Annual WWW Technical Progress Report

On the Global Data Processing and Forecasting System 2005

FINLAND

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 2005. The system is based on the HIRLAM NWP system (Undén et al., 2002), maintained by the international Hirlam consortium, which is formed by the national meteorological agencies of Denmark, Finland, Iceland, Ireland, The Netherlands, Norway, Spain and Sweden. During 2005, 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.

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

2. Equipment in use for numerical forecasting in Finland

Up till May 31, the operational forecasts were run on one IBM pSeries 690 node of the IBM cluster maintained by the CSC (the Finnish IT center for science), containing 32 Power 4 processors. There was 32 GB of memory in one node and the clock frequency of the processors is 1.1 GHz. Another node of the same cluster was used as a backup system.

Starting from June 1, 2005, the operational HIRLAM forecasts have been run on an Silicon Graphics Altix-350 computer, acquired by FMI during the spring 2005. The system consists of 16 Intel Itanium processors with a clock frequency of 1.5 GHz and a total of 64 GB of shared memory. During late 2005, a larger Silicon Graphics Altix-3700 BX system with 304 processors and 304 GB of shared memory was acquired and installed: This system is now in being tested and at the same acting as a backup system.

3. Data and products from GTS used in NWP

TEMP, PILOT, SYNOP, SHIP, BUOY, AMDAR, AIREP; ATOVS-AMSU-A satellite observations in test use.

4. Data input system

HIRLAM is written to accept observational input in BUFR format. ECMWF pre-processing has been implemented at FMI to convert WMO Alphanumeric messages into BUFR format.

5. Quality control system

Format is checked before transmission to the GTS.

6. Monitoring of the observing system

Surface and upper air observations are monitored on the national level.

7. Forecasting system

7.1 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.

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

	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

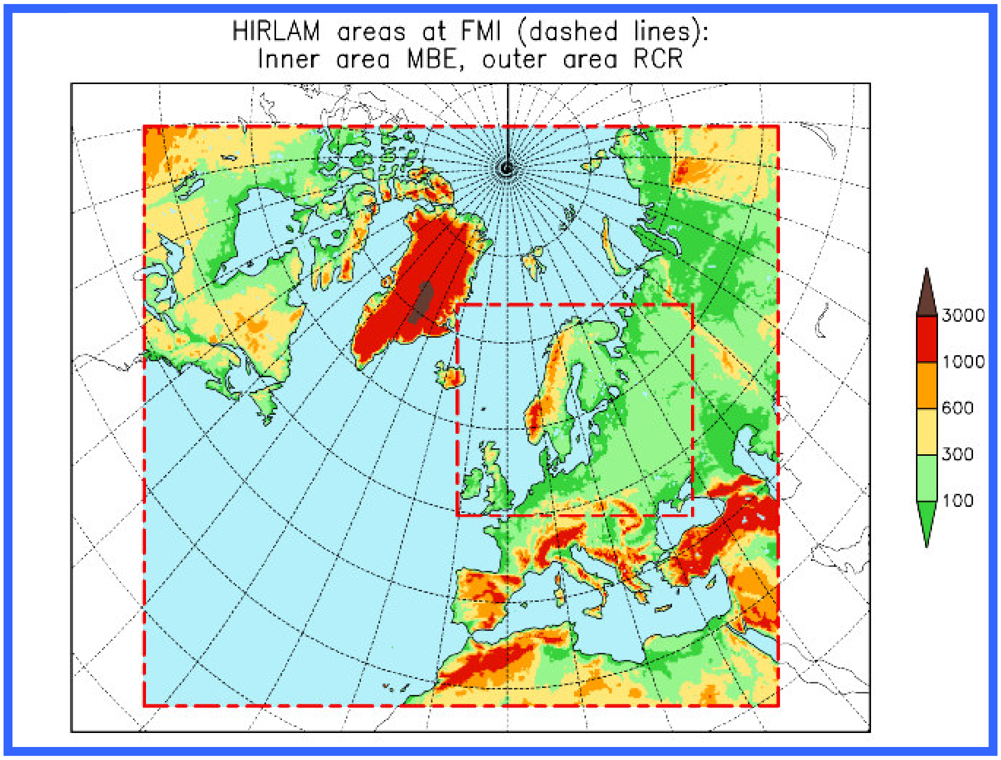

Figure 1. Integration area of the operational LAM suites.

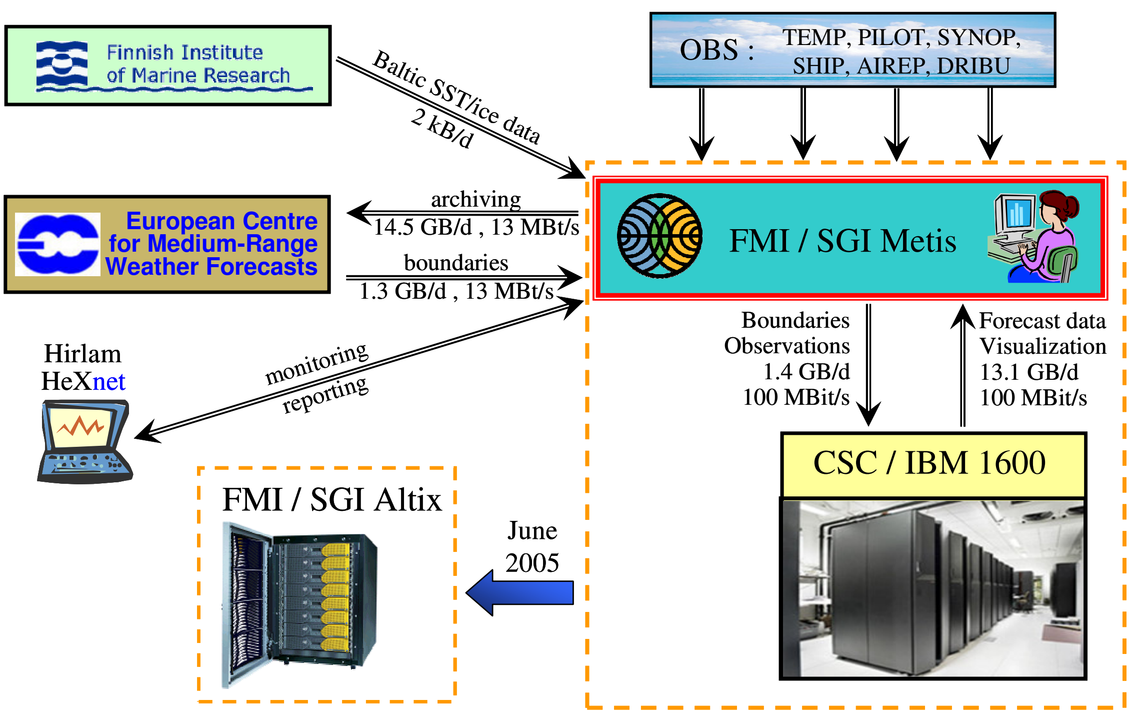

Figure 2.. Computers and data flows of the FMI LAM system.

7.2 The RCR forecasting system (short range forecasts)

7.2.1 Data assimilation, objective analysis and initialisation

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

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

7.2.2 Model

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, p_s, 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 .

7.2.3 Numerical weather prediction 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.

7.2.4 Operational techniques for application of NWP products

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.

7.3 The MBE forecasting system (short range weather forecasts)

7.3.1 Data assimilation, objective analysis and initialisation

Same as in RCR (above), except with six-hourly cycling (00, 06, 12, 18)

7.3.2 Model

Same as in RCR (above) with the following exceptions:

Integration domain:

- 406 x 306 grid points in transformed latitude-longitude grid, 40 vertical levels (as in the analysis)

Grid length:

- 0.08° (~9 km)

Time-integration:

- 2 time level semi-Lagrangean semi-implicit (time step = 3 min)

Forecast length:

- 54 hours at 00, 06, 12, and 18 UTC, forecasts available after 6 h 15 min

Boundaries:

- boundary values with hourly resolution are interpolated horizontally from the forecasts of the RCR suite.

7.3.3 Numerical weather prediction products

As in 7.2.3

7.3.4 Operational techniques for application of NWP products

As in 7.2.4

7.4 Specialized forecasts

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->) has been started, with 2000 ready and 2001 presently under work.

7.4.1 Data assimilation, objective analysis and initialization

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

7.4.2 Models

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, meso-to-continental, research and operational; size-segregated aerosol, sulphur oxides, up to 496 radioactive nuclides, natural pollen, probabilities (Sofiev et al., 2006)

7.4.4 Operational techniques for application of NWP products

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.

8. 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.

9. Plans for the future

9.1 Development of DGPFS

New computer facility (Silicon Graphics Altix-3700 BX system with 304) will be taken into operational use, speeding up computations significantly and reducing the time gap after which forecasts are available. In the models, grid spacing will be decreased and the number of vertical levels increased. The monitoring facility, including on-line model verification with meteorological mast measurements will be further developed.

9.2 Research activities in NWP

Assimilation of Doppler radar radial winds

FMI has participated in development and testing of assimilation modules for Doppler radar radial wind observations to the HIRLAM 3D-Var assimilation system. A set of one month experiments have been performed in order to study the fit of the radar radial wind superobservations (SOs) to the model counterparts. Also the thinned raw data is studied. The aim of the experiments is to define the optimal resolution for the SO generation from the NWP model point of view. The results indicate that when the thinned raw data is used, the errors in individual observations can be quite large. SO generation averages out the random errors quite effectively. The best fit between the SOs and model counterparts is obtained when the SO resolution is somewhat higher than the model grid spacing. The radar radial wind assimilation have been tested with two one month assimilation and forecast experiments. On average the impact of using radar wind information seems to be quite neutral. In certain severe weather cases, however, the forecast utilizing radar wind information performs better than the control run.

Assimilation of ground-based GPS data

The work on the ground-based GPS slant delay data assimilation has been continued. The implementation of the observation operator in HIRLAM 3D-Var assimilation system has been updated. The performance of the slant delay assimilation scheme has been evaluated with assimilation experiments using both hypothetical and real observations. The error statistics of slant delay observations and their model counterparts are studied. Also the use of the slant delay modelling algorithm for geodetic positioning applications has been considered.

Processes related to orography

Parameterizations of the mesoscale and small-scale orography effects have been further developed for implementation into the reference HIRLAM system (Rontu, 2006). Further development of the HIRLAM radiation scheme to take into account the effects of orography on the surface radiation balance is ongoing together with researchers of the Russian State Hydrometeorological University and University of Helsinki.

Stable boundary layer in high latitudes

NWP models, HIRLAM in particular, 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, parameterizations of cloud-radiation interactions (e.g. Rantamäki et al., 2005). 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 polar oceans (Vihma, 2005) has been addressed by process-oriented modelling studies with a focus on heat and moisture fluxes over leads

(Vihma et al., 2005). Model results have been validated against aircraft data. Snow and ice thermodynamics have been modelled 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; Cheng et al., 2006).

Sodankylä mast data for model comparison studies

Sodankylä mast is located at the Arctic Research Centre of the Finnish Meteorological Institute (FMI), or FMI-ARC for short, about 100 km north of Arctic Circle. The height of the mast is 48 meters. It is extensively instrumented, including temperature, humidity and wind measurements at several levels as wells as equipment for measuring radiation and thermal fluxes. Also, measurements from upper air soundings, high temporal resolution AWS data, soil and snow temperatures are available for comparison.

In addition to producing material for detailed studies, on-line measurements from the mast are also shown in the www on the Hirlam visualization pages that are available to all Hirlam project members.

Coastal mesoscale and boundary-layer processes

The impact and possible benefits of increasing the horizontal resolution in HIRLAM have been studied with detailed comparison and experiments with a non-hydrostatic version of HIRLAM and MM5 (Tisler et al., 2006). Special attention has been paid on different aspects of wind field forecasting in coastal zones (Savijärvi et al., 2005). Coastal cold-air outbreaks have been addresses with mixed-layer models focusing on the fetch-dependence of relative humidity over the sea.

Road condition modelling

Road weather model (RoadSurf) is a 1-dimensional energy balance model that is used to predict road surface conditions in varying weather. The model calculates vertical temperature distribution in the ground down to a depth of about 6 m, taking into account the special conditions prevailing at road surface and below it. The effect of traffic is also accounted for. Output from a weather forecast model is used as a forcing at upper boundary. In addition to calculating road surface temperature, the model also determines a forecast for road surface conditions, i.e., whether the road surface is dry or wet, or covered by ice, frost or snow.

The model has been enhanced to include surface condition determination of footways to be used in connection of weather warnings issued for pedestrians (Ruuhela et al. 2005) as well as road maintenance measures to be used in planning of road maintenance activities. A special system for localized real-time warning system for road transport vehicles, based on the road condition model, has also been developed. It employs mobile phone technology to localize and send special warnings to vehicles on road (AINO research programme, 2005).

Meso-gamma-scale physics and non-hydrostatic modelling

FMI's attention is paid to the development of physical parameterisation schemes in the framework of meso-gamma-scale (1-10 km) modelling. Main focus has been on the applicability of the grid-size-dependent convection parameterization on fine resolution. Both locally (Niemelä and Fortelius, 2005) and large-scale (Niemelä, 2005) forced convection has been considered. Studies has been made in the framework of a non-hydrostatic version of HIRLAM created by the group in the Tartu university.

10. References

AINO Research Program, project DriverAlert (2005). At http://www.aino.info/indexe.html .

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., 2006, in press.

Galmarini, S., Bianconi, R., Klug, W., Mikkelsen, T., Addis, R., Andronopoulos, S., Astrup, P., Baklanov, A., Bartniki, J., Bartzis, J. C., Bellasio, R., Bompay, F., Buckley, R., Bouzom, M., Champion, H., D'Amours, R., Davakis, E., Eleveld, H., Geertsema, G. T., Glaab, H., Kollax, M., Ilvonen, M., Manning, A., Pechinger, U., Persson, C., Polreich, E., Potemski, S., Prodanova, M., Saltbones, J., Slaper, H., Sofiev, M. A., Syrakov, D., Sùrensen, J.H., Van der Auwera, L., Valkama, I., Zelazny, R. (2004): Can the confidence in long-range atmospheric transport models be increased? The pan-European experience of ENSEMBLE. Radiation Protection Dosimetry, 109, Nos 1-2, pp. 19-24, DOI: 10.1093/rpd/nch261.

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., 2006, in press.

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

Kangas, M. (2003): Sodankylä mast data for model comparison studies. Hirlam Workshop Report: Baltic HIRLAM Workshop, St.Petersburg, 17-20 November, 2003, pp. 35-38. HIRLAM-6, c/o Per Undén SMHI, S-601 76 Norrköping, Sweden. Available electronically at: http://hirlam.knmi.nl/ .

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.knmi.nl/ .

Niemelä S. (2005): The flood case 27-29 July 2004. HIRLAM/NetFAM Workshop on Convection and Clouds, Tartu, Estonia, 24-26 Jan 2005.

Niemelä S. and Fortelius C. (2005): Applicability of large scale convection and condensation parameterization to meso-gamma-scale HIRLAM: a case study of a convective event. Mon. Wea. Rev., 133, No. 8, 2422-2435.

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., 2006, in press.

Rantamäki, M., Pohjola, M. A., Tisler, P., Bremer, P., Kukkonen, J. and Karppinen, A. (2005): Evaluation of two versions of the HIRLAM numerical weather prediction model during an air pollution episode in southern Finland, Atm. Env., 39, 2775-2786, 2005.

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

Ruuhela, R., Ruotsalainen, J., Aschan, C., Torkki, M. and Kangas, M. (2005): Preventing Pedestrian Slipping Accidents with Help of Weather Service. 17th International Congress of Biometeorology, ICB 2005. Annalen der Meteorologie, 41, Vol 1: 330-332.

Savijärvi, H., Niemelä, S. and Tisler, P.(2005): Coastal winds and low-level jets: Simulations for sea gulfs, Q. J. R. Meteorol. Soc., 131, 625-637, 2005.

Siljamo, P., Sofiev, M., Ranta, H. (2004): An approach to simulation of long-range atmospheric transport of natural allergens: an example of birch pollen. In Air Pollution Modelling and its Applications XVII (in press.), also in pre-prints of 27-th Int. Technical Meeting on Air Pollution Modelling and its Applications, Banff, 23-30.10.2004, Canada, pp. 395-402.

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.

Tisler, P., Gregow, E., Niemelä, S. and Savijärvi, H. (2006): Wind field prediction in coastal zone: operational mesoscale model evaluation and simulations with increased horizontal resolution, Journal of Coastal Research (accepted to publish), 2006.

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, S601 76 Norrköping, Sweden. Available electronically at http://hirlam.knmi.nl/ .

Vihma, T. (2005): Preface (for the Special Issues on the atmospheric boundary layer over sea ice), Boundary-Layer Meteorol., 117, 1-4, 2005.

Vihma, T., C. Lüpkes, J. Hartmann, and H. Savijärvi (2005): Observations and modelling of cold-air advection over Arctic sea ice in winter, Bound.-Layer Meteorol., 117, 275-300, 2005.