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Topographic and Atmospheric Controls on High-latitude Dust Deposition – An Example from James Ross Island, Antarctica

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1. INTRODUCTION

The Antarctic Peninsula (AP) is one of the well-known regions with high climate variability, recent atmospheric warming and related consequences to the cryosphere (Davies et al. 2014). The largest annual and winter air temperatures increase of 0.46 °C and 0.89 °C/decade was reported along the coast of AP (Turner et al. 2020). Changes in summer air temperature largely contribute to major part of the interannual variability of all cryospheric components, i.e. glacier mass balance, permafrost temperature or active layer thickness (Kaplan Pastíriková et al. 2023; Engel et al. 2024).

Historical observations suggest an increasing intensity of westerlies and their poleward shift since 1950s (Spence et al. 2014). The climatic forcing will cause a massive retreat of glaciers resulting in expansion of ice-free areas, especially in the AP region (Lee et al. 2017). The bare land left by retreating glaciers will be exposed to external agents shaping the landscape such as fluvial or aeolian processes. With the massive glacier mass loss recorded within the AP region (Cook et al. 2005), the fluvial processes were dominant. This is however likely to change when the glacier peak water is reached in the catchments affected by important glacier melt and the runoff declines (Huss and Hock 2018). Such drying of the landscape may consequently mean that the aeolian processes will become the leading factor shaping the deglaciated landscapes.

2. ARID ANTARCTIC LANDSCAPES DEVELOPMENT – JAMES ROSS ISLAND EXAMPLE

Despite the general observed trend of greening around the Antarctic Peninsula (AP) region (Roland et al. 2024), James Ross Island does not completely follow the trend. The greening i.e.

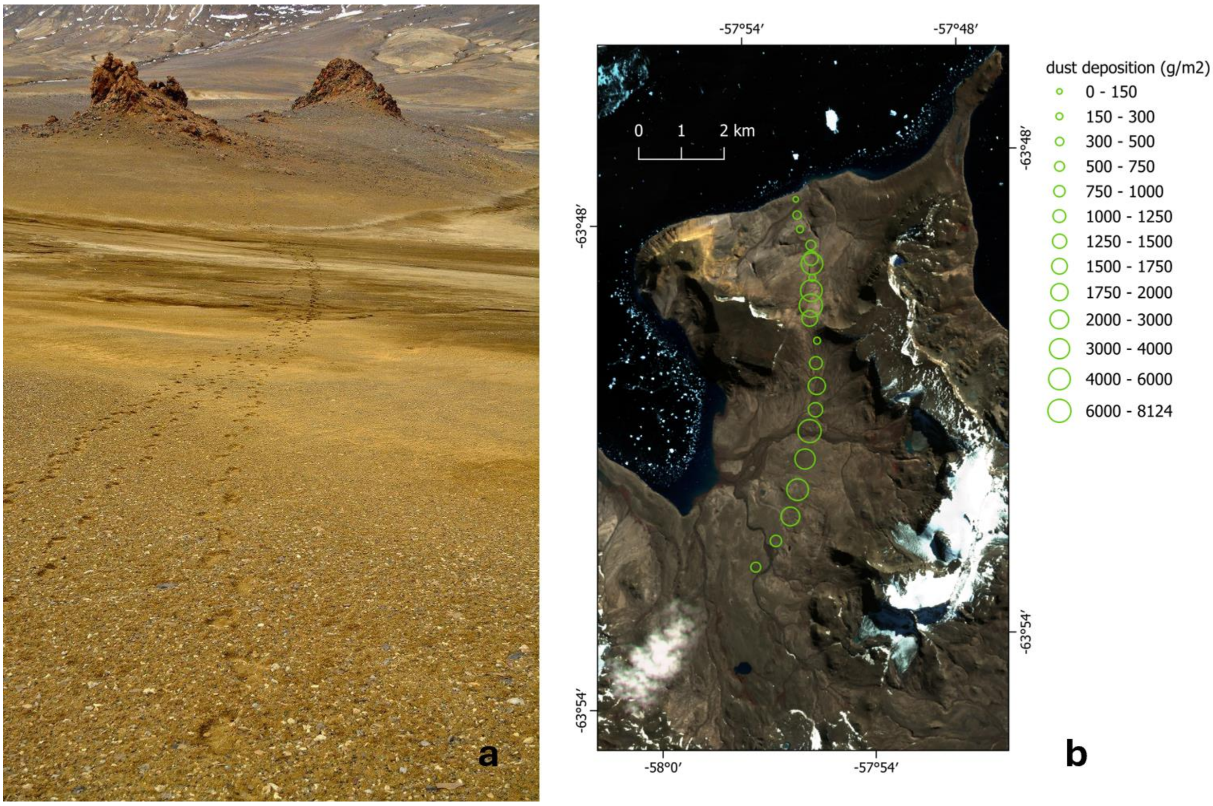

Fig. 1: (a) Dust deposition on the wet surface in the braidplain; (b) dust deposition pattern during the antarctic summer 2017/2018.

spreading of moss vegetation is observed in the western AP region influenced by increase of precipitation (Vignon et al. 2021) likely connected to increased intensity and frequency of atmospheric rivers (Maclennan et al. 2025). On the contrary, James Ross Island, located in the precipitation shadow of the AP mountain range, exhibits equally dramatic warming, but no trend in precipitation at all. This leads to prolonged snow free periods during summer, when the only source of freshwater is glacier/permafrost melt (Nedělčev et al. 2025). Recent warming is also reflected in persistent melt of local glaciers (Engel et al. 2023). The prolonged periods of snow free surface exposure during the summer resulted in increased likelihood of dust emissions and dust transport events as the surface dries out, supporting the uplift of mineral particles (Kavan et al. 2018), recorded also on the glacier surface (Kavan et al. 2020). The enhanced aeolian activity is also visible in the relief, where landforms typical for arid desert-like landscape can be found (Fig. 1a).

Transport of material by wind seems to be negligible on the first sight. However, our long-term measurements in passive aeolian samplers show that the amount of material transported by wind is approximately equal to fluvial transport in local streams. Moreover, based on the elemental composition analyses of fluvial and aeolian samples around the Bohemian Stream catchment, we hypothesize that aeolian material is by far the most important source of material further transported in the stream (Kavan et al. 2017; Kavan 2022; Stringer et al. 2024). Results from the network of passive aeolian samplers clearly indicated the areas where dust deposition was highest – the leeward sides of mountain ridges. Contrastingly, we recognized the river valleys as significant dust deposition centres with only minimum dust deposition on the leeward side of the streams (Fig. 1b).

3. FUTURE PERSPECTIVES

The continuous warming will likely result in significant differentiation between the western (maritime) and eastern (more continental) parts of the AP region. Prolonged snow-free periods will likely cause important surface drying and consequent intensification of the aeolian processes. One can assume that with the retreat and disappearance of local glaciers in the coming decades this process will become even more important.

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