THE SIGNIFICANCE OF AIR TEMPERATURE OSCILLATIONS IN THE LAST DECADE IN SPLIT - CROATIA

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Abstract

This paper deals with preliminary results of wider on-going scientific research about climate changes in Split Dalmatian County. Complete data base consisted of daily air temperature from January the 1st 1948 to December the 31st 2008 is taken into account but due to the nature of this article authors are focused only on the significance of air temperature oscillations in the last decade. For these reason standard deviation of air temperature is evaluated for the entire period of last sixty years and separately for each decade, each year and each month. The basic hypothesis that air temperature fluctuations from decade to decade have continuous upward trend is tested. The linear and polynomial air temperature oscillation trends for mean annual, mean five-year and mean ten-year air temperature are analyzed. The integral part of the research is the detailed comparative analysis of monthly air temperature oscillations for the last ten years.

Key words: *air temperature oscillations, standard deviation evaluation, mean air temperature trend polynomial, comparative analysis*

1. INTRODUCTION

Split Dalmatian County is located on the Adriatic coast and in the historical, cultural and socio-economic sense belongs to the Mediterranean climate region. By its geographical position the Adriatic Coast is one area with a temperate climate, where there is no distinct coldness or heat. In the summer time the air temperature maximum is in the range from 36°C to 38°C. The lowest winter air temperature oscillates from -

6°C in the South to -16°C in the Northern Adriatic. It is important to stress that in the Adriatic area there are small differences in daily and seasonal air temperature changes with no significant temperature amplitude.

Climate has a crucial impact on the economy of the whole Dalmatian region but it especially refers to its capital – Split. Split is the third passenger port of Mediterranean and one of the biggest Croatian tourist destinations. Dominant type of tourism is transit tourism and moreover numerous cultural, economic, sport and touristic outdoor manifestations often take place in Split throughout the whole year. For planning all mentioned it is extremely important to predict accurately movement of the basic climate indicators. That is why an interdisciplinary team of scientists has been engaged in research on climatic changes in the last decade and on predicting their effects on integral socio-economic life of Split-Dalmatia County. Data Source for entire research is from Meteorological Station Split-Marjan.

This paper deals with preliminary results of wider on-going scientific research about climate changes in mentioned region. Basic climate indicators related to air and sea temperature, precipitation as well as direction and strength of winds has been daily monitored at the Meteorological Station Split-Marjan since January 1st 1948. The whole rich data base about basic climate indicators is taken into account but due to the nature of this article authors are focused only on the significance of air temperature oscillations in the last decade. Official data on the air temperature at the Meteorological Center Split are monitored as air temperature in 7am, 2pm and 9pm for each day.

As the average daily air temperature in meteorology the simple arithmetic average of the above mentioned air temperatures has bee accepted. Namely, it is calculated as the simple arithmetic average of the sum of the temperature measured at 7am and 2pm and the double amount of temperature measured at 9pm divided with four.

In the last sixty years the air temperature oscillations have not been systematically measured. For these reason in this paper standard deviations of air temperature have been evaluated for the entire period of last sixty years and separately for each decade, each year and each month. The origin idea was to test the basic hypothesis that air temperature fluctuations from decade to decade have a continuous upward trend. However, previously conducted graphical analysis has clearly shown that there are no statistically significant fluctuations in air temperature neither at the annual nor at the monthly level of research.

The structure of the paper is organized as follows. In the second section the linear and polynomial air temperature oscillation trend for mean annual, mean five-year and mean ten-year air temperature are analyzed. In the third section air temperature standard deviations for each decade, each year and each month are table presented. The forth section estimates the results of the comparative graphic analysis of air temperature mean and standard deviation for each month in the last sixty years, while the fifth section summarizes the results of the research and provides conclusion remarks.

2. THE LINEAR AND POLYNOMIAL AIR TEMPERATURE OSCILLATION TRENDS

2.1. The linear and polynomial annual mean air temperature oscillation trend

The air temperature oscillations analysis has been started with analysing linear and polynomial trend of mean air temperature at the annual level. For this purpose the wider data base has been available, so at the Figure 1. the linear and polynomial annual mean air temperature oscillation trend for the entire period from 1926 to 2000. has been presented (data break is since war period from 1940 to 1946).

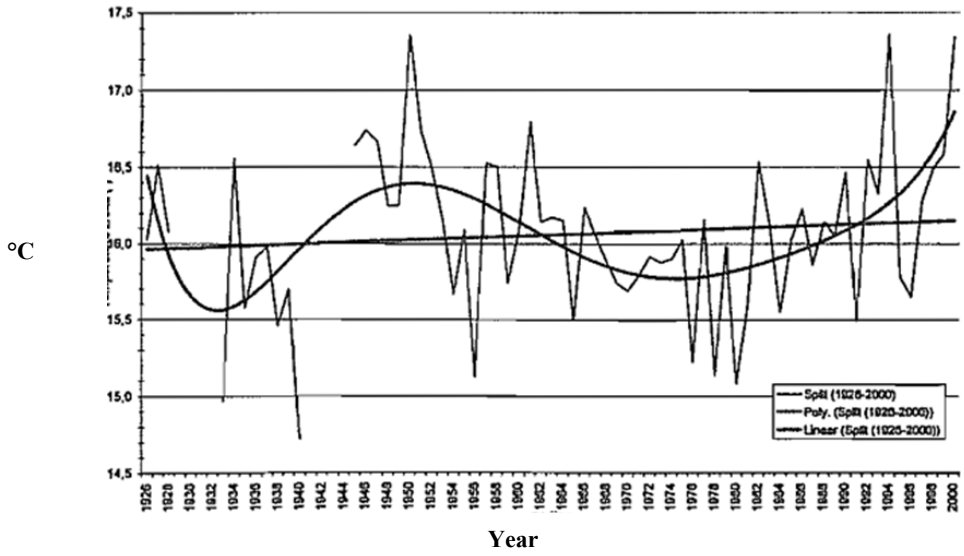

Figure 1.: Linear and Polynomial Trend of Mean Annual Air Temperature in °C for Split (1926.-2000.)

In the period from 1926 to 2000 mean annual temperature for Split according the linear trend at the previous picture shows a slight increase of +0.2°C. The polynomial trend shows visible negative oscillation around the early forties, and other less prominent oscillation around the eighties, until the first positive oscillation has been noted about the fifties and a larger increase in the last decade of the twentieth century. Absolute amount of increase in polynomial trend from 1975 to 2000 was +1.07°C, and at the end of the twentieth century it has been +1.11°C. (M. Hodžić, 2007.)

2.2. The linear and polynomial mean air temperature oscillation trend for periods longer than a year

The next step of the research of mean air temperature trends tendency has been extended to five-year period. Graphic presentation of the obtained results is presented in the Figure 2. The linear and polynomial trends of

mean values for five-year air temperature for Split in Figure 2. are based on data for period 1945-2000. The linear trend is poorly defined, with a negative coefficient of -0.2°C.

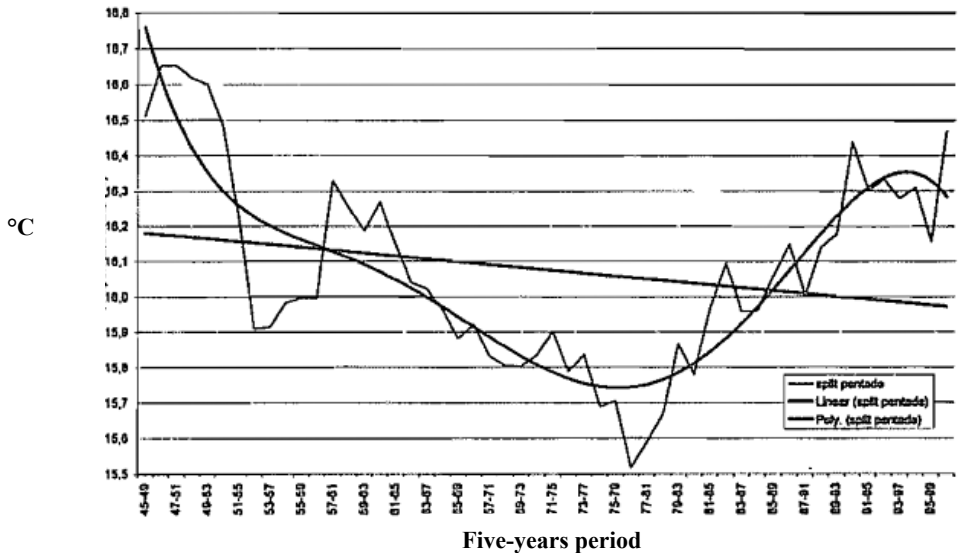

Figure 2.: Linear and Polynomial Trend of Mean Five-Years Air Temperature in °C for Split (1945.-2000.)

The polynomial trend has a wave shape from the beginning of the graph to five-year period 1976.-1981. Then there was a minimum with a negative trend in the amount of -1.02°C, followed with a positive trend until the end of the twentieth century, in the amount of +0.54 C. (M. Hodžić, 2007.)

Somewhat more complex interpretation of the results of our research imposes ten-year period air temperature analysis based on the data from the end of the Second World War to the end of the last millennium.

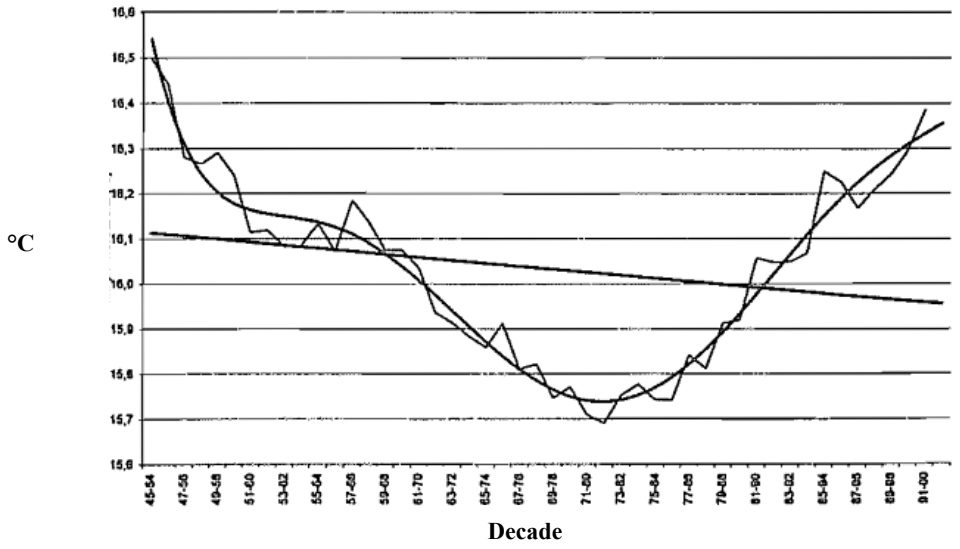

Figure 3.: Linear and Polynomial Trend of Mean Ten-Years Air Temperature in °C for Split (1945.-2000.)

The linear trend of the mean ten-year values of air temperature for Split since 1945 until 1990 is negative with a small amount of 0.16°C. The polynomial trend is wave formed with a negative direction from the beginning to the decade 1972.-1981. After that it becomes a positive trend until the end of the twentieth

century, with an increase of 0.62°C but in total the trend coefficient is -0.19°C. The longest clip time that is taken as the unit of the analysis of trends means air temperature in this study has been the period of thirty years. Figure 4. consists of the graphic presentation of the obtained results.

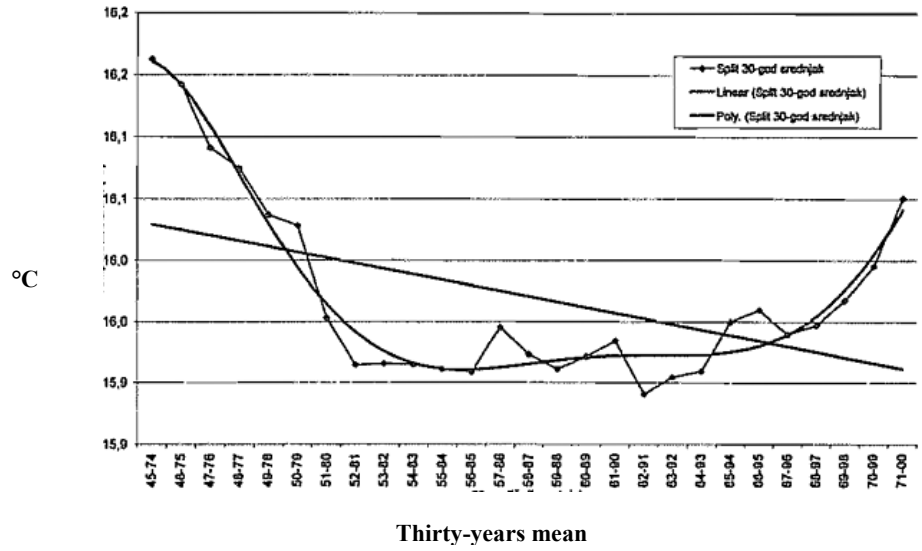

Figure 4.: Linear and Polynomial Trend of Mean Thirty-Years Air Temperature in °C for Split (1945.-2000.)

Linear thirty-years mean annual temperatures trend in Split (1945-2000) was negative and amounted to -0.12°C. In the same period polynomial trend is negative in the beginning to the thirty-years 1962-1991 period. After that the polynomial trend starts rising sharply towards the end of the century with a positive increase in the amount of +0.15°C. (M. Hodžić, 2007.)

Slight cooling of air temperature shown by the linear trend models for Split is in accordance with the latest research results on the impact of increased concentration of CO2 in the atmosphere. Namely, computations based on the modern theory of heat transfer in greenhouse effect (derived from the basic laws of physics and verified by experimental data) show that increasing concentration of CO2 in air should result in cooling rather than warming of the atmosphere. (V.Paar, 2010.)

It can be stressed that there is no difference in the final air temperature tendency trends conclusions whether the annual mean air temperatures or mean air temperature for longer time periods have been taken into consideration.

3. AIR TEMPERATURE STANDARD DEVIATION EVALUATION

The basic aim of this part of the research is to determine statistical significance of fluctuations in air temperature over the past decade. The following tables are review of the monthly air temperature variations

measured by standard deviations and variation coefficients. The full scale analysis has been done in order to compare them with those from the other observed periods.

Table 1: Monthly Air Temperature Means and Standard Deviations in the Last Decade at Meteorological Station Split-Marjan

Month	1999.		2000.		2001.		2002.		2003.		2004.		2005.		2006.		2007.		2008.	
	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C
January	8,29	3,17	6,05	3,19	9,73	3,01	6,95	3,31	8,59	2,52	6,41	3,82	7,12	3,04	6,85	2,84	10,53	2,13	9,54	2,47
February	6,57	3,20	8,61	2,15	9,34	3,59	10,65	1,98	4,95	2,47	8,52	2,98	5,56	2,59	7,74	3,64	11,01	1,42	9,32	3,10
March	11,14	2,45	10,41	2,60	13,72	2,20	13,09	2,69	10,91	2,55	10,31	4,08	10,05	4,99	9,35	3,62	12,45	2,37	11,42	2,40
April	14,59	2,12	16,24	4,01	13,70	2,72	15,01	2,24	14,01	3,93	14,72	2,15	14,34	2,59	15,29	2,22	17,38	1,94	14,72	1,94
May	20,04	2,46	21,75	1,73	20,63	2,61	20,02	1,99	22,69	2,44	17,40	2,00	20,46	3,43	19,66	3,01	20,91	3,16	20,61	2,92
June	24,18	2,52	25,16	2,17	22,65	2,91	25,23	3,83	28,03	2,53	23,19	3,27	23,80	4,29	23,54	5,74	25,47	2,99	24,53	3,94
July	25,91	1,87	25,68	3,27	26,69	2,08	26,64	2,05	27,88	1,64	26,89	3,04	26,56	2,38	27,59	2,17	27,86	3,14	27,01	2,98
August	26,5	2,42	27,78	2,34	27,71	2,24	24,48	2,27	29,24	1,96	26,65	1,27	23,92	2,84	24,13	2,90	26,49	2,59	27,42	2,00
September	22,91	1,71	21,54	1,97	19,04	2,50	20,20	2,89	21,05	1,46	22,08	2,91	22,00	2,37	22,30	1,99	19,69	2,84	20,59	5,23
October	17,71	3,01	18,49	1,96	19,09	2,24	17,14	1,55	15,89	3,80	19,19	1,80	16,72	1,82	18,81	2,20	16,31	3,87	18,11	1,50
November	12,03	3,56	15,16	2,34	11,38	3,20	14,58	3,21	14,29	2,30	12,74	5,05	11,93	4,24	12,48	2,35	10,72	3,15	13,33	4,02
December	9,19	3,51	10,98	3,49	5,76	3,10	9,78	2,68	9,92	3,09	10,86	3,18	8,38	2,71	10,53	2,52	7,98	2,66	9,93	3,22

Source: Authors construction

Table2: Monthly Variation Coefficients in the Last Decade at Meteorological Station Split-Marjan

Month	1999.	2000.	2001.	2002.	2003.	2004.	2005.	2006.	2007.	2008.
	in %	in %	in %	in %	in %	in %	in %	in %	in %	in %
January	38,24	52,73	30,94	47,63	29,34	59,59	42,67	41,46	20,23	25,89
February	48,71	24,94	38,49	18,62	49,78	34,93	46,63	47,03	12,89	33,32
March	22,04	24,93	16,03	20,56	23,36	39,57	49,68	38,77	19,03	20,98
April	14,49	24,70	19,83	14,95	28,09	14,57	18,09	14,54	11,18	13,18
May	12,30	7,93	12,65	9,95	10,75	11,47	16,75	15,32	15,12	14,18
June	10,41	8,62	12,85	15,18	9,03	14,12	18,05	24,41	11,75	16,06
July	7,20	12,74	7,78	7,68	5,88	11,31	8,95	7,82	11,27	11,02
August	9,14	8,43	8,08	9,29	6,69	4,95	11,89	12,03	9,79	7,28
September	7,45	9,14	13,14	14,31	6,93	13,18	10,79	8,94	14,42	25,41
October	17,00	10,62	11,73	9,02	23,94	9,38	10,90	11,71	23,72	8,27
November	29,64	15,44	28,15	22,04	16,09	39,67	35,50	18,87	29,36	30,17
December	38,26	31,81	53,80	27,36	31,14	29,26	32,34	23,95	33,33	32,43

Source: Authors construction

Variation coefficients from Table 2. are extremely high in the months with cooler mean air temperatures and much lower in the summer months. This principle applies in all the decades of the observed period. It is confirmed by the view of average month variation coefficients for the entire sixty years period shown in Table 10. Tables 3. to 8. contain the review of data on air temperature means and standard deviations for each month in each decade of the observed period.

Table 3. Standard Deviation and Mean Air Temperature for Each Month in period 1948.-1957. in ˚C

Month	January		February		March		April		May		June		July		August		September		October		November		December	
	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C
Celsius degrees	8,12	3,37	7,77	3,96	10,39	3,65	14,52	3,03	18,78	3,20	23,07	3,06	25,84	2,86	25,61	2,85	21,98	2,65	17,03	2,49	12,17	3,31	9,70	2,49

Source: Authors construction

Table 4. Standard Deviation and Mean Air Temperature for Each Month in period 1958.-1967. in ˚C

Month	January		February		March		April		May		June		July		August		September		October		November		December	
	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C
Celsius degrees	7,12	3,78	8,31	3,65	10,38	3,15	14,21	2,87	18,67	2,81	22,60	3,40	25,37	2,41	25,42	2,68	21,46	2,65	17,37	2,71	13,23	3,03	9,50	3,41

Source: Authors construction

Table 5. Standard Deviation and Mean Air Temperature for Each Month in period 1968.-1977. in ˚C

Month	January		February		March		April		May		June		July		August		September		October		November		December	
	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C
Celsius degrees	8,23	2,73	8,80	2,88	10,38	3,65	13,74	2,92	19,08	2,83	22,38	2,73	25,15	2,88	24,41	3,13	20,79	3,07	16,12	3,17	12,24	3,41	8,53	2,99

Source: Authors construction

Table 6. Standard Deviation and Mean Air Temperature for Each Month in period 1978.-1987. in ˚C

Month	January		February		March		April		May		June		July		August		September		October		November		December	
	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C
Celsius degrees	6,98	3,43	7,39	3,31	10,16	3,02	13,57	2,96	18,31	3,28	22,53	2,94	25,34	2,46	24,88	2,67	21,83	2,60	17,19	2,68	12,20	2,82	9,38	3,22

Source: Authors construction

Table 7. Standard Deviation and Mean Air Temperature for Each Month in period 1988.-1997. in ˚C

Month	January		February		March		April		May		June		July		August		September		October		November		December	
	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C
Celsius degrees	8,65	2,61	8,69	3,38	11,15	3,08	13,63	2,92	18,89	2,92	22,72	2,95	26,17	2,54	25,94	2,74	20,91	2,61	16,91	3,28	11,98	3,55	8,86	3,22

Source: Authors construction

Table 8. Standard Deviation and Mean Air Temperature for Each Month in period 1999.-2008. in ˚C

Month	January		February		March		April		May		June		July		August		September		October		November		December	
	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C
Celsius degrees	8,01	3,29	8,23	3,36	11,29	3,35	15,00	2,84	20,42	2,91	24,58	3,80	26,87	2,59	26,33	2,85	21,14	2,98	17,75	2,73	12,86	3,67	9,33	3,35

Source: Authors construction

Comparative analysis of the raw data indicates that from decade to decade there have been no significant changes neither in mean nor in standard deviation of air temperature for each month.

4. COMPARATIVE GRAPHIC ANALYSIS OF AIR TEMPERATURE CHANGES

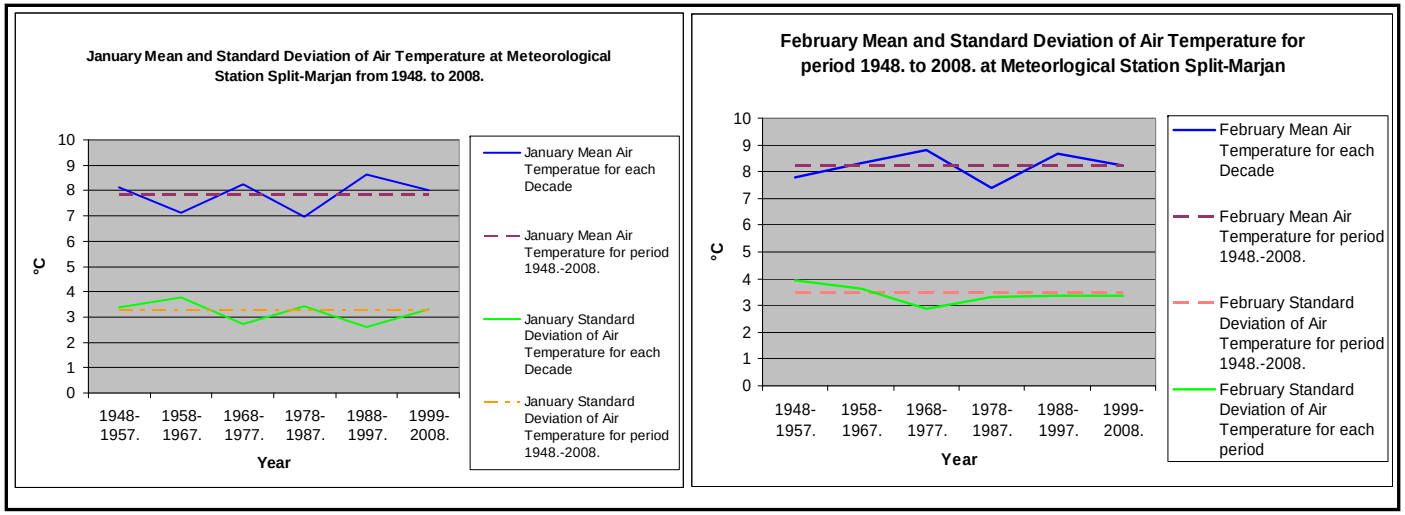

Figure 5.: *January and February Mean and Standard Deviation of Air Temperature for Period 1948. to 2008. at Meteorological Station Split-Marjan*

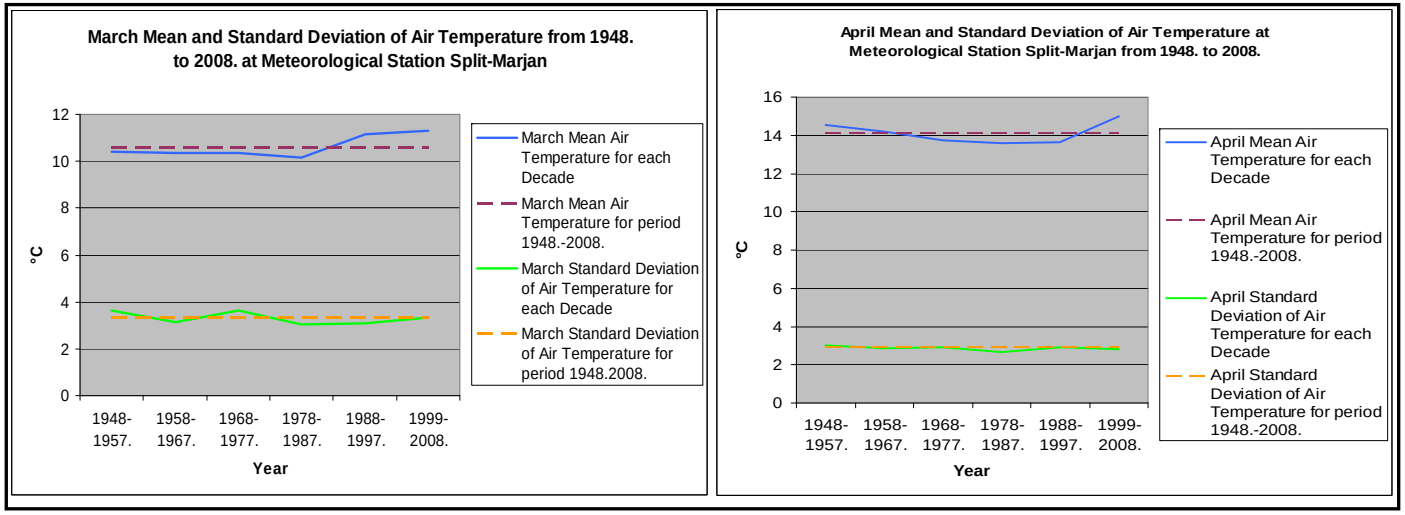

Figure 6.: *March and April Mean and Standard Deviation of Air Temperature for Period 1948. to 2008. at Meteorological Station Split-Marjan*

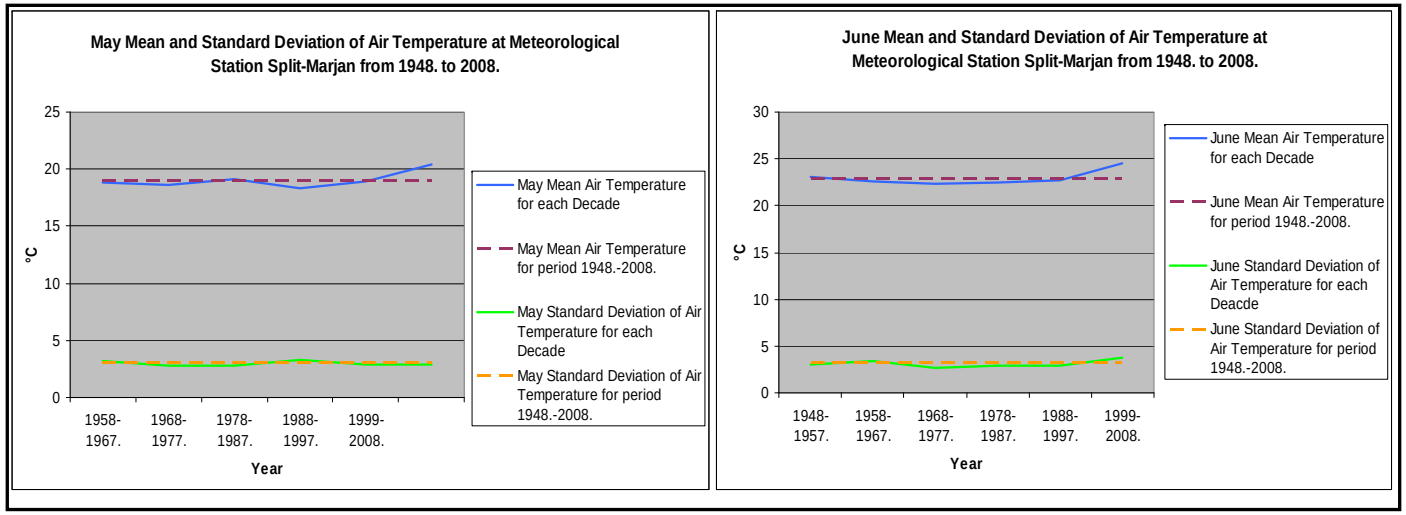

Figure 7.: *May and June Mean and Standard Deviation of Air Temperature for Period 1948. to 2008. at Meteorological Station Split-Marjan*

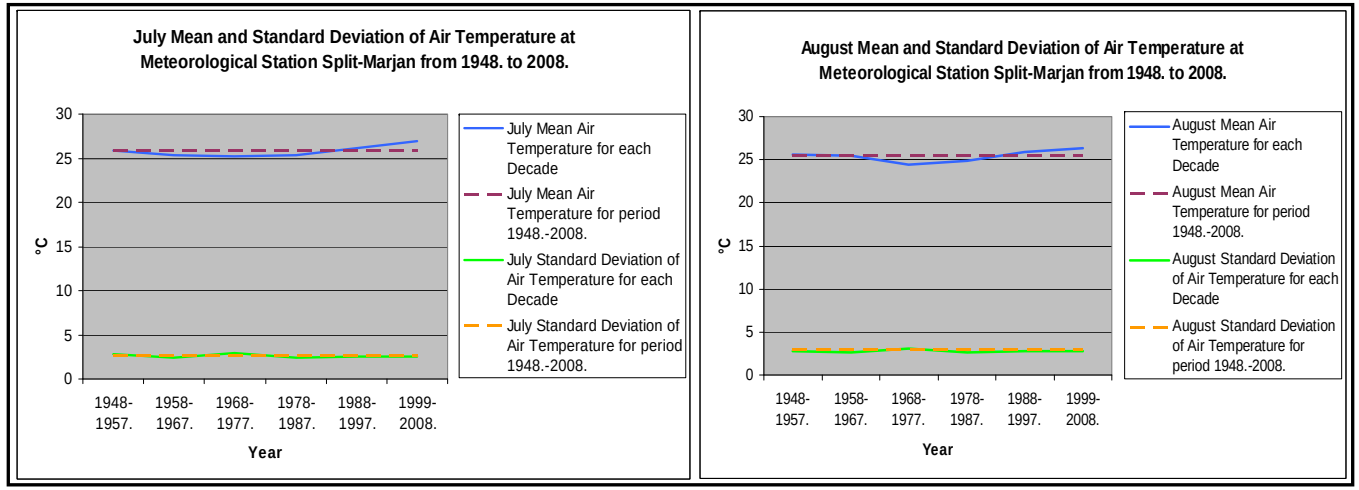

Figure 8.: *July and August Mean and Standard Deviation of Air Temperature for Period 1948. to 2008. at Meteorological Station Split-Marjan*

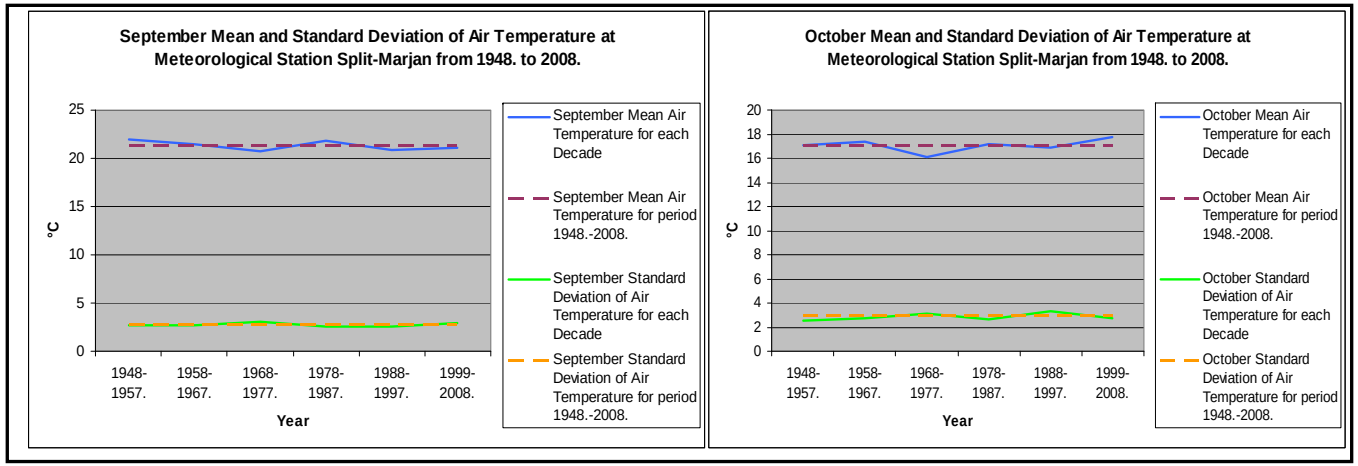

Figure 9.: *September and October Mean and Standard Deviation of Air Temperature for Period 1948. to 2008. at Meteorological Station Split-Marjan*

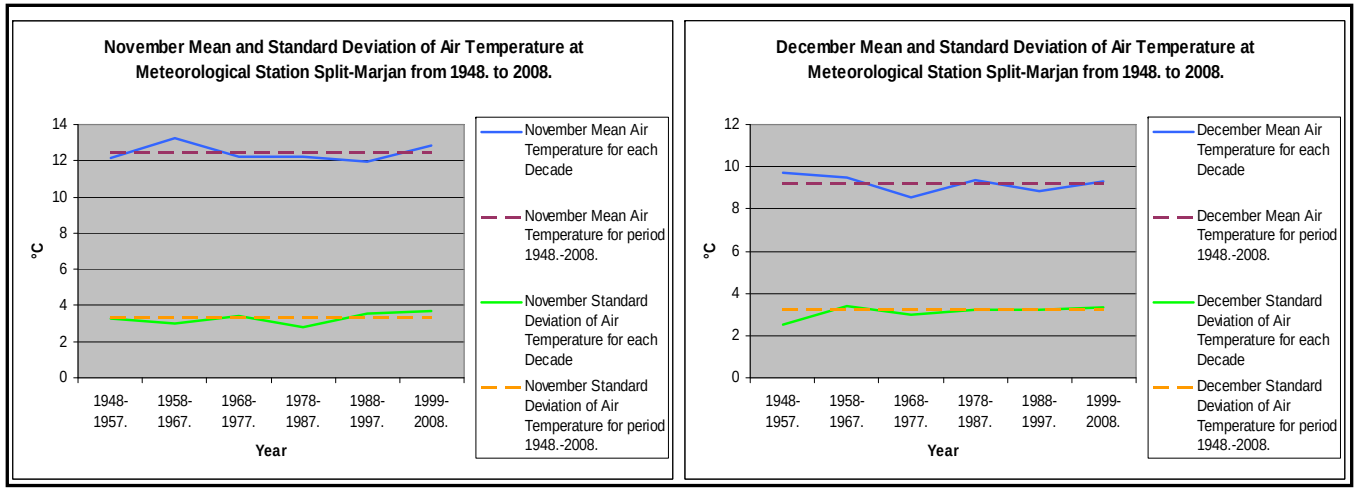

Figure 10.: November and December Mean and Standard Deviation of Air Temperature for Period 1948. to 2008. at Meteorological Station Split-Marjan

In Figures 5. to 10. air temperature means and standard deviations for each month from 1948.-2008. observed at Meteorological Station Split-Marjan are presented. Graphic analysis of the monthly air temperature oscillations around the mean as well as around the average standard deviation very clearly points to the conclusion that the oscillations in the both cases are not statistically significant. To confirm the results of graphical analysis in Table 9. air temperature means with corresponding standard deviations for each month for the entire analysis period have been estimated. Table 10. consists of the variation coefficients belonging values.

Table 9. Standard Deviation and Mean Air Temperature for Each Month in period 1948.-2008. in ˚C

Month	January		February		March		April		May		June		July		August		September		October		November		December	
	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C	Mean in °C	σ in °C
Celsius degrees	7,87	3,28	8,25	3,48	10,61	3,35	14,12	2,91	19,03	3,06	23,00	3,26	25,82	2,71	25,46	2,92	21,36	2,80	17,06	2,89	12,41	3,37	9,18	3,20

Table 10. Variation Coefficients in the Period of 1948.-2008. at Meteorological Station Split-Marjan

Month	January	February	March	April	May	June	July	August	September	October	November	December
	in %	in %	in %	in %	in %	in %	in %	in %	in %	in %	in %	in %
Celsius degrees	41,68	42,18	31,57	20,61	16,08	14,17	10,50	11,47	13,11	16,94	27,16	34,86

5. CONCLUSION

Although this paper deals with preliminary results of wider on-going scientific research about climate changes in Split Dalmatian County, they clearly indicate slight cooling of air temperature. This conclusion can be confirmed by analyzing the linear and polynomial air temperature oscillation trends for mean annual, mean five-years and ten-years air temperature. Variation coefficients are extremely high in the months with cooler mean air temperature and much lower in the summer months. Graphic analysis of the monthly air temperature oscillations around the mean as well as around the average standard deviation for each month points to the conclusion that the oscillations in the both cases are not statistically significant. From decade to decade there are no significant changes neither in mean nor in standard deviation of air temperatures for each month.

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