A SPECIAL FOEHN CASE IN NORTH-EASTERN APUSENI MOUNTAINS

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ABSTRACT. - A special foehn case in the North-Eastern Apuseni Mountains. The paper presents a case study for the 9-10 January 2015 period, when foehn processes were occurred on the eastern slope of the Apuseni Mountains. With a view to establishing the synoptic context in which the phenomenon was manifested, an analysis of the atmospheric fields was used, while for determining the intensity of the process several meteorological parameters (temperature, wind and relative humidity) were analyzed along three west-east profiles across the Apuseni Mountains. The analysis points out the presence of foehn processes on the eastern part of the Apuseni Mountains, the highest thermal and hygric differences being recorded on the north-eastern part of the mountains. The most important effect of this synoptic situation was the reduction of the snow cover depth.

Key words: foehn, Apuseni Mountains, occluded front, snow cover

1. INTRODUCTION

According to scientific literature, the foehn is considered to be a local short-lasted katabatic wind, warm and dry, which originates in the upwards displacement of humid air over a high enough orographic barrier, resulting in water vapor condensation, and then the descent of the air in the lee side, as a dry and warm wind, called foehn (Ciulache, 1987, Bogdan, 1993).

The genesis of this phenomenon is complex, and the theories explaining this process are varied. Hann (1866) explained the air heating on the lee side through thermo-dynamic processes, not linked to water vapor condensation. Bilwiller (1899, see Irimescu, 2014) shows that the process described by Hann does not differ from the heating resulted through anticyclonic subsidence. Ficker (1953) explains the air descent by the hydraulic bounce theory, showing that the downward wind is frequently associated with a thermal inversion located over the mountain barrier. Scorer and Klieforth (1959) use the long-waves theory to explain the air descent. Bâzâc (1983) shows that the foehn formation on the southern slope of the Southern Carpathians is the result of three processes: the release of latent heat, the exposure of the lee side to direct solar radiation, and the proper descent of the air on this lee side. By analysing the foehn processes produced on the external side of the Curvature Carpathians, Ion-Bordei (1988) sustains that the forced air descent along the slope in the lee is determined by the effect of ”cavity depression”, which exists right below the peak along the same

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slope in the lee, as a dynamic effect of air circulation over mountain ridges. Ciobanu (1998) explains the air descent through the difference between the mass of dry and humid air, where the dry one is heavier. Tilinca and all (1976, 1984) have analyzed the synoptic conditions of the foehn appearance in the eastern Apuseni Mountains, showing the importance of the frontal activity in producing the air descent (in 76.6% of cases), as well as the possibility of identifying the foehn with a meteorological radar, at the exact time of its appearance.

The article is a case study of a synoptic situation which generated a foehn appearance, including its effects on the eastern and north-eastern part of the Apuseni Mountains.

2. DATA AND METHODS

Once the appearance of the new theories about the genesis of the phenomenon, the foehn identification methods have been diversified**:** Vergeiner (2004) uses the potential temperature for determining the air mass characteristics; Irimescu (2014) mentions the existence of several methods to explore the appearance of the foehn: the clasical one, based on the thermal, hygric and wind criteria; the numerical simulation method; the cross section method; respectively the teledetection method, based on the satellite images.

For the present case study, respectively the 9-10 January 2015 period, we used the classical method, as well as some satellite images. For this purpose, three west-east cross profiles over the Apuseni Mountains were selected, including the following weather stations: 1st profile – Oradea (136 m), Borod (333 m), Vlădeasa (1836 m), Huedin (560 m); 2nd profile – Şiria (477 m), Ţebea (264 m), Alba Iulia (245 m), Sebeş (253 m), Blaj (334 m); 3rd profile – Arad (116 m), Vărădia de Mureş (156 m), Deva (240 m), Sebeş (fig. 1). The third one was used in order to point out the air heating in the lee as a result of the air circulation over orographic barrier, in comparison with the lower temperatures recorded on the western and southern slopes, when a western warm air advection is present.

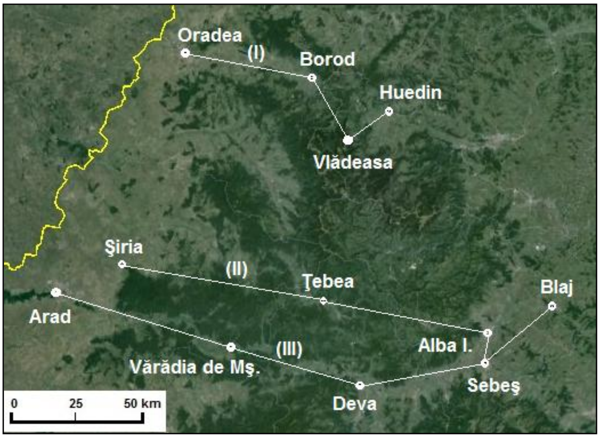

Fig. 1. ***Cross profiles position in the studied area***

The following meteorological data were used: hourly values of air temperature, relative humidity, wind speed and direction; the maximum air temperature values within 12 and respectively 24 hours; daily values of the average depth of snow cover. For the synoptic analysis there were used: thermal and geopotential field distribution maps at different atmospheric levels (500, 850, and 925 hPa); ground level synoptic maps; satellite images of the cloud distribution.

3. RESULTS

3.1. Synoptic analysis

The dynamics of the baric structures in the analyzed period has generated modifications in the weather evolution. At 500 hPa level, one can observe the presence of a ridge, extended over the southern half of Europe and having an eastern orientation of its axis. (fig. 2). The geopotential field structure and its western character facilitate the appearance of some atmospheric high level waves, which will generate warm and cold air advections, associated with a corresponding frontal activity. Thus, in the period 09.01, 12 GMT-10.01, 06 GMT, a cold high level wave affected the south-eastern part of the continent (see fig. 2).

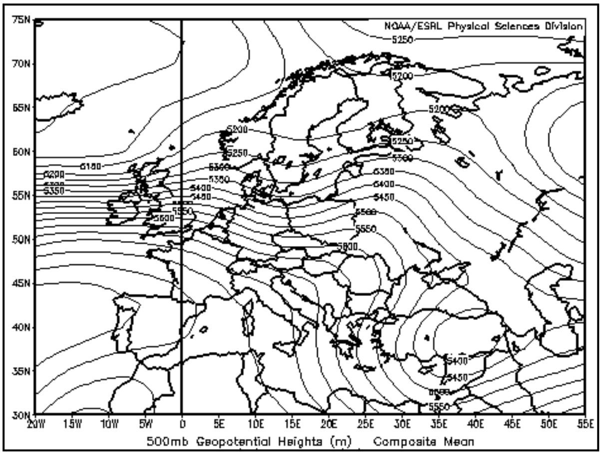

Fig. 2. ***The 500 hPa geopotential height on 9th January 2015, 00 GMT (processed after http://www.esrl.noaa.gov)***

The ground level synoptic analysis shows the presence of an anticyclone (1035 hPa) in the south-eastern part of Europe, with the tendency of displacement towards the south-east of the Mediterranean Sea (fig. 3). The presence of this high pressure field, of Scandinavian origin, as well as the geopotential structure configuration in the first decade of January 2015, determined a cold air advection over the eastern part of the continent. Thus, in Romania, there were recorded very low daily temperatures, under frost limit, even in daytime. Azores high pressure cell was positioned over south-western Europe, while the northern half of the

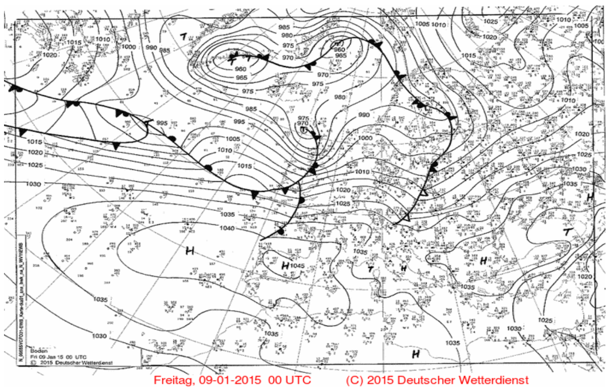

Fig. 3. ***Synoptic map at ground level on 9th January 2015, 00 GMT (Source: http://www1.wetter3.de)***

continent was under the influence of frontal activity, generated by the Icelandic Depression and the high level atmospheric structure (fig. 3).

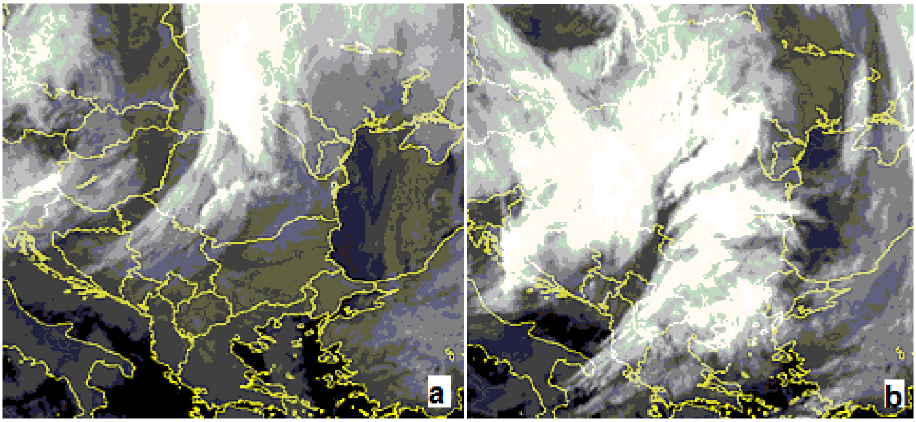

Fig. 4. ***Infrared satellite images of the cloud formations associated to atmospheric fronts over Romania on 9th January (a - 06 GMT, b – 18 GMT, Source: http://www.sat24.com)***

Under these conditions, during the morning of 09.01.2015, Romania was crossed from the north-west by a cold high level wave, without a corresponding front at the ground level (fig. 4a). In the afternoon and first half of the night of 09/10.01.2015, the country’s territory was affected by a westward warm occluded front (fig. 4b).

The analysis of the air temperature evolution in Romania during the day of 09.01.2015 at the 925 hPa level showed that at 12 GMT the values range between 2ºC in the south-western extremity of the country, and -2ºC in the south-eastern one, due to a west-south-west warm advection (fig. 5). After 12 hours we could observe an intensification of this advection against the background of warm post-frontal air advance, the air temperatures ranging between 5ºC in south-west Romania and 2ºC in the south-east (fig. 5).

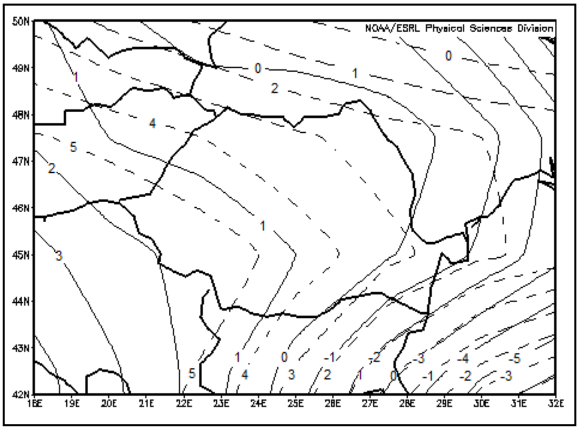

Fig. 5. ***The 925 hPa level temperature structure on 9th January at 12 GMT (continuous lines) and 10th January at 00 GMT (interrupted lines)(processed after http://www.esrl.noaa.gov)***

3.2 Discussion

The analysis of the air temperature variation along the three profiles mentioned above underlines the progressive increase of the thermal values during the day of 9th January (fig. 6). This was the result of the effective radiation reduction following a cloudiness associated with the cold front (00-06 GMT), and respectively due to the increase of direct solar radiation produced by a variable sky behind the cold front, as illustrated by the satellite images (fig. 4a). Also, during the afternoon and evening, the thermal values continued to grow against the background of warm air advection associated with the warm occluded front which affected Romanian territory from the west (fig 4b). This evolution is well emphasized by the profile Oradea-Borod-Vf. Vlădeasa-Huedin, with higher temperatures recorded in Huedin than in Oradea (9th January, 15-19 GMT, respectively 10th January, 00, 05, 06 GMT) (fig. 6a). The positive deviations at Huedin as compared to Oradea were up to 2.6 ºC (9th January, 19 GMT), while at 00 GMT of the same day, the temperature in Oradea was 10.5ºC higher than at Huedin (fig. 6a).

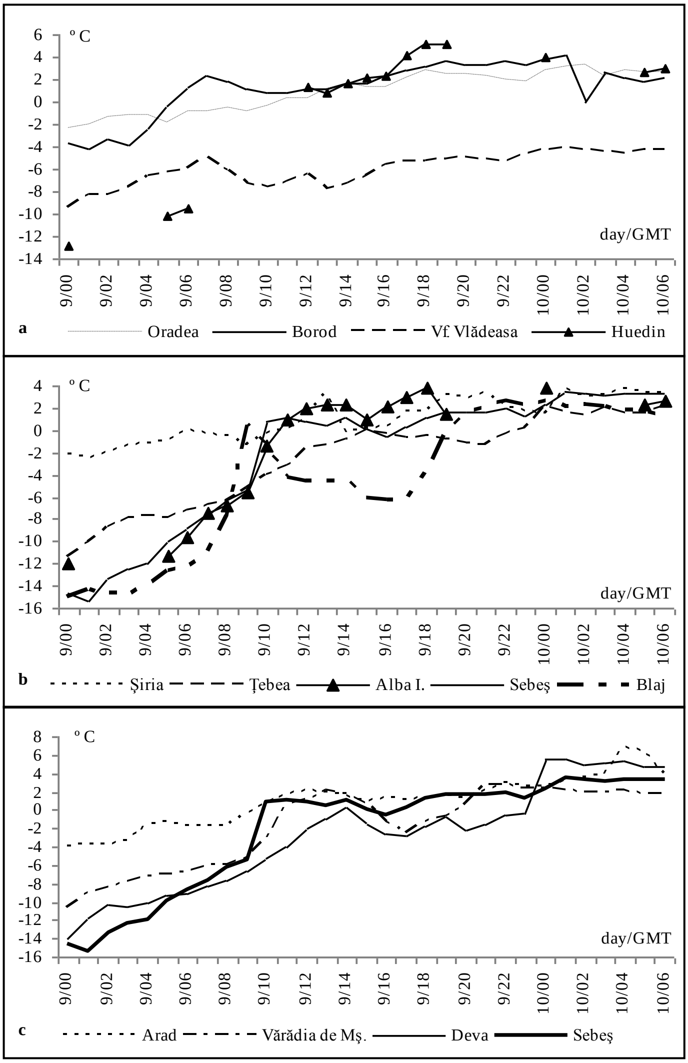

Fig. 6. ***Air temperature variation along the selected profiles for the period 9th January, 00 GMT – 10th January, 06 GMT***

The air temperature evolution on the Şiria-Ţebea-Alba Iulia-Sebeş-Blaj profile showed the highest values in the first part of 9th January in Alba Iulia (12-15

GMT), and respectively on 10th January, 00 GMT, at the same weather station (fig. 6b). The maximal deviation at Alba Iulia as compared to Şiria station was 2.5ºC, but the highest thermal values were registered in Huedin.

In the case of the 3rd profile, the highest temperatures recorded at Sebeş were only within the 18-20 GMT interval (fig. 6c), but the differences between the profile extreme points were very low (0.4ºC).

The hourly variation of the wind direction and speed points out the predominance of the western circulation on the entire period, as well as the increase of wind speed in the afternoon of January 9th (fig. 7). At Huedin station the increase of the average wind speed from 2-3m/s (15-17 GMT interval) to 5m/s (18 and 19 GMT) and the change of direction from west to south-west (fig. 7) correspond to the most important air temperature increase (fig. 6a). A similar evolution was observed in Alba Iulia and Sebeş, wind speed being more significant (fig. 7).

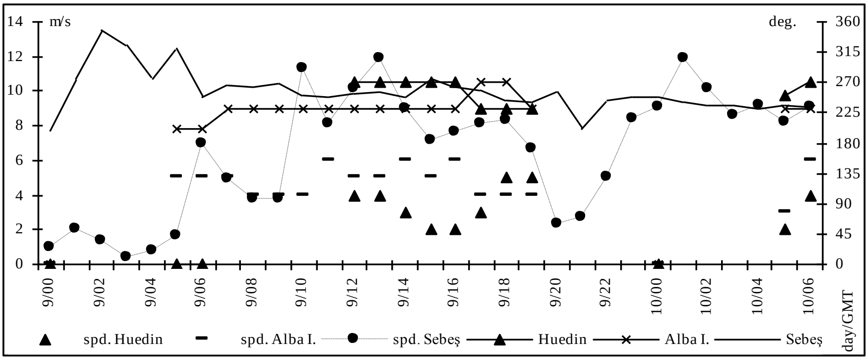

Fig. 7. ***Wind direction and speed variation at Huedin, Alba Iulia and Sebeş meteorological stations for the period 9th January, 00 GMT – 10th January, 06 GMT***

The relative humidity decreased by over 20% during the hourly interval when the temperature registered the most important increase, the decrease being sharper at Huedin (up to 67%) and Alba Iulia (up to 65%) (fig. 8).

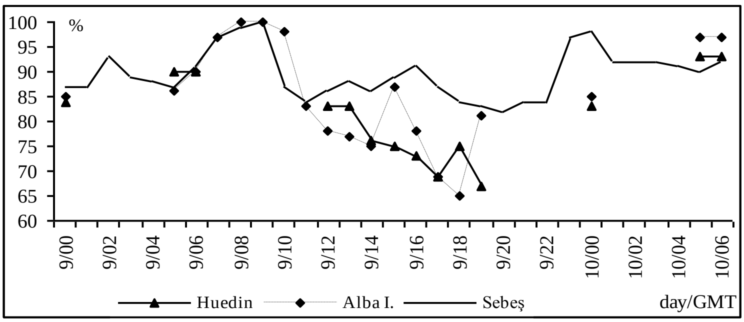

Fig. 8. ***Relative humidity variation along the 1st and 2nd profile for the period 9th January, 00 GMT – 10th January, 06 GMT***

Analyzing the maximum temperatures registered within a 12 hour period - a useful parameter for identifying the highest thermal values during the day and night, especially in the case of shorter meteorological observation program (Huedin, Alba Iulia) -, we observed that the heating process was present also during the night of

09/10.01.2015, both at Huedin and Alba Iulia, where the highest night values temperature per profile were recorded (table 1).

Table 1. ***Maximum air temperature (ºC) within a 12 hour period for the 1st and 2nd profile***

Meteorological station / Date, hour	1st profile				2nd profile				
	Oradea	Borod	Vlădeasa	Huedin	Șiria	Țebea	Alba I	Sebeş	Blaj
9.01.2015, 06 GMT	-0.8	1.7	-6	-8.3	0	-5.2	-9	-7.3	-12.2
9.01.2015, 18 GMT	3	3.4	-5	**5.4**	3.6	0.4	**4.2**	1.3	1.1
10.01.2015, 06 GMT	3.5	4.5	-4.1	**5.6**	3.9	2.7	**5.5**	3.6	3.3

On 09.01.2015, as a result of the katabatic heating process, against the background of a warm air advection, the highest maximum air temperatures in the Transylvanian Depression were registered at Huedin (5.4ºC), followed by Alba Iulia (4.2ºC). We noticed that with the exception of the above mentioned zones and of the south-western part of Transylvania, in all Transylvania the maximum thermal values were negative, mainly below -2ºC, the lowest reaching -5.8ºC at Dej. The immediate effect of the heating process was the snow cover melting. Analyzing the snow cover depth evolution, for all 3 profiles within a 24hrs interval, we could observe the reduction of 3-4 cm of the snow depth at each station, excepting Huedin where the reduction was more significant, up to 12 cm, so that on the morning of 10.01.2015 the snow cover became discontinuous (table 2).

Table 2. Average snow depth at the analyzed meteorological stations (cm)

Date, hour / Meteorological station	**9.01.2015, 06 GMT**	**10.01. 2015, 06 GMT**
Oradea	5	2
Borod	10	4
Vf. Vlădeasa	20	15
Huedin	12	< 0.5
Șiria	*	*
Țebea	*	*
Alba Iulia	7	3
Sebeş	3	< 0.5
Blaj	*	*
Arad	< 0.5	< 0.5
Vărădia de Mureş	*	*
Deva	7	4

** Not performed measurements on the snow depth*

4. CONCLUSIONS

The 09-10.01.2015 period was characterized by the existence of a foehn process developed against the background of a westward circulation over the Apuseni Mountains, in the context of a post-frontal warm air advection. This warm air replaced the pre-existent cold arctic mass air. This evolution emphasizes the capability of warm air to replace a cold air situated at the bottom of the lee.

The increase of air temperature on the eastern slope of the Apuseni Mountains occurred concurrently with the wind speed increase, the highest intensity being produced on the eastern slope of Vlădeasa Massif (Huedin

Depression), a situation less analyzed in the literature. The direct effect of the heating was the diminution of the snow cover depth.

The reduction of the meteorological observation program at some of the weather stations proved to be an impediment in the analysis of certain complex processes, such as that of the foehn occurrence.

The understanding of favorable conditions for the foehn development is very important for the meteorological forecast, especially in the cold season, when a significant reduction of the snow cover depth within a short time period can generate floods.

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