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Cold ice in a warm bath? Rapid retreat of a lake terminating glacier and warm proglacial lakes across Arctic Sweden

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Glaciers in contact with proglacial lakes show accelerated mass loss rates through mechanical and thermal processes, particularly through the formation of thermal notches in the ice front (Carrivick and Tweed, 2013). As glaciers retreat from their Little Ice Age maxima (∼100 years ago) and respond to increasing air temperatures (particularly in Arctic Scandinavia: cf July 2018) they often develop proglacial lakes. However, the prevalence, status and role of proglacial lakes in Arctic glacial systems have received relatively little attention. As a consequence, despite significant increases in air temperatures, a common assumption persists that smaller proglacial lakes remain at a uniform 1 C.

We present the first recorded proglacial lake temperatures and time lapse imagery from the front of an actively calving Arctic glacier (67.954878°N, 18.561535°E), which rapidly lost 10,523m2 of ice (0.67% of area in RGI, 2008) between 2014 to 2018. The changing geometry of the glacier terminus (including calving bay evolution) during this retreat is recorded throughout the melt season via high spatial resolution multispectral satellite imagery. We present temperature observations directly from the ice front in July 2017 from the innovative use of thermal infrared imagery, supplemented by several detailed thermistor temperature surveys (using a remote controlled boat). Previous melt models for lacustrine terminating glaciers have been compromised by a lack of data from the hazardous water to ice contact point and assume a uniform temperature (e.g. 1 C). Here we report night time temperatures of 3 C directly at the ice-water contact point following numerous ice berg calving events above thermal notches (captured in time lapse imagery). Day time maximum proglacial lake surface temperatures of 8 C were observed during the fieldwork and surface skin temperatures of 8C have been observed in ASTER satellite 2014 thermal image analysis.

We present thermistor data of lake surface temperatures that shows a strong validation (R2 = 0.9365) of the surface skin temperatures from the AST08 temperature product. At the regional scale, analysis of ASTER AST08 data demonstrate that 11 out of the 12 largest proglacial lakes in Arctic Sweden had daytime surface skin temperatures of >4 C in August 2014. Based upon these data we advocate (a) the extended use of the ASTER LST product for measurement of proglacial lakes surface skin temperatures for other regions and (b) the development of new high resolution thermal satellite sensors for investigating the surface skin temperature not only of proglacial lakes, but other water bodies and proglacial environments, such as fjord systems.

The temperatures reported by this study are substantially warmer than expected from an Arctic proglacial lake, which combined with rapid thermal notch development and associated calving, provides the first direct evidence of proglacial lake temperatures directly impacting on the retreat of an Arctic glacier.