TIME-DEPENDENT CALIBRATION OF MESSENGER'S WIDE-ANGLE CAMERA FOLLOWING A CONTAMINATION EVENT.

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Background: Analysis of orbital images taken by the wide-angle camera (WAC) of the Mercury Dual Imaging System (MDIS) on the MESSENGER spacecraft uncovered an unexpected and sudden decrease in responsivity that recovered over time. The change occurred on or about 24 May 2011, during the time the spacecraft experienced its first hot season, reaching the highest temperatures encountered in flight to that point. Although no cause has been explicitly identified, the timing and subsequent recovery suggest a contamination event, possibly due to outgassing from the spacecraft, as the most likely explanation.

Responsivity Effect: The contamination event appears to have affected all WAC filters to varying degrees. The 630-nm filter was the least affected of the eight filters (430, 480, 560, 630, 750, 830, 900, and 1000 nm) used to build the global color map during MESSENGER's primary mission. Images acquired through other filters were ratioed to 630-nm images to control for uncertainties in calibration. Images acquired for the global color map were taken during discrete seasons when the viewing geometries were optimal for color imaging, that is, with minimized incidence and emission angles. Images were separated into four time periods of approximately three months each (Table 1) that were not defined with respect to the event. The data taken during period 1 are prior to the contamination event, and the data acquired during period 2 are the most severely impacted by the contamination. Because of photometric constraints, no global color map images were being acquired during the event, only well before and after.

Table 1: Color base map image acquisition periods

Period #	Orbit #	MET (s)	Date
1 start	1	209013872	2011-03-19
1 end/2 start	150	215267030	2011-05-30
2 end/3 start	320	222653880	2011-08-24
3 end/4 start	500	230358820	2011-11-21
4 end	675	237816550	2012-02-15

Event Correction: To calibrate the post-event data, a new correction, in addition to those for dark current, frame transfer, nonlinearity, flat-field response, and photometry [1-3], is needed. Data with phase and incidence angles between 43.3° and 48.3° and emission angles between 0° and 5° were used to construct 259 eight-color sets spanning the entire MDIS temperature range experienced in orbit but minimizing photometric effects. The geographic distribution of the set therefore ranged between ±48.3° latitude. To minimize the effects of geologic variation throughout the dataset, medians of the images were used. The majority of the eight-color imagery was acquired during periods 1 and 2, covering the first Mercury solar day of the MESSENGER mission. Thus, the number of data points available to derive a correction decreased significantly in periods 3 and 4.

The ratioed-to-630-nm medians, while scattered, show an approximately linear increase with time after the contamination event. The 750-nm, 830-nm (Figure 1), and 900-nm filters appear to have returned to their pre-event medians (solid line) by the end of period 4, whereas the 430-nm, 480-nm, and 560-nm filters show some indications of a longer time response to the contamination event. For the initial correction, all filters were assumed to have the same time constant, returning to their pre-event medians by the end of period 4. The 1000-nm data were more variable, possibly due to scattered light effects; so, for this initial event correction, the 1000-nm correction function values were all set to 1.0.

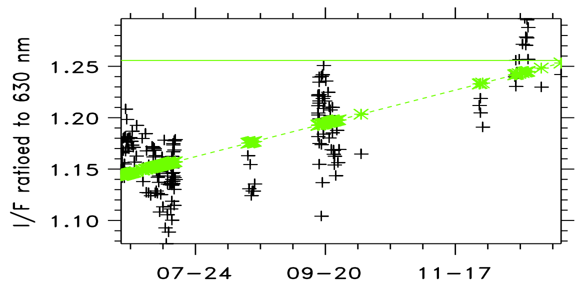

Figure 1. Linear fit to post-event ratios of 830 nm to 630 nm data as a function of date (month-day in 2011). The uncorrected ratios are indicated by black crosses, the fit by the colored asterisks and dashed line, and the pre-event median by the solid colored line.

Since the contamination effect diminished with time, the amplitude of the required correction function should decrease from the beginning of period 2 through the end of period 4. Initial attempts to derive this function assumed an exponential form for the correction and derived fitting coefficients solely from the post-event data. But the most successful approach was a linear interpolation between [a] the pre-event median and [b] a linear fit to short time-step medians of the event-contaminated data. This synthesized transition function was fitted with a function of the form

$$c - be^{-at}$$

where a, b, and c are regression coefficients, and t is time in seconds from the beginning of the event. The function was assumed to be discrete and to have the value 1.0 for all filters in period 1 and for all times after period 4.

Medians of (a) 430-nm and (b) 830-nm imagery before and after preliminary (as of January 2013) correction are shown as a function of time in Figure 2. At 430 nm, the post-event median is displaced by 0.05 from the pre-event median, suggesting that although much of the effect of event contamination has been removed, the response still did not return to the pre-event median by the end of period 4. Examination of eight-color and three-color sets from beyond the end of this period show a slow return to the pre-event median by October 2012. At 830 nm, the corrected post-event median is indistinguishable from the pre-event median, suggesting that the time constant of the event has been completely determined from periods 2–4. A function of the same exponential form as the ratioed-channel corrections was used to remove contamination effects in the 630-nm channel.

Example Corrected Spectrum: A small area near Tyagaraja crater was imaged both before and after the event. Figure 3 shows spectra of the area from pre- and post-event images with and without correction. The uncorrected contaminated spectrum shows a distinct kink between 630 nm and 750 nm that is largely eliminated by the event correction. Although the magnitude of the correction appears to be nearly optimal from 430 nm through 560 nm, the 750-nm through 900-nm channels, though improved, still differ from the pre-event values. Again, the 1000-nm channel was not corrected. Thus, interpretations of Mercury's surface made from MESSENGER MDIS spectra with the preliminary correction (available in the PDS in March 2013) need to take into account possible effects and artifacts from this contamination event, even after correction. Further refinements to the correction will be implemented for a second release of corrected images in March 2014.

Conclusions: A time-dependent correction function was developed to handle contamination of WAC imagery acquired during the first year of the orbital phase of the MESSENGER mission. This contamination correction function has been implemented in the Integrated Software for Imagers and Spectrometers (ISIS) [4] system, specifically in the *mdiscal* MESSENGER calibration application. Analysis is continuing to improve the time response of the correction and to handle specific filters under-corrected by the initial fitting functions.

References: [1] Hawkins S. E., III, et al. (2007), *Space Sci. Rev, 131,* 247–338. [2] Hawkins S. E., III, et al. (2009) *Proc. SPIE, 7441,* paper 74410Z. [3] Domingue D. L. et al. (2011) *Planet. Space. Sci., 59,* 1873–1887. [4] Anderson J. A. et al. (2004), *LPS 35*, 2039.

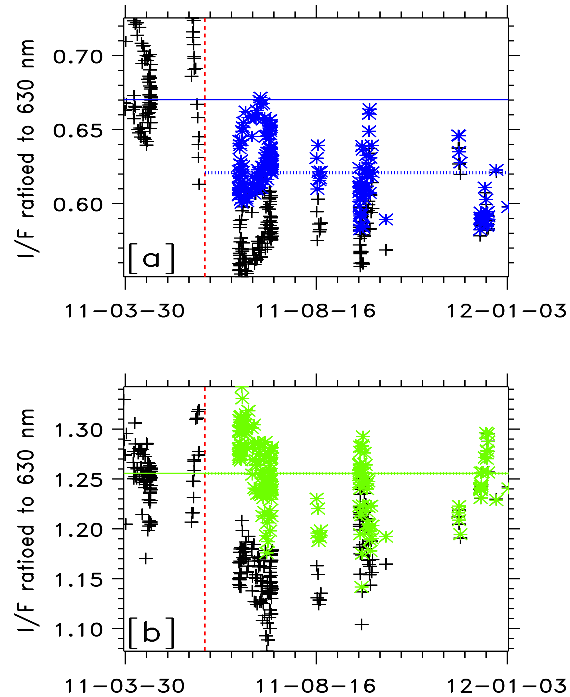

Figure 2. Application of the correction to images acquired in the (a) 430-nm and (b) 830-nm filters as a function of date (year-month-day). For both, the ratio to 630 nm values before correction are plotted as black crosses and the corrected data for the post-event period are shown as colored asterisks. Pre-event medians are indicated by a solid horizontal colored line, post-event medians of the corrected images by a colored dotted horizontal line, and the approximate time of the event by the vertical dashed red line.

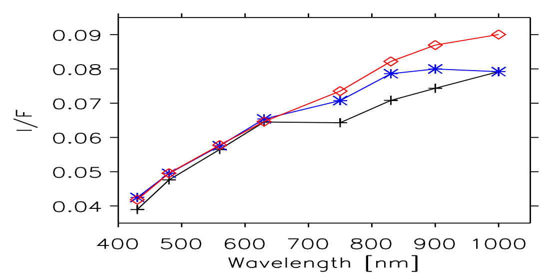

Figure 3. Absolute spectra for an area near Tyagaraja crater from pre-event (red) and post-event images, before (black) and after (blue) correction.