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Integrated Geophysical and Temperature Sensing Techniques Towards Scalable Monitoring of Permafrost Variability in Utqiagvik, AK

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Climate change is causing an increase in permafrost thaw, affecting both anthropogenically disturbed areas adjacent to infrastructure and undisturbed tundra regions. In this research, we use multiple geophysical methods—active and passive multichannel analysis of surface waves (MASW), electrical resistivity tomography (ERT), and ground temperature sensing—to study heterogeneity in permafrost’s geophysical characteristics in Utqiagvik, Alaska. To scale permafrost monitoring spatially and temporally, we deployed 2 km of distributed acoustic sensing (DAS) and distributed temperature sensing (DTS) cables that continually record passive seismic and temperature data for a three-year duration. MASW results from the active-source survey reveal a low-high-low shear wave velocities (V_s) pattern in most locations. A notable inverse correlation is observed between in-situ V_s and ground temperature. The V_s profiles and electrical resistivity profiles reveal cryostructures such as cryopeg and ice-rich zones in the permafrost layer. Corroboration of these geophysical observations with permafrost core samples’ stratigraphy and salinity measurements further validates these findings. This combination of geophysical and temperature sensing methods, along with permafrost core sampling, confirms a robust approach to assessing permafrost’s spatial variability in coastal environments. Continuous imaging of permafrost seismic structure through ambient noise DAS tomography, utilizing active-source survey V_s profiles as baseline models, may provide benchmarks for the rate of change in permafrost along the Arctic Ocean coast, thereby informing climate modeling efforts. Further, our results also indicate that civil infrastructure systems such as gravel roads and pile foundations affect

permafrost by thickening the active layer, lowering the Vs, and reducing heterogeneity. We show how the resulting Vs profiles can be used to estimate critical parameters for designing buildings in permafrost regions and maintaining existing infrastructure in polar regions.