Catena 149 (2017) 572–581

Contents lists available at ScienceDirect

Catena

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

Long term active layer monitoring at a warm-based glacier front from maritime Antarctica

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ARTICLE INFO

Article history:
Received 15 February 2016
Received in revised form 19 July 2016
Accepted 20 July 2016
Available online 30 July 2016

Keywords:
Soil thermal regime
Climate change
Cryosol
Permafrost
Periglacial regime

ABSTRACT

Knowledge on active-layer dynamics and permafrost distribution is of especial importance in Maritime Antarctica, where dramatic climate warming occurred in the last decades. Few long-term studies of active-layer temperatures in this region, and no one focus on recently deglaciated areas under paraglacial conditions. This paper analyses the long-term soil thermal regime of a warm-based glacial front site located at Low Head, King George Island. The monitoring system consists of soil temperature probes connected to a datalogger that recorded data at hourly intervals. We calculated the thawing days (TD), freezing days (FD), number of isothermal days (ID), number of freeze-thaw days (FTD), thawing degree days (TDD), freezing degree days (FDD), and the apparent thermal diffusivity (ATD). The results indicate that active layer thermal regime at Low Head is similar to other periglacial environments from Maritime Antarctica, with differences associated with the influence from the nearby warm-based glacier. Surface temperatures show greater variations during the summer resulting in frequent freeze and thaw cycles, mainly (1 cm and 10 cm). The temperature profile during the studied period indicates that the active layer thickness reached a maximum of 106 cm on February 7th 2015. Soil temperature buffering was limited by the low snow cover, low soil moisture, and absence of vegetation. Based on the high interannual variability detected during the five years monitoring run, we stress that longer monitoring periods are necessary for a more detailed knowledge on how permafrost respond to climate changes in this rapidly warming zone.

1. Introduction

International attention to permafrost degradation has increased since it has been recognized as a controller on landscape evolution and ecosystem responses to climate change in a global scale (Moss et al., 2010; IPCC, 2012; Bockheim et al., 2013; Mora et al., 2013). With reference to Antarctica, permafrost temperatures reported by an IPY extensive review by Vieira et al. (2010) were slightly below 0 °C in the South Shetlands Islands near sea-level, showing that this area of Antarctica is near the climatic boundary of permafrost. Also this region proved to have the highest sensitivity to climate change in this continent, according to a summary of active-layer and permafrost monitoring stations provided by Vieira et al. (2010).

Permafrost is a sensitive indicator of climate change, and temperatures ranges from −0.4 to −3.1 °C along the western Antarctic Peninsula region, where the greatest degree of warming (ca. 2.4–3.4 °C) has occurred over the past 50 years. A more detailed knowledge of the distribution and properties of Antarctic permafrost in this region is essential for the cryosphere and life sciences, since permafrost degradation represent a major control on ecosystem alteration following climate-induced changes (Vieira et al., 2010). The effects of climate warming on permafrost stability and distribution in the Antarctic Peninsula were discussed by Bockheim et al. (2013), highlighting a big gap in knowledge in many parts of Maritime Antarctica.

In the last several decades, glacier front recession in the Maritime Antarctic and Antarctic Peninsula region has accelerated with global

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http://dx.doi.org/10.1016/j.catena.2016.07.031
0341-8162/

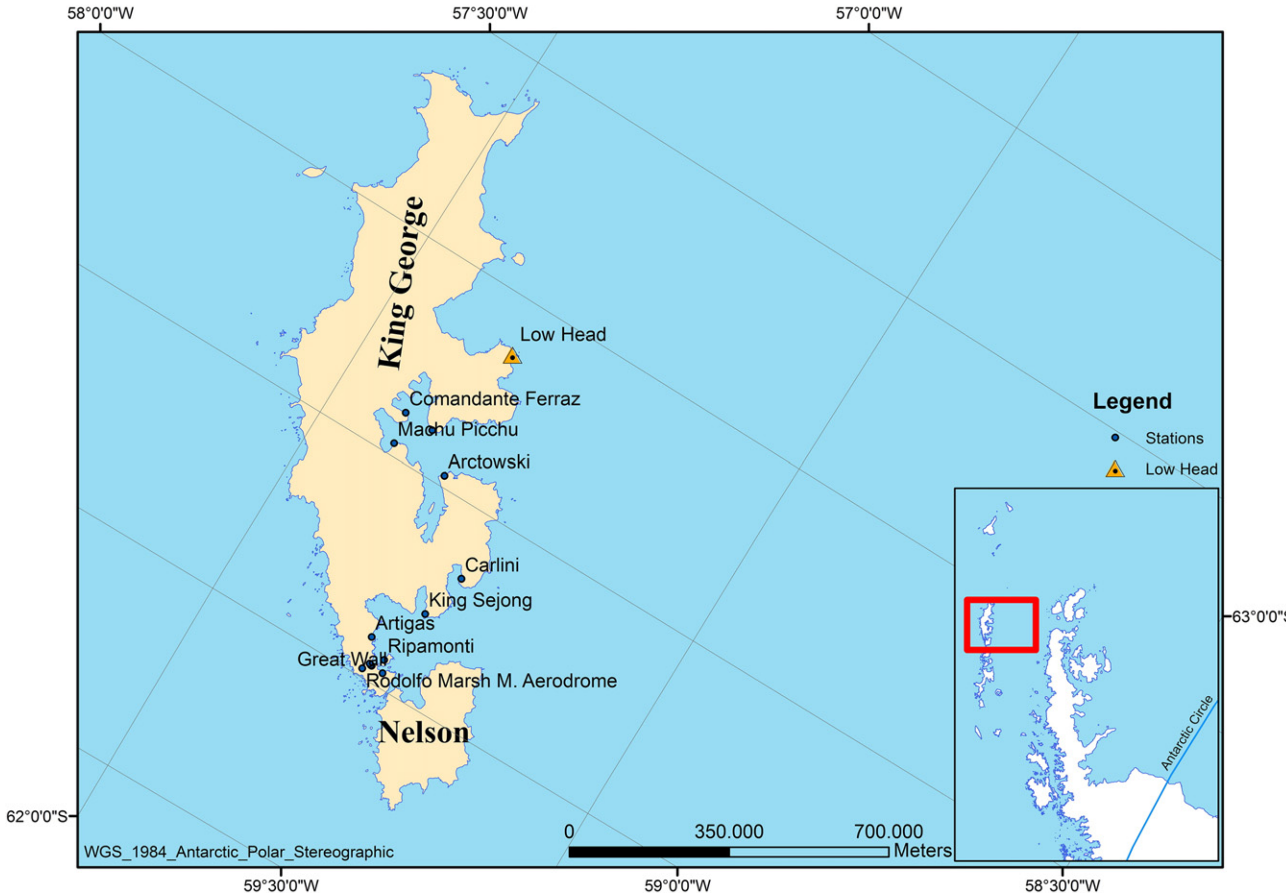

Fig. 1. Location of Low Head within Maritime Antarctica, South Shetlands Island and King George Island.

warming at unprecedent rates (Kozeretska et al., 2010; Rosa et al., 2011; Bockheim et al., 2013; Oliva et al., 2016b (this issue) leading to warm-based glaciers in most areas. Ferron et al. (2004) analyzing the monthly temperature averages recorded at various stations of King George Island detected an increase in the mean air temperature of 1.1 °C from 1956 to 2000, accompanied by a 12% frontal glacier retreat (Arigony-Neto, 2001). This process exposes new ice-free areas allowing plant colonization and formation of simple ecosystem at the glacier front zone, as well as frontal or lateral moraines. These new ice-free areas under paraglacial conditions quickly develop an active layer of unknown thermal regime. Changes in soil respiration rates, affecting the production or consumption of greenhouse gases (GHG) at the glacier retreat zone, especially CO_2 and N_2O, have been reported (Thomazini et al., 2015).

The regional climate exerts a first-order control on the active layer thermal regime, whereas local microclimate and the thermal state of the permafrost further affect ground surface temperatures at meso and microscales. Permafrost and active layer temperatures and distribution depend on climatic and topographic factors, such as air temperature, solar radiation, and snow cover, as related to aspect, slope angle and altitude (Luetschg et al., 2004). At a local scale, ground surface

Fig. 2. Landscape view of the monitoring site (A) and image of the soil profile (B).