### Analysing mesoscale structures using the COSMO numerical weather forecast, case study - 9 Oct. 2010

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# 1. Introduction

Mesoscale convective systems are defined as an ensemble of convective clouds whose ascending currents are continuously fed due to mesoscale circulation, determining severe weather phenomena at ground level on an area of at least 100km. In the past years, in Romania as well as in other European countries a series of extreme weather phenomena have been observed: flash floods, intense wind and large hail. Such phenomena often produce material damage and loss of human lives. Given the context, weather forecasting and issuing warnings with a high degree of confidence is mandatory. Taking these facts into account, it follows that numerical weather forecasts at high resolution can be of real help in anticipating such phenomena.

The COSMO model was implemented and is running in the National Meteorological Administration twice a day for two spatial resolutions (7 km and 2.8 km). The numerical weather forecast from the model is processed and illustrated graphically and is used daily in elaborating the weather forecast.

On the 9th October 2010 Regional Meteorological Centre Constanța issued three "Warnings for immediate meteorological phenomena" addressed to the Ministry of Environment, Emergency Situation Inspectorate (ISU) and harbour master offices for the following regions: Constanța, Tulcea, Brăila, Galați, Ialomița and Călărași. The warned phenomena were: intense wind from North-West for the next 6 hours (medium speed 40 - 60 km/h, gust speed 75 - 85 km/h), especially in the west part of the Black Sea, at the seaside and in the Delta of the Danube. As an associated phenomenon: rain - in quantities of over 15-20  $l/m^2$  on local areas. The first warning was issued at 9.45 and was put up to date at 15.55 and 21.55.

The COSMO regional model anticipated the phenomenon since the 7th October 2010 (three days' anticipation), suggesting the formation of a mesovortex structure in the South-East of Romania and the Black sea seaside. The forecast for maximum wind speed from the COSMO model was approximately 70 - 80 km/h. Precipitation quantities estimated by the model also concur with the observed ones.

# 2. Data and methods

Starting with June 2009, the COSMO model is run twice a day for two spatial resolutions (7 km and 2.8 km), on two domains which cover the area of Romania.

Characteristics for COSMO-7 km:

• Domain dimension: 201x177 grid points, 40 vertical levels



Figure 1: COSMO operational domains in Romania

- Model version: 4.6
- Coordinates system: rotated geographical coordinates (lat/lon), with an Arakawa-C type grid
- Boundary conditions: interpolated from the data coming from the GME global model (00, 12 UTC)
- Spatial discretisation: second order centred difference
- Time integration scheme: Runge-Kutta (irk\_order = 3), time step dt = 72 sec
- 78 hours forecast period
- Data assimilation: surface observations

Characteristics for COSMO-2.8 km:

- Domain dimension: 361x291 grid points, 50 vertical levels
- Model version: 4.6
- Coordinates system: rotated geographical coordinates (lat/lon), with an Arakawa-C type grid
- Boundary conditions: interpolated from the data coming from the COSMO 7km run (00, 12 UTC)
- Spatial discretisation: second order centred difference
- Time integration scheme: Runge-Kutta (irk\_order = 3), time step dt = 25 sec
- 30 hours forecast period
- No data assimilation



(a) 08.10.2010 06 UTC



(b) 08.10.2010 18 UTC



(c) 09.10.2010 06 UTC



(d) 09.10.2010 18 UTC



(e) 10.10.2010 06 UTC

Figure 2: Satellite images

At the beginning of the analysed period (8-10 October 2010), of interest for the geographical space of Romania is the East-European Anticyclone, which extended over the North, Centre, East and South-East of the continent, and the barometric depression formed over the Middle East. A cold air nucleus centred above the East of our country and the black Sea was also observed in the medium troposphere (500hPa) - (see Fig. 2(a),2(b)). This nucleus had been detached from the trough previously situated above Russia; it was amplified and travelled South-East on the anterior side of the ridge which extended beyond the Ural Mountains.

During the day of 8 October, the cold air nucleus from the superior strata of the atmosphere led to the amplification of the mesoscale structure on ground level which was blocked from travelling East by the ridge which had extended to the area of the Caspian Sea. This led to an inverse - western - trajectory of the cyclone. On the 9th of October, the cyclone activity grew very much and the retreat of the anticyclone towards East allowed the cyclone to reach the East of Romania and the west of the Black Sea in its mature phase (Fig. 2(c), 2(d)). Subsequent, on the 10th of October the cyclone came to occlude (the axis which connected the ground nucleus to the one in the middle troposphere is vertical), gradually lost its intensity and averted from the country (Fig. 2(e)) (http://www.satreponline.org).

This synoptic context favoured strong wind intensification in the eastern and south-eastern parts of Romania, especially during the 9th October, when the cyclone was situated over these regions in its maximum intensity phase. The wind manifested mostly in Dobrogea, at the seaside and in the Delta of the Danube, where wind gusts reached a speed of 13 m/s to 30 m/s. The registered wind speed was that of 30 m/s at Mahmudia, 20 m/s at Sulina, 17 m/s at Mangalia, 16 m/s at Constanța. Higher quantities of precipitation were registered on the same day, over 15 mm locally and over 30 mm isolated (up to 52 mm at Adamclisi Constanța County). These quantities were mostly due to the wet air mass (containing water vapours from the area of the Black Sea), which was brought by the cyclone to the East of Romania.

The evolution of a mesoscale cyclone structure formed in the north-west of the Black sea could be observed on radar and satellite images (Fig.3) starting with the afternoon of 9 October 2010 up until the morning of the following day.



(a) Radar reflectivity

(b) RGB satellite image

Figure 3: 09.10.2010 - 18 UTC

## 3. Results

The mesoscale cyclone structure of Mediterranean provenance formed over the area of the Black sea on the 9th October 2010 was simulated by the COSMO model starting with the 7th October (Fig. 4(a), 4(b)), on a three days' anticipation. The model caught the breakthrough of cold air of polar provenance behind the front, as well as the maintaining of the warm air on its anterior side. The contact between the masses of cold and hot air is emphasised in the forecast from the COSMO model through the convergence line which can be observed in the parameter for wind.

Forecasts from the model in the following days (Fig. 4(d)-4(l)) confirmed the initial one, seizing the evolution in time of the cyclone until 10 October 2010 (Fig. 5(b)), when it occluded. The real evolution of the structured could be followed both on radar reflectivity (Fig. 3(a)), as well as on satellite images (Fig. 3(b), Fig. 5(a)).



(a) Forecast from 07.10.2010 +66 hours, 1000 hPa



Luc USALE-STemperatura, vileza, geopolential (1000 mb)

(b) Forecast from 08.10.2010 +42 hours, 1000 hPa



Luc Costen-remperatura, viteza, geoplerital (1000 mb)

(C) Forecast from 09.10.2010 +18 hours,
1000 hPa



(d) Forecast from 07.10.2010 + 66 hours, 850 hPa



850 hPa



(e) Forecast from 08.10.2010 +42 hours, (f) Forecast from 09.10.2010 +18 hours, 850 hPa 850 hPa



(g) Forecast from 07.10.2010 + 66 hours, 700hPa

700hPa

(j) Forecast from 07.10.2010 +66 hours,

500 hPa



(i) Forecast from 09.10.2010 +18 hours, 700 hPa



(k) Forecast from 08.10.2010 +42 hours, (l) Forecast from 500hPa 500 hPa

(l) Forecast from 09.10.2010 +18 hours, 500 hPa

Figure 4: COSMO 7km forecast: wind speed (vector), temperature (shaded), geopotential (contour) - 09.10.2010

According to the representation of the spatial distribution for the observed quantities of cumulated precipitation for 24 hours, in the area of Constanța County were measured quantities of over 25 de 1/m2 (Fig. 6(d)). The COSMO model estimated correctly the precipitation in both spatial distribution and quantities, starting with the integration from 7 October 2010 (Fig. 6(a)-6(c)). This can also be observed in the radar reflectivity parameter which was simulated by the model COSMO (Fig. 7(b)), which concurs with the satellite images for precipitation clouds (Fig. 7(a)).



(a) RHV satellite image

(b) COSMO 7km forecast on 09.10.2010 +32 hours, wind-10 m



#### Figure 5: 10.10.2010 - 08 UTC

Figure 6: 24 hours cumulated precipitation for 09.10.2010 (forecast from COSMO 7km and observations)

## 4. Conclusions

High resolution models on a limited area do not solve forecast problems entirely. Nevertheless, due to the higher spatial run-down in comparison to global models, they can prove to be of real support to the meteorologists in taking decisions regarding severe weather phenomena.

Numerical simulations made with the regional weather forecast model COSMO for the atmospheric instability situation on 9 October 2010 anticipated by the regional Meteorological Centre Constanța by three "Warnings for immediate meteorological phenomena" show that



(a) Satellite image - precipitation clouds (b)

(b) Radar reflectivity - column maximum COSMO 7km

Figure 7: 09.10.2010 - 11 UTC

the model has a high ability to forecast such phenomena.

After analysing different meteorological parameters from the COSMO numeric model (wind speed and direction for various atmospheric levels, air temperature, pressure and so on) the mesoscale cyclonic structure of Mediterranean provenance formed in the area of the Black Sea seaside on the 9th October 2010 could be identified. The phenomenon was correctly anticipated by the COSMO model starting with the day of 7 October 2010, three days previous to the occurrence of the phenomenon. The breakthrough of cold air of polar provenance behind the front, as well as the maintaining of the warm air on the anterior side of the cyclone which were visible on satellite images were also emphasised by the COSMO model. The contact between the two masses of cold and warm air is noticeable in the convergence line present in the parameter for wind.

The following runs of the COSMO model on the dates of 8 and 9 October 2010 confirmed the initial forecast and showed the evolution in time of the cyclone up to the date of 10 October 2010, when the structure occluded.

The parameter for cumulated precipitation in 24 hours was also correctly estimated by the COSMO model in both spatial distribution and quantities, starting with the run from 7 October 2010, as was the radar reflectivity parameter which concurs with satellite imaging of rain clouds.

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