Table 3. High-Altitude (>14,000 km) and Low-Altitude (<2,000 km) Peak Areas for the Gamma Rays Analyzed in This Work[a]

Element	Gamma-Ray Energy (keV)	High-Altitude Count Rate (cnts/min)	Low-Altitude Count Rate (cnts/min)
Potassium	1461	0.396 ± 0.007	2.169 ± 0.041
Silicon	1779	0.191 ± 0.020	2.353 ± 0.039
Oxygen	6129	0.289 ± 0.004	1.783 ± 0.014
Thorium	2615	0.086 ± 0.004	0.156 ± 0.019

[a]Low-altitude data are restricted to nadir-pointing ($\theta_n \leq 15°$) measurements only. Peak areas are limited to the full-energy photopeaks, with the exception of the 6129-keV oxygen data, which include counts from the first- and second-escape peaks.

summed contributions from both the single and double escape peaks (5618- and 5107-keV, respectively), each of which has a peak area that is comparable to the photopeak. Prior to making the $\Omega_R(h)$ correction, each gamma ray count rate increases with increasing solid angle as expected. Following the correction, the Si and O gamma rays exhibit uniform count rates versus solid angle, whereas K still exhibits variation. The nature of the MESSENGER orbit results in a correlation between the solid angle and the latitude of the measurement (see Appendix B), and therefore Figure 5c is suggestive of latitude-dependent variations in the 1461-keV K planetary gamma-ray emissions.

4. Gamma-ray Count Rate Variations

4.1. Count Rate Versus Latitude and Longitude

[23] An initial search for compositional heterogeneity was carried out by investigating variations in the measured count rate as a function of latitude and longitude with the data analysis procedure outlined above. The statistical significance of the photopeaks determined the size of the pixels in latitude and longitude. Latitudinal sums were created with low-altitude, southbound data only, as these data have lower altitudes over the northern hemisphere and a corresponding higher spatial resolution than the GRS data acquired during the northbound portion of the orbit. Longitudinal sums were created with low-altitude, northbound data, which have lower spatial resolution but more complete coverage in longitude at small nadir angles. The resulting count rates are shown in Figure 6. Statistically significant variations in the 1461-keV count rate as a function of latitude (Figure 6e) are observed, with an overall variability of a factor of 3. Longitudinally correlated variations in the K abundance are also observed (Figure 6f). These results contrast with the measured 1779-keV Si and 6129-keV O count rates, which do not show statistically significant variations in latitude or longitude at the two-standard-deviation level.

4.2. Count Rate Mapping

[24] Gamma-ray count rate maps were created following the data analysis procedure outlined above. The resulting maps (Figure 7) show the measured gamma-ray count rates on a scale of zero to twice the average count rate, facilitating a direct comparison of the relative variations for all three gamma-ray count rates. Pixel sizes vary with latitude and were chosen to limit the maximum statistical error per pixel. The Si gamma-ray count rates have one-standard-deviation uncertainties of ≤15% over the entire map, with the majority of the uncertainties near 10%. The oxygen gamma-ray count rates have uncertainties of 15 to 20% over the entire surface. The K gamma rays have uncertainties of ≤10% for regions north of 45°N, and larger uncertainties for the southernmost pixels as a result of the lower count rates in those regions. These maps confirm the results of Figures 5 and 6, which indicate that the Si and O gamma-ray count rates do not show statistically significant variations over the surface at the two-standard-deviation level. This result contrasts with the K gamma-ray count rates, which exhibit large, statistically significant variations over the surface.

4.3. Abundance Mapping

[25] Converting the measured 1461-keV gamma-ray count rates to an elemental abundance map for K requires the application of a forward code to propagate the known ^{40}K gamma-ray decay rates at the surface per unit abundance to the flux at the position of the orbiting GRS. Application of the principles of radioactive decay, in conjunction with the known half-life of ^{40}K ($t_{1/2}$ = 1.248 × 10^9 yr), its isotopic abundance (0.0117%), and its probability for emitting a 1461-keV gamma ray (10.66%), yields a flux at the surface of 19.6 cnts min^{-1} cm^{-2} per wt% K [*Peplowski et al.*, 2011b]. The surface flux was propagated to the spacecraft for each 60-s GRS integration period in the data set to determine the flux per wt% at the spacecraft altitude. This flux was multiplied by the attitude-dependent cross-sectional area of the GRS, then corrected for the detection efficiency at 1461-keV (see Appendix A) to yield the expected count rate per wt% K. Dividing the measured count rate in each pixel by the corresponding calculated count rate per wt% K yielded a map of K abundances on the surface of Mercury (Figure 8). To maximize the coverage of the surface, pixels of varying size were used to increase the spatial coverage without reducing the statistical significance of the measurements.

[26] The K map shows a large variation in the elemental abundance over the surface, with a dynamic range of 300 to 2400 ppm. The highest abundances are found in the far northern regions, although high values extend southward at longitudes of ±90°. Correlations between the K abundances and large-scale geologic provinces (see Figure 8) are discussed in section 5.1. Measurements of the near-equatorial

Figure 5. Measured count rates plotted as a function of solid angle for the (a) 1779-keV Si, (b) 6129-keV O, and (c) 1461-keV K gamma rays, before (red) and after (black) applying the solid-angle correction $\Omega_R(h)$. The vertical scales for each figure range from zero to two times the average count rate prior to the $\Omega_R(h)$ correction, facilitating comparisons of the relative variations for all three elements. The dashed lines indicate the average post-correction count rate and are included to highlight the relative variations around this value. Figures 5a and 5b exhibit the expected dependence of gamma-ray count rate on solid angle, and after correction they exhibit no solid-angle dependence. The residual variation with solid angle in the post-correction K count rate (Figure 5c) suggests a non-uniform abundance of K on the surface.