

## Indexes of Spring Arrival between 2000 and 2010 in Oltenia

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### Abstract

The present paper deals with the conditions related to spring arrival in Oltenia between 2000 and 2010. A first general evaluation may be achieved by comparing the mean general indexes for the entire region of Oltenia for each spring, which are calculated as a mean of the indexes of spring arrival for all the meteorological stations from Oltenia, including the mountainous area.

Out of the 11 analysed years, the lowest value was 171.1°C, registered in the spring of 2003, which followed the coldest winter (2002-2003) of the studied interval (Bogdan, Marinică, Marinică, 2010); the highest value reached 460.7°C and it was registered in the spring of 2002 that followed a warm winter, 2001-2002, the general mean of which is on the 9<sup>th</sup> place in the increasing hierarchy of the general temperature means for winter during the analysed interval.

The general mean of the index for the 11 analysed years is 366.0°C with a positive percentage deviation of 43.2%, which, according to a Hellmann's type of criterion established by us, emphasizes that springs were early (E) during the entire period.

The negative deviation of the latest spring (2003) was of -29.1.1%, which means a late spring (L). The second value of the index was 262.9°C, which means a normal spring. The positive deviation of this general mean of the spring arrival index for the spring in question (2003) reached 7.1%, which means a normal spring, in fact, the single normal spring of the entire interval. For Oltenia, as well as for the entire country, the decade 2000-2010 was warm. It stands out through – the warmest winters, which also registered the highest frequency, the earliest springs, the hottest summers with the more extended dog days' periods, the exceeding of certain absolute thermal maximum values in the country, some of them considered real "climatic thresholds", all induced by the climate variation limits of the end of the 20<sup>th</sup> century and the beginning of the 21<sup>st</sup> century. The predominance of early springs represent a proof of the regional climatic changes during this interval.

**Keywords:** *spring arrival indexes, spring arrival criterion, spring arrival conditions, early springs, climatic risk of early spring arrival*

### Rezumat. Indici de imprimăvărare în perioada 2000-2010 în Oltenia

În prezenta lucrare sunt studiate condițiile de imprimăvărare în Oltenia în intervalul 2000-2010. O primă evaluare generală o putem face comparând indicii medii generali pentru întreaga regiune Oltenia din fiecare primăvară, care se obțin ca medie a indicilor de imprimăvărare calculați la stațiile meteorologice din Oltenia, inclusiv arealul de munte aferent Olteniei.

Din cei 11 ani luați în calcul, cea mai mică valoare a fost 181,1°C, înregistrat în primăvara anului 2003, care a urmat după cea mai rece iarnă (2002-2003) a acestui interval analizat (Bogdan, Marinică, Marinică, 2010) și cea mai mare valoare a fost 499,4°C înregistrată în primăvara anului 2002 (care a urmat după iarna caldă 2001-2002, a cărei medie generală ocupă locul 9 în ierarhia crescătoare a mediilor generale de temperatură pentru anotimpul de iarnă în intervalul analizat).

Media generală a indicelui de imprimăvărare pentru cei 11 ani este 366,2°C cu o abatere procentuală pozitivă de 43,2%, care după un criteriu de tip Hellmann (întocmit de noi) arată că în întreg intervalul analizat primăverile au fost timpurii (Ti).

Abaterea negativă a celei mai târzii primăveri (2003) a fost de -29,1%, ceea ce înseamnă o primăvară târzie (T). A doua valoare a indicelui de imprimăvărare a fost de 262,9°C, adică o singură primăvară normală. Abaterea procentuală pozitivă a acestei medii generale a indicilor de imprimăvărare a acestei primăveri (2003) a fost de 7,1%, ceea ce desemnează o primăvară normală (N), singura primăvară normală din tot acest interval. Pentru Oltenia ca și pentru întreaga țară, intervalul 2000-2010 a fost cald în întreg ansamblul său, remarcându-se prin: cele mai calde ierni care au avut și cea mai mare frecvență, cele mai timpurii primăveri, cele mai călduroase veri cu cele mai întinse perioade caniculare, depășirea unor maxime termice absolute pe țară și la stațiile meteorologice, unele din acestea considerate ca adevărate „praguri climatice” impuse de limitele de variație ale climatului de la sfârșitul secolului al XX-lea și începutul secolului al XXI-lea. Predominanța primăverilor timpurii reflectă o dovadă a schimbărilor climatice regionale remarcate mai ales în acest interval.

**Cuvinte cheie:** *indici de imprimăvărare, criteriu pentru imprimăvărare, condiții de imprimăvărare, primăveri timpurii, riscul climatic al primăverilor timpurii.*

## INTRODUCTION

Warming conditions are essential for vegetation development during the year. Generally, plants, animals, people, as well as the entire ecosystem are thermophilous. In case certain well-defined thermal standards are not reached, vegetation development is hardly possible or even entirely compromised. Food resources of a region depend on the good development of the vegetation and, in certain cases, the economic consequences are quite severe. Once climatic warming became a pregnant phenomenon, especially after 1990, early spring arrivals were more frequent due to the more intense and often penetrations of warm Mediterranean or tropical air in Romania (Bogdan and Marinică, 2009). Among the most affected regions were, of course, those located in the south and west of the country, where the frequency of western circulation, which bring warm and moist oceanic air, increased on the background of global warming.

## DATA AND METHODS

In order to quantify the thermal conditions during spring, it was defined *the spring arrival index as a sum of the mean daily positive values measured between the 1<sup>st</sup> of February and the 10<sup>th</sup> of April*.

In order to prove this situation, we have calculated the index of spring arrival (I) for each year and for the entire Oltenia, as well as its percentage deviation ( $\Delta$  %) compared to the normal (N)<sup>1</sup>, which allowed us the achievement of a Hellmann classification of different types of springs (Table no. 1).

We further render (Table no. 1) a type of Hellmann criterion made up by us for spring arrival index.

For Oltenia<sup>2</sup>, as well as for the entire country, the interval 2000-2010 was entirely warm, and we mention some of the warmest winters, which also registered the highest frequency, the warmest summers with the most extensive and intense hot periods, when certain absolute thermal maximum values were exceeded at some meteorological stations. Certain values were considered real "climatic thresholds" induced by the variation limits of climate during the 20<sup>th</sup> century.

<sup>1</sup> It was considered normal (N) the value obtained through the mediation of spring warming indexes for the interval 1901-1990 (we had archive data for this interval). The annual value of the spring warming index for each station comes from the sum of the positive daily mean temperatures for February, March and the first decade of April, and the general annual value represents the mean of the annual values registered at all the stations in the region.

<sup>2</sup> region located in southwestern Romania

**Table 1**  
Criterion of Hellmann type for the spring warming index

Deviation % compared to the normal I	Spring type	Abbreviation
$\leq -70$	Excessively late	<b>EL</b>
-69,9...-50	Very late	<b>VL</b>
-49,9...-30	Late	<b>L</b>
-29,9...-10	Little late	<b>LL</b>
-9,9...+10	Normal	<b>N</b>
10,1...30,0	Little early	<b>LE</b>
30,1...50,0	Early	<b>E</b>
50,1...69,9	Very early	<b>VE</b>
$\geq 70$	Excessively early	<b>EE</b>

Some climatologists believe these values are hard if not impossible to be soon exceeded. Thus, we mention the absolute thermal maximum value for July, which was exceeded twice in only 7 years, while the previous record had been dating for 86 year (Marinică, 2006; Bogdan and Marinică, 2007). We shall further analyse the early spring warming between 2000 and 2010 within Oltenia.

We may render a *first general evaluation* by comparing the general mean indexes for the entire Oltenia for each spring, which can be obtained as an average of the spring warming indexes calculated for each year at all the meteorological stations from the region, including the mountainous area (Table no. 2, Fig. no. 1).

We notice that out of the 11 studied years, the lowest value was 181.1°C, registered in the spring of 2003 (Table no. 2), which followed a cold winter (2002-2003) (Bogdan et al., 2010), while the highest value reached 499.4°C in the spring of 2002 and it was registered after a warm winter 2001-2002 (the general average is the 9<sup>th</sup> in the increasing hierarchy of the general winter temperature means of the analysed interval<sup>3</sup>).

*The general mean of the spring arrival index for the 11 years is 366.2°C, with a positive percentage deviation of 43.2%, which, according to the criterion proposed by us, indicate that all the springs were early (E) (Table no. 2). The negative deviation of the latest spring (2003) was -29.0%, which means a late spring (L) according to the aforementioned criterion. The second value of the*

<sup>3</sup> The hierarchy of the winters from the interval 1999-2000 – 2009-2010, according to the increasing values of the mean temperature for the entire region is: 2002-2003, 2009-2010, 2005-2006, 2008-2009, 2003-2004, 2007-2008, 1999-2000, 2004-2005, 2001-2002, 2000-2001, 2006-2007 (Bogdan, Marinică, Marinică, 2010).

spring warming index was 262.9°C for the spring of 2005, registered after the winter 2004-2005, the general mean of which is the 8<sup>th</sup> in the increasing hierarchy of winter temperature means. 2005 is also one of the rainiest years in the history of meteorological observations from Romania.

**Table 2**  
**Hierarchy of spring arrival indexes (°C), general average values for the entire Oltenia region<sup>4</sup>.**

Hierarchy	Year	Index	N	Δ°C	Δ%	T
1	2003	181.1	255.8	-74.3	-29.0	L
2	2005	262.9	255.8	7.1	2.7	N
3	2006	300.0	255.8	44.2	17.3	LE
4	2004	331.3	255.8	75.5	29.5	LE
5	2010	339.3	255.8	83.5	32.6	E
6	2009	360.0	255.8	104.2	40.7	E
7	2000	408.1	255.8	152.3	59.5	VE
8	2001	421.8	255.8	166.0	64.9	VE
9	2008	453.5	255.8	197.7	77.3	EE
10	2007	471.4	255.8	215.6	84.3	EE
11	2002	499.4	255.8	243.6	95.2	EE
Average		366.3	255.8	110.5	43.2	E

Source: Processed data

The percentage deviation of this general mean of the spring warming index (2005) was 2.7%, which according to our criterion, indicates a normal spring (N), the only normal spring during the analysed interval.

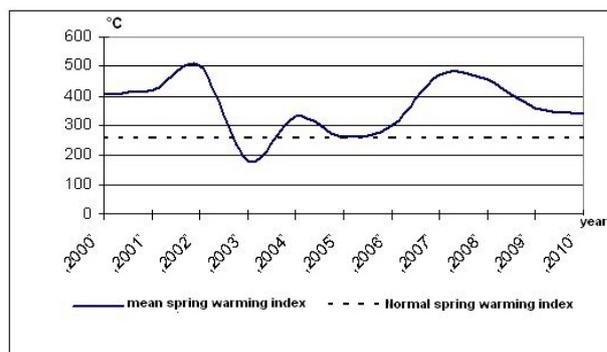
## DISCUSSIONS

### 1. The spring of 2000

2000 marked, in Oltenia as well as in the entire country, the appearance of intense heat waves and extended canicular periods.

The hot summer came after an early spring – the arrival index is the 7<sup>th</sup> in the increasing hierarchy for the analysed period in Oltenia (Table no. 2). The winter 1999-2000 was also warm and, according to the general mean, it is the 7<sup>th</sup> in the increasing hierarchy.

<sup>4</sup> Index = index of spring arrival, namely the sum of the positive daily mean temperatures from the interval February 1 – April 10 ( $\sum T^{\circ}\text{C}$ ) (<http://www.meteoromania.ro/>); N= multiannual mean of the spring warming index for the interval 1901-1990; Δ°C= deviation of the spring warming index (positive or negative) expressed in °C compared to the normal (N), namely (I-N); Δ%= The same deviation in % from the normal (N); Type see Table no. 1. From Table no. 2, it results: 1 late spring; 1 normal; 2 little early; 2 early; 2 very early and three exceptionally early. On the whole, in Oltenia, springs were early (E). T= Type of spring.



**Fig. 1 Variation of the mean spring arrival index in Oltenia between 2000 and 2010**

The general mean of spring arrival index for the entire Oltenia was 408.1°C and its deviation compared to the general multiannual mean was positive, respectively 59.5%, which make us classify this spring as very early (VE) (Table no. 2). The warming indexes calculated for the meteorological stations from Oltenia varied between 264.0°C at Voineasa and 574.3°C at Calafat; their percentage deviations compared to the multiannual mean values oscillating between 102.8% at Polovragi and 230.4% at Calafat. Within most of the region, this spring was excessively early (EE). In the mountainous area, spring warming was also excessively early with deviations between 119.0% at Ob. Lotrulului and 253.9% at Parâng.

Following the percentage share of the temperature sum of each month that express the percent of the arrival index achieved in the respective month at each station, one may notice that the highest rate of the early arrival corresponds to March. For each month the rapport was: in February, it oscillated between 14.0% at Voineasa and 26.9% at Calafat; in March, it varied between 42.0% at Polovragi and 48.5% at Băcleș, and the mean daily positive temperatures registered in the first decade of April contributed to the achievement of values of 26.5% at Calafat and 39.2% at Polovragi.

According to Hellmann criterion, February was warm (W) with deviations of the monthly means between 1.8°C at Voineasa and 4.3°C at Calafat. March was warmish (Ws) with deviations of the monthly mean values between 0.3°C at Voineasa and 2.2°C at Calafat compared to the normal, while April was warm (W), registering deviations of 1.4°C at Ob. Lotrulului and 3.4°C at Calafat.

### 2. The spring of 2001

The spring of 2001 was very early (VE) and the general mean of the spring arrival index reached 421.8°C, occupying the 8<sup>th</sup> place in the increasing hierarchy for the analysed period.

*Warming thermal conditions in 2001*

The positive deviation of the general mean compared to the general multiannual mean (N) was 166.0°C, namely 64.9%, which allows us to consider it as very early (VE). The values of the warming indexes at the meteorological stations from Oltenia oscillated between 308.6°C at Voineasa and 515.2°C at Calafat.

The positive deviations of spring arrival indexes compared to the multiannual means varied between 42.3% at Bechet and 99.7% at Voineasa.

Spring arrival was excessively early (EE) at 8 of 17 meteorological stations (including Ob. Lotrului) (47.1%), very early (VE) at 5 stations, and early (E) at 4 stations, namely 23.5%.

Within the mountainous area, the positive deviation of the spring arrival indexes was 81.5°C at Ob. Lotrului and 88.1°C at Parâng, what in percentage terms means deviations of 407.5% and, respectively, 383.0%.

*The sum of the positive daily mean temperatures in February* oscillated between 81.2°C at Rm. Vâlcea and 114.8°C at Dr. Tr. Severin and the percentage of these sums of the spring arrival index varied between 13.0% at Apa Neagră and 22.5% at Dr. Tr. Severin, the mean of this month reaching 14.3% for the entire Oltenia. According to Hellmann criterion, February 2001 was warm (W) within the entire region except for the mountain area where it was warmish (Ws). The sums of the positive daily mean temperatures in February are comparable to the ones registered in the first decade of April.

*The sum of the positive daily mean temperatures in March* oscillated between 207.6°C at Voineasa and 315.3°C at Calafat. The percentage share of these sums to the spring warming index was comprised between 56.0% at Dr. Tr. Severin and 68.1% at Parâng, the mean for the entire Oltenia being 61.3%. March 2001, according to Hellmann criterion, was warm (W) in the entire region.

*The sum of the positive daily mean temperatures in the first ten days of April* was 94.7°C at Polovragi and 119.0°C at Apa Neagră. The percentage of these sums to the warming index varied between 21.5% at Dr. Tr. Severin and 32.7% at Voineasa, while in the mountainous area it was 31.9% at Ob. Lotrului and 40.9% at Parâng

According to Hellmann criterion, April was thermally normal within the entire Oltenia.

We may conclude that the sums of the positive daily mean temperatures were preponderant for the spring warming index.

**3. The spring of 2002**

*The general mean of the spring arrival index* was 499.4°C, the highest value registered in the analysed interval. The deviation compared to the general multiannual mean (N) was of 243.6°C, namely 95.2%, which means it was an exceptionally early spring (EE), the highest deviation of the analysed interval.

*The sum of the positive daily mean temperatures in February 2002* oscillated between 30.4°C at Voineasa and 211.8°C at Calafat, the highest of the analysed interval. The percentage share of these sums to the spring arrival indexes calculated for each meteorological station varied between 30.1% at Tg. Jiu and 38.3% at Polovragi.

According to Hellmann criterion *February 2002* was very warm (VW) in the entire region and the positive deviations of the monthly mean values compared to the multiannual values varied between 5.3°C at Tg. Logrești and Apa Neagră and 7.6°C at Drăgășani (Bogdan, Marinică, Marinică, 2010).

*The sum of the positive daily mean temperatures in March 2002* were between 207.6°C at Polovragi and 319.4°C at Calafat, the highest of all March months of the interval 2000-2010. The percentage share of these sums to the spring arrival indexes were comprised between 51.0% at Polovragi and 55.6% at Tg. Jiu; in the mountains, it varied between 53.5% at Voineasa and 62.4% at Ob. Lotrului.

According to Hellmann criterion, *March 2002* was warm (W) and the positive deviations of the monthly means to the multiannual monthly means were of 2.7°C at Voineasa and 4.8°C at Drăgășani.

*The sum of the positive daily mean temperatures in the first decade of April 2002* varied between 57.4°C at Voineasa and 84.5°C at Craiova; the percentage of these sums to the spring arrival index oscillated between 10.8% at Polovragi and 14.8% at Craiova.

According to Hellmann criterion, *April 2002* was thermally normal (N) within the entire region. The deviations of the monthly means compared to the multiannual values were negative, most of them registering -0.9°C and -0.3°C.

**4. The spring of 2003**

It was a late spring (L) and the *mean of spring arrival indexes* registered the lowest value of the analysed interval, 181.1°C, with a negative deviation of -74.3°C, namely -29.0% (Table no. 2).

The spring of 2003 came after the coldest winter of the interval (Bogdan, Marinică, Marinică, 2010), the general mean value of which for the entire Oltenia was -1.3°C.

It is worth mentioning that after this late spring, at the European level, it followed a canicular summer called by the climatologists from Western and Central Europe “killer summer” due to the extreme intensity of the heat waves that generated an impressive number of casualties in July and August. It marked a rapid passage from a cool or even cold weather to an excessively hot one.

#### *Spring arrival conditions*

*Spring arrival indexes* oscillated between 133.5°C at Voineasa and 244.4°C at Dr. Tr. Severin, while the deviations compared to the multiannual mean values were all negative (except for one settlement). They were between -113.0°C at Dr. Tr. Severin and 5.4°C at Apa Neagră.

*February 2003* was cold (C) within the entire region (Bogdan, Marinică, Marinică, 2010) and the negative deviations of the monthly temperatures oscillated between -4.5°C at Apa Neagră and -3.5°C at Dr. Tr. Severin, Băilești, and Rm. Vâlcea.

Consequently, just a few mean daily values were positive and their sum for the entire month was between 0.0°C at Băcleș, Voineasa, Ob. Lotrului, and Parâng and 4.2°C at Apa Neagră. The percentage share of the positive mean monthly temperatures was insignificant – 0.0% at Băcleș, Voineasa, Ob. Lotrului, and Parâng and 2.0% at Tg. Logrești.

*March 2003* was also cold within most of the Oltenia, except for some reduced areas located in the south-west and the Subcarpathian Depression Tg. Jiu-Câmpu Mare, where it was normal (N). The negative deviations of the mean monthly temperatures oscillated between -1.9°C at Craiova and -0.5°C at Tg. Logrești and Tg. Jiu. The sum of the positive daily mean temperatures were the lowest of the analysed interval and varied between 79.6°C at Polovragi and 167.2°C at Dr. Tr. Severin. Their percentage share to the spring arrival index were between 62.0% at Craiova and Caracal and 69.1% at Băcleș. Within the mountainous area, these percentages varied between 66.6% at Voineasa and 92.5% at Ob. Lotrului. We conclude that the monthly sums of the positive daily mean temperatures essentially contributed to the achievement of the spring arrival indexes.

*April 2003* was cold within most of Oltenia, except for some reduced areas located in the south and the Subcarpathian Depression, where it was normal.

*The sums of the positive daily mean temperatures during the first decade of the month* varied between 44.6°C at Voineasa and 79.1°C at Calafat, while their percentage share to the spring

arrival indexes were between 29.7% at Apa Neagră and 37.7% at Craiova and Caracal. Cold weather registered in winter prolonged during spring leading to the late development of the vegetation, including crops, as well as to the extension of dwelling heating.

#### **5. The spring of 2004**

*The mean arrival index* was 331.7°C, the 4<sup>th</sup> as value in an increasing hierarchy; the positive deviation compared to the normal (N) was 75.5°C, namely 29.5%, which means a little early spring (LE).

*The spring arrival indexes* calculated for the meteorological stations were between 264.1°C at Polovragi in the Subcarpathian Depression and 428.9°C at Băilești, in the Oltenia Plain. *The deviations compared to the multiannual means* (N) were all positive and varied between 31.8°C at Dr. Tr. Severin and 135.1°C at Apa Neagră, while the percentage deviations oscillated between 8.9% at Dr. Tr. Severin and 77.0% at Voineasa.

*In the mountains*, spring arrival was excessively early (EE), registering high deviations from the normal, 119.0°C at Voineasa and 72.4°C at Ob. Lotrului.

#### *Spring arrival conditions*

*February 2004* was warmish (Ws) within most of the region, with positive deviations oscillating between 1.0°C at Tg. Logrești, Tg. Jiu, and Rm. Vâlcea and 2.8°C at Calafat, except for the Oltenia Plain and Drăgășani area, where it was warm (W) (Bogdan, Marinică, Marinică, 2010).

The monthly sums of the positive daily mean temperatures were between 19.2°C at Voineasa and 54.1°C at Calafat, while their percentage share to the spring arrival index oscillated between 6.9% at Băcleș and 13.6% at Calafat, in the south-west of the region.

*March 2004* was warmish (WS) within the entire region registering positive deviations of 0.7°C at Băcleș (the only area where this month was normal form the thermal point of view) and 1.9°C at Calafat.

*The monthly sums of the positive daily mean temperatures* oscillated between 156.2°C at Polovragi and 271.5°C at Băilești; the percentage shares of these sums to the spring arrival indexes were between 58.9% at Calafat and 63.3% at Băilești. *In the mountainous area*, these shares were significantly greater and varied between 59.6% at Voineasa and 67.2% at Parâng. We notice again that March thermal regime decisively contributed to the achievement of arrival indexes.

April 2004 was thermally normal (N) in most of the region and warmish (WS) within the Subcarpathian Depression and in the mountains. The positive deviations were between  $-0.1^{\circ}\text{C}$  at Rm. Vâlcea (the only exception!) and  $1.3^{\circ}\text{C}$  at Voineasa and Ob. Lotrului, and  $1.4^{\circ}\text{C}$  in the Parâng.

The sums of the positive daily mean temperatures during the first decade of the month varied between  $86.5^{\circ}\text{C}$  at Polovragi and  $116.0^{\circ}\text{C}$  at Caracal; the percentage shares of these months to the arrival indexes oscillated between 27.5% at Calafat and 33.3% at Voineasa.

## 6. The spring of 2005

The mean general index for Oltenia reached  $262.9^{\circ}\text{C}$ , namely the second value in the increasing hierarchy for the analysed period. Its positive deviation compared to the multiannual average of only  $+7.1^{\circ}\text{C}$ , namely  $+2.8\%$ , allows its classification as a normal spring (N), the only normal spring (Table no. 1). Within the Oltenia Plain, spring arrival varied from normal (N) to little late (LL), registering preponderantly negative percentage deviations from  $+17.1\%$  at Dr. Tr. Severin to  $8.0\%$  at Caracal. In the eastern part of the region and in the hilly area, spring arrival was normal (N) to LE (LE). The percentage deviations oscillated between  $-4.0\%$  at Tg. Jiu and  $23.6\%$  at Tg. Logrești, mainly due to the frequent thermal inversion phenomena from Oltenia, which are favoured by relief, types of circulations and pressure regime. In the high mountainous area, spring arrival was excessively early registering percentage deviations between  $127.8\%$  at Parâng and  $244.0\%$  at Ob. Lotrului.

It is worth mentioning that 2005 was the rainiest year in the history of meteorological observations and the excessively rainy period covered the interval April-September, the top corresponding to the summer months.

### Spring arrival conditions in 2005

In February, the monthly sums of the positive daily mean temperatures varied between  $13.1^{\circ}\text{C}$  at Voineasa and  $48.0^{\circ}\text{C}$  at Rm. Vâlcea, while their percentage shares to the arrival indexes were between  $5.6\%$  at Băilești and  $16.8\%$  at Rm. Vâlcea. According to Hellmann criterion, if taking into account the mean monthly temperature, February 2005 was cold (C) in the entire Oltenia. According to the monthly means registered at the meteorological stations, it was cool (CI) only in the Subcarpathian area, while in the rest of the region it was cold. The deviations compared to the multiannual monthly means were comprised

between  $-3.8^{\circ}\text{C}$  at Băilești and  $-1.0^{\circ}\text{C}$  at Polovragi and Parâng, with only one exception,  $0.6^{\circ}\text{C}$  at Băcleș.

In March, the sums of the positive daily mean temperatures varied between  $87.9^{\circ}\text{C}$  at Voineasa and  $182.5^{\circ}\text{C}$  at Calafat; their percentage shares to the spring arrival index were between  $47.4\%$  at Voineasa and  $62.7\%$  at Calafat. In the mountains, these oscillated between  $47.9\%$  at Parâng and  $61.5\%$  at Ob. Lotrului.

In April, the monthly sums of the positive daily mean temperatures during the first decade of the month oscillated between  $77.6^{\circ}\text{C}$  at Polovragi and  $102.5^{\circ}\text{C}$  at Băcleș; their percentage shares to the arrival indexes were between  $30.5\%$  at Calafat and  $45.6\%$  at Voineasa. In the mountain area, they were between  $38.4\%$  at Ob. Lotrului and  $52.1\%$  at Parâng.

## 7. The spring of 2006

The general mean of spring arrival indexes for the entire region was of  $300.0^{\circ}\text{C}$ , the third value in the increasing hierarchy for the analysed period; the percentage deviation was  $17.3\%$  which allows us to classify it as a little early spring (LE).

It was a rainy spring within whole Europe, with a rapid arrival following a winter with rich precipitation amounts, which brought to the registration of the highest discharge of the Danube ( $15,900\text{ m}^3/\text{s}$  at Baziaș on the 17<sup>th</sup> of April, 2006) and to severe floods along its lower course.

Spring arrival indexes oscillated between  $212.2^{\circ}\text{C}$  at Voineasa and  $357.2^{\circ}\text{C}$  at Dr. Tr. Severin. In the west of the Oltenia Plain, spring arrival was normal, while in the east and north, it was little early (LE) to early (E), registering positive percentage deviations of  $12.7\%$  at Caracal and  $37.7\%$  at Voineasa. In the mountains, spring arrival was exceptionally early as it installed by the end of February.

### Spring arrival conditions in 2006

According to Hellmann criterion, February 2006 was thermally normal (N) within most of the region, except for certain areas located in the hilly region and the Subcarpathian Depression (Tg. Logrești, Apa Neagră, Tg. Jiu) where it was cool (CI); the deviations of the monthly means compared to the multiannual means were negative and oscillated between  $-1.6^{\circ}\text{C}$  at Apa Neagră and Ob. Lotrului and  $-0.1^{\circ}\text{C}$  at Polovragi and Parâng. In the mountainous area, it was normal at Parâng and cool at Ob. Lotrului.

The monthly sums of the positive daily mean temperatures in February were comprised between  $27.4^{\circ}\text{C}$  at Voineasa and  $48.1^{\circ}\text{C}$  at Drăgășani, while

their percentage shares to the spring arrival indexes oscillated between 10.2% at Tg. Jiu and 13.9% at Bâcleș, with a general mean value of 12.2% for the entire Oltenia.

According to Hellmann criterion, *March 2006* was normal in the entire region, registering deviations of the monthly mean temperatures comprised between  $-0.9^{\circ}\text{C}$  at Voineasa and  $+0.8^{\circ}\text{C}$  at Tg. Logrești. *The monthly sums of the positive daily mean temperatures* oscillated between  $93.1^{\circ}\text{C}$  at Voineasa and  $197.5^{\circ}\text{C}$  at Dr. Tr. Severin. The percentage shares of these sums to the spring arrival indexes were between 43.9% at Voineasa and 55.3% at Dr. Tr. Severin.

*April 2006*, according to Hellmann criterion, was warmish (Ws) within most of the region, except for certain areas from the Oltenia Plain (Craiova, Cracal), the Subcarpathian Depression (Polovragi), and the mountains (Ob. Lotrului), where it was thermally normal (N). the deviations of the monthly mean values were comprised between  $0.2^{\circ}\text{C}$  at Polovragi and  $1.4^{\circ}\text{C}$  at Tg. Jiu. *The monthly sums of the positive daily mean temperatures* during the first decade varied between  $91.7^{\circ}\text{C}$  at Voineasa and  $119.6^{\circ}\text{C}$  at Băilești, while their percentage shares to the spring arrival indexes were between 32.2% at Dr. Tr. Severin and 43.2% at Voineasa.

### **8. The spring of 2007**

The general mean of spring arrival indexes was of  $471.4^{\circ}\text{C}$ , the 10<sup>th</sup> value in the increasing hierarchy for the analysed period, while the positive deviation compared to the multiannual mean reached  $215.6^{\circ}\text{C}$ , or 84.3%, which means an exceptionally early spring (EE).

*Spring arrival indexes* varied between  $343.2^{\circ}\text{C}$  at Voineasa and  $580.7^{\circ}\text{C}$  at Dr. Tr. Severin, while the deviations were all positive, comprised between  $188.7^{\circ}\text{C}$  at Voineasa and  $267.2^{\circ}\text{C}$  at Drăgășani. Their percentage shares oscillated between 62.5% at Dr. Tr. Severin and 122.0% at Voineasa. According to the established criterion, the spring of 2007 was excessively early (EE) within most of the Oltenia, except for the south-western part of the Oltenia Plain where it was very early (VE).

After a very dry January within most of the region, there followed *February and March that were exceptionally rainy*, then, *April very dry* (VD) in the entire region. During the last part of May, rains started again, then June and July were also very dry and exceptionally dry. The summer of 2007 was canicular, registering two heat

exceptional waves in June and July (Bogdan, Marinică, 2007, 2008).

#### *Spring arrival conditions in 2007*

After Hellmann criterion, *February 2007* was warm (W) within the entire region, registering positive deviations of the monthly mean temperatures compared to the multiannual values that oscillated between  $3.6^{\circ}\text{C}$  at Tg. Logrești and  $4.9^{\circ}\text{C}$  at Băilești and Caracal. *The monthly sums of the positive daily mean temperatures* were between  $85.1^{\circ}\text{C}$  at Voineasa and  $166.1^{\circ}\text{C}$  at Băilești, which represents the second place after February 2002. The percentage shares of these sums to the spring arrival indexes varied between 24.8% at Voineasa and 29.2% at Băilești.

*March 2007*, according to Hellmann criterion, was warm (W) in the entire region, registering positive deviations of  $2.2^{\circ}\text{C}$  at Bâcleș and  $3.3^{\circ}\text{C}$  at Tg. Jiu. *The monthly sums of the positive daily mean temperatures* were comprised between  $183.0^{\circ}\text{C}$  at Voineasa and  $298.2^{\circ}\text{C}$  at Dr. Tr. Severin, while their percentage shares to the spring arrival indexes were between 48.9% at Calafat and 53.3% at Voineasa.

*April 2007*, according to Hellmann criterion, was warmish (WS) within most of the region, except for the extreme south-west and the east of the Oltenia Plain where it was warm (W) and normal at Tg. Logrești, Polovragi, Voineasa, and Ob. Lotrului. The deviations of the monthly mean values compared to the multiannual values were between  $0.5^{\circ}\text{C}$  at Polovragi and Ob. Lotrului and  $2.6^{\circ}\text{C}$  at Calafat. *The monthly sums of the positive daily mean temperatures during the first decade* were comprised between  $75.2^{\circ}\text{C}$  at Voineasa and  $126.5^{\circ}\text{C}$  at Calafat, while their percentage shares to the achievement of the spring arrival indexes were between 20.9% at Tg. Logrești and 23.5% at Polovragi.

### **9. The spring of 2008**

*The general mean of spring arrival indexes* was of  $453.5^{\circ}\text{C}$ , the ninth value in the increasing hierarchy for the analysed period, while the positive deviation compared to the multiannual mean value was of  $197.7^{\circ}\text{C}$ , namely a percentage of 77.3%, which make us consider it an excessively early spring (EE).

*Spring arrival indexes* oscillated between  $359.9^{\circ}\text{C}$  at Voineasa and  $558.7^{\circ}\text{C}$  at Calafat; the deviations compared to the multiannual values were between  $173.3^{\circ}\text{C}$  at Rm. Vâlcea and  $270.1^{\circ}\text{C}$  at Apa Neagră, while the percentage ones, between 51.3% at Dr. Tr. Severin and 133.0% at Voineasa.

According to the criterion achieved by us, *spring arrival was very early* (VE) within the Oltenia Plain and certain areas of the Subcarpathian Depression (Tg. Jiu) and the Olt Couloir (Rm. Vâlcea) and *excessively early* (EE) within most of the region.

#### *Spring arrival conditions in 2008*

*February 2008* was warm (W) in the entire region according to Hellmann criterion, while the deviations of the monthly mean temperatures were comprised between 2.4°C at Tg. Logrești and 3.7°C at Calafat. *The monthly sums of the positive daily mean temperatures* were comprised between 80.1°C at Voineasa and 141.1°C at Dr. Tr. Severin, while their percentage shares to the spring arrival indexes varied between 19.0% at Caracal and 26.1% at Dr. Tr. Severin. *In the mountains*, these contributions were between 32.7% at Parâng and 39.3% at Ob. Lotrului.

*March 2008* was warm (W) within the entire region according to Hellmann criterion and the deviation of the monthly mean temperatures varied between 2.1°C at Voineasa and 3.8°C at Bechet and Caracal. The monthly sums of the positive daily mean temperatures were comprised between 185.1°C at Voineasa and 298.8°C at Bechet. The percentage shares of these sums to the spring arrival indexes varied between 51.3% at Polovragi and 56.9% at Caracal.

*April 2008* was warmish (WS) within most of the region, except for certain small hilly areas and parts of the Subcarpathian Depression where it was normal (N) (Tg. Logrești, Tg. Jiu, and Apa Neagră).

The deviation of the monthly means compared to the multiannual values were comprised between -0.1°C at Polovragi and 1.7°C at Calafat. *The monthly sums of the positive daily mean temperatures during the first decade* were between 93.4°C at Polovragi and 124.7°C at Calafat, while their percentage shares to the spring arrival indexes were between 22.0% at Dr. Tr. Severin and 26.3% at Voineasa.

### **10. The spring of 2009**

*The general mean of spring arrival indexes* reached 360.0°C, registering a positive deviation of 104.2°C, namely 40.7%, which signifies an early spring arrival (E).

*The spring arrival indexes* calculated for all the meteorological stations oscillated between 299.2°C at Polovragi and 419.8°C at Dr. Tr. Severin. The positive deviations compared to the multiannual mean values were between 62.4°C at Dr. Tr. Severin and 175.7°C at Apa Neagră, while the

percentages oscillated between 17.5% at Dr. Tr. Severin and 99.5% at Voineasa. Consequently, the spring arrival was little early (LE) in the south-west and extreme south-east of the Oltenia Plain, early (E) in Băilești Plain, Mehediți Hills, and the north of Dolj County, as well as partially within the Subcarpathian Depression and the Olt Couloir at Rm. Vâlcea, very early (VE) within the hilly area of Gorj and Vâlcea counties, and excessively early (EE) within the Subcarpathian Depression, at the foot of the mountains and in the mountainous area.

#### *Spring arrival conditions in 2009*

*February 2009* was thermally normal (N) within most of the region, according to Hellmann criterion, except for the extreme south-west of the Oltenia Plain where it was cold (C), at Calafat, and cool (Cl) at Bechet, as well as in certain parts of the Subcarpathian Depression (at Apa Neagră and Polovragi) and the mountainous area. The deviations of the monthly mean temperatures were comprised between -4.5°C at Calafat and Ob. Lotrului and 0.7°C at Voineasa (Bogdan, Marinică, Marinică, 2010). *The monthly sums of the positive daily mean temperatures* were comprised between 40.6°C at Voineasa and 75.5°C at Dr. Tr. Severin, while their percentage shares to the spring arrival indexes varied between 13.1% at Băcleș and 18.0% at Dr. Tr. Severin.

*March 2009* was warmish (Ws) within most of the region and thermally normal (N) within the Băilești Plain, certain areas of the Subcarpathian Depression, Mehediți Hills, and in the submountainous and mountainous area (Voineasa). The deviations of the monthly mean values compared to the multiannual temperatures were between 0.3°C at Voineasa and 1.3°C at Drăgășani and Tg. Jiu. *The monthly sums of the positive daily mean temperatures* oscillated between 128.9°C at Voineasa and Polovragi and 222.6°C at Bechet, while the percentage shares of these sums to the spring arrival indexes varied between 41.8% at Voineasa and 53.4 at Bechet.

*April 2009* was warmish (Ws) within most of the region and warm (W) in the areas of Drăgășani, Tg. Jiu, and Voineasa, thermally normal (N) in the south-west and extreme south-east of the Oltenia Plain, Polovragi area in the Subcarpathian Depression. *In the mountains*, it was warmish at Ob. Lotrului and warm at Parâng. The monthly sums of the positive daily mean temperatures during the first decade varied between 126.7°C at Bechet and Polovragi and 149.7°C at Apa Neagră, registering percentage shared to the achievement

of the spring arrival indexes between 30.3% at Bechet and 45.0% at Voineasa.

### 11. The spring of 2010

The general mean of spring arrival indexes was of 339.3°C, the fifth value in the increasing hierarchy for the analysed period, while the percentage deviation compared to the multiannual mean value was of 30.0%, which make us consider it an little early spring (LE), at only 0.1% from the class E.

Spring arrival indexes varied between 259.3°C at Polovragi and 403.8°C at Dr. Tr. Severin. The positive deviations compared to the multiannual mean values oscillated between 36.9°C at Calafat and 132.9°C at Tg. Logrești, while the percentage deviations between 10.7% at Calafat and 56.0% at Tg. Logrești. Spring arrival was little early (LE) within most of the Oltenia Plain and the Subcarpathian Depression, early (E) in the east of Oltenia, Mehedinți and Vâlcea Hills, very early (VE) partially within the Subcarpathian Depression, and excessively early in the mountains (EE).

#### Spring arrival conditions in 2010

February 2010 was cool (Cl) within most of the region, except for the south-west of the Oltenia Plain where it was cold (C), while at Tg. Jiu, Drăgășani, Rm. Vâlcea, and Parâng, it was thermally normal (N). The deviations of the monthly means were negative and varied between -3.2°C at Bechet and -0.2°C at Parâng. The monthly sums of the positive daily mean temperatures were comprised between 40.7°C at Băilești and 76.6°C at Rm. Vâlcea, while their percentage shares at the achievement of spring arrival indexes varied between 11.4% at Băilești and 20.6% at Rm. Vâlcea.

March 2010 was cold (C) within most of the region, except for the extreme south-west of the Oltenia Plain (Calafat) where it was cool, as well as at Drăgășani.

The deviations of the mean monthly temperatures were negative and varied between -1.3°C at Parâng and -2.8°C at Apa Neagră and Rm. Vâlcea.

In the interval March 6-12, the weather was cold characterized by snowfalls and blizzards which led to the formation of a thick snow cover and there were emitted yellow code warnings. The monthly sums of the positive daily mean temperatures were comprised between 187.4°C at Rm. Vâlcea and 220.5 at Dr. Tr. Severin, while their percentage shares between 50.5% at Rm. Vâlcea and 56.8% at Băilești.

April 2010 was cold (C) within most of the region, except for a mall area in the south-west of the Oltenia Plain (Calafat, Dr. Tr. Severin), Drăgășani and Rm. Vâlcea, where it was cool (Cl), while in the mountains, it was thermally normal. The deviations of the mean monthly values were negative and varied -3,6°C at Polovragi and -0,5°C at Parâng.

The monthly sums of the positive daily mean temperatures during the first decade oscillated between 80.3°C at Polovragi and 117.9°C at Dr. Tr. Severin, while the percentage shares to the achievement of the spring arrival indexes varied between 28.9% at Rm. Vâlcea and 32.0% at Caracal and Băcleș.

In Fig. 2, we render the spatial distribution of the spring arrival indexes registered in the 11 analysed years.

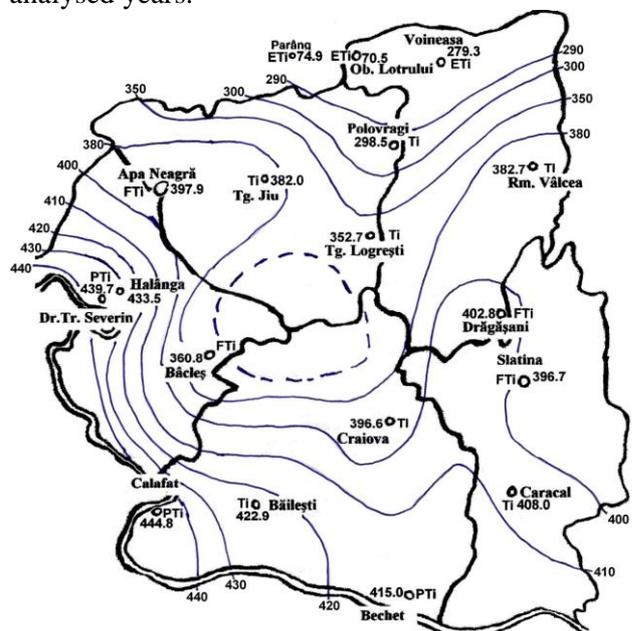


Fig. 2 Mean indexes of spring arrival for the interval 2000-2010

### CONCLUSION

During the analysed period, there were registered 9 early spring of a total of 11, which emphasizes that the rate of early springs reached 81.8%, a normal one (9.1%), and a late one (9.1%).

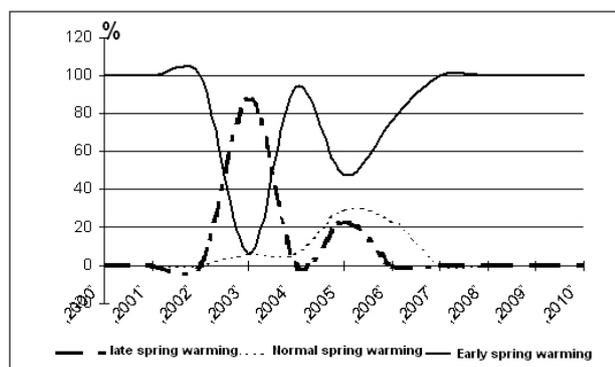
Among these, two springs were little early (LE) namely 18.2%, two were early (E), namely 18.2%, two very early – 18.2%, and three excessively early – 27.3%. According to the general mean of the spring arrival indexes for the 11 studied years and its deviation from the multiannual mean, the entire period is classified in the category of early springs (E) (Table 3). The predominance of early springs might be a proof of the regional climatic changes we noticed especially in the last decade of the 20<sup>th</sup>

century and the first decade of the 21<sup>st</sup> century. We consider eloquent the values rendered in Fig. 3.

*In the mountainous area*, most of the spring arrival was excessively early, thus confirming climatic arrival in this region, which is more intense than in the low plain or hilly-plateau areas.

The territorial distribution of these indexes emphasizes the presence of an area in the south-west and south of Oltenia that registered the earliest springs (Fig. 2). This is a consequence of the intensification of the atmospheric circulation from the southern part of the continent, the Mediterranean Sea and Northern Africa; warm tropical Mediterranean or continental (Asian or North-African) air advections reach the south-west of Romania during the entire year, but especially in winter and spring.

They penetrate in Oltenia through the Danube Defile and the Timok Valley and are blocked by the orographical barrier of the Carpathians in the region, which triggers massive winter and spring arrival.



**Fig. 3** Types of spring arrival according to the percentage values type/meteorological station of the indexes of spring arrival in Oltenia between 2000 and 2010

Spring arrival indexes decrease from south-west and south, northwards and north-eastwards, according to the direction of the landforms and altitude increase.

We remark the area located in the south of Gorj County, north of Dolj County, and west of Mehedinți County (where the three counties neighbours each other) where there are achieved more reduced warming indexes, even if there are also registered excessively early springs in certain years, according to the deviations from the multiannual means.

The earliest spring was registered in 2002, followed according to the decreasing value of the general mean of the spring arrival indexes for the entire Oltenia, by the springs of 2007 and 2008.

The highest share to the achievement of the spring arrival indexes is represented by the sums of

the positive daily mean temperatures registered in March, which makes it right to consider March as the first spring month.

*For the achievement of the excessively early spring arrival*, the sums of the positive daily mean temperatures registered in February had an important contribution.

Usually, the first decade of April is cold and there occur late hoarfrost by the end of the month. Early, very early, and excessively early springs were marked by the occurrence of cold or cool April months with sometimes quite intense hoarfrosts, which affected the already developed vegetation and produced important damages.

Early springs generally occurred after warm winters and thus, they came as a prolongation of the warm weather registered in winter.

Late or normal spring arrival occurred after cold winters.

During the cold or cool April months, vegetation, even if it is well developed, stagnates and it occurs its gradual deterioration, especially in the case of vegetables, orchards, and vineyards. Even if the hoarfrosts are not severe, low temperatures registered during the cold nights or even during the cold or cool days, hinder the fecundation processes at fruit-trees leading to extremely reduced fruit productions. This is why, we may consider *early spring arrival a climatic risk*.

During excessively early spring arrival, there were registered dry April and May months, which badly damaged agricultural crops and vegetal cover.

Spring arrival conditions are essential for the good development of crops during the entire agricultural year.

*If spring arrival is early*, all crops start the vegetation period in March or even February, and these discrepancy usually maintains during the entire agricultural year; in certain situations, cold weather registered in April reduces these differences, but it negatively affects vegetation.

*If spring arrival is late*, all crops start the vegetation period late and, in some cases, only in May the differences reduce, but, there are years when the differences are quite clear during the entire agricultural year, and the weather early cooling registered in autumn affect the crops that do not reach their maturity phase.

Our conclusions regarding the types of spring warming are well correlated with the monthly types of weather for the spring resulted after applying Hellmann criterion, which indicates the accuracy of our criterion for rendering the types of spring arrival.

Table 3 Spatial-temporal distribution of the types of spring arrival

Meteorological Station	Hm	Year and types of spring arrival											No cases			% types		
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	cL	cN	cE	cL%	cN%	cE%
Dr. Tr. Severin	77	E	E	VE	L	N	LL	N	VE	VE	LE	LE	2	2	7	18.2	18.2	63.6
Calafat	66	VE	E	EE	LL	LE	LL	N	VE	VE	LE	LE	2	1	8	18.2	9.1	72.7
Bechet	65	VE	E	EE	L	LE	LL	N	VE	VE	E	LE	2	1	8	18.2	9.1	72.7
Băilești	56	VE	E	EE	L	E	LL	N	EE	VE	E	LE	2	1	8	18.2	9.1	72.7
Caracal	112	VE	VE	EE	L	E	N	LE	EE	VE	LE	LE	1	1	9	9.1	9.1	81.8
Craiova	190	VE	VE	EE	L	LE	N	LE	EE	EE	E	LE	1	1	9	9.1	9.1	81.8
Slatina	165	EE	EE	EE	LL	E	LE	LE	EE	EE	E	E	1	0	10	9.1	0.0	90.9
Băceș	309	EE	EE	EE	L	LE	LE	LE	EE	EE	E	E	1	0	10	9.1	0.0	90.9
Tg. Logrești	262	E	VE	EE	LL	E	LE	LE	EE	EE	VE	VE	1	0	10	9.1	0.0	90.9
Drăgășani	280	EE	EE	EE	LL	E	LE	LE	EE	EE	VE	E	1	0	10	9.1	0.0	90.9
Apa Neagră	250	EE	EE	EE	N	VE	LE	E	EE	EE	EE	VE	0	1	10	0.0	9.1	90.9
Tg. Jiu	210	E	VE	EE	LL	LE	N	LE	EE	VE	E	LE	1	1	9	9.1	9.1	81.8
Polovragi	546	E	EE	EE	L	LE	N	LE	EE	EE	E	LE	1	1	9	9.1	9.1	81.8
Rm. Vâlcea	243	E	VE	EE	L	LE	N	LE	EE	VE	E	LE	1	1	9	9.1	9.1	81.8
Voineasa	587	EE	EE	EE	LL	EE	LE	E	EE	EE	EE	-	1	0	9	10.0	0.0	90.0
Ob. Lotrului	1404	EE	EE	EE	EL	EE	EE	EE	EE	EE	EE	-	1	0	9	10.0	0.0	90.0
Parâng	1585	EE	EE	EE	LE	EE	EE	EE	EE	EE	EE	EE	0	0	11	0.0	0.0	100.0
<u>Oltenia (average)</u>		VE	VE	EE	L	LE	N	LE	EE	EE	E	E	1	1	9	9.1	9.1	81.8
CL(No cases)		0	0	0	15	0	4	0	0	0	0	0	19	11	155	10.3	5.9	83.8
CN(No cases)		0	0	0	1	1	6	4	0	0	0	0						
CE(No cases)		17	17	17	1	17	8	14	17	17	17	17						
CL%		0.0	0.0	0.0	88.2	0.0	23.5	0.0	0.0	0.0	0.0	0.0	10.3					
CN%		0.0	0.0	0.0	5.9	5.9	29.4	23.5	0.0	0.0	0.0	0.0	5.9					
CE%		100.0	100.0	100.0	5.9	94.1	47.1	76.5	100.0	100.0	100.0	100.0	83.8					

Source: Processed data (Types of spring warming: cL=class of late spring warming= EL+VL+L+LL; cN=class of normal spring warming, namely the number of cases with normal spring warming N; cE=class of early spring warming=LE+E+VE+EE)

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