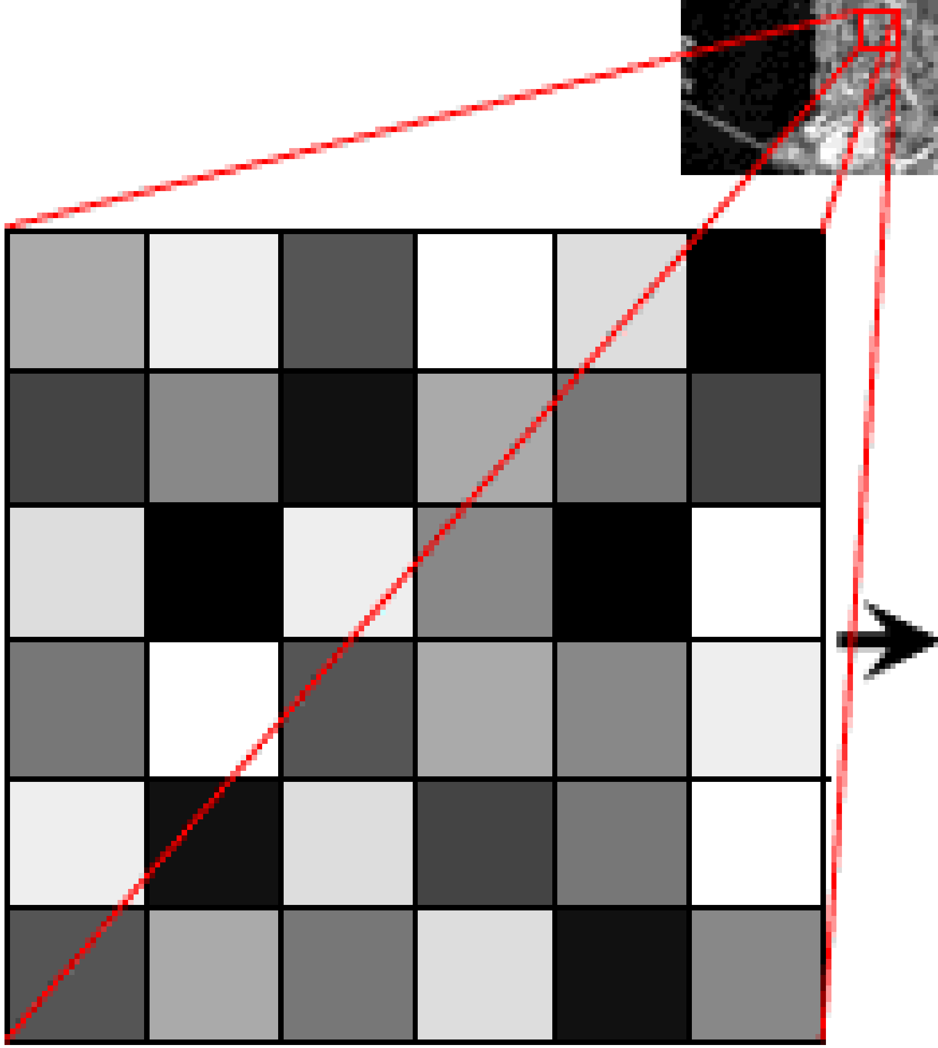
UNIT-3

DIGITAL IMAGE

What is a digital Image ?

- A digital image is composed of a **set of pixels** (picture elements), similar to dots on a newspaper photograph or grains on a photographic print, arranged according to a **predefined ratio of columns and rows**.
- A digital image is a **two-dimensional array** of small square regions known as pixels.
- The brightness of each pixel is represented by a numeric value known as **Digital Number (DN)** values.
- Gray-scale images typically contain values in the range from **0 to 255**
- 0 representing black
- 255 representing white
- values in between representing shades of gray.

Size of a cell - image resolution - PIXEL



170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

DIGITAL IMAGE PROCESSING

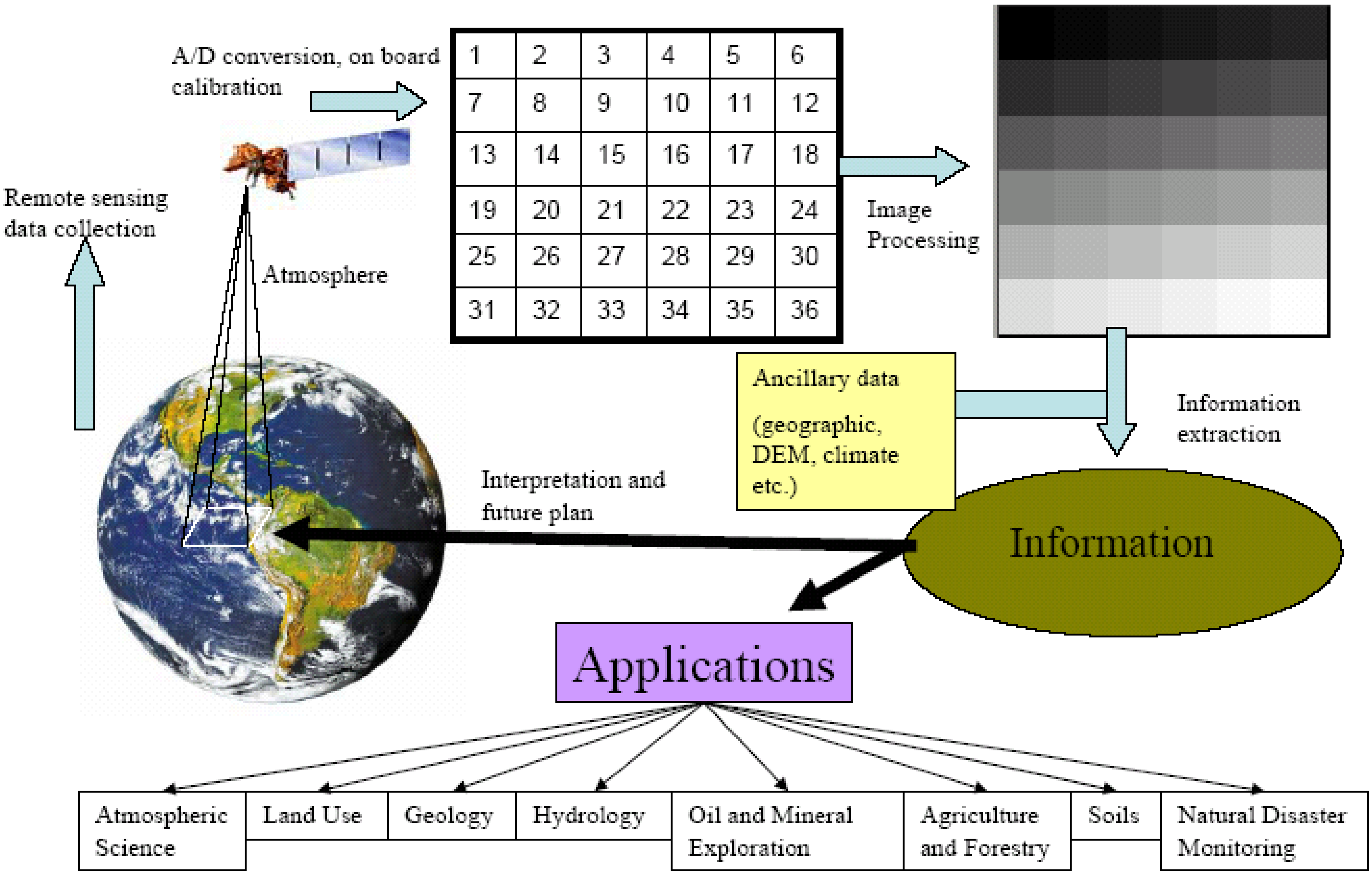
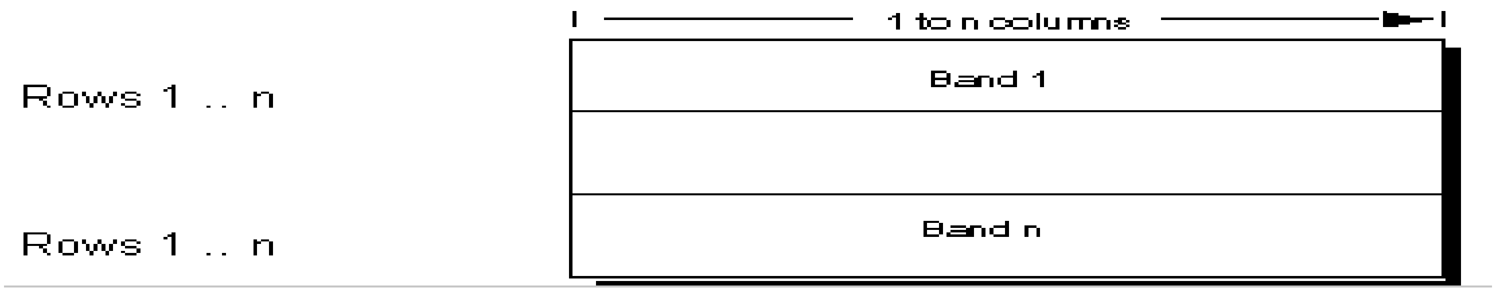


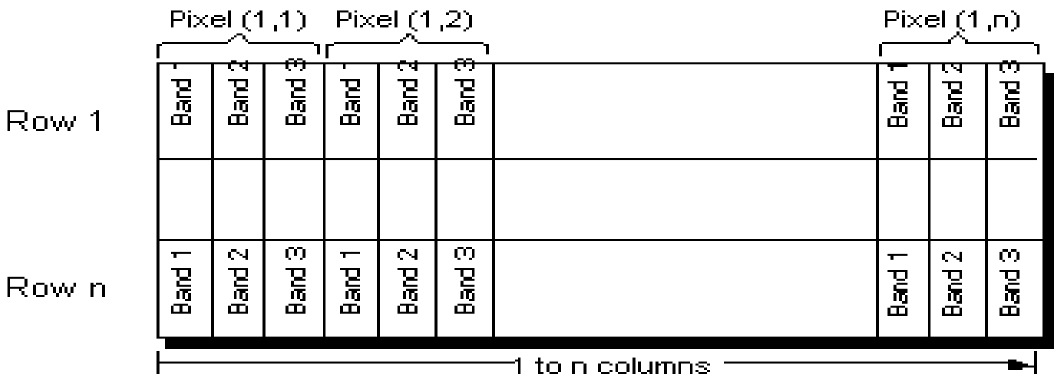
Image file formats

- **BSQ (Band Sequential Format): each line of the data followed immediately by the next line in the same spectral band**.
- Band sequential (BSQ) format stores information for the **image one band at a time**. In other words, data for all pixels for band 1 is stored first, then data for all pixels for band 2, and so on.
  Value=image(c, r, b)
- This format is optimal for spatial (X, Y) access of any part of a single spectral band.



- **BIP (Band Interleaved by Pixel Format): the first pixel for all bands in sequential order, followed by the second pixel for all bands, followed by the third pixel for all bands, etc., interleaved up to the number of pixels**. This format provides optimum performance for spectral (Z) access of the image data.
- BIP data is similar to BIL data, except that the data for each pixel is written band by band. For example, with the same three-band image, the data for bands 1, 2 and 3 are written for the first pixel in column 1; the data for bands 1, 2 and 3 are written for the first pixel in column 2; and so on.

Value=image(b, c, r)

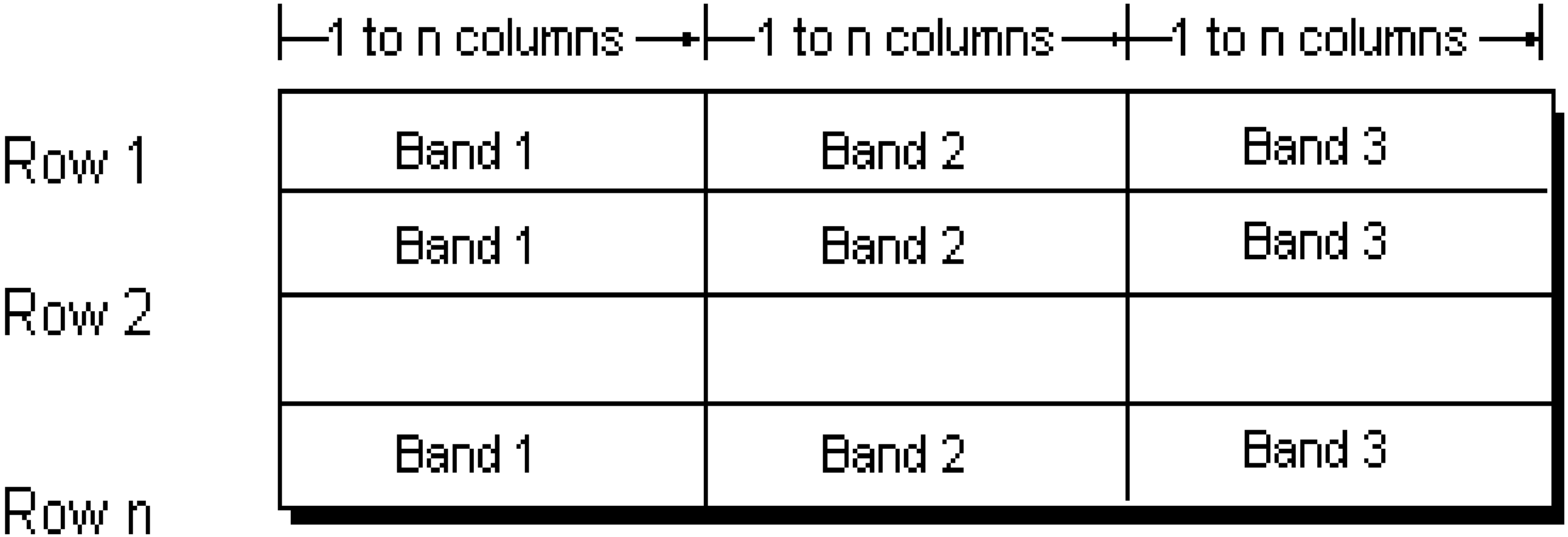


- **BIL (Band Interleaved by Line Format):**

  the first line of the first band followed by the first line of the second band, followed by the first line of the third band, interleaved up to the number of bands. Subsequent lines for each band are interleaved in similar fashion. This format provides a compromise in performance between spatial and spectral processing

- Band interleaved by line (BIL) data stores pixel information band by band for each line, or row, of the image. For example, given a three-band image, all three bands of data are written for row 1, all three bands of data are written for row 2, and so on, until the total number of rows in the image is reached.

  Value=image(c, b, r)


1 to n columns
1 to n columns
1 to n columns
Row 1
Row 2
Row n
Band 1
Band 2
Band 3
Band 1
Band 2
Band 3
Band 1
Band 2
Band 3

DIGITAL IMAGE PROCESSING

Enhancing an image or extracting information or features from an image.

DIP involves the manipulation and interpretation of digital images with the aid of computer.

The process of DIP consist of mainly three steps :

- Data Acquisition/Restoration
- Image Enhancement
- Information Extraction

- Others
  - Data merging and GIS integration
  - Hyperspectral image analysis
  - Image transmission and compression

DIGITAL IMAGE PROCESSING

1. Data Acquisition/Restoration
    - Digitize Analog Data
    - Collect or purchase Digital Data
2. Image Enhancement
    - Preprocessing
        - Radiometric Correction
        - Geometric Correction
    - For Visual Analysis
    - For further Digital Analysis
3. Information Extraction
    - Classification Scheme
        - Unsupervised Classification
        - Supervised Classification
    - Evaluate Accuracy

Image Pre-processing / Image Restoration

- Pre-processing operations, sometimes referred to as image restoration and rectification, are intended to **correct for sensor- and platform-specific radiometric and geometric distortions of data**.

- Pre processing functions are normally carried out **prior** to the main data analysis and extraction of information

- Preprocessing
  - Radiometric correction is concerned with improving the accuracy of surface spectral reflectance, emittance, or back-scattered measurements obtained using a remote sensing system. **Detector error correction, Atmospheric and topographic corrections**

  - Geometric correction is concerned with placing the above measurements or derivative products in their proper locations.

Radiometric Correction

Types of radiometric correction

- Detector error or sensor error (internal error)
- Atmospheric error (external error)
- Topographic error (external error)

Error sources

- ***Internal errors*** are introduced *by the remote sensing system*. They are generally **systematic (predictable)** and may be identified and then corrected based on prelaunch or in-flight calibration measurements. For example, *n*-line striping in the imagery may be caused by a single detector that has become uncalibrated. In many instances, radiometric correction can adjust for **detector miscalibration**.
- ***External errors* are introduced by *phenomena that vary in nature through space and time***. External variables include the **atmosphere, terrain elevation, slope, and aspect**. Some external errors may be corrected by relating empirical **ground observations** (i.e., *radiometric* and *geometric ground control points*) to sensor measurements.

Correcting detector or sensor error

Noise (**error)** can enter the data-collection system at several points. For eg., radiometric error in remotely sensed data may be introduced by the sensor system itself when the individual detectors do not function properly or are improperly calibrated. More common remote sensing system–induced radiometric errors:

- random bad pixels (shot noise),
- line-start/stop problems,
- line or column drop-outs,
- partial line or column drop-outs, and
- line or column striping.

Banding/Stripping/ Line-Dropouts

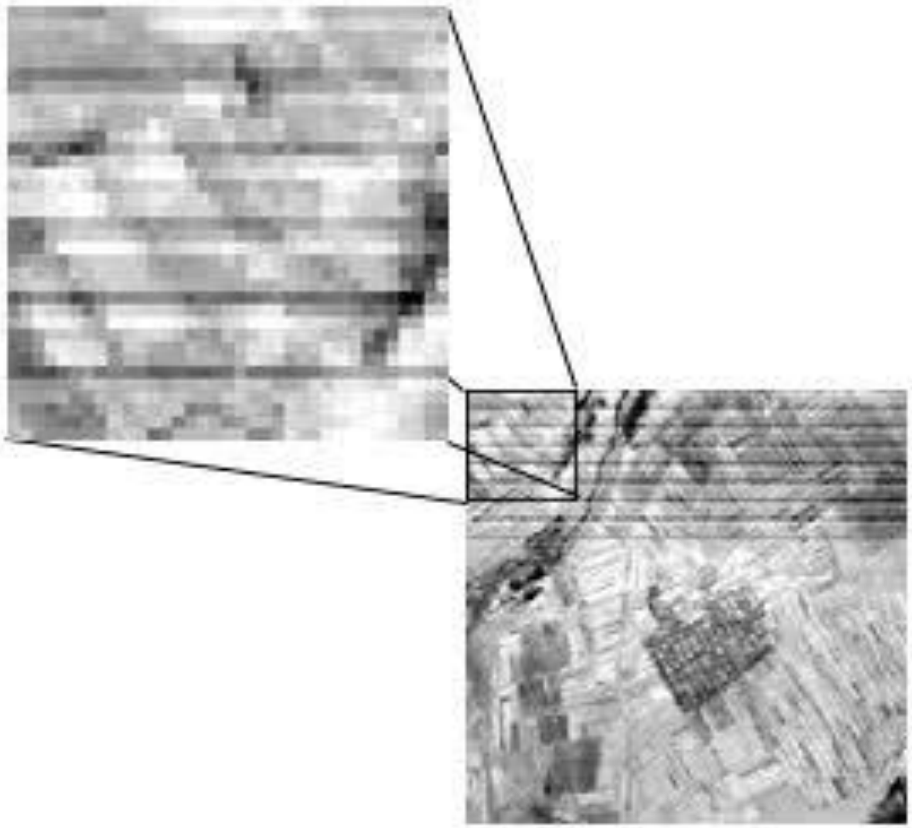
- A string of adjacent pixels in a scan line contain spurious DN. This can occur when a **detector malfunctions permanently or temporarily**.

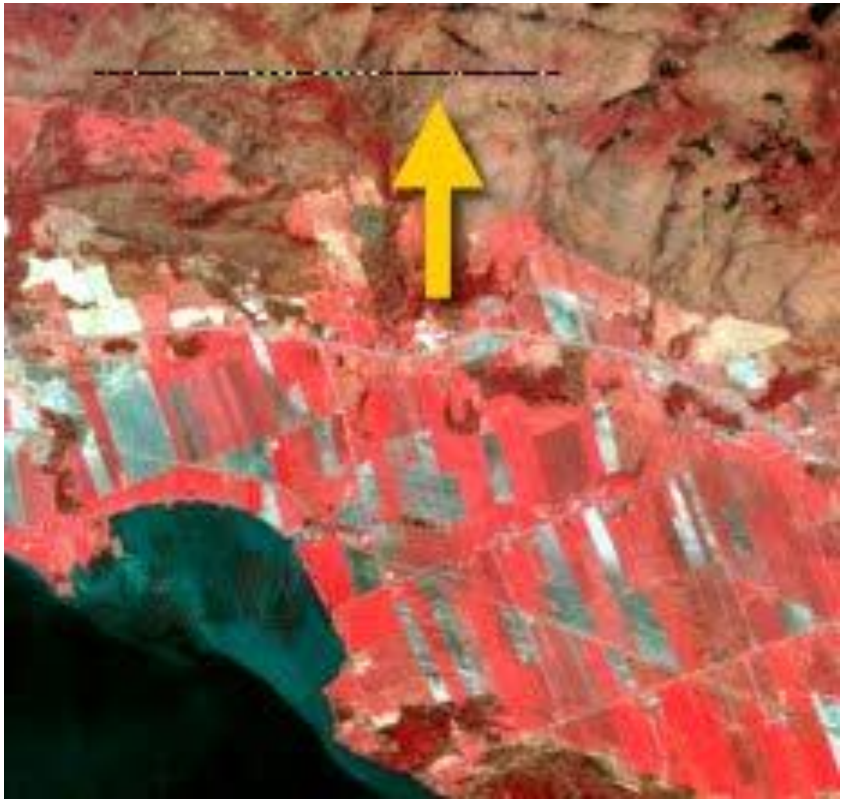
- Detectors are loaded by receiving **sudden high radiance**

- The systematic horizontal banding pattern seen on images produced by electro-mechanical scanners

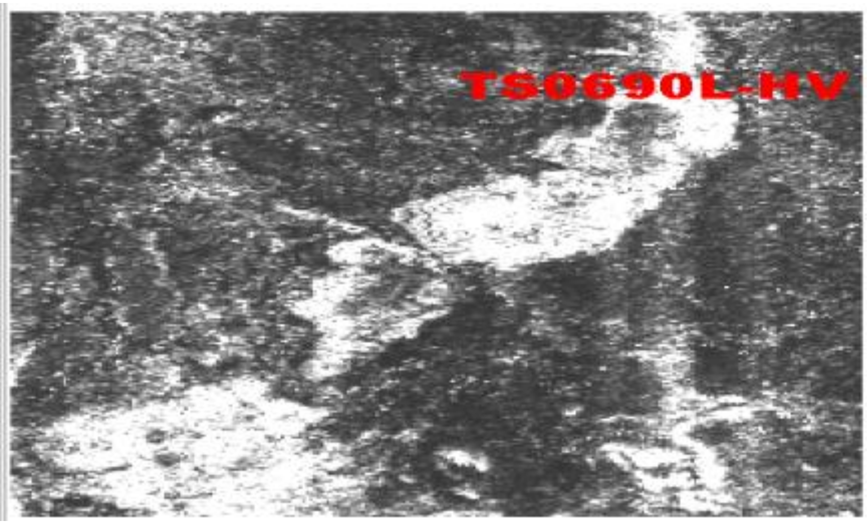
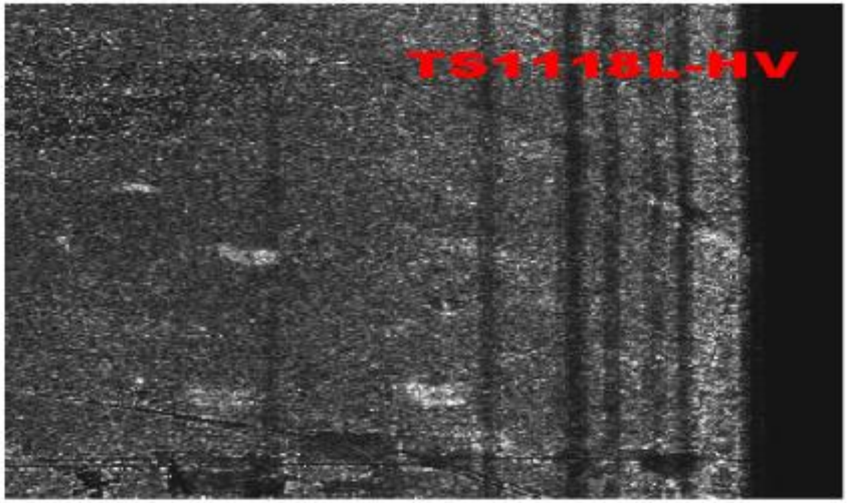
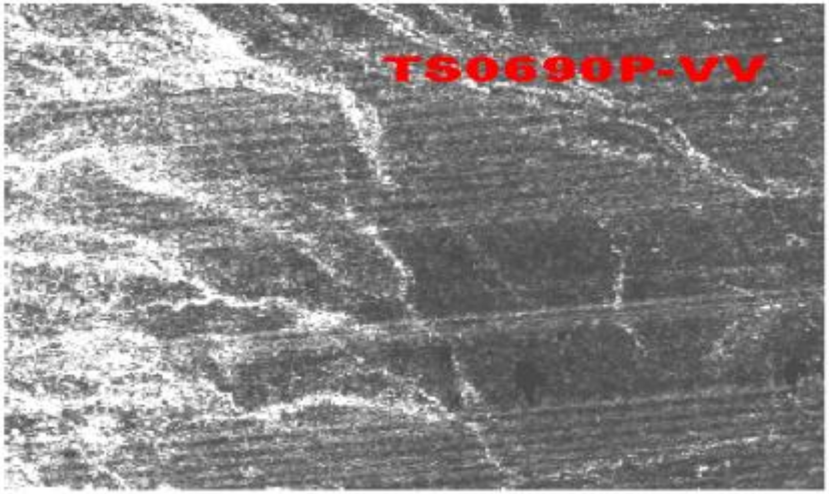
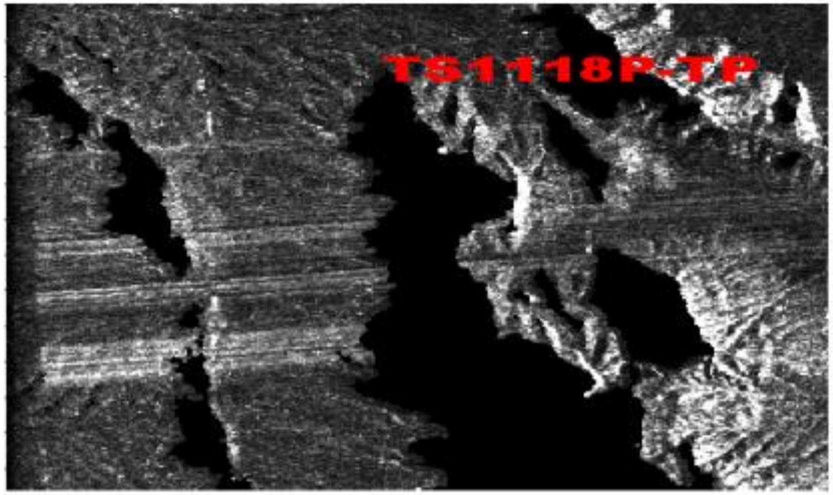
- Creating a line or partial line of data with the meaningless DN.

Line-Dropouts





Examples of Stripping and line dropouts


TS0690L-HV

TS1118L-HV

TS0690P-VV

TS1118P-TP

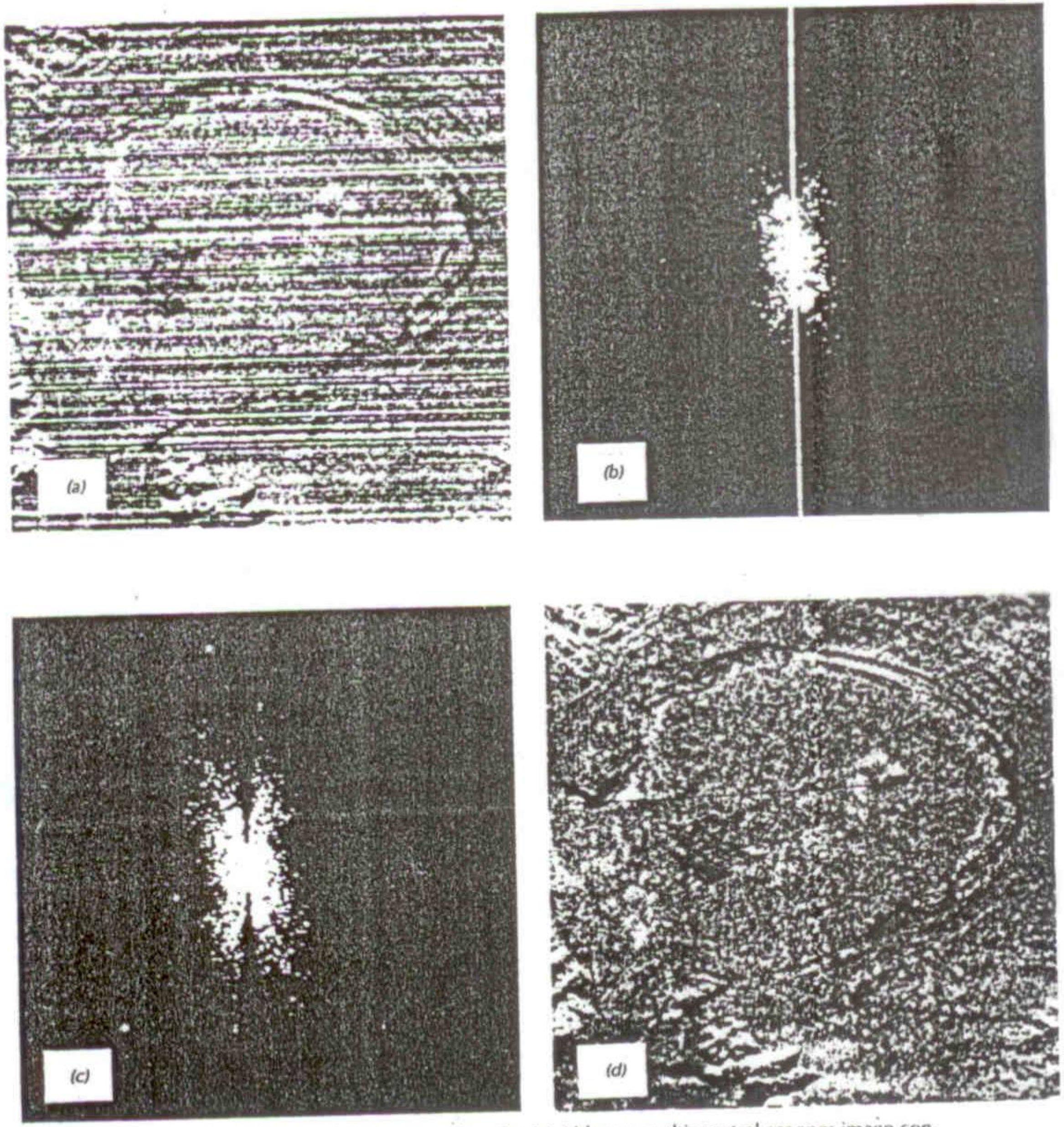
De-stripping

- Line dropouts are usually **corrected either by replacing the defective line by a**
  - **duplicate of preceding or subsequent line**
  - **taking the average of the two**
  - **Histogram**
  - **FFT**

If the spurious pixel, sample x, line y has a value DNx,y then the algorithms are simply:

$$DN_{x,y} = DN_{x,y}\text{-}1$$

$$DN_{x,y} = (DN_{x,y}\text{-}1 + DN_{x,y}\text{+}1)/2$$



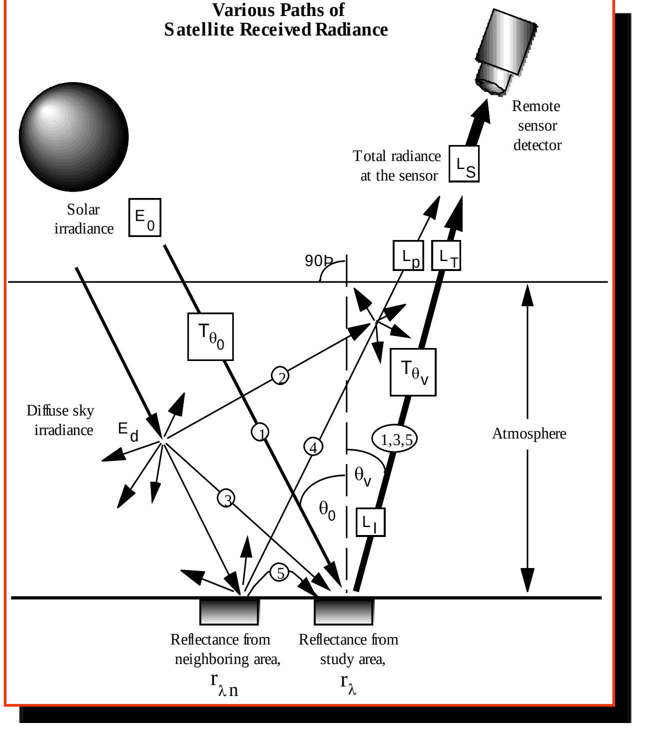
Noise elimination in the frequency domain. (*a*) Airborne multispectral scanner image containing noise. (Courtesy NASA.) (*b*) Fourier spectrum of (a). (*c*) Wedge block filter. (*d*) Inverse transform of (c).

De-Striping

Two reasons can be thus put forward in favor of applying a 'de-striping' correction :

- The visual appearance and interpretability of the image are thereby improved.
- Equal pixel values in the image are more likely to represent areas of equal ground leaving radiance, other things being equal.

Atmospheric correction



- There are several ways to atmospherically correct remotely sensed data.
- Some are relatively straightforward while others are complex.
- Two major types of atmospheric correction:
  - ***Absolute atmospheric correction***
  - ***Relative atmospheric correction***

Absolute atmospheric correction

Solar radiation is largely unaffected as it travels through the vacuum of space. When it interacts with the Earth's atmosphere, however, it is selectively **scattered and absorbed**. **The sum of these two forms of energy loss is called atmospheric attenuation**. Atmospheric attenuation may

- make it difficult to relate hand-held *in situ* spectroradiometer measurements with remote measurements
- make it difficult to extend spectral signatures through space and time
- have an impact on classification accuracy within a scene if atmospheric attenuation varies significantly throughout the image.

The goal of ***absolute radiometric correction*** is to turn the **digital brightness values (or DN) recorded by a remote sensing system into scaled surface reflectance values.**

These values can then be compared or used in conjunction with scaled surface reflectance values obtained anywhere else on the planet.

Radiative transfer-based atmospheric correction algorithms

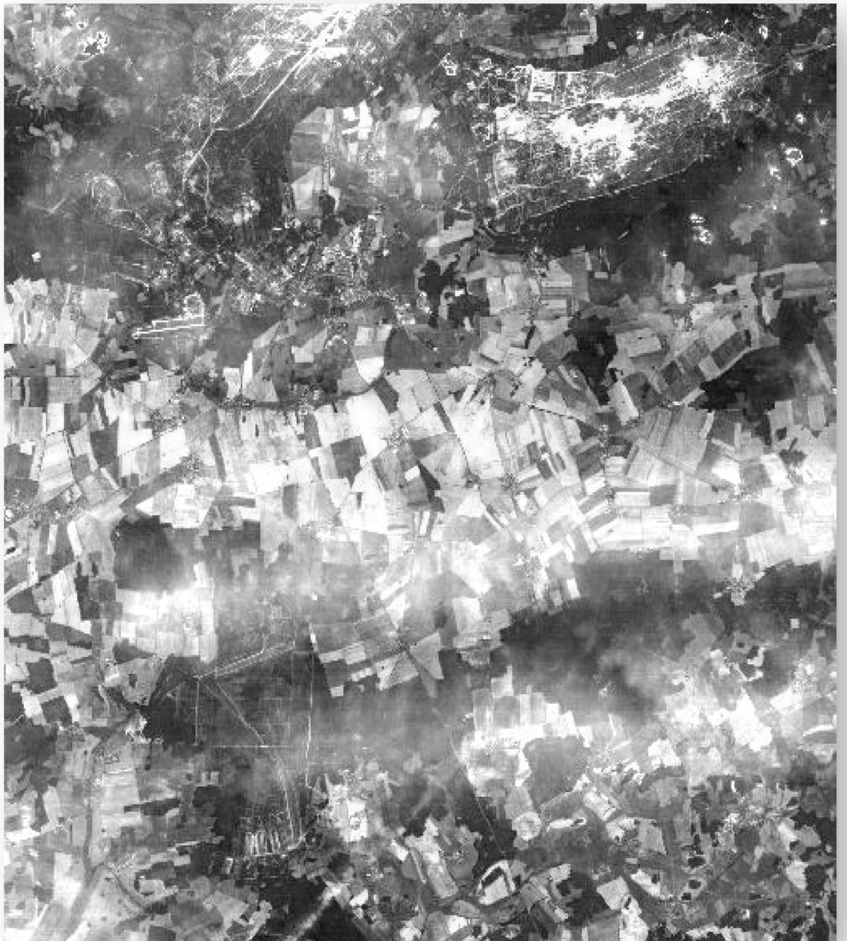
- Correcting images for atmospheric effects.
  - a number of ***atmospheric radiative transfer codes*** *(models)* that can provide realistic estimates of the effects of atmospheric **scattering and absorption** on satellite imagery.

  - 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***.

- Unfortunately, the application of these codes to a specific scene and date also 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**.
- Even today, **accurate scaled surface reflectance retrieval is not operational** for the majority of satellite image sources used for land-cover change detection.

Most current *radiative transfer-based atmospheric correction algorithms* can compute much of the required information if the user provides **fundamental atmospheric characteristic information** to the program

- **latitude and longitude** of the image scene,
- **date and exact time** of remote sensing data collection,
- image acquisition **altitude**
- an **atmospheric model**,
- **radiometrically calibrated image radiance data**,
- data about **each specific band**
- **local atmospheric visibility at the time** of remote sensing data collection (e.g., 10 km, obtained from a nearby airport if possible)



a. Before atmospheric correction.

b. After atmospheric correction.

a) Image containing substantial haze prior to atmospheric correction.
b) Image after atmospheric correction using ATCOR

Radiometric Correction for Atmospheric errors

- **Dark Pixel Subtraction Technique**

  There is a high probability that there are at least a few pixel within an image which should be black (0% reflectance). For deep clear water in IR, reflectance is zero, any signal for such area represents the path radiance – this value can be subtracted from all the pixels in that band

- **Histogram Adjustment Technique**

  Histogram of the each band is studied in combination to other and the offset is subtracted from the bands

- **Regression Adjustment Technique**

  The regression equation is derived and plotted. The offset on the x-axis is subtracted from the image.

Relative radiometric correction for Atmospheric Error

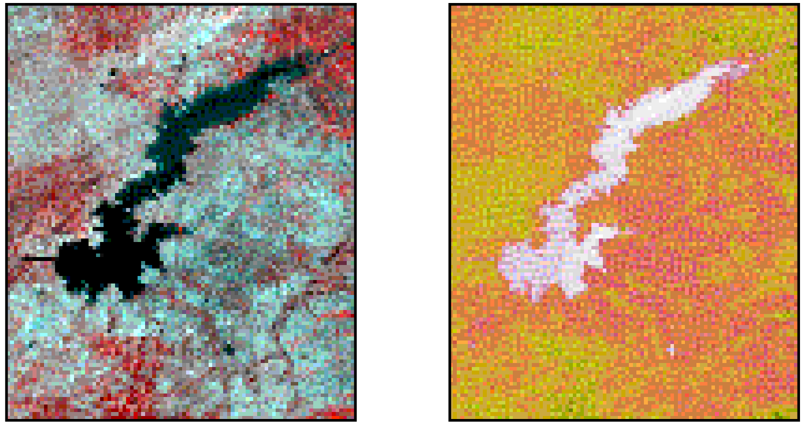
- When required data is not available for absolute radiometric correction, **relative radiometric correction** can be applied

- Relative radiometric correction may be used to
  - Single-image normalization using histogram adjustment
  - Multiple-data image normalization using regression

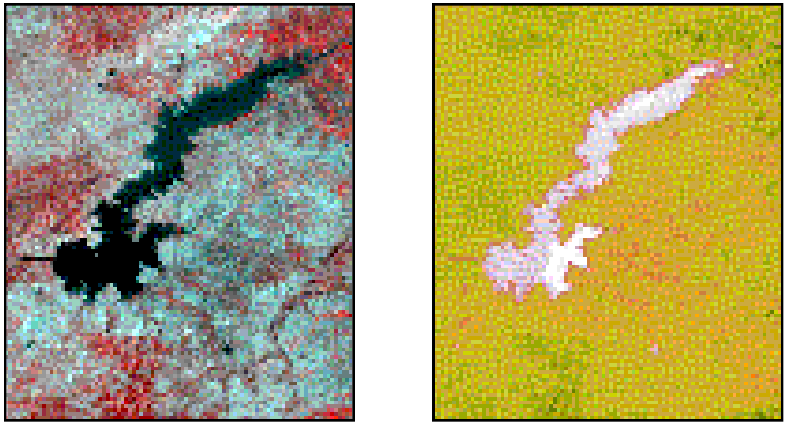
Multiple-data image normalization using regression

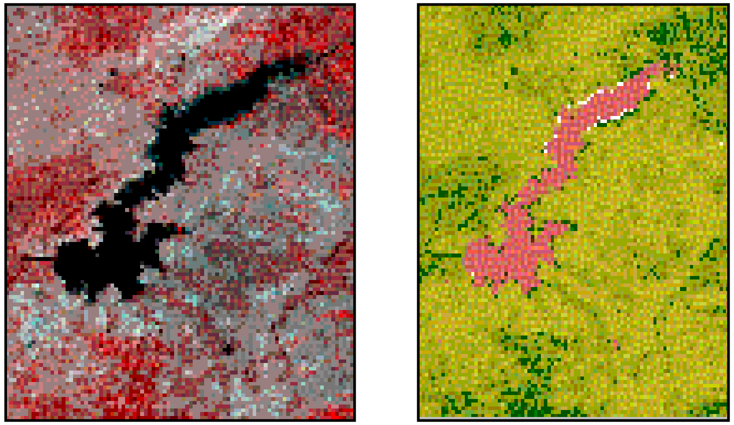
- Select **a base image** and then **transform** the spectral characteristics of **all other images** obtained on different dates to have approximately the **same radiometric scale** as the based image.
- Selecting a **pseudo-invariant features** (PIFs) or region (points) of interest is important:
  - Spectral characteristic of PIFs change very little through time, (deep water body, bare soil, rooftop)
  - PIFs should be in the same elevation as others
  - No or rare vegetation
  - PIF must be relatively flat
- Then PIFs will be used to normalize the multiple-date imagery

Radiometric Corrected Image and comparative NDVIs



Raw Data





Resultant of Dark Pixel Subtraction

Resultant of Scattering Correction

Topographic correction

- Topographic **slope and aspect** also introduce radiometric distortion (for example, areas in shadow)
- Slope-aspect correction is **to remove topographically induced illumination variation** so that two objects having the same reflectance properties show the same brightness value (or DN) in the image **despite their different orientation to the Sun's position**
- Based on DEM, sun-elevation

Geometric Correction

Geometric Corrections

- Imagery are inherently subject to geometric distortions.

- Distortions may be due to several factors, including:
  - the perspective of the sensor optics;
  - the motion of the scanning system;
  - the motion of the platform;
  - the platform altitude, attitude, and velocity;
  - the terrain relief; and,
  - the curvature and rotation of the Earth.

- Geometric corrections involve corrections for geometric distortions due to sensor-earth geometry and conversion of the data to real world coordinates (e.g. latitude and Longitude) on the earths surface

Geometric Errors

- Remotely sensed imagery typically exhibits
  - ***internal* and *external geometric error.***
  - error is ***systematic* (predictable) or *nonsystematic* (random)**
- **Systematic** errors is accounted by **accurate modeling of the sensor and platform motion and the geometric relationship** of the platform with the Earth.
- Other **unsystematic errors cannot be modeled and corrected** in this way. Geometric registration of the imagery to a known ground coordinate system must be performed
- Geometric **rectification** of the image is done using **geometry of satellite and polynomial transformation model**.

- It is usually necessary to ***preprocess*** remotely sensed data and remove geometric distortion so that individual picture elements (pixels) are in their proper planimetric (*x*, *y*) map locations.
- This allows remote sensing–derived information to be **related to other thematic information** in geographic information systems (GIS) or spatial decision support systems (SDSS).
- ***Geometrically corrected imagery*** can be used to extract accurate distance, polygon area, and direction (bearing) information.

Internal geometric errors

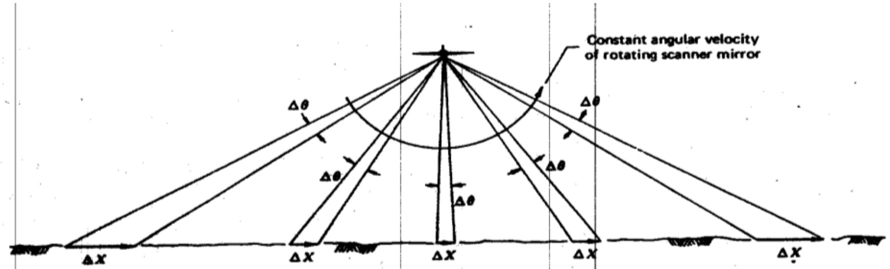
- ***Internal geometric errors*** are introduced by the **remote sensing system itself or in combination with Earth rotation or curvature characteristics**.

- These distortions are often ***systematic*** (predictable) and may be identified and corrected using pre-launch or in-flight platform ephemeris (i.e., information about the geometric characteristics of the sensor system and the Earth at the time of data acquisition).

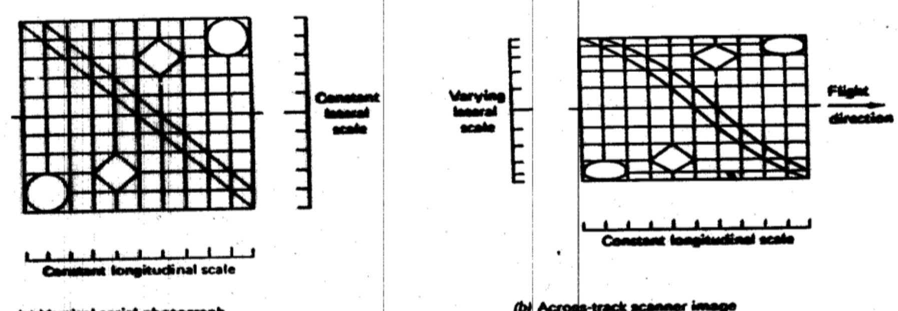
Internal geometric errors

- These distortions in imagery that can sometimes be corrected through **analysis of sensor characteristics** and ephemeris data include:
  - skew caused by Earth rotation effects,
  - scanning system–induced variation in ground resolution cell size,
  - scanning system one-dimensional relief displacement
  - scanning system tangential scale distortion.

- **Earth Rotation Effects**
  During the frame acquisition the **earth rotates from west to east while the satellite passed from pole to pole**. This phenomenon calls for data to be rearranged with respect to the angle of rotation and relative velocity.
- **Panoramic Distortion**
  Remote sensing data is acquired using scanners having **constant IFOV, which results in larger pixel size in the extremes**. It is generally found with the satellites having **large swath**.
- **Earth Curvature**
  It is the inclination of the earth surface over the swath that causes greater effect. **At the edges of the swath the earth surface is having stretched areas**.



Source of tangential scale distortion.



Tangential scale distortion in unrectified across-track scanner imagery.

External geometric errors

- *External geometric errors* are usually introduced by phenomena that **vary in nature through space and time**.

- **Variation in platform altitude, attitude and velocity at the exact time of data collection**
  - *altitude* changes, and/or
  - *attitude* changes (roll, pitch, and yaw).

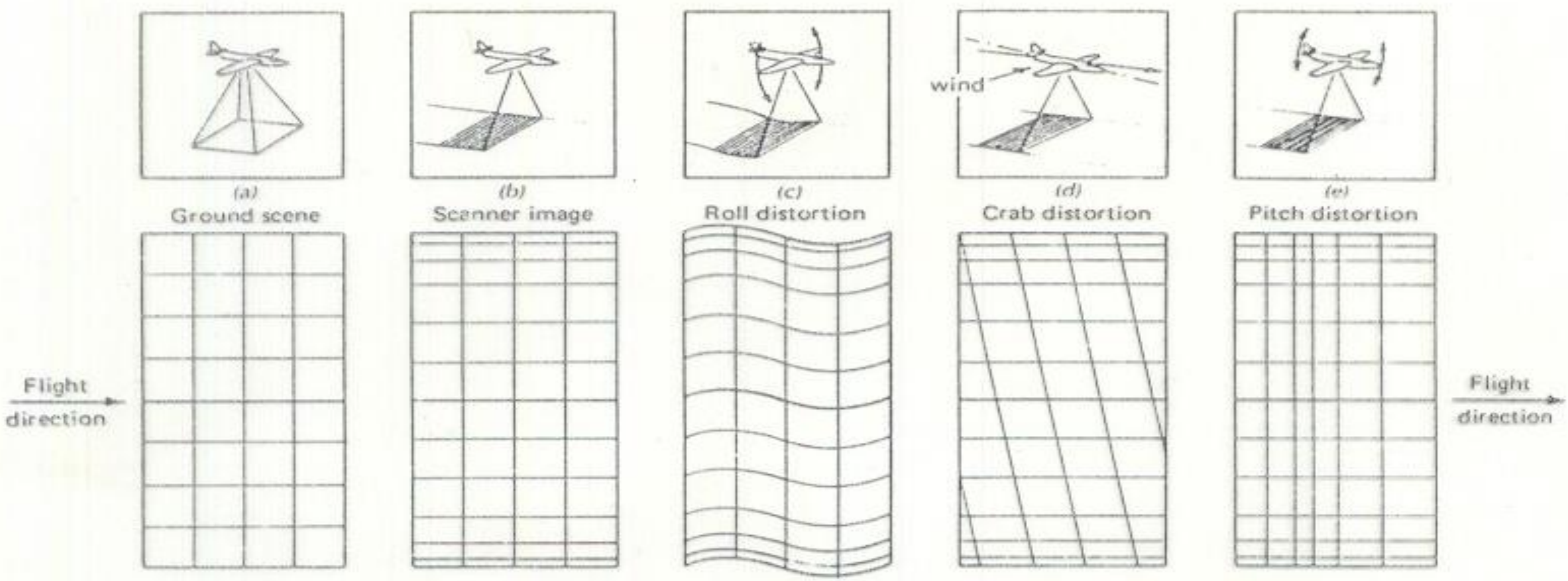
  Changes in IFOV and field view is observed. Similarly the change in **velocity of satellite** a scale change occurs.

Altitude Changes

- Remote sensing systems flown at a **constant altitude** above ground level (AGL) result in imagery with a **uniform scale** all along the flight line.
- If the aircraft or spacecraft **gradually changes its altitude** along a flightline, then the **scale** of the imagery will change.
- **Increasing the altitude** will result in smaller-scale imagery
- **Decreasing the altitude** of the sensor system will result in larger-scale imagery

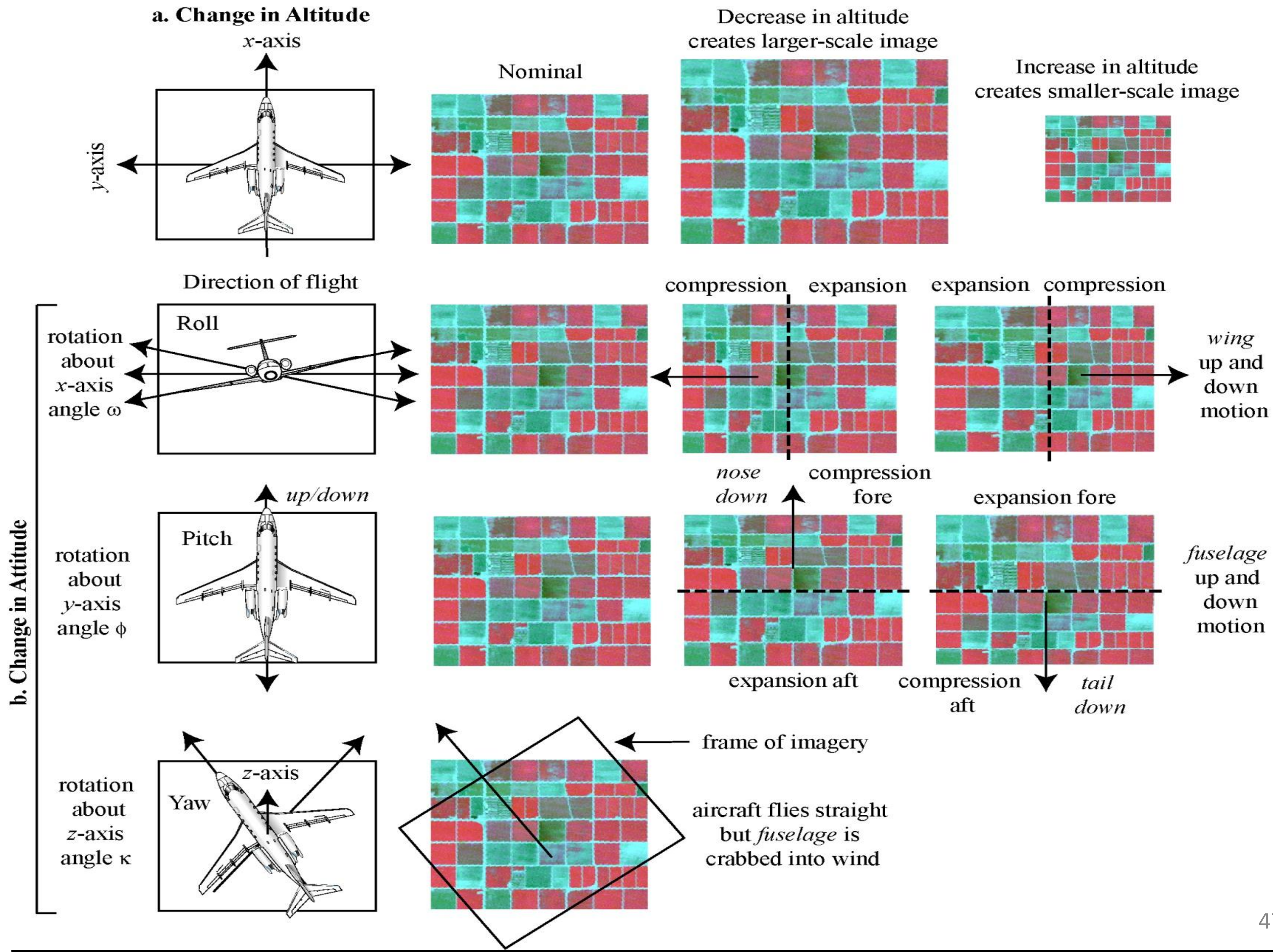
Attitude changes

- Satellite platforms are usually stable because they are not buffeted by atmospheric turbulence or wind. Conversely, suborbital aircraft must constantly contend with **atmospheric updrafts, downdrafts, head-winds, tail-winds, and cross-winds** when collecting data.
- Even when the remote sensing platform maintains a constant altitude AGL, it may rotate randomly about three separate axes that are referred to as *roll*, *pitch*, and *yaw*.
- Quality remote sensing systems often have **gyro-stabilization equipment** that isolates the sensor system from the roll and pitch movements of the aircraft.
- Systems **without stabilization equipment** introduce some geometric error into the dataset through variations in roll, pitch, and yaw that can only be corrected using *ground control points*.



Across-track scanner imagery distortions induced by aircraft attitude deviations.

Geometric Modification of Remotely Sensed Data Caused by Changes in Platform Altitude and Attitude



Ground control point

- A ***ground control point*** (GCP) is a location on the surface of the Earth (e.g., a road intersection) that can be **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
  - ***map coordinates*** (e.g., *x*, *y* measured in degrees of latitude and longitude, m in a Universal Transverse Mercator projection)
- The paired coordinates (*i*, *j* and *x*, *y*) from many GCPs (e.g., 20) 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 point

- Precisely identifiable in both images/ image and map
- Point not a line
- 30 to 40 pairs
- Well spread
- Should not change w.r.to time

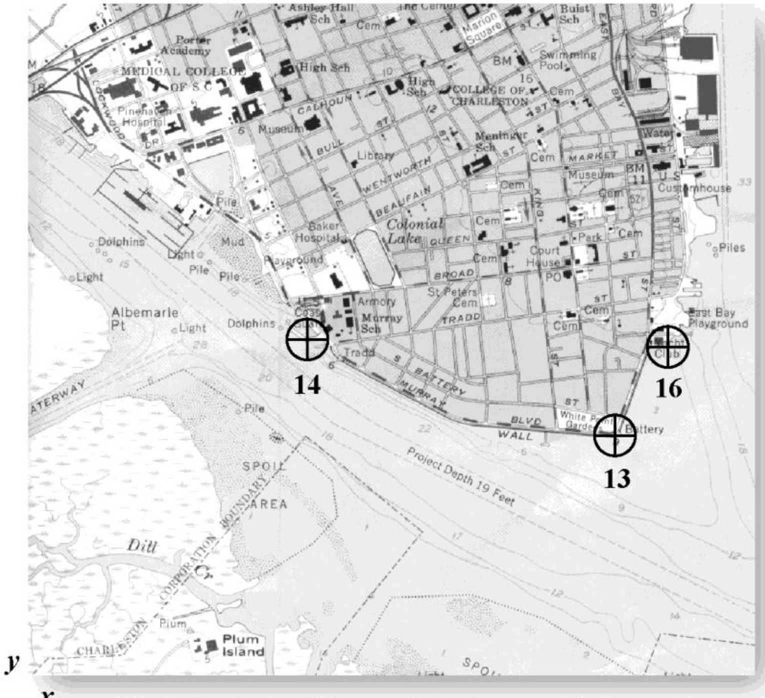
Geocoding: geographical referencing

- *Image to Map Geocorrection*
- *Image to Image Geocorrection*

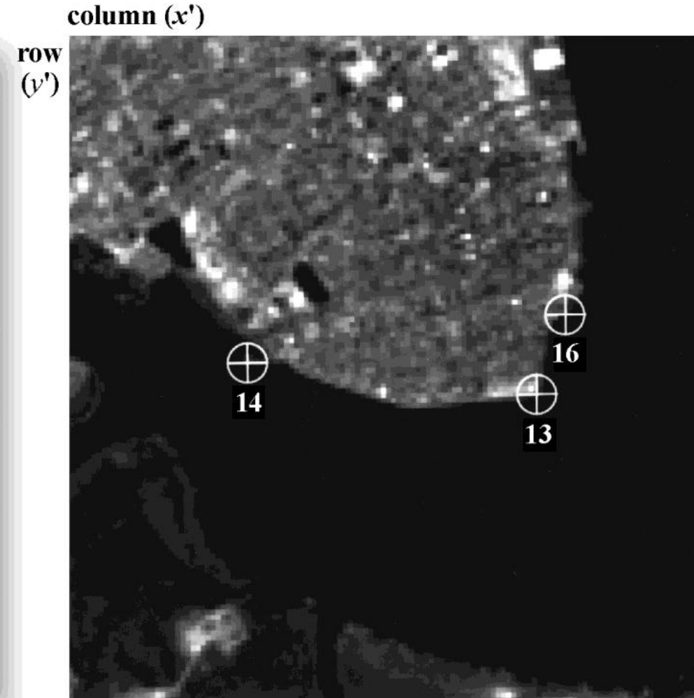
Conceptions of geometric correction

- **Registration**: geographically or nongeographically (no coordination system)
  - ***Image to Map Geocorrection***
    The correction of digital images to ground coordinates using ground control points collected from maps or ground GPS points.
  - Once several well-distributed GCP pairs have been identified, the coordinate information is processed by the computer to determine the **proper transformation equations** to apply to the original (row and column) image coordinates to map them into their new ground coordinates.

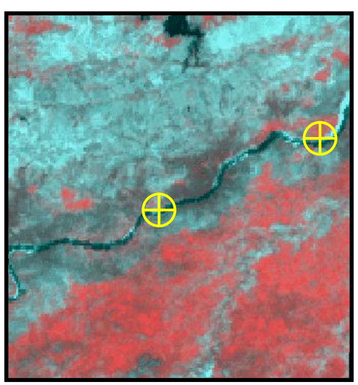
Selecting Ground Control Points for Image-to-Map Rectification



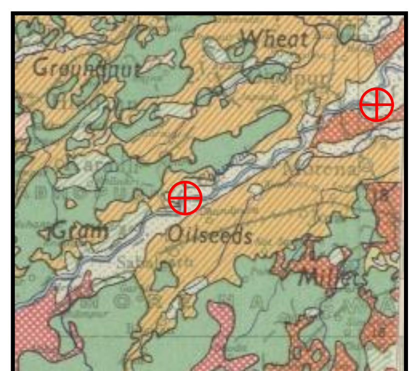
a. U. S. Geological Survey 7.5-minute 1:24,000-scale topographic map of Charleston, SC, with three ground control points identified.



b. Unrectified Landsat Thematic Mapper band 4 image obtained on November 9, 1982.



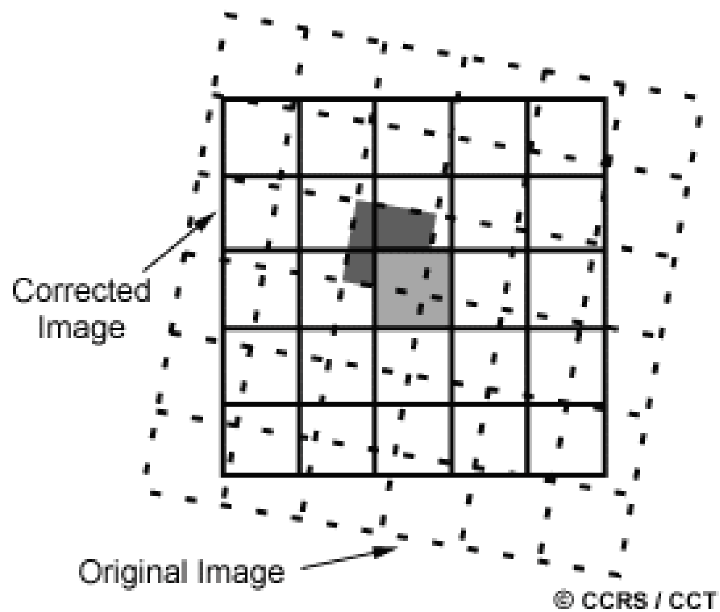
INPUT



REFERENCE

Image to Image Geocorrection

- Image to Image correction involves matching the coordinate systems or column and row systems of two digital images with one image acting as a reference image and the other as the image to be rectified.
- Geometric registration may also be performed by registering one (or more) images to another image, instead of to geographic coordinates.



THANK YOU