AIRBORNE RADAR STUDY OF MARS ANALOGS IN THE SOUTHWESTERN UNITED STATES.

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Introduction: The search for surface and near-surface liquid water on Mars is a central part of current and planned future exploration, which include radar sounders [1] on Mars Express and MRO and proposed synthetic aperture radar (SAR) imagers [2, 3]. In order to penetrate sand and dust cover, these systems are proposed for longer wavelengths (e.g, from [2]: 24 cm / L-band and 74 cm / P-band) than those considered optimal for the detection of soil moisture (6 cm / C-band) [4]. However, there has been some success in detecting soil moisture at longer wavelengths [5–7]. Given the size and mass constraints for Mars missions, the optimization of radar instrument parameters for meeting science objectives, such as searching for liquid water, is essential. In this on-going study, we are using repeat coverage of Mars analog sites with multi-frequency (C, L and P band) airborne radar and ground truth soil sample data to assess the detectability of soil moisture.

AIRSAR: In this study we used the 20 MHz chirp bandwidth for the polarmetric (POLSAR) mode of the NASA/JPL AIRSAR system, which images the ground at a slant range resolution of 6.7m in C, L and P (5.4, 23, 67-cm wavelength) bands in all polarizations. AIRSAR is able to transmit at 40 and 80 MHz chirp bandwidths (with 3.3 and 1.7-m slant range resolutions), but FCC regulations preclude use of P-band at those bandwidths inside the United States and C-band is not available at 80 MHz. Consequently, we used the lower resolution to hold resolution constant among the bands to produce a consistent data set. In comparision, proposed Mars SAR missions have a maximum resolution of 5m [2]. The first AIRSAR flight for this study was on Sept. 17, 2002, with repeat flights planned for March/April and July of 2003.

Radar backscatter is a function of a) incident angle, b) polarization, c) surface roughness and slope (held constant for this study), and d) complex dialectric constant of the ground (which is primarily a function of water content). Therefore, exact track repeat coverage of the same sites under different soil moisture conditions will enable an assessment of the ability to detect near-surface soil moisture and changes in water content of that soil in environments of interest for Mars.

Field Sites: Three primary field sites were selected for ground truthing during this study:

Little Colorado River, AZ: The Little Colorado River is ephemeral; the field site is in the flood plain near the confluence of Tohachi Wash with the Little Colorado River (35.71°N, 111.31° W). Corner reflectors were deployed to enable location in the radar image and soil samples were collected in three 20m by 20m nine point grids at four depths (0, 10, 20 and 40 cm) in increasing distance from the currently active channel. A time domain reflectometer (TDR) system was used to measure soil moisture to a depth of 13-cm within part of the first grid. Also covered within the same radar image is the Black Point lava flow, a wind streak previous studied by radar [8], and the FIDO test site for the Mars Exploration Rover program.

Death Valley, CA: An unnamed spring at the head of a gully at 36.984°N, 117.355°W, just south of the Grapevine Ranger Station was selected as an analog for martian gullies [9]. Soil samples were collected from 16 points in and around the gully at four depths (0, 10, 20 and 40 cm).

Arrastra Gulch, CO: This site includes a creek at 37.82°N, 107.62°W with surface flow from a cirque lake that becomes subsurface in a talus deposit. It was selected as an analog for gullies on Mars. A corner reflector was deployed at the point where the flow submerged into talus to enable location within the radar image and to assess the difference in backscatter between surface and sub-surface flows.

Data Analysis: Soil moistures were determined at Arizona State University and the University of Arizona using gravimetric methods; a root mean square error analysis was performed to assess data consistency. Volumetric water contents were measured for separate sample points from each of the grids at the Little Colorado River site.

The ENVI software package was used to process the radar data and extract decibel (dB) values for backscatter from pixels corresponding to sample sites for each band/polarizaton combination. These will be compared to the backscatter from the same points, with repeat soil sampling and moisture measurements, during the repeat track flights in 2003. The objective of this analysis will be to determine the relative signature of soil moisture at 0-40cm depth in C, L and P band in gully and channel environments analogous to Mars.

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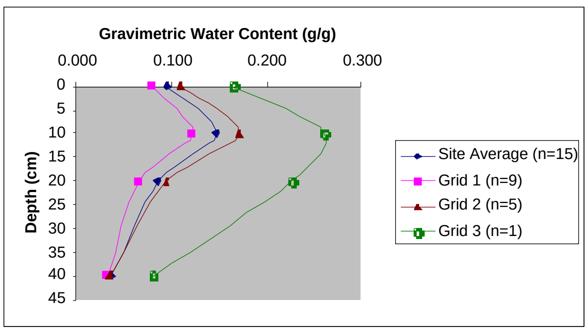

Figure 1: Subset of VV-polarized radar image showing Little Colorado River site, red = C-band, blue = L-band, green = P-band.

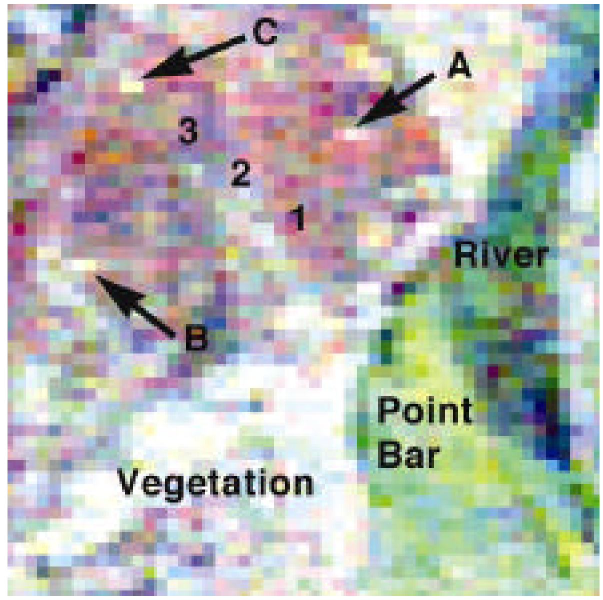

Figure 2: Subset of Figure 1, showing reflectors A, B and C, and soil sampling grids numbered 1, 2 and 3.

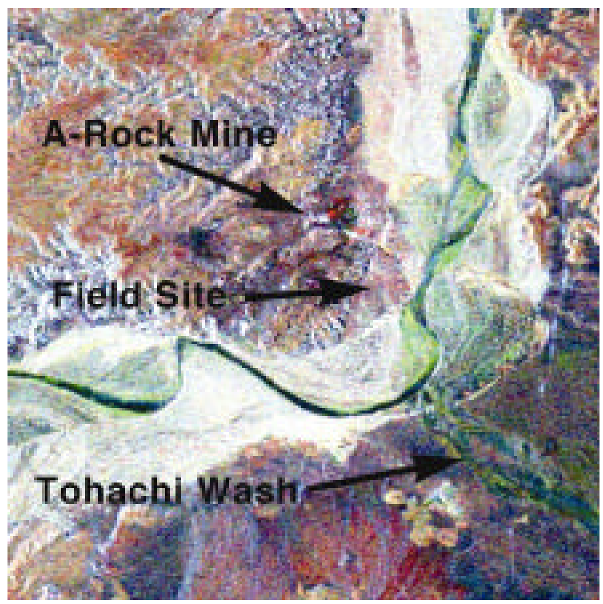

Figure 3: Gravimetric water contents for the Little Colorado River site, average of two redundant analyses with an RMS error of 0.032 for a range of 0.016 to 0.317.