EPSC Abstracts
Vol. 6, EPSC-DPS2011-817, 2011
EPSC-DPS Joint Meeting 2011

Surface compositional heterogeneity on Mercury inferred from MESSENGER spectral measurements

Mario D'Amore (1), Jörn Helbert (1), Alessandro Maturilli (1), Ann L. Sprague (2), Noam R. Izenberg (3), Gregory M. Holsclaw (4), William E. McClintock (4), Faith Vilas (5) Piero D'Incecco (1) and Sean C. Solomon (6)
(1) DLR, Rutherfordstrasse 2, Berlin, Germany, mario.damore@dlr.de; (2) Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, USA (3) Johns Hopkins University, Applied Physics Laboratory, Laurel, MD 20723, USA; (4) Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80303, USA; (5) Planetary Science Institute, Tucson, AZ 85719, USA; (6) Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA.

Abstract

We assess compositional heterogeneity on the surface of Mercury with data from MESSENGER'S Mercury Atmospheric and Surface Composition Spectrometer. The data were obtained during the spacecraft's early orbital phase and cover nearly a pole-to-pole portion of the planet from about 0° to -45°E longitude. We applied a statistical technique to extract underlying relationships among units. Without applying photometric corrections, we were able to cluster surface observations into distinct classes that correspond well to geomorphological units identified from MESSENGER images, such as plains and heavily cratered terrain. We also identified areas where the geometry of spectral observations matches that of biconical reflectance spectra obtained at the DLR Planetary Emissivity Laboratory, which will be exploited to infer possible mineralogical constituents of Mercury's surface materials.

1. Introduction

The MESSENGER spacecraft continues to provide new and view-changing data on the nature of Mercury's surface. Under the hypothesis that surface compositional information can be efficiently derived from spectral reflectance measurements with the use of statistical techniques, we have employed principal component and clustering analyses to identify and characterize spectral units from observations by MESSENGER's Mercury Atmospheric and Surface Composition Spectrometer (MASCS) instrument. This method proved successful on MASCS data obtained during MESSENGER's Mercury flybys even in the absence of a photometric correction.

2. The MASCS instrument

The MASCS instrument [1,2] consists of a small Cassegrain telescope with an aperture that simultaneously feeds an Ultraviolet and Visible Spectrometer (UVVS) and a Visible and Infrared Spectrograph (VIRS). VIRS is a fixed concave-grating spectrograph with a beam splitter that disperses the spectrum onto a 512-element silicon visible photodiode array and a 256-element indium-gallium-arsenide infrared photodiode array with a spectral resolution of 5 nm. VIRS has a circular field of view with a circular diameter of 0.023°. The visible (VIS) detector of VIRS covers the wavelength range from 300 to 1050 nm, and the near-infrared (NIR) detector covers the range 850-1450 nm. The study of Mercury's surface presented here uses only the VIRS channel of MASCS.

3. Data analysis

To retrieve and characterize the number and spectral shapes of the different components present in the dataset (Fig. 1), we apply principal component analysis (PCA), a well-established technique in remote sensing [3–5]. PCA expresses the data in a new vectorial basis set, for which the data covariance is minimized. PCA essentially reduces the dimensionality of the dataset and allows modeling of the data as a linear combination of the principal components or eigenvectors. The dimensionality of the new basis set measures the number components that influence the system, so finding the crossing point between principal and secondary eigenvalues is a primary task of PCA. In particular, we evaluated the eigenvalue ratio [3] and the reconstruction error, and we inspected visually the goodness of fit of spectra to the model. Each spectral eigenvector can be regarded as a representative of a distinct spectral class that varies in abundance along the track. The first eigenvector always displays a strong positive or "red" slope with increasing wavelength, probably strongly linked to effects associated with viewing geometry variations, and all eigenvectors show distinctive spectral signatures. PCA also provides factors to decompose each data point onto the eigenvector base (also called loading in classical

PCA). These concentration coefficients indicate that spectral units show substantial geographical variation. Because we do not photometrically correct the data, we can clearly see the dependence of the coefficients on geometrical parameters. We apply a decorrelation technique (i.e., the Mahalanobis transformation [6]) to partially remove dependence on observation angle in the retrieved concentration coefficients. The decorrelation removes the main variation directly linked to variations in illumination and viewing geometry. A variation along track remains that we suppose is the result of actual variations in reflectance across the surface. In particular, the locations of spectrally distinct units inferred from this analysis correlate well with those inferred from color imaging.

4. Conclusion

We observed the presence of distinct spectral units on Mercury that show a strong correlation with surface units mapped by the MESSENGER imaging system [7]. At the same time, we have begun to make use of the newly available visible and near-infrared biconical reflectance observations from DLR's Planetary Emissivity Laboratory (PEL) as a basis for testing possible surface constituents [8]. We use these data as a temporary substitute for upcoming high-temperature data that will allow us to make more appropriate comparisons. We filtered the available MASCS data for those matching the laboratory geometrical setup (incidence and emission angles near 45º; see green spots in Fig. 1) and found two broad areas, each with several examples of distinctive surface units seen in images. We are combining the classification/statistical approach with the spectral unmixing approach of Helbert et al. [8] to characterize these areas further.

References

[1] McClintock, W.E., et al., Science, 321, 92-94, 2008.

[2] Izenberg, N.R., et al., Eos Trans. AGU, 89(53), Fall Meet. Suppl., abstract U11C-05, 2008.

[3] Bandfield, J.L., et al., J. Geophys. Res., 105, 9573-9588, 2000.

[4] Ramsey, M.S., Christensen P.R., J. Geophys. Res., 103, 577-596, 1998.

[5] Smith, M.D., et al., J. Geophys. Res., 105, 9539-9552, 2000.

[6] Salomon, D., Data Compression: The Complete Reference, Springer, Berlin, 1092 pp., 2006.

[7] Denevi, B.W., et al., Science, 324, 613-618, 2009.

[8] Helbert, J., et al., EPSC-DPS 2011, this conference, 2011.

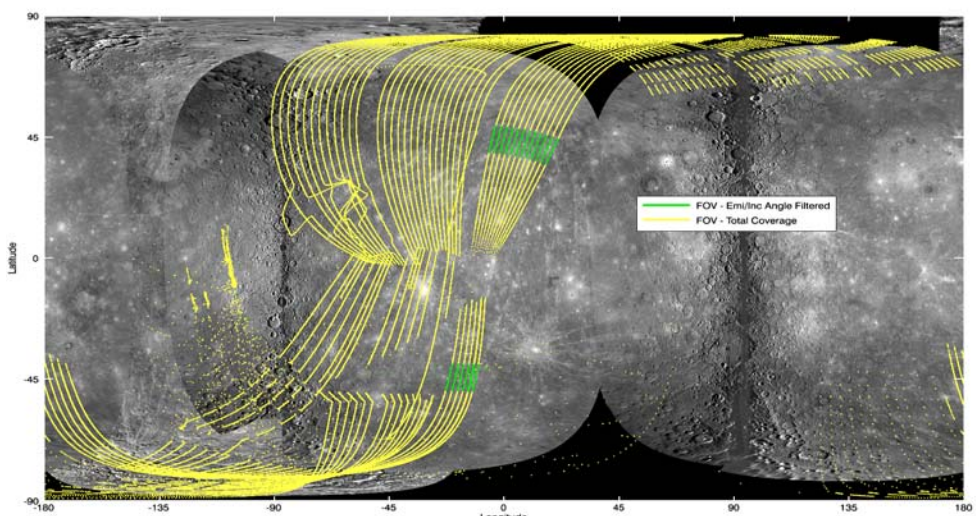

Fig 1. Surface coverage of MASCS data analyzed in this work. Center points of the MASCS fields of view are in yellow, and observations made with a viewing geometry matching that at PEL are in green.