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Measured Two-Dimensional Ice-Wedge Polygon Thermal Dynamics

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Ice-wedge polygons are perhaps the most dominant permafrost related features in the arctic landscape. The microtopography of these features, that includes rims, troughs, and high and low polygon centers, alters the local hydrology, as water tends to collect in the low areas. During winter, wind redistribution of snow leads to an increased snowpack depth in the low areas, while the slightly higher areas often have very thin snow cover, leading to differences across the landscape in vegetation communities and soil moisture between higher and lower areas. These differences in local surface conditions lead to spatial variability of the ground thermal regime in the different microtopographic areas and between different types of ice-wedge polygons.

To study these features in depth, we established temperature transects across four different types of ice-wedge polygons near Barrow, Alaska. The transects were composed of five vertical array thermistor probes (VATP) beginning in the center of each polygon and extending through the trough to the rim of the adjacent polygon. Each VATP had 16 thermistors from the surface to a depth of 1.5 m. In addition to these 80 subsurface temperature measurement points per polygon, soil moisture, thermal conductivity, heat flux, and snow depth were all measured in multiple locations for each polygon. Above ground, a full suite of micrometeorological instrumentation was present at each polygon. Data from these sites has been collected continuously for the last three years.

We found snow cover, timing and depth, and active layer soil moisture to be major controlling factors in the observed thermal regimes. In troughs and in the centers of low-center polygons, the combined effect of typically saturated soils and increased snow accumulation resulted in the highest mean annual ground temperatures (MAGT). Additionally, these areas were the last part of the polygon to refreeze during the winter. However, increased active layer thickness was not necessarily found in areas of higher MAGT. Active layer thickness does not appear to be correlated to mean annual air temperature but rather is a function of summer air temperature or thawing degree-days. While the refreezing of the active layer initiated at nearly the same time for all locations and polygons, we find differences in the proportion of top-down versus bottom-up freezing and the length of time required to complete the refreezing process.

Examination of the daily temperature dynamics using interpolated two-dimensional temperature fields reveal that during the summer, the predominate temperature gradient is vertical while the isotherms tend to follow the topography. However, as the active layer begins to refreeze and snow accumulates, the thermal regime diverges. The fall shows an increased temperature gradient horizontally with landscape positions containing higher soil moisture and/or snow depth (low centers and troughs) cooling more slowly than the adjacent ground (rims and high centers). This two-dimensional effect is greatest as the active layer refreezes and persists until mid-winter, by which time the temperature gradients are again mostly vertical and the isotherms follow the topography. Our findings demonstrate the complexity and two-dimensionality of the temperature dynamics in these landscapes.