MESSENGER ADVANCED PRODUCTS I: VIRS HYPERSPECTRAL CUBE, ENERGETIC ELECTRON EVENTS, THERMAL NEUTRON MAP. Noam R. Izenberg (noam.izenberg@jhuapl.edu)[1], David J Lawrence[1], Patrick N. Peplowski[1], Erick Malaret[2], Calogero Mauceri[2], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA. [2]Applied Coherent Technology Corporation, Herndon, VA 20170, USA.

Introduction: The Mercury Advanced Product (MEAP) project is a first effort to enhance the utility of MESSENGER data to the planetary science community with five new data sets that are not included in the mission's nominal deliverables. We introduce the first three of these products here, all of which have intended delivery dates to the Planetary Data system by the end of May 2016.

MEAP-1: The "**VIRS Spectral Cube of Mercury**", will be a 105-band global spectral cube of Mercury from 300-1450 nm at a scale of 500 meters per pixel using data from the Visible and Infrared Spectrograph (VIRS) component of the Mercury Atmosphere and Surface Composition Spectrometer (MASCS) [1].

MEAP-3: "**Energetic Electron Events**". Data from the MESSENGER Neutron Spectrometer (NS) [2] have been used to detect and characterize energetic electron (EE) events within Mercury's magnetosphere [3,4] MEAP-3 will be a database of EE events, and their characteristics (intensity, time, location) in relation to the magnetosphere.

MEAP-4: "**Thermal Neutron Maps of Mercury**". MESSENGER Gamma-Ray Spectrometer (GRS) Anti-Coincidence Shield (ACS) data has been used to map variations in thermal neutron absorbing elements across Mercury's surface, and in turn to map major geochemical units across the same region. MEAP-4 will be a thermal neutron map of Mercury.

The data for all MEAPs as proposed were acquired during 3 years of primary-plus-extended missions of MESSENGER [5] from 18 March 2011 to 17 March 2014, however, we intend to deliver data through the end of MESSENGER's orbital lifetime (30 April 2015). MEAP-2 (UVVS Cube) and MEAP-5 (Enhanced GRS global dataset) are to be delivered in 2017.

VIRS Global Data: MASCS VIRS provides spectral observations from 300 nm to 1450 nm at a 5 nm spectral resolution [1]. During the primary and extended missions in orbit around Mercury, VIRS acquired over 5 million spectra of Mercury's surface [6, 7]. The purpose of VIRS is to map spectral, and by extension mineralogical, variation across Mercury's surface, thus providing insight into the planet's composition and evolution. VIRS has a much higher spectral resolution than the Mercury Dual Imaging System (MDIS)'s color images [8]. VIRS orbital observations have varying spatial resolutions, as spacecraft altitude and ground speed changes the size and smear of the 0.023° circular field of view.

While individual spectra can be valuable, the global perspective is essential to understand spatial relationships and correlation with geology. Fig. 1a. is a three-color composite map, constructed using global coverage of five different VIRS wavelengths (Red = 575 nm reflectance, green = 415/750 nm reflectance ratio, blue = 310/390 nm reflectance ratio). This simple band-math highlights variations in the ultraviolet to near-infrared components of Mercury spectra, with implications for mineralogy, composition, and planetary mapping [e.g. 9, 10].

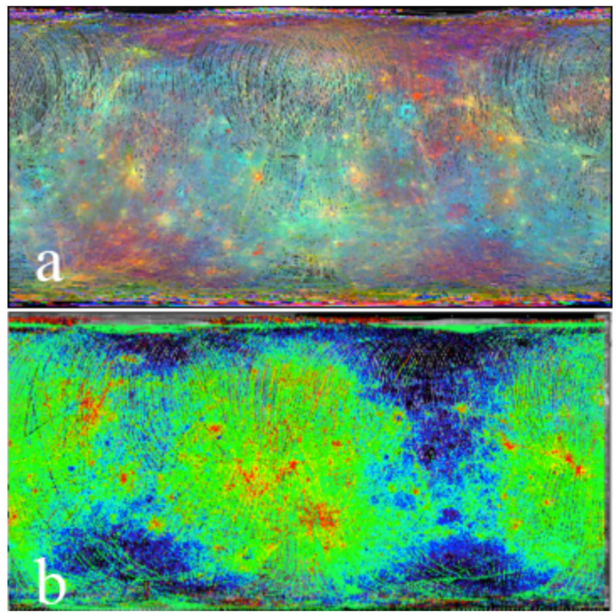

Fig. 1. VIRS global "layer" map products. a) color composite of reflectance and reflectance ratios using 5 UV-IR wavelengths. b) sulfide 'band depth' map using 3 wavelengths.

Fig. 1b shows a preliminary global "sulfide band depth" map applying a continuum subtraction method (using reflectance at 500 nm, 600 nm, and 700 nm) for several million individual spectra, for comparison with datasets like the XRS [11] global sulfur map. A VIRS spectral cube will enable rapid adjustment/refinement of models and comparison of such maps on a global scale. Figs. 1a and b were created using millions of spectra [9] filtered for extreme geometry and instrument state. A unifying dataset, where the fully calibrated and best quality spectral data is represented as uniformly and completely as possible, will be a valuable tool to the scientific end-user.

Energetic Electron Events: Data from the MESSENGER Neutron Spectrometer (NS) have been used to detect and characterize energetic electron (EE) events within Mercury's magnetosphere [3]. The NS indirectly detects EE events via bremsstrahlung photons that are emitted when instrument and spacecraft materials stop electrons with energies of tens to hundreds of keV. NS data taken from 18 March 2011 to 31 December 2013 identified over 2700 EE events. The duration of EE events ranges from tens of seconds to almost 20 minutes. EE events are classified as bursty or smooth, such that bursty events show large count rate variability within an event, and smooth events show small count rate variability. Almost all EE events are detected within Mercury's magnetosphere on closed field lines. The occurrences of EE events are statistical in nature, but are located in well-defined regions with clear boundaries that persist in time, and form "quasi-permanent structures" (Fig. 2). Bursty events occur closer to dawn and at higher latitudes compared to smooth events, which are seen near noon-to-dusk local times at lower latitudes. A subset of EE events shows strong periodicities that range from hundreds of seconds to tens of milliseconds.

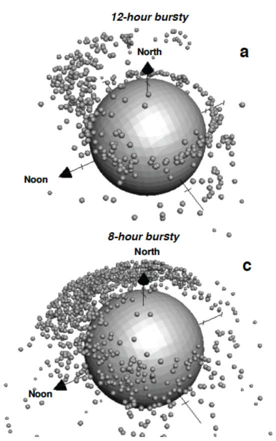

Fig. 2. Geographic locations of EE events around Mercury in coordinates of latitude, altitude, and local time separated by mission phase and the smooth and bursty classification. Panels a and b show events from the 12-hour mission phase, panels c and d show 8-hr-orbit measurements (figure from [4]).

The first MESSENGER detection of energetic electrons was via reported Energetic Particle Spectrometer (EPS) data [3]. The NS, however, has an order-of-magnitude larger sensitivity for EE events than the EPS. This increased sensitivity is illustrated by the fact that in the same time period (first MESSENGER year in orbit) that the EPS detected 51 EE events, the NS detected 733 events. At the time that the MESSENGER data archive was being planned, it was not anticipated that the NS would provide such a robust measure of EE events. Now that its capability has been demonstrated, these data will provide a valuable resource for many kinds of studies of Mercury's magnetosphere.

MESSENGER GRS Products: The MESSENGER Gamma-Ray Spectrometer (GRS) consists of a high-purity Ge (HPGe) sensor surrounded by a BC454 anti-coincidence shield (ACS) for background reduction. The ACS measured incident neutrons and charged particles, the former datasets provides a sensitive measure of variations in low-energy neutron emissions from Mercury that complements measurements from the NS. The ACS neutron measurement capability was enhanced on 25 February 2013, when an in-flight software upgrade resulted in the production of new data products from the ACS.

ACS measurements of Mercury, acquired from 1 March 2013 to 28 February 2014, were used to used to map variations in the abundances of thermal-neutron-absorbing elements across Mercury's surface (Fig. 3). Major neutron absorbing elements on Mercury include Cl, Na, and Fe. The creation of the ACS-derived Σ_a map is complete, and the results are published [13], however it has not been delivered to the PDS, as it was an unanticipated output of the GRS. The MEAP project will deliver this product to the PDS using the identical map product format used for the GRS K and XRS Mg/Si, Ca/Si, Fe/Si, and S/Si PDS maps.

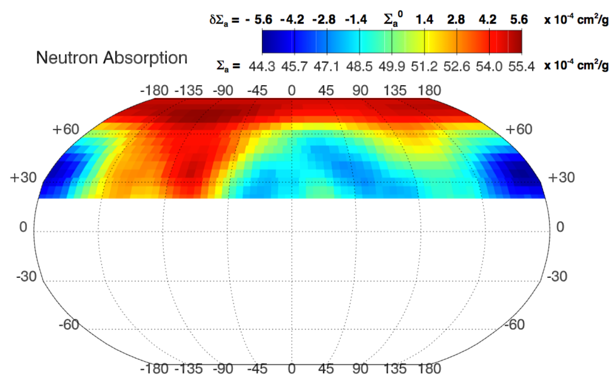

Fig. 3. Thermal neutron absorption (Σ_a) mapped across Mercury's northern hemisphere. Σ_a s a bulk parameter that describes the total neutron absorption capacity of the regolith to depths of 10s of cm. The top scale bar values report variability in absorption ($\delta\Sigma_a$), and the bottom scale bar values report a best estimate of the absolute values.

References: [1] McClintock W. E. and Lankton, *Space Sci. Rev.* 131, 481-521, 2007. [2] Goldsten J. O. et al., *Space Sci. Rev.* 131, 339-391. [3] Ho G. C. et al., *Science*, 333, 1865-1868, 2011. [4] Lawrence D. J. et al., *J. Geophys. Res.* 120, 2851-2876, 2015. [5] Solomon S. C. et al., *Space Sci. Rev.*, 131, 3-39, 2007. [6] McClintock W. E. et al., *Science*, 321, 62-, 2008. [7] Izenberg N. R. et al., *Lunar Planet. Sci., 40*, #1663, 2009. [8] Hawkins S. E. III, et al., *Space Sci Rev.* 131 247-338, 2007. [9] Izenberg N. R. et al., *Icarus* 228, 364-374, 2014. [10] D'Incecco P. et al., *Planet. & Space Sci.* 119, 250-263, 2015. [11] Weider S. Z. et al., *Earth & Planet. Sci. Lett.* 416, 109-120, 2015. [12] Peplowski P. N. et al., *J. Geophys. Res.* 117, 2012. [13] Peplowski P. N. et al., *Icarus* 228, 86-95, 2014.