Errors & Corrections in Remote Sensing Data

Geological Survey of India
Training Institute
Mission-V

Image Quality

- Many remote sensing datasets contain high-quality, accurate data.
- Unfortunately, **sometimes error (or noise)** is introduced into the remote sensor data by:

  - Environment (e.g., atmospheric scattering, cloud)
  - Random or systematic malfunction of the remote sensing system (e.g., an uncalibrated detector creates striping)
  - Improper pre-processing of the remote sensor data prior to actual data analysis (e.g., inaccurate analog-to-digital conversion).

ERRORS IN RASTER DATA

- Noise in data refers to deviation of DN from its original value
- Source of Errors

Internal

a. Systematic errors
b. Sensor driven
c. Applied to all images from the platform

External

a. Non systematic errors
b. Due to perturbations in platform
c. Atmospheric scene characteristics
d. Applicable to individual images

Systematic errors

- These errors are **system dependent** also called **platform based errors.**
- Mostly found in **mechanical sensors**.

➢ Scan Skew

➢ Mirror-Scan Velocity Variance

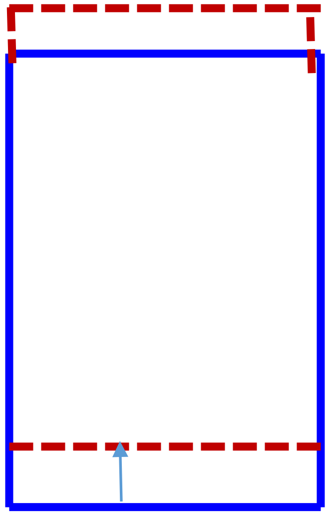
➢ Panoramic Distortion

➢ Platform Velocity

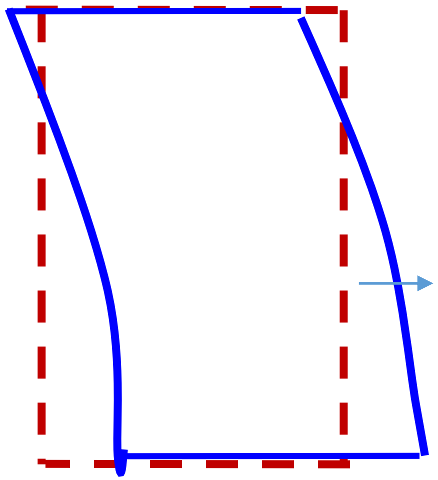
➢ Earth Rotation

Displacements on satellite imagery

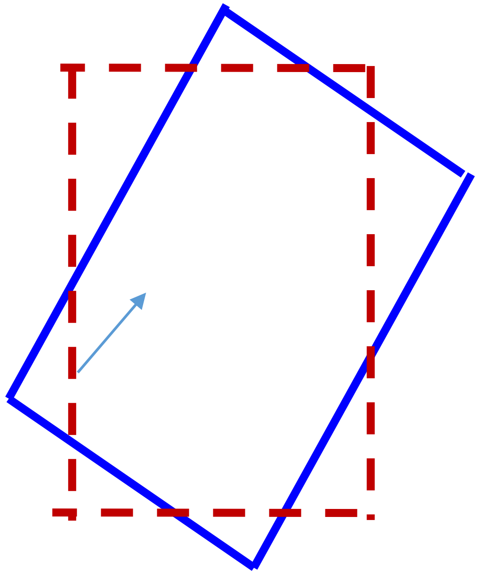
- Displacements due to sensor orientation



Forward/ aft tilt

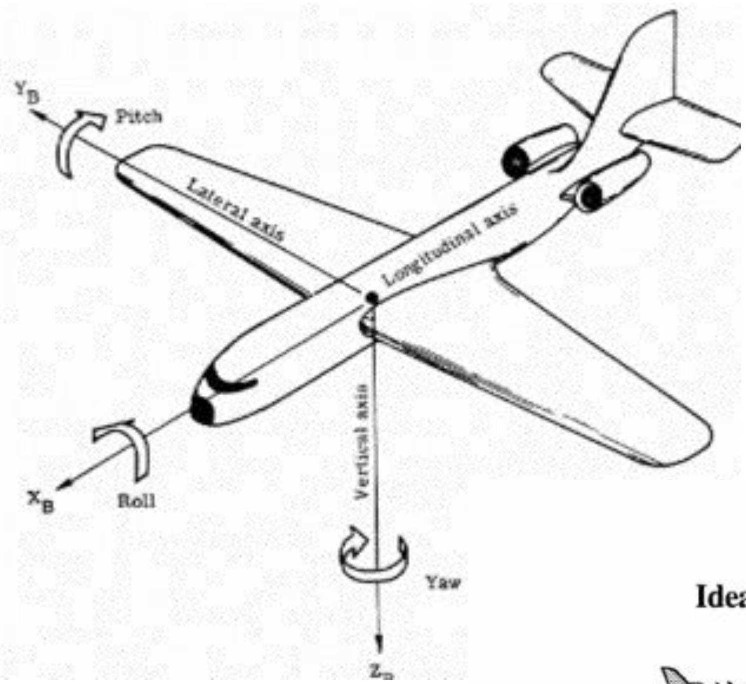


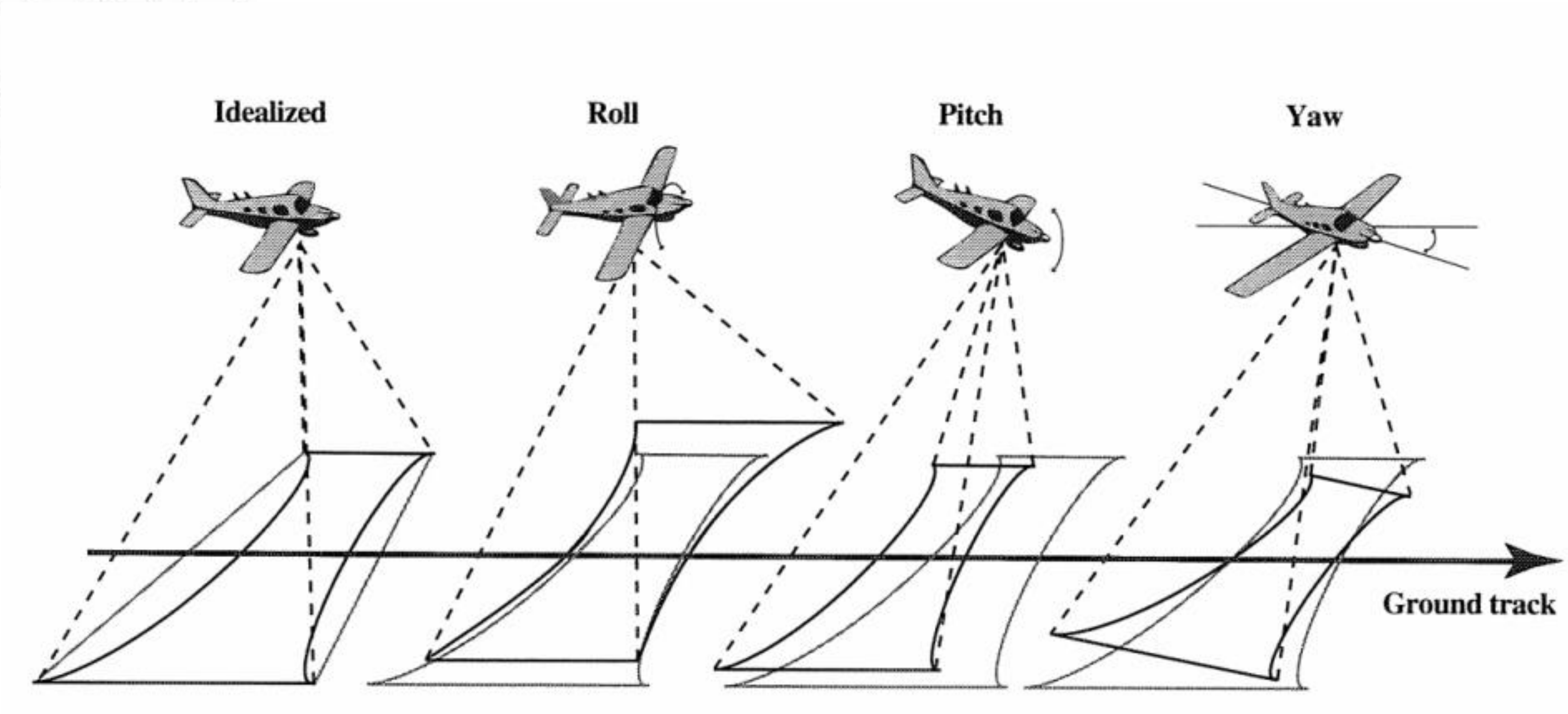
Sideward tilt



Rotation

Attitude Distortion





Source: Internet

Geometric Correction

- **<u>Preprocessing</u>** - to remove geometric distortions so that individual picture elements (pixels) are in their proper planimetric (*x*, *y*) map locations.

- ***Why?-*** *Geometrically corrected imagery* can be used to extract accurate distance, polygon area, and direction (bearing) information.

- **Will be discussed in details in Digital Image Pre processing**

Radiometric errors

Radiometric errors and inconsistencies are referred to as “noise” which could be considered any undesirable spatial or temporal variations in image brightness not associated with variations in the imaged surface.

- **System Errors**

  Line dropout - caused by a defective sensor system.

  Line stripping - caused by different responses of detectors to equal input (decalibration of detectors)

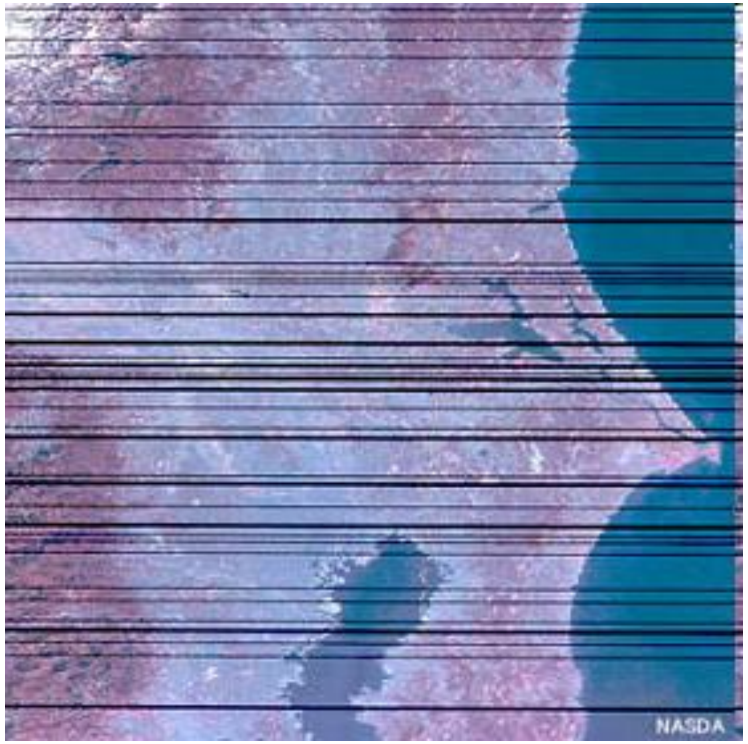
  Banding- caused by variations of neighboring forward and backward scans eg; in Landsat Thematic Mapper

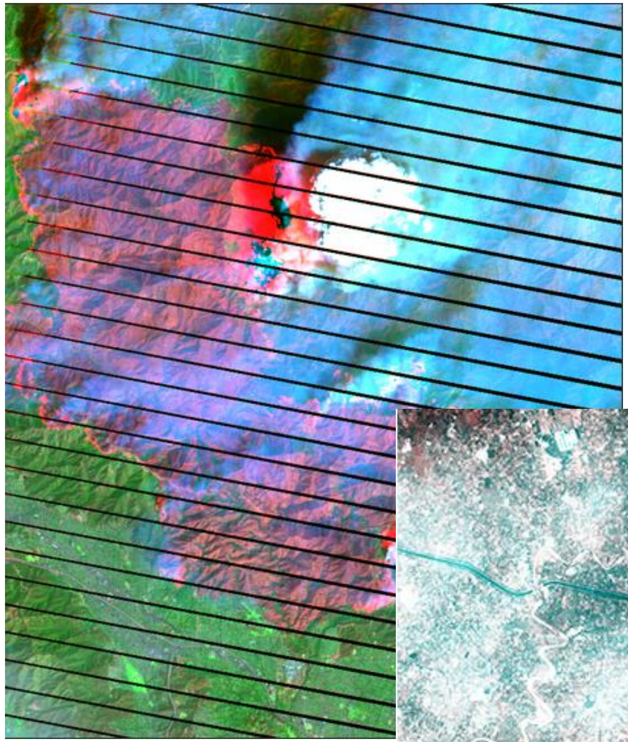
  Random noise or spike- caused by error during data transmission or to a temporary disturbance

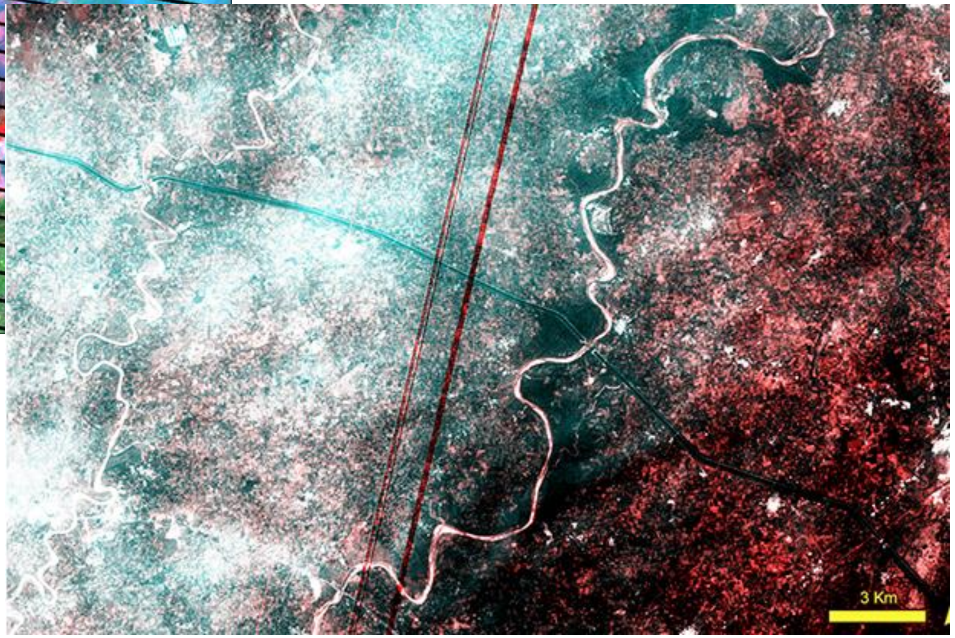
- **Non System errors Atmospheric errors**

  1. Scattering and absorption **2.**Topographic attenuation

Line Banding and stripping in Landsat 5-TM & 7- ETM Image







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Corrections for Remote Sensing Data

-Geometric Correction-

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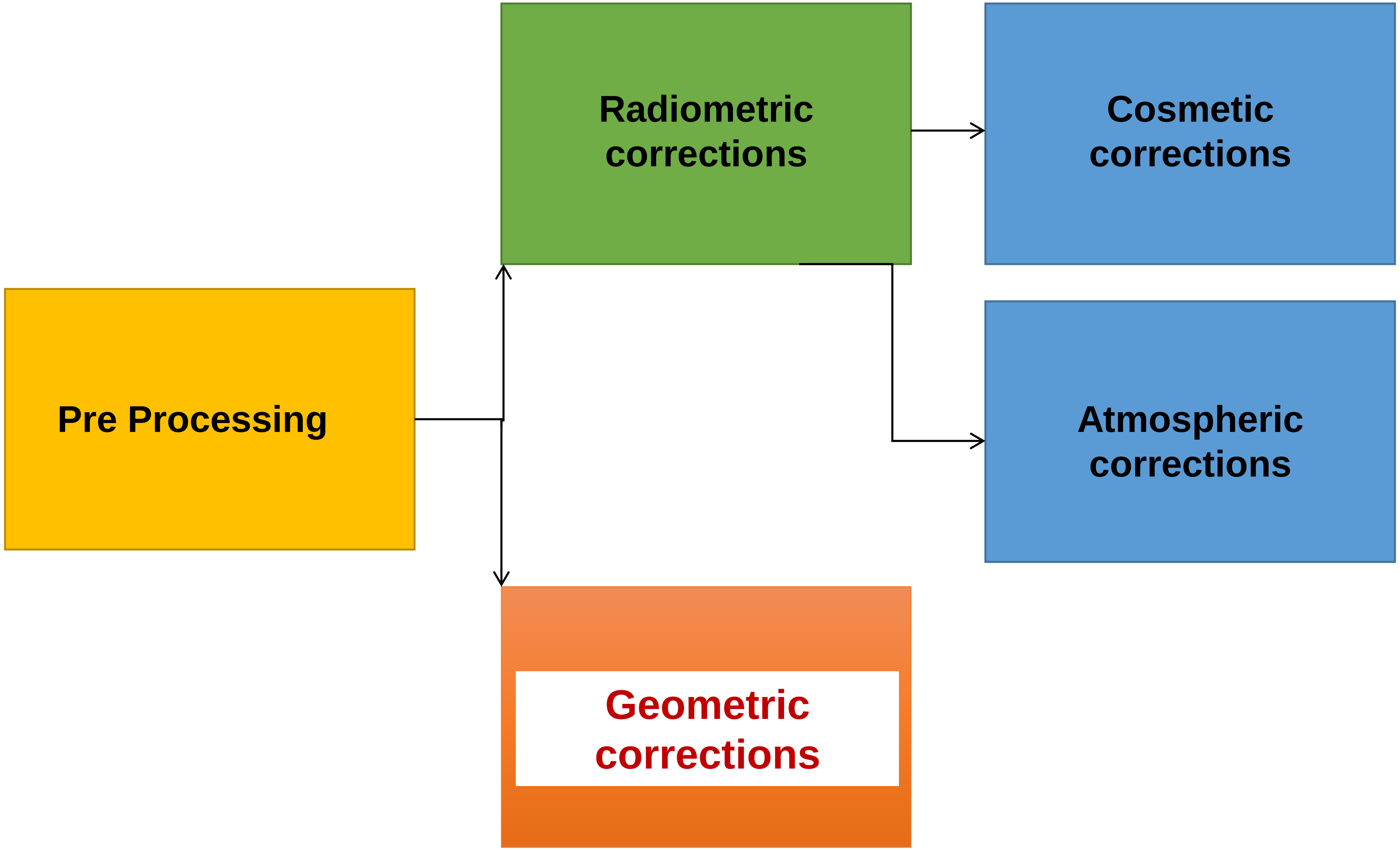
Introduction



Geometric Correction

In order to remove geometric distortions and so that individual picture elements (pixels) fits to their proper planimetric (x, y) map locations.

Why to do Geometric correction?

- Corrected imagery can be used to extract accurate distance, polygon area, and direction (bearing) information.
- Overlaying image data with other thematic layers.
- Sequential Change Detection studies.
- Deriving 2-dimensional and 3-dimensional coordinates.
- Visualizing image data in GIS environment.
- Merging Image data of different spatial resolution.
- Mosaicking of image.
- Overlaying vector data on image.

Ground Control Points

- A *ground control point* (GCP) is a location on the **surface identified** on **the imagery** and located accurately **on a map**.
- The image analyst must be able to obtain two distinct sets of coordinates associated with each GCP:

  - image coordinates specified in i rows and j columns, and
  - map coordinates (e.g., x, y measured in degrees of latitude and longitude or meters in a Universal Transverse Mercator projection).

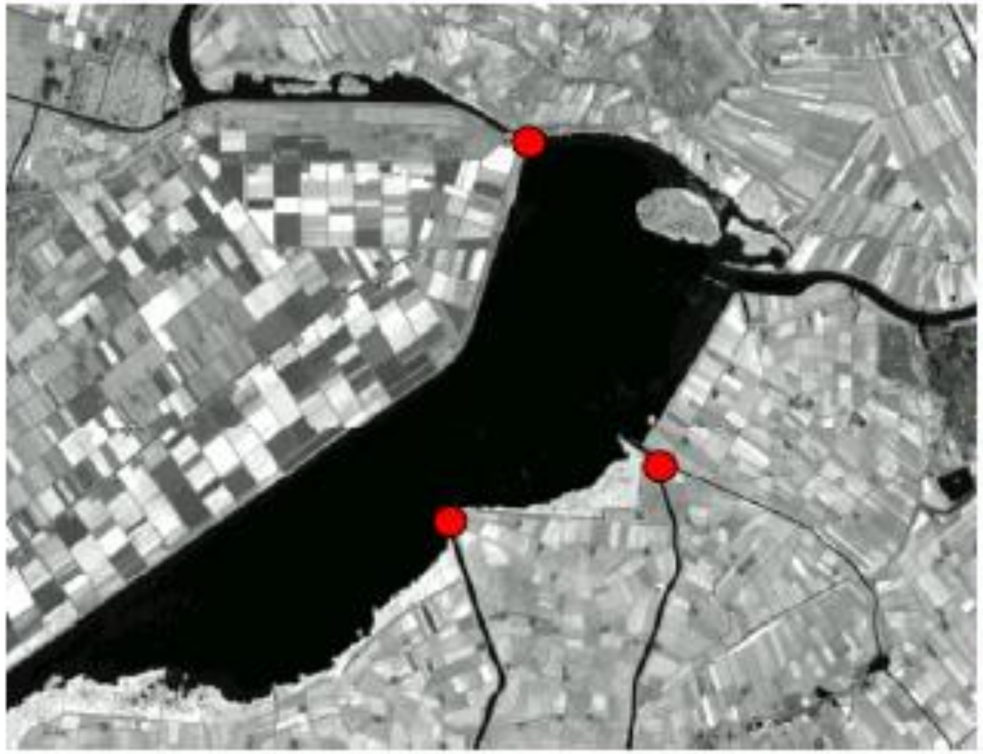
- The paired coordinates (*i, j* and *x, y*) from many GCPs can be modeled to derive *geometric transformation coefficients*.

- These coefficients may be **used to geometrically rectify** the remote sensor data to a standard datum and map projection.

Ground Control Points

- Several alternatives to obtaining accurate *ground control point* (GCP) for image-to-map rectification include:
  - Hard-copy planimetric maps -where GCP coordinates are extracted using simple ruler measurements or a coordinate digitizer.
  - Digital planimetric maps where GCP coordinates are extracted directly from the digital map on the screen.
  - Global positioning system (GPS) – GCP collected in the field with GPS instruments.

Ground Control Points (GCP's) or reference points



Source: Internet

How many?

Digital correction of image coordinates involves 2 steps

Georeferencing (Spatial interpolation)

It refers to the process of assigning map coordinates to Image data.

Geocoding (Intensity interpolation)

Geo referencing with additional resampling of the image, so that the pixels are exactly positioned within the terrain coordinate system.

Order of Transformation

- After the coordinate transformation, the raster cells may have been oriented differently than the way they were originally in the raster coordinate system.

- The positions of the original grid cells will have **to be interpolated** in the mapping coordinate system.

- Polynomial equations are used to convert source file coordinate into referencing map coordinates.

- Depending upon the distortion in an image, the number of GCPs used and their locations relative to one another complex polynomial equations may be required to express the **needed transformations**.

No of GCPs and order of Transformation

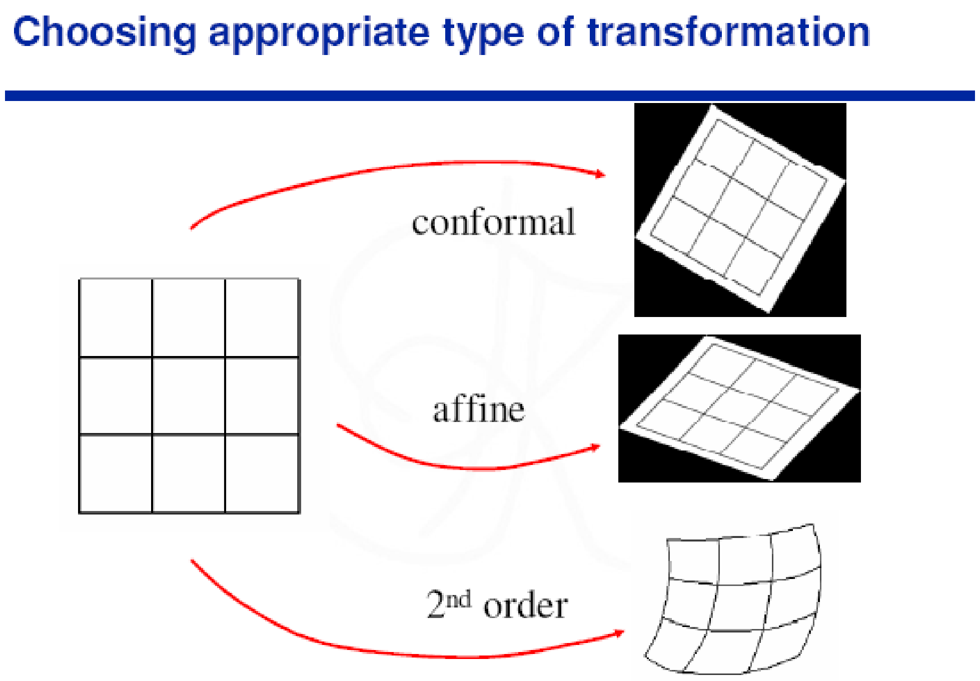
Use more than minimum number of GCPs whenever possible. Although it is possible to get a perfect fit, it is rare , no matter how many GCPs are used. For 1st through 10th –order transformations, the minimum number of GCPs required to perform a transformation is listed in the following table.

Order of Transformation	Minimum GCPs Required
1	3
2	6
3	10
4	15
5	21
6	28
7	36
8	45
9	55
10	66

Transformation methods

- Two dimensional Cartesian coordinates (x, y) can be transformed from one coordinate system to another coordinate system using three primary transformation methods which are:

- 1.Conformal
- 2.Affine
- 3. 2^{nd} Order Polynomial



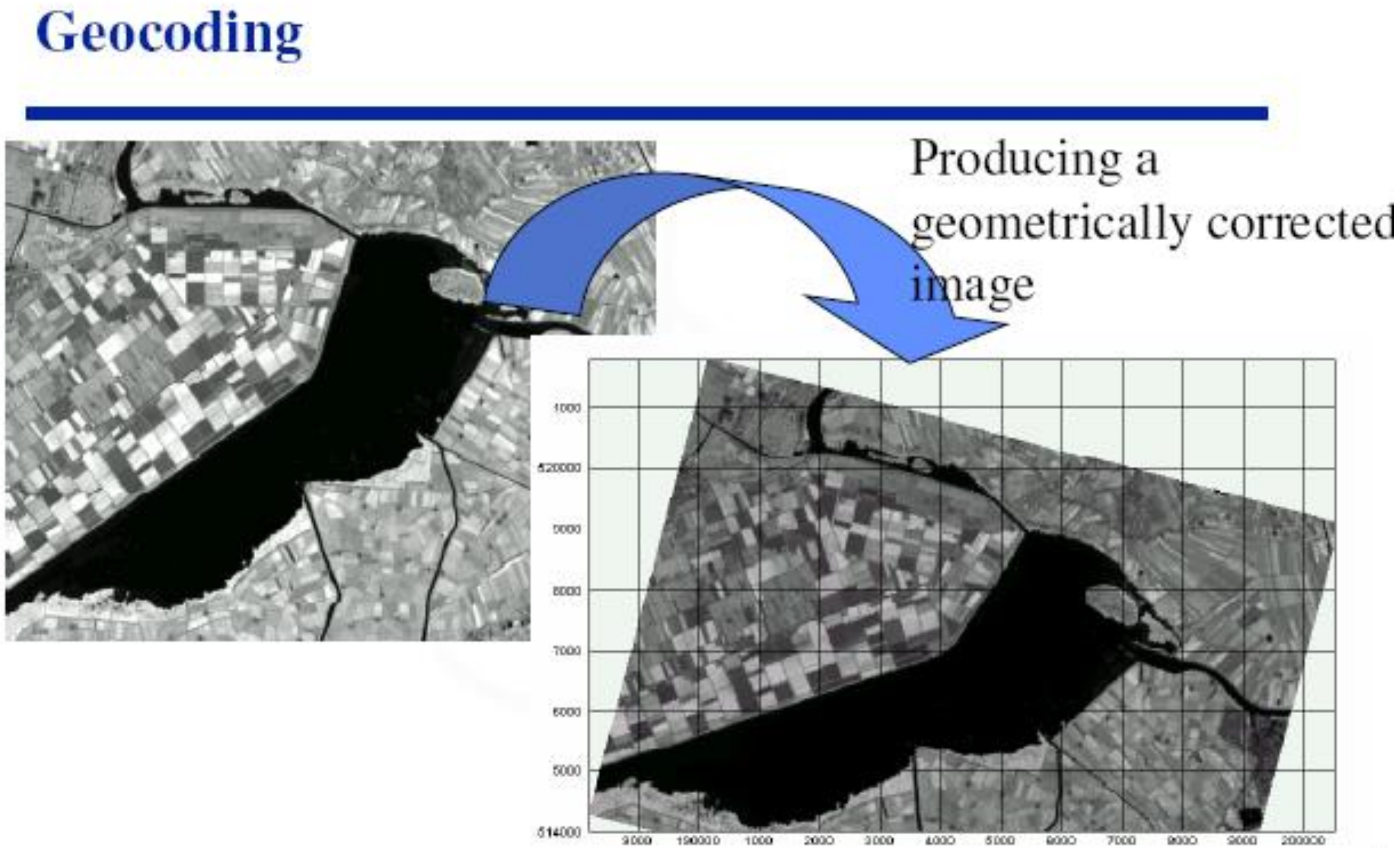
Source: Internet

RMS- Root Mean Square

- The statistical technique of least squares regression is generally used to determine the coefficients for the coordinate transformation equations.
- Want to minimize the residual error (RMS (root mean square) error) between the predicted (X’) and **observed** (X'_{orig}) locations.
- RMS error = SQRT[$(X' - X'_{orig})^2 + (Y' - Y'_{orig})^{2]}$

Geocoding

- Geo referencing with additional resampling of the image so that the pixels are exactly positioned within the terrain coordinate system.



Source: Internet

Resampling

- The attribute value is to be interpolated for the cells oriented to the new coordinate system. This is called resampling.

There are three common methods of resampling:

- **Nearest neighbor,**
- **Bilinear interpolation and**
- **Cubic convolution**

- The resampling is used to determine the digital values to place in the new pixel locations of the corrected output image. It is the process of fitting one raster grid to the new rectified raster grid. Input and output grids do not match exactly.

Three common methods of resampling

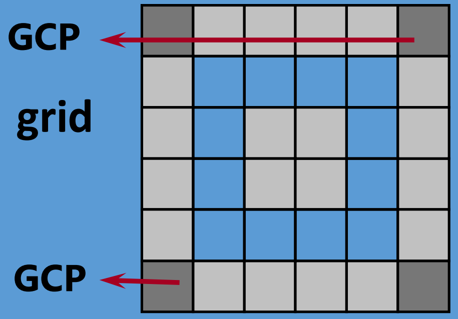
Nearest neighbor: In this method, the attribute value of the original cell nearest to a cell in the output raster layer is assigned to the corresponding cell.

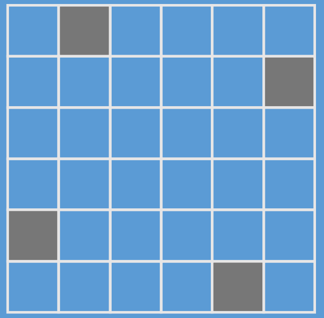
Bilinear interpolation: It assigns the value to a cell in the output raster layer by taking weighted average of the surrounding four cells in the original grid nearest to it.

Cubic convolution: It assigns the value to a cell in the output raster layer by taking weighted average of the surrounding sixteen cells in the original grid nearest to it.

Resampling

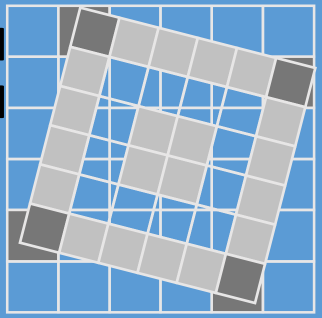
1. Source grid with GCPs

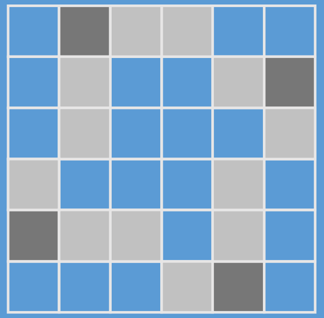




2. Output grid with GCPs

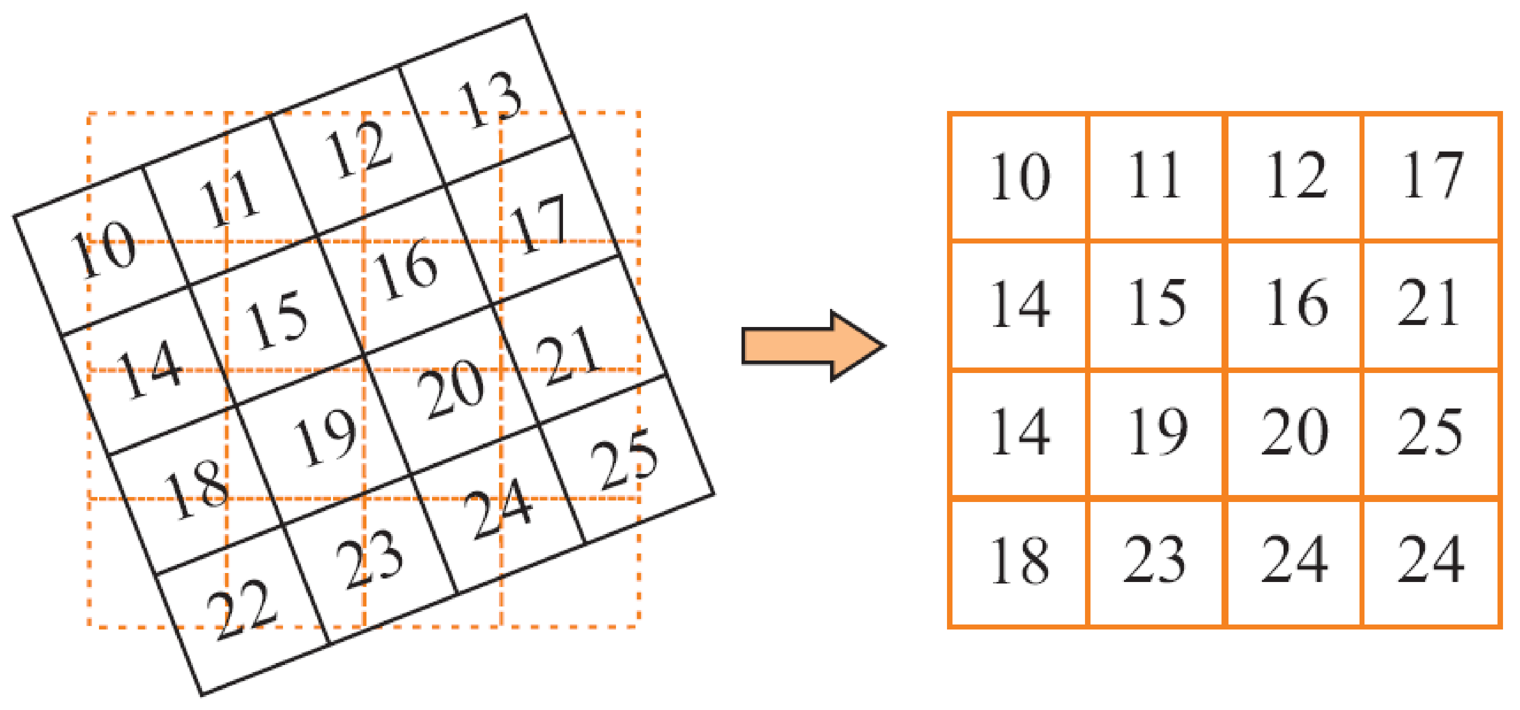
3. Source grid laid over output grid with GCPs aligned





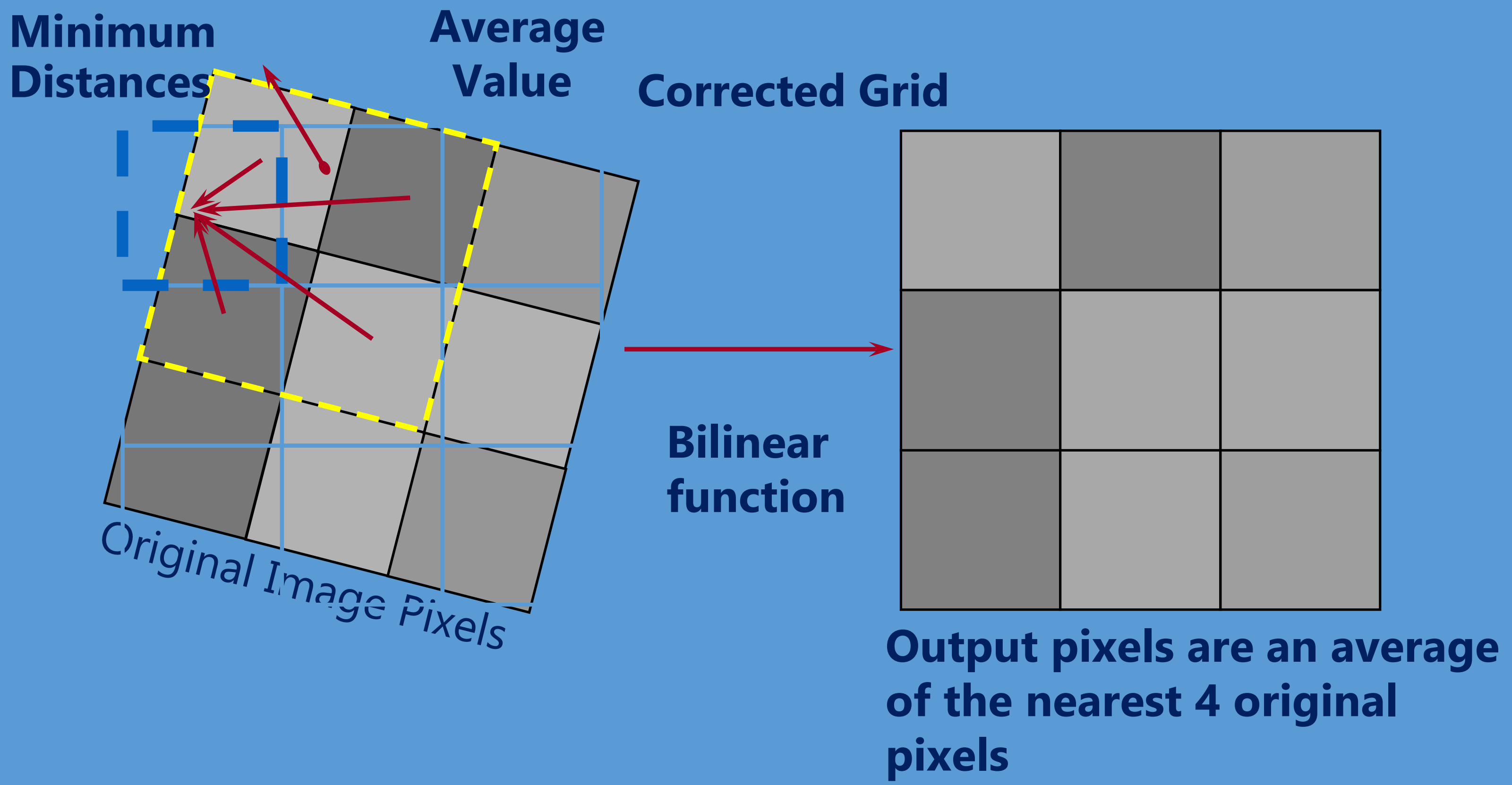
4. Pixel values from the source are assigned to pixels in output grid using a resampling method

Nearest Neighbour uses the input cell value closest to the output cell as the assigned value to the output cell.



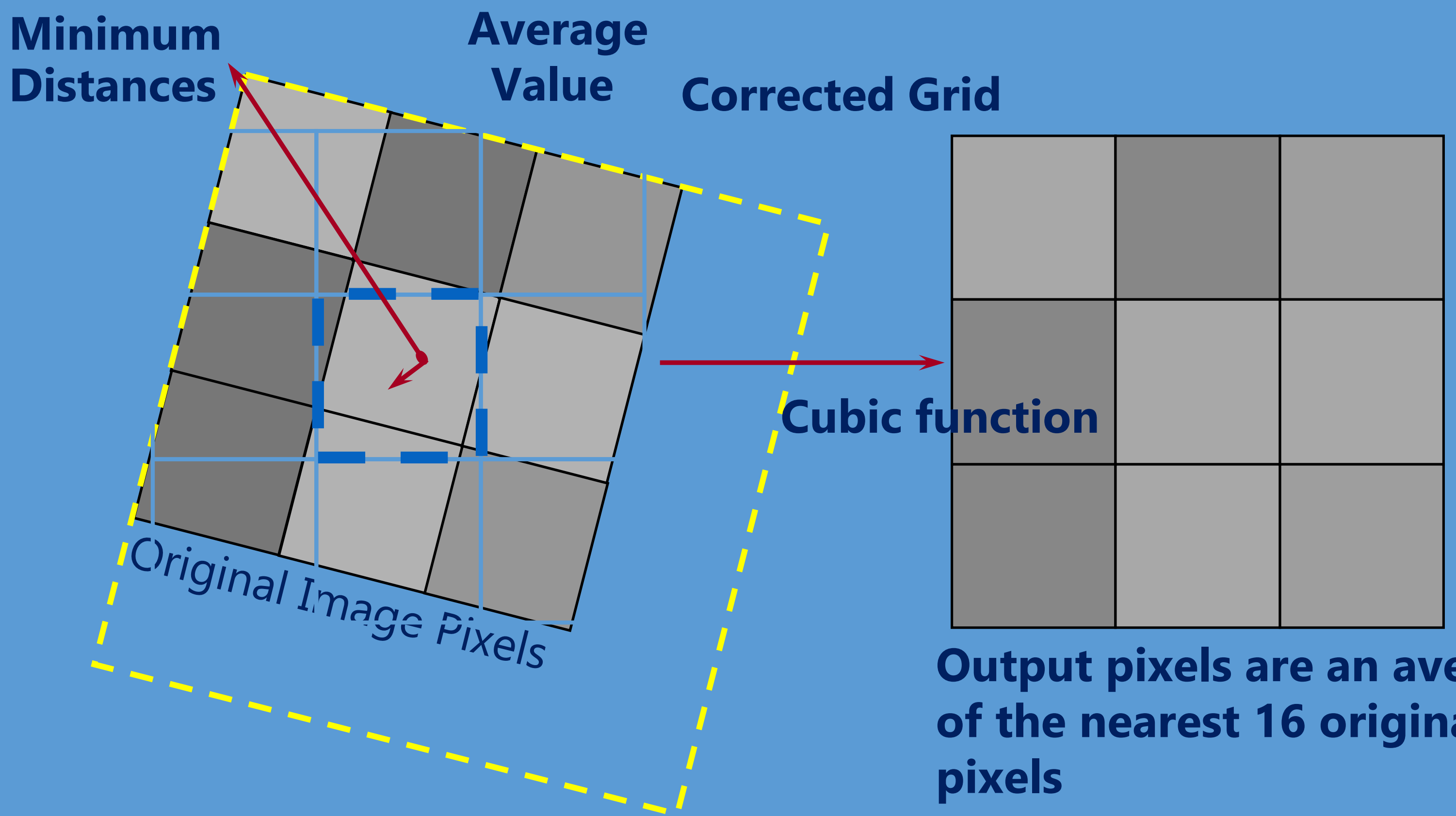
- **PROBLEMS**: Pixel duplication & drop-out
- **BENEFITS**: Original pixel value maintained; fastest

Bilinear Interpolation calculates the output cell value by calculating the weighted average of the four closest input cells based on distance.



- **PROBLEMS: Original pixel value integrity lost; slower**
- **BENEFITS: More spatially accurate; smooth transitions**

Cubic Convolution calculates the output cell value by calculating the weighted average of the closest 16 input cells based on distance.



Output pixels are an average of the nearest 16 original pixels

- **PROBLEMS:** Original pixel value integrity lost; slowest
- **BENEFITS:** Sharpen images and smooth noise

Types of Geometric Correction

- Two common geometric correction procedures are often used by scientists to make the digital remote sensor data of value:

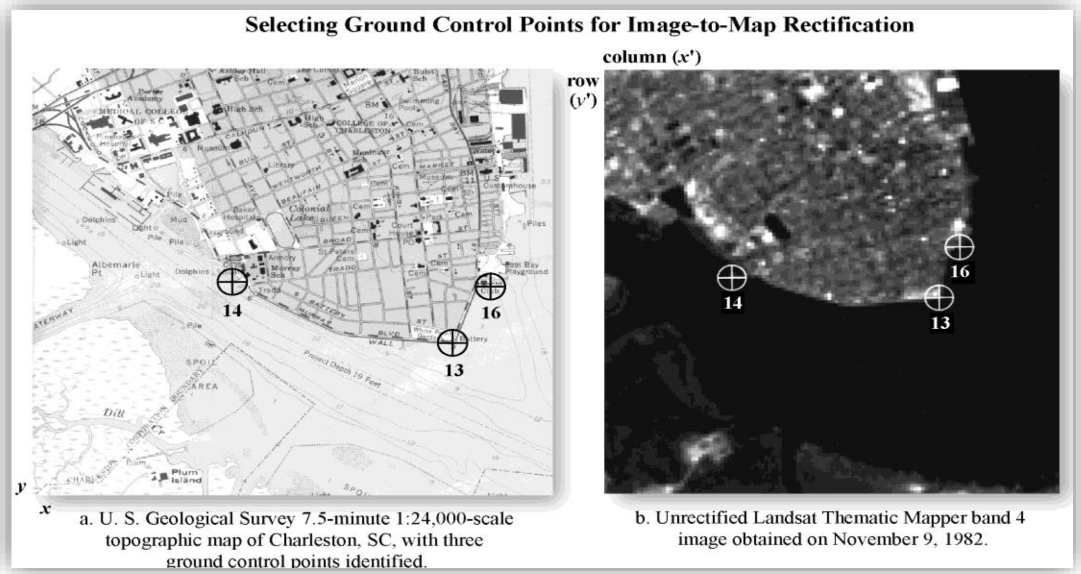
  - image-to-map rectification, and
  - image-to-image registration.

- The general rule of thumb is to rectify remotely sensed data to a standard map projection whereby it may be used in conjunction with other spatial information in a GIS to solve problems.

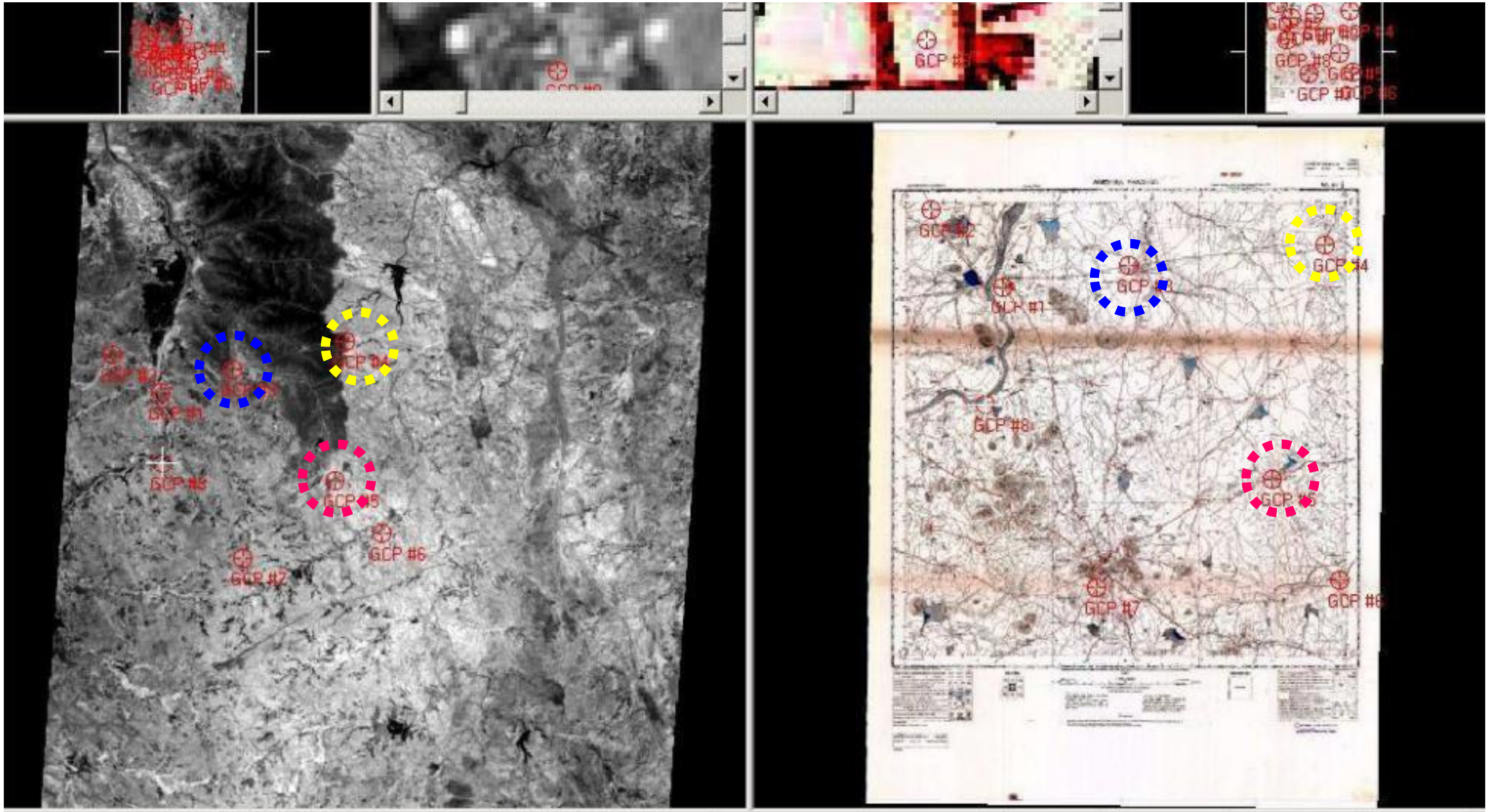
Types of Geometric Correction

- **Image-to-map Rectification**: a process by which the geometry of an image is made planimetric with reference to a projected map.

- It involves the measurement of the image coordinates of the reference cells (GCPs) and the corresponding ground coordinates to relate the image with the real world.



a) U.S. Geological Survey 7.5-minute 1:24,000-scale topographic map of Charleston, SC, with three ground control points identified (13, 14, and 16). The GCP map coordinates are measured in meters easting (*x*) and northing (*y*) in a Universal Transverse Mercator projection. b) Unrectified 11/09/82 Landsat TM band 4 image with the three ground control points identified. The image GCP coordinates are measured in rows and columns.



Point #	Point ID	>	Color	X Input	Y Input	>	Color	X Ref.	Y Ref.	Type	X Residual	Y Residual	RMS Error
6	GCP #6			7315.625	-8598.125			13048.064	-9285.370	Control	4.189	-0.398	4.20

Image to Image Registration:

- Image to Image registration is a method of **georeferencing a raster layer** with the **help of another raster**, which is already georeferenced by the process of image to map rectification.
- Control points are selected from the two raster layers, the coordinate transformation and resampling is then done in the similar manner as it is done for image to map rectification.
- The **image used as a reference** (with known projection and coordinates) is called the **master image**, and the **image to be registered** is called the **subject image.**
- It is important that the reference map or image is rendered in a standard map projection and coordinate systems.

Radiometric Corrections

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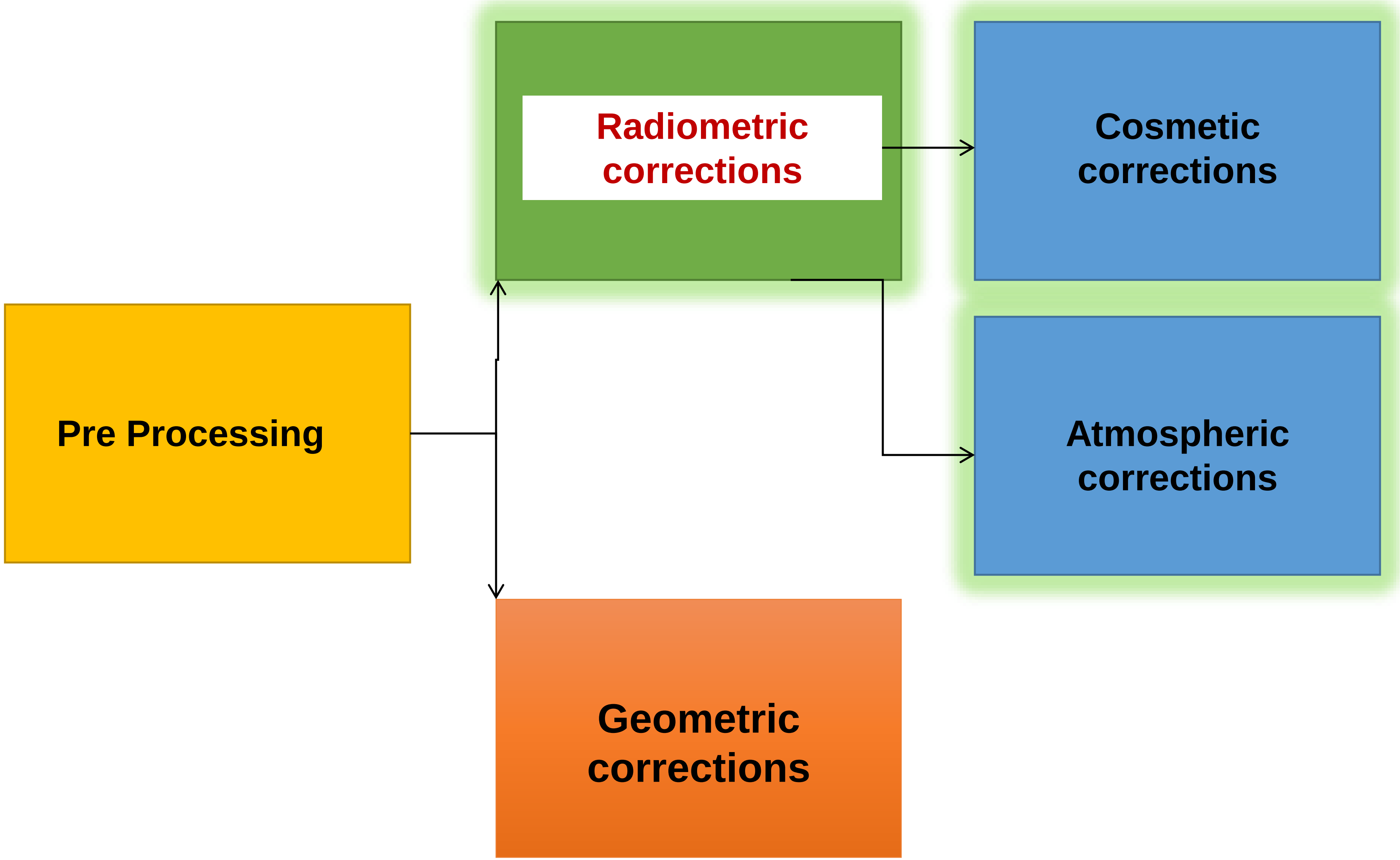
RADIOMETRIC CORRECTION



Radiometric correction

- Radiometric correction of remotely sensed data normally involves the processing of digital image to improve the **fidelity of the brightness value magnitudes.**

- It Reduces the **influence of errors or inconsistencies in image brightness** value that may limit one’s ability to interpret or qualitatively process and analyse digital remote sensing data.

Cosmetic Corrections

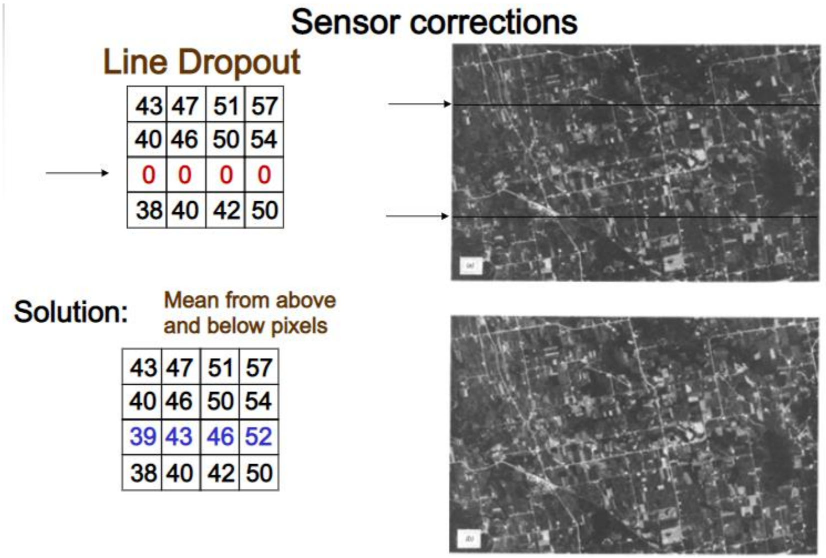
1.Line Dropout Correction

- The first step in the restoration process is to **calculate the average DN-value per scan line** for the entire scene.

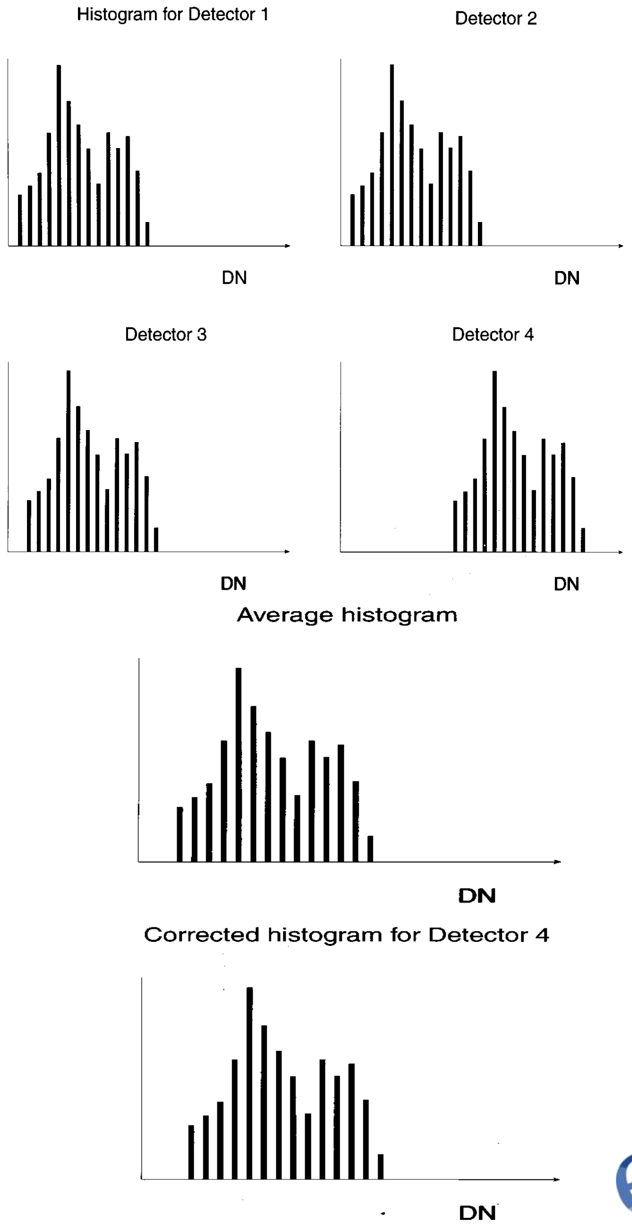
- The next step is to **replace the defective lines**.

- For each pixel in a defective line, an average DN is calculated using DNs for the corresponding pixel in the **preceding** and **succeeding scan lines.**

- The average DN is then substituted for the defective pixel.



2.Line Banding Correction



- If **one detector** is **no longer producing data** readings consistent with the other detectors, its **histogram will be different**.

- The **DNs produced by all** the detectors are altered so that their **histograms are then made to match** the average one.

- When this procedure is completed, the imbalance between the detectors is eliminated and the image is said to have been **de-striped.**

Atmospheric attenuation

- Solar radiation when it interacts with the Earth's atmosphere, it is selectively **scattered and absorbed.**
- The sum of these two forms of energy loss is called **atmospheric attenuation**.

How Atmospheric attenuation affects?

The **magnitude of radiance** leaving ground is attenuated by **atmospheric absorption** and the directional properties are **altered due to scattering**. Other sources of errors are due to the **varying illumination** geometry dependent on **sun's azimuth and elevation angles** with **ground terrain**.

ATMOSPHERIC CORRECTION

Absolute atmospheric correction:

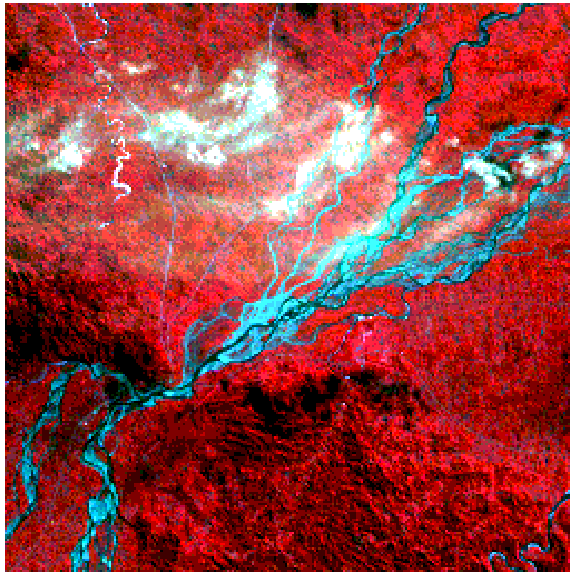
- The general goal of absolute radiometric correction is to turn the digital brightness values (or DN) into scaled surface reflectance values.

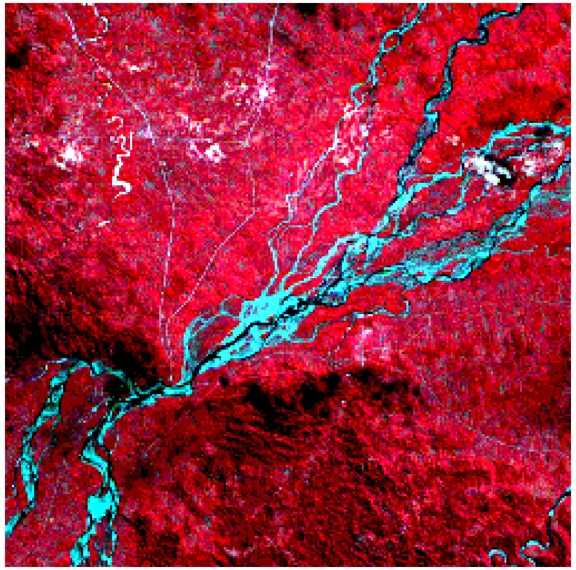
DN → RADIANCE → REFLECTANCE

Relative atmospheric correction:

- Also called image normalization, this procedure uses a standard image to normalize other, temporally adjacent images.
- The statistical or empirical based atmospheric correction models provide good estimates of the surface reflectance.

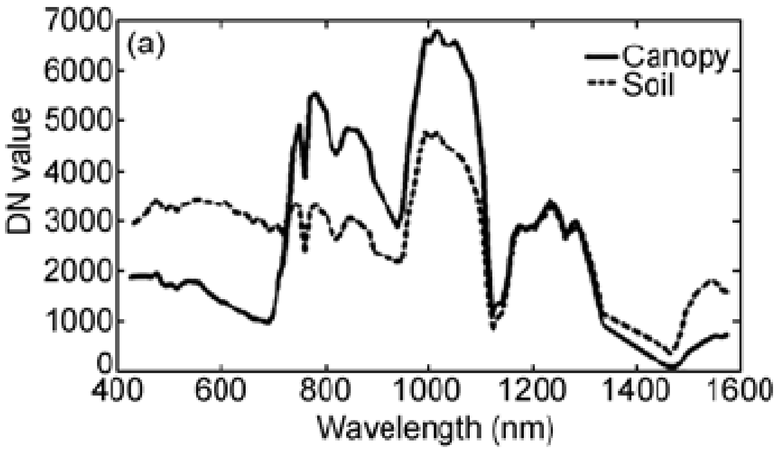
Effect of Atmospheric Correction on imagery



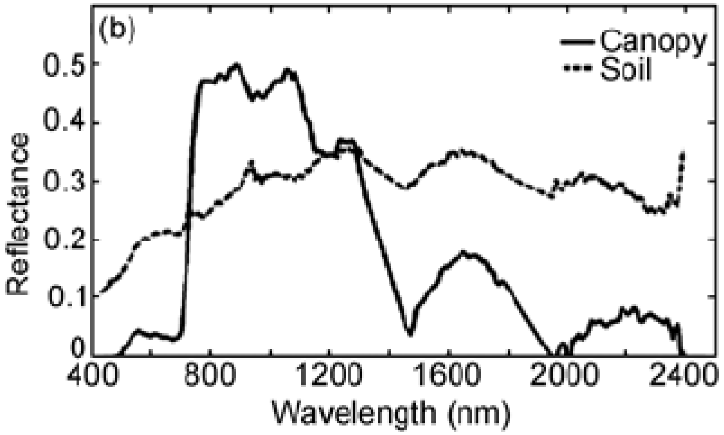


Before Correction   *After Correction*

Effect of Atmospheric Correction on Spectra

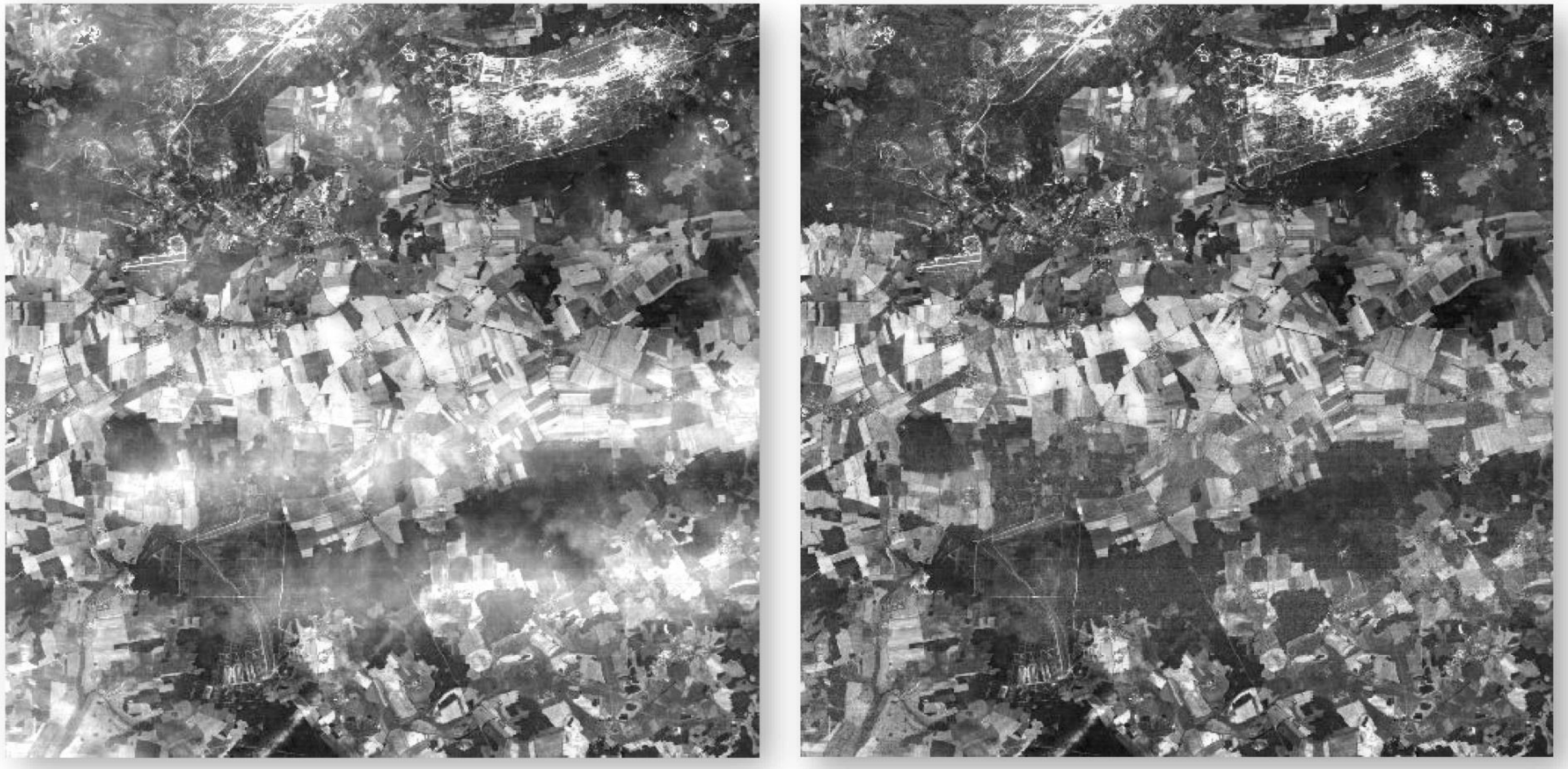


DN value before atmospheric correction



Reflectance value after atmospheric correction

Haze Reduction



a. Before atmospheric correction. b. After atmospheric correction.