INVESTIGATING MERCURY'S SOUTH POLAR WATER ICE DEPOSITS. Nancy L. Chabot[1], Evangela E. Shread[1], and John K. Harmon[2], [1]Johns Hopkins Applied Physics Laboratory, Laurel, MD, USA. (nancy.chabot@jhuapl.edu) [2]National Astronomy and Ionosphere Center, Arecibo Observatory, Arecibo, Puerto Rico.

Introduction: Two and a half decades ago, Earth-based radar observations of Mercury revealed the first evidence for water ice near Mercury's poles [1–3]. Subsequently, the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) mission obtained multiple datasets during its just over four-year orbital mission that provided compelling support for extensive water ice deposits within permanently shadowed regions near the poles [4–9]. However, MESSENGER's highly eccentric orbit about Mercury resulted in the spacecraft passing at low altitudes over the north polar region but remaining at altitudes of ~10,000 km over the south polar region. At the higher altitudes over the southern region, MESSENGER's Neutron Spectrometer (NS) [4] and Mercury Laser Altimeter (MLA) [5] were unable to obtain measurements. Consequently, MESSENGER studies of Mercury's polar deposits have largely focused on the north polar region. Here, we present new results that focus on investigating the water ice deposits near Mercury's south pole, from Earth-based radar observations and from MESSENGER images.

Earth-based Radar Observations: Previous radar observations of Mercury's south polar region were obtained at both Goldstone [10] and Arecibo [11] facilities, with range resolutions of 6 km and 1.5 km respectively. The higher-resolution Arecibo observations, shown in ***Fig. 1A***, were obtained from the two days of March 24–25, 2005, providing a limited viewing geometry with a substantial portion of the south polar region near 180°E longitude beyond the radar horizon [11]. New Arecibo observations, shown in ***Fig. 1B***, were acquired over a span of ten days from March 16–25, 2012, and with a mean radar viewing direction nearly opposite to that of the 2005 observations. Thus, these new 2012 observations are highly complementary to the 2005 images, providing views of Mercury's south polar region from distinct geometries that together result in a much more complete radar view of Mercury's south polar deposits than existed previously.

Illumination Conditions: Using images obtained by the Wide Angle Camera (WAC) of the Mercury Dual Imaging System (MDIS) from the first Mercury solar day of MESSENGER's orbital mission, permanently shadowed regions were identified in Mercury's south polar region at a pixel scale of 1.5 km [12]. However, during MESSENGER's full orbital mission, numerous Narrow Angle Camera (NAC) images were obtained of Mercury's south polar region, providing a factor of seven higher resolution than the WAC. In total, we identified 1,094 NAC images centered at or poleward of 77°S, grouped these images into 51 mosaics based on subsolar longitude, thresholded each mosaic into sunlit and shadowed regions, weighted each mosaic according to the fraction of the Mercury solar day it covered, and

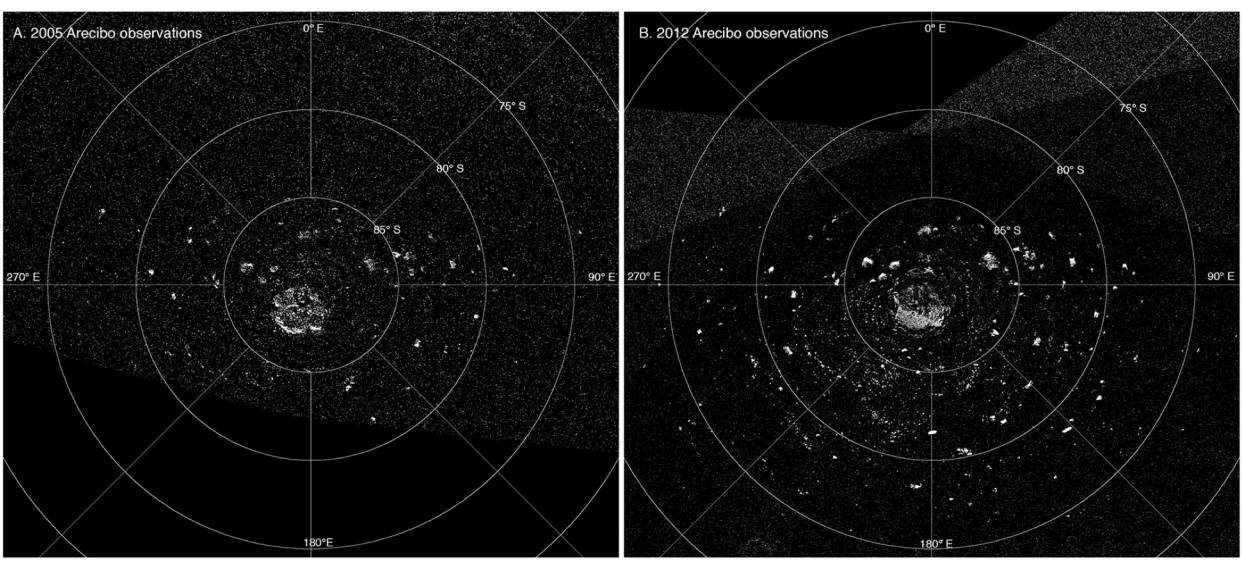

Fig. 1. Arecibo S-band (12.6 cm wavelength) radar observations of Mercury's south pole, with range resolution of 1.5 km. **A.** Weighted sum of two images acquired March 24–25, 2005, with a mean sub-Earth longitude of 11°E. **B.** Weighted sum of images that span ten days from March 16–25, 2012, with sub-Earth longitudes of 137–200°E.

combined the results to produce the illumination map shown in ***Fig. 2***.

In addition, MDIS acquired NAC images of Mercury's south pole with long exposure times (250–9989 ms), resulting in the sunlit surface being saturated, in an attempt to reveal surface features within permanently shadowed regions, as was done successfully with the WAC in Mercury's north polar region [8, 9]. However, the long-exposure NAC images were not successful at imaging permanently shadowed surfaces in Mercury's south polar region. In contrast, the long-exposure NAC images showed that some regions within Chao Meng-Fu that had been classified as permanently shadowed were actually dimly illuminated by direct sunlight. Taking these images into account, from 80°S and southward, 5.7% of the area is in permanent shadow. No permanently sunlit areas were identified, but several areas on the southernmost rim of Chao Meng-Fu are illuminated up to 74% of the Mercury solar day, the highest percent illumination in the region.

Implications: A radar image that combined the 2005 and 2012 observations shown in Fig. 1 was compared to the permanently shadowed regions mapped in Fig. 2, with the results shown graphically in ***Fig. 3***. Overall, 86% of the radar-bright features are located in or within 3 km of permanently shadowed regions. The remaining 14% of the radar-bright area is located within Chao Meng-Fu or in rough terrain, likely reflecting permanently shadowed regions below the scale captured by our shadow mapping approach. While radar-bright features are highly consistent with being located in permanently shadowed regions, only 45% of the permanently shadowed regions within 10° of Mercury's south pole also host radar-bright deposits. This lack of radar-bright deposits in all permanently shadowed regions is similar to that observed in Mercury's north polar region [7], raising the question of whether all of Mercury's cold traps are, or are not, occupied with water ice, with implications for its origin and evolution. The joint ESA-JAXA BepiColombo mission is well positioned to use the south polar maps produced here to guide further exploration of Mercury's south polar water ice deposits.

References: [1] Slade M.A. et al. (1992) *Science*, *258*, 635–640. [2] Harmon J.K. and Slade M.A. (1992) *Science*, *258*, 640–643. [3] Butler B.J. (1993) *JGR, 98*, 15003–15023. [4] Lawrence D.J. et al. (2013) *Science, 339*, 292–296. [5] Neumann G.A. et al. (2013) *Science*, *339*, 296–300. [6] Paige D.A. et al. (2013) *Science, 339*, 300–303. [7] Deutsch A.N. et al. (2016) *Icarus, 280,* 158–171. [8] Chabot N.L. et al. (2014) *Geology, 42*, 1051–1054. [9] Chabot N.L. et al. (2016) *GRL, 43*, 9461–9468. [10] Harcke L.J. (2005) *PhD thesis, Stanford, Univ.*, 201 pp. [11] Harmon J.K. et al. (2011) *Icarus, 211*, 37–50. [12] Chabot N.L. et al. (2012) *GRL, 39*, L09204, doi:10.1029/2012gl051526.

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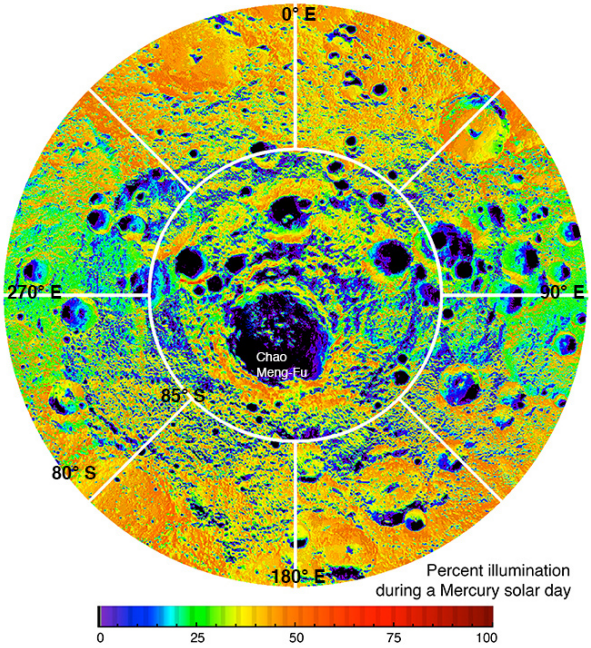

Fig. 2. Illumination conditions at Mercury's south pole, as determined by MESSENGER MDIS NAC images, with a pixel scale of 300 m.

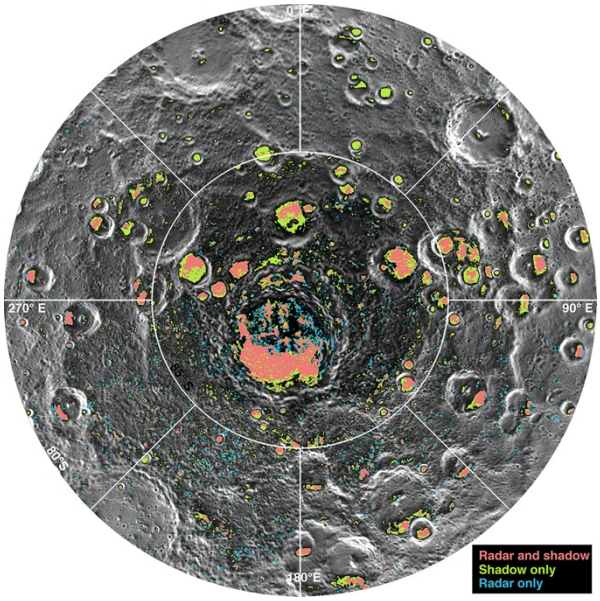

Fig. 3. Comparison of Arecibo radar images of Fig. 1 and permanently shadowed regions of Fig. 2. The radar-bright features are highly correlated with permanently shadowed regions, as predicted for water ice deposits.