COLD SPOTS ON MERCURY? OPPORTUNITIES FOR THE BEPICOLOMBO MERTIS TO STUDY IMPACT PROCESSES AND REGOLITH PROPERTIES. Ariel N. Deutsch[1,2], Karin E. Bauch[3], Harald Hiesinger[3], Paul O. Hayne[4], [1]NASA Ames Research Center, Moffett Field, CA, USA (ariel.deutsch@nasa.gov), [2]Bay Area Environmental Research Institute, Moffett Field, CA, USA [3]Universität Münster, Münster, DE, [4]University of Colorado Boulder Boulder, CO, USA.

Introduction: Thermal measurements of the lunar surface by Diviner [1] revealed the widespread presence of "cold spots," which have anomalously low nighttime temperatures and are associated with very young impact craters, often extending 10–100 crater radii from fresh impacts [2,3]. Lunar cold spots rapidly radiate heat after local sunset until they are at least 2 K colder than the surrounding terrain [2,3]. They have low thermal inertia and appear to be composed of decompacted regolith materials that have been "fluffed-up" by impacts [2].

Cold spots should also occur on Mercury (or any airless body with low thermal inertia and significant gravity [2]), but they have never been observed due to an absence of temperature measurements. Excitingly, the ESA/JAXA BepiColombo spacecraft will enter orbit around Mercury in late 2025 [4,5] and will have the opportunity to observe cold spots, enabling new studies of mercurian impact processes and regolith properties, as well as comparisons to the Moon.

Identifying Cold Spots on Mercury: The BepiColombo payload includes the MErcury Radiometer and Thermal Infrared Spectrometer (MERTIS). Similar to what Diviner does for the Moon, MERTIS will measure the spectral emittance of Mercury's surface. MERTIS combines a thermal infrared imaging spectrometer (7–14 μm) and thermal radiometer (7–40 μm), enabling surface measurements of various thermophysical properties, including temperature and thermal inertia [4,5]. It will be used to map the entire planet at a spatial resolution of 500 m and a signal-to-noise ratio of >100, and to map local regions of interest at even higher spatial resolution [4,5].

MERTIS thermal identification of cold spots. As on the Moon [2], the criteria for a cold spot on Mercury would be two-fold: (1) the presence of a spatially coherent pattern of relatively colder temperatures in nighttime data immediately surrounding a fresh crater and (2) the absence of topography that could be responsible for the colder temperatures.

On the Moon, cold spots are defined as having a surface temperature at least 2 K colder than the background rock-free regolith surface temperature at the local observation time [2]. This 2-K difference is significant in identifying thermophysically-distinct surfaces [2,6] and is greater than Diviner's 0.94-K standard deviation in rock-free regolith temperatures [1,2]. Measuring a statistically significant 2-K difference on Mercury might be challenging with MERTIS, which has a minimum required performance of ≤3 K and desired performance of ≤1 K [5]. Thus, perhaps cold spots on Mercury will need to be identified on the basis of a slightly larger temperature differential (e.g., ~5 K). We estimate this should still be ample difference to identify cold spots, which can be up to 20 K colder than their surroundings on the Moon. Furthermore, we might expect higher thermal anomalies on Mercury for the same thermal inertia difference due to larger diurnal temperature amplitudes (**Fig. 1**). Once BepiColombo orbital operations begin, noise character-istics of MERTIS may be refined based on individual measurements and a meaningful cold-spot temperature differential should be subsequently derived.

MERTIS temporal coverage of Mercury's surface. Daytime temperatures of lunar cold spots approach radiative equilibrium and are not distinct from the temperatures of surrounding terrain due to the regolith's low thermal inertia and the Moon's long diurnal cycle [2]. The same is expected for Mercury, which also has low thermal inertia and has even longer diurnal cycles. Thus, nighttime observations are required for the identification of cold spots on Mercury.

One difference between the Moon and Mercury is the length of a solar day. On the Moon, one full day-night cycle is ~29.5 Earth days; on Mercury, it is ~176 Earth days. A longer night provides more time for cold spots to equilibrate with their surroundings; thus, optimal viewing times would be in the first few Earth days following local sunset. BepiColombo will have a nominal mission lifetime of 1 Earth year, plus a possible 1-Earth-year extended mission [4,5], so MERTIS will have sufficient opportunities (~2–4 Mercury days) to observe cold spots.

Like the Moon, Mercury experiences large temperature variations during its diurnal period. However, unlike the Moon, these variations differ not only with latitude but also with longitude due to the planet's highly eccentric orbit and 3:2 spin-orbit resonance. At lower latitudes, greater diurnal tempera-ture variations are experienced at "hot-pole" longitudes (centered at 0°E and 180°E) than at "cold-pole" longitudes (90°E, 270°E). This affects the timing of when specific longitudes are in nighttime, and thus the timing of when cold spots could be observed (**Fig. 1**).

Spatial distribution of cold spots. We expect cold spots on Mercury will be most easily identifiable at mid-to-low latitudes, like they are on the Moon, because highlatitude rough and/or sloped surfaces tend to have residual temperature variations from variable solar heating that persist through the local night [2,3]. A more variable background terrain makes it more difficult to identify a cold spot.

A Cold Spot at the MESSENGER Impact Site: On 30 April 2015, NASA's MESSENGER spacecraft, traveling >3.91 km/s, deliberately crashed into Mercury, resulting in a crater estimated to be ~16 m in diameter at ~54.4°N, 210.1°E [9]. The impact site is an opportunity to study a very young crater and potential cold spot on Mercury. On the Moon, all new craters >40 m have cold spots, while new craters <40 m *sometimes* have detectable cold spots (where "new" designates the crater formed during Diviner operations) [10].

If a cold spot is present at the MESSENGER impact site and if we conservatively estimate it extends to 10x the crater radius [2,3] to form a ~160-meter-diameter splotch, then it is likely still too small to be visible even in high-resolution, targeted MERTIS observations. If the cold spot is at least 30x the crater radius, it should be possible to observe with MERTIS. (This is within the range of lunar cold spot sizes, which extend up to 100 crater radii [2,3].) Fading over time is the main control on variability in thermophysical properties between similarly sized lunar cold spots [10], so because the MESSENGER crater will be only ~10 years old during BepiColombo orbital operations, any cold spot characteristics should be relatively distinct.

In addition to the MESSENGER crater, BepiColombo will surely observe several other young craters, some of which should be larger and resolvable even in the nominal 500-mpp MERTIS data.

Key Science Questions and Predictions Related to Cold Spots on Mercury: *Cold spot ages and retention times*. Crater size-frequency distributions of cold spot craters can provide constraints on the formation ages and retention times of cold spots [3]. Retention times and cold spot thermophysical properties can subsequently be used to estimate impact gardening rates and regolith overturn depths [2,3,8].

We predict the number of cold spots will be higher on Mercury than on the Moon due to higher impact speeds and fluxes of m–km-sized impactors [11]. However, the flux of cm–m-sized impactors is about an order of magnitude lower at Mercury than at the Moon [12] and these impactors, along with their secondaries, are modeled to be the dominant impact gardeners [13]. As a result, regolith overturn depths may be relatively shallower on Mercury than on the Moon [13] and so retention times of cold spots on Mercury may be relatively longer than those on the Moon (~0.2–1.0 Myr [3]).

Young impactor populations. Cold spot locations can provide insight into the recent impactor population on Mercury. We predict that the density of cold spots on Mercury will decrease with latitude due to a higher probability of low-inclination impacts [14], similar to what is observed for the Moon [2,3,8].

Subsurface rock abundance. The proximal ejecta of craters with cold spots can provide constraints on the local subsurface rock content and depth over which the volume fraction of rock increases [6, 8, 15, 16]. We predict that subsurface rock content may be relatively higher in cold spot ejecta produced in smooth plains than in intercrater plains due to the smooth plains being more recently resurfaced.

References: [1] Paige et al. (2010) *SSR, 150,* 125. [2] Bandfield et al. (2014) *Icar, 231,* 221. [3] Williams et al. (2018) *JGRP*, *12,* 2380. [4] Hiesinger et al. (2020) *SSR, 216,* 110. [5] Hiesinger et al. (2010) *PSS, 58,* 144. [6] Vasavada et al. (2012) *JGRP*, *117,* E003987. [7] Bauch et al. (2021) *Icar*, *354*, 114083. [8] Hayne et al. (2017) *JGRP*, *122,* 2371. [9] https://www.nasa.gov/image-article/best-determination-of-messengers-impact-location/ [10] Powell et al. (2021) *AGU*, #EP24B-01. [11] Marchi et al. (2009) *AJ*, *137,* 4936. [12] Marchi et al. (2005) *A&A, 431,* 1123. [13] Costello et al. (2020) *JGRP*, *125,* E006172. [14] Pokorný et al. (2018) *ApJ*, *863,* 31. [15] Elder et al. (2019) *JGRP*, *124*, E006128. [16] Venkatraman et al. (2023) *PSS, 229,* 105662.

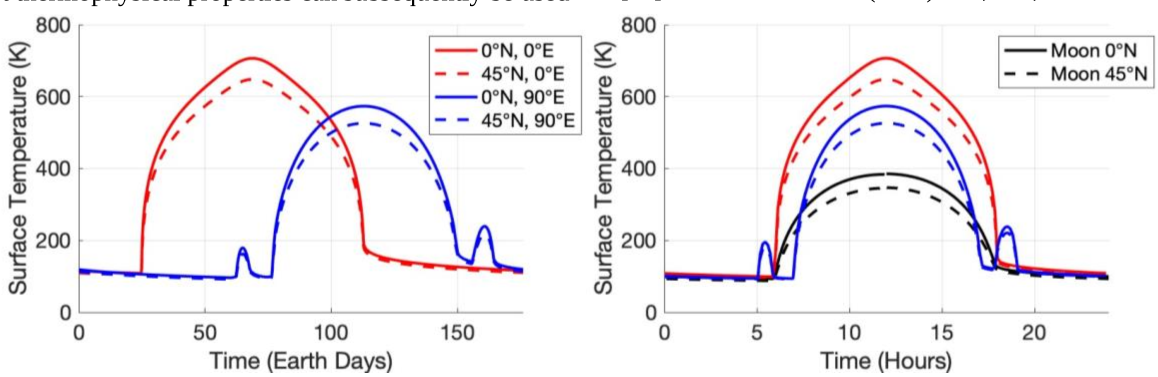

Fig. 1. (L) Modeled temperatures on Mercury [7] for one solar day. Note that at perihelion, Mercury's orbital velocity exceeds its spin rate, resulting in a secondary sunrise and sunset at cold-pole longitudes. **(R)** Temperatures on Mercury [7] normalized to a 24-hour day centered at local midnight for comparison to lunar temperatures [8].