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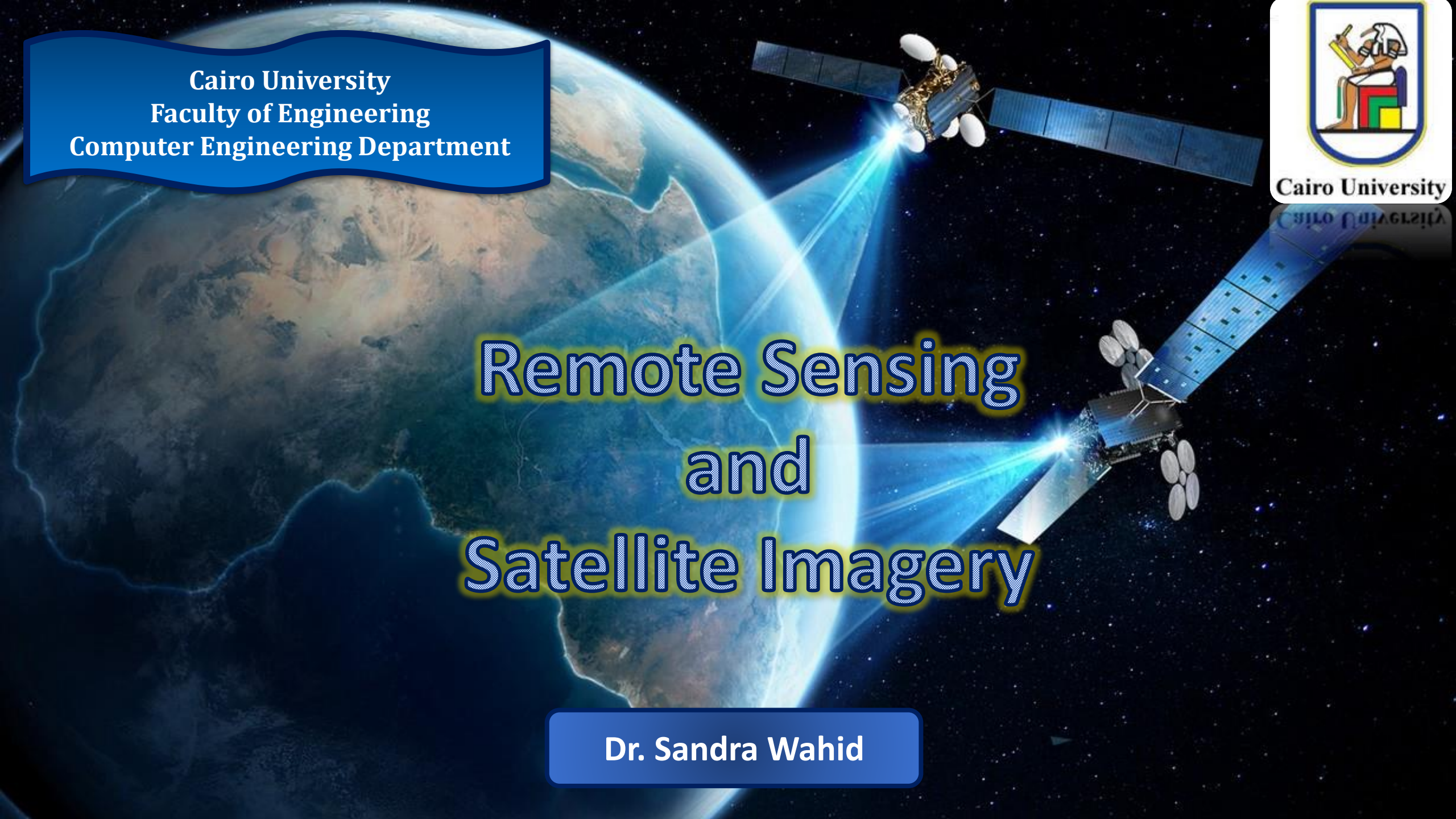


Remote Sensing and Satellite Imagery

Dr. Sandra Wahid

Remote Sensing

- Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft).

- Remote sensing is the acquiring of information from a distance. NASA observes Earth and other planetary bodies via remote sensors on satellites and aircraft that detect, and record reflected or emitted energy. Remote sensors, which provide a global perspective and a wealth of data about Earth systems, enable data-informed decision making based on the current and future state of our planet.

- In remote sensing, energy spreading out from the earth's surface is measured using a sensor mounted on an aircraft or spacecraft platform. That measurement is used to construct an image of the landscape beneath the platform.

Remote Sensing

- Provided an **energy source** is available, almost any wavelength could be used to image the characteristics of the earth's surface.

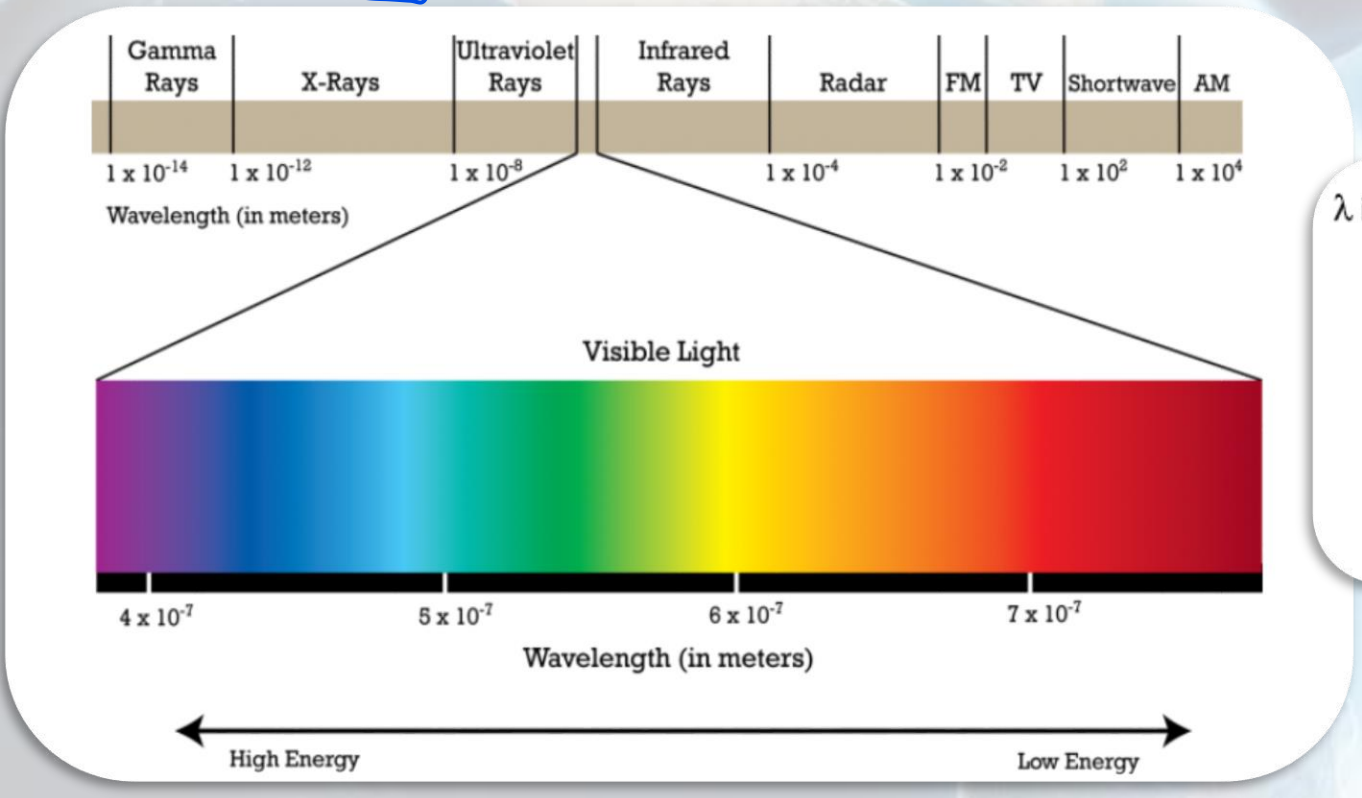
- **Sensors types:**

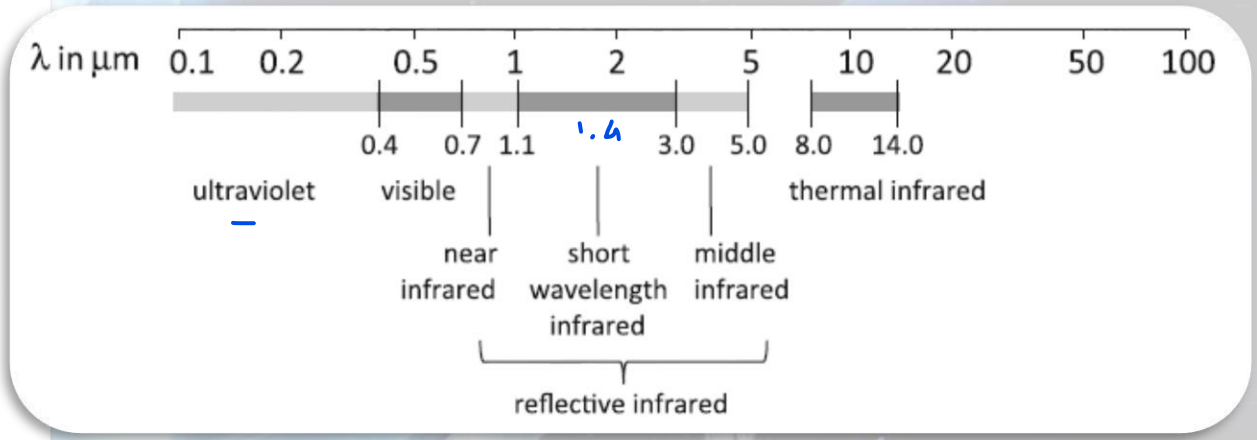
  - **Passive:** The sensors gather radiation that is emitted or reflected by the object or surrounding areas. Sunlight reflection is the most common source of radiation measured by passive sensors.

  - **Active:** The sensor embodies within itself the source of energy radiation. Energy is radiated from a platform onto the earth's surface. It is by measuring the energy scattered back to the platform that image data is recorded. For example, since earth emits too small microwave radiation to be measured, active sensors are used to record images at microwave wavelengths.

Energy Sources and Wavelength Ranges

- The electromagnetic spectrum:





IR divisions have variants

- The electromagnetic spectrum is broad and not all wavelengths are equally effective nor significantly interact with surfaces of interest for remote sensing purposes.

Applications of Remote Sensing

- **Land Cover and Land Use Mapping:**
  - Land Cover Mapping: represents information on different types (classes) of physical coverage of the Earth's surface, e.g. forests, grasslands, croplands, lakes, wetlands, …etc. Dynamic land cover maps include transitions of land cover classes over time and hence captures land cover changes.
  - Land Use Mapping: refers to the purpose the land serves, for example, housing, wildlife habitat, agriculture, …etc.

- **Weather Forecasting**

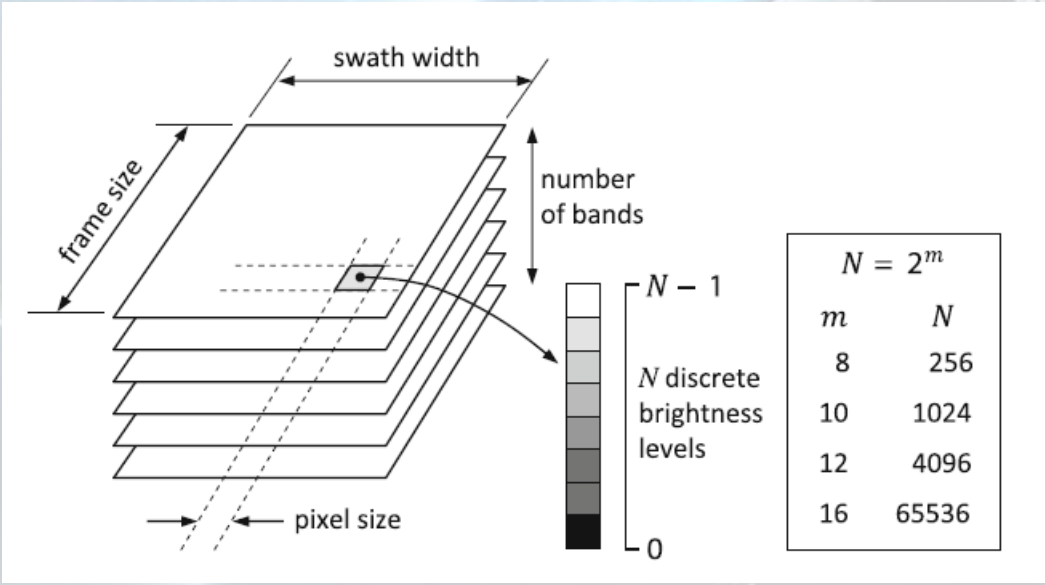
- **Environmental Study:** deforestation, degradation of fertile lands, pollution in atmosphere, desertification, oil spillage from oil tankers, …etc.

- **Study of Natural Hazards:** used to study damages caused by earthquakes, volcanoes, landslides, floods and melting of ice in polar regions. Also, remote sensing is helpful to predict the occurrence of natural hazards.

- **Resource Exploration:** updating existing geological maps, identifying the sites for the minerals and helpful in locating fuel deposits.

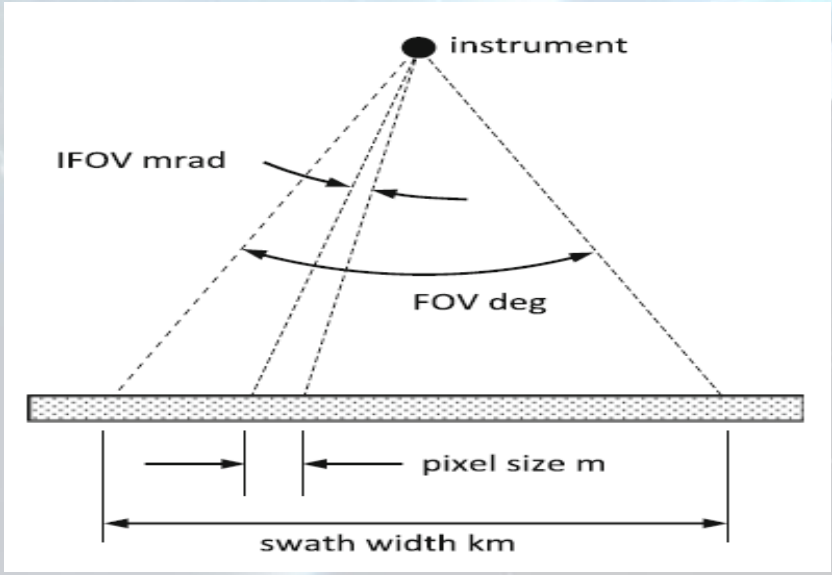
Primary Data Characteristics

- **Spectral resolution:** is the number and width of the spectral ***bands or channels*** that the satellite sensor detects.
- **Spatial resolution:** is described by the ***pixel size***.
- **Radiometric resolution:** is expressed in terms of the number of binary digits, or bits, necessary to represent the range of available ***brightness values***.
  - Data with an 8 bit radiometric resolution has 256 levels of brightness, while data with 12 bit radiometric resolution has 4,096 brightness levels.
- **Frame size:** the size of the recorded image frame is also an important property. It is described by the number of pixels across the frame or ***swath***, or in terms of the numbers of kilometres covered by the recorded scene.



Primary Data Characteristics

- Image properties like ***pixel size*** and ***frame size*** are related directly to the technical characteristics of the sensor that was used to record the data.
- The **instantaneous field of view (IFOV)** of the sensor is its finest angular resolution. When projected onto the surface of the earth at the operating altitude of the platform, it defines the smallest resolvable element in terms of equivalent ground metres, which is what we refer to as *pixel size*.
- The **field of view (FOV)** of the sensor is the angular extent of the view it has across the earth's surface. When that angle is projected onto the surface it defines the *swath width* in equivalent ground kilometres.



Example: Sentinel-2 Dataset

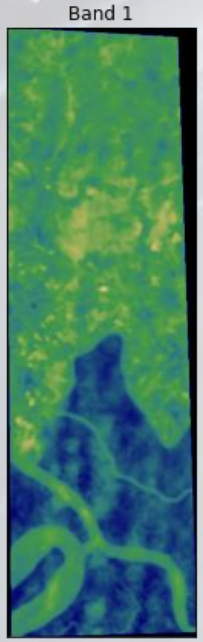
- Sentinel-2 (S2) is a wide-swath, high-resolution, multispectral imaging mission.
- The S2 Multispectral Instrument (MSI) samples 13 spectral bands ranging from 10 to 60-meter pixel size.
- There are **13** Sentinel-2 bands in total.
- Each band is **10, 20, or 60** meters in pixel size.
- Sentinel-2 consists of **2** satellites. First came Sentinel-2A which was launched in 2015. Next came Sentinel-2b in 2017.
- Two additional satellites (Sentinel-2C and 2D) were planned to launch in 2024.

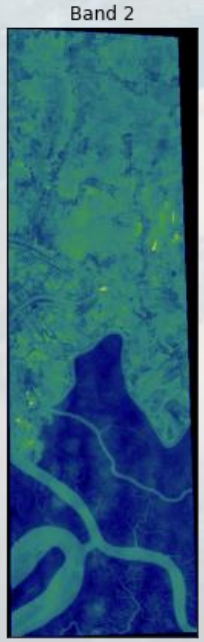
Example: Sentinel-2 Dataset

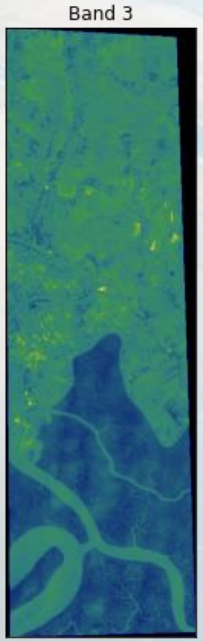
Band	Resolution	Central Wavelength	Description
B1	60 m	443 nm	Ultra Blue (Coastal and Aerosol)
B2	10 m	490 nm	Blue
B3	10 m	560 nm	Green
B4	10 m	665 nm	Red
B5	20 m	705 nm	Visible and Near Infrared (VNIR)
B6	20 m	740 nm	Visible and Near Infrared (VNIR)
B7	20 m	783 nm	Visible and Near Infrared (VNIR)
B8	10 m	842 nm	Visible and Near Infrared (VNIR)
B8a	20 m	865 nm	Visible and Near Infrared (VNIR)
B9	60 m	940 nm	Short Wave Infrared (SWIR)
B10	60 m	1375 nm	Short Wave Infrared (SWIR)
B11	20 m	1610 nm	Short Wave Infrared (SWIR)
B12	20 m	2190 nm	Short Wave Infrared (SWIR)

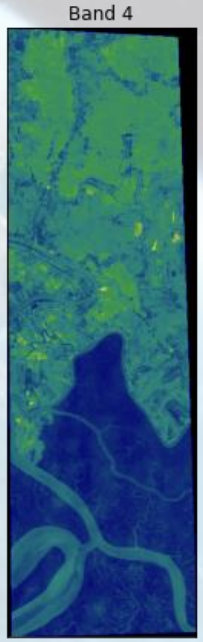
RGB

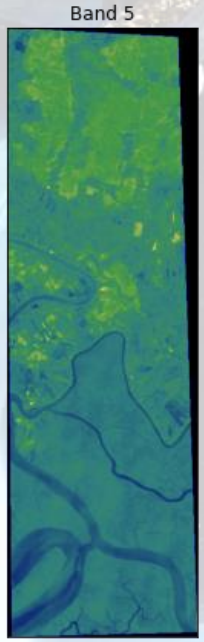
Example: Sentinel Bands Visualization

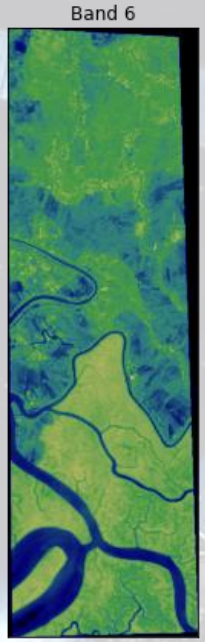


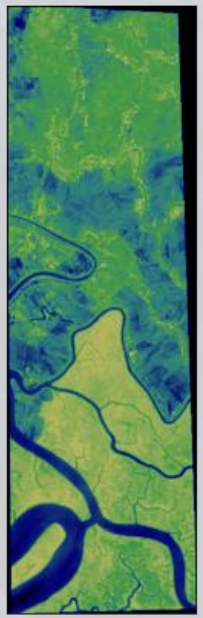


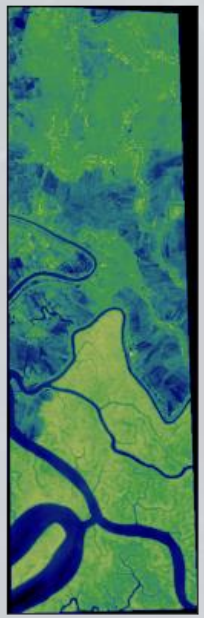


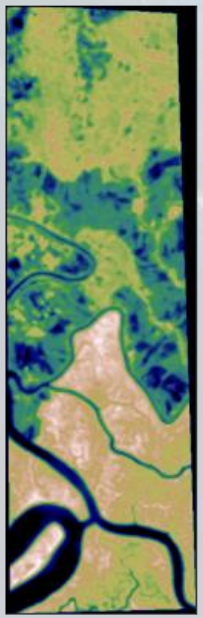


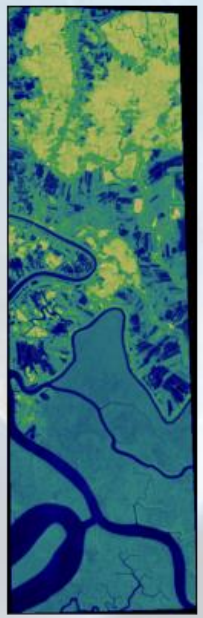


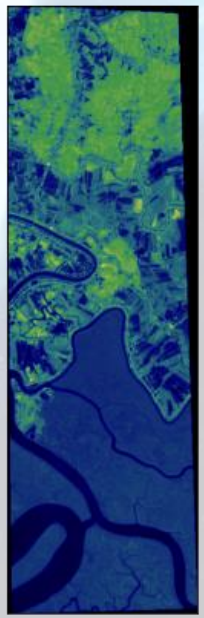


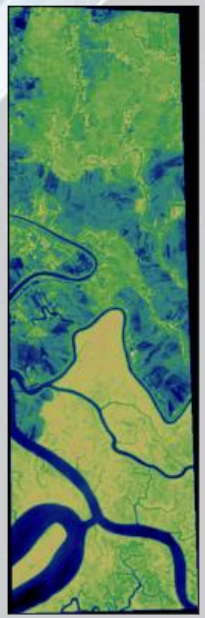












As viewed by human eyes
(RGB Composite Image)

Example: Sentinel Band Combinations

- We use band combinations to better understand the features in imagery.
- The way we do this is by rearranging the available channels in creative ways.
- By using band combinations, we can extract specific information from an image.
  - For example, there are band combinations that highlight geologic, agricultural, or vegetation features in an image.

Example: Sentinel Band Combinations

Natural Color (B4, B3, B2):

- The natural color band combination uses the red (B4), green (B3), and blue (B2) channels. Its purpose is to display imagery the same way our eyes see the world.
- Just like how we see:
  - healthy vegetation is green.
  - urban features often appear white and grey.
  - water is a shade of dark blue depending on how clean it is.

Example: Sentinel Band Combinations

Color Infrared (B8, B4, B3):

- The color infrared band combination is meant to emphasize healthy and unhealthy vegetation.
- By using the near-infrared (B8) band, it's especially good at reflecting chlorophyll. This is why in a color infrared image, denser vegetation is red. But urban areas are white.

Example: Sentinel Band Combinations

Short-Wave Infrared (B12, B8A, B4):

- The short-wave infrared band combination uses SWIR (B12), NIR (B8A), and red (B4).
- This composite shows vegetation in various shades of green.
- In general, darker shades of green indicate denser vegetation. But brown is indicative of bare soil and built-up areas.

Example: Sentinel Band Combinations

Agriculture (B11, B8, B2)

- The agriculture band combination uses SWIR-1 (B11), near-infrared (B8), and blue (B2).
- It's mostly used to monitor the health of crops because of how it uses short-wave and near-infrared.
- Both these bands are particularly good at highlighting dense vegetation that appears as dark green.

Example: Sentinel Band Combinations

Geology (B12, B11, B2)

- The geology band combination is a neat application for finding geological features.
- This includes faults (an extended break in a rock formation), lithology (the study of the general physical characteristics of rocks), and geological formations.
- By leveraging the SWIR-2 (B12), SWIR-1 (B11), and blue (B2) bands, geologists tend to use this Sentinel band combination for their analysis.

Example: Sentinel Band Combinations

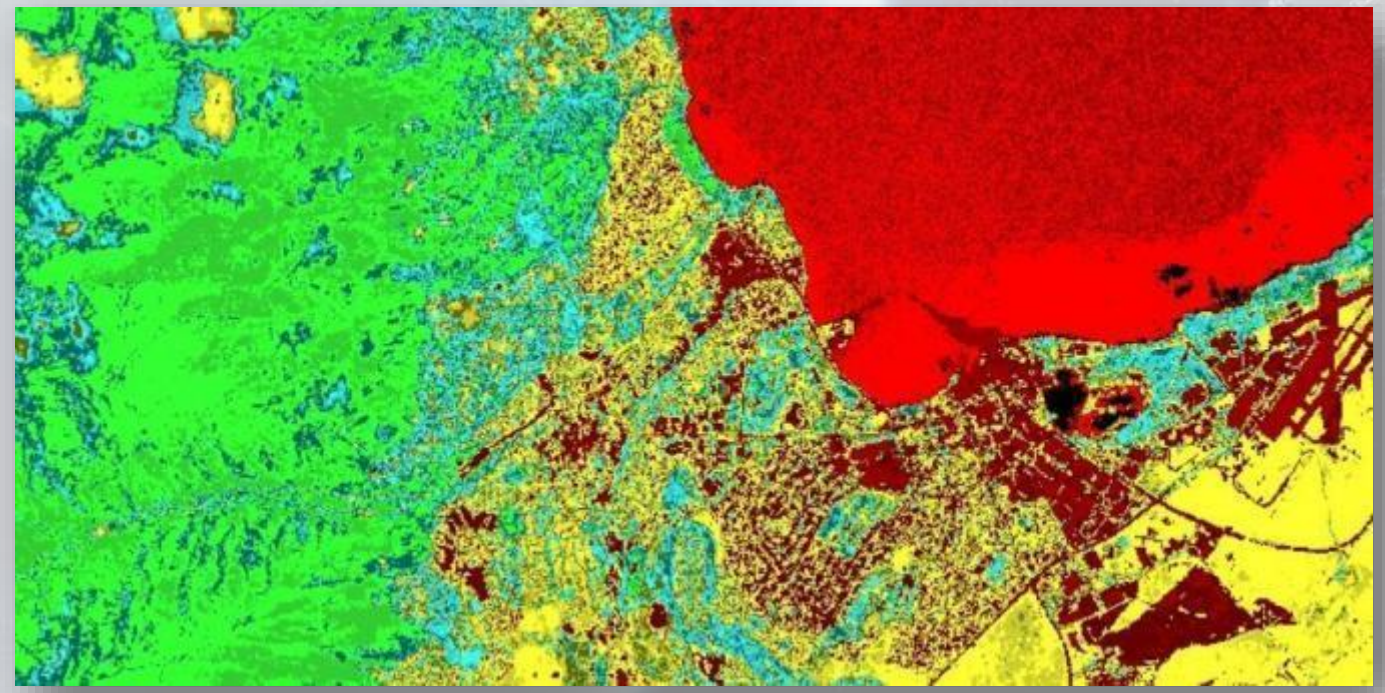
Bathymetric (B4, B3, B1)

- As the name implies, the bathymetric band combination is good for coastal studies.
- The bathymetric band combination uses the red (B4), green (B3), and coastal band (B1). Using the coastal aerosol band is good for estimating suspended sediment in the water.

Example: Sentinel Band Combinations

Vegetation Index (B8-B4)/(B8+B4)

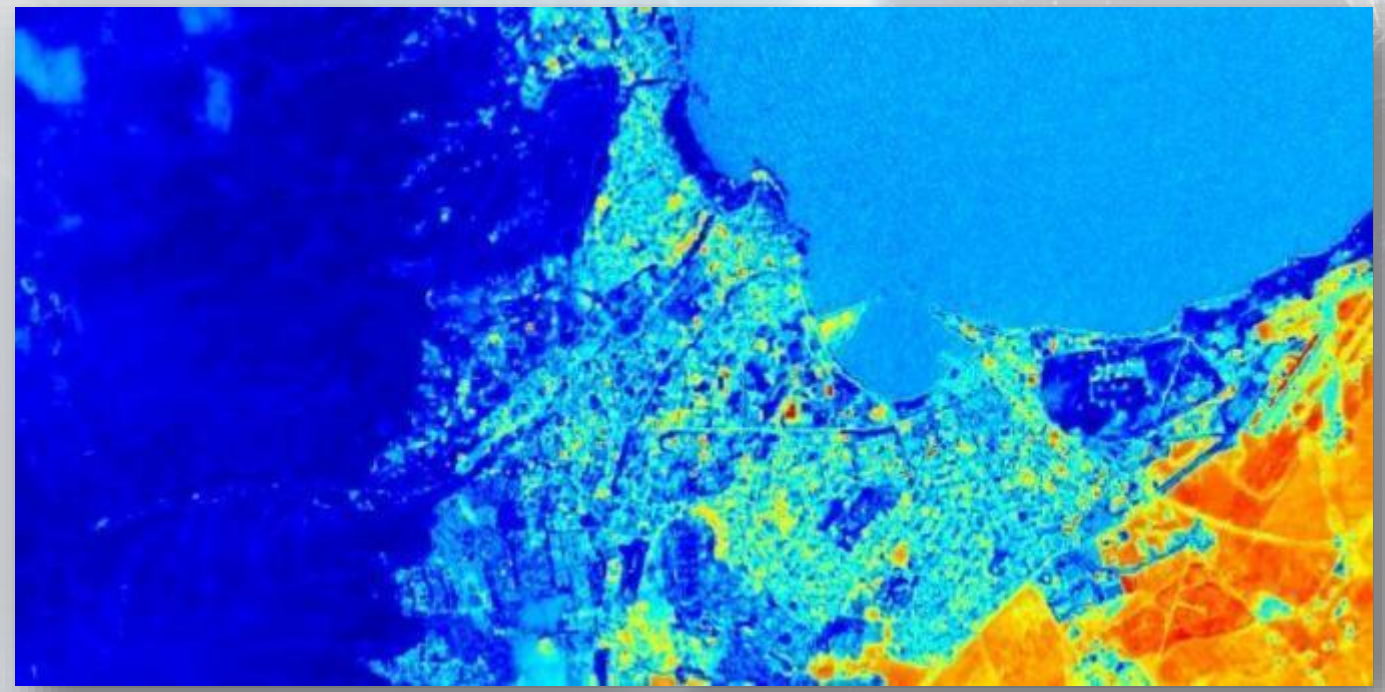
- Because near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs), the vegetation index is good for quantifying the amount of vegetation.
- The formula for the normalized difference vegetation index is (B8-B4)/(B8+B4).
- While high values suggest dense canopy (the uppermost branches of the trees in a forest), low or negative values indicate urban and water features.



Example: Sentinel Band Combinations

Moisture Index (B8A-B11)/(B8A+B11)

- The moisture index is ideal for finding water stress in plants.
- It uses the short-wave and near-infrared to generate an index of moisture content.
- In general, wetter vegetation has higher values. But lower moisture index values suggest plants are under stress from insufficient moisture.



Aerial Imagery vs Satellite Imagery

- Both offer a view of the ground and its features, objects from above: **"bird's eye view"**.

- The term **aerial imagery** refers to all imagery taken from an **airborne** craft which can include drones, balloons or airplanes.
- The term **satellite imagery** refers to all imagery taken by **artificial satellites**.

- While aerial photography implies images taken of the visible spectrum, **sensors** to measure bands within the nonvisible spectrum (e.g., ultraviolet, infrared, near-infrared) can also be fixed to aerial sources.

Thank You