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# Svalbard Permafrost Landforms as Analogues for Mars (SPLAM): Scientific outcomes and outlook

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Recent and present non-polar ice deposits (e.g., [1-6]) are important records of the changing dynamics of the Martian climate and constitute an important resource for possible future in-situ resource utilization (ISRU) [7]. Recently the mapping of such ice deposits has gained significant momentum, as several projects (e.g., SWIM; [8-9]) addressed the distribution of such deposits, and dedicated space missions have been suggested to study such deposits and their links to the climate history (e.g., COMPASS [10]; I-MIM/International Mars Ice Mapper Mission [11]; IceBreaker [12]; ice drilling plans of ESA and NASA, such as the ice-drilling Mars Life Explorer lander). Many of these ice deposits are associated with landforms that resemble glacial and periglacial surface features on Earth [13]. Moreover, a number of landforms on Mars have been hypothesized to have formed by the action of liquid water in the last few millions of years, and possibly even until today (e.g., [14]). Such landforms include, but are not restricted to, gullies and associated depositional fans, patterned ground, and flow lobes on slopes, which have been interpreted as evidence for debris flows, freeze-thaw cycles, and solifluction, respectively (e.g., [15-17]). However, under current conditions (low T, thin atmosphere), liquid water is not stable at the surface of Mars unless special conditions are met (e.g., [18-19]), although contemporary subsurface liquid water is debated [20]. Hence, a reconstruction of the planet's recent climate history involving liquid water is challenging (e.g., [21,22]). Furthermore, as morphologic interpretations are typically not unambiguous (the concept of equifinality, e.g., [23]), most if not all of these landforms may also have formed by alternative "dry" processes (see, e.g., the study of polygonal textures in Gale crater by ref [24]).

Fieldwork on terrestrial analogues is considered essential to understand planetary landforms and their evolution, as the Earth is still our "reference" to understand geologic processes [25]. The knowledge gained by fieldwork helps to establish multiple working hypotheses and test them (e.g., for the case of polygonal ground see ref [26]).

The remote Arctic archipelago of Svalbard constitutes  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 cold climate landforms on Earth and Mars.

The main questions driving our fieldwork on Svalbard are:

- Does the formation of cold-climate landforms on Mars require freeze-thaw processes and the melting of snow/ice (i.e., was there liquid water involved in their formation)?
- What are the rates of cold-climate processes on Mars (i.e. what are the possible time scales of their formation)?
- How do analogous landforms on Mars respond to changing climates, which on Earth has some of its most dramatic consequences in the Arctic? What are the hypothesized reasons for the recent environmental evolution of Mars?

We have been conducting Earth-analog studies for Mars in Svalbard since 2008. The program includes qualitative and quantitative studies of individual landforms, mapping efforts, and short- and long-term monitoring activities. We have acquired high-resolution aerial datasets of selected key regions in Svalbard in the years 2008, 2020, and 2024. Data sets derived from the aerial images include visual, NIR, and thermal image mosaics as well as high-resolution DEMs. Interpretations using these remote sensing data have been complemented by ground truth observations made in the field to gain insight, to characterize near-surface materials and conditions, and to produce very detailed geomorphological maps [27]. Fieldwork involves structure-from-motion techniques, pole and kite imagery, and measuring several weather and soil parameters during the active warm season. Moreover, using the KNaCK ultra-high resolution mobile LiDAR scanning system, we are able to measure the local topography with very high resolution (Fig. 1; [28]). Mobile LiDAR scanning with this resolution allow for ultra-high-resolution mapping and morphometric measurements, with repeatable control for change detection. All data are geodetically controlled, with dGPS precision of <2 cm.

Comparing LiDAR data from 2024 and 2025, we aim to identify cm-scale changes in patterned ground (sorted circles) over a timescales of days to a year. We can also compare these data with data acquired since the 1980’s [29] to extend our monitoring timeline to decades during which environmental conditions have changed significantly.

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