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Annual water temperature courses in two contrasting lakes at James Ross Island, Antarctica

Short Communication

Peter Váczi*, Josef Hájek

Department of Experimental Biology, Masaryk University, Kamenice 5, 625 00 Brno, Czech Republic

Abstract

In this Short Communication, long-term temperature courses of two contrasting Antarctic lakes are presented. The lakes differed in their different location, size, and origin. Big Lachman Lake is a typical coastal shallow lake located on a terrace at an altitude of about 9 m. Dulánek Lake is a small-area, shallow kettle lake located in the lateral moraine composed of the back-arc alkaline volcanic rocks of the James Ross Island Volcanic Group at the height of about 220 m a.s.l. The data presented in this study support an idea that the water courses differed between the two lakes due to altitude and local microclimate. Similarly, significant differences in annual and summer-season courses of water temperature were apparent when several consecutive seasons were compared. Such differences have consequences for water invertebrates and autotrophic organisms because of episodic drying out of some lakes and/or formation of long-term lasting ice.

Key words: lake, episodic drying, summer season, winter season, temperature differences

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Introduction

Since the beginning of Czech limnological and hydrological studies at James Ross Island research (2007), field studies have comprised water temperature measurements. Long-term temperature courses have been measured in several lakes and pools in northern part of Ulu peninsula (63.798 S, 57.810 W). In this study, two contrasting lakes, with different location, size, and origin were selected for measurements of water temperature courses. Big Lachman Lake is a typical coastal very shallow lake (Nedbalová et al. 2013) located on the early Holocene marine terrace

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*Corresponding author: Peter Váczi <vaczi@sci.muni.cz>
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(Ingólfsson et al. 1992) at the neck of Cape Lachman at an altitude of ~ 9 m (Czech Geological Survey 2009). The lake is fed by small snow patches accumulated on the lee side of the crest of the Cape Lachman neck. Nivation processes have been responsible for shaping both Lachman lakes basin (Davies et al. 2013). Summer season inflow might be insufficient and the lake may dry out episodically during some Antarctic summers, such as *e.g.* 2012 (Váczi et al 2011). The lake bedrock is made of Late Miocene glacigennic to glaciomarine sediments of the Mendel Formation (Nývlt et al. 2011) and covered by the Last Glacial Maximum sediments composed predominantly of large erratic boulders with sandy matrix of predominantly Antarctic Peninsula derived material deposited by northern Prince Gustav Ice Stream (Nývlt et al. in review). A very complex geological history of this area affects also the lithological heterogeneity of Lachman lakes sediments.

Dulánek Lake is a small and shallow kettle lake located in the lateral moraine composed of the back-arc alkaline volcanic rocks of the James Ross Island Volcanic Group (Nelson 1966, Košler et al. 2009). The lake is located nearby Windy Pass at the height of 220 m a.s.l. The area of the lake varies between seasons, however, it reaches mean value of about 20 m^2. The depth of water column varies within a season as well. It is about 1.1 m at the beginning of austral summer and declines to about 0.7 at the end of austral summer. Due to neighboring rock walls, it is sun-lit only for a limited period of a day which may have a consequence for water temperature in fully sunny days. Water temperature has been monitored since 2011 in this small-area pond (Váczi et Barták 2011).

Material and Methods

In Big Lachman Lake, water temperature was measured in the depth of about 0.3 m with temperature sensor (Cu-Co) linked to a data logging unit Minikin-Ti (Environmental Monitoring Systems, Brno, Czech Republic). The water temperature data has been recorded in 1h interval for the whole year. In this study, annual data of the years 2011 and 2012 are presented. In Dulánek Lake, the temperature measurement comprised the measurement of temperature profile within a water column. Temperature sensors (Pt-100) were set in the depths of 30, 40, 60 and 80 cm from the bottom of the lake. The sensors were connected to a datalogger EdgeBox V12 (Environmental Monitoring Systems, Brno, Czech Republic) and temperature data has been recorded in 30 min. interval.

Additionally, the comparative air temperature measurements were made. The sensors (Cu-Co) were placed in 30 cm over the stony surface close to the lake (close to surface, but not covered by snow) and the temperature were recorded in 30 min. interval by a MiniCube datalogger (Environmental Monitoring Systems, Brno, Czech Republic).

For each studied locality, annual courses of daily average temperature were calculated from measured data. For analysis of differences in annual courses, the data are presented as annual courses of daily average temperature differences calculated as a difference between daily average temperatures for particular day(s) of compared years (seasons). Thus, a single datapoint represents a difference between mean daily water temperature of a single day (*e.g.* Jan. 8th) in 2012 and 2011.

Results

Annual courses of water temperature for Lachman Lake are shown in Fig. 1. The daily average temperature varies in the range of -22.8°C (daily average recorded on August 8th 2011) to 12.2°C (daily average recorded on December 31st 2012). During austral summer, daily average temperatures varied form -3°C to 10°C usually (data from 2010-2012). With upcoming austral winter (March), average temperatures dropped below zero and remained till next summer (November). In all studied seasons, early winter temperature dropped in the second decade of March. During austral winter, daily average temperatures were under -10°C and rose over -5°C only occasionally. The beginning of summer season cannot be clearly identified from daily average temperatures above zero in the period from the second half of October to the end of November.

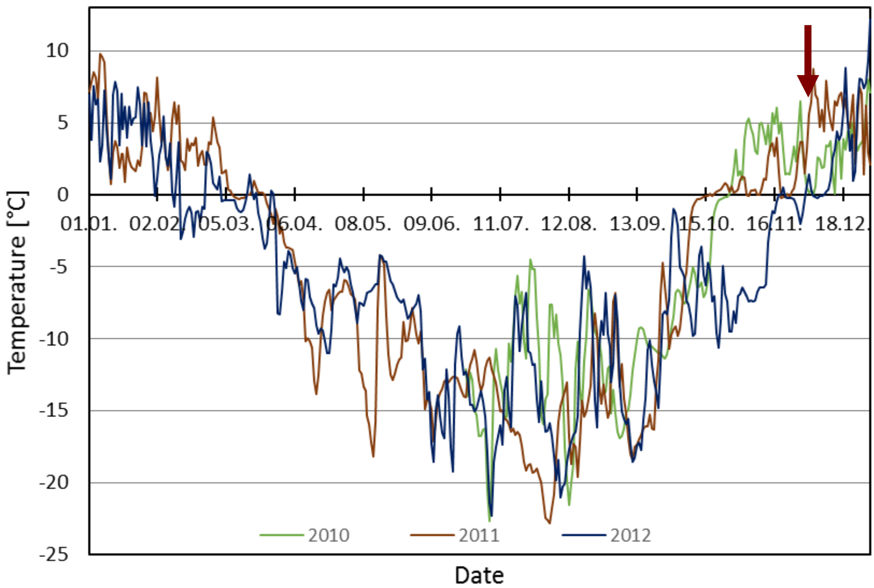

Fig. 1. Daily average temperature courses in Lachman Lake for years 2010, 2011 and 2012. Red arow indicates the beginnings of periods of non-freezing period probably caused drying out (2011) and refilling of the lake (2012).

For Dulánek Lake, daily average temperatures varied between minimum of -11.9°C (recorded on Aug. 5th 2011) and maximum 5.9°C (recorded on Feb. 2nd 2011), *see* Fig. 2. At the beginning of austral winter (during March), daily average temperatures decreased slowly from -1°C to their winter minima that varied between seasons from -8 to -12°C. At the beginning of austral summer (from the end of October to beginning of December), daily average temperatures rose from their minima to -2°C slowly. No ice was apparent at that period. Daily average temperatures below zero could be measured in mid-summer period (usually from first decade of January till first decade of February).

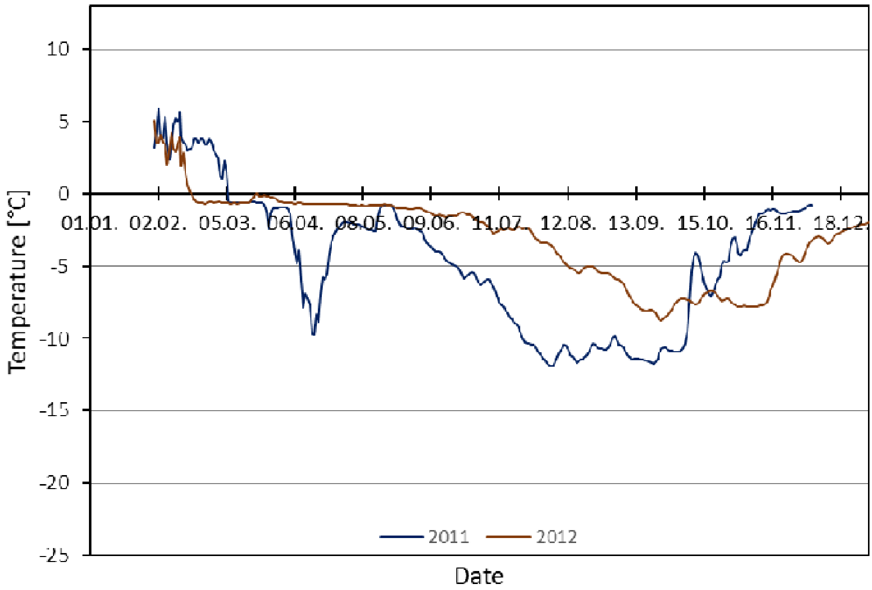

Fig. 2. Daily average temperature courses in Dulánek Lake for years 2011 and 2012.

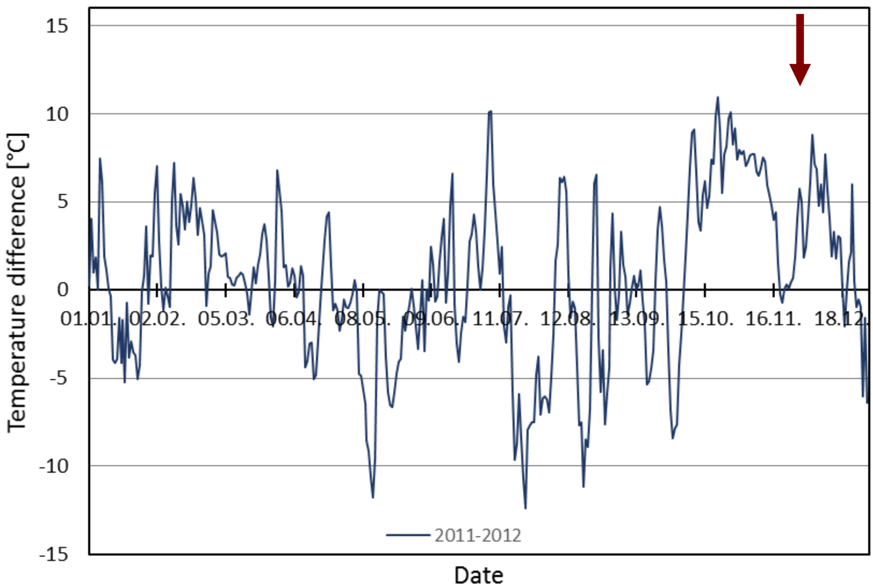

Fig. 3. Annual course of daily average temperature differences in Lachman Lake. Red arow indicates the beginnings of periods of non-freezing period probably caused drying out (2011) and refilling of the lake (2012).

However, daily average water temperatures may remain below zero during whole summer season. Thus, the lake is covered by ice during whole austral summer season occasionally, as happened *e.g.* in 2013 (data not presented).

Comparably, daily average air temperatures in 30 cm (data not shown) varied in similar manner, however, differences between maximo-minimum extremes were much more pronounced than in water. During austral summer (from April to September), daily average temperatures were around -0.25°C (mean) reaching maxima of 6.3°C (Nov. 12th 2012). Mean air temperature reached a value of about -14.3°C during austral winter (from December to February). Minimum daily average air temperature fell to a minimum of -29.8°C (July 25th 2011). Courses of daily average temperature differences for particular days of year in Lachman Lake varied between -12.7°C and +15.1°C.

Fig. 4. Annual course of daily average temperature difference in Dulánek Lake for 2011-2012 austral summer season.

Discussion and Concluding remarks

The data presented in this study support an idea that significant differences in annual and summer-season courses of water temperature may happen in Antarctic terrestrial lakes. Such differences have consequences for invertebrates and autotrophic organisms because of episodic drying out of some lakes and/or formation of long-term lasting ice „cores“ in some lakes resulting in reduction of physiologically active time for the organisms. In this Short Communication, we present an analysis of water temperature course in an Antarctic lake that can be used as indicator of temporal dying of shallow lake. It may be concluded that both mean daily temperature and/or difference between daily maxima and minima could be used as sensitive indicators of drying out and consequent re-establishment of water body at the beginning of winter season. In this Short Communication, we confirm that the period of dried lake Lachman 1 (Big Lachman Lake) lasted from end of November 2011 (25.11.2011 started longer nonfreezing episode) to the first decade of December 2012 (1.12.2012 started longer nonfreezing episode – possible thawing) as shown in Figs. 1 and 3. Such event will be expected to occur in future again when snow depositions in the lake surrounding are insufficient. Thus, temperature data may serve to evaluate the period of dry state of the lake when it happens.

In an earlier study (Hendy et al. 1972), it was demonstrated that water temperature beneath ice had a gradient according to dissolved chemical compounds and the amount of light penetrating through the ice layer. Later, the importance of long-term monitoring of water temperature in polar regions lakes has been stated many times. Hinkel et al. (2010) reported that the use of long-term water temperature data may contribute to the estimation of several processes ongoing in a shallow lake, such as *e.g.* sediment transport in the lake by wind-induced currents. Such data demonstrate that climatic gradients (*e.g.* temperature and wind), interacting with surface sediments and landforms, may have a spatially variable impact on lake dynamics. In Maritime Antarctica, a rapidly changing climate may lead to dramatic changes in freezing and thawing cycles of Antarctic lakes shown *e.g.* by Quayle et al. (2002) for the Signy Island. In recent studies, there is a trend towards functional analysis of the seasonal and inter-annual changes in physico-chemical parameters of Antarctic lakes and their effects on microbial community structure and development. It is particularly true for shallow, eutrophic, coastal lakes that freeze solid in the winter (Dieser et al. 2013). Winter freezing and, as shown in our Short Communication and earlier study (Váczi et Barták 2011), episodic summer drying may represent an important factor for microbial dynamics in a coastal lake. It will be a task for future studies at the James Ross Island to find a relation between physico-chemical lake characteristics, dominant species forming microbiological community and their physiological activities in particular. In this paper, we show that daily air/water temperature differences are indicative of episodic drying-out of an Antarctic lake.

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