ANALYSIS OF PRECIPITATION TOTALS AND SNOW COVER BEFORE AND AFTERWINDSTORM CALAMITY ON NOVEMVER 19, 2004

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Abstract. The calamity windstorm on November 2004 caused dramatic changes of the land cover and destroyed a huge forest area in the Tatra Mountains. In presented paper we deal with analysis of precipitation totals characteristic in the period 1999-2004 (before windstorm calamity) and 2005-2010 (after calamity) in comparisson with 30-years standard normal period 1961-1990 and we present characteristics of the snow cover in 4 climatological and 4 precipitation stations representing the sub- Tatra basin and 4 climatological station in the High Tatras.
We deal with analysis of monthly precipitation totals and occurrence of maximum daily precipitation totals. We present areal and temporal variability of the snow cover, maximum of the snow cover depth, sums of daily and monthly snow cover depths, altitudinal dependence of different snow cover and new snow characteristics in the Tatras (duration of snow cover seasons, number of days with snow cover).
It was showed that the maximum monthly precipitation totals fall on the beginning of the year (January to March) and summer (July) and minimum monthly totals on the April and on the end of year in November, December.
New snow together with the sums of the snow cover depths gives an overview of the accumulation of the snow cover, which variability is very large and depends on many meteorological, climatological and geographical factors.

Introduction

On 19 November 2004 in the territory of Slovakia swept extreme windstorm, which caused considerable material damages. Most forests have been affected, mostly in the High Tatras, where in the area of 12 000 ha was damaged more than 2 million m^3 (Koreň, 2005). Most trees were damaged at altitude of 1200 - 1300 m a.s.l. Most of them has been refuted or broken at the first impact.
Wind speed was like a hurricane, the meteorological stations were measured following maxima: Lomnický štít (2635 m) - 170 km/h, Skalnaté Pleso (1780 m) - 200 km / h, the upper forest limit (1480 m) - 230 km/h, cableway station Start (1150 m asl) - 80 km/h, Stará Lesná (820 m) - 130 km/h and Poprad (700 m) - 120 km/h. The ratio of windthrow and break was been 65:35. The species proportion of damaged trees was: 76 % spruce, 8 % pine, 7 % larch, 1, 5 % fir and 7, 5 % of deciduous trees. By the age distribution was the most damaged vegetation aged 60-120 years (Fleischer, 2011). The wind is on a long-term basis the main factor causing damage to forests in Slovakia. Large damage are caused by wind speeds 150 km/h and more, especially when windy weather is combined with the soaked soil, after intensive long-term rainfall (Gardiner et al 2010). The great wind calamity caused by bora wind (speed exceeding 150 km/h) occurred in the Tatra Mountains in the year 1915, 1919, 1941, 1961, 1981 and 2004. The calamity in 2004 was the most destructive for forests than any previous since 1915 (Koreň, 2005). The windstorm was such an exceptional occurrence in its scope and magnitude of damage to forests that caused great interest of domestic and international scientific community to monitor environmental changes. Microclimatic, hydrological, soil and vegetation relationships were observed in this area. Frequently mentioned concern with regard to storm in November 2004 is the increasing number of floods due to deforestation of large areas and due to changes in climatic conditions, mainly due to changes in rainfall and its distribution during the year. The aim of this paper was to establish whether the measured data of monthly precipitation and data of total snow cover in winter were related to changes caused by windstorm.

Material and methods

For the evaluation of precipitation and snow cover in the Tatra region, we used data from 12 climatological and precipitation stations. For a better and more transparent evaluation these stations were divided according to altitude: Lomnický štít (2635 m a.s.l.), stations with altitude above 1000 m a.s.l. (Skalnaté Pleso, Štrbské Pleso, Tatranská Javorina) and stations in the sub -Tatra basin (climatological stations: Tatranská Polianka, Podbanské, Tatranská Lomnica, Stará Lesná, and precipitation stations: Podspády, Ždiar, Štrba, Tatranská Kotlina).

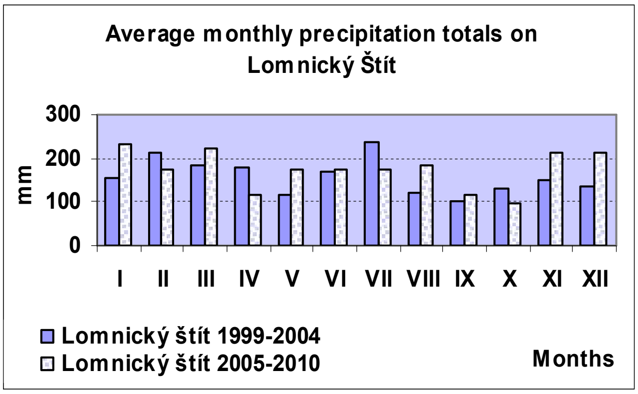
Altitude category	Station	No	Altitude
I.	Lomnický štít	1	2635 m a.s.l.
II. High Tatra area	Skalnaté Pleso	2	1778 m a.s.l.
	Štrbské Pleso	3	1322 m a.s.l.
	Tatr.Javorina	4	1013 m a.s.l.
III. Sub - Tatra basin	Tatr. Polianka	5	975 m a.s.l.
	Podbanské	6	972 m a.s.l.
	Podspády	7	910 m a.s.l.
	Ždiar	8	905 m a.s.l.
	Štrba	9	829 m a.s.l.
	Tatr. Lomnica	10	827 m a.s.l.
	Stará Lesná	11	808 m a.s.l.
	Tatr. Kotlina	12	760 m a.s.l.

Table 1. Distribution of climatological and precipitation stations by altitude

We evaluated data from period 1999 - 2004 (before the windstorm) and compared with data from period 2005 - 2010 (after the windstorm). When comparing the periods we analyzed the basic characteristics of precipitation, snow cover and total of new snow. For monthly precipitation were use to compare data for the normal period 1961 - 1990, and we evaluated each station separately.

Results and discussion

Spatial distribution of precipitation in the mountains depends on the altitude and relative position to the wind flow that delivers precipitation, therefore to flow from the Atlantic Ocean. Consequently, the western and northern exposures at the same altitude are richer in precipitation than southern and eastern positions. A very important characteristic of precipitation is its temporal distribution. Annual variation of precipitation and its monthly contribution have a similar character at all stations of High Tatras and sub-Tatra basin. Distribution of rainfall in each of the stations in 1999 - 2004 and 2005 - 2010 periods is



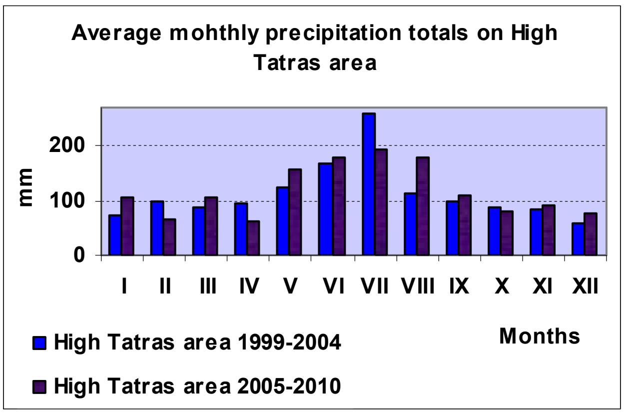
illustrated in figures 1 to 3.

Figure1: Average monthly precipitation totals on Lomnický Štít

Figure2: Average monthly precipitation totals of High Tatra areas

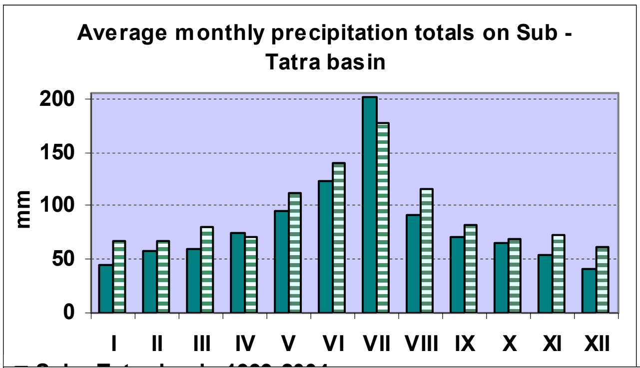
The figures show that the average monthly precipitation at High Tatras and sub-Tatra basin stations has a one peak distribution of the year. The exception is the Lomnický Štít station, which has two peak distributions - the main maximum of precipitation is in July and a second peak in winter (February – March). Minimum of precipitation is on autumn (September – October).

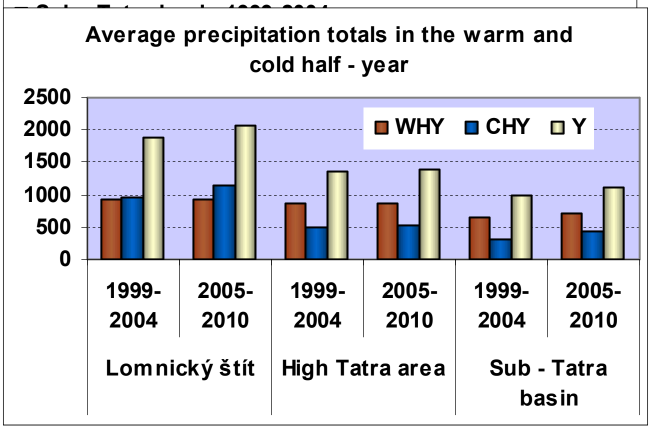
Figure3: Average monthly precipitation totals on



Sub-Tatra basin

If we consider the period before and after the windstorm in





November 2004 so we can say that the radical changes of amount and distribution of precipitation were not occurred. For a better representation of precipitation during the year, we assessed the average precipitation in warm and cold half-year and average annual precipitation in the period before and after the windstorm in three study areas (altitude categories) (Figure 4). The evaluation indicates the altitude dependence of precipitation, where precipitation increases with increasing altitude. On Lomnický Štít station there is higher precipitation total in cold half-year, in the lower altitude maximum of precipitation occures in warm half-year.

Figure 4: Average precipitation totals in the warm and cold half-year

The problem of temporal distribution of precipitation have extraordinary importance from hydrological and vegetation aspects. Abundant, rare precipitation or less abundant and often repetitive precipitation has different effects. Therefore, one of the basic characteristics of the probability of precipitation is the frequency of days with precipitation totals. In climatology it is generally recorded the number of days with precipitation totals > = 1 mm, > = 10 mm, > = 25 mm, > = 50mm and > = 100 mm.

Mean number of days with precipitation totals ≥ 1 mm													
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I.	**1999-2004**	18	20	20	20	16	18	21	15	14	18	17	19

	2005-2010	21	20	23	19	21	21	18	16	14	13	19	20
	1999-2004	16	18	17	17	16	17	20	14	13	16	16	16
II.	2005-2010	19	18	19	15	21	19	18	16	13	12	16	18
	1999-2004	11	14	13	13	14	14	17	11	10	12	11	11
III.	2005-2010	14	13	14	10	17	15	14	13	11	10	12	14
Mean number of days with precipitation totals ≥ 10 mm													
	1999-2004	13	14	13	14	12	14	15	9	9	12	12	13
I.	2005-2010	15	15	15	12	13	13	14	11	8	10	13	14
	1999-2004	10	11	11	11	11	13	16	9	9	11	9	9
II.	2005-2010	14	13	14	10	16	15	14	13	10	9	12	12
	1999-2004	5	6	6	7	7	8	11	6	6	6	5	5
III.	2005-2010	6	6	7	5	9	9	9	8	6	5	6	6
Mean number of days with precipitation totals ≥ 25 mm													
	1999-2004	13	16	15	14	12	13	16	9	8	11	13	14
I.	2005-2010	16	15	16	9	14	14	13	12	9	9	13	15
	1999-2004	8	11	10	10	10	12	15	9	8	9	9	7
II.	2005-2010	10	8	11	7	13	12	12	11	8	7	9	9
	1999-2004	4	5	5	6	6	8	10	5	5	5	4	4
III.	2005-2010	4	4	6	4	8	8	8	8	5	4	6	5
Mean number of days with precipitation totals ≥ 50 mm													
	1999-2004	9	14	12	11	8	10	13	7	6	8	10	9
I.	2005-2010	13	11	12	7	11	10	10	10	6	5	12	12
	1999-2004	4	7	6	7	8	9	12	6	6	6	6	4
II.	2005-2010	6	5	7	5	9	9	9	9	5	4	6	6
	1999-2004	1	2	2	3	4	5	7	3	3	3	2	2
III.	2005-2010	2	2	3	2	5	5	5	5	3	2	3	3
Mean number of days with precipitation totals ≥ 100 mm													
	1999-2004	5	8	7	6	5	7	8	4	4	5	6	5
I.	2005-2010	8	6	8	4	5	5	7	7	4	3	7	8
	1999-2004	2	3	3	3	4	6	8	4	4	3	3	1
II.	2005-2010	3	2	3	2	5	5	6	6	4	2	3	2
	1999-2004	1	1	1	1	2	3	4	2	1	1	1	1
III.	2005-2010	1	0	1	1	2	3	2	3	2	1	1	1

Table 2: Mean number of days with precipitation totals ≥ 1mm, ≥ 10mm, ≥ 25 mm, ≥ 50 mm a ≥ 100 mm

This table shows that in both periods was a number of days with precipitation totals ≥ 1mm, ≥ 10 mm, ≥ 25 mm, ≥ 50 mm and ≥ 100 mm similar, or in the period 2005-2010 was recorded a small growth.

In general it was confirmed that more precipitation occurs on the warm half-year, except Lomnický Štít station, where maximum of precipiation is in cold half-year.

In the number of days with precipitation totals more then 100 mm was confirmed the altitude dependecy. There is the highest number of this characteristic in highest possitions of the High Tatras. The maximum of days with precipitation total more then 100 mm is in summer (June - July) and minimum in autumn (September - October).

In the winter season we studied snow cover occurrence and depth. We detected slight incease of this characteristic on Lomnický štít and on the stations of Hight Tatras area in period 2005 -2010. In Lomnický štít there is a standard occurence of snow cover during the whole year, with maximum in March- April. In lower altitude the stations of Hight Tatras area have aximum of snow characterist in March too, but July and August are without snow cover. In the stations of sub- Tatra basin the snow cover occurrence is mainly from October to March. There are maximum values in February. We detected no change of snow cover in these stations.

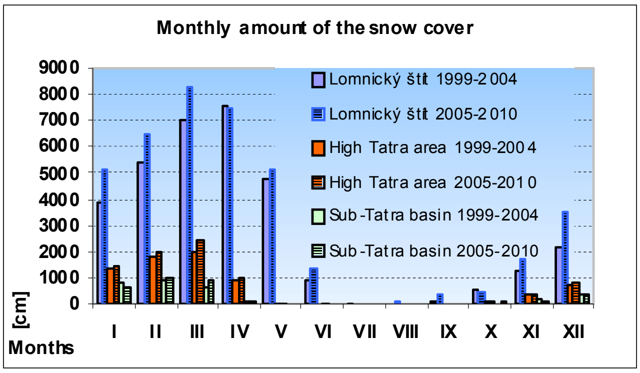


Figure5: Sums of monthly snow cover depths

	maximum SC depth		Absolute maximum
	1999-2004	2005-2010	
	date	date	date
Lomnický Štít	338	408	408
	11.4.2003	30.3.2009	30.3.2009
Skalnaté oPleso Pleso	153	170	187
	19.3.2000	20.3.2009	8.4.1967
Štrbské Pleso	185	199	280
	20.3.2000	14.3.2005	25.1.1976
Tatr.Javorina	140	140	140
	18,19.3.2000	25.3.2005	25.3.2005
Tatr. Polianka	101	131	131
	20.2.1999	10.3.2005	10.3.2005
Podbanské	132	134	134
	19,20.3.2000	14.3.2005	14.3.2005
Podspády	125	130	130
	22.1.2000	11.3.2005	11.3.2005
Ždiar	100	101	101
	22.1.2000	14.3.2005	14.3.2005
Štrba	100	130	130
	27,28.1.2000	24.2.2005	24.2.2005
Tatr. Lomnica	60	65	65
	22,23.1.2000	31.12.2005	31.12.2005
Stará Lesná	50	70	70
	22.1.2000	25.2.2005	25.2.2005
Tatr. Kotlina	82	122	122
	19.3.2000	14.3.2005	14.3.2005

Table 3: Maximum of the snow cover depth (in cm) in 1999-2004 and 2005-2010 periods and absolute maximum of the snow cover depth

Table 3 shows the dates and values of maximum snow cover depth in periods 1999-2004 and 2005-2010. Absolute maxima of snow cover depths were measured in climatological stations since 1961 and in precipitation stations (Podspády, Ždiar, Štrba a Tatranská Kotlina) since 1981 respectively.

The table above shows that in all stations except Skalnaté and Štrbské Pleso the maximum of snow cover depth was recorded in the winter 2004/2005 during the period 1999-2010, the Tatranská Lomnica station in the winter 2005/2006 and Lomnický Štít in the winter 2008/2009.

The absolute maximum of total snow cover depth was measured in Lomnický Štít, 408 cm. For stations above 1000 m a.s.l. (High Tatra area) the maximum 280 cm was measured in Štrbské Pleso and in the sub - Tatra region the value 134 cm was measured in the Podbanské station.

Conclusions

After the analysis of precipitation and snow cover in periods 1999-2004 (before a windstorm) and 2005 - 2010 (after windstorm) in Tatras we may state that the significant change in quantity and spatial distribution didn't occure during year. We confirmed increasing altitude dependence of precipitations total. Maximum of precipitation amount is in Lonmický štít in cold half-year but in the stations situated in Hight Tatras area and sub-Tatra basin this maximum occure in warm half-year. This confirms, the number of days with precipitation totals ≥ 1 mm, ≥ 10mm, ≥ 25 mm, ≥ 50 a ≥100 mm show this altitude dependece as well. We detected a slight increase of snow cover in the winter in period 2005-2010 in the station Lonmický Štít and in stations with altitude more then 100 m a.s.l. No change was detected in sub –Tatra area.

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