HIRLAM activities at the Finnish Meteorological Institute

Kalle Eerola

Finnish Meteorological Institute

Introduction

Significant changes have taken place in the operational HIRLAM system at the Finnish Meteorological Institute (FMI) during the latest year. The changes concern both the computational and the meteorological environment. The operational HIRLAM activities are also described by Eerola (2003).

On the computational side the co-operation with CSC has continued during the year, allowing FMI to use the most powerful computers in Finland. CSC is the Finnish IT center for Science, owned by the Ministry of Education. Its provides modeling, computing, and information services for universities, research institutions and industrial companies. In December 2002 the Cray T3E supercomputer at CSC was withdrawn and the operational HIRLAM routines were transferred to a new supercomputer, based on IBM technology.

On meteorological side, the new operational HIRLAM system, based on the HIRLAM version 5.1.4 and 3DVAR version 5.0.3, was tested thoroughly in 2002 and as a result of this work the new ATX suite was introduced into operational use in March 2003.

FMI is part of HIRLAM consortium and the research work in NWP is closely linked to the Scientific Plan of the HIRLAM project. A new step was taken in summer 2003, when FMI was appointed as a lead center of the Regular Cycle of the HIRLAM Reference System (RCR). This means that the next operational NWP systems at FMI will be based on the HIRLAM Reference System with minimal changes.

Technical environment

The replacement of the T3E parallel supercomputer at CSC with an IBM-based cluster was a major event, which affected very much all the HIRLAM-related work at FMI in the year 2002.

The features of the new computer environment are:

- IBM eServer Cluster 1600: a distributed memory supercomputer
- 16 IBM p690 nodes, each equipped with 32 Power4 processors.
- Clock frequency of the Power4 processors 1.1 GHz.
- One node (32 processors and 32 GB of shared memory) is totally dedicated for FMI purposes, mainly for running the operational and experimental HIRLAM runs.
- This solution fulfils in the best way the reliability requirements and the need of top priority of the operational HIRLAM runs.
- One of the "normal" nodes is nominated as a backup node, where operational HIRLAM can be run in emergency cases.

The operational HIRLAM uses 30 processors both in the 3DVAR analysis and in the forecast model inside one node. In both parts, the MPI parallelization software is used. In co-operation with IBM and CSC, the parallelization routines have been optimized to run efficiently on any platform using MPI. Also the IBM-specific mathematical libraries are used to improve the efficiency.

Concerning the parallelization efficiency of the forecast model, Figure 1 shows the speed-up of the operational ATX forecast model (256x186x40 gridpoints), when increasing the number of processors from one to 30. The scaling of the computations is excellent. Even when increasing the number of processors from 24 to 30 the speed-up is about 97% of the perfect speed-up. The bottleneck is the input/output, which reduces the scalability: almost 40% of the time of the forecast model is taken by the input/output, because a lot of output is produced with the frequency of one hour. In the current configuration the input/output is not parallelized, but parallel I/O method is under testing.

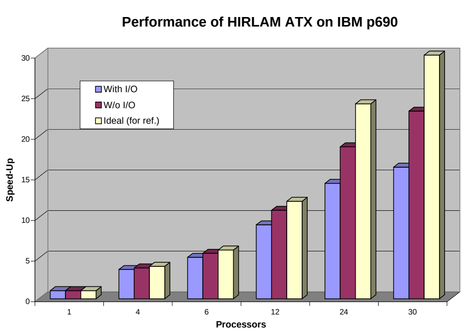

Figure 1. The apee-up of the HIRLAM forecast model on IBM p690 with different number of processors. The right bar: perfect scaling, shown for reference. Middle bar: measured speed-up for computations only. Left bar: measured speed-up for computation and hourly I/O. The size of the problem is 256x186x40 gridpoints.

At the moment the whole operational ATX suite takes about half an hour of wall clock time. Of this time, about 20 minutes is taken by the forecast model.

Operational HIRLAM environment

The operational ATX suite is based on HIRLAM version 5.1.4 and HIRLAM 3DVAR version 5.0.3, with some local modifications in both of them. The main features of are listed in Table 1. and the area is shown in Figure 2. The horizontal resolution is 0.3° and nine of the 40 vertical levels are in the lowest one kilometer. The lowest level is about 30 m above the ground. The semi-Lagrangian advection and semi-implicit time integration allow a time step of 450 s. The forecasts are available both on the model and constant pressure levels to the duty forecasters and applications with the frequency of one hour. The forecast length is 54 hours and the data assimilation cycle six hours.

In data assimilation only conventional observations are used at the moment. The cut-off time of observations is at the moment 2h 30min. Digital filter is used for initialization.

One modification to the reference HIRLAM 5.1.4 system is worth mentioning. We use the Canadian MC2 boundary scheme, implemented in HIRLAM by McDonald (2003) and tested by Järvenoja (2003).

The basic differences is of the boundary schemes:

- Original HIRLAM scheme:
  - The boundary relaxation is the last modification to the fields, i.e. done after the physical calculations.
- The MC2 treatment:
  - The fields are relaxed towards the host model after the dynamics.
  - After the physics the physical tendencies are relaxed towards zero in the boundary zone.

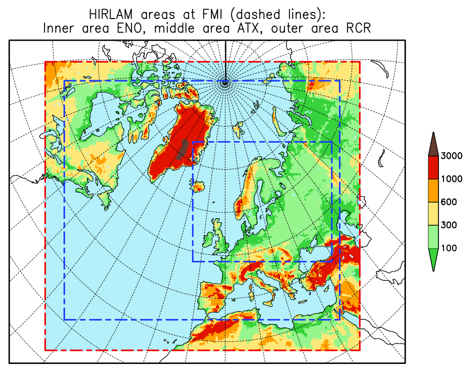

Figure 2. The areas of the different operational suites at FMI. RCR: outer area, ATX: middle area, ENO: inner area. The topography is from the RCR suite.

The experiments confirm that this prevents unrealistically large precipitation amounts close to the boundaries as seen in Figure 3 (from Järvenoja (2003)), which shows the difference of average 48h accumulated convective precipitation for a two-week period between MC2 scheme and the original HIRLAM scheme (MC2 - HIRLAM). The diffrences are negative close to the boundaries indicating that MC2 produces less precipitation. The MC2 scheme also prevents model blowing up in some extreme cases as did the old HIRLAM scheme. The MC2 scheme has now been included in the HIRLAM 6.2 reference system.

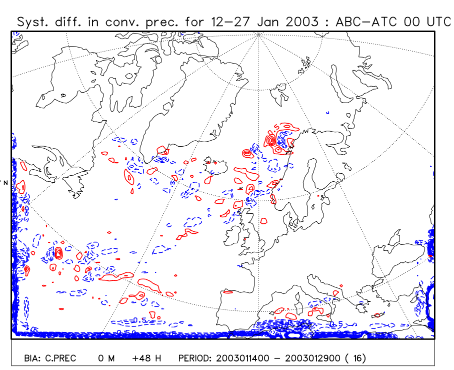

Figure 3. Systematic difference in 48 h convective precipitation between MC2 and original HIRLAM scheme (MC2 - HIRLAM) for a two-week period in January 2003. Positive values. in red and negative in blue. (From Järvenoja (2003))

At the moment (November 2003) the old ENO suite is still running with the horizontal resolution of 0.2°. The number of vertical levels is 31. The area contains mainly Northern Europe and is is shown in Figure 2. (inner area). This suite consists of OI analysis system based on HIRLAM version 5.0.0 and the forecast model based on version 4.6.2 with later updates.

Regular Cycle of the HIRLAM Reference System (RCR)

The HIRLAM-6 Memorandum of Understanding defines a number of priority tasks for the Project.

One of them is

"to maintain a regular cycle of analyses and forecasts to be carried out with the Hirlam Reference System at ECMWF or in one of the member institutes."

This activity is referred to as **RCR** (Regular Cycle with the Reference). From FMI's proposal it was agreed that FMI acts as Lead Centre for RCR (LC-RCR) within HIRLAM-6. This means that FMI adopts the Hirlam Reference System as the FMI operational HIRLAM forecasting system. This RCR will form the basis for a wide range of diagnostics and evaluation by HIRLAM and FMI staff.

The configuration of the RCR will be the Reference system with its default settings, including those determining observation usage. Some basic characteristics will be:

- The horizontal resolution is currently 0.2°.
- The number of vertical level is 40.
- The suggested area is shown in Figure 2 the outer area.
- The lateral boundaries from ECMWF will be received four times a day.
- They are used with the interval of 3 hours.
- The data assimilation cycle will be 3 hours.
- The cut-off time for observations is should be such that a good data coverage is obtained. Optionally, repeat analysis cycles may be introduced in order to assimilate late arriving observations.
- The number of forecasts up to 54 hours will be 4 per day.

FMI makes RCR products available in near-real time for any member of HIRLAM-6. The products consist of observation files, initial conditions, forecast fields and various diagnostics and verification like:

- observation usage
- analysis increments
- diagnostic parameters from the forecast model
- available verification
- verbal comments from the duty forecasters

On monthly basis a verification report is produced, which contains at least:

- Verification against observations
- Verification against analysis
- Data assimilation observation statistics
- means of data assimilation increments, fields and forecast errors for upper air, surface and soil fields
- Time series of observation coverage and forecast errors
- Vertical profiles of forecast errors
- Means of surface energy balance components as well as plots of the diurnal cycle
- Series of certain mast data together with forecast results

A preliminary version of the RCR run, based on HIRLAM version 6.1.2 and HIRLAM 3DVAR version 6.1.2 is run in a parallel suite already now.

Table 1. Characteristic features of the ATX suite

Data assimilation	
Upper air analysis	3-dimensional variational data assimilation
Version	HIRVDA 5.0.3
Parameters	Surface pressure, temperature, wind components, humidity
Surface analysis	Separate analysis, consistent with the mosaic approach of surface/soil processes, for: • SST, fraction of ice • snow depth • screen level temperature and humidity • soil temperature and humidity at two layers
Grid length	0.3° in the horizontal
Integration domain	256 x 186 gridpoints in rotated lat/lon grid
Levels	40 hybrid levels defined by A and B.
Observation types	TEMP, PILOT, SYNOP, SHIP, BUOY, AIREP, AMDAR
First guess	6 hour forecast, six hour cycle
Initialization	Digital filter
Cut-off time	2 h 30 min.
Assimilation cycle	6 hour cycle

Forecast model	
Forecast model	Limited area gridpoint model
Version	Hirlam 5.1.4
Basic equations	Primitive equations
Independent variables	λ, θ (transformed lat-lon coordinates), η , t
Dependent variables	T, u, v, q, p_s, cloud water, turbulent kinetic energy
Discretization	Arakawa C grid
Grid length	0.3° in the horizontal
Integration domain	256 x 186 gridpoints in rotated lat/lon grid
Levels	40 hybrid levels defined by A and B
Integration scheme	Semi-Lagrangian, semi-implicit, Δt=450 s.
Orography	Hirlam physiographic data base, unsmoothed
Physical parameterization	• Savijärvi radiation scheme • Turbulence based on turbulent kinetic energy • STRACO condensation scheme • Surface fluxes using the drag formulation • Surface and soil processes using mosaic tiles • No gravity wave drag
Horizontal diffusion	Implicit fourth order
Forecast length	54 hours
Output frequency	1 hour
Boundaries	• "frame" boundaries from ECMWF • received four times a day • forecast interval six hours • linear interpolation between six hours

REFERENCES

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