

Accelerated lowland thermokarst development revealed by drone photogrammetric surveys in the Stordalen mire, Abisko, Sweden

Maxime Thomas ¹(*Presenter*), Thomas Moenaert ¹, Julien Radoux ¹, Baptiste Delhez ¹, Éléonore du Bois d'Aische ¹, Maëlle Villani ¹, Catherine Hirst ^{1,2}, Erik Lundin ³, François Jonard ^{1,4}, Sébastien Lambot ¹, Kristof Van Oost ¹, Veerle Vanacker ¹, Matthias Siewert ⁵, Carl Magnus Mörtz ⁶, Michael Palace ⁷, Ruth K. Varner ⁷, Franklin Sullivan ⁷, Christina Herrick ⁷, Sophie Opfergelt ¹

AFFILIATIONS: 1. Earth and Life Institute, Université catholique de Louvain 2. Department of Earth Sciences, Durham University 3. Abisko Scientific Research Station, Swedish Polar Research Secretariat 4. Earth Observation and Ecosystem Modelling Laboratory, Université de Liège 5. Department of Ecology and Environmental Science, Umeå University 6. Department of Geological Sciences, Stockholm University 7. Department of Earth Sciences and Institute for the Study of Earth, Oceans and Space, University of New Hampshire

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One of the responses of permafrost terrains to climate change manifests locally by physical degradation, ground collapse and subsidence known as thermokarst development. Some thermokarst terrains can be monitored by satellite remote sensing, such as retrogressive thaw slumps or lake area losses, yet remain a challenge due to the highly dynamic nature and sometimes fine scale of these disturbances. For lowland landscapes for which thermokarst developments lead to the formation of ponds or wetlands, the study of degradation is even more complicated, since landscape deformations occur on a few tens of centimeters per year, both horizontally and vertically. Yet monitoring this type of thermokarst landscape is crucial, since greenhouse gas emissions from these landscapes are directly dependent on soil moisture conditions and microtopography. Here, we studied the rate of permafrost degradation in the form of lowland thermokarst using 10-cm resolution UAV-derived RGB orthomosaic and digital surface models over a time series from 2014 to 2022 in Stordalen, near Abisko, Sweden. It emerges that information on topography is crucial for obtaining a model with reasonable quality, i.e., it increases the overall accuracy of the model from 41% to 77%. We have shown that degradation accelerates significantly in recent years, with a decrease in intact permafrost area of 0.9 – 1.1%/a for 2019-2021, compared to 1970 – 2000 (~0.2%/a) and 2000 – 2014 (~0.04%/a). This physical degradation of permafrost leads to an increase in soil moisture, resulting in a decrease in organic carbon stability and a projected increase in methane emissions in the area. Similar studies across the Arctic also tend to show accelerating degradation in recent years: the loss of intact permafrost is expected to continue, with a non-linear decline, most likely at a higher rate than today. Using interferometric synthetic aperture radar (InSAR) satellite technology appears very promising for extending the analyses for larger areas, as they can detect vertical land surface motion at millimeter precision, yet still at a spatial resolution of several meters. Future work will need to examine the match between the degradation rates calculated using UAV-derived RGB orthomosaic and digital surface models and those calculated using InSAR.