



# The surface energy balance and its drivers in a boreal peatland fen of northwestern Russia



B.R.K. Runkle<sup>a,\*</sup>, C. Wille<sup>a</sup>, M. Gažovič<sup>b</sup>, M. Wilmking<sup>b</sup>, L. Kutzbach<sup>a</sup>

<sup>a</sup> Institute of Soil Science, Klima Campus, University of Hamburg, Allende-Platz 2, 20146 Hamburg, Germany

<sup>b</sup> Institute of Botany and Landscape Ecology, Ernst Moritz Arndt University Greifswald, Grimmer Straße 88, 17487 Greifswald, Germany

## ARTICLE INFO

### Article history:

Received 30 August 2013

Received in revised form 23 December 2013

Accepted 25 January 2014

Available online 4 February 2014

This manuscript was handled by Konstantine P. Georgakakos, Editor-in-Chief, with the assistance of Matthew McCabe, Associate Editor

### Keywords:

Energy balance  
Evaporation  
Boreal peatland  
Fen  
Russia  
Eddy covariance

## SUMMARY

Boreal peatland energy balances using the eddy covariance technique have previously been made in Alaska, Canada, Scandinavia, and Western Siberia, but not in the European portion of the Russian Federation. European Russia contains approximately 200,000 km<sup>2</sup> of peatlands and has a boreal (subarctic), continental climate influencing the region's energy balance. To help fill this research gap, the surface energy balance was determined for a boreal peatland fen in the Komi Republic of Russia for an 11-month period in 2008–2009 using the eddy covariance method. The total measurement period's cumulative energy balance closure rate was 86%, with higher closure during the critical summer growing season. Similar to other boreal peatland sites, the mid-summer shortwave radiation demonstrated albedo between 0.13 and 0.19 as calculated on a cumulative monthly basis, whereas monthly albedo was >0.9 during the months with greatest snow (January, February 2009). Mid-summer Bowen ratios averaged 0.20–0.25 on a cumulative basis, with monthly averaged mid-day values in the range 0.35–0.53 during the growing season. Latent energy (LE) fluxes exceeded 70% of net radiation and 60% of potential evapotranspiration. During the study period, total evapotranspiration (406 mm) was slightly greater than rainfall (389 mm), with later snowfalls creating excess moisture in the atmospheric water budget. These characteristics together point to a peatland whose energy balance behavior is generally consistent with data from other boreal fens. The LE fluxes were dominantly controlled by net radiation, with less canopy resistance than at other northern fens and a lighter role for vapor pressure deficit to play in the energy balance. The aerodynamic and canopy conductance terms were of similar magnitude, both through the season and through any given diurnal cycle. The consequently high decoupling coefficient ( $0.65 \pm 0.16$  in the growing season) allows further modeling of fens in this region with reduced effects from the uncertainties of parameterizing surface conductance terms and their responses to water table and vapor pressure deficit changes. The Priestley–Taylor method provides a reasonable approach to modeling evapotranspiration, given some assumptions about the site's energy balance closure. This understanding of the local drivers on the energy and water budgets has important implications for peatland ecology and growth, regional carbon dynamics, and downstream hydrology.

© 2014 The Authors. Published by Elsevier B.V. Open access under [CC BY-NC-ND license](https://creativecommons.org/licenses/by-nc-nd/4.0/).

## 1. Introduction

Boreal peatlands cover 3% of the earth's land surface and contain  $500 \pm 100$  Pg of organic carbon over their total peat depths (Yu, 2012), which is equivalent to 21% of the 2344 Pg that compose the global organic carbon stock stored in the first three meters of soil (Batjes, 1996; Jobbágy and Jackson, 2000). They are also susceptible to rapid changes in response to increased Arctic-region climate changes and variability (Bridgman et al., 2008; Dise, 2009). Recent studies have focused on the interactions between hydrology

and the carbon cycle in these environments, and there is general consensus that the hydrological cycle is an important first-order control to carbon fluxes, vegetation cover and changes, and on micro-topographic patterning (Billett et al., 2004; Couwenberg and Joosten, 2005; Limpens et al., 2008). Peatland hydrology, ecological functioning, and development are largely dependent on the local energy balance and whether precipitation is balanced by evapotranspiration (ET). Additional considerations include the effects of sensible (H) and ground (G) heat flux on the soil or moss surface temperature, which are critical for regulating bacterial activity and CO<sub>2</sub> or CH<sub>4</sub> production (Frolking et al., 2011).

The primary driver of latent energy fluxes (LE) in wetlands is generally seen to be net radiation ( $R_n$ ), with wetland LE/ $R_n$  ratios

\* Corresponding author. Tel.: +49 40 42838 2010; fax: +49 40 42838 2024.

E-mail address: [benjamin.runkle@zmaw.de](mailto:benjamin.runkle@zmaw.de) (B.R.K. Runkle).

generally exceeding 0.5 and fen values generally higher than bog values (Lafleur, 2008). The effect of the water table position is often of lesser importance though it does help determine canopy conductance ( $g_c$ ) as it controls the relative contributions of different ground components such as bare soil, mosses, or vascular plants (Lafleur et al., 2005; Sonnentag et al., 2010). Other studies have found some positive effect from lower water tables on ET, but these impacts may be confounded by the coupling to the synoptic meteorological conditions driving the water table conditions (i.e., less precipitation and higher vapor pressure deficit – VPD) (Wu et al., 2010). Tests of the peatland energy balance in land surface modeling schemes have estimated more accurate fluxes for fens than for bogs, in part due to the complexities of moss evaporation and its link to water table height, which often varies irregularly through a site (Comer et al., 2000).

The European part of Russia includes approximately 200,000 km<sup>2</sup> of peatlands, mostly in its boreal regions, thus composing more than 50% of the world's boreal peatland landscapes (Apps et al., 1993; Joosten et al., 2012). The potential of these sites for long-term carbon uptake is not assured due to a variety of climatic and biological factors ranging from increased temperature to carbon saturation in the sink mechanisms. While most research on northern peatlands focuses on Alaska, Canada, and Scandinavia, some energy flux research has been performed in the Russian taiga wetlands (Kurbatova et al., 2002). Their water relations and energy balances have long been studied (Romanov, 1968a; Ivanov, 1981), but the results of this research are often under-reported or delayed in English-language literature (Masing et al., 2010). For example, one relatively recent report (Shutov, 2004) describes the water balances of boreal peatland bogs in northwest European Russia based on investigations with weighing lysimeters in the 1970s. This report found significant reductions in peatland evaporation as the summer water level dropped below the threshold where the surface peat was wetted by the capillary fringe (i.e., to –50 cm). Comparing results from relatively wet and dry years, the authors found similar rates of evapotranspiration and assume it is driven more by vegetation cover than by water availability. As a result, in the relatively wet year, the ratio between evapotranspiration (ET) and precipitation (P), used as a climate wetness index with implications for peat growth and hydrology, was 0.38 whereas in the dry year the ET/P ratio was 0.47. In both cases, ET was 63% of global solar radiation so the change in the ET/P ratio was derived nearly entirely by the reduction in P rather than a change in ET. In contrast to the relative consistency of ET rates in different climate conditions, the authors do find spatial heterogeneity of ET across their peatland landscape, with open water and lake-filled regions evaporating more water than a hollow-ridge complex consisting of some bare peat surfaces.

There is some history of work using the eddy covariance methodology (Baldocchi, 2003) to determine the energy balance and drivers of evapotranspiration in the continental peatlands of Russia. For instance, a comparison between a European bog (Fyodorovskoye) and a central Siberian bog (Zotino) revealed strong LE fluxes relative to  $H$ , with higher Bowen ratios ( $H/LE$ ) in Fyodorovskoye (the approximate mid-summer average of a 5-day running mean ratio was 0.6–0.8 vs. 0.3, respectively) (Kurbatova et al., 2002). Both sites were characterized by close surface–atmospheric coupling through the effect of surface drying, limiting the role of net radiation in driving evaporative fluxes. This finding is in contrast to other work in a western Siberia bog (Shimoyama et al., 2004) that found a strong decoupling and therefore a large role for net radiation in driving the latent energy flux. Despite these studies, however, examples of the energy balance in Russian peatlands remain rare with a relative paucity of data compared to other regions (Lafleur, 2008; Wang and Dickinson, 2012). Finally, Russia's peatlands contain a diversity of hydro-ecological forms (Minayeva

and Sirin, 2012), and there seem to be no reports of Russian boreal fen energy balances in the eddy covariance literature.

Therefore the key objective of this study is to quantify and describe the diurnal and seasonal variations and drivers of the energy balance for a typical boreal peatland complex of the Russian Federation's Komi Republic. This site, like many in this region, contains both fen-like and bog-like portions. However, since the predominant wind direction at our measurement site created an average measurement footprint covering the fen portion, that region was made the focus of the study. This work compares the relative contributions of net radiation and vapor pressure deficit to controlling latent energy fluxes. It also explores drivers of canopy conductance and how these factors change over time. Finally, an 11-month energy balance is generated, and the evapotranspiration fluxes are contextualized within the water balance, including measured changes in the water table and rates of precipitation and snowfall.

## 2. Methods and site description

### 2.1. Site description and data collection

The study site is a typical river valley peatland in North-West Russia called the Ust-Pojeg mire complex (61°56'N, 50°13'E, 119 m a.s.l.) in the middle taiga region (Lopatin et al., 2008) of the Komi Republic (Fig. 1). The Komi Republic is at the eastern edge of European Russia and has a humid continental climate with warm summers and consistently freezing winter temperatures with continuous snow cover. The mean annual rainfall of Syktyvkar, capital of the Komi Republic and 50 km southeast of the field site, is 525 mm (1888–2012), and the mean annual temperature is 1.1 °C (RIHMI-WDC, 2013).

The river valley peatland site is in a transitional state from fen to bog following paludification and so consists of minerogenous, ombrogenous, and transitional zones; it lies within a region of the Komi Republic that has been classified as mainly containing ombrotrophic raised bogs (Vasander, 2007) and is not underlain by permafrost. The vegetation is dominated by sedges, dwarf shrubs, and *Sphagnum* mosses, and small microtopographic features such as hummocks, hollows, and lawns are evident. A transect survey through the site revealed peat depths of up to 2 m, and radiocarbon dating of the basal peat suggests that the peat development was initiated between 7500 and 9500 years ago, or even earlier (Pluchon, 2009).

The site's vegetation characteristics change in accord with the transitions between ombrogenous and minerogenous areas (Schneider et al., 2012). The ombrogenous bog in the site's northern part is dominated by *Sphagnum angustifolium* with dwarf *Pinus sylvestris* trees on hummocks. The minerogenous fen region in the south part contains *Sphagnum jensenii* and *Utricularia intermedia*. The transition region between the fen and bog parts of the peatland contains *Carex rostrata* lawns. Throughout the peatland the microrelief is further distinguished as tending to be composed of drier, elevated hummocks covered by *Andromeda polifolia*, *Chamaedaphne calyculata*, *Betula nana* and *P. sylvestris*; wetter hollows are composed primarily of *Scheuchzeria palustris* and *Carex limosa*. Canopy height and leaf area index therefore varied considerably through the site, though a reasonable average canopy height is approximately 20 cm. The vascular plant green leaf area index (GAI) was determined through measurements of leaf size and number in biweekly assays in 18 plots (60 cm × 60 cm; only the 9 plots in minerogenic areas are used for the GAI estimates referenced here); living moss cover was estimated as 0.75 m<sup>2</sup> m<sup>−2</sup> through the growing season (Schneider et al., 2012).

An eddy covariance system with a closed-path CO<sub>2</sub> and H<sub>2</sub>O gas analyzer (Li-7000, Li-COR Biosciences, USA) was used to measure

Download English Version:

<https://daneshyari.com/en/article/6413298>

Download Persian Version:

<https://daneshyari.com/article/6413298>

[Daneshyari.com](https://daneshyari.com)