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CLIMATE CHANGE AND ANOMALIES ASOCIATED IN THE REPUBLIC OF MOLDOVA

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Abstract. In the Republic of Moldova, regardless the limited area, regional climate change represents one of the major threats for sustainable development and is one of the biggest environmental problems, with negative consequences for the national economy. Displacement function analysis of the climate rules distribution which is characterizing mean annual temperature at different times in the Republic of Moldova shows that the last decade of the twentieth century (1989-1999) was the warmest decade of the century. At the same time, the first decade (2000-2012) of XXI century is the warmest decade of instrumental observations series (1887-2013). Measurement of the extreme values modification in the Moldova's climate evolution indicates that absolute maximum of temperatures and deficit (excess) of precipitation have a regular manifestation on the last period (2000-2012).

Introduction

According to the latest evaluation report on the climate change, issued under auspice of the Intergovernmental Panel on Climate Change [1], „Current climate change already have a significant impact on the natural ecosystems." In the Republic of Moldova, regardless of the limited area (33,3 square kilometers), regional climate change represents one of the major threats to sustainable development and is one of the biggest environmental problems, with negative consequences for the national economy.

1. Investigation materials and methods

Estimations are based on highlighting the trend for the average air temperature and annual amount of atmospheric precipitation, sorting the "dry-wet" and the "cold-warm" years during the history of instrumental observations - recorded data at Chisinau station, concerning thermal regime 1887-2010, and

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precipitation regime from 1891 to 2010. Taking into account the extremely pronounced variability of hydrothermal regime of the past 13 years (2000-2012) anomalies were estimated from the calculated multiannual average for the contemporary period 1960-2012, a period when it is felt the fastest rhythm of regional climate change.

2. Obtained results analysis

Thus, the average annual air temperature (fig. 1) in the Republic of Moldova had been registered an increase by 0.01 ºC/year during the years 1887-2010.

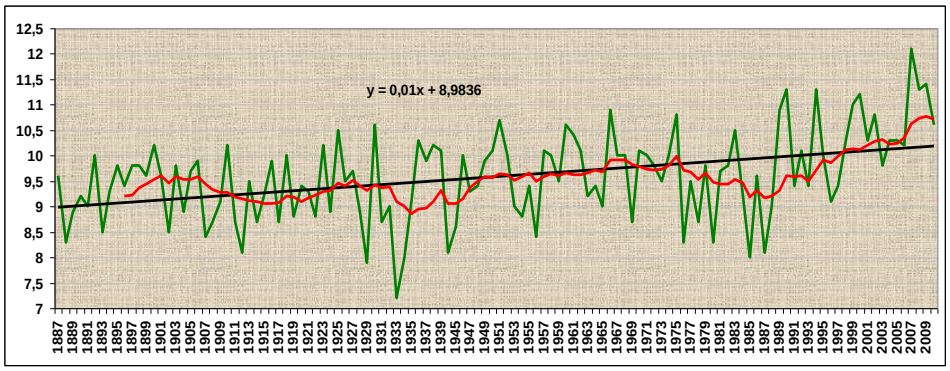

Fig. 1. The change tendency of annual average temperature (1887-2010

Analysis of annual thermal deviation denotes that they are characterized by the predominance of positive anomalies, especially at the end of 90s of XX century and beginning of XXI century (fig. 2).

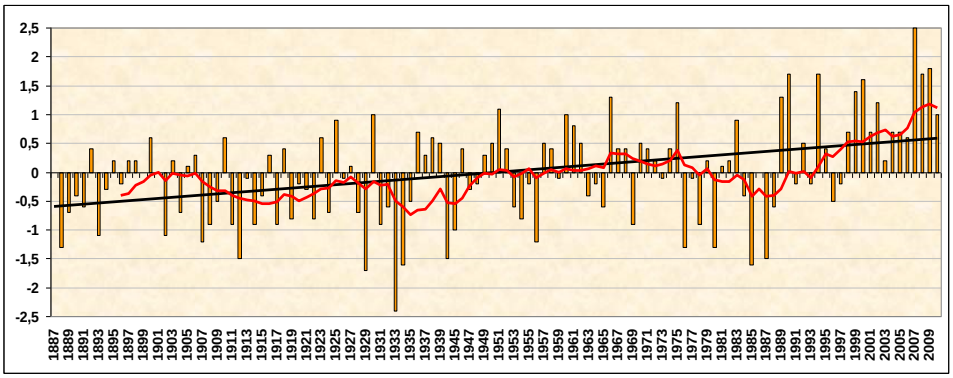

Figure 2. Evolution of annual thermal anomalies reported to the baseline period 1961- 1990

The 2007 year is the warmest year in the series of instrumental observations, average annual temperature exceeding the climatic norm with 2.5 ºC. The years 2009, 1990, 1994, 2008, 2000, 1999, 1966, 1989 and 2002 were extremely warm years, average annual temperature exceeded the value of 10.8 ºC and more (the climatic norm is equal to 9.6 ºC).

In the last two decades the manifestation of extremely warm years had repeatability once in 2 years (tab. 1). The lowest values of thermal were recorded in 1933 and 1929 when the average annual temperature was 7.2 – 7.9 ºC. Likewise with low values by 8-8.3 ºC is characterized the cold years: 1934, 1985, 1912, 1940, 1987, 1888, 1976, and 1980.

Tab. 1. Top of the coldest and warmest years recorded in the period 1887-2010

Coldest years (T, 0^0C)		**Warmest years** (T, 0^0C)	
1933	7,2	2007	12,1
1929	7,9	2009	11,4
1934	8	1990	11,3
1985	8	1994	11,3
1912	8,1	2008	11,3
1940	8,1	2000	11,2
1987	8,1	1999	11
1888	8,3	1966	10,9
1976	8,3	1989	10,9
1980	8,3	2002	10,8

Amount of precipitation in annual aspect (fig.3) in the Republic of Moldova had been registered an increase with 0.719 mm/year during the years 1891-2010.

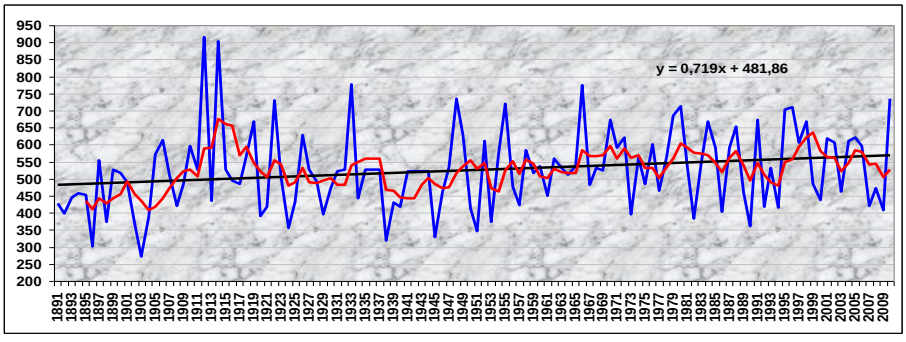

Fig. 3. The change tendency of average amount of annual precipitation (1887 - 2010)

In the last decades there are observed a frequent alternation of positive and negative anomalies, which demonstrates the highly variable character of both events years with precipitation excess as well as with precipitation deficit (fig. 4).

In 1903 the annual amount of precipitation was only 271.8 mm, and in 1912 were recorded the most significant values of 915 mm (tab.2).

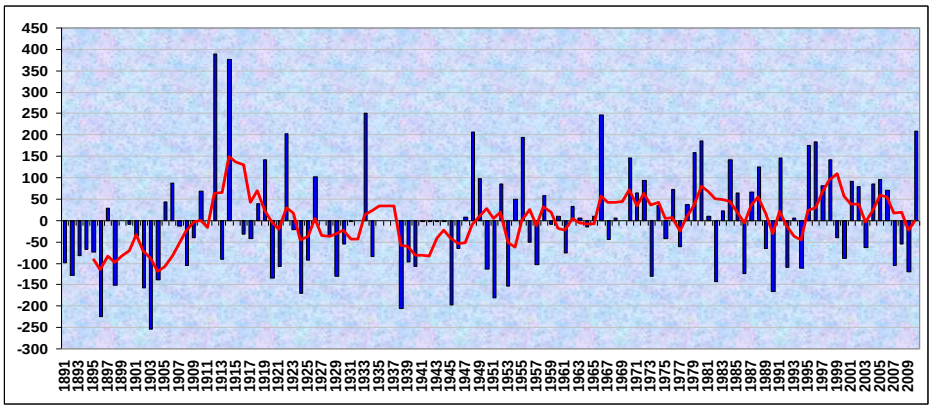

Fig. 4. Evolution of annual precipitation anomalies reported to the reference period 1961 – 1990

But, as previously was mentioned, in the past years (2000-2012), both the thermal as well as hydric extremes are to be the most significant.

Tab. 2. Top of years with pluviometric excess and deficit in the period 1891 - 2010

Dry years (mm)		**Rainy years** (mm)	
1903	271,8	1912	915
1896	301	1914	903
1938	320	1933	777
1945	329	1966	774
1951	345	2010	735
1924	357	1948	734
1990	361	1922	729
1902	368	1955	721
1953	373	1980	712
1898	374	1996	711

In the north of the country the significant values were recorded in 2012, followed by the 2007. In the central and southern part, contrary, thermal maximum in 2007 was the most significant followed by the 2012 (tab.3).

Thereby, calculation of absolute maximum temperature anomalies for the period 2000-2012 to their annual average for the period 1960-2012 reveals, different distribution in time from north to south, in most cases there is not respected the principle of zonality.

Tab.3. The anomalies of absolute maximum temperature from the period 2000-2012 compared to the multiannual average of absolute maximum temperature from the period 1960-2012

Briceni		Falesti		Chişinau		Cahul	
Years	Anomalies	Years	Anomalies	Years	Anomalies	Years	Anomalies
2000	3,9	2000	5,3	2000	4,1	2000	4,6
2001	0,7	2001	3,3	2001	2,2	2001	1,3
2002	1,6	2002	1,8	2002	2,8	2002	0,9
2003	0,8	2003	1,5	2003	1,3	2003	1,8
2004	-0,5	2004	0,3	2004	-1,4	2004	0,7
2005	1,4	2005	1,3	2005	1,2	2005	0,9
2006	-1,8	2006	-0,4	2006	-0,1	2006	1,6
2007	2,7	2007	5,7	2007	5,1	2007	4,8
2008	1,1	2008	3,2	2008	3,1	2008	3,3
2009	0,6	2009	4	2009	1,9	2009	3,3
2010	2,4	2010	2,7	2010	2,2	2010	2,2
2011	0,4	2011	1	2011	-0,8	2011	0,2
2012	4,5	2012	7,7	2012	4,8	2012	4,7

At the same time, we mention that in 2004 and 2006, in central and northern part of the country, thermal anomalies were lower compared to the multiannual average. The achieved results will serve as reference to highlight the influence of climate change on the autumn wheat productivity.

Comparative analysis (fig.5) of absolute maximum temperature anomalies from 2012 and 2007 reveal that the positive extremes in 2012 were above those recorded in 2007, mainly in the north of the country. Thermal maximum recorded at Falesti became absolute throughout the country. At the same time in the central and southern part absolute maximum reached the highest values in 2007.

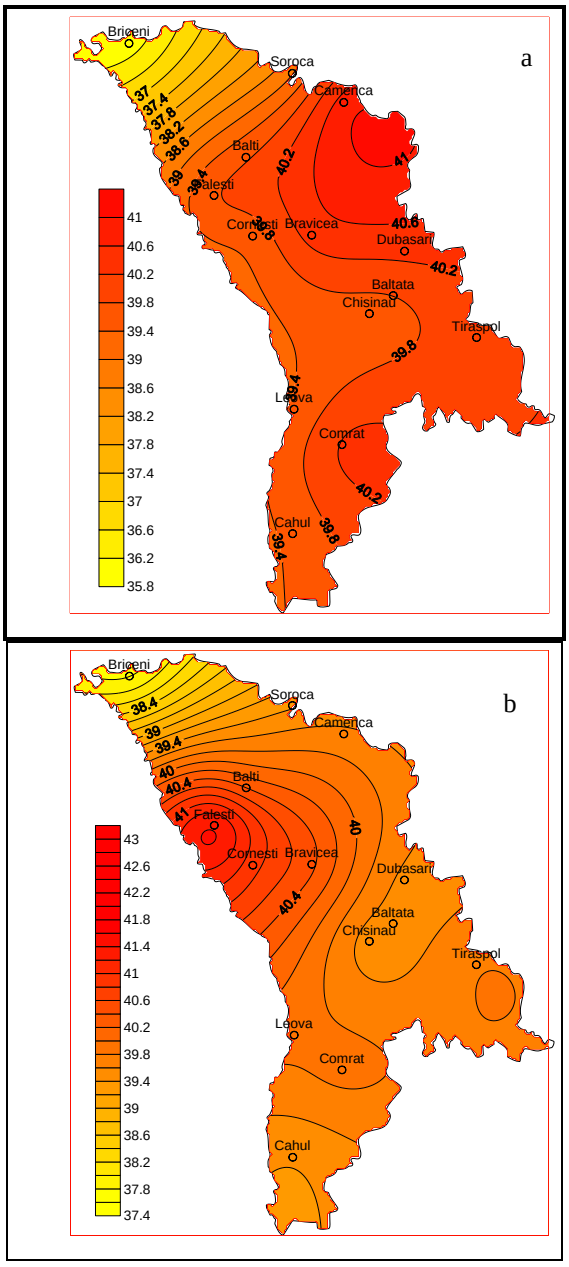

Fig 5. The distribution of absolute maximum temperature on the Republic of Moldova territory (a- 2007, b-2012)

Thus, the above mentioned results indicate, that the last 12 years are characterized by substantial variability in terms of maximum temperature manifestation both in time and in space.

In the last time a significant distribution records and absolute minimum. Although until recently it was thought that [2] the background of winters warming, absolute minimum in winter 2006 has a repeatability once in 24 years, climate variability in recent years shows that the winter from 2012, for example, differs only by 0.3 ºC in the north, compared to the winter of 2006 (tab. 4). In the top of cold winters, joined and winter of 2010, which essentially influenced multiannual crops wintering conditions in the Republic of Moldova.

Tab. 4. Consecutive arrangement of most significant absolute minimum (1960-2012) on the Republic of Moldova territory

Briceni		Chişinau		Cahul	
1963	-33,8	1963	-28,4	1963	-24,9
2006	-28	2006	-24,2	2006	-22,7
2012	-27,7	1967	-23,5	1996	-21,7
1996	-27,5	1961	-23	1976	-21,2
2010	-27,4	1987	-22,8	2010	-21,2
1987	-27,1	2012	-22,2	2012	-21,1
1966	-26	2010	-21,8	1972	-20,9
1972	-26	1972	-21,5	1961	-20,7
1976	-26	1996	-21,1	1964	-20,7
1985	-25	1994	-20,9	1985	-20,5

Calculation of absolute minimum temperature anomalies from the period 2000-2012 compared to the multiannual average of the absolute minimum from the period 1960-2012, reveal that these three winters registered the most essential thermal anomalies reported to the multiannual average. Thus, in the north of the country they constituted -6.1 ... -6.7 ºC, -4.4 ... -6.8 ºC in the center and in the south ... -4.3 -5.9 ºC. In the south there also are the winters of 2002, 2003 that compromised essential the autumn wheat crop in the region (tab.5).

Significant variability of the thermal regime in recent years requires highlighting the trends of change in this period of time (2000-2012) and in the atmospheric precipitation regime.

Table 5. Absolute minimum temperature anomalies from the period 2000-2012 compared the multiannual average absolute maximum temperature from the period 1960-2012

Briceni		Chisinau		Cahul	
2000	2,3	2000	1,8	2000	0,3
2001	1,8	2001	1,7	2001	0,6
2002	2,3	2002	0,9	2002	-1,8
2003	0,4	2003	0	2003	-1,1
2004	6,3	2004	4,3	2004	2,7
2005	-0,5	2005	1,9	2005	0,2
2006	-6,7	2006	-6,8	2006	-5,9
2007	3,2	2007	1,4	2007	0,9
2008	2,7	2008	2,1	2008	-0,2
2009	1,6	2009	0,6	2009	0,1
2010	-6,1	2010	-4,4	2010	-4,4
2011	3,6	2011	1,4	2011	1,7
2012	-6,4	2012	-4,8	2012	-4,3

Table 6. Annual pluviometric anomalies from the period 2000-2012 compared to the multiannual average from 1960-2012

Briceni		Chișinau		Cahul	
2000	-172,6	2000	-113,6	2000	-194
2001	87,4	2001	67,4	2001	64
2002	-44,6	2002	54,4	2002	34
2003	-5,6	2003	-91,6	2003	-229
2004	-108,6	2004	40,4	2004	-66
2005	176,4	2005	86,4	2005	-23
2006	52,4	2006	13,2	2006	-170
2007	-10,6	2007	-69,6	2007	-19
2008	149,4	2008	-85,6	2008	-92
2009	-182,6	2009	-103,6	2009	-131
2010	328,5	2010	184,1	2010	162,4
2011	-188,5	2011	-122,9	2011	-165,5
2012	-75,7	2012	-27,8	2012	58,4

The analysis of annual pluviometric anomalies from the period 2000-2012 calculated from the multiannual average from 1960-2012 (tab.6) reveal that they register a great variability in time and space. Thereby, in the southern part of the

country were reached the most significant pluviometric anomalies (-229 mm) reported to the climatic norm during the period taken under study. Significant pluviometric anomalies throughout the country were registered in 2000, 2009, 2011. The year 2004 in the northern part (-108.6 mm) and 2006, in the southern part (-170.0 mm) registered the same substantial negative pluviometric anomalies. Among the significant positive pluviometric anomalies recorded throughout the country, it is highlighted 2010 while in the north of the country they were highest in the period taken under the study (328.5 mm). Also, in the north of the country, during 2005, 2008, as well, registered significant positive pluviometric anomalies.

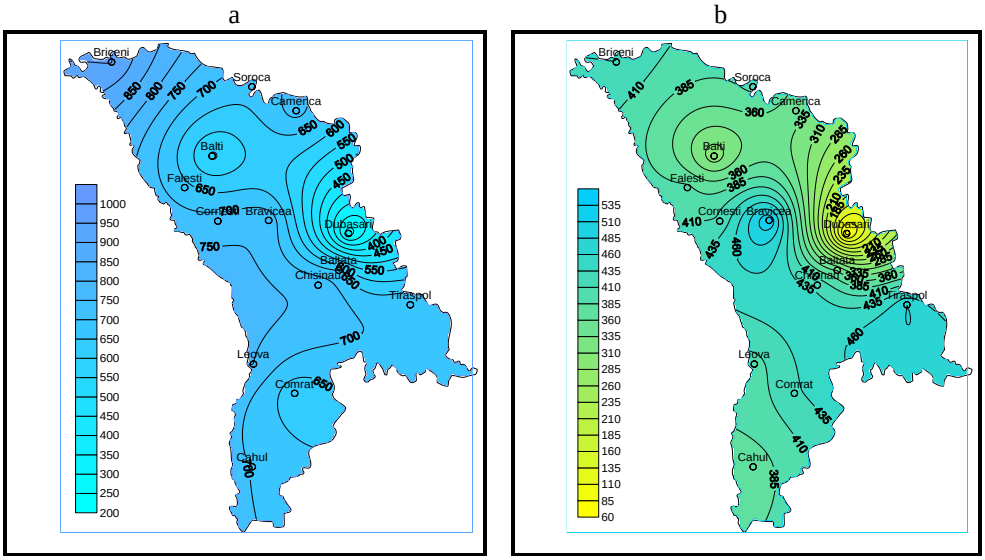

Figure 6. Cartographic modeling of annual precipitation (mm) in extreme years in terms of pluviometric regime (a -2010 - rainy year; b -2011 - dry year)

Cartographic Modeling (using Kriging interpolation program) allowed delimitation of "exposed" territories to excesses and, on the other hand, territories with insufficient regime of atmospheric precipitation (fig.6). Thus, in 2010 – a very rainy year, the highest values of atmospheric precipitation were recorded in the north-west in the center and at altitudes, values being within the limits 720-950 mm (fig.6a). In 2011 - an extremely dry year, the lowest values varied within 100mm in the middle Dniester Plain (mainly at Dubasari) followed by Balti Steppe - with values up to 290-300 mm (fig.6 b).

The results will be the basis for assessments with prognostic character in order to take appropriate measures for adaptation to new climatic conditions in the Republic of Moldova.

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