



Wind characteristics of CzeCOS's ecosystem station Bílý Kříž

***Vinh Xuan Nguyen**^{1,2,3*}, **Carlos P. Guerra Torres**^{1,2,4}, **Shilpi Yadav**^{1,2}, **Marian Pavelka**¹,
Marek V. Michal¹

¹ Global Change Research Institute CAS, Bělidla 986/4a, 603 00 Brno, Czech Republic,
email: nguyen.v@czechglobe.cz

² Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic

³ Department of Ecology, Institute of Tropical Biology VAST, 85 Tran Quoc Toan Street, District 3, Ho Chi Minh City, Vietnam

⁴ Department of Botany, University of Panama P.O. 0824-00077 Panama, Panama

Abstract: Nguyen V.X., Guerra Torres C.P., Yadav S., Pavelka M., Marek M.V. 2017: Wind characteristics of CzeCOS's ecosystem station Bílý Kříž – *Beskydy*, 10 (1, 2): 33–40

Eddy-covariance is a direct and accurate method to measure exchanges of greenhouse gases and energy between ecosystems and the atmosphere under good turbulent mixing conditions. Calm conditions can affect the accuracy of the eddy-covariance measurements by potential gas buildup below the measurement height. This study characterizes wind patterns and calm periods at Bílý Kříž Ecosystem Research Station, using four-year (2010–2013) wind data measured on an eddy-covariance tower at the site, located in Beskids Mountains, Czech Republic. The site is covered by young, dense Norway spruce forest on a 12.5° slope facing South. The results show that the prevailing wind direction was from S to SW direction (55 % frequency of occurrence), and to a much lesser extent from N, NE and NW but including the strongest winds above 12 m s⁻¹, possibly during gale or storm events. Calm condition ($u < 1 \text{ m s}^{-1}$) accounted for 34 % of year time. Summer and Spring were the calmest seasons. Occurrence frequencies of calm conditions for the six-month periods from May to October (plant growing season) were higher than those for the remaining parts of the year (on average 39 % vs 28 % respectively). One should be aware of the calm periods in May–October when processing eddy-covariance data, since it is the time period of most contribution of forest ecosystem as a sink of CO₂.

Keywords: Bílý Kříž, eddy-covariance, wind patterns, calm conditions

Introduction

The eddy covariance (EC) method is a micrometeorological technique for direct measurements of gas exchange between the surface and the atmosphere. It is widely used for quantifying CO₂ emission rates from natural, urban and agricultural ecosystems, including areas of agricultural carbon sequestration (Burba *et al.*, 2013). The method is based on turbulent transport across

the plane of flux measurement and storage changes below the measurement plane. Under stable, low-wind conditions when turbulence is not well developed, often occurred at night, EC systems located above terrestrial ecosystems may report little or no CO₂ exchange even when such exchanges are known to be occurring (Barr *et al.*, 2013).

Hence, understanding of the wind patterns and stability conditions of surface layer is needed in EC method. Flux data at very stable conditions may need to be corrected or discarded due to insufficient fetch of the ecosystem (Burba, 2013).

This study characterizes wind patterns and low-wind conditions at the Bílý Kříž Ecosystem Research Station, using horizontal wind speed data from the processed eddy-covariance data of four years (2010–2013) of the station.

Materials and Methods

The study site is located in Beskids Mountains of the Czech Republic near a mountain ridge, covered by young, dense Norway spruce (*Picea abies* [L.] Karst.) forest stand (planted in 1981, mean height of 13.9 m and stand density of 1,488 trees ha⁻¹ at the end of the growing season of 2010) on a 12.5° slope facing SSW (Sedlák *et al.*, 2010, Marková *et al.*, 2013).

Four-year data sets (2010–2013), measured by 3D sonic anemometer R3-100 until November 2011 and then by HS-50 (Gill, UK) as a part of the EC system placed on a meteorological tower at Bílý Kříž site (49.5021°N, 18.5368°E, 875 m a.s.l.) at the height of 18 m until October 2013 and 20.5 m afterwards, measured in 20 Hz and processed in form of half-hour records, were used to analyze the site's wind patterns. From 3–5 % records of yearly wind speed data were blank and removed from analysis. It is noted that there was a gap in wind data set of 2012, from January 21st to February 21nd.

Calm periods were defined by horizontal wind speed (*u*) less than 1 m s⁻¹, where turbulence is not well-developed (Burba, 2013). Periods with calm conditions were assessed in relation with their associated wind directions, day-time vs. night-time, monthly and seasonally. Horizontal airflow was divided into eight wind direction sectors: North (N) from 0–23 and 338–360, North-East (NE) 23–68, East (E) 68–113, South-East (SE) 113–158, South (S) 158–203, South-West (SW) 203–248, West (W) 248–293, and North-West (NW) 293–338 degrees.

Day-time is defined from 0600 to 1800 and night-time is from 1800 to 0600 next day. Comparison was made between November–April and May–October, where the later falls in the main growing season of plants in temperate areas of the northern hemisphere (Hájková *et al.*, 2012). This study also used meteorological seasons, which are reckoned by temperature, with

summer being the hottest quarter of the year and winter the coldest quarter of the year. For temperate areas in the Northern hemisphere, spring begins on the 1st of March, summer on the 1st of June, autumn on the 1st of September, and winter on the 1st of December (New World Encyclopedia, 2015). The data were analyzed using MS Excel.

Results

Wind characteristics

Wind direction: Figs. 1 and 2 showed a uniform pattern in wind roses from each year, in particular prevailing wind came upslope from S (38 % frequency of occurrence observed in the four year dataset). Other minor dominant wind directions were from SW (17 %) going upslope; and from the North (15 %), NW (8 %) and NW (8 %) blowing over the ridge and then downslope on the lee side. Wind roses constructed for each month of year 2010 in Fig. 3 also revealed the site was under influence of prevailing winds from S and SW throughout the year, and markedly during October to December.

Wind intensity: On average of four-year data (2010–2013), calm periods were recorded 34 % time of year (Tab. 1). Most strong winds (with speeds from 6–10 m s⁻¹) came from S and SW (Fig. 2). However, the strongest wind records (12–18 m s⁻¹, very strong wind, in Beaufort wind scale ranked from strong breeze to near gale and gale) observed in 2012 and 2013 came from N and NE, possibly during short storm or whirlwind events lasting from few hours to a couple of days in winter (November to early February). The maximum wind speeds observed from the datasets of half-hour records (i.e. already flattened out by averaging) was 18.9 m s⁻¹ from NE in January 2013.

Monthly wind roses of 2010 in Fig. 3 showed that there was a period of continuous six months with moderate (4–6 m s⁻¹) to strong winds (characterized by significant occurrence of periods with wind speeds of 6–8 m s⁻¹ and some periods with wind speeds of 8–10 m s⁻¹) from October to March. Other months were considered as with low wind conditions, especially from April to July (August for years 2013 and 2012) seemed to be the “calmest” months.

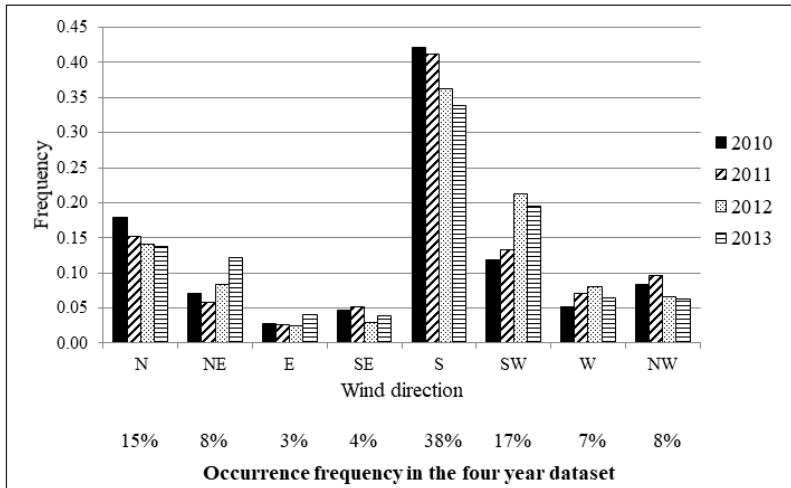


Fig. 1: Yearly wind direction frequency at Bílý Kříž Ecosystem Research Station during 2010–2013

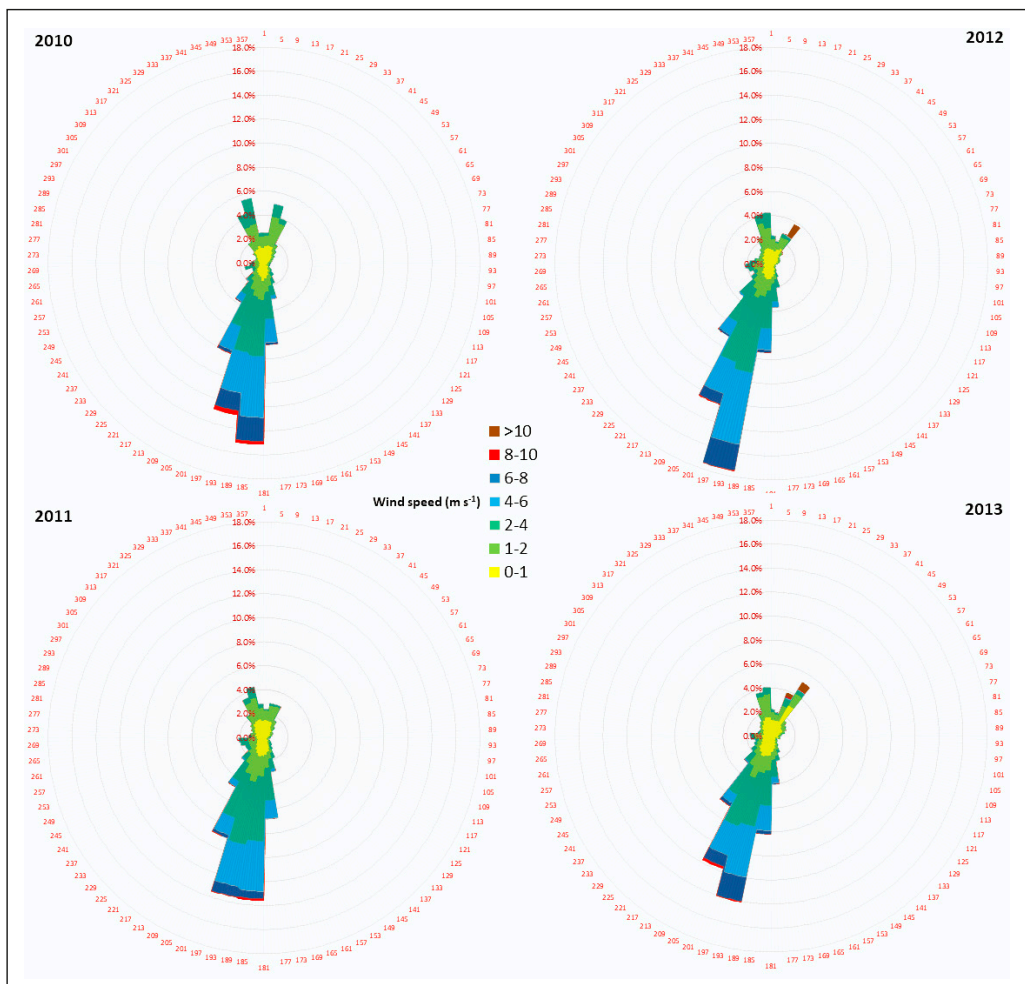
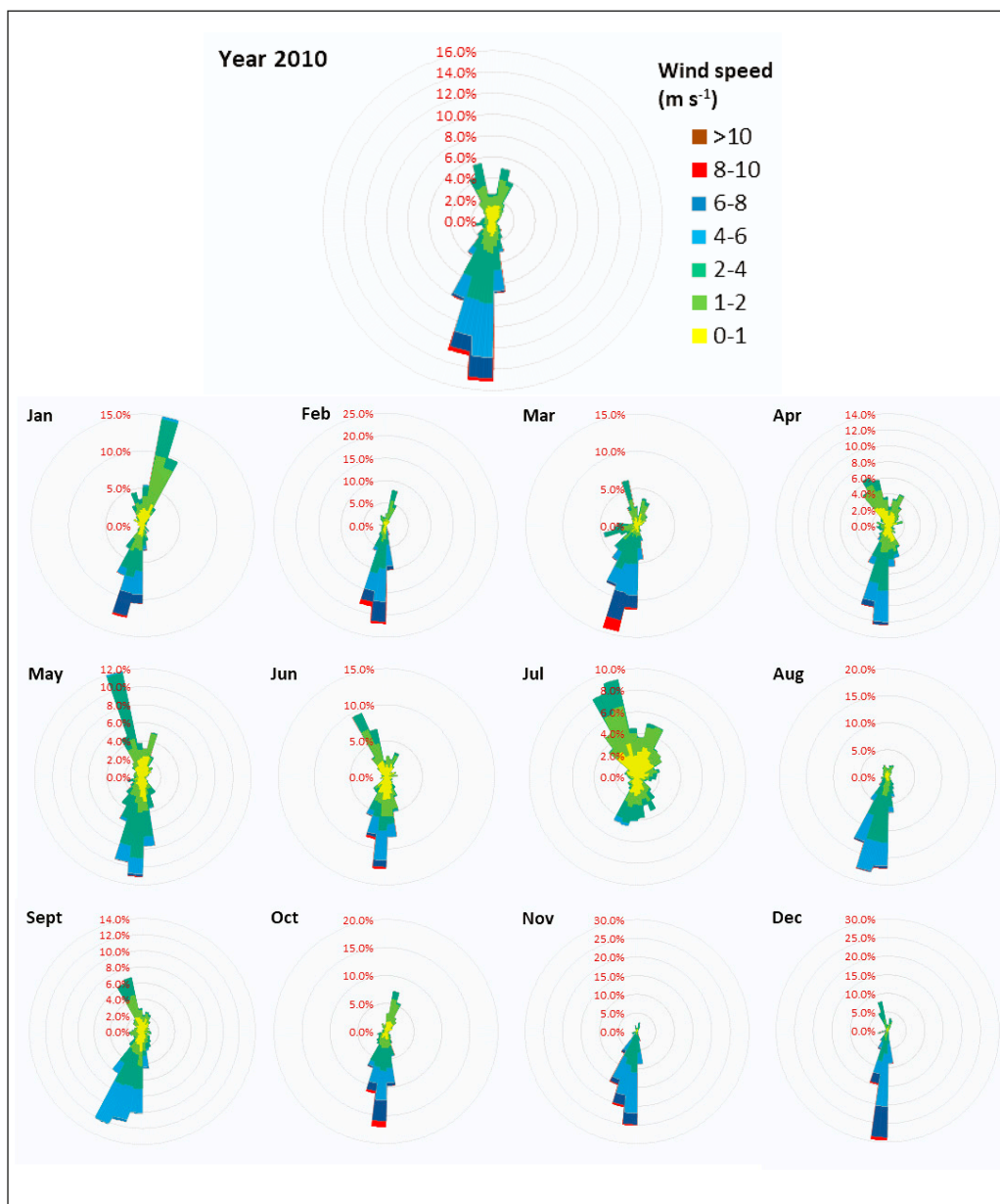


Fig. 2: Yearly wind roses at Bílý Kříž Ecosystem Research Station during 2010–2013



(Jan: January, Feb: February, Mar: March, Apr: April, May: May, Jun: June, Jul: July, Aug: August, Sept: September, Nov: November, Dec: December)

Fig. 3: Bílý Kříž wind roses of the whole year and each month of 2010

Seasonal patterns

From a closer look at meteorological seasons of four years, on average the highest frequency of calm periods occurred in summer (i.e. 11.4 % of whole year), spring ranked second (9.7 % of whole year) and winter was the least (Tab. 2 and Fig. 4).

For all study years, occurrence frequencies of calm records in six-month period of May–October (coincident with main growing season of plants in temperate climate region) were much higher compared against November–April period, specifically 39 % vs 28 % for respective periods (Tab. 1 and Fig. 5), or 21 % vs 13 % respectively of whole year.

Diurnal pattern

Similar values of calm periods were obtained when compared night-time vs day-time during May–October period (40 % of night-time vs 39 % of day-time) (Tab. 1). The difference was larger for November–April period, 30 % vs 26 % respectively.

Tab. 1: Calm conditions ($u < 1 \text{ m s}^{-1}$) in different periods at Bílý Kříž

Year	2010	2011	2012	2013	Average
Whole year	31	34	32	40	34
Day-time	30	33	30	39	33
Night-time	31	35	34	41	35
May–October	37	38	37	46	39
Day-time	38	37	35	44	39
Night-time	37	39	38	47	40
November–April	23	30	26	34	28
Day-time	21	28	24	33	26
Night-time	26	31	28	34	30

(All values are percent of the time during a particular period)

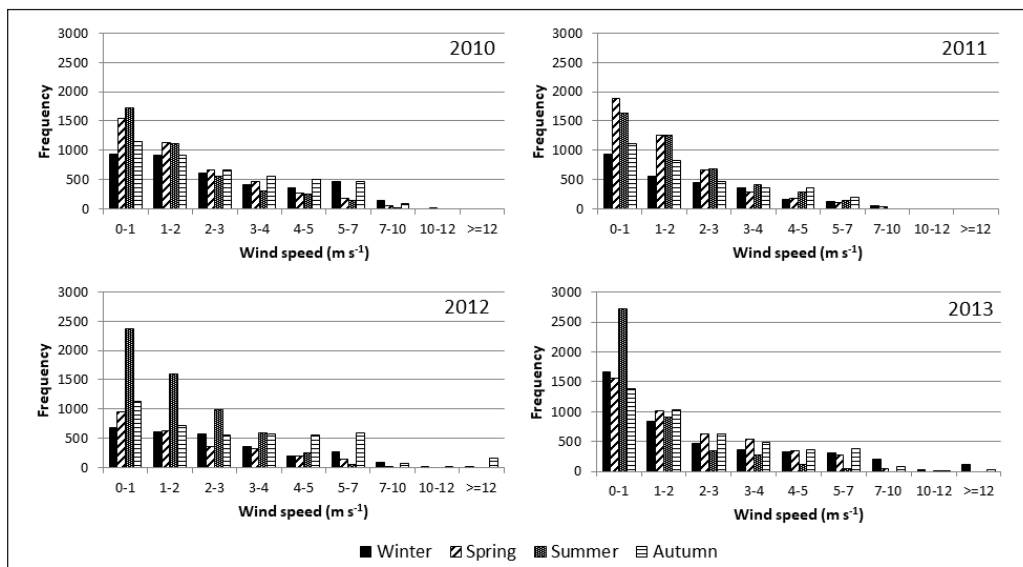


Fig. 4: Yearly wind speed frequency of occurrence for four meteorological seasons at Bílý Kříž

Tab. 2: Occurrence frequency of calm periods ($u < 1 \text{ m s}^{-1}$) compared among four seasons

Year	Winter (Dec–Feb)	Spring (Mar–May)	Summer (Jun–Aug)	Autumn (Sept–Nov)
2010	5.4	8.9	9.8	6.5
2011	6.0	10.8	9.3	7.7
2012	3.9	10.3	10.4	7.2
2013	7.4	8.9	15.9	7.8
Average	5.7	9.7	11.4	7.3

(All values are percentage of whole year)

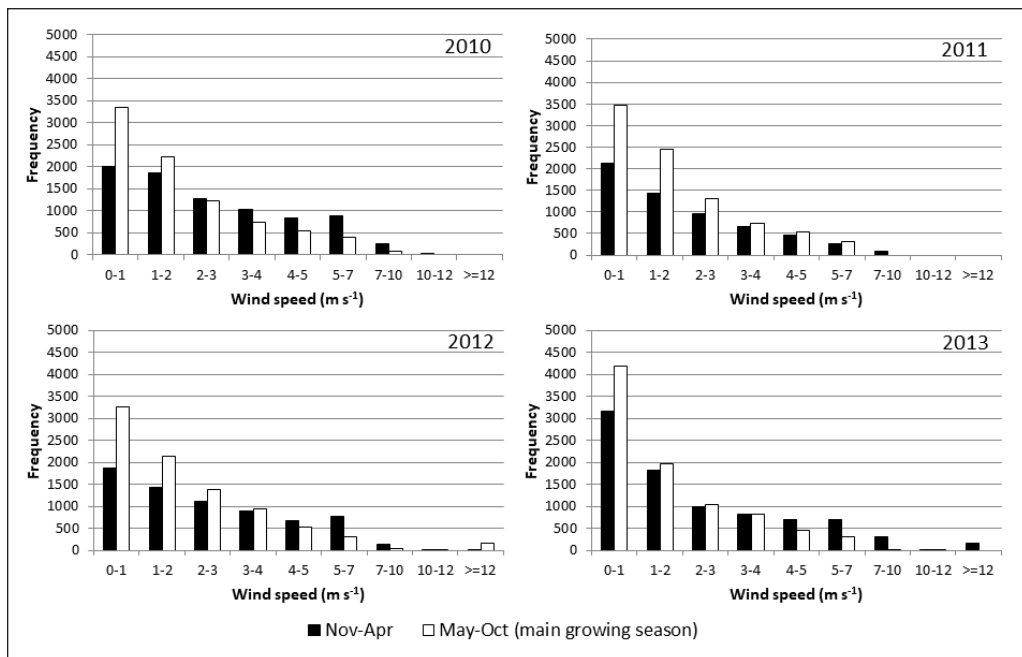


Fig. 5: Yearly wind speed frequency of occurrence for two six-month periods at Bílý Kříž

Discussion

Despite similarity of yearly wind patterns in Fig. 2, there was evidence of 10-degree angular rotation in wind roses of years 2010 and 2011, compared to those of years 2012 and 2013. At the end of 2011, sonic anemometer on the EC flux tower was changed. The replacement and new installation may have introduced a small difference in North spar registration between the old and new anemometers. It should be noted that the rotation angle was also limited by size of wind sector unit of 10 degree selected to create the wind roses. The difference between North spar orientations of the old and new anemometers is likely at the order of sub-degree or to a few degrees.

The topography of the Beskids Mountain range is quite complex. To certain extent, the prevailing winds above the site forest canopy coming from S, SW and N are shaped by local terrain. Havrankova and Sedláč (2004) reported that the flow at Bílý Kříž is strongly influenced by the surrounding terrain; and main features are the pronounced south-north flow channeling and local circulation patterns such as the mountain breeze. Findings from this study confirms the correct orientation of anemometer and gas analyzer on the EC flux tower, to the west of the tower.

In Bílý Kříž, summer was the calmest season (except in 2011) and winter was the least

calm season. This observation agrees with general patterns of atmospheric circulation in the mid-latitude region (area between 30° and 60° latitude). Mid-latitude surface winds are primarily westerly and their strength is largely determined by polar vortex, which strengthens in the winter and weakens in the summer due to its dependence on the temperature difference between the equator and the poles (Frauenfeld and Davis 2003, Randall, 2015).

The EC method often underestimates fluxes under stable, low-wind conditions at night when turbulence is not well developed (Barr *et al.*, 2013). Under calm conditions, gas concentration can build up or become depleted below the measurement height. Gusts of wind can move this buildup sideways or upward very quickly, so this flux may be either undetected or only partially detected (Burba, 2013). Calm periods, coded in yellow color in Fig. 3, made up large portions in the monthly wind roses for April, May, Jun, July and September of 2010 (39 %, 38 %, 47 %, 48 % and 34 % respectively). EC data measured during “calm” months of the growing season should be carefully processed as it is this period of time that most contribution of forest ecosystem as a sink of CO₂ takes place.

Higher wind speeds increase turbulence and decrease stability of atmospheric surface layer, which is better for eddy-covariance flux measurement method. However, under very strong wind conditions, signal brought to gas analyzer(s) may come from too close to the station. Flux data at very unstable conditions may need to be corrected or discarded due to the fact that a large portion of the flux may come from the disturbed area around the instrument tower (Burba, 2013).

Conclusions

In this study we assessed characteristics of wind patterns and calm conditions in Bílý Kříž Ecosystem Research Station. Key conclusions are:

- + Prevailing winds at Bílý Kříž site were mainly from S and SW, (including strong winds of 6–8 and some records up to 12 m s⁻¹) and to a much lesser extent from N, NE and NW but including the strongest winds greater than 12 m s⁻¹.
- + On average of four years (2010–2013), calm periods took up 34 % time of year.

- + Period from May to October (plant growing season) observed more calm records than period from November to April (39 % vs 28 % respectively).
- + 40 % of night-time vs 39 % of daytime were calm periods during May–October; and 30 % vs 26 % respectively during November–April.

Acknowledgements

This work was supported by the Ministry of Education, Youth and Sports of CR within the National Sustainability Program I (NPU I), grant number LO1415; and Project No. VAST.HTQT. Sec.01/16-17 of the Vietnam Academy of Science and Technology.

References

- BARR, A., RICHARDSON, A., HOLLINGER *et al.* 2013: Use of change-point detection for friction-velocity threshold evaluation in eddy-covariance studies. *Agricultural and Forest Meteorology*, 171–172: 31–45.
- BURBA, G. 2013: *Eddy Covariance Method for Scientific, Industrial, Agricultural, and Regulatory Applications: A Field Book on Measuring Ecosystem Gas Exchange and Areal Emission Rates*. LI-COR Biosciences, Lincoln, NE, USA, 331 pp.
- BURBA, G., MADSEN, R., FEESE, K. 2013: Eddy Covariance Method for CO₂ Emission Measurements in CCUS Applications: Principles, Instrumentation and Software. *Energy Procedia*, 40C: 329–336.
- FRAUENFELD, O. W., DAVIS, R. E. 2003: Northern Hemisphere circumpolar vortex trends and climate change implications, *J. Geophys. Res.*, 108, 4423, doi:10.1029/2002JD002958, D14.
- HÁJKOVÁ, L., VOŽENÍLEK, V., TOLASZ, R., KOHUT, M., MOŽNÝ, M., NEKOVÁŘ, J., NOVÁK, M., RICHTEROVÁ, D., STRÍŽ, M., VÁVRA, A., VONDRÁKOVÁ, A. 2012: *Atlas of the phenological conditions in Czechia*. Český Hydrometeorologický Ústav. Olomouc, Czech Republic, 320 pp.
- HAVRÁNKOVÁ, K., SEDLÁK, P. 2004: Wind Velocity Analysis for Mountainous Site Bílý Kříž. *Ekologia* (Bratislava), 23: 46–54.
- MARKOVÁ, I., PAVELKA, M., JANOUŠ, D. 2013: *Ročenka meteorologických měření 2011. Yearbook of meteorological measurements in 2011*. Brno: Czech-Globe, 125 pp. ISBN 978-80-87902-01-1.

NEW WORLD ENCYCLOPEDIA 2015: *Season*. [Online]. Accessible at: <http://web.newworldencyclopedia.org/entry/Season>. [Accessed: 2017, October 30].

RANDALL, D. A., 2015: *An Introduction to the Global Circulation of the Atmosphere*. Princeton University Press, 442 pp., ISBN-13: 978-0691148960.

SEDLÁK, P., AUBINET, M., HEINESCH, B., JANOUŠ, D., PAVELKA, M., POTUŽNÍKOVÁ, K., YERNAUX, M., 2010: Night-time airflow in a forest canopy near a mountain crest. *Agricultural and Forest Meteorology*, 150(5): 736–744.