JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2006

Finland / Finnish Meteorological Institute (FMI)

1. Summary of highlights

This report describes the essential features of the numerical weather prediction (NWP) system operational at the Finnish Meteorological Institute (FMI) during the year 2006. The system is based on the HIRLAM NWP system (Undén et al., 2002), maintained by the international HIRLAM consortium (http://hirlam.org/), which is formed by the national meteorological agencies of Denmark, Finland, Iceland, Ireland, The Netherlands, Norway, Spain and Sweden. During 2006, FMI has continued to work as the lead centre for operational employment of the common reference version of HIRLAM. In this capacity, FMI makes operational use of the reference version, and makes all forecast products available to the whole consortium in a common archive at the ECMWF. The lead centre duties also include maintaining a comprehensive technical and meteorological monitoring of the system, that can be followed in real time on the project web pages (Kangas, 2005). Some products of the reference runs are shared within the SRNWP-PEPS project. FMI also disseminates boundaries for EMHI (Estonian Meteorological and Hydrological Institute) local LAM model.

The reference HIRLAM RCR employs a horizontal grid spacing of 0.2 degrees. In addition to this, FMI also operates a meso-gamma scale version of HIRLAM MBE with a grid spacing of 0.08 degrees.

2. Equipment in use

The operational HIRLAM forecasts are run on FMI's own Silicon Graphics Altix-3700 BX computer with 304 processors and 304 GB of shared memory and Linux operating system. Of these, a subset of 42 processors is dedicated for HIRLAM to be used in operational computations. The rest of the processors, being also used for other duties at FMI, act as a backup system.

3. Data and Products from GTS in use

- TEMP
- PILOT
- SYNOP
- SHIP
- BUOY
- AMDAR
- AIREP
- ATOVS-AMSU-A

4. Forecasting system

4.1 System run schedule and forecast ranges

FMI maintains two nested data-assimilation/forecasting suites for limited area short range forecasting: an outer "Atlantic suite" (RCR) and an inner "European suite" (MBE). The outer RCR-suite serves as a reference run for the whole HIRLAM consortium in addition to serving domestic needs. The run schedule and forecast ranges are shown in Table 1, while the integration areas of these suites are visualized in Figure 1.

Figure 2 illustrates the computers and data flows of the FMI LAM system. The observations as well as the Baltic ice data from the Finnish Institute of Marine Research are first collected to an auxiliary operational UNIX server, processed, and then transferred to SGI/ALTIX for the actual computations. The same applies to the boundary data obtained from the ECMWF. After computations, the numerical results are loaded into the real time data base for different uses by duty forecasters, researchers, and automated forecast products. Likewise, the graphical products are made available through FMI intranet. A local archiving on another FMI Linux server also takes place. Finally, input and output data are made available to the HIRLAM community by archiving the data to the ECMWF's ECFS using the ecaccess gateway. A graphical interface for monitoring the system is provided to the HIRLAM community through the HeXnet facility at http://hirlam.org/.

	RCR		MBE	
	range	available	range	available
1	00 + 54 h	04:00 UTC	00 + 54 h	06:15 UTC
2	06 + 54 h	10:00 UTC	06 + 54 h	12:15 UTC
3	12 + 54 h	16:00 UTC	12 + 54 h	18:15 UTC
4	18 + 54 h	22:00 UTC	18 + 54 h	00:15 UTC

Table 1. Run schedule and forecast ranges of the FMI LAM suites.

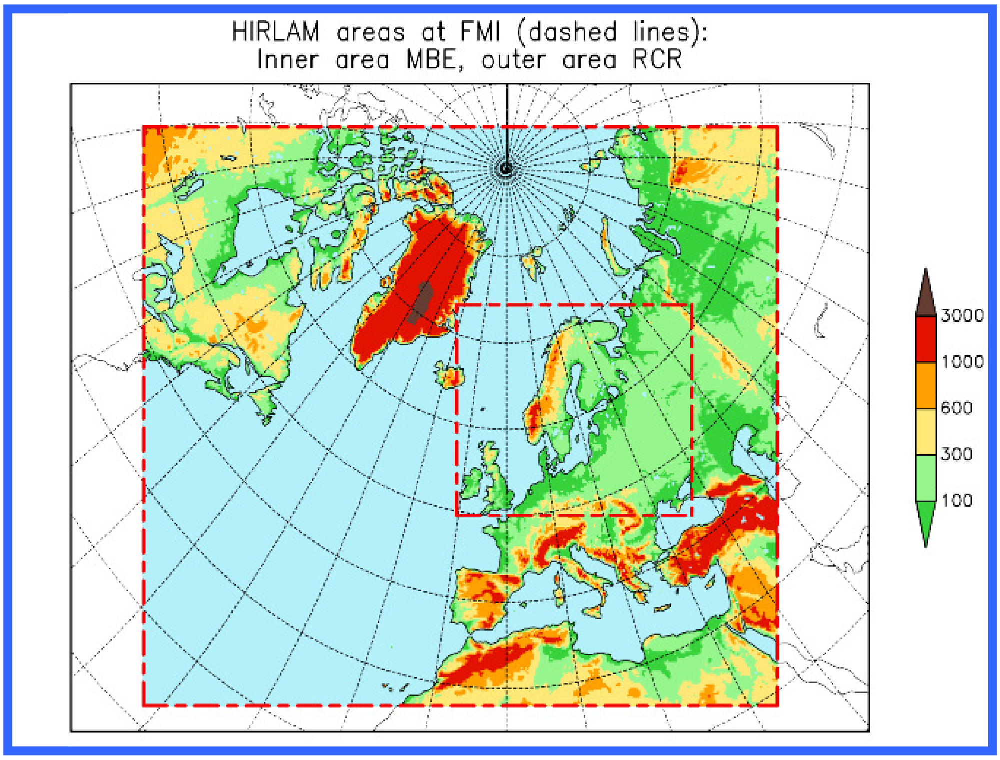

Figure 1. Integration area of the operational LAM suites.

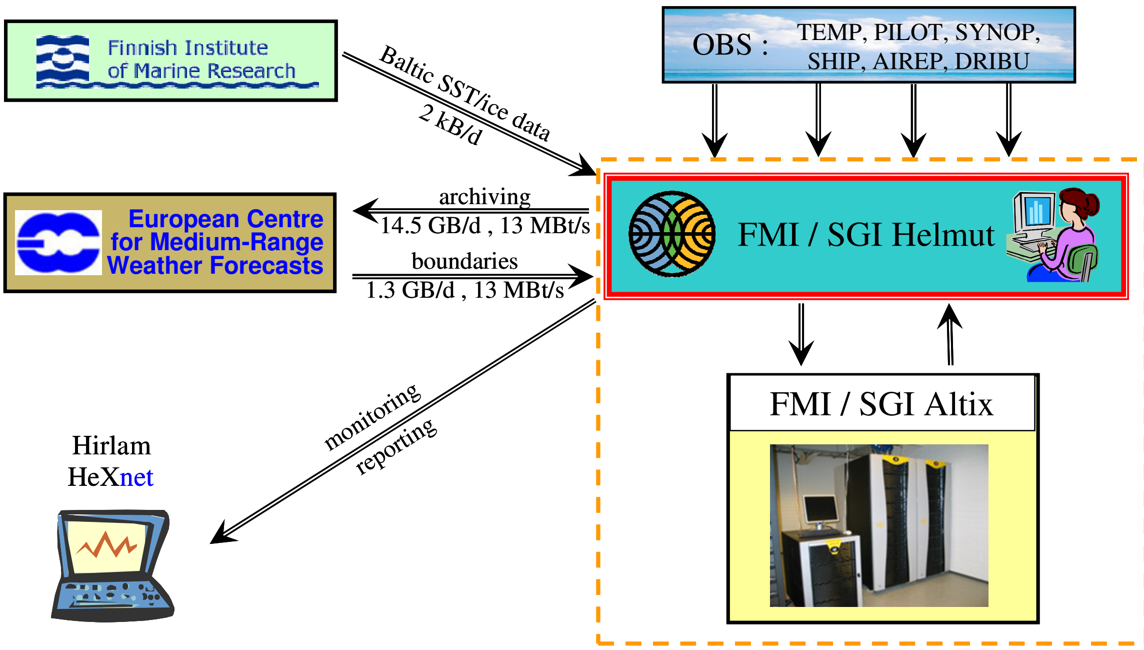

Figure 2. Computers and data flows of the FMI LAM system.

4.3 Short-range forecasting system (0-72 hrs)

4.3.1 Data assimilation, objective analysis and initialization

4.3.1.1 In operation

Upper air analysis

- 3-dimensional variational data assimilation
- Version: HIRVDA 6.2.1, FGAT option
- Parameters: surface pressure, temperature, wind components, relative humidity

Surface analysis

- Univariate statistical interpolation consistent with the mosaic approach of the surface/soil scheme.
- Parameters: SST, fraction of ice, snow depth, screen level temperature and humidity, soil temperature and humidity in two layers

Levels

- 40 hybrid levels defined by A's and B's. Levels are (assuming a surface pressure of 1013 hPa): 1009.2, 1008.9, 991 980, 967, 953, 937, 919, 899, 878, 855, 829, 803, 774, 744, 713, 680, 646, 612, 577, 541, 506, 470, 435, 400, 366, 333, 300, 270, 240, 212, 185, 160, 136, 113, 91, 70, 50, 30, 10 hPa

Observation types

- TEMP, PILOT, SYNOP, SHIP, BUOY, AMDAR, AIREP, AMSU-A

Boundaries:

- time dependent lateral boundary conditions from the ECMWF received four times each day on the RCR grid with a temporal resolution of 3 hrs, obtained via the ECMWF boundary conditions optional project

First guess:

- three hour forecast of the previous cycle

Initialisation:

- Digital filter

Cut-off time:

- 00, 06, 12, 18 UTC: 2h
- 03, 09, 15, 21 UTC: 4h 20 min

Cycling:

- 3h cycle
- re-forecast cycling with 4h 20 min data cut-off and blending with ECMWF analysis (RCR only)

4.3.1.2 Research performed in this field

Assimilation of Doppler radar radial winds

The work on assimilating Doppler radar radial winds has been continued. The bias estimation for Doppler radar radial wind observations requires special attention because of the measurement technique. A method in which the bias in wind speed and direction can be correctly estimated have been developed and introduced in Salonen et al. (2007).

Assimilation of ground-based GPS data

The variational data assimilation system of HIRLAM has been modified in order to allow taking the local observation error correlation of slant delay observations into account. The applied procedure is reviewed in Järvinen et al. (2007). Moreover the asymmetry properties of the slant delay observations have been investigated from the data assimilation point of view (Eresmaa et al., 2007). It is found that the data assimilation systems with grid spacing coarser than about 5 km are likely to be incapable of extracting the asymmetric information content of slant delay observations. Considering data assimilation using a coarser grid NWP model, slant delay observations will thus provide no improvement compared with assimilation of zenith delay observations.

4.3.2 Model (RCR)

4.3.2.1 In operation

Basic equations:
- primitive equations in flux form

Independent variables:
- λ,θ (transformed latitude-longitude coordinates, with the south pole at 30° S, 0°E), η, t

Dependent variables:
- T, u, v, q, ps, cloud condensate, turbulent kinetic energy

Integration domain:
- 438 x 336 grid points in transformed latitude-longitude grid, 40 vertical levels (as in the analysis)

Grid length:
- 0.2° (~22 km)

Grid:
- staggered grid (Arakawa C)

Time-integration:
- 2 time level semi-Lagrangean semi-implicit (time step=6 min)

Orography:
- HIRLAM physiographic data base, filtered

Physical parameterisation:
- Savijärvi radiation scheme
- STRACO- condensation/convection scheme
- turbulence based on turbulent kinetic energy and diagnostic mixing length surface fluxes based on a drag formulation
- surface and soil processes using a tiling scheme

Horizontal diffusion:
- implicit fourth order

Forecast length:
- 54 hours at 00, 06, 12, 18 UTC, forecasts available after 4h

Output frequency:
- 1 hour

Boundaries:
- time dependent lateral boundary conditions from the ECMWF received four times each day on the RCR grid with a temporal resolution of 3 hrs, obtained via the ECMWF boundary conditions optional project .

4.3.2.2 Research performed in this field

Stable boundary layer in high latitudes

NWP models have considerable difficulties in predicting correctly the near-surface wintertime inversions and related extremely cold temperatures. Several parameterization schemes are related to this problem: surface and soil parameterizations over snow-covered land and ice, parameterizations of the turbulent heat, moisture and momentum fluxes in the surface layer and in the whole atmospheric boundary layer, and parameterizations of cloud-radiation interactions. The surface data assimilation, which creates the initial conditions for the model, also influences the forecast. Data from the FMI Arctic Research Centre in Sodankylä has been used to understand this so-called Nordic Temperature Problem validate and develop the HIRLAM parameterizations.

The atmospheric boundary layer over the Antarctic sea ice zone has been studied applying the Polar version of MM5. The model results have been validated against drifting buoy data.

Warm air advection over Arctic sea ice and the development of stable internal boundary layer have been modelled applying HIRLAM and a two-dimensional research model. Aircraft observations have been used for model validation.

Over the Baltic Sea, snow and ice thermodynamics have been modelled (Cheng et al., 2006) during the spring snow melt period concentrating on the superimposed ice formation (Granskog et al., 2006), and parameterization of surface albedo (Pirazzini et al., 2006). Model results for snow and ice thermodynamics have been utilized in the interpretation of remote sensing data (Mäkynen et al., 2007).

Coastal mesoscale and boundary-layer processes

A case study on a wintertime cold-air outbreak over the Gulf of Finland has been made applying MM5 with validation against observations from several coastal and archipelago stations.

Moisture budget over the Antarctic

The ERA-40 reanalysis has been applied to calculate the moisture budget over the Antarctic ice sheet and the Southern Ocean. The calculations have been based on (a) analyses of atmospheric moisture flux convergence and (b) short-term (6-h and 24-h) forecasts of precipitation minus evaporation.

Processes related to orography

A new parameterization scheme for orographic effects on surface radiation fluxes has been developed and tested in HIRLAM (Senkova et al., 2007). Implementation of the new parameterizations of the mesoscale and small-scale orography effects (Rontu, 2006) into the reference HIRLAM has been continued.

Description of the surface properties

ECOCLIMAP data have been introduced into HIRLAM for experiments over Tanzanian domains with 3 - 11 km horizontal resolution. The research is done together with researchers of the Russian State Hydrometeorological University (RSHU) and Tanzanian Meteorological Agency.

Lake data and HIRLAM

Implementation of lake model FLAKE to HIRLAM has been continued with cooperation of colleagues from RSHU (Russian State Hydrometeorological University). An European lake database consisting of information of lake depths and coordinates has been created. The impact of considering both manual and satellite measured surface temperatures of lakes in operational setup of HIRLAM model is studied.

4.3.3 Operationally available NWP products

All the HIRLAM products on model and constant pressure levels are available for applications in the FMI real-time data base with the frequency of one hour.

HIRLAM forecasts are available to duty forecasters on workstations. The geopotential, temperature, relative humidity and three dimensional wind fields are available on constant pressure levels (1000, 925, 850, 700, 500, 400, 300 and 250 hPa). In addition, surface pressure, 10-metre wind, 2-metre temperature, intensity of precipitation and accumulated large-scale and convective precipitation, surface fluxes of sensible and latent heat and net radiation are available. Also several derived parameters such as type of precipitation, stability index, fog, cloudiness etc. are computed from every forecast.

Nearest grid point values are picked up to produce forecasted vertical soundings of temperature, dew point deficit and wind at selected points.

4.3.4 Operational techniques for application of NWP products

4.3.4.1 In operation

HIRLAM forecasts provide guidance to duty forecasters, and can be used as a basis for a large number of automated forecasts distributed to the general public and various authorities. They are also used as input (forcing) to many specialized applications, like forecasting road conditions, waves and currents in the Baltic Sea, potential dispersion of radioactive pollutants, and air quality.

4.4 Nowcasting and Very Short-range Forecasting Systems (0-6 hrs)

4.4.2 Models for Very Short-range Forecasting Systems

4.4.2.2 Research performed in this field

Since 2006, FMI has been running pre-operatively a 2.5 horizontal resolution model AROME in co-operation between HIRLAM and ALADIN consortia. The model is used as a dynamic downscaling of HIRLAM forecasts (22 km resolution), i.e. it contains no data assimilation system of its own. Number of vertical levels in the model is 40 and time step is 60 seconds. The integration area covers southern Finland and parts of Estonia. A short (24h) forecast is run twice a day (at 00 and 12 UTC).

4.5 Specialized numerical predictions

FMI operates a set of air-quality/pollution dispersion models. Forecasts of sea-waves and sea-ice, water levels and currents as well as river runoff are produced in cooperation with the Finnish Institute of Marine Research and the Finnish Environment Institute. A re-analysis of European and Fennoscandian pollution by particulate matter (2000->) is going on. A road weather model based on weather forecast model output to produce traffic and pedestrian walking conditions and warnings as well as road maintenance advice is run operationally several times/day during wintertime.

4.5.1 Assimilation of specific data, analysis and initialization (where applicable)

4.5.1.1 In operation

A variational data assimilation technique 4DVAR for a passive tracer developed for the emergency dispersion model SILAM has been extended to aerosols.

4.5.2 Specific Models

4.5.2.1 In operation

Meso-to-hemispheric scale dispersion models at FMI

- DMAT. Eulerian, regional-to-hemispheric, research; SOx, NOx, NHx, toxic metals and organic pollutants, long-living multi-media pollutants, mineral dust, size-segregated aerosol. (Sofiev, 2000)
- HILATAR. Eulerian, regional, research; SOx, NOx, NHx, toxic metals, mineral dust. (Hongisto, 2002)
- SILAM. Lagrangean and Eulerian, meso-to-continental, research and operational; size-segregated aerosol, sulphur oxides, up to 496 radioactive nuclides, natural pollen, probabilities (Sofiev et al., 2006), forest fire smoke, probabilities
- SILAM-POLLEN. European wide, heat sum based birch flowering model and pollen dispersion model (Sofiev et al., 2006b)

Road weather model and its derivatives.

- ROADSURF. 1-dimensional energy balance model to produce traffic conditions and warnings, pedestrian walking condition warnings and road maintenance timing advice (Kangas et al., 2006).

4.5.3 Specific products operationally available

Four times/day : 48-hour forecasts of probabilities and potential areas of risk in case of nuclear accidents at 5 nuclear power plants in Finland and the closest surroundings; made with SILAM on the basis of HIRLAM and/or ECMWF NWP forecasts. Several times/day (during wintertime): 48 hour forecast of road traffic and pedestrian walking conditions as well as road maintenance advice. European wide birch pollen concentration and dispersion forecasts once a day, 48 h forecasts; made with SILAM on the basis of HIRLAM NWP forecasts.

5. Verification of prognostic products

Due to the limited computational area of the operational forecast model, no verification summaries are computed for the areas suggested. However, standardized verification scores based on surface observations and upper air soundings are being provided operationally for the HIRLAM consortium.

6. Plans for the future

6.1 Development of the GDPFS

Enhancements planned for HIRLAM RCR to be introduced in near future include improved horizontal resolution (0.15 degrees), increase in the number of vertical levels to 60, new snow scheme to better account for Nordic stable boundary layer inversion problems, and 4DVAR data assimilation. Doppler radar wind assimilation will also be implemented in longer run. The "European suite" (MBE) of FMI will also be updated to the same level as RCR but with resolution 0.068 degrees). The planned version upgrade rate for HIRLAM RCR is two per year.

6.2 Planned research Activities in NWP, Nowcasting and Long-range Forecasting

Application of LAPS-based nowcasting system to Helsinki Testbed. Helsinki Testbed is a research project of mesoscale meteorology with a dense measurements network in and around Helsinki (http://testbed.fmi.fi/).

7. References

Cheng, B., T. Vihma, R. Pirazzini and M. Granskog (2006): Modeling of superimposed ice formation during spring snow-melt period in the Baltic Sea. Ann.Glaciol.,44, 139-146, 2006.

Eresmaa, R, Järvinen, H, Niemelä, S and K Salonen (2007): Azimuthal asymmetry in ground-based GPS slant delay observations and their NWP model counterparts. Atmos. Chem. Phys. Discuss., 7, 3179--3202.

Granskog, M, T. Vihma, R. Pirazzini, and B. Cheng (2006): Superimposed ice formation and surface fluxes on sea ice during the spring melt-freeze period in the Baltic Sea, J. Glaciol., 52, 119-127, 2006.

Hongisto, M. (2002): Hilatar, a limited area simulation model for acid contaminants. Part 1. Model description and verification. Atmospheric environment, 37/11, 1535-1547.

Järvinen, H, Eresmaa, R, Vedel, H, Salonen, K, Niemelä, S and J de Vries, 2007: A variational data assimilation system for ground-based GPS slant delays. Q. J. R. Meteorol. Soc., (accepted).

Kangas, M. and Sokka N. (2005): Operational RCR HIRLAM at FMI. Hirlam Newsletter 48, pp. 14-20. HIRLAM-6, c/o Per Undén SMHI, S-601 76 Norrköping, Sweden. Available electronically at: http://hirlam.org/.

Kangas M., Hippi M., Ruotsalainen J., Näsman, S., Ruuhela R., Venäläinen A. and Heikinheimo M. (2006): The FMI road weather model. HIRLAM All Staff Meeting, Sofia, Bulgaria, 15-18 May 2006. Hirlam Newsletter No. 51, October 2006, pp.117-123. Available electronically at: http://hirlam.org/.

Mäkynen, M., B. Cheng, M. Similä, T. Vihma, and M. Hallikainen (2007): Comparisons between SAR backscattering coefficient and results of a thermodynamic snow/ice model for the Baltic Sea land-fast sea ice, IEEE Transactions on Geoscience and Remote Sensing, 2007, in press.

Niemelä S., Andrae U., Hansen Sass, B. and Andersen, B.S. (2007): Convective precipitation in AROME. HIRLAM All Staff Meeting, Oslo, Norway, April 23-26, 2007. Available electronically at: http://hirlam.org/.

Pirazzini, R., T. Vihma, M. A. Granskog, and B. Cheng (2006): Surface albedo measurements over sea ice in the Baltic Sea during the spring snowmelt period, Ann. Glaciol., 44, 7-14, 2006.

Rontu L. (2006): A study on parameterization of orography-related momentum fluxes in a synoptic-scale NWP model. Tellus, 58A, 68-81.

Salonen, K., Järvinen, H., Eresmaa, R. and Niemelä, S. (2007): Bias estimation of Doppler radar radial wind observations. Accepted for publication in QJRMS.

Senkova A.V., Rontu L. and Savijärvi H. (2007): Orographic effects on surface radiation. Tellus, 59A, 279-291.

Sofiev, M. (2000): A model for the evaluation of long-term airborne pollution transport at regional and continental scales. Atmospheric Environment. 34, No.15, pp. 2481-2493.

Sofiev M., P. Siljamo, I. Valkama, M. Ilvonen, J. Kukkonen (2006): A dispersion system SILAM and its evaluation against ETEX data. Atmospheric Environment, 40, 674-685.

Sofiev M., P. Siljamo, H. Ranta, A. Rantio-Lehtimäki (2006b): Towards numerical forecasting of long-range air transport of birch pollen: theoretical consideration and a feasibility study. International Journal of Biometeorology, 50, 392-402

Undén, P. ,L. Rontu, H. Järvinen, P. Lynch, J. Calvo, G. Cats, J. Cuxart, K. Eerola, C. Fortelius, J. A. Garcia-Moya, C. Jones, G. Lenderlink, A. McDonald, R. McGrath, B. Navascues, N. Woetman Nielsen,V. Odegaard, E. Rodriguez, M. Rummukainen, R. Room, K. Sattler, B. Hansen Sass, H. Savijärvi, B. Wichers Schreur, R. Sigg, H. The, A. Tijm (2002):. HIRLAM-5 scientific Documentation, HIRLAM-5, c/o Per Undén SMHI, S¬601 76 Norrköping, Sweden. Available electronically at http://hirlam.org/.