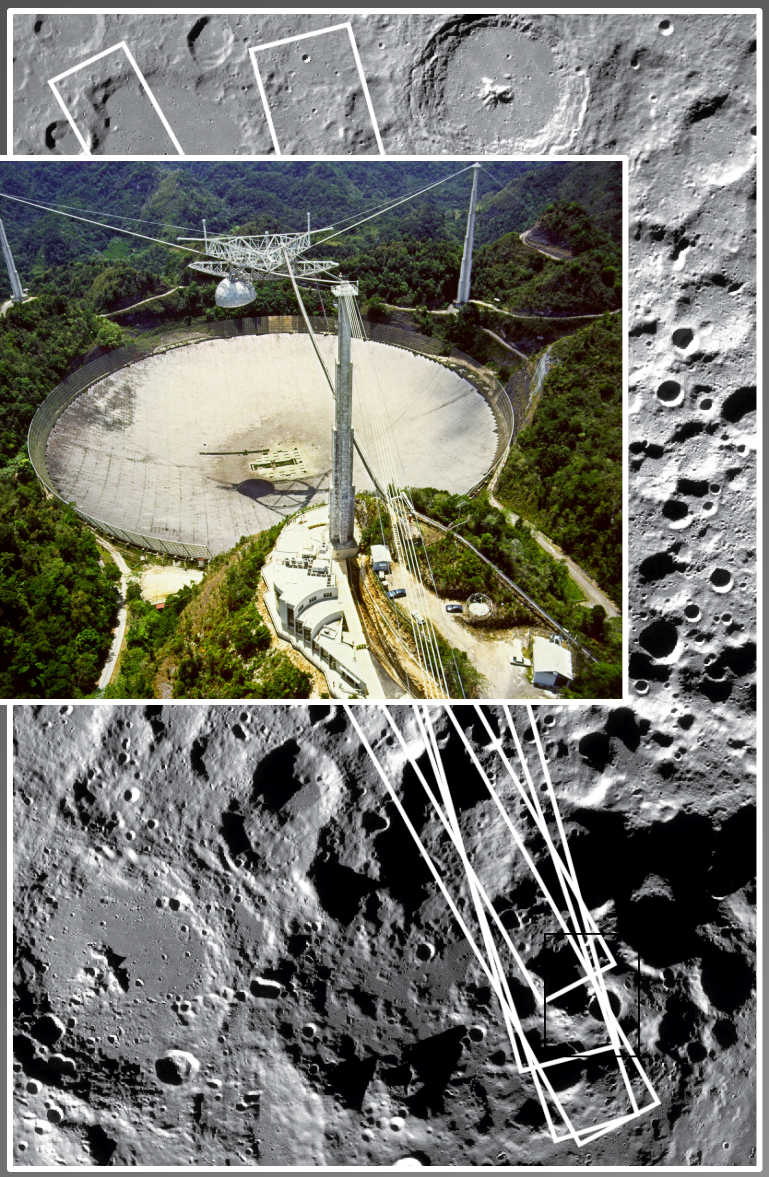
Mini-RF Bistatic Observations of Cabeus Crater



Wes Patterson[1], Ben Bussey[1], Angela Stickle[1], Josh Cahill[1], Lynn Carter[2], Paul Spudis[3], and the Mini-RF team

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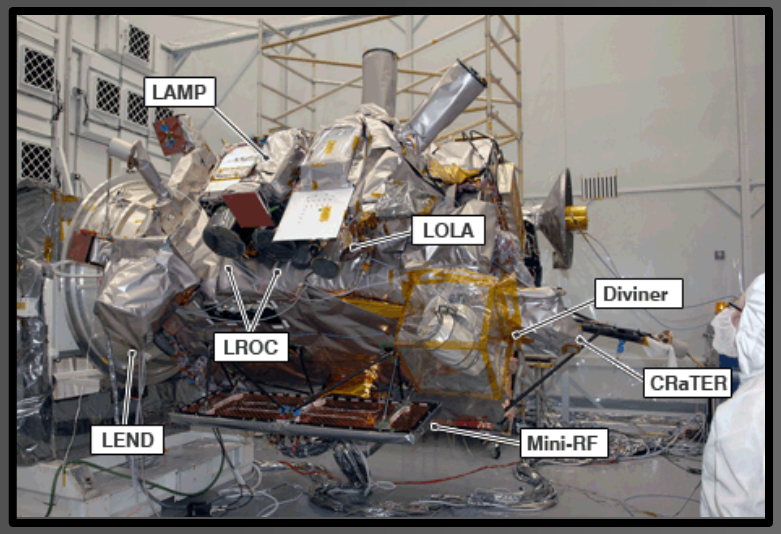
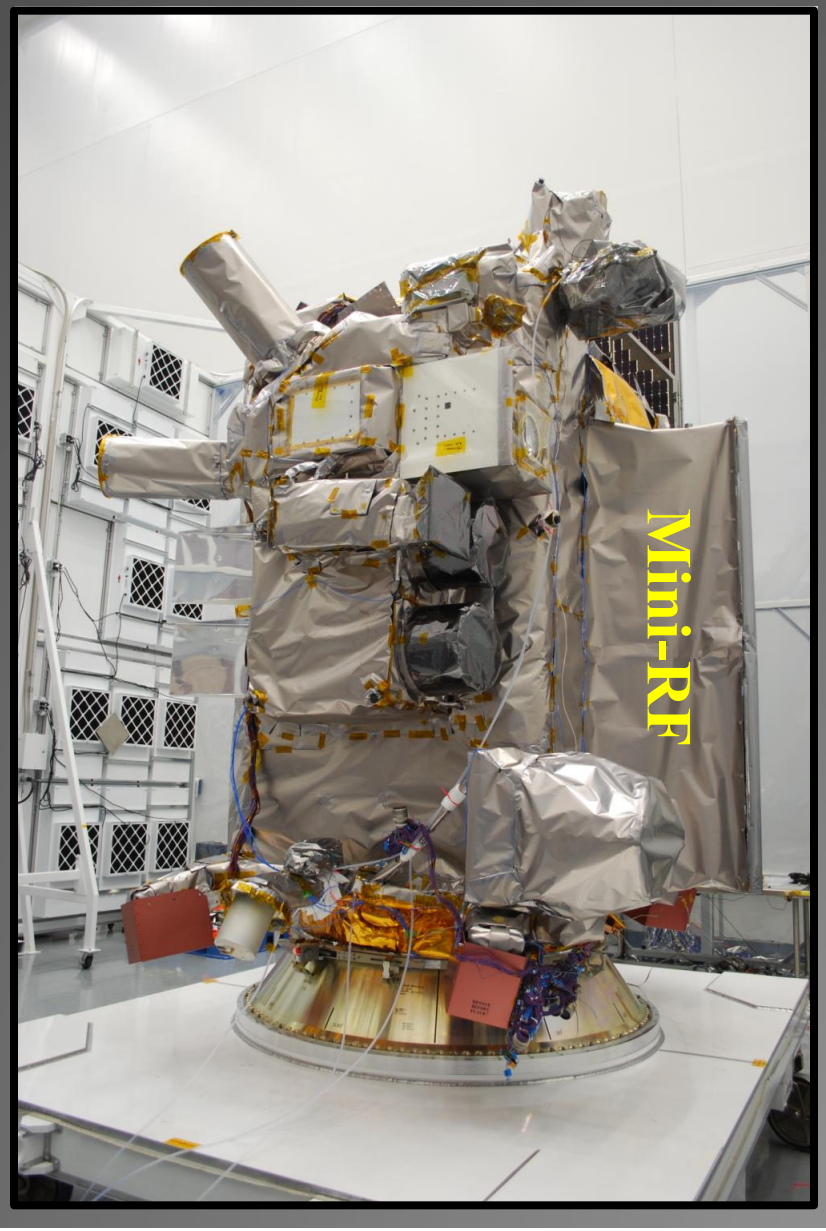
[2]NASA Goddard Space Flight Center
[3]Lunar & Planetary Institute

INTRODUCTION: INSTRUMENT

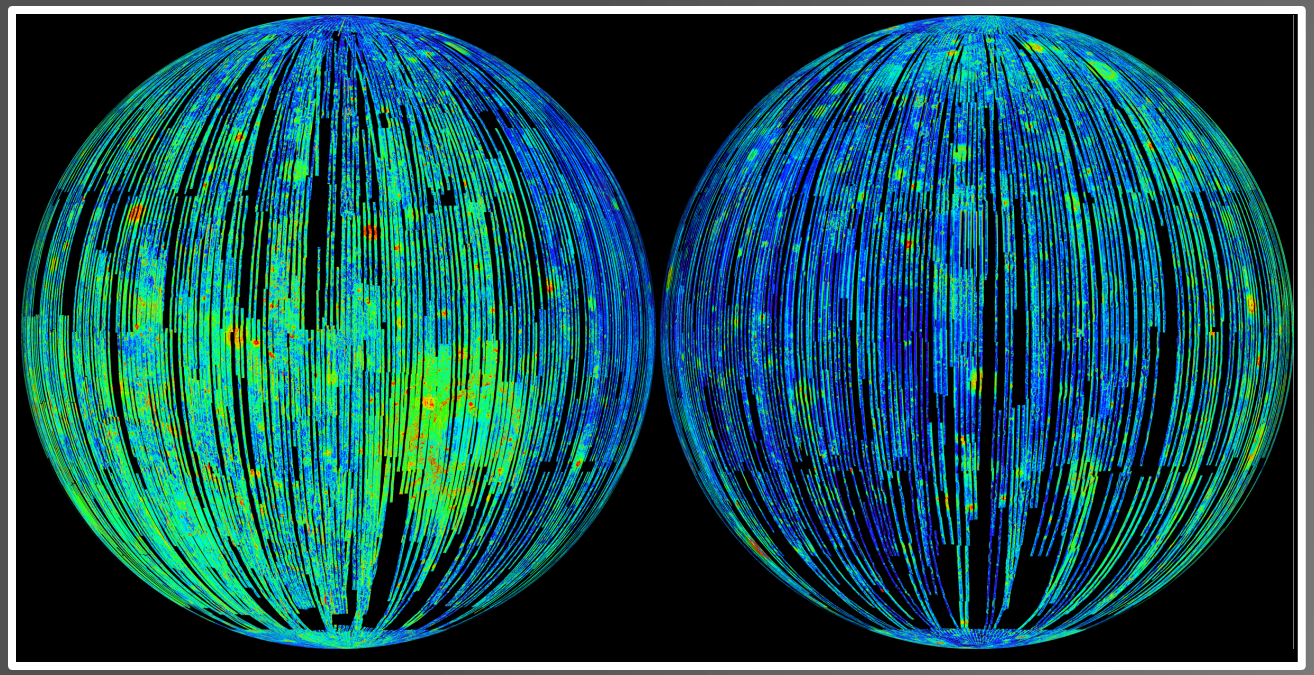
- Mini-RF is a hybrid-polarized, side-looking, SAR that transmits at both S-band (12.6 cm) and X-band (4.2 cm) wavelengths and can operate in two modes: a baseline mode with a resolution of 150 m and a zoom mode with a resolution of 30 m.

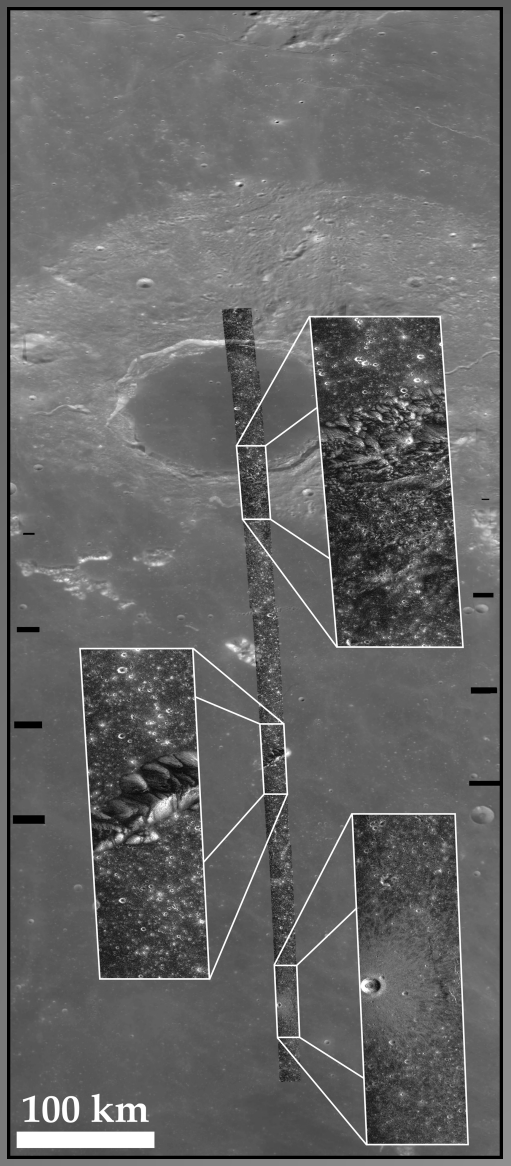




INTRODUCTION: DATA PRODUCTS

- Mini-RF measures returned signals in two orthogonal polarizations. These data allow for the calculation of the four Stokes parameters [S_1, S_2, S_3, S_4], which can be used to produce a variety of secondary products.



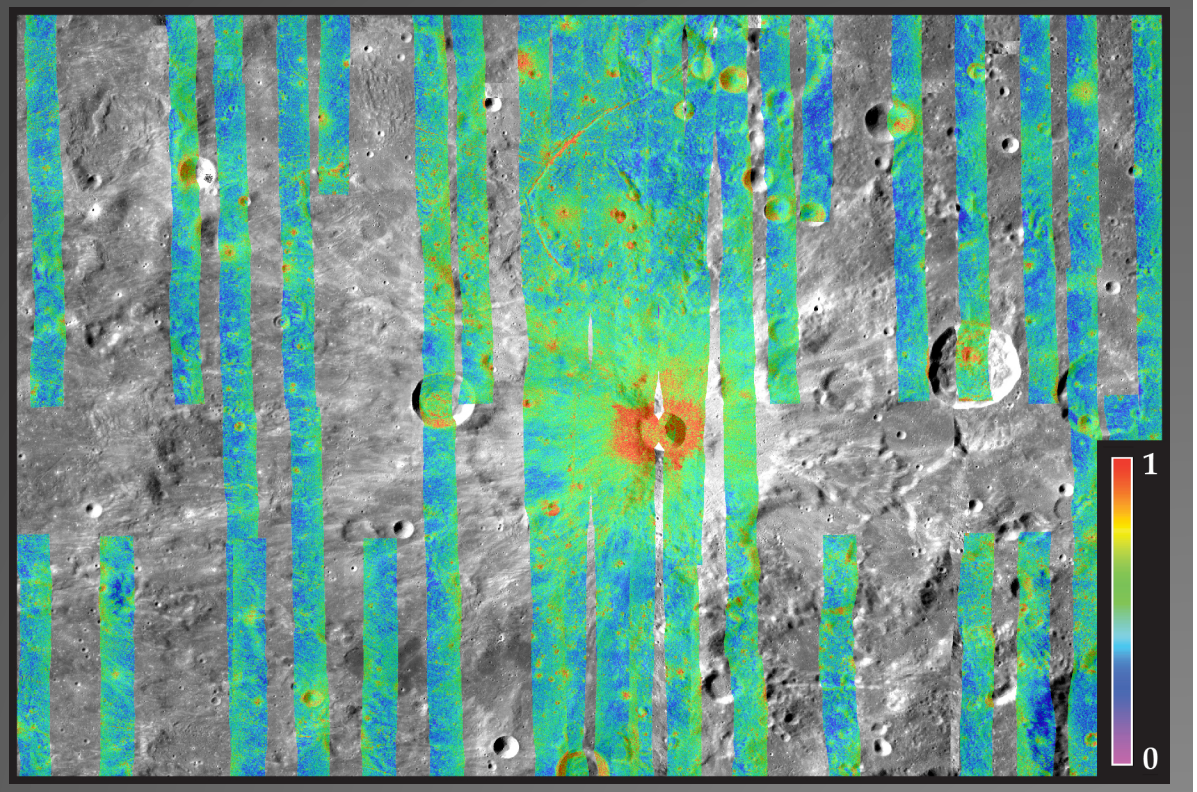


INTRODUCTION: DATA PRODUCTS

Circular Polarization Ratio (CPR)

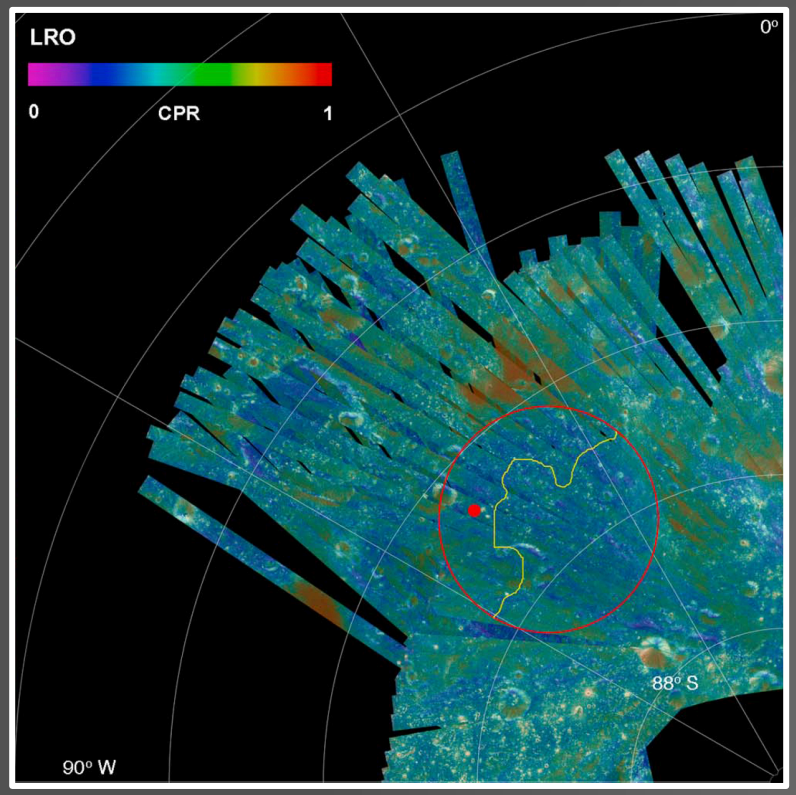
$CPR = (S_1 - S_4)/(S_1 + S_4)$

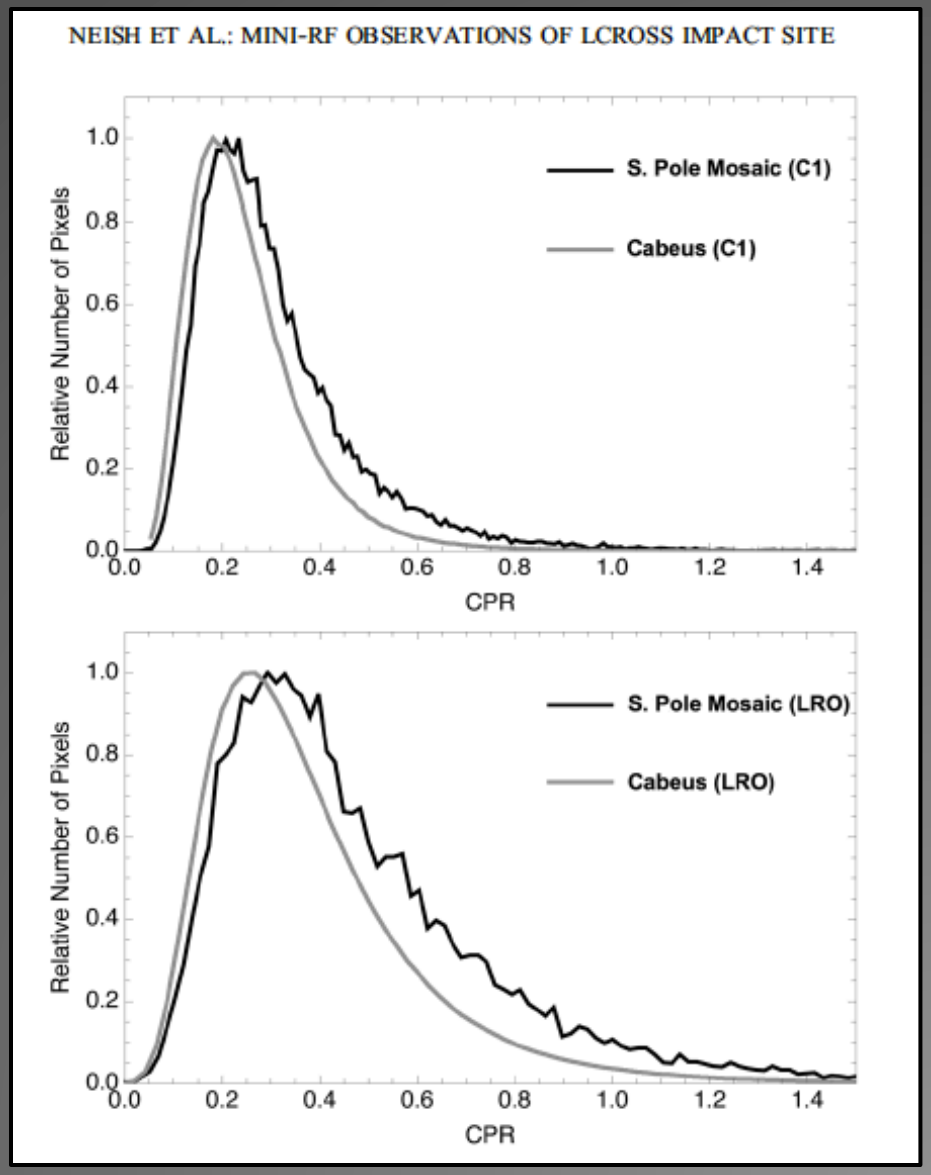
- Indicator of the roughness of a surface, as determined by the distribution of wavelength-scale and larger radar scatterers (*e.g.*, boulders), or of the presence of water ice.



MONOSTATIC DATA: CABEUS CRATER

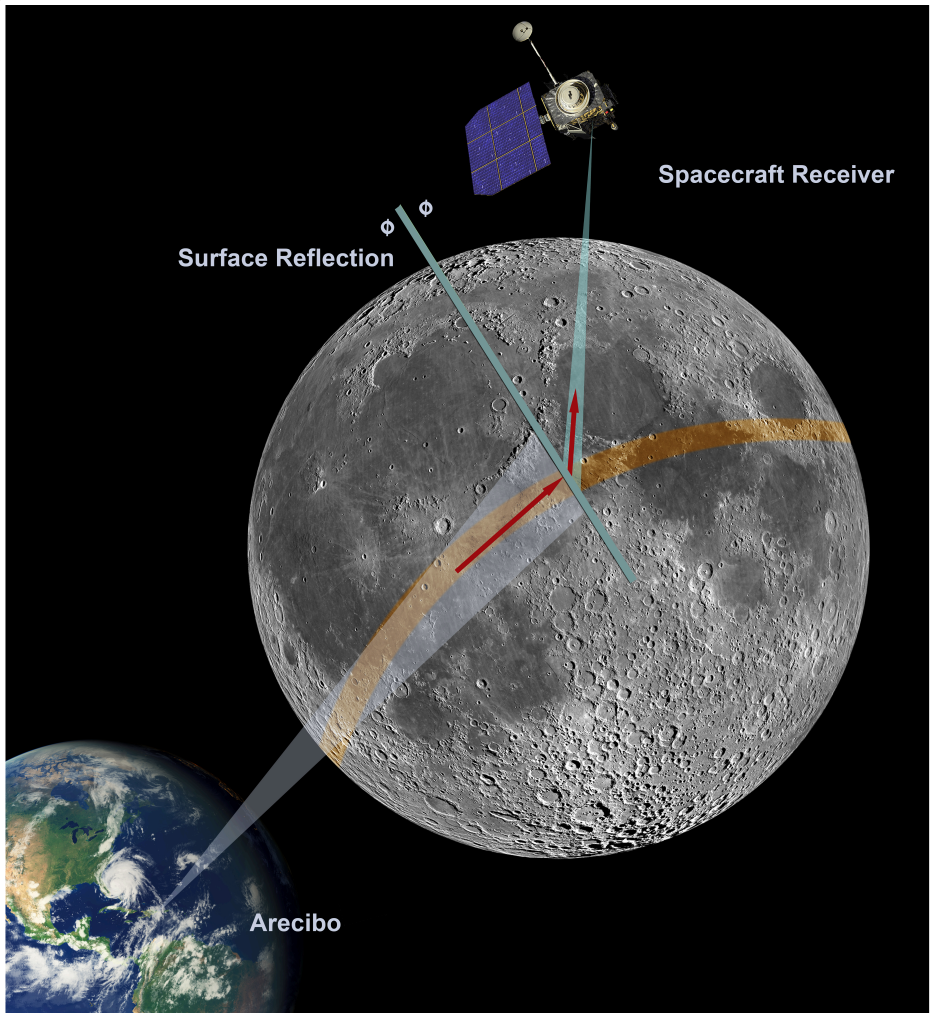
- Monostatic data indicate that water detected by LCROSS is not in a form observable by S-band radar (*Neish et al., 2011*)





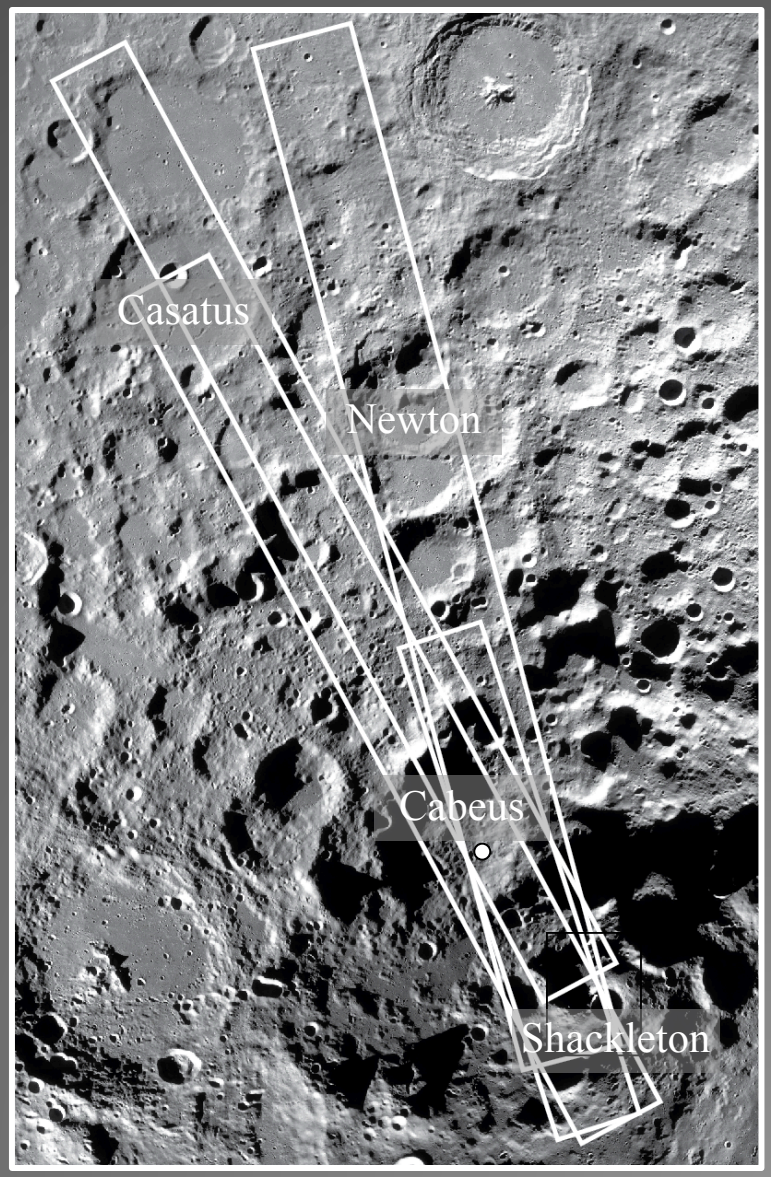
MINI-RF: BISTATIC OPERATIONS

- The Mini-RF transmitter ceased operating in December of 2010
- Mini-RF is currently operating in a bistatic mode, using the Arecibo Observatory as a transmitter
  - Provides information on scattering properties of lunar materials as a function of beta (phase) angle
  - Data of nearside and polar targets has been successfully collected on 23 occasions



Bistatic Data: Cabeus Crater

- Mini-RF has targeted the floor of Cabeus crater at varying beta (phase) angles on 4 occasions in the past 1.5 years
  - 2012-220 at ~2°
  - 2013-127 at ~7°
  - 2013-181 at ~0.5°
  - 2013-346 at ~10°
- The footprints of the data acquired for these targets encompasses additional terrain at a wide variety of beta (phase) angles



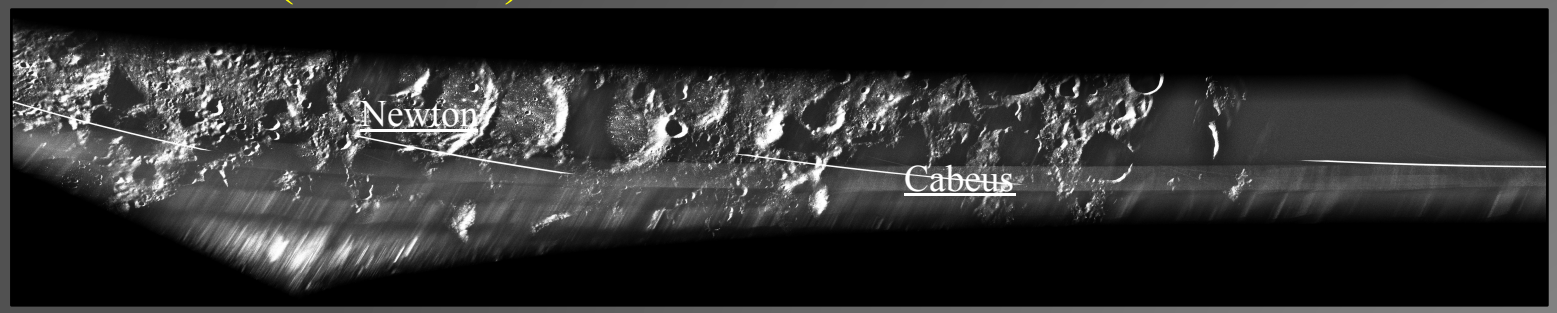
Bistatic Data: Cabeus Crater

2012-220 (Aug. 7)

S1 (total backscattered power)

2013-127 (May 7)

2013-181 (June 30)



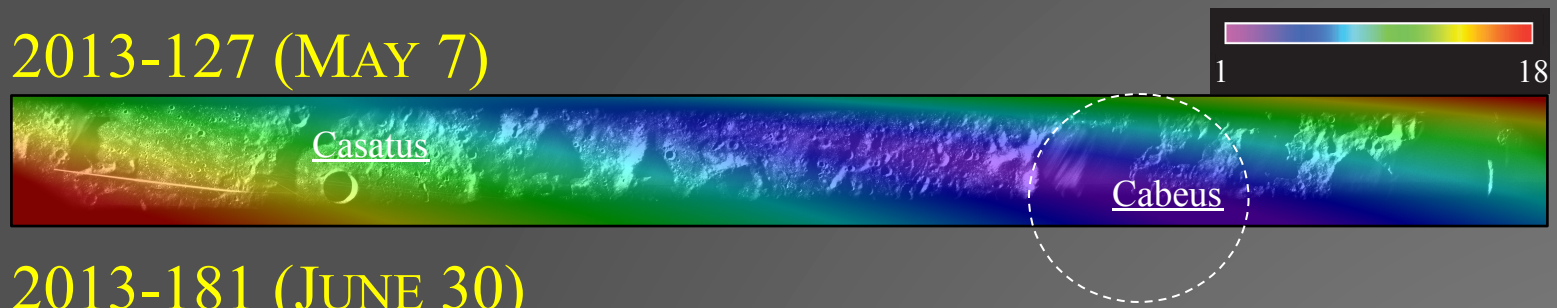
2013-346 (Dec. 12)

Bistatic Data: Cabeus Crater

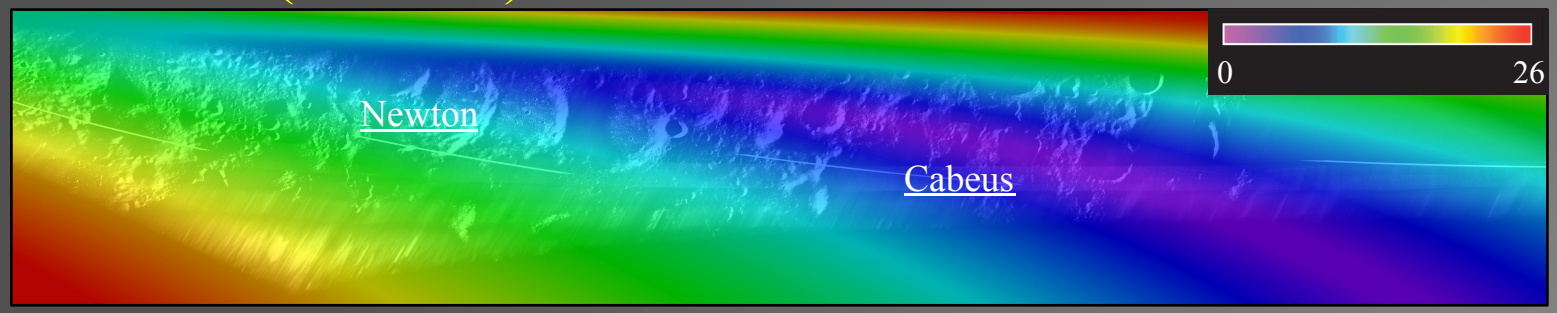
Bistatic Beta (Phase) Angle

2012-220 (Aug. 7)

2013-127 (May 7)



2013-181 (June 30)

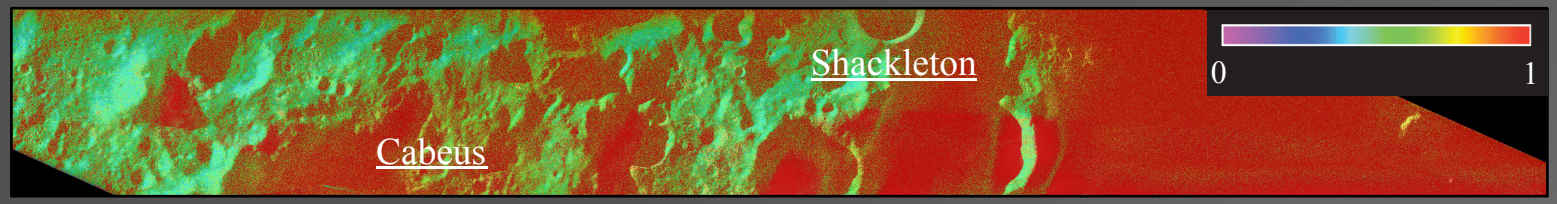


2013-346 (Dec. 12)

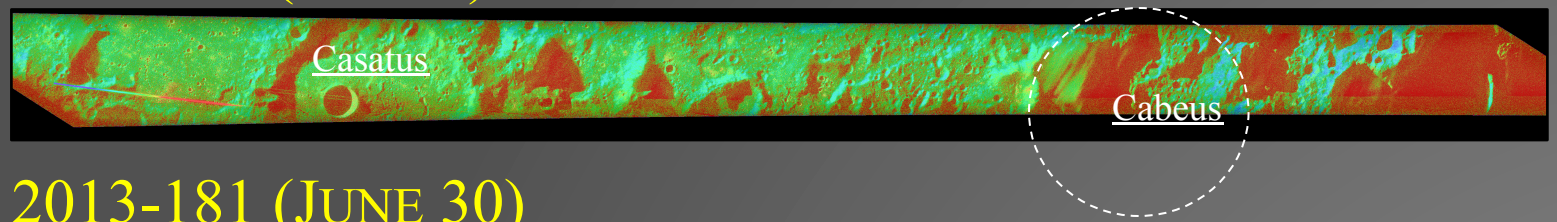
Bistatic Data: Cabeus Crater

Circular Polarization Ratio (CPR)

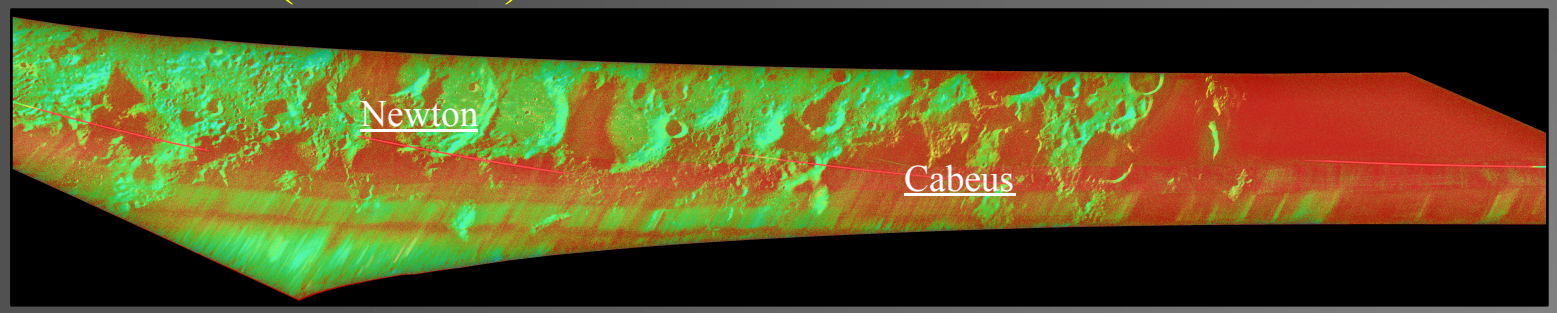
2012-220 (Aug. 7)



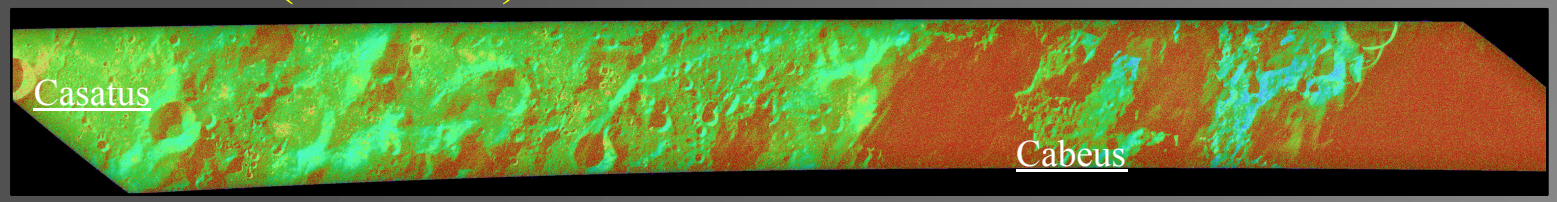
2013-127 (May 7)



2013-181 (June 30)



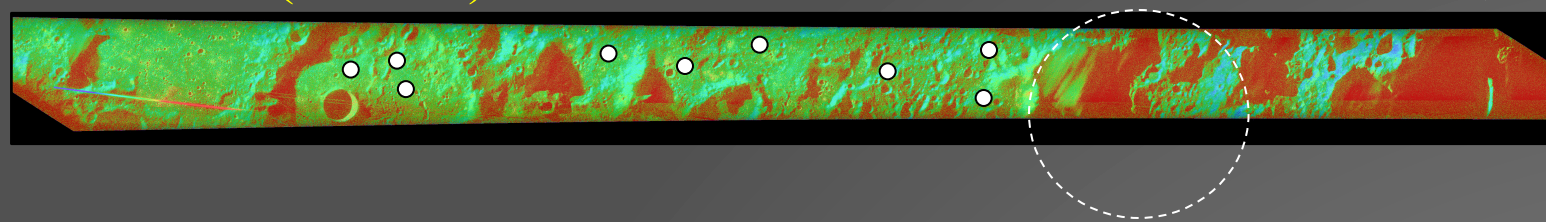
2013-346 (Dec. 12)

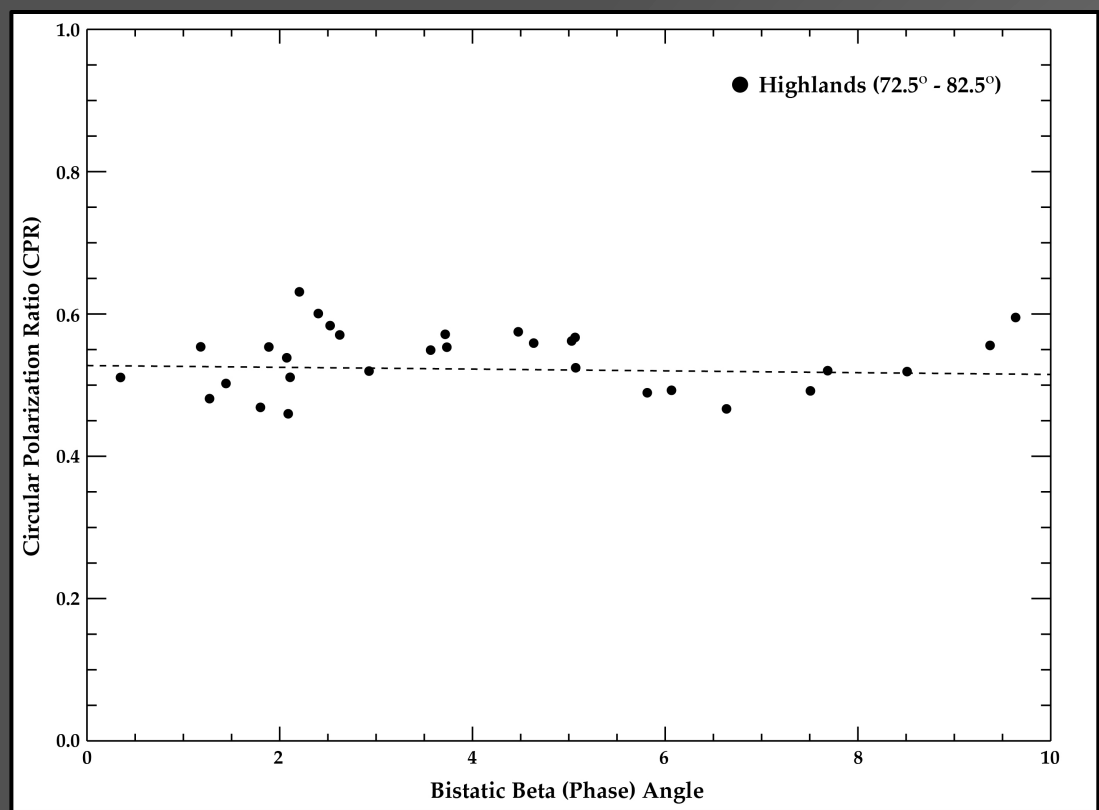


OBSERVATIONS: CABEUS CRATER

2013-127 (MAY 7)

Circular Polarization Ratio (CPR)



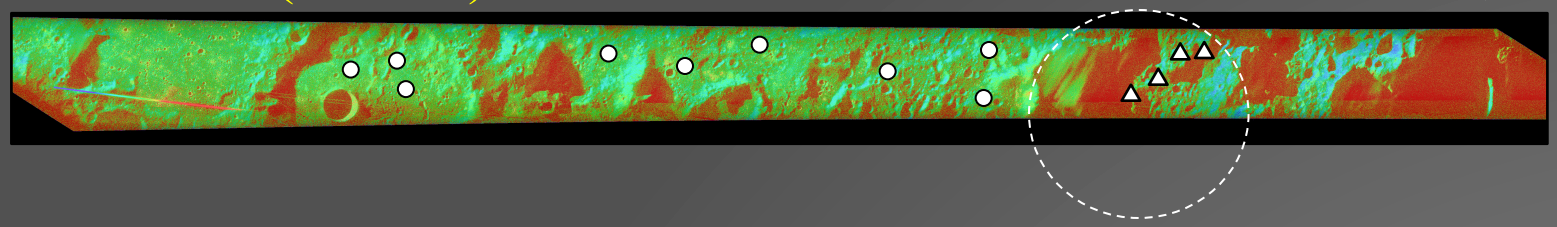


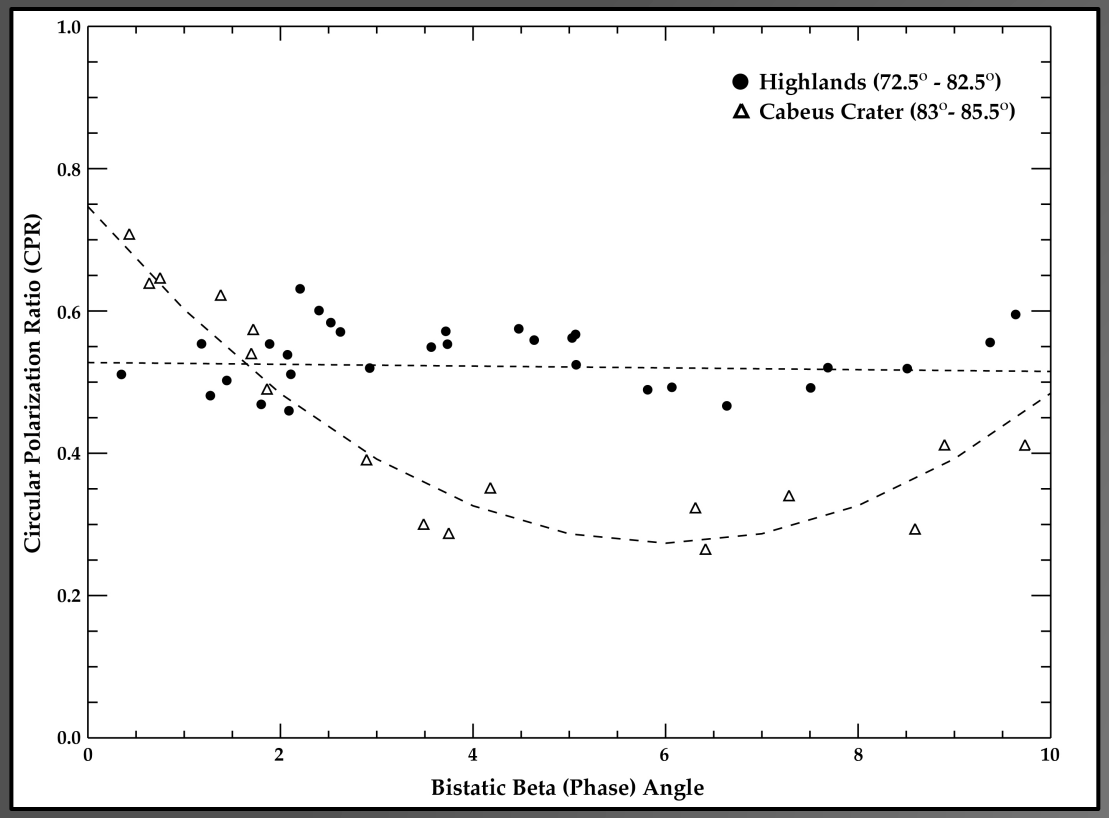
- The CPR of Lunar terrains equatorward of Cabeus crater are relatively uniform over phase angles <10°
  - This includes the floor of Casatus crater

OBSERVATIONS: CABEUS CRATER

2013-127 (MAY 7)

Circular Polarization Ratio (CPR)



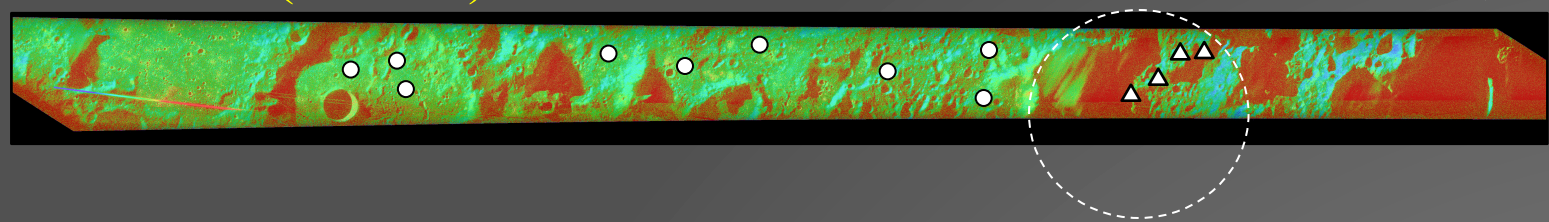


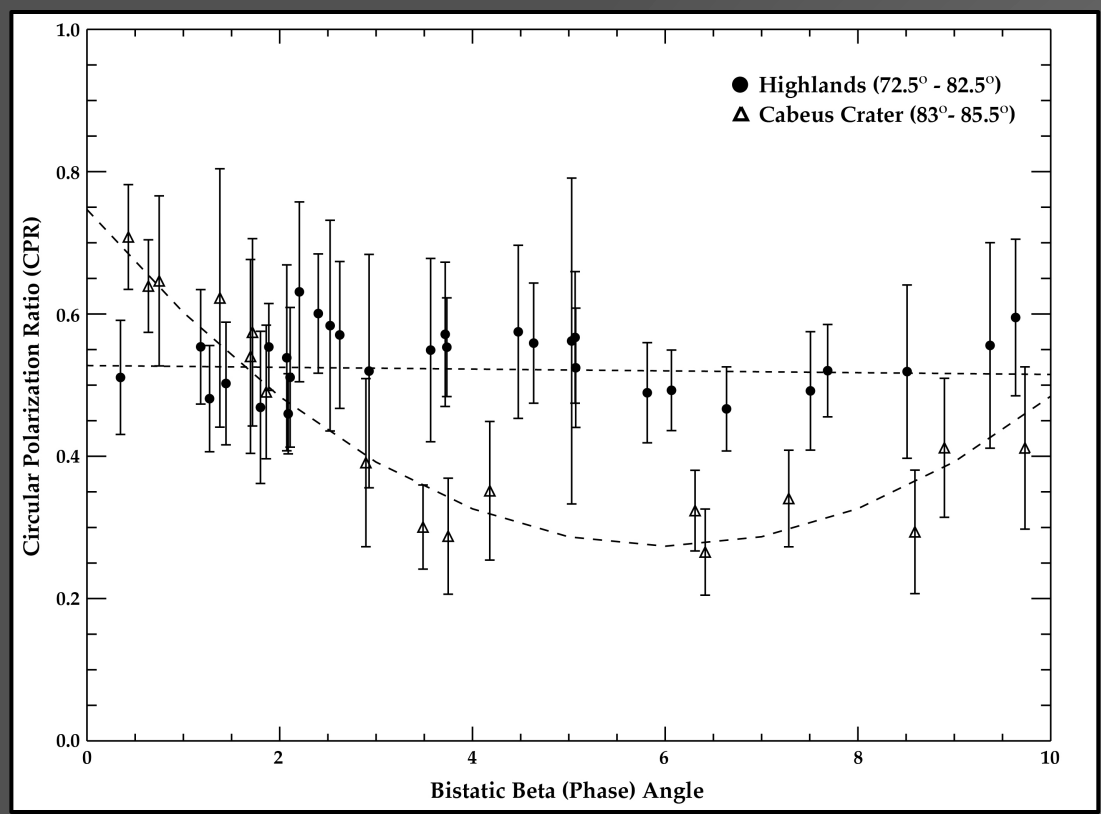
- The CPR of Lunar terrains equatorward of Cabeus crater are relatively uniform over phase angles <10°
  - This includes the floor of Casatus crater
- The CPR of the floor of Cabeus crater is variable as a function of beta (phase) angle

OBSERVATIONS: CABEUS CRATER

2013-127 (MAY 7)

Circular Polarization Ratio (CPR)

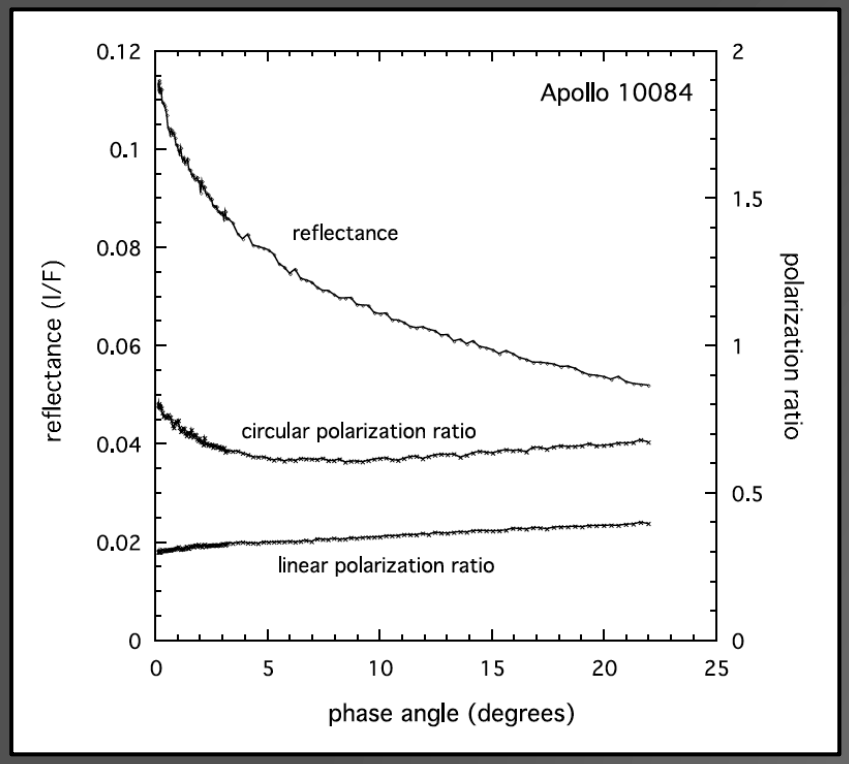




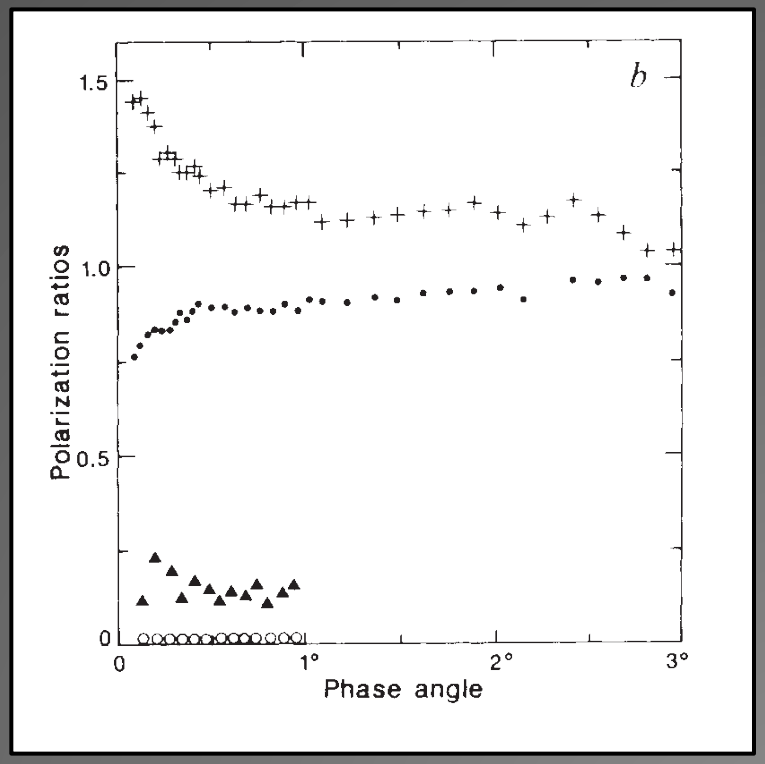
- The CPR of Lunar terrains equatorward of Cabeus crater are relatively uniform over phase angles <10°
  - This includes the floor of Casatus crater
- The CPR of the floor of Cabeus crater is variable as a function of beta (phase) angle
  - This response is characteristic of an opposition effect (i.e., CBOE)

Discussion: Opposition Effect

The polarization properties of lunar regolith and water ice vary with phase angle



Polarization properties of lunar regolith – Hapke et al., 2012

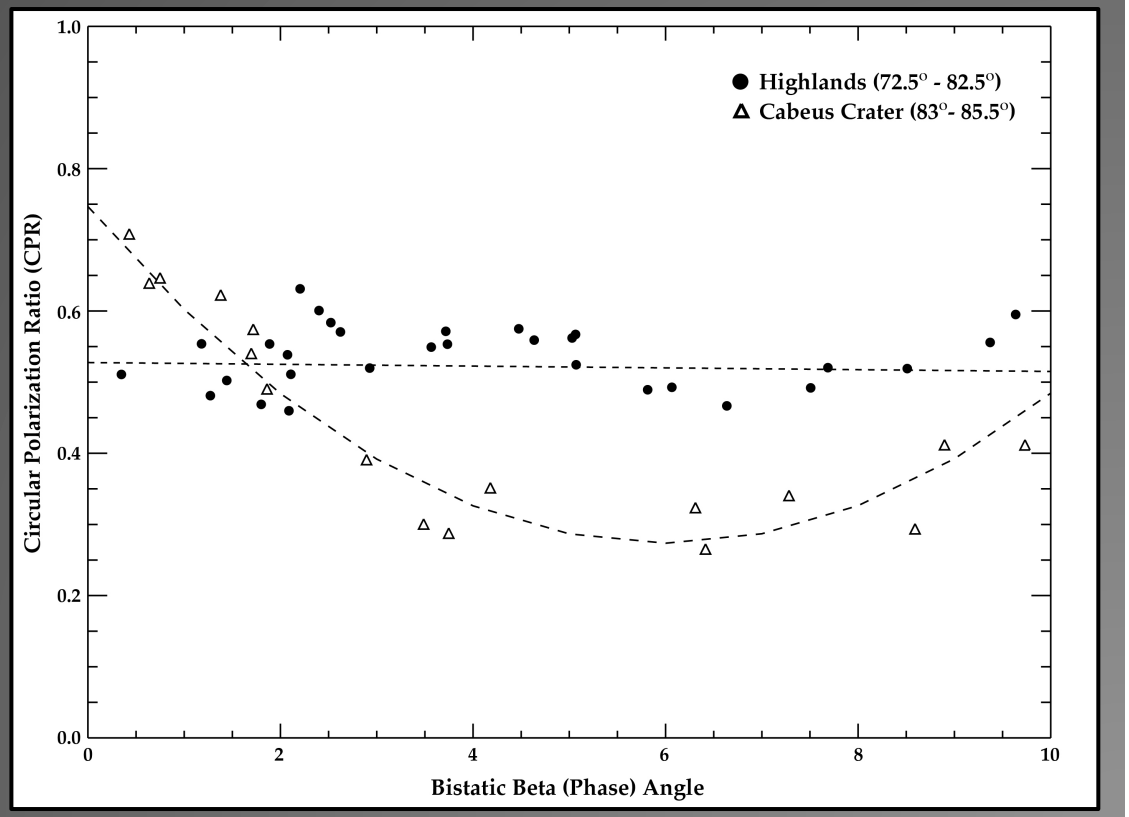


Polarization properties of an analog water-ice material – Hapke and Blewett, 1991

Discussion: Cabeus Crater

Observations of the floor of the south polar crater Cabeus show a response characteristic of an opposition effect

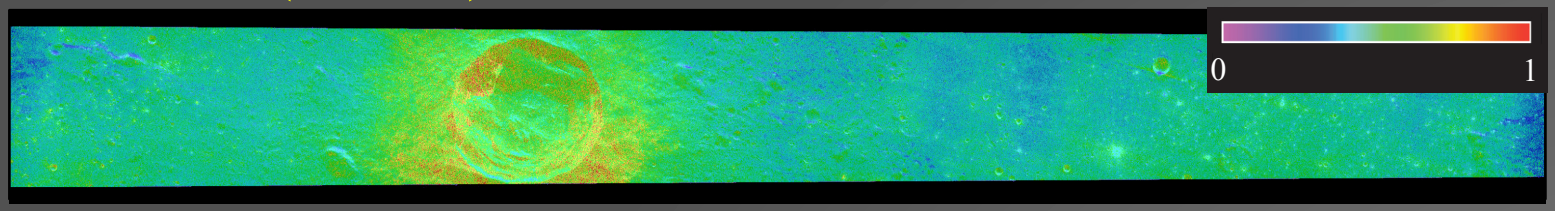
- This effect is observed for planetary surfaces that are rough, at the wavelength scale, or that are composed of water ice (*e.g., Hapke et al., 1993; Black et al., 2001*)
- Can we determine which is responsible for the response of Cabeus crater floor materials?
  - Inferred distribution of scatterers associated with other materials that have an OE response and observations of CPR magnitudes at larger phase angles provide important clues

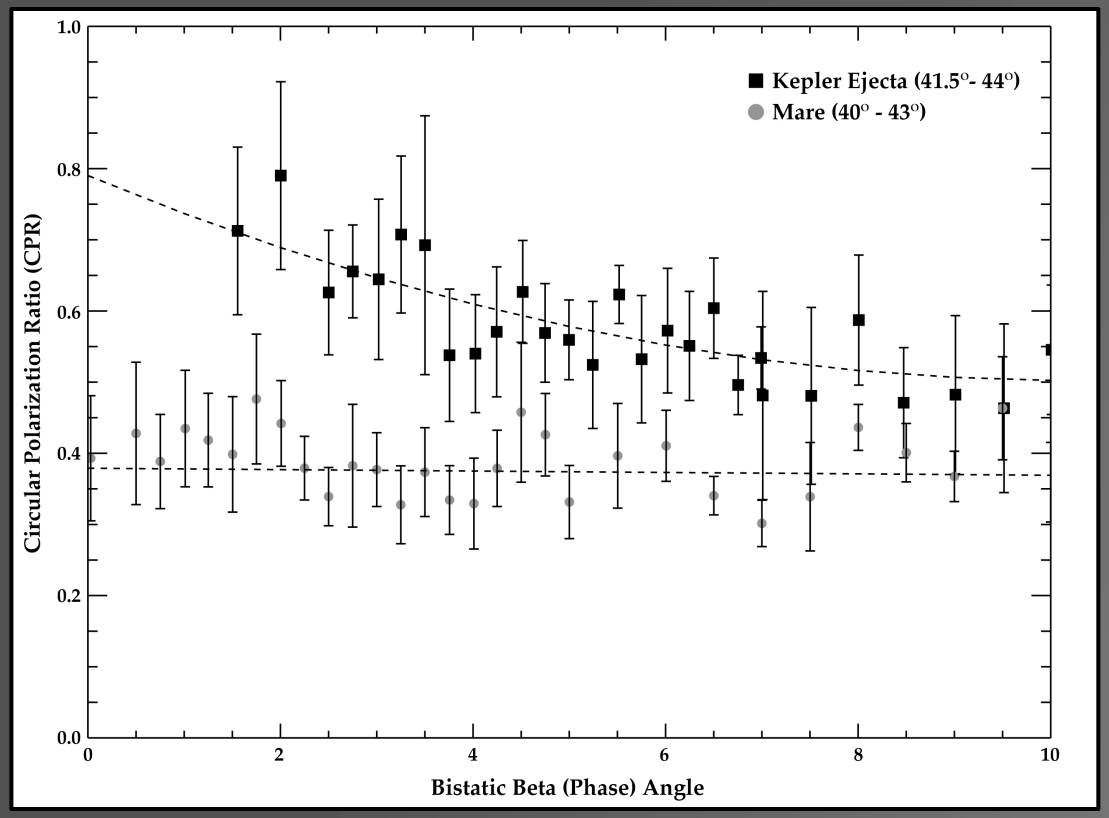


Observations: Kepler Crater

2012-276 (Oct. 2)

Circular Polarization Ratio (CPR)





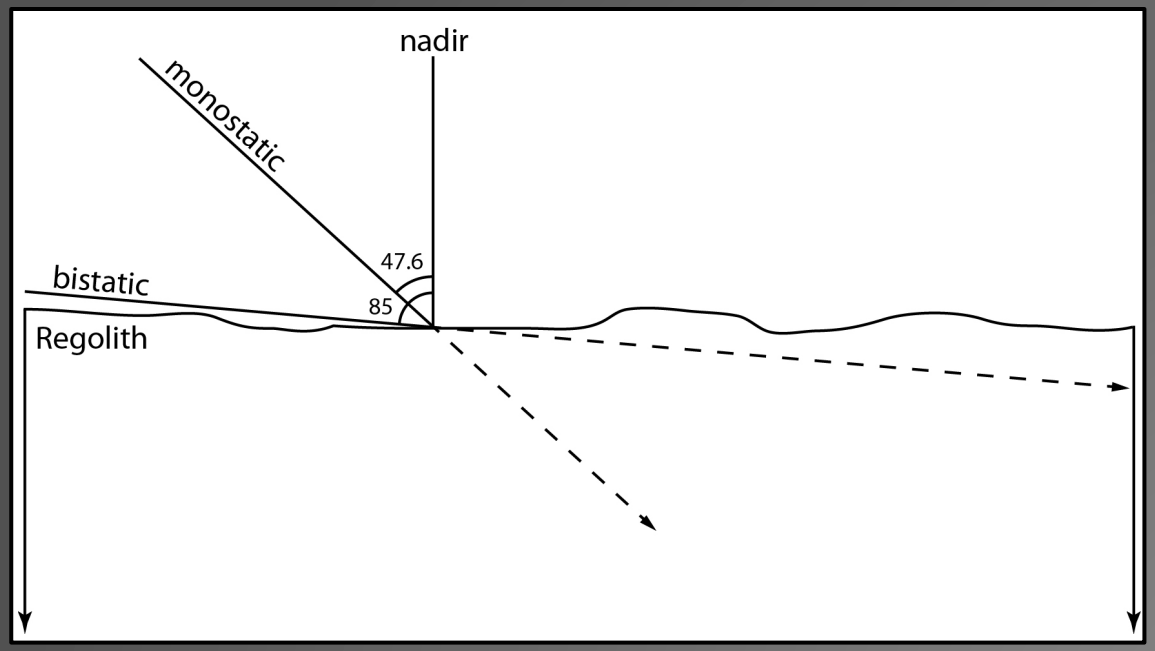
- Kepler is a 32 km dia. Copernican crater (8.1°N, 38.0°W)
  - Mare materials surrounding Kepler are not sensitive to variations in bistatic angle < 10°
  - Kepler crater ejecta show a clear bistatic angle dependance that differs from the response observed for Cabeus

CONCLUSIONS

- An opposition effect is observed in association with floor materials of the south polar crater Cabeus
  - A similar response is not observed for floor materials associated with the floor of Casatus crater
  - This response differs from that observed for rough surfaces associated with the ejecta of Kepler crater
    - At larger phase angles, the CPR magnitude of Cabeus floor materials is significantly less than that of surrounding background terrains
    - The width of the OE response is less than that of Kepler ejecta
- We propose the observed effect is consistent with the presence of near-surface water ice
  - This conclusion is supported by evidence from other datasets (e.g., hydrogen enhancement, ice stability, LCROSS impact)

Remaining Questions

- How do we reconcile our monostatic and bistatic results?
  - We suspect incidence angle plays a role
    - Would suggest that ice is present as a relatively thin layer near the surface



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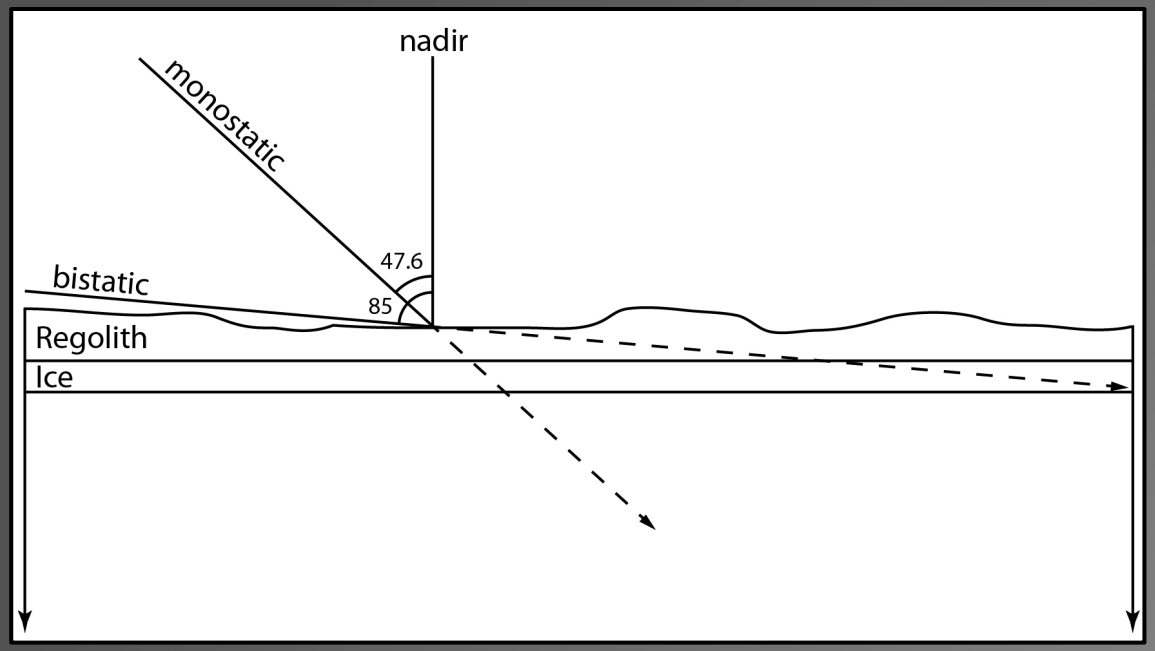
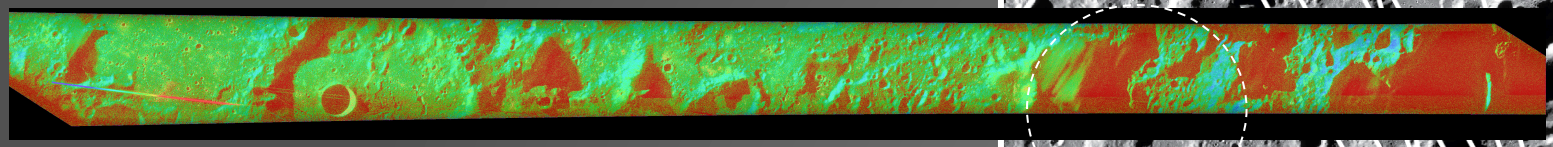
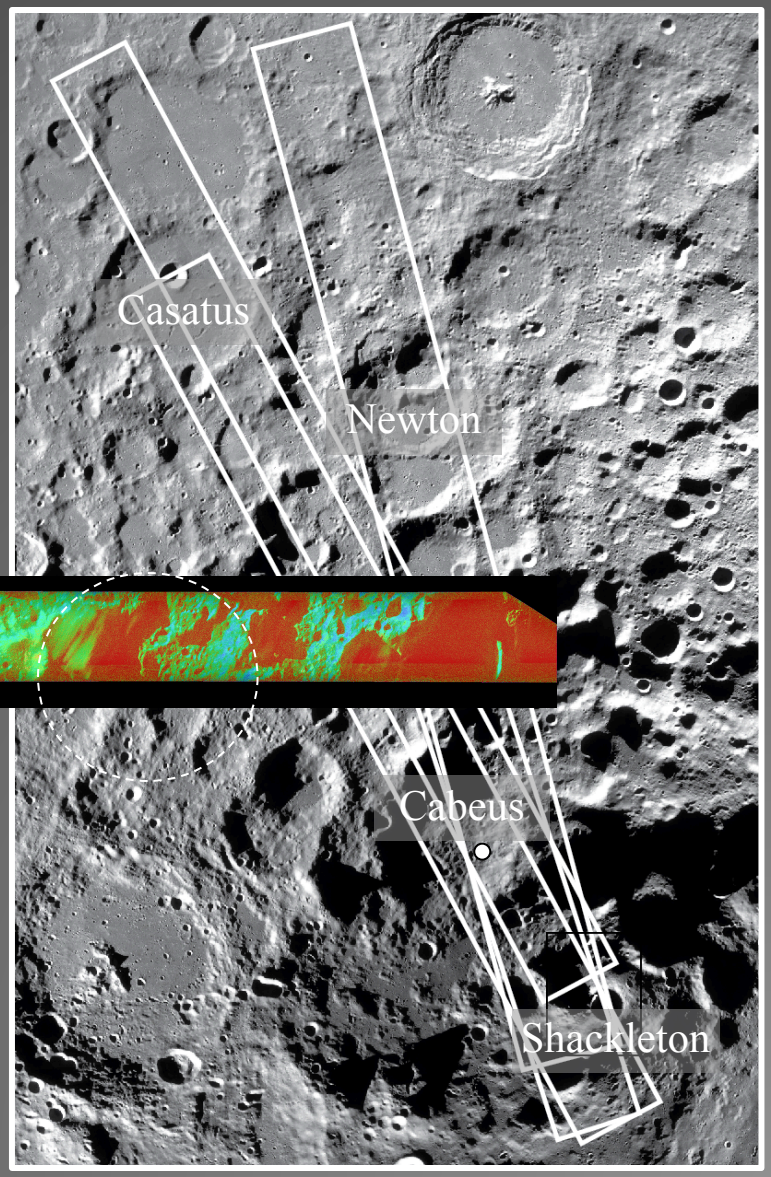


  - We are currently modeling this potential scenario (e.g., *Zimmerman et al., 2014*)

Remaining Questions

- Is this phenomena unique to Cabeus crater or more characteristic of polar terrain?
  - We look forward to addressing this in the coming months and into the next LRO extended mission!

2013-127 (May 7)