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ATMOSPHERIC PRECIPITATION AT SKALNATÉ PLESO AND LOMNICKÝ ŠTÍT

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Abstract :
Sixty-year time series of precipitation in two levels of the atmospheric layer were applied to the study of precipitation variability in the High Tatra region. The meteorological observatories at Skalnaté Pleso (φ = 49° 12´ N, λ = 20° 14´ E, h = 1778 m a.s.l.) and Lomnický štít (φ = 49° 12´ N, λ = 20° 13´ E, h = 2634 m a.s.l.) represent the slope and the top of this layer. Measurements are performed 3 times a day at 7, 14, and 21 h during the 1948-2007 period.
By processing of the extensive experimental material many statistical characteristics of the number of days with precipitation, as well as the precipitation totals in the High Tatra Mts were obtained.

Keywords: precipitation, occurrence and amount of precipitation, annual course, methods of mathematical statistics

1. Introduction

Precipitation regime in Slovakia has been significantly changed in the 20th century. It was probably due to by changes in the atmospheric circulation above Central Europe (*Hrvoľ et al. 2002; Lapin et al. 2003; Niedźwiedź, 2000*). This is a factor which determines many characteristics of the climatic system, including precipitation.

The different altitude, as well as the distinguished topographical conditions at the both observatories Skalnaté Pleso and Lomnický štít enables to study the temporal variability of precipitation in two different altitudes.

2. Material and methods

Measurements of precipitation at Skalnaté Pleso (φ = 49° 12´ N, λ = 20° 14´ E, h = 1778 m a.s.l.) and Lomnický štít (φ = 49° 12´ N, λ = 20° 13´ E, h = 2634 m a.s.l.) have been started in 1941 and with the interruption within the 2nd World War carry on up to this day. The measurements are carried out by the standard rain gauge with the receiving area of 500 cm^{-2} three times a day in the climatic terms 7, 14, and 21 h of the middle local time. Data during the 1948-2007 period are used at the study of time series in the High Tatra Mts.

The methods of mathematical statistics (*Anděl, 1985; Kendall and Stuart, 1968; Nosek, 1972*) were applied for the evaluation of described experimental data with focus on time series analysis.

3. Results and discussion

It is very difficult to study trends and other statistical characteristics of extreme meteorological and climatological elements such as precipitation totals. First of all, it is caused by their very high temporal and spatial variability (*Faško et al. 2006*). We will try to make this analysis in case of precipitation ($R \geq 0.1$ mm) in the high-mountain positions of Carpathian massif.

Based on the extensive experimental material of precipitation, from the Geophysical Institute of SAS and the Slovak Hydrometeorological Institute, some results are presented. By processing of these measurements many statistical characteristics of annual sums and number of days with precipitation were obtained: average, median, extreme values, standard deviation, coefficient of variation, etc. at Skalnaté Pleso and Lomnický štít (Table 1). Some of them have been yet published (*Ostrožlík, 2006b*)

Table 1. Statistical characteristics of annual amounts of precipitation (*R*) in mm and number of days with precipitation (n) at Skalnaté Pleso and Lomnický štít during the 1948-2007 period

	Skalnaté Pleso		Lomnický štít	
Variable	*R* [mm]	n	*R* [mm]	n
Sample size	60	60	60	60
Average	1356.7	207.6	1503.5	214.4
Median	1307.6	209.5	1497.8	216.5
Mode	1209.4	213.3	1486.2	220.6
Geometric mean	1340.4	206.6	1466.7	213.6
Variance	45608.06000	404.07460	115738.60000	352.25170
Standard deviation	213.56040	20.10161	340.20380	18.76837
Standard error	27.57053	2.59511	43.92012	2.42299
Minimum	911.3	133.0	893.3	178.0
Maximum	1892.6	239.0	2399.7	254.0
Range	981.3	106.0	1506.4	76.0
Lower quartile	1218.7	198.0	1231.8	199.0
Upper quartile	1513.5	221.0	1783.3	228.0
Interquartile range	294.8	23.0	551.5	29.0
Skewness	0.34112	-1.11576	0.52943	-0.00117
Kurtosis	-0.26109	2.17036	-0.07207	-0.69573
Coefficient of variation	15.74061	9.68285	22.62690	8.75186
Sum	81404.9	12456.0	90212.2	12867.0

The obtained results also confirmed that the precipitation increases with altitude in the High Tatra region (*Chomicz and Šamaj, 1974*). It was shown the mean annual sum of precipitation at Lomnický štít is about 10.8% higher than at Skalnaté Pleso. The main reason for this disagreement could be explained also by different conditions of cloudiness in both positions. In individual years the annual sums of precipitation varied between 893.3 mm (1976) and 2399.7 mm (2007) at Lomnický štít and between 911.3 mm (1961) and 1892.6 mm (2001) at Skalnaté Pleso. The value of the standard deviation of 340.20380 mm represents 22.6% from the long-term average at Lomnický štít while the standard deviation of 213.56040 mm at Skalnaté Pleso represents as much as 15.7%. These mentioned extreme values also confirmed that the precipitation is a very changeable meteorological element which varies in wide ranges.

On the other hand, the analysis of the number of days with precipitation shows that precipitation at Lomnický štít and at Skalnaté Pleso is not only abundant but also frequent. The number of days with precipitation is a little higher at Lomnický štít (214.4 days in annual mean) than at Skalnaté Pleso (207.6 days) in a year. The monthly and annual values of the number of days with precipitation vary in dependence on the air masses which occurred in our territory. The most frequent occurrence of precipitation at Lomnický štít was in the year 1952 (254 days) and the rarest in the next year 1953 (178 days), what represents 118.5% and 83.0% from the annual average, respectively. It was shown that the maximal occurrence at Skalnaté Pleso was 239 days in the year 1979, what represents 115.1% from the annual average. On the other hand, the minimal number of days with precipitation at Skalnaté Pleso (133 cases) in the year 1961 represents about 64.1% from the long-term average. The values of the standard deviation represent 8.8% and 9.7% from the long-term average, respectively. Many other characteristics are introduced in Table 1.

Regarding the homogeneity (*Štěpánek, 2005*) the time series of precipitation at Lomnický štít shows expressive marks of in-homogeneity around the early 1960s and above all at the beginning of 1990s. It is an interesting statement but it can be said that it is not of natural origin.

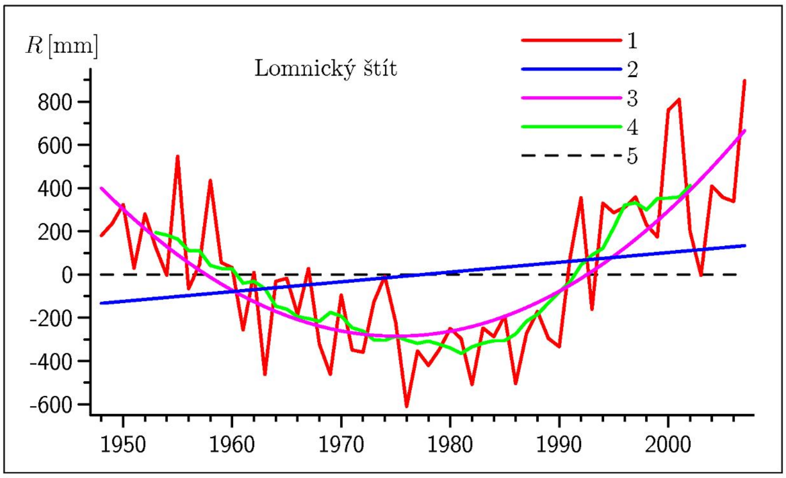
The deviations of the annual values of precipitation and the eleven-year running averages from the long-term average, as well as the trend components of the first and the first two harmonic of precipitation are presented in Fig. 1.

More detailed analysis shows (Fig. 1) that the deviations of annual precipitation from the long-term average do not lie on the curves but they are scattered about them. In spite of this fact to estimate the trend of the precipitation (*R*) with the time (*t*) (variable *t* denotes the corresponding year in the time series) the method of regression analysis (*Anděl, 1985*) was applied to the deviations. In the first approximation a simple linear model and a quadratic model were applied and by the method of the least squares the regression coefficients calculated. From the course of the curves it is evident, that the tendency of precipitation has a moderate positive trend and the mean annual precipitation increased about 266.5 mm and 65.5 mm in the last 60 years, respectively. The wave character of the curve for running averages indicates a certain decline to the middle of the 1980s and then the expressive growth up to now. Very low precipitation totals occurred during the 1970-1990 period, mainly at Lomnický štít.

Thus a question arises: are the suggested linear and quadratic models suitable for the mentioned analysis? A quantitative criterion which determines whether or not the fitted curve adequately represents the observations and which gives some idea of the goodness of the fit is the correlation coefficient (*r*) equivalent to the multiple correlation coefficient (*Brooks and Carruthers, 1953*) between the observed values of Y (the dependent variable) and the corresponding values, $E(Y)$, computed from the formula of the fitted curve. The value of r is easily computed from the formula

$$r^2 = 1 - \sum \varepsilon^2 / \sum y^2 , \qquad (1)$$

where $\varepsilon = Y - E(Y)$ and $y = Y - \overline{Y}$, $\overline{Y}$ being the mean value of the observed Y's.



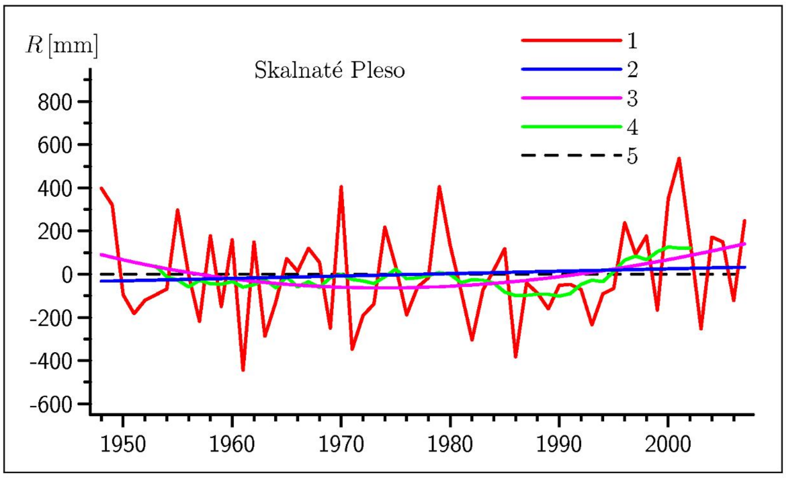


Figure 1. Course of deviations of annual precipitation from the long-term average (1), the linear trend component of these deviations (2), the quadratic trend (3), and course of deviations from the long-term average smoothed by eleven-year running averages (4) at Lomnický štít and at Skalnaté Pleso during the 1948-2007 period (value 0 mm refers to the long-term average (5)).

It is important to remember the fact that the comparison of the calculated values **(**r**)** with the corresponding values of the probable error **(**F**)** (*Conrad and Pollak, 1962*) confirms the correlation factor is significant only in case of the polynomial of second order at Lomnický štít. The calculated parabolic curve fits the measurements well. The linear model, very simple and often used in meteorological practice, is not suitable at all for the approximation of the precipitation in the high-mountain positions in the High Tatra.

Using the daily values of precipitation the mean monthly amounts can be easily calculated. Annual course of the mean monthly amounts of precipitation, and its the first and the first two harmonic components are graphically illustrated in Fig. 2. Harmonic analysis was used in these calculations (*Brooks and Carruthers, 1953; Conrad and Pollak, 1962*). The course of the curves in Fig. 2 indicates that at both localities the annual course of the precipitation is not simple. There are two maxima during the year – the main maximum in summer and a weak subsidiary maximum in winter. However, in individual years the course can be quite disturbed. The maximal monthly amount of precipitation may occur at any month of the year. Up to now the highest monthly amount was measured at Lomnický štít 429.4 mm in March 2000 and 490.2 mm in July 2001 at Skalnaté Pleso. Likewise, the minimal monthly amount of precipitation can fall to any month within a year although the highest probability is from October to March. It was shown that the driest month was October 1951 at the both investigated localities with the amounts 1.8 mm and 0.6 mm, respectively.

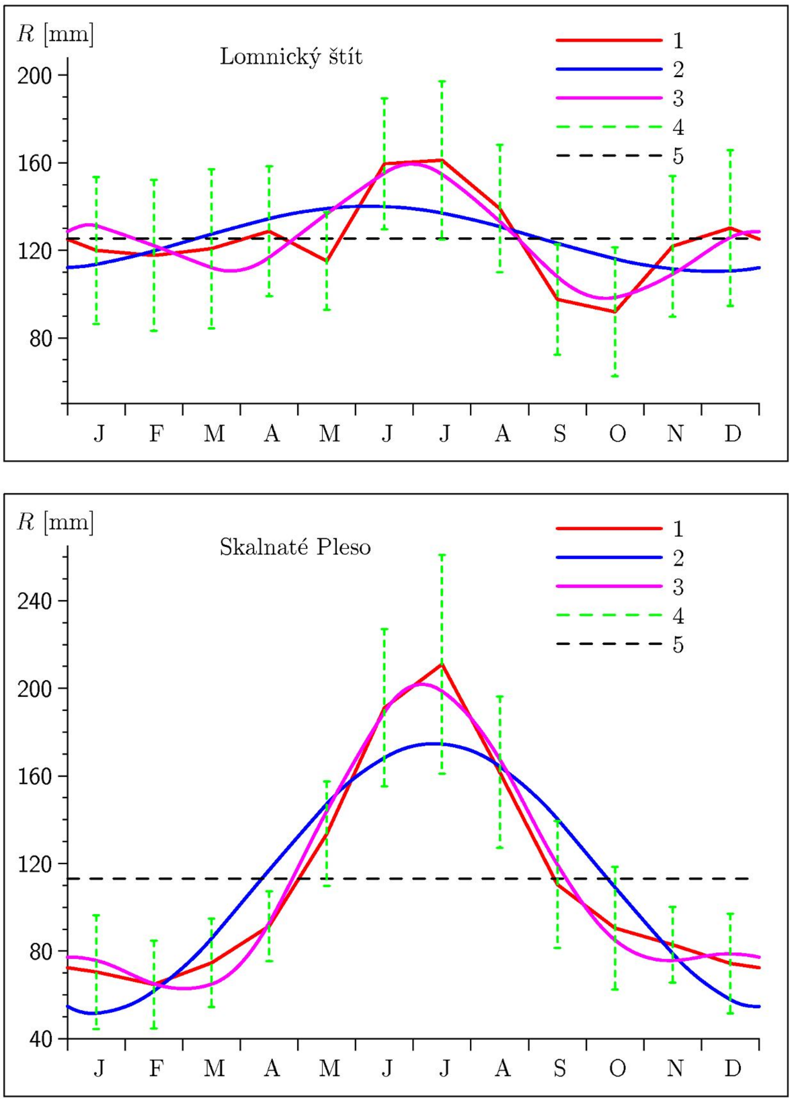


Figure 2. Annual course of mean monthly sums of precipitation (1), its first (2) and the first two (3) harmonic components, and error bars (4) that represent variance and indicate variability within the month at Skalnaté Pleso and Lomnický štít during the 1948-2007 period (value 0 mm refers to the long-term average (5)).

From the first comparison of the curves in Fig. 2 – experimental and calculated - we can see that in case of the annual course of precipitation the fitted curves of the first two harmonic components give a better agreement between the observed and calculated values than in case of its first harmonic component.

4. Conclusions

Obtained results showed the precipitation is abundant and frequent (in annual mean) in the investigated positions. Rainfall occurs approximately in 59% days of the year at Lomnický štít and in 57% days at Skalnaté Pleso. Extreme values also confirmed that the precipitation is a very changeable meteorological element. Trend analysis indicated that the precipitation total trend has a weak increasing tendency. It is an interesting result when we take into consideration the results which were published earlier (*Lapin, 2004; Ostrožlík, 2006a; Petrovič, 1960*). There was stated that the majority of the stations in Slovak territory have the decreasing tendency, mainly in the southwestern part of Slovakia. It is possible that our sites can be assigned to the stations at the Slovak northern border with the increasing or insignificant tendency in annual totals.

Seasonal variations of precipitation at Lomnický štít are less expressive than at Skalnaté Pleso. They are characterized by main maximum in June-July and by weak subsidiary maximum in December-January, mainly at Lomnický štít.

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