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# Canadian Arctic Permafrost Observatories: detecting ongoing climate change through inversion of multiple logs of subsurface temperatures

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Three long-term permafrost temperature and climate change observatories have been established in the northeastern Canadian High Arctic ($77^o$ to $82.5^o$N). Two sites (Gemini and Pat Bay) are abandoned petroleum exploration wells in which thermistor cables and automatic loggers were installed in the early 1990s in the upper $\sim$65 m of casing. These sites also have deeper (160 m, 850 m) temperature logs. The third site (Alert) consists of three 61-m boreholes with thermistor cables frozen into the permafrost, and has multiple temperature logs over 22 years. Deep logs from a fourth but uninstrumented site (Neil; 750 m) is included for regional completeness. Geothermal spectrum inversion is used to determine the ground surface temperature history (GST). When multiple temperature logs covering a period of time are inverted simultaneously, additional resolution to the GST comes from temporal differences between logs. The shallow, multiple temperature logs resolve ongoing, contemporary (decadal) changes in ground surface temperatures, while the deep logs at the same sites provide a century-level GST. From the inversion of the deeper logs, the Little Ice Age is identified in the mid-1700s to mid-1800s with surface temperatures $\sim$ 1K below the long-term mean; a subsequent recovery yields late $20^{th}$ century surface temperatures $\sim$3K higher. These results correlate (correlation coefficient = 0.9, 1800-1980s) with similar reconstructions reported for Greenland ice cap holes GRIP and Dye-3 some 1400-2100 km to the southeast of the Canadian boreholes (Dahl-Jensen et al., 1998). The Canadian and Greenland surface temperatures show a weak, inverse correlation (coefficient = 0.2 to 0.3; 1885-2000) with the North Atlantic Oscillation (NAO), suggesting recent climate variability as a common causal source. The similarity between the Canadian and

Greenland GSTs, and the correlation between the GSTs and the NAO suggest that there may be an atmospheric connection to both regions. Simultaneous inversions of multiple logs over 22 years at the 61-m holes (Alert) resolve 2 - 3 major cycles in GST variation over the latter half of the $20^{th}$ century. Here permafrost GSTs increase $0.3^{o}$ to $0.5^{o}$C/decade, compared to $0.6^{o}$C/decade for air temperatures; annual total snowfall measured at the Environment Canada station increases 22 cm/decade, and the resulting thicker snow cover may insulate permafrost from the larger transient trends in air temperatures. Finally, atmospheric temperature inversions prevalent in Arctic winters may contribute to anomalously high GSTs observed at a higher elevation site at Alert and Neil.