Seasonal variability of air circulation in the High Tatras region

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Abstract In the contribution the seasonal characteristics of the wind speed and wind direction in the High Tatras region are presented. The different altitude as well as the distinguished topographical conditions at the meteorological observatories GPI SAS Skalnaté Pleso (φ = 49° 12′ N, λ = 20° 14′ E, h = 1778 m a.s.l.) and Stará Lesná (φ = 49° 09′ N, λ = 20° 17′ E, h = 810 m a.s.l.) enable to study the temporal variability of air circulation in two different altitudes. Anemographic records of the mean hourly wind speed and wind direction covering the period of the years 1992-2006 were used as an experimental basis. The methods of mathematical statistics were applied for the evaluation of these time series.

Key words: *anemographic record, wind speed, wind direction, daily and seasonal courses, mathematic statistics*

Introduction

Wind is the most variable meteorological element, namely in the atmospheric boundary layer. Its local and weather variability depends upon the area contour and therefore the topographically highly complex terrain of the High Tatras creates various conditions for the surface air circulation. This complexity of topographic conditions in the High Tatras finds its expression also in considerable diversity of wind conditions. Therefore, it is required to use an adequate observation of wind direction and wind speed to obtain the analysis of wind in the High Tatras.

Wind conditions in different high-mountain localities in the High Tatras have been evaluated, yet. On the basis of wind speed and wind direction measurements in 3 times a day at 7, 14, and 21 h of the local time were published numerous works, as it follows from bibliography "Climate of Tatras" (Otruba and Wisniewski, 1974). In some works, there were also evaluated results of analysis of daily course of wind speed on the basis of evaluation of anemographs (Otruba, 1987; Ostrožlík, 1991; Otruba et al, 1988). However, the most detailed analysis and interpretation of the field of wind speed in the High Tatras region, which is based on surface measurements Otruba and Wiszniewski provide in the mentioned monographie.

Material and methods

Measurements and recording of wind speed and wind direction at Skalnaté Pleso (φ = 49° 12′ N, λ = 20° 14′ E, h = 1778 m a.s.l.) and Stará Lesná (φ = 49° 09′ N, λ = 20° 17′ E, h = 810 m a.s.l.) are carried out by central measurement data system ESM 200. The 10 minute scanning interval of the local time is used for sensor. These instantaneous data are stored in the centre measurement station. The hourly averages, each calculated from 6 instantaneous values, are loaded on magnetic medium. As a foundation the hourly data of anemographic measurements of wind speed and wind direction during the 1992-2006 period were used.

The methods of mathematical statistics (Anděl, 1985; Kendall and Stuart, 1968; Nosek, 1972) as well as harmonic analysis (Brooks and Carruthers, 1953; Conrad and Pollak, 1962) were applied for the evaluation of these time series.

Results and discussion

Based of numerical and graphical analysis of 15 year time series of hourly anemographic data of wind speed and wind direction at Skalnaté Pleso and Stará Lesná some quantitative characteristics a peculiarities in daily and annual courses in different topographic localities are evaluated and interpreted. In Table 1 many statistical characteristics are introduced: average, median, extreme values, standard deviation, coefficient of variation, etc. Processing of the extensive material showed that in spite of the fact that the occurrence of calm is more frequent at Skalnaté Pleso (3.5%) than at Stará Lesná (0.4 %) (in annual mean), the slope position of Skalnaté Pleso is windier (3.3 m s^{-1}) in comparison with mountain foot of Stará Lesná (2.1 m s^{-1}). Older data from Skalnaté Pleso show (Otruba and Wisniewski, 1974) the mean value of wind speed at Skalnaté Pleso during the period 1941-1950 and 1951-1960 (3.7 m s^{-1}, 3.8 m s^{-1}, respectively) was a little higher than during the investigated period.

Table 1. Statistical characteristics of the mean annual values of wind speed at Skalnaté Pleso and at Stará Lesná during the 1992-2006 period

Variable	Wind speed in m s^{-1}	
	Skalnaté Pleso	Stará Lesná
Sample size	15	15
Average	3.34	2.12
Median	3.30	2.06
Mode	3.20	1.96
Geometric mean	3.33	2.10
Variance	0.07152	0.07932
Standard deviation	0.26744	0.28163
Standard error.	0.06905	0.07272
Minimum	3.01	1.69
Maximum	4.02	2.64
Range	1.01	0.95
Lower quartile	3.13067	1.88283
Upper quartile	3.49475	2.39717
Interquartile range	0.36408	0.51433
Skewness	1.25161	0.21436
Kurtosis	1.81613	-0.73661
Coeff. of variation	7.99672	13.31415

The field of air flow in the surface atmospheric layer generated by general atmospheric circulation is extremely influenced by terrain morphology. High-mountain massif of High Tatras has a great part on wind field deformation because the massif represents a topographical barrier, especially for the northern components of general atmospheric circulation. It also demonstrates the distribution of the surface wind directions in Fig. 1. According to the data in Fig. 1, it can be seen that Skalnaté Pleso is characterized with prevailing south-western air flow components (mainly WSW and SW). On the opposite, the north-western components of wind are at least probable. On the other hand, at Stará Lesná the most frequent winds are with the south components of air flow (mainly S and SSW), while the north-eastern winds are the rarest.

The total windiness of a position may be expressed most simply by the total average wind speed regardless of direction and including calm. Wind speed in various wind directions is clearly illustrated in Fig. 2. An analysis of mean speed of wind directions according to wind roses gives a more detailed picture of a dissimilar intensity of flow of individual wind directions in various wind directions. Based on the vector sizes we can take measure the qualitative and partly quantitative dynamic conditions of general air circulation as well as wind speed changes due to by the mountain barrier. From the values of vectors, it can be seen which directions how participate on the whole wind roses in the slope position at Skalnaté Pleso as well as in the foothills at Stará Lesná. For example, it can be seen that the most numerous wind directions at Skalnaté Pleso (WSW and SW) have also the greatest wind speeds. Similar situation is at Stará Lesná, but here it can be seen that the greatest wind speeds are along the ENE-SSW axis.

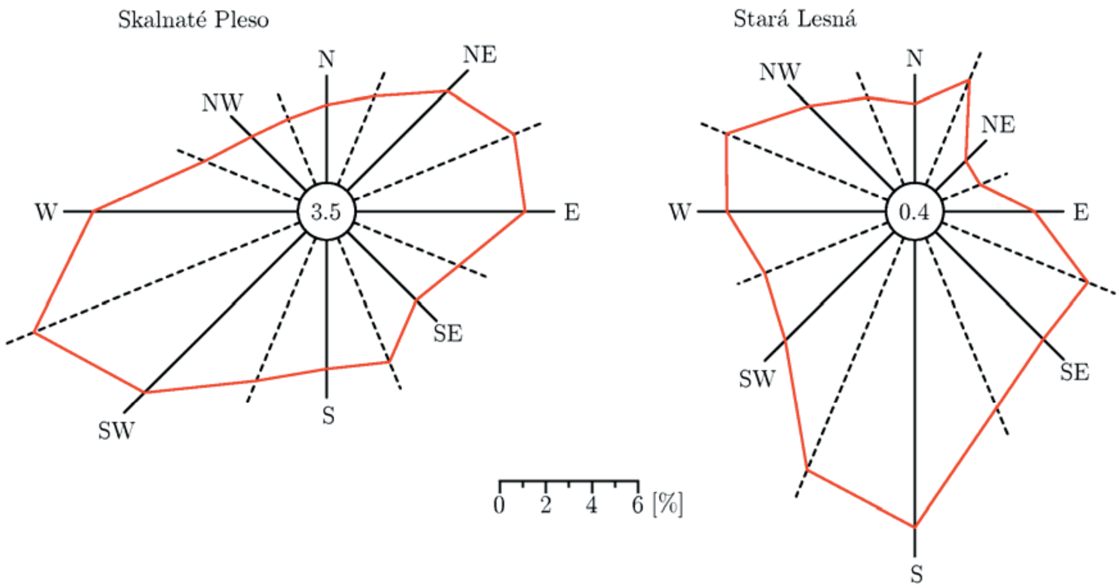

Fig. 1. Wind direction roses at Skalnaté Pleso and Stará Lesná during the 1992-2006 period. In the centre of the rose is percentage data of calm.

Besides the minimum mean wind speed is at Skalnaté Pleso during the winds with the south-eastern wind components (from E to S) while at Stará Lesná the minimum wind speed falls to the directions with the western wind components (from WNW to NW).

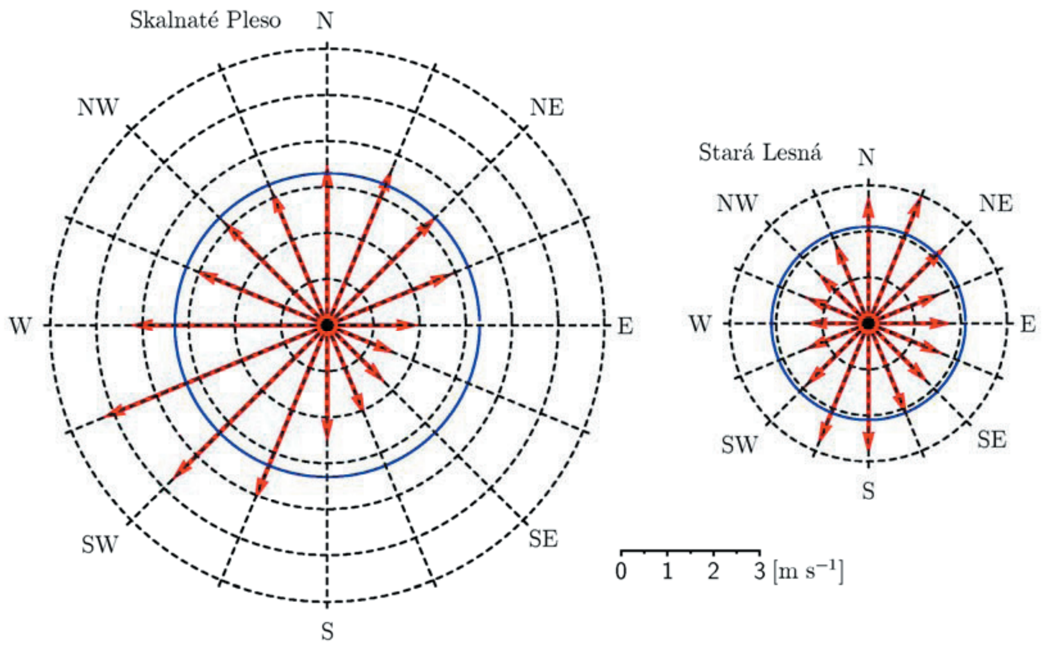

Fig. 2. Roses of mean speed of wind direction at Skalnaté Pleso and Stará Lesná during the 1992-2006 period. Mean value of wind speed of the investigated period is depicted by a circle in blue color.

Mean hourly values of wind speed during the year – experimental and theoretical (the first and the first two harmonic components) – are graphically presented in Fig. 3, to characterize the annual course of the total windiness at Skalnaté Pleso and Stará Lesná. Harmonic analysis was used in these calculations (Brooks and Carruthers, 1953; Conrad and Pollak, 1962). The course of the curves in Fig. 3 indicates that at both localities the annual course of the wind speed is not so simple. For example, there are two maxima during the year – in spring and in autumn. But this mean course can be absolutely different in individual years of the investigated period. Using of the harmonic analysis it can be seen that the first two harmonic components have a good fit to the experimental data.

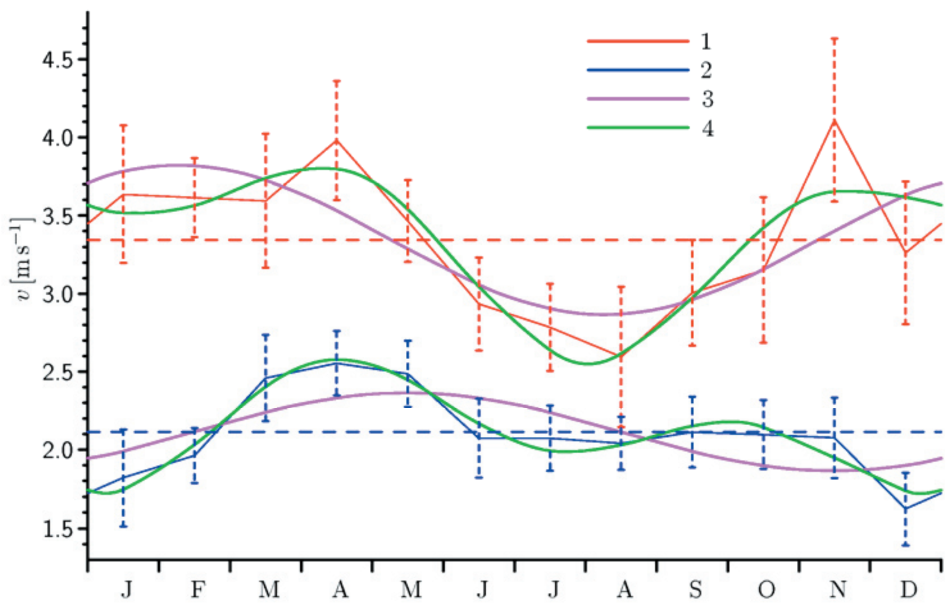

Fig. 3. Annual course of wind speed [m s^{-1}] at Skalnaté Pleso (1) and Stará Lesná (2), and its first (3) and the first two (4) harmonic components expressed by the deviations from the annual mean during the 1992-2006 period. Error bars represent variance and indicate variability within the month.

Character of the daily course of the wind speed in the high-mountain massifs is depended mainly on the locality in vertical profile of mountain range. This fact also confirms the results in Fig. 4. From the course of the curves it can be seen the wind speed at Stará Lesná has an expressive daily course characterized with one maximum and one minimum. During a daytime, with the sunrise and by the development of convective cloudiness, the wind speed increases. We can see that the highest values of wind speed occurs at noon (midday hours), and the mean values are 3.0 m s^{-1} (13 and 14 h). According to the expectation, the minimal values of wind speed occur in the evening and morning hours, and in interval from 24 to 8 h the values are in range 1.5 – 1.8 m s^{-1}. On the other hand, the daily course of wind speed at Skalnaté Pleso is not expressive and daily amplitude is only 0.3 m s^{-1}. Here we can see a certain two maxima: one in the morning from 10 to 13 h and second in the evening from 20 to 23 h. It also confirms that such unexpressive course of wind speed occurs in the transitive level zone, like a transition between lowland type of daily course of wind speed (daily maximum and nightly minimum) and high-mountain type (nightly maximum and daily minimum). Such vertical distribution of daily amplitude of wind speed demonstrates that the vertical stability increase of the surface atmospheric layer in the evening and morning hours a thermal turbulence during the daily hours induces the highest relative changes of wind speed in the lower part of the high-mountain massif. Daily course of wind speed at Stará Lesná is typical for the lowland localities in our country.

Comparison of the daily courses wind speed – experimental and theoretical – in Fig. 4 shows that the experimental values of the daily course can be good approximated with the first two harmonic components at both localities.

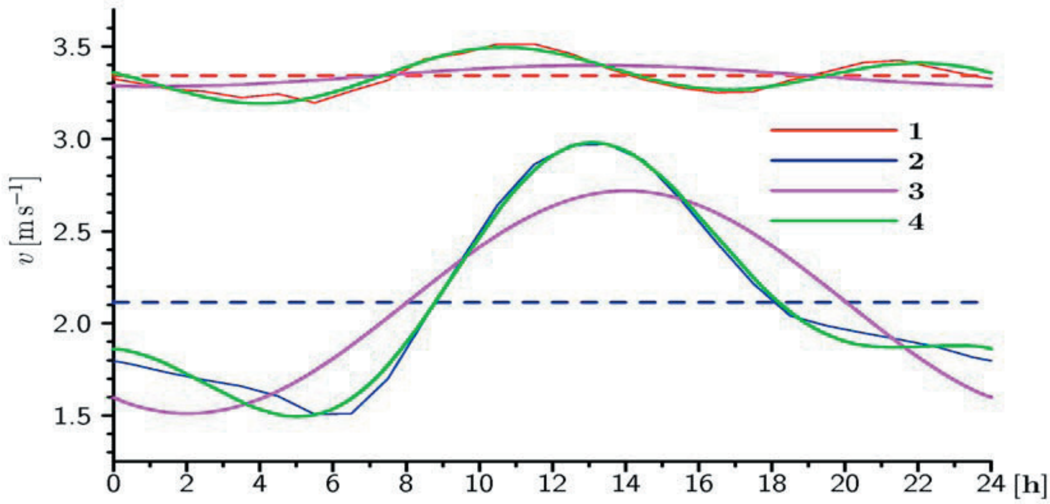

Fig. 4. Periodic daily course of wind speed [m s^{-1}] at Skalnaté Pleso (1) and Stará Lesná (2), and its first (3) and the first two (4) harmonic components expressed by the deviations from the annual mean during the 1992-2006 period.

Conclusions

By processing of the extensive material of wind speed and wind directions at Skalnaté Pleso and Stará Lesná during the 1992-2006 period many statistical characteristics were obtained. For example, it has been shown, in spite of the fact, that the occurrence of calm is more frequent at Skalnaté Pleso than at Stará Lesná (in mean sense), the position of Skalnaté Pleso is windier than Stará Lesná. While, Skalnaté Pleso is characterized with prevailing south-western air flow components at Stará Lesná the most frequent winds are with the south components of air flow. It has been shown that the annual course as well as diurnal one of wind speed at both localities can be approximated by the first two harmonic components.

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