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

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1. Summary of highlights

Assimilation of scatterometer (ASCAT) wind over sea was introduced on the operational HARMONIE-Arome model.

The MetCoOp Ensemble Prediction System (MEPS), was taken into production, replacing the previous deterministic HARMONIE-Arome forecasts.

The process began to extend the existing operational NWP cooperation MetCoOp between SMHI and MET Norway, to also include FMI (Finland)

2. Equipment in use at the Centre

SMHI operational forecasts are run at computers at NSC (National Supercomputer Centre at the University of Linköping, Sweden) and at NTNU (Norwegian University of Science and Technology of Trondheim, Norway).

SMHI operational forecasting system (HIRLAM weather forecasting and the oceanographic HIROMB model) is run on 2 separate computer systems, for redundancy.

The most recent HPC “Bifrost” was delivered to NSC in late 2014 and was made operational during the first quarter of 2015. Bifrost is a 10600 core Linux cluster, based on Intel Xeon E5 eight-core processors and Intel Truescale Infiniband QDR.

The backup setup is run on “Vilje”, the operational computer used by MET Norway which is situated at NTNU in Trondheim, Norway.
“Vilje” is used by the academical users as well as by MET Norway operation/research, and SMHI operational models.

The backup system at MET Norway is at the same time run at “Bifrost” at NSC, Linköping, Sweden.

The pre-processing of observational and boundary input to the models are run on Linux servers.

The output of the models are stored on a file-server and also put into SMHI operational database.

3. Data and Products from GTS in use

SYNOP, SYNOP SHIP, TEMP, PILOT, BUOY, AIREP, AMDAR and, over sea, AMSU-A.

HARMONIE-Arome (including MEPS) and HIRLAM accepts observational input in BUFR format.

SMHI uses a pre-processing software that processes observational BUFR-messages on GTS and converts it to BUFR-reports that are readable from the NWP systems.

4. Forecasting system

SMHI is part of the international HIRLAM project which has a goal to produce a Limited Area Model for operational use for short-range Numerical Weather Prediction in the participating National Meteorological Institutes. SMHI runs the HIRLAM analysis and forecast model for national use for forecasts up to +48 or +72 hours.

SMHI is also a member of ECMWF, European Centre for Medium-Range Weather Forecasts and uses the operational output, which is received in real time from ECMWF dissemination system. The products from ECMWF are mainly a +240 hours deterministic forecast twice a day and products from ECMWF EPS, Ensemble Prediction System and also products from the BC-project to provide horizontal boundaries for NWP 4 times a day.

The HIRLAM Programme has a co-operation with the ALADIN consortium particularly for the purpose of meso-scale modelling. The resulting HARMONIE model system with AROME configurations are available and used both operationally as well as for research and evaluation.

4.1 System run schedule and forecast ranges

At SMHI the operational short-range NWP system are run using the HARMONIE and HIRLAM models on several different domains:

- HARMONIE with AROME physics has a horizontal resolution of 2.5km (Lambert grid) and 65 vertical levels. The lateral boundaries come from ECMWF. The forecast length is +66 hours. During 2016 this model was expanded to a 10 member EPS (called MetCoOp Ensemble Prediction System, or MEPS for short)
- HIRLAM C11 with a horizontal resolution of about 11 km (0.10 degree on the rotated lat/long grid) and 40 vertical hybrid levels is run to +60 hours with a +2 hour data cut-off time. Lateral boundaries come from the ECMWF BC project with a 3 hour time resolution. The BC (Boundary Condition) project is run 4 times a day and provides 6 hour old boundaries.
- HIRLAM E05 has a horizontal resolution of 5.5 km (0.05 degrees on the rotated grid) and 65 vertical levels. It is run to +48 hours with a data cut-off of 1 hour 15 minutes. The lateral boundaries come from the ECMWF BC project.

4.2 Medium range forecasting system (4-10 days)

No medium range forecasts are run at SMHI. Products from ECMWF are used.

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

The HIRLAM analysis and forecast system are described in HIRLAM-5 Scientific Documentation (Undén, P. et al. 2002). The HARMONIE(Hirlam Aladin Regional/Mesoscale Operational NWP in Europe)-AROME (Application of Research to Operations at Mesoscale) system is described in Seity et al (2011)

4.3.1 Data assimilation, objective analysis and initialization

4.3.1.1 In operation

The analysis is 4DVAR on the HIRLAM C11 domain but 3DVAR with FGAT at HIRLAM E05 setup. For HARMONIE-AROME/MEPS a 3DVAR-RUC (Rapid Update Cycling) with 3 hourly updating is used.

Initialization is done with Incremental DFI, Digital Filter Initialization, developed within the HIRLAM project.

4.3.1.2 Research performed in this field

The research focuses on the HARMONIE-AROME system and on the ALADIN model that is used for regional reanalysis. The main tasks are:

1) the development of a flow-dependent background covariance error
2) the assimilation of high-resolution observations
3) surface data assimilation

For HARMONIE-AROME, a 4DVAR-scheme is now working and was used in different research projects, e.g. DNICast (http://www.dnicast-project.net/). Hybrid ensemble methods are planned to be included in HARMONIE-AROME within the framework of the OOPS design of ECMWF IFS system.

On the algorithmic side, efforts have continued to assess and improve various aspects of the performance of 3D-Var. The main aims are to increase and prolong the impact of observations, and to improve performance in the nowcasting range. Activities include the inter-comparison of various methods for generating structure functions in terms of impact, spin-up and the noisiness of increments; experiments with EDA on small scales in combination with several methods of accounting for the large scale; testing the impact of different methods for estimating optimal thinning distances.

In the regional reanalysis FP7-project UERRA (Uncertainties in Ensembles of Regional ReAnalysis), we have produced 55 years reanalysis data for entire Europe at a horizontal resolution of approximately 12 km.

Preliminary studies on the impact of e.g. ASCAT soil moisture and satellite snow data in more advanced assimilation schemes (Extended Kalman Filter) are already being done.

4.3.2 Model

4.3.2.1 In operation

The MEPS system is based on HARMONIE-AROME cycle 40..

The forecast model used for HIRLAM C11 is a somewhat modified HIRLAM version 7.1.2 with the following characteristics:

ISBA surface scheme
Kain-Fritsch convection scheme
Rasch-Kristjansson large scale scheme
CBR turbulence scheme
Savijärvi radiation scheme

For the E05 run a newer HIRLAM reference version 7.3 has been introduced. It includes an interactive snow surface scheme and a meso-scale orography parameterisation.

4.3.2.2 Research performed in this field

Adaptations have been made in the LCRIT option of HARMONIE-AROME of the shallow convection scheme to improve the description of freezing rain and of precipitation from shallow convective clouds under cold conditions, and changes introduced in the microphysics with the aim to achieve a more consistent use of ice crystal spectrum and CCN density in the microphysics processes.

Through the advection of falling precipitation and adaptations in the generation of sub-grid precipitation, the forecasts of precipitation from relatively shallow cumulus under cold conditions can be improved. Several small changes were made to harmonize the formulations between the microphysics and radiation schemes; these have also led to slightly better model performance. The cellular automata approach has been implemented in the Harmonie-Arome configuration, coupled to the EDMFm shallow convection scheme.

Extensive testing has been done for the so-called 2-patch option in HARMONIE-AROME Cy40h1.2 (introducing the use of two patches (for forest and open land), rather than one, in the calculation of fluxes for the nature tile). This 2-patch adaptation was introduced to tackle the problem of excessive latent heat flux in the model due to snow cover over open land. In combination with the removal of the CANOPY scheme it has also proven beneficial more in general for reducing T2m biases on several domains, but it has also been seen to give a slight deterioration in u10 in some cases.

4.3.3 Operationally available NWP products

The HIRLAM model produces output on files containing the model parameters like wind, temperature, specific humidity, cloud water and TKE (Turbulent Kinetic Energy) on all model levels as well as parameters that describe the state of the ground like temperature and available water on the different land tiles in the model and on the soil levels. The model files also contain physiographic data like orography and roughness.
In addition to the model files, the output can also, by namelist arguments, produce post-processed files for parameters on pressure levels and parameters like 2 m temp and 10 m wind.
Output from HIRLAM is written with 1 hour time resolution to disk and is also written to SMHI database.

4.3.4 Operational techniques for application of NWP products

4.3.4.1 In operation

Forecast products from different model, HIRLAM C11, E05, HARMONIE/AROME and ECMWF, are selected to create a forecast database, PMP. This database can also be manually edited. This database is then used to produce, automatically, different customer products. Other applications, like other models, can then also use this database for their meteorological input. For HARMONIE/AROME a neighbourhood technique is employed in order to take into account the unpredictability of the smallest spatial scales.

4.3.4.2 Research performed in this field

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4.3.5 Ensemble Prediction System

4.3.5.1 In operation

Development of the MetCoOp Ensemble Prediction System (MEPS) began during 2015 and the system was deployed operationally on November 8, 2016. MEPS is based on HARMONIE and uses identical domain and resolution as the previously operational HARMONIE-AROME system. MEPS has 10 members and utilizes the SLAF method to perturbate boundaries.

4.3.5.2 Research performed in this field

Initial condition perturbations that have been experimented with include downscaling from ECMWF EPS perturbations, lagging, and EDA-based perturbations. Small-scale perturbations by EDA were shown to have

most impact in the first 3h of the forecast. Investigations of the optimal number of ensemble members for EDA are ongoing. Combinations of EDA and mesoscale surface perturbations are being tested now as well.

Surface perturbations for e.g. soil moisture, SST and LAI, computed from a code kindly provided by Meteo-France, have been shown to give positive impact on T2m and RH2m, but do not seem to have much effect on other (near-)surface parameters. It is being considered how to further improve this type of perturbation, either by refining the perturbations in the presently used parameters or by introducing new. Work on perturbing surface fluxes and implementing different roughness lengths for heat and moisture is ongoing.

4.3.5.3 Operationally available EPS Products

EPS products from ECMWF and HIRLAM/GLAMEPS are available and used.

4.4 Nowcasting and Very Short-range Forecasting Systems (0-12 hrs)

4.4.1 Nowcasting system

4.4.1.1 In operation

An analysis model, MESAN, for analysis of weather parameters not normally analysed by meteorological models such as fresh snow-cover, visibility and 10 meter winds.

MESAN is used for diagnostic and now-casting purposes and uses an Optimum Interpolation technique.

4.4.1.2 Research performed in this field

Tests will be carried out of the new MESCAN horizontal spatialization scheme with respect to the present CANARI scheme.

4.4.2 Models for Very Short-range Forecasting Systems

4.4.2.1 In operation

No Very-short range Forecasts is run operationally at SMHI.

4.4.2.2 Research performed in this field

In order to improve very-short-range forecasts for direct normal irradiance, initialization of clouds with the use of Nowcasting SAF cloud masks and assimilation of clear-sky SEVIRI radiances was examined. A positive impact has been seen from assimilation of clear-sky SEVIRI data in the Hor2020 IMPREX project. The testing of predictors for VarBC of these clear-sky radiances is ongoing.

4.5 Specialized numerical predictions

MEPS and/or HIRLAM output is used as input data for a number of other models:

HIROMB. An oceanographic forecast model for temp, salinity, currents, ice cover and water-level.
NemoNordic. A novel oceanographic forecast model for temp, salinity, currents, ice cover and water-level.
SWAN. A wave model.
MATCH. A Transport, Dispersion and Atmospheric Chemistry model.
HBV model. A hydrological run-off model for different catchment areas.

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

4.5.1.1 In operation

Assimilation of scatterometer data (ASCAT) were introduced in the HARMONIE-AROME/MEPS model during 2016

4.5.1.2 Research performed in this field

For high-resolution observations, the assimilation of ground-based GNSS was developed (Arriola et al. 2016) and put into operations. GNSS data processing for Scandinavia has improved significantly since this has been taken over by the NGAA processing center, and the data are now of a quality comparable to other

GNSS processing centers. In the variational bias correction for GNSS zenith total delay (ZTD) data, tests are being done with a more extended predictor set.

4.5.2 Specific Models (as appropriate related to 4.5)

4.5.2.1 In operation
N/A

4.5.2.2 Research performed in this field
N/A

4.5.3 Specific products operationally available

N/A

4.5.4 Operational techniques for application of specialized numerical prediction products *(MOS, PPM, KF, Expert Systems, etc..)* (as appropriate related to 4.5)

4.5.4.1 In operation
A Kalman filtered temperature forecast is available.

4.5.4.2 Research performed in this field
A model for atmospheric icing is developed further.

4.5.5 Probabilistic predictions (where applicable)

4.5.5.1 In operation
N/A

4.5.5.2 Research performed in this field
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4.5.5.3 Operationally available probabilistic prediction products
N/A

4.6 Extended range forecasts (ERF) *(10 days to 30 days)*

4.6.1 In operation

No extended range forecasts are operational at SMHI.

4.6.2 Research performed in this field

N/A

4.6.2 Operationally available products

N/A

4.7 Long range forecasts (LRF) *(30 days up to two years)*

4.7.1 In operation

No long range forecasts are made at SMHI

4.7.2 Research performed in this field

Within the EC-EARTH consortium, SMHI examines the potential predictability of decadal forecasts for a forecast length of 1 to 30 years (Koenigk et al. 2012).

4.7.3 Operationally available products

N/A

5. Verification of prognostic products

HIRLAM output is continually verified using the EWGLAM (European Working Group on Limited Area Models) verification scheme to verify model output against observations in well specified station lists.

The forecasts are also verified to see its possibility to forecast specified events, like e.g. winds above a certain limit.

Verification results are published at the SMHI internal Website and on hirlam.org for our partners within the HIRLAM-consortium.

5.1 Annual verification summary

5.2 Research performed in this field

SMHI is contributing to the development of the HARP (HIRLAM-ALADIN R-package) verification tool.
Improvements for the so-called “Unbiased Identical” (UI) spread-skill relationship were developed for EPS in order to provide a reliable estimate of the spread-skill relationship.

6. Plans for the future *(next 4 years)*

6.1 Development of the GDPFS

6.1.1 Major changes in the operational DPFS which are expected in the next year

The SMHI HIRLAM C11 and E05 models will likely be decommissioned during 2017.

Work is underway for FMI (Finland) to be a full member of MetCoOp, planned to be completed during 2017. MEPS was made operational using the same domain as the previous HARMONIE-AROME run. The domain will likely be expanded once FMI is an operational member of MetCoOp, to cater for Finland domain requirements.

6.1.2 Major changes in the operational DPFS which are envisaged within the next 4 years

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

“[Summary of planned research and development efforts in NWP, Nowcasting, LRF and Specialized Numerical Predictions for the next 4 years]”
The joint HIRLAM-B programme will end in 2015. A continuation of the HIRLAM consortium in close collaboration with ALADIN is planned. At SMHI, the research will focus on high-resolution very short to short-range NWP and related applications. For data assimilation, efficient methods for mesoscale systems have to be developed. For the initialisation, high-resolution observations have to be assimilated, such as radiances from SEVIRI and IASI, AMV, Mode-S EHS winds and temperature, GNSS atmospheric humidity, scatterometer winds, etc. Some of these new observations such as Mode-S and AMVs might prove to be useful input to Nowcasting of clouds and precipitation. Furthermore, more research focus will lie on the surface data assimilation using remote sensing data. For model physics, development in cloud physics, boundary layer turbulence interaction with the surface and land surface modelling are foreseen. Development for specialized numerical predictions will be done within the fields of solar energy forecasting, wind energy forecasting, and road weather. An important aspect will be the development of probabilistic forecasts with a mesoscale EPS. For the long-range forecasting, decadal predictions will be further examined.

6.2.1 Planned Research Activities in NWP

Development of ensemble-based data assimilation schemes for upper air and surface are planned.

New observations have to be established in HARMONIE-AROME, such as Aeolus winds and more.

The spread-skill relationship in the mesoscale EPS will be improved.

A coupling between ocean surface waves and the atmosphere is planned to be included in HARMONIE-AROME.

6.2.2 Planned Research Activities in Nowcasting

Development of a nowcasting system based on the HARMONIE-AROME system is planned.

6.2.3 Planned Research Activities in Long-range Forecasting

The potential predictability for decadal predictions will be further examined with the EC-EARTH model.

6.2.4 Planned Research Activities in Specialized Numerical Predictions

Specialized predications will be continuously developed for solar energy, wind energy with a focus on the icing on wind turbines, and road weather.

More research activity is planned for urban meteorology using HARMONIE-AROME on 1km-scale and additional downscaling with radiative and fluid-dynamical models down to meter-scale.

7. References

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