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THE FOEHN WINDS IN NORTHERN OLTENIA. 18.08.2008 CASE STUDY

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Abstract: In Romania, foehn winds are short-time atmospheric phenomena of low-to-medium intensity, which do not appear always in the weather station-performed observations. Such situations require additional data to provide a larger and dynamic picture in comparison with the punctual information sent by stations. This paper aims to capture, present and analyze the characteristic parameters of northern Oltenia foehn winds, in the Carpathian-Balkan Internal Curvature. Herein, it is shown a typical foehn situation revealed by weather stations and also by satellite images (MSG), atmospheric radio soundings and numerical modeling.

Key words: foehn, northern Oltenia, climatic parameters, satellite images, atmospheric radio sounding, regional climatic model RegCM3

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INTRODUCTION

The Foehn, according to the World Meteorological Organization definition (1992), is a *wind warmed and dried by descent, in general on the lee side of a mountain.* It can occur any time of the year, but it is seen more often in winter and spring function of local circulation. Foehn winds depend on small-scale topographic features, although they require also adequate conditions on a larger scale than the regions wherein they occur.

The region of interest is located in South-Western Romania between the rivers Danube and Olt and the Carpathian-Balkan Internal Curvature's orographic barrage (figure 1). In 2007, Candrea putted into the GIS environment the geographical limits using the *„Geomorphological units"* (scale 1:800, 000) of Posea and Badea, 1984.

The northern Oltenia foehn is a small-scale phenomenon closely connected to the topographic features. In this regard a very fine measurement network is necessary to capture the phenomenon. In such context, METEOSAT8 (MSG) images have become a needed tool, given their fine temporal resolution (15 minute).

Regional Climatic Model RegCM3 output data for 23 altitude levels were also used, mostly for the active surface level (similar to station-recorded meteorological parameters) and the vertical levels related to the boundary layer and the lower troposphere (Kiehl at al., 1996; Ramanathan and Downey, 1986; Slingo, 1989; Dickinson et al., 1993; Giorgi at al., 1993).

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Unlike data recorded at weather stations (spaced more than 50 km apart), this model's outputs build up a unique database that describes 3-D meteorological parameters at a much higher resolution (10 km).

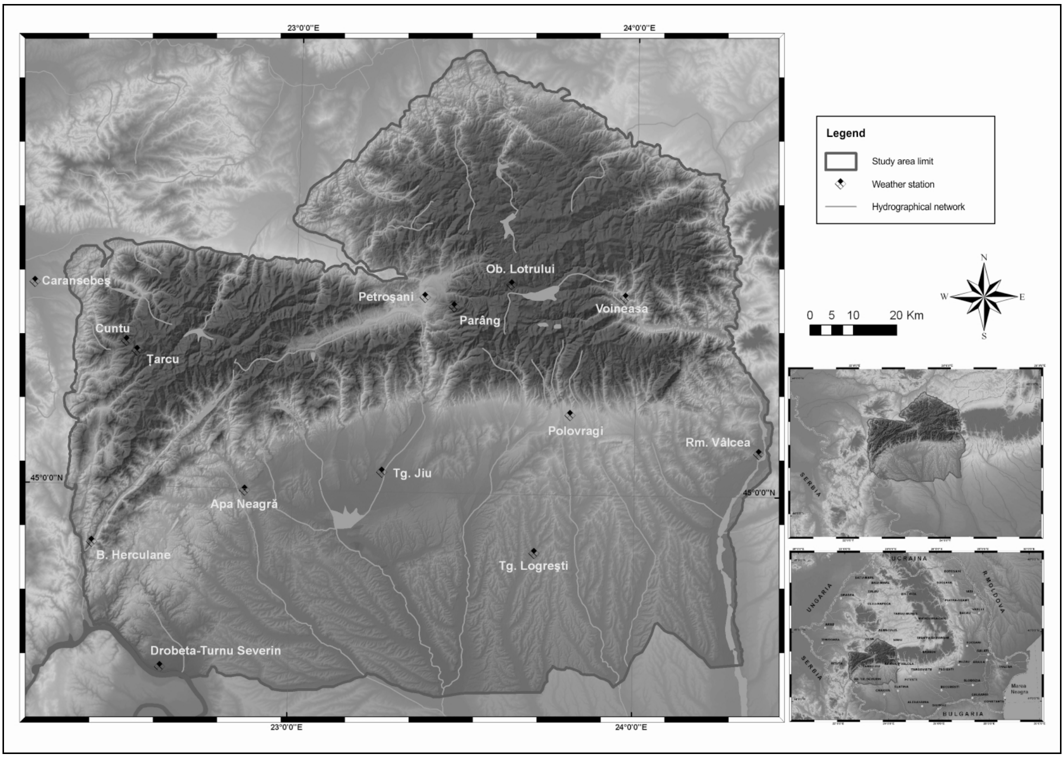

Figure 1. Location of the study area

AVAILABLE DATA

To identify and characterize a foehn in the interest region a number of data types have been used:

- synoptic maps;
- radio sounding data;
- meteosat Second Generation (MSG) images; images received every 15 minutes enable a temporal analysis of fast-developing meteorological events (the National Meteorological Administration archive);
- regional Climatic Model RegCM3 output data.

Standard climatologic analyses are mostly based on punctual data recorded by weather stations (the National Meteorological Administration archive) and include such parameters as air temperature, relative humidity and precipitation.

DATA ANALYSIS

To mark out the north Oltenia foehn, the quality of being representative was chosen as criterion for the 18 September 2008 situation.

Synoptic Analysis

Before this phenomenon, on ***17 September 2008,*** *12 UTC,* the synoptic situation over Europe was characterized by the presence of an Azores anticyclone centered on the North Atlantic, ridge extended north-east, while East Europe was under the influence of the East-European anticyclone that developed westward over the Scandinavian Peninsula, wherein the Scandinavian anticyclone was present. A baric low was interposed between these anticyclones areas, over the British Isles, in relation to a second low centered west of Portugal. The Mediterranean cyclone developed in the Eastern Mediterranean, extending its direct influence over Romania. It moved fast eastward so that at 18 UTC it was already centered over the Eastern Black Sea region.

On ***18 September 2008,*** *00 UTC*, the low centered over the British Isles disintegrated and the whole continent was under the dominance of an anticyclonic regime resulted from a merge between the Azores anticyclone and the East-European one. South-East Europe (the Eastern Mediterranean and Black Sea regions) was under the influence of the Mediterranean cyclogenesis (there were two cyclones in the Black Sea area). At 06 UTC, the North Europe anticyclonic belt extended southward a ridge that, in its motion along this trajectory, moved south-eastward the cold front of the cyclone centered over the Black Sea (figure 2). This situation continued over the next hours.

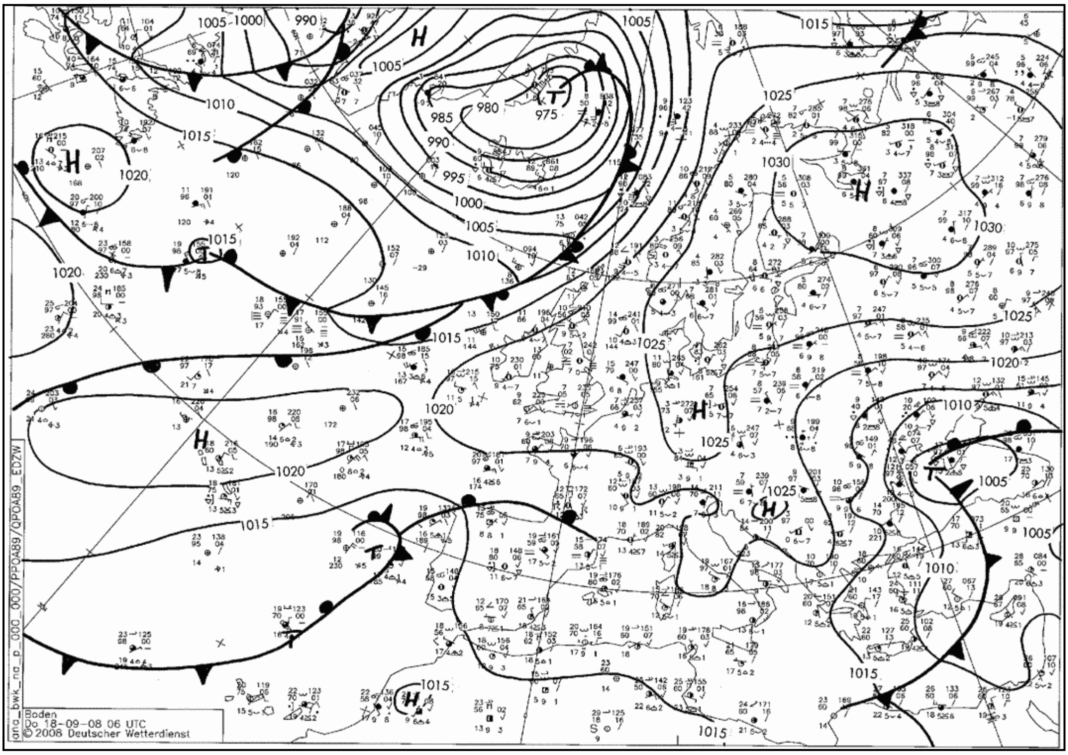

Figure 2. Spatial distribution of air pressure (Mean Sea Level Pressure) at 18.09.2008, 06 UTC (Source: www.wetter3.de)

Analyzing the satellite data information

In this context, the air masses came from north in the area of interest, which is clearly shown also on satellite images. Keeping watch over the evolution and motion of cloud systems on the 17 - 18.09.2008 METEOSAT8 images, it was found out the time when these systems changed direction (17 UTC) from south-west to north. It was also noticed the clear skies area is associated with the action of cloud-dissipating foehn (figure 3). This was a very large area. The above mentioned evolution continued throughout 18.09.2008. For this analysis there were used false-color images (product 018, R=WV6.2-WV7.3; G=IR9.7-IR10.8; B=WV6.2), to facilitate identification / detection.

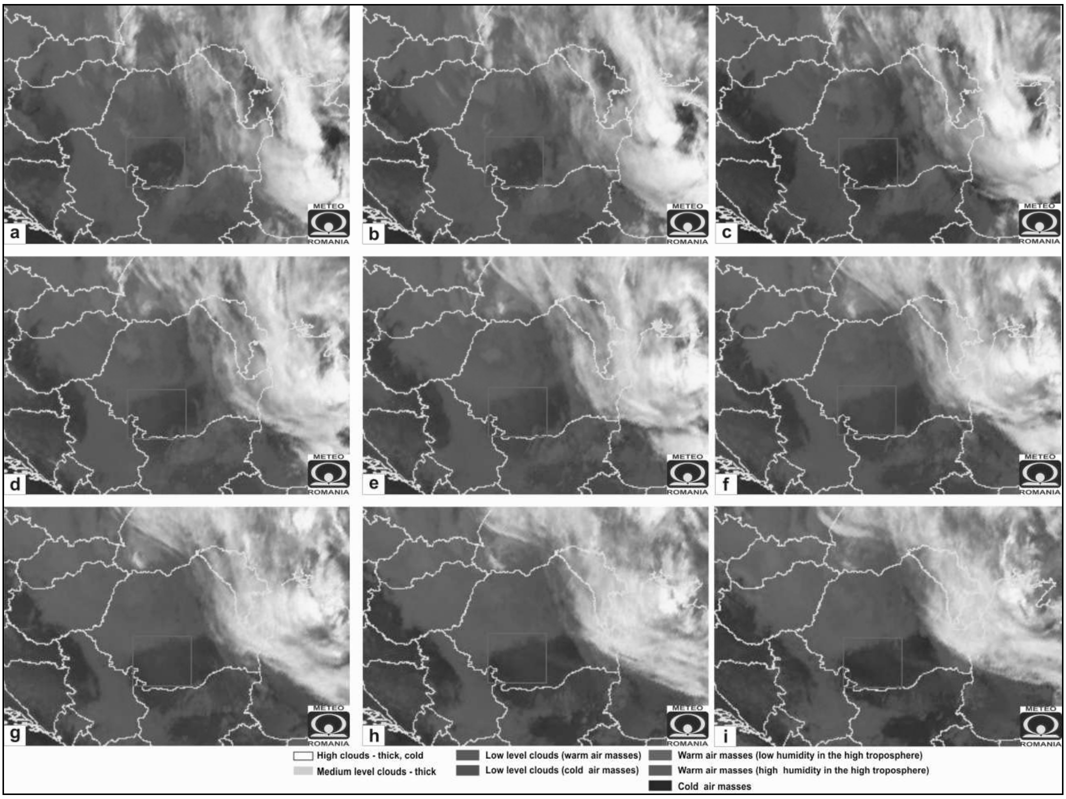

Figure 3. Evolution in time of cloud systems over the region of interest, 18.09.2008:
a) 00:00 UTC, b) 01:00 UTC, c) 02:00 UTC, d) 03:00 UTC, e) 04:00 UTC, f) 05:00 UTC, g) 06:00 UTC, h) 07:00 UTC, i) 08:00 UTC
(Source: data processed after MeteoRomania Archive)

Analyzing the radio soundings

On ***18.09.2008, 00 UTC***, this sounding revealed the presence of a colder sector and lower relative humidity at the Bucharest Station in comparison with the previous day, from ground level up to 1500 m altitude. Winds blew from south-east a few hundreds of meters from ground level and from north-east up to 3000 m altitude (figure 4).

Conditions changed at 12 UTC (figure 5):

- ***ground - level air temperatures were higher*** than a day before (there was recorded an increase in ***air temperature*** over the first 800 m while the ***equipotential temperature*** had a similar evolution only for the first 200 meters);

- ***relative humidity*** reached lower values than a day before from ground level to 5,000 meters and above;

- ***wind direction*** changed from the preceding radio sounding: south-westerly over the first 150 meters and westerly up to and beyond 10,000 meters.

Analyzing the meteorological data

On *18 September 2008*, *air temperatures* had the following features:

- a typical diurnal evolution at each analyzed station (Caransebeş, Târgu Jiu, Craiova and Țarcu);

- moderate diurnal amplitudes on the windward versant (1.4°C...2.1°C at Caransebeş and Țarcu, respectively) and more intense ones on the lee side (12.7°C at Târgu Jiu) as well as across the plains (10.0°C at Craiova);

- the thermal step between 06 UTC and 08 UTC was more marked across the Târgu Jiu depression as against the plain areas - Craiova Station (figure 6).

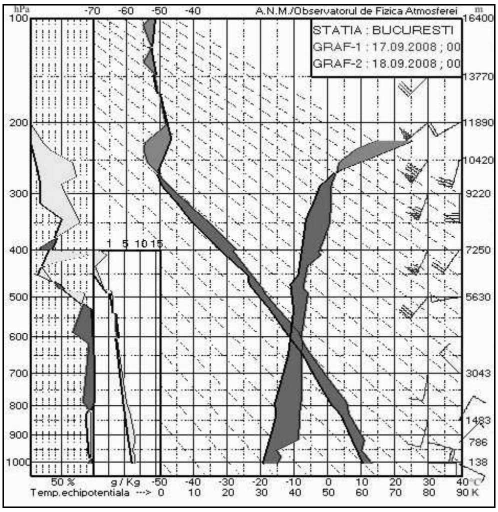

Figure 4. Atmospheric radio sounding on 18.09.2008, 00 UTC - Bucharest Station
(Source: data processed after MeteoRomania Archive)

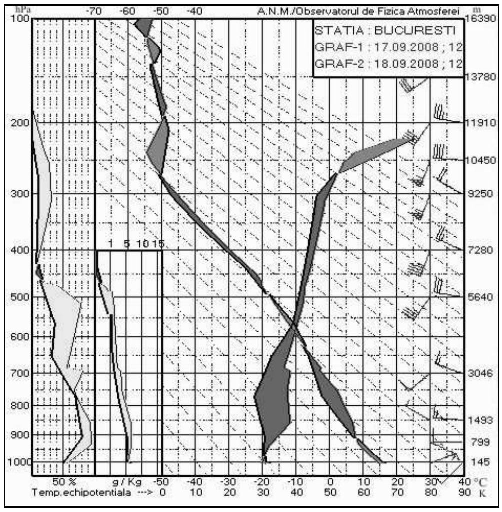

Figure 5. Atmospheric radio sounding on 18.09.2008, 12 UTC - Bucharest Station
(Source: data processed after MeteoRomania Archive)

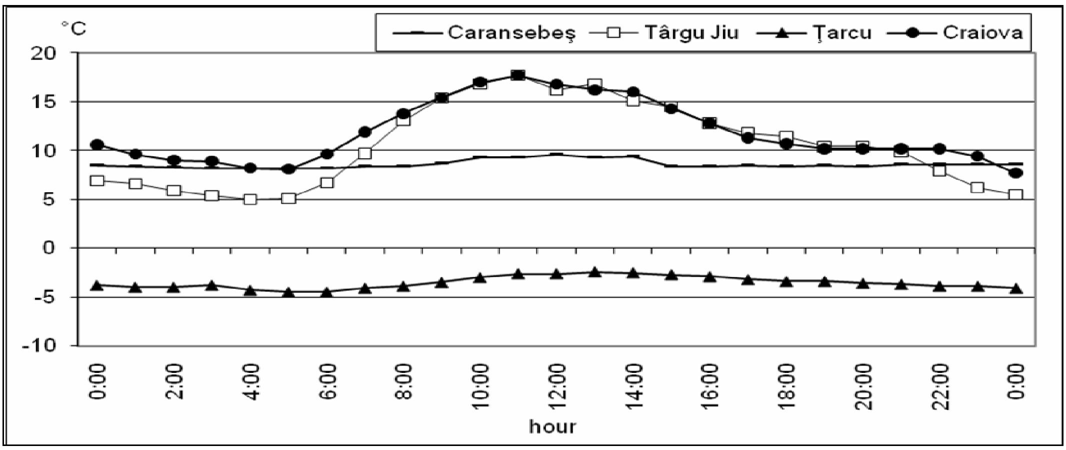

Figure 6. Air temperature evolution on 18.09.2008
(Source: data processed after MeteoRomania Archive)

An analysis of the ***relative humidity*** data showed that:

- on the windward versant (*Caransebeş)*, this parameter topped 80% throughout the day and 100% on the crest (*Ţarcu)*;

- on the lee side (*Târgu Jiu*) as well as in the plains (*Craiova)* these values ran down to 40% at 11 UTC (figure 7);

- from 10UTC to 21UTC, relative humidity at Târgu Jiu was lower than at Craiova.

A comparative analysis concerning ***air temperature and relative humidity*** revealed the presence of a foehn, which was highlighted by the fact that between 10 and 21 UTC, while temperatures were comparable, relative humidity was lower at Târgu Jiu than at Craiova, within different physical-geographical conditions.

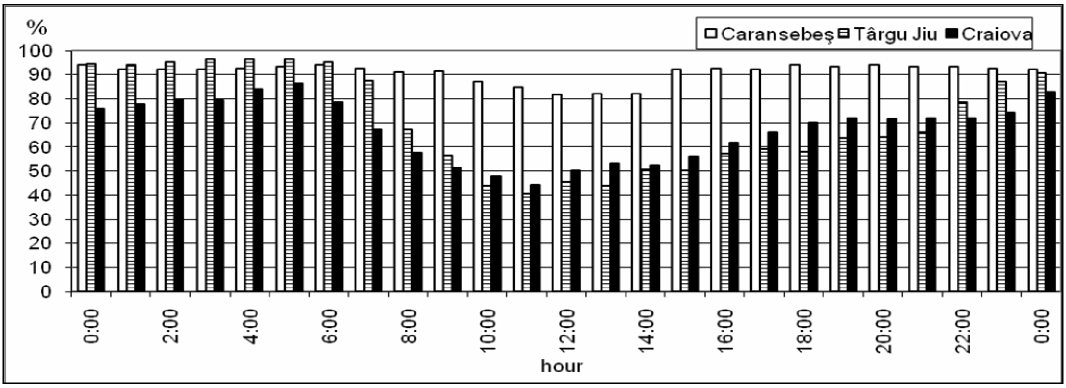

Figure 7. Relative humidity evolution on 18.09.2008
(Source: data processed after MeteoRomania Archive)

On the windward side, cloud formations brought on light atmospheric precipitation (1 - 10 mm), while on the lee side their absence caused a lack of precipitation (figure 8).

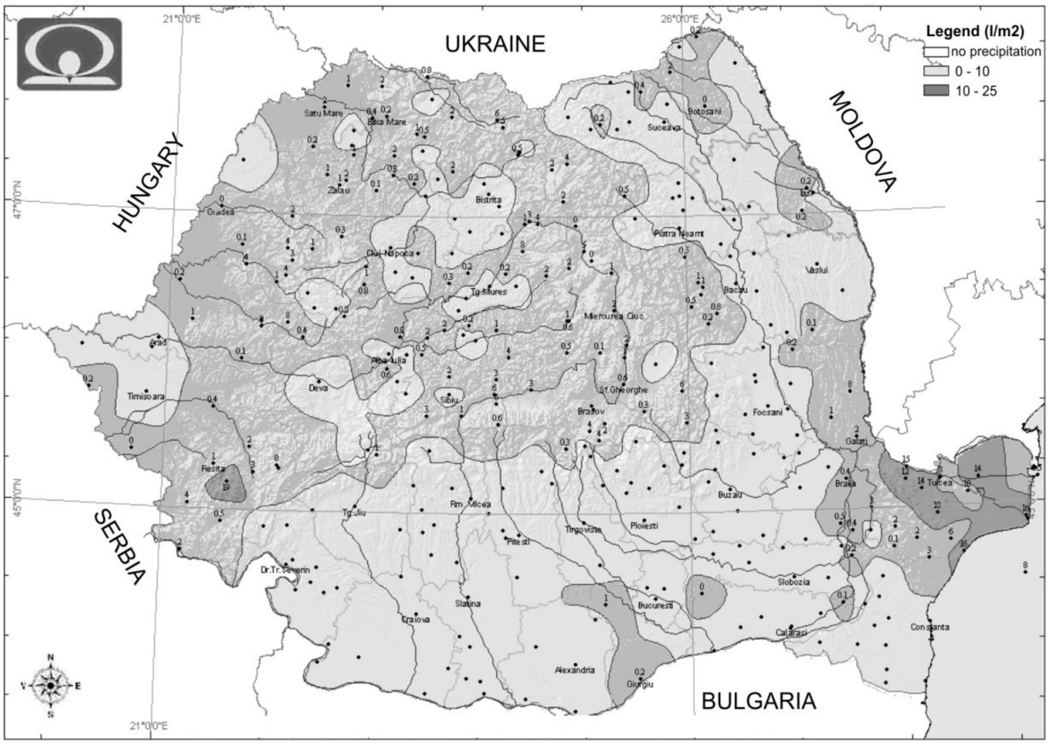

Figure 8. Spatial distribution of atmospheric precipitation on 18-19.09.2008
(Source: MeteoRomania Archive)

Numerical Modeling

By using the Regional Climatic Model RegCM3, there were analyzed the parameters connected to foehn action, grouped as follows: ***active surface-related parameters*** (2-m air temperature, 10-m wind speed and direction, distribution of precipitation); ***parameters derived from a vertical scan of the atmosphere*** (vertical air motion - upward / downward, air temperature, wind speed and direction, derivative of temperature).

The *first lead* is given by the *evolution in time of active surface-related temperature, wind speed and direction*. After analyzing these parameters, it was noticed an increase in temperature of about 1.5°C (figure 9, empty circle), winds from north (figure 9, full circle) with intensifications of at least 2.5m / s (figure 9, full quadrate) from 00UTC to 03UTC. Therefore, the first two criteria to identify a foehn were met.

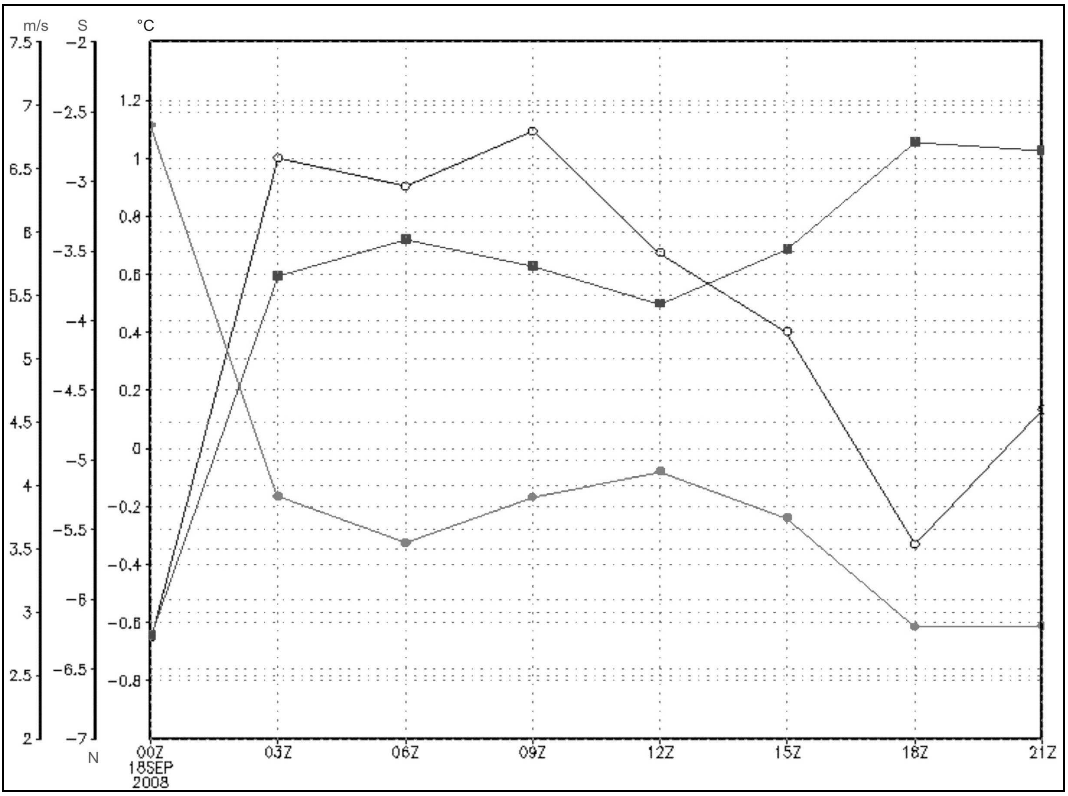

Figure 9. Evolution of temperature differences between the two reference regions (empty circle), meridional flow (full circle) and wind speed (full quadrate) on 18.09.2008
(Source: data processed after MeteoRomania Archive)

To mark out the above mentioned features, it was analyzed the space distribution of these parameters at model-related times (three hours for the active surface and six hours for the vertical evolution). So, at 06 UTC, on the active surface level there were several warmer areas in the region of interest (a 2°C difference in relation to the adjoining environment), winds from north and higher speeds beyond the mountain obstacle (figure 10).

At ***15 UTC,*** the warmer surfaces were still present and wind speed kept its 06 UTC features (figure 11). As it can be noticed, winds blew mostly from north across Romania, which can also be seen by analyzing the synoptic maps.

The analysis by vertical sections was focused on the following parameters: temperature, vertical motion of air (vertical velocity omega), wind speed and direction, and derivative of temperature. The first three were analyzed for five longitudinal profiles between 46°N and 43°N, while the derivative of temperature ($\partial T / \partial z$) was calculated for latitude profiles ranging between 23°E and 24°E. The vertical section-measured air temperatures for 23°E longitude show a difference of 6°C between the lee side and the windward one (up to 950 hPa). The warming process on ground level reached a high between 44.6 and 45.0°N, while wind speeds were highest a few latitude degrees to the north (figure 12).

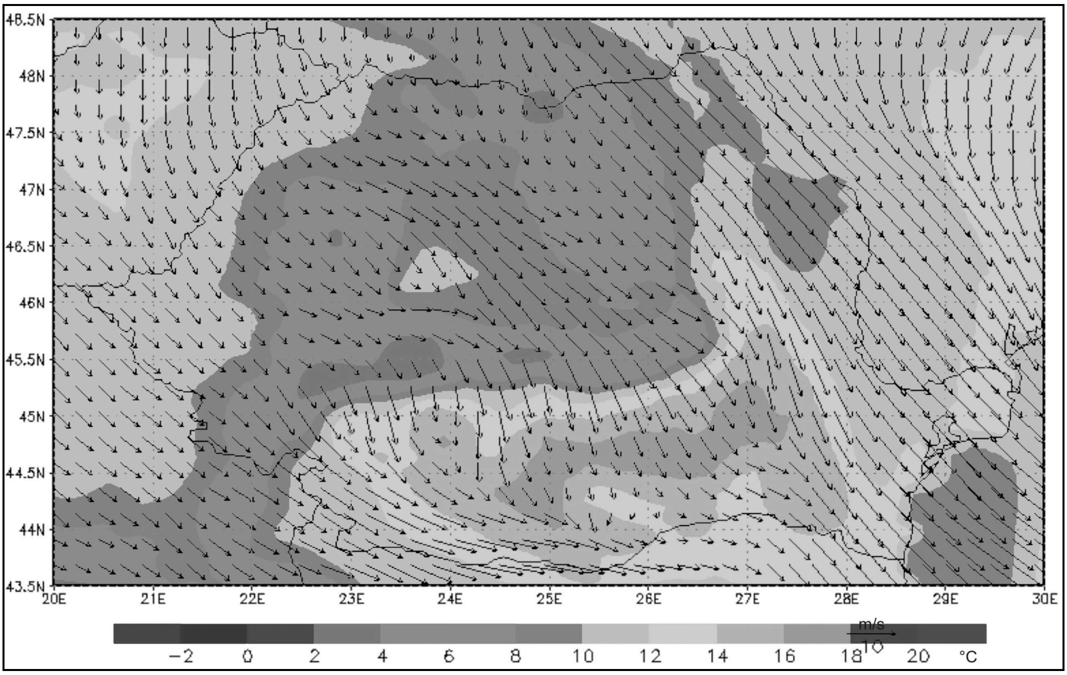

Figure 10. Spatial distribution of air temperature, wind speed and direction at 18.09.2008, 06 UTC
(Source: data processed after MeteoRomania Archive)

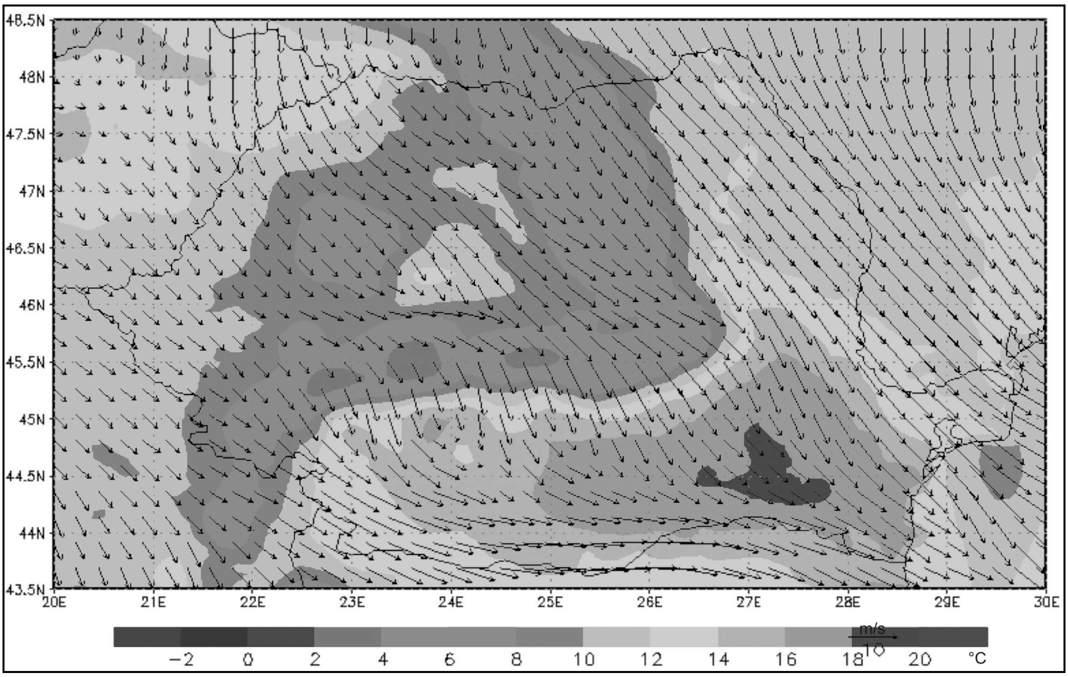

Figure 11. Spatial distribution of air temperature, wind speed and direction at 18.09.2008, 15 UTC
(Source: data processed after MeteoRomania Archive)

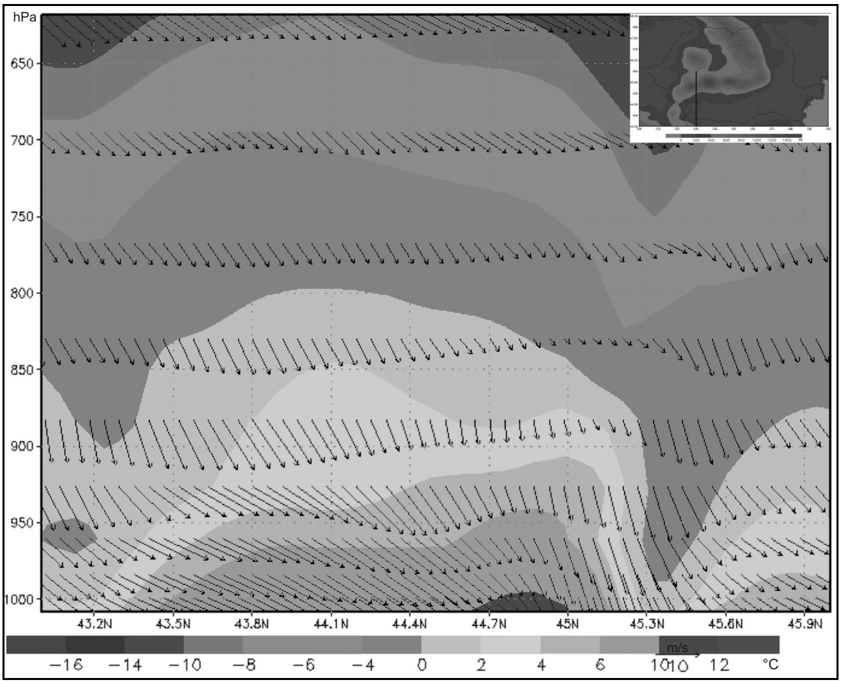

Figure 12. Distribution of air temperature (colored contour) and wind speed and direction (vector), 18.09.2008, 06UTC (vertical section, 23°E longitude)
(Source: data processed after MeteoRomania Archive)

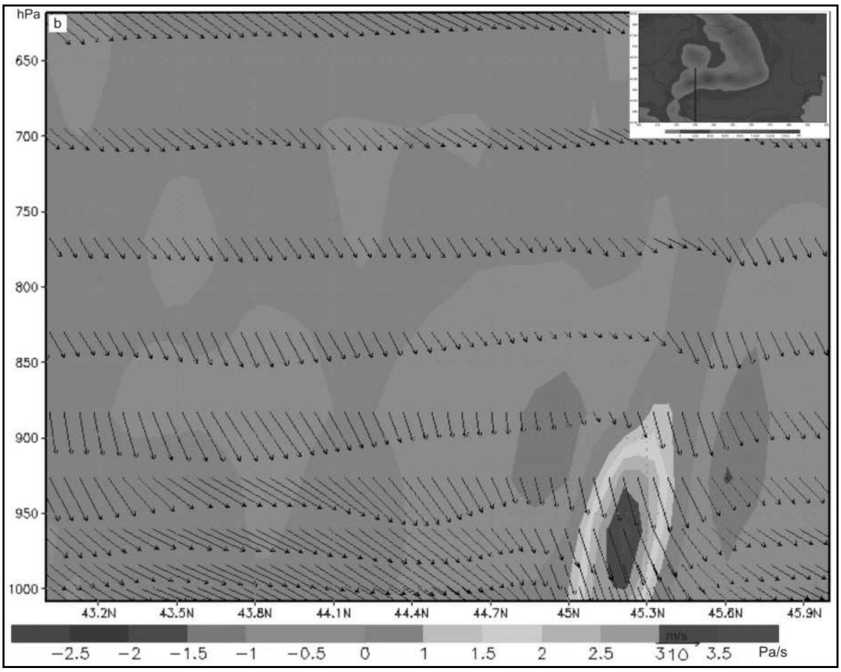

Figure 13. Vertical velocity omega (colored contour), wind speed and direction (vector), 18.09.2008, 06UTC (vertical section along 23°E longitude)
(Source: data processed after MeteoRomania Archive)

Figure 13 shows the ***vertical motion by vertical velocity omega*** $dP/dt*10^{-3}Pa/s$, where the negative values stand for upward motions and the positive ones for downward motions. On 23°E longitude, ascending air reached maximum speed at 45.6°N latitude, while the descending motion started at 45.4°N latitude and got highest speeds at 45.2°N latitude, followed by a new ascending motion (mostly above the ground level, while on ground level it could be noticed only around 44.6°N latitude) and again by a new descending one.

Afterwards, these waves could be found only in altitude, which highlights the undulatory motions of air when an obstacle is crossed – the Scorer-Klieforth theory (Atkinson, 1981). Taking into account the topography of the model, it can be noticed that, at this longitude the greatest heights are located on 45.35°N latitude. Therefore, air ascends on the windward side, while the descending motion occurs right after the crest is reached. It should be emphasized that the ***horizontal movement of air reaches highest speeds along the sectors of downward motion, from North-North-West.*** Above 45.9°N latitude, winds blow West-North-West on the first horizontal levels, tending to go round the mountain.

The North-North-West direction prevails along the entire height of the section.

The last element to analyze was the distribution of precipitation over the active surface. At 06 UTC, precipitation fallen during the previous three hours reached 20-30 mm north of 45.5°N latitude, on the windward side of the mountain, while on the lee side there were not recorded any precipitation amounts (figure 14).

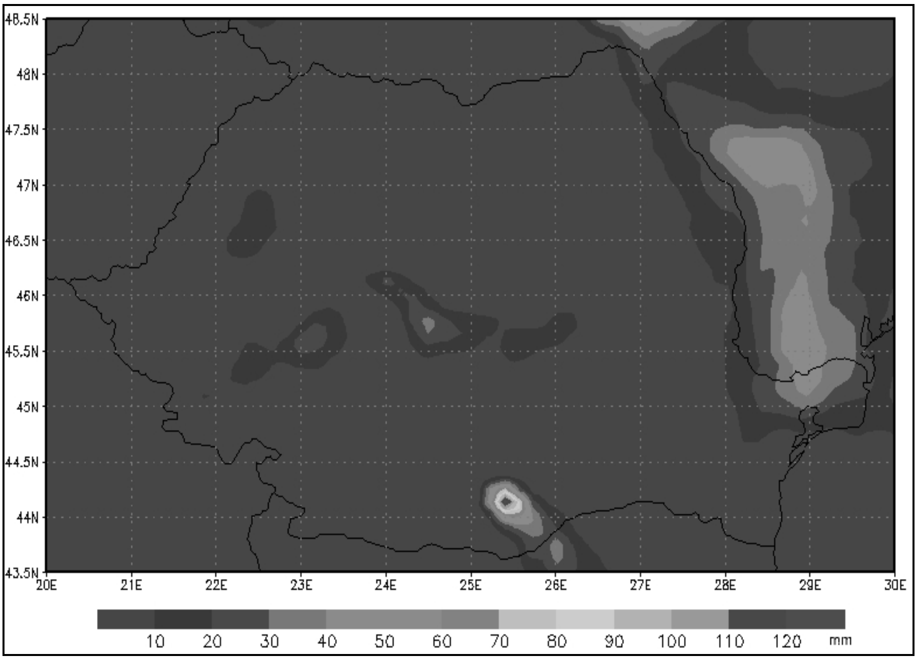

Figure 14. Distribution of atmospheric precipitation on 18.09.2008, 06 UTC
(Source: data processed after MeteoRomania Archive)

CONCLUSIONS

The intensity of foehn winds in the area of interest is significantly diminished as this area is located inside the curvature formed by the Carpathians and the Balkan Mountains. Foehn winds here have not the intensity of those in the Alps, whose effect is much more increased by the higher altitudes and a perpendicular orientation in relation to the more humid air masses, as against the Southern Carpathians case.

As the program of observations and measurements is getting shorter and some weather stations are liquidated, the features of foehn winds will be marked out and analyzed using the ***regional climate model RegCM3 results*** (with high space-time resolution: 10 km and 3 hours for the active surface and six hours for the vertical evolution), ***atmospheric radio sounding and satellite images,*** which add to ***the climatic information.***

From a synoptic point of view, the presence of fully developed cyclones in the Black Sea region and the anticyclonic belt of Northern Europe generated favorable conditions for foehn winds to occur on 18.09.2008 in the area of interest.

Every analyzed element confirmed the occurrence of foehn winds on 18.09.2008, which developed in the well known manner.

The features of the 18.09.2008 foehn winds are marked out by the following observations:

- ***air temperatures*** in the vertical section differed by up to 6°C between the two versants of the Southern Carpathians within the area of interest, the highest ground-level warming having occurred between 44.6 – 45.0°N latitude;

- ***relative humidity of air*** was recorded with differences of 40% between the lee side (Târgu Jiu Station) and the windward side (Caransebeş Station);

- ***wind speed*** from North-North-West reached highs along the sectors of downward motion, the most intense gusts having been recorded upstream the area of highest warming;

- ***precipitation*** on the windward side of the mountain reached up to 20-30 mm, while on the lee side they were absent;

- ***upward and downward motions*** (vertical velocity omega) provided information regarding the presence of undulatory motions (waves) on the lee side.

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