GLOBAL MAJOR-ELEMENT MAPS OF MERCURY UPDATED FROM FOUR YEARS OF MESSENGER X-RAY OBSERVATIONS. Larry R. Nittler[1,*], Elizabeth A. Frank[1], Shoshana Z. Weider[1], Ellen Crapster-Pregont[2], Audrey Vorburger[2], Richard D. Starr[3,4], and Sean C. Solomon[1,6]. [1]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA, [2]Department of Earth and Planetary Sciences, American Museum of Natural History, New York, NY 10024, USA [3]Physics Department, The Catholic University of America, Washington, DC 20064, USA. [4]Solar System Exploration Division, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA. [6]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964, USA. *E-mail: lnittler@ciw.edu

Introduction: The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft impacted the surface of Mercury on April 30, 2015, after slightly more than four years in orbit around the innermost planet. Its geochemistry instruments, the X-Ray Spectrometer (XRS) and Gamma-Ray and Neutron Spectrometer (GRNS), returned a wealth of data that can be used to determine the elemental composition of the surface and meet the overarching scientific goal of understanding the planet's origin and geological history. These data have shown that Mercury's crust is enriched in Mg and depleted in Al, Ca, and Fe relative to other terrestrial planets, and that it is surprisingly rich in volatile elements, including S, Na, K, Cl, and C [1–5]. Moreover, maps of elemental abundances and neutron absorption have revealed the presence of a number of distinct geochemical terranes [6, 7].

The previously published XRS elemental abundance maps were based on data acquired during the first 2.75 years of MESSENGER's orbital operations [6]. During the final year of the mission, however, the spacecraft periapsis altitude was much lower than it had been before. XRS data at higher spatial resolution were thus obtained during the final stages of the mission [8]. Here we report major-element ratio maps of Mercury derived from a comprehensive analysis of the data from the full MESSENGER orbital mission. These maps have higher resolution and improved spatial coverage (for S/Si, Ca/Si, and Fe/Si) than previous maps. They will be delivered to NASA's Planetary Data System in mid-2016 for use by the planetary science community.

Data and Methods: The XRS detected X-ray fluorescence (XRF) from the top tens of micrometers of Mercury's surface, induced by incident X-rays emitted from the Sun's corona. Following previous methods [6, 9], we combined individual XRS measurements with variable spatial resolution and statistical precision to generate maps of Mg/Si, Al/Si, S/Si, Ca/Si, and Fe/Si ratios. Whereas Mg, Al, and Si could be measured during typical non-flaring solar conditions ("quiet Sun"), S, Ca, and Fe all required solar flares to induce measurable signals. Since solar flares are sporadic in time and the spacecraft spent only a small fraction of each orbit above the northern hemisphere, spatial coverage for the heavier elements is unfortunately incomplete in the north, where spatial resolution is best.

The Mg/Si and Al/Si maps include data from 46,663 individual quiet-Sun XRS measurements and 1065 solar flare measurements collected throughout the orbital mission. Measurements that exhibit evidence of charged-particle interactions with the detector (and of other obvious problems) were excluded. We used a modified [6] spatial binning procedure to improve the statistical precision of the quiet-Sun data: Measurements with footprint diameters larger than ~100 km were binned into ~66×66 km^2 bins, those from footprints 50–100 km across were binned into ~26×26 km^2 bins, and those from footprints smaller than ~50 km were not binned. This procedure favors spatial resolution over statistical precision for the highest-resolution data.

The S/Si, Ca/Si, and Fe/Si maps are based solely on data acquired during flares and incorporate data from 1386, 1419, and 262 flare measurements, respectively. The different number of measurements in each map reflects varying precision between flares for the different elements and the exclusion of data with large errors.

Results and Discussion: The XRS elemental ratio maps and associated statistical error maps are shown in Figure 1. The spatial resolution of the maps ranges from ~10 km for the highest-resolution measurements to >2000 km at the south pole. Area-weighted planetary averages are indicated by horizontal red lines on the ratio map color bars.

Previously identified geochemical terranes are clearly visible in the maps, most notably the large high-Mg region (HMR) centered on 30°N, -90°E [6], which also clearly has low Al/Si and high Ca/Si, S/Si, and Fe/Si ratios; the low-Mg, high-Al Caloris basin (CB); and the low-Mg northern volcanic plains (NVP). Compared with earlier maps, the higher-resolution data included in our new maps allow for these – and other – regions to be explored in more detail than previously possible [e.g., 10]. Detailed comparisons of these XRS maps and other MESSENGER datasets will

substantially improve our understanding of Mercury's composition and geological history [e.g., 11, 12].

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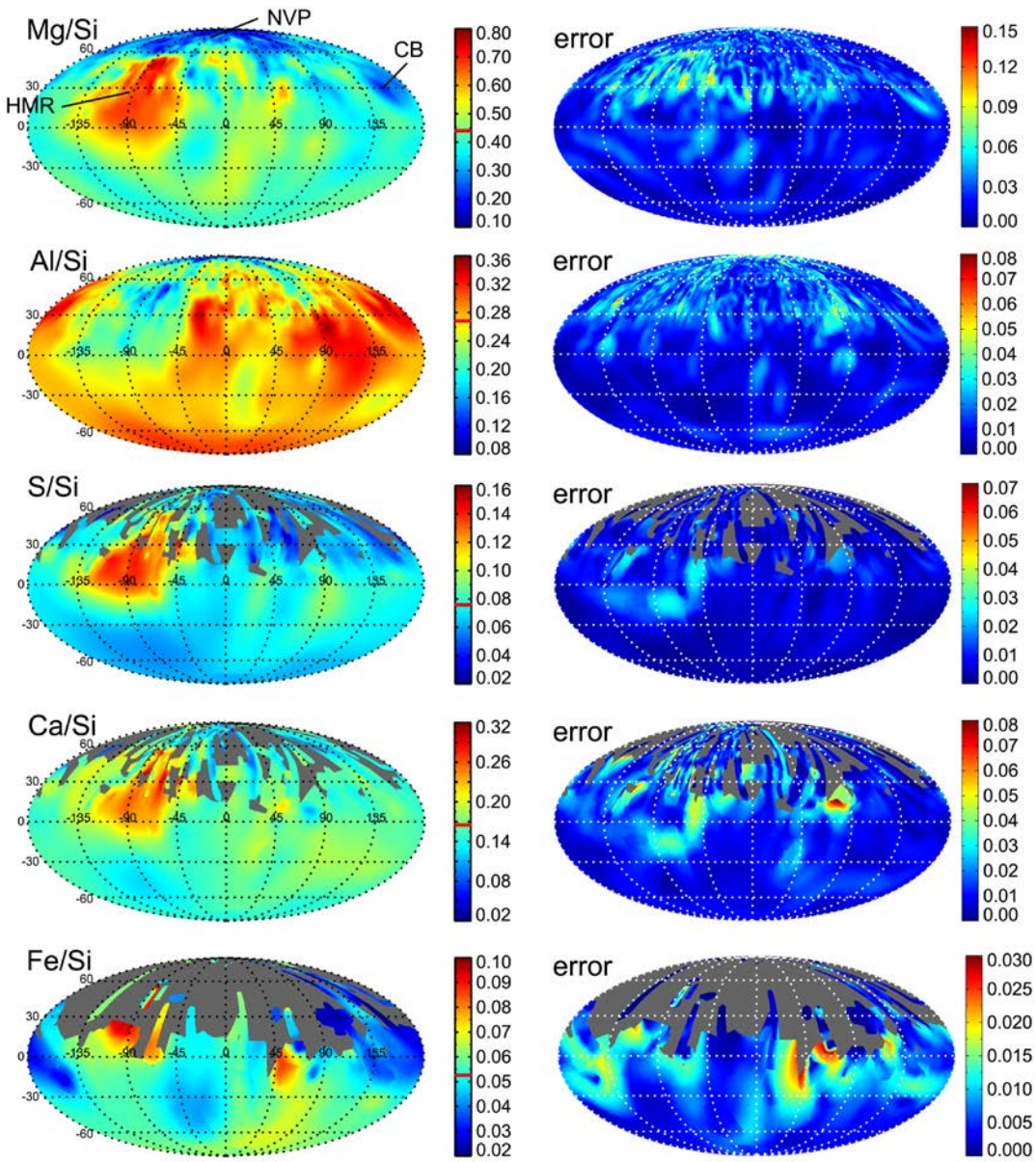

Figure 1. Maps of elemental ratios on Mercury and associated one-standard-deviation statistical errors, derived from MESSENGER XRS data. Maps are shown in a Molleweide projection, centered on 0°N, 0°E. HMR: high-Mg region. NVP: northern volcanic plains. CB: Caloris basin. Red lines in color bars indicate global averages.