JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2015

Romania, National Meteorological Administration (NMA)

1. Summary of highlights

During 2015 the NWP activities in NMA were continued in the frame of ALADIN and COSMO consortia by participating to the development of both models and using their respective new versions in the operational activity.

2. Equipment in use

- Message switch on GTS is a MESSIR-COMM system (Windows HP Proliant server);
- NWP operational models are running on an IBM LINUX BLADE cluster (28 nodes, 14 nodes with 2 x Intel(R) Xeon(R) CPU E5450 3.00GHz, 4 nodes with 2 x Intel(R) Xeon(R) CPU X5560 2.80GHz and 10 nodes with 2 x Intel Xeon 6C Processor CPU E5-2620 2.0GHz/1333MHz/15MB, 12 x 300 GB RAW cluster storage) and on an 8 CPU SUN Enterprise 4500.
- Linux/Unix servers for different meteorological data pre and post processing purposes;
- CISCO routers and switches.

3. Data and Products from GTS in use

Daily statistics

- SYNOP - 520 (130 x 4 times)
- TEMP(US, UK) - 200 (100 x 2 times)
- GRIB(ECMF, LFPW, EGRR, EDZW) - 8700 (4350 x 2 times)
- T4 Charts - 50

4. Forecasting system

The Romanian forecasting system encompasses the near-real-time pre-processing of GTS, the reception and post-processing of NWP data (mainly ECMWF dissemination products), the local integration, post-processing and archiving of the outputs of limited area atmospheric models from the ALADIN and COSMO families and of the wave model (VAGROM).

4.1 System run schedule and forecast ranges

The run schedule and the forecasting ranges of the used numerical models are summarized in the table below:

Suite	Run schedule	Forecast range
ALARO-RO	00 / 06 / 12 / 18 UTC	+ 78 / 54 / 66 / 54 h
ALADIN-RO	00 / 06 / 12 / 18 UTC	+ 78 / 54 / 66 / 54 h
COSMO-RO 7 km	00 / 06 / 12 / 18 UTC	+ 78 / 24 / 78 / 24 h
COSMO-RO 2.8 km	00 / 06 / 12 / 18 UTC	+ 30 / 18 / 18 / 18 h
VAGROM	00 UTC	+ 48 h
INPUFF	00UTC	+78h

Table 1 - Run schedule and forecast ranges of the Romanian operational forecasting system

4.2 Medium range forecasting system (4-10 days)

There is no local medium range forecast system; the ECMWF model products are operationally used.

4.2.1 Data assimilation, objective analysis and initialization

4.2.1.1 In operation
None.

4.2.1.2 Research performed in this field
None.

4.2.2 Model

4.2.2.1 In operation
No medium range model is integrated within NMA.

4.2.2.2 Research performed in this field
None.

4.2.3 Operationally available Numerical Weather Prediction Products

The ECMWF model output from 00 and 12 UTC run: temperature, u, v and w wind components, geopotential and relative humidity at selected pressure levels (1000, 925, 850, 700, 500,400, 300, 200, 150, 100 hPa), surface and mean sea-level-pressure, 10 meter wind, 10 meter wind gust 2 meter air temperature and relative humidity, convective precipitation, large-scale precipitation, total precipitation, snow fall, snow density, low, medium and high could cover, total cloud cover, convective available potential energy, total vapour, 2 meter maximum and minimum air temperature, boundary layer height, potential and relative vorticity, divergence soil temperature at level 1, skin temperature and sea surface temperature.

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

4.2.4.1 In operation
MOS technique is being applied to the ARPEGE model since 1998, to the ECMWF model since 2004 and to the ALADIN model since 2000. The MOS techniques are similar: multiple linear regression (MLR) and logistic regression (LR) are used for MOS models which are updated every two years. Available products: daily maximum and minimum temperature, total cloud cover (in category), 6 hour precipitation (in category), speed and wind direction. The results for all Romanian surface meteorological stations (163) are displayed on maps and in a text format as well. A version of MIXT_MOS using MOS_ECMWF and MOS_ARPEGE is used to forecast extreme temperatures from 163 weather stations. The results of this model are better then individual models.

4.2.4.2 Research performed in this field
Research activities were performed in co-operation with METEO FRANCE for developing MIXT-MOS models using ECMWF and ARPEGE MOS for total cloud cover, wind speed and daily precipitation.

4.2.5 Ensemble Prediction System (EPS)

4.2.5.1 In operation
None.

4.2.5.2 Research performed in this field
None.

4.2.5.3 Operationally available EPS Products

The ECMWF EPS forecast for 10 m wind, 2m temperature and extreme forecast indexes are mainly used operationally in NMA.

A Pseudo PP system is applied to the ECMWF-EPS model. This version has been in use since November 2008 and produces extreme and 6 hour temperatures at 163 meteorological stations, as well as wind speed. Different products such as box-plot diagrams over selected regions and maps are provided to the forecasters, twice a day.
Since 2014 the Ensemble Prediction System – Probabilities are displayed on the small domain covering Romania for 2m temperature, wind speed, temperature anomaly at 850 hPa, 24 hour cumulated precipitation, step at the end of the period, total precipitation mean and rate, 10m wind gust probabilities, maximum wind gust over 24 hours, step in the middle of the period.
COSMO-LEPS products from 16 members are available for Romanian territory. 3 and 24 hours cumulated precipitation, 2m temperature, maximum and minimum 2m temperature and 10m wind speed for each COSMO-LEPS member and ensemble mean values are graphically represented. These products are available for 78 hours anticipation, two times per day at 00 UTC and 12 UTC. Graphical representations of the specified parameters are available both for the entire Romanian territory and for selected locations.

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

4.3.1 Data assimilation, objective analysis and initialization

4.3.1.1 In operation

ALADIN model versions (ALADIN-RO, ALARO-RO): The initial state comes from the French global model ARPEGE which is interpolated in the model grid trough a specific model configuration taking into account the surface characteristics in the LAM grid, followed by a digital filter initialization. No data assimilation is performed.

The COSMO model (version 5.03) at a 7-km horizontal resolution is run operationally in dynamic adaptation mode. The initial state is obtained by the interpolation of the ICON (Icosahedral non-hydrostatic)
analysis followed by a digital filter initialization. Assimilation of SYNOP data is used with a nudging scheme for temperature, humidity, wind and pressure for all four runs of the model. The COSMO model at a 2.8-km horizontal resolution is also run operationally in dynamic adaptation mode. The initial and boundary conditions are obtained by the interpolation of the COSMO-RO 7km output. Assimilation of SYNOP (nudging scheme for temperature, humidity, wind and pressure) and Radar derived rain rates (assimilation of near surface rain rates based on latent heat nudging) data are used.

4.3.1.2 Research performed in this field
The work for using 3D-VAR data assimilation technique in ALARO-RO model was continued. For an accurate analysis of the model, all the observation (conventional and satellite data) available in OPLACE (the common database developed within RC-LACE - Regional Cooperation for Limited Area modelling in Central Europe) were used. Thereby, the radiances from NOAA -18/19 ATOVS instruments (like AMSU-A, AMSU-B and MHS) and METEOSAT-9 (SEVIRI) were assimilated in the model, a variational bias correction being applied. In order to evaluate the impact of all the observations, a series of case studies were performed for severe weather events occurred in Romania.

The research activities regarding COSMO data assimilation in Romania are focused on assimilation of all available observation in the integration domains: SYNOP, TEMP, PILOT, RADAR, AMDAR etc. for both COSMO-RO 7km and COSMO-RO 2.8km models. For this purpose, all available observations in the GTS (Global Telecommunication System) have been archived and validated. A series of tests using each type of observation were made in order to establish their influence in the quality of the model forecast.

4.3.2 Model

4.3.2.1 In operation

ALADIN model is the limited area counterpart of the French global model ARPEGE developed within the consortium with the same name which today includes 16 countries.

ALARO-RO (a version of the ALADIN model developed by the RC-LACE consortium for higher resolutions):
Characteristics:

- 0-baseline version
- boundary conditions: from the global model ARPEGE with a 3-hour coupling frequency;
- domain: linear grid, Lambert projection, 6.5-km horizontal resolution, 240 x 240 grid points, vertical finite element discretization, 60 vertical levels;
- hydrostatic dynamics;
- semi-implicit semi-Lagrangean two time level advection scheme, Δt=240 s;
- physical parameterizations:
  - flexible physics-dynamics interface;
  - revised versions of orographic drag and diagnostic cloudiness schemes (Catry et al, 2007);
  - improved radiation parameterization (NER formalism for thermal radiation, new transmission functions for optical depth computation, a more sophisticated treatment of cloud optical properties, Geleyn et al, 2005);
  - pseudo-prognostic turbulent scheme pTKE;
  - prognostic and integrated treatment of the moist physical processes under a specific organization of their parameterization called 3MT (Modular, Multi-scale, Microphysics and Transport);
  - improved PBL height computation;
  - ISBA surface scheme.

ALADIN-RO model - back-up solution for ALARO-0
Characteristics:

- a frozen version cy28t3
- boundary conditions: from the global model ARPEGE with a 6-hour coupling frequency;
- domain: quadratic grid, Lambert projection, 10-km horizontal resolution, 144 x 144 grid points, 41 vertical levels;
- semi-implicit semi-Lagrangean two time level advection scheme, Δt=400 s;
- physical parameterizations: no prognostic variables for condensed water and precipitation, diagnostic mass flux convection scheme (Bougeault 1985).

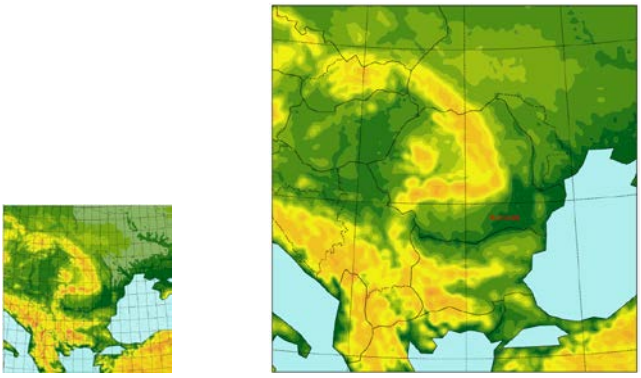

Fig.1 : Domains and model orography for ALARO- RO - left and ALADIN-RO - right

COSMO model (U. Schattler et all, November 2014) was developed in the Consortium for Small Scale Modelling (COSMO).

- Characteristics:
  - Non hydrostatic dynamics
  - 2-time-level Runge-Kutta time-split scheme
  - Numerical smoothing: 4-th order linear Horizontal diffusion with options for a monotonic version including an orographic limiter
  - Raylaigh dumping in upper layers
  - 3-d divergence damping and off-centering in split time steps
- Physical parameterizations:
  - ***Subgrid-scale turbulence***: Prognostic TKE closure at level 2.5 including effects from sub-grid scale condensation and from thermal circulations. Option for a diagnostic second order K-closure of hierarchy level 2 for vertical turbulent fluxes. Preliminary option for calculation of horizontal turbulent diffusion in terrain following coordinates (3D Turbulence).
  - ***Surface layer parameterization:*** A surface layer scheme based on TKE including laminar turbulent roughness layer. Option for a stability-dependent drag-law formulation of momentum, heat and moisture fluxes according to similarity theory (Louis (1979)).
  - ***Grid-scale Cloud and precipitation:*** Cloud-water condensation and evaporation by saturation adjustment. Precipitation formation by a bulk microphysics parameterization including vapour, cloud water, rain and snow with column equilibrium for the precipitating phases. Option for a new bulk scheme including cloud ice. Option for a 3-d precipitation transport.
  - ***Subgrid-scale clouds:*** Subgrid scale cloudiness is interpreted by an empirical function depending on relative humidity and height. A corresponding cloud water content is also interpreted.
  - ***Moist convection:*** Tiedtke (1989) mass-flux convection scheme with equilibrium closure based on moisture convergence. Option for the Kain-Fritsch 91992) convection scheme with non-equilibrium CAPE-type closure.
  - ***Radiation:*** δ-two stream radiation scheme (Ritter and Geleyn, 1992).
  - ***Soil Model*** – Multi-layer version of the former two-layer soil model after Jacobsen and Heise (1982) based on the direct numerical solution of the heat conduction equation. Snow and interception storage are included. Option for the (old) two-layer soil model employing the extended force-restore method still included.
  - ***Terrain and surface data:*** All external parameters of the model are available at various resolutions for a predefined region covering Europe.

- Domains: rotated latitude/longitude grid, Arakawa-C grid, generalized terrain-following vertical coordinate

1. COSMO-RO 7km
   - Horizontal resolution: 0.0625^0 (7km),
   - 201 x 177 grid points
   - 40 vertical layers

2. COSMO-RO 2,8 km
- Horizontal resolution: 0.0250 (2.8km)
- 361x291 grid points
- 50 vertical layers

- Boundary conditions
  1. COSMO-7 Km: from the global model ICON
  2. COSMO-2.8 Km: from the output of COSMO-7km:

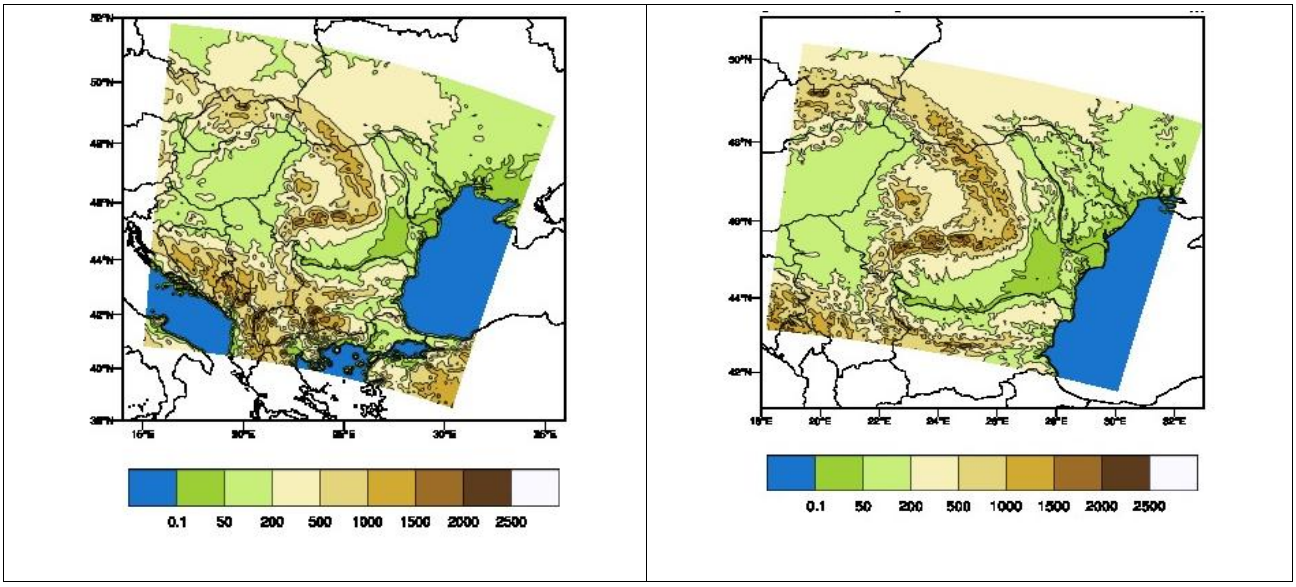

Fig.2 Domains and model orography for COSMO RO 7km (left) and COSMO RO 2.8 km (right).

4.3.2.2 Research performed in this field

ALADIN: The main research development activities were carried out within RC-LACE and ALADIN projects. Romania was involved in four main topics: physics (ALARO-1 physics testing), data assimilation, ensemble prediction system and dynamics. Also, wind in the lower atmosphere (up to 600 m above surface) from the ALARO simulations was compared with SODAR measurements at the Otopeni airport for two months period (May - July 2014).

COSMO: participation in Priority Projects developed in the frame of the COSMO Consortium: "VERification System Unified Survey 2", "NWP Meteorological Test Suite project", WG6-SPRT Support (on-going WG6 tasks) and "CDIC (Comparison of the dynamical cores of ICON and COSMO)".

4.3.3 Operationally available NWP products

- 2D fields: mean sea level pressure, surface pressure, surface temperature, convective and large-scale precipitation, cloudiness (low, medium, high and total), 10-m wind field, 2-m temperature, 2-m relative humidity, 2-m minimum and maximum temperature, pressure and temperature of the ICAO jet, total precipitable water, short wave radiation arriving to the surface, CAPE, MOCON, instability indexes.
  - COSMO: radar reflectivity
- 3D fields: available at several pressure levels, usually at: 1000, 990, 950, 925, 900, 850, 800, 700, 600, 500, 400, 300, 250, 200, 150, 100 hPa. The parameters are as follows: geopotential, temperature, wind, vertical velocity, relative humidity
- ALARO/ALADIN: pseudo-potential temperature, divergence, potential temperature, potential vorticity, absolute vorticity
- Diagrams: meteograms
  - COSMO: skew-T for 20 locations
  - ALARO: skew-T for 35 locations

4.3.4 Operational techniques for application of NWP products

4.3.4.1 In operation

The same method and techniques described in section 4.2.4.1 are applied for the short range forecast of the ECMWF, ARPEGE and ALADIN-RO models.

4.3.4.2 Research performed in this field

None.

4.3.5 Ensemble Prediction System

4.3.5.1 In operation

Locally none (ECMWF, COSMO_LEPS and ALADIN_LAEF products are used).

4.3.5.2 Research performed in this field

NMA contributed to the limited area EPS system LAEF developed in the frame of RC-LACE Consortium.

4.3.5.3 Operationally available EPS Products

- Graphical products available on the ECMWF and RC-0LACE web pages.
- ECMWF-EPS and COSMO-LEPS graphical products are locally generated for all Romanian meteorological stations (2-m temperature, 10-m wind speed, precipitation and cloudiness)

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

4.4.1 Nowcasting system

4.4.1.1 In operation

No specific nowcasting system is available to this purpose. Nevertheless, various limited-area NWP fields and parameters are used in addition to upper air sounding, AWOS, satellite, lightning detection and weather radar data to forecast, detect and monitor weather systems for the purpose of Nowcasting. All the above mentioned data sets are processed using dedicated software applications, some of these being able to integrate a great amount of data, thus making the final products available for analysis and display in a very rapid and user-friendly manner. These applications are operational at National Center for Forecasting, as well as at the Regional Forecasting Centres. National Meteorological Administration runs operationally weather radar data applications which make available to the forecaster a set of products very useful for the severe thunderstorm nowcasting, decision–making and warning system. Such products are tracking of convective cells, rainfall estimation, mesocyclone detection, probability of hail and severe hail. These products together with many other radar products and data enumerated above are used to issue storm-based warnings.

4.4.1.2 Research performed in this field

Current research is focused on improving the datasets available to forecasters, and to develop additional products that provide nowcasters with supplemental information to better forecast the convective events. Research on radar storm tracking algorithms is on-going, aiming at validation of the current algorithms and the development of new methods to track and predict the severe storms spatio-temporal evolution.

4.4.2 Models for Very Short-range Forecasting Systems

4.4.2.1 In operation

None.

4.4.2.2 Research performed in this field

None.

4.5 Specialized numerical predictions

The specialized numerical models concern the sea wave and air quality forecast respectively.

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

4.5.1.1 In operation
None.

4.5.1.2 Research performed in this field
None.

4.5.2 Specific Models (as appropriate related to 4.5)

4.5.2.1 In operation

VAGROM is an adapted version for the Black Sea of the French wave model VAGUE

- Spectral discretization: 18 directions of propagation and 23 frequencies
- Domain: 60 x 28 points, horizontal resolution: 0.25°x 0.25° latitude-longitude
- Input data: 10 m wind field from the ARPEGE NWP global model every 6 hours
- Output: every 6 hours in grib format

INPUFF
The INPUFF (INtegrated PUFF) code is designed to simulate dispersion from semi-instantaneous or continuous point sources over a spatially and temporally variable wind field. The algorithm is based upon Gaussian puff assumptions including a vertically uniform wind direction field and no chemical reactions.

Domain: 201x177 grid points,
Resolution: 0.0625^0 (7km),
Initial and boundary conditions: COSMO 7km

4.5.2.2 Research performed in this field
None.

4.5.3 Specific products operationally available

VAGROM : direction, mean period and height of wind and swell waves
INPUFF: maps showing the concentration and dispersion of pollutant in the wind field

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
None.

4.5.4.2 Research performed in this field
None.

4.5.5 Probabilistic predictions (where applicable)

4.5.5.1 In operation
None.

4.5.5.2 Research performed in this field
None.

4.5.5.3 Operationally available probabilistic prediction products
None.

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

4.6.1 Models

4.6.1.1 In operation

Locally none; ECMWF products are used.

4.6.1.2 Research performed in this field
None.

4.6.2 Operationally available NWP model and EPS ERF products

- Graphical products available on the ECMWF web site.
- The IFS_pseudoPP system applied to IFS ECMWF model has been in use since November 2008, to produce extreme temperatures at 163 meteorological stations. Different products: box-plot diagrams over a selected region, for one particular station and various maps are provided to the forecasters twice a week.

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

4.7.1 In operation
Locally none; ECMWF seasonal products are used.

4.7.2 Research performed in this field
None.

4.7.2 Operationally available EPS LRF products

The ECMWF seasonal forecast is used to produce a seasonal bulletin containing forecast maps for Romania area for the mean 2-meter air temperature in comparison with their corresponding multi-annual averages.

5. Verification of prognostic products

5.1 In operation

A dedicated web site is available for the verification of NWP products. Daily point-wise errors for all models -ECMWF, ARPEGE, ALADIN, ALARO and COSMO, maps and graphics are displayed daily on this web-site.

A monthly verification system (VERMOD) developed at NMA, has been in operation since 2007. The system performs direct model verification against point-observations for all available models: ECMWF – (0-180 h), COSMO (0-78 h), ALADIN(0-78 h), ARPEGE(0 – 102) and ALARO(0 – 78). Specialized statistical scores are computed for: 2-m temperature, total cloud cover, 6-hour total precipitation, wind speed, wind direction and components for all Romanian SYNOP meteorological stations. For continuous parameters, mean error, mean absolute error, root mean square error, correlation coefficients are computed along with Percent Correct, HSS, POD, FAR etc. for the categorical parameters. Confidence intervals are computed for all scores using the bootstrap method. Various types of graphics are updated monthly and are available on the web-site.
The GRIDSTAT tool implemented in 2014 is used in order to compare the NWP forecast quality with the corresponding observations using a grid to grid approach for the following parameters: 2m temperature, 10m wind speed, total cloud cover and relative humidity.

5.2 Research performed in this field
The MODE method was used for selective verification of total precipitation for specific cases.

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]*

6.1.2 *[major changes in the Operational DPFS which are envisaged within the next 4 years]*

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

6.2.1 Planned Research Activities in NWP

Continuous research activities in NWP will be carried out in the frame of the ALADIN and COSMO consortia as well as independently. The main point of interest is the improvement of data assimilation procedures for Romanian territory.

6.2.2 Planned Research Activities in Nowcasting

6.2.3 Planned Research Activities in Long-range Forecasting

6.2.4 Planned Research Activities in Specialized Numerical Predictions

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