High temporal and spatial resolution satellite image observations for the past decade highlight complexities associated with permafrost coastal bluff erosion in the Arctic

Benjamin M. Jones[1], Diana L. Bull[2], Louise M. Farquharson[3], Carson A. Baughman[1], Christopher D. Arp[3], Guido Grosse[4], Frank Günther[4], Mikhail Kanevskiy[3], Go Iwahana[3], Allen Bondurant[3], Richard M. Buzard[3], Torsten Sachs[5], Ingmar Nitze[4], Jeremy L. Kasper[3], Jennifer M. Frederick[2], Matthew Thomas[6], Alejandro Mota[2], Craig Jones[7], Jesse Roberts[2], Scott Dallimore[8], Craig Tweedie[9], Christopher Maio[3], Daniel H. Mann[3], Bruce Richmond[10], Ann Gibbs[10], Ming Xiao[11], & Vladimir E. Romanovsky[3]

[1] *Water and Environmental Research Center, Institute of Northern Engineering, University of Alaska Fairbanks, Fairbanks, AK, USA;*
[2] *Sandia National Laboratories, Albuquerque, NM, USA;*
[3] *University of Alaska Fairbanks, Fairbanks, AK, USA;*
[4] *Alfred Wegener Institute, Potsdam, Germany;*
[5] *GFZ German Research Centre for Geosciences, Potsdam, Germany;*
[6] *U.S. Geological Survey, Golden, CO, USA;* [7] *Integral Consulting, Santa Cruz, CA, USA;*
[8] *Geological Survey of Canada, Sidney, BC Canada;* [9] *University of Texas El Paso, Texas, USA;*
[10] *U.S. Geological Survey, Santa Cruz, CA, USA;* [11] *Penn State University, State College, PA, USA*

Eroding permafrost coasts in the Arctic are potentially valuable indicators for accumulating impacts of changes in the Arctic System. Decline in sea ice extent and an increase in open water duration, combined with more frequent and effective storms, sea level rise, and warming permafrost, make them increasingly susceptible to increased rates of erosion. However, few observation sites in the Arctic have yet to firmly link erosion rates with changing environmental conditions due to broad temporal gaps in suitable observations necessary to address the relative role of potential drivers of change. Here, we use high spatial resolution optical satellite imagery acquired at high temporal resolution between 2008 and 2017 to explore potential environmental forcing factors responsible for rapid erosion events. We quantify annual erosion magnitude and environmental forcing factors for a 9 km segment of permafrost coastline at Drew Point, Beaufort Sea Coast, Alaska. We then place our observations in the context of decadal scale observations between 1955 and 2007. Mean annual erosion for the decade, 2007 to 2016, was 17.2 m yr^{-1}, which is 2.5 times faster than between 1955 and 1979. Annually, mean erosion along the length of the study coast varied from 6.7 m in 2010 to more than 20 m in 2007, 2012, and 2016. We quantified the open water season using satellite remote sensing time series observations available from the NSIDC. We then correlated mean open water season erosion on an annual basis with the number of storms in a given erosion season, open water period, sea surface temperature, thawing degree day sums, near-surface permafrost temperature, and average storm power values. Multiple linear regression, forward stepwise regression, and best subsets regression of our annual erosion time series at Drew Point did not reveal any statistically significant relations. The lack of significant correlations between mean annual erosion and the suite of environmental variables compiled in this study means we are likely not accurately capturing all of the environmental forcing factors at adequate resolutions or accuracies, or that other not yet considered factors may be responsible for the increased erosion occurring at Drew Point. During a drilling campaign conducted in April 2018, we encountered a cryopeg at Drew Point that ranged in elevation from 0.3 m asl to > 2.3 m bsl. Ground temperature at this depth was ≈ -8 °C yet the material was unfrozen. It is conceivable that the 4 °C permafrost warming in the region over the past several decades has increased the erodibility of the saline permafrost deposits located at this critical elevation where thermo-mechanic erosional niches actively develop during periods of elevated water levels. This, combined with changes occurring in the marine system, are likely driving the well documented increase in erosion at Drew Point, Alaska, USA.