The air circulation over disaster area in the High Tatras

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A b s t r a c t : On November 19, 2004 forest stands in the High Tatras were affected by wind throw. During a few hours of the extremely strong wind the forest on areas about 100 km^2 was destroyed. Subsequently, one year later, wildfire broke out on a part of this affected area. After this disturbance the environment microclimatic conditions have changed. The new conditions in the High Tatras region are subject of the study from many scientific aspects. Meteorological monitoring enables to carry out microclimatic research under various vegetative surface conditions. Hourly values of the wind speed and the wind direction at the fire-area (FIRE site, $\varphi = 49^\circ\, 18'\,$N, $\lambda = 20^\circ\, 12'$ E) in the months May, June, and July were used to study wind conditions. These data were performed by WindSonic sensor at four levels: 0.5 m, 1.0, 2.0, and 4.0 m above the earth's surface.

Key words: wind speed, wind direction, windstorm, air circulation, surface atmospheric layer, high-mountain massif

1. Introduction

An extraordinary situation with a windstorm occurred in the High Tatras on 19 November 2004, and the large part of the forest stand was totally destroyed (*Hurtalová et al., 2008; Pribullová et al., 2005*). The windstorm will be registered for its destructive consequences and enormous damages in Slovak forests (Fig. 1).

According to older records similar destructive windstorms occurred in the High Tatras region for example: on 18 November 1915, 1 May 1919, and on 1-2 September 1941. The last of them was analyzed by *Končˇek (1944)*. In spite of the fact that the meteorological material from this period was insufficient, the author performed a detailed analysis of meteorological

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Fig. 1. The destroyed forest in the High Tatra Mts. a few days after 19th November 2004.

conditions which occurred a few days before the windstorm, within the windstorm, as well as a few days after the windstorm. Whereas the highest wind power of the windstorm event was exceeded in the High Tatras in the last years and did not cause such large damages in the forest, the widespread damages of the windstorm need to be assigned also to the precipitation, which accompanied the windstorm. Comparison of records of registration devices showed that the more strong airflows, fall-winds, at Skalnaté Pleso were manifested after transition of arctic fronts, which intensity increased by the growth of arctic air mass (*Konček, 1944*).

2. Material and methods

New environmental conditions in the affected High Tatras region became the object of interest of many scientists. Their research activities focuse on studying the damaged area from the different scientific aspects (*Bičárová and Fleisher, 2007; Fleischer and Giorgi, 2007; Gömöryová et al., 2007; Šimonovičová et al., 2007*).

It is remarkable that one of the most damaged areas in the High Tatras was also stricken by a fire (FIRE area) in the following year 2005. Meteorological monitoring above the investigated FIRE enables to carry out the microclimatic research under various vegetative surface conditions. The micrometeorological measurements are available within May – July 2007. The measurements of the wind speed and the wind direction were performed by WindSonic sensor in 10th minute intervals at four levels: 0.5 m, 1.0 m, 2.0 m, and 4.0 m above the earth's surface (*Hurtalová et al., 2008*). Hourly values of wind speed and wind direction at the FIRE site ($\varphi = 49°\,18'$ N, $\lambda = 20°\,12'$ E) in May, June, and July 2007 were used for the study of wind conditions above the fire-area surface.

3. Results and discussion

From archival materials, the cold front passed through our territory in November 19, 2004. On the back side of the deep cyclone the strong wind was flowing. Table 1 provides the data about wind which were measured at the meteorological observatories and stations of the High Tatras region during this extraordinary phenomenon.

According to the data of this table we can deduce that the cold front passed across the mentioned localities in the afternoon and evening hours.

Table 1. Some characteristics of the wind and the time of occurrence at the meteorological observatories and stations in November 19, 2004 (*Pribullová et al., 2005*)

	H m a.s.l.			Wind gust			Mean hourly wind speed		
				m s^{-1}	Direction	Time	m s^{-1}	Direction	Time
Poprad-Gánovce	706	20°19'	49°02'	32.5	WNW	14.44	16.9	WNW	15-16
Poprad-letisko	695	20°15'	49°04'	34.3	WNW	14.21	15.3	W-WNW	14-16
Stará Lesná	810	20°17'	49°09'	45.2	NW	17.27	19.7	NW	16-17
Štart	1200	20°15'	49°10'	15.0	-	19.15	11.4	NW	18-19
9th mast	1520	20°14'	49°11'	63.0	-	16.56	19.2	NNW	19-20
Skalnaté Pleso	1770	20°14'	20°11'	53.8	W	18.54	19.7	W	18-19
Lomnický štít	2634	20°13'	49°12'	46.1	W	15.27	-	WNW	-
Štrbské Pleso	1361	20°03'	49°07'	25.0	NNW	15.30	-	N	15.17

At first it was registered at Štrbské Pleso and then in the eastern High Tatras. While at Štrbské Pleso the strongest wind gusts were between 15 and 16 h, at Stará Lesná and Skalnaté Pleso wind gusts reached the highest power between 17 and 18 h (45.2 $\mathrm{m\,s^{-1}}$, resp. 53.8 $\mathrm{m\,s^{-1}}$). However, the strongest wind gusts (63.0 $\mathrm{m\,s^{-1}}$) were measured at the 9^{th} mast of the cable railway between Tatranská Lomnica and Skalnaté Pleso. The wind gusts over 30 $\mathrm{m\,s^{-1}}$ in Poprad lowland were caused by the result of intensification of wind under the transition from Liptovská to Poprad lowlands through the taper area in the Štrba surroundings.

Regarding the wind directions the windstorm in the High Tatras was characterized by the winds with the components from W to N directions. Some differences in the wind speeds, as well as in the wind directions among the mentioned sites are due to the different orientation of the main edge in the western and eastern half of High Tatra Mts.

For an illustration, in Fig. 2 there is the anemographic record at Stará Lesná on 19 November 2004.

As it was mentioned above the post-calamite research is monitoring from the microclimatic point of view. The measurements are performed by WindSonic sensor at four levels: 0.5 m, 1.0 m, 2.0 m, and 4.0 m above the earth's surface. The hourly values of wind speed and wind direction at the FIRE site are available. 393 measurements were carried out in May, 709 in June and 408 cases in July in year 2007.

The distribution of wind directions is determined particularly by topographical conditions of nearby and more distant surroundings of the investigated locality. Therefore, each position or area has in a multi-annual mean its own characteristic distribution of wind directions. High-mountain massif of High Tatras influences highly the wind field deformation in the High Tatras region. The mentioned massif represents a topographical barrier, especially for the northern components of the general atmospheric circulation. It also demonstrates the percentage distribution of the surface wind directions in Fig. 3. According to the data in Fig. 3, it can be seen that the FIRE site is characterized by prevailing west-north-west air flow component (WNW). On the opposite, the northern component of wind (N) is at least probable. Whereas the WNW component of air flow decreases with the height above the earth's surface, the percent occurrence of winds with northern component increases. Further, the wind directions do not show

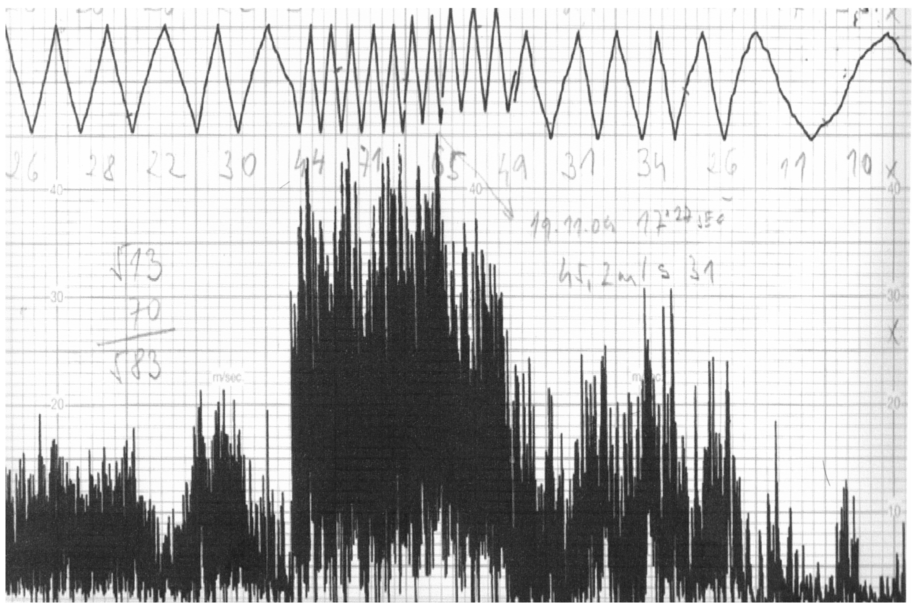

Fig. 2. The record of the instantaneous wind speed at meteorological observatory Stará Lesná in November 19, 2004.

higher variation with the height above the vegetated surface. The annual course of particular wind directions depends on the seasonal fluctuation of the general circulation, on the terrain wind swerving, on the occurrence of local thermic winds, as well as on the vegetation type and surface cover. The obtained wind roses from May until July also confirmed the general statement (*Otruba and Wiszniewski, 1974*), wind direction characteristics in the high-mountain positions of the High Tatra Mts. are generated by the following components:

– a component of general atmospheric circulation in Central Europe,
– a component of local thermic circulation,
– a topographical component,
– a vegetation and surface cover.

Table 2 summarizes the mean hourly values of wind speed at the FIRE area in individual months. A comparison of the data in Table 2 shows May was

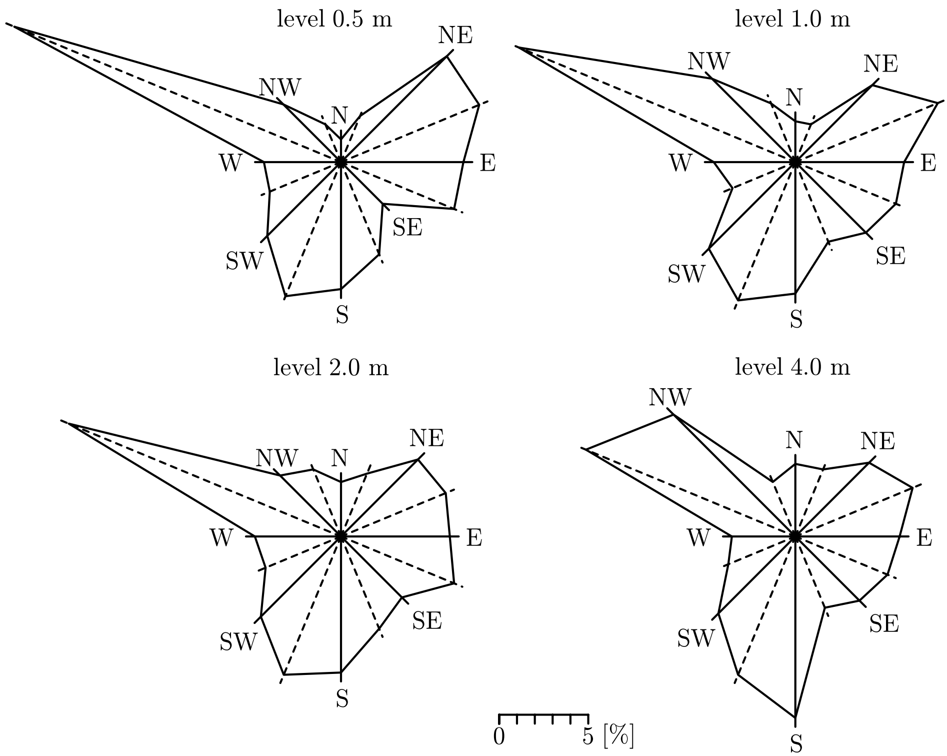

Fig. 3. Wind direction roses at the FIRE site in May from 15 to 31, 2007 at four levels: 0.5 m, 1.0, 2.0, and 4.0 m above the earth's surface.

Table 2. Mean hourly values of wind speed [m s^{-1}] at the FIRE area in May, June, and July 2007 at four levels

	n	0.5 m	1.0 m	2.0 m	4.0 m
May	393	0.779	1.211	1.743	2.436
June	709	0.195	0.717	1.505	2.319
July	408	0.093	0.509	1.535	2.551

most windy month as it was found out at Stará Lesná (*Ostrožlík, 2007*). According to the expectation the wind speed increases with the height above the earth's surface. On the other side, with the development of vegetation, the wind speed decreases in the lowest studied levels (0.5 m and 1.0 m).

The wind speed under the various wind directions is clearly illustrated in Fig. 4. An analysis of the mean wind speeds under the different directions gives a more detailed picture of a dissimilar intensity of the flow of the individual wind directions. Based on vector sizes we can take measure of the qualitative and partly quantitative dynamic conditions of the general atmospheric circulation, as well as wind speed changes due to the mountain

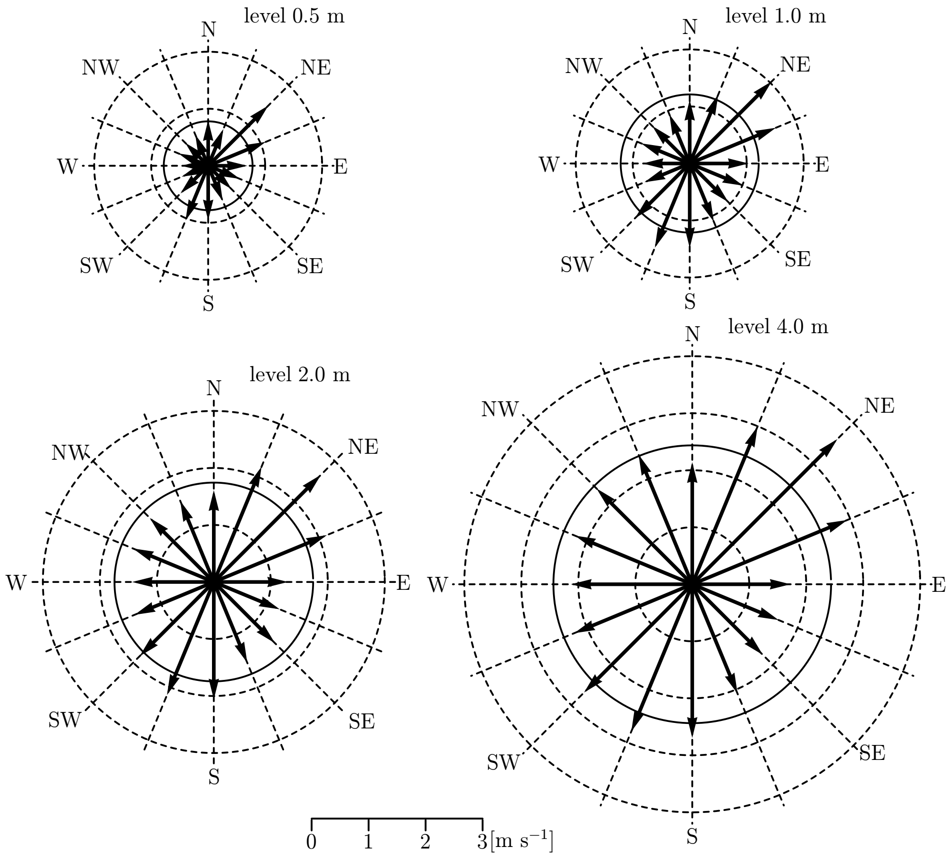

Fig. 4. Roses of mean speed of wind directions at the FIRE site in May from 15 to 31, 2007 at four levels: 0.5 m, 1.0, 2.0, and 4.0 m above the earth's surface. Mean value of wind speed of the investigated period is depicted by the solid circle.

obstacle. From the vector values, it can be seen which directions participate more on the whole wind roses in the study position at the FIRE side. For example, it can be seen that the most numerous wind directions WNW belong to the winds with the speed below standard. It is interesting that the highest wind speeds are along the NE and SW axis and that the highest values are under the NE directions. The wind speeds of four up to six wind directions are higher than the total average in the corresponding level. It was shown that the months June and July are characterized by the highest wind speeds from the S-W quadrant and the wind power of the NE wind components is under normal.

Daily changes of the processes, which are the reason of the daily course of wind speed and the wind direction, depend on the daily courses of both the radiative and thermal balance. Daily variability of the wind speed in the high-mountain zones of the High Tatras is due to the daily course of the turbulent exchange between the surface and the higher levels of the free atmosphere, as well as between lower and higher parts of the massif (*Otruba and Wiszniewski, 1974*). These results are in agreement with the course of the curves in Fig. 5. From the course of the curves it can be seen that the wind speed at the FIRE area has an expressive daily course characterized by main and subsidiary maxima and minima. Such daily course is typical for the sites in the slope positions in the High Tatras. To a certain extent it can be compared with the course at the nearest meteorological station Stará Lesná (*Ostrožlík, 2007*).

As it can be seen (Fig. 5) the smooth daily course of the wind speed is a little bit corrupted by some fluctuations, namely in May. These anomalies are apparently caused by the small number of analyzed cases, as well as by the inter-hourly turbulences. During the day, with the sunrise and by the development of thermal convection, the wind speed increases. Therefore, the highest values of the wind speed occur at noon and extreme values are a round 13 and 14 h. As expected the lowest values of wind speed are in the evening and above all in the morning hours (6 and 7 h). Stable atmospheric stratification causes a deceleration of the air exchange in evening and morning hours. With the culmination of summer the daily minimum is shifted to the 6 h. In addition it can be seen that the wind speed is the lowest at 0.5 m above the ground and the corresponding daily course is the most regular.

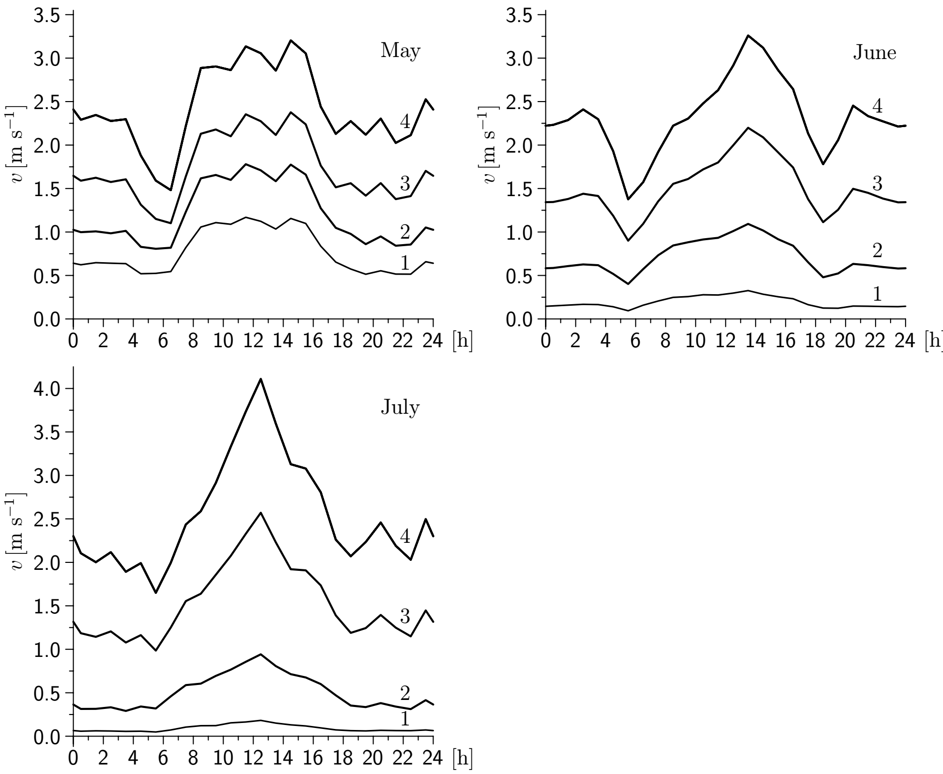

Fig. 5. Daily course of the wind speed in [m s^{-1}] at the FIRE area in May, June, and July 2007 at four levels: 0.5 m–1, 1.0 m–2, 2.0 m–3, and 4.0 m–4 above the earth's surface.

4. Conclusions

The work focused on studying the wind conditions in the surface atmospheric layer in the disaster area during the vegetative period from May to July. Obtained results indicated that changes in stand characteristics can affect the wind speed and the wind direction in the surface atmospheric layer above the stand. It is a pity that there are no available results about the air circulation at the FIRE area before the windstorm event. In spite of it, a certain comparison can be made with the results from the nearest station at Stará Lesná (*Ostrožlík, 2007*). Unlike Stará Lesná, the FIRE site is characterized by prevailing winds with the WNW component. The northern winds are at least probable. Whereas the frequency of WNW winds decreases with the height above the earth surface the percent occurrence of winds with northern component increases. The most numerous WNW directions belong to the winds with the speed below normal. The highest wind speeds are along the NE and SW axis, namely under the NE directions. With the development of vegetation from May to July, the wind speed decreases in the lowest two considered levels. It is possible that the reduction of forested surfaces in the disaster area can have, as a result, an increase of the variability of the wind speed and the wind direction.

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