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LATE SPRING COLD WAVES. CASE STUDY: THE COLD WAVE IN THE INTERVAL 25-29 MARCH 2013

VALURILE DE FRIG DE LA SFÂRȘITUL PRIMĂVERII. STUDIU DE CAZ: VALUL DE FRIG DIN INTERVALUL 25-29 MARTIE 2013

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Abstract: The paper analyzes the issue of late spring and early autumn cold waves. We present an evaluation criterion of these climatic hazard phenomena with a high degree of danger, which can damage the crops in their different development stages, vulnerable to the temperatures severe fall. The main climatic hazard phenomenon associated with these is the late spring and early autumn frost. Their occurrence can lead to significant economic damages. The paper analyzes weather severe cooling in the interval 25-29 March2013. Taking into account global climate warming and the increase of weather variability, it is expected that the frequency of these phenomena increases, as well as the degree of crop damage. The paper is useful to researchers in climate domain, agrometeorologists, master graduates and students.

Key-words: late spring and early autumn cold waves, cold advections, late spring and early autumn frosts**.**
Cuvinte cheie: valuri de frig de la sfârșitul primăverii și începutul toamnei, advecții ale aerului rece, înghețurile târzii de primăvară și timpurii de toamnă.

INTRODUCTION

The phenomenon of global warming continues although the report from November 2010 of Met Office appreciated that the rate of global warming has decreased (Vicky Pope, Chief Met Office, specialist in climatic sciences, http://www.metoffice.gov.uk/" target="_blank">Met). It shows that beginning with '70's, on long term, global warming was about 0.16°C, and it slowed down in the interval 2001-2010, reaching values of 0.05-0.13°C. Vicky Pope declared that: "the warming tendency has slightly fallen, yet there is still a warming, which does not vary faster than before." The causes of this slowdown are due to the increase of

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industrial NOx concentration, such as sulfur-base compounds, released in the atmosphere, which reflect solar radiation, producing an effect of cooling. NASA has a satellite, which monitor permanently the changing thermal field of our planet especially in the arctic zone, making images of Terra's thermal field.

However, as a proof of the heat accumulation in the terrestrial atmosphere and the continuation of global warming, a study carried out in 2012, under the coordination of Martin P. Tingley and Peter Huybers in Harvard University, department of Earth and Space Sciences, published in Nature magazine, showed that people from Northern Hemisphere, in the countries with the highest extreme temperatures located at latitudes higher than 45°N, confronted in the last years with the highest extreme temperatures in the last 6 centuries.

The frequency, with which the extreme temperatures were registered during the last summers, is a record in the last 600 years.

The study was carried out by analyzing three types of approaches of the extreme temperatures in the last centuries. The results show that the *Summers of 2005, 2007, 2010 and 2011 have been more warmish than any other summer in 1400 and up to present, in terms of average space distribution. The summer of 2010 has been the warmest in the last 600 years in Western Russia and probably the warmest in Greenland and Canada's arctic zone.*

The results are the same with ours from the studies on climatic variability in Romania, in different regional areas, especially in South-West.

The researches show that there is a direct connection between very cold winters in the last ten years in Europe and Asia and global climate warming. Although, apparently, the cold which came over Europe is slightly compatible with an increase of the temperature mean, as the prognoses showed, up to 6°C, until the end of this century, the lower and lower temperatures and the polar cold waves during winter, in the Northern Hemisphere, are the clear proof that global warming and climate changes are real and serious, (Business Recorder). The severe cold during winters is the consequence of arctic icecap melting, which lost 20% of its surface in the last 30 years because of the excessive heat during summers. Other studies show that this icecap could totally disappear during the summer months in this century, because sunrays, which will not be reflected by ice back in the atmosphere, will warm up even more the terrestrial surface in this area. Then, we will have an important warm flow, which will go upward in the atmosphere which we do not have when everything is covered by ice. It is a huge change (Stefan Rahmstorf, specialist in climate, Institute of Potsdam - Germany). The effect will be the formation of an anticyclonic field located in such manner that will push the advection of polar air clockwise (natural circulation in anticyclone), that is towards Europe (study published in *Journal de Recherche Geophysique,* 2013). According to this study, the phenomenon can be already felt, its effect consisting in the colder and colder and longer winters in Europe. *These anomalies could triple the probability of having extreme winters in Europe and Northern Asia*, (Vladimir Petouchov, study coordinator).

The increase of climate variability led to the increase of the frequency of warm winters, and during a calendar year rapid changes of weather type can be observed, from an excessively warm to an excessively cold weather, from an excessively droughty to an excessively rainy weather.

In some years, warm weather prolongs in the first two winter months, and the excessively cold weather with snowstorms and snowfalls appears in the last month of winter as for example the winter of 2011-2012. Other times, cold winter arrives early in November and continues until the end of March and the beginning of April (from example 1995-1996).

The winter of 2012-2013 represented a new exception in what the climatic variability in Romania concerns. The winter specific phenomena appeared relatively early in most part of the country, and in the South-West (where usually winter phenomena appear after 20 December) they appear early in the first decade of December. Then, in January and February, weather was warm, without a snow layer and with predominantly liquid precipitation. The same weather aspect perpetuated in most part of March and in the last five days of March a wave of cold air and snowfalls covered a part of the continent, including Romania, causing the extension of the snow layer on the continent and its formation in Romania.

In Poland the maximum temperature values fell below -5.0°C, and the daily minimum values below -24.0°C and 20 persons died of cold.

In some parts of Romania (North-East and North-West) it was snowstorm, and some roads were blocked. The border crossings with Hungary and Republic of Moldova were closed. In some counties, including the municipality of Bucharest classes in schools were suspended (the central heating had been closed about 2 weeks ago, and its turning on again was difficult). In Suceava County, in Liteni, the snowstorm covered the houses with snow heaps with a height of 2.5-3.0 m.

Warm weather, which has last previously this phenomenon for 84 days with preponderantly positive minimum temperatures and maximum temperatures that reached values of 10-14°C, led to the continuation of the vegetation stages in some species of plants, in autumn crops and some species of fruit trees as for example the apricot tree. On 18 March 2013, the apricot tree had floral buttons, and the flowering was imminent. A part of the migratory birds had already come from tropical countries and some of them died because of the frost and of the snow layer which made impossible their feeding. The phenomenon of frozen soil and lake surfaces occurred.

After the cold wave and snowfalls which formed a snow layer in the interval March 25-28, 2013, a significant part of the floral buttons fell as a consequence of frost, and in some crops, as for example vegetable crops from the unheated solariums and rape, total damages and/or plant damages occurred.

The cold waves during winter which lead to massive cooling are characterized by average temperature values ≤ -10°C and minimum temperature values of ≤ -30°C (Bogdan and Niculescu, 1999, p. 30).

From a calendar point of view March is the first spring month, but the spring equinox which, usually, occurs on 21 (most often according to astronomers on March 20), shows that astronomically winter continues up to March 20. Consequently, the instructions on observing and codifying meteorological phenomena indicate the issue of some warning messages for frost and hoar frost phenomena which occur on this date, *these being considered late spring frost and hoarfrosts.* In some years, the late snowfalls which appear after this date and the intense weather cooling cause significant damages of crops, vineyards and crops from unheated solariums, especially if they occur after a period of warm winter. The snowfalls are sometimes accompanied or followed by wind gusts that cause solarium destruction or electricity cut down, which amplifies the damages because of the heat break down in those with heating systems working on electricity. March is the last month of the cold season, and usually after the spring equinox the daily thermal balance becomes positive.

Regarding the weather cooling or warming, *Weather Diagnosis and Forecast, terminology and symbols,* state standard STAS 12977-91 (entered into force on April 1, 1991) shows that: *depending on the deviations size nuances can be made: slightly cold weather (deviations of 2…3°C), cold weather (deviations of 4…6°C), very cold weather (deviations of 7°C or more).*

Consequently, these forecasts can be a criterion to evaluate weather cooling occurred in the interval March 25-29, 2013, even if this intense weather cooling did not have the characteristics of a winter cold wave, taking into account also the late calendar period of its occurrence.

Starting from these forecasts we can formulate the following criterion[4] (table no. 1) for the evaluation of spring late cold waves.

Table no. 1. ***Weather types depending on the deviation (ΔT°C) of the daily air temperature means from the normal values (N).***

ΔT°C	Weather characteristic	Abreviere
>10°C	Excessively warm	EW*
7.0…10.0°C	Very warm	VW
4.0…6.9°C	Warm	W
2.1…3.9°C	Slightly warm	SW
-2.0…+2°C	Thermally normal	N
-3.9…-2.1	Slightly cold	SC
-6.9…-4.0	Cold	C
-10.0…-7	Very cold	VC
<-10°C	Excessively cold	EC*

(Source: procession according to the criterion from the *State standard STAS 12977-91,* page 14, the end lines marked with an asterisk are proposed by us, because the thermal deviations can be higher in some situations).

[4] Criterion proposed by us (table 1), is also useful for the study of autumn early and spring late heat waves

The meteorological instructions for the issue of warnings related to short term dangerous meteorological phenomena (1-7 days, entered into force on March 12, 2008) show that for extreme minimum temperatures ***a yellow code*** warning is issued if these are comprised between -25°C and -15°C and ***an orange code*** warning if they fall below -25°C, and these codes are valid for areas with altitudes less than 800 m and provided that the low temperature is maintained at least two consecutive days (the local climatic characteristics will be taken into account). No norms are stipulated for orange code of low temperatures (although there were cases in which it was issued, when temperatures fell below -35°C). It is not specified if these refer to the winter season or to the entire cold season.

Our opinion is that these are useful for ***winter season, when temperature frequency < -15°C is extremely high***. The criterion proposed by us is useful for the autumn early cold waves (from October and November) and the late spring cold waves (from March which are a part of the cold season and sometimes even the ones from April and the first decade of May) (table 1).

Weather late intense cooling, of spring, occurred also in April; we give as example the snowfall in the night of April 14/15, 1996, when it snowed in most of the country, and in the southern half of Oltenia the snow layer had thicknesses between 20 and 25 cm.

For May, the extremely late weather intense cooling is well known, in the interval May 7-9, 2011 when during the night of May 7/8, 2011 it snowed and a snow layer was formed in the north of Moldavia, in Suceava, Harghita, Covasna, Braşov and Sibiu Counties and Prahova Valley. On that date, the vegetation was in advanced development stages, trees were blossomed, vineyards and orchards were in leaf with sprouts growing etc., and the destructions caused by weather intense cooling, which has lasted for three days have been important. The cooling was then followed by some mornings with hoarfrosts.

For the autumn early cold waves we give as example the intense cooling associated with abundant snowfalls and snowstorm on November 5, 1995 which brought the winter with the longest duration of the snow layer in the history of meteorological observations (Marinică, 2006; Bogdan, Marinică, 2007).

2. The daily extreme temperatures in the interval 25-28 March 2013

On March 25, 2013 the minimum temperature values registered at the meteorological stations from Oltenia were negative excepting one single value (Dr. Tr. Severin in the extreme west of the region); they were comprised between ***-2.8°C in Polovragi and 0.5°C in Dr. Tr. Severin***.

The mean of the minimum temperature values for the entire Oltenia was -1.7°C.

In the same day, ***the maximum thermal values*** were negative in most part of the region and were comprised between ***-2.2°C in Bâcleş and 1.5°C in Voineasa***, and ***the mean of the daily maximum temperature values for the entire***

region was -0.3°C, thus a winter day[5] ***being registered*** in most part of the region (Table 2).

Table no. 2. Maximum (Tmax) and minimum temperature (Tmin) values registered during the cold wave in the period 25-29 March, 2013 (°C).

Meteorological Station	25.III.2013		26.III.2013		27.III.2013		28.III.2013		29.III.2013	
	Tmin	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin	Tmax
Dr. Tr. Severin	***0.5***	0.8	-0.8	1.4	-1.1	**3.1**	***-0.8***	2.6	0.5	2.5
Calafat	-0.7	-0.2	-1.7	0.5	-1.9	-0.4	-1.5	2.9	0.5	1.9
Bechet	-1.1	-0.5	-1.9	1.3	-1.9	1.7	-1.4	**3.4**	***0.9***	**3.8**
Băileşti	-0.6	0.0	-2.5	0.7	-2.4	-0.2	-2.4	2.5	0.0	2.3
Caracal	-1.5	-1.1	-2.6	0.4	-2.9	-0.6	-2.0	1.8	0.5	2.3
Craiova	-2.1	-1.6	**-3.4**	0.1	-3.3	-0.8	-2.7	2.4	-0.2	1.2
Slatina	-2.0	-1.5	-3.3	1.0	-3.1	0.4	-2.6	2.8	-0.1	1.2
Bâcleş	-2.3	***-2.2***	-3.2	***-0.5***	**-3.9**	-1.0	-3.1	0.0	**-1.2**	***0.2***
Tg. Logreşti	-1.3	-0.6	-1.5	2.3	-2.7	0.1	-2.9	2.2	-1.1	1.3
Drăgăşani	-2.4	-1.9	-3.2	0.6	-3.8	-0.8	-3.2	3.2	-1.1	0.6
Apa Neagră	-0.4	0.4	-2.2	1.8	-2.2	0.0	-2.5	1.4	-0.6	2.4
Tg. Jiu	-0.1	1.2	-1.1	2.8	-1.9	0.4	-1.7	2.6	0.0	2.5
Polovragi	**-2.8**	-1.0	-2.2	1.7	**-3.9**	***-1.6***	**-5.2**	***-0.5***	-2.5	1.4
Rm. Vâlcea	-1.2	1.1	***-0.4***	**3.9**	-2.4	0.7	-2.2	3.4	0.2	2.1
Voineasa	-0.4	**1.5**	-1.6	3.1	***-1.0***	1.5	-2.7	1.8	-1.1	1.2
Parâng	-8.6	0.1	-7.2	-3.0	-8.6	-4.0	-9.9	-2.5	-8.7	0.3
Mean/Oltenia	-1.7	-0.3	-2.4	1.1	**-2.9**	-0.1	**-2.9**	1.9	-0.9	1.7
Ob. Lotrului	-5.0	-1.2	-6.4	-1.2	-5.1	-0.6	-7.4	3.2	-7.0	0.0
Halânga	0.5	0.8	-0.6	2.2	-1.2	1.4	-0.8	2.5	0.8	2.5

(Source: processed data)

On 26 March, 2013 the minimum temperature values were comprised between -3.4°C in Craiova and -0.4°C in Rm. Vâlcea, and ***the mean of the minimum thermal values for the entire region*** was lower than in the previous day with 0.7°C, registering the value of -2.4°C.

On the same date, ***the daily maximum thermal values*** were comprised between -0.5°C in Bâcleş in Mehedinţ Hills and 3.9°C in Olt Couloir in Rm. Vâlcea, and ***the mean of the daily maximum temperature values was 1.1°C***, higher with 1.4°C than in the previous day, due to some short insulation intervals in the high area compared to the low area characterized through thermal inversion, which increased the mean for the entire region.

On March 27, 2013 the minimum temperature values were comprised between -1.0°C in Voineasa and -3.9°C in Polovragi and Bâcleş, and ***the mean of the minimum thermal values for the entire region*** was -2.9°C, lower with 0.5°C than in the previous morning, due to the continuation of the cold air advection, as well as of the nocturnal radiation in the presence of the snow layer.

[5] Winter day = day in which the maximum air temperature is ≤ 0°C

The daily thermal maximum values on March 27 were comprised between -1.6°C in Polovragi and 3.1°C in Dr. Tr. Severin, and ***the mean for the entire region*** was -0.1°C which again means a winter day according to the value of most maximum temperatures, and also to the mean of these maximum thermal values.

On March 28, 2013 the minimum temperature values were comprised between -0.8°C in Dr. Tr. Severin and -5.2°C in Polovragi (thus we notice that in Subcarpathian Depressions air temperature continued to fall), and ***the mean of the minimum thermal values was -2.9°C***, equal with the one from the previous day.

The maximum thermal values on March 28 were comprised between ***-0.5°C in Polovragi and 3.4°C in Bechet***, and ***their mean for the entire region*** was 1.9°C registering a slight increase of 2.0°C compared to the previous day.

On March 29, 2013 the minimum temperature values were comprised between -1.2°C in Bâcleş and 0.9°C in Bechet, and ***the mean of the minimum thermal values*** was -0.9°C thus registering an increase of 2.0°C compared to the previous morning.

The maximum thermal values on March 29 were comprised between 0.2°C in Bâcleş and 3.8°C in Bechet, and ***the mean of the daily maximum temperature values*** was 1.7°C registering a fall of 0.2°C compared to the previous day.

The intensity of weather cooling was calculated by applying the above criterion (table 1) for the daily extreme temperature means (the means from the minimum and maximum thermal values) which are closed to the daily means, the results thus obtained being significant[6].

On March 25, 2013 the means of the daily extreme temperature values were comprised between ***-1.9°C in Polovragi and 0.7°C*** in Dr. Tr. Severin, and ***their mean for the entire region*** was -1.0°C (table 3).

Their deviations from the multiannual average values (normal values calculated for the interval 1961-1990) were comprised between -10.6°C in Slatina and -5.4°C in Voineasa, and ***the mean deviation for the entire region*** was -8.6°C.

According to the above criterion, ***the thermal time types*** were comprised between ***cold*** (C) in Voineasa and Parâng and ***excessively cold*** (EC) in Craiova, Slatina and Drăgăşani, and according to the mean deviation for the entire region, weather was ***very cold*** (VC).

The spatial-temporal extension of the very cold time (VC) was of 70.6% compared to the region area, of the ***excessively cold*** (EC) ***time*** was of 17.6% and of the ***cold time*** of 11.8%.

On March 26 the means of the daily thermal extreme values were comprised between -1.9°C in Bâcleş and 1.8°C in Rm. Vâlcea, and ***their mean for the entire region*** was of -0.6°C.

[6] We opted for this approach because we do not have the multiannual daily means, but, in exchange, we have the multiannual daily means of the thermal extreme temperature values.

Their deviations from the multiannual average values were comprised between -10.5°C in Slatina and -5.5°C in Voineasa and for the ***mean of the entire region, the deviation was*** *-8.6*°C.

The thermal time type on that date were comprised between cold (C) in the high area in Rm. Vâlcea, Voineasa, Parâng (due to the thermal inversion) and excessively cold (EC) in Băileşti, Craiova, Slatina and Drăgăşani, and according to the ***thermal mean deviation for the entire region*** weather was ***very cold*** (VC).

The spatial-temporal extension of the very cold time (VC) was 58.8%, of the excessively cold time (EC) 23.5% and of the cold time 17.7%, which show the severe cooling.

On 27 March the means of the daily thermal extreme values were comprised between -2.8°C in Polovragi and 1.0°C in Dr. Tr. Severin, and ***the mean for the entire region*** was -1.5°C, lower compared to the previous day with 0.9°C.

Table no. 3, Weather types during the cold wave in the interval[7] 25-29 March, 2013 (MEx=mean of the daily thermal extreme temperature values on that date, N=multiannual mean of the daily thermal extreme temperature values on that day considered to be normal; ΔT°= deviation from the normal (MEx-N), WT= weather type.)

Meteorological Station	25.III.2013				26.III.2013				27.III.2013			
	MEx	N	ΔT°	WT	MEx	N	ΔT°	WT	MEx	N	ΔT°	WT
Dr. Tr. Severin	**0.7**	9.2	-8.5	**VC**	0.3	9.5	-9.2	**VC**	**1.0**	9.9	-8.9	**VC**
Calafat	-0.5	9.2	-9.7	**VC**	-0.6	9.4	-10.0	**VC**	-1.2	9.9	-11.0	**EC**
Bechet	-0.8	9.0	-9.8	**VC**	-0.3	9.3	-9.6	**VC**	-0.1	9.6	-9.7	**VC**
Băileşti	-0.3	9.0	-9.3	**VC**	-0.9	9.3	-10.2	**EC**	-1.3	9.9	-11.2	**EC**
Caracal	-1.3	8.3	-9.6	**VC**	-1.1	8.9	-10.0	**VC**	-1.8	9.4	-11.1	**EC**
Craiova	***-1.9***	8.4	-10.2	**EC**	-1.7	8.8	-10.4	**EC**	-2.1	9.0	-11.0	**EC**
Slatina	-1.8	8.9	***-10.6***	**EC**	-1.2	9.3	***-10.5***	**EC**	-1.4	9.4	-10.8	**EC**
Bâcleş	-2.3	7.6	-9.9	**VC**	***-1.9***	8.1	-10.0	**VC**	-2.5	8.4	-10.9	**EC**
Tg. Logreşti	-1.0	7.7	-8.6	**VC**	0.4	7.8	-7.5	**VC**	-1.3	8.3	-9.6	**VC**
Drăgăşani	-2.2	8.4	-10.5	**EC**	-1.3	8.8	-10.1	**EC**	-2.3	9.2	***-11.5***	**EC**
Apa Neagră	0.0	7.6	-7.6	**VC**	-0.2	7.6	-7.8	**VC**	-1.1	8.1	-9.2	**VC**
Tg. Jiu	0.6	8.3	-7.8	**VC**	0.9	8.4	-7.6	**VC**	-0.8	9.0	-9.7	**VC**
Polovragi	***-1.9***	6.6	-8.5	**VC**	-0.3	6.9	-7.1	**VC**	***-2.8***	7.3	-10.0	**VC**
Rm.Vâlcea	-0.1	8.3	-8.3	**VC**	**1.8**	8.4	-6.7	**C**	-0.9	8.9	-9.8	**VC**

[7] We do not take into account Halânga and Ob. Lotrului meteorological stations for the general mean calculated for the entire region, since they comprise short data ranges, but present them orientatively.

Voineasa	0.6	5.9	**-5.4**	C	0.8	6.3	**-5.5**	C	0.3	6.3	**-6.1**	C
Parâng	-4.3	0.1	-4.3	C	-5.1	0.8	-5.9	C	-6.3	1.1	-7.4	VC
Mean/Oltenia	-1.0	7.6	-8.6	VC	-0.6	8.0	-8.6	VC	-1.5	8.3	-9.9	VC
Ob. Lotrului	-3.1	0.4	-3.5	SC	-3.8	0.9	-4.7	C	-2.9	1.1	-4.0	C
Halânga	**0.7**	9.1	-8.4	VC	0.8	8.8	-8.0	VC	0.1	10	-9.9	VC
Staţia meteorologică	28.III.2013				29.III.2013							
	MEx	N	ΔT°	WT	MEx	N	ΔT°	WT				
Dr. Tr. Severin	0.9	10.2	-9.3	VC	1.5	10.0	-8.5	VC				
Calafat	0.7	10.1	-9.4	VC	1.2	9.3	-8.1	VC				
Bechet	**1.0**	10.0	-10.0	VC	**2.4**	9.8	-7.4	VC				
Băileşti	0.1	10.0	-10.0	VC	1.2	9.7	-8.6	VC				
Caracal	-0.1	9.4	-9.5	VC	1.4	9.2	-7.8	VC				
Craiova	-0.2	9.1	-9.3	VC	0.5	8.9	-8.4	VC				
Slatina	0.1	9.2	-9.1	VC	0.6	9.1	-8.6	VC				
Bâcleş	-1.6	8.7	-10.2	EC	-0.5	8.3	-8.8	VC				
Tg. Logreşti	-0.4	8.4	-8.7	VC	0.1	8.1	-8.0	VC				
Drăgăşani	0.0	9.1	-9.1	VC	-0.3	8.9	***-9.1***	VC				
Apa Neagră	-0.6	8.3	-8.8	VC	0.9	8.0	-7.1	VC				
Tg. Jiu	0.5	9.2	-8.7	VC	1.3	8.8	-7.6	VC				
Polovragi	***-2.9***	7.5	***-10.3***	EC	***-0.6***	7.1	-7.7	VC				
Rm.Vâlcea	0.6	8.9	-8.3	VC	1.2	8.6	-7.5	VC				
Voineasa	-0.5	6.1	**-6.6**	C	0.1	5.8	**-5.7**	C				
Parâng	-6.2	0.9	-7.1	VC	-4.2	0.1	-4.3	C				
Mean/Oltenia	-0.5	8.4	-8.9	VC	0.4	8.1	-7.7	VC				
Ob. Lotrului	-2.1	1.1	-3.2	SC	-3.5	0.8	-4.3	C				
Halânga	0.9	10.8	-10.0	VC	1.7	11.0	-9.3	VC				

(Source: processed data)

Their deviations from the multiannual average values were comprised between -11.5°C in Drăgăşani and -6.1°C in Voineasa, and the ***general mean deviation on the region*** from the normal was of -9.9°C.

Thermal time type on that date were comprised between cold (C) in Voineasa and excessively cold (EC) in Calafat, Băileşti, Caracal, Craiova, Slatina, Bâcleş and Drăgăşani.

The spatial-temporal extension of the very cold time (VC) was of 52.9%, of the excessively cold (EC) of 41.2%, and of the cold time of 5.9% indicating weather severe cooling.

On March 28, 2013 the means of the daily thermal extreme values were comprised between -2.9°C in Polovragi and 1.0°C in Bechet, and ***the mean for the entire region*** was -0.5°C.

The deviations from the multiannual average values were comprised between -10.3°C in Polovragi and -6.6°C in Voineasa, and of the ***general mean for the entire region*** of -8.9°C (with 1.0°C higher) than in the previous day).

The thermal time types on that date were comprised between cold (C) in Voineasa and excessively cold (EC) in Polovragi and Bâcleş, and for the entire region ***according to the general mean deviation,*** it was ***very cold*** (VC).

The spatial-temporal extension of the very cold time (VC) was of 82.3% (growing compared to the previous day), of the excessively cold time (EC) of 11.8%, and of the cold time of 5.9%, decreasing compared to the previous day, indicating ***the beginning of a slow process of temperature increase.***

On March 29, 2013 the means of the daily thermal extreme values were comprised between -0.6°C in Polovragi and 2.4°C in Bechet, and ***the general mean for the entire region*** was 0.4°C.

The deviation from the multiannual average values were comprised between -9.1°C in Drăgăşani and -5.7°C in Voineasa, and of ***the general mean*** of -7.7°C.

The thermal time types on that date were comprised between cold (R) in Voineasa, Parâng and ***very cold*** (VC) in most of the region.

The spatial-temporal extension of the very cold time (VC) was of 88.3%, and of the excessively cold time (EC) of 11.7%.

Therefore, we conclude that weather cooling reached the maximum intensity on March 27 and 28 when the thermal minimum temperature values were the lowest and the spatial-temporal extension of the thermal time types, excessively cold (EC) and very cold (VC) was maximum. The duration of the very cold time was of 5 days, exposing plants to extremely low temperatures.

3. **The synoptic causes which caused the cold wave**

Weather cooling occurred on March 24, and in the night of March 24/25 sparse snowfalls appeared.

Snowfalls fell all over the region on March 25, 26 and 27. On 24 March as well as during most part of the winter (January, February and March 1-24), the snow layer was present only in the mountainous area, and after these snowfalls, in Oltenia, in the morning of March 28 reached thicknesses comprised between 4 cm in Rm. Vâlcea and 21 cm in Târmigani in Mehedinţi County, being the highest in the country (Fig. 1).

The synoptic situation on March 25, 2013 when the snowfalls were the most abundant and the new formed snow layer was consistent is presented in fig. 2.

At the ground level, on March 25, 2013 at 12 UTC, in the Mediterranean Sea, there was a Mediterranean Cyclone formed on March 24 in the thalweg of an Atlantic Cyclone whose center with values of 990 hPa was located on the southern half of Italy. A large anticyclonic field extended from Canada’s coasts to Bosfor dominated a significant part of the Atlantic Ocean and Mediterranean Sea. Above Greenland and Scandinavia there was a strong large anticyclonic field, with values exceeding 1050 hPa in the center. In the Northern Africa and Asia Minor there was an anticyclonic field with values exceeding 1020 hPa, which was connected through an anticyclonic girdle over the Black Sea with the girdle in the north of the continent (Fig. 2).

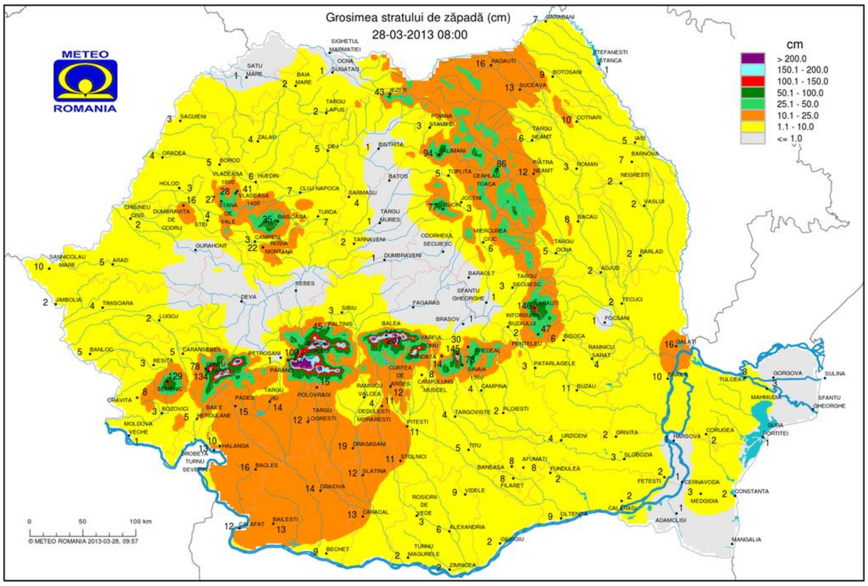

Fig. 1. ***The maximum thickness of snow layer in March 2013 registered on March 28, 2013*** **(according to NAM Bucharest).**

The position of the Mediterranean Cyclone and the cyclone in the Eastern Europe Plain in the periphery of the Greenlander Anticyclone with the Scandinavian ridge represented a true advection mechanism, in the inferior troposphere, of the extremely cold air from the North of the continent towards Romania.

The situation is typical for the winter season, namely the snowstorm phenomenon (different baric group, Mediterranean Cyclone in coupling with the Greenlander Anticyclone with the Scandinavian dorsal or united with the Scandinavian Cyclone) (Marinică 2006) and rarely encountered in spring in March.

In altitude at the level of 500 hPa, the extreme southern and western Europe was dominated by a geopotential field with high values, and over most part of the continent there was a low geopotential field with many closed nuclei.

For the situation with snowfalls on this date it is important the nucleus with the value of 520 damgp located over the Eastern Europe Plain whose large thalweg was extended towards the South of Italy (isohypse of 544 damgp)[8].

[8] On the altitude baric topography isohypses increase and decrease every 8 damp (are multiple of 8).

In these conditions, in the inferior troposphere, for Romania (and for Oltenia) air circulation was coming from the Southern-Eastern sector, with a mass of a slightly warm and moist air.

In altitude, Romania was located in the anterior part of the geopotential thalweg, and the mass of the extremely cold air, with temperature values below -10°C above Austria and Hungary, was advected towards South and afterwards towards North above Romania (Fig. 3).

This cold advection of cold air covered most part of Europe excepting the extreme West and South (Fig. 7).

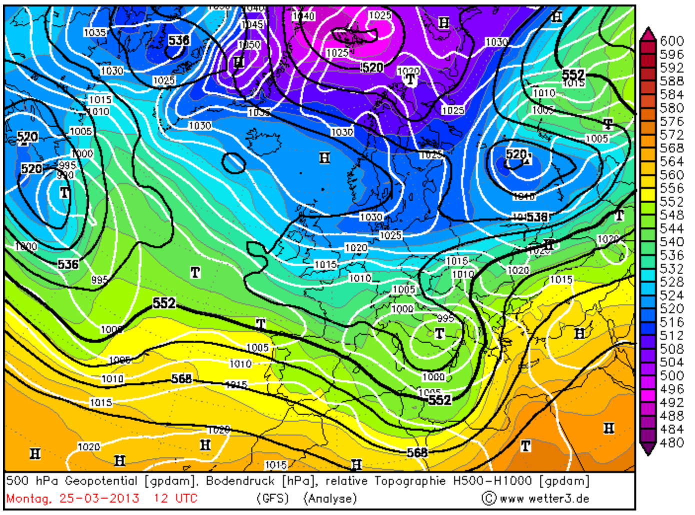

Fig. 2. The synoptic situation at the ground level in Europe, superposed on the one from the altitude of 500 hPa (about 5500 m) and *H500-H1000 gpdam baric topography, on March 25, 2013 at 12 UTC* (according to wetter3.de).

The aerologic survey on 25 March 2013, at 00 UTC, is typical to the snowstorm situation and highlights the (Fig. 6):

- advection of cold air, from the Eastern sector up to the level of 925 hPa,

- existence of the thermal inversion (between 900 hPa and 825 hPa) and of a layer comprised between 800 and 1500 m in which the air is saturated.

- two layers with different flowing characteristics:

- ground layer, in which the Northern-Eastern circulation following the frame of (Oriental and Meridional) Carpathians Mountains, due to which the mass of cold air is directed in the space between Carpathians and Black Sea;

- layer above the thermal inversion (exceeding the level of 775 hPa), characterized by a Southern-Western circulation, through which warmer air is advected;

- tropical warmer and lighter air glides slowly over the polar continental air, which is colder and moves forward at the ground surface;

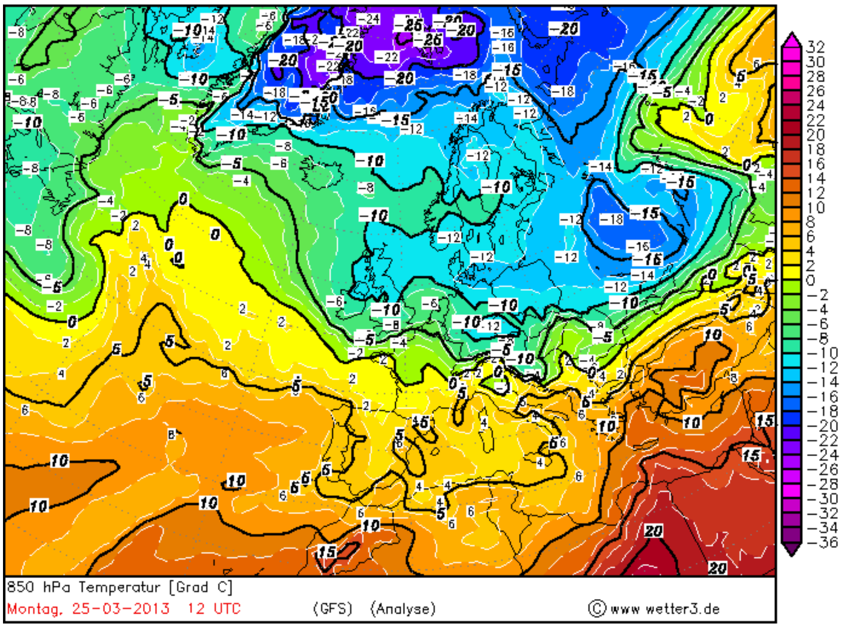

Fig. 3. The temperature field at the isobaric level of 850 hPa (about 1500 m altitude) over Europe, on March 25, 2013, at 12 UTC (according to wetter3.de).

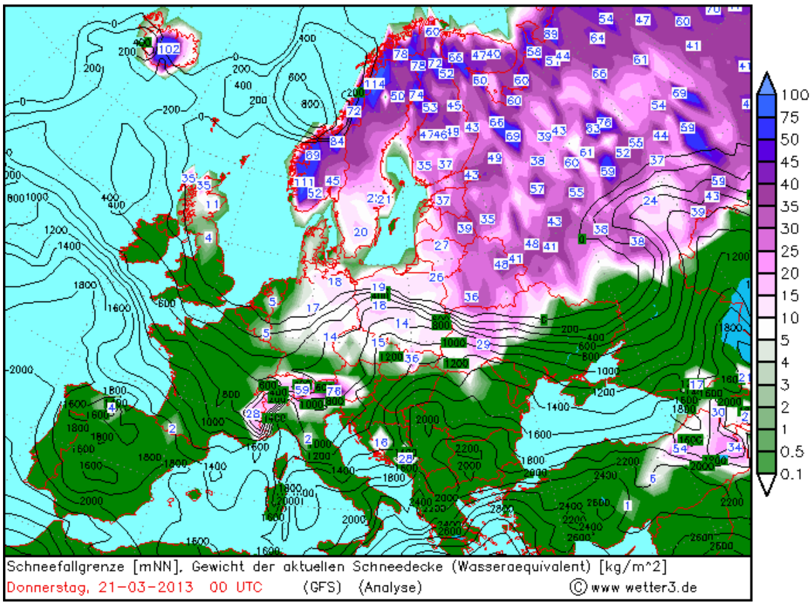

Fig. 4. The thickness of the snow layer (cm) in Europe on March 21, 2013 at 00 UTC
(according to wetter3.de).

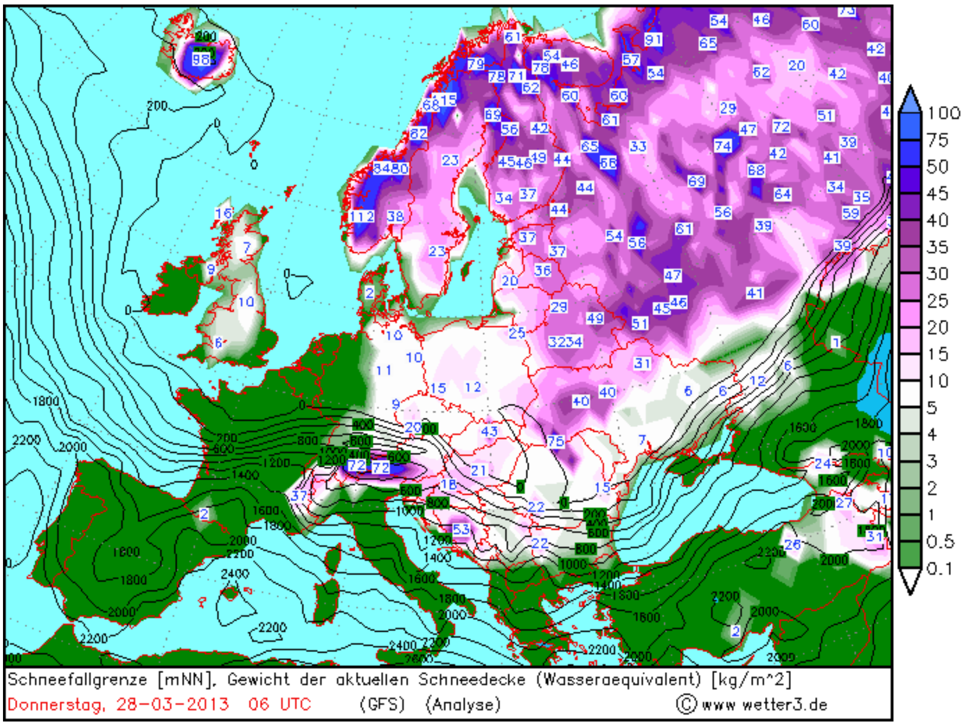

Fig. 5. ***The thickness of the snow layer in Europe on March 28, 2013 at 06 UTC*** **(according to wetter3.de).**

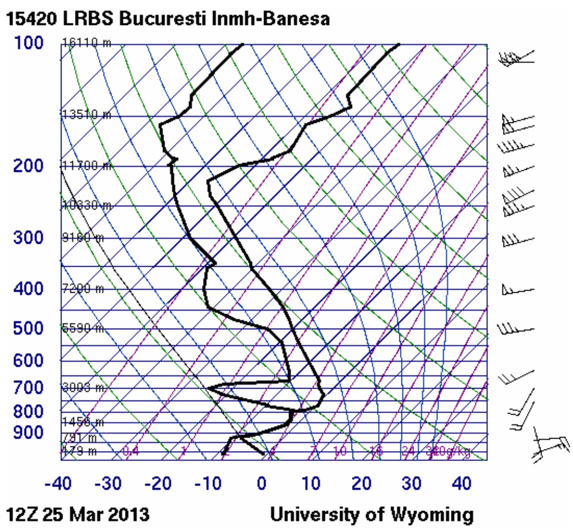

Fig. 6. ***The aerologic survey in Bucharest on 25 March 2013, at 12 UTC*** **(http://weather.uwyo.edu/upperair/sounding)**

- forced ascension of warm cold over the cold air caused a fast condensation of water vapors forming a thick nebulosity from which abundant precipitation fell mainly in the form of snowfall.

This type of survey maintained during the four days thus confirming the persistence of snowfall.

The large anticyclonic fields located in the periphery of the anticyclonic field, in interaction with the mass of cold air inside the anticyclone led to abundant snowfalls and snowstorms in a large part of the continent.

Therefore, on 21 March, 2013 the snow layer disappeared from most part of Europe excepting the Northern-Eastern sector and Scandinavia where it had thicknesses up to 114 cm (fig. 4), announcing an early spring. We mention that in January, February and the first 20 days of March there were registered for a large part of the continent many days with temperature means ≥ 0°C, namely "spring days".

After the interval 25-28 March, 2012 when it snowed on extended areas over the continent, ***the snow layer extended towards the west and south of the continent covering the northern half of Balkan Peninsula (fig. 5), which means that winter has come back strongly on the continent***.

After the extension of the snow layer, the advection of the cold air continued, and at night, the intense cooling due to radiation in the presence of the snow layer caused the severe fall of temperature and the advance of the cold air in the west of France (fig. 7).

Regarding Romania, we notice the fact that the ***role of orographic dam of Carpathians-Balkan Curvature*** was very important causing the "blocking" of moist air masses over Oltenia and the intensification of precipitation processes which led to the accumulation of the largest snow layer in the country, and the effect of sheltering is important for the area in the Northern Carpathians (fig. 1) where on extended areas no snow layer was formed in this period. Even the advection of the extremely cold air was somehow limited by this dam.

4. **Consequences of the cold wave**

The situations of weather intense cooling in the last decade of March were important for the climate of the spring of 2013, especially for the south-west of Romania.

Consequently, although during most part of March, the daily temperature means were positive, and in the interval March 25-28, 2013 they were mainly negative, leading to the drastic fall of the monthly means. Therefore, March 2013 was normal (N) from a thermal point of view, although the interval March 8-14, 2013 the means exceeded 10.0°C. This temperature fall also led to the registration of some indexes of spring arrival smaller than it was expected until March 25, which highlights the effect of late spring.

For the species of fruit trees whose floral buttons were formed, the consequence was the fall of a significant part of them, and those which resisted and blossomed did not put forth buds because of the destruction of flower stamens and pistil during the period of frost.

For the species of trees whose buds were not opened, the blossoming took place late, in the last part of April, due to the accumulation with the prolongation of cool weather in the first part of this month.

The development of spring and especially vegetable crops stagnated, and the vegetable crops from unheated solariums were destroyed.

Wind gusts in some intervals of time caused the destruction of solariums' wrap exposing crops to frost.

All these things had economic consequences, causing the late coming on the market of vegetables.

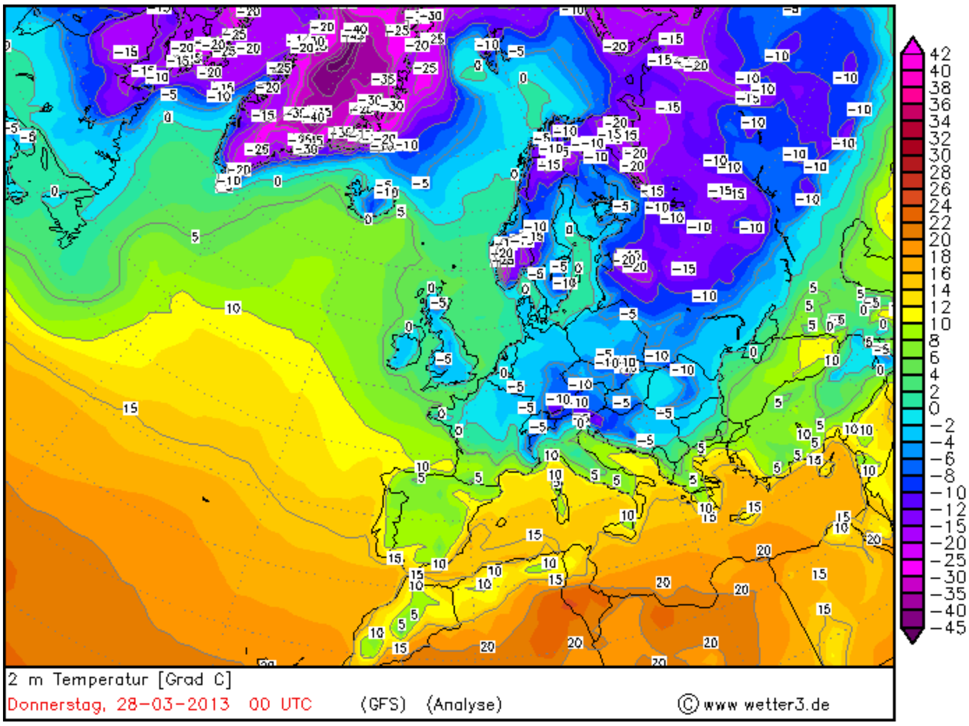

Fig. 7. ***The field of temperature at the ground level in Europe, on March 28, 2013 at 00 UTC* (according to wetter3.de).**

CONCLUSIONS

In the interval March 25-28, 2013 weather cooling, due to a cold wave which occurred after a long period of warm winter, caused significant destructions of spring crops and economic damages.

This interval represented ***a negative thermal oscillation*** which has lasted for five days and has brought the winter again in a large part of the continent, beginning with Great Britain (especially Scotland), where more than 2 000 persons were killed by the low temperatures, and then with France, Hungary, Russia, Ukraine, but also overseas, in the USA where schools were closed.

Although late spring and early autumn cold waves do not cause such an intense weather cooling as the winter cold waves, the consequences of their occurrence are important, leading to economic losses, especially in agriculture.

Their degree of damage and danger is high if they occur after long periods of warm weather, when the vegetative processes acted a long time, leading to advanced plant development stages.

These are ***directly connected with the variability of climate system, a record in its history, as the scientific researches in the last 20-30 years show.***

The issue of the spring late and early autumn cold waves must be handled taking into account the climate normal values of the period in which they occur and the climatic specificity of the affected area.

The macroprocess of spring arrival is complex, with significant thermal oscillations in March, when in Romania in time, the thermal variations were extremely high. In this context we remind you that ***the absolute maximum temperature value in Romania in March is 32.8°C registered on March 30, 1952 in Odobeşti; in the same day, in Constanţa and Călăraşi there was registered 30.8°C, and in Giurgiu and Sibiu 30.4°C (according to NAM website), values characteristic to summer days (according to some sources these values were registered on March 29, 1952). March is the last month of the cold season but also the first calendar month in which the daily thermal maximum values can reach and exceed 30°C***;

In the same month, March 1952, on March 9, 1952 there was registered in Romania, the absolute thermal minimum value of -31.4°C in Întorsura Buzăului,. Therefore, during 21 days, in Romania, in March, air temperature passed from -31.4°C to +32.8°C marking a maximum thermal jump of 64.2°C, which confirms the great climatic variability of March, when winter "meets" spring.

Such late cold waves can take place also later in April and May when negative temperatures can be registered. For example, the cold wave associated with snowfall and snowstorm which occurred in the interval April 1-2, 1904 when the storm-wept snow formed a thick layer of 10 cm all over Wallachia and Dobrudja; in addition, in the interval May 21-22, 1952 another strong cold wave, as a consequence of an advection of arctic cold wave, covered the entire country, leading to the appearance of hoarfrost which damaged all crops that were at that time in full development, excepting Danube Meadow and Delta where rich dew depositions were registered (Topor, 1958; Bogdan 1980).

These phenomena with continental manifestation at great scale are the consequence of climate oscillation at the level of the entire continent or even of the Northern Hemisphere, which reflects the influence of the North-Atlantic and Arctic Oscillation above Europe.

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