Publications of the Institute of Geophysics, Polish Academy of Sciences
Geophysical Data Bases, Processing and Instrumentation
vol. 455 (P-5), 2025, pp. 191–194
DOI: 10.25171/InstGeoph_PAS_Publs-2025-123
40th International Polar Symposium – Arctic and Antarctic at the Tipping Point, 4–7 November 2025, Puławy, Poland

Vegetation Cover as an Indicator of Active Layer Status in Maritime Antarctica: First Results from Model Plots on South Shetland Islands and Argentine Islands – Kyiv Peninsula Region

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1. INTRODUCTION

Investigating the effects of climate change on permafrost and vegetation dynamics in Antarctica is of great importance. Vegetation plays a key role in modulating soil thermal regimes and ecosystem processes under climate change in Antarctica.

Until recent, only limited results are available from distinctive Antarctic regions. In continental Antarctica, climate warming has led to an increase in the thickness of the active permafrost layer (0.3 cm/year), improved soil drainage resulting in lower moisture content, and greater diversity of vegetation–particularly lichens–in drier areas (Guglielmin et al. 2014a). The research (Guglielmin et al. 2014b) also highlights the critical role of vegetation in regulating the thermal regime of soils in continental Antarctica. Vegetation changes can affect soil temperature and the thickness of the active layer, with significant ecological consequences, particularly for carbon storage in ecosystems. A decrease in moisture in East Antarctica has caused significant shifts in the composition, distribution, and growth of local vegetation, highlighting the vulnerability of Antarctic ecosystems to climate change (Robinson et al. 2018).

These changes contrast with the maritime Antarctic, where warming is usually associated with increased moisture and a different vegetation response. In the maritime Antarctic, the thermal regime of the active layer under different vegetation types at Signy Island was analyzed (Guglielmin et al. 2008). Results showed that vegetation significantly influences permafrost thaw dynamics: areas covered with vegetation carpet of *Deschampsia antarctica* É. Desv. and *Sanionia uncinata* (Hedw.) Loeske had a shallower active layer and lower soil temperatures compared to bare ground and *Usnea aurantiacoatra* (Jacq.) Bory cover. This highlights the key role of vegetation cover structure and its thermal properties in regulating heat flow into permafrost in the maritime Antarctic. The study (Cannone and Guglielmin 2003) also emphasizes the importance of vegetation in regulating the thermal regime of the soil's active layer in the maritime Antarctic. Different vegetation types, in terms of their composition, 3-D structure and cover area, can influence soil temperature, which in turn can affect permafrost stability and the overall ecosystem. The findings also highlight the need to use the "thawing degree days" index rather than "growing days" when assessing favorable conditions for cryptogamic vegetation growth in Antarctica. The effects of climate (air temperature and solar radiation) and vegetation on ground surface temperature and active layer thickness (ALT) in three Antarctic Conservation Biogeographical Regions between 60° and 74° S was investigated (Hrbácek et al. 2020). These findings emphasize the importance of accounting for moss type and its water retention properties to accurately model ALT variation and its climate change feedbacks.

Our study investigates the composition and characteristics of vegetation, with an emphasis on cryptogamic species, across research plots to examine their relationship with variations in the active soil layer and to assess the potential impacts of climate change.

2. MODEL PLOTS

The study is conducted in two remote regions within the maritime Antarctic – the South Shetland Islands and the Argentine Islands – Kyiv Peninsula region (Fig. 1). In the South Shetland

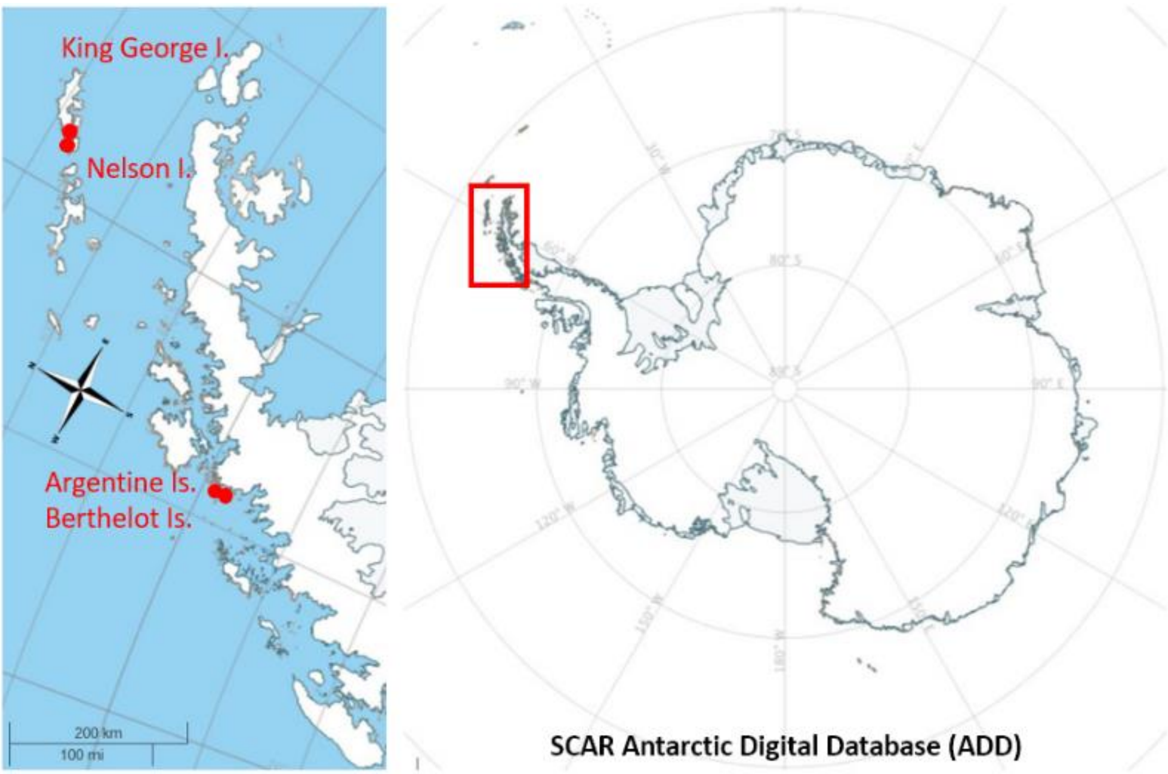

Fig. 1. Map showing the locations of research sites in this study.

Islands region, research plots have been established on Nelson Island and King George Island. On Nelson Island, in the northern part – the Stansbury Peninsula – model sites are located in various zones of the oasis. To encompass different vegetation types, contrasting biotopes caused by the differences in relief of the terrain were selected. The "Dry Hill" plot is dominated by dry Andreaea–Usnea association, with isolated patches of moss carpet sub-formation. On Fildes Peninsula of King George Island the study plot "Artigas" is dominated by dry Andreaea–Usnea association. The "Lakes" plot represents a typical area of bare soil with scattered moss patches. The "Green Valley" plot features a well-developed vegetation cover, represented by mosses with a relatively broad spectrum of diversity.

In the area of the Ukrainian Antarctic station Akademik Vernadsky, the Argentine Islands – Kyiv Peninsula region, regular monitoring sites were selected on Galindez Island (Argentine Islands) and the Berthelot Islands, a typical area of bare soil with patches of moss communities.

During the 3-year monitoring period, we developed and refined a specific measurement methodology. On the research plots, we conducted a study of the moss biodiversity with subsequent vegetation mapping within the plots. Using HydroSense II Handheld Soil Moisture Sensor (Campbell Scientific, USA) we measured moisture levels for individual vegetation fragments and bare soil. Additionally, using portable spectrometer PolyPen RP 410 UVIS (PSI, Czech Republic), we obtained the spectral characteristics of individual components of the moss communities.

3. RESULTS

The moisture in research plots ranged from 4.6 to 43.7% on dry Andreaea–Usnea association with fragments of relatively moist moss carpet sub-formation ("Dry Hill"), from 14.5 to 49% on moist moss carpet sub-formations ("Lakes"), from 11.8 to 68.7% on developed moist moss carpet formation with more dry margins with Andreaea–Usnea association ("Green Valley"), from 4.6 to 22.6% on dry Andreaea–Usnea association ("Artigas") in South Shetland Islands, and from 10.7 to 71.5% in moss turf and moss carpet sub-formations combination ("Galindez"), from 19.3 to 56.7% wet moss carpet sub-formation ("Berthelot") in Argentine Islands and Berthelot Islands, respectively. The lowest values were observed on bare soil plots, the highest values were measured in areas associated with rich bryophytes vegetation of moist moss carpet sub-formation. The contrast between dry Andreaea–Usnea association and wet moss carpet sub-formation registered. Within each polygon, certain fragments of moss communities dominated by specific moss species were also distinguished. These species differ in their characteristic moisture levels (including variations due to their physiological condition) and, accordingly, in their spectral characteristics.

Overall, the use of these differences provides a promising approach for identifying relationships between permafrost development, moisture levels, the composition of plant communities, and the spectral properties of individual species (and their physiological states) during large-scale monitoring using remote sensing methods. The heterogeneity of surface moisture and the associated condition of the vegetation cover that we have identified may be indicators of the dynamics of the active layer, which requires further research.

Acknowledgments. We express our gratitude Czech Science Foundation project (GM22-28659M) "Dynamics of the periglacial environment in the Antarctic Peninsula region under ongoing climate change". We are also grateful to the Ukrainian State Special-Purpose Research Program in Antarctica for 2011–2025.

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Received 15 September 2025
Accepted 20 October 2025