Landsat-Based Lake Distribution and Changes in Western Alaska Permafrost Regions Between 1972 and 2014

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Lakes are an important landscape and ecosystem component in the high northern latitudes and they are hotspots for biogeochemical processes in permafrost regions. In this study, we utilized Landsat MSS and OLI images from the 1970s and 2014 to assess broad-scale distribution and changes of lakes larger than 1 ha in 6 major lake districts from various permafrost zones (continuous, discontinuous, sporadic and isolated) located in western Alaska. The lake districts that we included are Beringia, Baldwin Peninsula, Kobuk Delta, Selawik, Central Seward Peninsula, and Yukon-Kuskokwim Delta covering a total area of 68,831.41 km^2 (Fig 1). These regions encompass various types of lakes; thermokarst lakes are the most common type, while oxbow and delta lakes are also widely distributed in the river floodplains and delta regions. Additional lake types include maar lakes. The highest density of lakes is found in Yukon-Kuskokwim Delta with approximately 16% of the mapped area covered with lakes. The least number of lakes are found in Baldwin Peninsula with only about 2.5% of the mapped area covered with lakes. The lake districts in river deltas have the highest lake coverage (limnicity) with all three deltas (Kobuk Delta, Selawik and YK Delta) having above 10% lake area.

For 3 study regions (Baldwin Peninsula, Kobuk, and Yukon-Kuskokwim Delta) an increase in total lake area by less than 4% was observed, while the other 3 regions (Beringia, Central Seward Peninsula, and Selawik) showed lake area decrease ranging between 4 -15% (Fig 1). The most significant change was noticed in Beringia and Central Seward Peninsula due to drainage of very large lakes. We found net lake area loss of about 15.3% (6318.1 ha or 108.1 ha/100 km^2 net loss) and 12.4% (6542.1 ha or 110.2 ha/100 km^2 net loss) since the 1970s in Beringia and Central Seward Peninsula, respectively. We noticed that 20 lakes larger than 100 ha drained in Beringia that contributed a total lake area loss of 4471.8 ha whereas 2 lakes larger than 100 ha drained in Central Seward Peninsula that contributed a total lake area loss of 6391.1 ha. Selawik experienced the highest number of drainage events but because most of the lakes that drained were small, the net lake area loss in Selawik is the smallest among all. Draining lakes in the 1-50 ha category in Selawik contributed an area loss of 5021.1 ha, which is about 81% of the total drainage area (6171.2 ha) in the region. Additionally, we saw expansion of lakes larger than 100 ha in Selawik by 7% (2812.3 ha) due to creation of water channels that coalesced multiple large lakes in the delta region. Hence, we observed a net lake area loss of 3.9% (3358.9 ha or 52.9 ha/100 km^2 net loss) in Selawik.

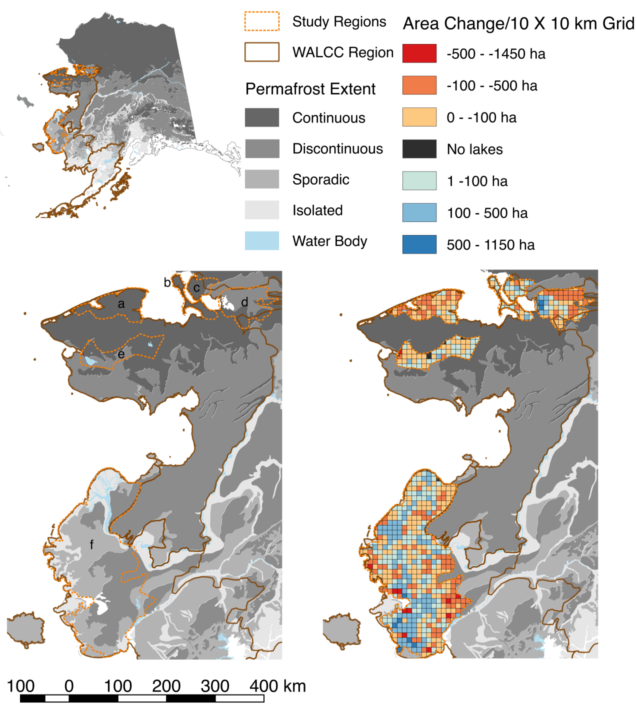

Figure 1: Maps showing study areas and lake area change in hectare per 10×10 km grid in each study site. Study sites are (a) Beringia, (b) Baldwin Peninsula, (c) Kobuk Delta, (d) Selawik, (e) Central Seward Peninsula, and (f) Yukon-Kuskokwim Delta. Permafrost extent overlaid on the maps is from Jorgenson et al. (2008)*

In Baldwin Peninsula, there was a net increase in total lake surface area by 3.9% (204 ha or 9.7 ha/100 km^2 net gain) due to expansion and coalescence of smaller lakes. In Kobuk, we observed formation of water channels fusing multiple large lakes in the delta region that contributed to a net lake area increase of 1.4% (383 ha or 19.9 ha/100 km^2 net gain). Complex hydrological and landscape characteristics of the Yukon-Kuskokwim Delta region as well as shifting precipitation patterns could have played an important role influencing lake area change variability across this large lake district. Therefore, despite numerous large drainage events in Yukon-Kuskokwim Delta, we observed only a slight change in total lake area by 0.5% (3922.8 ha or 8.4 ha/100 km^2 net gain).

Our assessment shows that lake drainage is widespread in the western Alaska study region. Overall, we found that a large number of lakes in the 10 -100 ha size category drained with an estimated drainage rate of 11 lakes/year that contributed to an area loss of 304.6 ha/year. Not surprisingly, partial drainage of large lakes created numerous remnant pond and hence, lakes smaller than 10 ha increased at a rate of 115 lakes/year and 290 ha/year. Regional permafrost ice content in the lake districts dictated lake change patterns even though there was no direct relationship between permafrost extent and direction of lake change. We observed that lake change patterns transitioned from net area gain due to lake expansion to net area loss in the ice-rich continuous permafrost region, whereas net lake area loss dominated most of the regions with non-continuous permafrost types. Thus, as climate gets warmer and permafrost continues to thaw, we expect increased numbers of drainage events in the continuous permafrost zone of the western Alaska study region. Additionally, as permafrost becomes less stable, influence of other factors such as surficial geology and landscape characteristics likely will magnify the variability of lake area change. Since high spatial and temporal resolution imageries are readily available, assessment of lake area change in high northern latitudes should be continued to quantify the feedbacks associated with lake changes in a warming climate as well as to assist in future planning and decision-making for land and resource management issues related to lakes.

* Jorgenson, T. M., Yoshikawa, K., Kanevskiy, M., Shur, Y. L., Romanovsky, V., Marchenko, S., Grosse, G., Brown, J., Jones, B. 2008. Permafrost characteristics of Alaska. In Proceedings of the Ninth International Conference on Permafrost, Kane DL, Hinkel KM (eds). Fairbanks, AK; 121–122.