Ikonos DN Value Conversion to Planetary Reflectance Values

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The following formula from the Landsat 7 Science Data Users Handbook was used to convert Ikonos DN values to planetary reflectance values:

$$\rho_p = \frac{\pi * L_\lambda * d^2}{ESUN_\lambda * \cos(\theta s)}$$

ρ_p = planetary reflectance
L_λ = spectral radiance at sensor's aperture
$ESUN_\lambda$ = band dependent mean solar exoatmospheric irradiance
θs = solar zenith angle
d = earth-sun distance, in astronomical units

For Landsat 7, the spectral radiance L_λ = gain * DN + offset, which can also be expressed as L_λ = (LMAX – LMIN)/255 *DN + LMIN. The LMAX and LMIN values for each of the Landsat bands are given below in Table 1. These values may vary for each scene and the metadata contains image specific values.

Table 1. ETM+ Spectral Radiance Range ($W/m^2 * sr * \mu m$)

	Low Gain		High Gain	
Band Number	LMIN	LMAX	LMIN	LMAX
1	-6.2	293.7	-6.2	191.6
2	-6.4	300.9	-6.4	196.5
3	-5.0	234.4	-5.0	152.9
4	-5.1	241.1	-5.1	157.4
5	-1.0	47.57	-1.0	31.06
6	0.0	17.04	3.2	12.65
7	-0.35	16.54	-0.35	10.80
8	-4.7	243.1	-4.7	158.3

(from Landsat 7 Science Data Users Handbook)

The Ikonos spectral radiance, L_λ, can be calculated by using the formula given in the Space Imaging Document Number SE-REF-016:

$$L_\lambda\ (mW/cm^2 * sr) = DN / CalCoef_\lambda$$

However, in order to use these values in the conversion formula, the values must be in units of $W/m^2 * sr * \mu m$. This can be accomplished by dividing the wavelength dependent $CalCoef_\lambda$ by 10 and dividing this number by the bandwidth for each band. The $CalCoef_\lambda$ is given in Table 2 for the various Ikonos bands and the bandwidths are given in Table 3. The Ikonos spectral radiance in units of $W/m^2 * sr * \mu m$ now becomes:

$$L_\lambda = DN/((CalCoef/10)/Bandwidth)$$

Table 2. Ikonos $CalCoef_\lambda$

Spectral Band	$CalCoef_k$ $DN*[mW/cm^2\text{-}sr]^{-1}$	Full Scale Dynamic Range (mW/cm^2-sr)
Pan (TDI 13)	161	11.80
Pan (TDI 18)	223	8.52
Pan (TDI 24)	297	6.39
Pan (TDI 32)	396	4.79
MS-1 (Blue)	637	2.98
MS-2 (Green)	573	3.32
MS-3 (Red)	663	2.87
MS-4 (VNIR)	503	3.75

(from Space Imaging Document Number SE-REF-016, Rev. N/C)

Table 3. Ikonos Bandwidth Characteristics

Band	Lower 50% (nm)	Upper 50% (nm)	Bandwidth (nm)	Center (nm)
Pan	525.8	928.5	403	727.1
MS-1 (Blue)	444.7	516.0	71.3	480.3
MS-2 (Green)	506.4	595.0	88.6	550.7
MS-3 (Red)	631.9	697.7	65.8	664.8
MS-4 (VNIR)	757.3	852.7	95.4	805.0

(from Space Imaging Document Number SE-REF-016, Rev. N/C)

The Landsat $ESUN_{\lambda,}$ also referred to as band pass values are given in the Landsat 7 Science Data Users Handbook and listed below in Table 4. The Ikonos $ESUN_{\lambda}$ values are also listed in Table 4 and were calculated using the formula:

$$ESUN_{\lambda} = \frac{\Sigma(RSR * \text{Solar Irradiance}) * \Delta\lambda}{\Sigma (RSR) * \Delta\lambda}$$

$ESUN_{\lambda}$ = The band average solar Spectral Irradiances (W/m2-μm):
RSR = wavelength dependent radiance spectral response (W/m^2 * μm)
Δλ = .005 μ
Solar Irradiance = top of atmosphere (W/m^2 * μm)

Table 4. Landsat 7 and Ikonos $ESUN_{\lambda}$ values

Band	Landsat 7	Ikonos
Blue	1970.000	1939.429
Green	1843.000	1847.400
Red	1555.000	1536.408
NIR	1047.000	1147.856

The final formula that incorporates the spectral radiance and band pass conversions for Ikonos DN values now becomes:

$$\rho_p = \frac{\pi * DN/((CalCoef/10)/Bandwidth)_\lambda * d^2}{ESUN_\lambda * \cos(\theta s)}$$

References:

1. Landsat 7 Science Data Users Handbook: http://ltpwww.gsfc.nasa.gov/IAS/handbook/handbook_htmls/chapter12/chapter12.html

2. Space Imaging Document Number SE-REF-016, Rev. N/C
