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Considerations upon extreme temperatures on Romanian territory

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Abstract

In this article we analyse the evolution in time of extreme temperatures significant for Romania with a focus on absolute extreme temperatures recorded on the overall present territory. After thoroughly investigating the credible sources referenced at the end of the paper, we present in chronological order the records for absolute minimum temperatures, and absolute maximum temperatures which were measured at the meteorological stations on the present territory of Romania, according to the availability of the data, i.e. the last two decades of the 19th century up until 2017. We classify and discuss the sources of climatological data in the form of minimum and maximum temperatures. The measurements of meteorological parameters on the current national territory were recorded since 1770 at Iași (cf. Dissescu 1931 and also *http://www.meteoromania.ro/anm2/despre-noi/istoric/* - page in Romanian as of 30.03.2017). For a systematic approach with credible data, at least another century passed, until Ștefan Hepites (1851-1922) founded in 1884 in Bucharest the Central Meteorological Institute of Romania (I.M.C. in Romanian) (Dissescu, 1931 and cf. the ANM web page quoted earlier). The newly created Institute did not include the meteorological stations which were present at that time in Transylvania, but only the ones on the official Romanian territory of 1859-1918 made up of Moldavia and Wallachia. This paper argues in favour of the process of global warming (GW) and its effects upon the evolution of extreme temperature values in a certain time interval. The conclusions stemming from the investigation of the dataset in this paper should provide a helpful and necessary point of departure in subsequent research of climatologists in their quest of identifying the correct model of future climate. Our article should be regarded as part of a series of analyses of the variability of the climate in Romania, the recent influence of global warming on it and on certain climatological parameters in particular.

Keywords: *absolute temperature records, global warming (GW), cold waves, heat waves*

Rezumat. Considerații asupra temperaturilor extreme pe teritoriul României

În lucrare este analizată evoluția în timp a unor extreme de temperatură semnificative pentru România și în mod deosebit a extremelor termice absolute pentru întreaga țară. După o cercetare amănunțită a surselor credibile menționate în bibliografie, am analizat în ordine cronologică recordurile absolute ale temperaturilor minime, respectiv ale celor maxime înregistrate la stațiile meteorologice de pe teritoriul actual al României, conform disponibilității datelor, începând cu ultima parte a secolului al XIX-lea și până în prezent. Sunt clasificate și discutate sursele datelor climatologice ale temperaturilor maxime și minime. Măsurătorile meteorologice pe actualul teritoriu național au fost înregistrate încă din 1770 la Iași (cf. Dissescu 1931 și *http://www.meteoromania.ro/anm2/despre-noi/istoric/* - pagină deschisă la 30.03.2017). Pentru o abordare sistematică însoțită de date credibile a mai trecut cel puțin un secol, până la înființarea la București a Institutului Meteorologic Central al României (I.M.C.) de către Ștefan Hepites în 1884 (Dissescu, 1931 și cf. cu site-ul ANM). Institutul nou creat nu includea stațiile meteorologice existente la momentul respectiv dincolo de Carpați, ci doar pe cele de pe teritoriul României din perioada 1859-1918 format din vechile state Moldova și Tara Românească. Lucrarea pune în evidență procesul încălzirii climatice și efectele acestuia asupra evoluției extremelor termice absolute pentru anumite intervale de timp. Precizările și clarificările obținute din analiza acestor date și surse sunt utile și necesare cercetătorilor în domeniul climei, pentru corectitudinea analizelor viitoare. Lucrarea face parte dintr-o serie extinsă de analize asupra variabilității climatului în România, a procesului de încălzire climatică și efectele acestuia asupra parametrilor climatici.

Cuvinte-cheie: *recorduri absolute de temperatură, încălzirea climatică, valuri de frig, valuri de căldură*

Introductory remarks

Throughout the past century and a half, the act of officially measuring air temperature on the Romanian territory was performed using a network of stations situated on all landforms, from the Black Sea up to the high peaks of the Carpathians. In time, methodologies have changed, the stations themselves were closed or moved to a better location, and the measuring equipment was changed several times and has lately been modernized (especially after 2000). Therefore, the historical data is only partially comparable to the data we obtain today by using the current modern network with the modern methodology and tools. However, a comparative analysis of the available dataset and especially of those considered extreme temperature values[1] for certain time intervals allows us to draw interesting conclusions just by noting how these evolved in time and under what atmospheric conditions their occurrence was favoured.

Data and methods used

For the present paper, the authors looked for data in the most credible written sources available. We have classified these sources into four categories, as follows:

[1] We call *extreme value* the smallest or the largest numerical value of a climatological parameter measured over a certain period of time. *The absolute extreme value* refers to the extremes from the entire sequence of climate data which were measured. Thus, we can talk about an extreme value for the whole country, for a certain area of it (for example a historical region of the country such as Oltenia), or an extreme value just for one station, one calendar season, one month, one year etc.

- *Primary sources* (raw data): the physical (paper) registry books of meteorological stations that owned thermometers for measuring minimum and maximum temperatures (at present, in modern automated stations electronic sensors). The correctness of the data from these registry books depends, in decreasing importance, on the following human factors: periodic calibration/replacement of alcohol and Mercury thermometers (currently periodically replacing temperature sensors), correct reading by the human eye of the extreme temperature showed by classical thermometers, correctly transcribing the figures read into the station's registry books. In case of automated stations quite common in the 21st century, the overall process is greatly simplified, the computer in the station practically showing on screen the temperature in real time using signals from the sensor, and, using a software, extracting by itself the minimum and maximum temperature over the last 12 hours, and then it can send these two parameters quickly to ANM (The National Meteorological Administration of Romania, based in Bucharest) in the hourly reports issued for 06.00 UTC and 18.00 UTC. The so-called autonomous stations (no meteorologist on site, for example Voineasa and Bâcleș in Oltenia) are completely automated, the classical paper-based registry book of the station is now a database in a computer which is the modern primary source of climatological data.

- *Secondary Sources* (elaborated data): the archive of the Institute of Meteorology built by gathering (transcribing or at present correctly inserting in a computer database of) the climatological information from the stations' paper/electronic registry books. This archive is kept both on paper and electronically under the name of *National Fund of Meteorological Data (FNDM).* We also include as secondary sources the monthly/yearly written reports (Bulletins or Annuals) of the Meteorological Institute which contain correctly transcribed data from the primary sources or from the paper/electronic archive. The archive for the current automated stations is updated by computer software, thus this connection between the electronic primary source and the electronic part of the database (FNDM) at ANM Bucharest has a minimum human influence[2]. The correctness of the data available in bulletins/annuals depends on the correct recording and storing of the primary (raw) data, under the assumption that that there is no printing error in written works.

- *Tertiary Sources*: synthesis written works elaborated by the Institute of Meteorology. Up until 2017 we have four: *The Climate of the Popular Republic of Romania (Clima R.P.R.,* 1962), *The Climate of the Socialist Republic of Romania (Clima R.S.R.,* 1966), *The Climatological Atlas of the Socialist Republic of Romania (Atlasul Climatologic al R.S.R.,* 1966), and *The Climate of Romania (Clima României,* 2008). These contain data collected from secondary sources, or even from primary ones, in case the secondary sources do not contain the pieces of data relevant to the context (or perhaps, they had not been archived at all – electronically archiving the historic raw data at ANM is still underway). The degree of accuracy for the published data is assumed to be the highest, because, in the process of elaborating these works – which can take even years –, a team of members of the Institute of Meteorology all with access to the written/electronic archive works in checking the availability and plausibility of both raw and elaborated data, before the proposal of publishing in such an important work is being made. As with any printed work, typing errors for figures are, however, possible.

- *Fourth Order Sources:* Books and research articles to which we add the internet websites, including the official one of ANM (*www.meteoromania.ro*). The accuracy of the data presented is to be judged case by case, not all of these written sources adopting a cautious style, that is if a temperature value or recording date is uncertain/unlikely, this is not published at all, or is published with a separate note explaining to the reader that the value is not accurate with 100% probability.

The authors of the present paper had no access to primary data for any information given in the text. According to their own classification, the secondary sources used are the electronic archive of ANM (by resorting to Law 544/2001 to obtain the desired information by e-mail) and the Bulletins of the Institute of Meteorology for the years 1893, 1896, 1910, 1929, 1937, 1942, 1946, 1951, 1954 and 1963. The tertiary sources used are all four (three books, one atlas) mentioned above, and the sources of 4th order are the bibliographical references in the main text, footnotes and end of the paper, together with the internet websites of ANM, WMO, DWD (German Meteorological Service) and www.wikimapia.org.

Results and assessments

Short history of absolute minimum temperatures

The -34.8°C value registered during the cold wave of 1-4.I.1888 at Șumuleu Ciuc (now Miercurea Ciuc – therefore not on the Romanian territory at that time) was, for a relatively brief period of time, *the minimum absolute temperature for the whole current territory of Romania* (source: 1962, *Clima R.P.R.,* page 71). As a side remark, on 4.I.1888 the absolute historical minimum of the Bucharest Filaret weather station was recorded: -30.5°C (Otetelișanu,

[2] Some primary data coming electronically from stations seem suspicious (for example the autonomous station Bâcleș, +42.6°C on 11th of August 2015, vegetation fire in the vicinity of the station, source: ANM via Oscar Stanciu, editor at *www.meteoplus.ro*) and are subject to a quality check inside ANM before permanent storage in the electronic database.

1914). The climate record of Miercurea Ciuc was valid only for 5 years, until 14.I.1893 (Otetelișanu, 1914), when at the meteorological station of Păncești-Dragomirești the alcohol dropped to -35.0°C (confirmation through Bulletins of I.M.C. 1893 and 1910). The geographical coordinates of the station at that time (Otetelișanu, 1914), 46°55′ N and 26°56′ E, show that this station was situated in an area currently inside the southern part of the city of Roman, Neamț county. According to Dissescu, 1931, the station had been founded in October 1885 and was placed inside the School of Agriculture of Păncești-Dragomirești, which later become the School of Agriculture of Roman.

The new national record[3] was valid for only one day, because on 15.I.1893 one measured -35.6°C at the meteorological station of Slatina Strihareț on the left bank of the Olt river (Otetelișanu, 1914). This meteorological station had been founded towards the end of 1884 inside the School of Agriculture of Slatina Strihareț (which, in turn, had been founded on 15.X.1883, and after 134 years became the National College of Agriculture "Carol I" of Slatina, Olt County). Judging by the geographical coordinates - 44°26′ N and 24°22′ E (Otetelișanu, 1914), the old station was situated practically on the same location with the current ANM meteorological station of Slatina (WMO Index = 15434, coordinates 44°26′32″ N and 24°21′16″ E according to the Oscar platform of WMO).

The national record of Slatina Strihareț[4] was valid for 36 years, until the great cold wave of February 1929. Then, on 10.II.1929, at the weather station of Vârful Omu (,,Casa-Omul" – 2504 m high above sea level – Omu peak in the Bucegi Mountains) one measured -38.0°C[5] (*Buletinul Lunar al Observațiunilor Meteorologice din România*, Vol. XXXIV, 1929, I.M.C., 1930; *Clima R.P.R.*, page 70 – C.S.A., I. M., 1962). This confirmed temperature reading is a record today, too, but only as an *absolute minimum temperature measured during the month of February* and an *absolute minimum temperature for the mountainous area of Romania*. (*Clima României*, 2008, page 178). The weather station at the Omu peak had been founded in 1927 (according to WMO), so just in time to "catch" this record, and is functional also today in the structure of ANM, being registered with WMO under the index 15280.

13 years later, on 25.I.1942, the air temperature was measured as low as -38.5°C (*Buletinul Lunar al Observațiunilor Meteorologice din România*, Volume XLVII, 1942, I. M. C. al României 1943) at the meteorological station of Bod (commune in Brașov county, on the left bank of river Olt, not far away North from the city of Brașov). This weather record for absolute minimum temperature ever recorded in Romania is valid today (2017), i.e. it has not been surpassed in 75 years. The geographical coordinates of this station were 45°45` N and 25°36′ E (cf. page XXVII of *Clima R.S.R*). As is probably common to any weather record, one questioned whether the reading on the minima thermometer on that morning was real, or perhaps, if so, the thermometer was correctly working. A skeptic would argue that at the Brașov-city weather station (coordinates 45°39` N and 25°36` E, *Clima R.S.R*) one measured on the same morning "only" -25.1°C (*Buletinul Lunar al Observațiunilor Meteorologice din România*, Volumul XLVII, 1942, I. M. C. al României 1943), thus 13.4°C warmer. At that time the Bod station was in altitude 52 m lower than the Brașov one according to the given platform heights in *Clima R.S.R.*, pages 27 and 64, thus in agreement with the general rule of temperature drop during thermal inversions in a mountainous depression, and only about 14 km by the geographical coordinates in *Clima R.S.R*. Significant thermal inversions of about 6°C on even shorter distances (just a few kilometres) were also recorded on 1.II.1937 between the weather stations Iași-Internat and Iași-Copou, and on 25.I.1963 between (Craiova) Balta Verde (South-West of Craiova – see note 6) and (Craiova) Șimnic (North of Craiova). A clear argument in favour of the record was that the reported value from Bod was immediately recognised by the Institute of Meteorology at Bucharest, being explicitely mentioned in the Bulletin of the Institute for the month of January 1942 (,,*Temperaturile minime absolute au oscilat în general în jurul lui -30°C, atingând minima absolută pe țara întreagă -38°5 la stațiunea Bod în ziua de 25 Ianuarie, valoare care reprezintă minima record în țară la noi și depășește cu 2°2 pe cea de până acum -36°3 înregistrată la I Februarie 1937 la Copou-Iași* – n.n. Este ignorată valoarea de la Vârful Omu, considerată stație de munte)[6]. The value measured at Bod in 1942 is confirmed officially in three documents, that is being mentioned in 1st volume of *Clima R.P.R.* (1962) on

[3] We call *national record* the thermal record or, generally, any climatic record for the whole current Romania. This term comes from mass-media usage and, by analogy, we can define a *regional climate record* (for a historical region of Romania, such as Oltenia or Muntenia) or a *climate record for a certain meteorological station* (local climate record).

[4] *The record of -35.6°C* (15.I.1893) from Slatina Strihareț is still today the absolute minimum temperature for Oltenia and the Getic Piedmont. *The record of -35.5°C* (25.I.1963) from the Balta Verde (Craiova) meteorological station is still today the absolute minimum temperature for the big relief unit the Romanian Plains.

[5] An equal value of temperature *(-38.0°C*) was recorded 34 years later at *Joseni (Harghita County) on 18.I.1963*. This is still today *the absolute minimum temperature for the Joseni weather station*.

[6] *"The minimum absolute temperatures generally oscillated around -30°C, reaching the absolute minimum for the whole country -38°5 at the Bod station on January 25th, value which is the record minimum in our country, surpassing by 2°2 the one until now of -36°3 recorded on February 1st 1937 at Copou-Iași"* – our note: the record at Omu Peak is ignored, for being a mountain station.

page 71, then in a table in the 2nd volume - *Clima R.S.R*. (1966) on page 64, and again mentioned on the map of absolute minima for the month of January in the Climatological Atlas of R.S.R. (1966). The fourth and most recent official confirmation appears in the book *Clima României* (2008). We also argue that the winter of 1941-1942 was an excessively cold winter (judging by Hellmann's criterion), and the minimum temperatures recorded at many stations in the northern hemisphere have not been surpassed until today (Marinică 2006, Marinică, A. F. Marinică 2014). The cold of this winter gave the first signal of turning the faith of WWII towards Germany's ultimate defeat (one can metaphorically say that ,,General Winter" defeated the mightiest and the most technologically advanced army of those times, about 130 years later after the disaster of the army led by Napoleon I, this time at a far greater scale in terms of people and war machinery involved). This historical event shows the great importance of research into climate and weather forecasting for human actions, and also the strategic relevance of climate and prognosis data.

Short history of absolute maximum temperatures

For maximum temperature values, we notice *the first significant heat wave* only in *August 1896*[7], when one measured at the București Filaret weather station in the current park Carol I the value of 40.8°C on the 7th day of the month (I.M.C. al României, 1897 - *Buletinul Observațiunilor Meteorologice din România*, Anul V, 1896). The absolute record for this station set in 1896 remained valid until 20.VIII.1945, when a new absolute maximum temperature was measured at 41.1°C (*Clima R.S.R*, 1966, page 59). *The national maximum temperature we can consider as the first record was 42.8°C - measured at the Giurgiu weather station on 7.VIII.1896* (I.M.C. al României, 1897 - *Buletinul Observațiunilor Meteorologice din România*, Anul V, 1896). This weather station at Giurgiu surpassed its annual record set then only on 5.VII.2000 (thus 104 years later) with the value of 43.5°C (*Clima României*, 2008, page 178). This value of *42.8°C was the record for the month of August at Giurgiu for 116 years until 2012, when also on the 7th, the temperature sensor showed 43.5°C* (source: SYNOP report issued on 7.VIII.2012 at 18 UTC used by www.dwd.de in the monthly report for August 2012 for the whole Region VI of WMO).

The absolute thermal record of Giurgiu in 1896 was surpassed only by 0.1°C twenty years later in 1916, during WWI, when at the Alexandria weather station one measured 42.9°C on 5.VII.1916 (Comitetul de Stat al Apelor de pe lîngă Consiliul de Miniștri. I. M. 1962 - *Clima Republicii Populare Romîne*, page 69; I. M. C. al României 1947 – *Buletinul Meteorologic Anual*, Seria III, Vol. XVI, Anul 1946). The absolute thermal record of Alexandria, even though no longer national, *is valid for this weather station even today in 2017, thus it has not been surpassed in 100 years*.

The thermal record of Alexandria (42.9°C) was *national* for 30 years, until *20.VIII.1946, when in Oltenia, at Strehaia weather station*, one measured a *maximum temperature of 43.5°C* (I.M.C. al României 1947 – *Buletinul Meteorologic Anual*, Seria III, Vol. XVI, Anul 1946). On *8.IX.1946*, thus only 19 days later, but this time during autumn, at the same station of *Strehaia the temperature rose again to 43.5°C* (I. M.C. al României 1947 – *Buletinul Meteorologic Anual*, Seria III, Vol. XVI, Anul 1946). The new national record was equalled at the same weather station during the same year, but in different calendar season. *The maximum temperature record of the month of September at national level* has been valid since 1946 (*Clima României*, 2008), thus not surpassed until 2017.

Another very strong heat wave was recorded five years later, in 1951, but this time the maximum intensity was in the Bărăgan Plain. To the north of this plain, at the Ion Sion weather station (coordinates 45°13 N and 27°37` E according to *Clima R.S.R*, 1966, page XXVII, today these correspond to the Movila Miresii[8] commune in Brăila county) the maximum thermometer showed 44.5°C (I. M. C. 1952 – Buletinul Meteorologic Lunar, 1-12, year 1951) on 10.VIII.1951. This temperature value has remained unequalled nor surpassed until today, almost 66 years later. This record, too, had its doubts, one being that the weather station was not strictly in the structure of the Institute of Meteorology of 1951, but was working inside a former privately owned farm (Marinică, 2005, 2008; Marinică & Marinică, 2016). At that moment, the weather station had been in place with climatological data since 1929 (the data was not available for some years), and, even though it was not included as a second order weather station[9] in the 1951 Meteorological Bulletin, the value measured then is explicitly mentioned in this yearly report of which we

[7] *This heat wave*, just as the *first big draught* affecting Romania, definitely not by chance, occurred after a long period of massive deforestation in Romania and also in the rest of Europe, due to the increasing need for agricultural land and timber for industry and commerce (cf. Hepites, 1902, 1906). *The first temperature values of ≥40.0°C* in Romania were measured in *1894* at *Giurgiu* și *Turnu Măgurele* (*Buletinul Meteorologic,* 1910), for example, *40.6°C at Giurgiu on 28.VIII.1894.*

[8] The literature typically ascribes the administrative ownership of the Ion Sion station to the commune of Râmnicelu (Brăila County). Based on the satellite analysis using the Wikimapia website, there are about 9 km between the two communes nowadays.

[9] According to the classification of Ștefan Hepites, the meteorological station of 1st order was the one at the Institue of Meteorology of Filaret (later Băneasa), the second order weather stations were the ones with complete climatological data, the third order weather stations called in Romanian *„termo-udometrice"* had measurements of temperature and precipitations only, and the fourth order weather stations were simple *pluviometric stations* (in Romanian *„stațiuni udometrice"*).

quote: *Temperaturile maxime mijlocii exceptând regiunea de munte au oscilat între 24°,7 și 32°. Maxima absolută pe țara întreagă se înregistrează în ziua de 10 August la stațiunea Ion Sion cu valoarea de 44°.5*[10]. Another official confirmations come from the same sources as the record of Bod, *Clima R.P.R.*, page 70, *Clima R.S.R.*, page 59 and *Atlasul Climatologic al R.S.R.* – the maps containing the absolute maximum temperatures of August and the extreme temperatures of weather stations. The likelyhood of this temperature value is given by the recognition by the Institute of Meteorology of two temperatures of 44.0°C on the same day at the stations of Valea Argovei in the meadows of Mostiștea river (station name and temperature according to the *Atlasul Climatologic al R.S.R.*, or I. C. Frimu, the name of the same commune in 1951 - *Clima R.P.R.*, page 70) and Amara[11] (station North of Slobozia town, according to the *Atlasul Climatologic al R.S.R.*, the maps of maximum temperatures during July and August).

The fact that one recorded at Ion Sion a temperature record persuaded the authors of the yearly Meteorological Bulletin to include the values of the climatological parameters in the monthly tables, so that the Bulletin of 1954 (we sought this to document the cold waves from end of January and February) contains for Ion Sion climatological data for temperature, pressure, precipitations etc. The climatological parameters of Ion Sion appear for the first time in the Meteorological Bulletin of 1952 (thus immediately after this record) which the authors used to document the heat wave of August 1952, as of now, still the strongest heat wave ever recorded in the intra-Carpathian area. *Clima R.S.R.,* 1966 mentions the availability of climatological data during 1896-1915; 1921-1954 at Bod weather station, and 1929-1931; 1936-1944; 1949-1955 at Ion Sion weather station (in the Bărăgan of Brăila).

Therefore, *the national temperature amplitude of Romanian territory* computed from official records is 83.0°C and corresponds to the general temperate and continental characteristic of Romanian climate which has excessive elements judging by the thermal contrast between winter and summer.

We have presented *5 records for minimum and 5 records for maximum temperatures*, all 10 *recorded in an interval of 63 years.* For these, we have used sources (according to our own classifications) of second and third order. If we include fourth order sources available to the authors, one record of the ten should be changed. According to Ciulache, S. & Ionac N. *Caracteristici ale temperaturilor minime în depresiunile intracarpatice din România* (*Comunicări de Geografie*, Vol. V, p. 238, Ed. Universitară din București, 2001), on 14.I.1893 at the Dorna (Vatra Dornei) weather station one measured -35.5°C, thus 0.5°C lower than the same day value of Păncești-Dragomirești, but 0.1°C more than the next day at Slatina Strihareț.

By analysing the evolution of thermal records over time, we notice that the absolute records for minimum temperatures have not been surpassed since 1985 (see later in the text), following a continuous global warming process which meant the *attenuation of cold waves* during winter, the more frequent warm winter months and warm winters in general. By contrast, the absolute maximum temperatures at very many weather stations in Romania have been surpassed especially during 2000-2012, as the global warming got more intense.

General considerations upon literature

The Academy member Ion Simionescu mentions in the 4th chapter of his book *Țara Noastră* (1938) the value of -34.9°C pentru January 1888 at Sibiu. This is not confirmed by Constantin Dissescu (the chief climatologist at I. M. C. in 1931) in his book *Date Climatologice* (Climatological Data) published in French in Bucharest in 1931. Dissescu gives -34.2°C which we later find in *Clima R.P.R.*, page 71 (C.S.A., I. M.[12] 1962, the second volume of this book appeared in 1966 after the official name change of Romania and is called *Clima Republicii Socialiste România* with the same authors members of the I.M).

In 1888 the București Filaret weather station of I.M. (founded in 1884) was still functional in a building belonging to the School of Agriculture and Silviculture of Herăstrău (Dissescu, *op.cit.*), thus outside Bucharest, to its North. One year later, in 1889, the Institute moved to the current park Carol I (Filaret area), where it remained until 1930. The director of the Institute of Meteorology Enric Otetelișanu in his book *Die Temperaturverhältnisse von Rumänien* (1914) published the temperature values measured during 1877-1888 at that weather station under the name Bucharest Filaret, while *Clima R.S.R* (1966) extended the interval to 1857-1955. As a consequence, the authors state that *the historical absolute minimum temperature for the Bucharest Filaret weather station is the one*

[10] The middle maximum temperatures except for the mountain region oscillated between 24°.7 și 32°.The absolute maximum for the whole country is recorded on August 10 at the Ion Sion station with a value of 44°.5.

[11] The extension of the *1951 heat wave* was treated by Bogdan and Niculescu (1999). In this book, in the table number 50, the Amara station is called Slobozia, while in the text Amara-Slobozia (page 174). The map from *Atlasul Climatologic al R.S.R.* (1966) with the maximums of July gives 38.5°C for 1951 at Amara, and 40.0°C at Slobozia in 1950 (5.VII.1950), thus as of 10.VIII.1951 the weather station at Slobozia was functional and independent from the Amara one. Yet the map of extreme temperatures during August from this atlas gives no value for Slobozia, neither minimum nor maximum temperature.

[12] I.M. = Institutul Meteorologic (the Meteorological Institute); I.M.C. = Institutul Meteorologic Central (the Central Meteorological Institute); A.N.M. - Administrația Națională de Meteorologie (the National Meteorological Administration)

recorded on 4.I.1888 (that is -30.5°C), and not the one of 25.I.1942 (-30.0°C, according to ANM via *Anuarul Statistic al României 2007/Romanian Statistical Yearbook 2007*).

Simionescu (op.cit.) mentioned the same value of -35.6°C at Giurgiu weather station measured on the same day of 15.I.1893. This value is rejected by Dissescu, (op.cit.): *En 1884 l'Institut Météorologique a fondé à Giurgiu une station de deuxième ordre. Elle fonctionne d'une manière peu satisfaisante jusqu'en 1894, après avoir eu une interruption en 1891. À partir de Février 1893, les observations sont faites par C. Săsseanu jusqu'en Septembre 1899 et elles donnent des résultats plus satisfaisants*[13] (the underline is made by the authors). Because of this, the sequence of accepted measurement values at Giurgiu begins with the year 1894 in *Die Temperaturverhältnisse von Rumänien* (Otetelișanu, E. 1914).) and with 1896 in *Clima R.S.R.*

The absolute minimum temperature at the Giurgiu weather station is -30.2°C recorded on 6.II.1954, according to *Clima R.S.R.*, page 65, confirmed by *Atlasul Climatologic*.

Unofficial sources mention for 11.II.1929 an absolute minimum of -38.5°C at Bod, in Brașov County. This value has not been documented by the I. M., because in the monthly Bulletin of February 1929 the author mentions „only" -34.5°C for the same day of 11.II.1929. This value (-34.5°C) is kept as absolute minimum temperature for Bod station during February (for the analysed period 1896-1954) both in the absolute minima table of *Clima R.S.R.* (1966), and on the map of absolute minimum February temperatures from *Atlasul Climatologic* (1966).

We found a slight *discrepancy* between the sources we found regarding the coordinates of the two stations of Bod and Brașov-city. In the *Buletinul Lunar al Observațiunilor Meteorologice din România*, Volume XLVII, 1942 (I. M. C. al României, 1943) we are given 45°46' N and 25°38' E for Bod, this is 1' N and 2' E more than in *Clima R.S.R.* (for Brașov they are the same). The distance between the stations would be 17 km instead of 14 km and a difference in altitude of 94 m (according to the Bulletin) instead of 52 m (according to *Clima R.S.R.*), thus more into justifying the big temperature difference, to which we can add an extra-cooling factor in the low inversion layer, which also accounts for the extreme low temperatures measured at the Ișalnița ICHV[14] and Craiova Balta Verde stations on the lower course of Jiu river during 24-26 January 1963. ANM registered under WMO the Brașov-Ghimbav weather station with foundation date 1.I.1921[15] and GPS coordinates of 45°41`45`` N, 25°31`34`` E and altitude 534 m (we confirmed them through www.wikimapia.org). In the Meteorological Bulletin of 1942, the station of Brașov has coordinates (no seconds) 45°39` N, 25°36` E. We can infer that the weather station of Brașov with coordinates from *Clima R.S.R|Buletinul Meteorologic al anului 1942* was situated in the winter of 1942 inside the administrative area of Brașov, to the centre of it, being later moved outside of inhabited area, on an open field now under the administration of Ghimbav town. From all the data available to the authors, the absolute minimum temperature of the Brașov station from 1921 up until 2017 was recorded on 8.I.2015, -33.3°C at Ghimbav.

Another *discrepancy* between the secondary sources that the authors found is in the *Buletinul Meteorologic al anului 1937*. In the table for Februaray one mentions for Copou-Iași the value of -36.0°C as the minimum for 1.II.1937. This is later changed to -36.3°C according to the *Buletinului Meteorologic al anului 1942*. *Clima R.S.R.* of 1966, however, quotes the minimum temperature of the Iași-Internat station (- 30.0°C on 11.II.1929 and 1.II.1937), not the one of Copou. Nonetheless, ANM, through the National Institute of Statistics, confirms the value of Iași Copou, -36.3°C, which it assigns as absolute minimum temperature of the current station of Iași in the interval 1901-2000 (*Anuarul Statistic al României, Anul 2007/Romanian Statistical Yearbook 2007*). ANM confirms the value of -36.3°C/1.II.1937 for Iași, in the table of absolute monthly minimum temperatures from *Clima României* (2008, page 182) – record minimum for February for stations with platform under 1000 meters altitude.

Analysis of extreme temperatures for weather stations under ANM in 2017

ANM has registered under WMO 158 meteorological stations with complete program of measurements as of 23.VIII.2016 (OSCAR platform). For all these, one measures the daily maximum and minimum temperatures every 12 hours (reporting from station to ANM for 06 UTC and 18 UTC). The stations at Bod and Ion Sion have been

13 In 1884 the Institute of Meteorology opened at Giurgiu a second order weather station. It worked in a less satisfactory manner until 1894, after having been interrupted in 1891. Beginning with February 1893 the observations are made by C. Săsseanu until 1899 and they give more satisfactory results.

14 ICHV=Institutul de Cercetări Horti-Viticole (Institute for Research in Horticulture and Viticulture). Especially in the 1960s, the ICHVs had weather stations associated to the Institute of Meteorology (Craiova-Ișalnița, Drăgășani, Cluj-Napoca, Bistrița, Tg. Jiu, Ighiu-Alba etc.).

15 This is more likely the date the station entered the structure of the Institute of Meteorology. According to a credible fourth order source (the book by Elena Mihai *Depresiunea Brașov: Studiu Climatic*, 1973, page 22), the first weather station in Brașov was founded in 1850, and later in 1912 the permanent station was also founded. Mihai also mentions on page 23 the existence in 1942 of a second station in Brașov, closer to its outskirts in the North, functional since 1938 (Brașov-airport). One measured -29.1°C here in the morning of 25.I.1942 (Mihai, op.cit., page 86).

decommissioned for more than 50 years. Taking into account only the current 158 working stations, we find two extreme temperature values:

- The thermal minimum of *-38.4°C* registered on *14.I.1985* at *Miercurea Ciuc* (source: ANM through written request based on law 544/2001). We asked for a written official confirmation due to the discrepancy we found in the literature. More precisely, in *Clima României* (2008, page 180), at Miercurea Ciuc the value of -38.4°C was recorded nine days later, on 23.I.1985. In the *European Climate Assessment and Dataset* (Bojariu, R., currently chief climatologist at ANM*)* through www.ecad.eu (opened on 11.II.2017) we find 14.I.1985 as the measurement date, while for 23.I.1985 the quoted minimum temperature is -10.9°C. The IGAR[16] specialist in climatology, Mrs. Octavia Bogdan (also scientific advisor for *Clima României*), confirms in her book *Riscurile Climatice din România* (Bogdan & Niculescu, 1999) these -38.4°C only for 14.01.1985.

- The thermal maximum of 44.3°C (Marinică, 2008; Marinică & Marinică 2016) measured on 24.VII.2007 at Calafat (Dolj County) during the longest and most spatially extended heat wave the Romanian territory witnessed during the last 125 years (for which we have relatively homogenous data). This statement comes from comparing the spatial extension of maximum temperatures equal or higher than 40.0°C and the number of consecutive days with maximum temperatures over 40.0°C for all the heat waves in the interval 1894-2012.

Taking into consideration only the current weather stations, the *thermal amplitude of Romania* would shrink compared to the historical one by 3 tenths of a Celsius degree to 82.7°C. An analysis made by ANM published in *Clima României* (2008) suggests an interval of 50 years for the recurrence probability of temperature values of ≥ 44.0°C along the Danube valley (in 2007 there were four values, one in Banat region, three in Oltenia; in 1951 there were three, all in Bărăgan plains), and 100 years for a value of 45.9°C also along the Danube course. In the context of a clear climate warming in the 21st century, as a consequence of human intervention on the environment especially by pollution with heat trapping gases, an analysis of the probability of a major cold wave like the ones in January 1942 and 1963 (these had minimum temperatures of < -30.0°C in the warmer Romanian Plains) should not be a subject of interest at this moment, because the absolute minimum temperatures we had in the past are quite unlikely to happen, due to the general attenuation of the intensity and spatial extension of cold waves. Nonetheless, in the context of three recent very warm years (2000, 2007, 2012) – judging by summer's maximum temperatures surpassing 43.0°C - this does not mean that the probability of atmospheric circulations able to produce temperatures under -35.0°C on isolated areas in the depressions of East Transylvania is much reduced compared to the 20th century. Actually, only during 2006–2015, the minimum temperature at the Întorsura Buzăului weather station dropped under -34.0°C in three different years, 2006, 2010 and 2015, with the absolute minimum of this 70 year old weather station recorded on 8.II.2006, -35.8°C (source: ANM by written request in March 2017 due to mismatching data in the literature).

Synoptic context for the absolute thermal extremes of Romania

For the *absolute minimum temperature of -38°5 at Bod* measured on 25.I.1942, the study of reanalysis maps (http://old.wetterzentrale.de/topkarten/fsreaeur.html) shows that the advection of cold air above Europe started on 24.XII.1941 and continued on almost the whole interval 24.XII.1941-31.I.1942.

A significant number of Mediteranean Cyclons produced snowfalls forming a thick layer of snow on extended areas across the continent and after each cyclone, the advection of cold air (cPk+A) intensified. Between the snowfalls, the anticyclone regime with clear nights was predominant, intensifying the air cooling favoured also by the snow layer. We will analyse the synoptic state from 25.I.1942, 00 UTC, when the cooling of the air across most of Europe was the most intense.

In the inferior troposphere at terrestrial level, the baric centres were positioned as follows: above the Atlantic Ocean, W of Iberic Peninsula, the Azoric Anticyclone with central values ≥ 1030 hPa; this was joint, over N Africa and Balkan Peninsula with the strong Scandinavian Anticyclone with central values ≥ 1045 hPa (fig. 1), while this was joint to E and NE to the East-European Anticyclone which was continued by the Russian-Siberian one[17] (Voeikov ridge).

[16] IGAR = Institutul de Geografie al Academiei Române (Institute of Geography of Romanian Academy); DWD = Deutscher Wetterdienst; ANM = National Administration of Meteorology; WMO = World Meteorological Organization; C.S.A. = Comitetul de Stat al Apelor (The State Committee for Waters).

[17] The Russian-Siberian Anticyclone is called in certain climatology books the Asiatic Anticyclone. The East-European Anticyclone was treated by the Romanian researcher Ecaterina Ioan Bordei. In climatological works (especially Russian ones) the belt of high pressure uniting the Azoric Anticyclone with the Siberian one is called the *Voeikov ridge*. Other notions bearing the name Voeikov: *Axis of Voeikov* – axis of the high pressure ridge on climatological maps joining in winter the Azoric Anticyclone to the Siberian one. It was discovered by the Russian climatologist A. I. Voeikov. *Variant: Axis of Voeikov – line separating the E and NE winds from the W and SW winds*. *Variant: Axis of Voeikov* – axis of the baric ridge formed by joining the W flank of the Siberian Anticyclone with the E flank of the Azoric Anticyclone, as a consequence the cold and dry air masses of Siberia (cPk+A) advance towards Western Europe, considerably lowering the ground temperatures (Source: Colta, V. – Dictionar Georgrafic Explicativ, Ed. Labirint, Chișinău, 2008, ISBN 978-9975-943-62-8)

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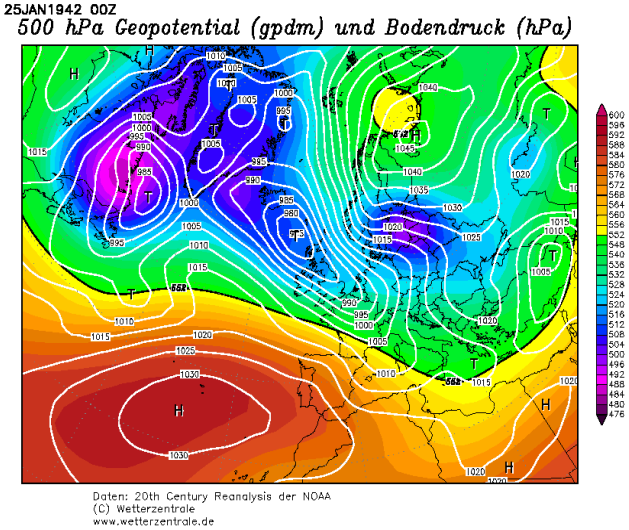

Fig. 1: Map of the pressure field above Europe superposed to the geopotential field at the level of 500 hPa on 25.I.1942, 00 UTC (after http://old.wetterzentrale.de/topkarten/fsreaeur.html)

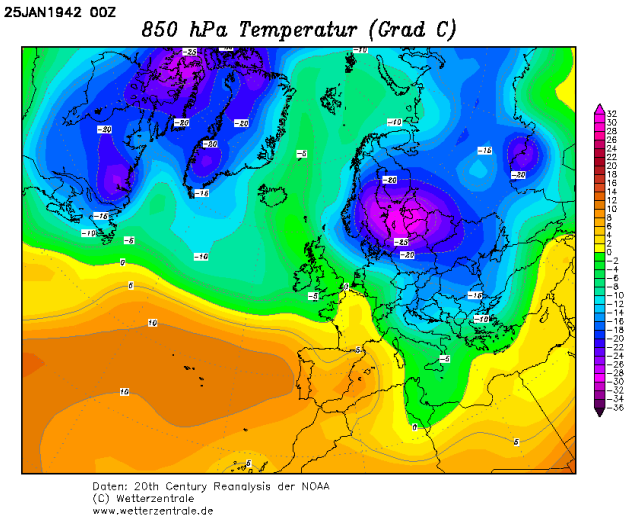

Fig. 2: Map of the temperature field above Europe superposed to the geopotential field at the level of 850 hPa on 25.I.1942, 00 UTC (after http://old.wetterzentrale.de/topkarten/fsreaeur.html)

At the boundaries of this vast high pressure field several cyclones were in position: The Icelandic Cyclone above NW Britain with central values ≤ 975 hPa, SE of Black Sea above Little Asia Peninsula a cyclone of the Black Sea with pressure values at centre ≤ 1005 hPa. NE of this cyclone, over the Russian Plains, there was an occluded cyclone, formerly pertaining to the Black Sea, with central pressure values ≤ 1020 hPa. This spatial positioning of baric centres forms a real mechanism of transport of very cold air cPk+A from above the large Russian Plains (where it had initially been transported from Siberia and the Arctic region) towards Central Europe and sometimes even to Western Europe.

At the level of 500 hPa, (fig. 1), one observes a vast high geopotential field above the Atlantic Ocean, with central values ≥ 598 damgp, a vast low geopotential field above northern Atlantic Ocean with values ≤ 484 damgp, another area of low geopotential was placed above NE Europe with central values ≤ 496 damgp. At this level, the advection of extremely cold air towards Romania was on a N-W component. As a consequence, the extremely cold air entered Romanian territory from two directions.

The analysis of the thermal field at the geopotential level of 850 hPa (approximately 1500 m altitude) (fig. 2) shows a massive advection of extremely cold air above Europe (isotherm of -15.0°C), while the limit of cold air reached northern Africa (isotherm of 0.0°C). Over the southern Scandinavian Peninsula, there was a nucleus of excessively cold air with temperature ≤ -30.0°C, which means that the temperature at ground level was ≤ -40.0°C. Over Romania the isotherms of -15.0°C and -20.0°C were positioned which give at ground level temperatures ≤ -30.0...-35.0°C, fact confirmed by the minimum temperatures recorded on 25.I.1942.

We conclude that the persistent advection of extremely cold air (cPk+A) over Europe, which happened during an interval of more than one month, due to extended favourable atmospheric circulation, an intense nocturnal cooling due to a thick ground snow layer and adding the long duration of January nights (15 hours on average), resulted in an intense air and terrestrial cooling which produced extremely low temperatures throughout Europe (including Romania), many of these not surpassed until today. The cold wave of January 1942 was the longest and most intense of all the history of climatic observations. To the accomplishment of the absolute minimum temperature in Romania (-38.5°C) we should note the essential contribution of local thermal inversion which was produced on the relief steps from the Brașov Depression.

For the *maximum absolute temperature in Romania*, the value of 44.5°C measured at the Ion Sion weather station (actually the farm Ion Sion, from Râmnicelu commune – cf. Bogdan, O. and Niculescu, E. 1999), Brăila county, on 10.VIII.1951, in the work *Riscurile Climatice din România* (The climatic risks from Romania) the authors assert: *Unlike January 1942, August 1951 has no territorial record of the most number of absolute and yearly thermal values ≥ 40.0°C, which shows that the massive warming produced at that date was relatively limited*[18] (page 173). This can be directly connected to the amplifying of climatic warming in the past 66 years (1951-2017),

[18] *„Of the 63 weather stations accross România at which one has measured until now* (n.n. 1999) *absolute maximum temperatures of ≥ 40.0°C, on different dates, only for 7 of these the value was measured in August 1951* (op. cit.). Presently, (2017), this has changed by a lot, the percentage being much smaller (n.n.). n.n.= authors' note.

which is characterised by the increase of intensitity of heat waves, increase of duration, frequency and spatial extension to North, while for the cold waves, as stressed before, one notices an attenuation of intensity, frequency and duration, while the frequency of overall warm winters, warm winter months and intervals of heating (heat waves in winter) during winter months has increased. In the mentioned book of Bogdan and Niculescu the genesis of the heat waves is analysed and it is stated that in general *August 1951 was a worm and rainy month*.

We analyse the *synoptic context* leading to this exceptional maximum temperature by using the reanalysis maps. The archive of maps shows that *overall the summer of 1951 was warm*[19], especially for the South, East and extreme West of the continent, while the heat waves for these areas started occurring as early as June, July being particularly hot in the Iberic Peninsula, Italy and the Balkans, including Romania.

Some thermal maximums for July 1951 recorded in Romania: 35.9°C at Nicorești, 37.5°C at Giurgeni, 38.5°C at Adjud and Valul lui Traian, 39.6°C at Ion Sion, 40.5°C at Bujor (*Buletinul Meteorologic al anului 1951*) etc., while for June 1951 the literatures mentions highs ≥35.0°C. In August, the heat amplified, reaching the maximum on 10.VIII, while the rest of the month was also warmer than average.

In inferior troposphere at terrestrial level, the main baric centres were situated as follows: above the Atlantic Ocean, the Azoric Anticyclone with pressure at centre ≥ 1030 hPa (fig. 3); this was joint through a weak high-pressure bridge over South Italy and the Black Sea with the East-European Anticyclone, positioned above Siberian Plains, E of Novaia Zemlya islands, with centre pressure values ≥ 1015 hPa. The North of Europe was under vast cyclone fields, of which we remark the Icelandic Cyclone with centre pressure ≤ 995 hPa, placed in southern Scandinavian Peninsula (this became a Skagerrian cyclone). The altitude thalweg of this cyclone was extended until N of the Island of Corsica.

At the level of 500 hPa (the atmospheric level of non-divergence), the extreme West, the South and the East of Europe were dominated by a vast high geopotential field with values of ≥ 592 damgp over the Atlantic Ocean. The North, the West and Central Europe were under the influence of a low geopotential field with a nucleus of ≤ 536 damgp positioned over the Skagerrak Straits. The thalweg of this low geopotential field was extended through the North of the Mediterranean Sea. This placement of the baric centres and of the geopotential fields cause in case of Romania a continental-tropical atmospheric circulation, because the extreme warm air (cT) is advected over the South of Italy and the Balkan Peninsula towards Romania. The cold air advected at the rear of this baric thalweg „displaces" the very warm air of northern Africa and causes its transport through the mechanism of tropical circulation towards Romania.

At the isobaric level of 850 hPa, the analysis of the thermal field (fig. 4) shows the isotherm of 22.0°C above East and South Romania (00 UTC) and 24°C above South Bulgaria and Greece.

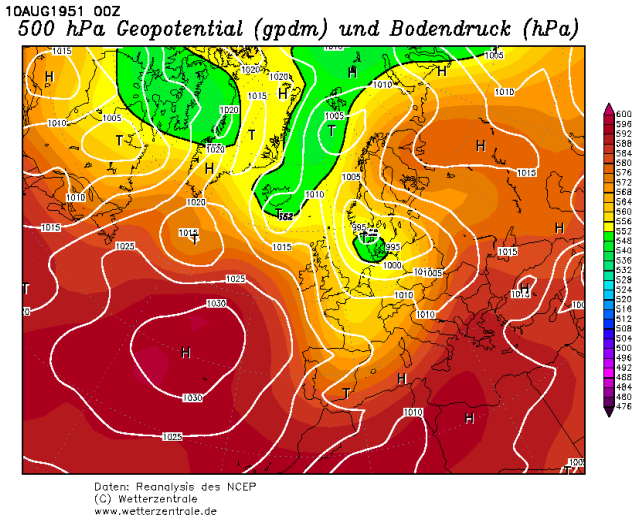

Fig. 3: Map of the pressure field above Europe superposed to geopotential field at 500hPa on 10.VIII.1951, 00 UTC (after http://old.wetterzentrale.de/topkarten/fsreaeur.html).

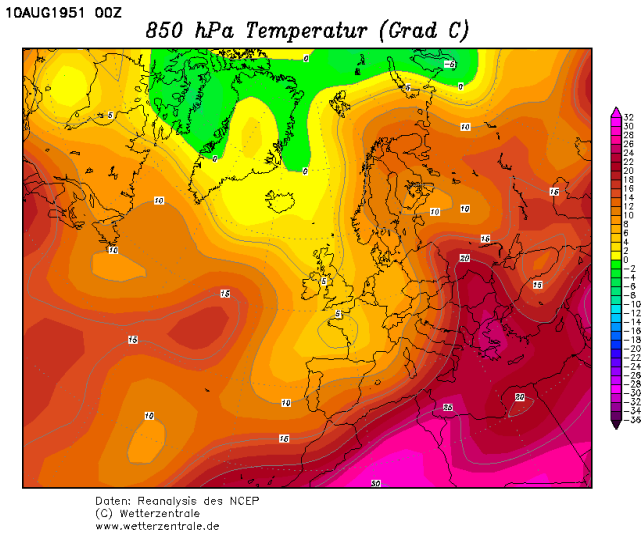

Fig. 4: Map of the temperature field superposed to the geopotential field at the isobaric level of 850 hPa on 10.VIII.1951, 00 UTC (after http://old.wetterzentrale.de/topkarten/fsreaeur.html)

This synoptic context caused the conditions for the absolute maximum temperature of Romania in the warm summer of 1951, as an extreme of its heat. During the most intense and extended heat waves occurring starting with the year 2000, over Romania, at this pressure level, there were the isotherms of 24°C and even 26°C, which allows to conclude that it is

[19] We mention that the period 1945-1952 was warm throughout Europe, not just Romania.

highly likely that on 10.VIII.1951, above Romania the air would have temperatures exceeding 22.0°C (more likely about 26.0°C), as the reanalysis maps were developed from a relatively small number of historical surface and high altitude data.

Conclusions

During the years, for various reasons, there were discrepancies regarding the dates of recording of extreme temperatures, their values and even of the places where they occurred. Certainly, there are other climatic values sharing the same problem, and it is not the fault of the authors. A detailed research of all problems and correcting the inaccuracies by the authors – who have highly restricted access to the A.N.M. database (FNDM) – are quite difficult, which is why the authors of the present work urge for the publishing of a new volume of exact climatic data since the beginning of regulated meteorological observations, as was the case with *Clima RSR Vol. II* (1966 – timeframe analysed 1896-1955), which we see as a necessity for the correctness of future works of research on the climate of Romania. We find discrepancies even in works of national importance, which gained prizes from academic institutions, so in the absence of such a book, the problems could propagate and amplify in the future.

The results we obtained by searching a limited number of sources should be a small part of all absolute thermal records, and the recent warming of the climate caused its increase in variability, so that almost on a daily basis we find out that daily records, monthly records and even yearly records for various weather stations in Romania have been surpassed, thus such a suggested new work needs also periodic updates.

The Voeikov ridge, which causes essential characteristics of the climate of the vast Atlantic-European and Asiatic regions, is also formed during summer, not only in winter, and its persistence in time, its extension and positioning vary significantly due to the global warming. In summer, this thermo-baric formation of large scale is sometimes interrupted in various sectors, such as along the meridians in the 10°-20° E sector, by the thalwegs of the Icelandic and Mediterranean Cyclones. All these considered, the climatic warming caused the breaking of maximum temperature records in all months of the year, while the minimum ones have not even been equalled, though some close values were recorded.

The thermal regime across Romania up to current date (2017) is bordered by two big climatic limits: -38.5°C, recorded at Bod on 25.I.1942, and 44.5°C, recorded at the Râmnicelu commune (Brăila County, *https://en.wikipedia.org/wiki/Râmnicelu,_Brăila*), at the Ion Sion farm (the Buzău river meadows) on 10.VIII.1951. However, during the 20th century the global climate was cooler[20], at least by comparing to the interval 2000-2017, and the continuation and possible amplification of global warming could confirm this conclusion for the whole current century. The global climate analyses, monthly or yearly, obtained by ground and satellite measurements confirm for the moment the net warming tendency.

Two major directions for the advection of air masses are found, which are able to produce thermal extremes for the whole year: the North and North-Eastern directions, for the extremely cold air masses of polar (cPk) and arctic (A) type, which are associated to the ultra-polar and polar circulations, and the South-West direction for the extremely warm and dry air masses of continental tropical (cT) type advected from the North of Africa[21], which is associated to the continental tropical circulation, both of which are tightly connected to the spatial positioning of the Voeikov ridge.

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[20] Again not by chance, *the cooler and wetter climate of the 20th century* was possible in a global context in which across the surface of the Earth *the forest cover was greater, the Polar ice caps (especially the North one) were more extended, and the human-caused air pollution was incomparably smaller than the one in 2017.*

[21] Africa and the Arabian Peninsula are the largest reservoirs or warm air not only for Europe, but also for the Northern Hemisphere.

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