HIRLAM Progress Report for EWGLAM 2003.

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1 Introduction

The HIRLAM-5 Project finished at the end of 2002 and much of the work and tasks are continuing in the HIRLAM-6 Project. A comprehensive review of the member's views and demands was made during 2002 and a new Memorandum of Understanding was compiled and agreed. (The members are the National Meteorological Services in Denmark, Finland, Iceland, Ireland, Netherlands, Norway, Spain and Sweden. There is a research cooperation with Météo-France.)

The scientific strategy involves both optimising the performance of the synoptic scale modelling whilst gradually transferring resources to meso-γ scale modelling. Hirlam needs a non-hydrostatic model at the convective resolving scales of a few km. An an-elastic version has been developed by the Tartu group and experience is being gained from this, whilst the Project is aiming for a version using the full compressible set of equations. This means more intense collaboration with Météo-France to use the dynamics of ALADIN in one way or another.

The physical parameterisation is being improved for the synoptic scale model while also developing useable schemes for the meso-scale as a first stage, to gain experience in high resolution.

Data assimilation has evolved a lot in the 4D-VAR area to the stage of an efficient scheme for high resolution (20 to 10 km at this stage). For the meso-scale, there are varying views about the applicability of 4D-VAR due to both economics and non-linearities and time scales. We do however argue that a 4D-VAR (or ensemble Kalman filter) scheme is necessary to use high resolution moisture related data since the multi-variate relationships at the km resolution are not known explicitly.

The Regular Cycle with the Reference system (RCR) of analyses and forecasts is still a very important activity and is initially continuing at ECMWF, but will become the role of one member's operational system (Finland). When the RCR has become the operational system of a member institute (FMI), the requirements for testing each major release will be even higher. This work will be carried out at ECMWF by various members. Furthermore results from the runs and probably also of the RCR will be made available to the Hirlam members through the HEXNET server at KNMI.

2 Scientific Progress

2.1 Data Assimilation

3D-VAR has been introduced as the Reference at ECMWF and has been used by several members operationally for several years and only two are still using OI. The FGAT option (First Guess at Appropriate Time) has been implemented and also a seasonal variation of background errors. A new version management system (CVS) is being employed for the code.

Learning and development of the ensemble assimilation technique has been started. A 10-member ensemble assimilation has been carried out for a 10-day period with observation perturbations. The NMC-software for computing analysis structure functions has been modified to work on the ensemble assimilation output.

An effort to generate 3D-VAR background error statistics for the 40 level model version at 30 km horizontal resolution has been done by collecting a 4 month data set from the SMHI pre-operational forecast system. Applying the NMC-software on this data set and the analysis of the results remains to be done.

The feasibility study together with a fairly extensive testing of 4D-VAR have been carried out and written up in a submitted Technical Report. Positive impact of 4D-VAR was shown for the December 1999 period with the intensive storms, although the impact was neutral for the following February period (2002). Tangent linear and adjoint code of the semi-Lagrangian scheme of the spectral model for 4D-VAR has been written and tested. This will make the execution of 4D-VAR much more economical. Also the multi-incremental formulation has been implemented, and this again opens for further economy for the minimisation. A proposal paper discussing the prospects for Hirlam 4D-VAR has been written.

In the surface analysis, the SHIP observation weights have been tuned and BUOY data are not used anymore (for the SST). The scientific documentation of the surface analysis together with the new surface parameterisation have been produced.

The sea surface temperature (SST) OI analysis has been developed, in anticipation of the SST products from the Ocean Sea Ice SAF. The ice fraction product is available and work has started to process that for the surface analysis.

A new snow analysis using OI has been written and found to be better than the existing scheme. Tuning of T2m and RH background error statistics has been done based on long assimilations.

Extensive impact studies with QuikScat have been run and show slightly positive results or neutral, depending on period. A few important events dominate the impact.

A lot of results have been documented in the recent ATOVS technical report. Use of ATOVS data over ice has been prepared. The EUMETSAT re-transmission service is working with data from three stations, Tromsø, Las Palomas and Søndre Strømfjord. The 3 others will come later. A licence agreement between the Hirlam Project and the NWP SAF has been signed in order to use the radiative transfer software, RTTOV7, used in 3D-VAR. Reception equipment for the EUMETSAT ATOVS re-transmission service

has been installed in several places and work on using the data in that way is underway. Positive impact of the AMSU-A data was shown at DMI and the data are now used operationally there.

Assimilation of humidities from (more) GPS stations has continued and data collection ensured. Further work has been done on understanding the bias problems. MODIS satellite retrieved humidities have been assimilated.

Observation operator work for radar doppler winds has continued, mainly to address biases in the data. An impact study of the European wind profilers has been carried out and has been written up. There is a marginal positive impact.

SSSM/I 1D-Var code developed in NWP SAF has been implemented in HIRVDA. Integrated Water Vapour and wind speed can be retrieved and the data has been assimilated.

2.2 Forecast model

The increasing negative bias of surface pressure as a function of forecast time has been shown to be strongly correlated with cyclones and their too slow filling. The CBR turbulence scheme has been further developed to use a Richardson number dependency for the length scale in stable conditions and with a Blackadar surface layer matching. Based on arguments of existence of sub-grid scale variations in shear and stability and effect of averaging stability is not the same as the stability of the average, an additional term has been added. For momentum the shear may be due to gravity waves and is applied in the troposphere, whereas for temperature it is in the boundary layer. Furthermore, there is both experimental and theoretical evidence for that the turbulence continues further than the current cut-off, and an extra term has been added for this and the mixing is not allowed to go to exactly zero. Also this term is applied in the boundary layer only. After a number of trials and tuning, the effect is quite remarkable for curing the pressure (and geopotential) problem without affecting the other parameters to any significant degree.

Full assimilation-forecast experiments covering all seasons show the same large improvement in rms msl pressure and in precipitation scores. The modified scheme has been tested extensively both at KNMI and at DMI. The positive effects for most parameters were counteracted by the higher positive wind speed bias (even though standard deviations were not affected). A more realistic tuning of roughness length has been done (to take into account actual landscape features). This in combination with a somewhat reduced stable mixing (enhancement) seems to retain most of the large scale pressure benefits and give almost unbiased near-surface winds.

There is also a moist version of the CBR schemes developed and it has been tried in a 1D-context and shown to be beneficial, particularly at very high vertical resolution.

The new surface package (ISBA tiled scheme + analysis of surface variables) has been studied in a 1 year assimilation run to check the seasonal evolution of soil water content and screen variables errors.

Pre-operational testing in Sweden revealed a problem that frozen ground had too much resistance certain days in the transition season. A revision to have a much smaller barrier effect has been developed. The Météo-France soil freezing and thawing approach based on

the introduction of two additional variables (surface and total frozen soil water) was coded in the frame of the tiled surface scheme and compared against the current method based on the "barrier effect" for the thermal constant. The results show that the Météo-France method is better and this has been implemented.

As a consequence of the tiling, there are alternative ways of computing the grid average postprocessed 2m temperatures and humidities. Averaging over the land tiles gives consistently better observation verification, but may not be what all users want. Therefore the normal 2m values are reverted to be averaged over all tiles and a new parameter used for the land averaged ones.

The new snow tile scheme with heat conduction has been interfaced with data assimilation. It performs well but will be tested more extensively. In the Swedish operational model, time step diagnostics are stored for three sites in order to verify against flux measurements.

The Reference snow scheme has been investigated intensively since there were pronounced positive temperature biases in the very cold winter periods experienced in the Nordic countries. In fact the ISBA implementation used the old snow scheme, with heat conduction from climate, for the snow treatment as it is known that the ISBA snow scheme is not very realistic. A partial solution to address the problem was found, in terms of using saturation pressure over ice instead of over water and ice combined. This reduces the error by about 1 degree or a bit more.

Further updates to the STRACO convection/condensation scheme reducing the lateral entrainment formulation and adjusting the parameter which determines the fraction of moisture convergence available for convection have been proposed and tested. This set of updates cures the extreme and unrealistic precipitation episodes taking place under very warm and humid conditions with strong convergences and the release of small precipitation amounts from too warm and shallow model clouds. It is additional to the ones described before (cloud parcel ascent, shallow convection parameterisation, microphysics thresholds, cloud cover changes). Extended tests have been done and show a clear improvement in precipitation contingency tables but with quite a large reduction of cloud cover and increased winter negative 2m temperature bias.

The convection sub-project has continued and completed the concerted testing effort (at met.no, KNMI, INM and SMHI) of comparing Kain-Fritsch (KF) with STRACO, and the material has been published in Newsletter No 42. The scores are very similar for most parameters, except for the vertical profile of humidity where KF is consistently better, indicating that the clouds or cloud cover is better (it is better in standard deviation but has a negative bias). It has been agreed that a KF version will be installed as an option with the Reference and be maintained that way. The computing efficiency has been of some concern, but it is not excessively expensive on most computers including the CRAY SV1, but it is still on the NEC. The Bechtold version (Météo-France) has been shown to be efficient (on Fujitsu) and this is a likely code to be used in the future.

An extensive report documenting the Sub Grid-Scale Orography (SSO or "Gravity Wave Drag") scheme and all the experimentation has been published. The impact of the SSO scheme has been compared with Météo-France and verified to be very similar in behaviour. The overall effect in HIRLAM is neutral, although the effects of the scheme can clearly be seen. The SSO scheme introduces extra drag but this retards the surface winds and

the turbulence scheme becomes less active in a corresponding way. The way of doing it through the SSO parameterisation is however deemed to be more physically correct than to have increased turbulence (and enhanced roughness length).

The radiation scheme has been reviewed in some aspects. New and clean interface routines to the tiled ISBA scheme have been written and are tested together with a correction of an older modification concerning the condensation nuclei plus a long wave modification described written and documented early in the Project. Testing of the radiation scheme updates and new interface have continued and show slightly positive impacts.

The ECMWF physics interface to HIRLAM has been updated to HIRLAM version 5.0.6. Meteorological assessment was done for one December month and one May month. Results showed better scores of screen variables for the ECMWF physics than with the old Hirlam physics, and particularly for one of the periods. The advantage of ECMWF physics was mainly gone after the implementation of the new surface treatment in HIRLAM (ISBA) including analysis of surface variables.

Work on physics-dynamics coupling has proceeded following two approaches of averaging physical tendencies. Results give small improvements of forecasts and better stability (for longer time steps). Radiation, convection and lately also vertical diffusion have been treated in the improved coupling.

The modifications of the semi-Lagrangian scheme for the noise problems at 10 km have been tested and will be implemented, following some more tests. An alternative method to compute vertical velocities with a finite volume approach has also been tried, but does not solve the problem.

The work on transparent Lateral Boundary Conditions (LBC) continued with inclusion of orography in the real-data demonstration. The transparent LBC have been tested for the non-linear shallow water equations in a nested environment with real data. Work on a number of proposals for well posed LBC, e.g., opaque, characteristic, first order transparent, "semi-Lagrangian", has proceeded and compared with HIRLAM's. Results, particularly wind forecast, are slightly better than the current Davies scheme when characteristic boundary conditions are applied.

The work has continued with waves whose advection speed are higher than the gravity waves and b.c. have successfully been implemented in the shallow water context. Another step which has been planned for a long time is the proper boundary condition for the semi-implicit Helmholtz solver, instead of having a zero b.c. for the second derivative of divergence, specify geopotential. This has been tested in 3D and had a large impact (for this one case).

Work on transparent Lateral Boundary Conditions (LBC) based on a mixed finite elements formulation of the shallow water equations has been conducted at met.no and the 3D formulation is being worked out.

Work has been done to evaluate boundary errors in a double nested HIRLAM set up. Varying the spatial resolution between the outer and inner area, show that the errors due to the Davies boundary formulation are smaller than the errors obtained from using coarser boundary fields.

Following the Dublin Workshop the boundary relaxation from the MC2 model, updating

before physics (and then relaxing the physics tendencies towards zero), was shown to cure completely a problem with blow ups in the boundary zone in the new Finnish area. It has also been tested for an extended period. It gives more realistic precipitation patterns near the boundaries and prevents code crashes experienced at FMI which manifested as grid point storms near the boundaries.

The nonhydrostatic, two-time level, semi-Lagrangian, semi-implicit Hirlam model has been developed and implemented for a parallel-computing Beowulf-cluster environment. The semi-Lagrangian version has some noise due to interpolation which is being sorted out.

A model comparison study (including the following models: Nonhydrostatic Aladin, Meso-NH and NH HIRLAM) has been carried out at Météo-France. Two ideal cases of dry flow over mountains have been selected for the comparison exercise. Hirlam showed to be more dissipative than the others.

The model has been further tested in 2.5, 5 and 10 km resolution, and the NH effects (differences) are mainly seen at 2.5 km. The SI version has been observed to overdevelop some cyclones in recent tests.

Testing was conducted at KNMI to study the possible effect of Digital Filtering Initialisation (DFI) on the damping of initial developments. The backward adiabatic step creates imbalance due to lack of boundary layer friction and the forecast after TDFI starts with pressure perturbations and with lowered values of some physical parameters. A solution is to do forward launching (at +1 hour) instead and has been developed. Still the incremental DFI is slightly better and does not have the problem of not producing initialised fields (at 0h).

Encouraging results and plans were shown at the INM/SRNWP European LAM EPS Workshop, where several interesting and very positive results were shown, by using ECMWF perturbations (met.no, DNMI and COSMO/Bologna.) and at NCEP (with bred perturbations) where very significant improvements in verification scores were seen. These effects are of course due to filtering effects. Some were showing multi-model results and improvements from this whereas other evidence from the Met Office showed that it was not necessarily adding much (if the 12h time handicap is removed). Singular vectors are inherently superior for finding the real analysis uncertainties whereas breeding is almost for free and shown to work in LAM, provided also globally bred vectors are supplied at the boundaries.

Plans for LAM EPS have been set up at INM, following last October's Workshop, and initial experiments have been done. The spread is difficult to reach in the short range.

The LAM EPS work with Hirlam has continued at met.no. Evolved Singular Vectors from ECMWF seem to give better results than non evolved ones.

3 System developments

The 3D-VAR analysis has now been introduced in the Reference system, following quite a bit of technical work at ECMWF. Tests were made for correctness of implementation.

The general quality of the system is in no doubt as e.g. shown by the 5 members who have implemented it operationally. The upper air scores were very much in favour of the new release due to 3D-VAR.

Many members are testing with increased vertical resolution and the polynomial representation of levels has been enhanced and used to derive the definition of 40 (and 50 and 60) levels consistent with the current height of the lowest level at about 30 m.

The HIRVDA system at ECMWF was upgraded to its latest version, and scripts were updated accordingly. HIRVDA is being integrated with the rest of the reference and some aspects remain.

At the end of 2002, actions to move the system at ECMWF from Fujitsu to IBM were initiated and accelerated in March. The Hirlam Reference system was provided on the IBM from the beginning of April. Verification tests were carried out to validate its equivalence with earlier results run on the Fujitsu.

A "unified" version of asynchronous I/O (called Hirlam Gribfile Server, HGS) was introduced as an option in Hirlam version 5.2.2. There are two underlying implementations, called the IPC and MPI versions of HGS. The IPC version is based on the code developed by Jan Boerhout (Hirlam Newsletter 39). The MPI version is based on code developed in Finland at CSC/FMI, but is modified to provide the same functionality as the IPC version. The unified version is described in Hirlam Newsletter 41.

The climate system has undergone extensions and corrections. The filtering of orography and all the new codes and fields for the SSO scheme are also being implemented. New data for the ISBA scheme have been added and this will be implemented. Several improvements and extensions to the climate generation system were implemented. There are now global coverages and orography and roughness length computation following Kai Sattler have been prepared. The filtering of orography has also been prepared and is being tested.

The DMR runs have continued but still remain to be brought under the control of mini-SMS. A new version of the Delayed Mode Runs based on Hirlam 5.2.3 was developed and implemented. This version uses mini-SMS, a 0.2° model grid, 40 vertical levels, "frame" boundaries from the ECMWF LBC project, and 3D-VAR for data assimilation. This version has been implemented on the hpc IBM at ECMWF.

A proposal has been made from FMI to host and run a DMR centre (or Regular Run of the Reference system, RCR), where the FMI would actually run the Reference system as its operational run. An agreement was made and it was approved by the Hirlam Council. Operational attention to the runs and real time monitoring are some of the advantages. Near real time data will be made available to members. Extensive experimentation and parallel runs as well as a lot of diagnostics would be carried out by Hirlam and FMI staff. New Reference system releases will be much more scrutinised and acceptance agreed between the Hirlam and FMI management. Having the Reference system run operationally will raise its status significantly.

The Project Leader has continued the discussion with ECMWF about the Optional Project short cut-off data assimilation and forecasts. ECMWF has investigated how verification of the other (than 00) cycles can be done and how the data can be stored (or short time archived; archiving was not part of the agreement). This has now been

implemented by ECMWF.

The HeXnet has been maintained. Many documents were added. A new hosting machine at KNMI, outside its inner firewall, has been installed and is available. Security issues have been studied and a proposal for a safe access from the Hirlam members has been formulated. A new HeXnet system is being implemented on that machine, with both the remote access, for outside users to add contents, and with a modern overall design.

4 Meetings

- 1st European workshop on short range LAM EPS, 3-4 October 2002, INM, Madrid.
- EWGLAM/SRNWP meeting, 7-10 October, KNMI, De Bilt.
- Hirlam workshop on Meso-scale modelling, 14-16 October 2002, Dublin.

5 Publications

HIRLAM Newsletter No. 41, June 2002.

SRNWP Mesoscale Verification Workshop (23-24 April 2001) , September 2002.

HIRLAM Newsletter No. 42, November 2002.

HIRLAM-5 Scientific Documentation, December 2002.

HIRLAM workshop on Meso-scale modelling, 14-16 October 2002, Dublin. Workshop Report, January 2003.

HIRLAM Newsletter No. 43, June 2003.

HIRLAM-5 Final Report, September 2003.

The Technical Reports are available on the open HEXNET, http://hirlam.knmi.nl/ During the period, the following ones have appeared:

56. Parametrization of subgrid-scale orography effects in HIRLAM Laura Rontu, Kai Sattler and Robert Sigg. Norrköping, October, 2002.

57. Four-dimensional variational data assimilation for a limited area model. Xiang-Yu Huang, Xiaohua Yang, Nils Gustafsson, Kristian Mogensen and Magnus Lindskog. Norrköping, December, 2002.

58. Analysis of surface variables and parameterization of surface processes in HIRLAM. Part I: Approach and verification by parallel runs. Ernesto Rodríguez, Beatriz Navascués, Juan José Ayusoand Simo Järvenoja. Norrköping, January, 2003.

59. Analysis of surface variables and parameterization of surface processes in HIRLAM. Part II: Seasonal assimilation experiment. Beatriz Navascués, Ernesto Rodríguez, Juan José Ayuso and Simo Järvenoja, January, 2003.

60. Assimilation of ATOVS data in the HIRLAM 3D-VAR System. Harald Schyberg, Tomas Landelius, Sigurdur Thorsteinsson, Frank Thomas Tveter, Ole Vignes, Bjarne

Amstrup, Nils Gustafsson, Heikki Järvinen and Magnus Lindskog. Norrköping, April, 2003.

61. A Feasibility Study of Assimilating European Wind Profiler Data Using the HIRLAM 3D-VAR System. Xiang-Yu Huang and Magnus Lindskog. Norrköping, August, 2003.