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Hydrology, Sediment or Permafrost: Why Do High Latitude Rivers Move So Slowly?

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Due to climatic conditions, high latitudes have unique land surface properties and hydrology. Up to 24% of the northern hemisphere is underlain by permafrost. The presence of frozen soils strongly controls hydrological responses such as infiltration and runoff. Most high latitude rivers and streams exhibit nival hydrological regimes with snow dominated spring floods, flow limited to a fraction of the year, and ice cover during winter and spring months. Additionally, frozen soils and ground ice lead to thermally mediated erosion and creep processes. Even though three out of the 10 largest (by drainage area) rivers on earth flow across watersheds underlain by permafrost, there has, to date, been no systematic examination river erosion rates in these environments. With low sediment production rates in arctic landscapes, bank erosion in these systems is a major source of sediment to rivers and heavily influences the exchange of carbon from permafrost-dominated floodplains to rivers and oceans. We measured up to four decades of bank erosion rates on over 5,000 km of high latitude rivers using satellite imagery and aerial photography. Comparing these results to our newly assembled global compilation of published erosion rates, we find that erosion rates of high latitude rivers are significantly lower than rates on lower latitude rivers. To explain this systematic difference in erosion rates, we explore the possible influences of high latitude hydrology, sediment loads, and permafrost on bank erosion rates and river migration. Based on field studies, we also explore how permafrost, ice break up, bank grain size, and hydrology influence both spatial and temporal variability in erosion rates along both a small meandering (Selawik) and a large multi-threaded (Yukon) river in Alaska. Our results highlight the sensitivity of high-latitude rivers to both changes in Arctic hydrology and temperatures. Alterations in river bank erosion will likely alter both the magnitude and composition of sediment, nutrients and carbon that are release from the land to rivers and the ocean.