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Increasing bed-to-surface transfer of topographical variations affects the distribution of surface lakes on the Greenland Ice Sheet after 2100

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Supraglacial (surface) lakes play a key role in the hydrological system of the Greenland Ice Sheet (GrIS) as they provide abundant and continuous water supply required for the establishment of hydraulic connections to the ice bed through thick ice. This process affects the seasonal evolution of the subglacial drainage system and ice flow velocity. The presence of surface lakes also decreases surface albedo, which leads to more intensive surface melting. Coverage of surface lakes expanded significantly towards higher elevations on the GrIS between 1972 and 2012 (Howat et al., 2013), yet projections of the changing future distribution of surface lakes are scarce, assume constant ice surface topography, and concern only the 21st century.

We recently demonstrated that the transfer of mesoscale – i.e. length-scales comparable to the ice thickness – basal topographical variability to the ice surface strongly determines the distribution of surface lakes on the GrIS through influencing the distribution of surface depressions (Ignéczi et al., 2018; Ng et al., 2018). Here we use this relationship – along with modelled GrIS geometry, ice flow and surface mass balance – to project the changing distribution of surface lakes on the GrIS until 2300 assuming both constant and evolving ice surface topography.

Our results show that the average increase in surface topographical variability on the GrIS will be 2.3-3.6% by 2100 and 35.1% by 2300, compared to 1980-1999. Although the increase in the total volume of surface lakes will slow down after 2100 – due to the lower density of surface depressions at high elevations – the effect of evolving surface topography becomes increasingly important. This effect will cause an extra 0.8-1.7% increase in the total volume of surface lakes by 2100 and 12.2% by 2300, compared to projections where the surface topography is constant. However, this is not uniform across the GrIS; the largest extra increase (exceeding 100% by 2300) is calculated in the interior of NW and NE Greenland, while close to the ice sheet margin a moderate decrease (< 25% by 2300) is projected. In conclusion, we propose that the assumption of constant surface topography does not significantly hinder the accuracy of surface lake projections made by previous studies for the 21st century. However, projections beyond 2100 should consider the effects of evolving surface relief.

References

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