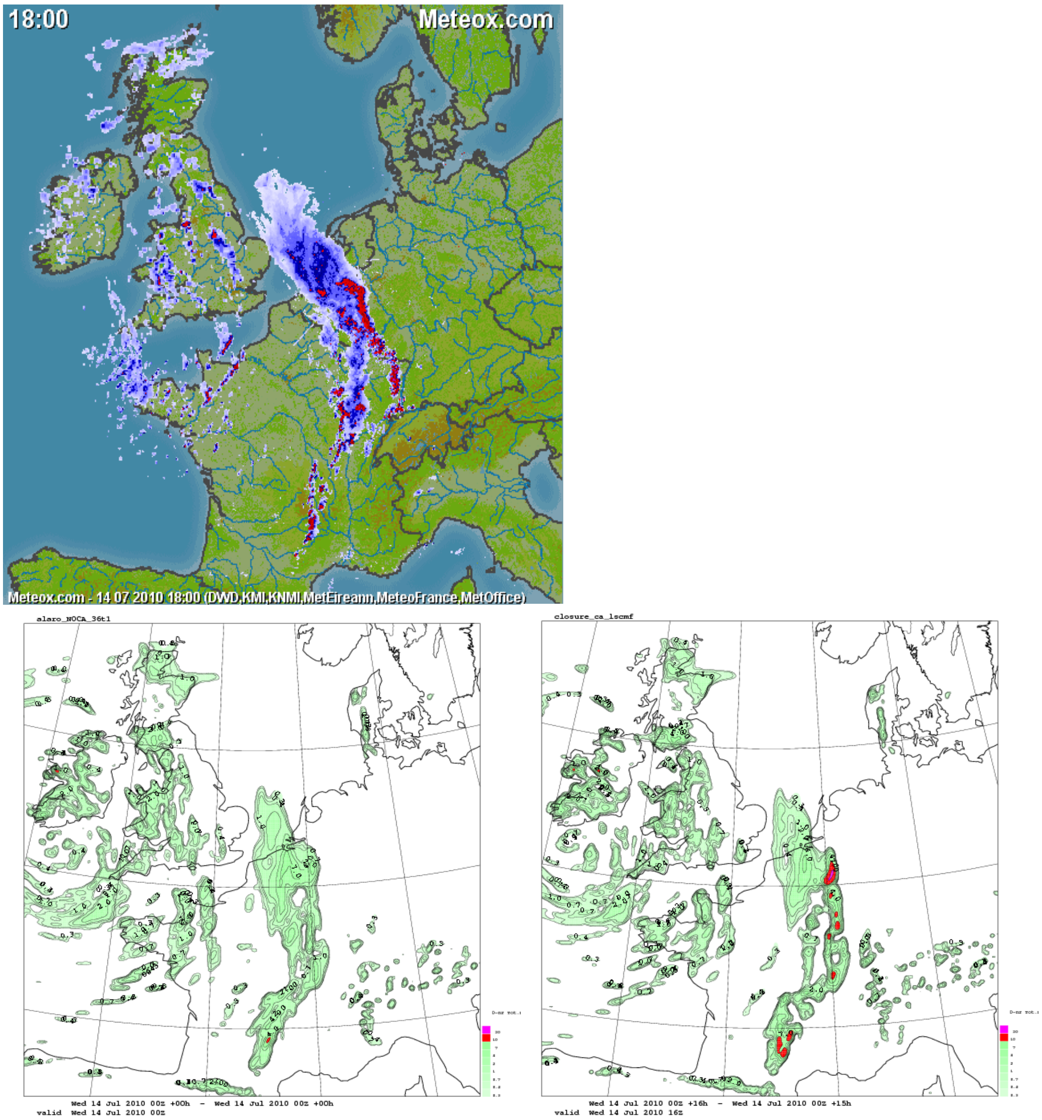

Fig.4. Case study of an extreme convective event over the eastern border of the Netherlands (14 July 2010). Above the radar composite of that day. Below two runs of ALARO without (left) and with (right) cellular automata. The cellular automata is most active in the leading edge of the squall line, leading to more realistic (more intense and organized) convection.

List of publications/reports from the project with complete references

Baklanov, A., Mahura, A., and Sokhi, R. (Eds.) (2011): Integrated Systems of Meso-Meteorological and Chemical Transport Models, Springer, ISBN:978-3-642-13979-6, 242 p. (with several chapters focusing on HIRLAM/Harmonie)

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Summary of plans for the continuation of the project

(10 lines max)

In the coming year, the data assimilated into Harmonie are to be enhanced with more remote sensing observations, in particular radar and GPS data, and the impact of these data will be assessed and optimized. The performance of hybrid ensemble data assimilation, air-mass dependent background error covariances and rapid update cycling will continue to be studied. 4D-VAR will be developed further but at a lower priority. Forecast model developments will focus on improving the description of low clouds, fog and the winter stable boundary layer at present resolutions, enhancing the snow and forest aspects of the surface scheme, and experimentation with different initialization strategies. Experimentation with use of the model at sub-km resolutions which has recently started, will be intensified in the coming year.