Retrieving Subsurface Properties of Mars-Analog Glaciers with Drone-Based GPR

Roberto J. Aguilar[1] (roberto@lpl.arizona.edu), Tyler M. Meng[2], Michael S. Christoffersen[3], Stefano Nerozzi[1], Jack W. Holt[1,4]

UA SCIENCE LUNAR & PLANETARY LABORATORY

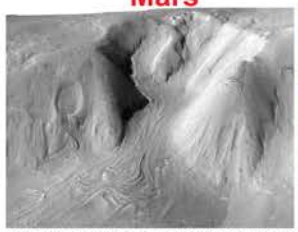
[1]Lunar and Planetary Laboratory, University of Arizona, [2]Department of Earth, Environmental and Planetary Sciences, Washington University in St. Louis, [3]School of Earth and Atmospheric Sciences, Georgia Institute of Technology, [4]Department of Geosciences, University of Arizona.

1. Goals

- Investigate the detectability of supraglacial debris, glacial base, and internal layering in terrestrial debris-covered glaciers using a drone-based ground penetrating radar (DGPR)
  - Compare the results of DGPR with surface-based GPR at at multiple frequencies
  - Validate the detection of subsurface reflectors with clutter simulations

2. Background

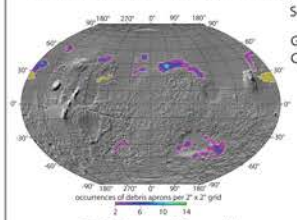
Mars



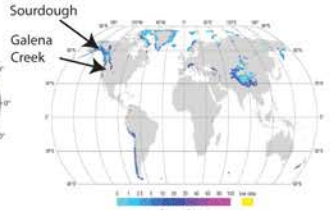
Debris-covered glacial landform
DEM from HiRISE and CTX

Earth

Sourdough Rock Glacier, Alaska
Airborne photo by Eric Petersen

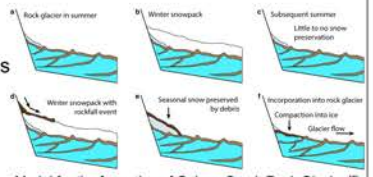


DCGs on Mars [1]



DCGs on Earth [2]
(excluding Antarctica)

- Lobate debris aprons (LDAs) are debris-covered glacial landforms at the mid-latitudes of Mars, formed in multiple episodes during the Amazonian age [0.3 – 1 Ga] [3,4]
  - The radar sounder SHARAD (15–25 MHz) onboard the Mars Reconnaissance Orbiter (MRO) has confirmed that the bulk composition of LDAs is nearly water ice [5]
  - SHARAD hasn't directly resolved the supraglacial debris to ice contact or near surface stratigraphy [6]
- On Earth, debris-covered glaciers (DCGs) are planetary analogs for LDAs



Model for the formation of Galena Creek Rock Glacier [7]

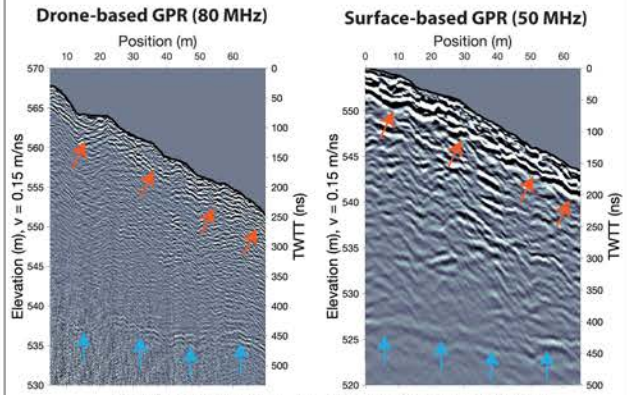
3. Platform

Platform:
- Drone DJI Matrice 600 Pro
- GPR MALA Geodrone 80
  - Impulse radar
  - Center frequency: 80 MHz
  - Bandwidth: 40 MHz

Navigation:
- Automated flight path
- Speed (1 m/s)
- Altitude (3 m—5 m)
  - Real-time terrain following

Total takeoff weight: 10 Kg

4. Supraglacial debris and bulk thickness

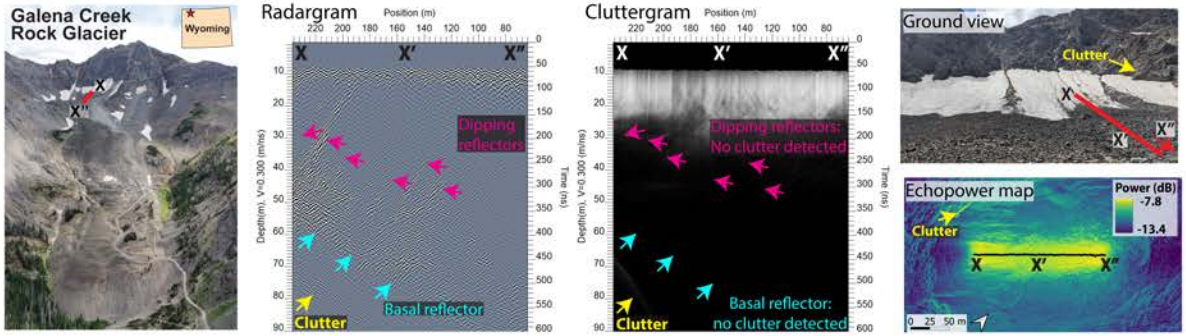


Profiles at the toe of Sourdough Rock Glacier

We manually picked the following reflectors:
- Surface (first return)
- Debris/ice interface
  - Debris thickness calculated with a velocity of 0.1 m/ns
- Basal reflector
  - Bulk thickness calculated with a velocity of 0.15 m/ns

* Velocity was retrieved with a common-midpoint (CMP) survey [8]

5. Internal debris layering and clutter simulations



The clutter simulator [9-10] used as input the digital elevation models (DEMs) aquired with drone photogrammetry (5 cm/px) [11]

6. Conclusions

- We successfully employed a DGPR platform to survey terrestrial DCGs, resolving debris-ice contacts, internal glacier stratigraphy, and total glacial thickness.
- The DGPR platform and our results over Martian analog ISRU targets demonstrate the potential for drone-based planetary exploration.

7. Future work

Development of a drone-based chirped radar

- Test behaviour of current and future radars, with a frequency between 10 MHz to 1.1 GHz
- Flight altitude ~120 m, mass < 5 kg.
  - within the specifications of the Mars Science Helicopter [12]

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