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Active Layer Thermal Regime on James Ross Island, Antarctica

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1. INTRODUCTION

The active layer and permafrost are key elements of periglacial landscapes in Antarctica's ice-free regions. Variations in factors like permafrost temperature and the thickness of the active layer are valuable indicators of climate change, given their strong responsiveness to climate fluctuations (e.g. Vieira et al. 2010; Hrbáček et al. 2023). The northern part of James Ross Island, Ulu Peninsula, is probably the largest ice-free area in the Antarctic Peninsula region. Local conditions in terms of altitude, lithology, topography or vegetation abundance therefore provide favourable conditions for the soil wide range of research activities including thermal state of the active layer and topmost permafrost. In this contribution, we present the data on active layer thermal regime in the period 2006 to 2023.

2. METHODS

The monitoring network on active layer thermal regime managed by Department of Geography, Masaryk University, was initiated in 2006 when the first automatic weather stations providing also data of soil temperature up to 50 and 75 cm depth were installed. Since then, the monitoring was initiated at 12 localities (Fig. 1) containing more than 20 profiles with soil temperature monitoring between the surficial part of ground (2 cm) up to topmost part of permafrost (75 to 200 cm). The locality of the sites was selected to provide representative data for different lithologies and altitudes.

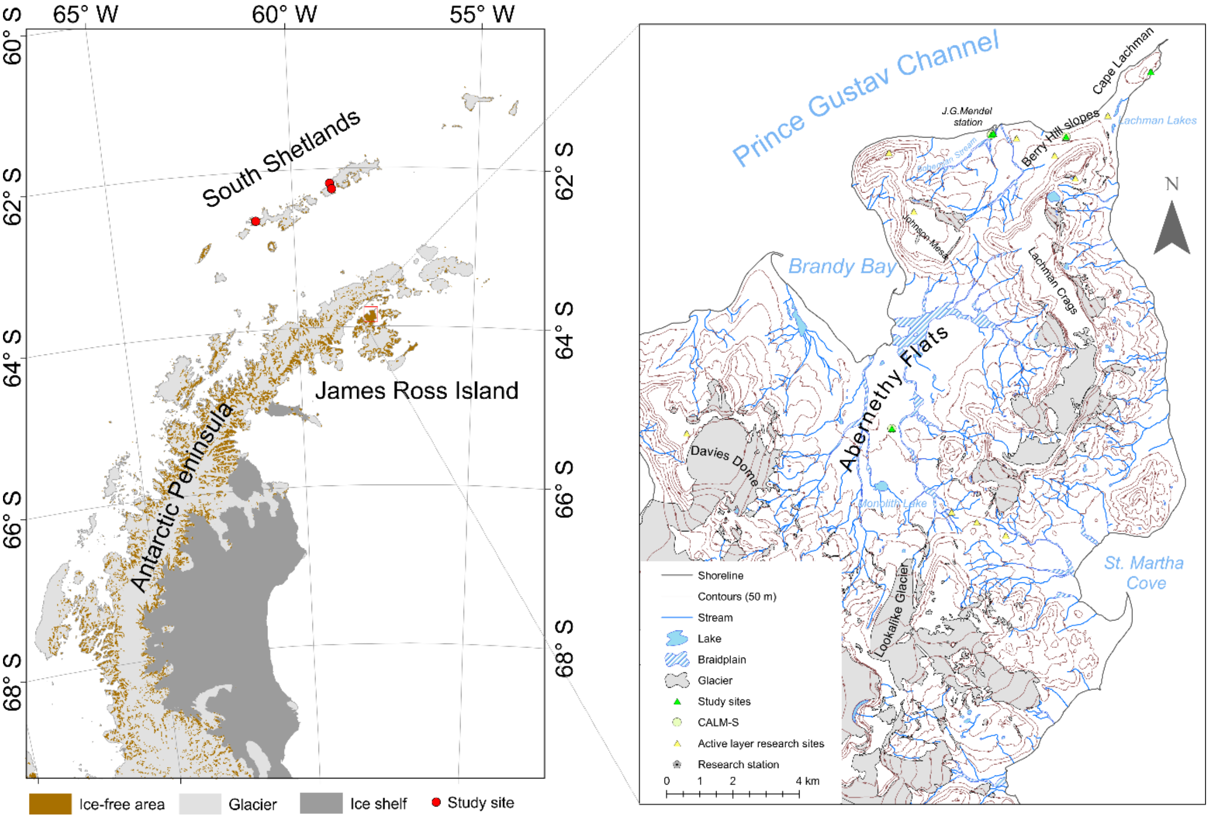

Fig. 1. Regional setting and the position of study sites on James Ross Island.

All sites have similar instrumental setting using resistance temperature detectors Pt100/8 or Pt1000/8 with an accuracy ±0.15 °C and record interval 30 minutes. In 2014, the first Circumpolar Active Layer Monitoring South (CALM-S) monitoring was initiated near to Johann Gregor Mendel Station, another two CALM-S measurements were started in 2017. To better understand active layer physical properties such as soil moisture and soil heat flux are also monitored on the selected sites. Further, the samples from selected localities were collected to set the soil texture, density, and soil thermal properties in laboratory conditions.

3. RESULTS AND CONCLUSIONS

The mean annual soil temperature on Abernethy Flats (45 m a.s.l.) providing the longest dataset available ranged from –5.7 °C to –6.0 °C at a depth 5 and 50 cm, respectively, in the period 2006 to 2023 (Fig. 2). The soil temperatures on other site of Ulu Peninsula were usually within +0.5 °C (lower elevated site) to –2.0 °C (higher elevated sites) when compared to Abernethy Flats. The study period can be divided into part of pronounced cooling by from 2006 to 2013/2014 which turned into warming continued until 2023, which was the warmest year recorded on James Ross Island. Overall, we detected warming trends of 1.81 °C/decade (5 cm, non-significant) and 1.43 °C/decade (50 cm, significant at $p < 0.1$).

Active layer thickness on James Ross Island is highly variable depending mostly on lithology and altitude. The usual annual thicknesses observed on automatic meteorological stations are between 50 and 90 cm. The maximum values > 130 cm were detected by manual probing on Circumpolar Active Layer Monitoring site near to Johann Gregor Mendel Station (CALM-S JGM). Importantly, the CALM-S JGM site very well express the importance of the lithological conditions which caused the differences in active layer thickness > 30 cm in the area of 80 to 70 m. Similarly, to ground temperature, active layer thinned before 2013/2014 (ca. 10–15 cm/decade) whereas thickening of the similar rate was observed since then.

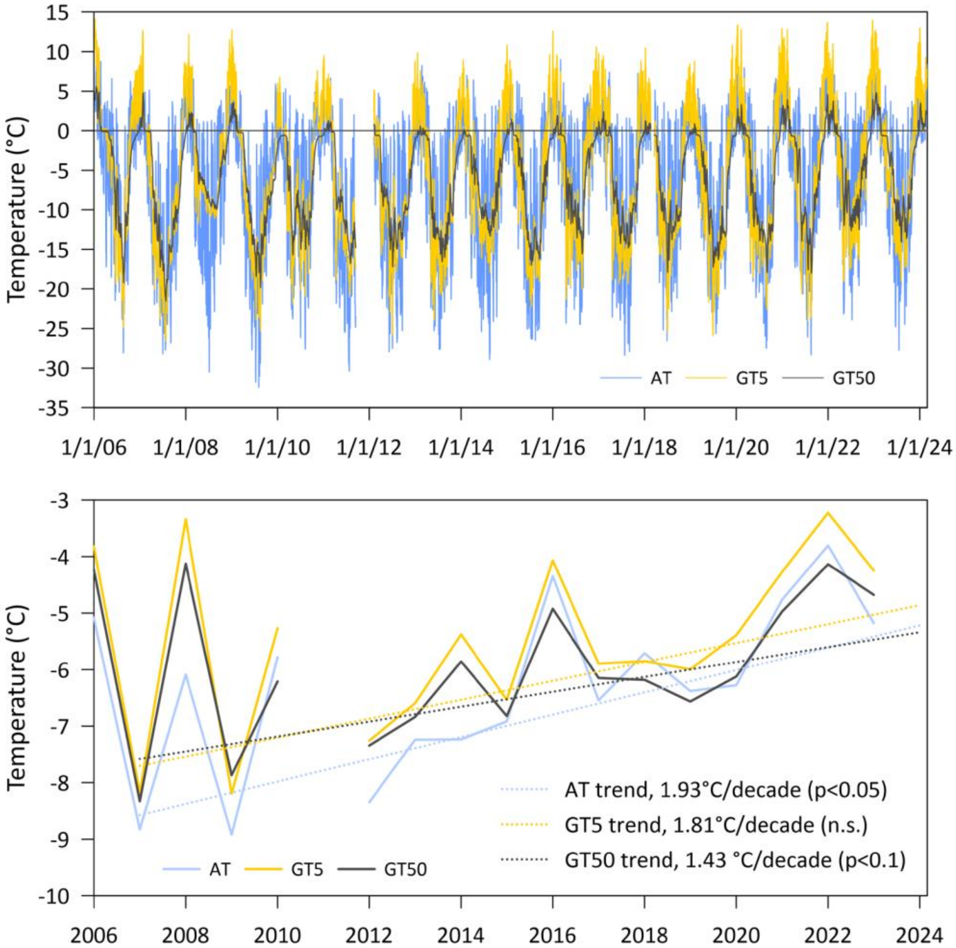

Fig. 2. Variability of mean daily (top) and mean annual (bottom) air temperature and soil temperature at a depth of 5 cm (GT5) and 50 cm (GT50).

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