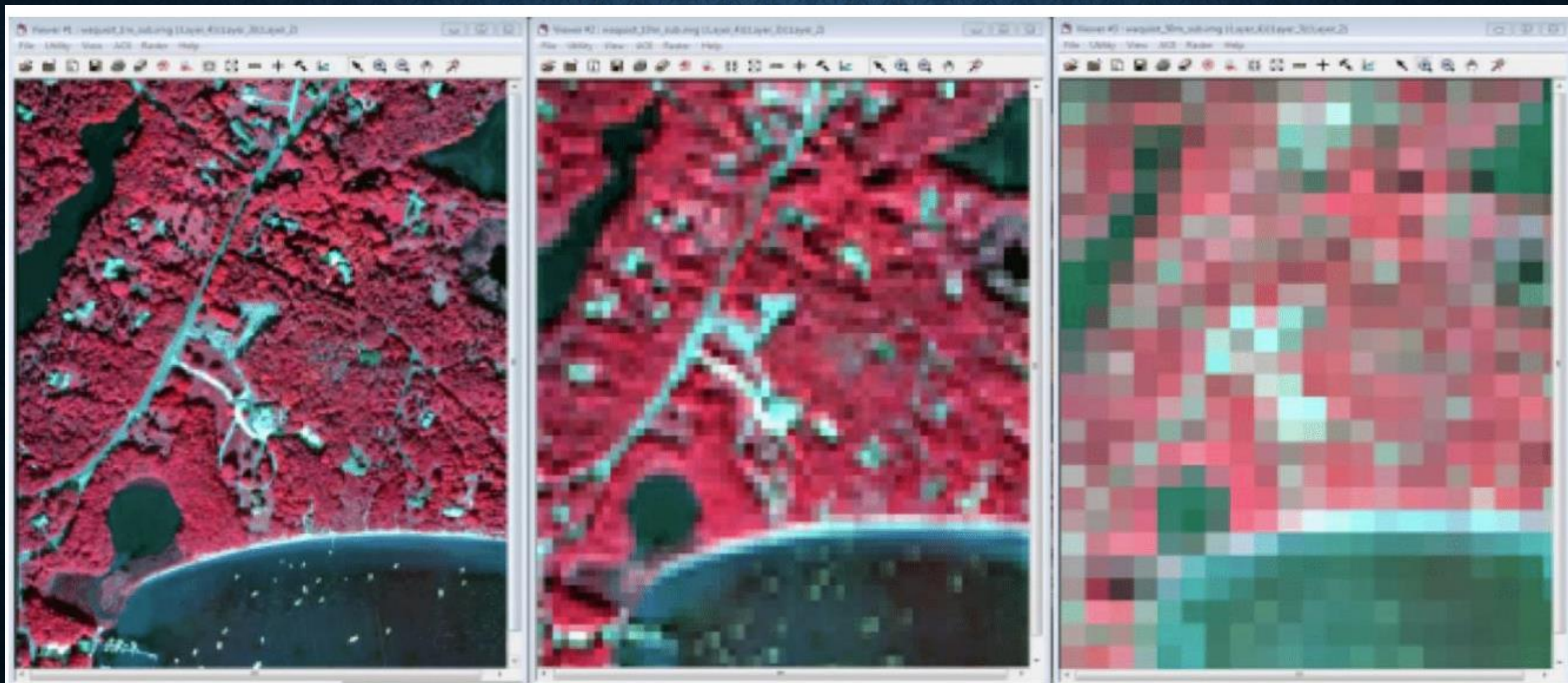


COURSE: SATELLITE IMAGE PROCESSING

LECTURE 7 – Image Spatial Resolution and Enhancement

Lecturer: Dr. Tingneyuc Sekac, Ph.D. PNG University of Technology

Spatial Resolution

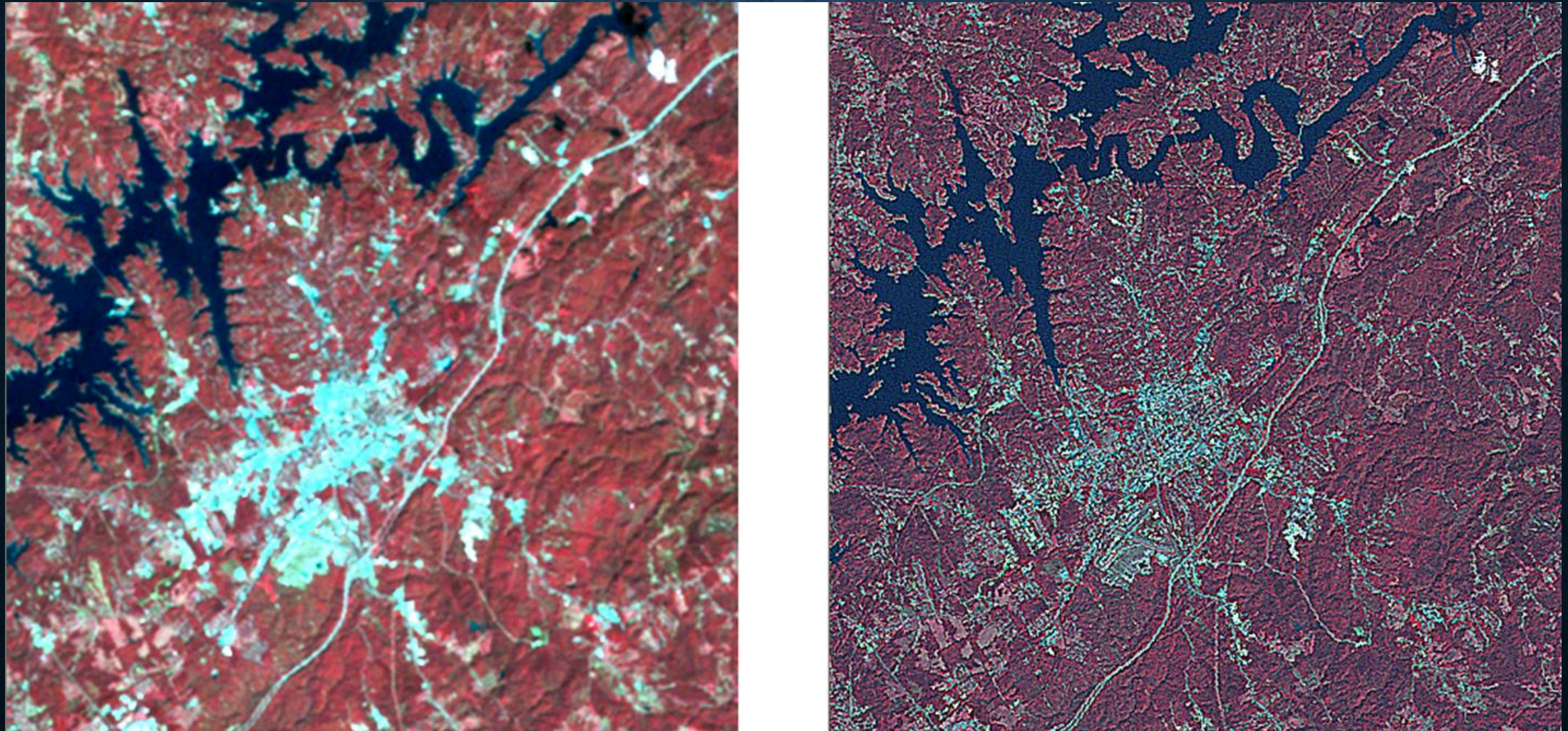


Spatial Resolution

Landsat 8 image of Reykjavik, Iceland, acquired July 7, 2019, illustrating the difference in pixel resolution.



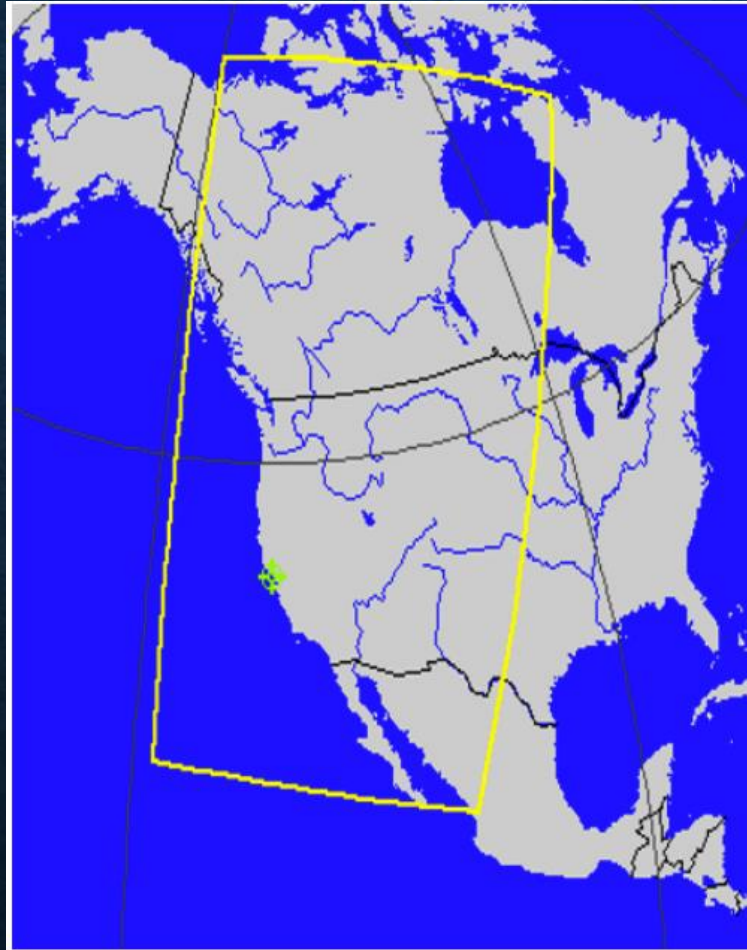
Spatial Enhancement



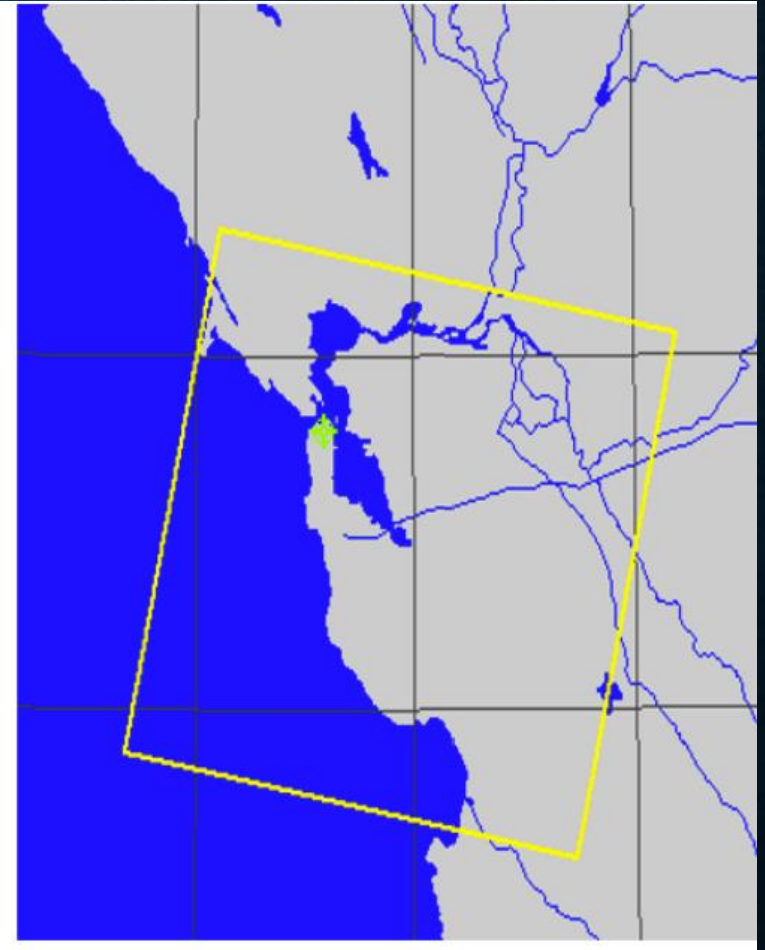
Landsat 7 ETM +

Spatial Resolution Vs Spatial Extent

Generally, the higher the spatial resolution, the less area is covered by a single image.



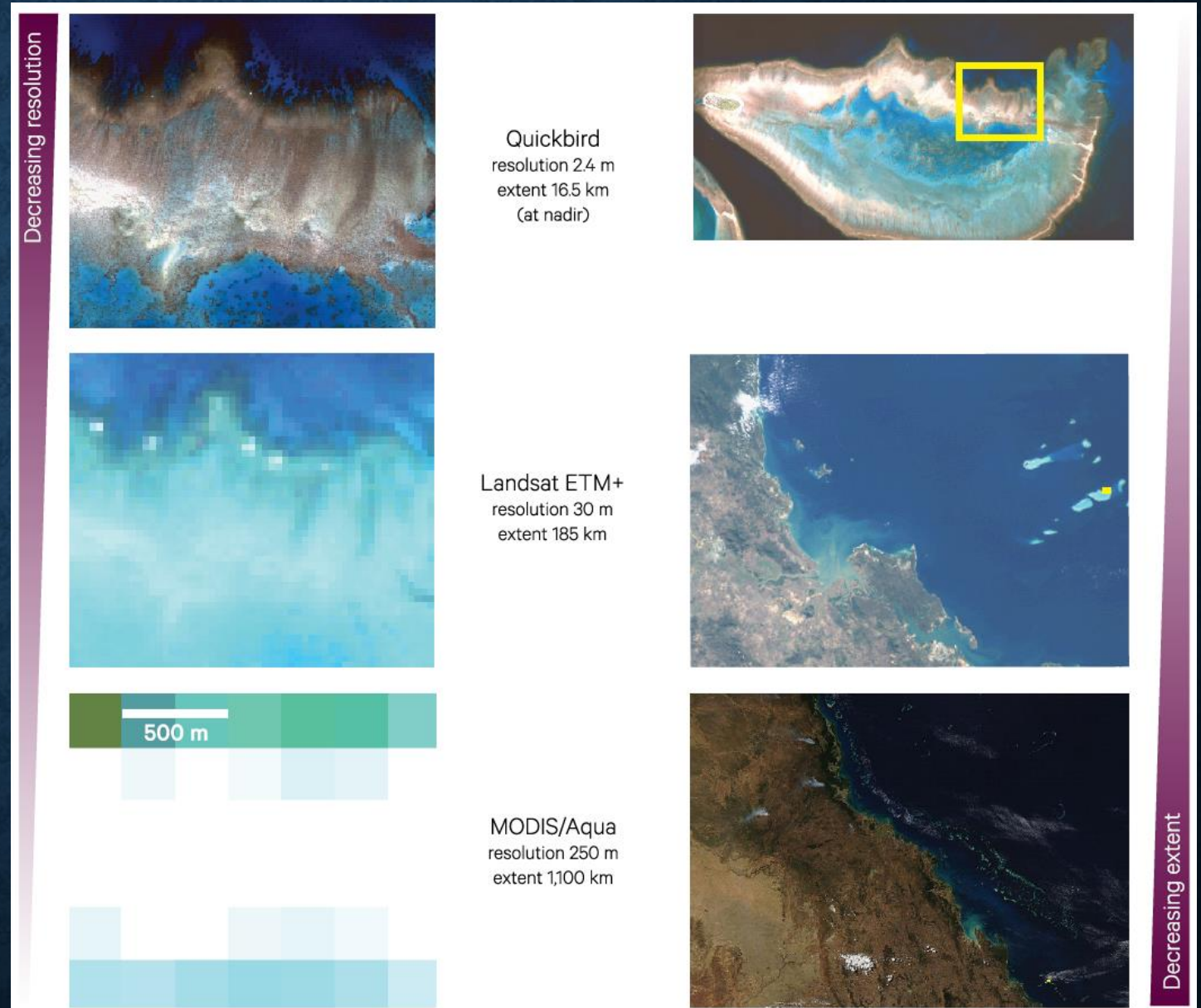
MODIS (250 m - 1 km)



Landsat OLI (30 m)

Spatial Resolution Vs Spatial Extent

Generally, the higher the spatial resolution, the less area is covered by a single image.



Remote Sensing – Types of Resolution

- Spatial Resolution
 - Smallest spatial measurement
- Temporal Resolution
 - Frequency of measurement
- Spectral Resolution
 - Number of independent channels
- Radiometric Resolution
 - Sensitivity of the detectors

Remote Sensing – Types of Resolution

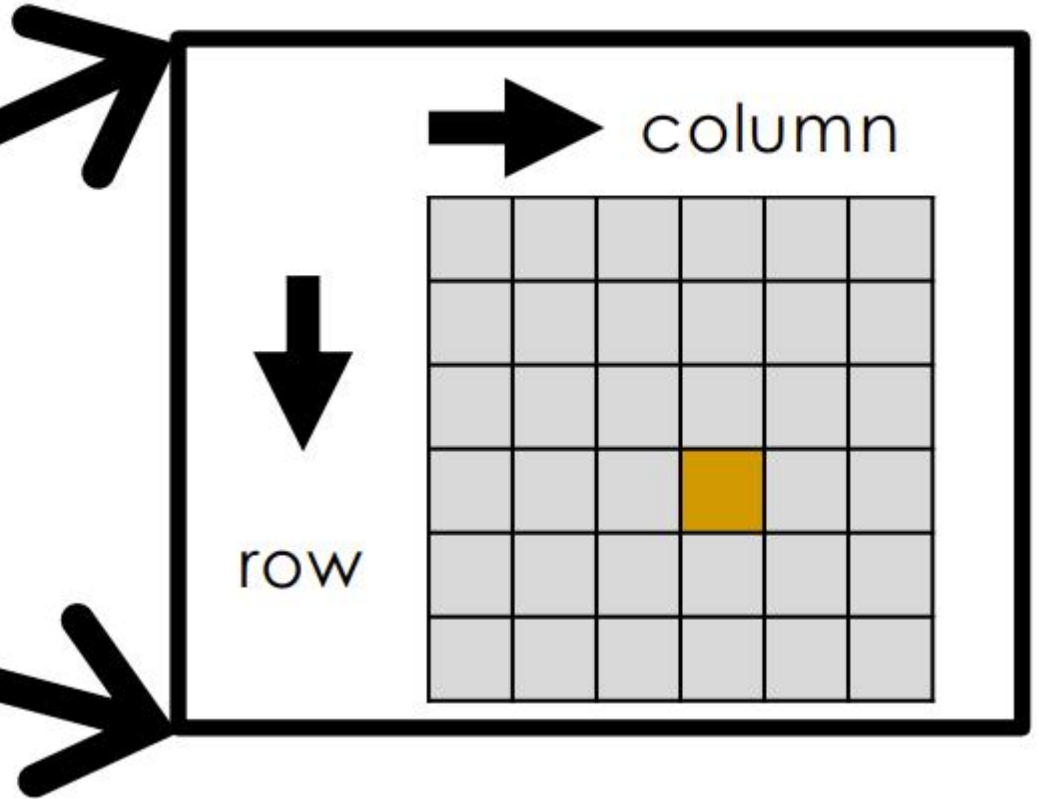
- ❑ Each resolution depends on the satellite orbit configuration and sensor design.
- ❑ Resolutions are different for different sensors.

Spatial Resolution and Pixel Size

A digital image is composed of a two-dimensional array of individual picture elements – called pixels – arranged in columns in rows;

- Each pixel represents an area on the Earth's surface
- A pixel has an intensity value and a location address in the 2D image
- Spatial resolution is defined by the size of a pixel

Pixel Size



Spatial Resolution

Imagery of Harbor Town in Hilton Head, SC, at Various Spatial Resolutions



a. 0.5×0.5 m.



b. 1×1 m.



c. 2.5×2.5 m.



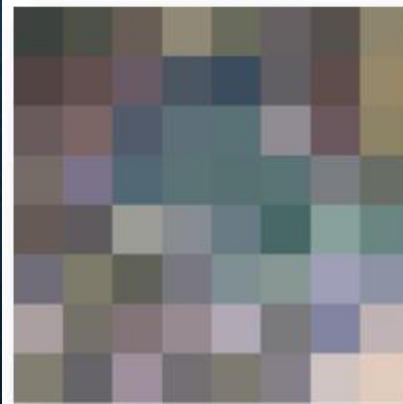
d. 5×5 m.



e. 10×10 m.



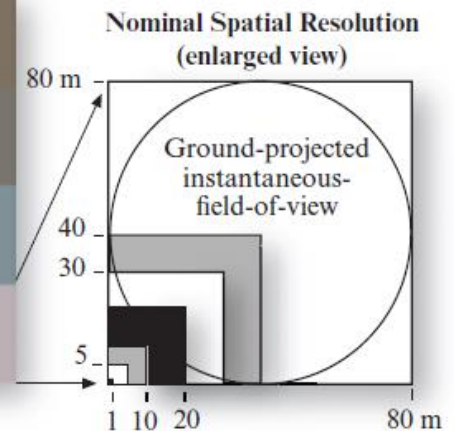
f. 20×20 m.



g. 40×40 m.



h. 80×80 m.

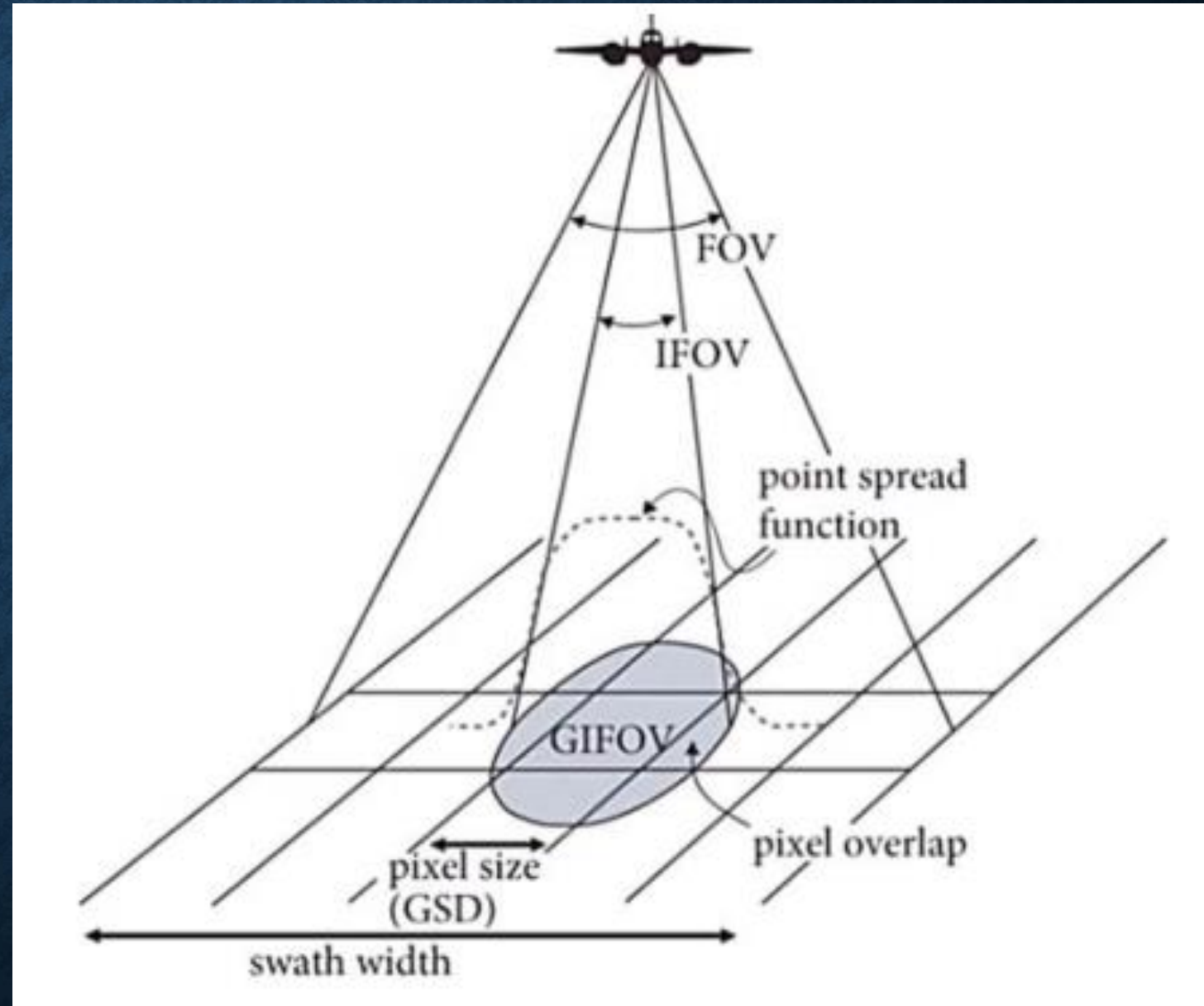


Definition of Spatial Resolution

- ❑ Spatial resolution defines the level of spatial detail depicted in an image.
- ❑ It is described as a measure of the smallness of objects on the ground that can be distinguished.
- ❑ In this sense, spatial resolution is directly related to image pixel size.

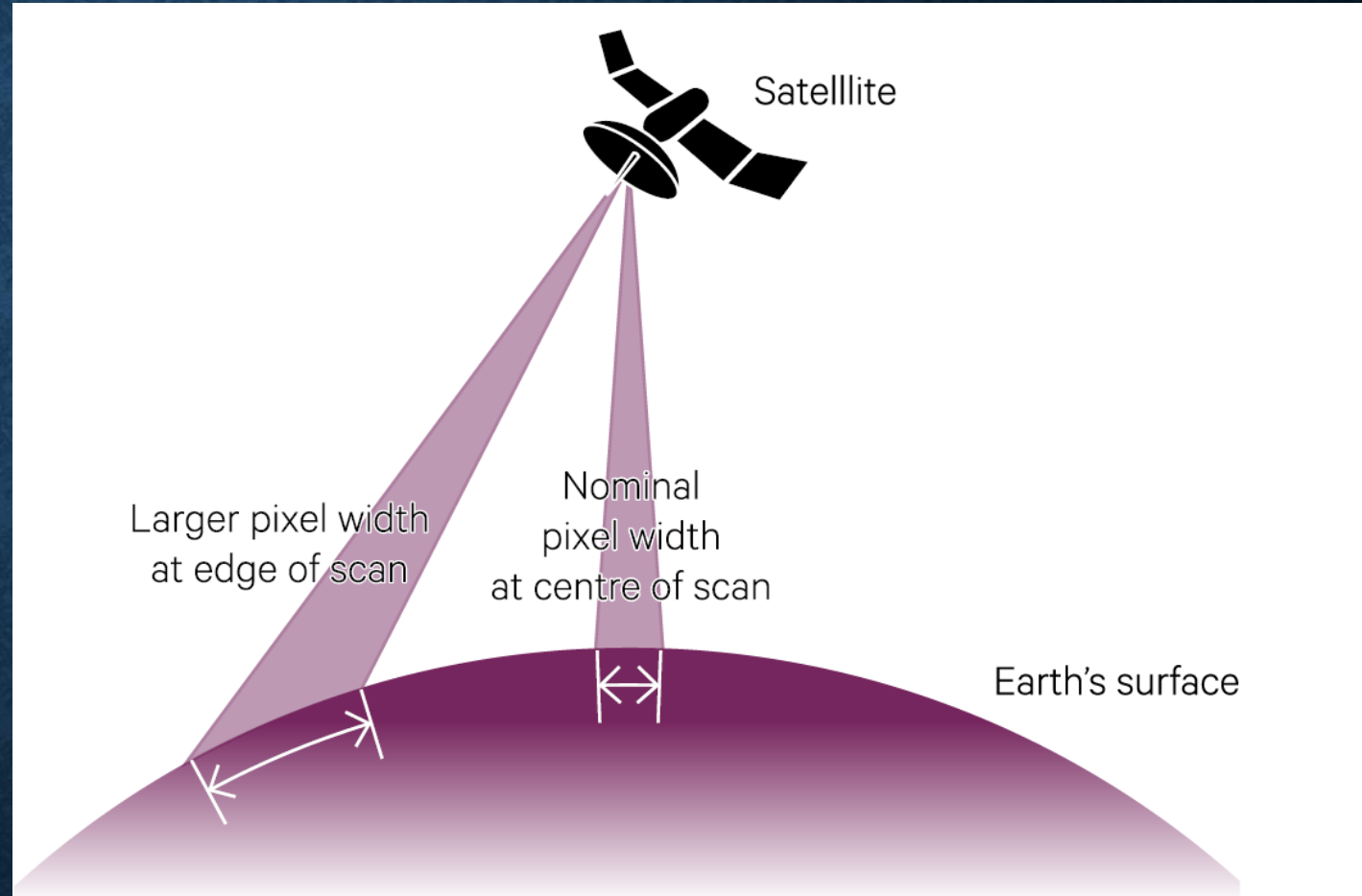
Definition of Spatial Resolution

- ❑ FOV = field of view, defines the swath width.
- ❑ IFOV = instantaneous field of view, defines the angle of the individual sensors.
- ❑ GIFOV = ground instantaneous field of view, is the IFOV projected onto the ground.
- ❑ GSD = ground sample distance (from GIFOV, detector size), defines the resulting pixel size



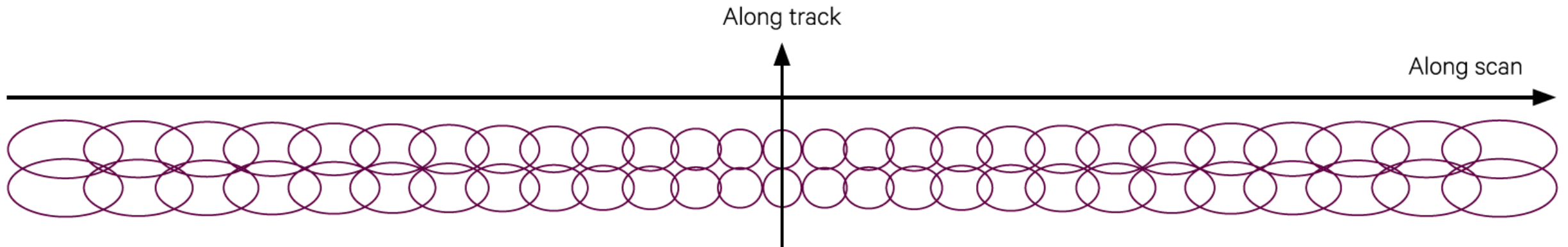
Scanning Angle and Spatial Resolution

- ❑ For wide scan angles, as occurs with AVHRR, pixel size increases away from the center of an image swath.
- ❑ This effect is further exaggerated by Earth curvature, especially for sensors imaging wide swaths such as AVHRR.



Scanning Angle and Spatial Resolution

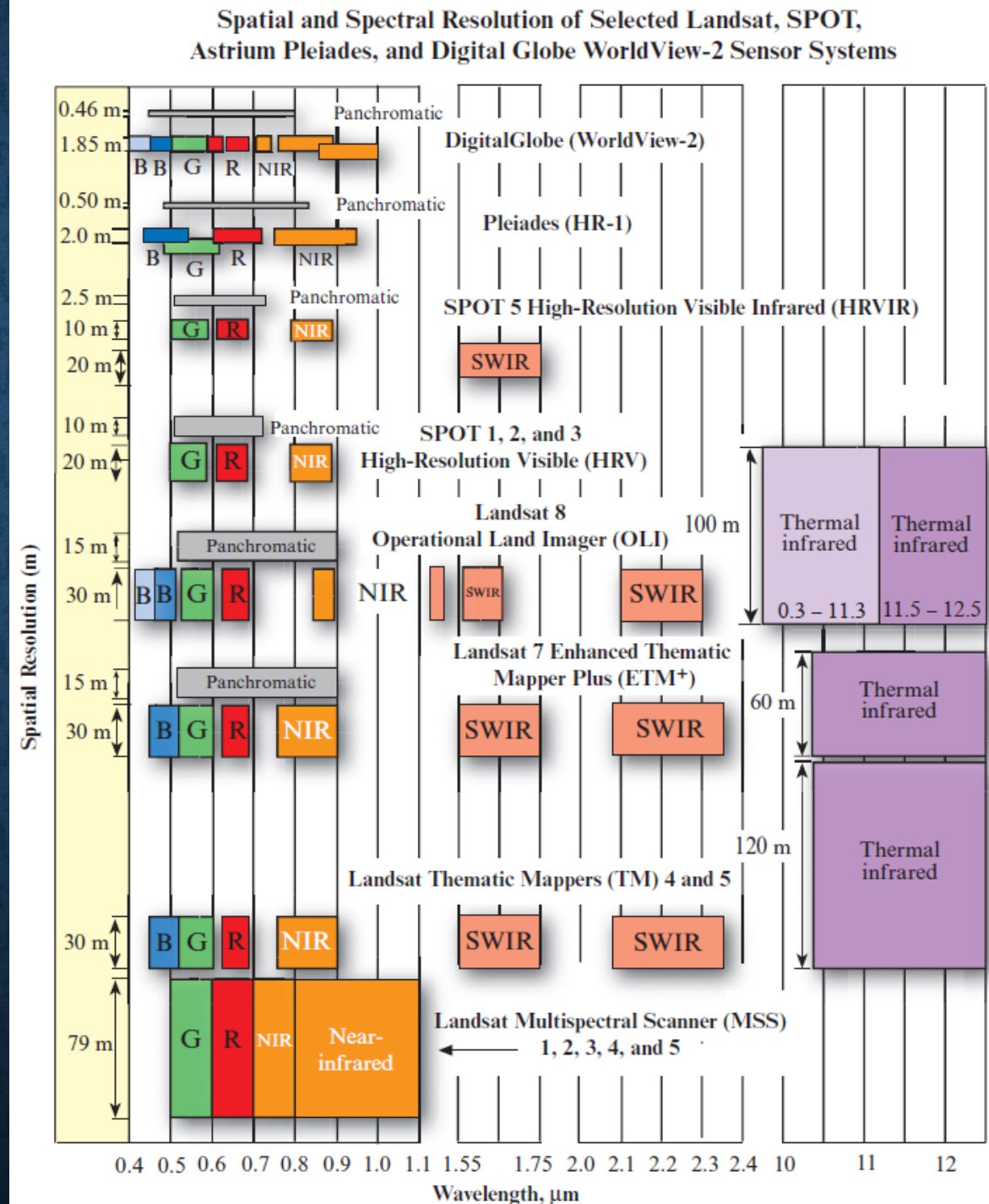
- ❑ When looking vertically down to Earth at the center of each scan line (or nadir), the sensor detects radiance from a circular ground area.
- ❑ As the sensor looks away from the image center (off-nadir viewing), a larger ground area is imaged in both the along scan and along-track directions.
- ❑ A greater increase in the imaged area occurs in the along-scan direction, resulting in the optical pixel shape changing from a circle to an ellipse



Spatial Resolution Comparison

□ Spatial and spectral resolution of the Landsat Multispectral Scanner (MSS), Landsats 4 and 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 OLI, SPOTs 1, 2, and 3 High-Resolution Visible (HRV), SPOT 5 High-Resolution Visible Infrared (HRVIR) sensor, Pleiades HR-1, and Digital-Globe WorldView-2 sensor systems.

□ The SPOTs 4 and 5 Vegetation sensor characteristics are not shown (it consists of four 1.15×1.15 km bands).



Landsat 8 characteristics

Landsat 8 Operational Land Imager (OLI)			Landsat 8 Thermal Infrared Sensor (TIRS)		
Band	Spectral Resolution (μm)	Spatial Resolution (m) at Nadir	Band	Spectral Resolution (μm)	Spatial Resolution (m) at Nadir
1 Ultra-blue for coastal/aerosol	0.433 – 0.453	30 × 30	10 Thermal	0.3 – 11.3	100 × 100
2 Blue	0.450 – 0.515	30 × 30	11 Thermal	11.5 – 12.5	100 × 100
3 Green	0.525 – 0.600	30 × 30	Sensor Technology	Pushbroom	
4 Red	0.630 – 0.680	30 × 30	Swath Width	185 km	
5 Near-infrared	0.845 – 0.885	30 × 30	Data Rate	400 WRS-2 scenes per day	
6 SWIR-1	1.56 – 1.66	30 × 30	Revisit	16 days	
7 SWIR-2	2.1 – 2.3	30 × 30	Orbit and Inclination	705 km, Sun-synchronous Inclination = 98.2° Equatorial crossing 10:00 a.m.	
8 Panchromatic	0.52 – 0.90	15 × 15	Quantization	12-bits (dramatic improvement over ETM ⁺)	
9 Cirrus	1.36 - 1.39	30 × 30	Signal to Noise	1–2 orders of magnitude improvement	

What Spatial Resolution Do I need

Different spatial resolutions can be used for specific observational or research needs.

This image shows spatial resolution examples for common NASA sensor products and a research scale for which they are suited (regional, national, continental, etc.).



Spatial enhancement

- ❑ Process of improving the spatial resolution, clarity, and detail of satellite imagery.
- ❑ Improve the visual quality of an image
- ❑ It involves various techniques aimed at sharpening the image to reveal finer details.

Spatial enhancement techniques

□ Spatial filtering:

Applying filters to satellite imagery to enhance specific spatial features or reduce noise.

□ Pan-sharpening (Resolution merge):

Combining high-resolution panchromatic (black and white) imagery with lower-resolution multispectral (color) imagery to produce a single, high-resolution color image.

Types of Spatial enhancement techniques

- ❑ Super-resolution:

Using algorithms to generate higher-resolution imagery from multiple lower-resolution images.

- ❑ Edge enhancement:

Highlighting edges and boundaries within the image to improve visual clarity and interpretability.

- ❑ Resampling:

Interpolating pixel values to adjust the spatial resolution of the image.

Spatial Frequency

- ❑ Spatial frequency in the context of image processing refers to the rate of change of pixel intensity values across space within an image.
- ❑ It represents the variation in brightness or color within different regions of the image.
- ❑ Spatial frequency analysis is used to characterize the patterns and structures present in an image at different scales.

Spatial Frequency

- ❑ **Low spatial frequency**— an image consisting of a smoothly varying grayscale; eg; Terrain slopes, vegetation patches
- ❑ **High spatial frequency** - Represents features with rapid changes or sharp transitions in pixel values, eg; edge, boundary line, texture patterns

SPATIAL FILTERING

High-Frequency Kernels:

- ❑ A high-frequency kernel, or high-pass kernel, has the effect of increasing spatial frequency.
- ❑ High-frequency kernels serve as edge enhancers, since they bring out the edges between homogeneous groups of pixels.

$$\begin{array}{ccc} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{array}$$

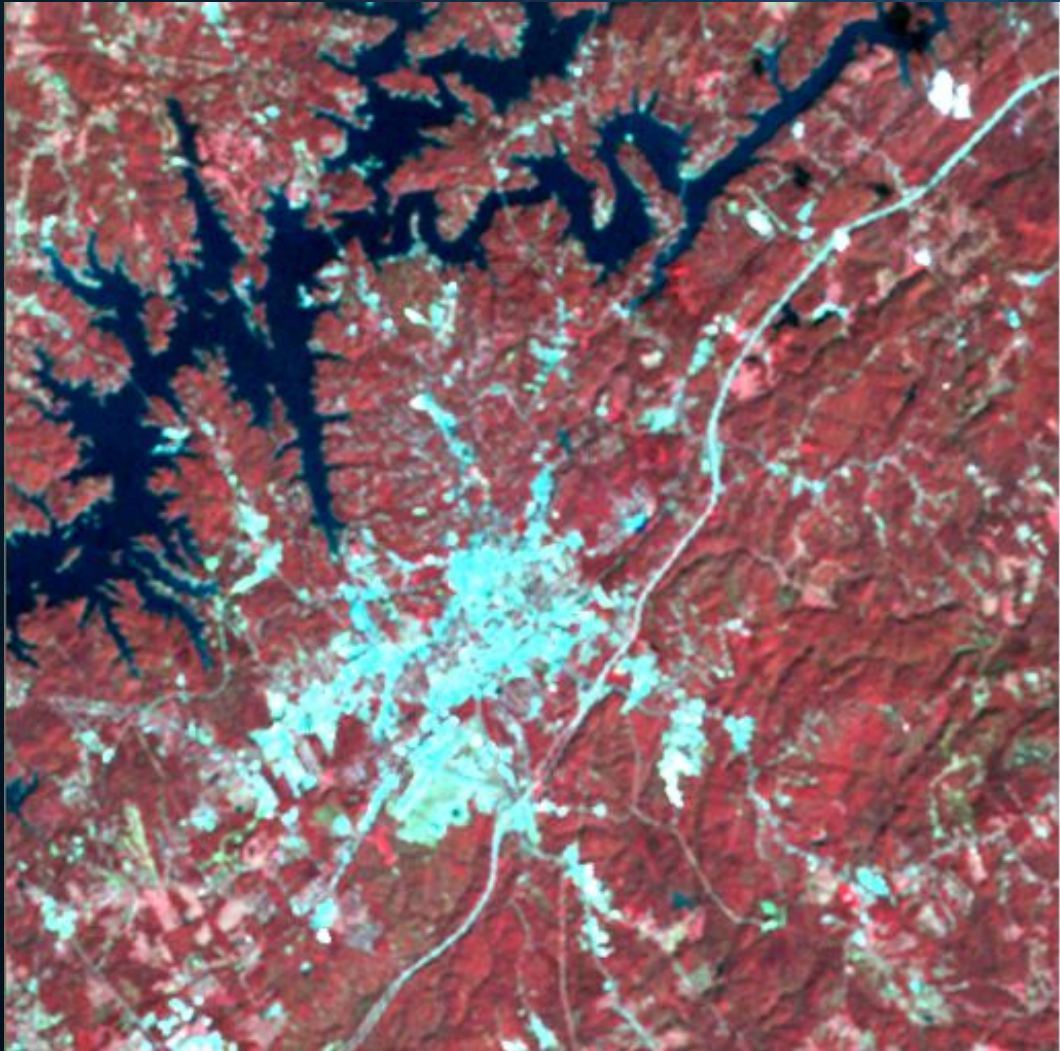
SPATIAL FILTERING

Low-Frequency Kernels:

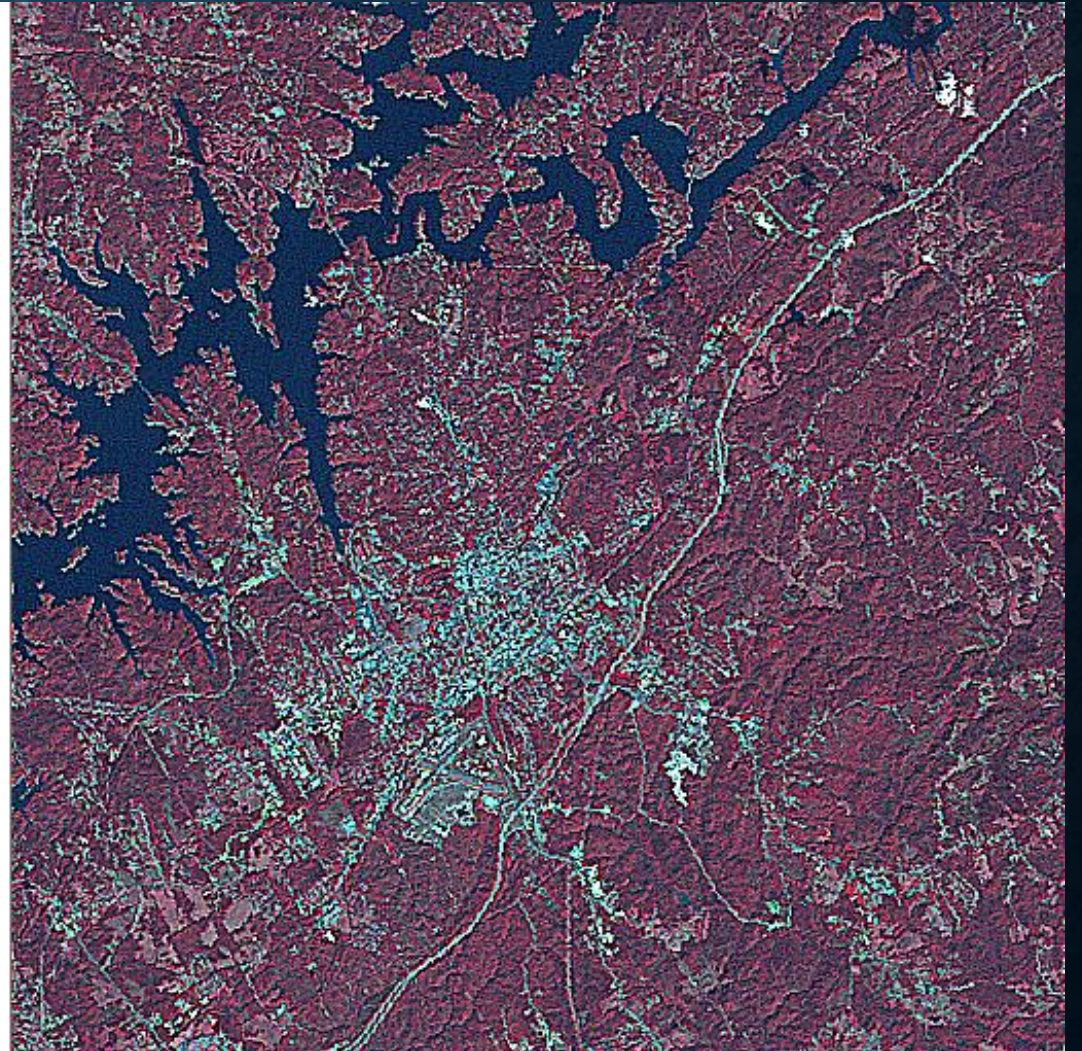
- ❑ Below is an example of a low-frequency kernel, or low-pass kernel, which decreases spatial frequency.
- ❑ This kernel simply averages the values of the pixels, causing them to be more homogeneous. The resulting image looks either more smooth or more blurred.

$$\begin{matrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{matrix}$$

SPATIAL FILTERING



After Low pass filtering



After High pass filtering

SPATIAL FILTERING

Spatial Filtering of Raster Data



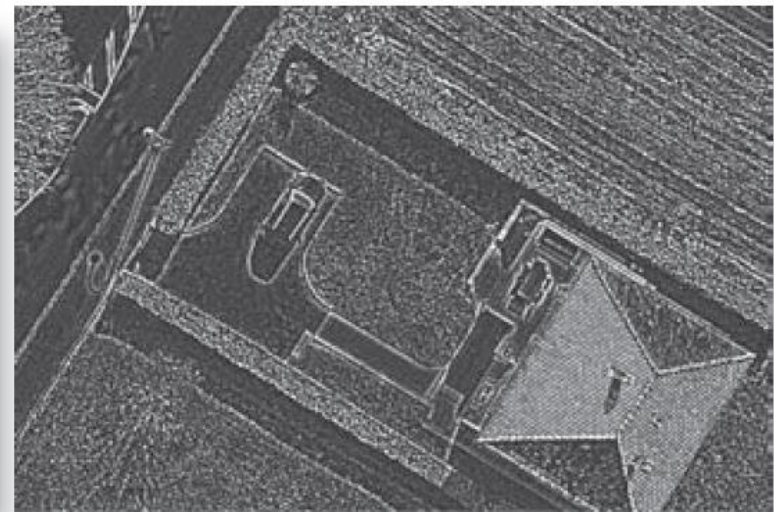
a. Original contrast stretched.



b. Low-frequency filter applied to the red band.



c. Median filter.

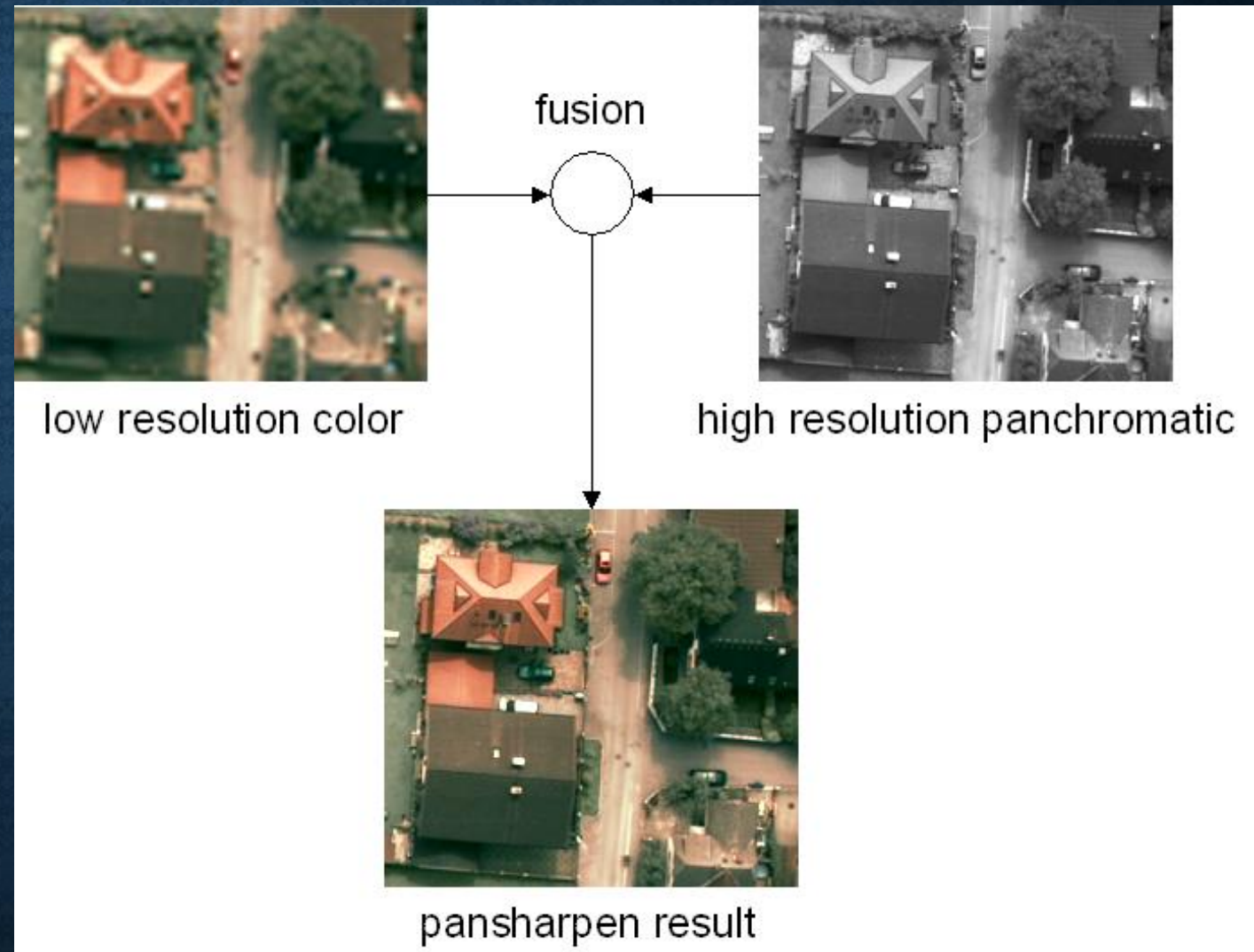


d. High-frequency sharp edge filter applied to the red band.

RESOLUTION MERGE/PAN-SHARPEN

The idea of pansharpening is to combine a low-resolution multi-spectral image with a high-resolution panchromatic image to one high-resolution multi-spectral one.

- Improves classifications accuracy
- Enhance the performance of the change detection
- Sharpen multi-spectral imagery



RESOLUTION MERGE/FUSION/PAN-SHARPEN

The question remains why fusion is important.

Most Earth observing satellites, such as:

- SPOT,
- IRS,
- Landsat 7&8,
- IKONOS,
- Quickbird or
- OrbView,
- plus modern airborne sensors,

provide both panchromatic images at a higher spatial resolution and multi-spectral images at a lower spatial resolution.

RESOLUTION MERGE/FUSION/PAN-SHARPEN

The reason why these sensors collect panchromatic and multi-spectral data at different spatial resolutions comes from the following considerations:

1. Incoming radiation energy:

A panchromatic image covers a broader wavelength range, in most cases the visible spectrum from 400 to 700nm [Gonzalez and Woods, 2001] (a range of 300nm), while a multi-spectral red, green or blue band covers a narrow spectral range of about 70nm Each

RESOLUTION MERGE/FUSION/PAN-SHARPEN

2. Data volume:

Data volumes of high-resolution multi-spectral sensors are high.

If only collecting a high-resolution panchromatic and lower resolution multi-spectral image, the data volume is reduced.

This solution can solve the problem of limited on-board storage capacity or limited data transmission rates from satellite to ground.

References:

Jensen, John R., 2015- *Introductory digital image processing : a remote sensing perspective* / John R. Jensen, University of South Carolina. pages cm. -- (Pearson series in geographic information science) 4th ed.

CRCSI (2017) *Earth Observation: Data, Processing and Applications. Volume 1B: Data—Image Interpretation*. (Eds. Harrison, B.A., Jupp, D.L.B., Lewis, M.M., Forster, B.C., Coppa, I., Mueller, N., Hudson, D., Phinn, S., Smith, C., Anstee, J., Grant, I., Dekker, A.G., Ong, C., and Lau, I.) CRCSI, Melbourne.