JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2016

Finland / Finnish Meteorological Institute (FMI)

1. Summary of highlights

This report describes the essential features of the numerical weather prediction (NWP) systems operational at the Finnish Meteorological Institute (FMI) during the year 2016. The systems are based on mesoscale ALADIN-HIRLAM forecasting system HARMONIE-AROME, hereafter called HARMONIE (http://hirlam.org/index.php/hirlam-programme-53/general-model-description/mesoscale-harmonie, Bengtsson et al. (2017)) and the synoptic scale HIRLAM (http://hirlam.org/index.php/hirlam-programme-53/general-model-description/synoptic-scale-hirlam,Undén et al., 2002) NWP systems, maintained by the international HIRLAM-C consortium (http://hirlam.org/). HIRLAM-C is formed by the national meteorological agencies of Denmark, Estonia, Finland, Iceland, Ireland, Lithuania, the Netherlands, Norway, Spain, and Sweden. The development of HARMONIE is a joint effort of two European modelling consortia: HIRLAM-C and ALADIN.

HARMONIE is a non-hydrostatic, convection-permitting meso-gamma scale model with horizontal resolution of 2.5 km. During 2016, HARMONIE version cy38h12 was in operational use at FMI as the main NWP product.

HIRLAM is a hydrostatic model with 7.5 km horizontal resolution. It is maintained at version 7.4, but is not developed further. During 2016, FMI has continued to work as the lead centre for operational running of the common reference version of HIRLAM (RCR). In this capacity, FMI uses operationally the reference version, and makes all forecast products available to the whole consortium in a common archive at the ECMWF.

A comprehensive technical and meteorological monitoring of the forecast systems (HARMONIE and HIRLAM) can be followed in real time on the project web pages (Kangas and Sokka, 2005). An on-line model intercomparison showing forecast v. measurements for a set of meteorological measurement masts is also included in the monitoring suite (Kangas, 2011; Kangas et al. 2016).

Several research projects address development and improvements of specific features of the NWP models, such as surface interactions especially over snow/ice surfaces and lakes. Some products of the reference runs are shared within the EUMETNET SRNWP-PEPS project.

2. Equipment in use

The operational HARMONIE and HIRLAM forecasts are run on FMI's own Cray XC30 computer with 2 x 3420 cores and peak performance of 70 TFlops. The computer consists of two identical units, one being the main operational platform and the other one acting as a backup and research system.

3. Data and Products from GTS in use

The GTS data used by FMI models include:

HARMONIE	HIRLAM
SYNOP	SYNOP
SHIP	SHIP
BUOY	BUOY
AIREP	AIREP
AMDAR	AMDAR
ACARS	ACARS
TEMP	TEMP
PILOT	PILOT
	ATOVS-AMSU-A
	ATOVS-AMSU-B
	ATOVS-MHS

4. Forecasting system

4.1 System run schedule and forecast ranges

FMI is using ECMWF global products for medium range forecasting. In addition, FMI maintains two nested data-assimilation/forecasting suites for limited area short range forecasting: HARMONIE and HIRLAM.

The run schedules and forecast ranges of the models are shown in Table 1, while the integration areas of the suites are visualized in Figure 1. HARMONIE covers Scandinavia, while HIRLAM covers a larger "Atlantic area".

As an example, Figure 2 illustrates the computers and data flows of the FMI HIRLAM system. The observations from various sources including Baltic SST/ice data from the FMI Marine Service group and Finnish lake surface temperature observations from Finnish Environment Institute (SYKE) are first collected to an auxiliary operational server, processed, and then transferred to the main computing platform for the actual computations. The same applies to the boundary data obtained from the ECMWF. After computations, the numerical results are loaded into the FMI real time data base for various uses by duty forecasters, researchers, and automated forecast post-processing applications. Likewise, the graphical products are made available through the FMI intranet. A local archiving on an FMI server also takes place. Finally, in accordance with the RCR status, input and output data of the HIRLAM 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 a common web portal at http://hirlam.org/.

For HARMONIE, a similar system is used. Main differences are that no Baltic or lake data is used as input and that only local archiving of the results takes place. HARMONIE forecasts can also be monitored through http://hirlam.org/.

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

4.3.1 Data assimilation, objective analysis and initialization

4.3.1.1 In operation

HARMONIE

Upper air analysis
- 3-dimensional variational data assimilation (3DVAR)
- Version: HARMONIE cy38h12
- Parameters: surface pressure, temperature, wind components, specific humidity

Surface analysis
- Optimal interpolation
- Parameters: SST, snow depth, screen level temperature and humidity, soil temperature and humidity in two layers

Levels
- 65 hybrid levels

Observation types
- SYNOP, SHIP, BUOY, AIREP, AMDAR, ACARS, TEMP, PILOT

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

Background:
- Three hour forecast of the previous cycle valid at the beginning of the date window

Cut-off time:
- 1h 45 min (00 and 12 UTC), 1h 30min (03, 06, 09, 15, 18, and 21 UTC)

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

	HARMONIE		***HIRLAM***	
	range	available	range	available
1	00 + 54 h	02:45 UTC	00 + 54 h	03:10 UTC
2	03 + 54 h	05:15 UTC		
3	06 + 54 h	08:45 UTC	06 + 54 h	09:10 UTC
4	09 + 54 h	11:15 UTC		
5	12 + 54 h	14:45 UTC	12 + 54 h	15:10 UTC
6	15 + 54 h	17:15 UTC		
7	18 + 54 h	20:45 UTC	18 + 54 h	21:10 UTC
8	21 + 54 h	23:15 UTC		

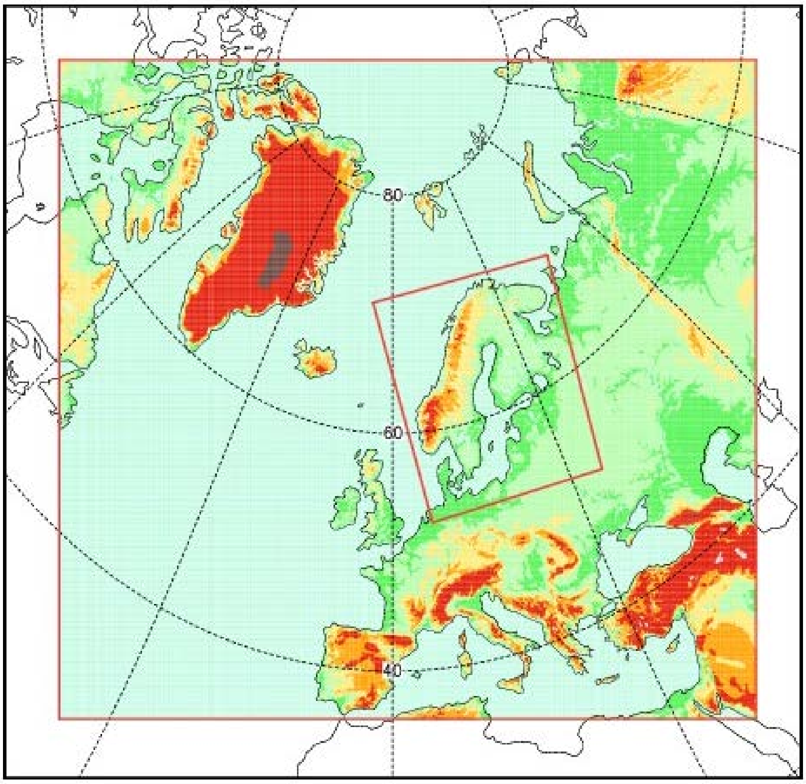

Figure 1. Integration areas of the operational LAM suites (RCR > HARMONIE).

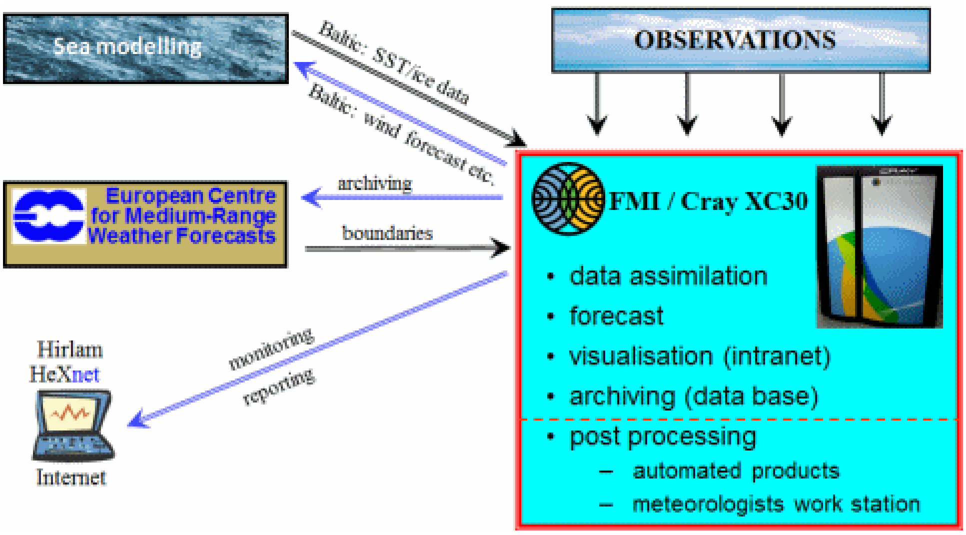

Figure 2. Computers and data flows of the FMI LAM system (RCR-HIRLAM shown here).

Cycling:
- 3h cycle

HIRLAM

Upper air analysis
- 4-dimensional variational data assimilation (4DVAR) with no explicit initialization
- Version: HIRLAM 7.4
- Parameters: surface pressure, temperature, wind components, specific humidity

Surface analysis
- Separate analysis, consistent with the mosaic approach of the surface/soil treatment
- Parameters: SST, fraction of ice, snow depth, screen level temperature and humidity, soil temperature and humidity in two layers
- Finnish lake surface temperature observations (from Finnish Environment Institute)

Levels
- 65 hybrid levels

Observation types
- SYNOP, SHIP, BUOY, AIREP, AMDAR, ACARS, TEMP, PILOT, ATOVS-AMSU-A, ATOVS-AMSU-B, ATOVS-MHS

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

Background:
- Three hour forecast of the previous cycle valid at the beginning of the date window

Cut-off time:
- 2h

Cycling:
- 6h cycle
- Reanalysis step every 6 h, before the main run, to blend with large-scale features of the ECMWF analysis

4.3.1.2 Research performed in this field

Satellite Application Facility cloud mask

The Nowcasting Satellite Application Facility (NWC SAF) cloud mask from the Meteosat Second Generation (MSG) satellite has been assimilated into Harmonie cy38h12 using similar methods as in de Haan and der Veen, 2014. MSG cloud-top temperatures and cloud-base height, either obtained from synoptic station information or from pre-defined height categories (related to MSG cloud-type), are combined at analysis time. The new cloud initialization scheme (with modified ingest routines and micro-physics) is applied to experimental Harmonie runs, with the intention to improve cloudiness and, at the end, radiation parameters for the nearest 6-12 hours.

Lake data-assimilation

In operational HIRLAM system, the lake water surface in-situ measurements are used for the analysis, but not for the initialisation of the prognostic lake parametrisations within the new NWP model cycle. For the objective analysis of the lake surface state, the structure functions for the sea surface temperature are currently used. New structure functions based on the lake water surface temperature (LSWT) observations have been obtained and tested. For the first time, the dependence of the statistical properties of LSWT on lake depth was determined (Kheyrollah Pour et al., 2017). An overview of the recent lake activities may be found in the 5th Workshop "Parameterisation of Lakes in NWP and climate modelling" (http://www.flake.igb-berlin.de/Lake17/.

Snow data assimilation

The implementation of satellite-based snow data to the HARMONIE and HIRLAM surface data assimilation system has been continued in international cooperation. Snow extent data from EUMETSAT H SAF H31 (geostationary orbiting satellites) and H32 (polar orbiting satellites) were compared with HARMONIE analysis fields, SYNOP observations and the GLOBSNOW project data. Assimilation of the spaceborne microwave radiometer data with the snow emission model as forward operator applying of EKF algorithm to initialise the snow density, temperatures and albedo are being discussed. FMI NWP research group actively participates in COST Action ES1491 HarmoSnow. The main purpose of the Action is the harmonization of snow observations, with the perspective to advance snow data assimilation in European NWP and hydrological models and show its benefit for the relevant applications.

Validation of atmospheric reanalyses

Eight reanalyses were validated against independent research aircraft observations in the Antarctic Peninsula region (Nygård et al, 2016b). The reanalyses had generally too moist profiles with too low wind speeds, but otherwise the errors in the reanalyses had large spatial differences. On the eastern side of the peninsula, the near-surface temperatures were largely overestimated. None of the reanalysis outperformed the others in all variables, at all altitudes and on both sides of the peninsula. Generally, NCEP-CFSR and MERRA had the smallest errors in temperature profiles, JRA-55 had marginally the most accurate specific humidity profiles and NCEP-CFSR had the best wind profiles. The reanalyses were coherent, although biased, on the western side of the Antarctic Peninsula, but on the eastern side the spread was large.

4.3.2 Models

4.3.2.1 In operation

HARMONIE

Basic equations:
- Non-hydrostatic fully compressible Euler equations

Independent variables:
- Bi-fourier wave numbers, hybrid level, time

Dependent variables:
- Horizontal wind vector, vertical divergence, non-hydrostatic pressure departure, temperature, specific humidity, 5 species of condensed water, cloud cover, turbulent kinetic energy

Integration domain:
- 720 x 800 grid points in in a Lambert conformal conic projection grid, 65 vertical hybrid levels

Grid length:
- 2.5 km

Grid:
- Arakawa-A (unstaggered)

Time-integration:
- Two-time level semi-implicit semi-Lagrangian

Orography:
- GTOPO30 database

Physical parameterisation:
- SW radiation : ECMWF Morcrette radiation scheme with 6 spectral bands
- LW radiation : ECMWF RRTM scheme with 16 spectral bands
- Shallow convection using combined eddy diffusivity mass flux scheme
- Pinty-Jabouille microphysics including five categories of micrometeros
- 1D prognostic Cuxart-Bougeault TKE scheme
- SURFEX surface scheme with four ground tile types

Horizontal diffusion:
- SLHD (Semi-Langrangian-Horizontal diffusion) non-linear scheme

Forecast length:
- 54 hours at 00, 03, 06, 09, 12, 15, 18, and 21 UTC

Output frequency:
- 15 minutes

Boundaries:
- Boundaries from the ECMWF optional BC runs
- Projected onto the HARMONIE grid at ECMWF
- Boundary file frequency 3 hours, updated four times daily

HIRLAM (RCR)

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 (hybrid level), t (time)

Dependent variables:
- Logarithm of surface pressure, temperature, wind components, specific humidity, specific cloud condensate, turbulent kinetic energy

Integration domain:
- 1036 x 816 grid points in transformed latitude-longitude grid, 65 vertical hybrid levels

Grid length:
- 0.068° (~7.5 km)

Grid:
- staggered grid (Arakawa C)

Time-integration:
- 2 time level semi-Lagrangian semi-implicit (time step 2.5 min)

Orography:
- HIRLAM physiographic data base, filtered

Physical parameterisation:
- Savijärvi radiation scheme
- Orographic radiation parameterisation
- Kain-Fritsch convection scheme
- Rasch-Kristjansson microphysics
- Turbulence based on turbulent kinetic energy
- Surface fluxes according to drag formulation
- Surface and soil processes using mosaic approach; specially treated interactions between forest canopy and snow: double energy balance formulation
- Meso-scale orographic drag parameterisation
- Lake parameterisation, freshwater lake scheme FLAKE

Horizontal diffusion:
- Implicit fourth order

Forecast length:
- 54 hours at 00, 06, 12, and 18 UTC

Output frequency:
- 1 hour

Boundaries:
- Frame boundaries from the ECMWF optional BC runs
- Projected onto the HIRLAM grid at ECMWF
- Boundary file frequency 3 hours
- Updated four times daily

4.3.2.2 Research performed in this field

Large-scale atmospheric circulation

The linkages between the melting and warming Arctic and mid-latitude weather patterns were addressed by Overland et al. (2016). The focus was on the role of Arctic thermal forcing in a chaotic dynamical system and the related challenges in detecting and understanding the response of the mid-latitude atmosphere. A review was made on the atmospheric role in the Arctic water cycle, addressing the processes, past and future changes, and their impacts (Vihma et al., 2016a). During recent decades, specific humidity and precipitation have generally increased in the Arctic, but changes in evapotranspiration are poorly known. Trends in clouds vary depending on the region and season. Climate model experiments suggest that increases in precipitation are related to global warming. In turn, feedbacks associated with the increase in atmospheric moisture and decrease in sea ice and snow cover have contributed to the Arctic amplification of global warming. Climate models have captured the overall wetting trend but have limited success in reproducing regional details. For the rest of the 21st century, climate models project strong warming and increasing precipitation, but different models yield different results for changes in cloud cover.

Boundary layer and mesoscale meteorology

Single-column version of the WRF model was applied to investigate clear-sky stable boundary layers with low winds over snow-covered surfaces (Sterk et al, 2016). The focus was on the relative impact of snow-surface coupling, long-wave radiation, and turbulent mixing on the development of the stable boundary layer over snow. Overall, the model underestimated vertical gradients of temperature and moisture but decreasing the process intensities via tuning of parameterizations improved this. The impact was strongest with reduced turbulent mixing. Considering wind gusts, Suomi et al. (2016a) presented a novel methodology to calculate the gust factor on the basis of research aircraft measurements. The methodology was applied to the Arctic marine boundary layer. Wei et al. (2016a) addressed the impact of meteorological conditions on snow and ice thickness in an Arctic lake. Pezza et al. (2016) presented a short climatology of Southern Hemisphere polar mesocyclones and explosive cyclones. Mesoscale cyclones are more frequent in winter, with a maximum concentration around the Antarctic but also occurring as far north as Tasmania and New Zealand.

Development of measurement techniques

Hole et al. (2016) presented a novel method for atmospheric measurements applying controlled meteorological balloons. Two balloons were operated in the Antarctic, and they remained airborne for 60 and 106 hours with trajectory lengths of 886 km and 2367 km, respectively. The balloons carried out multiple controlled soundings on the atmospheric pressure, temperature and humidity up to 3.3 km. Wind speed and direction were derived from the balloon drift. The balloons detected a mesoscale anticyclone, which was reproduced by the WRF model with reduced intensity. The results suggest that CMET balloons could be an interesting supplement to Antarctic atmospheric observations, particularly in the free troposphere.

Observation networks

A conceptual design for multidisciplinary observations of the global change and its effects was presented in Hari et al. (2016). The design is based on a hierarchical observation network. The most comprehensive observations are envisioned to occur in flagship stations, with which the process-level understanding can be expanded to continental and global scales together with advanced data analysis, Earth system modelling and satellite remote sensing. The denser network of the flux and standard stations allows application and up-scaling of the results obtained from flagship stations to the global level. With a focus on the northern parts of the Eurasian continent, Lappalainen et al. (2016) presented pathway towards holistic understanding of the feedbacks and interactions in the land–atmosphere–ocean–society continuum. Focusing on the Arctic, Vihma et al. (2016c) presented a plan for application of circumpolar observations of the International Arctic Systems for Observing the Atmosphere (IASOA) in studies of atmospheric transports into and out of the Arctic for the Year of Polar Prediction.

Radiation parametrization

The development of radiation parametrizations for the HARMONIE-AROME NWP model has been continued within the ALADIN-HIRLAM community. Documentation of the present default scheme was included the HARMONIE-AROME documentation by Bengtsson et al. (2017). An overview of HARMONIE radiation studies during past six years, including installation and comparison of two optional radiation schemes from the ALADIN (Mašek et al., 2016; Geleyn et al., 2017) and HIRLAM (Rontu et al., 2017b), was presented by Rontu et al. (2016a) and Rontu et al. (2017a).

Lake and sea ice modelling

FMI scientists continue research and developments to represent lakes in NWP and climate models. FMI has studied modelling of Arctic lakes (Shevnina and Kourzeneva, 2017). Technical testing of the lake model FLake in SURFRX/ECOCLIMAPII and in HARMONIE shows promising results. A gap in SURFEX PGD interpolation/aggregation methods with grids of different resolution was recognized and improved. In international cooperation, FMI participates in the development of the new sea ice model block for HARMONIE.

4.3.3 Operationally available NWP products

All HARMONIE and HIRLAM products on both model and constant pressure levels are available for applications in the FMI real-time data base with a frequency of one hour. In compliance with the European Directive on the re-use of public sector information (Directive 2003/98/EC, known as the 'PSI Directive'), the latest forecasts of both HARMONIE and HIRLAM are freely available via the FMI Open Data interface (https://en.ilmatieteenlaitos.fi/open-data).

HARMONIE and HIRLAM forecasts are also 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, visibility, icing index, lightning intensity, CAPE etc. are computed from every forecast.

The 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

HARMONIE and HIRLAM forecasts provide guidance to duty forecasters, and are 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) for many specialized applications, such as forecasting of road conditions, waves and currents in the Baltic Sea, potential dispersion of radioactive pollutants, toxic chemicals, forest fire smoke, volcanic ash, pollen, 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

The development of LAPS (Local Analysis and Prediction System; Albers et. al., 1996) has been continued for utilization in now-casting activities and within other operational products at FMI. The system is in daily operational use, producing 3D-analysis at every hour. The model area covers both the Finland and the whole Scandinavian domain with 3 km grid size. Measurements utilized within the analysis are taken from MSG9-satellite, NWCSAF products, radars, NORDLIS-lightning data, lidars, air-reports (AMDAR), SYNOP, METAR, road-weather stations and the dense measurements network in and around Helsinki (http://testbed.fmi.fi/). New observational data sources are investigated as ingest for the LAPS analysis: scatterometer data, IASI sounder profiles, GPS etc.

The LAPS system generates a fine-scale analyses of weather elements such as 2D surface analysis and 3D cloud-, temperature- and wind analysis. These products are used for now-casting activities, post-processed radiation calculations and for the determination of wind power potential (including losses due to icing) etc. The LAPS-analysed upper air fields are ingested by HARMONIE in order to generate a short-term forecasts (0-12 hours), a system which is running 4 times per day.

Special focus has been on developing the LAPS 1-hour precipitation accumulation analysis. To accomplish this, LAPS assimilates radar and lightning data, together with surface rain-gauge observations (Gregow et. al., 2013, Gregow et. al., 2017). The LAPS precipitation accumulation output is applied in FMI operational products, such as fire-weather index and road weather model, and delivered to end-users within hydrological applications (e.g. the Finnish Environment Institute (SYKE)). LAPS has also been used in research of wind-power production in winter conditions, i.e. icing on wind-turbine blades; Gregow et al. 2015.

4.5 Specialized numerical predictions

FMI operates a set of air-quality / pollution dispersion models. A re-analysis of global, European and Fennoscandian air pollution by trace gases and particulate matter (1980 -> 2017) is going on, the first version of the dataset has been finished. A detailed air quality simulations with 1km resolution covering the whole Finland has been conducted.

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 a day during wintertime.

4.5.1 Assimilation of specific data, analysis and initialization

4.5.1.1 In operation

A 3D-VAR based chemical data assimilation system is in use with the SILAM model for near-real time analysis of the previous day concentrations of O_3, SO_2, NO_2, and $PM_{2.5}$. On annual basis, the re-analysis of birch pollen concentrations is performed using 4D-VAR.

4.5.2 Specific Models

4.5.2.1 In operation

Meso-to-global scale dispersion models at FMI

- SILAM. Lagrangian and Eulerian, meso-to-global, research and operational (Sofiev et al., 2015b)
  - basic inorganic and organic gas-phase pollutants following the CBM-4 chemical mechanism definition.
  - size-segregated inorganic and organic aerosols,
  - up to several hundred radioactive nuclides
  - forest fire smoke, probabilities, age of air
  - natural pollen: European wide flowering and dispersion model for multiple species (Sofiev et al., 2015a)
- HILATAR. Eulerian, regional, research; SOx, NOx, NHx, toxic metals, mineral dust. (Hongisto, 2002)

Road weather model RoadSurf and its derivatives (Kangas et al., 2015).

- road surface temperature and road condition as well as traffic warnings
- pedestrian walking condition and warnings ; also a hi-res version employing LAPS analysis
- road maintenance timing advice
- road surface friction; a statistical model for friction between road surface and tires (Juga et al., 2013)
- snowdrift index (Hippi et al., 2014)

Ocean modeling

- Storm surge models
  - OAAS and WETEHINEN 2D water level models. Forecast the sea level at the Finnish coast of the Baltic Sea, level correction to the forecasts is made utilising Finnish tide gauge observations. Forecast length +54h using HIRLAM RCR forcing and +120h with ECMWF forcing
  - A new system to produce ensemble water level forecasts has been impmemented. The 2D modelling system has two components: a water-balance component to describe the Baltic Sea water volume variations and anotherone to calculate the short-term variations in the Baltic Sea water levels. The model uses ECMWF EPS forecast as forcing (control and 50 perturbated forecasts) and the forecast length is 10 days
- Wave model WAM
  - Wave forecasts for the Baltic Sea with wave model WAM cycle 4.5.4 (e.g. Komen et al., 1994)
  - Horizontal resolution of 4 nmi and 1nmi for the Baltic Sea and nested grid with 0.5 nmi for the Archipelago Sea; the model grid is built to take into account the specific characteristics of the dissected shorelines of the northern Baltic Sea (e.g. Tuomi et al., 2012, Tuomi et al., 2014)
  - Forecasts are made four times a day using wind forcing from FMI's NWP system HIRLAM with forecast length of 54 hours and two times a day using wind forcing from ECMWF deterministic NWP system with forecast length of 5 days (with the 4 nmi grid) and from FMI's NWP system HARMONIE (1nmi)

    - Seasonal ice cover is taken into account by excluding from calculation grid points having over 30% ice concentration; the ice conditions are updated daily based on data produced by FMI's Ice Service
- Circulation model HBM
    - Temperature, salinity, and current forecasts for the Baltic Sea with 3D circulation model HBM. Provides also forecasts for sea ice and sea level
    - Horizontal resolution of 1 nmi for the Baltic Sea with two-way nested grid at the Danish Straits with 0.5 nmi resolution
    - Forecasts made two times a day (00 and 12 UTC) using meteorological forcing from FMI's NWP system HIRLAM with forecast length of 54 hours and two times a day using meteorological forcing from ECMWF deterministic NWP system with forecast length of 3 days
- Ice model HELMI
    - Forecast of ice concentration and ice drift for different ice classes for the Northern Baltic Sea with 1 nmi resolution
    - Forecasts made four times a day using meteorological forcing from FMI's NWP system HIRLAM with forecast length of 54 hours

Icing-model for predicting risk of atmospheric icing on wind turbines

- based on ISO STANDARD 12494. Previously used to create Finnish Icing Atlas (Hämäläinen and Niemelä, 2016).
- frequency and intensity of icing is post-processed from HARMONIE-AROME output: wind, temperature, liquid water content.
- pre-operational predictions for atmospheric icing have been continued, operational runs are due to start in 2017.
- test users (wind energy producers) will report on their experience

4.5.2.2 Research performed in this field

Intelligent transportation systems

The FMI road weather model (Kangas et al., 2015) is being developed to use mobile observations. In December 2015, a measurement campaign in Oulu in which surface temperature and friction measurement instruments were attached to a local commuting bus, was performed. Surface temperature measurements were used in the initialization of the model with positive results (Karsisto and Nurmi, 2016). During 2016, FMI participated in several projects which aim to develop methods to optimally implement mobile observations to the forecasting system (Karsisto et al., 2017a). In Intelligent Arctic Trucks project, observations are performed by additional devices attached to mining trucks driving a route between Kemi Harbour and Kevitsa copper and nickel mine in northern Finland. The observations are used to make dedicated road condition forecasts for the route. A larger scale project WiRMa (Industrial Internet Applications in Winter road Maintenance) aims to develop real-time analytics and forecasting system to support winter road maintenance. The project area covers northern Finland, Sweden and Norway.

The road weather model has been developed to take the local surroundings into account when determining radiation conditions. This is done within the ASSIST (Advanced Snow plough and salt Spreader based on Innovative Space Technologies) project that pilots satellite assisted road maintenance services. The role of FMI is to provide forecasts for the test areas in Norway and Sweden. The Norway test area is especially challenging due to the mountainous surroundings. A sky view factor and local horizon angles in eight directions were calculated for each forecast point in the Norway test area from a 100 m resolution height map. The model uses these parameters to adjust the radiation values from the NWP model HARMONIE-AROME that assumes open field conditions.

A comparison study between FMI road weather model and the Royal Netherlands Meteorological Institute's (KNMI) recently developed road weather model was performed (Karsisto et al., 2017b). The models were run with the same HARMONIE-AROME input data for several road weather stations in the Netherlands. The KNMI model gave slightly more accurate forecasts than the FMI model. However, the FMI model is developed for Finish winter conditions, whereas the KNMI model is optimized for Netherlands conditions. The study highlights the importance to adjust the model physical properties when implementing it to a new area.

4.5.3 Specific products operationally available

- 48-hour forecast of air quality in Northern Europe based on HARMONIE forecasts, resolution 0.022°
- 120-hour forecast with 24 hour hindcast of air quality in Europe based on IFS forecast dissemination, resolution 0.1°
- 120-hour forecast of air quality in Asia based on IFS forecast dissemination, resolution 0.1°

- 120-hour forecast of global atmospheric composition based on IFS forecast dissemination, resolution 0.5°
- 48 hour forecast of road traffic and pedestrian walking conditions as well as road maintenance advice, several times/day (during wintertime):
- wave forecast 4 times a day for the Baltic Sea using wind forcing from FMI's NWP system HIRLAM with forecast length of 54 hours and 2 times a day for the Baltic Sea using wind forcing from ECMWF deterministic NWP system with forecast length of 5 days (with the 4 nmi grid) and from FMI's NWP system HARMONIE (1 nmi)
- sea Surface Temperature, salinity, and current forecasts for the Baltic Sea two times a day (00 and 12 UTC) using meteorological forcing from FMI's NWP system HIRLAM with forecast length of 54 hours and two times a day using meteorological forcing from ECMWF deterministic NWP system with forecast length of 3 days
- ice concentration and drift forecast for the Baltic Sea region four times a day using meteorological forcing from FMI's NWP system HIRLAM with forecast length of 54 hours

5. Verification of prognostic products

5.1 Annual verification summary

The figures below show the monthly bias (lower curves) and rms-error (upper curves) of screen level temperature and 10m wind for HIRLAM RCR version V74 starting for HIRLAM (Figs. 3 and 4, starting from 1995) and for HARMONIE-AROME (Figs. 4 and 5, starting from 2009). The verification is done for observations from the so-called EWGLAM station list (HIRLAM) and from Finnish stations (HARMONIE). The forecast length is 48 hours for HIRLAM and 24 hours for HARMONIE. Line colours indicate model versions, black line shows running average.

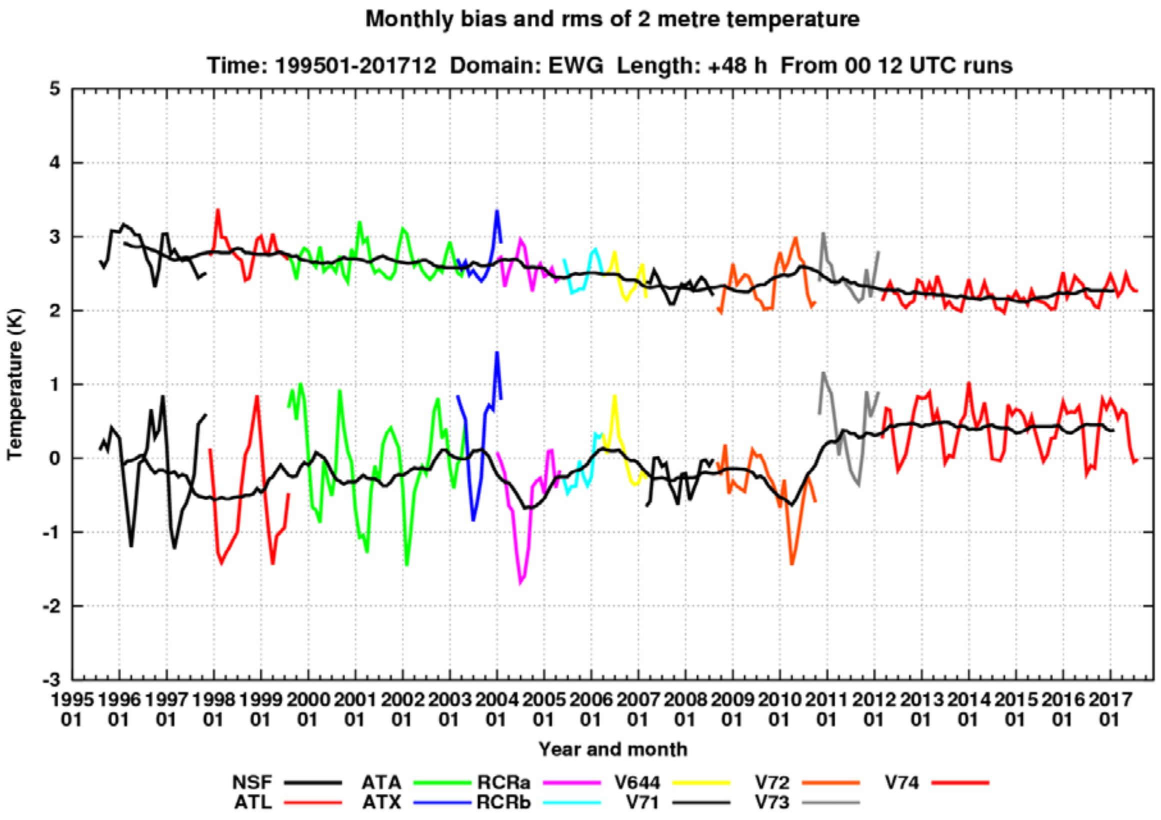

Figure 3 : HIRLAM long-term verification: screen level temperature.

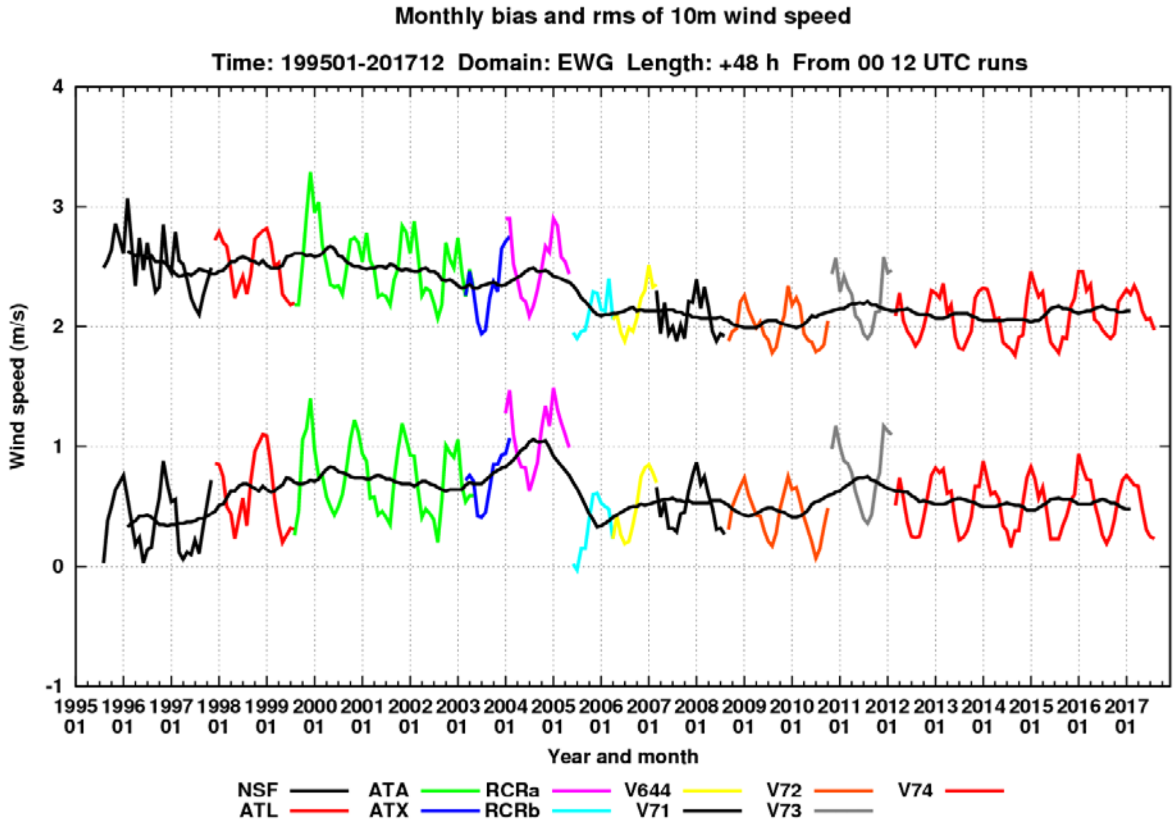

Figure 4 : HIRLAM long-term verification : 10m wind.

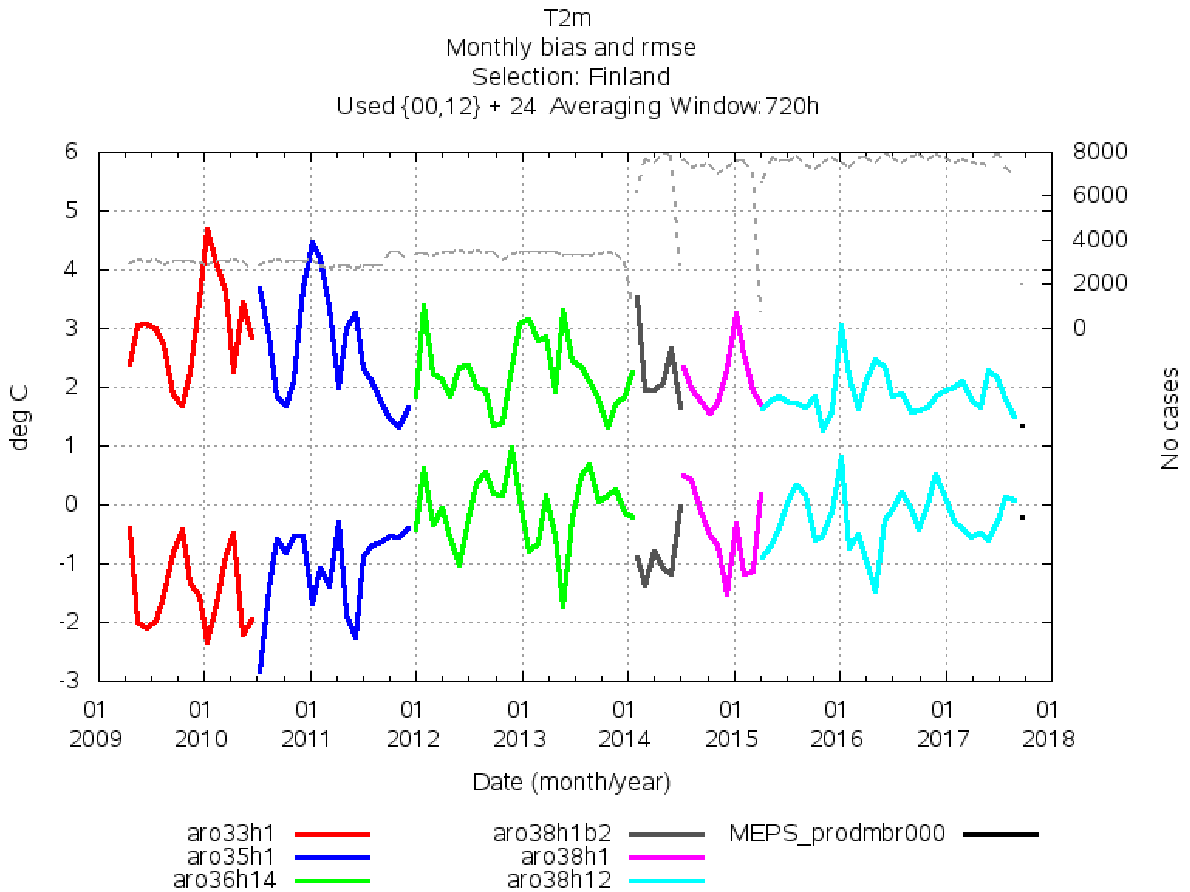

Figure 5 : HARMONIE long-term verification: screen level temperature.

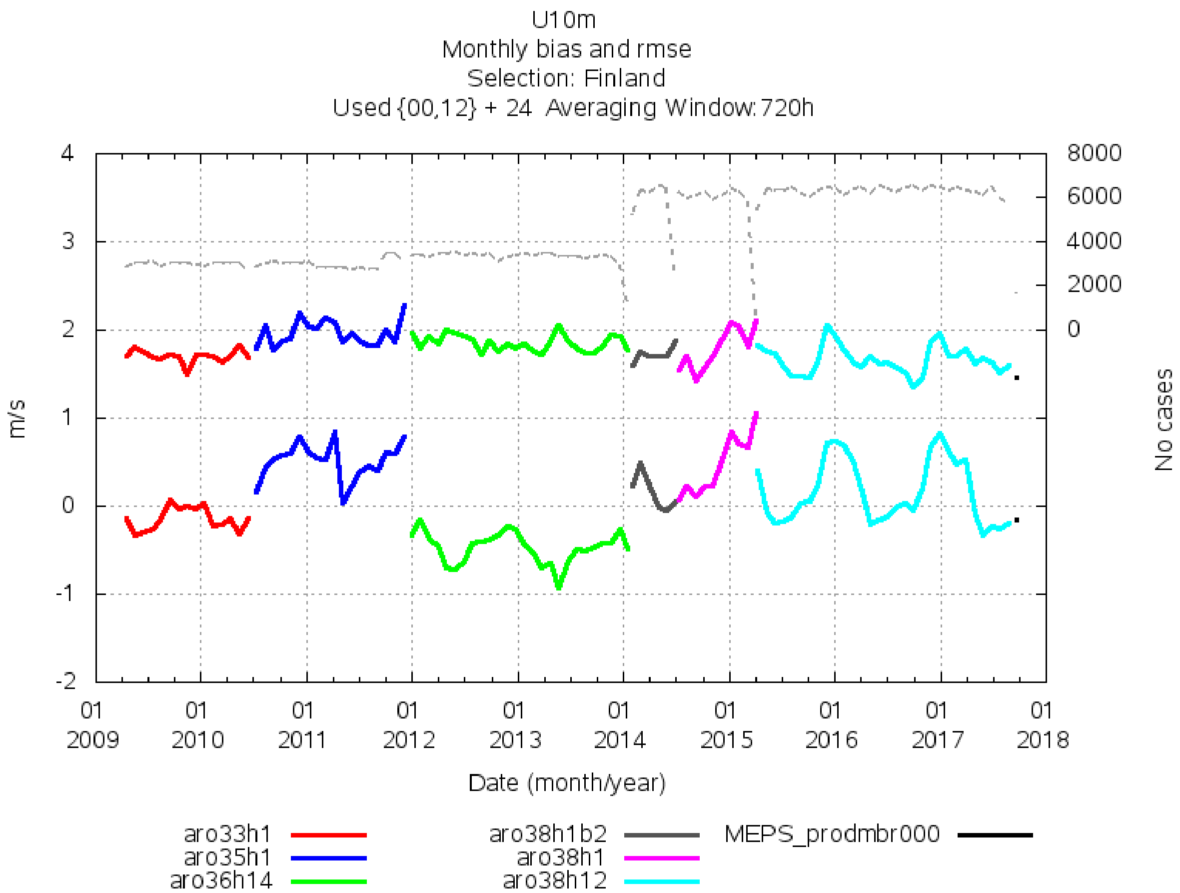

Figure 6 : HARMONIE long-term verification: 10m wind.

6. Plans for the future

6.1 Development of the GDPFS

During 2016, as first steps of realizing common Nordic NWP (NORDNWP), FMI has been making the final preparations to join the MetCoOp joint NWP production with Norway and Sweden in 2017, delivering a convection-permitting ensemble forecast, and aiming to produce frequently-updated short range forecasts serving nowcasting and very short lead time forecasting. The observation usage in HARMONIE will then be extended to include remotely sensed observations (AMSU-A, AMSU-B, MHS, RADAR (dbz), ASCAT, GNSS, IASI). The lake scheme FLAKE (already in use in HIRLAM) will be implemented into HARMONIE

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

Current research activities in atmospheric modelling include

- the assimilation of remote sensing data
- surface data assimilation (lakes, snow)
- effect of orography and aerosols
- utilization of probabilistic forecasting for renewable energy production (HARMONIE-EPS)
- modelling of built environment and related forecasting

Research and development of SILAM are concentrated on:

- development of data assimilation algorithms, EnKF / EnKS and 4D-VAR, and related topic of inverse problem solution
- ensemble forecasting
- data fusion
- pollen forecasting
- chemistry mechanism development
- fire system development

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