Modeling Radar Scatter from Icy and Young Rough Lunar Craters

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Contents

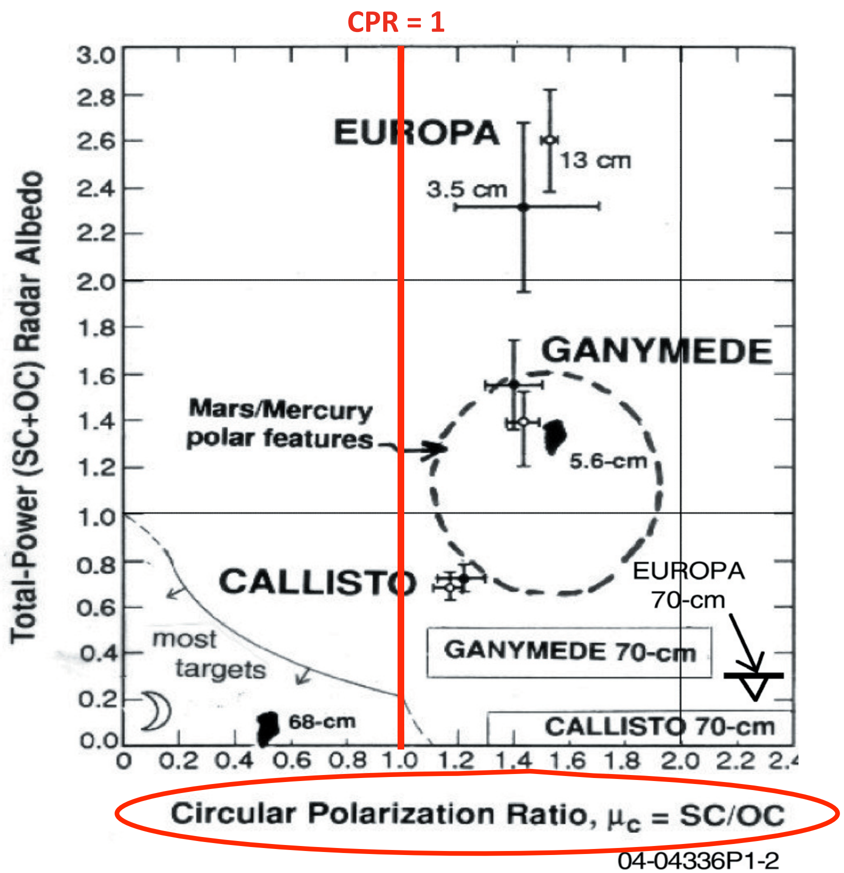
- **Rationale for Modeling and Mini-RF Overview**
- **Modeling Lunar Radar Backscatter Cross-sections Assuming Differences in Quasi-Specular and Diffuse Scattering Components**
- **Preliminary Comparison of Model with LRO Mini-RF Polar Data**

<u>References</u>

- ***Modeling Radar Scattering from Icy Lunar Regoliths at 13-cm and 4-cm Wavelengths, Thompson, Ustinov, and Essam Heggy, JGR, Jan, 2011***
- ***Initial Results for The North Pole of the Moon from Mini-SAR, Chandrayaan-1 Mission, Spudis et al. GRL, Vol. 37, 2010***

Rationale for Modeling and Mini-RF Overview

Rationale for Modeling



From Ostro, 2002

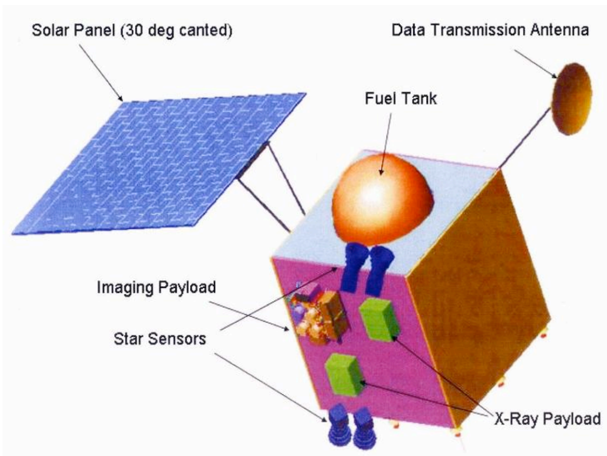
If there is ice on the Moon like that at the poles of Mercury and Mars or like the Galilean satellites, then it would have echo enhancement of 10 or more and a Circular Polarization Ration (CPR) greater than unity.

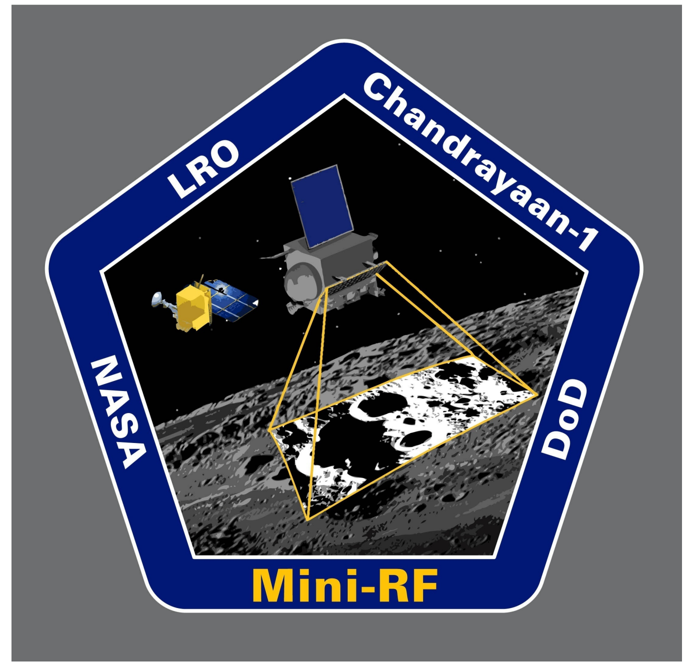
This is not yet observed on the Moon.

Thus, can we generate models that predict how these otherwise strong signals are muted/masked by regolith?

Chandrayaan-1 and LRO Mini-RF Radars

Chandrayaan-1





LRO

Chandrayaan-1 and LRO were in polar orbits thus enabling the Mini-RF observations of polar regions.

Chandrayaan Mini-RF Overview

Mini-RF Objectives
- **Discover and map near-polar putative water-ice deposits**
- **Characterize lunar surface, especially permanently shadowed areas**

Radar parameters:
- **S-band 13 cm wavelength / Angle of incidence (at the surface) = 39° ± 10°**
- **Resolution = 150 m / Looks = 16 (about the same as Magellan)**

Radar Implementation
- **Transmit right-circular polarization (RCP)**
- **Receive opposite (H and V) Linears and generate Circular Polarization Ratio (CPR = RCP/LCP) via Stokes Parameters (CPR = (S1 – S4) / (S1 + S4),**
- **Expected Ice signature = High reflectivity, large CPR, and Stokes parameters**

Imaging Strategies
- **Strip maps on sequential orbits for 28 days converted to mosaics**
- **Swath width 18 km or more / Repeat left and right at both North and South Poles**

Expected Results:
- **Total reflectivity and CPR of both poles with imagery and/or scatterometry**

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Chandrayaan-1 and LRO Mini-RF Radar Parameters

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Parameter	Chandrayaan-1	LRO S-Band	LRO X-Band
Frequency	2380 MHz	2380 MHz	7140 MHz
Wavelength	12.6 cm	12.6 cm	4.2 cm
Pixel Spacing	75 m	7.5 and 75 m	7.5 and 75 m
Number of Looks	16	8 and 16	8 and 16
Swath Width	8 km	4 and 6 km	4 km
Angle of Incidence (Center-Beam)	35°	49°	49°
Antenna Beam-Width (Azimuth)	5°	6°	2°
Antenna Beam-Width (Range)	10°	10°	3.3°

Chandrayaan-1 Mini-RF Operations – October'08 – August'09

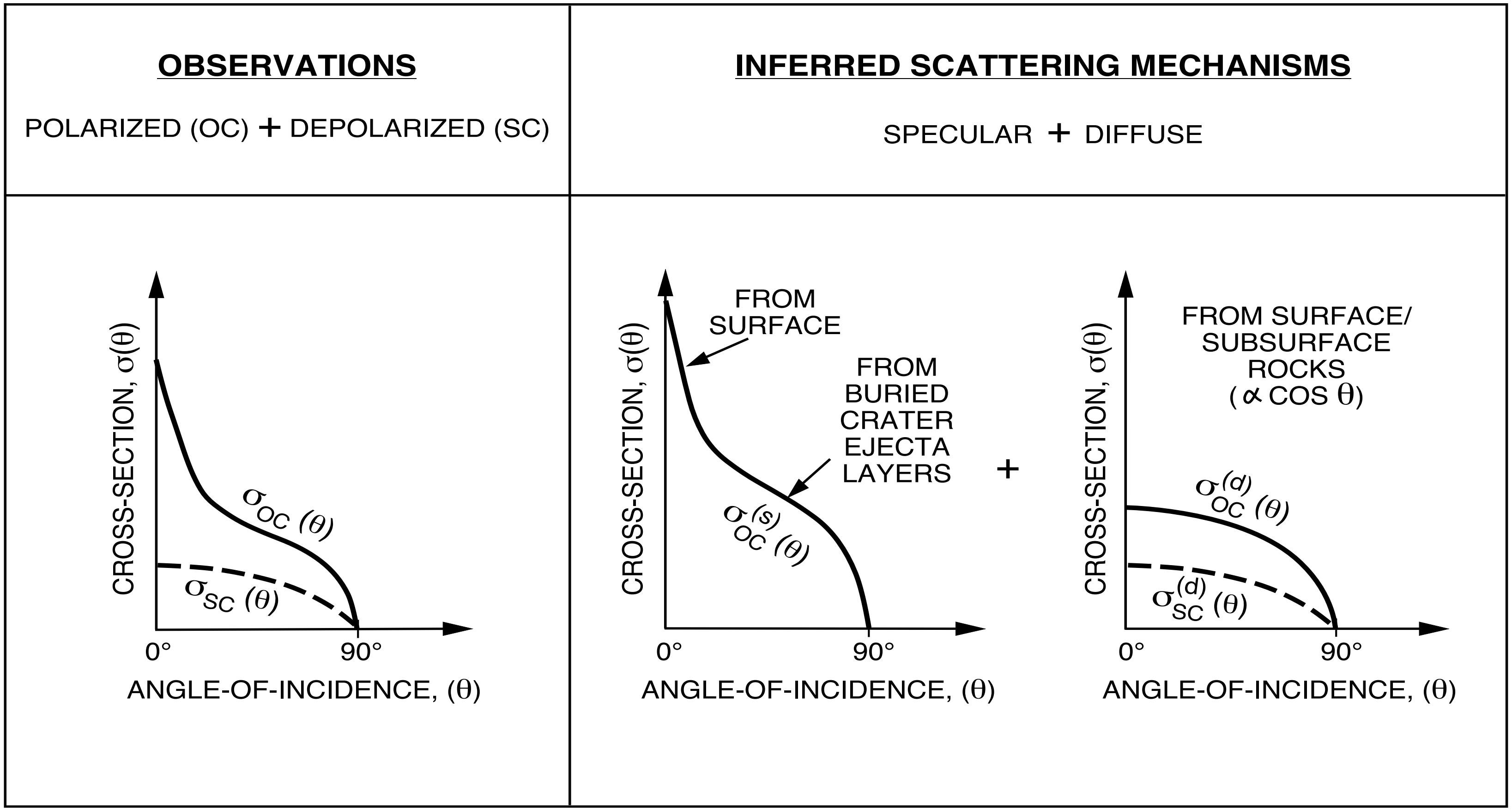
LRO Mini-RF Operations July'09 – December'10

Modeling Lunar Radar Backscatter Assuming Differences in Quasi-Specular and Diffuse Scattering Components

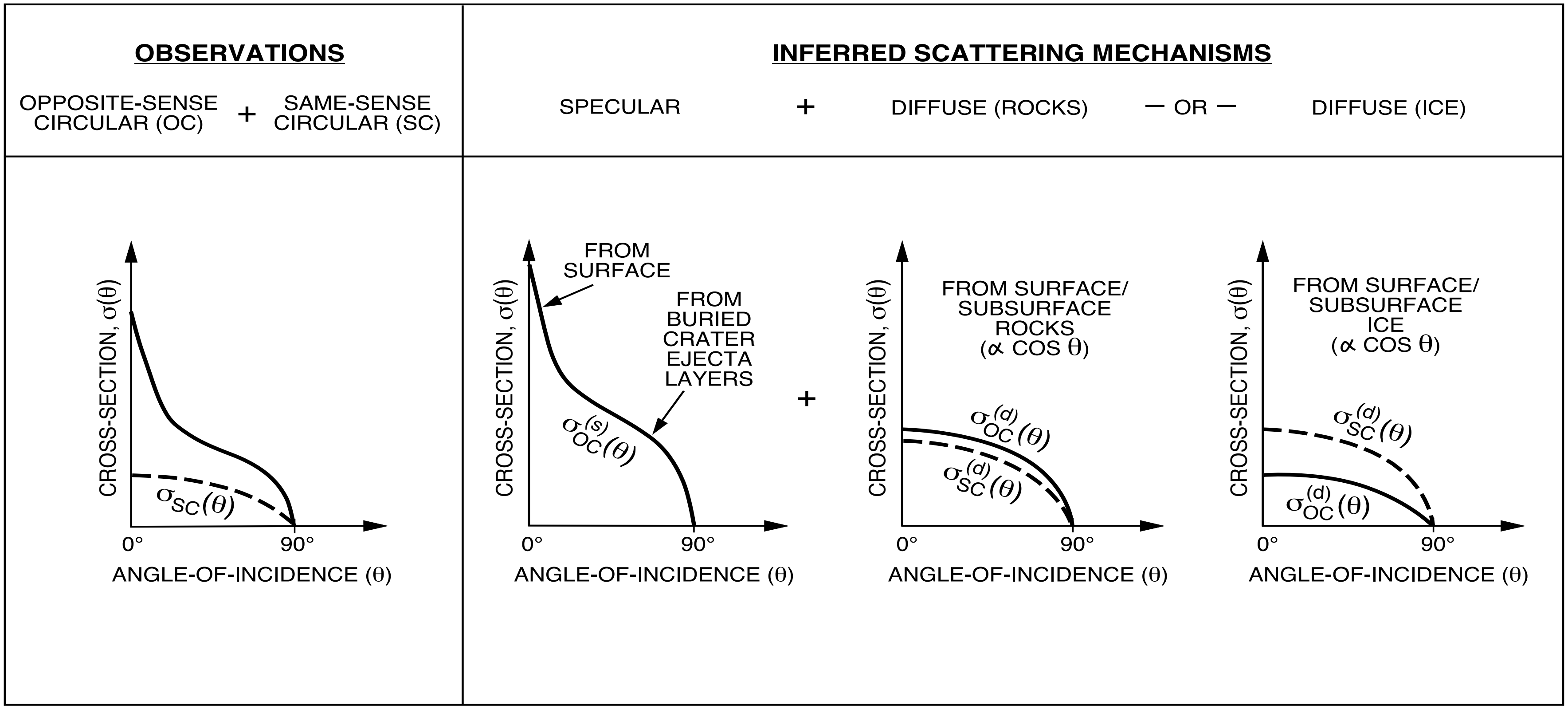
Reference

Modeling Radar Scattering from Icy Lunar Regoliths at 13-cm and 4-cm Wavelengths, Thompson, Ustinov, and Essam Heggy, JGR, Jan, 2011

Average Lunar Radar Behavior



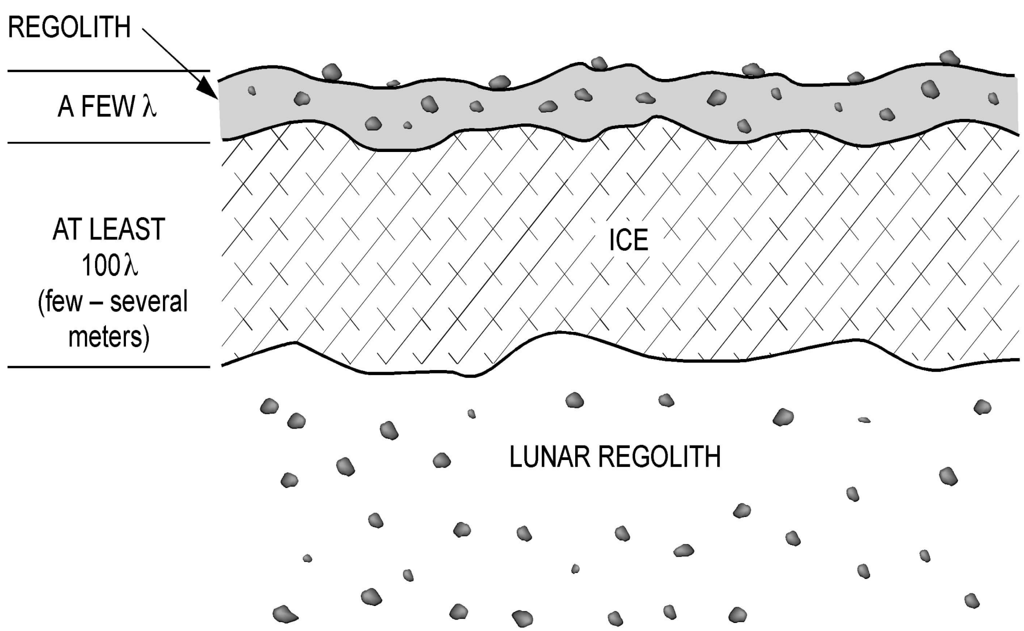
Modelling Lunar Radar Scattering
Diffuse and Specular Components



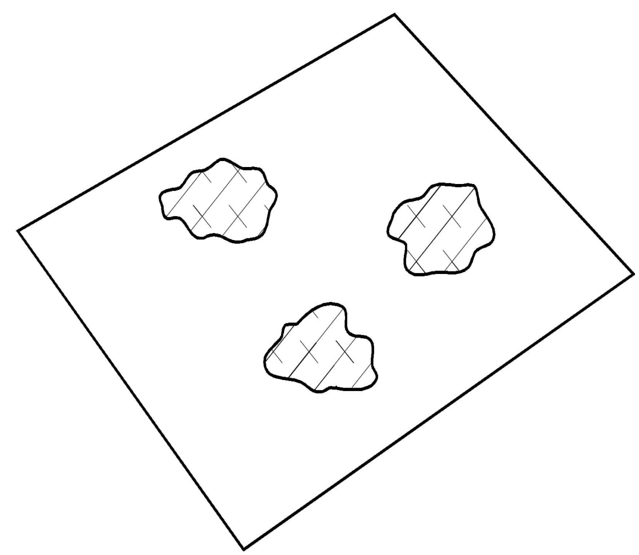
Note – Only Diffuse scattering contribute to SC (Same-Sense Circular) echoes

Assumed Lunar Ice Conditions

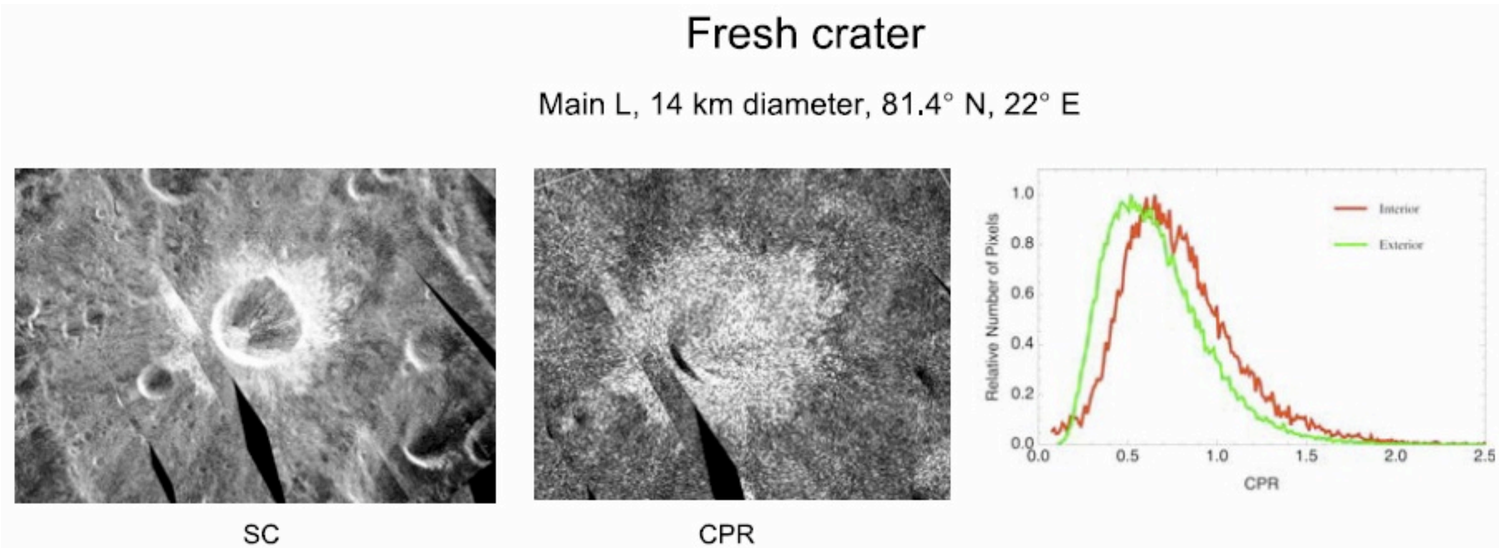
Thick (>100λ) ice lens covered with thin regolith

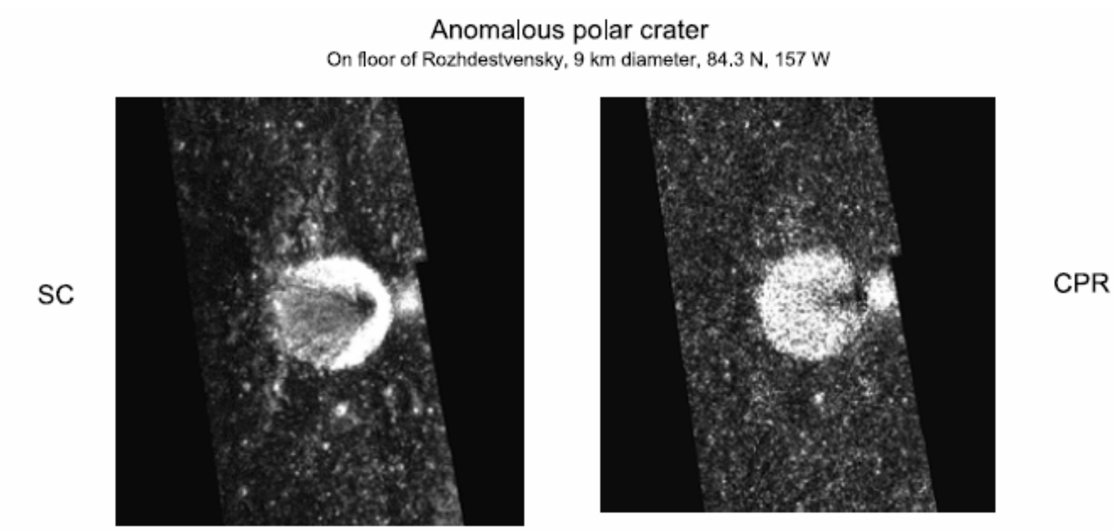


Ice patches inside a radar pixel



Examples of Blocky and Icy Craters

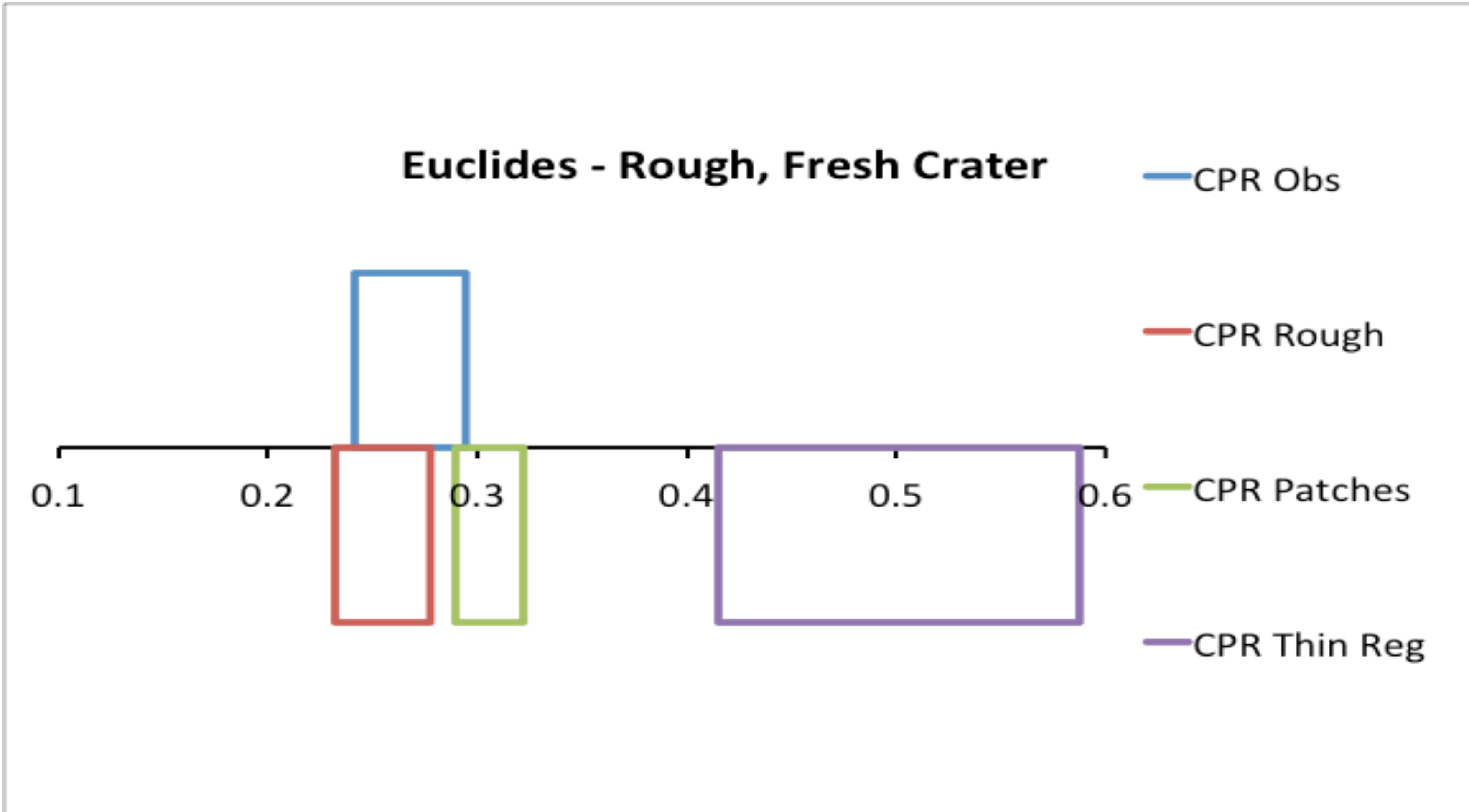




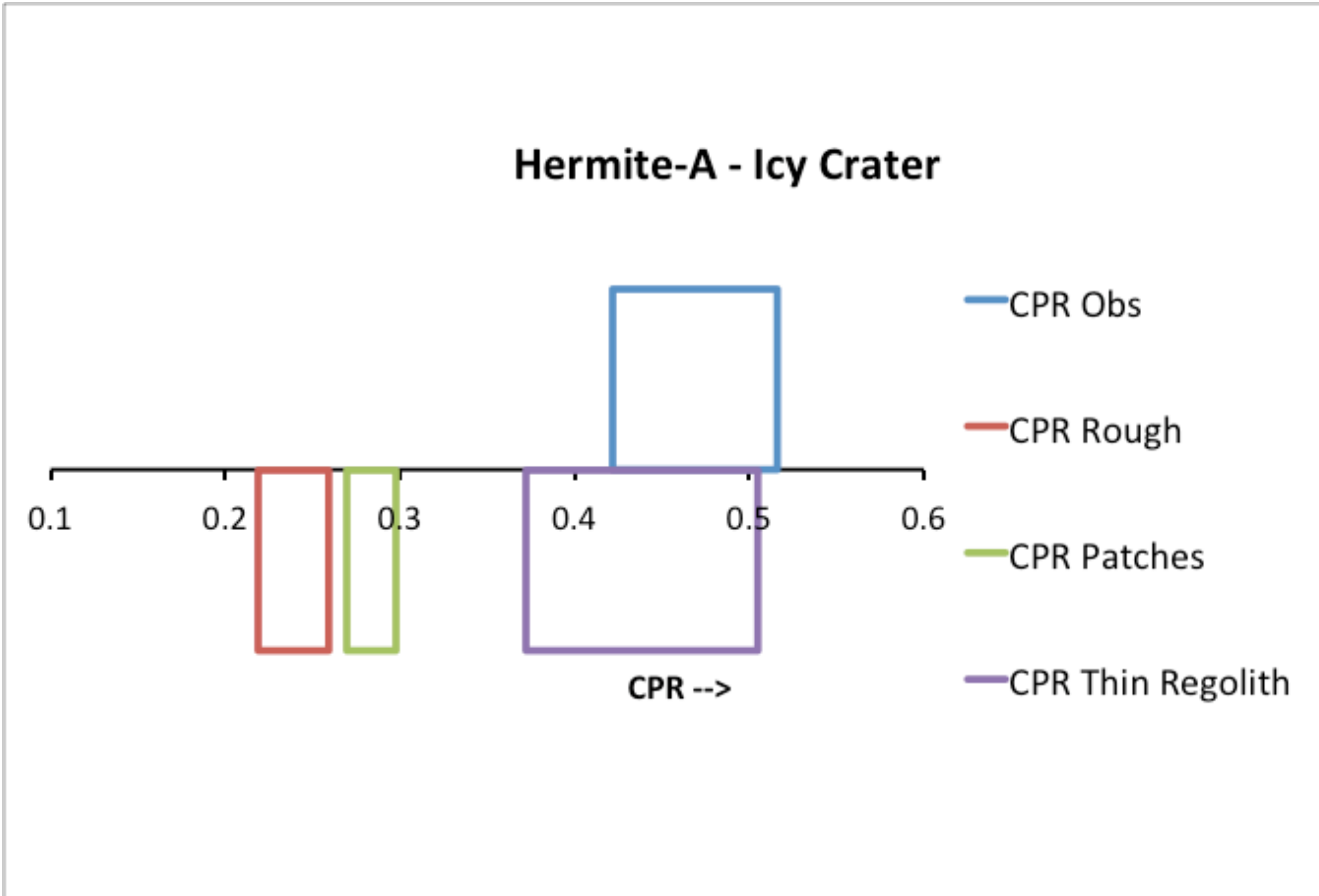
From Spudis et al., Initial results for the north pole of the Moon from Mini-SAR, Chandrayaan-1 mission, *GRL*, 2010.

Preliminary Comparison of Model with LRO Mini-RF Polar Data

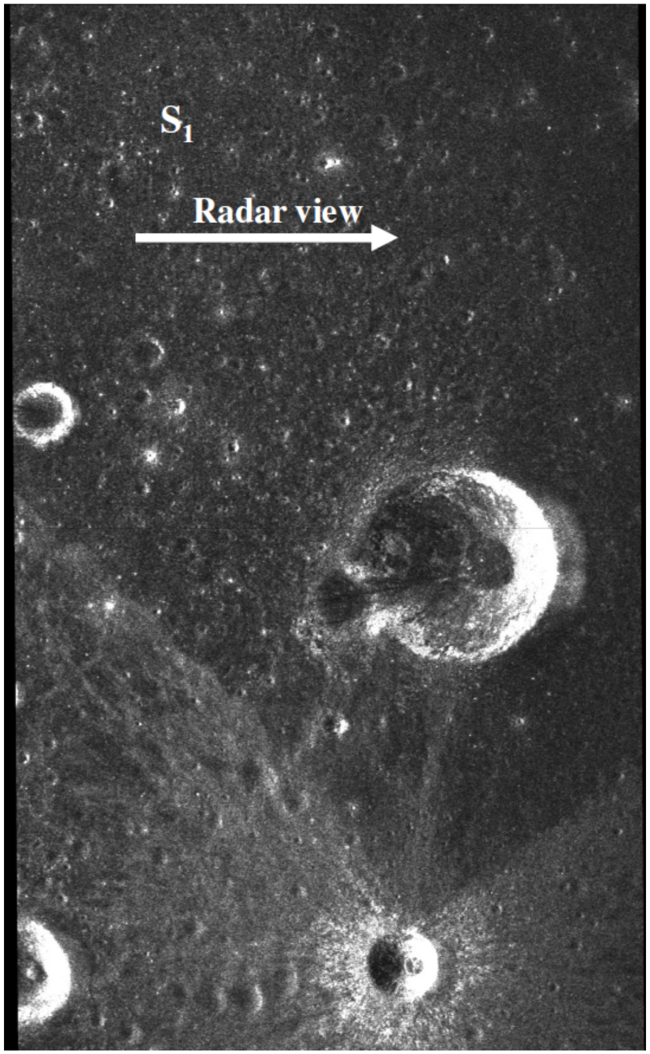
Modeling Results – Rough, Fresh Crater

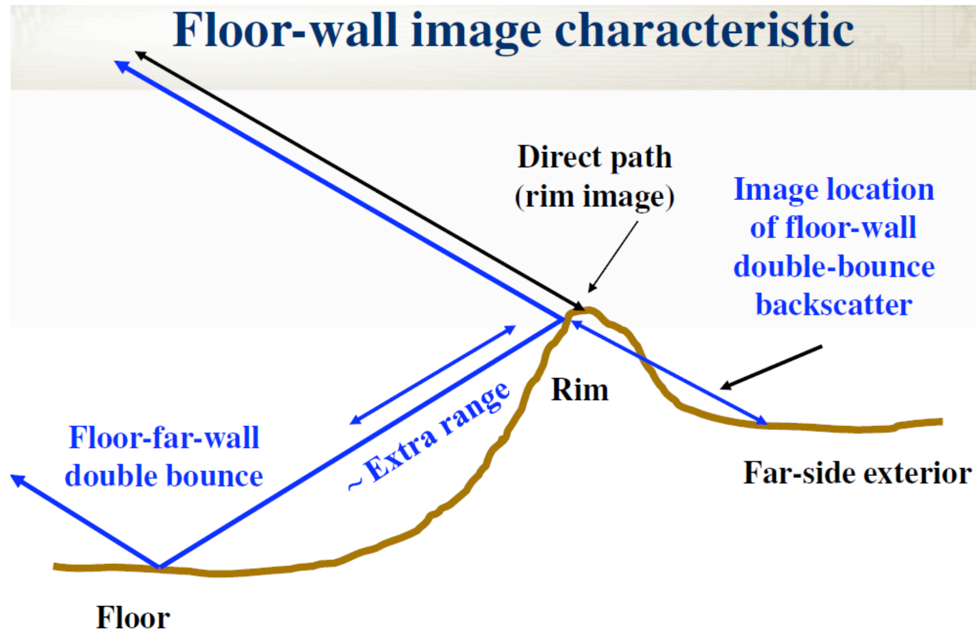


Modeling Results – Icy Crater



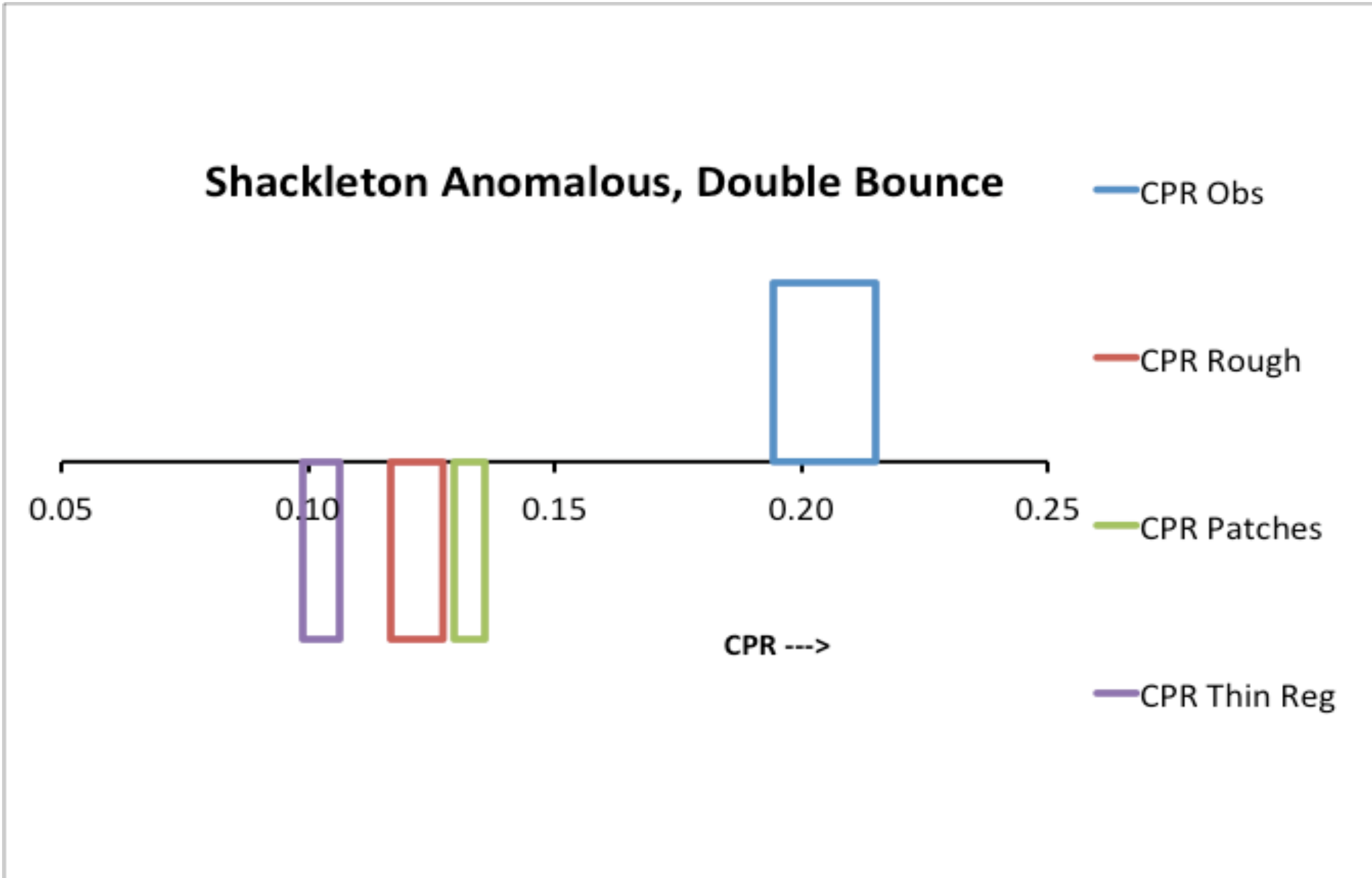
Double Bounce – Anomalous Crater



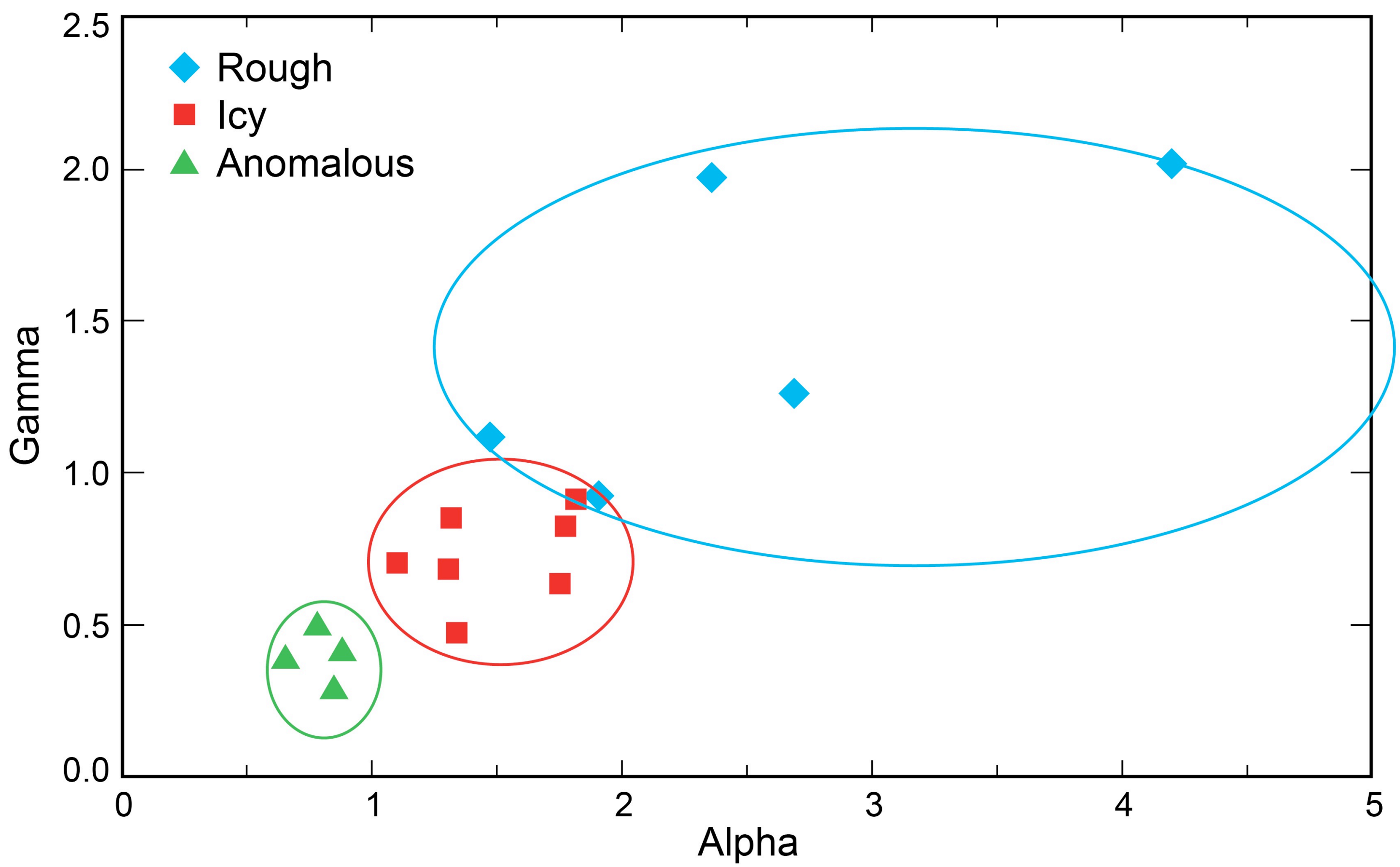


Courtesy of Keith Raney, APL, 2011

Modeling Results – Anomalous, Double Bounce Crater

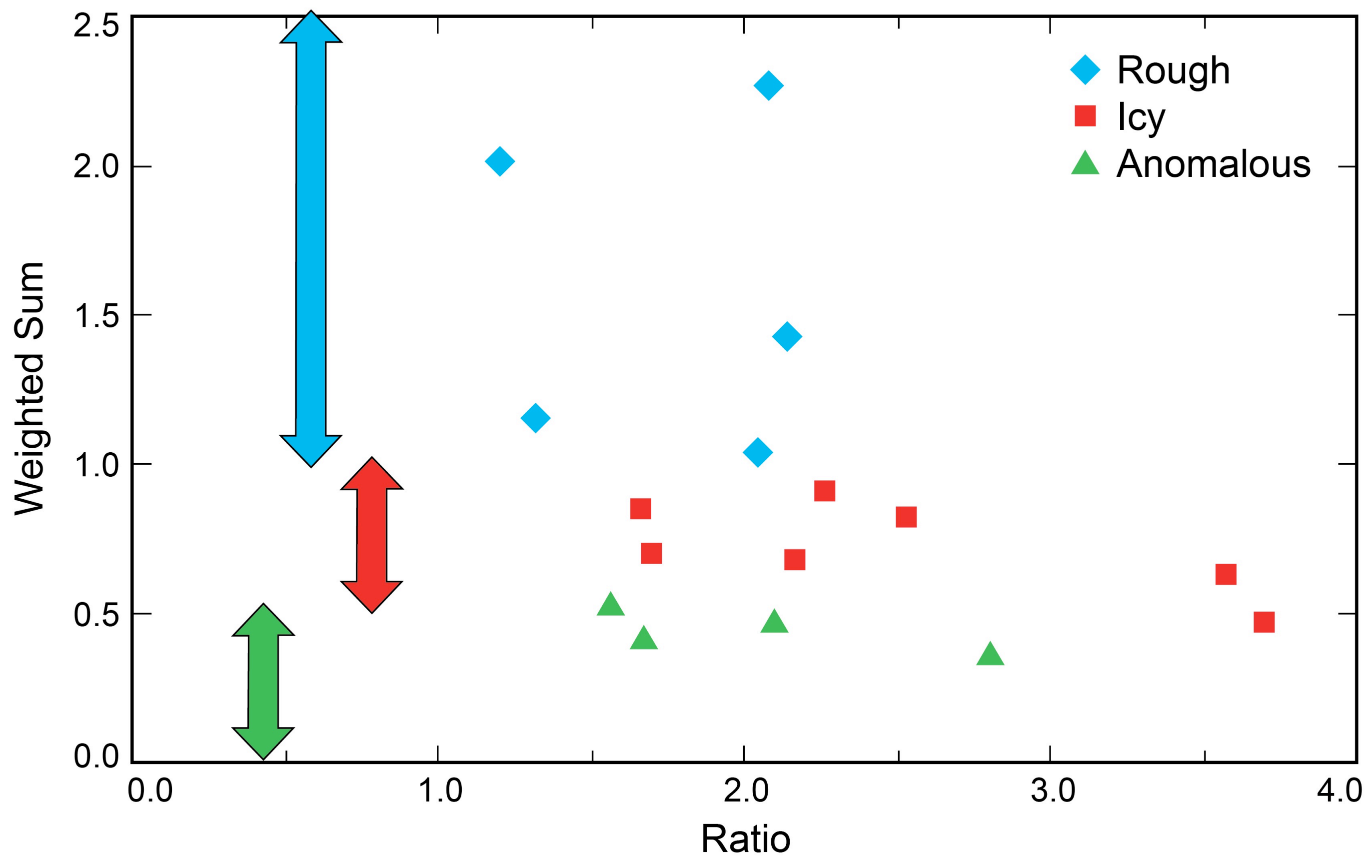


Modeling Results: Alpha vs. Gamma



Alpha = SC Enhancement / Gamma = OC Enhancement

Modeling Results: Weighted Sum vs. Ratio



Alpha = SC Enhancement / Gamma = OC Enhancement
Ratio = Alpha/Gamma - Proxy for Circular Polarization Ratio (CPR)
Weighted Sum = 0.12 Alpha + 0.88 Gamma = Total Power Enhancement

Rules of Engagement / Next Step

For Blocky Craters:

Alpha > 1.5; Gamma > 1.0 or 1.25

Ratio (Alpha/Gamma) > 1.25 or 1.5

Weighted Sum > 1.0 or 1.25

For Icy Craters:

Alpha > 1.0 or 1.25; 0.5 < Gamma < 1.0 or 1.25

Ratio (Alpha/Gamma) > 1.5

0.5 < Weighted Sum < 1.0

For Anomalous, Double Bounce Craters:

Alpha < 1.0; Gamma < 0.5

Ratio (Alpha/Gamma) > 1.5

Weighted Sum < 0.5

- **Next Step: Produce North and South Polar mosaics using automated identification of Icy, Rough Fresh and Double Bounce classes of craters**

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Concluding Remarks

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- We tested our model assuming diffuse and specular scattering components by examining 12 polar and 4 non-polar craters using LRO Mini-RF data for the Lunar North Polar Region

- Results indicate that there are 3 separable classes of craters based upon their SC enhancement (Alpha) and OC enhancement (Gamma)
  - Icy
  - Rough Fresh
  - Double Bounce (Anomalous)

- Next Step: Produce North and South Polar mosaics using automated identification of Icy, Rough Fresh and Double Bounce classes of craters