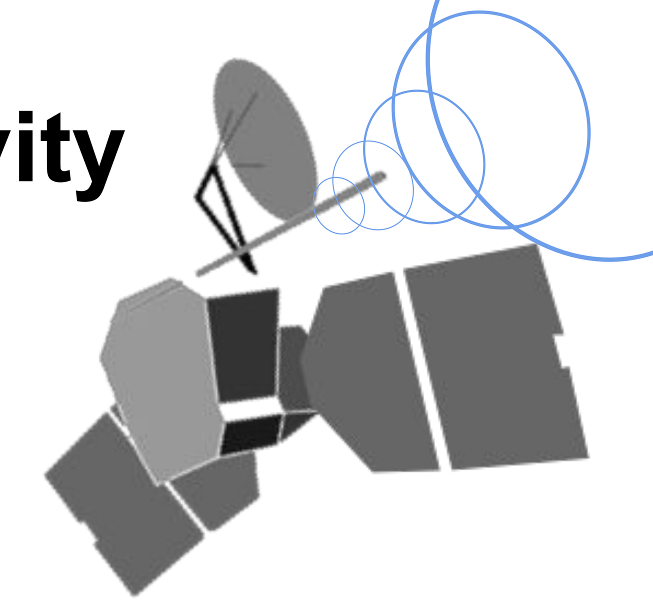
Mars Subsurface Water Ice Mapping (SWIM): Radar Surface Reflectivity

Z. M. Bain[1], G. A. Morgan[1], N. E. Putzig[1], B. A. Campbell[2], A. M. Bramson[3], E. I. Petersen[3], M. Mastrogiuseppe[4], M. R. Perry[1], D. M. H. Baker[5], I. B. Smith[1], R. H. Hoover[5], H. G. Sizemore[1]

[1]Planetary Science Institute, [2]Smithsonian Institution, [3]University of Arizona Lunar and Planetary Laboratory
[4]California Institute of Technology, [5]NASA Goddard Space Flight Center, [5]Southwest Research Institute



What is SWIM?

The Subsurface Water Ice Mapping (SWIM) in the Northern Hemisphere of Mars Project supports an effort by NASA's Mars Exploration Program to determine in situ resource availability for future human exploration. Using several techniques and instruments, we are performing global reconnaissance mapping as well as focused multi-dataset mapping from 0º to 60ºN. Results presented on this poster are focused on the radar surface reflectivity analysis of the SWIM project.

For results from the other datasets, see the other SWIM Project posters at this LPSC:
Bramson et al. (subsurface reflectors) Perry et al. (SWIM infrastructure)
Hoover et al. (thermal analysis) Putzig et al. (geomorphology)
as well as the talk by Morgan at al. (overview) at 9:45 AM Friday morning

Final results will be presented at the next Human Landing Site Selection workshop.
Our maps are being made available to the community on the SWIM Project website.
Follow us on Twitter for project news and product release information.

https://swim.psi.edu/ @RedPlanetSWIM

Proposed Extension Activities

- Better calibrate the radar surface return data by accounting for spacecraft configuration using auxiliary information provided with SHARAD data
- Incorporate a new evaluation of SHARAD roughness
- Integrate results from MARSIS data

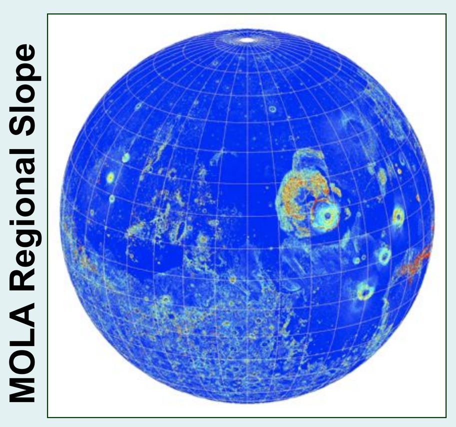
Radar Surface Reflectivity

- SHARAD was designed to study the subsurface structure of Mars through the detection of reflections originating from boundaries between underground layers with contrasting dielectric properties.
- **HOWEVER**, Echoes returned from the surface of Mars also contain a wealth of useful information, including *surface roughness* and near-surface *Fresnel reflectivity*.
- Fresnel reflectivity is related to the *dielectric properties* and *density* of the shallow (< 5 m) subsurface.
- It is thus possible to isolate **the signature of ice in low power surface returns**, due to its **low density** [Mouginot, J. et al., 2010].

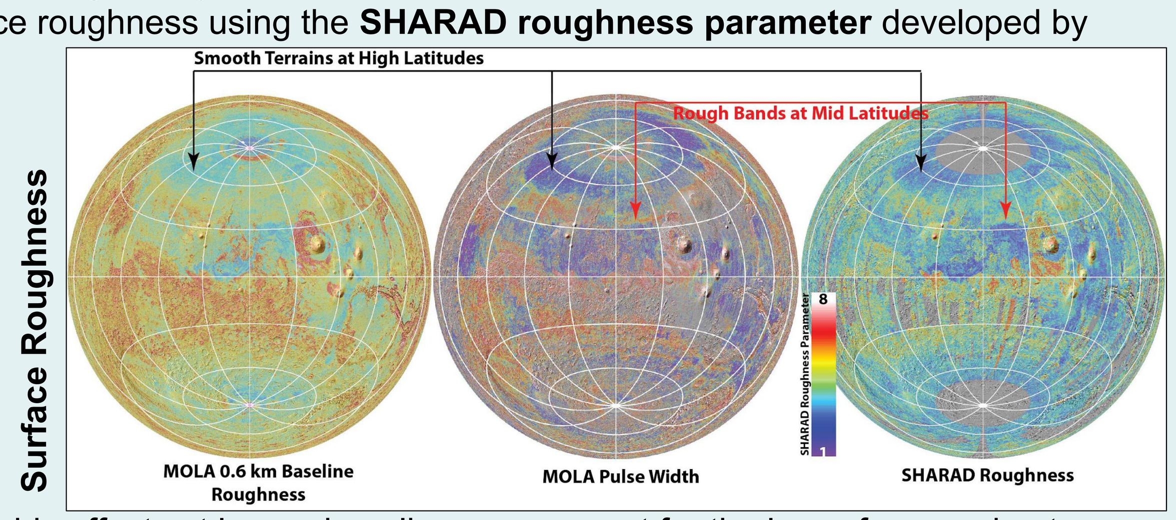
So how do we **isolate** the Fresnel reflectivity from the surface power return?

1. Limit ionosphere effects by excluding all daytime tracks.
2. Normalize the power for surface roughness using the **SHARAD roughness parameter** developed by [Campbell et al., 2013].

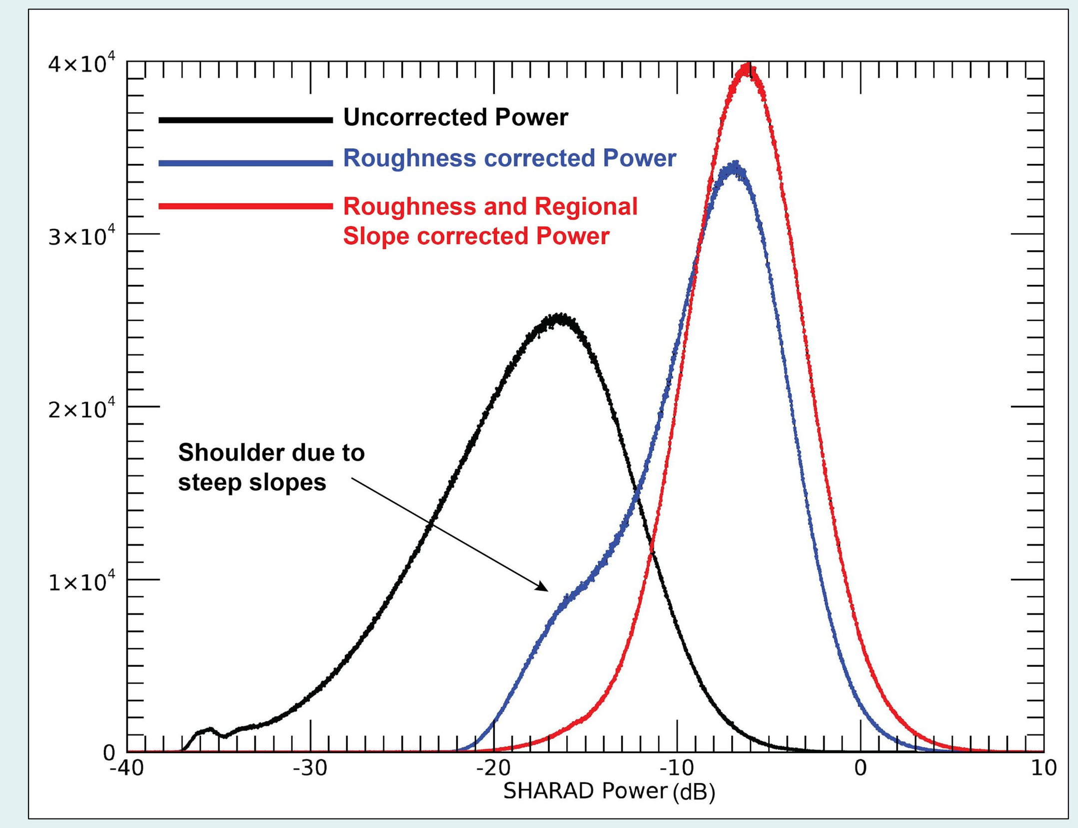
MOLA Regional Slope



Surface Roughness



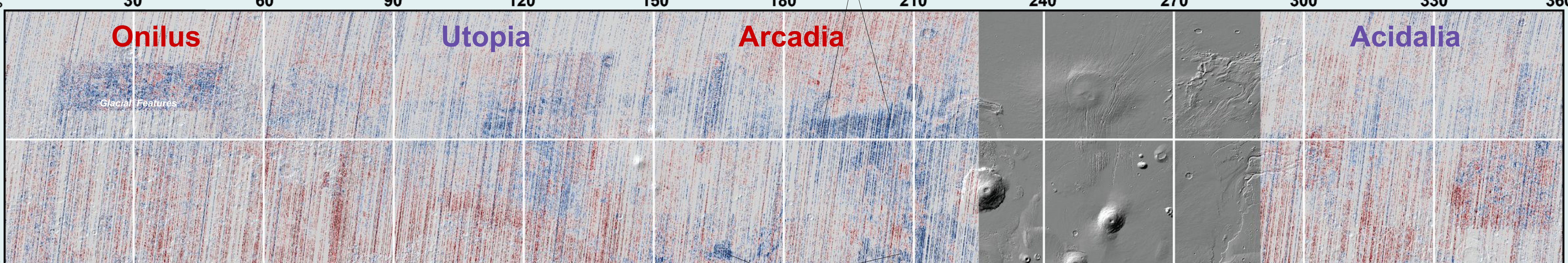
3. To further account for topographic effects at longer baselines, we correct for the loss of power due to regional slope using the median MOLA slope value over a Fresnel zone.
4. Finally, to account for additional MRO influences (spacecraft roll angle, solar panel configuration), we take the median value of corrected SHARAD returns sampled over 1/12° bins.



***Above**: Normalizing the SHARAD surface power for topography results in a narrowing of the power distribution and thus further constrains the influence of near-surface density.*

***Far Left**: MOLA median regional slope values over a SHARAD fresnel zone. **Left:** Comparison of MOLA (Kreslavsky and Head, 2000: **base-length** and Neumann et al 2003: **pulse width**) versus **SHARAD** derived roughness datasets. All methods reveal similar surface features including those associated with periglacial landforms.*

Results and Products

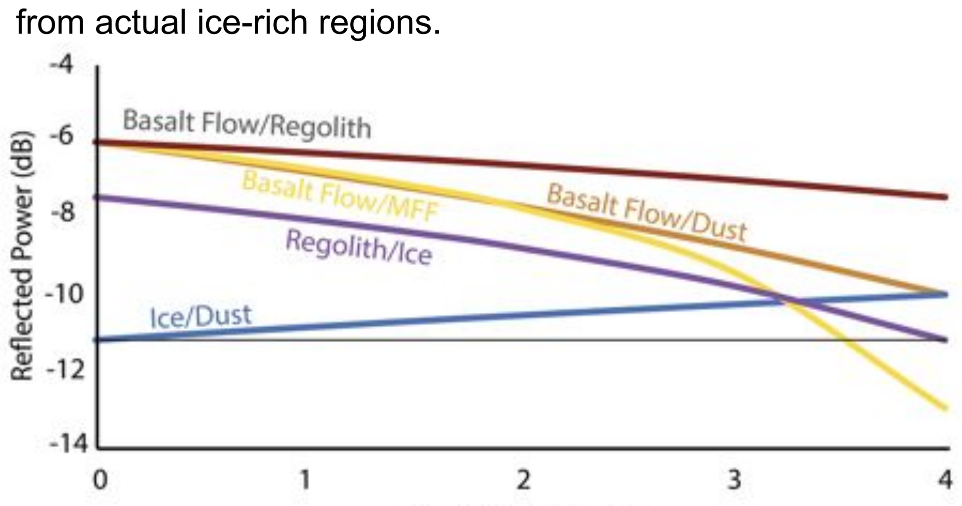


Consistency

Martian Northern Hemisphere Radar Surface Reflectivity Ice Consistency Map. As the surface power return is governed by the bulk density of the upper ~ 5m, we assume that low power (thus low density) values are **consistent with the presence of ice**. The consistency values displayed in the map are scaled according to the corrected power distribution presented up top. The power data show ice consistency in many distinct regions of the northern plains, including areas associated with the extensive glacial features present in 'Onilus'. The equator-straddling Medusae Fossae Formation (MFF) also exhibits high consistency values. Previous sounding studies of the MFF have revealed it to consist of icy or anonymously very low density (dry) material [Walters et al., 2007; Carter et al., 2008; Morgan et al., 2015].

Measuring Near-surface Density

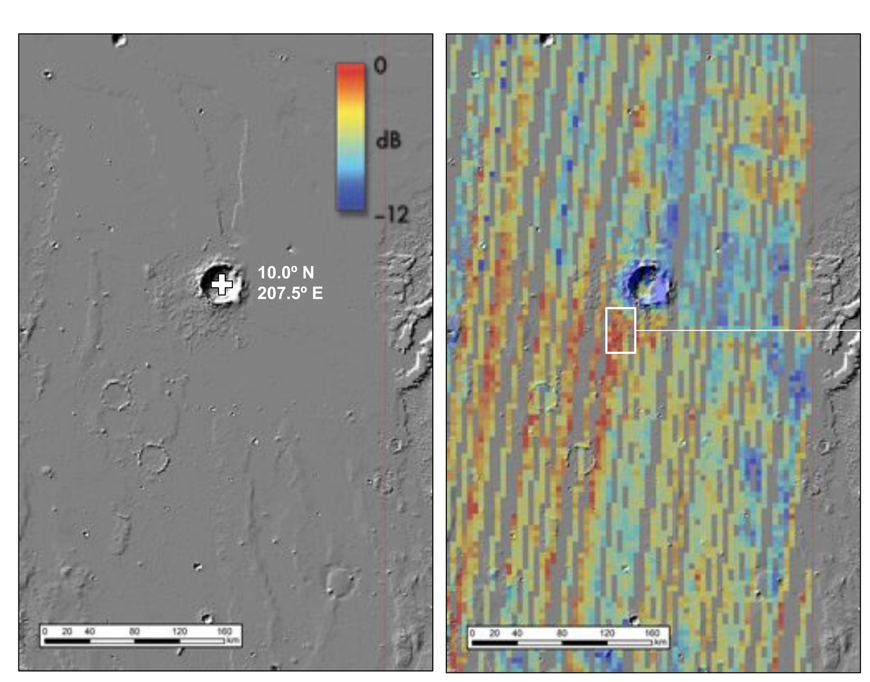
Due to the low density of ice relative to other, more typical (basalt-derived) Martian materials, high concentrations within the shallow subsurface will result in a distinctive low power return. However, like SHARAD dielectric measurements, ice mixed with progressively larger concentrations of other materials will result in non-unique reflectivity values. Through the integration of SHARAD surface power maps with other datasets, the SWIM approach provides a means to isolate 'false positives' (see center) from actual ice-rich regions.



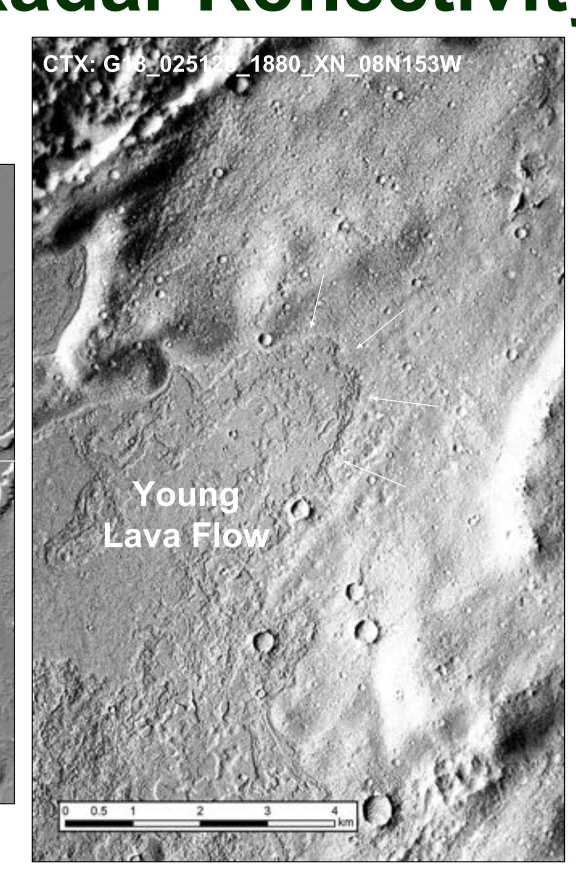
Simple two-material model depicting the influence adding a secondary material (within the upper 4 m of the subsurface) has on the expected reflected radar power.

Comparisons between Radar Reflectivity and Geomorphology

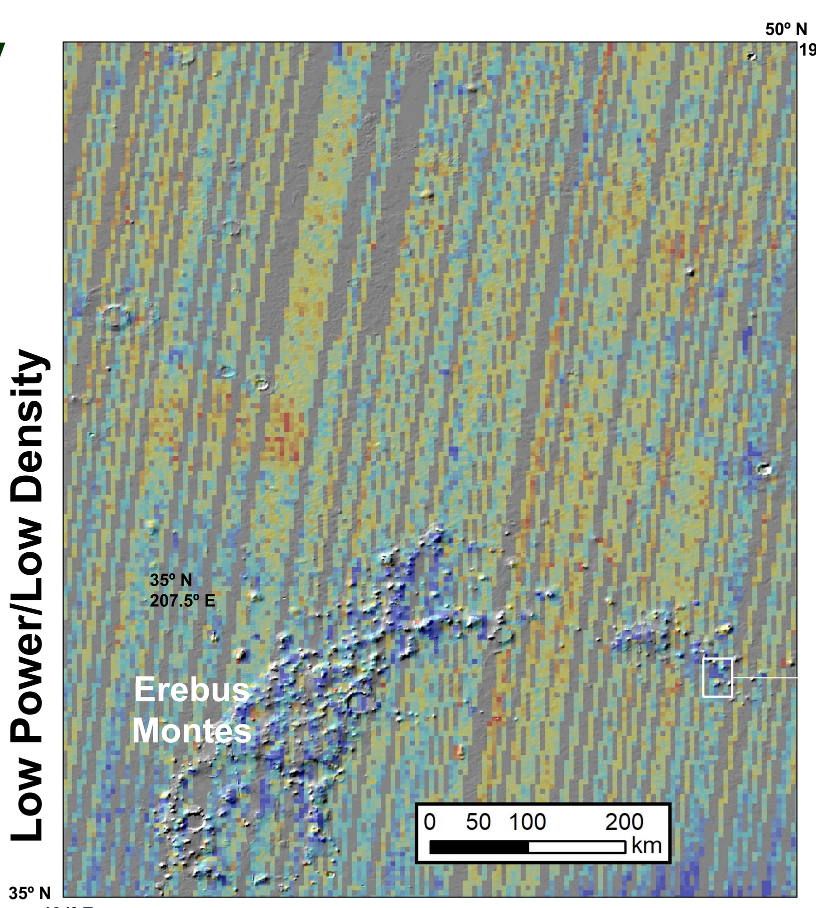
High Power/High Density



Amazonis Planitia **SHARAD Power Return**



Low Power/Low Density



SHARAD Power Return

Glacial Features (Lobate Debris Aprons)

REFERENCES: Campbell, B. A., et al., (2013). Roughness and near-surface density of Mars from SHARAD radar echoes. J. Geophys. Res, 118(3), 436–450; Carter, L. M., et al. (2009), Shallow radar (SHARAD) sounding observations of the Medusae Fossae Formation, Mars, Icarus, 199(2), 295–302; Kreslavsky, M.A. and J.W. Head (2000), Kilometer-scale roughness of Mars: Results from MOLA data analysis, J. Geophys. Res., 105,26,695–26,711; Morgan, G. et al., (2015) Evidence for the episodic erosion of the Medusae Fossae Formation preserved within the youngest volcanic province on Mars. GRL, 42(18), 7336–7342. Mouginot, J. et al., (2010) The 3–5MHz global reflectivity map of Mars by MARSIS/Mars Express: Implications for the current inventory of subsurface H2O. Icarus, 210, 612–625. Neumann, G. A. et al., (2003), Mars Orbiter Laser Altimeter pulse width measurements and footprint-scale roughness, Geophys. Res. Lett., 30, 1561, doi:10.1029/2003GL017048; Watters, T. R., et al. (2007), Radar sounding of the Medusae Fossae Formation Mars: Equatorial ice or dry, low-density deposits?, Science, 318(5853), 1125–8