Data Set Guide for Mercury

This document outlines the data sets available within the OpenSpace astrovisualization software (version 0.15.1). These data sets were compiled from the results of MESSENGER mission. They provide insight into the topographical features, evolution, and physical processes on the surface of Mercury.

Alexis Harris (Intern)
Rachel Smith (Supervisor)
Astronomy & Astrophysics Research Lab
North Carolina Museum of Natural Sciences

OpenSpace

NASA

Mercury Surface Data Sets

MESSENGER Mission

- MErcury Surface, Space ENvironment, GEochemistry, and Ranging

The MESSENGER mission is an investigation of the innermost planet, Mercury. This planet is one of the terrestrial planets in our solar system. In order to gain a better understanding of the other terrestrial planets (Venus, Earth, and Mars), it is important to understand Mercury and its evolution.

The MESSENGER spacecraft orbited Mercury after three flybys of the planet. The data gathered from the flybys will serve as the guide for the orbital phase. These data include information about the geology of Mercury, its surface composition, as well as its internal structure and magnetosphere. Many data sets were put together using the Mercury Dual Imaging System (MDIS). This instrument possesses two cameras: wide- and narrow-angle cameras (WAC and NAC, respectively). The two cameras on the MDIS instrument gathered topographic information, tracked surface spectra, and mapped landforms. In addition to the MDIS, there are other instruments on the craft that were used to gather images and data that were then analyzed and pieced together to form data sets and global maps. The information for the following data sets was obtained via the MESSENGER mission site overviews, as well as the Planetary Data System, in which catalogs provide technical information about the data set maps.

For more information on MDIS and the other instruments used on the MESSENGER spacecraft, see the MESSENGER website's information about the spacecraft and instruments:

- https://messenger.jhuapl.edu/About/Spacecraft-and-Instruments.html

OpenSpace

To access the MESSENGER data on OpenSpace, first the focus must be on Mercury. When opening the software, the default scene will be on Earth. Using the *Focus* section of the Menu, it is possible to change the focus to Mercury. If Mercury is still not close enough to see its surface, hold the right mouse button and drag away from yourself to zoom in.

Once Mercury is in focus, there are different viewing options under *Scene* on the menu. First, it may be necessary to uncheck the *Perform shading* box to allow for easier viewing of the desired datasets. The images created from MESSENGER's datasets (discussed in detail below) can be selected from the list of *ColorLayers* available under the dropdown menu *Layers* under *Renderable.* The *Renderable* menu is available for Mercury in the *Scene* menu. Many of the datasets will have [Utah] or [Sweden] following the acronym. Select the one closest to your current location for better image quality and viewing. The global maps that are in color will be discussed and each color region will be designated below. All of the images included below were obtained using OpenSpace.

MDIS BDR

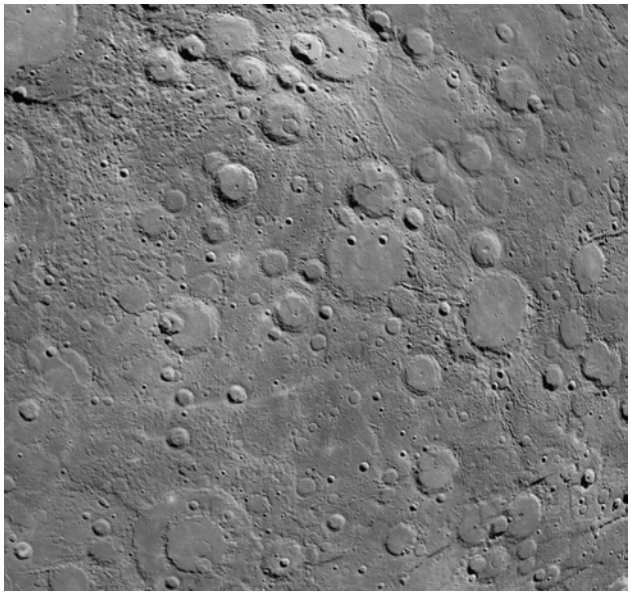
Overview: The MDIS BDR is another ColorLayer available when viewing Mercury on OpenSpace. This data set is the projected Basemap RDR (reduced data record). The images created from this global data set and subsequent images at similar illumination geometries and low emission angles are pieced together into fifty-four non-overlapping tiles that are the basemap data records (BDRs). The tiles are at a resolution of 256 pixels per degree. Using both the WAC and NAC of the MDIS instrument, the 750-nm images are those that best fit the intended geometry and emission angle and incidence angle (~74^{o}). The data that were mosaicked was collected at low emission angles for cartographic purposes, and at moderate to high incidence angles to highlight topography. The BDR data are projected onto a global model of elevation that is presented as a global monochrome map of reflectance.

OpenSpace: The BDR global map is the default ColorLayer when viewing Mercury's surface in OpenSpace. This is a monochrome map that allows the viewing of impact craters and other

significant topographical features. The high resolution of the BDR data set allows for clear images of the surface of Mercury when zoomed in very close.

For more information on the BDR Data Set, see:

- Astropedia, Mercury MESSENGER MDIS Global basemap BDR 166m: https://astrogeology.usgs.gov/search/map/Mercury/Messenger/Global/Mercury_MESSENGER_MDIS_Basemap_BDR_Mosaic_Global_166m
- NASA PDS: Planetary Data System, Data Set Information for MESSENGER MDIS MAP PROJECTED BASEMAP RDR V1.0 https://pds.nasa.gov/ds-view/pds/viewProfile.jsp?dsid=MESS-H-MDIS-5-RDR-BDR-V1.0



MDR: Multispectral Reduced Data Record

Overview: MDRs consist of 54 non-overlapping, 64 pixel/degree tiles. The tiles are mosaicked from the 8-color imaging from the MDIS instrument. Each tile is corresponding to one of the four quadrants (NE, NW, SW, or SE) of pre-existing Mercury non-polar charts or one of the two polar charts.

OpenSpace: The MDR map is similar to the BDR map in its appearance. The MDR data set is lower in pixel/degree resolution than the BDR data.

For more information on this data set see PDS: Cartography and Imaging Sciences Node.

- MESSENGER: Instrument and Data Archive Information - Multispectral Reduced Data Record (MDR) Data Set Description
- https://pdsimage2.wr.usgs.gov/data/mess-h-mdis-5-rdr-mdr-v1.0/MSGRMDS_5001/CATALOG/MDIS_MDR_DS.CAT

HIE: High-Incidence Angle Basemap Illuminated from the East RDR

Overview: The MESSENGER MDIS HIE data set is a complementary dataset to the BDR. The high-incidence angle of the HIE data allows for the visualization of less evident low-relief topography. When illuminated from the East, asymmetric topographic features are favored that slope more steeply to the East than to the West.

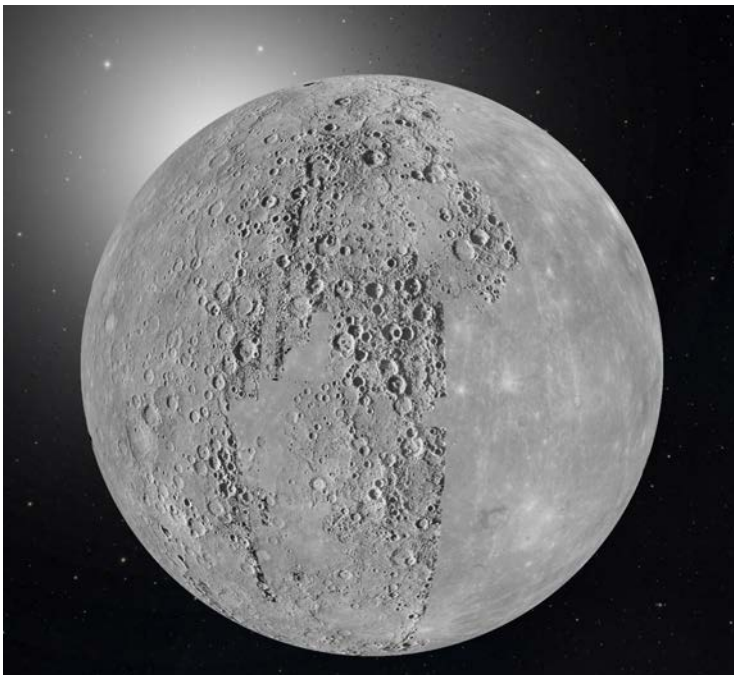
OpenSpace: Another complementary dataset to BDR, the HIE data are also a monochrome global map. When compared to the HIW global map, the illumination from the East highlights a specific perspective of the surface of Mercury.

For more information on this data set: PDS: Cartography and Imaging Sciences Node

- MESSENGER: Instrument and Data Archive Information - Map Projected High-Incidence Angle Basemap Illuminated from the East Reduced Data Record (HIE) Data Set Description
    - https://pdsimage2.wr.usgs.gov/archive/mess-h-mdis-5-rdr-hie-v1.0/MSGRMDS_7001/CATALOG/MDIS_HIE_DS.CAT

HIW: High-Incidence Angle Basemap Illuminated from the West RDR

Overview: Another complementary dataset is the MDIS HIW dataset. Like its counterpart, HIE, this dataset also highlights the less evident low-relief topography on Mercury's surface. Because illumination is from the West in the images produced from these data, the favored topography is asymmetric that is more steeply sloped to the West than to the East. These images have a resolution of 256 pixels per degree.



OpenSpace: The HIW global map is very similar to the HIE map in that it is also a monochrome map that is complementary to the default BDR. The HIE and HIW maps appear similar as well, however, the HIW map highlights topographic features from a different perspective.

For more information on this data set visit PDS: Cartography and Imaging Sciences Node.

- MESSENGER: Instrument and Data Archive Information - Map Projected High-Incidence Angle Basemap Illuminated from the West Reduced Data Record (HIW) Data Set Description
    - https://pdsimage2.wr.usgs.gov/archive/mess-h-mdis-5-rdr-hiw-v1.0/MSGRMDS_7101/CATALOG/MDIS_HIW_DS.CAT

LOI: Low Incidence Angle Basemap Reduced Data Record

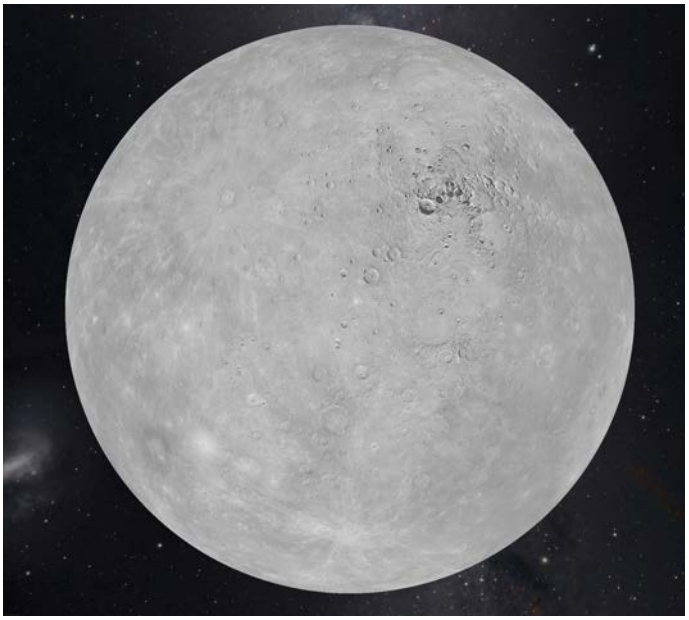
Overview: The LOI ColorLayer is a monochrome mosaic that minimizes the visible shadows on Mercury's surface. Because of this, it shows the differences in the properties of reflection of materials making up the surface composition. LOI is a global map of I/F on the surface of Mercury, showing the incident solar flux. This data set is complementary to the BDRs used to highlight topography because of the illumination at lower solar incidence angles that are not included in the basemap BDR. Rather than highlighting topographic features, the LOI data set highlights albedo variations. Albedo is the proportion of incident light reflected by a surface.

The images produced by the LOI dataset have a higher resolution when monochrome rather than color. As a result, viewing these data will be possible in higher spatial resolution than viewing the colored mosaics. The projection for this data was simple cylindrical, with a center point at 0^{o} latitude and 0^{o} longitude.

OpenSpace: The LOI ColorLayer is complementary to the BDR data. When viewing the LOI images, they will appear as a monochrome map that will highlight topographic features that may not be visible using only the BDR data.

For more information on this data set see:

- The MESSENGER mission site, Global Mosaics
  https://messenger.jhuapl.edu/Explore/Images.html#global-mosaics
- PDS: Cartography and Imaging Sciences Node: MESSENGER: Instrument and Data Archive Information - Map Projected Low-Incidence Angle Basemap Reduced Data Record (LOI) Data Set Description:
  https://pdsimage2.wr.usgs.gov/archive/mess-h-mdis-5-rdr-loi-v1.0/MSGRMDS_7201/CATALOG/MDIS_LOI_DS.CAT



SHADE

Overview and Important Features: The Mercury SHADE ColorLayer on OpenSpace is a global topographical model. Important features of the SHADE data include the indication of the highest and lowest points of elevation on Mercury's surface.

- *Highest*: 2.78 miles/4.43 km above the average elevation
- *Lowest*: 3.34 miles/ 5.38 km below the average elevation

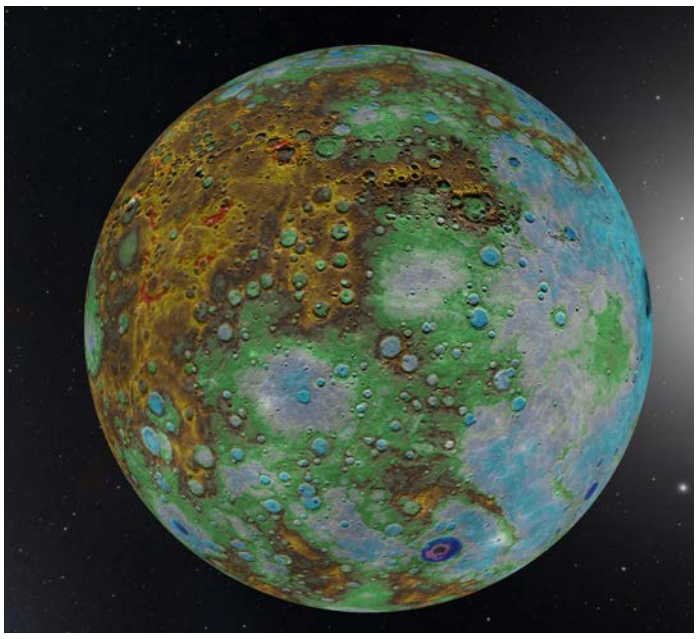
The images created by the SHADE data provide a more in-depth depiction of Mercury's North Pole. This region is covered by layers of lava from prior volcanic activity. Images shown in the SHADE data reveal the evolution of the topography of this region. The northern volcanic plains are visible in more detail with the data collected and can be seen as a smooth region near Mercury's North Pole.

MESSENGER's spacecraft is equipped with an instrument that provides the ability to collect the data necessary to create the SHADE global map. The Mercury Laser Altimeter (MLA) is used to map the topography of the surface of Mercury, along with the MDIS for high-resolution surface morphology.

OpenSpace: SHADE is a global map that highlights elevation and topography in color. Areas of higher elevation are shown in warm colors, with the highest elevations in red. Cool colors are used to indicate lower elevations, and darker blue is indicative of the regions with the lowest elevation.

For more information on the SHADE data set, see:

- The MESSENGER mission site, *The Ups and Downs of Mercury's Topography*
  - https://messenger.jhuapl.edu/Explore/Science-Images-Database/gallery-image-1566.html
- NASA, First Global Topographic Model of Mercury
  - https://www.nasa.gov/feature/first-global-topographic-model-of-mercury



Surface Composition

Overview: OpenSpace possesses ColorLayers maps of Mercury's surface composition. These maps include:

- Al/Si (alsimap): aluminum/silicon ratio
- Ca/Si (casimap): calcium/silicon ratio
- Mg/Si (mgsimap): magnesium/silicon ratio

- Fe/Si (fesimap): iron/silicon ratio
- S/Si (ssimap): sulfur/silicon ratio

Each map depicting the elemental ratios is a colorful representation of the abundances of thermal-neutron-absorbing elements on the surface of Mercury.

Data Collection: MESSENGER contains an X-Ray Spectrometer (XRS) that measures the abundance of rock-forming elements. These elements include: magnesium (Mg), aluminum (Al), silicon (Si), sulfur (S), calcium (Ca), and iron (Fe). X-rays from the Sun's corona excite the electrons of surface and near-surface atoms. When these excited electrons return to the ground state, they fluoresce. The XRS measures the solar X-ray spectrum and fluorescence. The data gathered is then used to determine the abundances of each element. Under "quiet-Sun" conditions in which the coronal plasma temperature is low (only a few megakelvin, MK), the only detectable elements are magnesium, aluminum, and silicon. During solar flares, the temperature is raised to tens of megakelvin, allowing the heavier elements (S, Ca, Fe) to fluoresce.

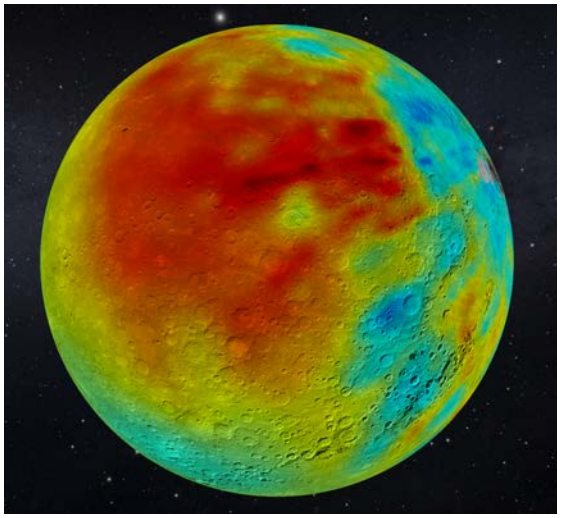
Description of Data Set: To create the maps seen on OpenSpace, the abundances of each element are normalized to silicon. Silicon is the major element with an abundance that varies less than that of the other major elements. Systematic uncertainties can be eliminated by the normalization of abundances to silicon. This is why each map is presented as a ratio: they each show the ratio of the abundance of a specific element to the abundance of silicon. These composition maps highlight the areas of chemical diversity on the planet. For example, the Caloris Basin is an area with low Mg/Si but high Al/Si. These maps are also useful in determining the evolutionary history of Mercury.

- Ex: the casimap shows the abundance of calcium on the surface of Mercury relative to the amount of silicon that is present.

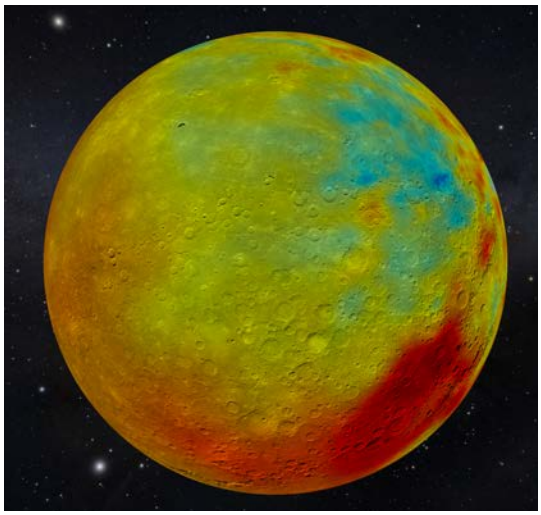
OpenSpace: When viewing the surface composition maps in OpenSpace, the relative abundances of each element will be shown in colored global maps. For each one, regions with a higher abundance of the specific element will appear in red. The image of the aluminum/silicon map is an example of an area with a high amount of aluminum. Likewise, areas with low abundances are shown in blue, and other cool colors. The area shown in the magnesium/silicon image below provides a great example of the range of colors representing the range of chemical abundance on the surface of Mercury.

For more information about the surface composition data, see:

- The MESSENGER mission site, *Showing Some Chemistry:*
  - https://messenger.jhuapl.edu/Explore/Science-Images-Database/gallery-image-1572.html
- Along with articles and news about chemical diversity on the MESSENGER site:
  - https://messenger.jhuapl.edu/Resources/Articles.html#news-273



Magnesium/Silicon Map



Aluminum/Silicon Map

Other Useful Material

Starr, R. D., Schriver, D., Nittler, L. R., Weider, S. Z., Byrne, P. K., Ho, G. C., Rhodes, E. A., Schlemm, C. E., Solomon, S. C., and Trávníček, P. M. (2012), MESSENGER detection of electron-induced X-ray fluorescence from Mercury's surface, *J. Geophys. Res.*, 117, E00L02, doi:10.1029/2012JE004118

- https://doi.org/10.1029/2012JE004118