PERMAFROST THAW

Diminishing Arctic lakes

The Arctic is home to the largest surface water fraction of any terrestrial biome, containing thousands of low-lying lakes. Now, it appears that some Arctic lakes are drying due to rising air temperatures and autumn rains, causing permafrost to thaw and water bodies to drain.

Rebecca Finger-Higgens

In the Arctic, scattered lakes of different shapes and sizes decorate the tundra landscape (Fig. 1). Yet some of these characteristic water bodies are disappearing. The most likely culprit for this vanishing act is thawing permafrost, which, as it degrades, leaves holes in a once stable layer of impenetrable frozen soil[1]. Lakes can empty rapidly as the water escapes through these holes as if someone had just pulled the drain from a bathtub. Now, new developments in remote sensing and machine-learning algorithms are advancing our abilities to estimate the extent and potential causes of northern-latitude lake declines[2]. Writing in *Nature Climate Change*, Elizabeth Webb and colleagues[3] present findings from satellite-derived data showing changes in Arctic surface waters over the past two decades, suggesting that northern lakes may be declining faster than previously predicted.

The Arctic is particularly vulnerable to change due to a rapid rate of warming that has already increased average temperatures in the region by 3 °C since the mid-1960s[4]. Longer periods with temperatures above freezing can cause permafrost soils, defined as Earth material that has been frozen anywhere from two years to several millennia, to thaw. Permafrost thaw impacts surface water balance through two common mechanisms: shrinking lakes due to subsurface drainage and expanding lakes as ice-rich soils create new water bodies[1]. When lakes drain, carbon-rich peat and vegetation can reclaim the area, potentially providing much-needed insulation to fragile permafrost and therefore serving as a global carbon sink with negative feedback to climate change[5]. Conversely, expanding lakes due to permafrost thaw may increase carbon flux to the atmosphere as previously frozen soils decompose and become a carbon source[6].

Additionally, because lakes are relatively dark compared with the more reflective surrounding tundra, the total surface water area is important for surface energy balance. Most models forecasting future lake dynamics have predicted that permafrost thaw will lead to an increased number of northern lakes through the early to mid-twenty-first century[6], potentially leading to more positive feedback with anthropogenic climate change. However, many of these predictions remain untested.

One factor that makes understanding the dynamics of Arctic surface hydrology particularly challenging is that the magnitude, and often even direction, of change is greatly impacted at both temporal and spatial scales. The Arctic is a vastly undeveloped region with limited roads, airports and urban areas, thus previous climate change research has been constrained to a few well-studied areas[7]. Recent advances in remote sensing and computing make even the most distant reaches of the Arctic easier to study, allowing for accurate observations and predictions of temporal lake dynamics across the Circumpolar North. The deployment of the Moderate Resolution Imaging Spectroradiometer (MODIS) in late 1999 now provides a 20-year archive of daily satellite-derived imagery that is available for the entire planet. Coupling MODIS-derived data with highly accurate reanalysed climate data allows skilled researchers to draw parallels between changes in the observed lake area and other potentially important variables.

Given the importance of understanding Arctic lake dynamics in a changing climate, Webb and colleagues took on the challenge by exploring potential changes with 20 years of satellite-derived MODIS data. Using the superfine water index (SWI) to quantify surface water change across lake-rich regions (at least 5% lake density by area) of the Arctic, the authors observed declines in the SWI for 82% of the modelled region. These findings of widespread declines in surface water area corroborate recent work that has explored more limited spatial scales of Arctic lake drainage[8], but contradict some of the proposed models that suggest that the early twenty-first century would bring about an increase in lake surface area[6].

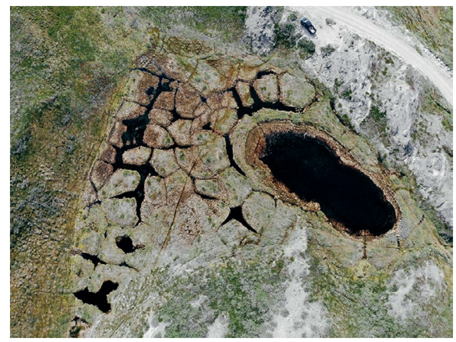

Fig. 1 | Aerial image of an Arctic lake in west Greenland with adjacent polygonal permafrost thaw ponds. In many parts of the Arctic, water bodies like this are draining as increases in average temperatures and fall rain are causing the underlying permafrost to decay. Credit: Robert Gill / Dartmouth College.

To explain the plausible mechanisms for lake area change, Webb and colleagues employed a machine-learning model incorporating both landscape and climate variables. The analysis shows that rising annual air temperatures and additional rain in the previous fall were the key drivers of surface water decline. Interestingly, changes in evapotranspiration did not appear to impact observed declines in Arctic lakes, suggesting that lake declines were driven more via subsurface drainage (likely due to permafrost thaw) than from a loss of surface waters to the atmosphere. Fall rain is particularly detrimental for permafrost stability as it can directly increase soil temperatures and thaw depth and indirectly delay freeze-up due to increases in latent heat[9]. These results also highlight the importance of considering changes in seasonal climate signals, as the magnitude and timing of precipitation events can influence regional hydrology.

The numerous lakes of the Arctic are vital to endangered wildlife, struggling rural communities, and carbon and energy balance, making their disappearance of immediate concern. An important next step to this work is to gain a better understanding of how Arctic carbon emissions might be impacted by drying lakes. As dry Arctic lake beds might serve as carbon sinks[5], this drying could mean that some predictions of carbon emissions from abrupt permafrost thaw may be too high[6]. Climate change is also credited with drying lakes in many temperate regions[10], meaning that Arctic lake drying might be part of a much larger global phenomenon. ❐

Rebecca Finger-Higgens ✉
US Geological Survey, Southwest Biological Science Center, Moab, UT, USA.
✉*e-mail: rfinger-higgens@usgs.gov*

Published online: 29 August 2022
https://doi.org/10.1038/s41558-022-01466-7

References

1. Smith, L. C., Sheng, Y., MacDonald, G. M. & Hinzman, L. D. *Science* **308**, 1429 (2005).
2. Nitze, I., Grosse, G., Jones, B. M., Romanovsky, V. E. & Boike, J. *Nat. Commun.* **9**, 5423 (2018).
3. Webb, E. E. et al. *Nat. Clim. Change* https://doi.org/10.1038/s41558-022-01455-w (2022).
4. Ballinger, T. J. et al. *Surface Air Temperature* OAR ARC; 21-02 (NOAA, 2021).
5. Jones, B. M. et al. *Nat. Rev. Earth Environ.* **3**, 85–98 (2022).
6. Turetsky, M. R. et al. *Nat. Geosci.* **13**, 138–143 (2020).
7. Metcalfe, D. B. et al. *Nat. Ecol. Evol.* **2**, 1443–1448 (2018).
8. Liljedahl, A. K. et al. *Nat. Geosci.* **9**, 312–318 (2016).
9. Douglas, T. A., Turetsky, M. R. & Koven, C. D. *npj Clim. Atmos. Sci.* **3**, 28 (2020).
10. Woolway, R. I. et al. *Nat. Rev. Earth Environ.* **1**, 388–403 (2020).

Competing interests

The author declares no competing interests.