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ScienceDirect
Russian Geology and Geophysics 50 (2009) 579–586
RUSSIAN GEOLOGY AND GEOPHYSICS
www.elsevier.com/locate/rgg

Temperature monitoring in Bakchar bog (*West Siberia*)

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Received 10 June 2008; accepted 27 August 2008

Abstract

We report the results of continuous temperature monitoring (812 days, from 28 June 2005 to 26 September 2007) in a 80 cm layer of peat soil in Bakchar bog (West Siberia), at sampling rates of 60 min in wintertime and 15 min in summertime. Both annual and daily temperature patterns are controlled by water table position and weather conditions. Wintertime soil temperature patterns are disturbed by the formation of a seasonal frozen layer with its thickness (freezing depth) depending on the time when steady snow cover sets up and on soil moisture. During the period of frozen layer thawing, the temperature of peat becomes sensitive to peat moisture and water table position as well as to the air and peat surface temperature. The warm-season soil temperature patterns bear effects of peat warming by rainwater percolation, both in night- and daytime. The patterns with soil warming during rainfall and phase change during seasonal freezing-thawing cycles record disturbances to conductive heat transfer.

Keywords: soil temperature patterns; autonomous digital temperature recorder; peatland soil; seasonal frozen layer; rainwater percolation; Bakchar bog

Introduction

Soil temperature is critical for many biotic and abiotic soil processes, such as plant growth and productivity, soil organic matter decomposition and mineralization, emission of greenhouse gases (Golovatskaya et al., 2008; Moore and Dalva, 1993; Vomperskii, 1994), release of dissolved organic carbon (Prokushkin and Guggenberger, 2007), etc. Soil temperature patterns are controlled by current climate, physiography and Earth's orbit, as well as by air-soil thermal interaction driven by geobotanic and geomorphologic factors (Pavlov, 1979). Below-zero air temperatures in the cold season produce a seasonal frozen layer in soils, which causes the respective changes to the thermal regime. The frozen layer increases the surface runoff during snow melting and rainfall, and prevents moisture from percolating down the soil profile.

Peat (organic) and mineral soils have different temperature patterns. Peat soil is a complex organic-mineral system with high water content and porosity, and with large amounts of underdecomposed organic matter (Romanov, 1961). Peatlands are the main source of greenhouse gases (CO_2, CH_4, and N_2O). Increase in these gases, which are produced by temperature-dependent microbial metabolism (Glagolev et al., 2008; Golovatskaya et al., 2008; Lafleur et al., 2005), has been a largely discussed but still poorly understood cause of the ongoing climate change (Kabanov, 2000; Semenov, 2004). On the other hand, warming of soil associated with climate warming increases emission of greenhouse gases. Methane and carbon dioxide production continues in wintertime as well, and their emission occurs through the seasonal frozen layer and snow (Pannikov and Dedysh, 2000).

Soil temperature monitoring in peatlands is important because the current climate warming is especially rapid in northern areas (Houghton, 2001; Ippolitov et al., 2007), the main pool of peat (and carbon). Peatland ecosystems have been estimated to store 120 to 455 billion tons carbon (Gorham, 1991; Vomperskii, 1994). The resources of peat carbon in Russia amount to 215 billion tons (Botch et al., 1995), of which up to 70 billion tons are sequestered in peatlands of West Siberia (Sheng et al., 2004). Climate change or human activity may cause this great amount of carbon to partly release into the atmosphere as CO_2 or CH_4 and thus to change the atmospheric carbon budget.

In addition to the climate change implications, high-resolution monitoring of soil temperatures can provide clues to the

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doi:10.1016/j.rgg.2008.08.010

complex patterns of heat transfer from near-surface air into rocks.

Below we discuss the instruments, methods, and results of soil temperature monitoring at a site of the Vasyugan mire in southern West Siberia. Preliminary results of the study were reported in (Dyukarev et al., 2006).

Background and instruments

Air and soil temperatures were measured in an oligotrophic pine–dwarf shrub–sphagnum bog (low ryam) at the Bakchar bog site (Bakchar district, Tomsk region). The low ryam microtopography is made up of 30 to 50 cm high flat moss hummocks occupying about 70% of the area and narrow (up to 2 m) hollows between them.

The local vegetation belongs to a pine-shrub-sphagnum community with low *Pinus silvestris f. litwinowii* in the suppressed tree layer. The tree layer consists of 2–3 m high and ~3 cm thick trees, with a projective cover of 30%. The shrub layer, abundant in hummocks, with a total projective cover of 60–70%, is composed of *Chamaedaphne calyculata* Linnaeus, *Andromeda polifolia* and *Vaccinium uliginosum*, with *Ledum palustre* L. and *Oxycoccus microcarpus* on hummocks. The grass layer has a projective cover less than 5 % and consists of *Eriophorum vaginatum* L., *Rubus chamaemorus* L. and *Drosera rotundifolia* clumps. The moss layer includes common *Sphagnum fuscum* Klinggr. on hummocks (95%) and *Sph. angustifolium* and *Sph. magellanicum* in hollows (Golovatskaya and Porokhina, 2005).

The low-ryam peat deposit is 2 m thick and has a mixed structure with low peat below high peat (up to 1.5 m thick) of medium (magellanicum) and low (fuscum) degrees of decomposition, separated by a thin transitional layer of woody-moss peat (Kabanov, 2003).

Air temperatures (T_a) were measured by an Onset corporation *HOBO Water Level Logger* (USA) at every 15 min.

Soil temperatures (T_s) were sampled at eight depth levels below the surface by an autonomous digital temperature recorder designed at the Trofimuk Institute of Petroleum Geology and Geophysics, Novosibirsk (Duchkov et al., 2005; Kazantsev and Duchkov, 1992). See Fig. 1 for the instrument layout and Table 1 for technical specifications. The digital recorder (Fig. 1) consists of a 16-bit analog-digital converter (ADC) and a microcontroller (single-crystal micro-computer). The microcontroller controls the ADC operation as well as switch of sensors and data storage and exchange with the external PC. Incoming signals from temperature sensors (thermistors) enter ADC through a switch and become stored as a digital code in a permanent flash storage for up to 20,000 eight-channel sessions. The basic ATR modification has eight measurement and two calibration channels. The recorder is started by a special integral timer (DS 1305). The sampling interval is programmed and can range from tens of seconds to tens of hours. After reading, preprocessing, and saving all data, the microcontroller switches the station to the standby mode. Drain is about 20 mA in the operating mode and about 50 μA in the standby mode. Power supply to the recorder is from a 3 V battery. Data are read on a PC connected to the recorder through a standard RS232 COM port. Memory fill is programmed; stored data are read and saved as table files. Before starting the recorder, the user specifies the sampling interval and cleans the memory if necessary. Once the PC is off, the recorder takes up the operating mode automatically.

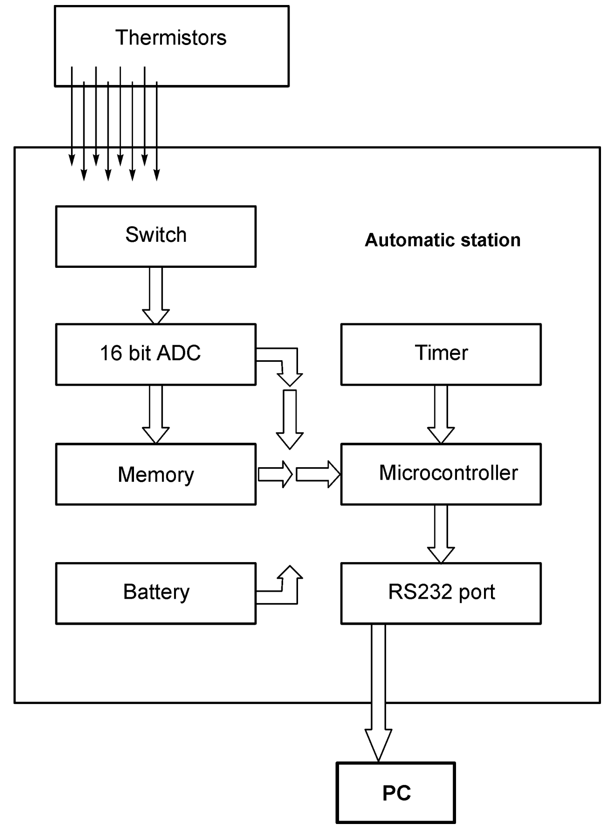

Fig. 1. Autonomous digital temperature recorder: Functional diagram.

The MMT-6 10,000 Ohm thermistors were calibrated against 0.01 °C mercury thermometers on a special laboratory stand and, correspondingly, the absolute temperatures were measured to a precision of 0.01–0.02 °C. According to our

Table 1
Specifications of autonomous digital temperature recorder

Parameter	Specification
Number of thermistors	1 to 16 (basic layout)
ADC, bit	16
Temperature precision	to 0.02 °C
Temperature sensitivity	to 0.002 °C
Operation temperatures	from –20 to +60 °C
Memory	permanent flash, up to 20,000 eight-channel sessions
Power	3–6 V Li-ion battery
Read-out	USB or RS232 port
Autonomous run period	up to 12 months
size; weight (in a water-proof container)	∅ = 40 mm, *L* = 200 mm; 1 kg