Personal Note of Remote Sensing

Muhammad Angga Muttaqien

University of Tsukuba (筑波大学), Japan

1. What is Remote Sensing?

Remote sensing refers to the process of acquiring information about the Earth's surface or other objects from a distance, typically using sensors and instruments mounted on aircraft or satellites. It involves the collection and interpretation of data without direct physical contact with the object or area of interest. Remote sensing enables scientists, researchers, and professionals to gather valuable information about the Earth's features, environmental conditions, and processes. By providing a bird's eye view of the Earth, remote sensing allows for comprehensive and continuous data collection, aiding in informed decision-making and enhancing our understanding of the planet.

A remote sensing satellite floating in space (source: niras.com)

The primary tool used in remote sensing is the remote sensor, which can be a camera, scanner, or instrument that detects and records electromagnetic radiation. These sensors measure the energy reflected or emitted by the Earth's surface or atmosphere in various wavelengths, such as visible light, infrared, microwave, or ultraviolet. Different features or materials reflect or emit

radiation differently, allowing remote sensing to provide valuable information about land cover, vegetation health, temperature, pollution levels, and more. The diverse range of remote sensing sensors and wavelengths enables the extraction of detailed and specific information about the Earth's surface and atmosphere, facilitating comprehensive analysis and understanding of our planet.

Remote sensing data can be collected from different platforms, including satellites, aircraft, and drones. Satellites are commonly used due to their wide coverage and ability to capture large-scale data repeatedly. Once the data is collected, it undergoes processing, analysis, and interpretation to extract meaningful information. This can involve techniques such as image classification, change detection, and spatial analysis. The processed remote sensing data is valuable for a wide range of applications, including environmental monitoring, disaster management, resource planning, climate studies, and urban development.

Remote sensing finds applications in various fields, including environmental monitoring, agriculture, forestry, urban planning, disaster management, and natural resource exploration. It provides a valuable tool for understanding and managing Earth's resources, monitoring changes over time, and making informed decisions based on accurate and up-to-date information. The use of remote sensing technology continues to expand, driving innovation and advancements in fields such as climate change research, biodiversity conservation, water resource management, and renewable energy planning.

2. Types of Remote Sensing

Remote sensing can be broadly categorized into two types: active remote sensing and passive remote sensing.

1. Active Remote Sensing: Active remote sensing involves the transmission of energy from a sensor or instrument towards the target area or object, and then detecting and analyzing the energy reflected or backscattered by the target. In active remote sensing, the sensor itself

emits pulses of energy, such as radar or laser beams, and measures the time it takes for the energy to return after interacting with the target.

Active Sensors
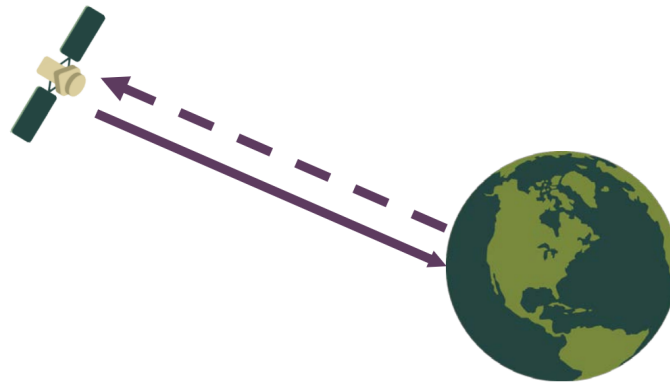
An illustration of active remote sensing (source: nasa.gov)

One example of active remote sensing is radar (Radio Detection and Ranging), which uses radio waves to detect and measure the distance, speed, and other characteristics of objects or surfaces. Radar is commonly used for mapping terrain, measuring ocean currents, detecting precipitation, and even imaging distant celestial bodies. Radar technology is also employed in various applications, including aviation for detecting and tracking aircraft, in meteorology for weather forecasting and storm tracking, and in military and defense operations for surveillance and target detection.

2. Passive Remote Sensing: Passive remote sensing, on the other hand, involves the detection and measurement of natural energy emitted or reflected by the Earth's surface or atmosphere without actively transmitting energy. Instead, sensors record the naturally occurring radiation, such as sunlight or thermal radiation, and analyze the received energy to extract information.

Passive Sensors
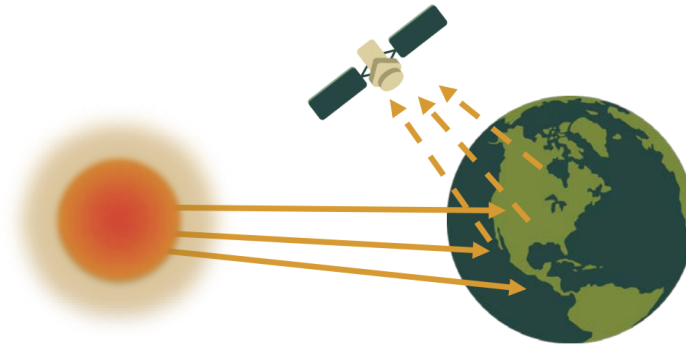
An illustration of passive remote sensing (source: nasa.gov)

One common example of passive remote sensing is multispectral or hyperspectral imaging, where sensors capture the reflected or emitted energy in different wavelengths across the electromagnetic spectrum. This data is used to analyze and classify land cover, monitor vegetation health, detect environmental changes, and study various atmospheric properties. Passive remote sensing is extensively used in satellite imagery, where sensors capture the natural energy reflected by the Earth's surface in visible, infrared, or microwave regions. This enables the creation of detailed maps, monitoring of climate patterns, assessment of crop health, and tracking changes in land use over time.

Both active and passive remote sensing techniques offer unique advantages and applications depending on the desired information and the characteristics of the target area or object. By combining these methods, scientists and researchers can gain a comprehensive understanding of the Earth's surface, atmosphere, and processes. This integrated approach allows for a more accurate and holistic assessment of environmental changes and facilitates informed decision-making for various fields such as agriculture, climate science, disaster management, and urban planning.

3. Satellites and Orbits

Satellites play a crucial role in remote sensing as they provide a platform for acquiring data about the Earth's surface and atmosphere from space. These artificial objects are placed in specific orbits around the Earth to optimize their coverage, resolution, and data collection capabilities. Satellites act as "eyes in the sky," allowing us to gather valuable information about our planet. By strategically placing them in different orbits, scientists can ensure that they capture data from various perspectives, giving us a comprehensive understanding of Earth's features and changes over time.
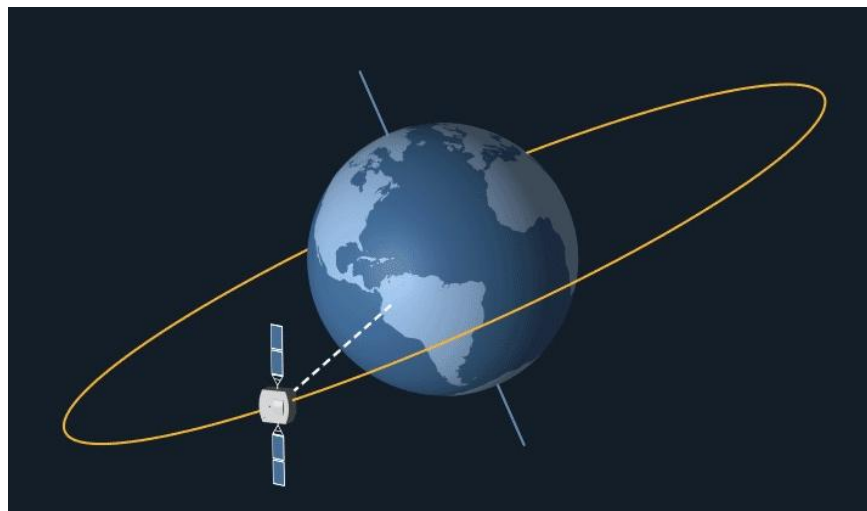

An illustration of remote sensing satellite placed in earth orbit (source: nasa.gov)

Satellites used for remote sensing are typically equipped with sensors and instruments that capture images, measure radiation, detect signals, and gather other relevant data. They can be classified into two main types: polar-orbiting satellites and geostationary satellites. These sensors and instruments on remote sensing satellites enable us to collect a wide range of data about the Earth's surface and atmosphere, helping us gain valuable insights into our planet and its processes.

Polar-orbiting satellites follow a near-polar trajectory, circling the Earth from pole to pole. As they orbit, the Earth rotates beneath them, allowing them to cover the entire planet's surface over a period of time. These satellites capture images and collect data in a series of narrow strips, creating a global mosaic over time. They provide high-resolution imagery and are

particularly useful for applications such as weather monitoring, climate studies, and environmental monitoring.

Geostationary satellites, on the other hand, are positioned at a fixed point above the Earth's equator. They orbit the Earth at the same rotational speed, resulting in their ability to remain stationary relative to a specific location on the Earth's surface. Geostationary satellites provide continuous monitoring of a specific area, capturing images and data at regular intervals. They are mainly used for applications such as weather forecasting, telecommunications, and tracking large-scale weather patterns.
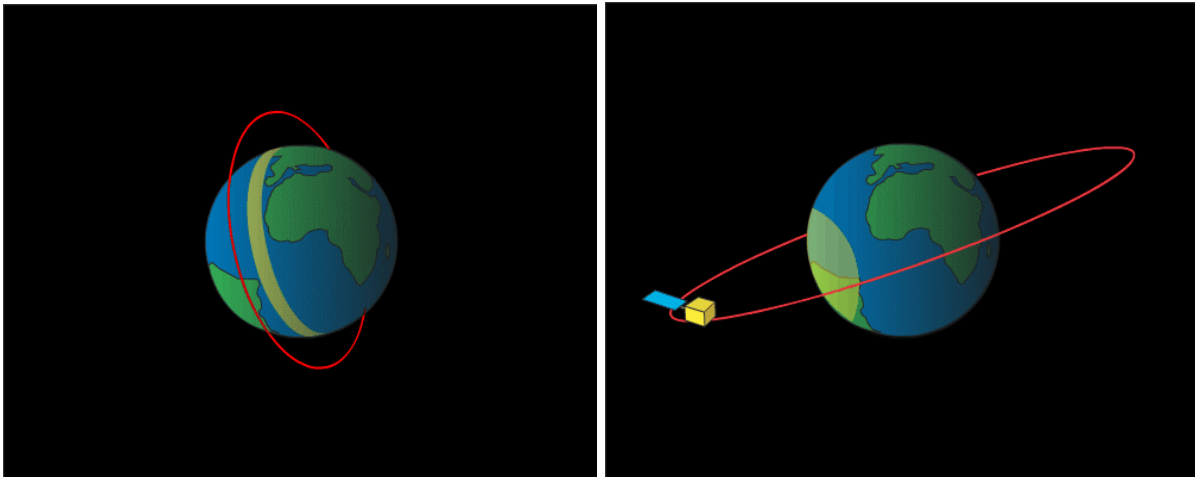
An illustration of polar orbit the left and geostationary on the right (source: nasa.gov)

According to JAXA's official site, Japan operates a variety of satellites that serve different purposes. The Advanced Land Observing Satellite (ALOS) captures images of the Earth's surface from a Sun-synchronous orbit. Himawari-8 and Himawari-9 are meteorological satellites positioned in geostationary orbits, providing continuous weather monitoring over the Asia-Pacific region. The Quasi-Zenith Satellite System (QZSS) enhances GPS positioning accuracy using a highly elliptical orbit, particularly in urban areas. These satellites, with their unique orbits, contribute to Earth observation, weather forecasting, and navigation capabilities specifically in Japan.
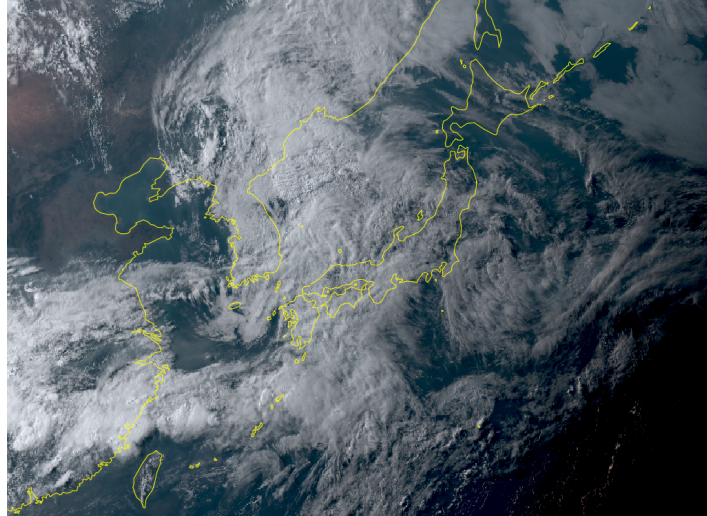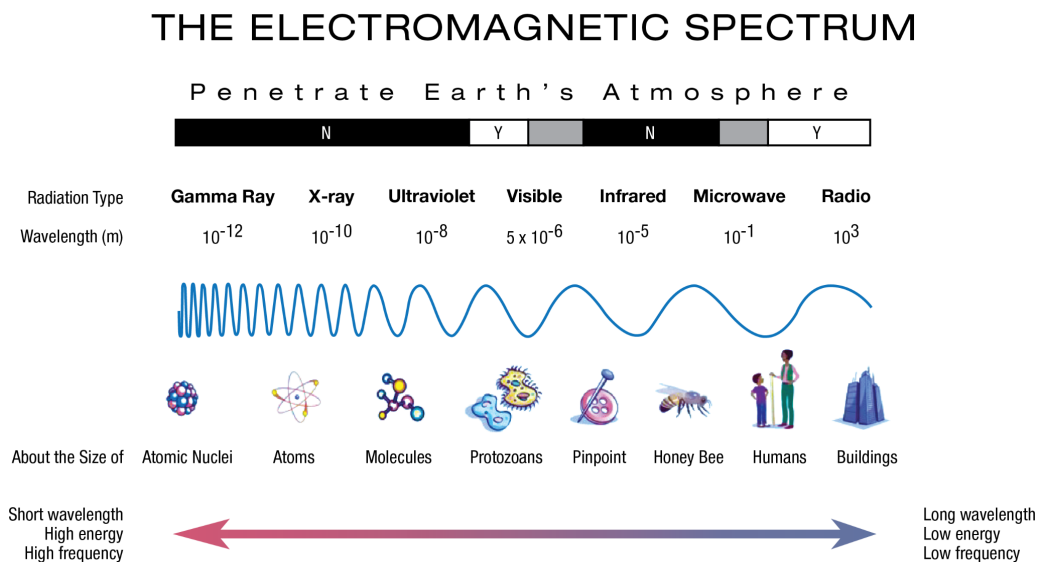
Overview of JAXA Himawari Monitor (source: jaxa.jp)

The selection of satellite orbits depends on the desired application, spatial coverage requirements, revisit time, and data resolution needed. Additionally, satellite constellations, which involve multiple satellites operating together, can further enhance the capabilities of remote sensing by providing improved coverage, revisit times, and data collection efficiency. By carefully considering orbit selection and leveraging satellite constellations, remote sensing systems can optimize data acquisition, maximize observational capabilities, and meet the diverse needs of applications ranging from scientific research to operational decision-making.

4. Electromagnetic Radiation (EMR)

Light is a key component of remote sensing technology. Remote sensing is the process of acquiring information about an object or area from a distance, using sensors that detect electromagnetic radiation (EMR) in various wavelengths, including visible light. When light strikes an object, it interacts with the object in different ways, depending on the properties of the object. Some of the light is absorbed by the object, while some is reflected, scattered, or transmitted through the object. Remote sensing sensors are designed to detect and measure the amount of EMR that is reflected, scattered, or emitted from the object being studied.

Electromagnetic radiation (EMR) refers to a type of energy that is propagated through space in the form of an electromagnetic wave. EMR includes a wide range of wavelengths, frequencies, and energies, which collectively make up the electromagnetic spectrum. The electromagnetic spectrum includes radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays, in order of increasing frequency and energy. Each type of EMR has unique properties and interacts differently with matter.

THE ELECTROMAGNETIC SPECTRUM

Penetrate Earth's Atmosphere

| | N | | Y | | N | | Y |

Radiation Type	Gamma Ray	X-ray	Ultraviolet	Visible	Infrared	Microwave	Radio
Wavelength (m)	10^{-12}	10^{-10}	10^{-8}	5×10^{-6}	10^{-5}	10^{-1}	10^{3}
About the Size of	Atomic Nuclei	Atoms	Molecules	Protozoans	Pinpoint	Honey Bee	Humans	Buildings

Short wavelength
High energy
High frequency

Long wavelength
Low energy
Low frequency

Electromagnetic Spectrum Diagram (source: nasa.gov)

In remote sensing, the sensors are typically mounted on a platform, such as a satellite or aircraft, that is positioned at a distance from the object being studied. The sensors collect data about the EMR that is reflected or emitted from the object, and this data is used to create images or maps of the object or area being studied. Different types of remote sensing sensors are designed to detect EMR in specific wavelengths, or bands, of the electromagnetic spectrum. For example, some sensors detect visible light, while others detect infrared radiation or microwaves. Each type of sensor has unique capabilities and is used to gather different types of information about the object being studied.
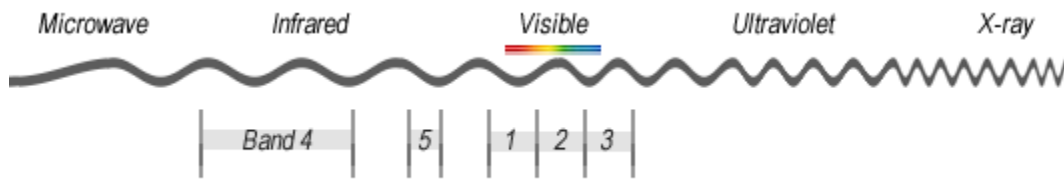
5. Bands in Remote Sensing

In remote sensing, "bands" refer to the specific regions of the electromagnetic spectrum that are used to capture data about the Earth's surface. The electromagnetic spectrum includes a range of wavelengths, from very short gamma rays to very long radio waves. Remote sensing sensors are typically designed to capture data in specific bands of the electromagnetic spectrum, based on the characteristics of the objects and features being studied. By analyzing the data acquired from different bands, remote sensing techniques can provide valuable information about vegetation, water bodies, urban areas, and various other environmental parameters.

For example, visible light has a wavelength range of approximately 400 to 700 nanometers (nm), and remote sensing sensors may be designed to capture data in several bands within this range. The most common visible light bands used in remote sensing are blue (approximately 450-520 nm), green (approximately 520-600 nm), and red (approximately 630-690 nm). Each visible light band captures specific information about the reflectance and absorption properties of the Earth's surface, allowing for the identification and characterization of different land cover types and features.

In addition to visible light, remote sensing sensors may also capture data in other bands of the electromagnetic spectrum, such as the infrared (IR) or ultraviolet (UV) regions. Infrared radiation has a longer wavelength than visible light, and can be used to detect differences in temperature and moisture content of the Earth's surface. Ultraviolet radiation has a shorter wavelength than visible light, and can be used to detect properties such as vegetation health and water quality. By utilizing multiple bands across the electromagnetic spectrum, remote sensing techniques enable scientists and researchers to gather a comprehensive understanding of various Earth system processes, including climate dynamics, ecosystem health, and geological features.

Remote sensing technology encompasses both multispectral and hyperspectral sensors, each offering unique advantages in capturing data across the electromagnetic spectrum. Multispectral sensors capture data in specific bands, including visible light, infrared, and ultraviolet, providing a broad understanding of Earth's surface. In contrast, hyperspectral sensors capture data in numerous narrow bands, enabling highly detailed and precise information retrieval, aiding in in-depth analysis and characterization of objects and features under study.

Multispectral Sensors in Remote Sensing (source: gisgeography.com)
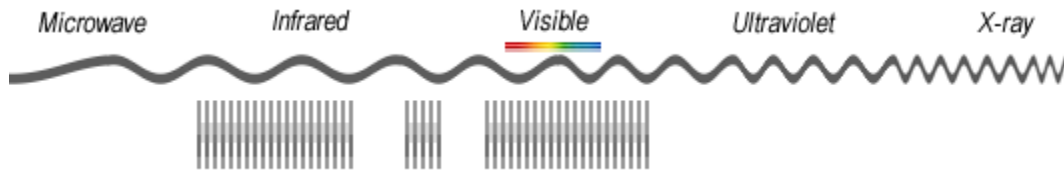
Hyperspectral Sensors in Remote Sensing (source: gisgeography.com)

6. Short & Long Wavelengths

Shorter wavelengths of electromagnetic radiation, such as those in the ultraviolet (UV) and visible portions of the spectrum, have several advantages in remote sensing. Remote sensing sensors that operate in the visible and UV portions of the spectrum can achieve higher spatial resolutions, which means they can capture more detailed images of the Earth's surface. This is because shorter wavelengths allow for smaller pixel sizes, which results in higher spatial resolution. In addition, shorter wavelengths in the UV and visible spectrum are more sensitive to fine-scale surface features, such as small changes in vegetation health or variations in water quality, enhancing the detection and analysis of such phenomena in remote sensing applications.

The utilization of shorter wavelengths in remote sensing brings about enhanced discrimination capabilities for capturing small-scale features present on the Earth's surface. This heightened resolution enables the identification and analysis of minute details, ranging from individual leaves on plants to subtle cracks in rocks. By leveraging the advantages of shorter wavelengths, remote sensing techniques facilitate precise characterization of vegetation,

geological formations, and various other intricate features, thereby contributing to a more comprehensive understanding of the Earth's diverse landscapes.

Longer wavelengths of electromagnetic radiation, on the other hand, such as those in the infrared (IR) and microwave portions of the spectrum, also have several advantages in remote sensing. Longer wavelengths can penetrate clouds, smoke, and other atmospheric particles more effectively than shorter wavelengths, making them useful for imaging in conditions where visible or UV light may be blocked. Moreover, longer wavelengths in the infrared and microwave spectrum possess the ability to penetrate vegetation canopies, providing valuable insights into the underlying structure, health, and moisture content of forests and agricultural crops, making them crucial for monitoring and managing these ecosystems.

Longer wavelengths in the thermal infrared portion of the spectrum can also be used to detect subtle temperature variations on the Earth's surface, which is important for applications such as monitoring volcanoes, detecting forest fires, and identifying heat sources in cities. Furthermore, the utilization of longer wavelengths in thermal infrared remote sensing allows for the measurement of thermal emission, providing valuable insights into energy exchanges and heat distribution across various landscapes. This information proves essential for understanding climate patterns, analyzing urban heat island effects, and facilitating effective decision-making in fields such as disaster management and urban planning.
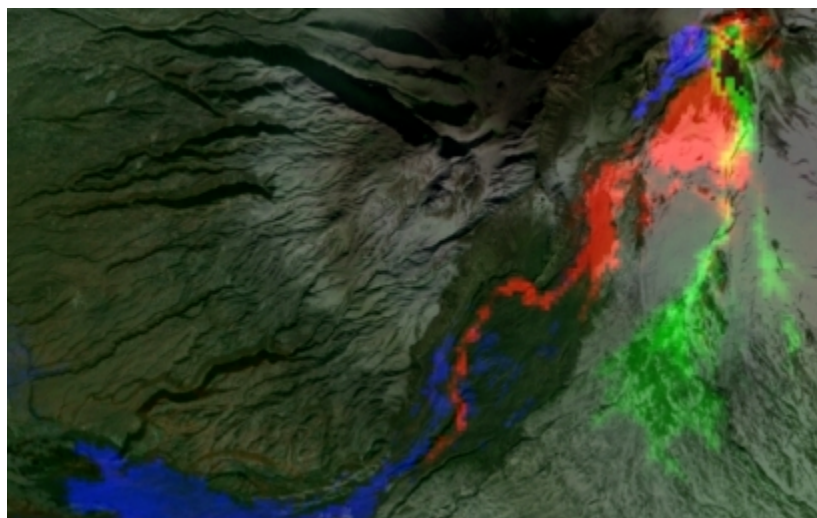
Volcanic Activity Monitoring using Remote Sensing (source: Remote Sensing Journal)

7. Applications of Remote Sensing

Remote sensing has a wide range of applications across various fields. Here are some common applications of remote sensing:

1. Land Use and Land Cover Mapping: Remote sensing enables the mapping and monitoring of land use and land cover changes. It provides valuable information about urban areas, agricultural land, forests, wetlands, and other land features. This data is used for urban planning, resource management, and environmental assessments.

2. Natural Resource Management: Remote sensing plays a crucial role in managing natural resources such as forests, water bodies, minerals, and energy sources. It helps in monitoring deforestation, assessing water quality and availability, identifying mineral deposits, and optimizing resource extraction.

3. Environmental Monitoring and Conservation: Remote sensing supports environmental monitoring by providing data on ecosystem health, biodiversity, and habitat degradation. It aids in assessing the impact of human activities on the environment, identifying areas of conservation concern, and guiding conservation efforts.

4. Disaster Management and Emergency Response: Remote sensing is instrumental in disaster management and emergency response. It facilitates the rapid assessment of disaster-affected areas, helps in identifying hazards and vulnerabilities, and supports search and rescue operations. It also assists in post-disaster recovery and reconstruction.

5. Climate Change Studies: Remote sensing data is extensively used to study and monitor climate change. It helps in tracking temperature patterns, ice melt, sea level rise, and changes in vegetation cover. Remote sensing aids in understanding the impacts of climate change and supports climate modeling and mitigation strategies.

6. Agriculture and Crop Monitoring: Remote sensing plays a vital role in agriculture by providing information on crop health, yield estimation, and irrigation management. It aids in early detection of crop diseases, assists in optimizing fertilizer application, and supports precision farming techniques.

7. Urban Planning and Development: Remote sensing data supports urban planning and development by providing information on land use, infrastructure, and population dynamics. It assists in assessing urban growth, monitoring transportation networks, and facilitating efficient resource allocation in cities.

These applications highlight the diverse and essential roles of remote sensing in various fields, ranging from environmental monitoring to disaster management and resource planning. Remote sensing serves as a powerful tool for informed decision-making and sustainable development by providing valuable insights into our changing planet.

8. Artificial Intelligence in Remote Sensing

According to some literature, I found that Artificial Intelligence (AI) has revolutionized the field of remote sensing by enhancing the capabilities and efficiency of data analysis and interpretation. Remote sensing involves the acquisition of information about the Earth's surface from sensors mounted on satellites, aircraft, or drones. AI algorithms and techniques enable the automated extraction, classification, and interpretation of vast amounts of remote sensing data, thereby enabling scientists and researchers to gain valuable insights into various aspects of the Earth's environment.

AI-based remote sensing applications encompass a wide range of areas, including agriculture, urban planning, environmental monitoring, disaster management, and natural resource exploration. In agriculture, for instance, AI algorithms can analyze remote sensing imagery to assess crop health, monitor irrigation needs, detect pest infestations, and optimize crop yield. These applications allow farmers to make informed decisions, improve resource allocation, and enhance overall productivity. The subsequent paragraphs provide a brief

overview of various remote sensing applications wherein AI is employed to enhance its functionality.

In urban planning, AI-powered remote sensing plays a crucial role in mapping and monitoring urban areas. By analyzing satellite imagery and LiDAR data, AI algorithms can automatically identify and classify land use patterns, detect changes in infrastructure, and monitor urban growth. This information assists urban planners in making informed decisions regarding zoning, infrastructure development, and resource management. Furthermore, AI-powered remote sensing enables urban planners to assess the impact of proposed projects, simulate scenarios, and optimize urban designs, leading to more sustainable and resilient cities.


A Satellite Imagery of Urban Development (source: nasa.gov)

Environmental monitoring benefits significantly from AI in remote sensing. AI algorithms can analyze satellite data to monitor deforestation, track changes in land cover, detect illegal mining activities, and assess the health of ecosystems. Such insights enable policymakers and conservationists to develop effective strategies for preserving biodiversity, managing natural resources, and mitigating environmental degradation. Moreover, AI in remote sensing empowers early detection and response to environmental hazards such as wildfires, pollution, and natural disasters, aiding in proactive mitigation and ensuring timely protection of ecosystems and human populations.
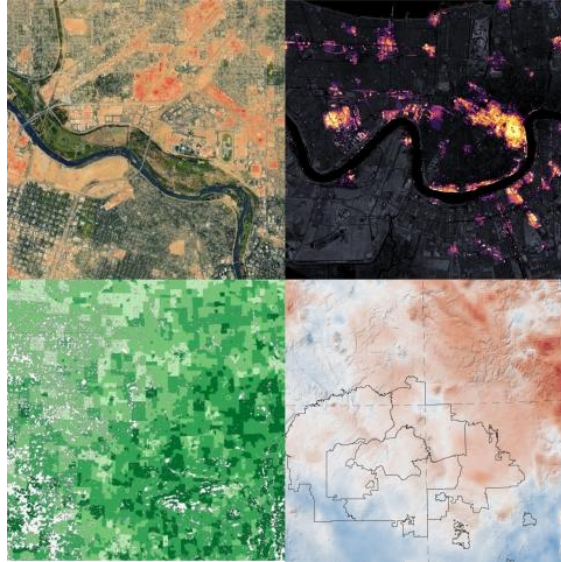
Environmental Data Catalog (source: nasa.gov)

AI-based remote sensing is also invaluable in disaster management. By analyzing remote sensing data, AI algorithms can rapidly identify and assess the extent of natural disasters such as floods, wildfires, and earthquakes. This information aids in emergency response planning, resource allocation, and damage assessment, thereby facilitating effective disaster relief efforts. Through the analysis of remote sensing data, AI algorithms play a crucial role in disaster management, enabling rapid identification, assessment, and response to natural disasters, ultimately saving lives and minimizing the impact on affected areas.
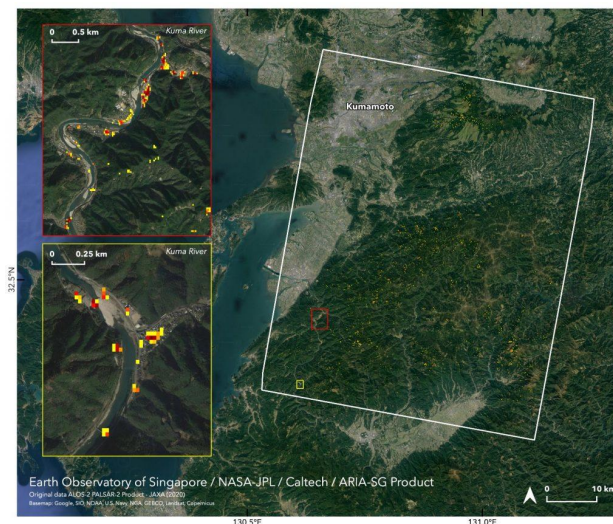
Map of Damaged Areas in Kumamoto Prefecture, Japan (source: nasa.gov)

In the realm of natural resource exploration, AI algorithms can analyze remote sensing data to identify potential mineral deposits, oil and gas reserves, and groundwater resources. This assists geologists and mining companies in identifying promising areas for further exploration and optimizing resource extraction operations. These AI algorithms have the potential to greatly improve efficiency, accuracy, and cost-effectiveness in natural resource exploration, revolutionizing the way we discover and utilize valuable resources from the Earth.
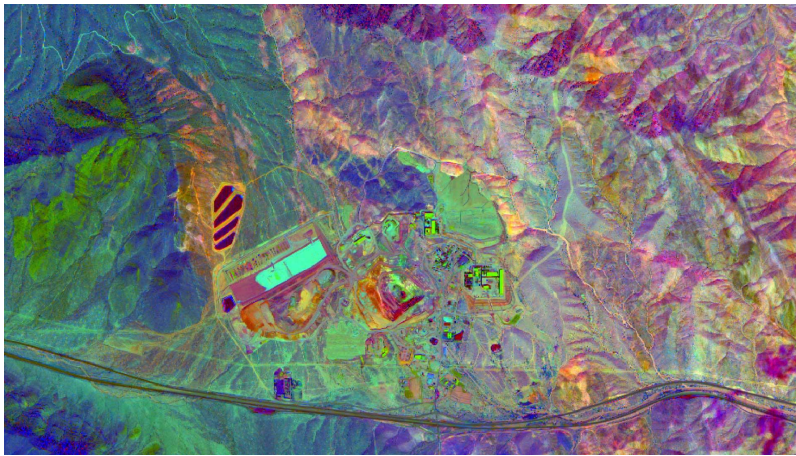
Mineral Exploration from Space (source: esri.com)

The integration of AI in remote sensing enhances the speed, accuracy, and scalability of data analysis, unlocking new insights and enabling more informed decision-making across various applications such as environmental monitoring, agriculture, disaster management, and urban planning. By leveraging the power of AI, remote sensing is poised to revolutionize our understanding of the Earth's dynamics, providing valuable information for sustainable development and addressing global challenges.