The presence and degradation of residual permafrost plateaus on the western Kenai Peninsula Lowlands, southcentral Alaska

Benjamin M. Jones[1], Carson A. Baughman[1], Vladimir E. Romanovsky[2], Andrew D. Parsekian[3], Miriam C. Jones[1], Guido Grosse[4], & Edward E. Berg[5]

[1] *U.S. Geological Survey, USA*
[2] *University of Alaska Fairbanks, USA*
[3] *University of Wyoming, USA*
[4] *Alfred Wegener Institute, Germany*
[5] *U.S. Fish and Wildlife Service (retired), USA*

Permafrost influences roughly 80% of the Alaskan landscape (Jorgenson et al. 2008). Permafrost presence is determined by a complex interaction of climatic, topographic, and ecological conditions operating over long time scales such that it may persist in regions with a mean annual air temperature (MAAT) that is currently above 0 °C (Jorgenson et al. 2010). Ecosystem-protected permafrost may be found in these regions with present day climatic conditions that are no longer conducive to its formation (Shur and Jorgenson, 2007). The perennial frozen deposits typically occur as isolated patches that are highly susceptible to degradation. Press disturbances associated with climate change and pulse disturbances, such as fire or human activities, can lead to immediate and irrevocable permafrost thaw and ecosystem modification in these regions.

In this study, we document the presence of residual permafrost plateaus on the western Kenai Peninsula lowlands of southcentral Alaska (Figure 1a), a region with a MAAT of 1.5±1 °C (1981 to 2010). In September 2012, field studies conducted at a number of black spruce plateaus located within herbaceous wetland complexes (Figure 1b) documented frozen ground extending from 1.4 to 6.1 m below the ground surface, with thaw depth measurements ranging from 0.49 to >1.00 m. Ground penetrating radar surveys conducted in the summer and the winter provided additional information on the geometry of the frozen ground below the forested plateaus. Continuous ground temperature measurements between September 2012 and September 2015, using thermistor strings calibrated at 0 °C in an ice bath before deployment, documented the presence of permafrost. The permafrost (1 m depth) on the Kenai Peninsula is extremely warm with mean annual ground temperatures that range from -0.05 to -0.11 °C (Fig. 1c).

To better understand decadal-scale changes in the residual permafrost plateaus on the Kenai Peninsula, we analyzed historic aerial photography and high-resolution satellite imagery from ca. 1950, ca. 1980, 1996, and ca. 2010 (Fig. 1d). Forested permafrost plateaus were mapped manually in the image time series based on our field observations of characteristic landforms with sharply defined scalloped edges, marginal thermokarst moats, and collapse-scar depressions on their summits. Our preliminary analysis of the image time series indicates that in 1950, permafrost plateaus covered 20% of the wetland complexes analyzed in the four change detection study areas (Fig. 1a), but during the past six decades there has been a 50% reduction in permafrost plateau extent in the study area. The loss of permafrost has resulted in the transition of forested plateaus to herbaceous wetlands (Fig. 1b).

The degradation of ecosystem-protected permafrost on the Kenai Peninsula likely results from a combination of press and pulse disturbances. MAAT has increased by 0.4 °C/decade since 1950, which could be causing top down permafrost thaw in the region. Tectonic activity associated with the Great Alaska Earthquake of 1964 caused the western Kenai Peninsula to lower in elevation by 0.7 to 2.3 m (Plafker 1969), potentially altering groundwater flow paths and influencing lateral as well as bottom up permafrost degradation. Wildfires have burned large portions of the Kenai Peninsula lowlands since 1940 and the rapid loss of permafrost at one site between 1996 and 2011 was in response to fires that occurred in 1996 and 2005. Better understanding the resilience and vulnerability of the Kenai Peninsula ecosystem-protected permafrost to degradation is of importance for mapping and predicting permafrost extent across colder permafrost regions that are currently warming.

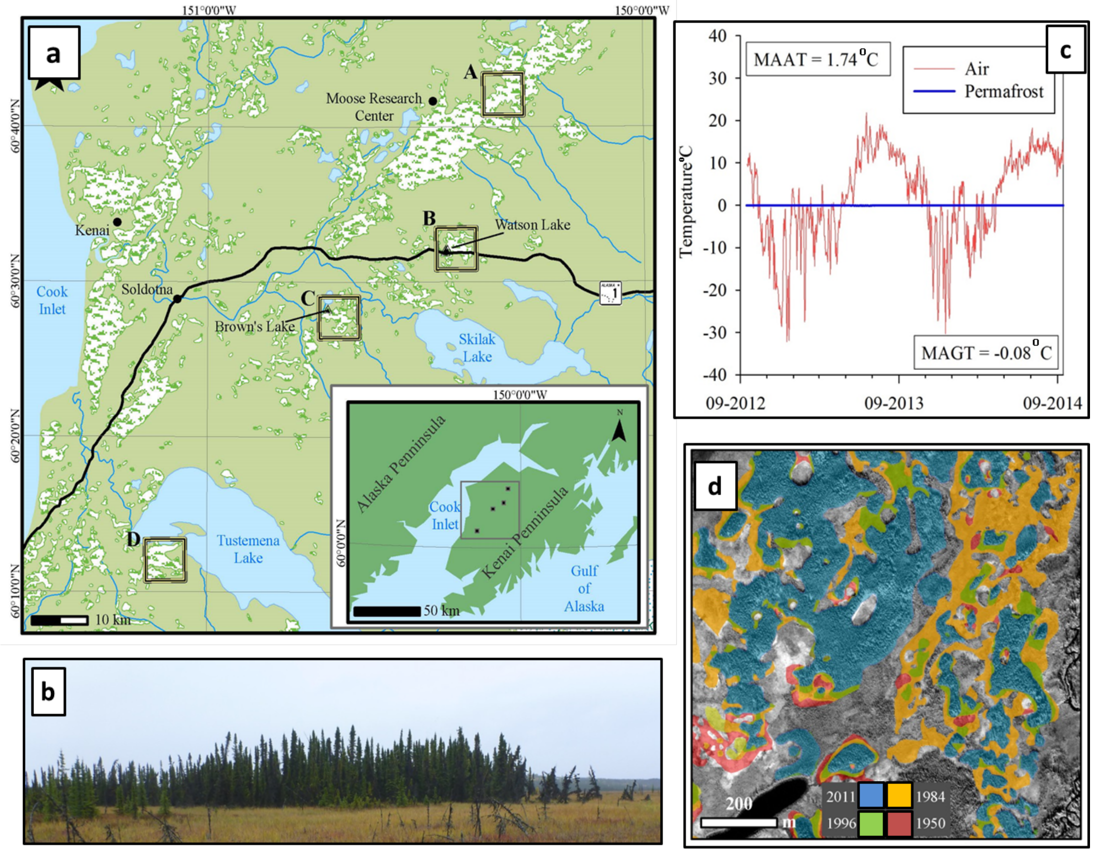

Figure 1: (a) The western Kenai Peninsula lowlands study region showing the location of ground temperature stations (Browns Lake and Watson Lake) and the four permafrost change detection study areas (A-D). (b) An ecosystem-protected permafrost deposit in the Browns Lake wetland complex. The residual permafrost plateau is surrounded by a thermokarst moat and the standing dead black spruce trees in the foreground and on the right side of the image indicate ongoing permafrost degradation. (c) Plot of air (Moose Research Center) and permafrost (1 m depth) temperature (Browns Lake wetland) between September 2012 and September 2014. (d) Change in residual permafrost plateau extent between 1950 and 2011 for a portion of the northerly change detection study area (A). Red shades indicate that permafrost disappeared between 1950 and 1984, orange between 1984 and 1996, and green between 1996 and 2011. The light blue shade indicates mounds mapped in 2011 imagery.