Investigating the Distribution of Surface Ice in Mercury's Northernmost Craters. Allison K. Glantzberg[1], Nancy L. Chabot[1], Colin D. Hamill[1,2], Michael K. Barker[3], Erwan Mazarico[3], Matthew A. Siegler[4], Jose M. Martinez Camacho[5,4], Stefano Bertone[6,3], Ariel N. Deutsch[7], Edgard G. Rivera-Valentín[1], Heather Meyer[1], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, [2]Purdue University, West Lafayette, IN, [3]NASA Goddard Space Flight Center, Greenbelt, MD, [4]Planetary Science Institute, Tucson, AZ, [5]Southern Methodist University, Dallas, TX, [6]University of Maryland Baltimore County, Baltimore, MD, [7]NASA Ames Research Center, Moffett Field, CA.

Abstract: Earth-based radar observations by Goldstone and Arecibo Observatory revealed radar-bright features in Mercury's polar regions that have been interpreted as evidence for water-ice deposits [1–3]. Following these observations, the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft collected a myriad of evidence in its time orbiting Mercury that confirmed the hypothesis that the radar-bright deposits consist primarily of water ice. MESSENGER data were then used to identify Permanently Shadowed Regions (PSRs) [4] in Mercury's north polar region and model their thermal environments [5]. These models indicated that the radar-bright regions correspond to extensive PSRs in the northernmost craters on Mercury, which have thermal environments conducive to the presence of exposed water ice at the surface. However, detailed illumination and thermal studies of these northernmost craters have been impeded by the limited topographic data acquired by MESSENGER's Mercury Laser Altimeter (MLA) within 5° of the north pole [6].

In this study, we constructed local high-resolution (125 m/pixel) digital elevation models (DEMs) for four of the largest northernmost craters, Kandinsky (60 km), Chesterton (37 km), Tolkien (50 km), and Tryggvadóttir (31 km), using MLA data in conjunction with the Shape-from-Shading (SfS) techniques [7] applied to Mercury Dual Imaging System (MDIS) images collected by MESSENGER. These DEMs were then leveraged to create high-resolution illumination and thermal models. The illumination models mapped out accurate PSRs for each crater and informed how scattered light reflecting off the topography could be responsible for brightness variations observed in MDIS images (rather than variations in volatile composition). Our high-resolution thermal models were used to determine the maximum and average surface temperatures over a Mercury solar day, from which we inferred the depth at which various volatiles would be stable down to 2.5 m. Figure 1 highlights some of our new model results for these four craters.

Using these new high-resolution models, we investigated where thermal modeling predicts that ice or volatile organic compounds are stable at the surface in these craters. Previous work concluded that coronene is one appropriate volatile to model the low-reflectance surfaces observed within many of Mercury's PSRs that have thermal conditions too warm for the presence of water ice at the surface [8]. We then searched for evidence of ice or coronene at the surface in the MLA and MDIS data to confirm the predictions of our thermal models. Preliminary MLA results agree with previous findings [9] that these craters have a surface reflectance that is much brighter than the average reflectance of Mercury, suggesting the presence of water ice at the surface. However, preliminary comparisons to the limited MDIS images that reveal the surface features within the PSRs are so far inconclusive to verify the presence of high-reflectance regions due to water ice or low-reflectance regions due to complex organic compounds.

The limited MESSENGER data for these high-latitude craters impeded our ability to identify the precise boundaries of the volatile deposits, however, our new, high-resolution models support the stability of extensive water ice at the surface. Our MLA and MDIS analysis is also consistent with these predictions, making these four craters exciting targets for BepiColombo to explore during its upcoming orbital exploration of Mercury beginning in 2025.

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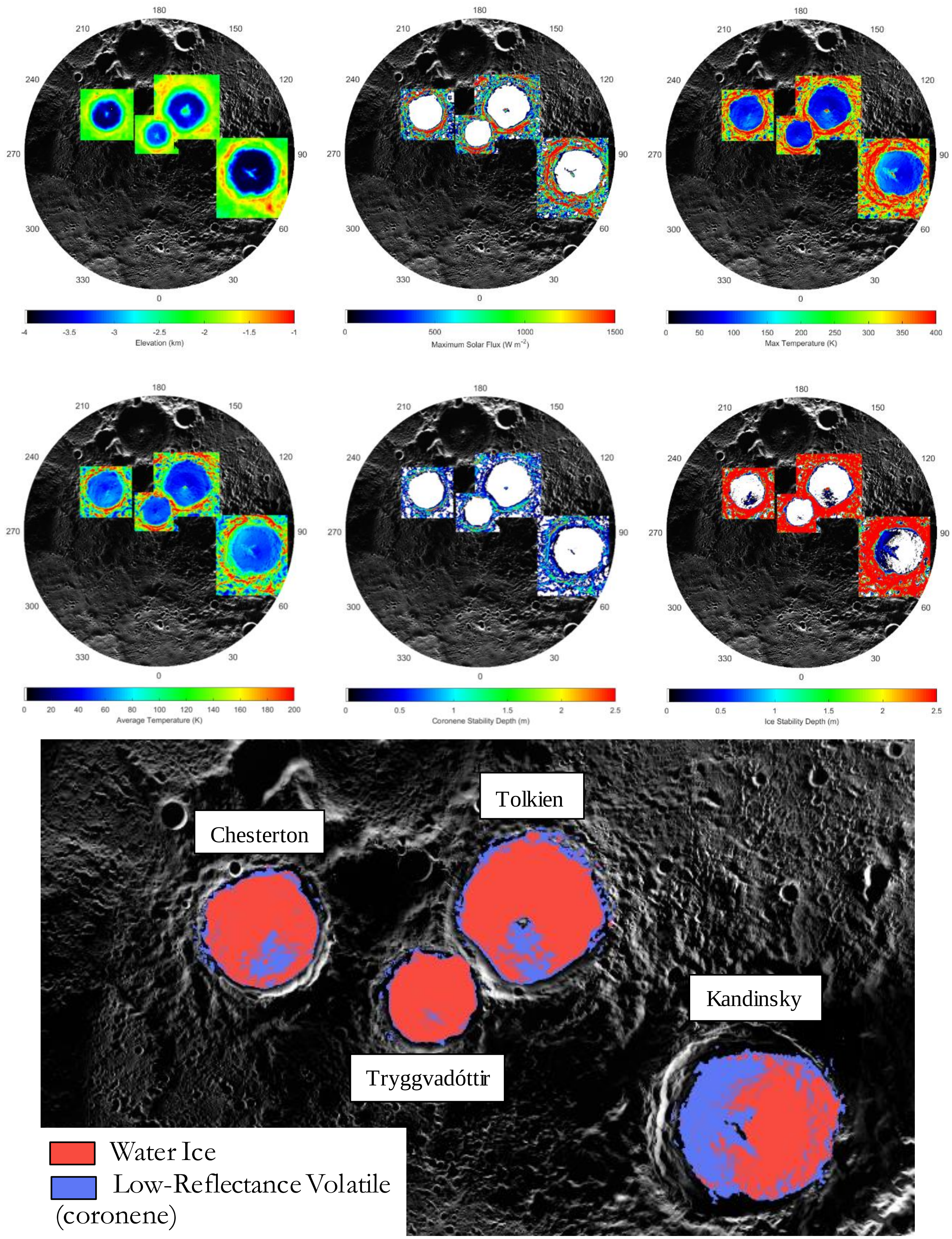

Figure 1: *High-resolution models of Mercury's largest northernmost. (Top Left) MLA + SfS DEM (km). (Top Middle) Maximum solar flux incident on the surface (W/m^2). The white regions represent the PSR. (Top Right) Maximum temperature over a Mercury solar day (K). (Middle Left) Average temperature over a Mercury solar day (K). (Middle Middle) Coronene stability depth (m). The white regions represent where coronene is thermally stable at the surface. (Middle Right) Ice stability depth (m). The white regions represent where water ice is thermally stable at the surface. (Bottom) Prediction depicting the regions where water ice (red) and coronene (blue) are expected to be thermally stable at the surface.*