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 2014 – June 2015……………………………

Project Title: HIRLAM-B (2d phase 2014-2015) Special Project …………………………………………………………….……

Computer Project Account: spsehlam…………………………………………………

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

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Affiliation: KNMI…………………………………………………

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

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Start date of the project: 1 January 2014………………………………………..……

Expected end date: 31 December 2015…………………………………..……

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	6500000	6500000	6500000
Data storage capacity	(Gbytes)	20000	20000	20000	20000

Summary of project objectives
(10 lines max)

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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)

The HIRLAM Special Project; July 2014 – June 2015

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 jointly with Meteo-France and the ALADIN consortium. The emphasis in the HIRLAM-B Special Project at ECMWF is on experimentation with, and evaluation of, the Harmonie model. 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 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>

Hirlam data assimilation activities have remained focused on the use of high-resolution observations, and on the development of more flow-dependent assimilation algorithms. In addition, the work on the realization of the OOPS redesign of the data assimilation system is presently taking shape.

For upper air observations, priority has been given to the inclusion of radar, GNSS ZTD, ASCAT, Mode-S EHS and IASI observations, and observation impact studies with these data. Most Hirlam members are able to technically assimilate observations from these high-resolution data sources. The challenge is how to get optimal impact from these observation types (in terms of quality control, level of thinning, error characteristics etc), particularly in combination with each other. In the past year, developments in this area have focused on observation quality control and pre-processing, sensitivity studies and on impact studies for combinations of high-resolution observations.

In addition to national radar volume data, members have begun to incorporate radar data from other countries; e.g. DMI is now able to routinely assimilate data from ~60 radars from Denmark and ~10 neighbouring countries. Quality control of radar data remains problematic, hence it is of interest to test alternative quality control algorithms. After velocity de-aliasing, Odyssey radar wind data sometimes still contain unrealistic spikes. For radar reflectivity, a more intelligent manner of thinning or superobbing of the data has been shown to be beneficial. It remains to be seen if this can be helpful also for radial wind data. If not, then the use of an alternative (non-Baltrad) radar wind quality control algorithm should be considered. Also, the option is being discussed of receiving raw radar reflectivity data from the Baltrad server (which have not passed through Baltrad quality control) and to try e.g. the DMI quality control algorithms on them.

Rapid update cycling (RUC) studies have been done to explore optimal setups and limitations of the RUC approach for individual data sources, testing e.g. optimal levels of thinning and spin-up properties. RUC experiments were made at 3-hourly, hourly and sub-hourly intervals, involving GNSS ZTD, Mode-S observations, radar reflectivities and winds, ASCAT winds and selected wind profilers.

Until now, the impact of individual new high-resolution observation types in 3D-Var configurations with hourly or 3-hourly cycling has generally been positive but limited in both size and duration of the impact. E.g. in DMI studies, the main impact of radar reflectivity data with 3D-Var is seen in a much reduced cloud cover bias in the first 12h of the forecast, and assimilation of Mode-S winds at KNMI was seen to affect mainly wind speed and direction positively during the first 6-12h. When combining data sources, a degradation is sometimes seen (e.g. experiments with assimilating radar reflectivity and wind at SMHI and with Mode-S and radar wind data at KNMI). In radial wind data strange features can sometimes be seen in the analysis increments. Work is ongoing to find the causes of this. Model errors and noise in the analysed fields clearly play a role here. Use of the cubic grid in the model dynamics (see below) leads to smoother model fields, and this seems to be beneficial for data assimilation purposes. More research on the appropriate weighting of observation and model errors and the scales at which high-resolution observations should be assimilated, is clearly needed.

There are many indications that the limited impact of high-resolution data is at least partly due to the strong limitations inherent in the default 3D-Var setup. Experiments have indicated that the balances which are assumed to exist between the model variables are in fact poorly kept in Harmonie at convection-permitting scales, in particular the balance between temperature and mean sea level pressure, and humidity. Improved structure functions have been prepared using small-scale perturbations of observations in an ensemble of Harmonie members. Introducing greater flow-dependency in the background errors is believed to be of critical importance, both for creating a stronger and longer lasting impact of observations, and for reducing model spin-up. The two options which are being considered for this are 4D-Var and a hybrid 3D-Var/ETKF scheme.

A 3-hourly 4D-Var setup in conjunction with Arome/ Surfex has been developed and is run routinely in real-time, assimilating conventional, Mode-S and radar data, on a small domain at KNMI. Generally, in these real-time runs, 4D-Var appears to give more realistic results than 3D-Var and better verification scores (see fig.1). However, many options remain to be tested by which the scheme can be made more robust, and there are several important technical issues to be solved, among others concerning the ability to run 4D-Var over large domains and to reduce its computational cost. On the longer term, it is aimed to develop a so-called Gaussian quadrature version of 4D-Var, in which multiple outer loops can be avoided, leading to a significant reduction in computational costs. Research on implementing this Gaussian quadrature method has started in 2014 at met.no.

Work has begun on the construction of a hybrid 3D-Var/ETKF scheme, as a first step in the realization of a 4DEnVar framework of methods for data assimilation and ensemble forecasting. An LETKF scheme has also been set up and is undergoing first tests.

Several methods have been developed which have proven their capabilities to enhance a variational analysis: a simple cloud initialisation method by means of MSG data, and a hybrid 3D-Var/field alignment (FA) system, to correct for model displacement errors. Stand-alone versions of these methods have been developed. At a later stage, both techniques will be integrated in the future 4DEnVar framework. Impact studies with cloud initialization have shown benefits for both cloud properties and other parameters up to 24h into the forecast, and very positive impact on situations in which the model had severely overestimated fog over sea. The method will be extended to more advanced cloud products from MSG, and it will be studied to what extent the impact is affected by integrating this initialization approach within the 3D-VAR framework in different manners. In Spain, the hybrid 3D-Var/FA method using radar wind and reflectivity information, is being prepared for operational use. Positive impacts of up to 24h has been observed.

Surface data assimilation in Harmonie is presently based on OI, but a new framework called the Surfex Offline Data Assimilation (SODA) system is under construction which is based on an extended Kalman Filter (EKF) approach for all surface variables. A basic version of SODA has been created, and this will be gradually extended in a number of ways, in particular in the number of different (remote sensing) observation types it can handle. Experiments with snow assimilation of in-situ observations and various satellite products have continued at met.no, FMI and IMO. In snow assimilation, the first priority at present is to include as many as possible in-situ snow observations. A more effective use of satellite data in an EKF snow assimilation scheme will be possible after the introduction of a more sophisticated 3-layer snow scheme (expected in 2015). In the context of several externally funded projects, work has started on the assimilation of hydrological information from satellite radiance and backscatter data (AMSR2/GCOM-W1, MIRAS/SMOS, SAR/Sentinel-1, ASCAT soil moisture). For lake data assimilation, investigations are ongoing aiming to develop more realistic structure functions and to assess the impact of various types of satellite observations.

In the context of the IFS OOPS project, the data assimilation code is being redesigned and refactored, also for the LAM IFS models like Harmonie. A working LAM 3D-Var scheme following the OOPS redesign has been introduced and tested successfully by Meteo-France, and work is proceeding with 4D-Var. The refactoring of the Fortran data assimilation code will focus initially on the observation operators, where the global and LAM IFS partners will work in parallel on different observation types. Within the COPE redesign of the observation pre-processing, Hirlam staff at the moment are working primarily on the filters used for the quality control of radar observations.

Forecast model:

Progress has been made in the tackling of some persistent forecast failures with respect to clouds and convection. Forecast problems in Scandinavia with winter T2m and too frequent low level ice clouds have been significantly alleviated by the introduction of modifications in the microphysics affecting the balance between cloud liquid water and ice processes. These modifications led to improvements in low clouds, cloud cover and all near-surface scores on various other domains as well. The downside of this change, however, has been in some areas an overall increase in low water clouds and a too great reduction in ice clouds, as well as a slight increase in the already positive bias of u10. The new HARATU (HArmonie with RAcmo TUrbulence) turbulence scheme, which generally has enhanced mixing with respect to the default turbulence scheme, has been shown to have the benefit of reducing this too great low cloud cover and u10 bias (fig.2). Evaluation against Cloudnet sites, such as started by Bengtsson and as incorporated in the KNMI testbed for Cabauw, is a powerful tool to study the sensitivity of model cloud behaviour to the details of the cloud, microphysics and turbulence schemes, the cloud-radiation interaction, and the surface-atmosphere interaction. It has been agreed to extend the functionality of the KNMI testbed and to perform specific 1D and 3D tests with modifications in the above-mentioned schemes.

Wintertime surface temperature problems appear to mostly occur in highly stable conditions with very low near-surface wind speeds, which are notoriously difficult to model except at very high vertical resolution. In this context, it is being investigated whether Zilitinkevitch' turbulence energy and flux budget (EFB) scheme can provide a better description of stable boundary layer conditions. A contributing factor to the temperature problems is presumably deficiencies in the model description of snow over vegetation. The introduction of a new snow over vegetation scheme which has been proposed to address this, has unfortunately been delayed until this autumn.

Work has continued on an inter-comparison study between the Harmonie default radiation scheme and that of spectrally less detailed, but more frequently run alternative schemes, such as hlradia from the Hirlam model, and the Acraneb-2 scheme from Alaro. These studies have led to several improvements to the three schemes, after which the performance of the three schemes was shown to be of comparable quality. Several long climate runs and re-analyses for MSG revealed that the Harmonie model with default radiation has a bias in the SW downward flux. This has been interpreted as being caused by the model clouds being too transparent. Modifications in the cloud optical properties and microphysics largely removed this bias.

The radiation studies have continued with the testing of the potential benefits of a more consistent treatment of clouds and aerosols, including an orographic parametrisation and the direct aerosol effect in the radiation scheme. Simulations have been done including the aerosol direct effect on radiation for all three radiation schemes, using different sources of information on aerosols in the determination of vertically integrated atmospheric optical depth AOD and parametrized optical properties within the radiation scheme: a monthly aerosol climatology by Tegen et al. (default), a monthly climatology derived from a MACC reanalysis, daily MACC analyses, and AERONET observations. For the Russian wildfire case (Aug 2010), utilizing measured aerosol optical properties directly gave significantly better results than using only observed atmospheric optical density AOD and aerosol types with pre-defined optical properties (fig.3). Using observed optical properties, all three radiation schemes were able to represent the global radiation well. An implementation of the indirect aerosol effect is under construction and will be tested later this year.

Meteo-France has been experimenting with a 2-moment microphysics scheme LIMA, which appears to be quite promising in terms of meteorological performance, and which is being prepared for operational introduction by end 2016. Such a 2d-moment scheme is a more natural vehicle for inclusion of aerosol cloud condensating nuclei properties into the model.

An orographic radiation parametrization has been implemented in Arome by ZAMG in the way proposed by Hirlam, and tested by ZAMG and Meteo-France against Alpine valley and mountain station observations. These sensitivity studies showed that the orographic parametrizations appear to work as expected. The greatest impact appears to come from the limited sky view in valleys during winter (warming during the night). The positive impact of the scheme increases at higher resolutions (at which steeper slopes are better represented).

A non-hydrostatic vertical finite element discretization with a mass-based vertical coordinate has recently been introduced. Although the VFE scheme in all tests has proven to be as stable as finite differences, no obvious benefits have yet been seen in terms of classic verification scores. This may be due to the fact that the scheme is not yet fully “finite element”, in that it still contains finite difference operators in the vertical velocity and top and bottom boundary conditions. New operators have been formulated to replace the remaining finite differencing operators, but these have not yet been shown to be fully stable.

Experiments at (sub-)km resolutions are continuing in several places (Spain, Ireland, Netherlands, Norway, Finland). To prevent the model from becoming numerically unstable at these resolutions, a predictor-corrector scheme has been used until recently, but this roughly doubles the cost of the dynamics. As the stability problems mainly occur at or near the model top, instead upper boundary nesting was introduced. By applying this vertical nesting, the encountered stability problems were shown to disappear. Vertical relaxation appears to result in better behaved energy spectra, is computationally cheaper and also appears to permit longer time steps than the predictor-corrector scheme. One example of this was e.g. on 10 January 2015, when runs for several Harmonie suites crashed due to instability at the model top, caused by unusually strong stratospheric winds. This could be overcome by reducing the model time step temporarily. With the use of vertical relaxation, the model remained stable for longer (although it eventually also failed) and a smaller decrease in time step was needed than when using the predictor-corrector scheme.

Experimentation has started with testing a cubic grid as alternative to the present linear grid. In a cubic grid, Semi-Lagrangian advection is more accurate because it uses smoother velocity fields than is the case with the linear grid. The limit of stability is in principle twice that of the linear grid, thus potentially permitting longer time steps, which is attractive from a computational efficiency point of view. Preliminary results show that the use of a cubic grid gives an overall meteorological quality comparable to that of the linear grid, although significant differences can be seen in the vertical profiles. The greater smoothness of fields derived with the cubic grid may be beneficial for data assimilation purposes (see above). In models at 1km - sub-km scale, spurious oscillations in mean sea level pressure over sea have regularly been observed. It remains to be studied what effect the use of the cubic grid will have on these cases. Also the stability of the cubic grid in more extreme weather situations like 10 January 2015 requires further investigation.

Longer-term research in alternative types of dynamics schemes and grids is ongoing at MeteoFrance and RMI, and also in the context of the PolyMitos project at ECMWF and the ESCAPE Hor2020 project.

A new physics-dynamics interface is being implemented, which should be suitable to handle the Arome, Alaro and Arpege physics packages. This is also being used as an opportunity to thoroughly clean up the time step organization code, to achieve a more consistent treatment of microphysics in the cloud, condensation and radiation schemes, and to look into its code transparency and efficiency aspects.

Surface:

A new version of Surfex (v8) has been released recently, with many new features and scientific developments relevant for both NWP and climate modeling purposes. A new diffusion-based version of the ISBA soil scheme, ISBA-DIF, has been incorporated in addition to the present force-restore scheme ISBA-FR. Two new snow schemes have been added: the 1-layer Extended Snow (ES) scheme and the 3-layer CROCUS snow pack model. The MEB snow-over-vegetation scheme has been incorporated in combination with ISBA-DIF and the ES scheme. The FLAKE lake model has been included. The TEB urban scheme has been extended in several ways. Several parts of the code have been optimized and parallelized, the SODA assimilation and other surface assimilation options have been introduced, and generally there has been a substantial amount of technical code cleaning.

Hirlam surface modeling activities have remained focused on snow, sea ice and lakes. A simple thermodynamic sea ice scheme has been introduced. Two more complex sea ice models, HIGHTSI (FMI) and GELATO (Meteo-France) are still under development. A sea ice data assimilation algorithm is also under construction. Tests of the ES snow and simple sea ice model over Svalbard showed promising results. The more advanced snow pack model CROCUS is undergoing testing for the purpose of avalanche forecasting. A new version of the Global Lake Data Base (GLDB-v3) has been released, with more realistic estimates for lake depths for many lakes derived from geological data. First steps have been taken to develop a new high resolution GLDB, on the basis of Globcover data. The combination of FLake with the new lake depth and climate databases will be tested this year.

Staff at met.no have been experimenting with coupling Harmonie 1-way and 2-way with the ocean wave model WAM. Over sea, near-surface winds in the model tend to be too strong in the high wind speed range. It has been suggested that that could be due to the underestimation of the surface drag exerted by ocean waves. First experiments with 1- and 2-way coupled Harmonie-WAM models showed that indeed the coupling reduced the overestimation of strong winds, and that in this respect 2-way coupling gives better results than 1-way coupling (fig.4). Further work on this will be needed.

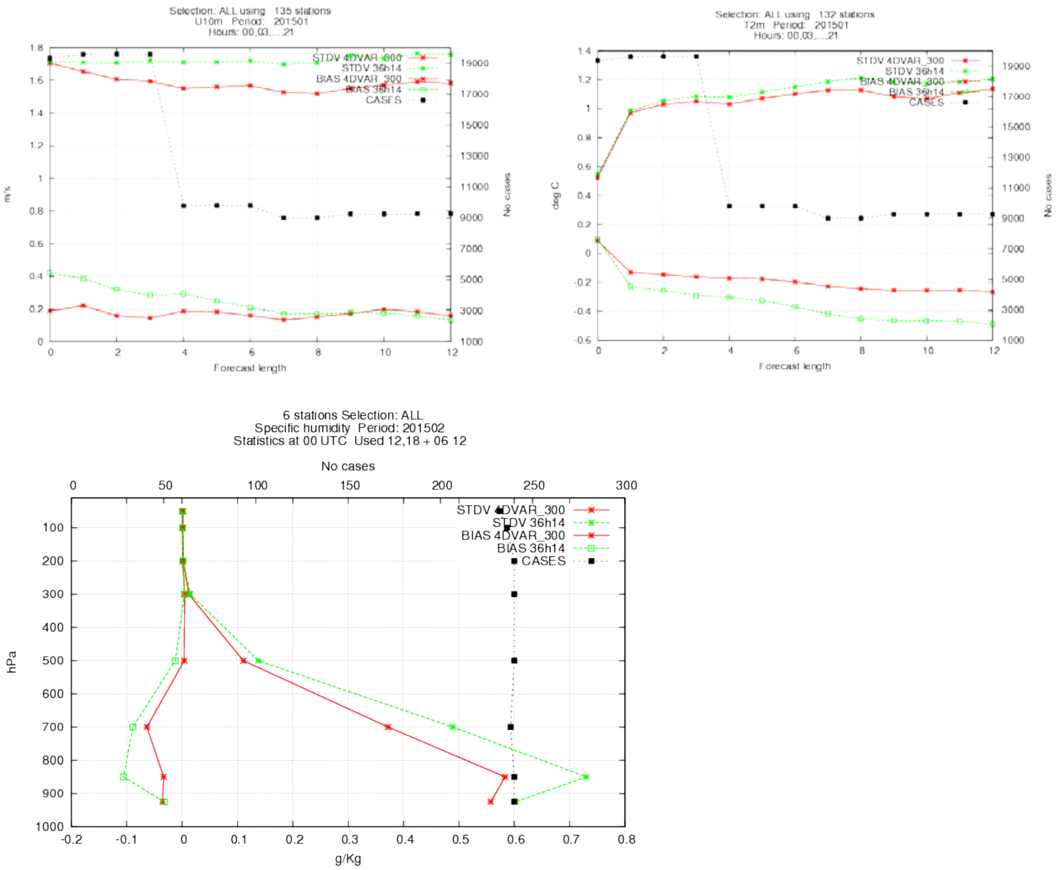

Fig. 1: Verification results for January and February 2015, comparing the experimental 4D-Var run with conventional and Mode-S data (red curves) against the operational Harmonie-KNMI (green) for standard deviation of u10, T2m, and specific humidity profiles. The 4D-Var run generally performs better.

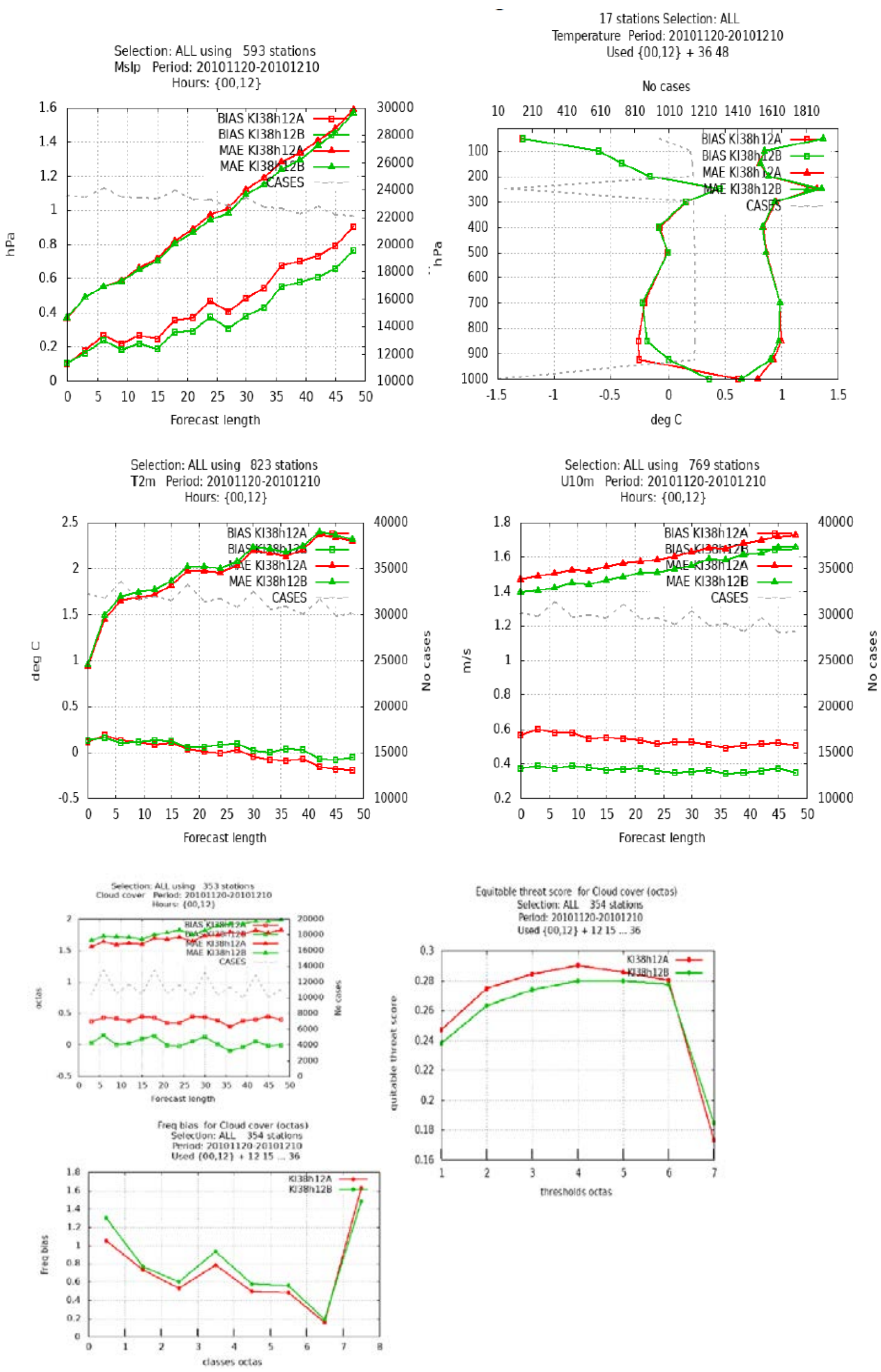

Fig. 2: Experiment on the impact of the new HARATU (HArmonie with RAcmo TUrbulence) turbulence scheme on profiles, near-surface parameters and cloud cover in a winter month over Sweden. Verification results are shown for bias and mean absolute error as a function of forecast lead time for the default Harmonie Cy38h1.2 (red) and for Cy38h1.2 with the HARATU scheme (green), for mean sea level pressure (top left panel), T2m (second row left), u10 (second row right) and cloud cover (third row left), and for the vertical temperature profile (first row right). Also shown are the equitable threat score and frequency bias for cloud cover (third row right and bottom row). The new turbulence scheme generally produces stronger mixing in the lower atmosphere, leading to a beneficial reduction in (low) cloud cover, a reduction in the positive bias of u10, and general improvements in pmsl error and the temperature profile.

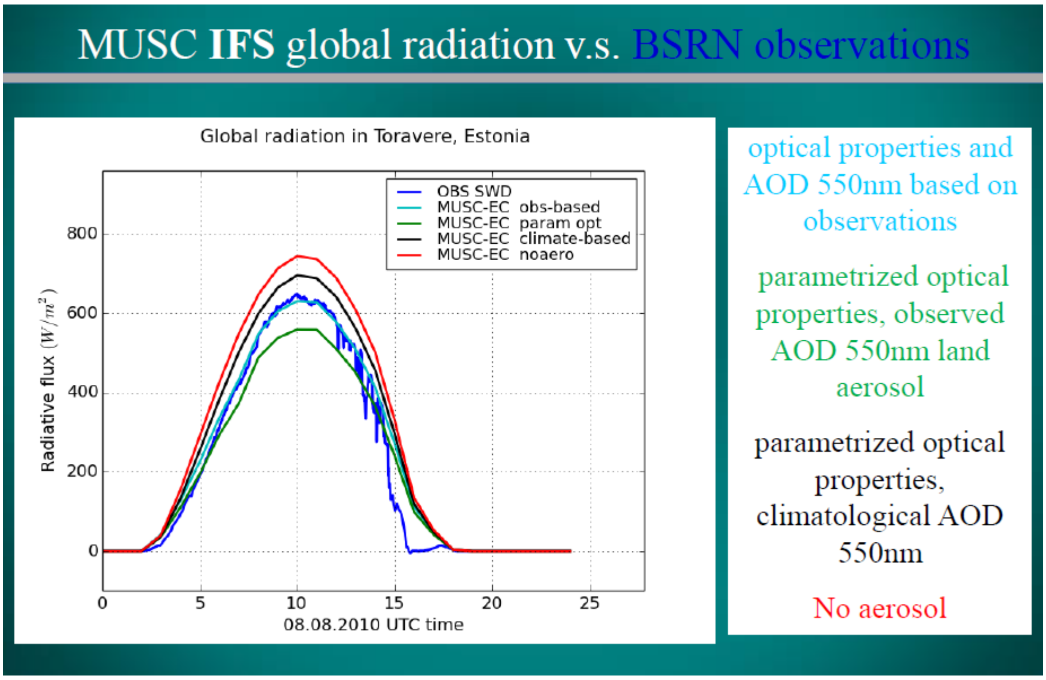

Fig. 3: Measurements at station Toravere (Estonia) and Harmonie single column (MUSC) model simulations of the short-wave radiative flux on 8 Aufgust 2010, during an episode of high aerosol conditions due to forest fires in Russia. The figure shows the observed SW flux at Toravere (dark blue) against model simulations without the aerosol direct effect (red) and with three different sources of input aerosol information to compute the AOD and parametrized optical properties in the radiation scheme: (a) AOD and optical properties both based on observations (light blue), (b) AOD from observations, parametrized optical properties based on climatology (green), and (c) AOD and parametrized optical properties both climatological. The observations are most closely matched by the model including direct aerosol effect, and aerosol input directly from observations.

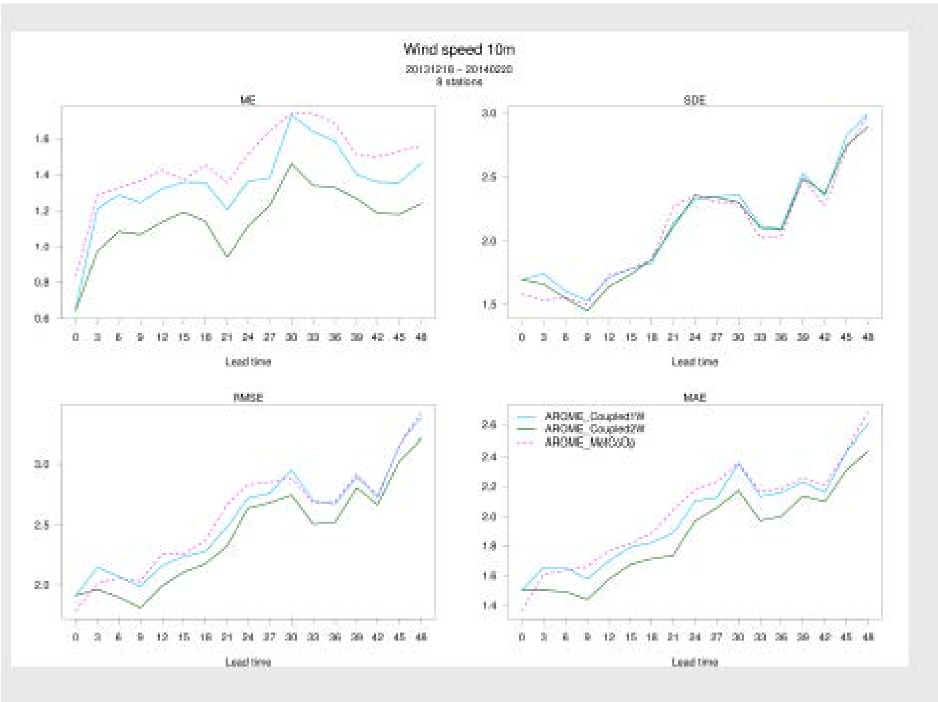

Fig. 4: A two-month winter experiment of Harmonie uncoupled and coupled with the WAM wave model. Shown are verification results for Dec 2013 – Feb 2014 for 6 sea stations off the coast of Norway: mean error, standard deviation, rms error and mean absolute error in u10 forecasts as function of forecast lead time. Pink lines indicate the uncoupled Harmonie model, light blue Harmonie coupled 1-way with WAM, and green Harmonie coupled two-way (every timestep) with WAM. The overestimation of u10 is reduced by the coupling, and the lowest errors are achieved with the two-way coupling.

List of publications/reports from the project with complete references

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Summary of plans for the continuation of the project

(10 lines max)

2015 is the final year of the HIRLAM-B programme. A new programme, HIRLAM-C, will run from 2016-2020. A new proposal will be submitted for special project resources for HIRLAM-C, with a similar purpose (experimentation and testing of the Harmonie Reference System), but with updated scientific goals.