CASA0023 Remotely Sensing Cities and Environments Learning Diary

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Hello, RS!

This is a Quarto book.

1 Introduction to Remote Sensing

1.1 Summary

Key Aspect	**Description**
Definitions	Remote sensing as a technique for collecting Earth's surface information from a distance.
Platforms	Satellites, planes, drones ("spectroradiometer"in a lab or in the field)used for data acquisition.
Sensor Types	Passive and active sensors, their principles and examples.
Electromagnetic Radiation	Interaction with Earth's surface and atmosphere.
Data Formats	Focus on raster data and its applications.
Resolutions	Spatial, spectral, temporal, radiometric resolutions in remote sensing.
Applications	Land cover, agriculture, climate change, disaster management.

1.1.1 Definitions

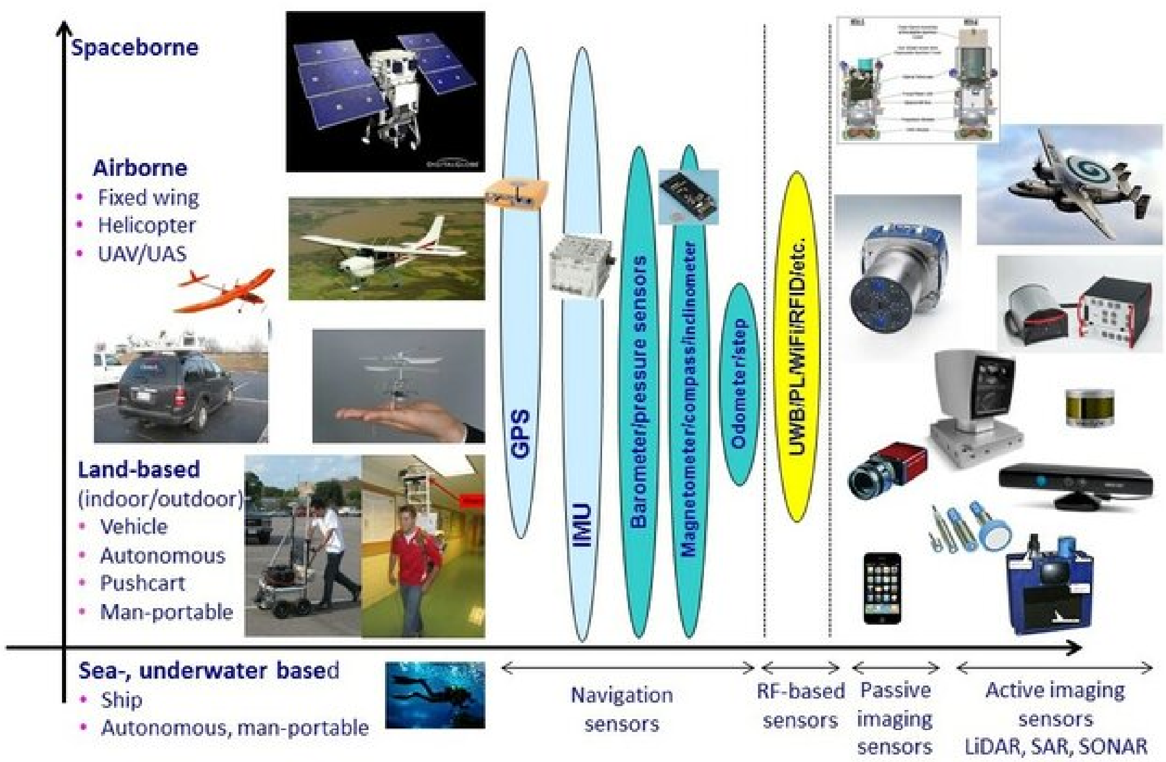
NASA defines remote sensing as **the process of acquiring information from a distance**, commonly associated with Earth Observation (EO), utilizing sensors on platforms like satellites, drones, and more. Currently, over 150 satellites equipped with these sensors orbit Earth, collecting essential data. However, the proliferation of space technology has led to a challenge with space debris, with NASA tracking over 27,000 pieces, underscoring the need for strategies to manage and mitigate space pollution.

1.1.2 Platforms

Remote sensing is accomplished using sensors mounted on various platforms, each offering unique capabilities for data collection from the Earth's surface, atmosphere, and oceans:

- **Satellites:** Capable of systematically covering vast areas, satellites revisit the same points on Earth from daily to every 16 days. This regular observation schedule is crucial for tracking environmental changes, weather patterns, and monitoring natural disasters on a global scale.

- **Planes (aerial imagery):** Provide targeted, high-resolution imagery for specific areas, making them invaluable for detailed surveys, agricultural assessments, and environmental monitoring.
- **Drones:** Offer unparalleled flexibility and precision, capturing detailed data at low altitudes for applications such as precision agriculture, construction monitoring, and environmental conservation.
- **Phones:** Enable widespread, citizen-driven data collection, contributing to urban studies, crowd-sourced mapping projects, and local environmental observations.
- **Free standing on the ground or sea (with handheld devices):** Ground and maritime platforms, like tripods, buoys, and hand-held devices, allow for direct, in-situ measurements of soil, water, and atmospheric conditions, essential for localized research and monitoring.



Various platforms and sensors used for remote sensing   Source: Toth (2018)

1.1.3 Sensor Types

Remote sensing sensors are broadly classified into two categories based on their operational principles: passive and active sensors.

- **Passive Sensors:** Capture energy naturally reflected or emitted by objects, relying on sunlight as the primary light source. Examples include **cameras and satellite sensors**, ideal for environmental monitoring and Earth observation during daylight hours.
- **Active Sensors:** Generate their own energy to illuminate targets, measuring the reflected energy. Technologies like **LiDAR and radar** fall into this category, enabling detailed surface mapping and atmospheric studies, regardless of day or night conditions.

Choosing between passive and active sensors depends on the project's goals, like desired detail, target area conditions, and when data is collected. While passive sensors excel in natural light conditions, active sensors offer versatility in challenging environments (e.g., night-time or cloud-covered areas). For example, Synthetic Aperture Radar (SAR) excels in overcoming challenges posed by clouds, volcanic ash, and darkness, thanks to its ability to operate at longer wavelengths across different bands (e.g., P, L, S, C, X, Ku, K). This versatility enhances Earth observation capabilities, enabling data acquisition in nearly all weather and lighting conditions.

1.1.4 Electromagnetic Radiation

Electromagnetic radiation (EMR) is essential for remote sensing, acting as the medium that carries information from the Earth's surface to sensors located on satellites, aircraft, or ground-based platforms. EMR encompasses a spectrum of wavelengths, including visible light, infrared, and microwaves, each interacting uniquely with different surface materials and atmospheric conditions.

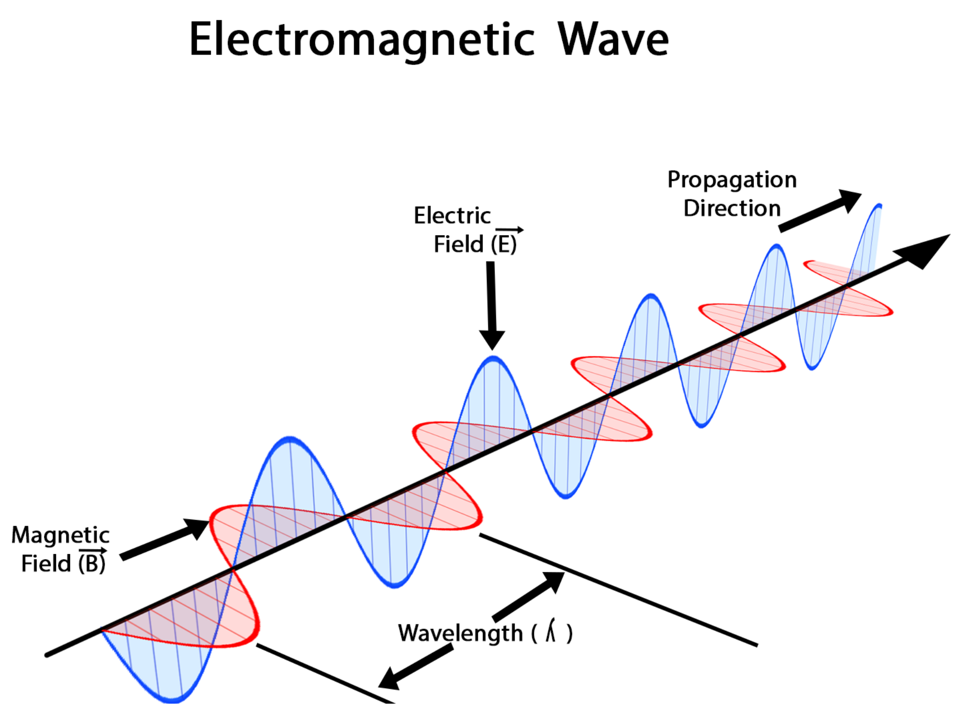
Fundamental Principles:

- **Wavelength ( ):** The distance between consecutive wave peaks, determining the radiation's energy and type.
- **Frequency ( ):** The number of wave cycles per second, inversely related to wavelength (=c/), where c is the speed of light (3×10 m/s)

EMR propagates through space, carrying energy with oscillating electric and magnetic fields at right angles to each other and the direction of travel.

How do electromagnetic waves wave   Source: imathworks.com

Interaction with **Earth's Surface**:



The interaction of electromagnetic radiation (EMR) with the Earth's surface—encompassing reflection, absorption, transmission and scattering—fundamentally shapes the data captured by remote sensing technologies. Reflective properties reveal surface textures and compositions, absorption characteristics inform on material types and conditions, and transmission data offers insights into the substance's transparency to specific EMR wavelengths.

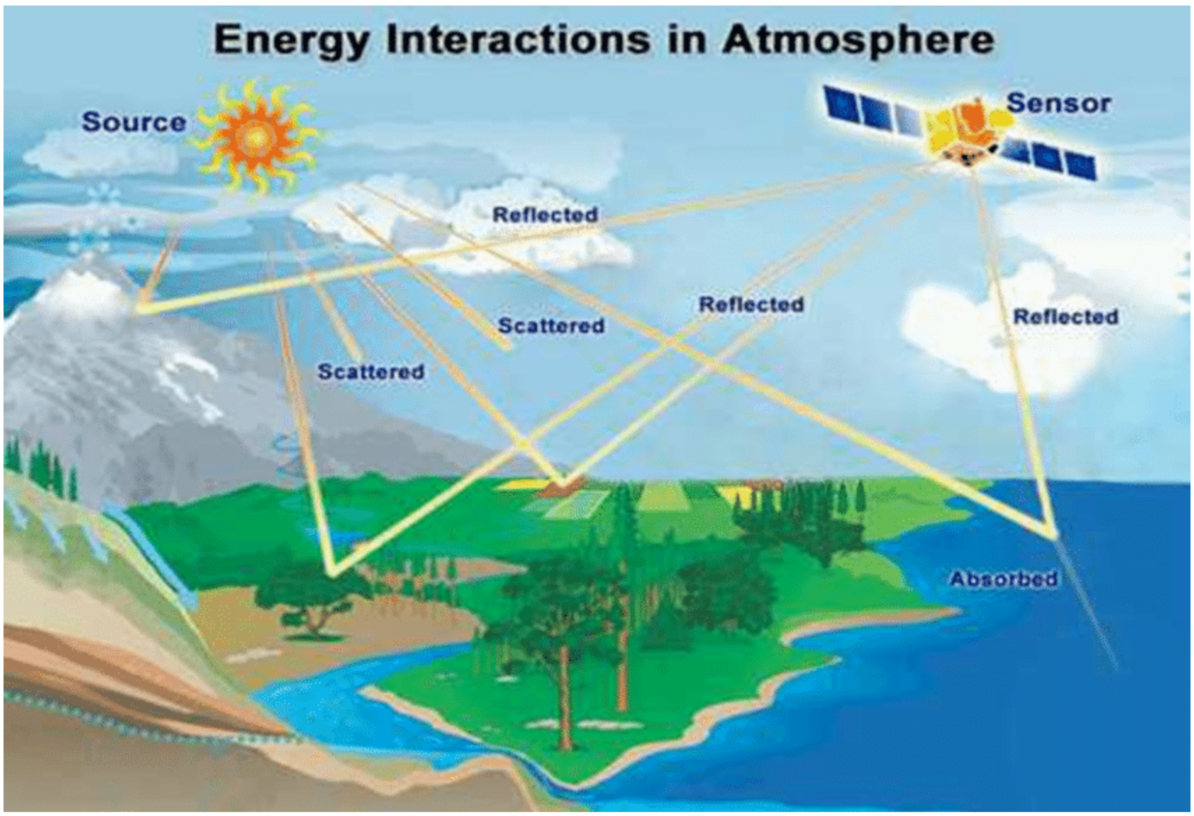
Atmospheric Influence:

While traversing the atmosphere, EMR may be scattered by particles or absorbed by gases, altering its path and intensity before reaching the surface.

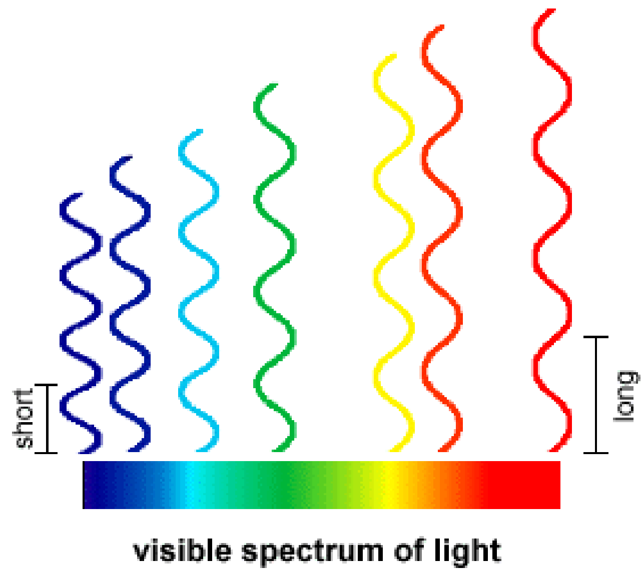
Electromagnetic radiations' interactions with Earth's surface and atmosphere Source: Deepak Kumar Soni (2013)

Scattering Phenomena:

- **Rayleigh Scattering:** Predominant when atmospheric particles are significantly smaller than the radiation's wavelength, primarily affecting shorter wavelengths and coloring the sky blue.
- **Mie Scattering:** Arises when particle sizes are comparable to the wavelength, altering all wavelengths somewhat uniformly, noticeable during light's passage through atmospheric pollutants or moisture.


Energy Interactions in Atmosphere
Source
Sensor
Reflected
Reflected
Reflected
Scattered
Scattered
Absorbed

- **Non-selective Scattering:** Manifests when particles exceed the radiation's wavelength in size, impacting all wavelengths alike and contributing to clouds' white appearance.



Comparison of visible wavelengths   Source: vertebratepest.wordpress.com

Influence on Visual Perception:

Blue light scatters more intensely in Earth's atmosphere due to its shorter wavelength, creating a blue sky and vivid sunsets with red and orange hues as the sun's rays travel through more atmosphere. In contrast, the Moon's lack of atmosphere results in a black sky and challenges in distance perception due to no scattering, while the ocean's blue color arises from the absorption of longer wavelengths and scattering of shorter blue wavelengths, deepening in hue with increased depth.

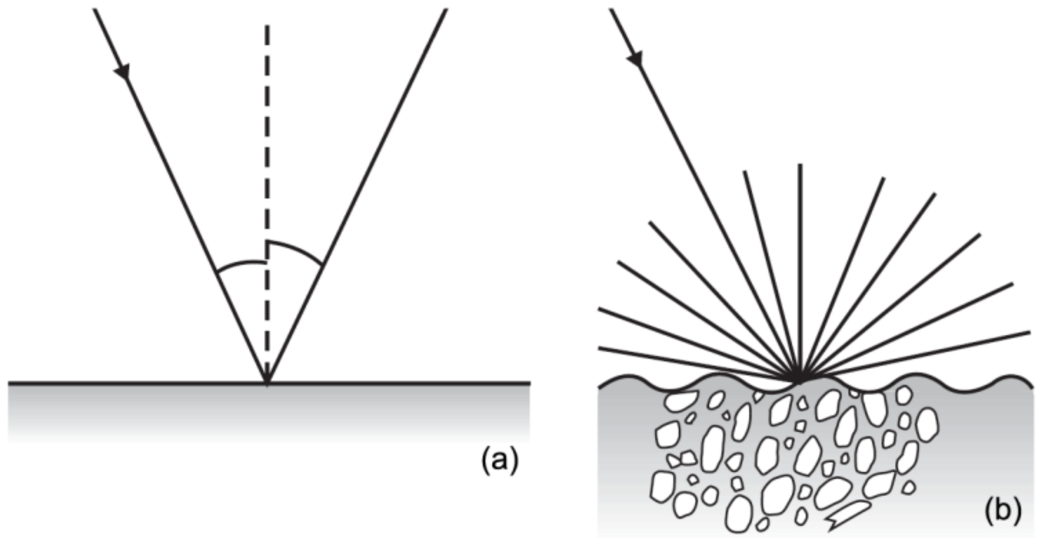
Specular Reflection VS Diffuse Reflection

Specular and diffuse reflection Source: Tempfli, K. et al. (2009)

1. **Specular Reflection** occurs on smooth surfaces (like water or polished rocks), where light reflects in a single, specific direction. This reflection is directional, causing bright spots in images if the angle aligns with the sensor.

2. **Diffuse Reflection** happens on rough surfaces (such as soil or vegetation), scattering light in multiple directions. This reflection is uniform, providing consistent information regardless of the viewing angle.

3. **Impact on Remote Sensing:** The main difference is how they affect image brightness and information consistency. Specular reflection can vary with observer angle, leading



to potential bright spots. Diffuse reflection offers reliable data about the Earth's surface, useful for applications like vegetation monitoring or land cover classification.

In the forthcoming studies, by exploring phenomena such as the Bidirectional Reflectance Distribution Function (BRDF), polarization, and fluorescence, we will gain a deeper understanding of the complexities of electromagnetic radiation's interaction with the Earth's surface...

1.1.5 Data Formats

Remote sensing data primarily uses raster formats, organizing the Earth's surface into pixels, each representing specific information like reflectance or temperature. Key raster data formats include:

- **Band Interleaved by Line (BIL):** Facilitates line-by-line analysis across multiple bands.
- **Band Sequential (BSQ):** Groups all pixels of a band together, suitable for single-band processing.
- **Band Interleaved by Pixel (BIP):** Stores all band values for each pixel together, ideal for multi-spectral analysis.

Videro: Organizing Multi-band Image Data (BIL,BIP and BSQ Formats)

- **GeoTIFF:** The most common format, incorporating geographic metadata, and widely supported across GIS and remote sensing platforms.

- **LiDAR data:** Capturing 3D point information, illustrates the adaptability of these formats for specific applications like elevation modeling.

1.1.6 Resolutions

In remote sensing, data quality and applicability are determined by four key resolutions: spatial, spectral, temporal, and radiometric. Each plays a crucial role in how Earth observation data is captured, analyzed, and utilized.

Spatial Resolution

Source: gisgeography.com

Spatial resolution refers to the size of one pixel in a raster image, which can range from as fine as 10 cm to several kilometers. It determines the smallest object that can be detected on the Earth's surface, with higher resolutions providing more detail.

Spectral Resolution

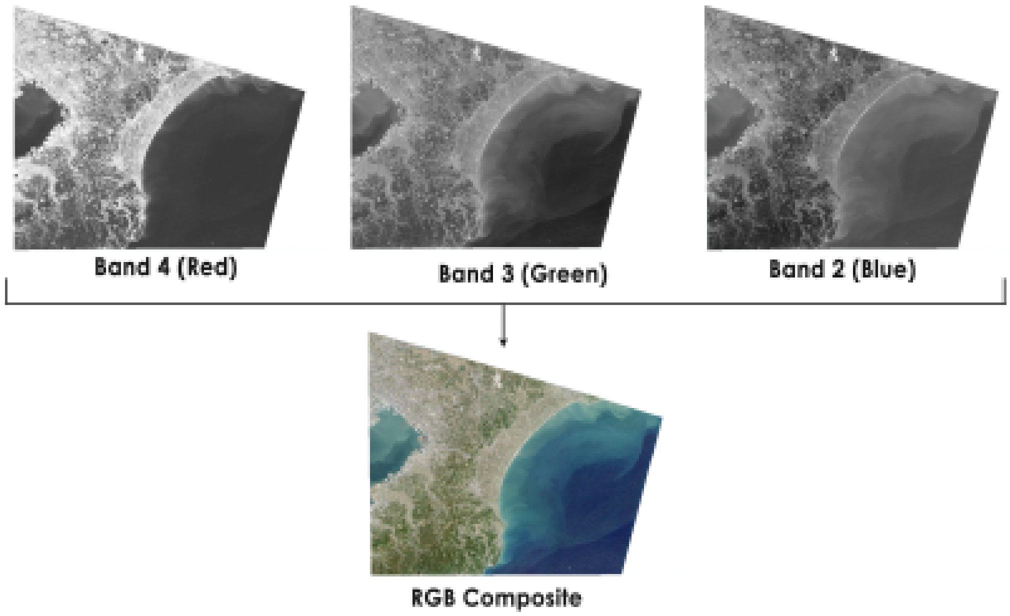
Source: gisgeography.com

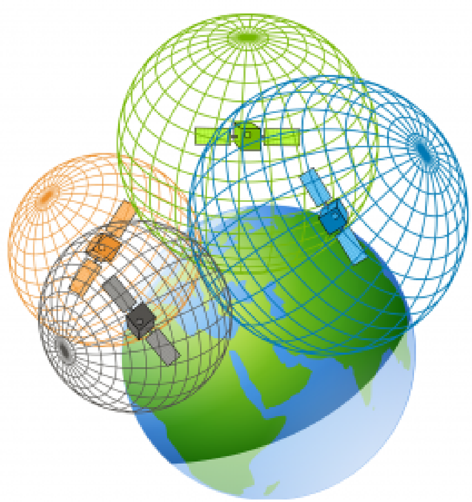
Spectral resolution describes the ability of a sensor to define wavelength intervals or bands. It ranges from broad bands capturing basic color information in the visible spectrum to narrow bands that can identify specific spectral signatures of materials. Spectral signatures are unique to each feature on Earth but are limited by atmospheric windows that allow only certain wavelengths to pass through unabsorbed.

Temporal Resolution

Source: gisgeography.com

Temporal resolution is about the frequency at which a sensor revisits the same location, which can vary from multiple times a day to once every few weeks. This is vital for monitoring changes over time, such as vegetation growth, urban development, or the progression of natural disasters.


Band 4 (Red)
Band 3 (Green)
Band 2 (Blue)
RGB Composite



Radiometric Resolution

Source: USGS

Radiometric resolution indicates a sensor's sensitivity to detect slight differences in light or reflectance levels, essentially the range of possible values a sensor can record. This can vary from 256 levels (8-bit) to over 2048 levels (11-bit), affecting the sensor's ability to distinguish between similar surfaces.

Each type of resolution has its balancing act, influenced by the sensor's design and the orbit type, whether geosynchronous or geostationary. The choice of sensor and its resolutions is dictated by the specific needs of a project, including the size of features to be observed, the date range of interest, revisit requirements, spectral sensitivity, and budget constraints. Understanding these resolutions is essential for selecting the appropriate remote sensing technology to answer specific scientific, environmental, or planning questions.

1.2 Applications

In the practical section, we learned how to download and process Sentinel and Landsat satellite data, and analyzed the downloaded data using QGIS, SNAP, and R software.

1.2.1 SNAP

SNAP (Sentinels Application Platform) is a free and open-source software platform developed by the European Space Agency (ESA) designed to provide comprehensive support for processing and analyzing data from the Sentinel satellite series. This platform is specifically aimed at earth observation data, offering a wide array of tools for the preprocessing, analysis, and visualization of remote sensing data.

The platform includes a series of toolboxes, each targeting specific data processing tasks such as image correction, classification, image synthesis, and change detection. These toolboxes offer a broad range of algorithms that enable users to perform complex analyses and interpretations of remote sensing data.

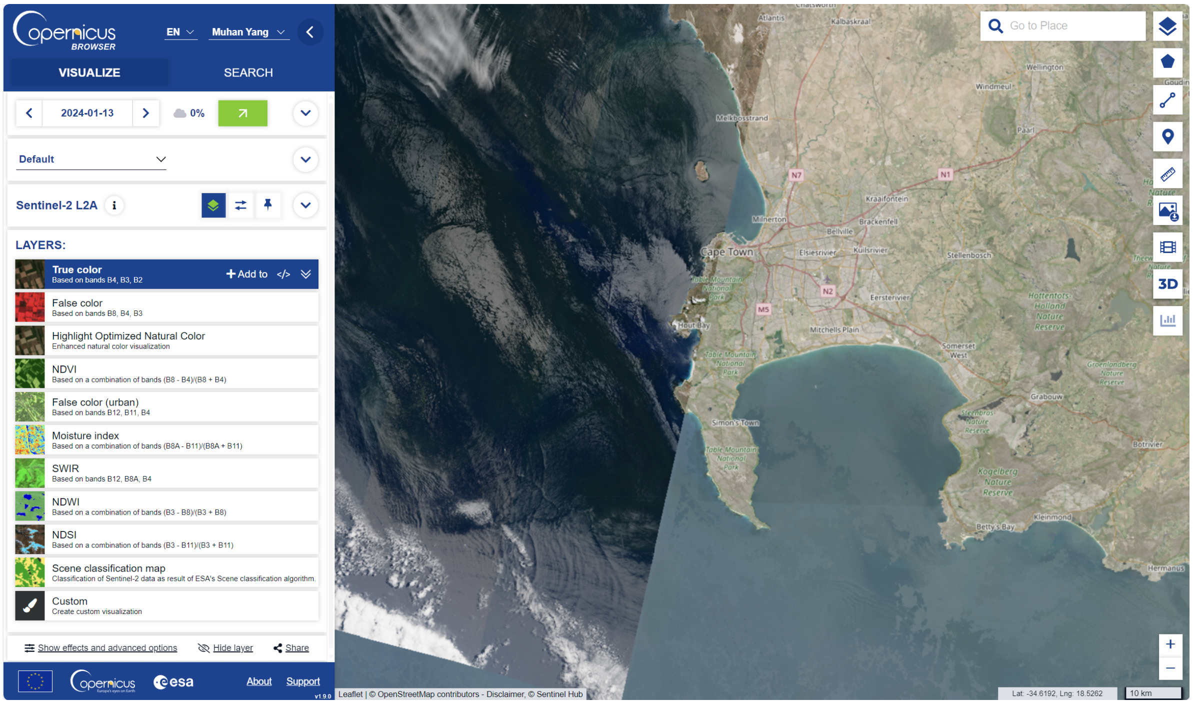
1.2.2 Sentinel

The Sentinel satellites are part of the Copernicus program, a cornerstone of the European Union's efforts to monitor the Earth and its environment for the benefit of all European citizens. This fleet of satellites provides a unique set of observations, starting from high-resolution land and ocean monitoring (Sentinel-1 radar and Sentinel-2 optical sensors) to atmospheric composition (Sentinel-5P). Sentinel data is pivotal for a wide range of applications, including climate change, land use change detection, urban planning, and natural disaster assessment and management.

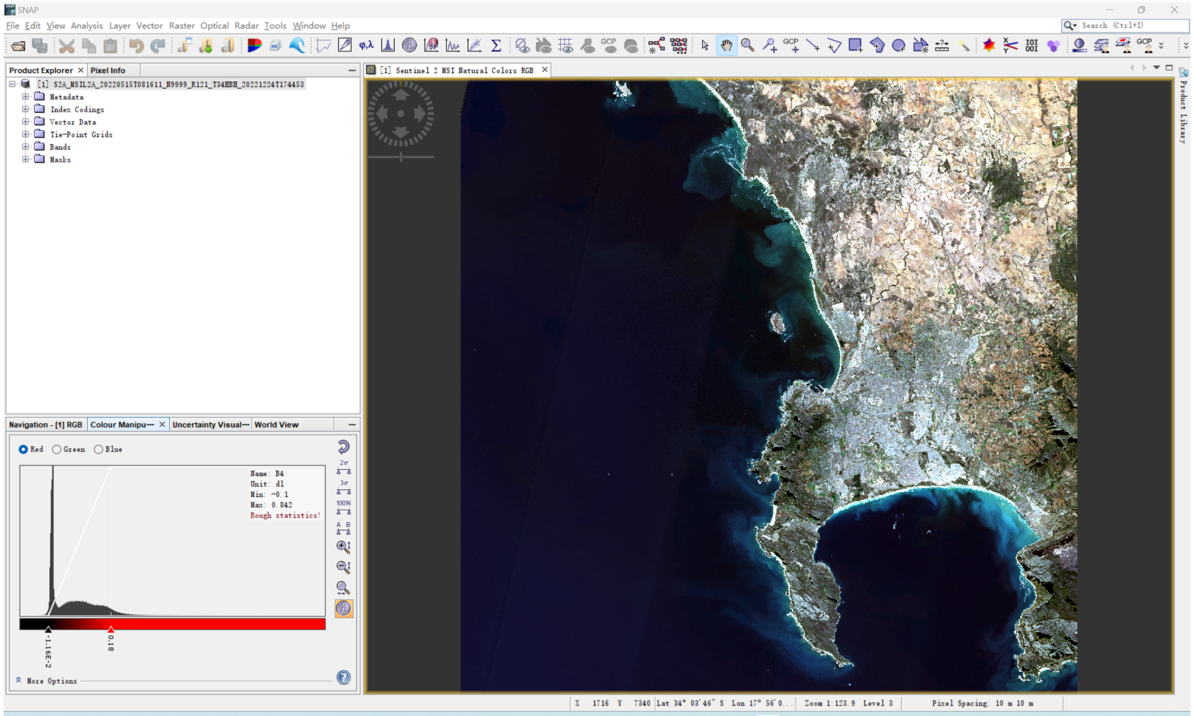
SNAP is particularly well-suited for processing Sentinel data. It offers specialized toolboxes for Sentinel-1, Sentinel-2, and Sentinel-3, among others, facilitating tasks such as radar interferometry, land cover classification, and water color monitoring. These capabilities are enhanced by SNAP's ability to handle the large data volumes produced by the Sentinel fleet, providing efficient data access and processing tools that cater to both scientific research and operational monitoring needs.

1.2.3 Landsat

While SNAP is primarily designed for Sentinel data, its flexibility and broad range of functionalities also make it useful for processing Landsat data, one of the longest-running sources

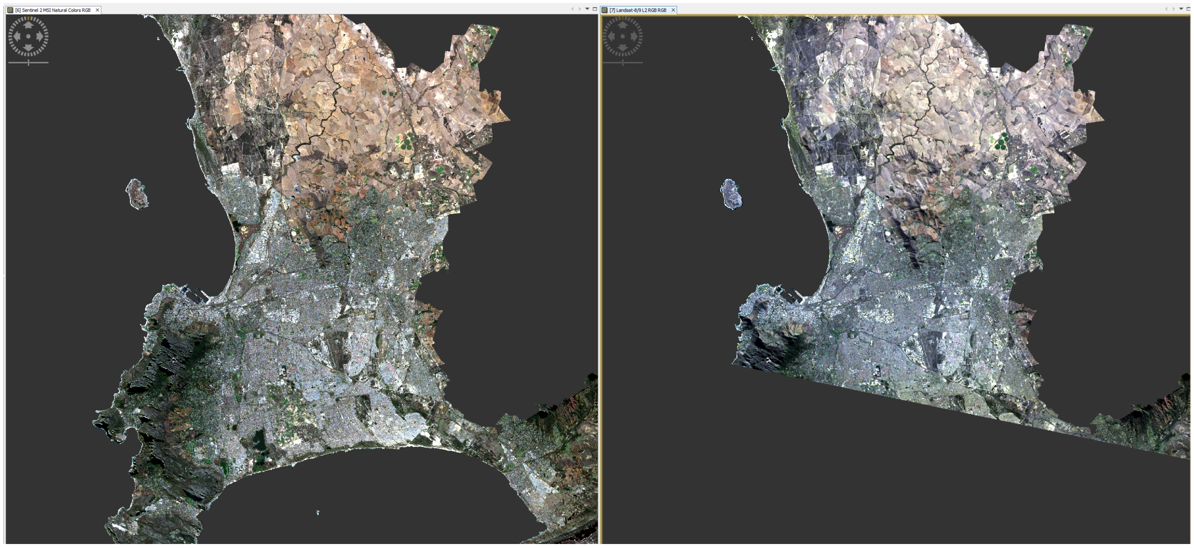


BROWSER
VISUALIZE
SEARCH
2024-01-13
Default
Sentinel-2 L2A
LAYERS:
True color
Based on bands B4, B3, B2
False color
Based on bands B8, B4, B3
Highlight Optimized Natural Color
Enhanced natural color visualization
NDVI
False color (urban)
Based on bands B12, B11, B4
Moisture index
SWIR
Based on bands B12, B8A, B4
NDWI
NDSI
Scene classification map
Custom
Create custom visualization
Show effects and advanced options
Hide layer
Share
About
Support
Go to Place
Cape Town



SNAP
File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help
Product Explorer
Pixel Info
Metadata
Index Codings
Vector Data
Tie-Point Grids
Bands
Masks
Red
Green
Blue
More Options

of satellite imagery used for studying land changes over time. Landsat data complements Sentinel data by offering a historical perspective on land use and land cover changes, going back over four decades. This long-term dataset is invaluable for understanding environmental changes, assessing ecosystem health, and planning land management strategies.

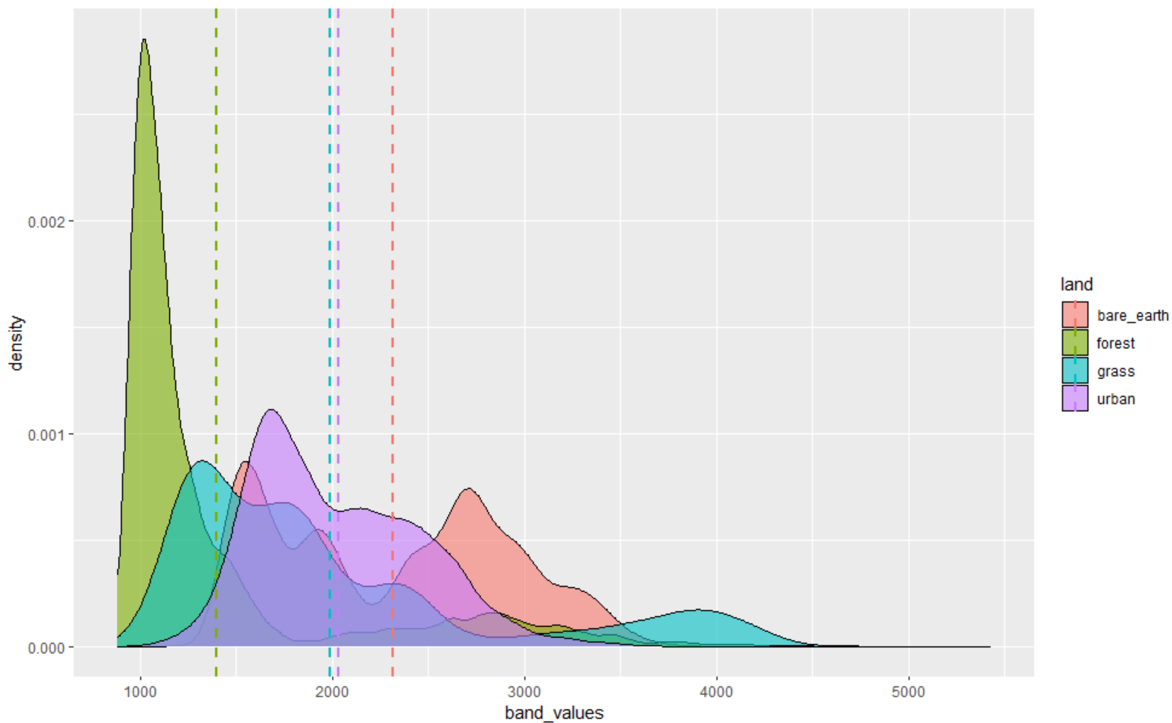


Using SNAP for Landsat data involves leveraging its preprocessing, analysis, and visualization capabilities to manage Landsat's multispectral imagery. Although SNAP does not include dedicated toolboxes for Landsat as it does for Sentinel satellites, its generic tools for raster data handling, image correction, and classification can be applied to Landsat images. This allows users to integrate Landsat data with Sentinel observations for comprehensive Earth observation analyses, offering a broader temporal and spectral range of environmental monitoring capabilities.

1.2.4 Using R

The process involves exporting Sentinel and Landsat data from SNAP as GeoTIFFs and shapefiles, then analyzing these in R using packages like **`terra`** for direct pixel value extraction. Custom R functions facilitate efficient processing and statistical analysis of spectral signatures for different land cover types. The analysis culminates in visualizing spectral signatures through density plots and comparative graphs, leveraging R's graphical capabilities for detailed environmental analysis. This streamlined approach in R enhances the flexibility and depth of spectral analysis.

Randomly selected various land use types in Cape Town for a comparative analysis of their spectral characteristics



1.2.5 Practical Application of RS

- **Urban Planning and Infrastructure Monitoring**

  Remote Sensing and GIS Data Fusion   Source:Talat Munshi (2013)

  Utilizing spatial resolution principles, high-resolution imagery enables precise urban layout mapping and infrastructure changes over time, critical for sustainable urban development. GeoTIFF's geographic metadata facilitates detailed spatial analyses in GIS platforms, optimizing land use and planning.

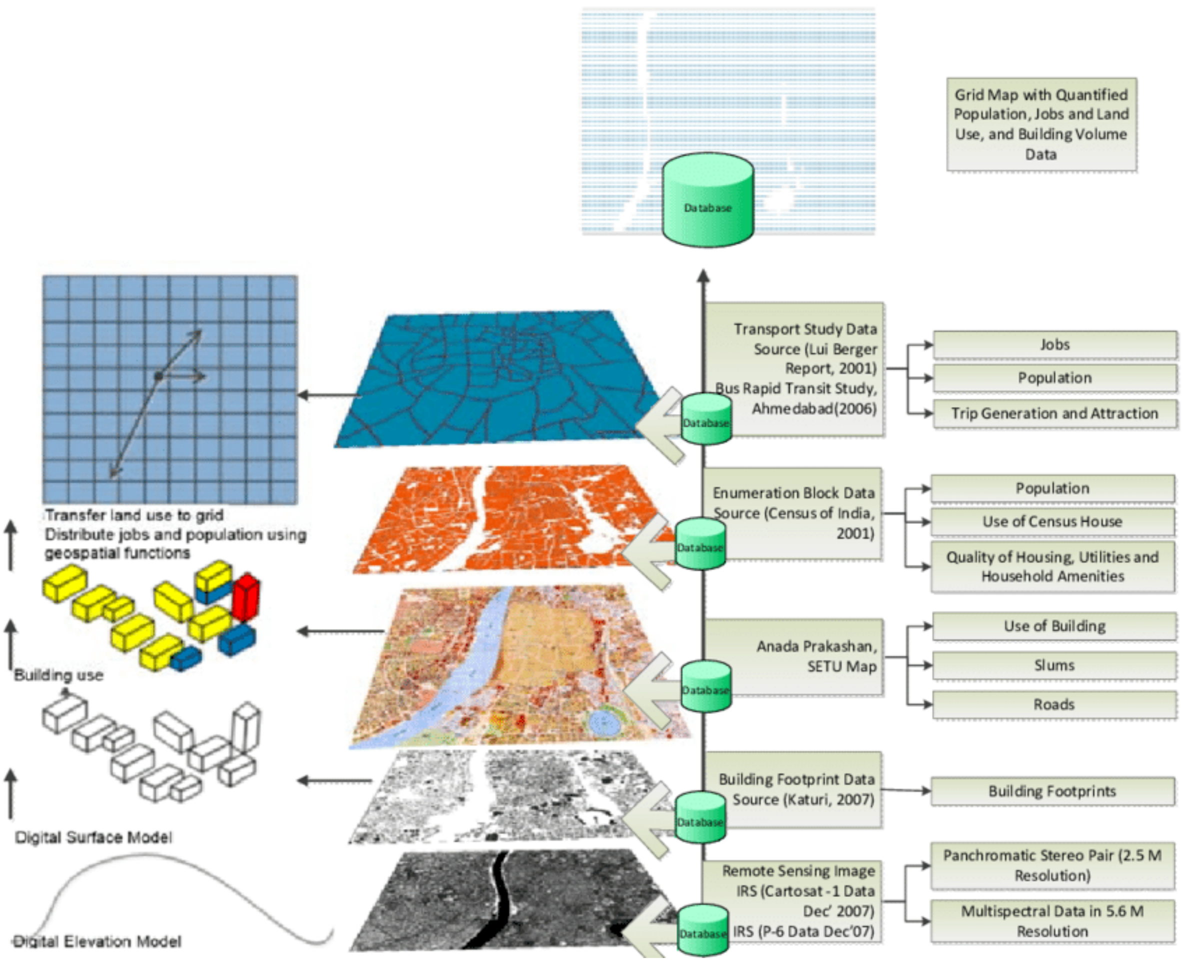
- **Environmental Monitoring and Conservation**

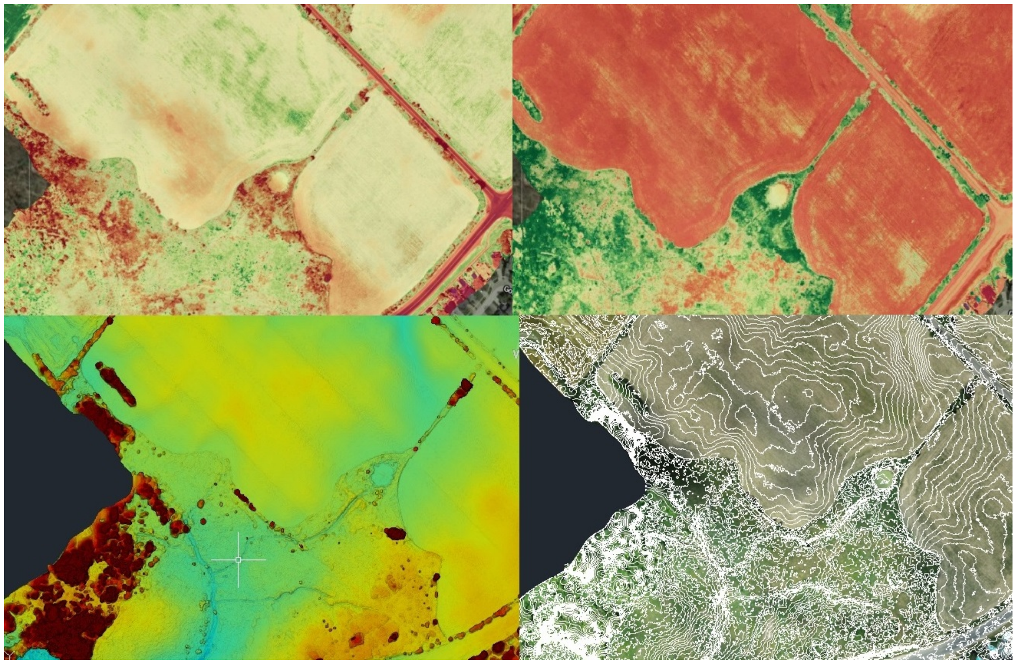
  Agriculture Mapping, Crop & Plant Health   Source: dronesurveycanada.ca

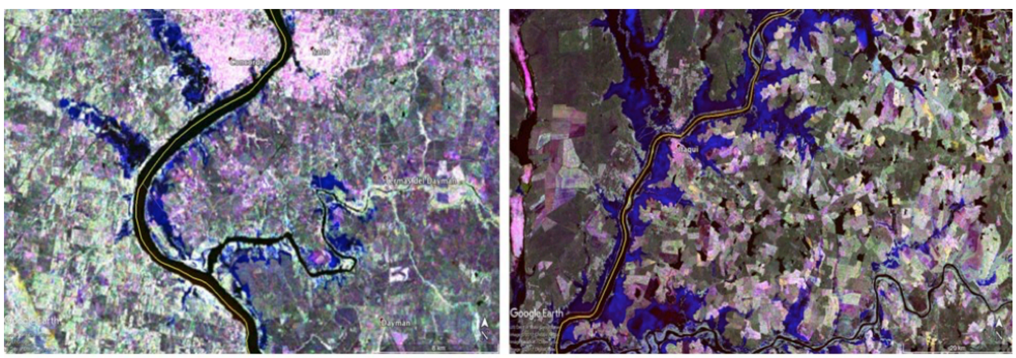
  Informed by spectral resolution and EMR interactions, remote sensing precisely monitors ecosystem health, identifying vegetation types and assessing environmental changes. Multispectral and hyperspectral imagery, capturing extensive wavelength data, are essential for detailed environmental analyses.

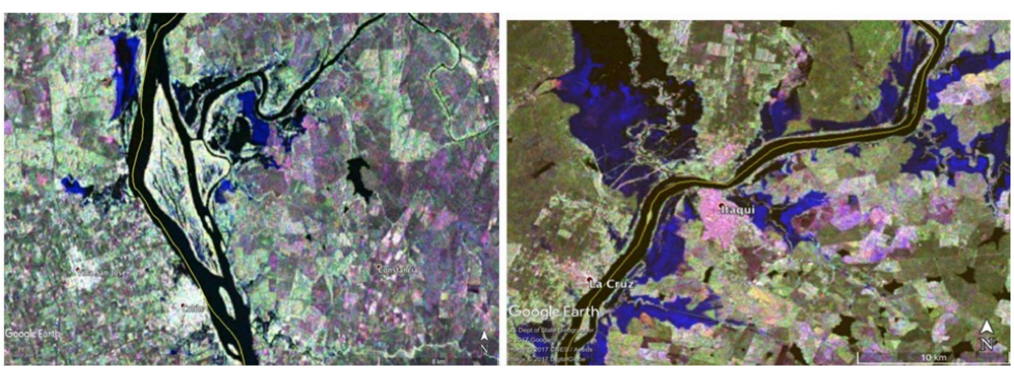
- **Disaster Response and Climate Change Tracking**

  SAR Flood Map for 2017 Uruguay Flooding Source: disasters.nasa.gov


Grid Map with Quantified Population, Jobs and Land Use, and Building Volume Data
Database
Transport Study Data Source (Lui Berger Report, 2001) Bus Rapid Transit Study, Ahmedabad(2006)
Jobs
Population
Trip Generation and Attraction
Enumeration Block Data Source (Census of India, 2001)
Population
Use of Census House
Quality of Housing, Utilities and Household Amenities
Anada Prakashan, SETU Map
Use of Building
Slums
Roads
Building Footprint Data Source (Katuri, 2007)
Building Footprints
Remote Sensing Image IRS (Cartosat -1 Data Dec' 2007) IRS (P-6 Data Dec'07)
Panchromatic Stereo Pair (2.5 M Resolution)
Multispectral Data in 5.6 M Resolution
Transfer land use to grid
Distribute jobs and population using geospatial functions
Building use
Digital Surface Model
Digital Elevation Model

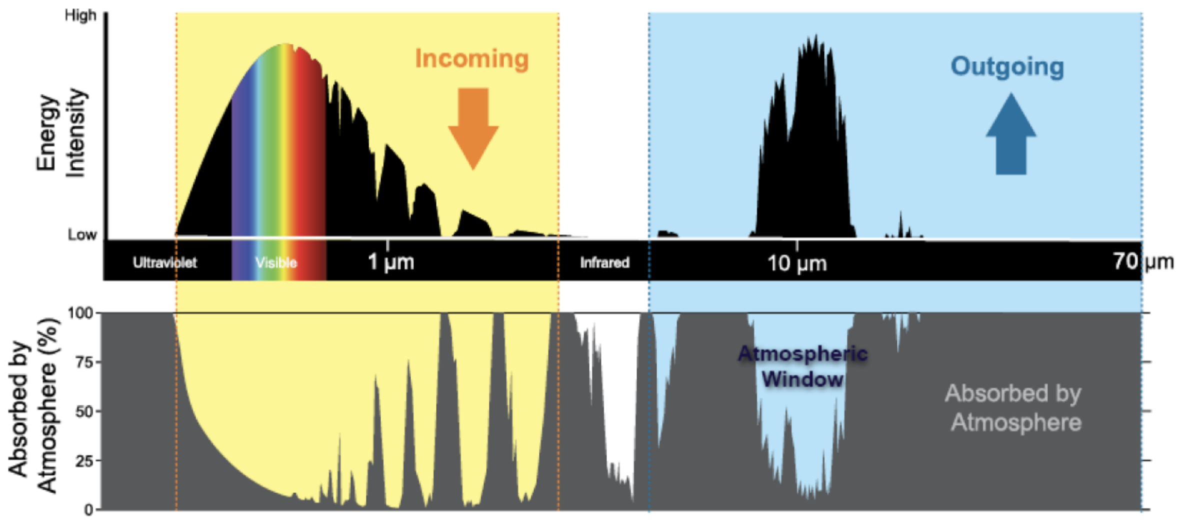



Google Earth
Itaqui


Google Earth
Itaqui
La Cruz
Google Earth
10 km
N

Temporal resolution's importance is underscored in disaster management and climate change studies, where SAR imagery's all-weather capability ensures continuous monitoring. This is vital for quick disaster response and understanding long-term environmental trends.

- **Navigating Atmospheric Challenges**



Atmospheric windows   Source: noaa.gov

Addressing atmospheric absorption issues is crucial for uninterrupted Earth observation. Remote sensing techniques that penetrate atmospheric barriers enable consistent monitoring of the planet's surface. For example: the places with limited or almost no absorption by the atmosphere is known as the atmospheric window, allowing us to peer into the atmosphere at various wavelengths.

1.3 Reflection

As a master's student specializing in Urban Spatial Science, I found my encounter with CASA0023 (Remotely Sensing Cities and Environments) to be truly fascinating. It has provided me with a fresh perspective that beautifully complements my prior studies in Geographic Information Systems (GIS) under CASA0005. This course illuminated the synergy between Remote Sensing (RS) and Geographic Information Systems (GIS), showcasing their combined strength in shaping my academic and professional path.

RS provides a broad perspective essential for environmental mapping, whereas GIS offers precision in spatial analysis, critical for urban planning. This shift from GIS's detail-oriented analysis to RS's wide-ranging observation highlights the complementary nature of spatial sciences.

Their collaboration is especially impactful in areas like disaster management and climate change, where integrating RS and GIS data leads to actionable insights for complex challenges.

Through CASA0023, I aimed to enrich my understanding of RS and GIS's collaborative potential to address urban and environmental issues. Beyond gaining technical skills, this journey fostered a critical perspective on utilizing these technologies innovatively, aiming for sustainable solutions that consider their limitations and the complexity of their integration.

1.4 References

Drone Survey Canada, n.d. Drone Survey & Aerial Survey Plant Variability. Available at: https://dronesurveycanada.ca/drone-survey-aerial-survey-plant-variability/ [Accessed 13 January 2024].

GIS Geography, n.d. Remote Sensing Earth Observation Guide. Available at: https://gisgeography.com/remote-sensing-earth-observation-guide/ [Accessed 14 January 2024].

iMathWorks, n.d. How do electromagnetic waves wave. Available at: https://imathworks.com/physics/physics-how-do-electromagnetic-waves-wave/ [Accessed 13 January 2024].

Munshi, T., 2013. Built form, Travel Behaviour, and Low Carbon Development in Ahmedabad, India. DOI: 10.13140/2.1.1217.9845.

Soni, D., 2018. Estimation of Rainfall-Runoff in a Watershed Using Remote Sensing and GIS.

Spatial Post, 2023. Types of Platforms In Remote Sensing: A Comprehensive Guide. Available at: https://www.spatialpost.com/types-of-platforms-in-remote-sensing/#google_vignette [Accessed 13 January 2024].

Tempfli, K. et al., 2009. Principles of remote sensing: an introductory textbook. Enschede: International Institute for Geo-Information Science and Earth Observation.

Toth, C., 2018. The Future of Remote Sensing: Harnessing the Data Revolution. *GeoActa*, 42(2), pp.1-6.

USGS, n.d. What is Radiometric Resolution? Available at: https://www.usgs.gov/faqs/what-radiometric-resolution [Accessed 14 January 2024].

2 Xaringan Sentinel-3

3 Remote Sensing Technologies: Pre-processing

TBD...

3.1 Summary

Key Aspect	Description
Remote Sensing Evolution with Landsat 9	A historical journey highlighting the development of remote sensing technology, focusing on Landsat 9 and the significant contributions of Virginia Norwood. Initially, NASA preferred analog RBV cameras for remote sensing, capturing green, red, and NIR spectra. Norwood advocated for a digital Multispectral Scanner (MSS), foreseeing its potential to capture both visible and invisible wavelengths, leading to the adoption of MSS as a standard for future remote sensing endeavors.
Data Corrections and Pre-processing	Detailed exploration of essential pre-processing steps necessary for remote sensing data usability, including geometric, atmospheric, orthorectification/topographic, and radiometric corrections. These corrections address errors introduced by sensor imperfections, atmospheric conditions, Earth's rotation, and perspective distortions due to elevation and view angle, ensuring the accuracy and reliability of the remote sensing data.
Radiometric Calibration and Remote Sensing Jargon	Clarification of terms like Digital Number (DN), radiance, and reflectance, explaining the calibration process that converts DNs into meaningful spectral radiance values.

Key Aspect	Description
Atmospheric Correction Types	Explores atmospheric correction methods, distinguishing between relative and absolute approaches to adjust imagery for atmospheric influences. Techniques include Dark Object Subtraction (DOS), Psuedo-invariant Features (PIFs), and use of atmospheric radiative transfer models like MODTRAN and 6S. These corrections are pivotal for accurate earth surface representation, especially when deriving biophysical parameters or comparing data across time and space.
Orthorectification and Topographic Correction	Focuses on adjusting images for relief displacement caused by terrain, ensuring that imagery accurately represents the Earth's surface as if viewed directly from above. Utilizes sensor geometry and elevation models, alongside cosine correction and other mathematical models, to correct for distortions, a crucial step for applications requiring precise location accuracy.
Data Joining and Enhancement	The process involves mosaicking to create seamless imagery, with techniques like feathering and histogram matching to ensure consistency across images. Enhancements such as contrast adjustment, filtering, PCA, texture analysis, and fusion (e.g., pan-sharpening) are employed to improve image quality, interpretability, and application relevance. These techniques help in highlighting specific features, reducing data dimensionality, and integrating data from multiple sensors, thereby enhancing the utility of remote sensing imagery for various applications.

3.1.1 Remote Sensing Data Processing and Correction Formulas

1. **Geometric Correction Solution Model**:

   - New x coordinate: $x = a_0 + a_1 x_i + a_2 y_i + \epsilon_i$
   - New y coordinate: $y = b_0 + b_1 x_i + b_2 y_i + \epsilon\_i$
   - These formulas are used for transforming distorted image coordinates to more accurate positions, where (x_i, y_i) are the locations in the original image, and (a_0, a_1, a_2, b_0, b_1, b_2) are geometric transformation coefficients derived from Ground Control Points (GCPs).

2. **Inverse Mapping Method** (for Geometric Correction):

   - Original x coordinate: $x_i = a_0 + a_1 x + a_2 y + \epsilon\_i$
   - Original y coordinate: $y_i = b_0 + b_1 x + b_2 y + \epsilon\_i$

- The inverse mapping method is used to deduce the original image's location from the corrected image positions to ensure accurate pixel value mapping.

3. **Root Mean Square Error (RMSE)**:
   - $RMSE = \sqrt{\frac{\sum(observed - predicted)^2}{n}}$
   - RMSE is used to evaluate the difference between model predictions and actual observations. The goal in ground control point correction is to minimize RMSE for improved accuracy.

3.1.2 Remote Sensing Data Enhancement Formulas

1. **Empirical Line Correction**:
   - Reflectance (field spectrum) = Gain × Radiance (input data) + Offset
   - This method corrects the data by performing linear regression against the satellite's raw digital numbers combined with spectral data measured on the ground.

2. **Solar Zenith Angle and Viewing Zenith Angle**:
   - $cos(i) = cos(\theta\_p)cos(\theta\_z) + sin(\theta\_p)sin(\theta\_z)cos(\phi\_a - \phi\_o)$
   - Where θ_p is the slope angle, θ_z is the solar zenith angle, ϕ_a is the slope aspect, and ϕ_o is the solar azimuth. This formula is used for correcting the received radiance, especially when performing topographic correction.

3.1.3 Remote Sensing Data Analysis Formulas

1. **Normalized Burn Ratio (NBR)**:
   - $NBR = \frac{(NIR - SWIR)}{(NIR + SWIR)}$
   - This formula is used to detect burned areas or vegetation changes by comparing the reflectance between Near-Infrared (NIR) and Short-Wave Infrared (SWIR) bands.

2. **Principal Component Analysis (PCA)**:
   - PCA is utilized to transform multispectral data into a set of linearly uncorrelated variables (principal components), often for dimensionality reduction and highlighting significant variables.

3.2 Applications

- **Atmospheric Correction**:
- **Geometric Correction**:

- **Mosaicking**:
- **Image Enhancements**:
- **Data Fusion**:

3.3 Reflection

The strategic application of advanced remote sensing techniques has the potential to revolutionize our understanding and management of urban environments…

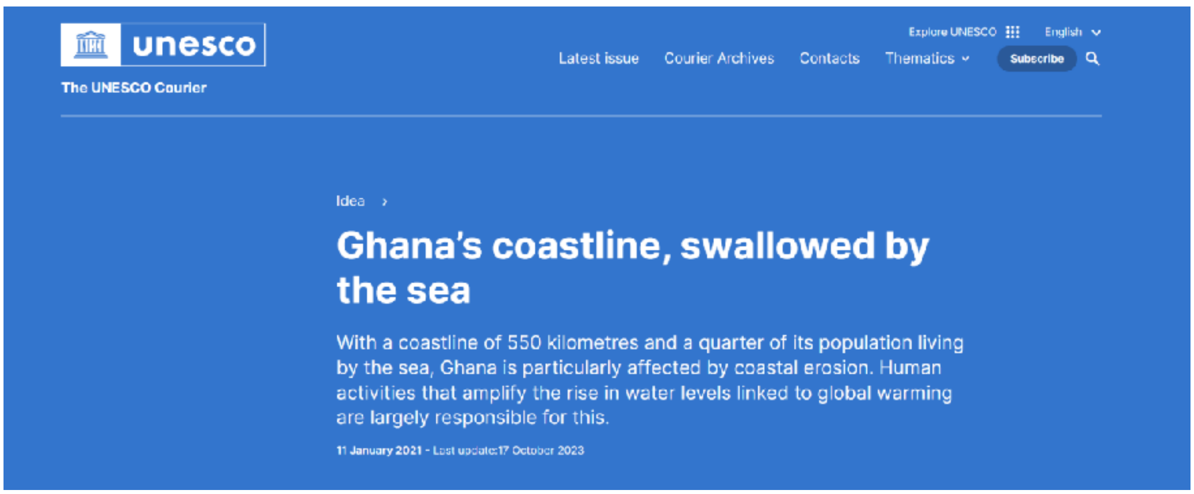
The challenge lies in harnessing this complexity to deliver clear, actionable insights for urban planning and environmental management, ensuring that the sophistication of the data translates into tangible benefits for urban communities and ecosystems…

3.4 References

4 Policy: Coastal Erosion Management in Ghana

4.1 Summary

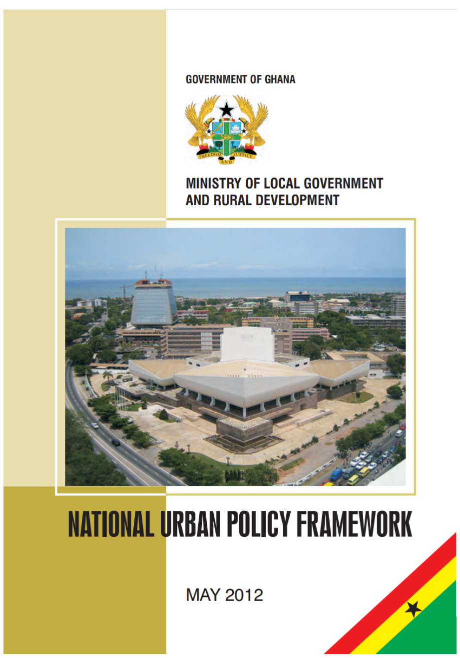
4.1.1 Background of Coastal Retreat



Ghana's coastline, swallowed by the sea Source: The UNESCO Courier

Ghana's coastline stretches over 550 kilometers and is crucial to the country's socio-economic fabric, with significant activities like fishing, tourism, and industry. However, this coastal region faces severe erosion, with land receding at alarming rates due to **natural processes exacerbated by human activities**. Factors contributing to the erosion include rising **sea levels linked to global warming, unchecked industrial activities, and infrastructure development.** This has led to the loss of land, negatively impacting livelihoods, cultural heritage, and biodiversity.

Video: Erosion wearing down Ghana's coast



Increasing environmental deterioration

Environmental deterioration arises from conflicting land uses; unsatisfactory collection, disposal, and treatment of waste; choked drains and frequent flooding; coastal erosion and denudation; ineffective management of quarrying of mineral aggregates; ineffective land use management and environmental protection; and the attitudinal indiscipline of the growing urban population.

3.4 Initiatives to achieve Objective 4: ***Improving environmental quality of urban life***

i. Develop and manage infrastructure systems with the appropria technology needed to provide basic hygienic conditions in towns ar cities.
ii. Prepare and implement sanitation action plans for all leading urban centres, including related statutory regulations and bylaws for ensuring effective collection, disposal and treatment of solid, liquid and toxic waste.
iii. Generate environmental awareness by increasing mass media public education programmes on sanitation in schools and public places.
iv. Provide adequate equipment and operational funds to support waste management activities.
v. Protect open spaces, green belts, forest reserves, water bodies, wetlands, water catchment areas and other ecologically sensitive areas from physical development and urban encroachment.
vi. Develop and implement a systematic programme of flood control measures in urban communities.
vii. Pursue rigorous public education and law enforcement against reprehensive public attitudes and conduct that induce environmental degradation.
viii. Establish adequate measures against natural hazards in urban areas.
ix. Prepare and implement coastal management plans to effect coastal re-vegetation and erosion control of denuded and neglected coastal towns.
x. Protect the environmental quality of mining towns and their hinterlands.
xi. Educate the general public and communities to utilize marine, coastal and wetlands resources with negligible or minimal environmental hazards to coastal towns and cities.

2.1.4 Mainstreaming Environmental concerns into Urban Development

Urban inhabitants have a right to the sustainable development of human settlements, environmental quality, good health, and wellbeing. This is a key guiding principle in accordance with Ghana's Environmental Policy and its related SEA.

3.10 Initiatives to achieve Objective 10: ***Promoting climate change adaptation and mitigation mechanisms***

i. Intensify public information and awareness campaigns on energy conservation, climate change and mitigation strategies.
ii. Encourage progressive reduction of hazardous substances by industry.
iii. Promote settlement structure plans designed to achieve a high level of amenity as well as the prevention of effluent and refuse pollution.
iv. Promote and strengthen cooperation of adjoining MMDAs in collaboration with traditional authorities and other relevant stakeholders in management of water bodies and other natural resources.
v. Avoid coastal zone development which affects ecologically-sensitive areas.
vi. Impose and enforce more effective coastal zone and wetlands management regulations.
vii. Strengthen the capacities of agencies that are charged with promoting environmental standards.
viii. Generate public awareness on climate change and litigation strategies through mass media educational campaigns.

4.1.2 Local Government Policy Overview

In response to these challenges, the Ghanaian government has developed and implemented policies aimed at mitigating coastal erosion. The "Coastal Management Plan" focuses on constructing seawalls at critical points along the coast to protect against erosion. Moreover, the "National Urban Policy Framework - Ghana" discusses broader urban challenges, including coastal erosion, and emphasizes the socio-economic impacts and the importance of an integrated approach to urban management.

- **Policy Initiatives for Achieving Objective 4: Improve the Quality of the Urban Environment**

  ...

  Formulate and implement coastal management plans to achieve coastal revegetation and erosion control in degraded and neglected coastal towns.

- **Policy Initiatives for Achieving Objective 5: Ensure Effective Planning and Management of Urban Growth and Expansion**

  ...

  Strengthen the use of remote sensing (such as aerial photographs and satellite images) and Geographic Information Systems (GIS) to enhance urban development and management.

These initiatives underscore the government's dedication to tackling coastal erosion by combining infrastructural interventions with sustainable management approaches.

4.1.3 Alignment with United Nations SDGs

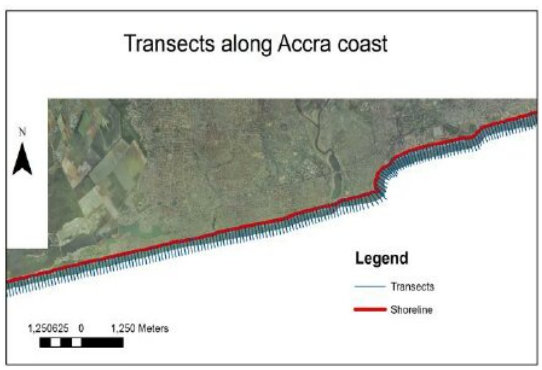
Ghana's efforts to manage coastal erosion resonate with several United Nations Sustainable Development Goals (SDGs). Specifically, these efforts align with **Goal 11 (Sustainable Cities and Communities)** by enhancing urban sustainability and living conditions, **Goal**

13 (Climate Action) by addressing a significant effect of climate change, and **Goal 14 (Life Below Water)** by protecting marine ecosystems and biodiversity. These alignments underscore the multifaceted benefits of Ghana's coastal management policies, extending beyond erosion mitigation to broader environmental and socio-economic improvements.

4.2 Applications

4.2.1 Accra as a Case Study in Coastal Erosion

Coastal erosion along portion of western Accra coast Source: Appeaning Addo et al. (2013)



Orthogonal transects for rates of change estimations Source: Appeaning Addo et al. (2008)

Next, Accra was specifically chosen as a case study to explore regional dynamics. The Accra region confronts severe coastal erosion, with substantial land loss affecting livelihoods and infrastructure. From 2005 to 2017, about 37% of the coastal land succumbed to erosion and flooding. Combining local insights with scientific research has been pivotal in tackling this challenge, revealing an erosion rate of -0.91 m/year.

While the Ghanaian government has implemented seawall constructions as a countermeasure, researchers stress the importance of adopting a more comprehensive approach beyond solely relying on structural defenses.

4.2.2 Leveraging Remote Sensing for Coastal Management

The application of remotely sensed data can play a crucial role in supporting the policy goals set by the Ghanaian government for coastal erosion management. High-resolution optical satellite imagery (e.g., Sentinel-2, Landsat 8, Gaofen-1), Synthetic Aperture Radar (SAR) data (e.g., Sentinel-1), and Digital Elevation Models (DEMs) such as ASTER GDEM and SRTM, offer valuable tools for monitoring, planning, and managing coastal erosion efforts effectively.

- **Monitoring and Assessment**: By regularly comparing high-resolution satellite images, authorities can identify the most severely eroded areas and the rate of erosion. SAR data, capable of penetrating cloud cover, is invaluable for assessing the coastline's status during and after storm events, providing crucial information for emergency response and recovery efforts.

- **Planning and Implementation**: DEMs offer a three-dimensional representation of the surface, aiding in understanding the erosion process and its impact on coastal landscapes. This information can be used to strategically plan the location and design of seawalls and other protective measures, ensuring they are both effective and environmentally sustainable.

- **Public Engagement and Awareness**: Visualizations created from remotely sensed data can enhance public awareness about coastal erosion. By making this information accessible, the government can foster community participation in coastal protection efforts, aligning with the policy's emphasis on community involvement.

Using remote sensing technologies, Ghana can improve coastal resilience, make better decisions, respond faster, and adopt a proactive coastal management strategy. This also includes evaluating the success of seawall constructions, ensuring the effectiveness of coastal protection efforts.

4.3 Reflection

Reflecting on my background as a landscape architecture student, my approach to addressing coastal erosion has traditionally focused on designing landscape features and interventions on a smaller scale to mitigate erosion and enhance the living environment for communities. This perspective emphasized the physical design and creation of spaces that directly interact with the coastal dynamics, such as dunes restoration, vegetation buffers, and community parks that double as protective barriers.

Now, having learned about the capabilities of remote sensing, I see a broader scope of possibilities for contributing to coastal erosion management. Remote sensing allows for a macro-scale understanding of coastal dynamics, providing data that can inform not only the design of individual landscape projects but also larger, strategic planning efforts. It offers a way to monitor the effectiveness of landscape interventions over time and adapt strategies based on real-world feedback. This integration of technology and design can lead to more resilient and sustainable coastal landscapes.

As a landscape architecture student, the shift from a micro to a macro perspective, enabled by remote sensing, represents a significant expansion of the tools available to me. It opens up new avenues for collaboration with scientists, policymakers, and communities in the fight against coastal erosion. By combining design principles with cutting-edge technology, I can contribute to creating more effective, adaptive, and holistic solutions that address the root causes of coastal erosion while enhancing the quality of life for affected populations. This learning journey underscores the importance of interdisciplinary approaches in tackling complex environmental challenges.

4.4 Reference

Appeaning Addo, K., Walkden, M. & Mills, J.P., 2008. Detection, measurement and prediction of shoreline recession in Accra, Ghana. *Journal of Photogrammetry and Remote Sensing*, 63, pp.543–558.

Appeaning Addo, K., 2013. Assessing Coastal Vulnerability Index to Climate Change: the Case of Accra – Ghana. In: Proceedings of the 12th International Coastal Symposium, Plymouth, England, *Journal of Coastal Research*, Special Issue No. 65, pp.1892-1897.

Appeaning Addo, K. & Appeaning Addo, I., 2016. Coastal erosion management in Accra: Combining local knowledge and empirical research. *Jàmbá: Journal of Disaster Risk Studies*, 8(1), p.274. Available at: https://jamba.org.za/index.php/jamba/article/view/274 [Accessed 31 Jan. 2024].

"Ghana's coastline, swallowed by the sea," 2021. *UNESCO Courier*. [online] Available at: https://courier.unesco.org/en/articles/ghanas-coastline-swallowed-sea [Accessed 31 Jan. 2024].

Government of Ghana Ministry of Local Government and Rural Development. 2012. *National Urban Policy Framework*. Available at: https://nupdb.urbanpolicyplatform.org/listings/Ghana [Accessed 31 Jan. 2024].

Ministry of Works and Housing, 2019. *2019 Meet-the-Press Highlights*. [pdf] Available at: https://www.mwh.gov.gh/wp-content/uploads/2019/05/MEET-THE-PRESS-high-light-web-1.pdf [Accessed 31 Jan. 2024].

United Nations Development Programme, n.d. *Sustainable Development Goals*. [online] Available at: https://www.undp.org/sustainable-development-goals [Accessed 31 Jan. 2024].

Ayisi, E., 2022. *As rising seas destroy Ghana's coastal communities, researchers warn against a seawall-only solution*. Mongabay. Available at: https://news.mongabay.com/2022/03/as-rising-seas-destroy-ghanas-coastal-communities-researchers-warn-against-a-seawall-only-solution/ [Accessed 31 Jan. 2024].

Modern Ghana, n.d. *Rising Sea Levels: How coastal dwellers in Accra are coping*. [online] Available at: https://www.modernghana.com/news/1103977/rising-sea-levels-how-coastal-dwellers-in-accra.html [Accessed 31 Jan. 2024].

References