CHANGES IN THERMAL GROWING SEASON LENGTH ON DANUBE DELTA COASTIN THE FIRST DECADE OF XXIst CENTURY

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Abstract

During the first decade of the XXI st century Danube Delta coast had a warming trend. The mean warming of the average of Sulina stations was 1.0°C for the decade, a large value for a decade. The warming trend of spring and autumn was positively correlated with change of growing season length. The start of growing season has advanced with 11 days, the end of growing season has delayed with 13 days, and the growing season length was 269.7 days.

Key words: warming trend, thermal growing season length, spring warming, growing season lengthening, Danube Delta coast

INTRODUCTION

The second half of XXth century was characterized by a global warming due to the increase greenhouse gasses concentration, especially CO_2, which has the strongest radiative forcing (IPCC, 2001). For same period of time, it has been demonstrated that for the northern and central part of Europe, the temperature changes were more evident during winter and early spring (Sparks et al., 2002). For the beginning of XXIst century the predictions are for a cooling trend (Easterbrook, 2008; Wendler et al., 2012).

The global warming changes climates and affects biological phenomena. One such phenomenon is the growing season length (GSL), which implies modifications of phenological phases of plants and increasing of photosynthetic activity.Thus, for the middle and high latitudes from North Hemispherewere reported earlier appearances of spring phenophases and delayed appearances of the autumn ones (Menzel et al., 2005). These facts have conducted to increasinglength of growing season (Robenson, 2002; Linderholm et al., 2005; Walther & Linderholm 2005; Linderholm, 2006).

From phonological point of view, GSL is defined as the period between bud burst and leaf fall (Linderholm, 2005). Climatologically, GLS is regarded as the entire period in which growth can theoretically take place, and should be distinguished from growing period which is the period of actual growth (Carter, 1998). To define thermal GLS, the most used criteria are freeze criteria and temperatures averaged over a number of days (Bootsma, 1994; Jones &Briffa, 1995; Carter, 1998; Frisch et al. 2002).

For middle and high latitudes 5°C mean temperature threshold is widely accepted for determining the thermal growing season because 5 °C is generally recognized as the lowest temperature threshold for plant vegetation. Thus, Frisch et al. (2002) defines the GSL as the period between when daily temperatures are> 5 °C for 5 days and when daily temperatures are < 5 °C for 5 days.

According to Chmielewski and Rötzer (2002), the high positive North Atlantic Oscillation (NAO) in the late XXth century led to a nearly Europe-wide warming in the early spring (February-April) over the last 30 years (1969-1998) from the 20th century and this warming led to an earlier beginning of growing season by 8 days. Thus, since 1960s, the onset of spring has been advancing in the northern hemisphere on average by 2.5-2.8 days every decade (Nagy et al., 2013).

The changes and variations of the growing season length have important implications for the competition and fitness of plants, which implies profound ecological consequences (Walther et al., 2002) such as extension of species range boundaries by establishment of new local populations causing extinction of former populations (Karlssonet al., 2007).

Variations of GSL are an indicator of climate changes.Since November 1999, GLS is one of 10 suggested and used indicators for monitoring change in climate extremes world-wide that have recommended by World Meteorological Organization Commission for Climatology/ Climate Variability Working Group on Climate Change Detection (Frich et al., 2002), and then by Mitchel andHulme (2002)**.**

This paper analyzes the air temperature variations and GSL in the first decade of XXIst century inthe eastern part of Danube Delta (DD) area.

MATERIAL AND METHOD

The aim of this work is to investigate possible changes of the GSL on eastern part of DD in the first decade of XXIst century. The study area corresponds with marine delta plain, which is composed by beach ridges plains and shallow depressions covered by lakes and reed marshes.

Daily, monthly and annual mean values of air temperature recorded at Sulina climatological station over 2001-2010 periodswere computed and plotted. The climate data weredownloaded from http://www.tutiempo.net/en/Climate/SULINA/153600.htm. The mean monthly and annual air temperatures values for 2001-2010 decade were compared with reference values of the 1961-1990, 1971-2000 and 1981-2010 climate normal.

For each year of 2001-2010 decade, GSL was determined using the definition suggested by Frisch et al. (2002): the start and the end of the growing season are defined as when the daily mean air temperatures are above or below 5 °C during 5 consecutive days, respectively.

The fallowing climate indices were evaluated:Johansson Continentality Index (Baltas, 2007), KernerOceanity Index (Baltas, 2007), Kira's Warmth Index (Hugget&Cheesman, 2002), Holdridge Annual Biotemperature (Lugo et al., 1999).

RESULTS AND DISCUSSION

Air temperature

Air temperature is the main meteorological parameter that determines the climatic characteristicsof a particular area. In eastern part of DD, the mean annual air temperature in the first decade of XXIst century was 12.4 °C, highest than annual average of each climate normal.Annual air temperature has varied from 11.2 °C in 2003 to 13 °C in 2007. Except 2003 year, which was the coldest year of decade, in all other years, annual air temperature was higher than climate normal values. For first two climate normal annual air temperatures were 11.4 °C and for the last one it was 11.8 °C.The average value of the hottest month, July, was 23.9 °C, which was equal with mean of August month.Noteworthy, in the analyzed decade, for these two months were recorded the highest average values from whole history of measurements at Sulina climatological station, since 1887. It is about 25.8 °C in 2002 for July and 26.2 °C in 2010 for August, respectively.

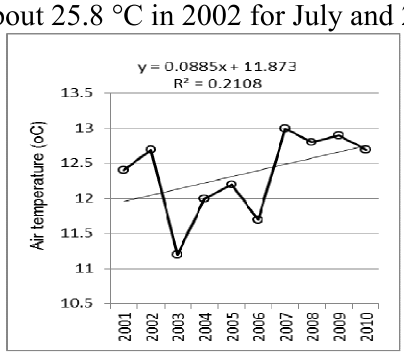

Fig.1 Mean annual air temperature at Sulina (2001-2010)

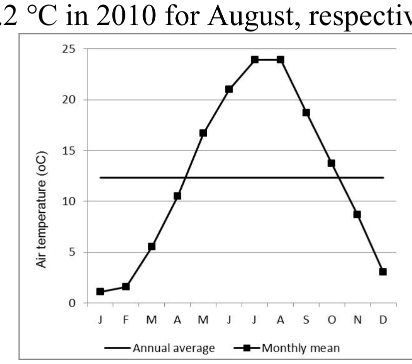

Fig. 2 Mean monthly air temperature at Sulina (2001-2010)

Also, mean air temperature of June has increased. Thus, mean air temperature of summer season increased progressively, from 21.3°C in 1961-1990 periods to 22.9°C in 2001-2010 decade. This increase was due mainly bywarming ofJuly and August months. The average value of the coldest month, January, was 1.1°C, higher than climate normal values. The annual range has increased, too, from 21.8°C in the last part of 20th century to 22.8 °C in first decade of XXIstcentury.

Also, for first decade of XXIst century, there was a warming of March month and November month compared to all climate normal values. For comparison, deviations 2001-2010 decade from each standard climate normal are showed in figure 2. As can be seen, for all months there were positive deviations, the highest values being for March, July, August and November. Thus, winter and autumn seasons became warmer and summer became hottest. Besides, the average air temperature value of March surpassed the 5°C mean temperature threshold. In these circumstances, except forthe winter months, in all other the average air temperature is above 5°C and the value of Kira's Warmth Index [$WI= \sum(T-5)$, for month in which $T> 5°C$] is 97. The value of Holdridge's annual biotemperature ($ABT=\sum T/12$, for month in which $0°C<T<30$ °C).

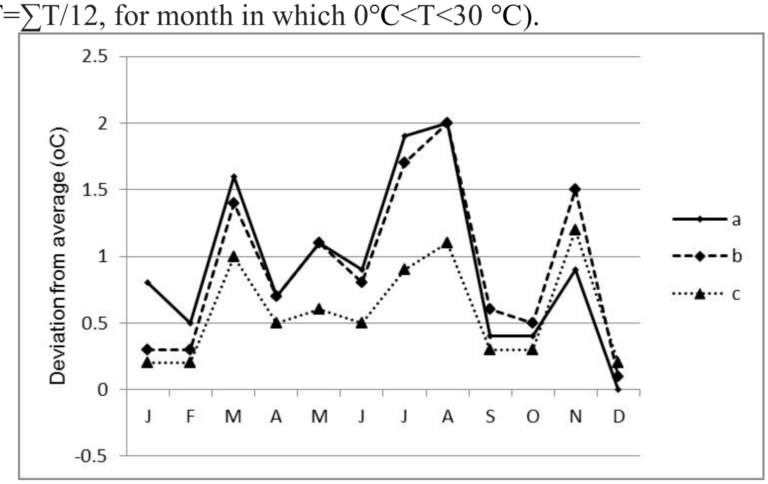

Fig. 2 Averaged mean monthly temperature (2001-2002) deviation from the climate normal at Sulina climatological station. a), 1961-1990; b), 1971-2000; c) 1981-2010

The Johansson Continentality Index is used for the climatic classification between continental and oceanic climates. The index is calculated by the following formula: $K= (1.7\ E/\sin\varphi) - 20.4$ where: E = annual range of monthly mean air temperatures, in ºC, (difference between the maximum and minimum monthly mean air temperatures) and φ = station's geographical latitude. Having regard the calculated value of this index for Sulina station is 25.2, the climate of the eastern part of Danube Delta is characterized as marine because *k* is lower than 33.

To assess oceanity degree of the climate it was calculated the KernerOceanity Index. This index expresses the influence of marine air masses over inland, based on fact that in marine climates the spring months are colder than the autumn months. The formula is: KI=100 (To-Ta)/E, where *To* and *Ta* are the October and April mean values of air temperature respectively and E is the annual range of monthly mean air temperatures, in ºC. For Sulina station, the value is 14.03. Because the value is higher than 10, the climate is characterized as oceanic.

Growing Season Length

In the first decade of XXIst century, the mean thermalGSL in eastern DD area was 269.7 days. This value is greater than average of GSL for second half of XXth century, when the GSL was 244 days (Strat, 2012).

The average date of starting growing season was 11 March and the average date of ending growing season was on 6 December. The earliest start was in 2002when it began on 9 Februaryand GSL was 339 day. The latest start of growing season was in 2006, on 27 March. In that year, the GSL was 269 days.

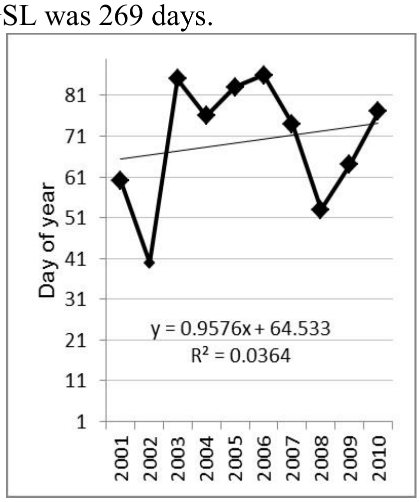

Fig. 3 Annual data start of growing season in first decade of 21st century at Sulina climatological station, Danube Delta

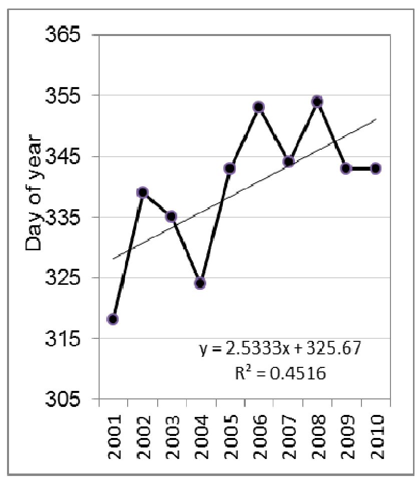

Fig. 4 Annual data end of growing season in first decade of 21st century at Sulina climatological station, Danube Delta

The earliest end of growing season was in 2001, on 14 November. In that year the GSL was only 259 days. The latest end of growing season for same period was in 2008, on 20 December, when the GSL was 302 days.

The longest growing season in the 2001-2010 intervals was 302 days in 2008 and the shortest growing was in 2004, only 249 days. Thus, the amplitude was 53 days andthe GLS over 2001-2010 ranged by an average of 17.2 days from de mean of 269.7 days.

The results reveal that there has been an increase in length of growing season over the first decade of 21th century across theDD coast as against second half of twentieth century.

This fact is related to air temperature increases. Since the end of 1980s clear changes in air temperature have been observed in DD (Sararu, 2008; Strat, 2010) just as in the rest of Europe (Frisch et al., 2002).

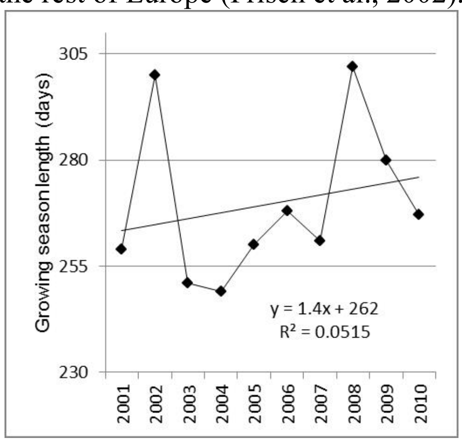

Fig. 5 Annual growing season length in Danube Delta coastal area

The increase of air temperature on DD coastline in first decade of XXI^st century confirms,to the local scale, predictions of global warming that had made by Intergovernmental Panel on Climatic Change although there are evidences about a global cooling starting from begging of 21th century (Easterbrook, 2008;Wendler et al., 2012). The temperature in winter and in the early spring changed distinctly (fig. 5).

The lengthening of growing season arose equally from an earlier of spring, because and a later onset of winter, although the delaying the start of winter was more significant. Air temperature of March has increased with 1.6 °C and air temperature of November has increased with 1.1°C. Thus, the beginning of growing season in Eastern Danube Delta has advanced with 11 daysand the end of growing season has delayed with 13 days, in comparison with 1951-2000.Warming of March and November led significant changes of start, end and length of growing season.

CONCLUSION

The first decade of new century was warmer than climate normals. Averaged mean annual temperature has increased with 1 °C for decade. The highest increase was for summer months – July and August, but warming trend of spring months, especially March, led to advancing of the beginning of growing season. Also, the lengthening of growing season was caused by delaying of end date with two weeks, thereby increasing growing season length to 269.7 days.

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