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

Czech Republic/ Czech Hydrometeorological Institute

1. Summary of highlights

Czech Hydrometeorological Institute (CHMI) operates the high resolution ALADIN model. Recently, the production forecast has been prolonged up to 72 hours for runs from analysis at 0h, 6h and 12h UTC, while the run length from 18h analysis remains at 54 hours.

There has been a significant enhancement of the model physics, where two new schemes for turbulence and radiation were put in the operations. The turbulence parameterization named TOUCANS (Third Order moments Unified Condensation and N-dependent Solver) takes a full advantage of recent theoretical proposals, abandoning the concept of the critical Richardson number. The radiation scheme is conceived for high resolution short range NWP, enabling the interaction with rapidly evolving cloud scene at each model time-step thanks to the selective intermittent computations.

Data assimilation relies on the so-called BlendVAR technique, where a blending step ensures keeping the advantages from the advanced 4D-VAR data assimilation system of the host model ARPEGE at larger scales and where a 3D-VAR step acts on local scales. Recently the observations in use were enlarged by MODE-S MRAR aircraft data.

2. Equipment in use

The data processing centre is equipped with a vector supercomputer NEC SX-9, two nodes with 16 processors and 1 TBytes shared memory each. There are two front-end servers NEC Express 5800/140Rf-4 and Global File System NEC gStorageFS with capacity of 100 Tbytes.

A cluster of Oracle T5-8 servers for central database (Oracle 12c and RAC and partitioning) are used (128 cores, 4TB RAM, Solaris 11) including two NetApp FAS 8060 disk arrays (2 controllers, SSD Shelf 12x400GB, 7200 RPM Shelf 24x2TB, 10 000 RPM Shelf 24x 600 GB) installed at the end of 2015 Old Sun M8000 server is used as an developing environment.

Central cluster uses Solaris virtualization resource – zoning environment.

SAN 2/4/8 Mbps storage infrastructure is in operation in Prague.

The MSS at the DCPC RTH Prague consists of coupled Oracle Servers (Sun Fire X4470) and disc Arrays (NetApp FAS 3210) using the metro cluster technology. Software used for MSS is MovingWeather and Discover Weather SW - producer IBL Software Engineering

Backup activities are performed on the upgraded server Sun Fire V490 connected to the Qualstar TLS46120 tape library (software Legato).

Archiving activities are performed on the cluster of two Oracle T4-1 servers using disk capacity of Oracle ZS3-2 disc arrays and Tape Library StorageTek SL3000 (1200 slot licensed, 8x Tape Driver T10000D) .

System logs collecting was installed on SunBlade 6000.

Virtualisation platform service use one Oracle Blade chassis with 7 blade Intel processor based servers. One Blade server is used for service purposes. It uses VMware virtualisation software. Six Blade servers use KVM virtual machine platform software. Virtual servers, running on this platform, are LDAP master server, CHMI Identity Management system, web servers. All virtual servers are based on Linux.

Portal farm consist of Intel based four Web server 8000A and two Loadbalancer HW 400A2

Emergency air pollution dispersion model operations were also moved to new front-end servers of the HPC System. Each server is equipped by four Intel quad-core Xeon 7350 processors (2.93GHz) and 32GB of memory. They run under Linux SUSE operating system. The model development is now supported also by these front-end servers.

Branch offices use database services centralised in Prague now.
IBL Software product VisualWeather, Linux Server version was put in operation in headquarters and six branch offices in 2008 and updated at the end of 2013. Two servers are in each Branch Office.

3. Data and Products from GTS in use

- SYNOP
- SHIP
- TEMP
- TEMP SHIP
- PILOT
- AMDAR
- WINDPROFILER
- BUOY
- CLIMAT
- BUFR
- GRIB
- T4

The amount of data exchange in GTS is 155 000 messages (2,3 GB) per 24hour on Input and 250 000 messages (650 MB) on Output.

4. Forecasting system

4.1 System run schedule and forecast ranges

Medium range forecasting system (4-10 days):
We do not run such a system ourselves. We use NWP products from ECMWF (EPS products included), from NOAA/NCEP, MetOffice UK, and DWD.

Short range forecasting system (0-72 hours):
We operate the high resolution ALADIN System, which we developed jointly with other fifteen NM(H)Ss of the ALADIN Consortium (Termonia et al., 2017). The production forecast is run four times a day up to 72 hours (except the run from 18h UTC analysis, which length is 54 hours), with output frequency of 1 hour. We produce objective analysis, based on 3D-VAR and surface analysis every hour for the needs of nowcasting.

Besides, we use the ALADIN EPS configuration called ALADIN/LAEF, namely for the precipitation forecast, which is the result of the RC LACE consortium of seven Central European NM(H)Ss. ALADIN/LAEF is run twice a day up to 72 hours.

Nowcasting and very short range forecasting system (0-12 hours):
We operate a set of nowcasting tools, targeted namely for flash floods, developed by us. Where convenient, ALADIN System products are used in the nowcasting system.

4.2 Medium range forecasting system (4-10 days)

4.2.1 Data assimilation, objective analysis and initialization

4.2.1.1 In operation
"[information on Data assimilation, objective analysis and initialization]"

4.2.1.2 Research performed in this field
"[Summary of research and development efforts in the area]"

4.2.2 Model

4.2.2.1 In operation

"[Model in operational use, *(resolution, number of levels, time range, hydrostatic?, physics used)*] "

4.2.2.2 Research performed in this field

"[Summary of research and development efforts in the area]"

4.2.3 Operationally available Numerical Weather Prediction Products

"[brief description of variables which are outputs from the model integration]"

4.2.4 Operational techniques for application of NWP products *(MOS, PPM, KF, Expert Systems, etc..)*

4.2.4.1 In operation

"[brief description of automated (formalized) procedures in use for interpretation of NWP ouput]"

4.2.4.2 Research performed in this field

"[Summary of research and development efforts in the area]"

4.2.5 Ensemble Prediction System (EPS)

4.2.5.1 In operation

"[Number of runs, initial state perturbation method, perturbation of physics?]" *(Describe also: time range, number of members and number of models used: their resolution, number of levels, main physics used, perturbation of physics, post-processing: calculation of indices, clustering)*

4.2.5.2 Research performed in this field

"[Summary of research and development efforts in the area]"

4.2.5.3 Operationally available EPS Products

"[brief description of variables which are outputs from the EPS"

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

4.3.1 Data assimilation, objective analysis and initialization

4.3.1.1 In operation

For upper air model variables the so-called BlendVAR technique is used: the high resolution guess is blended first with the 4D-VAR analysis of the global model ARPEGE of Météo-France, which also yields lateral boundary conditions. Like that all the advantages of the advanced global data assimilation are preserved at larger scales, which can't be satisfactorily analysed over the limited area (Brožková et al., 2001). To improve the information at small scale part of the spectra owing to the high resolution of the model, a 3D-VAR analysis step (Fischer et al., 2005) is performed. Assimilated observation types: air pressure from ground stations, temperature, relative humidity, wind speed and direction from aerological soundings, radiances from Spinning-Enhanced Visible and Infrared Imager (SEVIRI) on board the geostationary Meteosat-10 satellite, derived satellite product AMV (Atmospheric Motion Vector), temperature, wind speed and direction from aircraft measurements AMDAR and from MODE-S MRAR.

Surface analysis is based on the optimum interpolation algorithm to analyse screen level variables. Analysis increments are then translated into soil variables' increments (Giard and Bazile, 2000). Assimilated observations are screen level temperature and relative humidity.

The assimilation cycle is run with 6h update. Besides, every hour an analysis is computed for purposes of nowcasting, combining 3D-VAR and surface analysis. For initialization, a weak incremental digital filter based on (Lynch et al., 1997) is used.

4.3.1.2 Research performed in this field

Research is performed on topics which are important for a high-resolution limited area model. It is a proper choice of background error structure functions on the one hand, suitable for the BlendVAR algorithm (Bučánek and Brožková, 2017), and selection of high resolution representative observations on the other hand. We investigate the use of MODE-S EHS data, appropriate satellite data bias correction adapted to the case of a limited area model, in near future we shall focus on the assimilation of radar reflectivity and on the 3h data assimilation cycling instead of the 6h one.

4.3.2 Model

4.3.2.1 In operation

The ALADIN model is a primary tool of short-range weather forecasting at the CHMI. It is a spectral limited-area model with horizontal resolution of 4.7 km (elliptical truncation 269×215 waves, linear collocation grid of 540×432 points, covering the whole of Central Europe) and 87 hybrid-type vertical levels.

Dynamics - hydrostatic primitive equations, two-time-level semi-implicit semi-Lagrangian scheme (Temperton et al., 2001; Radnóti et al., 1995); spectral discretization in horizontal, vertical finite element discretization in vertical (Untch and Hortal, 2004);
Horizontal diffusion: local selective semi-Lagragian interpolator based scheme (Váňa et al., 2008) is the main diffusion operator, completed by spectral diffusion especially at high atmosphere;
Physics: the so-called ALARO-1 version of physics parameterization is used. The interface to the dynamics is formulated in a flux form, according to the governing equations for moist physics (Catry et al., 2007)
Radiation scheme: broad band in solar and thermal spectra, NER (Net Exchange Rate) algorithm retained for the thermal band, cloud interaction every time-step, selective intermittency applied (Mašek et al., 2016; Geleyn et al., 2017);
Moist deep convection: 3MT (Multi-scale, Modular, Microphysics and Transport) prognostic scheme with memory (Gerard et al., 2009);
Microphysics: one momentum Kessler type, with parameterization of the processes based on Lopez (2002). The sedimentation is treated statistically with a variable fall speed (Geleyn, 2008). Geometry of cloudiness and falling precipitations is introduced to also cope with the sub-grid-scale condensation input, since the microphysics acts jointly on the grid-scale and sub-grid-scale (net condensation in the parameterized updraft) condensation input;
Turbulence and shallow convection: the so-called TOUCANS (Third Order moments Unified Condensation and N-dependent Solver) scheme is used, more concretely the so-called turbulence model II of Ďurán et al. (2014). There are two prognostic equations, one for the turbulent kinetic energy and one for the moist total turbulent energy. Third order moments are also parameterized.
A parameterization of sub-grid orographic effects comprises gravity wave drag, wave deposition and trapping, form drag and mountain lift effect according to Catry et al., (2008).
For surface model, ISBA (Interaction Soil Biosphere Atmosphere) scheme is used (Noilhan and Planton, 1989).

4.3.2.2 Research performed in this field

The research effort is oriented to the completion of the vertical finite element vertical discretization option for the non-hydrostatic fully compressible kernel, the multi-scale setting of the horizontal diffusion scheme and its interaction with turbulence.

In the physics we have completed a major step of developing new original schemes of radiation and turbulence, on which we shall capitalise. Currently works are done on the shallow convection closure, where a new way of computing moist Brunt-Vaisalla is explored, i.e. how to best account for phase changes due to condensation and/or evaporation of cloud water and ice. Further research goes on the unification of the cloudiness scheme used in microphysics and radiation schemes.

4.3.3 Operationally available NWP products

The raw and post-processed data outputs are produced every hour of the forecast on both the original Lambert-projection integration area (a 4.7 km mesh) and the transformed domains regular in the geographic coordinates with various resolutions and geographical areas. All standard variables are processed to pressure levels, PV levels, isentropic levels, height levels, screen level, completed by a set of specialised customised outputs (such as height of boundary layer, ventilation index, various computations of CAPE, CIN, moisture convergence, surface fluxes, etc).

Also time series are available both in graphical and simple text format
Forecasted and diagnostic fields are provided in GRIB format and netCDF format. Number of special products for downstream hydrological and environmental applications is provided, as well as customized data forms for various end users and publishers (defence, Integrated Rescue System, energy sector, transport sector, agriculture sector, TV broadcast, on-line media servers, and smart phones' applications, etc.).

4.3.4 Operational techniques for application of NWP products

4.3.4.1 In operation

"[brief description of automated (formalized) procedures in use for interpretation of NWP ouput]"
(MOS, PPM, KF, Expert Systems, etc..)

4.3.4.2 Research performed in this field
"[Summary of research and development efforts in the area]"

4.3.5 Ensemble Prediction System

4.3.5.1 In operation
C.f. RC LACE ALADIN/LAEF System.

4.3.5.2 Research performed in this field
Calibration of the precipitation EPS forecast of ALADIN/LAEF. Application of the BlendVAR algorithm in ALADIN/LAEF.

4.3.5.3 Operationally available EPS Products

From the ALADIN/LAEF System namely precipitation, screen level temperature, cloudiness and solar radiation are used at CHMI.

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

4.4.1 Nowcasting system

4.4.1.1 In operation
COTREC – areal radar echo extrapolation up to 180 minutes.

CELLTRACK – convective cells are approximated by radar reflectivity cores. CELLTRACK tracks and extrapolates reflectivity cores up to 90 minutes.

INCA – temperature, wind and precipitation analyses available to the public. Precipitation extrapolation and combination with NWP is computed up to 6 hours with 10 minute time step. Temperature and wind forecast computed with 1 hour time step up to 12 hours. This system is not developed further.

JSWarnView – gives warning to the observers if precipitation, hail probability or lightning activity is higher than given threshold.

JSMeteoView – displays primarily radar data and also other data sources (satellite, lightning, station data), GIS features

HydroView – precipitation analyses and forecasts for defined catchments, gives warnings for individual catchments if precipitation sums are higher than given threshold. It is performed when danger of floods.

FFG – Flash Flood Guidance – publicly available application. It computes soil saturation and hazardous short term precipitation rates that might trigger direct runoff. It also computes runoff response of small catchments and issues real-time flash flood warnings.

4.4.1.2 Research performed in this field
NWC SAF – Satellite Application Facility on Support Nowcasting and Very Short Term Forecasting software package produces several kinds of products – Cloud Products, Precipitation Products, Clear Air Products, Winds, Conceptual Model and Conception Products. Software runs automatically, its output isn't currently used operationally.

Two hydrological models are used for flash flood nowcasting in Brno regional office. Model HYDROG (also used in routine within the Flood Forecasting Service) and fuzzy logic based model. Both models are implemented for testing operation (HYDROG on 20 catchments and fuzzy model on 219 catchments). Final forecast is derived from a set of discharge forecasts based on various precipitation nowcasting input data.

CELLCOTREC – combination of CELLTRACK and COTREC extrapolation field is under development.

4.4.2 Models for Very Short-range Forecasting Systems

4.4.2.1 In operation

"[information on models in operational use, as appropriate related to 4.4]"

4.4.2.2 Research performed in this field

"[Summary of research and development efforts in the area]"

4.5 Specialized numerical predictions

MEDIA model: radioactive air pollutant dispersion model developed by Météo-France, is operated on an area covering the Czech Republic and surroundings using the meteorological fields forecast by ALADIN.

For information on a possible transport of air pollution from a more remote source, a simple trajectory model TRAJEK using the ECMWF deterministic forecast wind data is operated.

Hydrological forecasting systems AQUALOG and HYDROG, using real time observations and/or ALADIN precipitation and temperature forecast are run operationally to provide hydrological flow forecast.

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

4.5.1.1 In operation

"[information on the major data processing steps, where applicable]"

4.5.1.2 Research performed in this field

"[Summary of research and development efforts in the area]"

4.5.2 Specific Models (as appropriate related to 4.5)

4.5.2.1 In operation

MEDIA – radioactive pollution;
TRAJEK – pollution trajectory;
AQUALOG, HYDROG – systems for modelling runoff.

4.5.2.2 Research performed in this field

Optimal interface between atmospheric and river catchment models;
Implementation of the chemistry transport model CAMx coupled with the ALADIN atmospheric model.

4.5.3 Specific products operationally available

Pollution trajectories up to 5 days over large area;
Radioactive pollution concentration and deposition fields at high resolution; Other pollution concentration fields at high resolution;
Flow forecasts at selected water gauging profiles including ensemble forecast.

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

“[brief description of automated (formalized) procedures in use for interpretation of specialized NP output]”

4.5.4.2 Research performed in this field

"[Summary of research and development efforts in the area]"

4.5.5 Probabilistic predictions (where applicable)

4.5.5.1 In operation

Probabilistic hydrological forecast based on ALADIN/LAEF, 16 Members, twice a day, computed only when flood conditions are likely to arise.

4.5.5.2 Research performed in this field

"[Summary of research and development efforts in the area]"

4.5.5.3 Operationally available probabilistic prediction products

Simple tabular representation of probability of exceedance of flood limits within 6h periods covering 2 days lead time of the forecast.

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

4.6.1 Models

4.6.1.1 In operation

"[information on Models and Ensemble System in operational use, as appropriate related to 4.6]"

4.6.1.2 Research performed in this field

"[Summary of research and development efforts in the area]"

4.6.2 Operationally available NWP model and EPS ERF **products**

"[brief description of variables which are outputs from the model integration]"

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

4.7.1 In operation

"[Describe: Models, Coupled? (1 tier, 2 tiers), Ensemble Systems, Methodology and Products]"

4.7.2 Research performed in this field

"[Summary of research and development efforts in the area]"

4.7.2 Operationally available EPS LRF products

"[brief description of variables which are outputs from the model integration]"

5. Verification of prognostic products

5.1 Verification of the ALADIN forecast is made operationally with respect to ground measurements and radio-sounding measurements in the area of Central Europe. Conventional scores such as bias, root mean square error and standard deviation are computed for geopotential, temperature, wind and relative humidity (for upper air levels) and for temperature (also minimum and maximum), mean sea level pressure, wind, humidity, cloudiness, precipitation (6h) at screen level. Recent scores, they long term series, as well as their annual and trimestral gliding means are produced.

Besides, there are more elaborated verification tools for assessing quality of the quantified precipitation forecast, such as frequency bias, equitable thread score, fraction skill scores etc.

5.2 Research performed in this field

"[Summary of research and development efforts in the area]"

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

6.1 Development of the GDPFS

6.1.1 ALADIN: Switch to higher resolution of 2km, non-hydrostatic kernel.

Operational implementation of the chemistry transport model CAMx coupled with ALADIN. New associated products – forecast of NO_2, SO_2, PM10, PM2.5, O_3 and CO.

6.1.2 Higher forecast production cadence with ALADIN – passing to 8 runs per day, assimilation cycle at 3h, use of new observation types (e.g. radars). Use of aerosols' concentrations of the day. Further enhancements of the model physics, namely of the microphysics and use of the new surface scheme SURFEX.

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

6.2.1 Planned Research Activities in NWP
Data assimilation:
- futher improvements of the BlendVAR algorithm;
- optimal selection of satellite channels, variational bias correction of satellite data, use of MODE-S EHS data, use of radar reflectivities;
Model:
- non-hydrostatic dynamics – vertical finite elements, strong orographic forcing, interface to physics;
- microphysics – introduction of aerosols;
- cloud scheme – unification for radiation, microphysics, shallow and deep convection schemes, introduction of more memory;
- turbulence and shallow convection – moist turbulence, mixing length;
- radiation – enhancements to climate modelling use of the new scheme;
- surface – implementation of the SURFEX scheme (Masson et al., 2013).

6.2.2 Planned Research Activities in Nowcasting
Further development of the flash-flood warning system;
High frequency analysis.

6.2.3 Planned Research Activities in Long-range Forecasting

6.2.4 Planned Research Activities in Specialized Numerical Predictions
Optimal interface between atmospheric and river catchment models;
Emission processing improvement, study of biogenic NOx soil emission impact, development of very high resolution air pollution modelling tools adapted to major cities and industrial plants.

7. References

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