GeoEye-1 Radiance at Aperture
and Planetary Reflectance

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GeoEye

At-Aperture Spectral Radiance

The spectral radiance observed at the sensor aperture can be calculated from the digital number values in the GeoEye-1 image product using the radiometric gain and offset values in the product metadata by the equation,

$$L_\lambda = Gain_\lambda \bullet DN_\lambda + Offset_\lambda$$

where,

λ	=	Specific spectral band of image: Near-IR, Red, Green, Blue or Panchromatic.
L_λ	=	Spectral radiance for band λ at the sensor's aperture (mW/cm^2/μm/str),
$Gain_\lambda$	=	Radiometric calibration gain (mW/cm^2/μm/str/DN) for band λ from product metadata.
DN_λ	=	Digital number values for band λ of image product.
$Offset_\lambda$	=	Radiometric calibration offset (mW/cm^2/μm/str) for band λ from product metadata.

The at-aperture radiance is equivalent to the exoatmospheric radiance.

Bandwidth Calculation

The bandwidths for the GeoEye-1 bands are given in Table 1. Bandwidths are calculated by integrating over the relative spectral response curve of each band filter,

$$\Delta_\lambda = \int RSR_\lambda d\lambda \, .$$

where,

Δ_λ	=	Bandwidth (μm) of band λ.
RSR_λ	=	Relative spectral response of band λ.

Figure 1 shows the relative spectral response curves for the GE-1 bands. Detailed relative spectral response data for each band are can be found in the Appendix at the end of this document.

Table 1. GeoEye-1 Band-dependant Parameters

GeoEye-1 Band (λ)	Bandwidth (μm)	Esun$_\lambda$ (mW/cm^2/μm)
Panchromatic	0.3074	161.7
Blue	0.0584	196.0
Green	0.0646	185.3
Red	0.0316	150.5
Near IR	0.1012	103.9

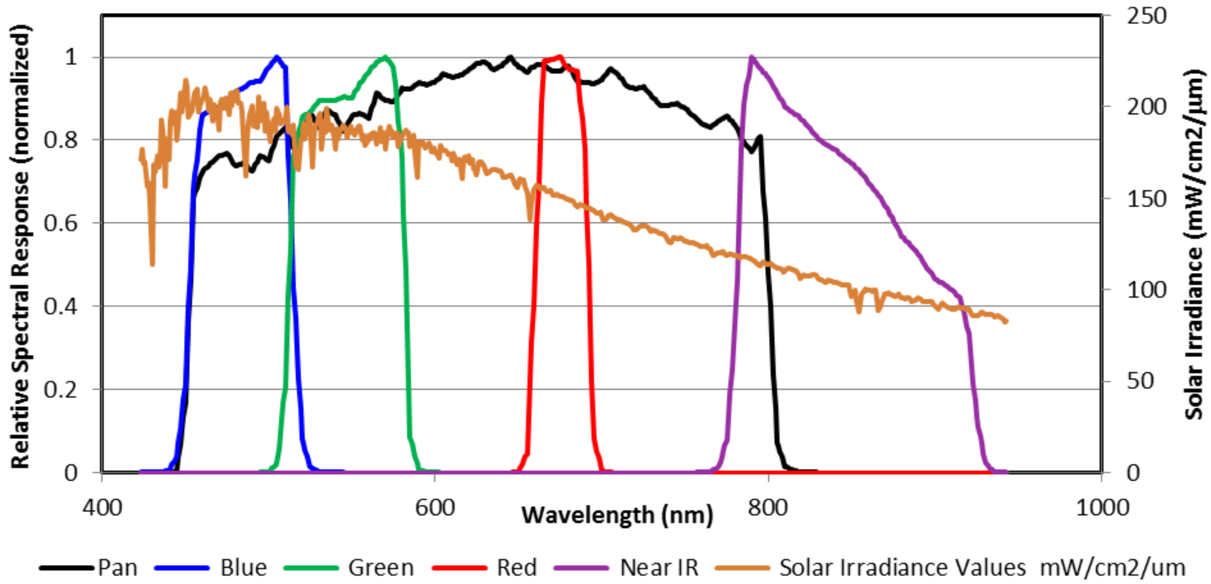

Figure 1. GeoEye-1 Relative Spectral Response and Solar Spectrum

Planetary Reflectance

Planetary reflectance (ρ_p) is sometimes used with Earth imagery to reduce the image-to-image illumination differences by normalizing for solar irradiance. The following equation for band-dependant planetary reflectance was taken from the *Landsat 7 Science Data User's Handbook*[1]. Note that planetary reflectance is an exoatmospheric correction and does not correct for atmospheric effects such as absorption or scattering.

Planetary reflectance is defined as,

$$\rho_{\mathrm{p}} = \frac{\pi \bullet L_{\lambda} \bullet d^{2}}{\mathrm{E}_{\mathrm{SUN}\,\lambda} \bullet \cos\theta_{\mathrm{S}}},$$

where,

ρ_{p}	=	Unitless planetary reflectance,
d	=	Earth-Sun distance (astronomical units)
$\mathrm{E}_{\mathrm{SUN}\,\lambda}$	=	Mean solar exoatmospheric spectral irradiances (mW/cm^2/µm), at an Earth-Sun distance of one astronomical unit (A.U.).
θ_{S}	=	Solar zenith angle.
L_{λ}	=	Spectral radiance for band λ at the sensor's aperture (mW/cm^2/µm/str),

The earth-sun distance (*d*) in astronomical units (A.U.) can be obtained from any nautical handbook or interpolated from the values listed in Table 2 adapted from Reference 1.

Table 2. Earth-Sun Distance in Astronomical Units (A.U.)

Julian Day	Distance A.U.	Julian Day	Distance A.U.	Julian Day	Distance A.U.	Julian Day	Distance A.U.	Julian Day	Distance A.U.
1	0.9832	74	0.9945	152	1.0140	227	1.0128	305	0.9925
15	0.9836	91	0.9993	166	1.0158	242	1.0092	319	0.9892
32	0.9853	106	1.0033	182	1.0167	258	1.0057	335	0.9860
46	0.9878	121	1.0076	196	1.0165	274	1.0011	349	0.9843
60	0.9909	135	1.0109	213	1.0149	288	0.9972	365	0.9833

The GeoEye-1 mean solar exoatmospheric irradiance ($\mathrm{E}_{\mathrm{SUN}\lambda}$) is calculated for each of the GeoEye-1 bands by integrating the relative spectral response of each band (RSR_{λ}, see Figure 1 and Appendix RSR) and the solar irradiance over wavelength,

$$\mathrm{E}_{\mathrm{SUN}\,\lambda} = \frac{\int (RSR_{\lambda} \bullet SolarIrradiance_{\lambda}) d\lambda}{\Delta_{\lambda}}.$$

The solar irradiance used to calculate the $\mathrm{E}_{\mathrm{SUN}\lambda}$ values listed in Table 1 were obtained from the 2000 American Society for Testing & Materials (ASTM) Standard Extraterrestrial Solar Spectrum Reference E-490-00 (see Figure 1 and Reference 2).

The solar zenith angle is calculated from the solar elevation angle,

$$\theta_S = 90^\circ - SolarElevationAngle\ .$$

For any GeoEye-1 image product, the *Solar Elevation Angle* is available from the product metadata.

References

1. Landsat 7 Science Data User's Handbook: http://landsathandbook.gsfc.nasa.gov/pdfs/Landsat7_Handbook.pdf

2. 2000 American Society for Testing & Materials (ASTM) Standard Extraterrestrial Solar Spectrum Reference E-490-00: http://rredc.nrel.gov/solar/spectra/am0/

Appendix: Relative Spectral Response (RSR)

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