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Modelling of active layer thickness evolution on James Ross Island in 2006-2015

Filip Hrbáček (1) and Tomáš Uxa (2,3)

(1) Masaryk University, Brno, Czech Republic (hrbacekfilip@gmail.com), (2) Department of Geothermics, Institute of Geophysics, Academy of Sciences of the Czech Republic, Praha, Czech Republic, (3) Department of Physical Geography and Geoecology, Faculty of Science, Charles University in Prague, Praha, Czech Republic

Antarctic Peninsula region has been considered as one of the most rapidly warming areas on the Earth. However, the recent studies (Turner et al., 2016; Oliva et al., 2017) showed that significant air temperature cooling began around 2000 and has continued until present days. The climate cooling led to reduction of active layer thickness in several parts of Antarctic Peninsula region during decade 2006-2015, but the information about spatiotemporal variability of active layer thickness across the region remains largely incoherent due to lack of active layer temperature data from deeper profiles. Valuable insights into active layer thickness evolution in Antarctic Peninsula region can be, however, provided by thermal modelling techniques. These have been widely used to study the active layer dynamics in different regions of Arctic since 1990s. By contrast, they have been employed much less in Antarctica. In this study, we present our first results from two equilibrium models, the Stefan and Kudryavtsev equations, that were applied to calculate the annual active layer thickness based on ground temperature data from depth of 5 cm on one site on James Ross Island, Eastern Antarctic Peninsula, in period 2006/07 to 2014/15.

Study site (Abernethy Flats) is located in the central part of the major ice-free area of James Ross Island called Ulu Peninsula. Monitoring of air temperature 2 m above ground surface and ground temperature in 50 cm profile began on January 2006. The profile was extended under the permafrost table down to 75 cm in February 2012, which allowed precise determination of active layer thickness, defined as a depth of 0°C isotherm, in period 2012 to 2015. The active layer thickness in the entire observation period was reconstructed using the Stefan and Kudryavtsev models, which were driven by ground temperature data from depth of 5 cm and physical parameters of the ground obtained by laboratory analyses (moisture content and bulk density) and calculations from ground heat flux measurement (thermal conductivity and thermal capacity). Model results were validated using the reference active layer thicknesses from the summer seasons of 2012/13 to 2014/15 with very good accuracy of 0 to 4 cm and -4 to 1 cm for the Stefan and the Kudryavtsev models, respectively.

Average active layer thickness on Abernethy Flats varied between 62 cm (Stefan model) and 60 cm (Kudryavtsev model) in period 2006/07-2014/15. Both models showed average active layer thinning of -1.3 cm.year-1 (Stefan model) and -2.3 cm.year-1 (Kudryavtsev model). Maximum active layer thickness was predicted in summer season 2008/09, reaching 75 cm (Stefan model) and 83 cm (Kudryavtsev model), while the minimum active layer thickness was observed in summer season 2009/10 when both models predicted 36 cm. Our results show that both models are well suited for conditions of Antarctica because their accuracy is in the order of the first centimetres. The nine-year series confirmed thinning of active layer in this part of Antarctic Peninsula region, which was mainly related to variability of summer air temperature.

References:

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