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Mini-RF Monostatic Observations of Ice in Polar Craters

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Abstract

The possibility that water ice could be present in lunar polar craters has long been postulated [e.g., 1,2]. More recently, measurements from instruments on a number of spacecraft have all pointed to the presence of water at the lunar poles [e.g., 3-7]. Water ice can exhibit a strong response at radar wavelengths in the form of a Coherent Backscatter Opposition Effect (CBOE) and the circular polarization ratio (CPR) of the returned data can be a useful indicator of such a response—i.e., measured CPRs for icy materials typically exceed unity [8]. Mini-RF is currently operating as part of the Lunar Reconnaissance Orbiter (LRO) Cornerstone Extended Mission to address driving questions related to the form/abundance of water on the Moon and its vertical distribution. Using geodetically controlled monostatic polar mosaics, we investigate the radar evidence for water at the lunar poles, and find insufficient evidence for distributions of water ice on the scale of S-band radar. These data reaffirm previous studies suggesting polar water ice must exist in small, heterogeneous deposits.

1. Introduction

The Lunar Crater Observation and Sensing Satellite (LCROSS) impact into a permanently shadowed portion of Cabeus crater (84.9°S, 35.5°W; 98 km dia.) has provided the most direct evidence for the presence of water in the form of ice [9]. Measurements of near-infrared absorption and ultraviolet emissions indicated that water ice and vapor were present in the resulting ejecta plume at between 3 and 10% by weight. However, ground-based radar observations of the lunar south polar region did not observe a strong CBOE, contradicting the presence of water ice [10]. This radar result was supported by later Mini-RF and Mini-SAR (Chandrayaan-1) monostatic observations of Cabeus [11] but was contradicted by Mini-RF bistatic observations that showed a clear opposition response, at S-band (λ=12.6 cm) for Cabeus crater floor materials [12].

2. Mini-RF Observations

Mini-RF is a hybrid-polarized, side-looking synthetic aperture radar (SAR) that was designed as a monostatic system – i.e., the antenna operated as a transmitter and receiver. In this operational mode, it transmitted a left-circular polarized signal and received orthogonal linear polarizations [13]. Controlled monostatic mosaics of these data for both poles have been produced by the USGS following the methodology outlined in [14]. These mosaics provide shadow-free access to polar crater floors at a resolution of 30 m/pixel (Fig 1.).

This analysis focused on comparing the radar response of permanently and non-permanently shadowed regions for the floors of craters polar craters with dia. > 15 km. The analysis regions were selected using LOLA-based shadow models and LOLA-based slope maps. Because sloped surfaces (such as crater walls or peaks) can result in spurious additions to the returned radar signal, we restricted our analysis to regions with slopes < 5°. These flat regions were then divided into permanently shadowed and non-permanently shadowed regions using the shadow model. Finally, we considered only craters where both the flat permanently and non-permanently shadowed regions were spatially expansive enough to be considered statistically significant (i.e., > 1 km^2 total).

Our final dataset included 10 north polar craters and 11 south polar craters (Fig. 1). Preliminary results indicate that the majority of the craters examined do not show an anomalous CPR signature indicative of the presence of water ice (for PSRs and non-PSRs within the craters). This is consistent with previous results from polar observations with bistatic angles < 0.5° [10, 11]. Three of the craters examined (Kocher, Wiechert E, and Wiechert J) have crater floor CPR values that are higher than surrounding terrain by a significant margin. Inspection of the floor morphology of those craters suggests that this signature is likely a result of surface roughness.

3. Conclusions

Preliminary analysis of the CPR of 18 polar craters in Mini-RF monostatic radar data suggest that a signature indicative of surficial/near-surface water ice is not present (i.e., at least not in quantities detectable at S-band wavelength). This is consistent with previous Mini-RF results from polar observations with bistatic angles < 0.5° [10, 11]. The CPR values of 3 other polar crater floors are elevated with respect to their surrounding but this signature is likely a result of surface roughness. While these data are not consistent with large, pure water ice deposits, we emphasize that they do not rule out smaller, heterogenous ice deposits, or surficial frost. Mini-RF is continuing operation in a bistatic architecture, collecting observations over a range of bistatic angles to more fully explore a variety of penetration depths and more fully explore the structure of the lunar polar regolith.

4. Figures

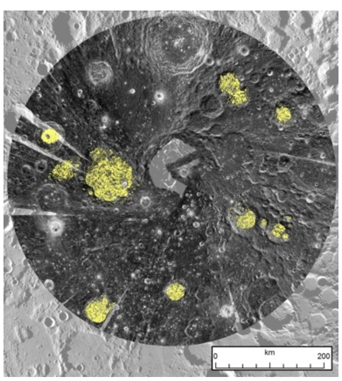

Figure 1: Mini-RF controlled polar mosaic of the lunar north pole (80° N to 90° N), overlain on the LROC WAC 100 m basemap. Yellow indicated crater floors analysed in this study.

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