COURSE: SATELLITE IMAGE PROCESSING

LECTURE 4 – Atmospheric and Topographic Correction

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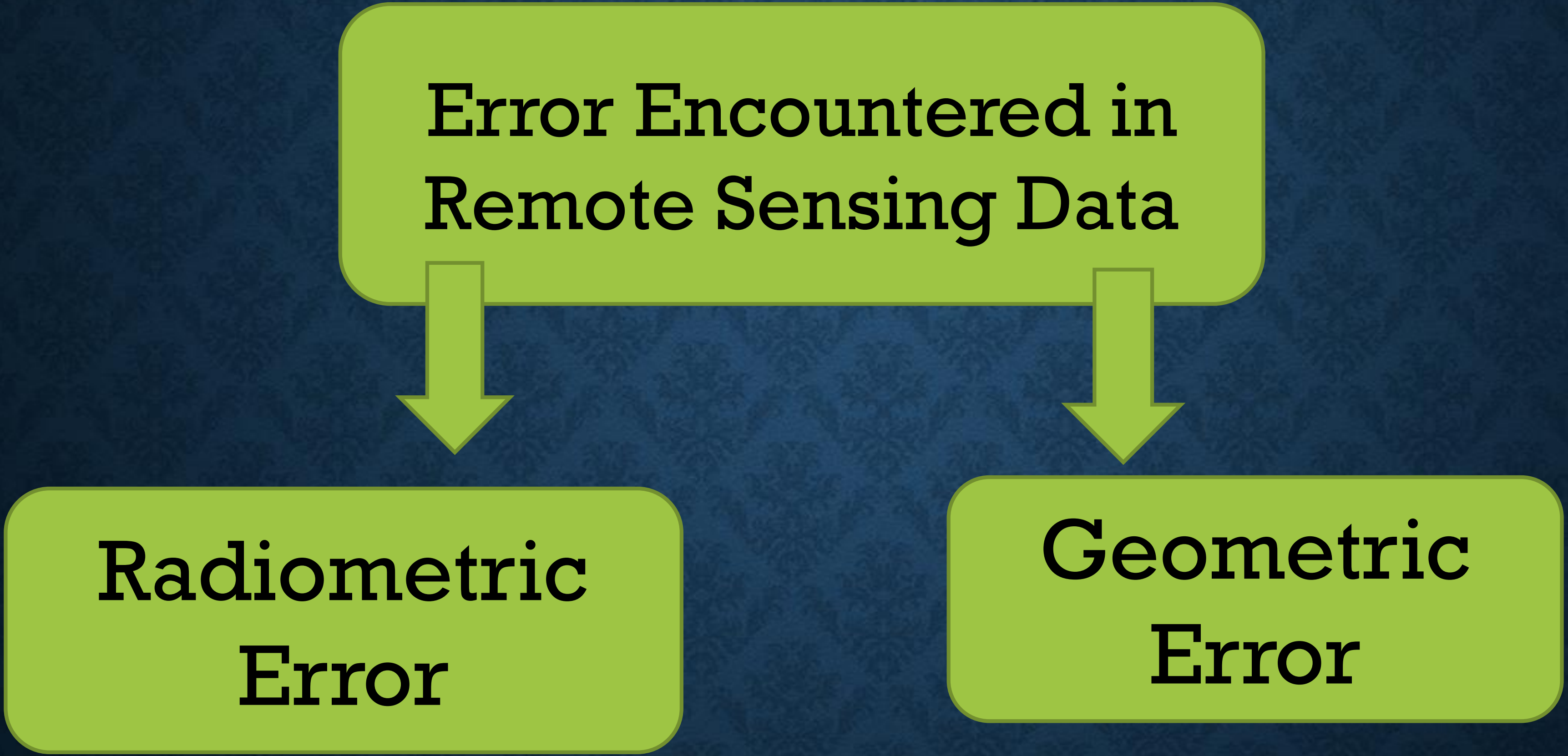
Atmospheric/Topographic Correction for Satellite Imagery

- Landsat-7ETM+scene
- The top right image is the atmospherically corrected scene employing a haze removal over land and water.
- The haze removal over water is one of the new features of the 2011 release.

Source: R.Richter and D.Schlapfer, 2012

Error Encountered in Remote Sensing Data



Error Encountered in Remote Sensing Data

Radiometric Error

Geometric Error

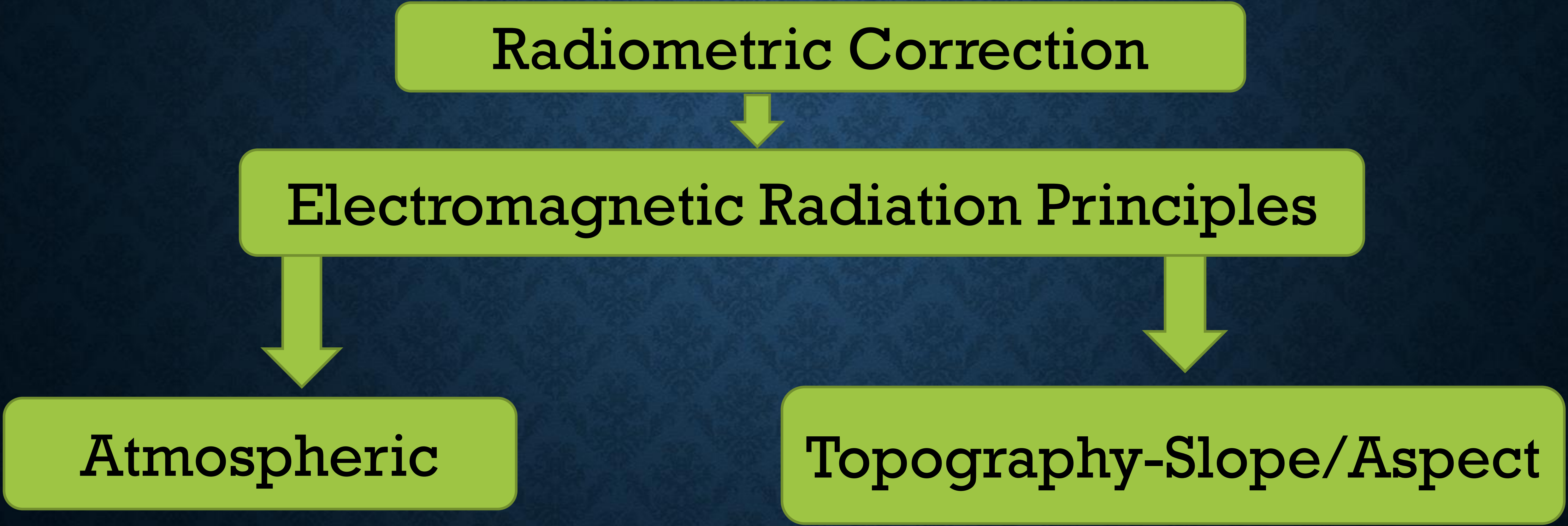
Radiometric and Geometric Correction

- ☐ Radiometric correction is concerned with improving the accuracy of surface spectral reflectance, emittance, or back-scattered measurements obtained using a remote sensing system

Source: (Johannsen and Daughtry, 2009; San and Suzen, 2010).

Source: John R. Jesen, 2015, 4th Ed,

Atmospheric/Topographic Correction for Satellite Imagery



Radiometric Correction

Electromagnetic Radiation Principles

Atmospheric

Topography-Slope/Aspect

Atmospheric Energy – Matter Interactions

1. Refraction
2. Scattering
3. Absorption
4. Reflectance

Source: John R. Jesen, 2015, 4th Ed,

Atmospheric Energy – Matter Interactions

- ❑ Once electromagnetic radiation is generated, it is propagated through the Earth's atmosphere almost at the speed of light in a vacuum.

- ❑ Unlike a vacuum in which nothing happens, however, the atmosphere affect:

- speed of radiation
- wavelength,
- intensity,
- spectral distribution.

Source: John R. Jesen, 2015, 4th Ed,

Remote sensing Atmospheric Correction

Two most important sources of environmental attenuation are:

1) atmosphere attenuation caused by scattering and absorption in the atmosphere,

2) topographic attenuation

Source: John R. Jesen, 2015, 4th Ed,

Remote sensing Atmospheric Correction

- ❑ Not necessary to atmospherically correct the remote sensor data for all applications.

- ❑ The decision to perform an atmospheric correction is a function of the;

1. nature of the problem,
2. the type of remote sensing data available, the
3. amount of in situ historical and/or concurrent atmospheric information available,
4. and how accurate the biophysical information to be extracted from the remote sensing data.

Source: John R. Jesen, 2015, 4th Ed, He and Chen, 2014

Unnecessary Atmospheric Correction

- Sometimes it is possible to ignore atmospheric effects in remote sensor data completely

(Cracknell and Hayes, 1993; Song et al., 2001).

- For example, atmospheric correction is not always necessary for certain types of classification and change detection.

- As long as training data is available, it is good.

Source: John R. Jesen, 2015, 4th Ed,

Unnecessary Atmospheric Correction - Example

- ❑ Land-cover classification using a single date of Landsat Thematic Mapper data.
- ❑ Rayleigh and other types of scattering add brightness to the visible bands (400-700 nm).
- ❑ Atmospheric absorption reduces the brightness values of pixels in the near- and middle-infrared region (700 - 2,400 nm).
- ❑ If we do atmospheric correction, the primary effect will be a simple bias adjustment applied separately to each band.
- ❑ This action would adjust the minimum and maximum values of each band downward.

Source: John R. Jesen, 2015, 4th Ed, He and Chen, 2014

Necessary Atmospheric Correction

☐ Sometimes it is essential that the remotely sensed data be atmospherically corrected

Example:

1. Extracting biophysical parameters from the water body:

- Chlorophyll
- Sediment
- Temperature
- Other

2. NDVI Calculation

Source: John R. Jesen, 2015, 4th Ed,

Types of Atmospheric Correction

- ☐ There are several ways to atmospherically correct remotely sensed data.

- ☐ Some are relatively straightforward while others are complex,

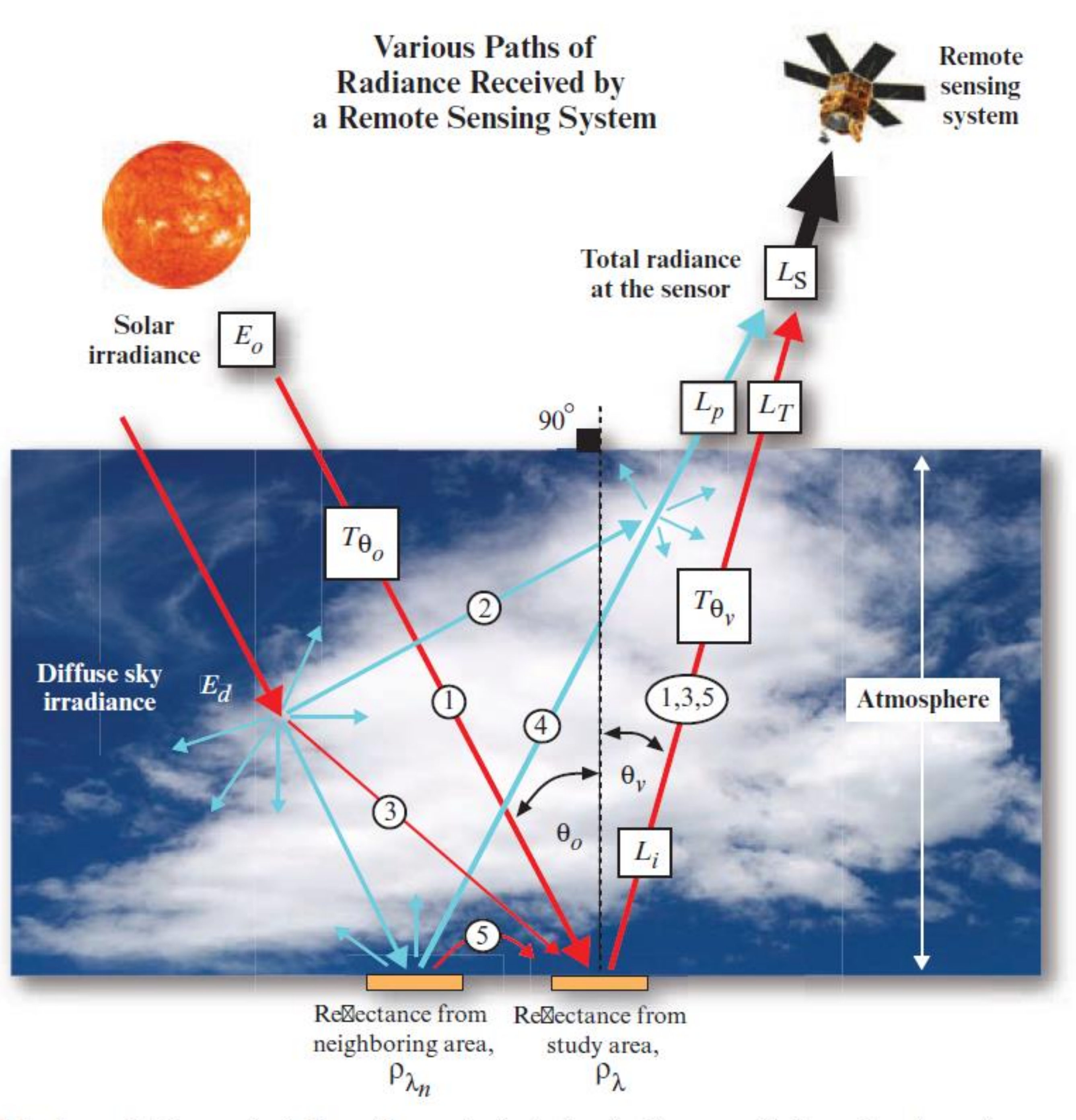
1. Absolute atmospheric correction, and

2. Relative atmospheric correction.

Source: John R. Jesen, 2015, 4th Ed,

Types of Atmospheric Correction

- Radiance (L_T) from Path 1, 3 and 5 contains intrinsic Valuable spectral information about the target of interest.
- The path radiance (Lp) from path 2 and 4 includes diffuse sky irradiance or radiance
- The path radiance generally introduces unwanted radiometric noise in the Remotely sense data and complicates the image interpretation process.

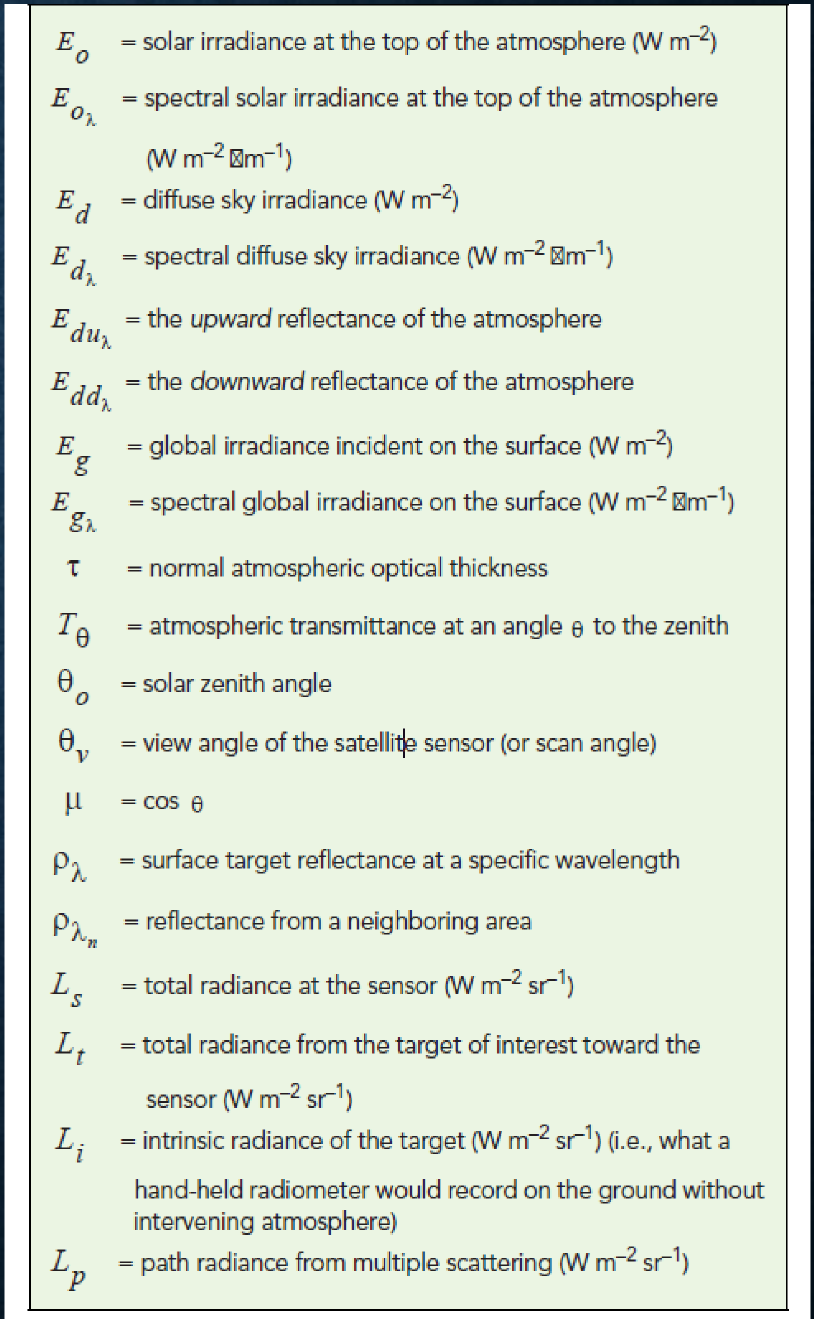


Source: John R. Jesen, 2015, 4th Ed,

Absolute Atmospheric Correction

- ❑ The general goal of absolute radiometric correction is to turn the digital brightness values recorded by a remote sensing system into scaled surface reflectance values.

Radiometric Variables used in Remote Sensing



E_o = solar irradiance at the top of the atmosphere (W m^{-2})

E_{o_λ} = spectral solar irradiance at the top of the atmosphere (W m^{-2} μm^{-1})

E_d = diffuse sky irradiance (W m^{-2})

E_{d_λ} = spectral diffuse sky irradiance (W m^{-2} μm^{-1})

E_{du_λ} = the *upward* reflectance of the atmosphere

E_{dd_λ} = the *downward* reflectance of the atmosphere

E_g = global irradiance incident on the surface (W m^{-2})

E_{g_λ} = spectral global irradiance on the surface (W m^{-2} μm^{-1})

τ = normal atmospheric optical thickness

T_θ = atmospheric transmittance at an angle θ to the zenith

θ_o = solar zenith angle

θ_v = view angle of the satellite sensor (or scan angle)

μ = cos θ

ρ_λ = surface target reflectance at a specific wavelength

ρ_{λ_n} = reflectance from a neighboring area

L_S = total radiance at the sensor (W m^{-2} sr^{-1})

L_t = total radiance from the target of interest toward the sensor (W m^{-2} sr^{-1})

L_i = intrinsic radiance of the target (W m^{-2} sr^{-1}) (i.e., what a hand-held radiometer would record on the ground without intervening atmosphere)

L_p = path radiance from multiple scattering (W m^{-2} sr^{-1})

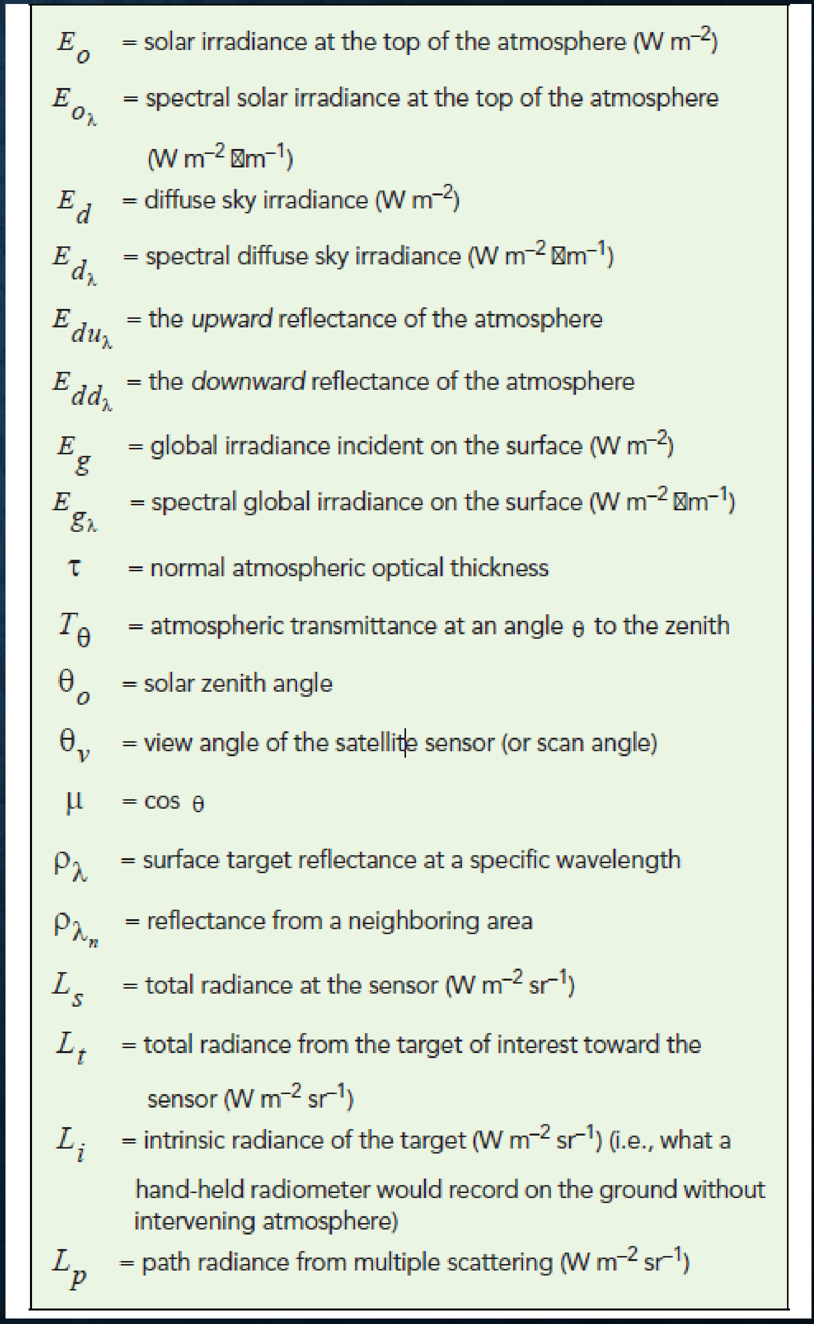
Source: John R. Jesen, 2015, 4th Ed, Du et al., 2002

Absolute Atmospheric Correction

- ❑ For a given spectral interval in the electromagnetic spectrum (e.g., λ1 to λ2 could be from 0.6 - 0.7 µm or red light), the total solar irradiance reaching the Earth's surface, is an integration of several important components:

$$E_{g_\lambda} = \int_{\lambda_1}^{\lambda_2} (E_{o_\lambda} T_{\theta_o} \cos\theta_o + E_{d_\lambda})\, d\lambda \; (\text{W m}^{-2} \boxtimes \text{m}^{-1}).$$

Radiometric Variables used in Remote Sensing



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Source: John R. Jesen, 2015, 4th Ed,

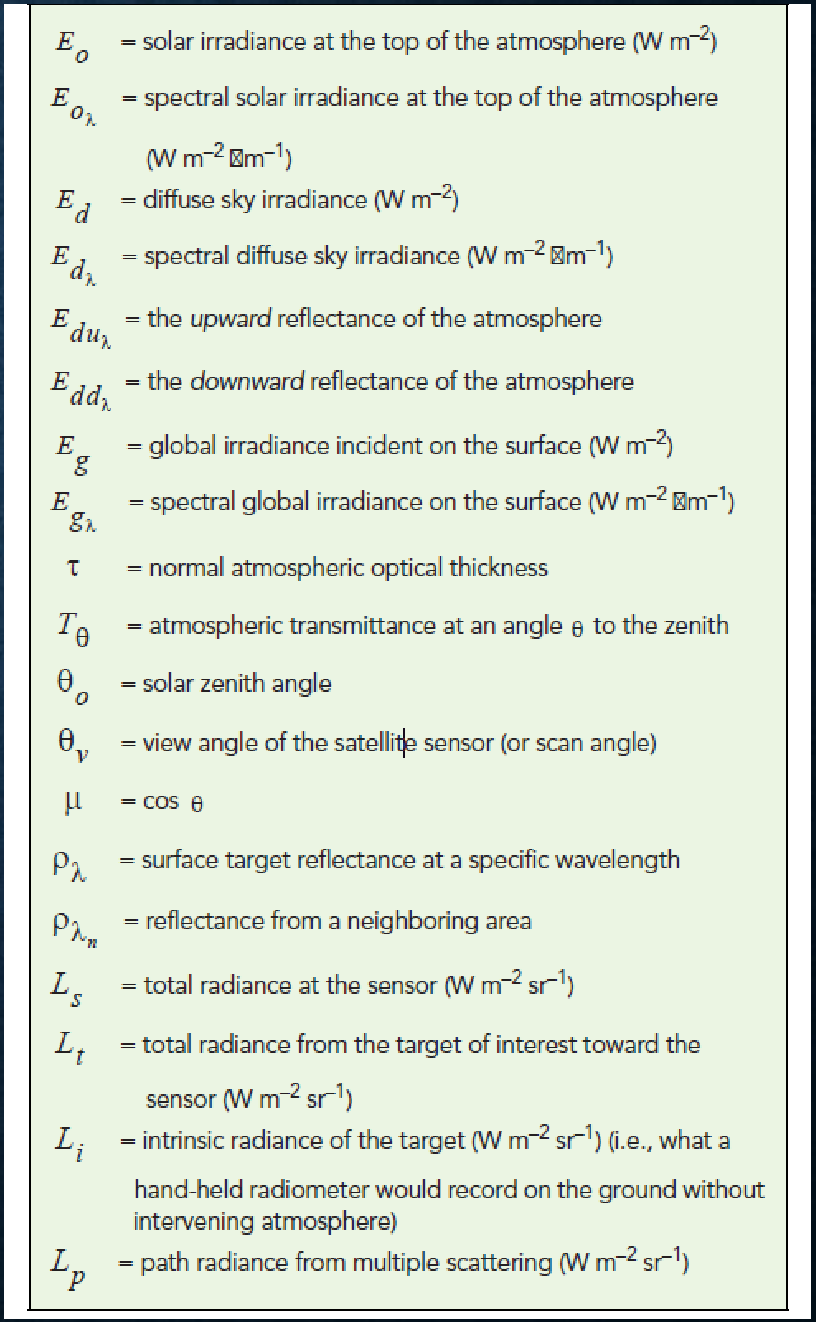
Absolute Atmospheric Correction

- ❑ Only a small amount of this irradiance is actually reflected by the terrain in the direction of the satellite sensor system.
- ❑ If we assume the surface of Earth is a diffuse reflector, the total amount of radiance exiting the target study area (L_T) toward the sensor is:

$$L_T = \frac{1}{\pi}\int_{\lambda_1}^{\lambda_2} \rho_\lambda\, T_{\theta_v}(E_{o_\lambda} T_{\theta_o} \cos\theta_o + E_{d_\lambda})\,d\lambda\,.$$

Source: John R. Jesen, 2015, 4th Ed,

Radiometric Variables used in Remote Sensing



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L_p = path radiance from multiple scattering ($\text{W m}^{-2}\ \text{sr}^{-1}$)

Absolute Atmospheric Correction

❑ It would be wonderful if the total radiance recorded by the sensor, L_S, equaled the radiance returned from the target study area of interest, L_T.

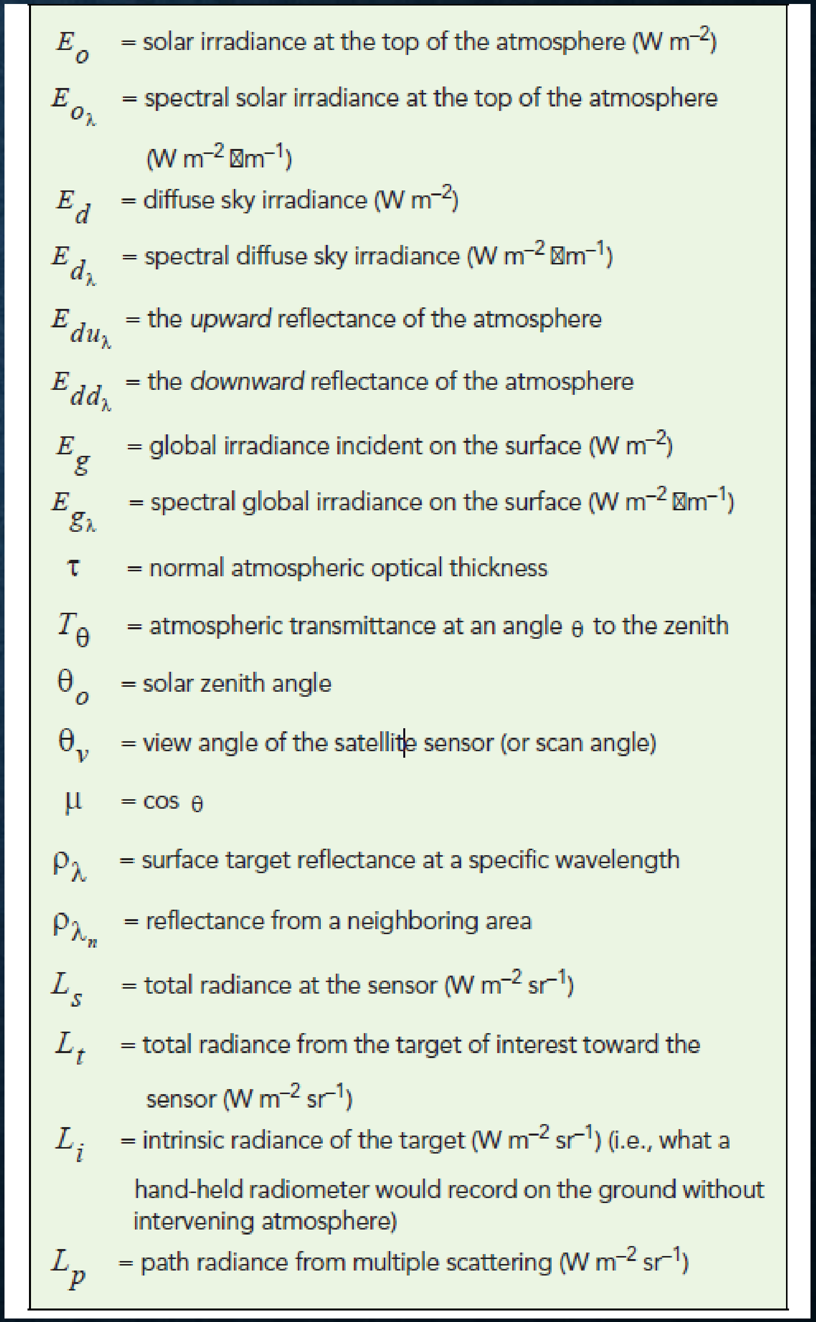
❑ Unfortunately, *LS* is not equal to L_T because there is some additional radiance from different *paths* called, L_P .

❑ Thus, the total radiance recorded by the sensor becomes:

$$L_S = L_T + L_P \text{ (W m}^{-2}\text{ sr}^{-1}\text{).}$$

Source: John R. Jesen, 2015, 4th Ed,

Radiometric Variables used in Remote Sensing



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Removing Path Radiance (Lp)

Radiative transfer model programs such as;

- MODTRAN,
- Second Simulation of the Satellite Signal in the Solar Spectrum (6S) and
- others may

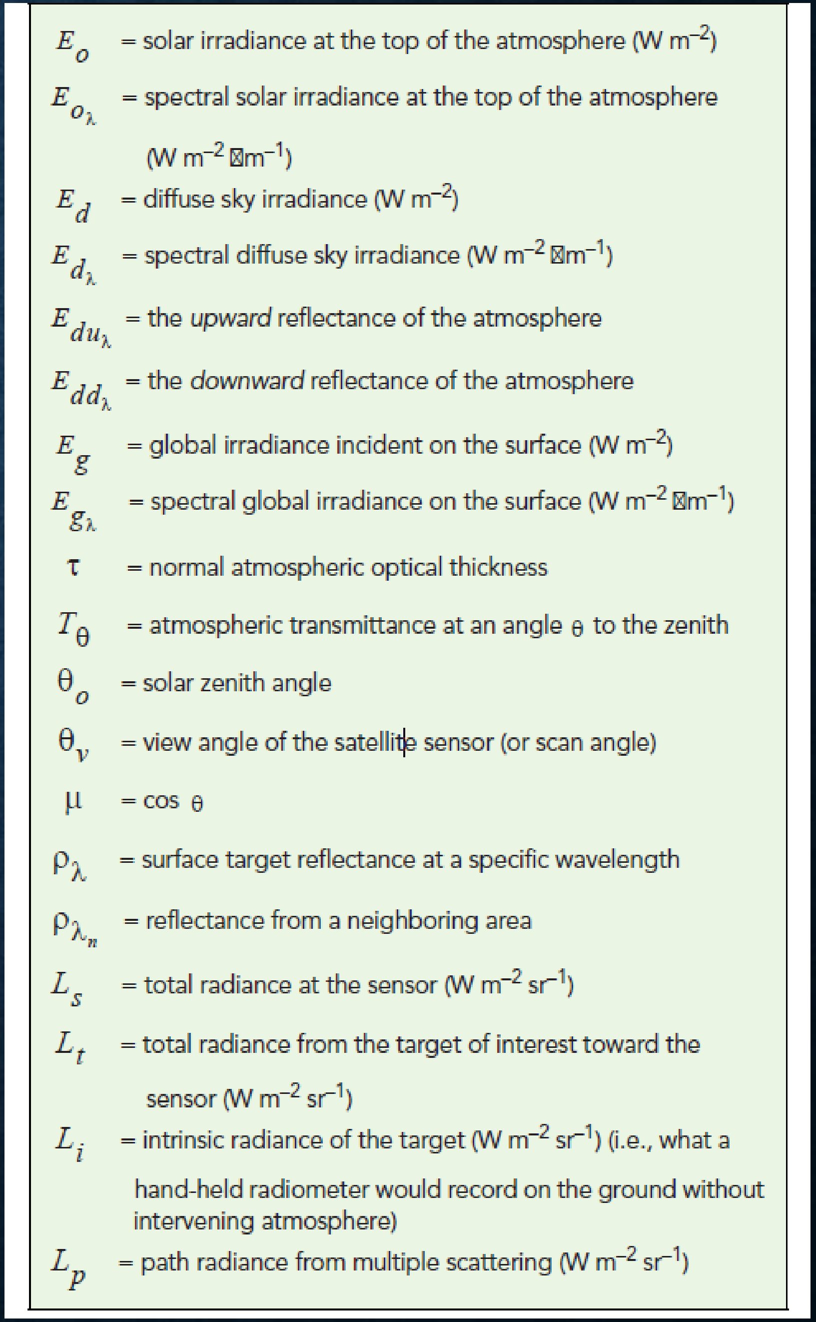
be used to predict path radiance on a particular day for a particular study area

(Source: Alder-Golden et al., 1999, 2005; M atthew et al., 2000; Gao et al., 2009; Richter and Schlapfer, 2014).

$$L_S = L_T + L_P \ (\mathrm{W\ m^{-2}\ sr^{-1}}).$$

Source: John R. Jesen, 2015, 4th Ed,

Radiometric Variables used in Remote Sensing



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Relative atmospheric correction.

- ❑ In the absolute radiometric correction, the atmospheric radiative transfer code requires:

- ✓ Date of scene captured
- ✓ Sensor spectral profile
- ✓ Atmospheric properties at the time of remote sensing data collection
- ✓ other

- ❑ If all this information available then it is easy to convert the imagery to scaled surface reflectance.

- ❑ If such information is not available, then relative radiometric correction technique can be used.

Source: John R. Jesen, 2015, 4th Ed,

Relative atmospheric correction.

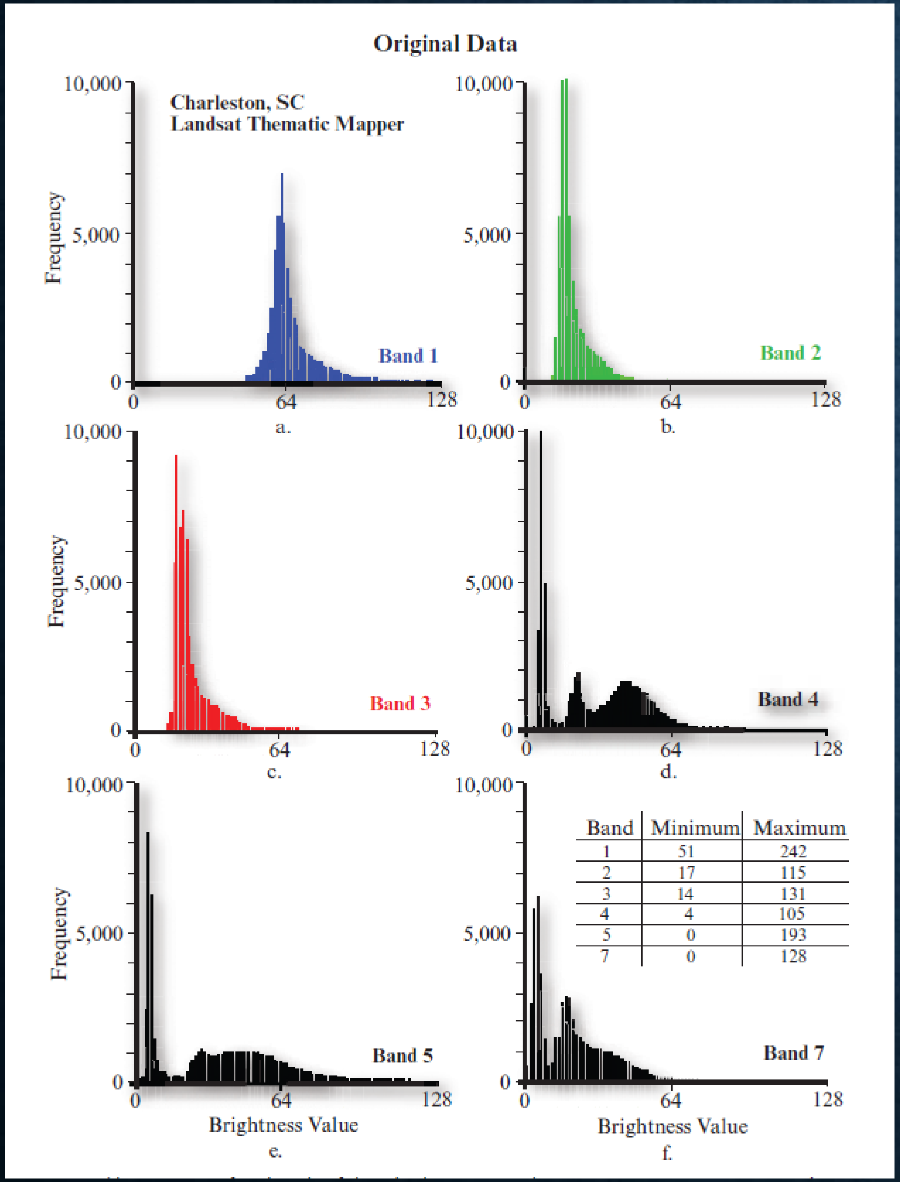
Relative radiometric correction may be used to;

1) to *normalize* the intensities among the different bands within a single-date remotely sensed image,

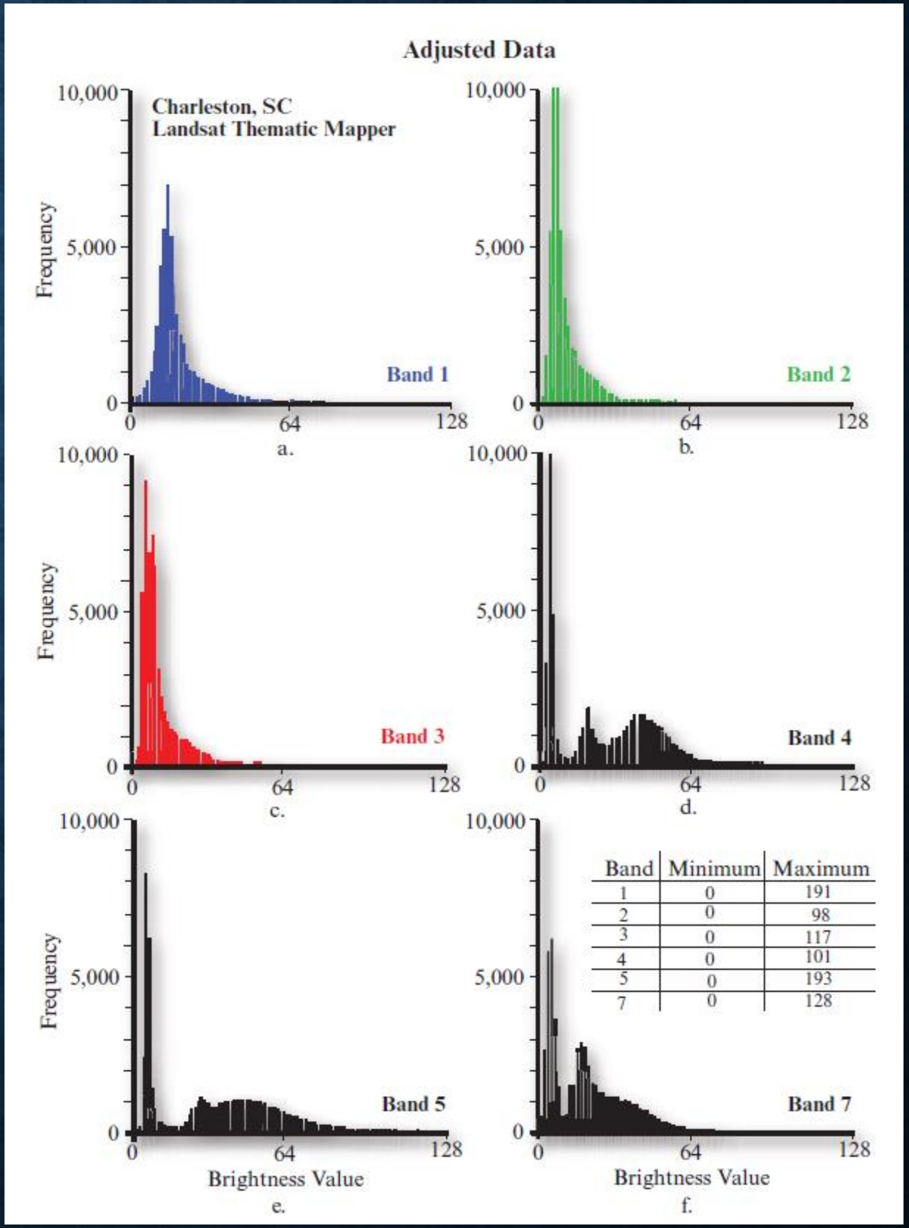
2) to *normalize* the intensities of bands of remote sensor data in multiple dates of imagery to a standard scene selected by the analyst.

Source: John R. Jesen, 2015, 4th Ed,

Relative atmospheric correction.



Band	Minimum	Maximum
1	51	242
2	17	115
3	14	131
4	4	105
5	0	193
7	0	128



Band	Minimum	Maximum
1	0	191
2	0	98
3	0	117
4	0	101
5	0	193
7	0	128

Source: John R. Jesen, 2015, 4th Ed,

Topographic Correction – Slope and Aspect effect.

- ❑Topographic slope and aspect introduce radiometric distortion of the recorded signal.
- ❑In some locations, the area of interest might even be in complete shadow, dramatically affecting the brightness values of the pixels involved.

Source: (Civco, 1989; M eyer et al.,1993).

Source: John R. Jesen, 2015, 4th Ed,

Topographic Correction – Slope and Aspect effect.

- The goal of a slope-aspect correction is to remove topographically induced illumination variation so that two objects having the same reflectance properties show the same brightness value in the image despite their different orientation to the Sun’s position.

- If the topographic slope-aspect correction is applied effectively, the three dimensional impression we get when looking at a satellite image of mountainous terrain should be somewhat subdued.

- A good slope-aspect correction is believed to improve forest stand classification when compared to non corrected imagery

Source: (Civco, 1989; M eyer et al.,1993).

Source: John R. Jesen, 2015, 4th Ed,

Four types of Topographic slope aspect Correction

1. Simple cosine correction,
2. two semi-empirical methods (the Minnaert method
3. The *C* correction
4. A statistic-empirical correction.

Source: Teillet et al. (1982)

Source: John R. Jesen, 2015, 4th Ed,

Simple cosine correction,

- ☐ The amount of irradiance reaching a pixel on a slope is directly proportional to the cosine of the incidence angle i, which is defined as the angle between the normal on the pixel in question and the zenith direction.

- ☐ This assumes;

1) L ambertian surfaces,
2) a constant distance between Earth and the Sun, and
3) a constant amount of solar energy illuminating Earth (somewhat unrealistic assumptions).

Source: Teillet et al. (1982)

Source: John R. Jesen, 2015, 4th Ed,

Simple cosine correction,

❑ Only the part *cos i* of the total incoming irradiance, *Eg*, reaches the inclined pixel.
It is possible to perform a simple topographic slope-aspect correction of the remote sensor data using the following cosine equation:

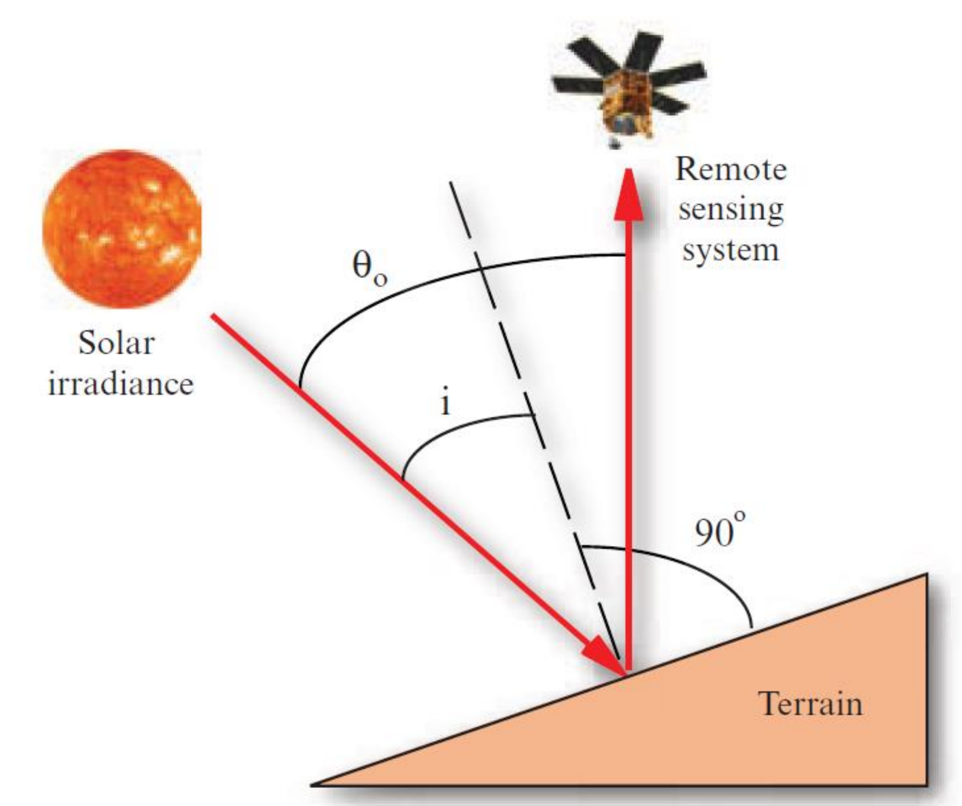
$$L_H = L_T \frac{\cos \theta_o}{\cos i}$$

L_H = radiance observed for a horizontal surface (i.e., slope-aspect-corrected remote sensor data)

L_T = radiance observed over sloped terrain (i.e., the raw remote sensor data)

θ_0= Sun’s zenith angle

i = Sun’s incidence angle in relation to the normal on a pixel.



Source: Teillet et al. (1982)

Source: John R. Jesen, 2015, 4th Ed,

Representation of the Sun’s angle of incidence, I, and the solar zenith angle, θ_0

The Minnaert Correction

Minnaert correction to the basic cosine function:

- The constant varies between 0 and 1 and is a measure of the extent to which a surface is Lambertian.
- A perfectly Lambertian surface has k = 1 and represents a traditional cosine correction.

Where k = Minnaert constant.

$$L_H = L_T\left(\frac{\cos\,\theta_o}{\cos\,i}\right)^k$$

Source: Teillet et al. (1982)

Source: John R. Jesen, 2015, 4th Ed,

A Statistical–Empirical Correction

For each pixel in the scene, it is possible to correlate;

(1) the predicted illumination (cos i × 100) from the DEM with

(2) the actual remote sensor data.

$$L_H = L_T - \cos(i)m - b + \overline{L_T}$$

i = Sun's incidence angle in relation to the normal on a pixel
m = slope of the regression line
b = y -intercept of the regression line.

$\overline{L_T}$ = average of L_T for forested pixels (according to ground reference data)

Source: M eyer et al. (1993)

Source: John R. Jesen, 2015, 4th Ed,

The C Correction

Introduced of an additional adjustment to the cosine function called the *c* correction:

$$L_H = L_T \frac{\cos \theta_o + c}{\cos i + c}$$

$$C = \frac{b}{m}$$

In the previous regression equation

Similar to the Minnaert constant, c increases the denominator and weakens the overcorrection of faintly illuminated pixels.

Source: Teillet et al. (1982)

Source: John R. Jesen, 2015, 4th Ed,

References:

R.Richter and D.Schlapfer, (2012), Atmospheric/Topographic Correction for Satellite Imagery (ATCOR-2/3UserGuide,Version8.2BETA. Retrieve: https://www.dlr.de/eoc/en/Portaldata/60/Resources/dokumente/5_tech_mod/atcor3_manual_2012.pdf

Jensen, John R., 2015- Introductory digital image processing : a remote sensing perspective / John R. Jensen, University of South Carolina.
pages cm. -- (Pearson series in geographic information science) 4th ed.