Permafrost, the perennially frozen ground spanning the Arctic, stores large stocks of ‘old’ and labile organic carbon (OC). Sharply rising circum-Arctic temperatures accelerate the thaw of this vulnerable OC pool, making it accessible to remineralization and erosion. Upon remineralization, the previously freeze-locked OC is emitted to the atmosphere as carbon dioxide or methane and causes a feedback mechanism that further amplifies the greenhouse effect, warming, and permafrost thaw. Erosion/mobilization of permafrost OC into aquatic settings, such as rivers and coastal oceans, leads to additional OC remineralization but also burial and sequestration in sediments. Reburied permafrost represents an archive of past permafrost dynamics beyond observational records, which allows assessing the sensitivity and response of permafrost OC to natural climatic as well as anthropogenic forcing. This information is critical to predict the future response of permafrost to climate change, which has already had profound effects for Arctic ecosystem functions, infrastructure and economies, and the livelihood of local communities. This research project, we quantify past and present permafrost OC fluxes to the Canadian Arctic Ocean in response to natural climatic and anthropogenic forcing. Marine sediments, permafrost field samples, and laboratory-based microcosm experiments will be used on different spatial and temporal scales to determine the quantity and quality of permafrost OC released following warming-induced permafrost thaw and the associated atmospheric and oceanic feedbacks. This project will assess permafrost vulnerability to erosion, gain a holistic understanding of changing molecular permafrost dynamics, and investigate feedbacks to the ocean carbonate system. This program will help solve a conundrum in the global carbon cycle by delivering unprecedented insight into the molecular isotopic heterogeneity of terrestrial OC on land, during transfer into and alteration/priming in the ocean, and burial in sediments.