MER Landing Site Radar Data

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Available Mars Radar Data

Facility	Wavelength	Polarization	In Hand
NAIC Arecibo	12.6 cm	OC	No
Coded Long Pulse		SC	Yes
GSSR/VLA	3.5 cm	OC	Yes
Continuous Wave Interferometric Mapping		SC	Yes
GSSR	3.5 cm	OC	Yes
Delay-Doppler			

Radar Glossary

Circular polarization: Planetary radar astronomy typically uses circularly polarized transmitted beams to avoid uncertainties due to the Earth's ionosphere, while terrestrial radar remote sensing uses linear polarization. Circular polarization data can be derived from fully polarimetric terrestrial data.

OC: Opposite sense of circular polarization received echo as compared to transmitted.

SC: Same sense of circular polarization received as compared to transmitted.

Polarized echo: OC polarization echo.

Depolarized echo: SC polarization echo.

Specular echo: Near-nadir mirror-like reflection of the incident energy in the OC/Polarized channel only. Generally understood to be produced by radar-facing reflecting facets 10x to 100x the wavelength.

Diffuse echo: Scattering due to roughness elements (surface or volume) at or near the wavelength scale. Is the dominant scattering mechanism at incidence angles > 20 degrees from normal incidence.

Polarization ratio: SC/OC indicates importance of multiple scattering.

Radar Information

- **Specular echo is required for radar altimeter system (RAS) to function properly; reflected in requirements:**

  The RAS shall be able to acquire and maintain track over surface with an equivalent Hagfors Fresnel reflectivity greater than 0.03 and a Hagfors model RMS surface roughness less than [8] degrees.

- **Specular echo information from GSSR delay-Doppler database.**

- **Diffuse echo relates to roughness at scales of interest to trafficability.**
- **Diffuse echo information from NAIC Arecibo and GSSR/VLA data sets.**

GSSR Specular Echo Data

Site	Track Date	Latitude	ρ_0	θ_{rms}
Hematite	May 3, 2001	1.83°S	0.050±0.009	1.3°±0.4°
	May 5, 2001	1.82°S	0.045±0.009	1.2°±0.4°
Melas	No data			
Gusev	No data			
Isidis	Jan. 21, 1993	5.11°N	0.023±0.007	3.8°±0.7°
	Jan. 23, 1993	4.86°N	0.032±0.002	3.3°±0.5°
Eos	No data			
Athabasca	Dec. 22, 1992	10.15°N	0.074±0.029	4.1°±1.1°
	Dec. 31, 1992	8.56°N	0.031±0.001	2.3°±0.4°

Values reported in this table are averages over all longitudes between the east and west Extremes of the 3-sigma MER ellipses, except for Athabasca where the values are for single resolution cells nearest 155°E.

GSSR Comparison Data

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Site	Track Date	Latitude	ρ_0	θ_{rms}
Pathfinder	Jan. 27, 1995	19.96°N	0.04±0.01	4.5°±0.6°
	Jan. 29, 1995	19.79°N	0.08±0.02	5.2°±1.8°
	Jan. 30, 1995	19.69°N	0.05±0.01	4.3°±0.8°
Viking 1	Jan. 27, 1995	19.96°N	0.05±0.01	3.4°±0.5°

Values reported in this table are averages for the 1-sigma MPF ellipse (approx ±50 km) which is a similar size to the 3-sigma MER ellipses, and the VL1 latitude is of course well south of the landing site.

GSSR Site Unit Related Data

- **What to do about sites not directly crossed by radar tracks? Look at radar data from (nearby) surfaces that are mapped as the same geomorphic unit [**Scott and Tanaka, 1986; Greeley and Guest, 1987**].**

Site	Unit	ρ_0	θ_{rms}
Hematite	Npl_2	0.05±0.03	3.2°±1.1°
Melas	Avf	0.02±0.01	4.2°±2.3°
	Hvl	0.02±0.02	4.4°±2.5°
Gusev	Hch	0.04±0.02	4.7°±1.6°
Isidis	Aps	0.06±0.02	2.2°±0.8°
	Hvr	0.06±0.01	2.0°±0.3°
Eos	Hch	0.04±0.02	4.7°±1.6°
Athabasca	Achu	0.03±0.01	3.2°±0.9°
	Aps	0.06±0.02	2.2°±0.8°

Specular Echo Summary

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- All the sites would provide sufficient echo for the RAS to detect the surface.
- From the geomorphic/map unit comparison, for specular, near-nadir scattering, which is controlled by roughness at around the decimeter to meter length-scales, the rougher sites are:
  - Gusev, Melas, and Eos

  and the smoother sites are
  - Hematite, Isidis, and Athabasca
- The "rougher" sites would be comparable to VL1 or MPF by this comparison.

G-VLA Diffuse Scattering

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- **Approach to G-VLA diffuse scatter analysis:**

  Fit the radar data to a backscatter model like

  $$R_p(h) = A_p \cos^{n_p}(h)$$

  where ‘h’ is the incidence angle, and ‘p’ indicates the polarization. Then:

  A_{SC} and A_{OC} are the radar reflectivities at 0 incidence angle for SC and OC polarizations,

  n_{SC} and n_{OC} are the scatter model exponents for SC and OC polarizations,

  C_{SC}, and C_{OC} are the ‘radar albedo’ (or ‘cross-section’) for SC and OC polarizations from $C_p = A_p / (n_p + 2)$,

  and

  μ is the circular polarization ratio: $\mu = C_{SC} / C_{OC}$

  For the OC fits, use only data at h > 30 degrees.

G-VLA Diffuse Scattering cont.

Site	A_{sc}	n_{sc}	C_{sc}	A_{oc}	n_{oc}	C_{oc}	μ
Hematite	0.028	0.18	0.013	0.064	0.47	0.026	0.50
Melas	0.033	0.28	0.014	0.082	0.53	0.033	0.44
Gusev	0.082	0.78	0.029	0.149	1.07	0.049	0.61
Athabasca	0.234	0.86	0.082	0.198	0.51	0.079	1.04
Isidis	0.077	0.59	0.030	0.100	0.14	0.047	0.63
Eos	0.041	0.26	0.018	0.110	0.63	0.042	0.44
VL1	0.062	0.76	0.022	0.078	0.12	0.037	0.60
VL2	0.041	0.03	0.020	0.161	0.14	0.075	0.27
Pathfinder	0.038	0.20	0.017	0.085	0.17	0.039	0.43

The Athabasca Story

- **Athabasca selected as prime site at 2nd workshop.**
- **Thereafter realized that its diffuse cross section was frighteningly high (see previous page).**
- **After presentation of radar data to landing site steering committee, Athabasca demoted to back-up.**

Arecibo Coded Long Pulse

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Arecibo Mars landing site diffuse scattering cross-sections and terrestrial analog surfaces.

Site	σ^o_{SC}	Incidence Angle	Resolution
VL1	0.0191±0.0015	36°	3x3°
	0.0316±0.0024	29°	3x3°
VL2	0.0165±0.0017	55°	4x4°
	0.0124±0.0028	50°	4x4°
Pathfinder	0.0144±0.0015	34°	3x3°
	0.0208±0.0024	42°	3x3°
Athabasca	0.1	22°	1x1°
Terrestrial Sites			
Mauna Iki a'a	0.1	29°	
Mauna Iki pahoehoe	0.03	32°	
Black Rock flow	0.05	28°	
Kilauea caldera pahoehoe	0.013	30°	
	0.01	40°	
Kilauea ponded pahoehoe	0.004	35°	

Arecibo Coded Long Pulse con't

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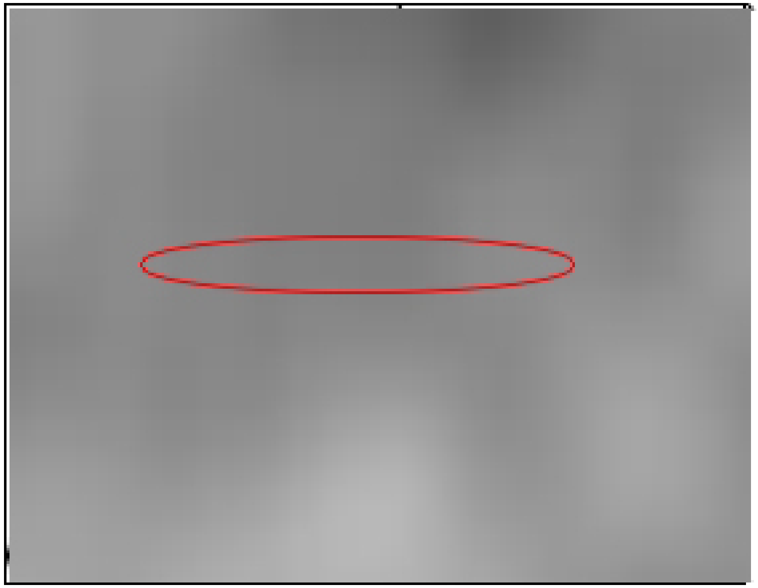
MOLA Topography



Radar Backscatter
Harmon et al. 1999

G-VLA Athabasca

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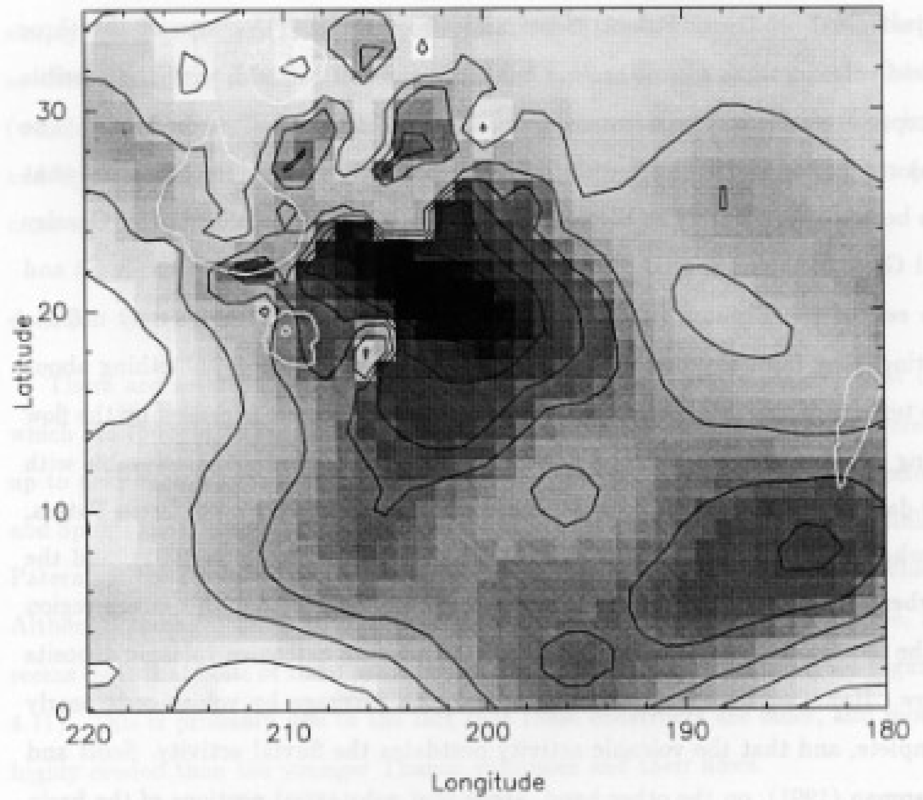

Figure 4.16: Simple Cylindrical projection of A_{ss} from the global backscatter fits showing the Elysium region. Contours are at 5% increments. The white outlines denote the approximate geological boundaries of the calderas and flanks of the three Elysium shield volcanoes (Hecates Tholus to the north, Elysium Mons in the center, Albor Tholus to the south), and Orcus Patera to the east (from Greeley and Guest (1987)). Gray scale range is from 3.0% to 40.7%.

GSSR delay-Doppler

Site	Latitude	Longitude	ρ_0	θ_{rms}
Pathfinder	19.96 N	33.534 W	0.046±0.017	4.8°±0.8°
	19.79 N	33.478 W	0.079±0.039	7.6°±1.8°
	19.69 N	33.505 W	0.062±0.009	5.1°±0.4°
Viking 1	19.96 N	48.0±1.8 W	0.05±0.01	3.4°±0.5°
Athabasca	8.56 N	204.884 W	0.031±0.001	2.3°±0.4°
	8.56 N	205.382 W	0.04±0.04	5.0°±4.5°
	10.15 N	204.956 W	0.074±0.029	4.1°±1.1°

GSSR con’t

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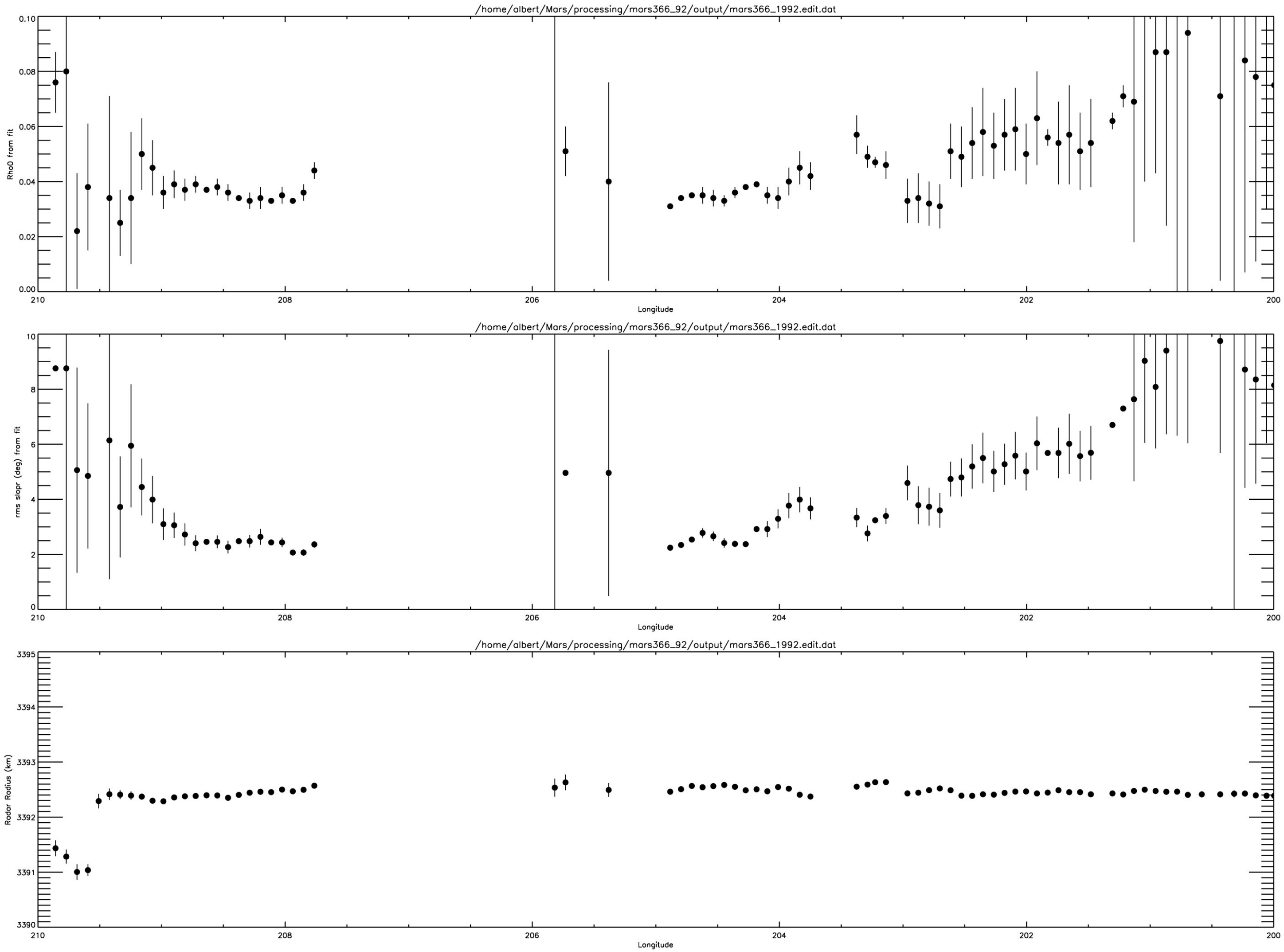

Interpretation

- G-VLA polarization ratio > 1 implies multiple scattering.
- *Harmon et al.* [1999] list 4 hypotheses to explain enhanced multiple scattering from Martian lava flows which to the radar appear rougher than terrestrial flows:
  1. more chaotic texture,
  2. blockier texture,
  3. enhanced dielectric constant,
  4. or volume scattering.

  These hypotheses about texture and physical properties hold even if the surface is not a lava flow.
- Three possible configurations envisaged:
  1. rock-strewn plain with enhanced volume-scattering,
  2. regolith-filled rough or blocky rock surface, or
  3. gently undulating rock-strewn plain where regolith surface is very rough at decimeter scale.