KNaCK LiDAR SCANNING OF MARS ANALOG PERIGLACIAL MORPHOLOGIES ON SVALBARD.

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Introduction: The remote Arctic archipelago of Svalbard represents a unique terrestrial analog environment for comparison to latitude-dependent cold climate landforms on Mars. Svalbard contains abundant periglacial features in close proximity, allowing for an integrated landscape analysis approach to understand the evolution of morphologies on Earth and Mars [1]. Here, we present new measurements using ultra-high resolution mobile LiDAR scanning techniques to characterize the 3D morphology of periglacial features (e.g. sorted stone circles (SSCs), thaw-slumps, glacial moraines) at the centimeter scale, and provide preliminary measurements of short duration (days) change detection using LiDAR. Studying these types of features is important to understand formation mechanisms and place constraints on timescales on both planets. These data are part of a broader long-term research program that includes airborne remote-sensing imaging, mm-scale 3D modeling with photogrammetry, and subsurface investigations of periglacial features on Svalbard [2], with support from the German Alfred Wegener Institute and the French Polar Institute (AWIPEV).

Methods: In July 2024, various periglacial features were scanned using the Kinematic Navigation and Cartography Knapsack (KNaCK), a person-mounted mobile LiDAR scanning system [3]. The KNaCK uses an Ouster OS-1-64 LiDAR sensor, with an HG1700 inertial measurement unit (IMU) and Novatel PwrPak7 SPAN GNSS system and allows the operator to create ~2-3 cm/pixel digital elevation models of areas along traverses. Point clouds are initially produced using simultaneous localization and mapping (SLAM) algorithms developed at NASA MSFC that scan matches LiDAR data and fuses it with IMU and GNSS data. Data are map projected to UTM 32N/33N and exported as las point cloud files. Data collection in the field is done by walking around the area of interest while the sensor scans a ~100 m wide field of regard around the user. Data processing time is on the order of ~2:1 for initial map creation (i.e. 1 hour of traverse takes ~2 hours of processing). The open-source software CloudCompare [4] is used for LiDAR point cloud post-processing, including statistical outlier removal, georeferencing, and segmentation, and rasterization for export to ArcGIS.

Results and Discussion: *Sorted Stone Circles:* More than 350,000 m^2 of the Kvadehuksletta peninsula on Svalbard was scanned with KNaCK, with extensive coverage over 12 long-term sorted stone circle monitoring sites. LiDAR data was also taken along previous GPR transects of SSCs [5] to provide topographic correction. An example of ~2 cm/pixel resolution digital elevation model is shown in Fig. 1. Stone circles are rare on Mars but have been observed in prospective periglacial environments [6, Fig. 1b].

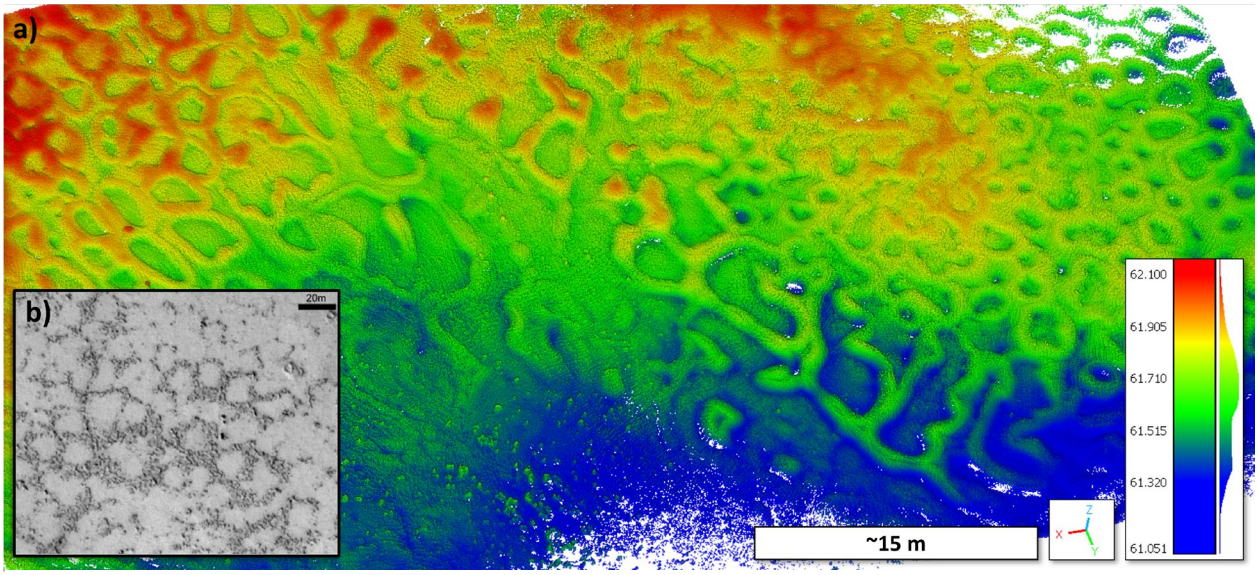

Figure 1: a) Example of typical periglacial sorted stone circles, Kvadehuksletta, Svalbard. the circular shape elongates with minor (<3-5°) slope changes. KNaCK LIDAR allows large-area morphometric investigation of these features, as well as serve as a baseline for long-term change detection. b) Example of stone circles on Mars (modified from [6], HiRISE PSP_004072_1845).

Understanding the relationship between diameter, clast distribution, and depth to permafrost on Svalbard can help constrain evolution of these features on Mars.

Thaw-Slump Change Detection: To determine geomorphic change, two different methods were used that compare scans of the same area taken at different times. Fig. 2 shows scans of a thaw-slump region of an ice-cored lateral moraine were taken on July 7th and July 20th (13 days apart). Cloud-to-Cloud Distance (C2CD) [4] and Multi-scale Model-to-Model Cloud Comparison (M3C2) [7] methods both compare the distance between point clouds. C2CD uses a quadratic function to determine the height difference between a local plane determined by a search radius of 6 nearest neighbor points in each of the scans. M3C2 is a more robust method that first computes a model of core points at a specified radius and samples the center of gravity of a projection cylinder in each of the clouds and then calculates the difference between corresponding points in each cloud. Both methods are useful in detection of change, with the product of C2CD being slightly more visually intuitive and M3C2 being more accurate at detecting very small-scale differences. In our 13-day change detection measurements, headward erosion of the thaw-slump exceeded 1 m and altered the overburden of material to expose the ice core of the moraine – with the ice-soil horizon acting as a décollement and leading to further solar insolation melting.

Conclusions: A catalog of periglacial features including sorted stone circles, polygonal patterned ground, glacial moraines, gullies, and others has been created to allow 3D morphometric analysis from ultra-high resolution LiDAR data. The rapid data collection method allows for repeat scanning of dynamic features, which aid in determining rates of change and formation process. By applying these methods to terrestrial features, we can more completely characterize periglacial phenomena and constrain Mars surface evolution. Combined with long term field observations and remote-sensing image analysis, we will be able to further refine how these types of features change, and model analogous processes under Martian conditions.

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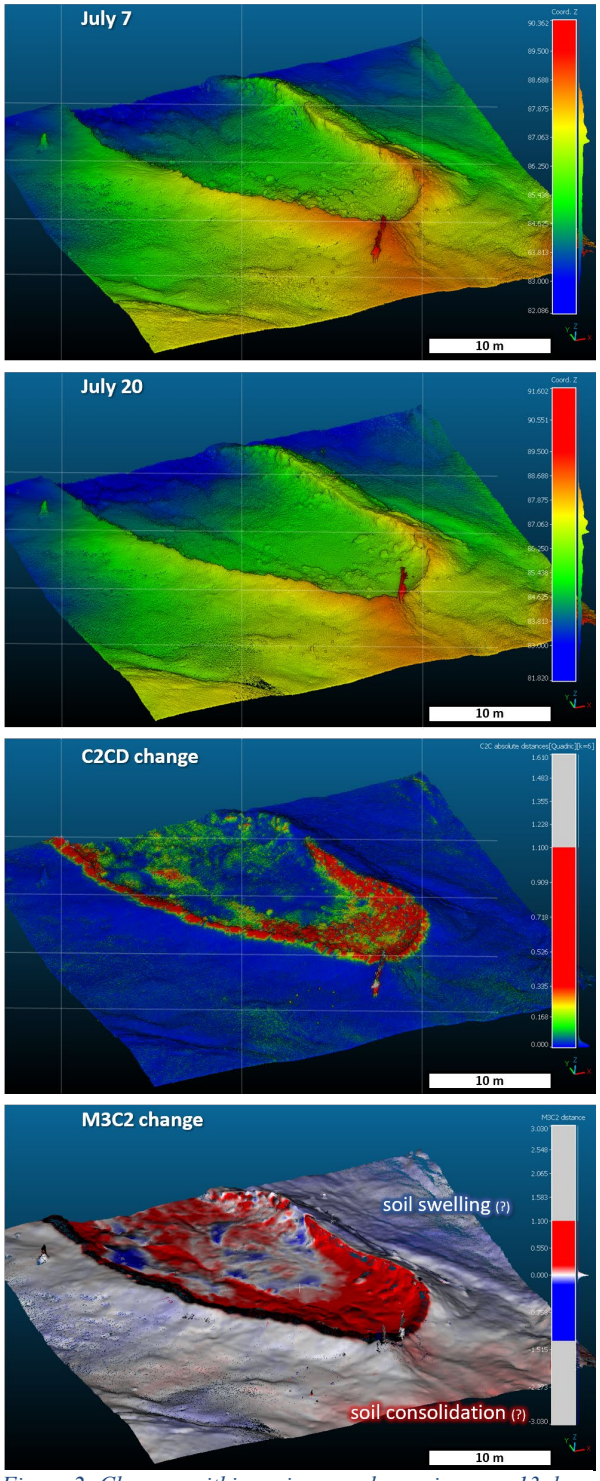

Figure 2: Changes within an ice-cored moraine over 13 days measured using the KNaCK LiDAR system. Retreat of the headwall of more than 1 m, as well as potential soil swelling and consolidation of ~5-10 cm are visible (team member for scale near headwall in each image).