Az OTKA K75638 kutatási pályázat zárójelentése

Az elvégzett munka - az OTKA támogatás feltüntetését tartalmazó publikációkkal dokumentáltan - ellenőrizhetően fedi a pályázatban tervezett kutatást. A fontosabb eredmények közé tartozik a talajlégzés-mérő rendszer kifejlesztése, s az ezzel a rendszerrel mért eredmények publikálása. Kiemelendő, hogy a közölt anyag egyik fontos része az említett saját fejlesztésű eszköz, illetve kalibrációjának és tesztelésének leírása (Nagy et al., 2011, Biogeosciences). A talajlégzés abiotikus és biotikus meghatározottságának jellemzése a munka további fontos eredménye (Balogh et al. 2011, Soil Biology & Biochemistry). A vegetáció reflektanciájának jellemzésére szolgáló légifelvételek 2010-ben és 2011-ben elkészültek, kiértékelésük - CO_2 áramoknak való megfeleltetésük - folyamatban van.

Eredmények:

- A talajlégzés mérésére automata, többkamrás (bővíthető), rendszert fejlesztettünk ki és - független rendszerrel szemben - kalibráltunk. A rendszer hosszabb idő (~3 hónap) alatt is megfelelően működött.
- A fenti rendszer eredményei alapján valószínű, hogy az eddy kovariancia módszerrel az ökoszisztéma légzés értékét alábecsüljük.
- A gradiens-alapú talajbeli CO_2-fluxus mérésekkel kimutattuk, hogy a bruttó primer produkció (GPP), illetve a nettó ökoszisztéma CO_2 gázcsere (NEE) és az ökoszisztéma légzés (R_{eco}) között a GPP=-NEE+R_{eco} kapcsolat az általában alkalmazott félórás skálán nagy valószínűséggel nem, hanem csak hosszabb időtartamra reprezentálhatja az ökoszisztémában lezajló folyamatokat. A hiba fő oka a lassúbb dinamikájú talajlégzés, illetve ennek a R_{eco}-n belüli dominanciája.
- A fenti hiba szárazságstresszelt ökoszisztémákban a talajrétegek között lefelé irányuló, jellemzően csapadékesemények után fellépő CO_2-áramok következtében jelentős lehet.
- az eddy kovariancia módszerrel kapott adatsorok jelentős hányadát általában pótolni kell, ezért fentiek az adatpótlásban okozhatnak szignifikáns hibát.
- A fentiek alapján az eddy kovariancia módszerrel rövidebb (félórás) időszakra meghatározható *felszín* szén(dioxid)-mérleg, nem azonos az *ökoszisztémában* lejátszódó folyamatokból ugyanarra az időszakra számított szénmérleggel.
- Kimutattuk, hogy a talajlégzés szempontjából optimális talajnedvesség-tartomány szignifikánsan függ a talaj agyagtartalmától, illetve meghatároztuk az említett változók közötti kapcsolatot.
- Kimutattuk, hogy a talajlégzésre (talajnedvesség és talajhőmérsékletre, mint független változókra) illesztett felület hőmérséklet-függést megadó egyik paramétere (az aktivációs energiát jellemző E_0) szignifikáns negatív kapcsolatban van a talaj felső 10 cm szerves szén tartalmával.
- Igazoltuk a talajlégzés nettó ökoszisztéma gázcserétől való szignifikáns függését, illetve meghatároztuk a két folyamat közötti átlagos késés mértékét.

További eredmények részletesebb leírását a közleményjegyzékben felsorolt publikációk adják. A fenti főbb eredményeket két cikkben közöltük, amelyek mérete meghaladja az OTKA honlapon megadott limitet (5MB), ezért ezen közleményeknek csak az első - az absztraktot tartalmazó - oldalát csatoltuk a jelentéshez.

Gödöllő, 2012 január 26.

Dr. Nagy Zoltán

Biogeosciences, 8, 2523–2534, 2011
www.biogeosciences.net/8/2523/2011/
doi:10.5194/bg-8-2523-2011

Biogeosciences

Carbon fluxes of surfaces vs. ecosystems: advantages of measuring eddy covariance and soil respiration simultaneously in dry grassland ecosystems

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Received: 26 January 2011 – Published in Biogeosciences Discuss.: 4 February 2011
Revised: 10 August 2011 – Accepted: 24 August 2011 – Published: 9 September 2011

Abstract. An automated open system for measurement of soil CO_2 efflux (R_{sc}) was developed and calibrated against known fluxes. The system was tested in the field, while estimating soil respiration simultaneously by the gradient method (R_{sg}) at a dry, sandy grassland site (Bugac, Hungary). Ecosystem respiration (R_{eco}) was measured using the eddy covariance technique. The small chamber size (5 cm in diameter) made it possible to use the chambers in vegetation gaps, thereby avoiding the necessity of removing shoots and disturbing the spatial structure of vegetation and the upper soil layer. Low air flow rates associated with small chamber volume and chamber design allowed the overpressure range to stabilize between 0.05–0.12 Pa. The correlation between ecosystem and soil CO_2 efflux rates as measured by the independent methods was significant, R_{eco} rates were similar or even lower than R_{sc} in the low flux (up to 2 µmol CO_2 m^{-2} s^{-1}) range but the differences were within the uncertainty limits for the two fluxes. R_{sc} from trenched and non-trenched plots amounted to 16 % and 44 % of R_{eco}, respectively. The gradient method showed both up and downward CO_2 fluxes originating from the main rooting zone after rains. Diffusive retardation played a smaller role than CO_2 production considering the soil air CO_2 concentration increase after rains in a given layer. Downward fluxes within the soil profile amounted to 15 % of the simultaneous upward fluxes and to ~7.6 % of the total (upward) effluxes during the 3-month study. The upper 5 cm soil layer contributed to ~50 % of the total soil CO_2 efflux. Downward fluxes are expected to seriously affect (1) the R_{eco} vs. temperature response functions and (2) the net ecosystem exchange of CO_2 (NEE) vs. photon flux density response functions, therefore potentially affecting the gap filling procedures and to lead to a situation (3) when the measured surface and the real time ecosystem fluxes will necessarily differ in the short term. Simultaneous measurements of R_{eco} and soil CO_2 effluxes may reveal the timing and magnitude of the decoupling, thereby contributing to decreasing uncertainty associated with eddy flux measurements over flat terrains. While the correlations between CO_2 effluxes measured by independent systems are strong, R_{sg} was generally larger than R_{sc} or R_{eco}, mainly due to overestimation of effective diffusivity in the soil.

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1 Introduction

The emission of CO_2 from the soil surface (R_s) represents the largest fraction (60–80%) of ecosystem respiration (Raich and Schlesinger, 1992; Janssens et al., 2002; Luo and Zhou 2006). Currently, most of the commercially available systems for R_s measurements use chambers with a diameter of 10 cm or greater. This size often necessitates the removal of aboveground plant biomass, especially in closed grasslands, where the average gap size between tussocks is <10 cm. Removal of above-ground biomass prior to taking measurements (usually 24 h before the measurements, Bahn et al., 2008) is a serious intervention, as it destroys the spatial structure of the vegetation, which can influence vegetation dynamics (Hook et al., 1994). Cutting and biomass removal affects radiation at the surface, soil temperature and moisture, increases plant stress and disrupts the photosynthate supply to roots and rhizospheric microbes (Tang et al., 2005a; Cao et al., 2004).

Published by Copernicus Publications on behalf of the European Geosciences Union.

Soil Biology & Biochemistry 43 (2011) 1006–1013

Contents lists available at ScienceDirect

Soil Biology & Biochemistry

journal homepage: www.elsevier.com/locate/soilbio

Dependence of soil respiration on soil moisture, clay content, soil organic matter, and CO_2 uptake in dry grasslands

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A R T I C L E I N F O

Article history:
Received 22 July 2010
Received in revised form
7 January 2011
Accepted 16 January 2011
Available online 2 February 2011

Keywords:
Soil respiration
Soil water content
Soil temperature
NEE
Clay content
TOC
Model
Activation energy
Substrate supply

A B S T R A C T

The effects of abiotic and biotic drivers on soil respiration (R_s) were studied in four grassland and one forest sites in Hungary in field measurement campaigns (duration of studies by sites 2–7 years) between 2000 and 2008. The sites are within a 100 km distance of each other, with nearly the same climate, but with different soils and vegetation. Soil respiration model with soil temperature (T_s) and soil water content (SWC) as independent variables explained larger part of variance (range 0.47–0.81) than the Lloyd and Taylor model (explained variance: 0.31–0.76). Direct effect of SWC on R_s at much smaller temporal and spatial scale (1.5 h, and a few meters, respectively) was verified.

Soil water content optimal for R_s (SWC_{opt}) was shown to significantly (positively) depend on soil clay content, while parameter related to activation energy (E_0) was significantly (negatively) correlated to the total organic carbon content (TOC) in the upper 10 cm soil layer. Dependence of model parameters on soil properties could easily be utilized in models of soil respiration. The effect of current (a few hours earlier) assimilation rates on soil respiration after removing the effect of abiotic covariates (i.e. temperature and water supply) is shown. The correlation maximum between the R_s residuals (R_{s_res}, from the R_s (SWC, T_s) model) and net ecosystem exchange (NEE) was found at 13.5 h time lag at the sandy grassland. Incorporating the time-lagged effect of NEE on R_s into the model of soil respiration improved the agreement between the simulated vs. measured R_s data. Use of SWC_{opt} and E_0 parameters and consideration of current assimilation in soil respiration models are proposed.

1. Introduction

In the last decades, a strong interest has arisen in soil respiration, due to widely used eddy flux studies and its problems on partitioning NEE. Eddy flux partition methods require simple but effective models in which main abiotic and biotic drivers of R_s are both taken into account.

At an annual scale, soil respiration (R_s) contributes 60–80% of ecosystem respiration (R_{eco}, Raich and Schlesinger, 1992) or 40–60% of gross primary production (GPP, Janssens et al., 2002). As a biochemical process, respiration is governed by temperature, and has been studied and described extensively (Lloyd and Taylor, 1994; Fang and Moncrieff, 2001). The dependence of soil respiration on temperature is generally utilized when partitioning R_{eco} (Campbell et al., 2004; Bahn et al., 2008). However, temperature dependence of R_{eco} has been shown to be strongly different between active and inactive periods due to the higher overall (active leaves and fine roots) activity of the vegetation in active periods (Reichstein et al., 2005). In other cases R_{eco} was shown to be connected only weakly to temperature, leading to problems with eddy data gap filling (Falge et al., 2001). These uncertainties in R_{eco} could arise from uncertainties in the estimation of soil respiration.

In addition to the temperature response, R_s was proven to be significantly limited both by low (Wan et al., 2007) and high (Davidson et al., 1998; Byrne et al., 2005; Saiz et al., 2007) soil water contents (SWC). Taking SWC into account is important when modeling the process of soil respiration in water limited ecosystems (Xu and Baldocchi, 2004; Jia et al., 2007; Nagy et al., 2007; Li et al., 2008). Simultaneous use of soil temperature (T_s) and SWC as independent driving variables in empirical models (Bahn et al., 2008) is straightforward in water limited cases (Wu et al., 2010). The importance of water filled pore space and tortuosity has already been elucidated in studies investigating physical soil properties and diffusion of solutes and gases in the soil (Moldrup et al., 1999; Jassal et al., 2004; Reth et al., 2008). One of the most difficult modeling tasks is the estimation of the effect of temporal

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0038-0717/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.soilbio.2011.01.017