ANALYSIS OF DAILY TEMPERATURES DATA IN TÂRGU MUREŞ FROM THE PERIOD 1951-2014

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ABSTRACT. – Analysis of daily temperatures data in Târgu Mureş from the period 1951-2014. Statistical analysis of 365 x 4 time series (daily mean temperatures DMT, daily maximum temperatures TN, daily minimum temperatures TX and diurnal temperature ranges DTR), each content 64 values (1951-2014) were made from data registered at Târgu Mureş meteorological station. In case of DMT standard deviations of summer days are less than of winter days, while in case of DTR spring and autumn days have greater values of this parameter. Kolmogorov-Smirnov normality tests reveal that in almost cases time series follow a normal distribution, but some other test (e.g. Shapiro-Wilk) show that in winter there are time series of days in which case one cannot assume normality. By far most outliers were found in winter days (e.g. 15 outliers were registered in 1985, which is one of the coldest years). Linear trend was analysed using Mann-Kendall test. In case of DMT statistical significant increasing trends are present in greater numbers in days of warm months (e.g. in August there are 10 such days), which is similar to monthly linear trends. In order to decide whether a time series have constant variance or not, range-mean plots were created. Mainly downward sloping lines are present, e.g. in January (DMT) there are 15 days when the variance is decreasing in the mean. Two parts regressions have different points (year) when the regression line is changing, but usually the second line has an upward slope. In case of extreme temperatures (TN and TX) 1st and 3rd quartiles were determined, and analysed how the number of values greater respectively less than the quartiles is distributed in time. So for example, in case of summer days (TN) two thirds of values greater than 3rd quartile are placed in the second parts of studied periods, while in winter half parts of values greater than the 1st quartile are placed in the last 32 years. Analyses from this paper were made using the following statistical software: XLSTAT, Gretl, AnClim and Microsoft Excel.

Keywords: daily temperatures, Targu Mures, outliers, trends, quartiles

1. INTRODUCTION

Daily temperature analysis are not common compared to annual, seasonal and monthly studies. However, often occurs pronouncements as „mean (or maximum, minimum) temperature for today was outdated”. The aim of this paper is to present the main characteristics of daily temperature data and how much they match monthly data.

Statistical analysis of 365 x 4 time series (daily mean temperatures DMT, daily maximum temperatures TN, daily minimum temperatures TX and diurnal temperature ranges DTR), each content 64 values (1951-2014) were made from

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data registered at Târgu Mureş meteorological station (lat. N 46°32’, long. E24°32’, elevation 308 m).

2. STANDARD DEVIATIONS

In the case of daily mean temperatures standard deviations of summer days are less than those of winter days (Table 1., fig. 1., 2.). At same, summer monthly standard deviations are less than those of winter monthly values (Rusz, 2011).

Table 1. ***Standard deviation of daily mean temperatures***

Standard deviation of DMT	mean	maximum value	minimum value
Spring days	3.614	5.021	2.690
Summer days	2.907	3.409	2.281
Autumn days	3.519	4.520	2.419
Winter days	5.229	6.739	3.795

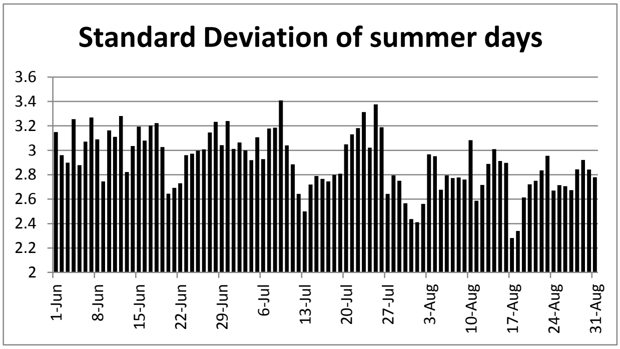

Fig. 1. ***The standard deviations of summer days (daily mean temperatures)***

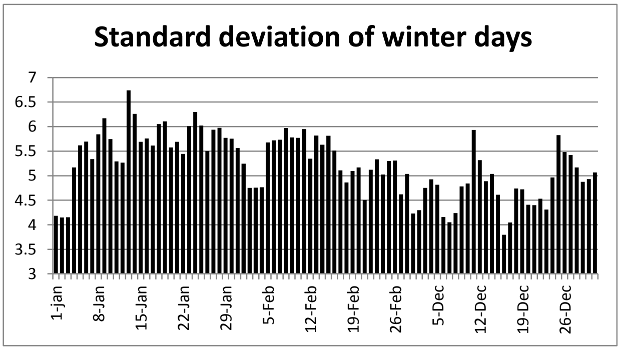

Fig. 2. ***The standard deviations of winter days (daily mean temperatures)***

In the case of diurnal temperature ranges spring and autumn days have greater values of standard deviation (Table 2.)

Table 2. ***Standard deviation of daily temperature range***

Standard deviation of DTR	Mean	Maximum value	Minimum value
Spring days	4.457	5.626	3.438
Summer days	3.717	4.857	2.987
Autumn days	4.619	5.466	3.456
Winter days	3.807	5.004	2.757

3. NORMALITY TESTS

Kolmogorov-Smirnov normality tests reveals that in almost cases time series follow a normal distribution. There are four days in the winter in which cases on cannot assume normality. This test is less powerful, and other normality tests (Shapiro-Wilk, Lilliefors, Anderson-Darling, Jarque-Bera) show that in winter, especially in January and February, there are many time series of days in which case one cannot assume normality. These tests were applied using *XLSTAT* and *AnClim* software (http://www.xlstat.com).

4. OUTLIERS

Outliers are values in a set of data which have an abnormal distance from other values. In the case of daily mean temperatures most outliers were found in winter days: 126, while in autumn there are only 40. Many of winter's outliers were registered in 1985, which is one of the coldest year until the last decades. In 26 January the number of outlier is 5 (fig.3.). Outliers were identified with *XLSTAT* soft (http://www.xlstat.com).

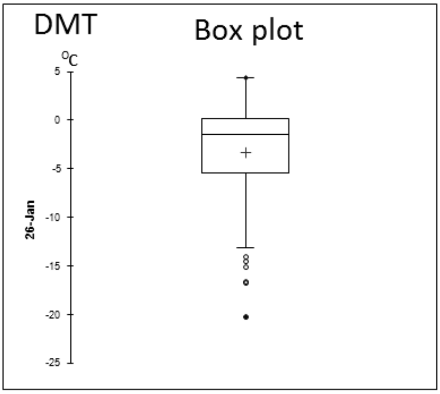

Fig. 3. ***Outliers in 26 January (registered in 1954, 1963, 1992, 2006, 2010)***

In case of diurnal temperature range, outliers are rare, but it is noticeable the values from 4 September: 24.4 °C (1992).

5. LINEAR TRENDS

Linear trend was analysed using Mann-Kendall test (Mann, 1945; Kendall, 1975), Sen's slope estimate (Sen, 1968) and *Makesense* soft (Salmi et al., 2002). In the case of daily mean temperatures statistical significant increasing trends are present in greater numbers in days of warm month. In August there are 10 such days and in July 7. Usually, positive trends are present, but in cold months there are some days with a decreasing trend. In December 18 days have a negative trend, but only 2 are statistical significant (Table 3., fig.4.).

Table 3. ***Sen's slope estimate in case of daily mean temperatures. Statistically significant trend (at 5% level) are present in bold***

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-0.04	0.00	0.04	-0.02	0.05	-0.01	0.04	0.03	0.01	0.01	-0.01	-0.03
2	-0.01	-0.01	**0.06**	0.01	0.04	-0.01	0.04	**0.04**	-0.01	0.02	0.00	-0.01
3	0.00	-0.02	0.05	0.03	0.05	0.01	0.03	**0.06**	-0.02	0.03	-0.02	0.02
4	-0.01	0.00	**0.06**	0.03	0.03	0.04	0.04	**0.05**	0.00	0.02	-0.03	0.03
5	0.03	0.01	0.05	0.03	0.03	0.03	0.02	**0.04**	-0.04	0.03	-0.05	0.03
6	0.04	0.03	0.02	0.01	0.02	0.02	0.03	**0.05**	**-0.06**	**0.05**	-0.03	0.03
7	0.02	**0.07**	0.02	0.00	0.01	0.03	0.04	0.04	**-0.06**	0.04	-0.03	0.01
8	0.02	0.06	0.01	0.02	0.02	0.03	**0.05**	0.01	-0.03	0.03	0.02	-0.01
9	0.04	0.06	0.05	0.00	0.02	0.03	0.04	0.02	0.00	0.01	0.01	0.00
10	0.06	0.05	0.03	0.01	0.03	**0.06**	0.04	0.00	-0.01	0.04	-0.01	-0.02
11	0.06	0.07	0.03	0.01	**0.05**	**0.05**	0.03	0.01	0.01	0.03	-0.04	-0.01
12	0.04	0.01	0.02	0.02	0.05	**0.06**	0.00	0.01	0.01	0.03	-0.05	-0.01
13	0.02	0.00	0.03	0.02	0.04	**0.05**	0.00	0.03	0.01	0.00	-0.03	0.00
14	0.07	-0.01	0.02	0.00	0.02	0.04	0.02	0.03	0.03	-0.01	-0.04	-0.02
15	0.04	-0.02	0.03	-0.02	0.02	0.02	0.00	0.02	0.04	0.00	-0.03	0.01
16	0.04	-0.02	0.00	0.00	0.03	0.02	-0.02	0.02	0.04	0.02	-0.01	0.00
17	0.03	-0.03	0.03	0.01	0.04	0.02	0.00	0.02	0.02	0.01	0.03	-0.02
18	0.07	0.00	0.02	0.01	**0.05**	0.00	0.02	**0.04**	0.00	0.00	0.02	-0.01
19	0.06	-0.02	0.02	0.03	0.04	0.01	0.03	**0.04**	0.00	-0.01	-0.01	-0.01
20	**0.08**	0.01	0.02	0.04	**0.04**	0.02	**0.05**	**0.05**	0.01	-0.01	0.01	-0.02
21	**0.10**	0.02	0.00	0.05	**0.04**	0.03	0.04	0.03	0.02	0.00	0.00	-0.02
22	0.07	0.03	0.01	0.05	**0.04**	0.03	0.04	0.02	0.01	0.01	0.02	-0.02
23	**0.07**	0.04	0.02	0.04	**0.05**	0.02	0.04	**0.04**	0.01	0.03	0.01	-0.01
24	0.04	0.03	0.03	0.05	0.03	0.00	0.04	**0.05**	0.04	0.03	0.02	0.00
25	0.04	0.03	0.01	0.05	0.03	-0.01	**0.05**	0.02	0.03	-0.01	0.03	0.00
26	-0.01	0.04	0.02	**0.05**	**0.05**	-0.01	**0.05**	0.02	0.04	-0.02	0.01	0.00
27	0.01	0.04	0.00	0.04	0.04	-0.02	**0.05**	0.02	0.03	-0.03	-0.01	0.00
28	0.02	0.03	0.01	0.04	0.03	0.00	**0.04**	0.02	0.03	-0.02	-0.03	-0.02
29	0.03		0.01	0.04	0.05	0.02	0.03	0.01	0.01	-0.01	0.01	-0.05
30	0.02		-0.01	0.04	0.04	0.04	**0.04**	0.00	0.00	-0.02	0.00	**-0.07**
31	0.00		-0.02		0.01		0.02	0.00		-0.03		**-0.07**

As well, the linear trend of monthly mean temperatures are statistical signficant with an increasing trend in the case of the warm months (Rusz, 2012).

The same aspects are present in the case of linear trend of diurnal temperature ranges: especially in spring and summer days there are statistical significant and increasing trends, while in winter (mainly in January) negative trends are quite common.

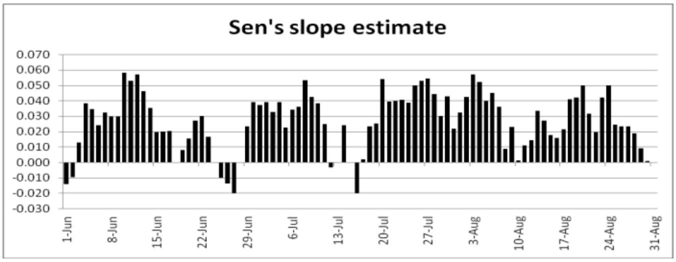

Fig. 4. ***Sen's slope estimate in case of summer day (mean temperatures)***

6. RANGE-MEAN PLOTS

In order to decide whether a time series have constant variance or not, range-mean plots were created using *Gretl* software (http://gretl.sourceforge.net). Mainly downward sloping lines are present, which means that the variance is decreasing in the mean (Table 4., fig. 5.).

Table 4. ***Range-mean plots: number of days with downward and upward sloping line (statistical significancy: 10%)***

	Range-mean plots			
	Spring	Summer	Autumn	Winter
Number of days with downward sloping lines	15	9	5	28
Number of days with upward sloping lines	2	4	1	1

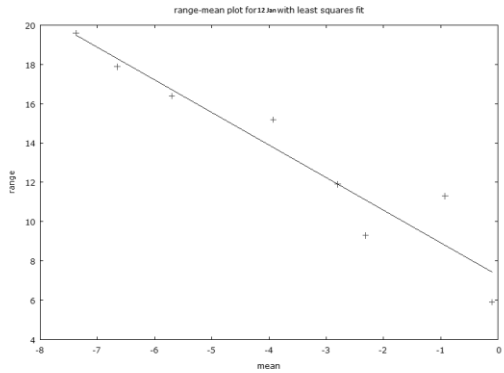

Fig. 5. ***The downward slope for 12 January***

7. TWO PARTS REGRESSION

Two parts regressions have different points (year) when the regression line is changing, but usually the second line has an upward slope (Table 5., 6., fig. 6., 7.). Regression lines were created using *AnClim* software (Stepanek, 2007).

Table 5. ***Two parts regression: distributions of decades when the regression line is changing***

	Change of regression line			
	Spring days	Summer days	Autumn days	Winter days
1951-1960	13	10	14	11
1961-1970	21	11	18	29
1971-1980	21	9	18	12
1981-1990	6	27	10	11
1991-2000	15	13	6	11
2000-2014	16	22	25	17

Table 6. ***Two parts regression: the slope of regression lines before and after changing***

	Number of days with :	Spring days	Summer days	Autumn days	Winter days
Before changing regression line	Downward slope	47	58	46	50
	Upward slope	45	34	45	41
After changing regression line	Downward slope	33	40	33	23
	Upward slope	59	52	58	68

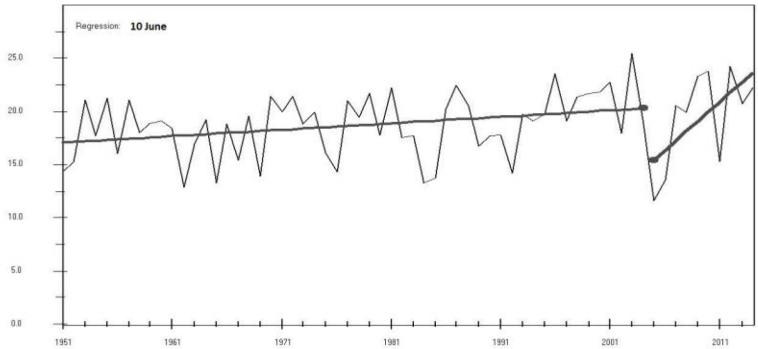

Fig. 6. ***Two parts regression in case of 10 June. Both of lines have an upward slope***

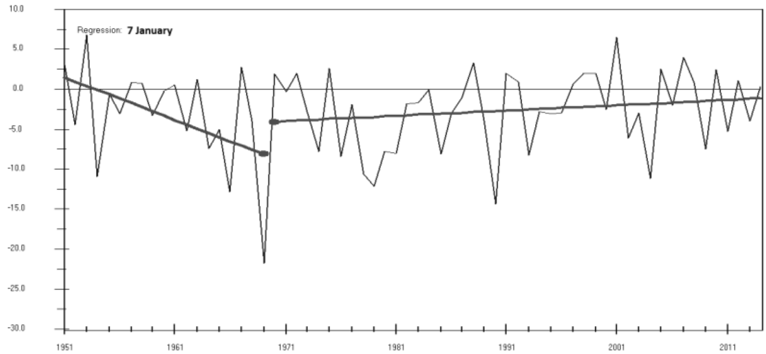

Fig. 7. ***Two parts regression in case of 7 January. The first line has an downward slope, and the second line an upward slope***

Monthly data reveal (Rusz, 2012) that summer months have the 80s as changing years of regression lines, which correspond with daily summer temperature data (the most of change of the regression line -27- belong to the period 1981-1990).

8. DAILY MAXIMUM AND MINMUM TEMPERATURES

In case of extreme temperatures (daily maximum and minimum temperatures) 1st and 3rd quartiles were determined, and analysed how the number of values greater respectively less than the quartiles is distributed in time. It was calculated the number of cases for the last 32 year (the second part of the studied period) compared to the all (64) years (in percentages), when the value of maximum temperature and is less than the 1st quartiles and respectively greater than the 3rd quartiles (Table 7). In case of summer days (TN) two thirds of values greater than 3rd quartile are placed in the second parts of studied periods The same operations were made for minimum temperatures (Table 8).

Table 7. The number of cases for the last 32 year compared to the all (64) years (%), when TX< 1st quartiles respectively TX>3rd quartiles

	Spring	Summer	Autumn	Winter
The number of cases for the last 32 year compared to the all (64) years (%), when TX< 1st quartiles	42	40	52	48
The number of cases for the last 32 year compared to the all (64) years (%), when TX>3rd quartiles	57	63	52	52

Table 8. The number of cases for the last 32 year compared to the all (64) years (%), when TN< 1st quartiles respectively TN>3rd quartiles

	Spring	Summer	Autumn	Winter
The number of cases for the last 32 year compared to the all (64) years (%), when TN< 1st quartiles	47	44	53	45
The number of cases for the last 32 year compared to the all (64) years (%), when TN>3rd quartiles	56	58	50	51

9. CONCLUSIONS

Daily temperature data (daily mean temperatures DMT, daily maximum temperatures TN, daily minimum temperatures TX and diurnal temperature ranges DTR) registered at the Targu Mures meteorological station in the period 1951-2014, in some cases show the same pattern as monthly values.

Except Kolmogorov-Smirnov test, mainly in winter on cannot accept normal distribution. Standard deviation of summer days are less than of winter days, this corresponds with monthly data. Most outliers were found in winter days. Linear trend analysis (Mann-Kendall test, Sen’s slope estimate) reveals that statistical significant increasing trends of DMT are present in greater numbers in days of warm months, which is similar to monthly linear trends. Also, mainly summer days have positive trends as regard DTR. Range-mean plots highlighted that mainly downward sloping lines are present, especially in winter, when the variance is decreasing in the mean. Two parts regressions have different points (year) when the regression line is changing, but usually the second line has an upward slope. In case of summer days, the 80s are the changing points, which match with monthly data analysis of warm months.

In case of extreme temperatures (TN and TX) 1st and 3rd quartiles were determined, and analysed how the number of values greater respectively less than the quartiles is distributed in time. In the second part of the studied period, there are some sign of warming as regard extreme temperatures (e.g. in case of maximum temperatures of summer days two thirds of values greater than 3rd quartile are placed in the second parts of studied periods).

These statistical analyses reveal that climate change and global warming are reflected at local level not only in annual and monthly data, but also daily data (belong to sufficiently long time series) are affected. These effects consist mainly in a warming trend of many summer days (in case of mean temperatures and diurnal temperatures ranges), with an upward slope at the second part of studied period. Also daily extreme temperatures have become higher in the last decades.

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