Modeling Temperatures and Ice Distribution at Mercury's South Pole. J. M. Martinez-Camacho[1,2], M.A. Siegler[1,2], S. Bertone[3,4,5], N. L. Chabot[7], E. Mazarico[4], D. A. Paige[6] [1]Planetary Science Institute, Tucson, AZ, [2]Dept of Earth Sciences, Southern Methodist University (jmartinezcamacho@smu.edu), Dallas, TX, [3]National Institute for Astrophysics: Turin, Piedmont, IT, [4]NASA Goddard Space Flight Center: Greenbelt, MD, US, [5]Universität Bern: Bern, BE, CH, [6]Earth and Space Sciences, University of California, Los Angeles, California, USA. [7]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD, USA

Introduction: The polar environments of Mercury surprised many when highly backscattering radar deposits were discovered in the polar regions [1,2]. As time progressed, radar data painted a clear picture that these deposits appear to align with craters that remained unimaged at the time [3], South Polar data shown in in Figure 1, leading to the prevailing theory that they were dominated by water ice trapped within polar shadowed craters. With the arrival of the MESSENGER mission [4,5,6] low altitude passes over Mercury's North Polar region, confirmed the presence of hydrogen rich deposits that aligned well with regions where ice should be stable thermally, based on MESSENGER topography [7].

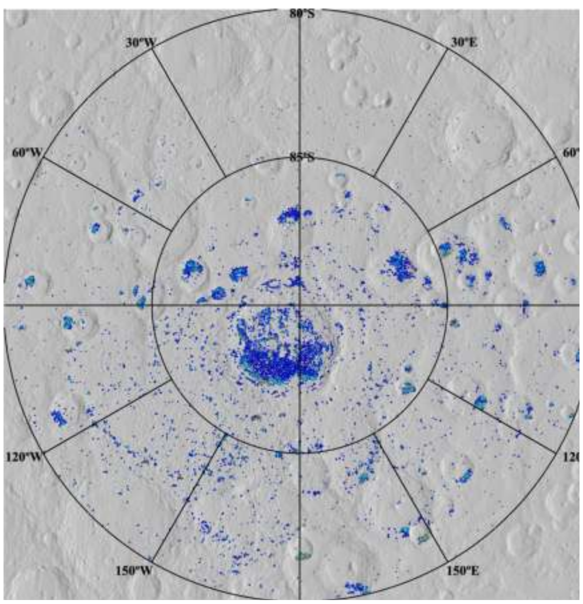

Figure 1: Radar observations from Arecibo telescope.

Due to MESSENGER's highly elliptical orbit, South Polar laser altimeter data could not be returned and images were at a far lower resolution than for the North. With advances in shape-from-shading topographic models [8], high resolution topography from MESSENGER imagery is now available for the South Polar region. While these models require some interpolation for areas within permanent shadow, they mark a huge advance over existing topography. Here we present the first thermal model and ice stability results for Mercury's South Pole, following the methods of Paige et al. [7]. This provides the first look at the full inventory of water ice stability on Mercury at a resolution that can be directly compared to radar data.

Thermal Model: To simulate temperatures in Mercury's south pole, we first generate a triangulated surface mesh from a 250 m/pixel topographic model [8]. Two triangulated meshes were used to model temperatures poleward of 80ºS: the first mesh was kept at 250 m resolution and included topographic data within 85ºS while the second mesh extended up to 80ºS and was simplified using a fast-quadratic mesh simplification algorithm to reduce the number of triangles while preserving topography. Temperature results were then combined to produce Figures 2 and 3.

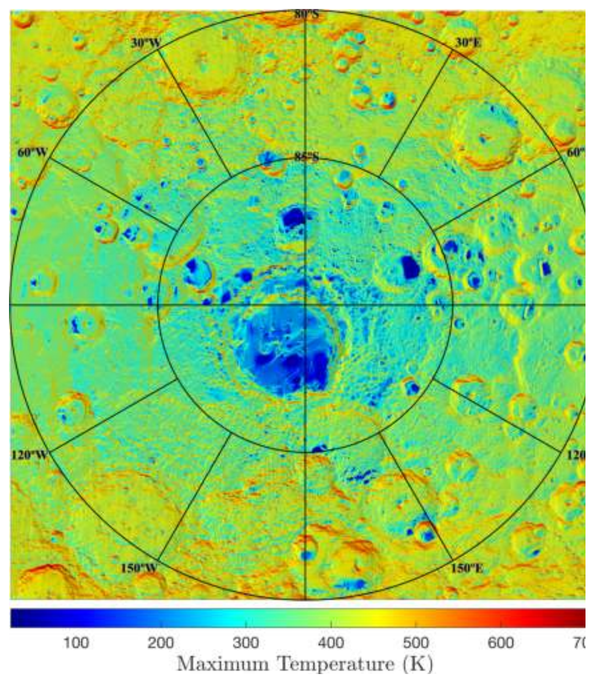

Figure 2: Thermal modeling results of maximum surface temperatures at Mercury's south pole (<80ºS).

Solar insolation at the South Pole and its effects on temperature were simulated using a ray-tracing thermal model [7]. The Sun was modeled as a circular disk made up of 128 triangular facets with luminosities varying with radius to match limb darkening observations and appropriately distanced from Mercury's center using ephemeris data (subsolar longitude, subsolar latitude, and Mercury's heliocentric distance). This ephemeris was collected from JPL's Horizons System and spanned the julian dates 2455000 to 2455879.7 at 0.7 Earth-day increments.

A ray tracing algorithm is implemented to determine which surface facets are illuminated by the Sun at each modeled time-step. For each surface facet, the direct solar flux and indirect flux (due to reflection and infrared emission) from other visible facets in the mesh are calculated assuming Lambertian emission and reflection.

Temperatures are calculated at each facet using a one-dimensional thermal model that accounts for vertical heat conduction between 150 layers reaching a depth of ~2.5 m. The maximum surface temperature for one orbital cycle is shown in Figure 1.

Ice Stability: Surface ice on airless bodies is stable against sublimation at temperatures < 110 K [9]. For airless bodies with a stable low obliquity, this temperature range is sustained in permanently shadowed regions, such as crater floors situated at high latitudes, where the surface temperatures remain cold enough to trap water ice for billions of years [10]. Buried ice can remain stable at higher temperatures compared to exposed surface frost. We model subsurface ice stability depths based on [7,10] in which the stability of ice depends on its sublimation rate as a function of temperature and diffusion through the overlaying regolith.

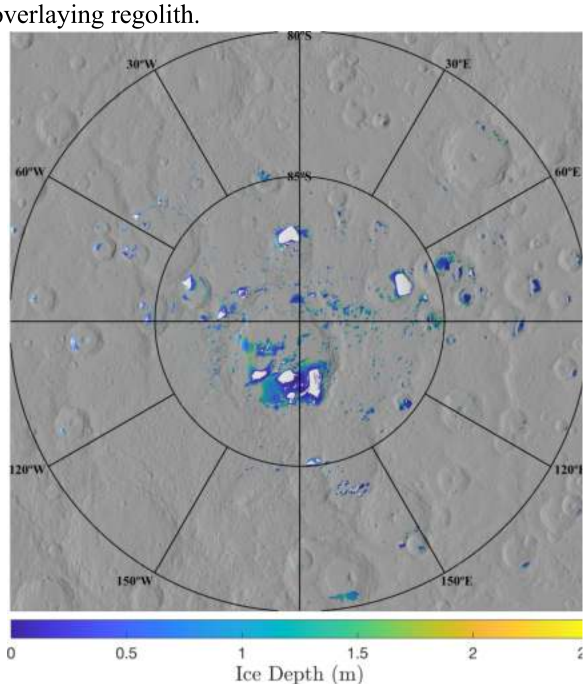

Figure 3: Depth at which water ice would be stable against a sublimation rate of 1mm/Gyr. White regions represent stable surface ice and gray areas are regions where water ice is not stable at depths < 2.5 m.

References: [1] Slade et al., 1992, Science [2] Paige et al. 1992, Science [3] Harmon et al., 2011, Icarus [4] Chabot et al., 2014, Geology [5] Lawrence et al., 2013 Science [6] Neumann et al., 2013 Science [7] Paige et al 2013, Science [8] Bertone et al., 2022, PSJ [9] Vasavada et al., 1999, Icarus [10] Schorghofer and Taylor, 2007, Icarus.