Permafrost, Hydrology & Climate Change on the Seward Peninsula

The Seward Peninsula lies at the southern boundary of continuous permafrost. In this environment, slight changes will cause long lasting alterations to the permafrost and consequently the quality and availability of freshwater. The arctic hydrologic system is particularly sensitive to changes in permafrost, rain- and snowfall, the timing of freeze-up and break-up, and the intensity of storm activity. It is likely that much of what has been documented to date, and will be observed in the future, arises from changes in these domains. The combined observations and documentation form a case that the arctic hydrologic system may be entering a state not seen before in historic times.

Permafrost and hydrology

Ice-rich permafrost maintains a relatively low permeability, greatly restricting infiltration of surface water to the subsurface groundwater and vice versa. Wetlands and numerous tundra ponds exist around Seward Peninsula. These ponds are sustained above the permafrost, or perched, due to the limited internal drainage. This drainage barrier also affects the way river runoff flows from the hills.

Consequences of permafrost thaw

As the climate warms in summer and winter, the permafrost will become warmer. The active layer (the layer of soil above the permafrost that freezes and thaws every year) will become thicker and the bottom of the permafrost will become closer to the ground surface (Figure 1). When the permafrost thaws, unfrozen channels develop between and below ponds allowing subsurface drainage to occur throughout the year. Talik formation (a patch of unfrozen ground in an area of permafrost) can also occur.

Permafrost degradation and internal drainage have significant impacts on large and small scales and will affect every aspect of the surface water balance and energy balance. Future river runoff of Seward Peninsula, with a reduced permafrost extent, will probably show increased winter flow and summer base flow rates, presumably due to more groundwater infiltration. Increased flow rates could have a wide range of impacts, including changes in stream chemistry and aquatic habitat, increased stream and river icing, and other uncertain implications on erosion and sediment flux.

Evidence of recent climatic changes

The Seward Peninsula is underlain mainly by discontinuous permafrost (92% or less of the ground area has permafrost below it); however it appears that in the recent past the region was predominantly underlain by continuous permafrost. Geophysical surveys, including ground penetrating radar and direct boring with complementary temperature measurements reveal that the permafrost is in the process of degrading.

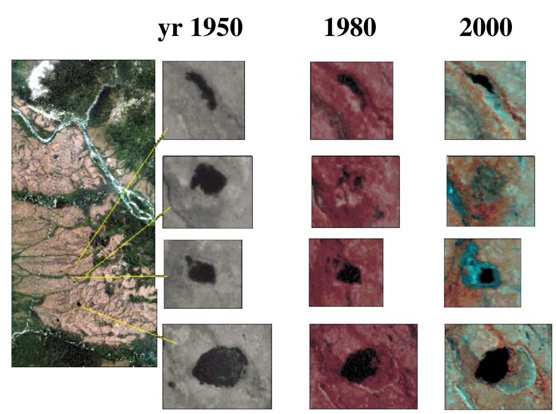

Figure 2. Thaw lakes near Council.

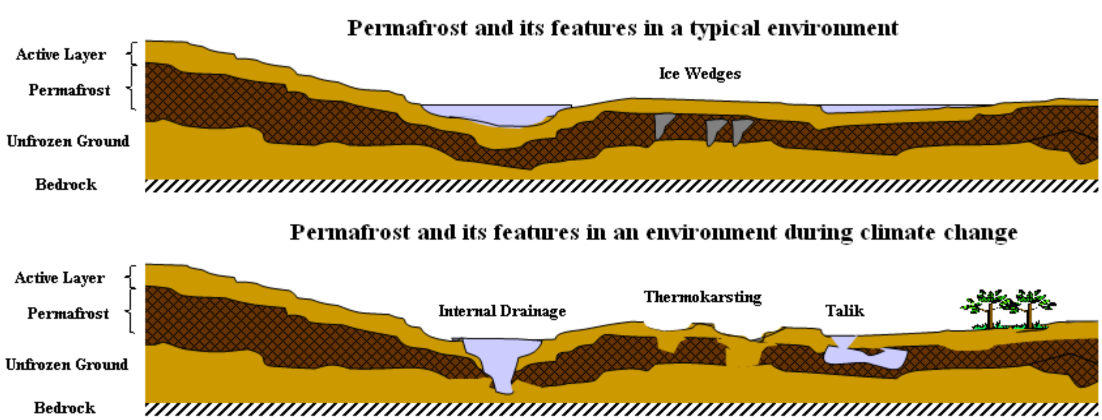

Figure 1. Consequences of a climate warming on permafrost and hydrology. Thawing of permafrost result in drainage of ponds, thermokarsting where ice-rich soil and ice-wedges degrade, talik formation and deepening of the active layer.

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Evidence of recent climatic changes: Continued

Extensive thermokarsting (i.e. surface sinking due to thawing permafrost) is evident throughout the area. Studies indicate that ponds are shrinking (Figure 2) due to an increase in internal drainage following degradation of permafrost between 1950 and 2000 (Yoshikawa and Hinzman, 2003) and a shift in vegetation type has been documented at Seward Peninsula (Lloyd *et al*., 2003).

Modeling permafrost distributions

Projections of changes in permafrost are necessary to accurately predict changes in hydrology and ecology. Model simulations of permafrost extent in the early 20th century, the present time, and the end of the 21st century are done by estimating the temperature at the top of the permafrost table (Figure 3). The past projection uses air temperatures and precipitation from Nome (1908-1912), present data is from eleven meteorological stations across the Seward Peninsula maintained by National Weather Service, SNOTEL, RAWS and UAF's Water and Environmental Research Center. Climate information representing the 21st century comes from several General Circulation Models approved by the International Panel on Climate Change.

Hydrological analysis and modeling

Following model simulations of changes in permafrost distributions, we will conduct hydrological modeling of runoff, soil moisture and evapo-transpiration (water that evaporates directly from a surface and/or is transpired by plants). The tool being used is a hydrological model developed in our laboratory. Our hydrologic model will be applied across the entire Seward Peninsula to predict changes in water resources. It can only be rigorously tested and validated at the few places where stream and river discharge has been measured. River discharge will probably be the best information available for long-term detection of change.

References

Yoshikawa, K., and Hinzman, L. D., 2003. Shrinking Thermokarst Pond and Groundwater Dynamics in Discontinuous Permafrost near Council, Alaska. Permafrost and Periglacial Processes, 14:151-160

Lloyd, A. H.,Yoshikawa, K., Fastie, C. L., Hinzman, L. D., Fraver, M., 2003. Effects of Permafrost Degradation on Woody Vegetation at Arctic Treeline on the Seward Peninsula, Alaska. Permafrost and Periglacial Processes, 14:93-101

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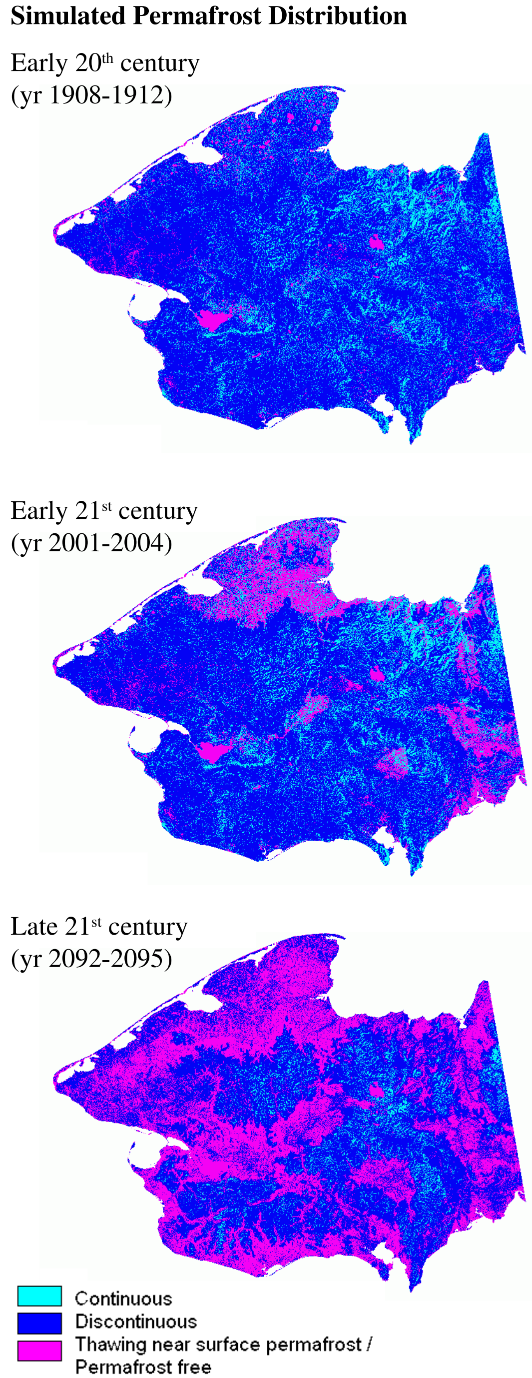

Figure 3. Simulated permafrost distribution at Seward Peninsula in the early 20th, 21st and late 21st century. Continuous permafrost represents annual average ground surface temperatures colder than 23°F and discontinuous permafrost colder than 32°F but warmer than 23°F.