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Influence of topography on mountain permafrost distribution through variable air and ground surface lapse rates, Yukon Territory, Canada

A.G. Lewkowicz (1) and P.P. Bonnaventure (2)

(1) Department of Geography, University of Ottawa, Ottawa. Canada (alewkowi@uottawa.ca), (2) Department of Geography, University of Ottawa, Ottawa. Canada (pbonn075@uottawa.ca)

The objective of this study is to evaluate the variability in air and ground surface temperatures in relation to topography and elevation in the southern half of the Yukon Territory, Canada. In particular, we explore the importance of persistent winter and nocturnal summer atmospheric temperature inversions on the variability in mountain climates in the region. Since permafrost is partially climatically controlled, this variability may impact its distribution. Five study areas from 60°-65°N are discussed: Johnson's Crossing, the Sa Dena Hes mine site, Faro, Keno and Dawson. In each area, 10-12 monitoring sites, selected to cover a range of elevations, aspects and topographic situations (e.g. ridge crests, valley bottoms, long slopes), operated in 2007-2008. They extended from below to above tree-line in and in total covered an elevation range of 300-2000 m a.s.l.. At each monitoring site, Onset Hobo Pro loggers were used to measure hourly shielded air temperature, ground surface temperature, and temperature near the top of permafrost (if present). In addition, site snow depths were monitored using miniature iButton temperature loggers arranged in a vertical array above the ground surface. Results can be described by individual area and collectively for the entire region. When grouped together, summer air temperatures show normal lapse rates that in July are close to the standard environmental lapse rate of -6.5°C/km. In contrast, winter lapse rates are strongly inverted, with an increase of +11°C/km in January 2008. The combined effect of these two trends cause air temperature amplitudes to decrease with elevation and a normal, but much reduced, lapse rate of about -4°C/km. Temperatures at the ground surface in summer follow the air temperature trend within the same season and exhibit a normal lapse rate (-5°C/km) with a higher degree of scatter that relates to the buffering effect of vegetation and the substrate. In winter, the variable effect of snow transforms the strong inversion in the air temperatures into highly scattered points that exhibit no trend with elevation, although there are trends within individual study areas. A similar result was obtained for ground surface temperatures averaged over the year. The regional trends in air and ground temperatures are fairly clear for the southerly sites and follow those outlined above. However, for the northern sites (Keno and Dawson), complex patterns emerge relative to elevation because cold air drainage into depressions at any elevation appear to play important roles in both winter and summer. We conclude that air temperature trends in the Yukon mountains are influenced by topography at a variety of scales, with significant seasonal differences. Spatial complexity is accentuated for ground surface temperatures due to variable surface offset effects resulting from snow and vegetation. As a consequence, permafrost distribution is heterogeneous: perennially frozen ground can be present in valley bottoms at low elevations which are colder in winter, and above tree-line at high elevation locations which are colder in summer.