

Indices of climate extremes for the growing season length at foothill station Stará Lesná (1988-2013)

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Abstract

This paper presents evaluation of classical climatic measurements at Meteorological Observatory GPI SAS in Stará Lesná carried out in the years 1988-2013. Selected indices of extremes were calculated according to the European project ECA&D (European Climate Assessment & Dataset project) for the growing season length (GSL) period. Duration of GSL on average 195 days, usually from April to October, proves appropriate climatic conditions for the growth of forest vegetation. Interannual variation of GSL indicates no significant changes during considered period. On the other hand, indices derived from daily temperature extremes such as maximum of daily temperature or numbers of summer days show a slight warming at foothill of the High Tatras. Precipitation GSL amount fluctuated around mean value of 539 mm. The longest dry period covering 22 consecutive days without precipitation occurred in 1999, 2009, and during extraordinary dry event in 2011.

Key words: ECA&D indices, submontane climate, growing season, bioclimatology

Introduction

Meteorological measurements at location Stará Lesná are provided by the Geophysical Institute of the Slovak Academy of Sciences (GPI SAS) since 1987. Research activities are focused on the study of physical and chemical

processes in the atmospheric boundary layer, and regional climate of the High Tatra Mts. (Smolen and Ostrožlík, 1998; Bilčík and Mišaga, 1998; Matejka et al., 2008; Holko et al., 2012; Bičárová et al., 2013). Until 2013, experimental programme of GPI SAS included classical climatological observations realised in cooperation with Slovak Hydrometeorological Institute. Climatological weather observations at Stará Lesná for the years 1988-2013 represents the enclosed period of measurement using classical methods. Since 2014, automatic weather station provides continuous, homogenous and high quality measurement data needed for sophisticated models and interdisciplinary research. The purpose of this paper is to evaluate classical climatic observations (1988-2013) and to provide complex characteristic related to key bioclimatological factor such as growing season length (GSL) period for foothill zone of the High Tatra Mts. where the station Stará Lesná is located.

Materials and methods

Daily data of basic climatic elements obtained at station Stará Lesná during period 1988-2013 were used for investigation of climate characteristics typical for growing season of foothill zone in the High Tatras. Standard daily observations covered three different times measurements (7 a.m., 2 p.m. and 9 p.m. of local time) recorded by the observer. Air temperature and air humidity were measured by glass thermometers (dry temperature, wet temperature, minimal and maximal temperature in °C). Daily precipitation total (mm) was measured by standard rain gauge with collecting area of 500 cm². The amount of cloudiness was determined visually, in this work we used the data of cloud coverage (in tenths). The Campbell-Stokes recorder equipped with paper tape was used for continuous registration of sunshine duration (hours) as sunlight intensity climatic element. Meteorological instruments were serviced and calibrated in cooperation with the Slovak Hydrometeorological Institute (SHMI). Stará Lesná is part of national climatological station network of Slovakia. Observation area Stará Lesná is situated in submontane zone of the High Tatra Mts. (49°09'N, 20°17'E, 810 m a.s.l.). Forest is dominant vegetation type in the lower (supramontane) part of Skalnatá dolina (up to 1500 m a.s.l.). Absolutely

dominant tree species is Spruce (*Picea abies*), high percentage reaches also European larch (*Larix deciduas*) (Škvarenina and Fleischer, 2013). Climatic data obtained at station Stará Lesná was processed according to recommendation of the European Climate Assessment & Dataset project (ECA&D). This project (eca.knmi.nl) presents information on changes in weather and climate extremes, as well as the daily dataset needed to monitor and analyse these extremes (Klein Tank, 2002). Descriptions of selected ECA&D climatic characteristics and indices used for evaluation of Stará Lesná dataset are included in the head of result tables.

Results and discussion

- a) ECA&D groups of selected climatic indices: temperature, heat, cold, sunshine, cloudiness

Air temperature is basic climatic element that reflects heat conditions in the atmosphere and controls vegetation phenological patterns in dependency of latitude and altitude. In much of Europe, daily mean temperature of at least 5 °C is considered to be favourable for growing of indigenous vegetations. The growing season length (GSL), according to ECA&D is expressed as number of days between the first occurrence of at least 6 consecutive days with mean daily temperature (TG) > 5°C and the first occurrence after 1 July of at least 6 consecutive days with TG < 5 °C. At location Stará Lesná, for the period 1988 to 2013 the average GSL was 194 days (6.4 months) and ranged from 166 (min) to 229 (max) days (Tab. 1). Comparison of mean annual GSL courses for different ECA&D climatic stations in Slovakia and that for location Stará Lesná (Fig. 1) shows similar shapes for colder climate locations such as Stará Lesná, Oravská Lesná and Poprad until year 2004. During last years larger differences were identified. GSL values for warmer climatic lowland regions represented by stations such as Bratislava, Hurbanovo, Piešťany, Košice were substantially higher, in some cases exceeded 300 days in year (10 months). Typical GSL lasting from April until October or November. Mean air temperature TGg related to GSL period was 12.3 ± 0.8 °C. Both GSL and TGg indices show no significant changes during considered period 1988-2013. On the other hand, indices

derived from daily air temperature extremes indicate moderate warming of growing season due to increasing tendency of daily maximal temperature (TXg, TXx) as well as daily minimal temperature (TNg, TNx). Significant correlation for increase of summer days (SU) was also identified (Fig. 2). Annual sum of sunshine duration (SS) was on average 1193 hours per GSL. Annual maximum and minimum SS ranged between 1436 hours in 2000 and 911 hours in 2010, respectively. High cloudiness (CCg) about 7/10 cloud cover suggests rarely occurrence of mostly sunny days and abundance of cloudy days. Interannual variability of SS and CCg is relative stable with no significant changes.

b) ECA&D groups of selected climatic indices: rain, humidity, drought

Climatic indices derived from measurement of daily precipitation amount (RR) show that sum of precipitation aggregated over GSL fluctuated around mean value of 539 mm. The highest precipitation deficit was in 2003. In this year extraordinary heat wave occurred during summer season. It was the hottest summer on record in Europe over centuries. On the other hand, unusual precipitation abundance was in 2010 with the maximum value of 744 mm. Rare abundant rainfall events during May and June 2010 caused devastating floods across several Central European countries. For the last 26 years (1988-2013) no significant trends in GSL precipitation as well as for other climate precipitation characteristics were found (Tab. 2). Wet days (RR1) were almost 1/3 of GSL period. On average 6.7 mm/wet day was calculated as simple daily intensity index (SDII). Average number of heavy precipitation days (RR10) and very heavy precipitation days (RR20) were 17 and 6 days, respectively. Extreme rainfall amounts 88.1 mm for the highest 1-day precipitation (RX1) and 138.7 mm for the highest 5-day precipitation in July 2002 were recorded. Wet periods of consecutive wet days (CWD) were shorter than periods of consecutive dry days (CDD). Maximum with 22 of consecutive dry days (CDD) was recorded during extraordinary dry event in Europe at the end of autumn in 2011 and, in addition, in years 1999 and 2009. Maxima of consecutive wet days (CWD) varied between 5 and 13 days during GSL. Observed RHg values at about 75.2 % with moderate changes from 69.5 to 79.9 % document high degree of water vapour saturation in air. It corresponds with high cloudiness about 7/10 cloud cover.

Conclusions

Mountain climate is characterised by a larger variability, both spatial and temporal compared with lowlands at the same latitude. Colder and more humid conditions influence growth of forest vegetation including Spruce-fir-beech, Spruce, Mountain pine and Alpine a typical Carpathian vegetation stages (Škvarenina and Fleischer, 2013). Location Stará Lesná is situated at the foothills of the High Tatra Mts. and represents submontane climate zone favourable for temperate coniferous and mixed forest vegetation. Evaluation of measurements at Stará Lesná (1988-2013) presented in this paper provides information about climate of submontane location useful for interdisciplinary research. Based on this data, location Stará Lesná is characterised by length of grow season on average 195 ± 17 days per year. Mean air temperature 12.3 ± 0.8 °C and mean precipitation amount 539 ± 98 mm were calculated for GSL period. ECA&D indices derived from air temperature extremes show increasing tendency of daily air temperature maxima as well as number of summer days. Average sunshine duration was 1193 ± 135 hours per GSL. Most days were cloudy with average cloudiness about 7/10. Relative air humidity 75.2 ± 2.6 % corresponds with high number of cloudy days. Maximal wet periods lasted from 3 to 13 consecutive wet days (CWD), substantially longer were dry periods from 8 to 22 days (CDD). The higher air temperature and the sufficient amounts of precipitation can increase the wood production of the tree species growing there. The next negative factors (windstorms and other meteorological extremes, harmful insects, fungi pathogens, acid pollutants, photooxidants etc.) can change the assumed development (Škvarenina et al., 2004).

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Acknowledgement

This research was supported by the Grant Agency of the Slovak Republic under the project VEGA No. 2/0053/14.

Summary

Horská klíma sa vyznačuje väčšou priestorovou a výškovou variabilitou v porovnaní s nížinnými oblasťami. Lesná vegetácia reaguje na rastúcu nadmorskú výšku zmenou zastúpenia dominantných drevín. Na základe lesníckej typológie sa lesné porasty v oblasti Vysokých Tatier zaraďujú do týchto (lesných) vegetačných stupňov (od najnižších polôh): smrekový, kosodrevinový. V alpínskom vegetačnom stupni už stromová vegetácia nerastie (Škvarenina a Fleischer, 2013). Lokalita Stará Lesná sa nachádza na úpätí Vysokých Tatier hôr a reprezentuje podhorské klimatické pásmo s priaznivými podmienkami pre rast ihličnatých a zmiešaných lesných porastov. Z vyhodnotenia klasických meraní na stanici GFÚ SAV v Starej Lesnej (1988-2013) vyplýva, že v podhorskej oblasti Vysokých Tatier vegetačné obdobie trvá v priemere 195 ± 17 dní v roku. Počas vegetačného obdobia je priemerná teplota vzduchu $12,3 \pm 0,8$ ° C a priemerný úhrn zrážok 539 ± 98 mm. Indexy

ECA&D odvodené z meraní teplotných extrémov poukazujú na mierne otepľovanie v dôsledku tendencie nárastu denných teplotných maxím ako aj počtu letných dní. Vo vegetačnom období je priemerná dĺžka slnečného svitu 1193 ± 135 hodín. Väčšinu dní je však zamračené s priemernou oblačnosťou asi 7/10. Relatívna vlhkosť vzduchu $75,2 \pm 2,6\%$ zodpovedá vysokému počtu oblačných dní. Najdlhšie neprerušované zrážkové obdobia trvajú 3 až 13 dní, podstatne dlhšie sú periódy bez zrážok a to od 8 do 22 dní. Zvyšujúca sa teplota vzduchu pri dostatočnom množstve zrážok môže priaznivo pôsobiť na rast a produkciu lesných drevín. V oblasti Vysokých Tatier sú pre lesné porasty rizikovejšie víchrice a ďalšie klimaticky podmienené faktory ako škodlivý hmyz, hubové patogény ako aj fotochemicky aktívne polutanty (Škvarenina et al., 2004).

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Tab. 1. Selected ECA&D climate indices for the growing season length (GSL) at foothill location Stará Lesná (1988-2013)

ECA&D climate indices									
Abbr.									
Unit									
Growing season length (6 consecutive days 5°C > TG < 5°C)									
GSL									
days									
Mean of daily mean temperature									
TGg									
°C									
Mean of daily maximum temperature									
TXg									
°C									
Maximum value of daily maximum temperature									
TXx									
°C									
Summer days (criterion: TX >25°C)									
SU									
days									
Mean of daily minimum temperature									
TNg									
°C									
Maximum value of daily minimum temperature									
TNx									
°C									
Sunshine duration									
SS									
hours									
Mean of daily cloud cover									
CCg									
tenths									
Year	GSL	TGg	TXg	TXx	SU	TNg	TNx	SS	CCg
1988	181	12.4	18.1	30.1	14	6.8	15.4	1106	6.0
1989	218	11.3	16.9	28.4	12	6.2	16.6	1150	6.8
1990	207	10.7	16.6	27.7	16	5.0	13.3	1212	6.5
1991	191	11.5	16.8	28.2	11	6.2	17.3	1025	6.9
1992	178	13.2	19.4	31.7	28	7.2	16.5	1252	5.9
1993	187	12.4	18.3	29.2	14	6.5	15.7	1205	6.4
1994	166	14.1	20.1	31.5	29	8.0	14.7	1113	6.4
1995	186	12.1	17.9	28.2	11	6.6	14.0	1125	6.9
1996	186	11.8	17.2	27.8	8	6.4	14.0	1017	7.2
1997	172	12.3	18.3	28.4	5	6.7	14.5	1024	6.8
1998	213	11.2	16.9	31.3	21	6.2	18.7	1138	7.1
1999	198	12.3	18.4	28.6	13	7.1	16.9	1135	7.1
2000	229	11.7	18.1	31.2	20	6.3	15.8	1436	6.3
2001	184	12.7	18.8	28.2	21	7.6	15.5	1125	6.7
2002	179	13.1	19.5	29.4	19	7.8	17.2	1113	6.8
2003	182	13.5	20.3	29.8	40	7.3	16.0	1323	6.5
2004	205	11.1	17.3	28.0	9	6.1	14.5	1162	7.1
2005	208	11.8	18.3	30.6	17	6.6	19.6	1314	6.8
2006	197	12.8	19.8	29.4	34	7.3	17.0	1369	6.8
2007	184	13.2	20.2	34.2	31	7.4	16.5	1376	6.2
2008	197	12.3	18.7	29.3	21	7.1	16.8	1193	6.8
2009	195	12.9	20.1	30.7	26	7.0	18.5	1408	6.0
2010	167	13.3	19.4	30.4	32	8.5	18.3	911	6.8
2011	215	12.0	19.0	29.5	26	6.8	19.5	1362	6.5
2012	200	13.2	19.7	32.2	44	7.6	16.3	1123	6.3
2013	226	11.7	18.5	33.1	30	6.5	18.0	1291	6.5
Summary statistics									
Avg	195	12.3	18.6	29.9	21	6.8	16.4	1193	6.6
SDev	17	0.8	1.1	1.7	10	0.7	1.7	135	0.4
Min	166	10.7	16.6	27.7	5	5.0	13.3	911	5.9
Max	229	14.1	20.3	34.2	44	8.5	19.6	1436	7.2
Statistically significant correlations between variables: Year and TGg elements									
Corr.	:	:	0.543	0.439	0.597	0.426	0.542	:	:
Coef.	:	:	0.543	0.439	0.597	0.426	0.542	:	:
P-val	:	:	0.004	0.024	0.001	0.030	0.004	:	:

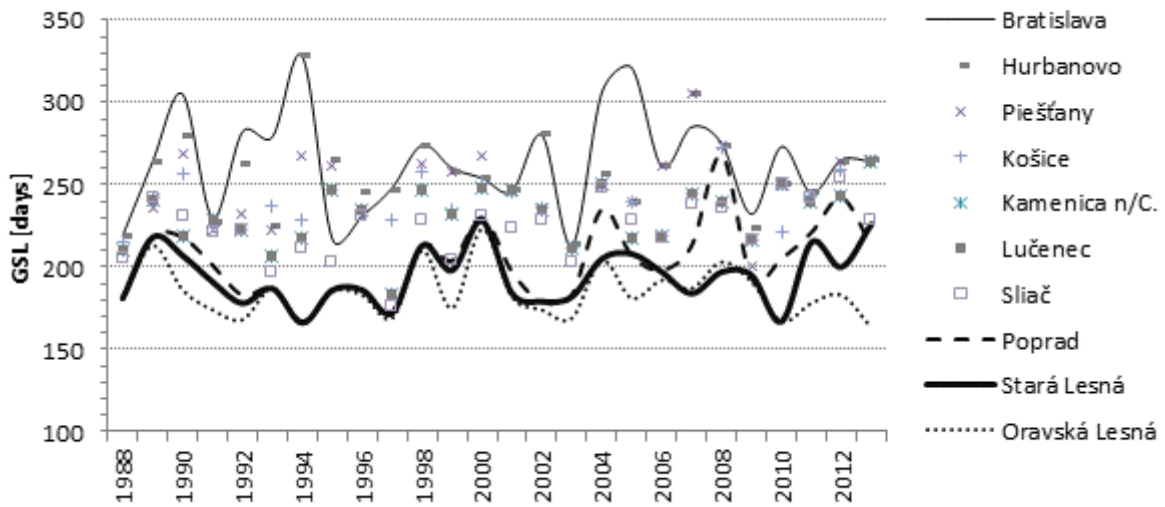


Fig. 1. Growing season length (GSL) at foothill location Stará Lesná in comparison to GSL at Slovak stations including in ECA&D database.

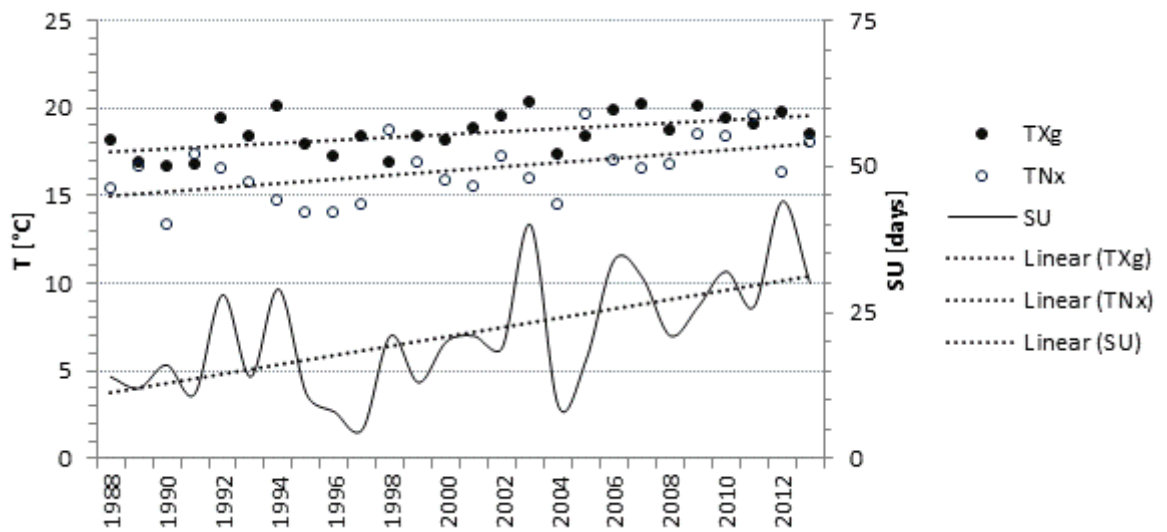


Fig. 2. Statistically significant increase of air temperature extremes (TXg, TNx) and number of summer days (SU) for GSL period at foothill location Stará Lesná during the years from 1988 to 2013.

Tab. 2. Selected ECA&D climate indices aggregated over the growing season length (GSL) at foothill location Stará Lesná (1988-2013)

ECA&D climate indices								Abbr.	Unit	
Precipitation of daily amount								RR	mm	
Wet days (criterion RR ≥ 1 mm)								RR1	days	
Simple daily intensity index (mean precipitation amount at wet days)								SDII	mm/wet day	
Heavy precipitation days (criterion RR ≥ 10 mm)								R10	days	
Very heavy precipitation days (criterion RR ≥ 20 mm)								R20	days	
Highest 1-day precipitation amount								RX1	mm	
Highest 5-day precipitation amount								RX5	mm	
Maximum no of consecutive wet days (criterion RR ≥ 1 mm)								CWD	days	
Maximum no of consecutive dry days (criterion RR < 1 mm)								CDD	days	
Mean of daily relative humidity								RHg	%	
Year	RR	RR1	SDII	RR10	RR20	RX1	RX 5	CWD	CDD	RHg
1988	461	58	8.0	15	5	37.8	64.3	5	19	74.9
1989	562	76	7.4	20	5	38.9	74.4	9	14	74.2
1990	576	72	8.0	21	4	45.4	95.0	6	12	75.0
1991	500	60	8.3	12	5	47.0	80.6	5	9	74.5
1992	366	47	7.8	9	4	50.5	56.6	3	15	70.3
1993	392	61	6.4	12	4	29.7	60.9	5	11	70.7
1994	338	53	6.4	12	1	24.5	33.9	3	13	69.5
1995	583	53	11.0	20	11	51.5	73.0	4	19	75.7
1996	658	80	8.2	21	7	66.1	126.8	5	10	76.7
1997	548	67	8.2	13	8	68.4	97.3	6	10	76.3
1998	590	88	6.7	19	5	30.1	47.1	10	10	78.3
1999	545	65	8.4	16	6	59.6	80.7	8	22	76.0
2000	560	73	7.7	17	8	39.2	71.6	4	13	76.0
2001	639	67	9.5	21	7	60.8	110.7	13	14	77.7
2002	634	67	9.5	18	7	88.1	138.7	8	18	78.2
2003	388	54	7.2	11	3	34.5	75.6	6	13	73.5
2004	652	79	8.3	24	3	62.6	77.6	7	14	79.9
2005	596	71	8.4	19	5	45.0	71.0	6	21	74.9
2006	476	74	6.4	13	4	30.1	70.2	8	19	73.7
2007	517	61	8.5	21	5	33.4	69.4	5	15	72.9
2008	529	61	8.7	17	8	35.4	84.4	6	8	76.8
2009	548	58	9.4	17	8	43.6	85.1	11	22	74.1
2010	744	75	9.9	25	8	44.8	90.7	11	10	79.6
2011	639	69	9.3	18	8	52.5	86.6	5	22	74.1
2012	477	70	6.8	15	4	23.9	53.8	7	9	75.3
2013	507	62	8.2	18	8	31.6	69.5	8	18	76.0
Summary statistics										
Avg	539	66	8.2	17	6	45.2	78.7	7	15	75.2
SDev	98.0	9.7	1.2	4	2	15.4	22.7	2.5	4.5	2.6
Min	338	47	6.4	9	1	23.9	33.9	3	8	69.5
Max	744	88	11.0	25	11	88.1	138.7	13	22	79.9
No statistically significant correlations between variables: Year and selected indices										