IKONOS Planetary Reflectance and Mean Solar Exoatmospheric Irradiance

Martin Taylor
IKONOS Vehicle Payload Specialist
GeoEye

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,

$$\rho_p = \frac{\pi \cdot L_\lambda \cdot d^2}{ESUN_\lambda \cdot \cos\theta_S},$$

where,

ρ_p = Unitless planetary reflectance,
L_λ = Radiance for spectral band λ at the sensor's aperture (W/m^2/μm/sr),
d = Earth-Sun distance in astronomical units from Table 1,
$ESUN_\lambda$ = Mean solar exoatmospheric irradiances from Table 2 (W/m^2/μm),
θ_S = Solar zenith angle.

L_λ can be obtained in the correct units from the IKONOS image product by converting from digital values (DN_λ) using the equation,

$$L_\lambda = \frac{10^4 \cdot DN_\lambda}{CalCoef_\lambda \cdot Bandwidth_\lambda}$$

where,

$CalCoef_\lambda$ = Radiometric calibration coefficient [DN/(mW/cm^2-sr)]
$Bandwidth_\lambda$ = Bandwidth of spectral band λ (nm)

Both $CalCoef_\lambda$ and $Bandwidth_\lambda$ for the IKONOS bands are given in Table 2. Further information on the calibration coefficients can be found in Reference 2 and the bandwidth in Reference 3.

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

Table 1. Earth-Sun Distance in Astronomical Units[1]

Julian Day	Distance	Julian Day	Distance	Julian Day	Distance	Julian Day	Distance	Julian Day	Distance
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 IKONOS mean solar exoatmospheric irradiance (E_{SUN_λ}) is calculated for each of the IKONOS bands by integrating the relative spectral response of each band (RSR_λ, see Figure 1 and Reference 4) and the solar irradiance over wavelength,

$$E_{SUN_\lambda} = \frac{\int (RSR_\lambda \bullet SolarIrradiance) d\lambda}{\int RSR_\lambda d\lambda}.$$

The solar irradiance used to calculate the E_{SUN_λ} values listed in Table 2 was obtained from the 2000 American Society for Testing & Materials (ASTM) Standard Extraterrestrial Solar Spectrum Reference E-490-00 (Figure 1 and Reference 5).

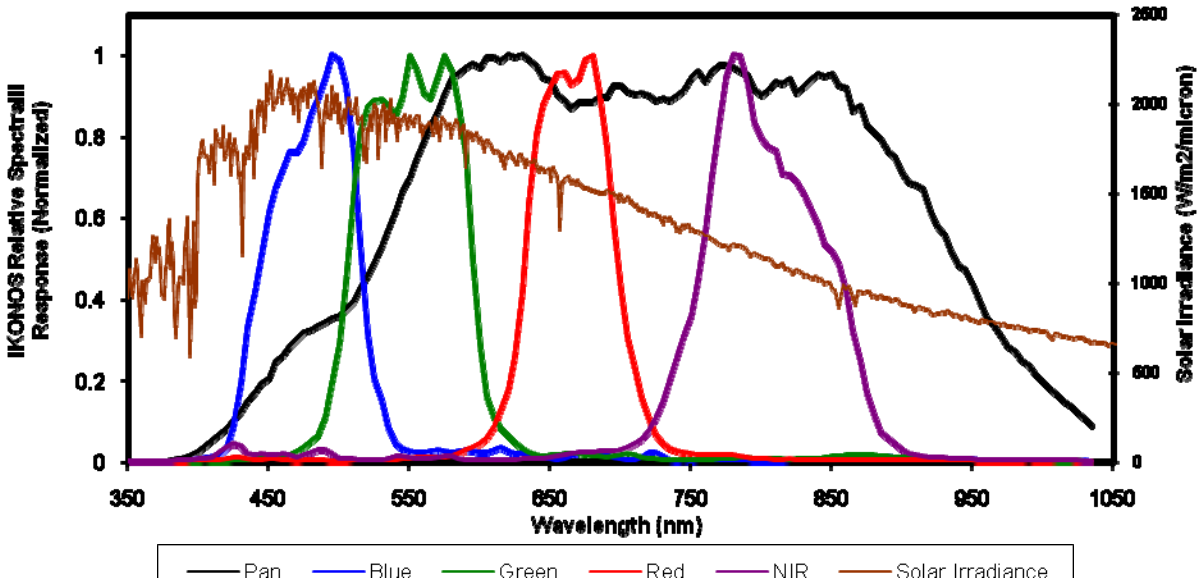

Figure 1. IKONOS Relative Spectral Response and Solar Spectrum

Table 2. IKONOS Band-dependant Parameters

IKONOS Band (λ)	***CalCoef*$_\lambda$** Pre 2/22/01* (DN/(mW/cm^2-sr))	***CalCoef*$_\lambda$** Post 2/22/01* (DN/(mW/cm^2-sr))	***Bandwidth*$_\lambda$** (nm)	**Esun**$_\lambda$ (W/m^2/μm)
Pan (TDI-13)	161	161	403	1375.8
Blue	633	728	71.3	1930.9
Green	649	727	88.6	1854.8
Red	840	949	65.8	1556.5
NIR	746	843	95.4	1156.9

* - Image production date. Coefficients are for the 11-bit products. See References 2 & 3.

The final variable used in calculating ρ_p is the solar zenith angle,

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

For any IKONOS image product, the *Solar Elevation Angle* is available from the image metadata.

References

1. Landsat 7 Science Data User's Handbook: http://landsathandbook.gsfc.nasa.gov/handbook.html

2. Martin Taylor (2005), *IKONOS Radiometric Calibration and Performance after 5 Years on Orbit*, Proceedings of CALCON 2005 Conference, Logan, Utah, 22-25 August 2005: http://www.geoeye.com/CorpSite/assets/docs/technical-papers/2005/A_MartinTaylor2005_IKONOSRadiometricCalibration.pdf

3. M. Cook, *et al.* (2001). *IKONOS Technical Performance Assessment*, Proceedings of SPIE Vol. 4381-10, Orlando, Florida, 16-20 April 2001: http://www.geoeye.com/CorpSite/assets/docs/technical-papers/2001/A_IKONOSTechnicalPermormanceAssessment.pdf

4. IKONOS Relative Spectral Response: http://www.geoeye.com/CorpSite/assets/docs/technical-papers/2008/IKONOS_Relative_Spectral_Response.xls

5. 2000 American Society for Testing & Materials (ASTM) Standard Extraterrestrial Solar Spectrum Reference E-490-00: http://rredc.nrel.gov/solar/spectra/am0/