Ponding vs. baydzherakh formation on Yedoma uplands: Implications for modern thermokarst development and thaw subsidence in North Yakutia

Frank Günther[1], Guido Grosse[1], Alexandra Veremeeva[2], & Georgy Maximov[3]

[1] *Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany*
[2] *Institute of Physicochemical and Biological Problems in Soil Sciences, RAS, Pushchino, Russia*
[3] *Melnikov Permafrost Institute, Russian Academy of Sciences, Siberian Branch, Yakutsk, Russia*

Permafrost landscapes of Northern Yakutia recently experienced a widespread warming of mean annual air temperatures and mean positive daily air temperatures during the arctic summer (Federov et al, 2014). Especially in the tundra zone this has led to increased active layer thickness (ALT) and suggests that thermokarst processes reactivate or intensify. However, particularly in the light of the enormous area underlain by ice and carbon-rich permafrost, still only few observations of permafrost-thaw related landscape dynamics exist. Permafrost degradation has consequences for local hydrology, ecosystems, biogeochemical cycling, and sometimes communities. For example in East Siberia, widespread and irreversible thaw subsidence of up to 11 cm per year has been detected on the arctic island Muostakh (Günther et al., 2015), where coastal erosion at average rates of 1.8 m/yr has not only reduced the island's area by 25% over more than 60 years, but also provides a constant renewal of the erosional base. In this case, favorable drainage conditions provide the prerequisite for active layer thickness deepening during warm summers, when ground ice stability thresholds are exceeded and ground ice thaw and subsequent terrain lowering take place. Our combined approach of ground-based ALT measurements and remote sensing-derived observations of elevation change revealed an inverse connection of shallow seasonal thaw and strong long-term subsidence, which is related to the minimum depth where permafrost thaw encounters pure ground ice bodies.

In this study, we focus not only on monitoring thermokarst and subsidence, but also aim to find commonalities and differences of change or no change on yedoma uplands, slopes, and thaw depressions on the landscape scale using multi-temporal digital elevation models (DEMs) from historical aerial photographies, modern satellite stereo imagery, and on-site repeat laser scanning campaigns. In this context, a best practice strategy for remote sensing data fusion combining 2D and 3D information from very high resolution imagery (GeoEye, WorldView, Kompsat, Alos Prism), complemented by local field measurements (meterology, ground temperature, geodetic surveys) on the Bykovsky Peninsula and Sobo-Sise in the Lena Delta, has been developed. In order to capture a large variety of sites across the Yedoma region, additional sites at Cape Mamontov Klyk in the Anabar-Olenyok Lowland, Bolshoy Lyakhovsky on the New Siberian Islands, and Cape Maliy Chukochiy in the Kolyma Lowland with less or no topographical ground control, were considered from the perspective of larger areal coverage.

Our high spatial resolution monitoring for the last decades and in comparison for the last years, shows that the current relief development in ice-rich permafrost enhances not only drainage of thermokarst lakes, but also drainage of the entire terrain, which leads to the formation of thermokarst mounds (baydzherakhs) on slopes of yedoma uplands. In contrast, simultaneous ponding on poorly drained massive Yedoma blocks in immediate proximity, suggests thermokarst development. However, formation of new thermokarst lakes on yedoma uplands is limited by topographical and stratigraphical constraints (Morgenstern et al., 2011). Geomorphological mapping of Yedoma and Alas surfaces, baydzherakh fields and areas of newly formed ponds allows to differentiate and link observed topographical changes to specific processes of either thermokarst or denudation. First results show that widespread modern baydzherakh formation is indicative for large-scale permafrost thaw subsidence on yedoma uplands.

References

Morgenstern, A., Grosse, G., Günther, F., Fedorova, I. & L. Schirrmeister [2011]: Spatial analyses of thermokarst lakes and basins in Yedoma landscapes of the Lena Delta, *The Cryosphere*, 5, 849-867,

doi:10.5194/tc-5-849-2011.

Günther, F., Overduin, P.P., Yakshina, I.A., Opel, T., Baranskaya, A.V. & M.N. Grigoriev [2015]: Observing Muostakh disappear: permafrost thaw subsidence and erosion of a ground-ice-rich island in response to arctic summer warming and sea ice reduction, The Cryosphere, 9, 151-178, doi:10.5194/tc-9-151-2015.