Mapping the Extent and Timing of Water Tracks with High Temporal Resolution Satellite Imagery in the McMurdo Dry Valleys, Antarctica: Can Subsurface Melt Conditions be Deduced from Orbital Imagery for RSL-Analogs?

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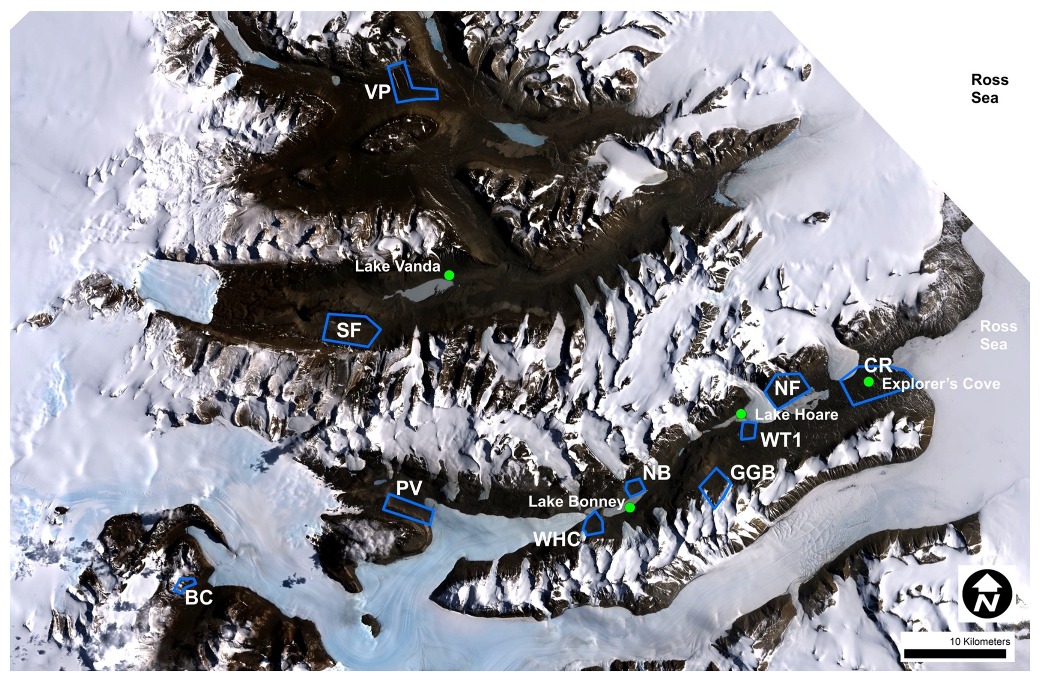
Background

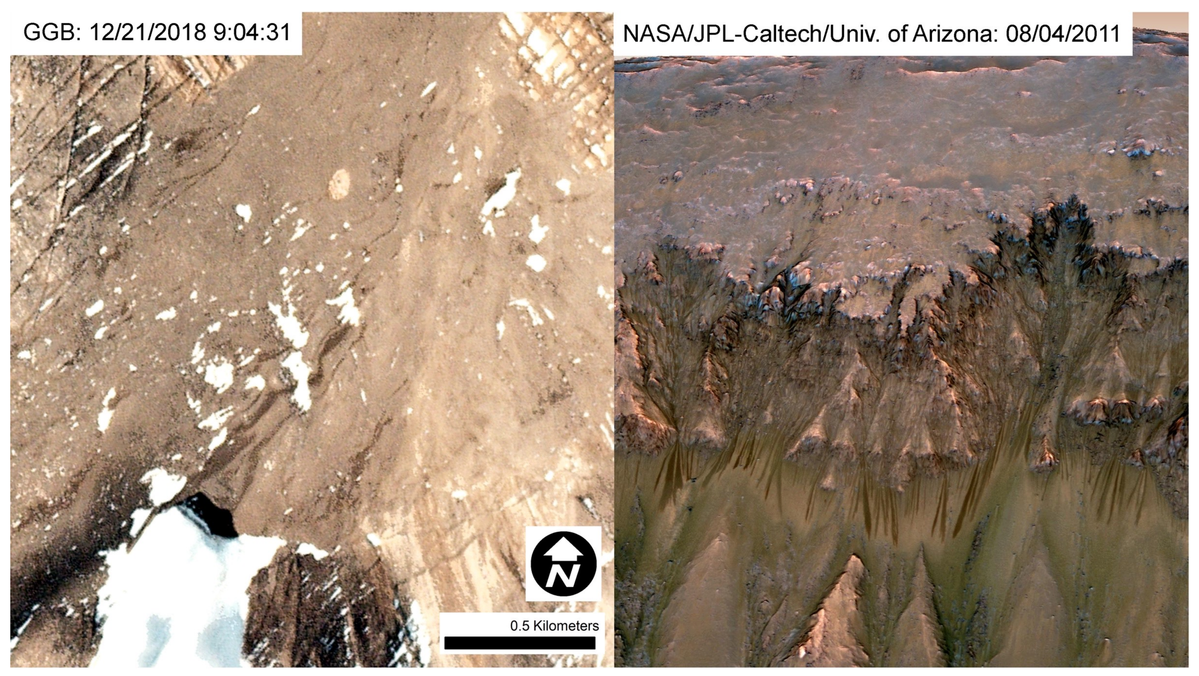
The cold desert ecosystem of the McMurdo Dry Valleys (MDV) features a variety of seasonal meltwater features, including water tracks, which are soil meltwater conduits that flow during summer months.[1] Satellite imagery shows water tracks as dark, linear patches that form branching networks. Morphologically similar recurring slope lineae (RSL) are present on Mars, and liquid subsurface water has been hypothesized to explain RSL formation.[2] However, multiple competing mechanism have been hypothesized to explain patterns of RSL advance and disappearance.

The spatial extent of these meltwater features has been studied previously[3], but they have not yet been temporally constrained. Considering the seasonality of both water tracks and RSL, it is necessary to analyze their timing to evaluate formation mechanisms affected by seasonal climate processes. By studying satellite images collected on a daily to sub-weekly basis across 2-5 months at ten sites (seen below), we seek to answer the following research questions:

- *What is the hydro-period of water tracks in the McMurdo Dry Valleys?*
- *Can active water track sites be identified from orbit using satellite imagery?*
- *What mechanisms drive water track/RSL formation?*



Site map indicating the ten possible water track locations across the Taylor, Wright, and Barwick Valleys.



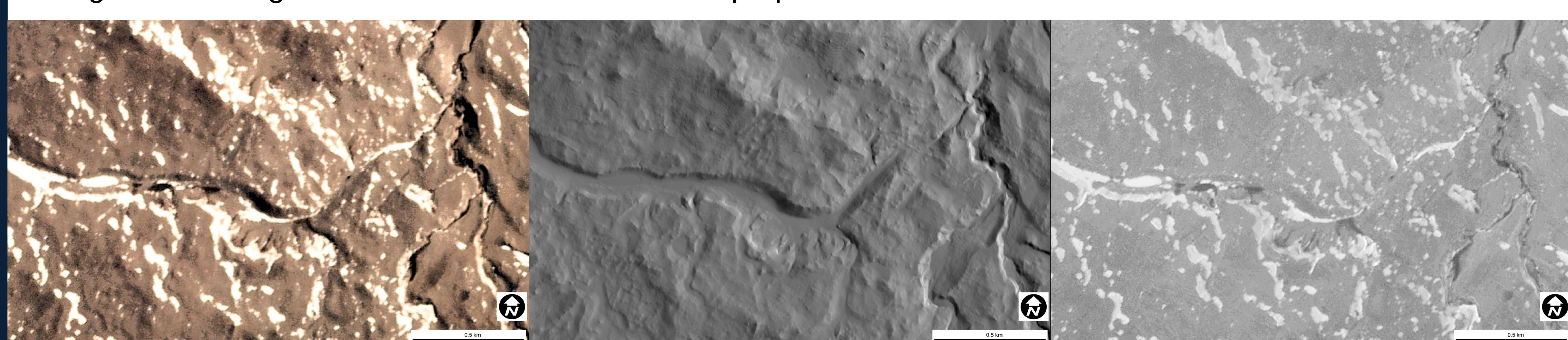
Comparison of Goldman Glacier Basin water tracks (*left*) with Martian RSL (*right*).

Methods

We used satellite imagery to identify water track activity across ten sites to determine the start of the hydroperiod (when liquid water is available in the soil). The satellite imagery used here was:

- Planet Labs Planetscope 8-bit visual image data with ~3 m/pixel spatial resolution
- Daily to sub-weekly revisitation during the 2018-2019 austral summer
  - November-December 2018 (*analyzed here*)
  - January-March 2019 (*ongoing*)

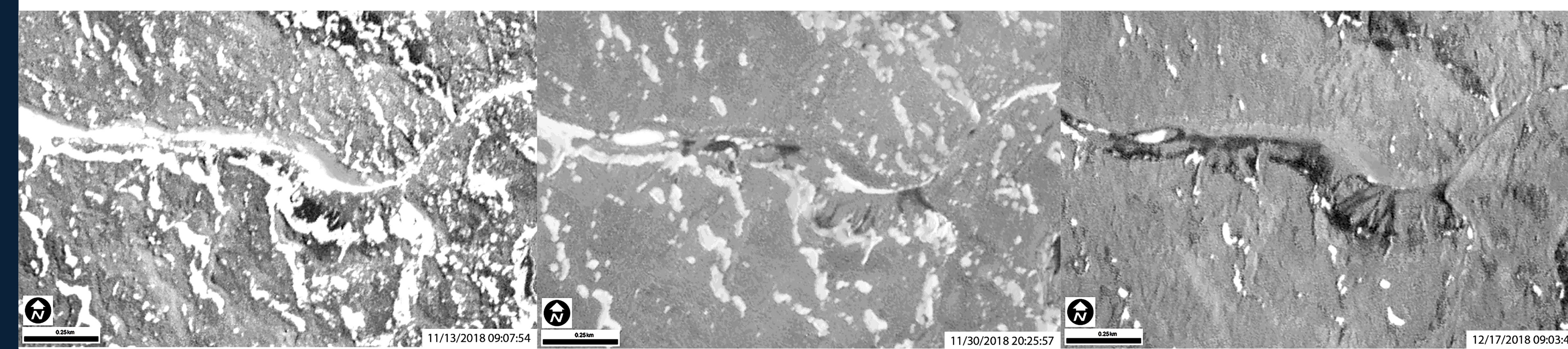
To account for inconsistencies in surface reflectance resulting from topographic features, a terrain-corrected image processing technique was fitted to our needs[4]. A time-of-collection hillshade was produced for each scene, which provided the basis for calculating a linear model for PlanetScope scene DNs that captures the best fit for pixels between the dark and light extremes. The result of this method is an image whose brightness changes are tied to surface reflectance properties instead of direct illumination.



Examples from terrain-correction process. In order from left to right: PlanetScope visual image of Coral Ridge water track site; time-of-collection hillshade; and terrain-corrected image indicating regions with confirmed water track activity (red arrows).

Results

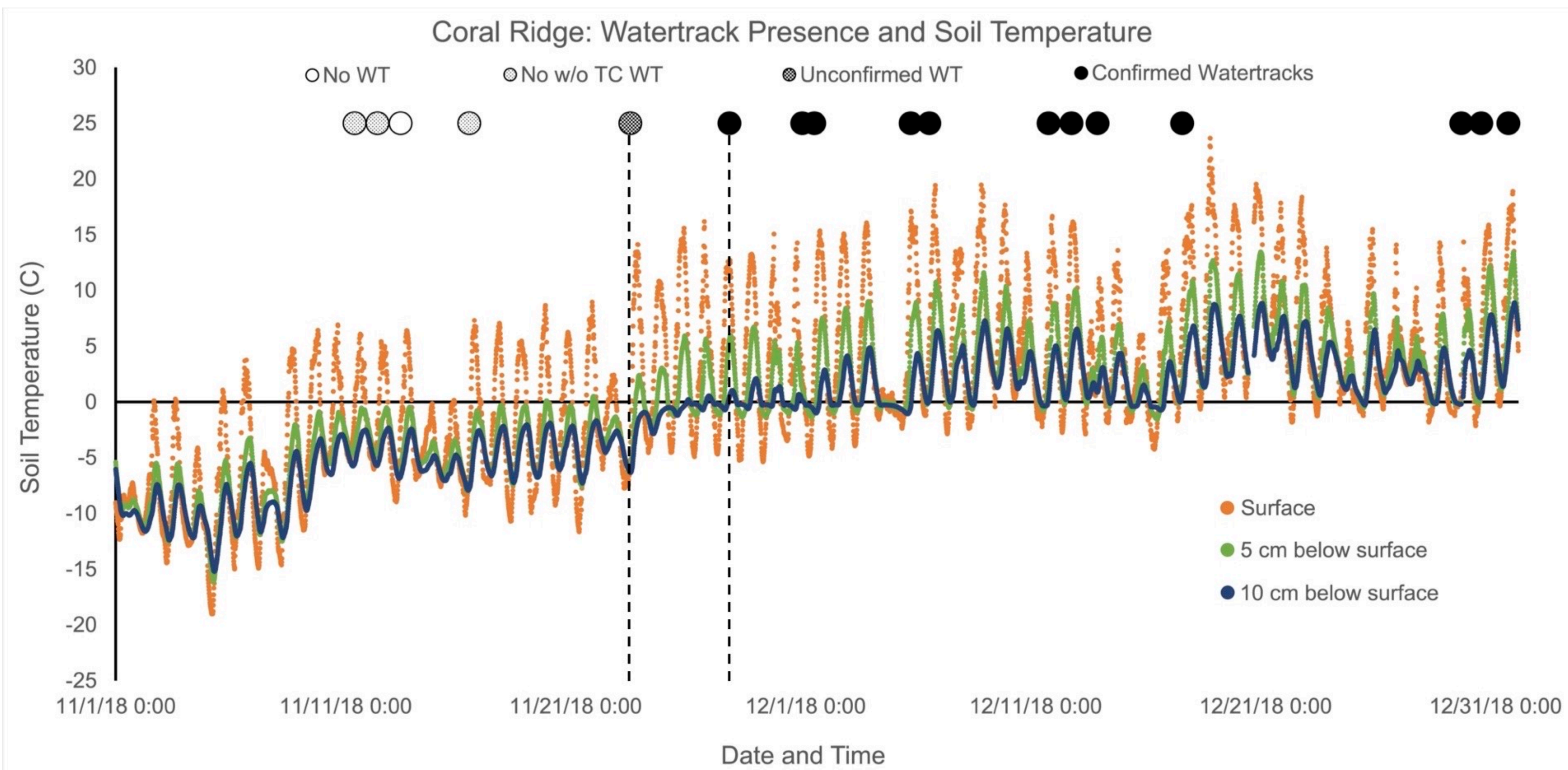
Using the TC-images, it is possible to identify when water tracks are active or inactive. The first confirmed date with water track activity at the Coral Ridge site begin is November 30th, 2018, with formation occurring as early as the 25th. The water tracks in each active site can be seen growing incrementally over the course of the season. Additionally, the start of water track activity on south-facing slopes was delayed by two months.



Incremental growth (~two weeks between images) of water tracks at the Coral Ridge site.

Major Findings

- Water track activity begins in many sites during mid-late November, which is earlier than was previously thought. This suggests a longer duration for the biogeochemical processes taking place in the soils (solute transport, habitable zones of liquid water, movement of nutrients, etc.)[5-7]
- Water tracks at south-facing sites demonstrate a delayed start date from the timing of the north-facing sites. The relationship between the start of water track activity and slope orientation suggests that water track activity is driven by seasonal changes in incoming solar radiation (which affect soil temperature) and not seasonal changes in air temperature.



- The start of water track activity corresponds to subsurface soil temperatures reaching the zero-degree isotherm. This indicates a subsurface meltwater source for water tracks.
- Furthermore, water tracks appear weeks after surface temperatures reach the zero-degree isotherm, suggesting that surficial snow is not a significant meltwater source.

The findings here show that water tracks form through seasonal changes in incoming shortwave radiation and have a subsurface meltwater source that is protected from diurnal temperature cycling across the zero-degree isotherm. Further data collection seeks to confirm the end dates for the water track activity to compare with the RSL fading season. As RSL-analogs, the protected water source and capillary wicking formation mechanism of water tracks encourages the possibility of a liquid water or briny-water source for seasonal RSL activity.

1. Levy, J. S. et al. (2011) GSA Bul., 123, 2295–2311. 2. McEwen, A. S. et al. (2011) Science 333, 740–743. 3. Langford, Z. L., et al. (2012) Ant. Sci., 27(2), 197–209. 4. Salvatore, M. (Personal communication). 5. Ball, B. A. & Levy, J. S. (2015) JGR-Biogeo., 120, 270–279. 6. Levy, J. (2012) Icarus, 219, 1–4. 7. Levy, J. S. et al. (2013) Ant. Sci., 26, 153–162.