Using the USGS Landsat Level-1 Data Product

By Landsat Missions

Landsat Collections Level-1 data can be rescaled to top of atmosphere (TOA) reflectance and/or radiance using radiometric rescaling coefficients provided in the metadata file that is delivered with the Level-1 product. The metadata file also contains the thermal constants needed to convert thermal band data to TOA brightness temperature. Formulas for these conversions are provided on this page.

Landsat Collections Level-1 data products consist of quantized and calibrated scaled Digital Numbers (DN) representing the multispectral image data. Landsat 8 products data acquired by both the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) are delivered in 16-bit unsigned integer format. Landsat 1-7 products are generated from single sensor data and are delivered in 8-bit unsigned integer format.

Specific to Landsat 8, since the satellite's launch in 2013, energy from outside the normal field of view (stray light) has affected the thermal data collected by both thermal bands. The amount of stray light varies throughout each scene, depending upon radiance outside the instrument field of view. The stray light correction applied to Landsat 8 Collection 1 Level-1 data substantially improves image uniformity and absolute calibration in typical scenes. See Section A1 of the Landsat 8 Data Users Handbook for more details about Landsat 8 TIRS Stray Light.

Prior to the Landsat Collections processing, solar exoatmospheric spectral irradiances (ESUN) values are required to calculate radiance and reflectance of Landsat 1-7 data. Details about ESUN is listed on the bottom of this page.

Conversion to TOA Radiance

Landsat Level-1 data can be converted to TOA spectral radiance using the radiance rescaling factors in the MTL file:

$$L_\lambda = M_L Q_{cal} + A_L$$

where:

L_λ = TOA spectral radiance (Watts/(m^2 * srad * μm))
M_L =Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)
A_L=Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number)
Q_{cal} = Quantized and calibrated standard product pixel values (DN)

Conversion to TOA Reflectance

Reflective band DN's can be converted to TOA reflectance using the rescaling coefficients in the MTL file:

$$\rho_\lambda' = M_\rho Q_{cal} + A_\rho$$

where:

ρ_λ' = TOA planetary reflectance, without correction for solar angle. Note that $\rho\lambda'$ does not contain a correction for the sun angle.
M_ρ=Band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_BAND_x, where x is the band number)
A_ρ =Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x, where x is the band number)
Q_{cal} = Quantized and calibrated standard product pixel values (DN)

TOA reflectance with a correction for the sun angle is then:

$$\rho_\lambda = \frac{\rho_\lambda'}{\cos\left(\theta_{SZ}\right)} = \frac{\rho_\lambda'}{\sin\left(\theta_{SE}\right)}$$

where:

ρ_λ= TOA planetary reflectance
θ_{SE} = Local sun elevation angle. The scene center sun elevation angle in degrees is provided in the metadata (SUN_ELEVATION).
θ_{SZ} =Local solar zenith angle; $\theta_{SZ} = 90° - \theta_{SE}$

For more accurate reflectance calculations, per-pixel solar angles could be used instead of the scene center solar angle. While per-pixel solar zenith angles are not provided with the Landsat Level-1 products, tools are provided which allow users to create angle bands.

Conversion to Top of Atmosphere Brightness

Conversion to Top of Atmosphere Brightness Temperature

Thermal band data can be converted from spectral radiance to top of atmosphere brightness temperature using the thermal constants in the MTL file:

$$T = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda}+1\right)}$$

where:

T = Top of atmosphere brightness temperature (K)where:
L_λ =TOA spectral radiance (Watts/(m2 * srad * μm))
K_1 =Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the thermal band number)
K_2 =Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number)

Solar exoatmospheric spectral irradiances (ESUN) for the Landsat 1-7 data

NOTE: this ESUN information is not relevant to Landsat Collection 1 data so we do not recommend using the ESUN values with Collection 1 Level-1 data products. The Collection data products for Landsat 1-7 are cross-calibrated to L8 OLI and provide two sets of scaling factors, one to calculate the TOA reflectance and the other to calculate TOA radiance, just as it has always been the case for L8 OLI. Thus, the ESUN values are not needed any more to do conversions between TOA radiance and TOA reflectance.

(For data prior to Landsat Collections processing) The recommended ESUN values Landsat 1-7 are listed in the table below. These values used with Landsat products currently generated at EROS ensure consistent radiometric calibration of data from all these sensors. (Note: although the data are consistently calibrated, calculated TOA reflectance over the same target may differ among the sensors due to the spectral bandpass difference.)

Recommended Solar Exoatmospheric Spectral Irradiances (ESUN) Values (in W/m2/μm)

Band Number	Landsat 7 ETM+	Landsat 5 TM	Landsat 4 TM	Landsat 1-5 MSS
1	1970	1958	1958	1848
2	1842	1827	1826	1588
3	1547	1551	1554	1235

4	1044	1036	1033	856.6
5	225.7	214.9	214.7	-
7	82.06	80.65	80.70	-
8	1369	-	-	-

*The values listed can be applied to all MSS sensors, due to cross-calibration of all the MSS sensors to match the Landsat 5 instrument.

ESUN values are not required for Landsat 8 data because Landsat 8's metadata file provides coefficients necessary to convert to radiance and reflectance from the quantized and calibrated DNs of the product.

Relative Spectral Response (RSR) of the OLI spectral bands can be used along with the user's preferred solar spectrum to calculate ESUN values corresponding to Landsat 8 OLI bands. ESUN values are derived from the ChKur spectrum.

The ChKur spectrum is the combined Chance-Kurucz Solar Spectrum within MODTRAN 5 (2011, Berk, A., Anderson, G.P., Acharya, P.K., Shettler, E.P., MODTRAN 5.2.0.0 User's Manual).