MEASURING THE THICKNESS OF MERCURY'S POLAR WATER ICE DEPOSITS USING THE MERCURY LASER ALTIMETER. H.C.M. Susorney[1], P. B. James[2], N. L. Chabot[3], C. M. Ernst[3], E. M. Mazarico[4], and G. A. Neumann[4], [1]Johns Hopkins University, Baltimore, MD 21219 (hsusorn1@jhu.edu), [2]Lunar Planetary Institute, Houston, TX 77058, [3]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, [4]Goddard Space Flight Center, Greenbelt, MD 20771

Introduction: Impact craters in Mercury's polar regions host radar bright deposits that are consistent with the presence of water ice [e.g., 1–4]. Low-light imaging revealed deposits in some craters with surfaces that have a distinct albedo as compared to the surrounding crater floor [5]. Measuring the thickness of the polar deposits is key to estimating their volume and understanding their origin and deposition. The Mercury Laser Altimeter (MLA) measured the topography of craters in Mercury's north polar region. Visual examination of individual MLA tracks that cross over the radar-bright deposits cannot determine if there is a change of topography associated with the edges of these deposits. More robust analysis of topographic data is required to determine the thickness of these deposits.

Previous studies have placed constraints on the thickness of these deposits using two methodologies. An earlier study compared the depth-to-diameter ratios of craters that do and do not host radar-bright deposits [6]. No statistical difference in depth/diameter was found between the two populations of craters, but an upper limit of ~ 300 m for the thickness of the radar bright deposits was found. A more recent study [7] used interpolated gridded topography to compare the height of the topography within six craters hosting radar-bright deposits to six craters without radar-bright deposits; they found elevated topography on radar bright deposits of 50 ± 35 m, placing an upper limit of ~85 m on the thickness of the deposits.

Using individual MLA tracks rather than interpolated gridded topography has the potential to produce measurements of the thickness of Mercury's polar deposits that are more robust than these previous studies. Measurements from individual MLA tracks eliminate errors due to interpolation over regions with no data or due to mismatches between tracks. In this study we measure the thickness of Mercury's polar deposits using two different methodologies using individual MLA tracks. First, we looked for a statistical jump when the MLA track crosses the boundary of the radar-bright deposit on the crater floor in the crater Prokofiev. Second, we measured the difference in topography for individual MLA tracks between regions of the crater floor that do and do not host radar-bright deposits for the craters Prokofiev and Desprez.

Measuring a Jump at the Deposit Boundary: In this analysis, we searched for a discrete jump of Δz (change in topography) in MLA tracks associated with the edge of Prokofiev crater's radar-bright deposit (Fig. 1). The biggest complication in this measurement is the undulations in topography that are associated with the crater morphology rather than deposit thickness. To limit the effect of topographic undulations, we avoid the crater rim and consider only the locations where MLA tracks cross into the deposit from the north (where the deposit meets the crater floor). We also discard MLA measurements that come within two radii of the superimposed craters at 85.10ºN, 58.9ºE and 85.05ºN, 67.3ºE with diameters of approximately 7 km and 4 km, respectively. Finally, we de-trend crater floor topography, which is approximated as a 6 m/km increase in topography from the crater center toward the rim.

We identify 19 MLA tracks that cross into the radar-bright region from the crater floor. By considering MLA shots within 4 km of the radar-bright boundary, we solve for a single discrete jump in topography at the crossing point that minimizes RMS misfit. This method assumes a uniform height across the ice deposit. This yields a topographic jump of Δz = 0 ± 46 m at the boundary of the radar-bright region. Low-light imagery suggests that the geographic extent of ice may be more accurately represented by the extent of permanent shadow, so we analyze MLA tracks that cross into permanent shadow as well [8]. For the 15 MLA tracks that cross into permanent shadow with low geologic variability, the mean topographic jump is Δz = 2 ± 48 m.

The uncertainties on the best-fit topographic jump make it impossible to rule out the null hypothesis of a negligible topographic jump (Δz = 0 m ± 1 m, the standard error of a MLA height measurement). Using a Student's t-test for the MLA tracks crossing into permanent shadow, we find an upper bound for the mean value of Δz of 19 m at the $p < 0.01$ significance level.

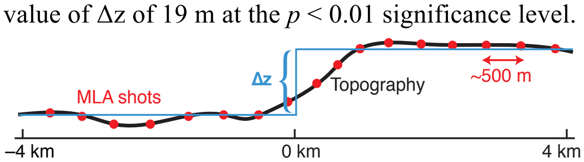

Figure 1. Schematic of how the step function was calculated from MLA tracks.

Measuring the Thickness of the Deposit: This methodology looked at difference in height of the radar-bright deposits compared to the crater floor of individual MLA tracks in the craters Prokofiev and Desprez. The tracks were first edited to focus on the crater floor (Fig 2). Then topography of the central peak and from subsequent small craters on the floor was removed.

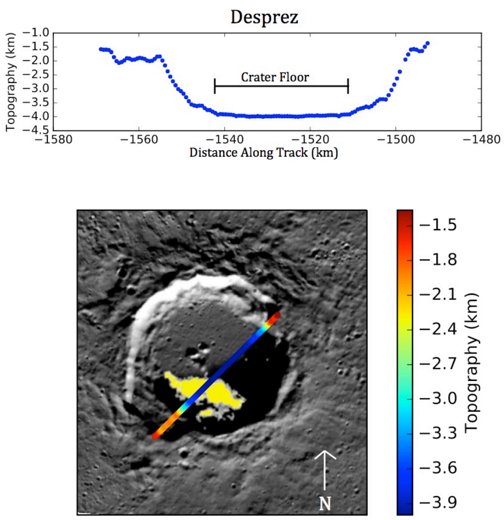

Figure 2. A single MLA track through the 47-km-diameter crater Desprez (yellow indicates the radar bright deposit) with the crater floor identified.

For each individual edited MLA track, the difference in mean topography for the radar-bright deposit on the crater floor and for the region of the crater floor outside the radar-bright deposit was calculated. Figure 3 shows the resulting difference in height for 55 tracks in the crater Desprez. While the majority of the tracks show higher elevation on the radar bright region of Desprez's floor, some tracks show lower elevation in the radar bright deposit compared to the surrounding crater floor.

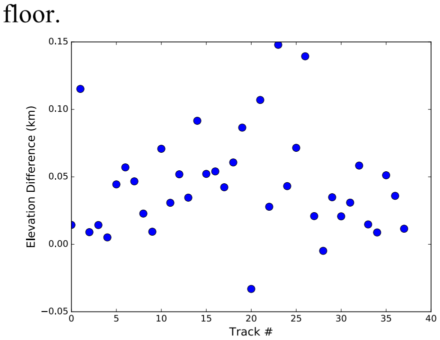

Figure 3. The difference in topography between the crater floor in the radar-bright region and the crater floor outside the radar-bright region for the crater Desprez. Elevation difference refers to the mean topography on the crater floor that contains radar bright deposits minus the mean topography of the remaining crater floor.

The mean difference in height (the thickness of the deposit) for MLA tracks in the craters Desprez and Prokofiev are shown in Table 1. The one standard deviation of the difference in height for all the tracks is reported as uncertainty. The uncertainty on the difference in height for Desprez is almost as large as the measurement of the deposit thickness itself. For Prokofiev, the uncertainty is larger than the measured thickness of the deposit.

Table 1. Information on two craters where we measured the radar bright deposit thickness by comparing tracks across the crater floor.

Crater Name	Latitude/ Longitude	Diameter	Deposit Thickness
Prokofiev	86°N 63°E	112 km	33 ± 60 m
Desprez	81°N 259°E	47 km	45 ± 38 m

The large uncertainties in the measurements of the thickness of Prokofiev's and Desprez's radar-bright deposits are likely due to geologic variability of the crater floor or to errors in MLA data taken at high emission angles. While the crater floor appears smooth in images, the actual topography at small scales (tens of meters) may be quite rough due to small impact craters, boulders, and variations in the melt thickness. This natural variability may be on the same scale or larger than the thickness of the ice deposits, preventing an accurate measure of the deposit's thickness.

Conclusion: We measured the thickness of two of Mercury's radar-bright deposits using two different methodologies. We found no statistically distinct jump in topography across the boundary of the crater Prokofiev's radar-bright deposit. We were able to place an upper bound on the deposit of 19 m. We compared the topography of the crater floor that does and does not contain radar-bright deposits for Prokofiev and Desprez craters. The resulting thickness estimates were 45 and 33 m respectively but with large uncertainties for both craters, which we attribute to natural variability of the crater floor. If we use an estimate in areal coverage of the radar bright deposits of 10,000 km^2 we end up with an estimate of volume of water ice deposits of ~200 km^3. These approaches support the conclusion that Mercury's polar deposits are on the lower end of the previous thickness constraints, with an upper limit of tens of meters.

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