orbit insertion. This annealing process removed some, but not all, of the radiation damage to the crystal.

3.3. Galactic Cosmic Ray Corrections

[12] The source of gamma-ray emission from stable elements is nuclear excitation by surface-incident GCRs (see section 2.1). Analysis of data from previous planetary gamma-ray spectrometers demonstrated a correlation between the time variability of the GCR flux and the measured gamma-ray count rates [e.g., *Lawrence et al.*, 2004; *Maurice et al.*, 2004; *Boynton et al.*, 2007]. To test whether the time-dependent GCR flux drove count rate variations in the MESSENGER GRS data set, the daily, low-altitude 1779-keV Si gamma-ray count rate was compared with an onboard proxy for the GCR flux. Confirmation of a correlation between the measured Si gamma-ray count rate and the GCR proxy would have necessitated the introduction of a GCR correction to the measured stable-element count rates.

[13] There are multiple GRNS measurements that have some degree of sensitivity to the spacecraft-incident GCR flux, but ongoing analysis of data from the Neutron Spectrometer (NS) has demonstrated that the triple-coincidence counter is the most robust. The NS is composed of three sensitive volumes, a borated plastic scintillator located between two adjacent lithium glass scintillators [*Goldsten et al.*, 2007]. These scintillators were designed to detect neutrons through capture reactions on ^{10}B and ^{7}Li, but they are also sensitive to energy deposition by energetic charged particles. When a charged particle is sufficiently penetrating to deposit energy in each of the three detectors, a triple-coincidence event is registered. The geometry of the NS limits such events to those particles originating from a limited portion of the detector field of view, which has an unobstructed view of open space. Radiation transport modeling of charged particles passing through the NS revealed that protons with energy >120 MeV or electrons with energy >20 MeV are required to generate a triple-coincidence signal [*Feldman et al.*, 2010]. Solar energetic particle (SEP) events are the only source of >10 MeV electrons, and GCRs and SEP events are the only source of >100 MeV protons. Since SEP-compromised data have been removed from the data set used for this analysis (section 3.1), the triple-coincidence measurements are a measure of the NS-incident GCR proton flux at energies above 120 MeV. As >100 MeV protons drive the production of neutrons within a planetary surface [*McKinney et al.*, 2006], the triple-coincidence rate is a valid GCR proxy.

[14] The high-altitude (>8000 km), time-dependent NS triple-coincidence rate (Figure 2) exhibits an overall variability of $\sim$15% during the time period considered here. The high-altitude selection criteria for the triple-coincidence counter results in 17.3 h of data per day, which coupled with the measured count rates (31–37 counts/min) results in a negligible statistical error of $\sim$0.5% for each daily triple-coincidence measurement. Low-altitude (<2000 km) measurements of the 1779-keV Si gamma ray for the same period exhibit an overall variation of a factor of 3 (Figure 2), and the errors for each value originate from the one-standard-deviation uncertainties in the fitted peak areas (section 3.5). The triple-coincidence measurements are limited to high altitudes to avoid the obscuration of NS-incident GCRs by Mercury, whereas low-altitude Si count rates are used to quantify the changes in the GCR-induced, Mercury-originating signal. The variation in the Si gamma ray count rate is primarily due to the low statistics for daily measurements, although there are also long-term trends in its magnitude.

[15] The daily and weekly averaged 1779-keV Si count rates are plotted versus the corresponding triple-coincidence counter measurements for both data sets in Figure 3. The 1779-keV Si gamma-ray count rate and onboard GCR proxy are not found to be correlated for either the daily or weekly averaged data sets (correlation coefficients of 0.189 and -0.194, respectively). The lack of a correlation between the two measurements negates the need to apply a GCR correction to the data, as any variations due to changes in the incident GCR flux occurred at a magnitude that is smaller than the statistical precision of the Si gamma-ray measurements. Future analysis of MESSENGER GRS data may contain sufficiently low statistical uncertainties to identify and warrant such a correction.

3.4. Spectral Summing

[16] At low altitudes, individual GRS spectra are collected in 60-s integration periods. These spectra do not contain sufficient statistics to be used to characterize the gamma-ray peaks. It is therefore necessary to sum together many spectra over a given region of interest (hereafter referred to as a pixel) to produce a summed spectrum with sufficient statistical significance to characterize the gamma rays of interest. This process is accomplished by summing the optimal, low-altitude, temperature-corrected GRS AC spectra within subsets that correspond to the sub-spacecraft position on the surface during each measurement period. The size of the resulting pixels is determined by the desired statistical significance for each summed spectrum, the details of which are presented in sections 3.6, 4.1, and 4.2 as applied to the characterization of the gamma-ray peaks versus altitude, latitude and longitude, and mapping.

3.5. Gamma-Ray Photopeak Fitting

[17] Determining the total number of events in each gamma-ray photopeak on a pixel-by-pixel basis is the first step in calculating measured gamma-ray count rates as well as the corresponding elemental abundances on the surface. For isolated peaks (e.g., 6129-keV O gamma-ray photopeak and its single- and double-escape peaks), this determination is accomplished by counting the number events in the photopeak that are above the background continuum. Analysis of the 1779-keV Si, 1461-keV K, and 2615-keV Th gamma-ray photopeaks are complicated by the presence of overlapping interference peaks, requiring spectral fitting of these complex regions to isolate the peak areas of interest. Spectral fitting is carried out using exponentially modified Gaussian (EMG) functions [*Felinger*, 1994] with polynomial backgrounds, a procedure that was outlined by *Peplowski et al.* [2011b] and is briefly overviewed here. These fits were carried out with the nonlinear least squares fitting routine MPFIT [*Markwardt*, 2009], which is based on the Levenberg-Marquardt fitting algorithm [*Moré*, 1978]. The one-standard-deviation errors for each fit parameter are calculated from the covariance matrix for each fit.