Data Quality
Radiometric Distortion
Radiometric Error Correction

Relevant reading: Richards, sections 2.1 – 2.8; 2.10.1 – 2.10.3
Data Quality/Resolution

• Spatial  ➔ IFOV  ➔ GIFOV
  Resolution, Pixel Size

• Spectral  ➔ \( \lambda \) Range, Bandwidth, \( \Delta \lambda \)

• Temporal  ➔ \( \Delta t \)

• Radiometric  ➔ SNR, Dynamic Range
  Quality, Resolution
Spatial Resolution

- **IFOV**: The angular extent of the sensor independent of the altitude.
- **GIFOV**: A measure of the spatial resolution of a remote sensing system, the projection of the IFOV onto the ground (pixel size), altitude dep.

\[
\text{GIFOV (Nadir) = 2*Altitude*tan(IFOV/2)}
\]
Signal to Noise Ratio (SNR)

• Signal strength depends on radiance flux reflected or emitted from the surface, pixel size, altitude, spectral band width.

• Ratio of a signal power to the noise power corrupting the signal. A ratio higher than 1:1 indicates more signal than noise.

• Compares the level of a desired signal (such as music) to the level of background noise. The higher the ratio, the less obtrusive the background noise is.
Signal-to-Noise Ratio

SNR = Signal/RMS noise

\[ \text{RMS} = \sqrt{\frac{\sum_{i=1}^{n} (\text{signal}_i^2 - \bar{x})}{n-1}} \]

\begin{align*}
\text{Data} &= 185 \ 197 \ 204 \\
& \quad 205 \ 200 \ 220 \ 210 \\
& \quad 190 \ 180 \ 199 \\
\text{Mean} &= 199 \\
\text{RMS} &= \sim 12 \\
\text{SNR} &= \sim 17
\end{align*}

\begin{align*}
\text{Noise} &= 0.01 \rightarrow \text{SNR} = 100 \\
\text{Noise} &= 0.01 \rightarrow \text{SNR} = 10 \\
\text{Noise} &= 0.01 \rightarrow \text{SNR} = 1
\end{align*}
**Dynamic Range**

**Bits:** Each digital value is recorded as a series of binary digits known as bits.

**Brightness or Intensity Level:** The number of discrete levels for describing the radiance level of a pixel, scaled from zero brightness to the highest brightness that would be expected. The more discrete levels (or bits of information), the more precisely the radiance of the scene can be measured. We typically deal with 8-bit brightness measurements or 256 levels, also referred to as *dynamic range*.

Dynamic Range determines the number of distinct colors or representations that imagery can be resolved into

**Possible Combinations with:**

1 bit: 0 or 1 = 2 or $2^1$

2 bits: 0,0, 0,1 1,0 1,1 = 4 or $2^2$

3 bits: 0,0,0 0,0,1 0,1,0 0,1,1 1,0,0 1,0,1 1,1,0 1,1,1 = 8 or $2^3$

N bits: = $2^N$
Gain and Offset (Bias)

Bias, Offset, Dark Current

Ground Scene Brightness (Input)

Image Brightness (Output)

Actual Sensor Response

Ideal Sensor Response
Contributions to Instrument Signal

Reflected solar radiation: 107 W m\(^{-2}\)

Incoming solar radiation: 342 W m\(^{-2}\)

Outgoing longwave radiation: 235 W m\(^{-2}\)

Emitted by the atmosphere: 165 W m\(^{-2}\)

Atmospheric window: 40 W m\(^{-2}\)

Absorbed by the surface: 30 W m\(^{-2}\)

Absorbed by the surface: 390 W m\(^{-2}\)

Absorbed by the surface: 324 W m\(^{-2}\)

Evapotranspiration: 78 W m\(^{-2}\)

Latent heat: 78 W m\(^{-2}\)

Greenhouse gases: 40 W m\(^{-2}\)

Thermals: 24 W m\(^{-2}\)
Distortion

Distortion: a change, twist, or exaggeration that makes something appear different from the way it really is.

• Radiometric Distortion: Errors in pixel brightness values
  – Instrumentation
  – Wavelength dependence of solar radiation
  – Effect of atmosphere

• Geometric Distortion: Errors in image geometry, (location, dimensions, etc.)
  – Platform and instrument relative motions
  – Scan angles and scan patterns
  – Rotation of the Earth
  – Attitude and altitude variability
Radiometric Distortion

- Relative brightness differs from what exists on the ground
- Relative brightness of a single pixel from band to band can be different from the true spectral reflectance characteristics on the ground
- Primarily effect from atmosphere
Basic Radiometric Terms

• **Irradiance**: The amount of energy incident on a given area of a surface in a given amount of time (W/m$^2$).

• **Radiance**: The amount of energy scattered in a particular direction (W/m$^2$/sr).

• **Solid angle**: The ratio of the area of a spherical surface to the square of the radius.

\[ \Omega = \frac{A}{r^2} \]
Basic Radiometric Terms

- **Spectral Irradiance**: The amount of energy available across wavelength range \((W/m^2/\mu m)\).
- **Hemispherical reflectance**: The ratio of the radiant flux from a surface to the radiant flux incident to it.
- **Hemispherical transmittance**: The ratio of the radiant flux transmitted through a surface to the radiant flux incident to it.
- **Hemispherical absorptance**: The ratio of the radiant flux absorbed by a surface to the radiant flux incident to it.
Fig. 2.1. The effect of the atmosphere in determining various paths for energy to illuminate a (equivalent ground) pixel and to reach the sensor.
Absence of an Atmosphere

In absence of an atmosphere surface irradiance between wavelengths is

\[ E_s = \int_{\lambda_1}^{\lambda_2} E_{\lambda} \cos \theta d\lambda \quad \text{Wm}^{-2} \]

Where: \( E_{\lambda} = \) solar spectral irradiance at the earth.
\[ \theta = \) solar zenith angle.

For most remote sensing devices the wavelengths are small enough that:

\[ E_s = E_{\Delta\lambda} \cos \theta \Delta\lambda \quad \text{Wm}^{-2} \]
Absence of an Atmosphere

• If the surface has a reflectance of R, the radiance reflected back to the atmosphere is

\[ L = E_{\Delta \lambda} \cos \theta \Delta \lambda \frac{R}{\pi} \ Wm^{-2} \ sr^{-1} \]

• Knowing L, we can determine the Irradiance at the Sensor from a digital number C (e.g. 0-255)

\[ L_s = Ck + L_{\min} \ Wm^{-2} \ sr^{-1} \]

Where: \( k = (L_{\max} - L_{\min})/C_{\max} \) and

\( L_{\max} \) and \( L_{\min} \) are the maximum and minimum measurable radiances as indicated by the instrument manufacturer.
With the Atmosphere

- Some irradiance is attenuated by the atmosphere (function of wavelength) as defined by atmospheric transmissivity along an angular path ($T_\theta$)
- Some irradiance is incident upon the pixel from the sky ($E_D$)

$$E_G = T_\theta \left[ E_{\Delta\lambda} \cos \theta \Delta\lambda \right] + E_D \quad \text{Wm}^{-2}$$
With the Atmosphere

- Total radiance due to the global irradiance of the pixel becomes

\[ E_G = T_\theta \left[ E_{\Delta \lambda} \cos \theta \Delta \lambda \right] + E_D \quad \text{Wm}^{-2} \text{sr}^{-1} \]

- Above the atmosphere, we have to add in scattering from other pixels into the observing path along the path at the angle \( \phi \) between the pixel and the sensor, and scattering from the atmosphere itself (\( L_p \)), and we have to remove what is attenuated by the atmosphere in the direction of the sensor (\( T_\phi \))

\[ L_T = \frac{RT_\phi}{\pi} \left\{ T_\theta \left[ E_{\Delta \lambda} \cos \theta \Delta \lambda \right] + E_D \right\} + L_p \quad \text{Wm}^{-2} \text{sr}^{-1} \]

These are the components of the equation used to relate the digital number to measured radiance.
With the Atmosphere

- Some irradiance is attenuated by the atmosphere (function of wavelength) as defined by atmospheric transmissivity along an angular path ($T_\theta$).
- Some irradiance is incident upon the pixel from the sky ($E_D$).

\[
E_G = T_\theta \left[ E_{\Delta \lambda} \cos \theta \Delta \lambda \right] + E_D
\]

- Total radiance due to the global irradiance of the pixel becomes

\[
L_T = \frac{R}{\pi} \left\{ T_\theta \left[ E_{\Delta \lambda} \cos \theta \Delta \lambda \right] + E_D \right\}
\]

- Above the atmosphere, we have to add in scattering from other pixels into the observing path along the path at the angle $\phi$ between the pixel and the sensor, and scattering from the atmosphere itself ($L_p$).

\[
L_T = \frac{RT_\phi}{\pi} \left\{ T_\theta \left[ E_{\Delta \lambda} \cos \theta \Delta \lambda \right] + E_D \right\} + L_p
\]

This is what should be plugged into equation at bottom of previous page.
Correcting for Atmospheric Effects

- Factors that influence atmospheric distortion effects
  - Humidity
  - Temperature
  - Pressure
  - Aerosols, clouds, particulate matter, etc.
- These characteristics determine optical thickness ($\tau$) of the atmosphere

\[
\frac{I}{I_0} = e^{-\tau/\cos\theta} \quad T_{\theta} = e^{-\tau/\cos\theta} \quad T_{\phi} = e^{-\tau/\cos\phi}
\]

- Optical thickness and scattering mechanism (mie, rayleigh and non-selective) in turn determine the radiance available to reach the sensor
- Corrections are typically theoretically derived with radiative transfer models
Bulk Atmospheric Correction

- Often it is sufficient to assume there are pixel values close to zero in the imagery (e.g. water).
- In this case, any brightness observed will be a result of atmospheric contributions (Primarily $L_p$ but also $E_D$).
- Histograms of each channel will show an offset from zero as a result.
  - Wavelength dependent.
- Subtracting this offset from the entire image will remove the vast majority of atmospheric effects.
AIRS measures upwelling radiances in 2378 spectral channels covering the IR spectral band, 3.74 to 15.4 µm. A set of four channels in the Visible/Near-IR (VIS) observes wavelengths from 0.4 to 1.0 µm to provide cloud cover and spatial-variability characterization.
Striping in Imagery

Southern Maruitania near the Senegal border, October 10, 1980, LANDSAT 4 Multi-Spectral Scanner (MSS). The majority of the land-cover consists of riparian vegetation, poor grassland, and barren ground.