COURSE: SATELLITE IMAGE PROCESSING

LECTURE 3 – Geo-Referencing and Geometric Correction

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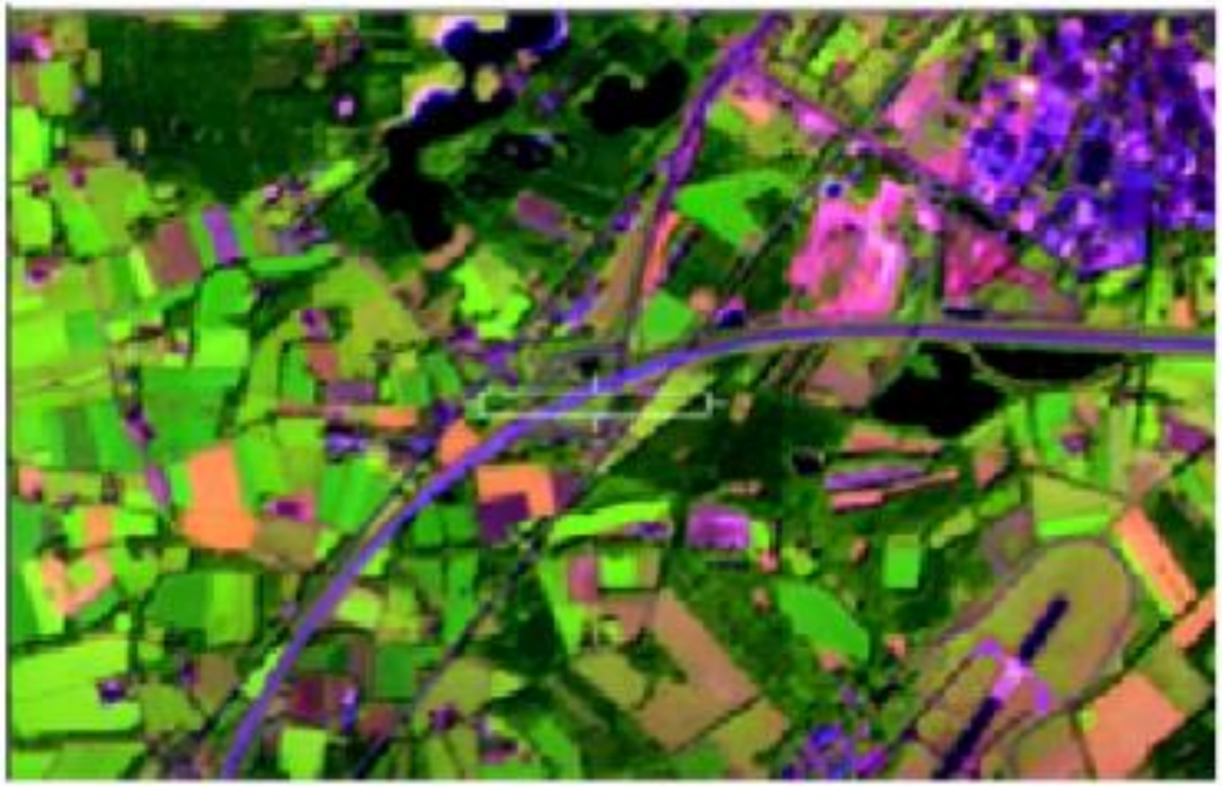
Geo-Referencing & Geometric Corrections



Satellite Imagery

Topo-sheet

Source: https://geolearn.in/geometric-corrections-in-remote-sensing-images/

Geo-Referencing & Geometric Corrections

- Geo-referencing process is part of the Geometric Corrections,
- The major difference is;

- Geo-referencing focuses specifically on assigning geographic coordinates or coordinate transformation.
- Geometric corrections focuses specifically on correcting geometric distortions that includes rectification process.

Geometric Corrections

- The correction of errors in remotely sensed data, such as those caused by satellites or aircraft not staying at a constant altitude or by sensors deviating from the primary focus plane.

- Images are often compared to ground control points (GCP) on accurate basemaps and resampled so that exact locations and appropriate pixel values can be calculated.

Source: https://support.esri.com/en-us/gis-dictionary/geometric-correction

Geometric Corrections

- Satellite and airborne images contain a number of geometric distortions that are Unavoidable.

- The geometric distortions can be due to:

- Data recording procedure

- Shape and rotation of the Earth

Source: Green, E.P., Clark, C.D., Edwards, A.J. (2000)

What is Geometric Corrections

- Geometric correction is the process of correcting the distortions and assigning the properties of a map to an image.

- The geometry of the image should be warped so that it conforms to that of the required map projection and a coordinate system should be put in place so that the user can either interrogate a point on the image and find its true coordinate, or input a coordinate of a field site and be able find it on the image.

Source: Green, E.P., Clark, C.D., Edwards, A.J. (2000)

Importance of Geometric Corrections

Today, geometric distortion is much more of a concern because:

- the spatial resolution of the remote sensor data is much finer (e.g., often $< 1 \times 1$ m)
- many images are acquired at off-Nadir viewing angles;
- the image data is more digital now;
- it is common to fuse or merge different types of remote sensor data to complete a project
- it is common to merge both raster and vector digital geospatial data for modeling purposes.

Source: John R. Jesen, 4th Ed,

Importance of Geometric Corrections

- Geometrically accurate remote sensor data are required to create remote sensing-derived products that the general public can trust.

- Geometrically corrected imagery can be used to extract accurate;

- distance,
- polygon area,
- direction (bearing) information

(Source: Gonzalez and Woods, 2007; Wolf et al., 2013).

- Geometrically inaccurate remote sensor data can have very serious impacts on remote sensing–derived products.

(Source: McRoberts, 2010).

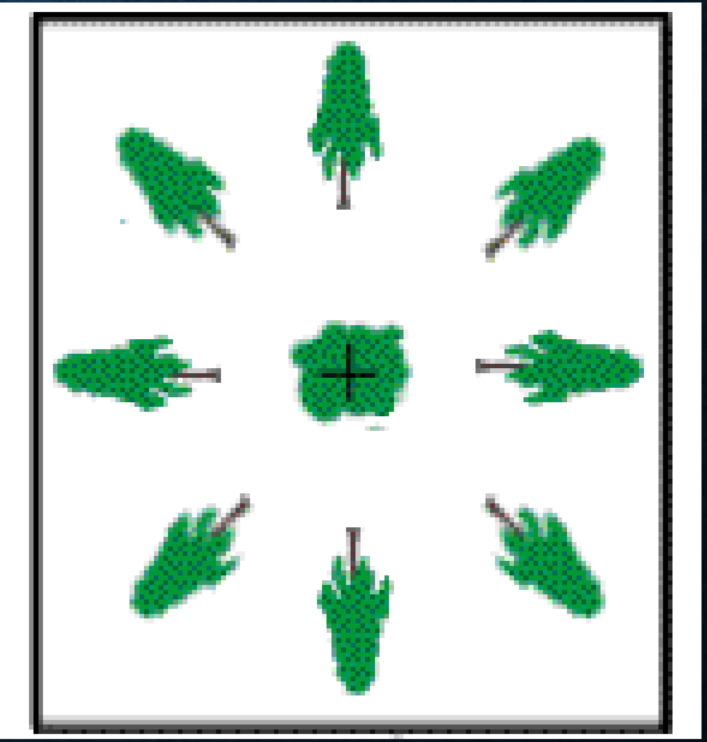
Source: John R. Jesen, 4th Ed,

Geometric Distortion in imagery

- All remote sensing images are subject to some form of geometric distortions, depending on the manner in which the data are acquired.

- These errors may be due to a variety of factors, including one or more of the following, to name only a few:

  - the perspective of the sensor optics,
  - the motion of the scanning system,
  - the motion and (in)stability of the platform,
  - the platform altitude, attitude, and velocity,
  - the terrain relief, and
  - the curvature and rotation of the Earth.



Source: John R. Jesen, 4th Ed,

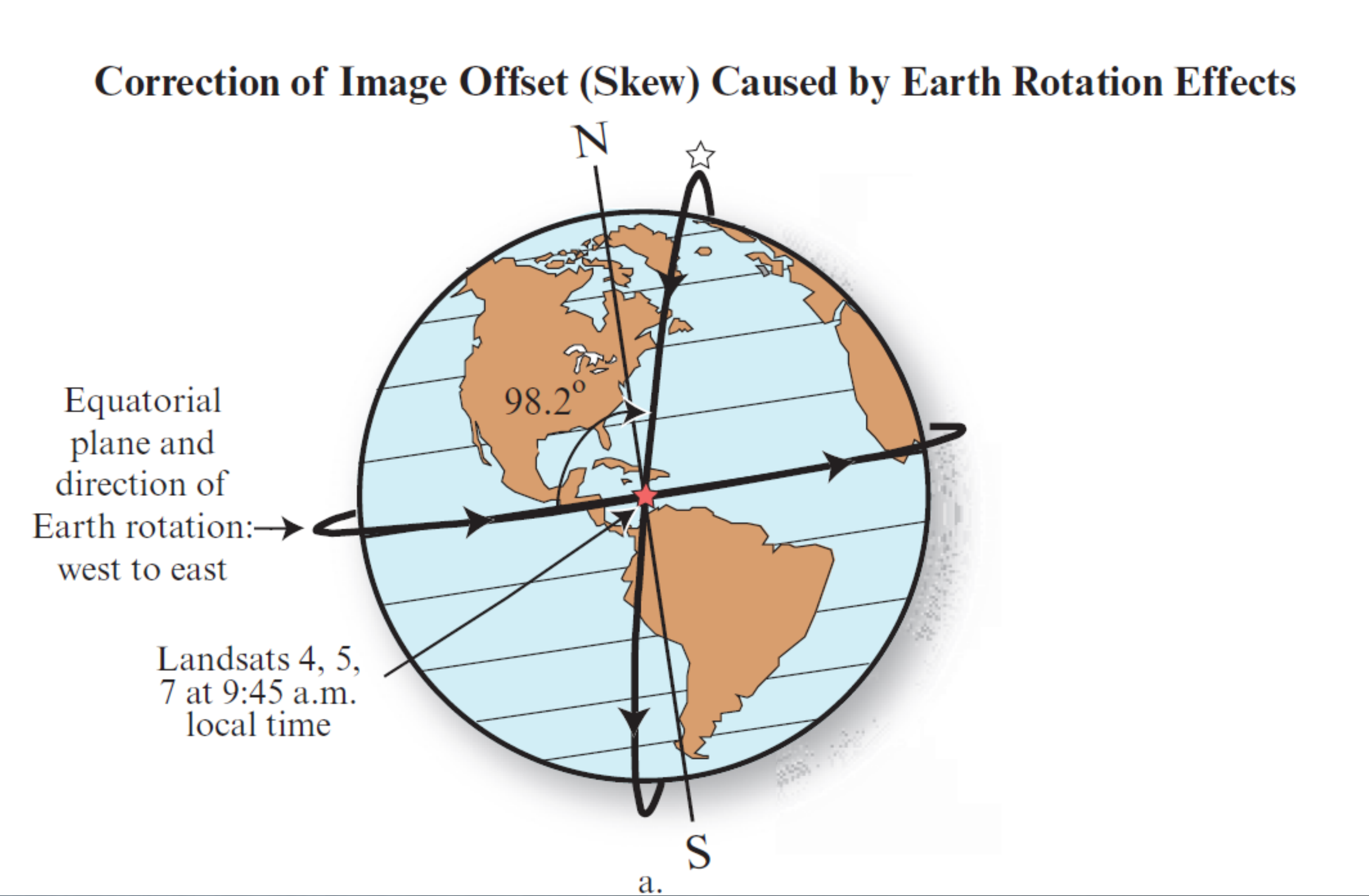
Source: CCRS/CCT,

Earth Rotation and Geometric Corrections Concept

- Landsat satellites 4, 5, and 7 are in a Sun-synchronous orbit with an angle of inclination of 98.2ë.

a). The Earth ro-tates on its axis from west to east as imagery is collected.

This interaction between the fixed orbital path of the remote sensing system and the Earth's rotation on its axis skews the geometry of the imagery collected.



Source: John R. Jesen, 4th Ed,; NASA, 1998

Earth Rotation and Geometric Corrections Concept

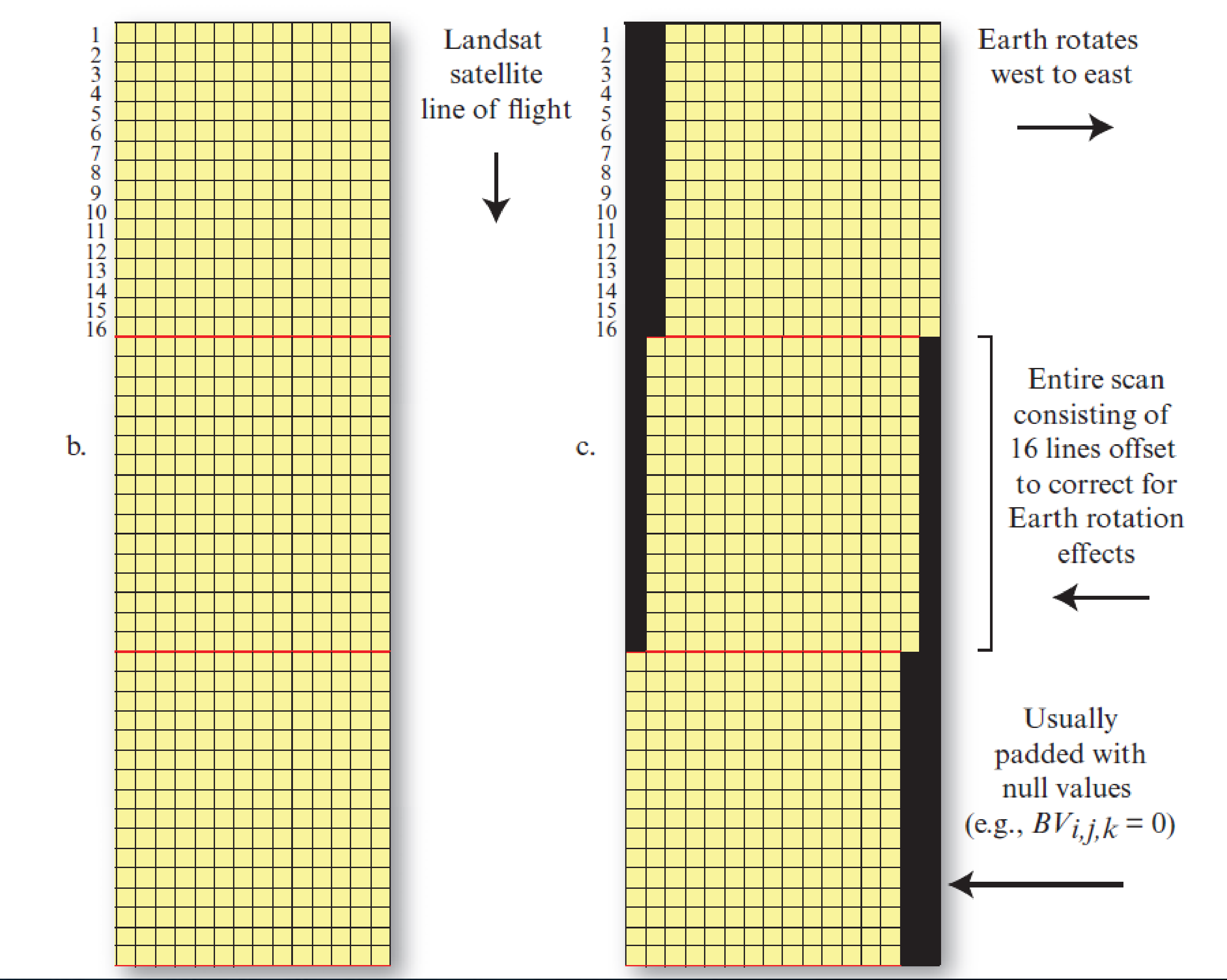
b) Pixels in three hypothetical scans (consisting of 16 lines each) of Landsat TM data.

While the raster may look correct, it actually contains systematic geometric distortion caused by the angular velocity of the satellite in conjunction with the surface velocity of the Earth as it rotates.

c) The result of adjusting (de-skewing) the original Landsat TM data to the west to compensate for Earth rotation effects.

Prior to correcting for earth rotation effects

Corrected for earth rotation effects



Source: John R. Jesen, 4th Ed,; NASA, 1998

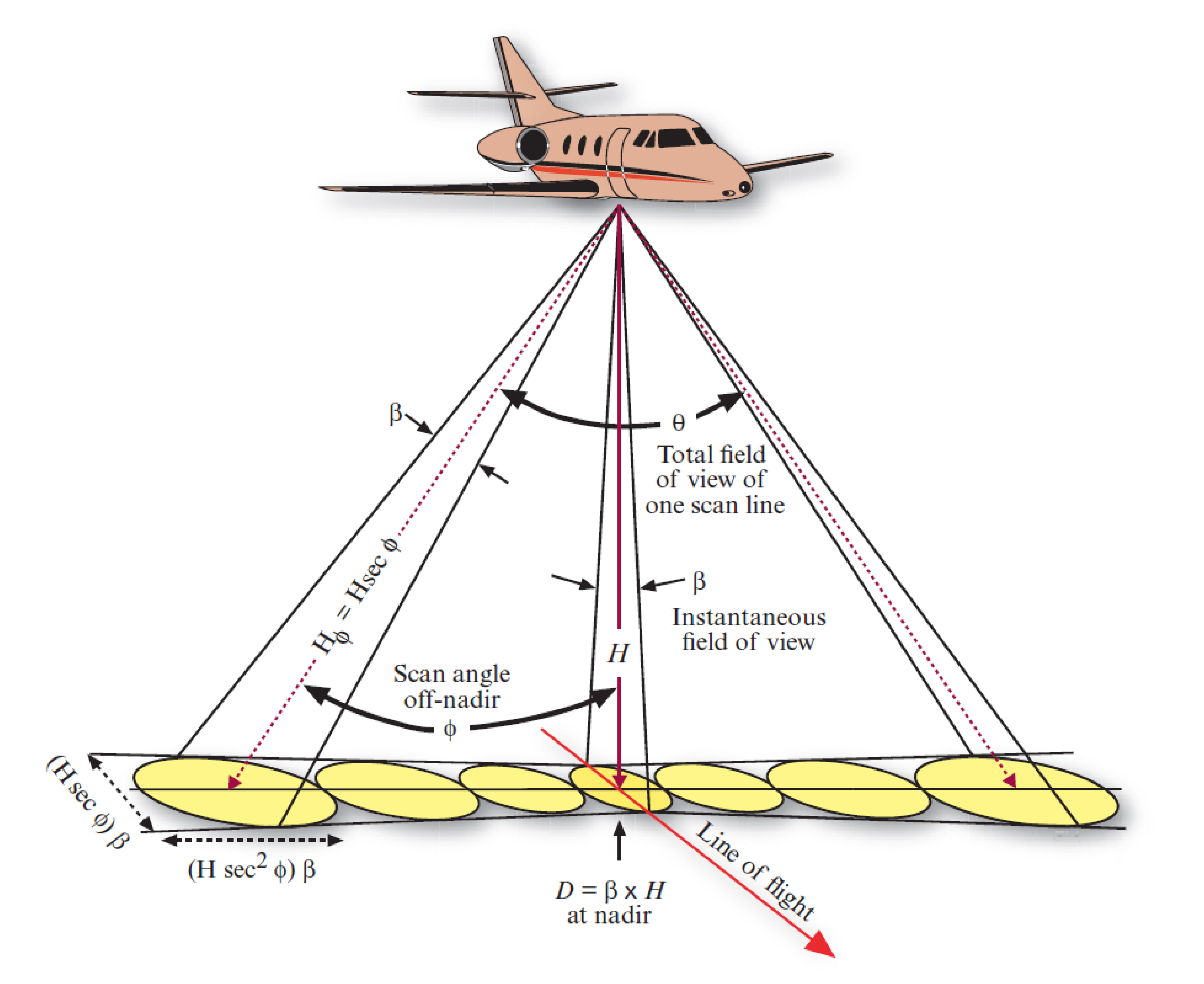
Scan Angle and relief Distortion and displacement

- The ground resolution cell size along a single scan flight is a function of:

a) the distance from the aircraft to the observation at nadir and off-nadir;

b) the in-stantaneous-field-of-view of the sensor,

c) the scan angle off-nadir,



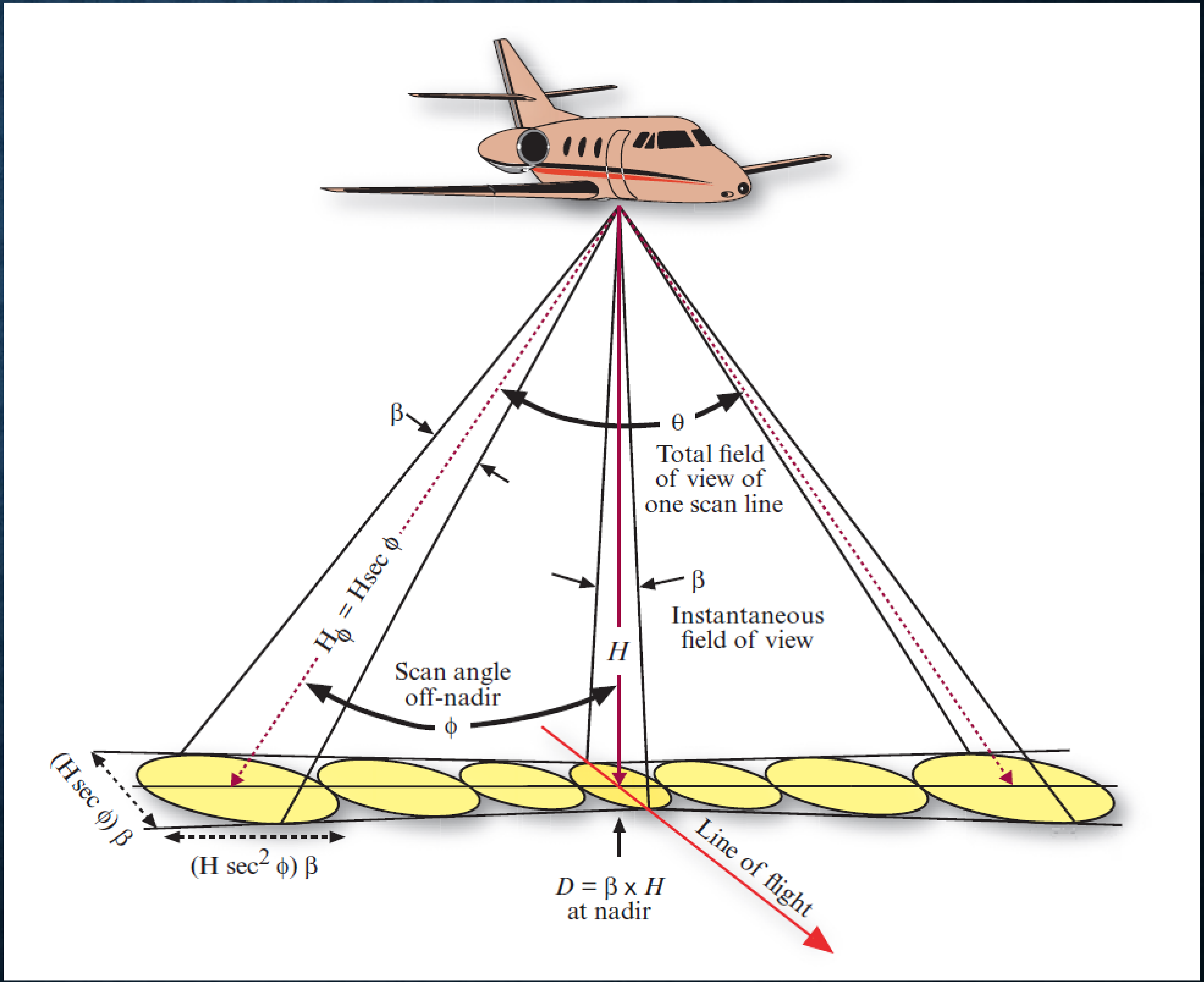
Source: John R. Jesen, 2015, 4th Ed,

Scan Angle and relief Distortion and displacement

- ❑ Pixels off-nadir have diameters that define the resolution cell size.

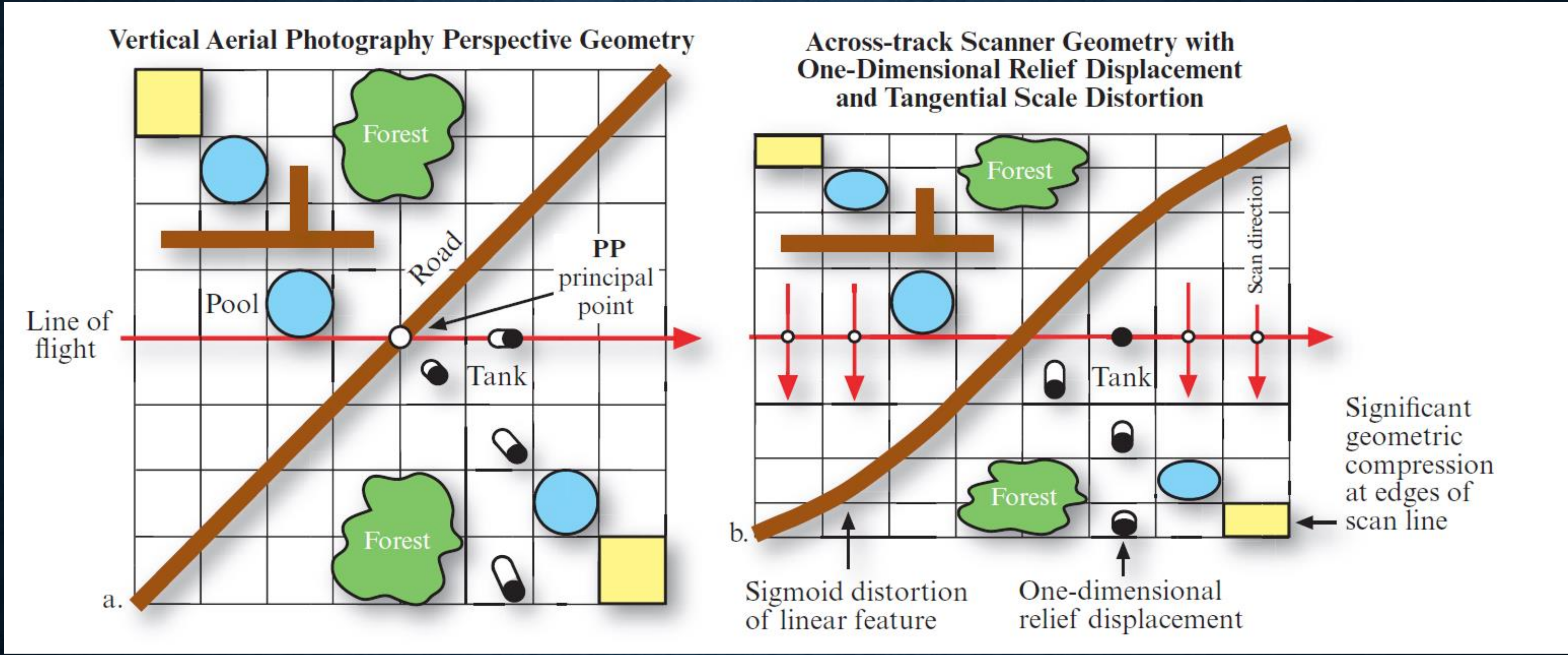
- ❑ Considering of the total field of view of one scan line;

One-dimensional relief displacement and tangential scale distortion occur in the direction perpendicular to the line of flight and parallel with a line scan.



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

Scan Angle and relief Distortion and displacement



The size of the ground-resolution cell increases as the angle increases away from nadir

$$D_\phi = (H \times \sec\phi) \times \beta$$

$$D_\phi = (H \times \sec^2\phi) \times \beta$$

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

External Geometric Errors

- External variables that can cause geometric error in remote sensor data are random movements by the aircraft (or spacecraft) at the exact time of data collection, which usually involve:

- Altitude changes,
- Attitude changes:
  - roll,
  - pitch
  - yaw

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

External Geometric Errors - Altitude Changes

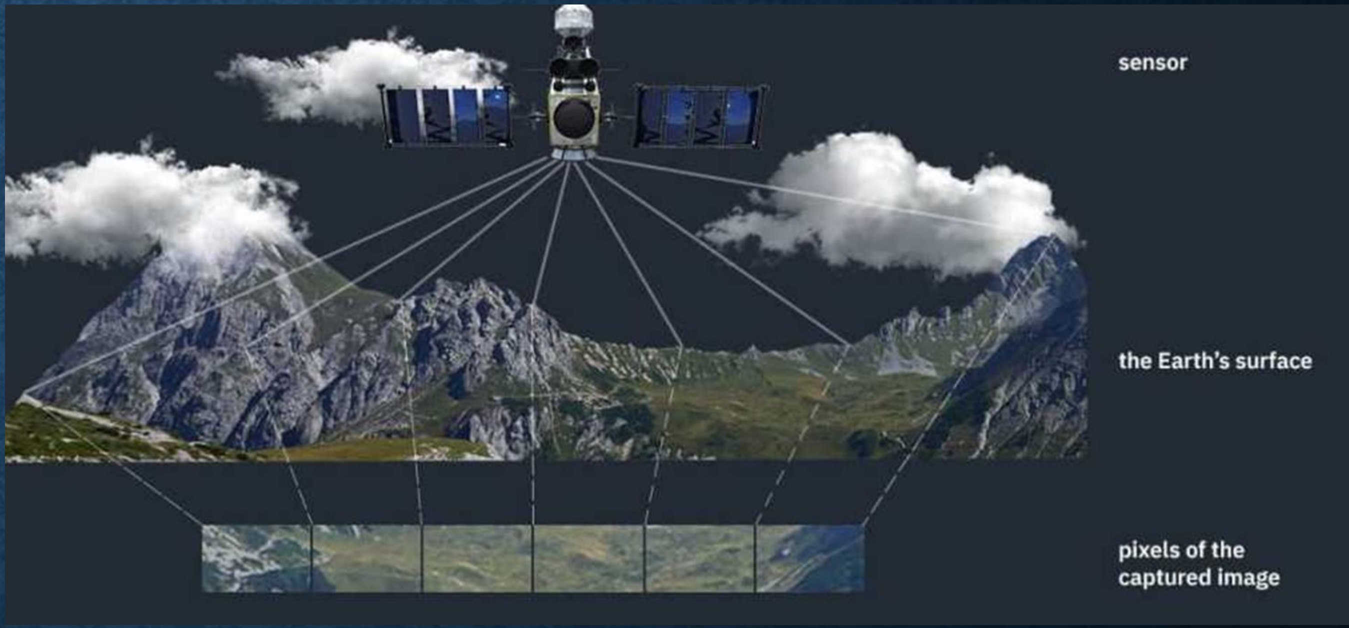
- A remote sensing system is ideally flown at a constant altitude above ground level resulting in imagery with a uniform scale all along the flight line.

- If the aircraft or spacecraft gradually changes its altitude along a flight-line, then the scale of the imagery will change

- This occurs when the terrain gradually increases or decreases in elevation (i.e., it moves closer to or farther away from the sensor system.

- *D* ; the spatial resolution is a function of the instantaneous field- of-view (β) and the altitude above ground level (H) of the sensor system, i.e.

$$D = (\beta)\ x\ H$$

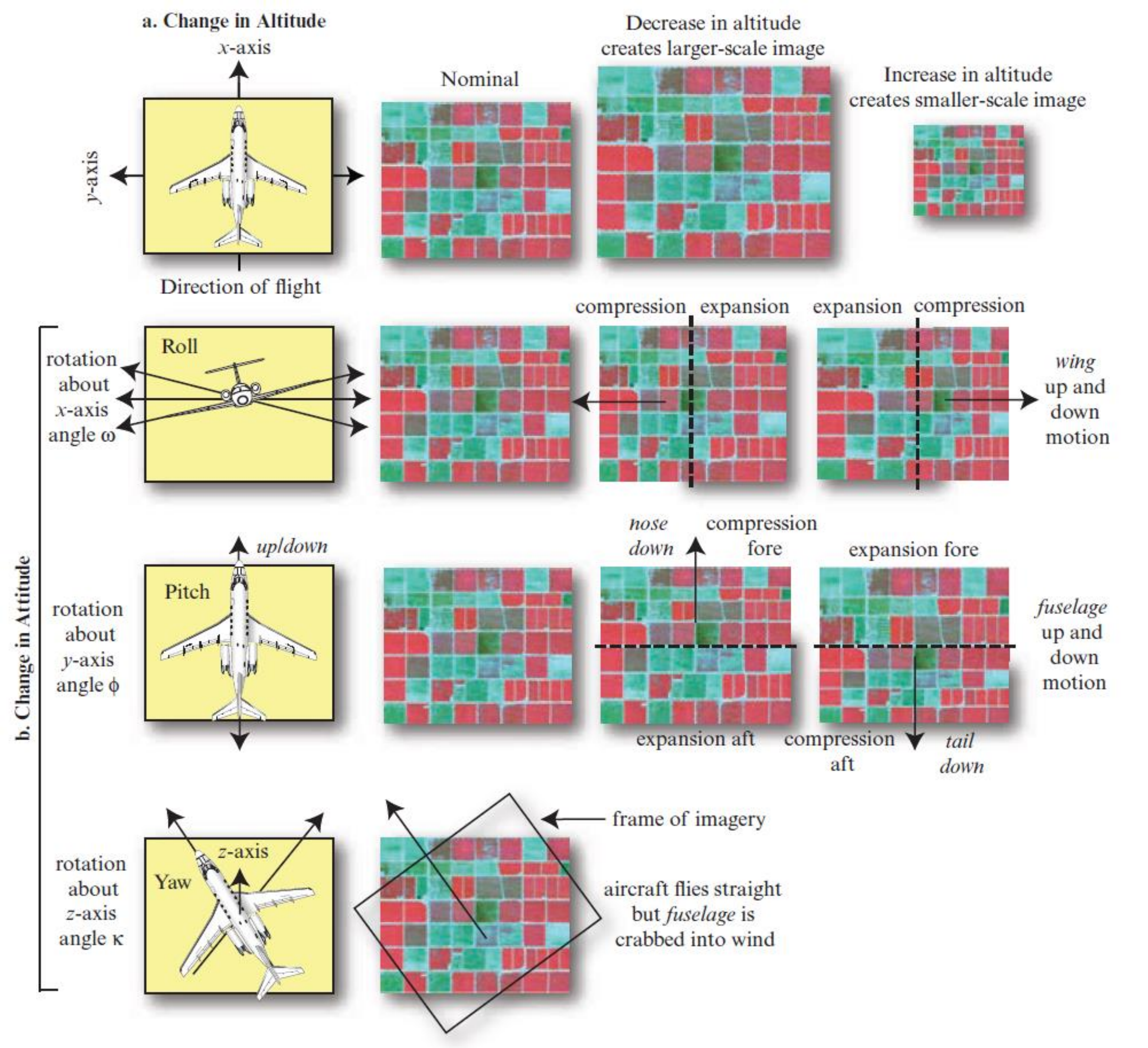


Source: https://geolearn.in/geometric-corrections-in-remote-sensing-images/

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

External Geometric Errors – Attitude Changes

- Roll occurs w hen the aircraft or spacecraft fuselage maintains directional stability but the wings move up or down,
- Pitch occurs when the wings are stable but the fuselage nose or tail moves up or down
- Yaw occurs when the wings remain parallel but the fuselage is forced by wind to be oriented some angle to the
- left or right of the intended line of flight,



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

Geometric Correction Procedures

Ground Control Points (GCP) and Geometric correction procedures

- ❑ Geometric distortions introduced by sensor system attitude (roll, pitch, and yaw) and/or altitude changes can be corrected using GCP and appropriate mathematical models (e.g., Im et al., 2009).

- ❑ Two common geometric correction procedures;

• image-to-map rectification, and

• image-to-image registration.

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

Geometric Correction Procedures

Image-to-map rectification

- Image-to-map rectification is the process by which the geometry of an image is made planimetric. Whenever accurate;

- area,
- direction, and
- distance measurements

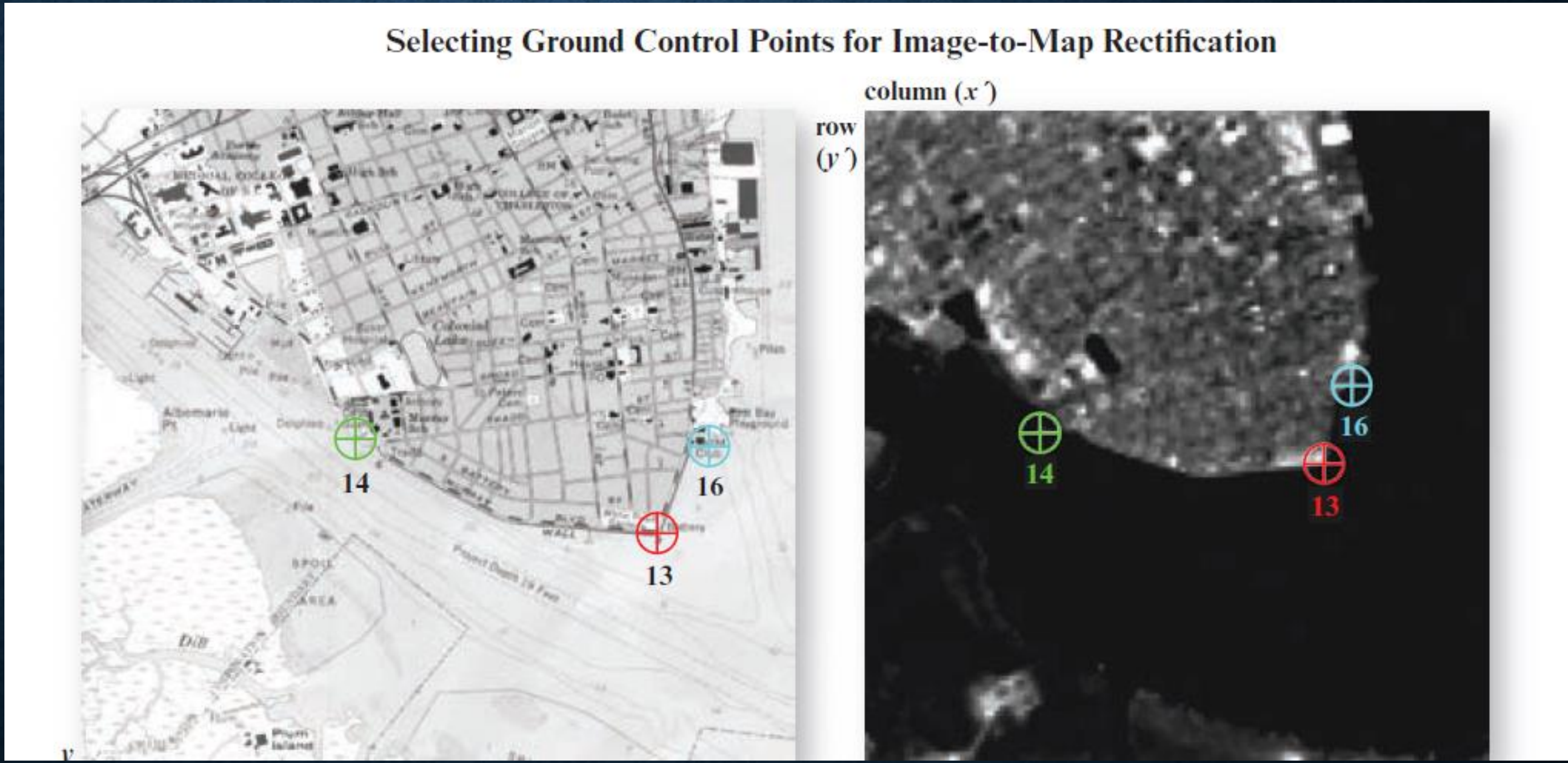
are required, image-to-map geometric rectification should be performed.

Geometric Correction Procedures

Image to Map Rectification

- Example of image-to-map rectification.
- The coordinates are extracted from the already rectified topographic map.
- Other wise use GPS to get coordinates on the field that is to +-20cm

Jensen and Jensen, 2013



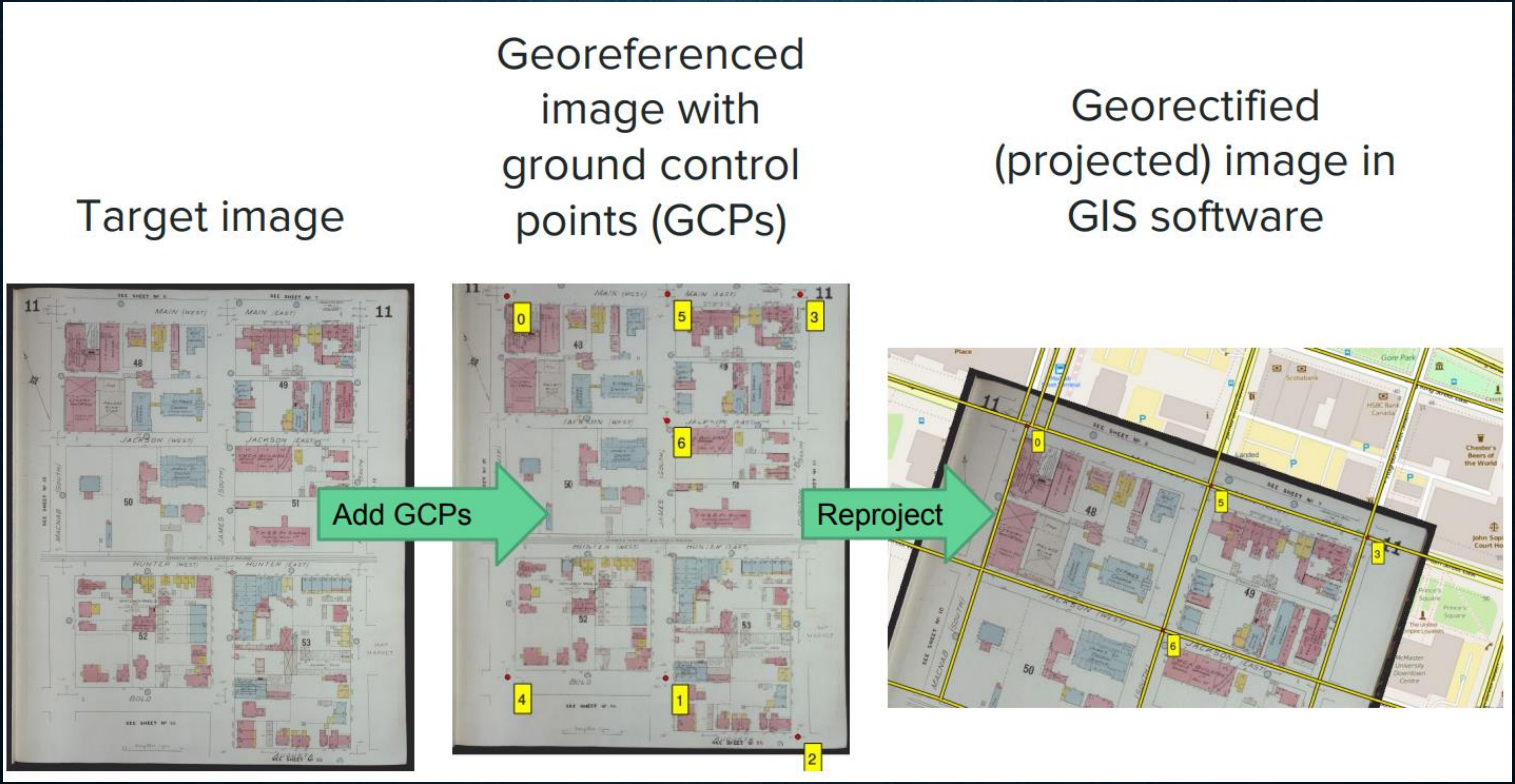
Rectified Topo. map

Image courtesy of NASA

Unrectified Landsat Imagery

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

Geometric Corrections



Source: Jay Brodeur 2019, workshop; and on http://digitalarchive.mcmaster.ca/islandora/object/macrepo%3A33284

Geometric Correction Procedures

Image-to-image registration

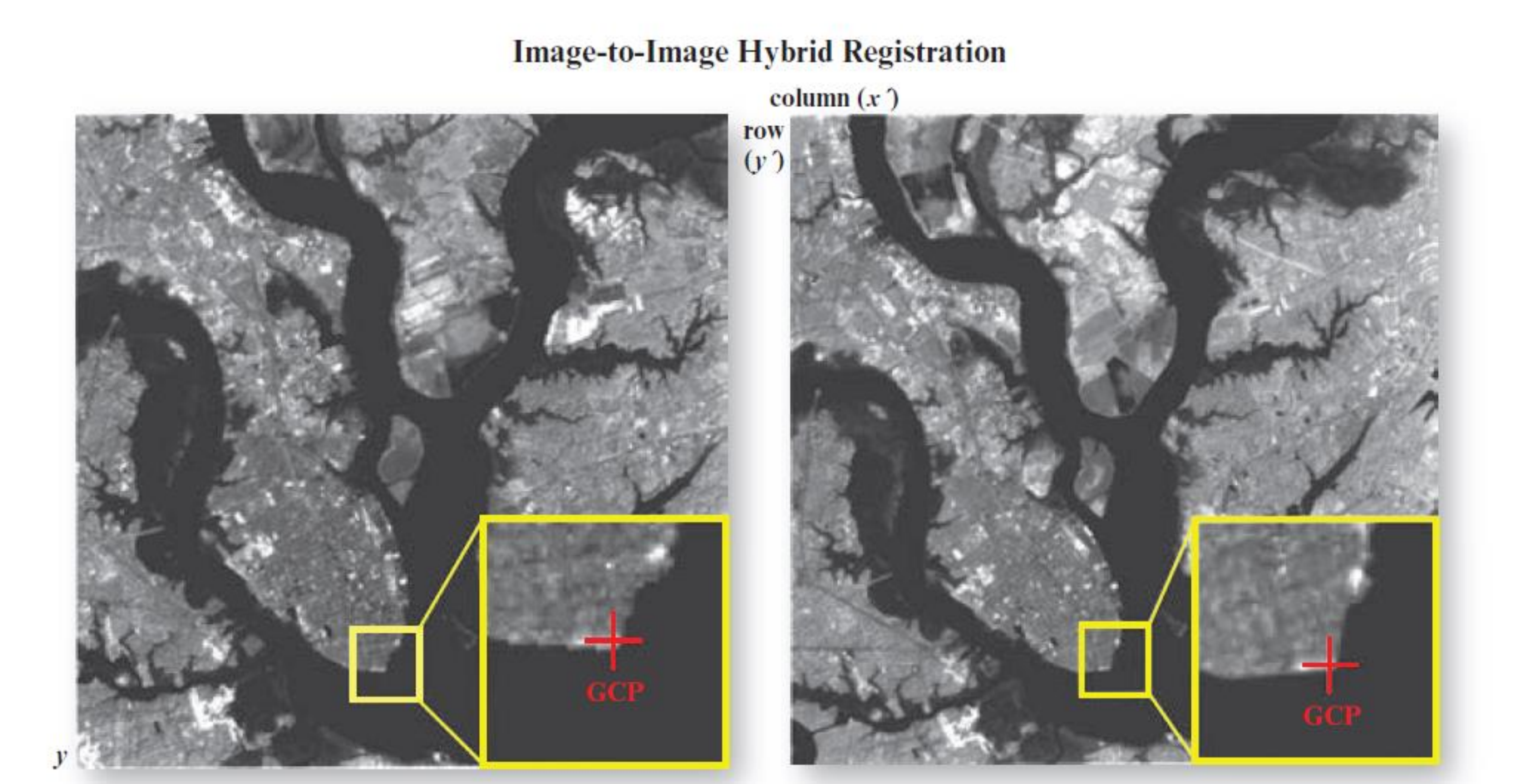


Image courtesy of NASA

Rectified Landsat

Un-rectified Landsat

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

Geometric Correction Procedures

Geometric Rectification Logic

- Two basic operations must be performed to geometrically rectify a remotely sensed image to a map coordinate system:

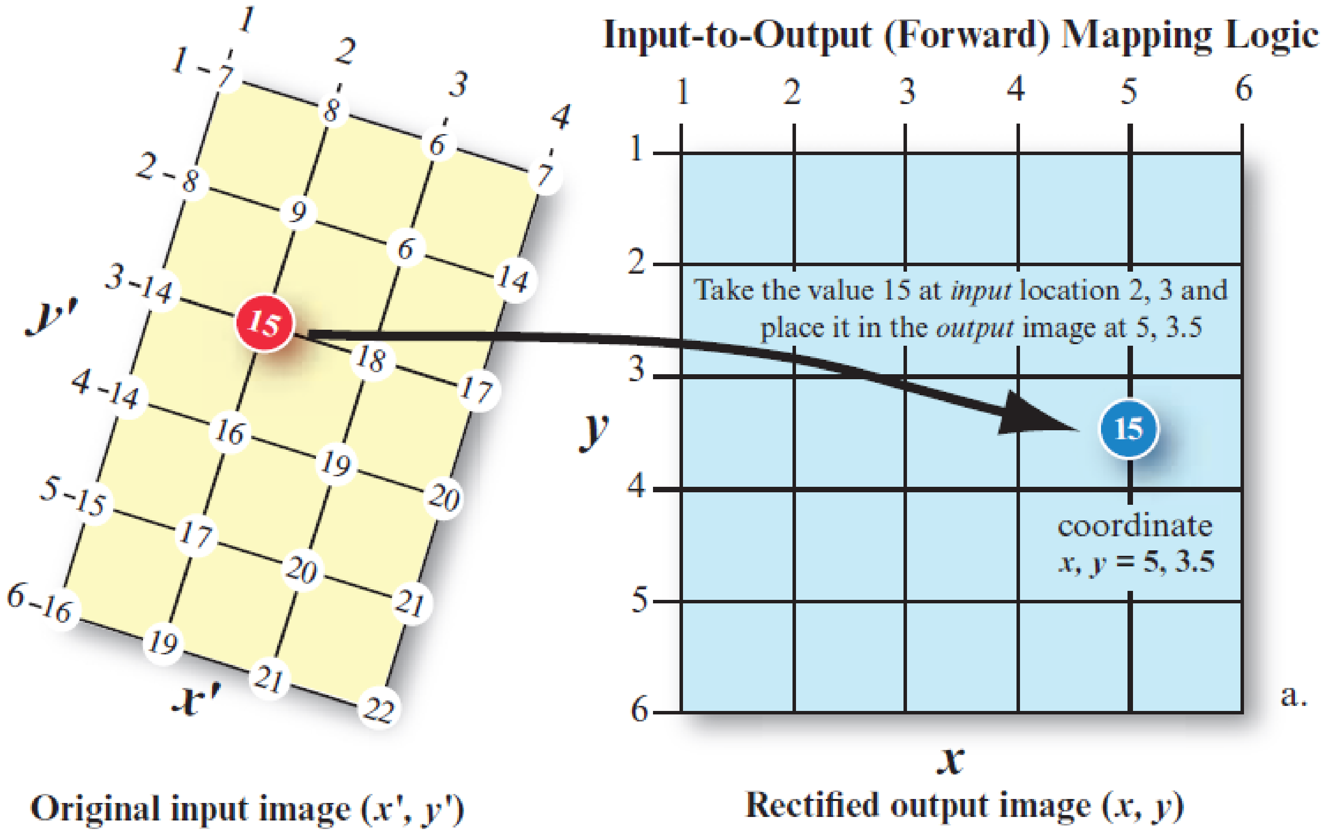
1. Spatial Interpolation (Coordinate Transformation)– Determining correct pixel coordinates

2. Intensity Interpolation (Resampling) – Assigned data value to each of this newly pixels

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

Geometric Correction Procedures

Spatial Interpolation



$x = a_0 + a_1 x' + a_2 y'$

$y = b_0 + b_1 x' + b_2 y'$ where

x' and y' are locations in the original *input* image,

x and y are locations in the rectified *output* image.

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

Geometric Correction Procedures

Spatial Interpolation Using Coordinate Transformations

- Depending on the distortion in the imagery, the number of GCPs used, and the degree of topographic relief displacement in the area, higher-order polynomial equations may be required to geometrically correct the data

$$Xo = b1 + b2xi + b3yi$$
$$Yo = a1 + a2xi + a3yi$$

X_i and Y_i are source co-ordinates (input)
X_o and Y_o are rectified co-ordinate (output)

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

Geometric Correction Procedures

Spatial Interpolation Using Coordinate Transformations

- Following is the example of a 1st order polynomial equation that can be solved with just 3 pairs of GCPs.

$$N = (P + 1) * (P + 2) * 0.5$$

N = No of Ground Control Points

P= Polynomial Order

1St Polynomial Order: $N = (P + 1) * (P + 2) * 0.5$

$$N = (1 + 1) * (1 + 2) * 0.5$$

$$N = 3$$

- Shift Origins
- Rescale
- Rotate

Geometric Correction Procedures

Spatial Interpolation Using Coordinate Transformations

Following is the example of a 2nd order polynomial equation that can be solved with just 3 pairs of GCPs.

$N = (P + 1) * (P + 2) * 0.5$

N = No of Ground Control Points

P= Polynomial Order

2nd Polynomial Order: $N = (P + 1) * (P + 2) * 0.5$

$N = (2 + 1) * (2 + 2) * 0.5$

$N = 6$

- ✓ Non- Linear convert
- ✓ Corrects for earth Curvature
- ✓ Corrects camera lens distortion

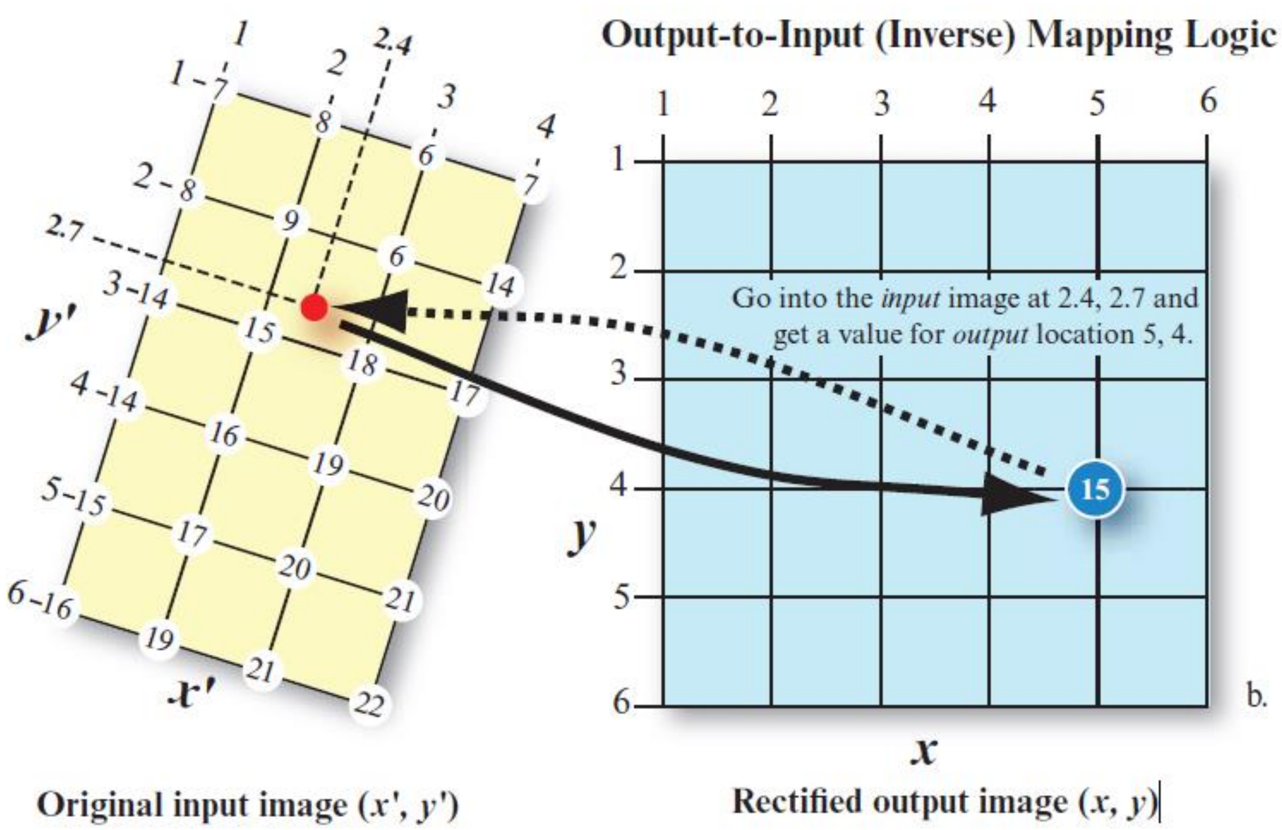
Geometric Correction Procedures

Intensity Interpolation - Resampling

- The intensity interpolation process involves the extraction of a BV from an location in the original (distorted) input image and its relocation to the appropriate x, y coordinate location in the rectified output image.

1. Creates New output pixel grid that is relocated

2. Populates this output grid with DN values



$$x' = a_0 + a_1 x + a_2 y$$
$$y' = b_0 + b_1 x + b_2 y$$

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

Geometric Correction Procedures

Intensity Interpolation – Resampling techniques

- The several methods of brightness value (BV) interpolation can be applied, including:

  - nearest neighbor,
  - bilinear interpolation, and
  - cubic convolution.

- The practice is commonly referred to as *resampling*.

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

References:

Green, E.P., Clark, C.D., Edwards, A.J. (2000) Geometric correction of satellite and airborne imagery, pp. 93-108, in: Green, E.P., Mumby, P.J., Edwards, A.J., Clark, C.D., (Ed. A.J. Edwards). Remote Sensing Handbook for Tropical Coastal Management. *Coastal Management Sourcebooks 3*, UNESCO, Paris.

Jensen, John R., 2015- Introductory digital image processing : a remote sensing perspective / John R. Jensen, University of South Carolina.
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