Image Pre-processing: Radiometric Corrections

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The Concept

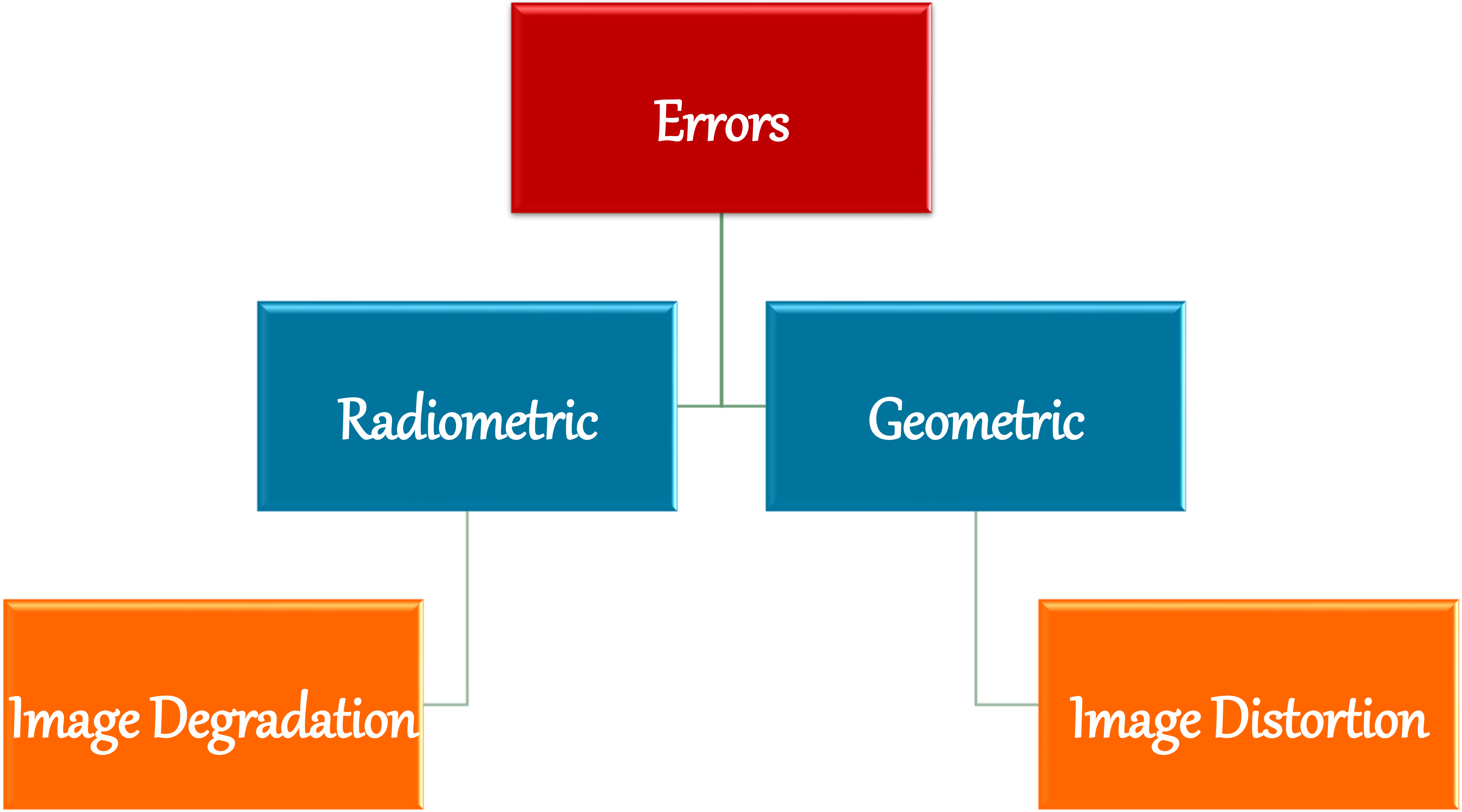
- Remote Sensing systems **do not function properly**.
- The Earth's **atmosphere, land, and water are complex** and do not lend themselves well to being recorded by remote sensing devices that have constraints such as **spatial, spectral, temporal, and radiometric resolution**.
- Consequently, error creeps into the data acquisition process and can **degrade the quality of the remote sensor data** collected.
- Data sets have to be corrected for these errors (pre-processed) **before analysis and interpretation** process.

Digital Image Processing

Digital image processing can be defined as the **computer manipulation of digital values** contained in an image for the purposes of **image correction, image enhancement and feature extraction.**

Collects or restore data before analysis so that it is as close as possible to true radiant energy

1. **Data Acquisition/Restoration** - Compensates for data errors, i.e. Preprocessing (Radiometric and Geometric)
2. **Image Enhancement** - **Alters the visual impact** of the image on the interpreter to improve the information content
3. **Information Extraction** - Utilizes the decision making capability of computers to recognize and **classify pixels** on the basis of their signatures



Both the errors may be Internal (Systematic/ Predictable/ Constant) or External (Non-systematic/ Unpredictable)

INTERNAL errors

- Created by the **sensor** itself
- May be determined from **pre-launch** or in **flight calibration** measurements..

EXTERNAL errors

- Due to **platform perturbations** and the modulation of **atmosphere** and **scene** characteristics, which are variable in nature.
- Such errors have to be determined by relating points on the ground (GCPs) to sensor system measurements.

Raw Satellite Image

↓

Image Pre-Processing

Radiometric and Geometric corrections of remotely sensed data are normally referred to as PREPROCESSING OPERATIONS because they are performed prior to information extraction.

↓

Corrected Image

Radiometric Correction

Radiometric error = noise in the Brightness Value/BV/ DN

Radiometric correction attempts to improve the accuracy of

- ✓ **Spectral Reflectance**,
- ✓ **Emittance**, or
- ✓ **Back-scattered** measurements

obtained using a remote sensing system

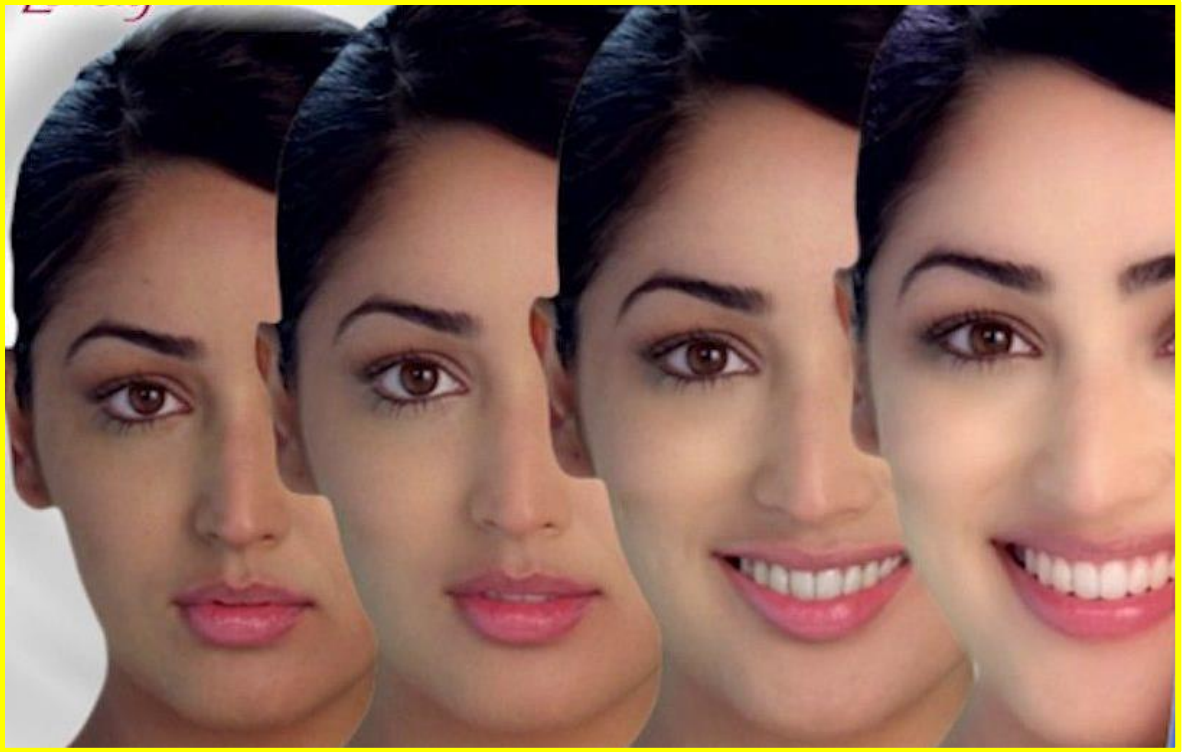
- It includes correcting the data for **sensor irregularities** and **unwanted sensor or atmospheric noise**, and converting the data so they accurately represent the reflected or emitted radiation measured by the sensor.

Why Radiometric Errors occurs???
Causes

- **Ideally**, the radiance recorded by a remote sensing system in various bands is an accurate representation of the radiance actually leaving the feature of interest (e.g., soil, vegetation, water, or urban land cover) on the Earth's surface. Unfortunately, noise (error) can enter the data-collection system at several points.

- RADIOMETRIC ERROR may be introduced by the

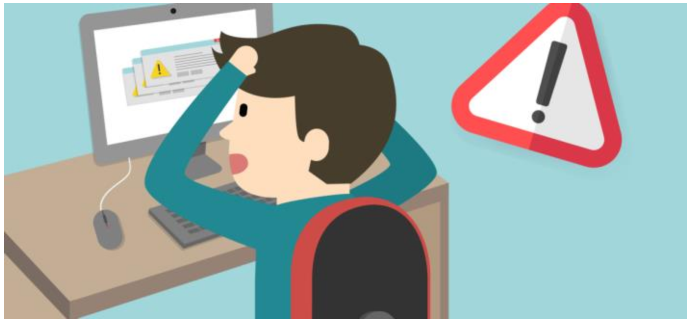
1. **Sensor system itself** when individual detectors do not function properly or are improperly calibrated.
2. **Atmospheric attenuation** – energy recorded by the sensor does not resemble which was **reflected** or **emitted by the terrain**.



Radiometric corrections are also called as cosmetic corrections and are done to improve the visual appearance of the image.

Common Radiometric Errors

- Line or Column dropouts
- Partial line or column drop outs
- Line or column stripping
- Line-start/stop problems
- Random bad pixels (Shot noise)



Line Drop-Out

- If a **detector fails to function** this can result in an entire line or column of data with **no spectral information.**
- The bad line or column contains **DN value=zero**

Correction

- It is first necessary to **locate each bad line** in the dataset.
- A **simple thresholding algorithm** makes a pass through the dataset and flags any scan line having a **mean brightness value at or near zero.**
- **This is a serious condition because there is no way to restore data that were never acquired. However, it is possible to improve the visual interpretability of the data by introducing estimated brightness values for each bad scan line.**
- This is **performed for every pixel in a bad scan line**.
- The **result is an image consisting of interpolated data** every nth line that is **more visually interpretable** than one with horizontal black lines running systematically throughout the entire image.

Correction…

1. Replacement by either the preceding or the succeeding line

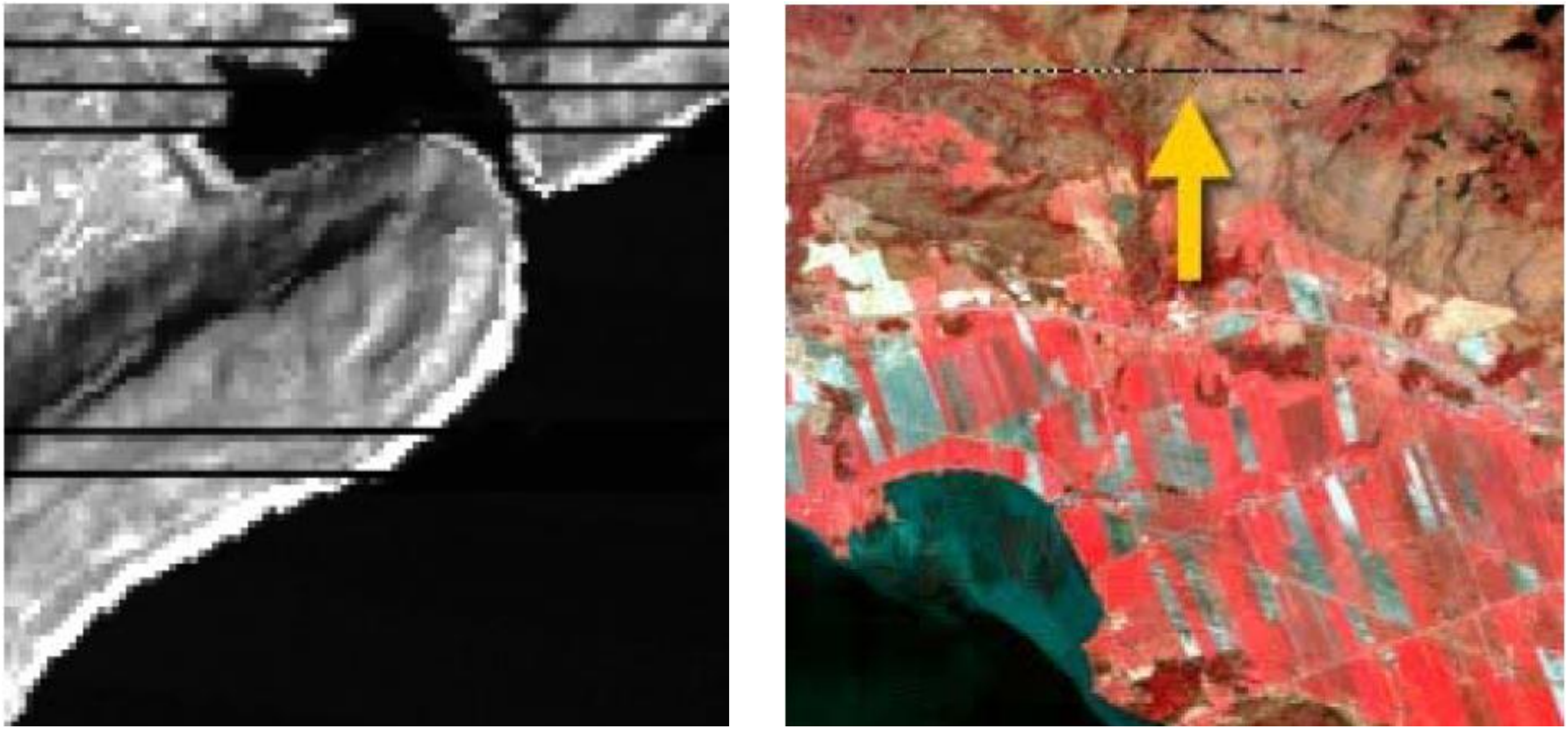
$$BV_{I,J} = BV_{I,J-1} \text{ or } BV_{I,J} = BV_{I,J+1}$$

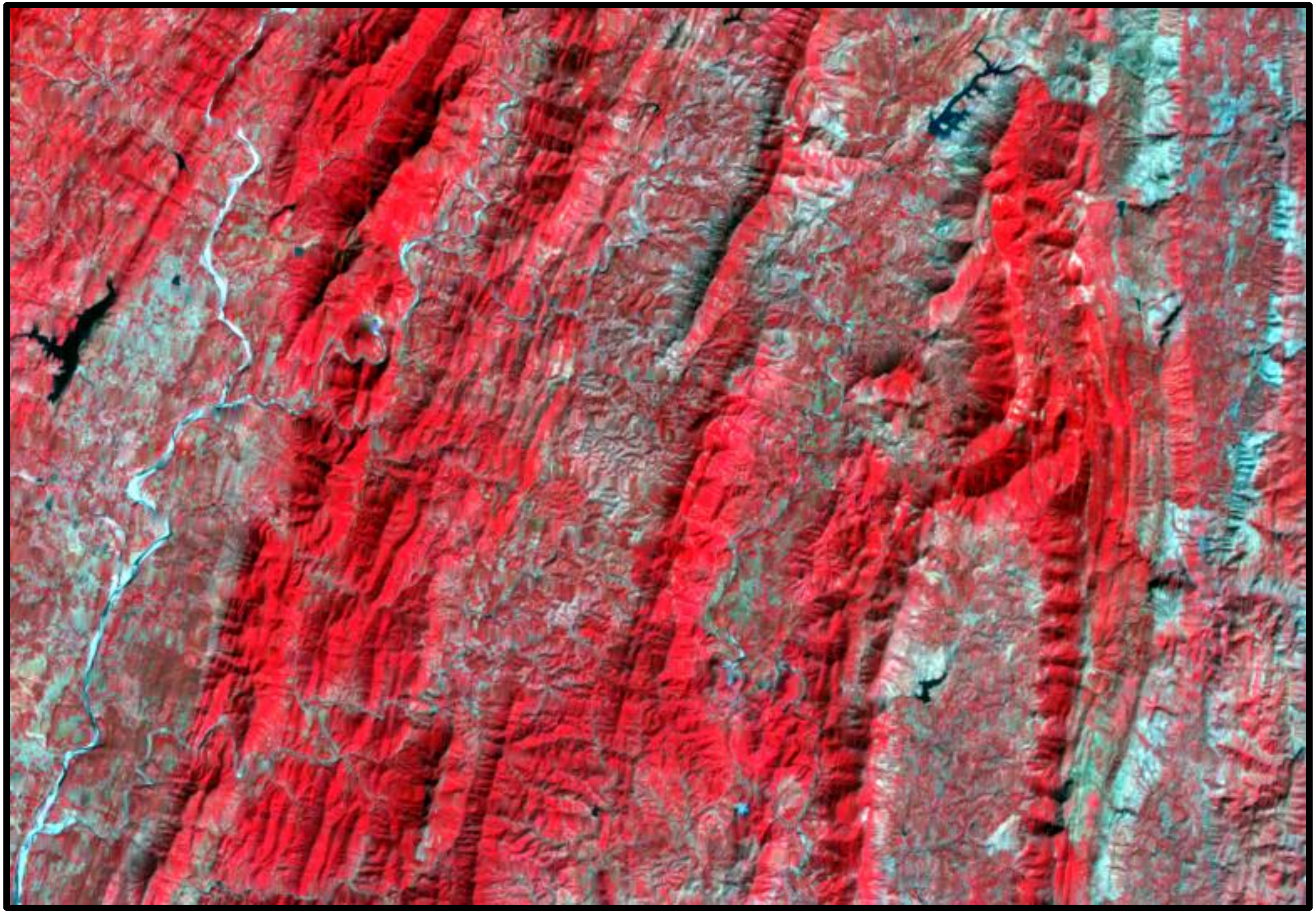
$$BV_{I,J} = \text{missing pixel value of scan line}$$

2. Averaging of the neighboring pixel values

$$BV_{I,J} = (BV_{I,J-1} + BV_{I,J+1})/2$$

3. Replacing the line with other highly correlated band.



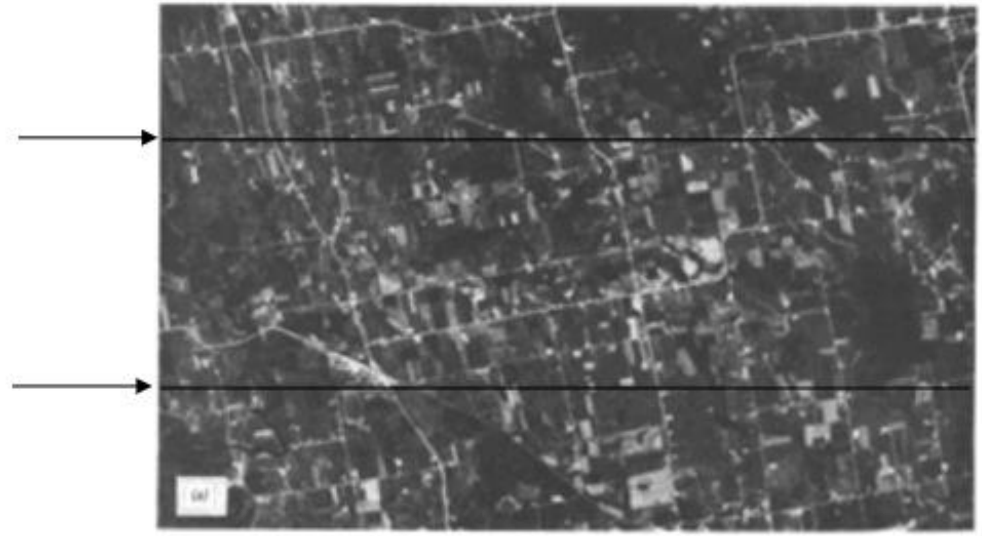


Landsat 7 ETM+ image (SLC-off) Oct., 2005

Corrections

Line Dropout

43	47	51	57
40	46	50	54
0	0	0	0
38	40	42	50



Solution: Mean from above and below pixels

43	47	51	57
40	46	50	54
39	43	46	52
38	40	42	50

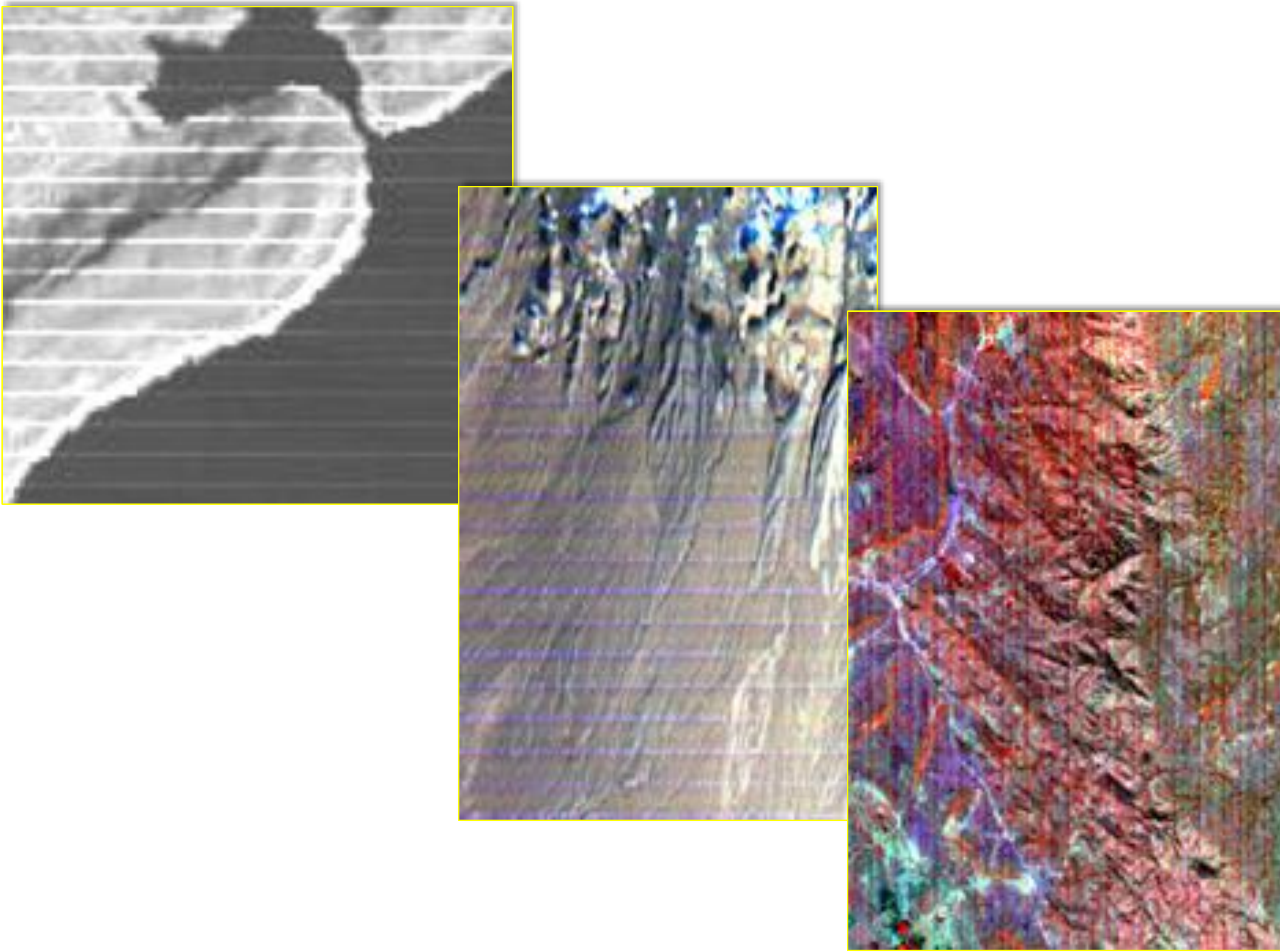
Or use other spectral band

Line Stripping (Banding)

- The response of some of the detectors may shift towards **lower** or **higher** end causing the **presence of a systematic horizontal / vertical** banding pattern

- Banding is a **cosmetic defect** and it interferes with the **visual appreciation of the patterns** and features on the image.

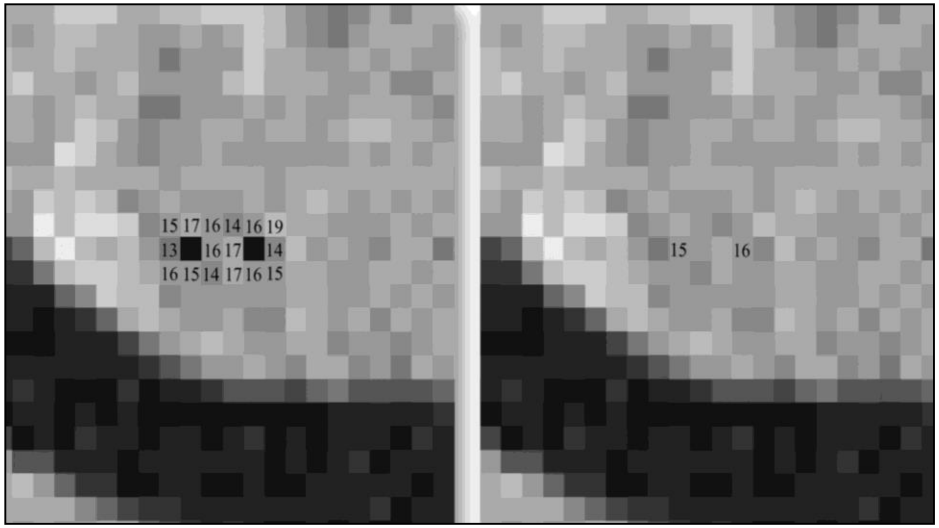
- **Variation in gain and offset** of each sensor (linear sensor characteristic)as the sensor deteriorates in time.



Random Bad Pixels (Shot noise)

- Sometimes an individual detector does not record spectral data for an **individual pixel**.

- When this occurs **randomly**, it is called a **bad pixel**.



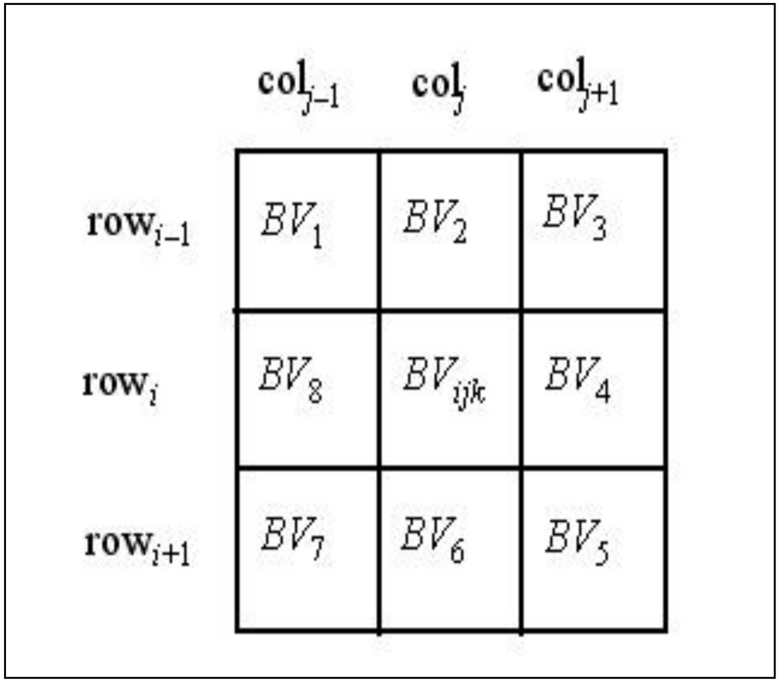
- When there are **numerous random bad pixels** found within the scene, it is called **shot noise** because it appears that the image was shot by a shotgun. **('Salt' & 'Pepper' effect)**

- Normally these bad pixels contain values of **0** or **255** (in 8-bit data) in one or more of the bands.

Shot noise: Corrections

Shot noise is identified and repaired using the following methodology:

- It is first necessary to **locate each bad pixel** in the **band k** dataset.
- A **simple thresholding algorithm** makes a pass through the dataset and flags any pixel ($BV_{I,J,K}$) having a brightness value of zero (assuming values of 'ZERO' represent shot noise and not a real land cover such as water).
- Once identified, it is then possible to **evaluate the eight pixels surrounding** the flagged pixel



The **mean of the eight** surrounding pixels is computed and the value substituted for **$BV_{I,J,K}$** in the corrected image

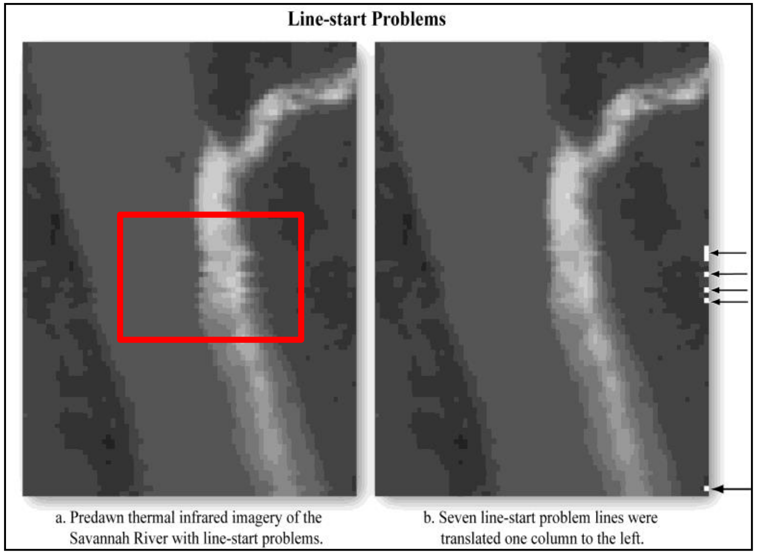
45	56	59
48	**53**	61
46	53	58

Line Start or Stop Problem

- Scanning detector **fails to start or out of sequence with other detectors** = <u>**Bad Line Start**</u>
- **Results in displaced rows** with the pixel data at inappropriate locations along scan lines

How to fix it:

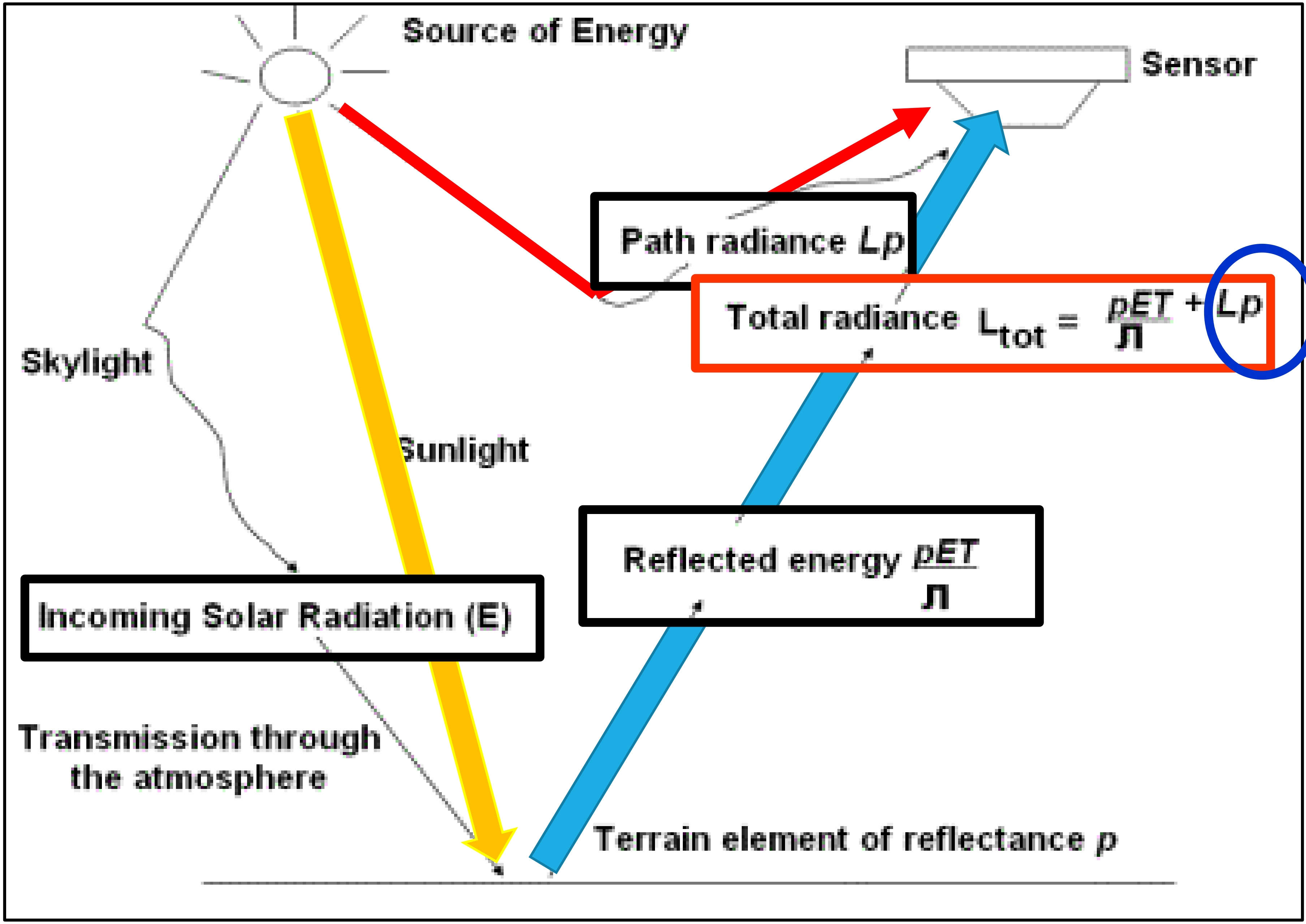
- Determining rows impacted and offset
- Scripting a standard offset for affected rows



Atmospheric Influence

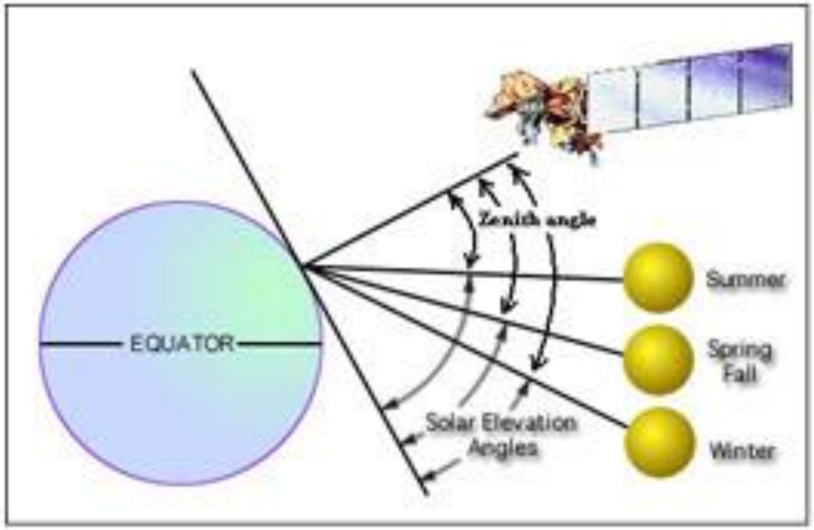
Correcting for Atmospheric Influence:

1. **Attenuates (reduces)** – **Absorption** [CO_2, $H_2O(g)$, O_3]
2. **Act as Reflector** – **Scattering** [particulate matter], adding extraneous '**Path Radiance**' to the signal detected by the sensor.


Source of Energy
Sensor
Path radiance Lp
Total radiance $L_{tot} = \frac{\rho ET}{\pi} + Lp$
Skylight
Sunlight
Reflected energy $\frac{\rho ET}{\pi}$
Incoming Solar Radiation (E)
Transmission through the atmosphere
Terrain element of reflectance ρ

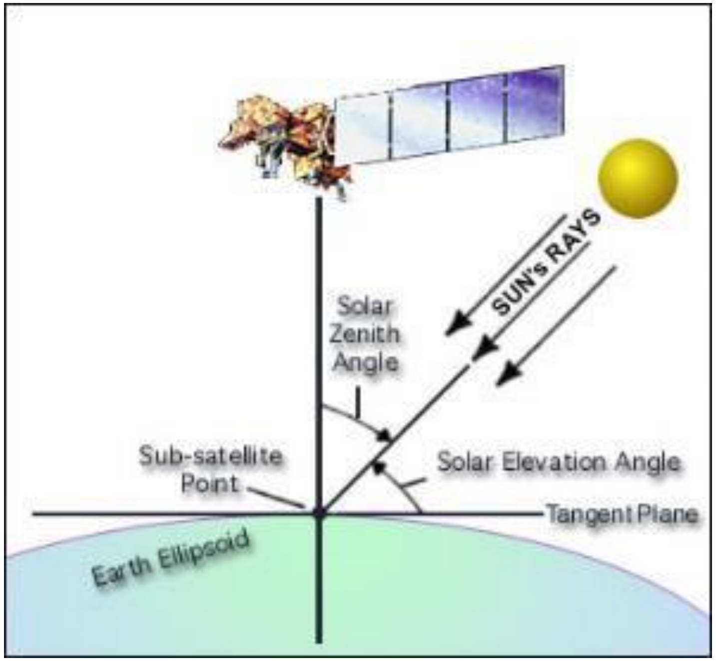
Sun Angle Correction

- The **position of sun relative to earth changes depending** on time of day and day of year.
- **Solar elevation angle** : Time-and location dependent
- Sun elevation correction accounts for the seasonal position of the sun relative to the earth



Sun Angle Correction...

- **Image data acquired under different solar illumination angles need to be normalized to a constant solar position**
- In the northern hemisphere the solar elevation angle is smaller in winter than in summer
- **The solar zenith angle is equal to 90 degree minus the solar elevation angle**
- **Irradiance varies with the seasonal changes** in solar elevation angle and the changing distance between the earth and sun.



Correction necessary for <u>mosaicking</u> and <u>change detection</u>

Atmosphere Induced Errors

Haze:

- ✓ **Scattered light** reaching the sensor from the atmosphere
- ✓ **Additive effect**, reducing **CONTRAST**

Diffused Skylight:

- ✓ Scattered light reaching the sensor after being reflected from the Earth's surface
- ✓ Multiplicative effect

Sun Angle:

- ✓ Time/Seasonal effect changing the atmospheric path
- ✓ Multiplicative effect

The method to be applied is a function of

- ✓ Nature of the problem
- ✓ Type of **RS data** available
- ✓ The amount of **in situ historical information** available
- ✓ **Degree of accuracy** required

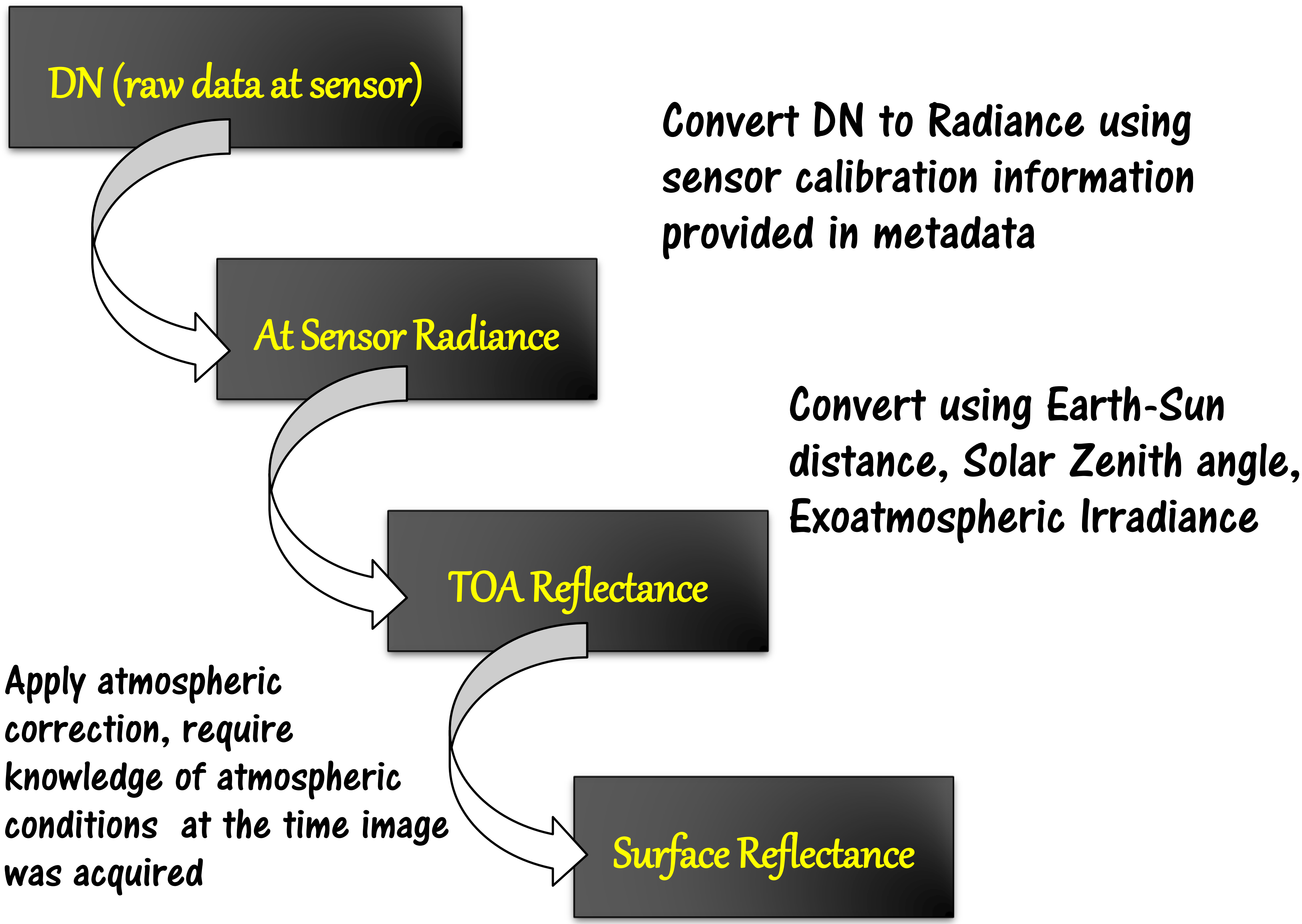
Two major types of atmospheric correction:

1. **Absolute** atmospheric correction
2. **Relative** atmospheric correction

Absolute Atmospheric Correction

DN to Surface Reflectance

Use a MODEL ATMOSPHERE in conjunction with in situ atmospheric measurements acquired at the time of data collection to correct the remotely sensed data


DN (raw data at sensor)
Convert DN to Radiance using sensor calibration information provided in metadata
At Sensor Radiance
Convert using Earth-Sun distance, Solar Zenith angle, Exoatmospheric Irradiance
TOA Reflectance
Apply atmospheric correction, require knowledge of atmospheric conditions at the time image was acquired
Surface Reflectance

Atmospheric Correction Models Based on Radiative Transfer Modeling

- MODTRAN
- QUAC
- FLAASH

(Fast Line-of-sight Atmospheric Analysis of Hypercubes)

- ATCOR
- 6S

✓ These MODELS can provide realistic estimates of the effects of atmospheric scattering and absorption on satellite imagery.

✓ Once these effects have been identified for a specific date of imagery, each band and/or pixel in the scene can be adjusted to remove the effects of scattering and/or absorption.

✓ The image is then considered to be atmospherically corrected.

Inputs to These Models

- **Latitude** and **longitude** of the remotely sensed image scene,
- **Date** and exact **time** of remote sensing data collection,
- Image acquisition **altitude** (e.g., 20 km AGL)
- **Mean elevation** of the scene (e.g., 200 m ASL),
- An **atmospheric model** (e.g., Mid-latitude summer, mid-latitude winter, tropical),
- Radiometrically calibrated image radiance data (**Gain & Offset**)
- Data about each specific band
- Local atmospheric visibility at the time of remote sensing data collection

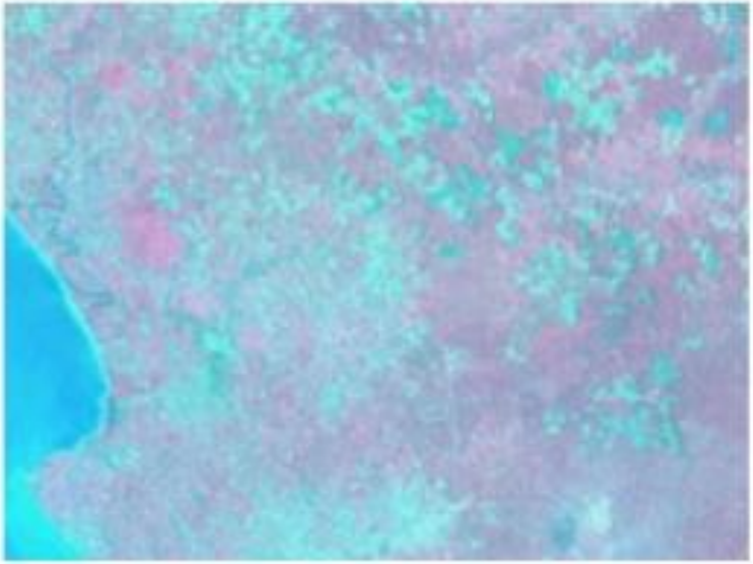
Constraints...

- ✓ Requires knowledge of both the sensor spectral profile, and
- ✓ The atmospheric properties at the same time.
- ✓ Atmospheric properties are difficult to acquire even when planned.
- ✓ For most historic satellite data, they are not available.

Relative Atmospheric Correction

- ✓ Relative correction is **to normalize multi-temporal data** taken on different dates to a **selected reference data** at specific time
- ✓ **Does not require collection of atmospheric measurements** at the time of data collection, which are very difficult to obtain when using historical remotely sensed data

Atmospheric Haze Effect



Haze Effect

Corrected Image

DN VALUE of object in a single band

Object 1 DN = 20 + 20 | DN = 20

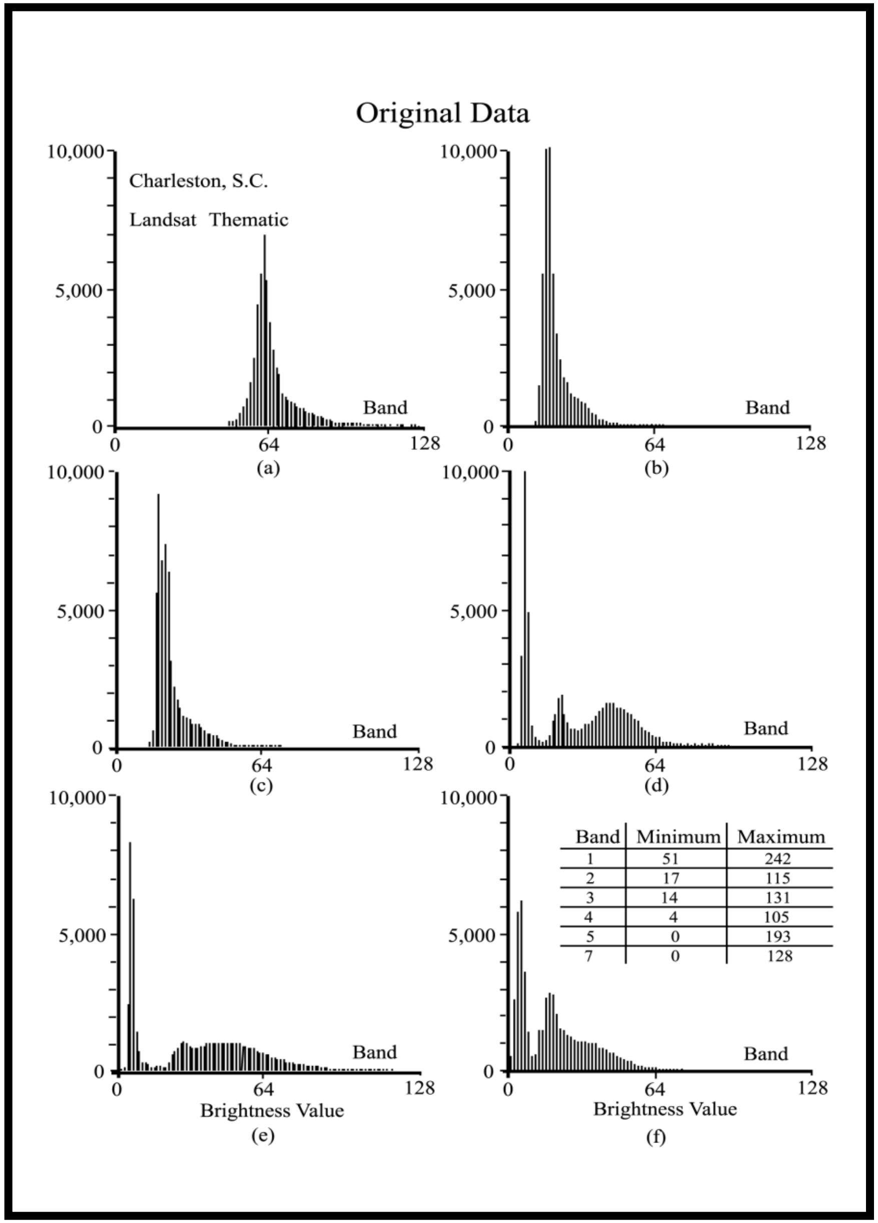
Object 2 DN = 20 + 40 | DN = 40

CONTRAST 60/40 = 1.5X | CONTRAST=40/20 = 2X

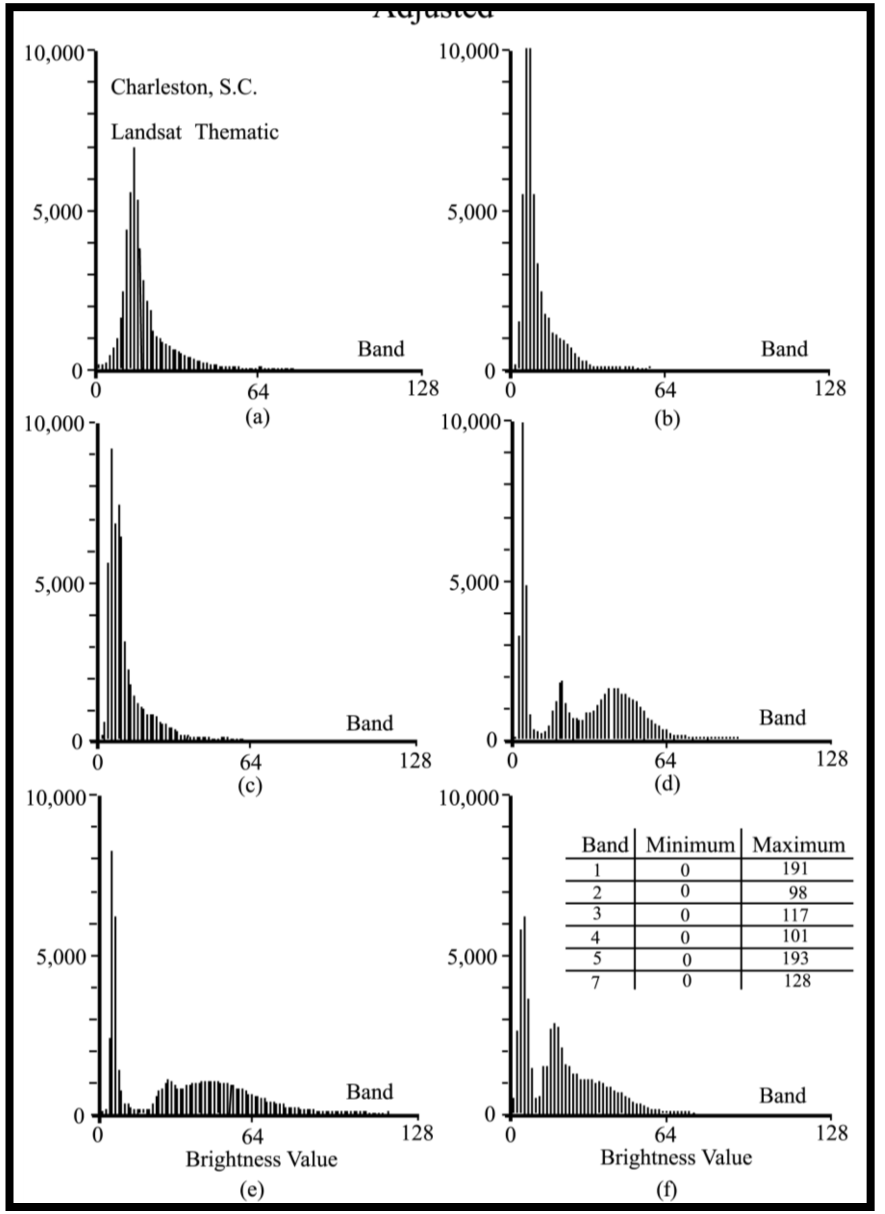
Haze Correction-Dark Object Subtraction DOS

- Histogram Minimum Method
- **Assumption:** Infrared bands are not affected by haze
- Identify black bodies: **clear water** with **zero reflectance** in the infrared bands
- These DN are entirely due to haze.
- **Subtract the minimum of the DN values** related to black bodies of a particular band from all the pixel values of that band.

Landsat 7 Data



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

Original Data

Bands	Min	Max
1	51	242
2	17	115
3	14	131
4	4	105
5	0	193
7	0	128

Adjusted Data

Bands	Min	Max
1	0	191
2	0	98
3	0	117
4	0	101
5	0	193
7	0	128

< Demo of DOS in SAGA >