Rožnovský, J., Litschmann, T. (ed): „Bioklimatologické aspekty hodnocení procesů v krajině", Mikulov 9. – 11.9.2008, ISBN 978-80-86690-55-1

SEASONAL COURSE OF CO_2 EFFLUX IN GRASSLAND AND FOREST ECOSYSTEMS IN BESKYDY MTS.

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Abstract

Respiration is an important part of the carbon flux. It can be measured as CO_2 efflux into atmosphere and it is variable spatially (in the local and regional scale) and also temporally (diurnally, seasonally, annually).

Our aim was to determine seasonal changes of CO_2 efflux of the mountain grassland and of the soil and stems in the mountain Spruce forest at the Experimental Ecological Study Site Bílý Kříž, Moravian-Silesian Beskydy Mts., during the growing season (May to October) in 2007. The CO_2 efflux was measured continuously throughout the season using the automatic closed gasometrical systems.

CO_2 efflux depends exponentially on the temperature and this dependency differs between experimental objects and due to changing conditions. For elimination of the temperature dependency of CO_2 efflux, standardized CO2 efflux R_{10} (CO_2 efflux at temperature of 10°C) is usually used. That allows comparison of CO_2 efflux in different times and in different sites.

Mean R_{10} was about 2.50, 5. and 0.97 $\mu molCO_2\ m^{-2}\ s^{-1}$ for grassland, forest soil and stems, respectively. In grassland the R_{10} course did not show obvious trend during the experimental period but there was a slight decrease after cutting of the grass.. Whereas in the forest soil, the significant increase at the beginning and decrease at the end of the season occurred, but without any distinct maximum. Similar increase and decrease in R_{10} at the beginning and the end of the season was observed in the stem CO_2 efflux course as well. But there was a maximum which lasted from the second half of June to the first half of July.

The temperature CO_2 efflux sensitivity expressed by Q_{10} value (the proportional change in respiration resulting from 10 °C increase in temperature) was in average about 3.04, 1.90 and 2.25 for the grassland, forest soil and stems, respectively.

The temperature sensitivity in the forest soil was quite low during dry periods and increased shortly after rain. It resulted in a rapid increase in CO_2 efflux of the soil as a response to rain.

Response of the grassland to the rain was much weaker and no clear response occurred in stems.

Keywords: CO_2 efflux, grassland, forest, soil, stem

Introduction

Respiration is an important part of the carbon flux. It is a great source of CO_2 released to atmosphere. Because of its sensitivity to temperature, it is supposed that global climatic changes will have an effect on respiration rates in the future (Jones et al. 2005, Pendall 2004).

Soil respiration is the important portion of ecosystem CO_2 efflux (Bolstad et al. 2004, Miyama et al. 2006) and its contribution to the total ecosystem respiration changes during the year (Shibistova et al 2002). The most important factors affecting respiration are temperature and soil moisture (Davidson 2006, Janssens 1999). They drive temporal respiration variability from diurnal to interannual scale (Flanagan et Johnson 2005, Reichstein et al. 2003, Rey et al. 2002). The temperature sensitivity of aboveground biomass is higher than that of soil (Atkin et al. 2005, Loveys et al. 2003) and within the soil, the autotrophic part (roots) of respiration is more temperature sensitive than the heterotrophic (Boone et al. 1998, Guay et al 2008).

Soil and aboveground biomass are in a tight relationship so they influence each other´s respiration (Asensio et al. 2007, Craine et Wedin 2002, Ekblad et Hogberg 2001).

Widely used method for CO_2 efflux measuring at different levels of ecosystem (soil, stem, leaves) is a gasometrical method (e.g. Cooper et al 2006, Pavelka et al. 2007, Tang et al. 2008, Zha et al. 2004). It is based on measuring of changes of CO_2 concentration within a respiration chamber which contains the observed object (e.g. leaf), or it is fixed on the observed object (soil or stem surface).

In this study, we determined temperature normalized CO_2 efflux rate and its seasonal changes of three different objects: mountain grassland, and soil and tree stems in the mountain Spruce forest. Moreover, we wanted to asses the effect of rain to CO_2 efflux and temperature sensitivity of these objects.

Materials and methods

Sites and measurements

Measurements were carried out at two sites, grassland (dominated by *Festuca rubra agg.* and *Nardus stricta*) and Norway spruce (*Picea abies* [L.] Karst) forest at the Ecological Experimental Study Site (EESS) Bíly Kříž 49°30´ N, 18°32´ E, 850 and 890 m a.s.l., respectively), Moravian-Silesian Beskydy Mts., the Czech Republic. EESS Bílý Kříž is characterized by mean annual temperature of 5.5 °C and annual precipitation of 1100 – 1400 mm.

Measurements of soil and stem CO_2 efflux in the forest were made using similar automatic modified closed gasometrical (non-steady-state through-flow) systems (Institute of Systems Biology and Ecology, the Czech Republic). Grassland CO_2 efflux was measured by three chambers of the height of 60 cm and diameter of 60 cm (inserted about 3 cm deep into the soil). Forest soil CO_2 efflux was measured by eight chambers of the height of 20 cm and diameter of 30 cm (inserted about 3 cm deep into the soil). Tree stem CO_2 efflux was measured by eight chambers installed on the northern surface of trees in the height of about 1.3m. The chambers had a half cylinder shape with height of 12 cm and diameter of 6.5 cm.

Soil temperature was measured at 1.5 cm soil depth in grassland and forest soil in all chambers (Pavelka et al. 2007). Stem temperature sensors were installed under each measured position in the cambium layer. They were inserted on the northern side of stems (to avoid direct solar radiation).

Data were collected continuously throughout the growing season 2007 (from 1.5. to 31.10.) in the forest. In the grassland, the measurements were carried out only during nights. During days, the chambers were removed to minimize the chamber shading influence on grass.

Precipitations were measured using perception gauge (Amet, CR). Daily sum was calculated.

Data analyses

The natural logarithm of the CO_2 efflux rate and the soil or woody-tissue temperature were regressed using a linear model.

$$\ln(\text{respiration}) = \alpha * T + \beta$$

where α and β are the regression coefficients. Q_{10} (the proportional change in CO_2 efflux from 10 °C increase in temperature) was calculated (Linder and Troeng, 1981) from:

$$Q_{10} = e^{10*\alpha}$$

where α is the regression coefficient obtained from the previous equation. Then, CO_2 efflux was normalized to the temperature of 10 °C according to equation:

$$R_{10} = R_i/Q_{10}^{(T-10)/10}$$

where R_i is the measured respiration rate at T of soil or woody tissue.

Results and discussion

CO_2 efflux was positively correlated to the soil or stem temperature. Temperature sensitivity of the whole season expressed as Q_{10} value was 3.04, 1.90 and 2.25 for the grassland, forest soil and stems, respectively.

Temporal dynamics of CO_2 efflux of all three experimental objects followed the seasonal pattern of soil temperature with maximum in summer months (Fig. 1)

Seasonal mean R_{10} was about 2.50 (SE = 0.02)), 5.29 (SE = 0.07)) µmol CO_2 m^{-2} s^{-1} (m^2 means soil area) for grassland and forest soil, respectively, and 0.97 (SE = 0.02) µmol CO_2 m^{-2} s^{-1} (m^2 means stem bark area) for stems. In the grassland, the course of averaged nocturnal R_{10} did not show any distinct pattern throughout the experimental season but there was a slight decrease in R_{10} values after mowing on 30. 7. 2007 (Fig. 2-A). In the forest soil R_{10} course, it was possible to observe an obvious increase in May and decrease in September and October (Fig. 2-B). The forest soil did not show any distinct maximum. In stem respiration there was a rapid increase in daily R_{10} values in May and reached maximum in June and the first half of July. After that, R_{10} slowly decreased until the end of October (Fig. 2-C).

Precipitations had a strong effect on CO_2 efflux from the forest soil. It caused an increase in R_{10} shortly after rain. Also the temperature sensitivity of CO_2 efflux increased, as shown in Fig. 3-B, where the regression curve became steeper.

The grassland respiration also increased shortly after the rain but the regression curve of temperature and CO_2 efflux had very similar slope (Fig 3-A) and so similar Q_{10}.

Stem CO_2 efflux did not show any immediate response to the rain (Fig. 3-C). Nevertheless, a heavy or long-term rain possibly caused the increase in CO_2 efflux, e.g. around the date of 6.9. 2007 as indicated by Fig. 2-C.

In this study, we compared seasonal course of mean daily (or nocturnal) R_{10} values (standardized rate of respiration at 10°C) of the grassland, forest soil and tree stems, and thus identified changes in respiration independent of temperature. We also observed different temperature sensitivity of CO_2 efflux of the experimental objects and its response to rainfalls.

The most common way how to express the temperature sensitivity of respiration is Q_{10} value (Davison et al. 2006). It is the factor by which respiration is multiplied when temperature increases by 10 °C. Q_{10} values can change temporally in dependence of temperature and moisture. It declines with the increase in temperature and the decrease in soil moisture (Janssens et Pilegaard 2003, Flanagan et Johnson 2005, Tjoelker 2001, Xu et Qi 2001). In our study, we observed differences in Q_{10} values of different experimental objects. The highest mean Q_{10} (3.04) of the whole experimental season occurred at the grassland and belonged to the whole ecosystem (soil and aboveground biomass). For the tree stems, the mean Q_{10} value was equal to 2.25, and the lowest value (1.90) was at the forest soil. Boone et al. (1998) or Guay et al. (2008) claimed that the autotrophic part of soil respiration is more sensitive than the heterotrophic, and the higher temperature sensitivity of leaves than of soil was also observed (Loveys et al. 2003, Atkin 2005).

Seasonal mean R_{10} was about 2.50 and 5.29 µmolCO_2 m^{-2} s^{-1} (m^2 means soil area) for grassland and forest soil, respectively, and 0.97 µmolCO_2 m^{-2} s^{-1} (m^2 means stem bark area) for stems.

Soil respiration is the important portion of ecosystem CO_2 efflux. It changes temporally in dependence mainly on soil temperature and moisture (Davidson et al. 2006, Janssens et al. 1999). In our experiment, CO_2 efflux of the grassland, forest soil and tree stem copied tightly the course of soil temperature. But calculating standardized rate of respiration at 10 °C, R_{10}, we could determine changes in respiration independent of changes in temperature. R_{10} of the forest soil showed a positive response to rainfall after at least short time of drought. This response was mostly very rapid and strong. After rainfall, the temperature dependency of forest soil CO_2 efflux was also significantly higher. Nevertheless, during the long time rain, R_{10} decreased (e.g. at the beginning of September) due to too high soil moisture.

Stem CO_2 efflux into atmosphere is the highest portion of the total flux of respired CO_2 in stem. The next largest flux is CO_2 transport in the xylem stream, and the last, CO_2 storage within stem, is only small proportion of the total flux (McGuire et Teskey 2004). Stem CO_2 efflux is positively correlated to stem temperature (Kim et Nakane 2005, Saveyn 2008) which is caused by increase in cell respiration and decrease in CO_2 solubility as a result of higher temperature (McGuire et al. 2007). The same study showed that stem respiration was less at high sap velocity compared with low sap velocity. But the cause for this response was unknown. However, sap flow has an effect on the portion of CO_2 efflux. At high sap velocity the transport of CO_2 in xylem sap is significantly greater than at low sap velocity and it causes the opposite response of CO_2 efflux to sap velocity when CO_2 efflux is significantly less at high sap velocity than at low sap velocity (Gansert et Burgdorf 2005, McGuire et Teskey 2004).

Average daily R_{10} of tree stems increased at the beginning of the season and reached maximum in June and the first half of July. After that R_{10} values decreased gradually. The similar course was observed also in other studies (Shibistova et al. 2002, Stockfors and Linder 1998). The June-July maximum is generally explained as a result of extra respiratory requirements associated with stem growth (Lavigne and Ryan 1997, Stockfors and Linder 1998). This agrees with our data. The maximum of stem growth at our study site occurred in June (data not shown).

The rainy weather caused the decrease in stem temperature which led to the decrease in measured stem CO_2 efflux. Nevertheless, there was a possibility to fit just one regression curve through all data. It indicates that the CO_2 efflux dependency on temperature and R_{10} values did not differ before and after rain. Saveyn et al. (2008) observed that rain caused the increase in xylem sap CO_2 concentration in young *Populus deltoides*, which led to the increase in CO_2 efflux. This response can occur after an extreme drought at mature trees. During our experimental period, we did not observe any long term period of drought to indicate this effect.

R_{10} values of the grassland ecosystem remained similar in the period from May to October 2007. But there was a slight decrease after mowing (grass was cut of about 50 cm to 15 cm height) on 30.7. 2007. Mowing significantly decreases aboveground biomass respiration rate. Moreover, there is also reduction of autotrophic (root) and heterotrophic part of soil respiration (Kuzyakov et Cheng 2001). A large portion of the variation of R_{10} values can be explained by seasonal variation in the amount of aboveground biomass and available soil moisture (Flanagan et Johnson 2005), so mowing caused decrease in grassland ecosystem R_{10} values in our experiment.

Precipitations increased grassland R_{10} values. However, the curve of CO_2 efflux dependency on the soil temperature has very similar slope, which means that the Q_{10} values did not differ much. There has been observed an increase in Q_{10} values with increasing soil moisture (Reichstein et al 2002, Janssens et Pilegaard 2003). However, this effect can be probably less obvious in grassland ecosystem than in the forest soil because of the presence of aboveground biomass. Chou et al. (2008) observed seasonal changes of the effect of rainfall on grassland CO_2 efflux. The effect of the rainfall was stronger in the beginning of the growing season (especially before the germination of the annual grass) than its end, and after a period of drought than of high soil moisture. When the soil is dry, the rainfall can increase the CO_2 efflux in different mechanisms. The first and fastest response is degassing of soil when additional water fills soil pores and replaces CO_2 concentrated air into the atmosphere. Addition of water to a dry soil also activates microbe activity, resulting in an increase of soil CO_2 efflux (Huxman et al. 2004, Chou et al. 2008, Liu et al 2002).

Conclusions

In conclusion, we can say that the seasonal course of temperature standardized CO_2 efflux values differed between our experimental objects. While it remained very similar during the whole period from May to October in the grass ecosystem, the significant increase in May and decrease in October occurred in the forest soil. The increase in R_{10} values was displayed also by tree stems but after a maximum in June and July they started to decrease slowly until October.

The experimental objects differed also in the response to the rain. While the forest soil responded rapidly with the increase in measured CO_2 efflux and temperature sensitivity, grassland ecosystem increased CO_2 efflux but the temperature sensitivity remained similar. Stem CO_2 efflux decreased as a result of decrease in temperature after rain but the temperature sensitivity was the same.

Acknowledgements

This work was supported by grants MSMT CR 2B06068 (INTERVIRON) and MSMT CR 1P05OC027 (COST 634)

References

Asencio, D., Penuelas, J., Ogaya, R. and Llusia, L. (2007): Seasonal soil and leaf CO_2 exchange rates in a Mediterranean holm oak forest and their responses to drought conditions. Atmospheric Environment 41: 2447–2455.

Atkin, O. K., D. Bruhn, Hurry, V.M. and Tjoelker, M.G. (2005): The hot and the cold: unravelling the variable response of plant respiration to temperature. Functional Plant Biology 32(2): 87-105.

Bolstad, P. V., Davis, K. J., Martin, J., Cook, B. D. and Wang, W. (2004): Component and whole-system respiration fluxes in northern deciduous forests. Tree Physiology 24(5): 493-504.

Boone, R. D., Nadelhoffer, K. J. Canary, J.D. and Kaye J.P. (1998): Roots exert a strong influence on the temperature sensitivity of soil respiration. Nature 396: 570-572.

Chou, W.W., Silver, W.L., Jackson, R.D., Thompson, A.W. and Allen-Diaz, B. (2008): The sensitivity of annual grassland carbon cycling to the quantity and timing of rainfall. Global Change Biology 14(6): 1382-1394.

Craine, J. M. and Wedin D.A. (2002): Determinants of growing season soil CO_2 flux in a Minnesota grassland. Biogeochemistry 59(3): 303-313.

Cooper, C.E., Thomas, S.C. and Winner, W.E. (2006): Foliar respiration in an old-growth *Pseudotsuga–Tsuga* forest. Canadian Journal of Forest Research 36(1): 216 – 226.

Davidson, E.A., Janssens, I. and Luo, Y. (2006): On the variability of respiration in terrestrial ecosystems: moving beyond Q_{10}. Global Change Biology 12(2): 154-164.

Ekblad, A. and Hogberg, P. (2001): Natural abundance of C-13 in CO_2 respired from forest soils reveals speed of link between tree photosynthesis and root respiration. Oecologia 127(3): 305-308.

Flanagan, L.B. and Johnson, B.G. (2005): Interacting effects of temperature, soil moisture and plant biomass production on ecosystem respiration in northern temperate grassland. Agricultural and Forest Meteorology 130: 237-253.

Gansert, D. and Burgdorf, M. (2005): Effects of xylem sap flow on carbon dioxide efflux from stems of birch (*Betula pendula* Roth).

Guay, D.G., Black, T.A., Barr A.G., Jassal, R.S. and Nesic, Z. (2008): Biophysical controls on rhizospheric and heterotrophic components of soil respiration in a boreal black spruce stand. Tree Physiology 28(2): 161-171.

Huxman, T., Cable, J., Ignace, D., Eilts, J., English, N., Weltzin, J. and Williams, D. (2004): Response of net ecosystem gas exchange to a simulated precipitation pulse in semi-arid grassland: the role of native versus non-native grasses and soil texture. Oecologica 141(2): 295-305.

Janssens, I.A., Meiresone, L., Ceulemans, R.(1999): Mean Soil CO_2 Efflux from a Mixed Forest : Temporal and Spatial Integration. In: Forest Ecosystem Modelling, Upscaling and Remote Sensing, Ceulemans R., Veroustraete F., Gond V., VanRensbergen J. (eds.), SPB Academic Publishing, The Hague, 19-31.

Janssens, I. A. and Pilegaard, K. (2003): Large seasonal changes in Q(10) of soil respiration in a beech forest. Global Change Biology 9(6): 911-918.

Jones, C., McConnell, C., Coleman, K., Cox, P., Falloon, P., Jenkinson, D. and Powlson, D (2005): Global climate change and soil carbon stocks; predictions from two contrasting models for the turnover of organic carbon in soil. Global Change Biology 11(1): 154-166.

Kim, M.H. and Nakane, K. (2005): Effects of flow rate and chamber position on measurement of stem respiration rate with an open flow systém in a Japanese red pine. Forest Ecology and Management 210: 469-476.

Kuzyakov, Y. and Cheng, W. (2001): Photosynthesis controls of rhizosphere respiration and organic matter decomposition. Soil Biology &Biochemistry 33: 1915-1925.

Lavigne, M. B. and Ryan, M. G. (1997). Growth and maintenance respiration rates of aspen, black spruce and jack pine stems at northern and southern BOREAS sites. Tree Physiology. 17: 543-551.

Linder, S. and Troeng, E. (1981): The seasonal variation in stem and coarse root respiration of a 20-year-old Scots pine (*Pinus sylvestris* L.). In: Tranquillini W, eds, Dickenwachstum der Bäume, Mitt. Forstl. Bundesversuchsanst. Wien. 142: 125-140.

Liu, X.Z., Wan, S.Q., Su, B., Hui, D.F. and Luo Y.Q. (2002): Response of soil CO_2 efflux to water manipulation in a tallgrass prairie ecosystem. Plant and Soil 240(2): 213–223.

Loveys, B.R., Atkinson, L.J., Sherlock, D.J., Roberts, R.L., Fitter, A.H. and Atkin, O.K. (2003): Thermal acclimation of leaf and root respiration: an investigation comparing inherently fast- and slow-growing plant species. Global change biology 9(6): 895-910.

McGuire, M. A. and Teskey, R. O. (2004): Estimating stem respiration in trees by a mass balance approach that accounts for internal and external fluxes of CO_2. Tree Physiology 24(5): 571-578.

McGuire, M. A., Cerasoli, S. and Teskey, R. O. (2007): CO_2 fluxes and respiration of branch segments of sycamore (*Platanus occidentalis* L.) examined at different sap velocities, branch diameters, and temperatures. Journal of experimental botany 58(8): 2159-2168.

Miyama, T., Kominami, Y., Tamai, K., Goto, Y., Kawahara, T., Jomura, M. and Dannoura, M. (2006): Components and seasonal variation of night-time total ecosystem respiration in a Japanese broad-leaved secondary forest. Tellus Series B-Chemical and Physical Meteorology 58(5): 550-559.

Pavelka, M., Acosta, M., Marek, M. V., Kutsch, W. and Janouš, D (2007): Dependence of the Q(10) values on the depth of the soil temperature measuring point. Plant and Soil 292(1-2): 171-179.

Pendall, E., Bridgham, S., Hanson, P. J., Hungate, B., Kicklighter, D. W., Johnson, D. W., Law, B. E., Luo, Y. Q., Megonigal, J. P., Olsrud, M., Ryan, M. G. and Wan, S. Q. (2004): Below-ground process responses to elevated CO_2 and temperature: a discussion of observations, measurement methods, and models. New Phytologist 162(2): 311-322.

Reichstein, M., Rey, A., Freibauer, A., Tenhunen, J., Valentini, R., Banza, J., Casals, P., Cheng, Y. F., Grunzweig, J. M., Irvine, J., Joffre, R., Law, B. E., Loustau, D., Miglietta, F., Oechel, W., Ourcival, J. M., Pereira, J. S., Peressotti, A., Ponti, F., Qi, Y., Rambal, S., Rayment, M., Romanya, J., Rossi, F., Tedeschi, V., Tirone, G., Xu, M. and Yakir, D., (2003): Modeling temporal and large-scale spatial variability of soil respiration from soil water availability, temperature and vegetation productivity indices. Global Biogeochemical Cycles 17(4).

Reichstein, M., J. D. Tenhunen, et al. (2002)" Severe drought effects on ecosystem CO_2 and H2O fluxes at three Mediterranean evergreen sites: revision of current hypotheses? Global Change Biology 8(10): 999-1017.

Rey, A., Pegoraro, E., Tedeschi, V., De Parri, I., Jarvis, P. G. And Valentini, R. (2002): Annual variation in soil respiration and its components in a coppice oak forest in Central Italy. Global Change Biology 8(9): 851-866.

Saveyn, A., Steppe, K., McGuire, M. A., Lemeur, R. and Teskey, R. O. (2008): Stem respiration and carbon dioxide efflux of young *Populus deltoides* trees in relation to temperature and xylem carbon dioxide concentration. Oecologica 154: 67-649.

Shibistova, O., Lloyd, J., Evgrafova, S., Savushkina, N., Zrazhevskaya, G., Arneth, A., Knohl, A., Kolle, O. and Schulze, E. D. (2002): Seasonal and spatial variability in soil CO_2 efflux rates for a central Siberian *Pinus sylvestris* forest. Tellus Series B-Chemical and Physical Meteorology 54(5): 552-567.

Stockfors, J. and Linder, S. (1998). Effect of nitrogen on the seasonal course of growth and maintenance respiration in stems of Norway spruce trees. Tree Physiology. 18: 155-166.

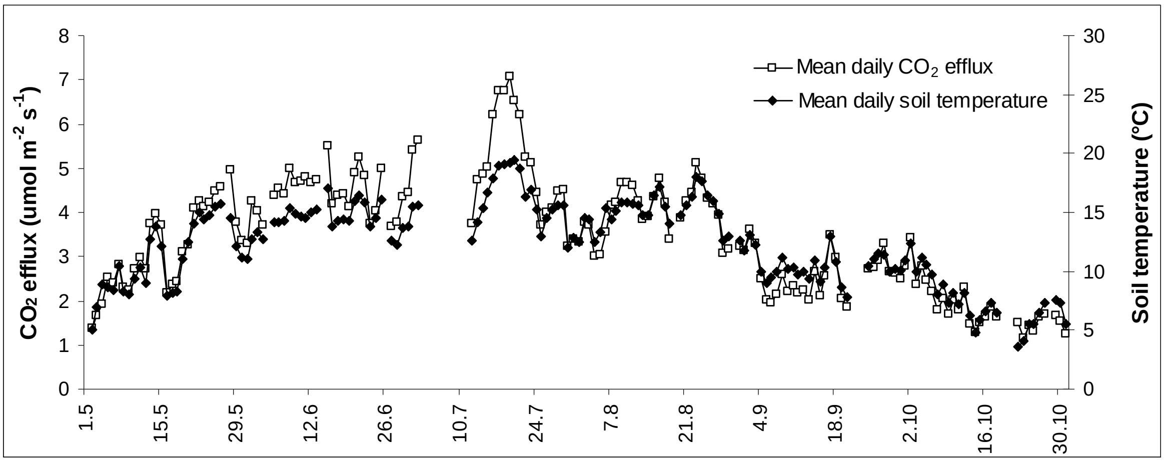
Tang, J.W., Bolstad, P.V., Desai, A.R., Martin, J.G., Cook, B.D., Davis, K.J. and Carey, E.V. (2008): Ecosystem respiration and its components in an old-growth forest in the Great Lakes region of the United States. Agricultural and Forest Meteorology 148: 171-185.

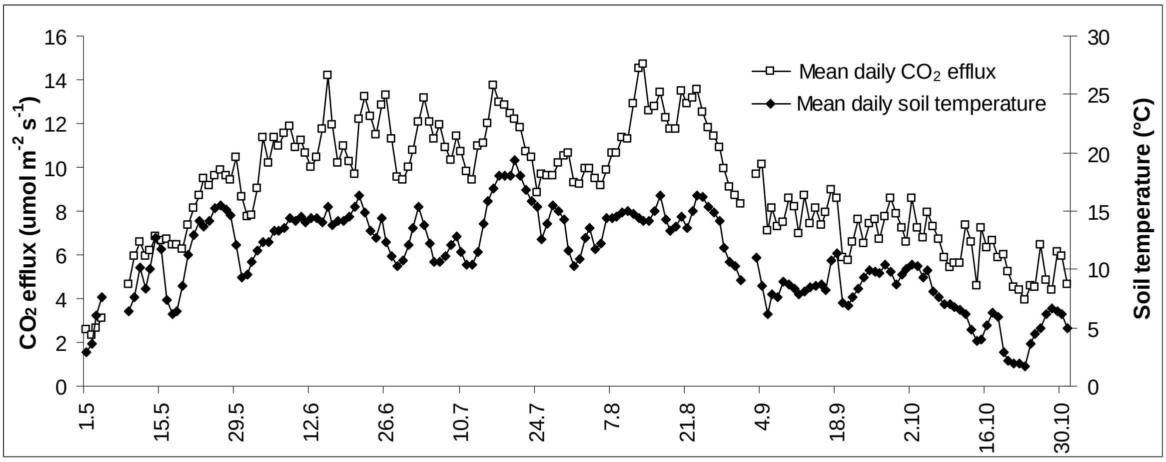
Tjoelker, M. G., Oleksyn, J. and Reich, P. B. (2001): Modelling respiration of vegetation: evidence for a general temperature-dependent Q(10). Global Change Biology 7(2): 223-230.

Xu, M. and Qi, Y. (2001): Spatial and seasonal variations of Q(10) determined by soil respiration measurements at a Sierra Nevadan forest. Global Biogeochemical Cycles 15(3): 687-696.

Zha, T.S., Kellomaki, Z., Wang, K.Y., Ryyppo, A. and Niinisto S. (2004): Seasonal and annual stem respiration of scots pine trees under boreal conditions. Annals of Botany 94(6): 889–896.

Supplement





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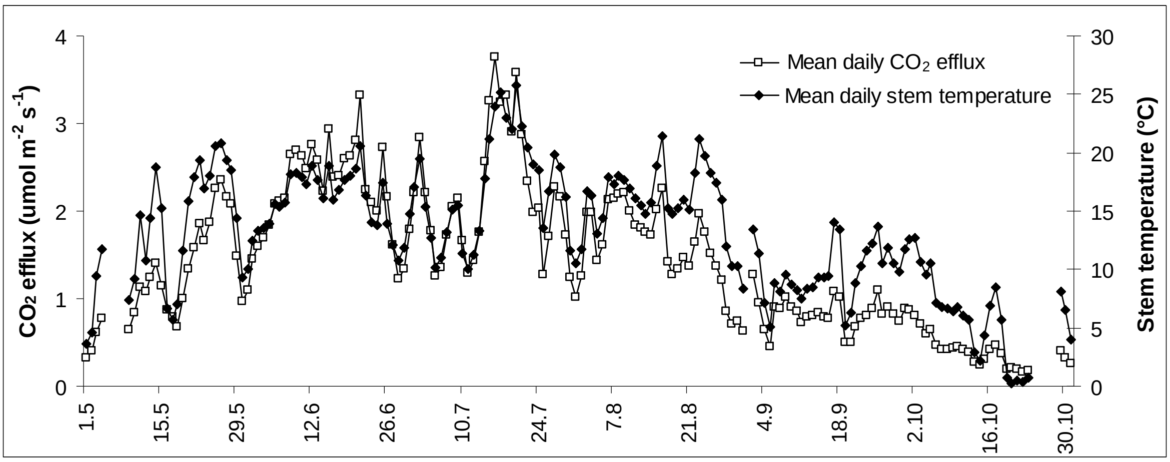
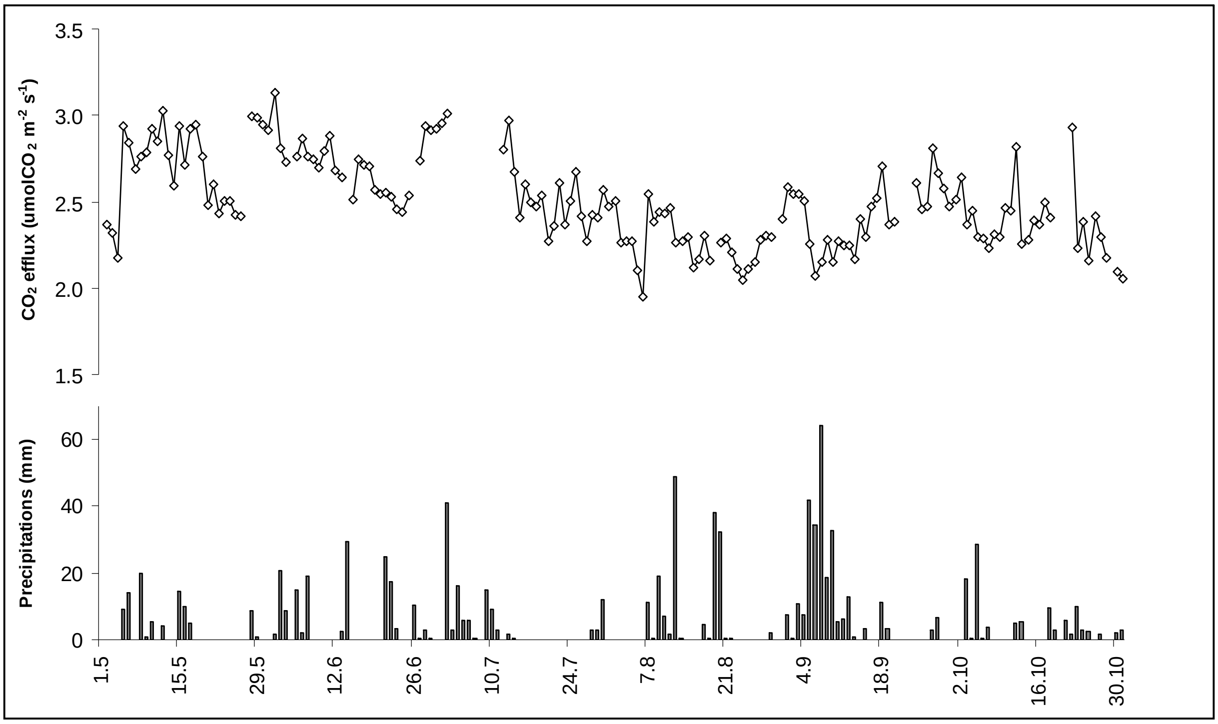
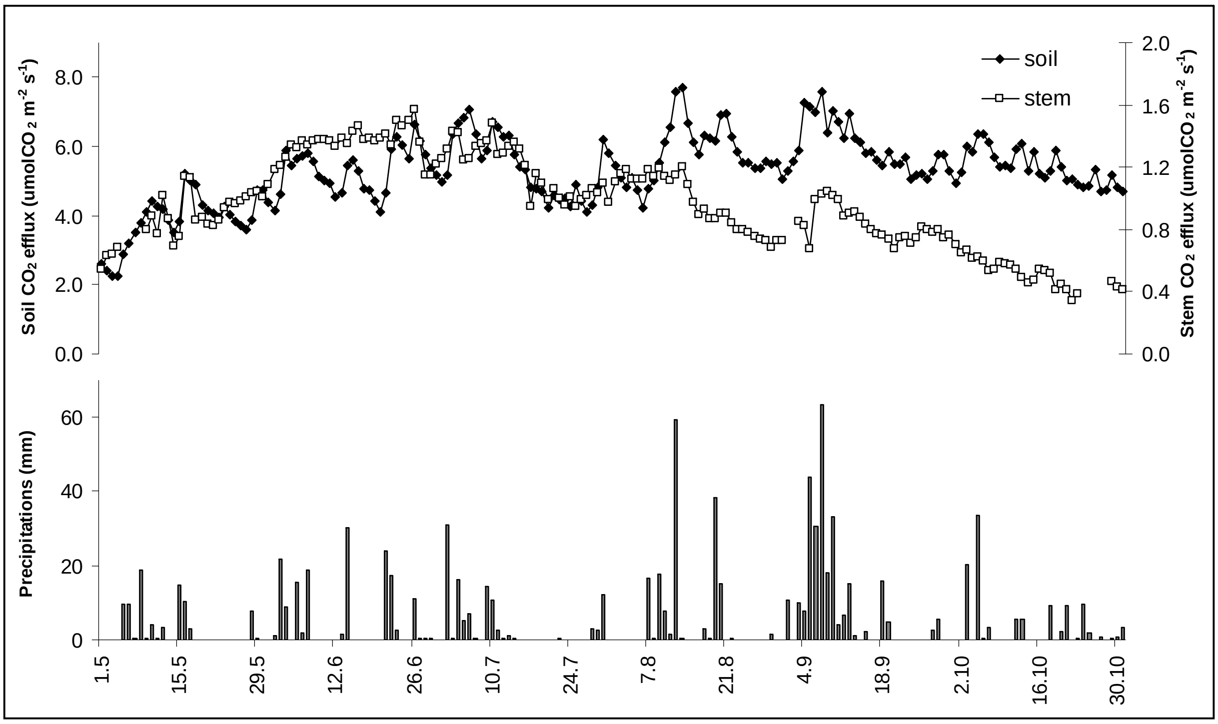


C

Fig. 1: Seasonal course of CO_2 efflux and temperature in the grassland (A), forest soil (B) and tree stems (C).



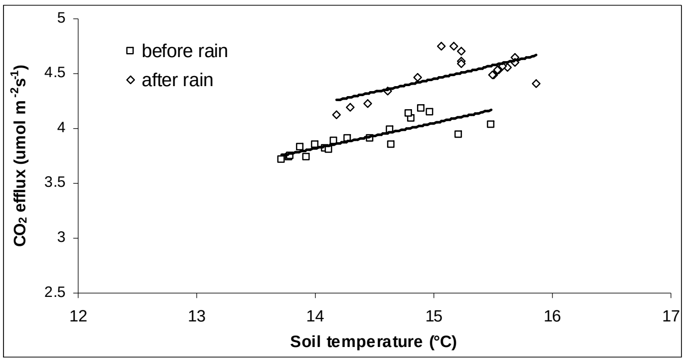
A

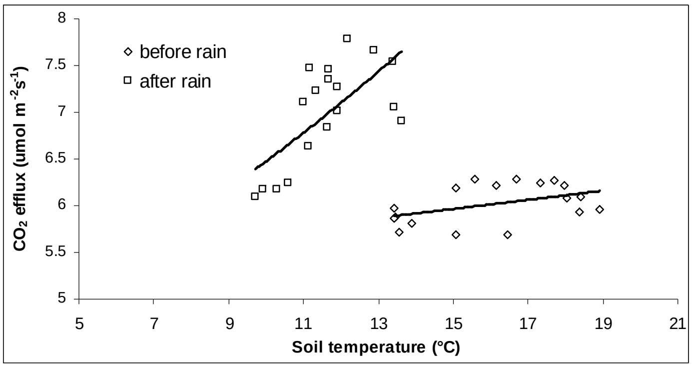


B

Fig. 2: Seasonal course of mean daily R_{10} and precipitations.
A – grassland, B – forest soil and tree stems

Rožnovský, J., Litschmann, T. (ed): „Bioklimatologické aspekty hodnocení procesů v krajině“, Mikulov 9. – 11.9.2008, ISBN 978-80-86690-55-1





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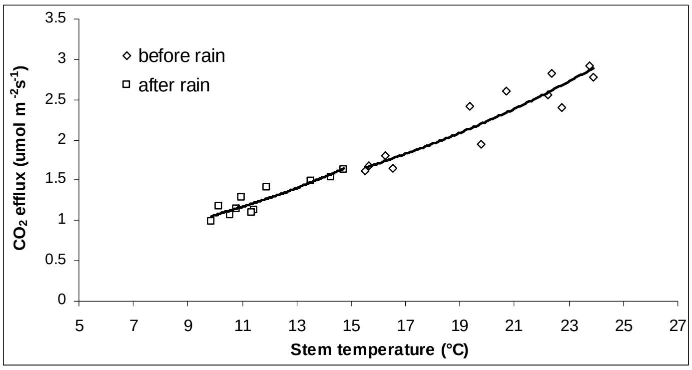

C

Fig. 3: CO_2 efflux dependence on soil temperature before (27.7.) and after (30.7.). The rain was of strength 3.08 mm on 28.7, 2.70 mm on 29.7. and 12.32 on 30.7.
A – grassland, B – forest soil, C – tree stems