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Sky Scanners: Using Satellite Remote Sensing to Figure Out What Earth is Like

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Abstract

Satellite remote sensing has changed the way we look at, study, and learn about the Earth's changing systems. Orbiting sensors take data from many different spectral bands, giving us constant, large-scale information about land, oceans, and the atmosphere. This study discusses the fundamental concepts of satellite remote sensing, including the various types of sensors, methods for data acquisition, and techniques for interpreting images. It talks about important uses like monitoring the environment, figuring out how climate change is affecting agriculture, predicting disasters, and building cities. The incorporation of sophisticated machine learning methods and cloud-based systems has greatly enhanced the efficiency of data processing and the precision of analyses. The focus is on how modern technologies like high-resolution imagery, real-time data processing, and integration with geographic information systems (GIS) have made things more accurate and easier to get to. These technologies facilitate time-series analysis, allowing for the identification of subtle environmental changes over long durations. The article also talks about problems including limited data, interference from the atmosphere, and the necessity for competent analysis. To tackle these problems, correction algorithms and easy-to-use analytical tools have been developed. In the end, satellite remote sensing is a valuable instrument for sustainable development since it helps us make better decisions and learn more about how quickly our planet is changing.

Keywords: Satellite remote sensing, earth observation, geospatial analysis, climate monitoring, GIS integration, environmental mapping

INTRODUCTION

Satellite remote sensing provides a worldwide view of the Earth's surface, making it possible to keep track of changes over time caused by natural and human-made stresses. Satellites primarily use electromagnetic radiation to examine land, surface temperature, and atmospheric conditions. Surface materials absorb, reflect, or emit electromagnetic radiation, which gives them unique characteristics [1].

It is always hard to keep an eye on things effectively. The recent creation of distributed satellite constellations should make it easier to keep an eye on the Earth over time than it is now. The examination of surface moisture and vegetation indices in individual satellite pictures demonstrates significant potential for the non-tidal, large-scale assessment of climate variability and drought situations. During big disasters like earthquakes, floods, and volcanic eruptions, we need to be able to respond quickly. This means we need to do more research on how well current and future satellite systems work and how accurate the information they give us is. Distribution and planning for appropriate satellite systems must adopt a global perspective, taking into account regional opportunities and prioritisation to facilitate the development of standardised materials for applications such as climate modelling and environmental assessment.

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Satellite remote sensing is now a useful way to watch, investigate, and regulate both natural and man-made systems on Earth. Satellite sensors gather electromagnetic radiation that is either reflected or sent out from the surface of the Earth. This information is necessary for monitoring the environment, managing resources, and figuring out how dangerous things are. Recent developments in sensor resolution, data processing methods, and cloud-based platforms have made remote sensing applications much more accurate and easier to use [29].

THE BASICS OF SATELLITE REMOTE SENSING

People often say that remote sensing is the art and science of getting information about something without actually touching it [1]. Satellite remote sensing is the process of getting information about the Earth and its surroundings from a sensor system that is based on a satellite.

Most of the time, satellites that provide remote sensing go through orbit on rather predictable routes that can be chosen to meet mission goals. Most of them are in orbits that are close to the poles, sun-synchronous, and at altitudes of about 700 to 900 km. These satellites make one orbit every 100 minutes and cross a certain latitude at the same moment on the local clock each time, thus the way light and shadow fall on the Earth's surface stays virtually the same from day to day. That little or no change is very important for finding and mapping changes on the ground or for systematic time series analysis. However, sideways-pointing sensors can also be used to allow reasonably frequent revisits, even as short as a few days. Geostationary meteorological satellites that are higher up in the atmosphere cover most of the continental areas and can almost always see clouds and haze.

There are now many different types of earth observation satellites and sensors on the market. These satellites and sensors can work in optical/infrared, microwave, passive, and active modes. This is because technical concepts for satellite design, deployment, and sensor miniaturisation have advanced quickly. These sensor systems can tell you about several things that happen on the surface of the Earth, such as land cover and use, flora growth, snow and ice, and water resources. When choosing the right data, it is important to know the satellite's characteristics, resolution, and the numerous sorts of data it can collect, as well as the multiple ways it can send that data. Pixels collected during satellite operations can be analysed in multispectral or hyperspectral wavelengths to derive the physical characteristics of terrestrial and cover materials. As the volume of satellite data grows around the world, several processing methods are utilised to get useful information from it. There are many different types of satellites, which means that a lot of surface information may be acquired at different times and in different spectral bands. This makes it feasible to systematically monitor adjacent earth conditions.

Principles of Physics and Sensor Technologies

Satellite remote sensing collects data on spatial and temporal events happening all over the world and sends these Earth observations to us all the time using satellite sensors. The research topics are on the basic physical laws that make satellite remote sensing systems work and how they get their data. It is important to understand these basic parts of Earth observation work because they affect everything else, from collecting the right data to choosing the right processing methods. Satellite remote sensing makes it possible to see the Earth in ways that can help solve a lot of problems in society.

Satellite remote sensing uses a wide variety of instrument platforms, sensor types, measurement methods, and data kinds [1]. The Earth’s surface—capable of absorbing, reflecting, and emitting electromagnetic radiation [2] —is the central object of these heterogeneous remote sensing activities, which support numerous applications addressing critical societal issues such as environmental monitoring, disaster risk reduction, and climate change adaptation.

Resolutions for Space, Time, and Radio Waves

To get useful information from satellite data, you need to choose the right items that will work with the application. The decision is based on a number of factors, known as the "resolutions" of the image, which include spatial, spectral, temporal, and radiometric factors. These resolutions determine the data's quality and detail, which in turn affects how well processing algorithms work. The best mysterious way to describe these ideas is as the "dimensions" of the pictures. They can be as simple as a one-dimensional time signal for monitoring noise or as complicated as three-dimensional images that can get a lot of data from the ground.

In remote sensing, spatial resolution is the size of the smallest thing on the ground that can be seen. You can say the indicator in other ways, like ground sample distance (GSD), pixel pitch, field of vision, and dominant wavelength. There are two types of light imaging systems for satellites: optical and thermal. The more the aperture gain, the better the pixel resolution and the lower the GSD. A prototype spatially resolvable estimate algorithm utilising wavelet transform was created to objectively evaluate the spatial resolution of remote sensing images. The estimation assessed the pixel pitch in both horizontal and vertical orientations, as well as in angular directions of any luminous systems [3].

GETTING AND PROCESSING DATA

Satellites use sensors on board to collect remote sensing data from different platforms and send it back to Earth. Satellite triangulation can be used to find the three-dimensional position of an object that is touching another object using a remote sensing satellite. Examining multiband photos from various perspectives or data from alternative sensors can significantly reduce the potential locations of an object. But each satellite makes a lot of data that needs to be stored, and there are different ways to lower the data rate before sending it to ground stations. A strawman design can be suggested to bring together data from several sensors, planes of different sizes, and models with different sorts of data into one common space [2]. Sensors gather data about the Earth from far away without touching it. An electromagnetic field can transmit several types of information on distinct physical sources, including temperature, composition, and material.

The initial stage in the data acquisition chain is to go from the radiometric readings of the different channels at different times to the raw satellite measurement files. These files are usually just a set of photos acquired at different periods with no more information. This sensor data is collected on board and sent to ground receivers with information about frequency, polarisation, range resolution, Doppler rate, and more. A processing stage aboard the satellite combines calibration and pointing data and uses certain processing methods to prepare the satellite remote sensing data for better image interpretation. To see if changes to the geometry and radiometry are needed, milestone 3 needs some information, such as the satellite number, frequency, bounding boxes, and physics models. For the most part, the acquisition system provides this metadata. However, a satellite library company can also provide them from other data sources. Pre-processing is the term for all the methods used on the signal that is picked up on board that don't need data from additional sensors. There are two main types of picture pre-processing methods that are well-known in the literature: feature extraction and restoration.

Fixing and Calibrating Data

Satellite images that the user wants at a specific spatial resolution must be calibrated to get valuable information from ambiguous radiometric data [4]. The data is collected at different times, in different shapes, and under varied conditions, such as the weather and the type of sensor. So, the radiance values at the image pixels must be calibrated so that data from multiple sources may be compared and combined. If not, characterising and measuring a change in land cover would not be precise or dependable.

Calibration include land cover mapping derived from a single image, as well as the calibration of time series data and the analysis of multi-sensor satellite data. When the Landsat 8 satellite was released, a number of innovative methods and pieces of art were shown in an effort to use temporal logic algorithms to calibrate Landsat 8 archive data. These efforts may FUSE data from the Legacy Landsat 4, 5, and 7 sensors with Landsat 8 data to get useful temporal and spectral information that improved the satellite image without losing temporal resolution.

Image Preprocessing and Feature Extraction

Satellite and airborne platforms mostly take remote sensing photographs, which typically have a lot of information that has to be pulled out for more study. Feature extraction is a key part of processing remote sensing photos. Its goal is to take features from images and provide them with the most descriptive aspects so that they may be analysed later. There are two main types of feature extraction methods: those that work with pixels and those that work with objects. [5] proposes and illustrates various widely accepted feature extraction techniques applicable to high-resolution remote sensing imagery, covering comprehensive theoretical descriptions and practical implementations through the open-source software package Orfeo ToolBox, so that relevant practitioners can easily understand these algorithms. In the extensive descriptions of the algorithms, the requirements for the input data, how the extraction results should be shown, and the expected application areas are all explained in detail. This makes it easier to choose the right techniques based on the data and the goals of the project. The features used were meant to help with scene categorisation, object recognition, and semantic segmentation by building on the advances gained in both object-based and pixel-based feature extraction. A fundamental classification of optical remote sensing or aerial data processing is suggested, whereby system components such as acquisition devices, scanning capabilities, sensor kinds, data attributes, coverage, and spectrum information are encapsulated for reference. The digital high-resolution images we got, which have a ground sampling distance of about 1m and a spatial extent of over km, have a lot of information about the ground objects. They can be divided into two groups: man-made objects and natural objects. By examining the distribution and identifying the symbolic numbers or letters, the artificial components of counting systems like odometers and electric meters serve as excellent tools for monitoring urban traffic and energy consumption. The exploratory technique for data processing is further delineated according to the fundamental components of information extraction, such as preprocessing, feature extraction, and the following creation of an intelligent model, to consistently direct the operational phases. [6] talk about how important remote sensing image processing is for better analysis and understanding. They also show a new pseudo-coloring technique that uses virtual colours to make single-band satellite images look better.

Combining data from Different Sources and Sensors

Combining data from diverse sources can make satellite remote sensing products more better. In general, systems with more and overlapping spectral bands and higher spatial resolution work better. However, combining information from more than one sensor, which can include different times, places, platforms, and acquisition principles, usually works even better [7]. Integration can happen before any analysis is done, such when B- and C-sensors are combined to make one image or, in the case of data cubes, one volume. It can also happen after features that are important to certain applications have been extracted. This part talks about ways to combine data from several sensors, such as co-registration, scale harmonisation, and figuring out how much information is gained.

WAYS TO OBSERVE THE EARTH

To remotely sense the Earth from space, you need to capture electromagnetic waves that are reflected or emitted by the surface and get multi-dimensional data that describes the scene. There are many satellite systems with a wide range of sensor types, both active and passive. These systems can pick up signals from all parts of the electromagnetic spectrum, from UV to radio waves. The platform's height, spatial resolution, spectral bands, revisit times, and chances of being cloud-free all affect how well a sensor works for a certain task. Optical and multispectral data, encompassing the visible and near-infrared (VNIR) bands and accessible in near real-time from various installations, remain extensively utilised, particularly for data assimilation in hydro-meteorological models and for delivering severe weather information to humanitarian organisations [2, 8].

Remote Sensing with Passive Optical Sensors

Environmental monitoring often uses remote sensing techniques to take pictures of the Earth's geo-physical features. Passive optical remote sensing is a way to get information about the Earth's surface by looking at energy that naturally reflects or comes from the Earth. Sensors capture radiant energy in a number of spectral bands. This gives us data products like classified land-use maps, leaf-area indices from threshold-band vegetation indices, or environmental-lapse-temperatures from a single channel. Observations of the Earth's surface can be conducted throughout ultraviolet, visible, near-infrared, thermal infrared, and microwave domains; however, optical, thermal, and radar technologies are the predominant remote-sensing methodologies. Each sensor modality focuses on a certain set of characteristics, necessitates various data-processing protocols, and has distinctive benefits and drawbacks [9].

Earth observation seeks to acquire precise data regarding terrestrial occurrences by methodologies such as assessing the chemical composition of the surface, tracking alterations in landforms, and analysing the spread of human settlements. The signals obtained from target materials (e.g., soil, rocks, vegetation, structures) consist of reflected or emitted radiations that are unique to specific satellite positions and observation times. These signals give important information about the surface, like how it changes in time, space, and spectrum. Satellite systems with the right sensors can then keep an eye on changes in land cover, land use, water quality, and mineral content [10]. Thermal and hyperspectral bands are very important for many jobs that involve observing the Earth. Passive satellite optical remote sensing can use these spectral bands to find both temperature/emissivity and materials.

Thermal bands let you figure out the surface temperature and emissivity of materials. These are key factors for figuring out different things that happen with materials and objects. People usually think of the surface temperature as an important indicator of the Earth's health since it affects the energy and water balance of ecosystems. Galvaing et al. [2] said that emissivity is an important material feature that can be employed in satellite systems to find out the liquid level in tanks, the amount of biomass in forests, and to keep track of and document a wide range of oil spills. Thermal hyperspectral systems can be helpful for figuring out the surface temperature and emissivity of certain materials. Thermal sensors pick up noise from changes in the temperature of the air and from other hot surfaces nearby that give off similar temperatures. Because of this, it's not straightforward to get surface temperature and corresponding emissivity. Along with keeping an eye on temperature and emissivity, it is also necessary to be able to tell what materials make up the ground from a distance, like identifying the difference between clay and sand, which are two major types of ground that make up many sections of the Earth. You can't know the types of soil that affect things like salinity and texture without knowing what the soil is made of. This separation of mixtures is in line with how hyperspectral spectral unmixing approaches define intermixing materials. You can group things together into one class if they are similar, like red-oak leaves, clover, and alfalfa.

Radar and Synthetic Aperture Radar

Radar sensor systems use electromagnetic waves that are longer than those that an optical sensor can use. A radar satellite with a Synthetic Aperture Radar (SAR) sensor can work at any time of day or night and can see through clouds, fog, and rain. This makes it perfect for surveillance in any weather [11]. The radar sensor's capacity to see a lot of things lets it keep an eye on a lot of different target groups and find things like line and point targets and changes to the surface. The radar backscattering properties of each target are influenced by the material, shape, and backscattering response of the surface of each target. There are two main types of radar backscatter that can be seen on the surface of the earth: coherent and incoherent. In coherent backscatter, the waveform's phase information is kept, whereas in incoherent backscatter, it is lost [12].

Remote Sensing using LiDAR

LiDAR (Light Detection and Ranging) is an active imaging system that sends out laser pulses and estimates distances by figuring out how long it takes for the energy to bounce back. LiDAR systems have been used a lot to find out how high things like the forest canopy and how deep bodies of water are [1]. It is better to use sensors that work in the laser spectrum to build the ground and canopy surface.

The wavelength of the laser affects how accurate the measurement is in terms of the spatial structure, the shape of the illuminating beam, and how well it scatters. People often utilise the Global Positioning System (GPS) and the Inertial Navigation System (INS) to figure out where the sensor is in aerial LiDAR systems. But occasionally, being able to get to navigation data and telemetry data sent during flight makes it hard to fully reconstruct the laser point cloud. This section talks about how to process LiDAR data to make Digital Terrain Models (DTMs), Digital Surface Models (DSMs), ground and vegetation extraction, forest parameter estimation, and canopy structure recovery. It starts with how to make LiDAR cloud points.

LiDAR systems can be used on the ground, in the air, or in space. Spaceborne LiDAR systems, like the Geoscience Laser Altimeter System (GLAS) on the Ice, Cloud, and Land Elevation Satellite (ICESat) and the Vegetation Canopy LiDAR (VCL) on the Orbital Carbon Observatory (OCO), make it possible to map large areas of topography and estimate vegetation. The GLAS instrument sends out pulses at 1064, 532, and 1540 nm wavelengths and measures ToF. This makes it possible to make global Digital Elevation Models (DEMs). The Vegetation Canopy LiDAR makes point clouds from ToF measurements in the near-infrared (NIR) range to show how plants are structured.

USES IN ENVIRONMENTAL MONITORING

Environmental monitoring, encompassing land use and land cover mapping (LULC), climate and water resources observation, biodiversity and ecosystem services evaluation, and catastrophe risk mitigation and response, continues to be an essential use of satellite remote sensing. Mapping land use and land cover (LULC) is an important part of global sustainability and development [1]. It is an established use of optical remote sensing, with many different classification schemes, validation protocols, and accuracy assessment measures. In semiarid areas where weather data are hard to come by and evapotranspiration is very important for managing water resources, spaceborne photography works well with ground and in-situ data. To keep ecosystems and services going, we need to map biodiversity hotspots and use landscape metrics to measure habitat fragmentation. Earth observation data play a big part in disaster management. For example, they can be used to quickly map the breadth of a disaster before it happens, analyse the effects after it happens, and look at markers of exposure and resilience.

Mapping of Land Use and Land Cover

Land use and land cover are important environmental elements that affect the health and makeup of ecosystems, biodiversity, natural resources, and biogeochemical cycles and climate change [13]. Land usage is the socioeconomic reason for buying and selling land, which means people are involved. Land cover, on the other hand, is the surface that is provided (natural or man-made). It is very important to know the difference between the two ideas in order to accurately measure habitat conditions and changes in ecosystems. Land-cover maps are the most important part of environmental assessments and models, like climate modelling, hydrological simulation, or habitat fragmentation. They let us group together bodies of water, woods, and other types of urban surfaces. Mapping changes in land cover is important for keeping an eye on how people are affecting the Earth, for protecting biodiversity, and for planning land use in a way that is good for the environment. Multi-temporal observation, like Landsat data, is often used to keep track of how quickly human activities change on a global scale. There are many classification algorithms that are regularly tested for land-cover mapping change. These algorithms help global projects like the Global Forest Change Monitoring project.

Climate and Water Resources

Satellite remote sensing technology allows us to keep an eye on the climate system and water resources at different times and places. This helps us get ready for and deal with droughts and floods. Climate change makes it harder to establish sustainable agriculture, makes food less secure, makes poverty worse, raises the danger of disasters, and slows progress toward the United Nations Sustainable Development Goals [14]. This is why we need such advanced monitoring technology. Satellite data sets are helpful for studying big environmental events and circumstances since they give you a basin-wide view of climate conditions that can be used to support integrated hydrological modelling. The MODIS satellite remote sensing system has provided near-real-time data for calculating basin-wide actual evapotranspiration as a climate anomaly indicator and for computing normalised difference vegetation index layers in drought monitoring systems. Other remote-sensing indicators, such as the effective drought index, the water-stressed evaporative fraction of total evaporation, and the Vegetation Dampness Index, have been processed and added to existing hydrological models to predict how rainfall will affect the depths of surface and groundwater. These signs can help farmers figure out if there is a drought quickly.

Analysing drought indices from satellite remote sensing data on a macro to micro scale gives us a way to keep an eye on changes in climate and hydrology in real time. Satellite remote sensing has been very helpful in keeping an eye on climate and water resource characteristics all over the world, especially in India. Many climate-change research require long-term, reliable measurements of the basic elements of the atmosphere, oceans, land surface, and severe weather events. For long-range research, integrating satellite data with several parameters is even further proof of how important satellite data is. Since 1982, the analysis of time-series data of specific parameters such as outgoing long-wave radiation, surface temperature, sea-surface temperature, soil moisture, cloud motion, and vegetation from the Indian National Satellite System (INSAT) and Indian Remote Sensing (IRS) satellites has significantly enhanced the understanding of the Indian monsoon and climatic phenomena.

Climate data from IRS multi-thematic satellites like IRS-1A, IRS-1B, IRS-1C, and IRS-P6 have been very helpful for a number of research on climate change, as well as for figuring out changes in the geodelic and hydrological systems. IRS photographs help make monthly maps of cloud cover that are accurate to one kilometre and allow for full vegetation mapping in both numbers and pictures. These observations have facilitated the study of land-use dynamics and vegetation-cover change resulting from varied climatic conditions and marked the establishment of the National Multi-Agency Centre for Disaster Management [15], aiding in the evaluation of climate abnormalities at national and state levels.

Ecosystem Services and Biodiversity

Biodiversity and ecosystem services are essential components of global ecological stability and human survival. Unsustainable human demands continue to harm both biodiversity and ecological functioning, which are increasingly the focus of international agreements. numerous countries still have trouble keeping track of and evaluating biodiversity and ecosystem functioning because they don't have enough long-term data on numerous variables and measurements. Satellite remote sensing has the ability to address these concerns on a global scale by monitoring biodiversity and ecosystem functioning. Remote sensing techniques are utilised to monitor land-use and land-cover change, land surface phenology, land surface temperature, snow cover dynamics, biomass, toxic algal blooms, and various other metrics pertinent to alterations in ecosystem condition, as elaborated in the broader literature [16].

It is still important to know how biodiversity, biogeography, and geodiversity are spread out throughout space in order to evaluate the abiotic and biotic parts of ecosystems and how they work. Satellite remote sensing is changing how we think about the connections between biodiversity and geodiversity at different levels of space and time. There have been big improvements in satellite sensors, big-data collection, storage, and analysis, as well as spatial-statistical modelling methods that make it possible to map both geodiversity and environmental variability in more detail. These are important for species distribution and biodiversity. Global elevation models, like those from the space-based Shuttle Radar Topography Mission, let us figure out the topography diversity at a resolution of 3 arc seconds. Several satellite-based instruments can collect climatic and climate-related data monitored by numerous sensors operating at varying temporal frequencies, whereas geodiversity, referred to locally as topography and climatic diversity, may be elucidated by climatic variability. Methods that use both optical and hyperspectral data make it possible to get a more detailed and accurate picture of the amount of soil cover, rock types, ecosystem kinds, plant communities, and biodiversity components in different haitats [17].

Reducing and Responding to Disaster Risk

Quick damage assessment and satellite-based emergency mapping are two parts of disaster risk mitigation and response. Remote sensing techniques facilitate damage detection using multi-temporal SAR data and the extraction of tsunami-impacted cropland through morphological profiles, in addition to coherent change detection with SAR [18]. Satellite remote sensing and geographic information systems are an important feature of disaster management [19]. The United Nations helped local, national, and international operational response by sharing standardised terms. New methods for estimating change that were more cohesive also made detection more accurate and cut down on false positives.

ETHICS AND DATA PROBLEMS

Satellite data gives us new knowledge about Earth that we can see from anywhere and that lets us see processes in many different ways. Nonetheless, the surge of knowledge presents considerable hurdles [20]. Different kinds of data sources, different physical mechanisms, and different geographical, spectral, temporal, and radiometric resolutions make selection environments more complicated. The problem is made worse by the fact that there are so many different types, such as processed pictures, feature maps, indexes, thematic maps, auxiliary data, models, and estimations [21]. To get useful knowledge, you need to know where it came from, how it relates to other things, and how to use it correctly. The principles and techniques found in the literature provide fundamental interpretations for many Earth observation phenomena and facilitate the adaption of extensive datasets to particular environmental variables [22]. Raw-data images from basic physics appear when initial principles are established; nevertheless, as selections rely on the analysis of increasingly processed images, greater integration between monitoring and models is necessary.

Access to Data, Privacy, and Sovereignty

Satellite remote sensing gives us quick, wide-ranging views of Earth, but getting the data is a big problem. In commercial arrangements, private companies still control access to satellite images, which raises problems about privacy, ownership, and the public good. Satellite technology lets people see things beyond national borders, which makes it harder to follow national laws and protect data sovereignty. The industry is nonetheless subject to national security rules, which often limit how data may be shared and used [23]. Satellite images have been very helpful for managing emergencies, reducing disasters, and helping people in need. These applications have spurred endeavours to guarantee that imaging is accessible at the utmost temporal frequency, facilitating prompt evaluations of changing circumstances and near-real-time analysis [24].

Uncertainty, Validation, and Reproducibility

Earth Observation (EO) via satellites provides unique benefits in tackling complex modern issues. But just because there are high-quality datasets doesn't mean that data-limited apps can't work; easy access to satellite data doesn't mean that the data will be analysed correctly. To analyse and share results, you need to set up workflows and save related information as metadata that goes along with the data products itself.

Uncertainty quantification and validation techniques are what we use to figure out how reliable data and information from remote sensing measurements are. Sharing the essential methods along with observations or analysis also encourages reproducibility, which is another important part of both science and policy. Keeping an eye on data gaps and uncertainty in closely related fields like vegetation and climate helps with rigorous evaluations of indirect effects. There is also a focus on creating metadata standards for dispersed EO data and then organising satellite EO data products using EO Open Data

Cube (ODC) architectures [25]; and on evaluating confidence in related multi-criteria decision analyses [26].

NEW TRENDS AND WHERE THEY ARE GOING

Satellite remote sensing is a crucial field that supports several human endeavours by providing comprehensive perspectives of aquatic, terrestrial, and atmospheric elements. It is important for keeping an eye on urban growth, deforestation, water resources, and variations in sea surface temperature caused by global warming [1]. Recent developments in cloud computing and big data analytics have led to a new generation of data-heavy applications that require a complete redesign of Earth-observation provision and analytics architectures. This part goes into more detail about the main trends and future directions that are affecting satellite remote sensing.

Cloud Computing and Big Data Analysis

Satellite observation systems are always making and sending out huge amounts of remotely sensed images. To combine so many different types of data, process satellite photos, and look at new information using multiple big data architectures, you need processing systems that can grow. Cloud architecture must enable extensive data sharing and reproducibility, allowing scientists to monitor the processing operations of other users and completely replicate analyses. Cloud infrastructures must be well-documented so that users can easily understand the models and parameters utilised and choose the right algorithms. Researchers can find the right datasets and preworks and pipelines for processing images by knowing about cloud data that is available to the public [27].

Real-Time Monitoring with Small-Satellite Groups

More and more people are interested in and need real-time information about the state of the environment on Earth, including plants, water, weather, and dangers, to help them make decisions and take action quickly. Spaceborne sensors can get new information. For instance, data from the Sentinel-2 satellites is usually available within a few hours, which is close to real-time. People were very interested in satellite constellations, which were the basis for the first satellite communication systems. After a lot of testing, the agency that took over the job concluded that only systems with permanent stations along the Equator could be kept running. Multi-waveband forest fire detection systems had also been of great interest to other people. The issues could be resolved using current technology. There were also space- and ground-based technologies that could map traffic flows [28].

Satellite systems in low Earth orbit (LEO) nowadays can't give real-time information on the weather, spacecraft, or emergencies. To keep an eye on spaceship traffic, data is collected at set periods through gateways or stations that are far apart from each other. A distributed networking idea doesn't operate very well because it doesn't have enough people. Before choosing whether to relocate the spacecraft, data for analysing its de- or near-miss trajectory must be available. So, data collection needs to be quick and accurate. The issue seemed to be solvable. The goal was to use information from fixed ground stations that tracked vision satellites using NIR (near-infrared) sensors. Those bands don't have much light pollution. Satellite monitoring of the sunlight on the surfaces of both the Earth and the Moon.

Unmanned Aerial Systems and Proximal Sensing

Earth observation from space is enhanced by proximal sensing obtained at shorter distances, offering greater detail. Unmanned aerial systems (UAS) have proximal sensors that take pictures and other data at far greater resolutions than what can be done from space. A number of missions have added low-cost, quickly gathered proximate data on a wide range of topics to data from orbit. Collecting and processing UAS data is cheaper than getting satellite data, which has made it easier for many people to get started. Even tiny amounts of extra proximal data can help make projects like continual monitoring of change, assessing damage from disasters, supporting global crop-monitoring initiatives, and combining satellite and proximal-sensing data on issues of scale more full and scalable.

Proximal data obtained from UAS addresses the complex integration of multi-resolution satellite and proximal data. When choosing satellite data, you have to think about the trade-offs between temporal, spectral, geographic, and beam-sensor options. All of these options are related to field sizes and UAS data that is close to the ground. Information regarding integration problems that comes from firsthand experience on many missions and is kept in a separate repository helps make decisions throughout the satellite–proximal combination endeavour. Proximal aerial data usually has natural and vegetation spectra that are different from satellite data. However, proximal multispectral monitoring at a lower resolution and simultaneous hyperspectral along-the-path spectral data can be useful. Monitoring done through extensive sampling makes it easier to combine proximal data gathered during satellite overpasses. Also, constant movement along a high-density monitoring path lets you collect data from nearby satellites throughout many passes in different seasons. This data can be used to make observations about built, unbuilt, and other changes that help with associated analysis [28, 29].

CONCLUSION

Satellite remote sensing has greatly enhanced scientific comprehension of Earth and its dynamics . It helps with study on natural disasters, resources, and human growth. Newer sensor designs, image processing, and analysis have made it possible to create advanced applications including feature extraction, change detection, and predicting natural disasters. Integration with geographic information systems makes analysis easy, which helps with decision-making in disaster management and resource planning. Researchers are working on strong algorithms and automated data processing systems for environmental monitoring, resource management, and early warning.

A systematic review of satellite remote sensing—its foundations, acquisition and processing, information extraction, and mainstream applications—enriches the field by developing a broader and deeper awareness of current practices, trends, possibilities, and difficulties. Such knowledge could assist researchers in evaluating the viability of satellite remote sensing for particular applications, developing appropriate dual methodologies, and facilitating the transfer of established techniques across disciplines, so fostering further innovation in Earth observation for both scientific and societal purposes.

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