**JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2012**

**ROMANIA, National Meteorological Administration (NMA)**

## 1. Summary of highlights

During 2012 the NWP computing platform was reconfigured for a better resources management allowing the NWP models upgrade to newer versions and the implementation of an air quality model.

Special efforts were dedicated to the implementation and testing of the data assimilation system for the limited area atmospheric models in use at NMA. The COSMO model operationally assimilates SYNOP data; pre-processing procedures for TEMP, PILOT and local RADAR were developed as well.

Significant improvements at the radar receivers and processing procedures have been made for the purpose of integrating the radar data into the OPERA European composite and for their use into the local assimilation system.

## 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 (18 nodes, 14 nodes with 2 x Intel(R) Xeon(R) CPU E5450 3.00GHz and 4 nodes with 2 x Intel(R) Xeon(R) CPU X5560 2.80GHz , 12 x 300 GB RAW cluster storage) and on an 8 CPU SUN Enterprise 4500.
- RETIM system for the reception of alphanumerical and binary data through satellite communication;
- 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)
GRID - 60 (30 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 (VAGROM) and air quality (CHIMERE) models.

### 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 /60 h |
| ALARO-SELAM | 00 / 12 UTC | + 78 / 66 h |
| ALADIN-RO | 00 / 06 / 12 / 18 UTC | + 78 / 54 / 66 /60 h |
| COSMO RO7km | 00 / 12 UTC | + 78 / 78 h |
| COSMO RO2.8km | 00 UTC | + 30 h |
| VAGROM | 00 UTC | + 48 h |
| CHIMERE | 00 UTC | + 78 h |

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

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. column ozone.

### 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 ECMWF since 1998. Multiple linear regression (MLR) and discriminant analysis (DA) are used for MOS models which are updated every two years. Available products: daily maximum and minimum temperature, total cloudiness (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.

4.2.4.2 Research performed in this field

Research activities were performed in co-operation with METEO FRANCE for developing a MIXT-MOS models using ECMWF and ARPEGE MOS for total cloudiness, wind sped and daily precipitation. Also, the Kalman Filter procedures will be applied on the MOS output.

### 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

At NMA in operations there are mainly used the ECMWF EPS forecast for 10 m wind and 850 temperature and extreme forecast indexes.

A Pseudo PP system is applied to the ECMWF-EPS model. This version is in use since November 2008 and it produces extreme and 6 hour temperatures at 163 meteorological stations, and wind speed. Different products: box-plot diagrams over selected region and maps are provided to the forecasters, twice on a day.

## 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 models**: The initial state comes from the French global model ARPEGE which is interpolated in the model grid trough a specific model configuration tacking into account the surface characteristics in the LAM grid, followed by a digital filter initialization. No data assimilation.

**COSMO** model at a 7-km horizontal resolution is run operationally in dynamic adaptation mode. The initial state is obtained by the interpolation of the GME analysis followed by a digital filter initialization. Assimilation of SYNOP data is used with a nudging scheme for temperature, humidity, wind and pressure.

#### 4.3.1.2 Research performed in this field

The 3D-VAR data assimilation for the ALADIN model was validated during 2012; it uses the common RCLACE (Regional Cooperation for Limited Area modeling in Central Europe) database. The tests carried out for February 2012 showed the beneficial impact of including local surface observations.

The research activities regarding COSMO data assimilation in Romania are focused on:

- SYNOP data assimilation using a nudging scheme for temperature, humidity wind and pressure
- RADAR-derived precipitation rate on the ground using a latent heat nudging scheme for the 2.8 km horizontal resolution.
- For COSMO at a 7-km horizontal resolution, the procedures to assimilate all available PILOT and TEMP data have been started.

### 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 encompasses 16 countries.

ALARO model: is a version of the ALADIN model

- Characteristics:
  - hydrostatic dynamics
  - semi-implicit semi-Lagrangean two time level scheme
    $\Delta t$=240 s for a 6.5- km resolution, $\Delta t$=450 s for a 11.5- km resolution
  - physical parameterizations: ALARO-0 set up (including a flexible physics-dynamics interface, a prognostic and integrated treatment of the moist physical processes under a specific organization of their parameterization called 3MT, pseudo – prognostic TKE scheme, radiation based on Geleyn Hollingworth with NER for thermal band, ….), surface ISBA scheme
- Domains: linear grid, Lambert projection
  1. ALARO-RO
     - 6.5-km horizontal resolution
     - 49 vertical levels,
     - 240x240 grid points,
  2. ALARO-SELAM: covers the entire Black Sea for marine applications
     - 11.5- km horizontal resolution
     - 49 vertical levels,
     - 240x192 grid points,
- Boundary conditions:
  1. ALARO-RO from the global model ARPEGE with a 3-hour coupling frequency
  2. ALAR_SELAM from the global model ARPEGE with a 6-hour coupling frequency

ALADIN-RO model**:** back-up solution for ALARO-RO

- Domain:
  - 10-km horizontal resolution,
  - 41 vertical levels
  - 144x144 grid points,
  - quadratic grid, Lambert projection
- Characteristics: a frozen version (cy28t3)
  - semi-implicit semi-Lagrangean 2TL; $\Delta t$=400 s
  - physical parameterizations: no prognostic variables for condensed water and precipitation, diagnostic mass flux convection scheme (Bougeault 1985)
- Boundary conditions: from the global model ARPEGE with a 6-hour coupling frequency

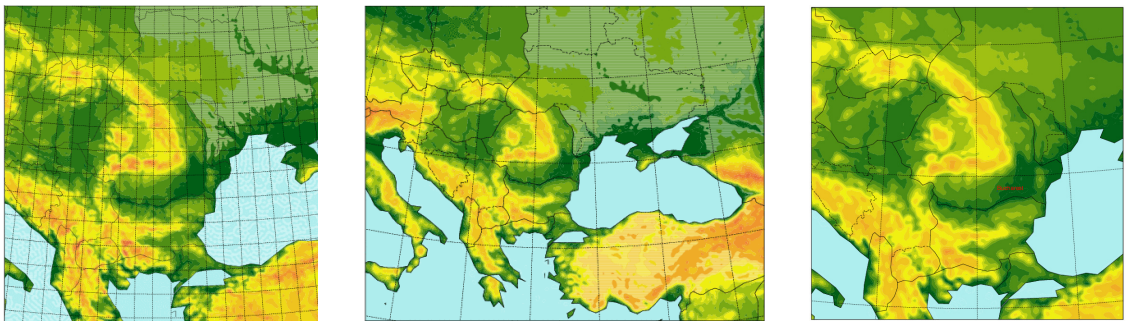

Fig.1 : Domains and model orography for ALARO- RO - left, ALARO-SELAM and ALADIN-RO - right

COSMO model was developed in the Consortium for Small Scale Modeling (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.
    - Surface layer parameterization: Surface layer scheme based on TKE including laminar turbulent roughness layer.
    - 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: 2-layer soil model after (Jacobsen and Heise, 1992) employing the extended force-restore method; snow and interception storage are included. Option for a new multi-layer version of the model based on the direct numerical solution of the heat conduction equation.
    - 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
     - $0.0625^0$ (7km),
     - 201 x 177 grid points
     - 40 layers

2. COSMO-RO 2,8 km
   - Horizontal resolution: $0.0625^0$ $0.025^0$ (2.8km)
   - 361x291 grid points
   - 50 vertical layers

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

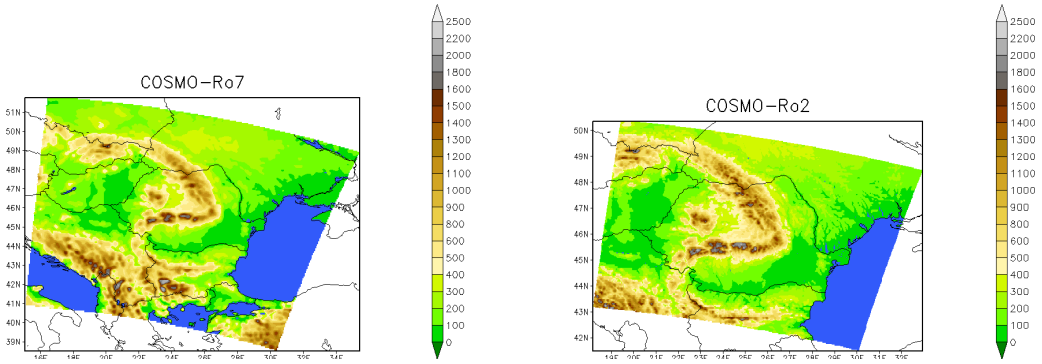


Fig.2 Domains and model orography for COSMO RO 7km (left) and COSMO RO 2.8 km (right).

#### 4.3.2.2 Research performed in this field

ALADIN: The main research&development activities are carried out within RC-LACE and ALADIN projects. Romania was involved in three main topics: physics (ALARO prognostic convection, AROME PBL representation function of vertical resolution, data assimilation and ensemble prediction system.

COSMO: participation in Priority Projects belonging to the COSMO Consortium: *"VERification System Unified Survey 2", "NWP Meteorological Test Suite project", "KENDA (Km-Scale Ensemble-Based Data Assimilation)".*

### 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: such fields are 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, vertical sections for 20 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

ANM contributed to the limited area EPS system LAEF developed in the frame of RC LACE (Regional Cooperation for Limited Area modeling in Central Europe) Consortium.

#### 4.3.5.3 Operationally available EPS Products

- Graphical products available on the ECMWF and RC LACE web pages.
- ECMWF-EPS and DOSMO-LEPS graphical products are locally generated for 163 meteorological stations in Romania (2-m temperature, 10-m wind speed, precipitation and cloudiness)

## 4.4 Nowcasting and Very Short-range Forecasting Systems (0-6 hrs)

### 4.4.1 Nowcasting system

#### 4.4.1.1 In operation

Various NWP fields and parameters, upper air sounding, AWOS, satellite, lightning detection and weather radar data are used to forecast, detect and monitor weather systems All data sets are processed using specific software applications making them available for analysis and display in the integrated visualization system at the National Centre and Regional Forecasting Centres.

Satellite data

- Enhanced color tables for channel IR10.8 for convective features;
- RGB images from MSG channels for specific nowcasting purposes (cloud microphysics, fog and low clouds, strong convection, dust, ash, fire and air mass)
- MSG NWCSAF version 2012 products for MSG images - operational: cloud mask, cloud type, cloud phase, cloud top temperature and height, convective rainfall rate (instant and 1- hour accumulation), precipitating clouds, SEVIRI physical retrieval products – total precipitable water, boundary/middle/high layer precipitable water, instability Indexes (K index, Lifted Index and Showalter Index).

Radar data

Weather radar measurements, both reflectivity and Doppler radial velocities, are used in the subjective recognition of several conceptual models developed for severe storm forecasting and recognition as well as storm radar signatures, in accordance with local climatology and local flows, for diagnose and for very-short range forecast purposes.

Weather radar data applications operationally generate a set of base products (reflectivity, Doppler velocity, spectrum width), and a large set of derived products (e.g., rainfall intensity, rainfall accumulations over certain intervals, maximum reflectivity, vertically integrated liquid, echo tops, VAD). In addition, the radar product generator outputs derived products (e.g. tracking of convective cells, tornado vortex signature, mesocyclone detection, probability of hail and severe hail) that are extremely useful for the forecaster in evaluating the storm environment and structure, thereby helping in the severe thunderstorm nowcasting and warning decision–making process.

#### 4.4.1.2 Research performed in this field

Currently, research activities are performed to improve the datasets and to generate additional products that may help nowcasters to better forecast the convective storms. Cloud-to-ground lightning climatologies were performed to illustrate the areas with a major risk to lightning strikes. Both radar data quality and quantitative precipitation estimation (QPE) studies are performed with the aim that the results should provide better data and improved QPE estimates. Studies on the adjustment of radar rainfall estimates using ground measurements provided by rain gauges, using various correction methods (e.g. mean field bias, geo-statistical methods) are undergoing.

Analysis of weather events (case studies) making use of satellite data (single channel and RGB´s) and SAF nowcasting products from MSG satellite, radar, NWP in case of flooding events, severe wind gusts, thunderstorms and heavy snow and blizzard.

### 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

CHIMERE model:

- Domain 1: 75 x 50 grid points (0.405 degrees horizontal resolution);
- Domain 2 (nest): 156x93 grid points (0.081 degrees horizontal resolution);
- Forecast range: one integration per day (00 UTC) up to 72 hours;
- Boundary conditions:
  - Domain 1: monthly climatologies of GOCART,MOZART,LMDzINCA
  - Domain 2: from Domain1
- Initial condition: EMEP emissions for the anthropogenic inventory and the MEGAN model output for the biogenic one;
- Dynamical parameters: from the NWP WRF model
- Vertical coordinate: sigma-pressure
- Vertical layers: 8 vertical layers, from ground level up to 500 hPa;
- Grid type: regulate latitude-longitude grid;
- Time Integration: Gauss-Seidel iterations;
- Chemistry mechanism: MELCHIOR2, includes the ISORROPIA code for gas/particle conversion

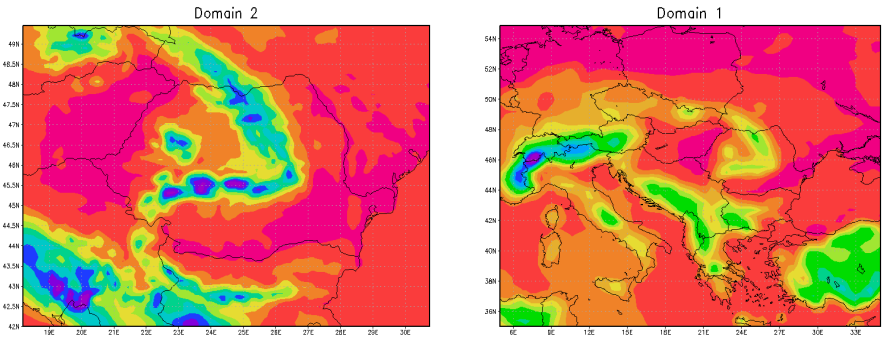


Fig.2: Domains and model orography for CHIMERE: Domain 1 (left) and Domain 2 (right).

4.5.2.2 Research performed in this field

None.

### 4.5.3 Specific products operationally available

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

- VAGROM : direction, mean period and height of wind and swell waves
- CHIMERE: NO, NO2, O3, SO2, PM10, PM2.5, CO, SO4, NH4, NO3, etc.

### 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.
- **IFS_pseudoPP** system applied to IFS ECMWF model are 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 [annual verification summary to be inserted here]

**Daily procedures**: spot daily errors - (direct model nearest point-observation) for all models - ECMWF,ARPEGE,ALADIN,ALARO and COSMO ; maps and graphs are displayed daily on the specialized web-site -"Statistical post-processing and Verification - **AS**".

**Monthly procedures:** The verification system **VERDMO –** developed at NMA performs direct model verification against point-observations. This system is in operation since 01 June 2007. The models verified are: ECMWF – (0-180 h), COSMO (0-78 h), ALADIN(0-78 h), ARPEGE(0 – 102) and ALARO(0 – 78). The verified parameters are: 2-m temperature, total cloudiness, 6-hour total precipitation, wind speed, wind direction and components, for 163 meteorological stations.(SYNOP messages).

Verification scores are: mean error, mean absolute error, root mean square error, correlation coefficients for the continuous variables and Percent Correct, HSS,POD, FAR etc for the categorical ones. For all scores we compute the confidence interval using the bootstrap method. Various graphs are monthly displayed on the web-site, for each model or all model scores are plotted on the same graph in order to compare the performance of the models over Romania.

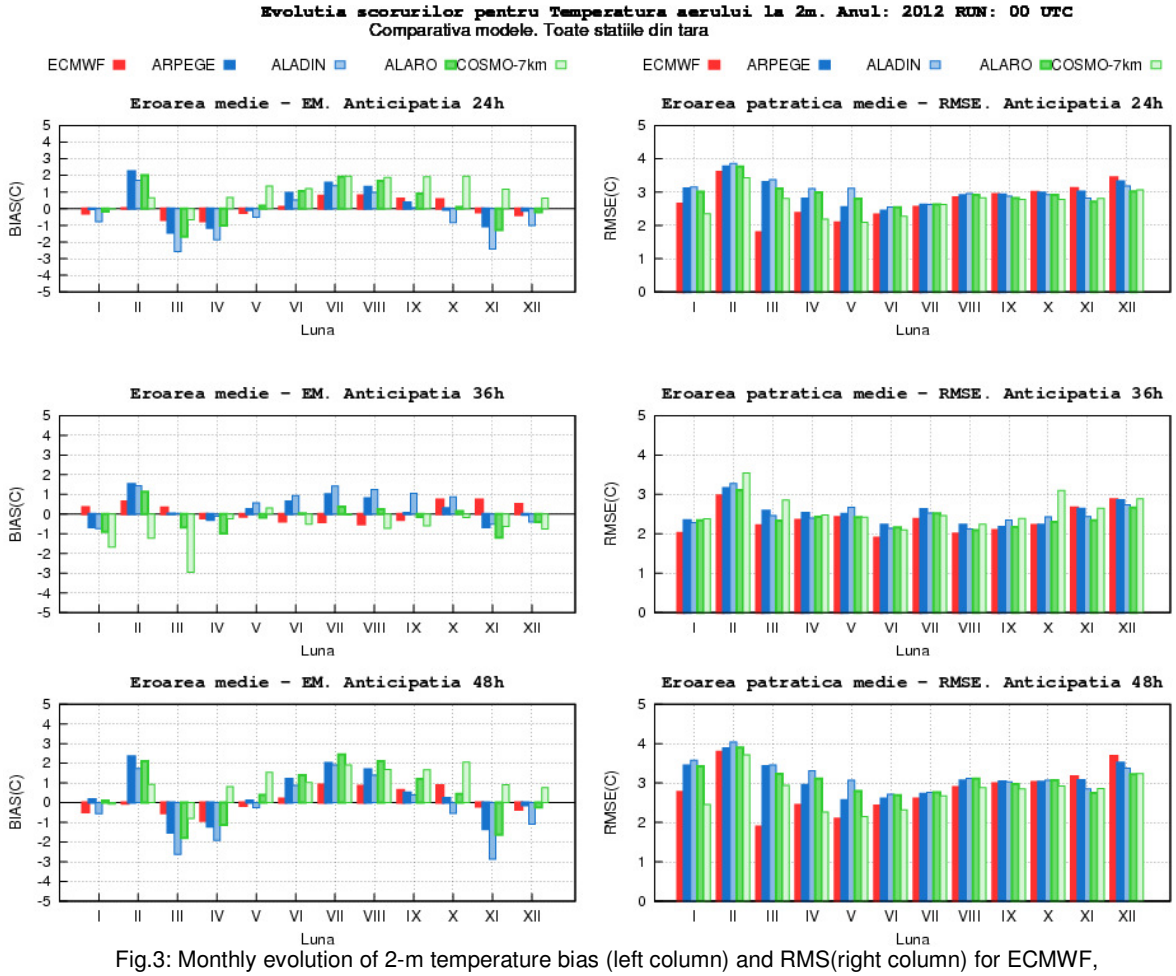


Fig.3: Monthly evolution of 2-m temperature bias (left column) and RMS(right column) for ECMWF, ARPEGE, ALADIN-RO, ALARO-RO, COSMO-7km models forecast: 2012, 00 + 24, 36 and 48 hours.

5.2 Research performed in this field

**Spatial verification**. We have tried to use the tools developed by NCAR -Metv4.0. Promising results were obtained using MODE intensity-scale decomposition approaches.

## 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 during 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

"[Summary of planned research and development efforts in NWP, Nowcasting, LRF and Specialized Numerical Predictions for the next 4 years]"

**6.2.1** Planned Research Activities in NWP

In the next years the improvement of the numerical models and data assimilation system will continue. For a more detailed forecast it is necessary to increase the model's resolution (especially the vertical one) and the domain's size but this depends on the computing power available in future.

**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

## 7. References


* * * www.cnrm.meteo.fr/aladin/
* * * www.cosmo-model.org/
* * * www.rclace.eu
* * * www.ecmwf.int