TEMPERATURE SUMS AND CLIMATIC VARIATIONS IN THE PARG REGION

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Abstract: Time series of temperature sums for the different temperature thresholds from the Parg station in the Croatia mountain area during the vegetation period from 1951 to 2004 have been analysed. The temperature differences between mean temperatures and temperatures thresholds are called the temperature sums or degree days and they are frequently applied in agrometeorology. The results of linear trend analysis and the Mann-Kendall test are shown that the significant linear trends temperature sums exit above thresholds 15°C and 20°C (increasing by time) which are the consequence of significant increase in mean maximum temperature in spring and summer.

Key words – temeperature sums, linear trend, climatic variations, the mountain Parg station

1. INTRODUCTION

The growth of plants is correlated more or less closely with the accumulated air temperature above specific temperature threshold. By knowing the mean temperature sums during the vegetation period it is possible to give an estimate of the temperature conditions in a region and to plan the growing of plant species. These temperature sums, however, can be used in the same way as other meteorological parameters to analyse climatic variations. Thus, the temperature sums above thresholds 0°C, 5°C, 10°C, 15°C and 20°C and their linear trends have been analyzed at the mountain Parg stations (863 m a.s.l.) for the vegetation period (April–September) from 1951 to 2004. As the growth of plant depends on the other climatic parameters too, linear trends of air temperature, pressure, relative humidity, precipitation, snow cover, cloudiness, insolation duration and atmospheric phenomena have been also presented.

The previous analysis of temperature sums in the Croatian mountain area and lowlands did not establish the existence of a significant linear trend not even for any threshold (Vučetić and Vučetić, 1994 and 1996) but these analyses did not include last twelve years. Designation in the sense of chronology increasing in temperature sum over 20°C was noticed in the north-western part of Croatia.

2. METHOD AND RESULTS

An analysis of temperature sums was undertaken for five temperature thresholds by means of application of relation (M. Vučetić and V. Vučetić, 1994):

$$TS = \sum_{i=1}^{n} (S_i - T) \qquad S = \frac{t_{\max} + t_{\min}}{2} \qquad S_i > T \qquad (1)$$

where are T - temperature threshold, t_{max} - maximum daily temperature, t_{min}- minimum daily temperature and n - number of days in a certain period.

Before analyse of linear trends it will be presented the main climatic conditions at the Parg station during the period 1951–2004:

- the mean annual air temperature is 7.2°C with the absolute maximum of 33.5°C and minimum -23.2°C,
- the mean annual number of cold days ($t_{min} < 0$°C) is 122 days from which are 35 icy days ($t_{min} \leq -10$°C) and 14 freezing days ($t_{max} < 0$°C),
- the mean annual number of warm days ($t_{max} \geq 25$°C) is 19 days from which is only 1 hot day ($t_{max} \geq 30$°C),
- the mean annual insolation duration is 1689 hours with 46 clear days and 143 overcast days in average,
- the mean annual air pressure is 917.5 hPa,
- the mean annual relative humidity 83% with 5 dry days (RH≤ 30%) and 129 wet days (RH ≥ 80%) in average,
- the mean annual amount of precipitation is 1848 mm with maximum daily amount of 226.7 mm,

- the mean annual number of precipitation days ≥ 0.1 mm is 173 from which is 140 rainy days,
- the absolute maximum of snow cover height is 156 cm and the mean number of snow days is 53 days,
- the mean annual number of days with snow cover height ≥1 cm is 99 days from which is 11 days above 50 cm,
- the mean annual number of days with fog is 65 days, frozen 32 days, rime 5 days, supercooled rain and glaze 2 days, dew 101 day, thunder 52 days and hail 4 days.

The range of the mean temperature sums at Parg was from 2381.5°C for T= 0°C to 11.5°C for T= 20°C. The greatest variations of temperature sums from year to year are for T= 20°C what indicate the great value of standard deviation (Tab. 1). In some years as 1978 and 1997 mean daily temperature did not go over 20°C. However, in 2003 this sum reached the absolute maximum value of 94°C (Fig. 1) and it was the extreme warm year in the entire Croatia. According to the curves of a 5-year series of moving average, which is eliminate very short-term fluctuations, wamer period was noticed for all threshold last five years.Vegetation begins for most plant species when sufficient warmth over the threshold of 5°C has accumulated and due to these temperature sums is also called the growing degree days.

Table 1. Mean, maximum and minimum temeperature sums for different tresholds with standard deviations and amplitude and their lineat trends (°C /10 years) and α parameter of the Mann-Kendallov test for Parg during the vegetation period (April–September) from 1951 to 2004. The trend with the 0.05 significant level is marked by yellow.

TS	≥0°C	≥5°C	≥10°C	≥15°C	≥20°C	TS	trend	α
MEAN	2381.5	1496.3	714.0	184.8	11.5	≥ 0°C	25.06	0.1299
STD	142.8	137.2	115.2	66.4	14.6	≥ 5°C	24.72	0.1299
MAX	2857.9	1979.4	1147.6	491.3	94.0	≥ 10°C	21.12	0.0848
MIN	2095.3	1232.2	495.5	83.8	0.0	≥ 15°C	24.65	0.0163
AMPL	762.6	747.2	652.1	407.5	94.0	≥ 20°C	3.00	0.0500

One of the methods which enables us to estimate statistically significant changes of the level around which are distributed the terms of the time series i. e. linear trend estimate of existence is the non-parametric Mann-Kendal rank test (Mitchell et all, 1966). According to linear trend analyses and this test at the 0.05 confidence level, the existence of a significant linear trend of temperature sums above thresholds 15°C and 20°C has been established which is the consequence of significant increase in mean maximum temperature in spring and summer (Tabs. 1 and 2). The increase of absolute maximum temperature is the greatest during the winter time and the smallest during the spring, while in autumn they show a negative trend. Significant increases of the mean seasonal temperature and absolute minimum temperature have been established only in spring. The annual values of mean air pressure, number of warm days and days with dew also show significant positive trend (Fig. 2).

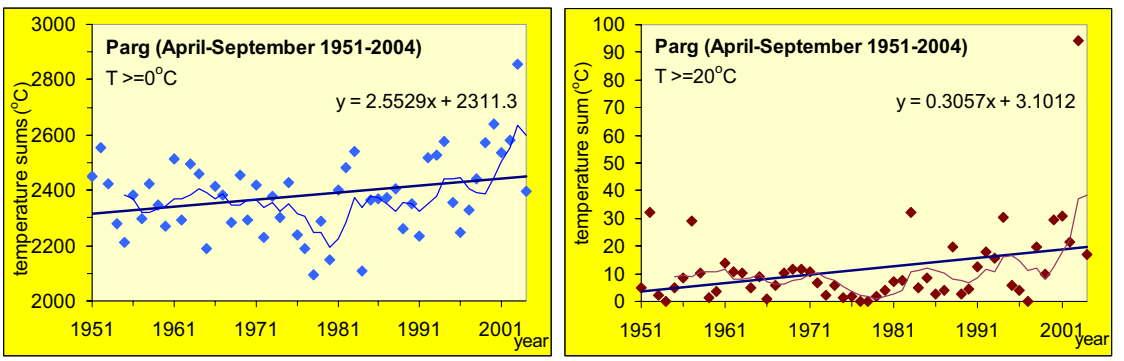

Figure 1. Time series (dots) of temperature sums above 0 °C and 20 °C (°C), the curves of a 5-year series of moving average and the linear trends for Parg during the vegetation period (April–September) 1951–2004. x is a number of years (1,2,3…n).

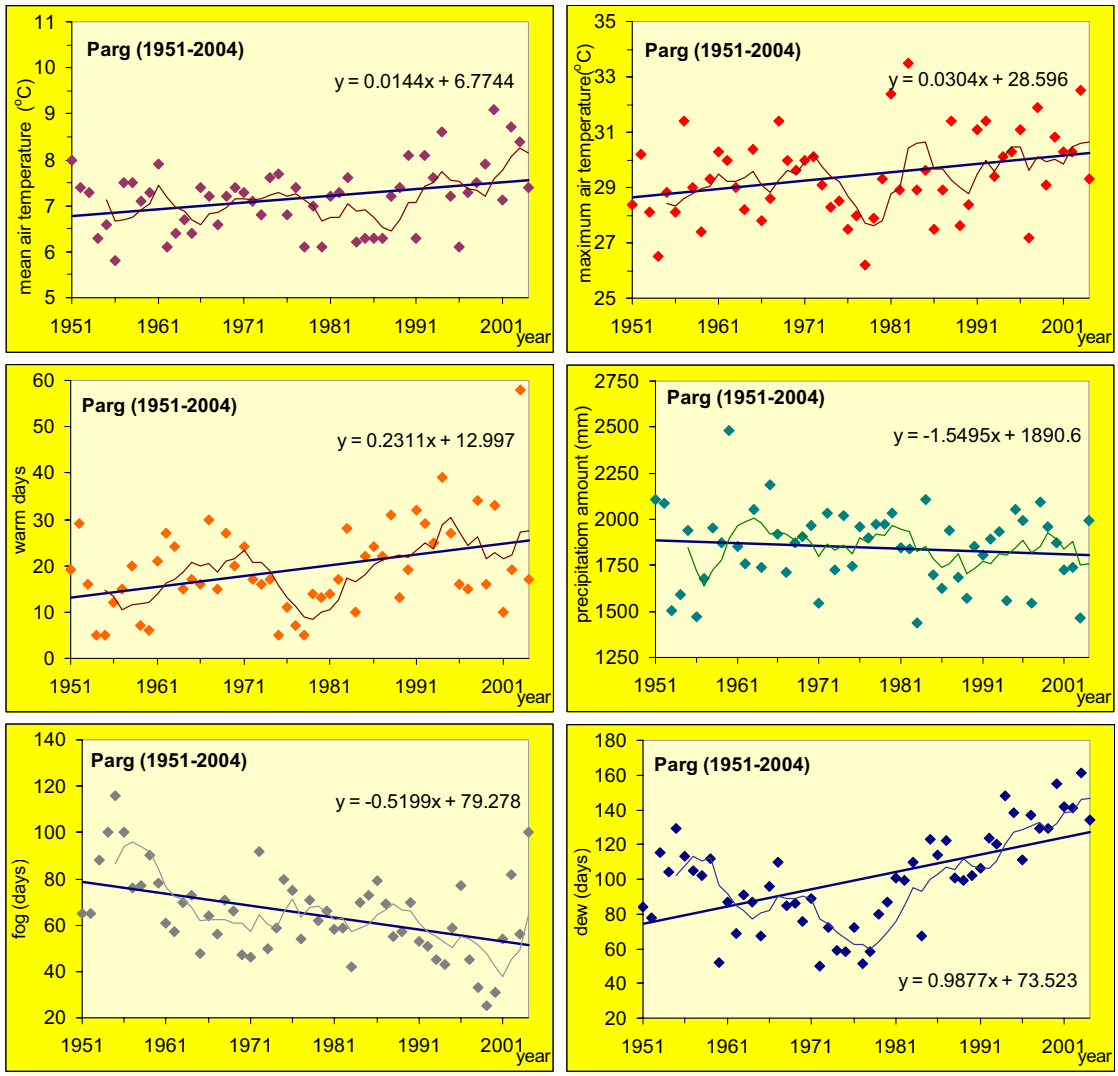

Figure 2. Time series (dots) of mean and maximum annual air temperature (°C), warm days, precipitation amount (mm) and days with fog and dew, the curves of a 5-year series of the moving average and the linear trends for Parg during in the period 1951–2004. x is a number of years (1,2,3…n).

The greatest climatic variations were observed in winter. While the mean air pressure, mean and absolute maximum temperature and insolation duration are increasing, the number of days with fog, rime and snow grain is decreasing. A tendency towards a decrease in the annual and seasonal values of precipitation amount and increase in mean air temperature and insolation duration (not only in summer but also in winter) is also noticed.

3. CONCLUSION

The analyses of temperature sums and the temperature, relative humidity, pressure, precipitation, insolation and number of days with different characteristics at the mountain Parg station is shown the significant climatic variations. There are less frequent of freezing and icy days in winter but more frequent of warm days in summer which indicate not only warmer summer but winter. We believe that the main reason for this is increasing frequency of anticyclonic situations that could have a negative influence on the mountain flora.

Table 2. Linear trends for different meteorological elements (/10 years) and α parameter of the Mann-Kendallov test for Parg during the period 1951–2004. MMAX and MMIN are the mean maximum and minimum air temperature. The trend with the 0.05 significant level is marked by yellow.

	WINTER		SPRING		SUMMER		AUTMN		YEAR	
	trend	α	trend	α	trend	α	trend	α	trend	α
Air temperature (°C)										
MEAN	0.20	0.2844	0.24	0.0167	0.19	0.1120	0.14	0.8222	0.14	0.0605
MMAX	0.28	0.1588	0.34	0.0025	0.35	0.0002	0.00	1.0000	0.21	0.0003
MMIN	0.04	0.4539	0.09	0.2780	0.06	0.8986	-0.08	0.3768	0.06	0.6712
MAX	0.48	0.0103	0.28	0.0595	0.31	0.0397	-0.25	0.2667	0.30	0.0311
MIN	0.04	0.7412	0.50	0.0326	-0.25	0.0302	-0.12	0.9283	0.16	0.1906
Air pressure (hPa)										
MEAN	0.89	0.0012	0.20	0.2677	0.09	0.1302	-0.06	0.5646	0.27	0.0024
Air relative humidity (%)										
MEAN	-0.71	0.0170	-0.33	0.5007	-0.06	0.8340	-0.15	0.6208	-0.29	0.2751
MIN	-0.91	0.0607	0.00	0.9575	0.11	0.4304	0.63	0.2550	-0.20	0.8783
Precipitation (mm)										
SUM	-16.76	0.1675	-4.85	0.7036	-8.11	0.3320	14.52	0.5067	-15.21	0.5163
MAX	0.91	0.6436	0.40	0.2469	1.08	0.9583	0.63	0.8990	0.93	0.9940
Snow cover (cm)										
MAX	1.66	0.2030	-0.02	0.6631	-	-	2.33	0.3644	-0.71	0.6582
Cloudiness (1/10)										
MEAN	-0.12	0.0606	0.11	0.0226	0.19	0.0077	0.14	0.1011	0.09	0.5808
Insolation (h)										
SUM	11.72	0.0298	13.64	0.0267	4.16	0.3988	-2.11	0.9755	19.85	0.1225

days	trend	α	days	trend	α	days	trend	α	days	trend	α
freezing	-1.16	0.0769	R≥ 0.1mm	-0.98	0.6310	SC ≥ 1 cm	-0.52	0.9761	rime	-1.05	0.0069
icy	-1.25	0.3862	R≥ 10 mm	-0.91	0.1980	SC ≥ 20cm	0.85	0.6310	glaze	0.24	0.3575
cold	1.13	0.3105	R≥ 20 mm	-0.32	0.4241	SC ≥ 30cm	0.35	0.9163	supercooled rain	0.45	0.0009
warm	2.27	0.0076	R≥ 50 mm	0.16	0.4725	SC ≥ 50cm	0.58	0.7087	fog	-5.10	0.0006
hot	0.31	0.0814	rainy	0.02	0.5425	snowy	-2.23	0.1287	dew	9.69	0.0001
clear	-5.37	0.0003	RH ≤ 30%	0.28	0.2142	snow grains	-1.61	0.0044	thunder	1.32	0.1978
overcast	-0.83	0.2501	RH ≥ 80%	-1.16	0.7292	frozen	-1.28	0.4725	hail	-0.48	0.1182

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