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Next-Generation Satellite Remote Sensing: Innovations, Applications, and Future Prospects

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Abstract

Advances in satellite remote sensing have revolutionized our ability to monitor, analyze, and understand the Earth's environment across various scales. Over the past few decades, the field has seen remarkable progress in sensor technology, data processing techniques, and analytical methodologies. Modern satellites now provide high-resolution imagery and multi-spectral data, enabling enhanced monitoring of land cover, atmospheric conditions, oceanic dynamics, and natural disasters. These advancements have facilitated improvements in climate change modeling, resource management, urban planning, and disaster response. Furthermore, the integration of machine learning and artificial intelligence has significantly boosted the accuracy and efficiency of data interpretation, fostering innovative applications in environmental monitoring and forecasting. This article explores the latest trends in satellite remote sensing, focusing on new technologies, data acquisition systems, and interdisciplinary applications, while also addressing challenges such as data privacy, accessibility, and the need for international collaboration in space-based observation efforts.

Keywords: Remote sensing, space-based observation efforts, range of applications, cryosphere

INTRODUCTION TO SATELLITE REMOTE SENSING

Satellite remote sensing has been rapidly bolstered starting in 1972 with the launch of Landsat 1 through the more recent launches by a variety of nations including, though not limited to, resources from Europe, Japan, India, and the People's Republic of China. The overall detection process was developed mostly with the intent of using Landsat 1 and similar additional satellites to determine concentrations of temperature, suspended sediments, color-dissolved organic matter, and nutrients in Cargo Roads, Chesapeake Bay, and coastal waters. The selection of these water quality determinations relates to the expected application to detect discharge as well as tidal and storm-induced plumes in these areas. The detection process includes methods for determining the necessary atmosphere upwelling and downwelling properties. The upwelling radiances are determined from radiative transfer calculations based on ancillary meteorological data acquired from an aircraft, from the ground or predicted by software. Downwelling illuminance is calculated internally based on the solar and satellite positions, a combination of standard clear atmosphere models, and a simple physiographic characteristic parameterization. Although the process was developed considering the specific characteristics expected for a series of Landsat-type satellites, it is intended in that the approach will be valid with or with minimum revision for future satellite systems of remote sensing that will include hardware suitable for the measurement of ocean sun-angle reflected radiances in the wavelength interval at excessive spatial resolutions.

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HISTORICAL DEVELOPMENT OF REMOTE SENSING TECHNOLOGIES

Since the first Landsat was launched on June 23, 1972, satellite remote sensing has progressed tremendously from observations of a few broad wavelengths taken at the scale of counties, to observations of many narrowband wavelengths every few days at the sub-pixel level. New satellite instruments with improved resolution, coverage, and especially spectral characteristics now frequently monitor the Earth from several satellite systems. Inter-calibration and relative calibration of the measurements must account for the differences in sensor characteristics. Great strides have been made using ground-based, airborne, and space-borne instruments to improve radiative transfer models of atmospheric perturbations. However, unmentioned measurement uncertainties are likely much larger than that due to imperfect knowledge of the topography of the Earth's surface [1].

Though discussions of a critical evaluation of remote sensing capabilities are emerging, observing biogeochemically relevant surface characteristics is still left largely to serendipity. Sensibly placed investments at moderate cost could greatly benefit the atmospheric modeling and remote sensing community. Thus, satellite remote sensing, airborne measurements, modeling studies, and the free component of many in situ measurements have been vital observations for understanding our planet through time. That one or more Landsat or SPOT satellites have been in operation is largely taken for granted yet not very long ago the non-interrupted acquisition of such observations on a global basis (the whole point of the mission) was just a hope.

TYPES OF SATELLITE SENSORS

There are essentially three classes of sensors that have been under consideration: those that present their data in pictorial form, those that present data as a function of a single point (as in spectral analysis by ground or airborne instruments), or those that present data in some numerical format. Television and similar scanning sensors produce information in pictorial form, that is, in format equivalent to that presenting regular photographs. Such sensors, while they can produce large volumes of data, have a number of inherent limitations. One of these limitations is the inherently small size, and hence the small data capacity of the sensors [2]. The ready availability of satellites in useful orbits has increased interest in the remote sensing of the earth's resources using television sensors. These sensors are attractive for many purposes since they can provide information in basically the same form as people have always observed the earth. It is relatively easy to understand what is being seen. However, except for meteorological purposes, the sensors operational in space are flying in sun-synchronous orbits with morning or afternoon equatorial crossing times and provide little opportunity for looking at large areas of the earth during hours of bright sunshine.

Sensors that view a single pixel at a time are not so greatly restricted in spectral response or resolution by the small size of the sensor, and it is feasible to build spectrophotometers rather like conjunctive filters that provide significant discrimination in only a few bands. The other class of sensors in use present their data in numerical form. Telemetry has virtually always been used to carry information from space, and this can easily be in numerical form. In recent years, there has been extensive exploration of the possibility of using data recorded on board spacecraft in digital form from which transmittable data could be formatted. Fundamentally, the sensors that have been built to date to operate on aircraft or spacecraft are single-axis scanners that, for example, look at the ground as the platform moves along in its orbit. Scanners can simply be built to operate over the entire optical wavelength range and may have the capability of measuring the radiance of the sunlit portion of the earth to an accuracy of 1% or better. They can also provide a much greater photometric dynamic range than photographic systems. The requirements imposed by these different data formats bid for very different types of sensors.

Passive Sensors

Satellite remote sensing has progressed tremendously since the first Landsat was launched on June 23, 1972, well over 50 years ago. These observations have led to dramatic improvements in numerical simulation models of the coupled atmosphere-land-ocean systems at increasing accuracies and predictive capability. This entire issue discusses new sensors planned for launch in the immediate and the more distant future. When these are in orbit, much of the Earth's environment, including its biota, will be observing new ways and in great detail never before possible. The mediators and some of the key drivers of ecological and biogeophysical process will be observed from space with new algorithms and novel techniques now under development [1]. These include: (1) pollution in all its forms, including CO, CO_2, SO_2, CH_4, O_3, NO and others measured globally on diurnal, daily and weekly scales, and locally in the plumes of their sources; (2) greenhouse gas exchange and fluxes between the Earth and the atmosphere in different land cover types and over partial time spans less than a year; (3) the age of air, the time for a unit volume of air after its last contact with the Earth's surface, determined by moving large-scale inhomogeneities of SO_2, dust, O_3, and the ultraviolet (UV) background; (4) ventilation and renewal rates of the oceans generated by the suction of large sea-surface thermal signatures from above; (5) and estimates of the size distribution of cloud condensation nuclei sparked by oceanic biota based on the visible red, green, and blue channels of a polar orbiting platform.

Satellite remote sensing has documented the Earth's climate. Observations made since the first Nimbus satellite was launched in 1964 are driving the consensus that humans are changing our climate through the emission of greenhouse gases. Over the past quarter century, the Earth Observation Satellite (EOS) program has been responsible for the design and launch of a new generation of Earth Observation Platforms. The sequencing of the EOS satellites is timed to provide continuous observational data over a fixed area during the entire day. At the core of this program are the Polar Orbiting Platforms (POPs) and the geostationary meteorological platforms (GMPs) [3].

Active Sensors

Spaceborne active microwave sensors are known to have the unique capability of remotely sensing planetary surfaces and atmospheres independently of the presence of sunlight or cloud coverage [4]. These sensors are either altimeters, radar, sounders, or lasers sensors. To date, these sensors have been flown on a variety of spacecraft. During the next two decades such sensors will be operated as solo missions, constellations, and carrier spacecraft for large passive microwave array antennas. There will be advances in active microwave sensor technology, capabilities, and observational techniques, and spaceborne active microwave sensing will develop in several innovative ways. Particular emphasis will be scenarios from the Earth Observation program, namely the ERS-1 as well as "add-on" in combination with passive sensors on polar orbiting and geostationary spacecraft or on a TOPSAT array. During the 1990s operational launches are expected for EOS-A (spaceborne earth sensing uses a variety of electromagnetic spectrum regions and methodologies, including active microwave, provides an important non-complementary supplement to those sensors).

Ground-based short radiometer measurements from dry regions, in conjunction with a semi-empirical radiative-transfer model, have been used to establish implied similarities of temporal stability between the remotely-sensed TVX water vapor retrievals thus obtained and in situ rain gauges. While the radar instrument flies on canon, the approach of passive remote sensing of hydro-meteorological data, is expected to lead to relatively straight forward application to a variety of satellite microwave sensor configurations. It is shown that the long-term temporal stability of the radiometer measurements significantly degrades the implied quality of the TVX water vapor retrievals. Likewise, the consistency between the TVX troposphere path delay retrievals obtained from collocated ascending and descending passes of the SIR-C X-band boat well below the expected level of agreed precision agreement. However, the volumetric precipitation contrast between ascending and descending SIR-C data from the tropical continent is significantly more than sufficient to influence the results of the instrumental wet-zel test.

DATA ACQUISITION AND PROCESSING TECHNIQUES

1. Data Acquisition and Data Processing Techniques: Data acquisition of satellite remote sensing systems has been recognized as a dynamic interdisciplinary technology. With the advent of high-resolution, hyperspectral, multi-angular, full polarization, or even full-pulse waveform data, great challenges have been imposed on the field of data processing as an integral part. This includes the following topics: Data acquisition, in general, of satellite remote sensing sensor systems. Two

types: active and passive sensors. Specifically speaking, active sensors record the signal emitted from the sensor itself and received back when it reflects off the surface of the earth. A synthetic aperture radar (SAR) system is a microwave system that emits pulsed electromagnetic waves to illuminate the ground surface. The reflected waves are detected by the airborne or space-borne sensor. The sensor height and the pulse length determine the cross-range resolution of the SAR system. In incoherent single-pass interferometry, two antennas mounted on two closely spaced platforms illuminate the same target. The radar signals pointed to the target are coherent scattering from the surface; however, after scattering a phase disturbance is observed at both antennas due to terrain relief. The coherence between the received signals depends on the distance between the antennas, the height of the target and on the geometrical arrangement and trajectory of the flight. Interferometric SAR satellite missions were launched in the framework of coherent scatterometer experiments. L-band SAR is an integral part of the HRWS (high resolution wide swath) capacity mission. In the past years, several approaches to map soil moisture were proposed to mitigate drawbacks of the often-employed empirical transfer model approximation. These models are based on the exploitation of signatures components of SAR images with the aim of separating surface and volumetric contributions.

2. Height and Derived Data: The word ‘map’ is widely referred to as visualized planning for land and ocean territories and styles as organized plans. In remote sensing, derived data can be taken as measurements and such phenomena as detailed astrophotography, digital elevation models, and even 3D holographic display are close to conventional mapping. The multi-frame composite charts, air surveillance piloting book, or even simple images or graphic immersion schematics onboard the ship are further referred to as charts under naval terms. The object chart may represent any topological or geographical data collected or created, especially when involving land planning or use of environmental significance. In practical terms, the target of a chart (or map or navigation chart), as well as a nautical chart, aeronautical chart, topographical chart, touristic chart, etc., may represent more than a single subject, but provide a synthesis contamination of a number of relevant information including elevation, cardinal points, obstacles, relief, chlorophyll presence in water, ready-win navigation routes, etc. Remote sensing-based object chart building overcomes the risk of incomplete or missing cartographic dependence of terrains on sea available information for propagation modeling in coastal area. The satellite monitoring data concern both the progradational and degradation coastal phenomena.
3. Image Classification: Urban maps comprise buildings, roads, and green areas. These objects are very diverse in form and size and hard to describe using simple shape and size criteria or color components. L-band synthetic aperture radar satellite images form a novel data source for urban object detection in areas where other data sets are scarce. A simple, yet effective, urban object classification framework for L-band SAR satellite images is presented using low-cost data augmentation techniques and deep learning. The framework includes the modeling of physical filter response properties based on a simplistic urban growth model. Object detection results are validated qualitatively and quantitatively on three different study areas having diverse geometric characteristics. Impact of different characteristics of SAR data on object detection is studied. For the area with the lowest and homogeneous urbanization, the pixel-wise model works the best. Moreover, the combination of k-means clustering with mask and weighted logistic loss functions gives the best results. For the medium level of urbanization, the filter-based model shows the best performance combined with a bounding box generation using the watershed transform and contrast enhancement of backscatter images. From this study, it is possible to conclude that simulated L-band SAR satellite images can be used as a low-cost data source for monitoring urban objects in areas with sparse or unavailable up-to-date optical or radar satellite acquisitions.

Data Collection Methods

Since the first Landsat was launched on June 23, 1972, there have been dramatic advancements in satellite remote sensing systems, platforms, and the algorithms used to process and analyze the data. Following the launch of the first Landsat, there were two analogous Earth observation systems put in place: the French SPOT satellite launched on February 22, 1986 and the Indian Remote Sensing satellite system developed in the 1980s. However, due to international and national security reasons, these three systems observed the Earth from space without outside observers needing a special security clearance for the data. This data was sensitive and treated as classified information because the antagonists, as they were called during the Cold War, were primarily interested in the biomass and other natural resources in foreign countries. The user base for free Earth observing satellite data on the Internet for peer-reviewed research was essentially zero until 2009, 37 years after the first Landsat was launched.

After the mid-1980s, there were striking developments in both the spatial and spectral resolution of Earth observing satellite systems. On August 30, 1984, the Landsat 5 platform carrying a new Thematic Mapper (TM) was launched. Since that time, the townships in Landsat scenes viewed by the TM and Enhanced Thematic Mapper Plus (ETM+) instruments have been 8-bit data with 30-meter spatial resolution. Free data on the internet for TM and ETM+ systems were put on the websites in 2008 and 2010, respectively. The development of polar orbit Earth observing satellites with two instruments that swing back and forth while flying overhead was an important milestone in satellite remote sensing. There have been two such A-train systems established. The first flying satellite, Aqua, was launched on May 4, 2002 and the last was launched on December 18, 2008, with a total of six satellites flying over the same parts of the Earth within an hour of each other. While investigating the ongoing fires in Indonesia, a study was conducted to better understand the atmospheric composition and aerosol loading over the last two decades in the vicinity of some of the most extensive peatland fires in human history. The results were produced using the Collection 6 Level 2 aerosol data sets that are part of the AOD (aerosol optical depth) data product.

Image Processing Techniques

Geographic information system (GIS) and remote sensing techniques provide valuable tools for spatial information extraction, data analysis, and visualization. Such data can offer a wealth of geophysical, biological, environmental, and anthropogenic information. These data have been employed for study of changes in climatic regimes, taking inventory of forest resources, desertification, urbanization, and infrastructure development studies [5]. However, such analysis requires suites of tools and algorithms that can enhance the raw satellite data and simplify the extraction of relevant information from these processed images. This section suggests few appropriate tools to accomplish the above objectives.

Image processing tools are suggested for improved visualization and increasingly better analysis of the remotely sensed images. An optimal method for image enhancement of the images using fuzzy based approaches and few optimization tools is proposed. Three types of images, namely, mean, mode, and weighted mean are subsequently obtained after enhancing the original images. An optimal approach for fusion of the above images is introduced which would better highlight the features and the visual inspection would be more apparent on these fused images. The resultant images are then post-processed to suppress the high frequency noise by removing the pixel values which are not likely to be representative of the majority of the data. Following the above operation, the images are processed by the spatial filtering technique. The resultant images are subsequently obtained after removing the noise effect have better visual appearance for objects to be identified. The fuzzy optimization tools are suggested to appropriately tune the weights and standard deviations needed for spatial filtering. The segmentation images subsequently obtained after de-noising will be classified into distinct information and appropriate conclusions would be drawn with regard to forest, agriculture, environmental effect, and crop assessment.

APPLICATIONS IN ENVIRONMENTAL MONITORING

Environmental monitoring in developing countries is often difficult due to low levels of awareness about environmental concerns, lack of funds, technological obstacles, a dearth of operational or research experts, and political situations that are not always stable. Satellite remote sensing technology has the potential to present a partial solution. The land remote sensing program was started in 1972 using two satellites. Such an undertaking was not chosen simply to assist the agricultural sector. However, in the course of the program, the science of remote sensing developed quickly and extensive research was conducted, which fueled an increase in the number of application researchers in various countries [6]. A variety of sensors were carried by satellite platforms in order to address the requirements of a user and to extract further information from the analyzed area. Since the advent of the second half of the 20th century, with the launch of four meteorological satellites deployed with the Channel Visible (CV) system, large-scale fire disasters have been monitored by satellites. In later years, sensors for mapping small-scale vegetation fires were developed, gaining practical operational experience. A wide array of applications has followed the launch of many satellites, including geostationary meteorological, oceanic, and earth observant satellites, which developed means to scan and capture multiple channels. Major examples include various satellite systems. Global environmental change and sustainable development are among the most important endeavors directed by humankind.

Water covers 71% of the earth's surface, and oceans account for 97.5% of global reserves. More than 90% of commercial products (except salt) are transported by water. On one hand, the world is seeking to contemplate better ways to exploit the underwater resources. On the other, the pollution of water becomes more and more serious, resulting in damage caused to water ecology. Although fire was beneficial to early humans, who depended on it for heat, protection, and the ability to cook food, it sometimes devours essential resources. In current day habitats, fire remains a valued tool, but it can quickly transform from friend to foe. Animal fat, as the primary fuel source, is burned by fire resulting in massive damage. Studies have examined the potential for fire damage in various regions. In addition, it is well known that a huge quantity of CO_2 and CH_4 is emitted into the atmosphere, which contributes greatly to the greenhouse effect and accelerated global warming. This paper discusses the natural and anthropogenic factors affecting fire and presents basic principles for post-fire assessment based on research.

Climate Change Studies

The INSAT system consists of a constellation of geo stationary satellites in the Indian Ocean region. Besides the primary INSAT-2 series, the system consists of second-generation instruments like Very High-Resolution Radiometer (VHRR), Shortwave Solar Infrared Radiometer (SSWIR) and Sounders (MSU) which are to provide observations in High-Resolution Picture Transmission (HRPT) formats. The developed software package, Environmental and Atmospheric Science Imaging - Processing System for Universal Calibration and Atmospheric Transmission (EASI-PSUCAT), is an integrated package for generating scene specific radiance. This package can be utilized to process data of any platform with HRPT compatible sensors. It processes clear radiance, Earth-Sun distance and platform specific meteorological information into Commasat format. The validated package has been successfully applied to NOAA (National Oceanic and Atmospheric Administration) since 1990 and achieved very good results for the total ozone and SBUV/2 comparisons. The software EASI-PSUCAT produces calibrated TOVS data in the required format at improved quality particularly for long-term studies [7].

We first describe the INSAT system which is the primary satellite for weather surveillance in this part of the globe. It is a multipurpose geostationary satellite that caters to the requirements of meteorology and communication. It carries a met payload called very high-resolution radiometer (VHRR) that enables us to have visible, infrared and now even water vapor images. The image data at different frequencies/regions of INSAT help in retrieving certain atmospheric parameters on a routine basis viz., outgoing long wave radiation, surface skin temperature etc. From every INSAT observation the observations at surface and 10 μm and 6.7 μm channels in HRPT formats has been collected. With a view to understand the current status of ARGO RHS radiosondes observations are of cyclists and attempts have been made to identify a co-location match of radiosondes with INATS, equatorially crossing IRS-1A and 1B satellites. These measurements are used in the validation of GOES-8 SOUNDER data.

The emphasis is given on observations made in the lower troposphere and the upper troposphere. The new techniques have been developed for processing the radiosondes observations and satellite sounder data of INSAT and GOES. Intensive study has been carried out on build-up of insulation development and subsequent northward propagation. This is achieved through various properties such as wind, temperature and humidity fields as observed by atmospheric motion vectors, INSAT. The GOES sounder data up to 300mbar has been processed using the eigenvector technique and the stable correlation has been obtained with radiosondes for temperature and humidity.

Biodiversity Assessment

Different scientific disciplines share a common need to monitor Earth's biodiversity. Mapping biogeographic distributions, setting conservation priorities, monitoring threats, or understanding impacts of climate change require detailed knowledge of where species live and ecological processes that underpin ecosystem functioning. Conservation research and field monitoring programs to monitor biodiversity elements have mostly focused on charismatic species. However, field surveys can cover only a fraction of globally-distributed habitats, which need to be sampled much more frequently and systematically. Over decades, a new generation of sensors on research and operational satellites has been developed, and sunlight reflected by these areas contains the absorption, scattering, and fluorescence signatures of the surface ocean, underwater optical properties, atmospheric composition, and the shape and coverage of biologically-structured habitats. This reflectance can be used to evaluate essential biodiversity variables (EBVs), which include the distribution and abundance of populations of species (species populations) or assemblages of two or more species, especially traits of these organisms as well as those of a particular habitat in which they live (such as coral reefs, saltmarshes), and the extent or fragmentation of different elements of that habitat [8]. All of these EBVs must be characterized over similar (coarse) spatio-temporal scales. Although satellite Earth observations have been used to characterize some of these targets individually, a significant challenge is to combine present sensors and their observations to characterize all these targets simultaneously. In particular, it highlights a new generation of satellite sensors need for the 'Characterize Biodiversity from Space' grand challenge. The elements of ecosystems found within each habitat and the habitat itself are tightly interlinked, the latter supporting the provision of ecosystem services (provisioning, regulating, supporting, cultural) by the former. Ecosystem elements can change rapidly with or other disturbances like storm events (e.g., extreme tides, temperatures, winds, waves), altered river discharge (e.g., turbidity, extreme fresh or salt water availability), and other anthropogenic use (e.g., directed fishing, aquaculture expansion). The loss in habitat area since the mid-20th century has been recognized as the primary driver of the decline in ecosystem services, such as food provisioning, water security, opportunities for smallpox compensation, and removal of pollutants. There is a growing need to characterize much more consistently and frequently (daily to weekly) the Anthropocene-coast changes, as well as their impacts upon these ecosystem services.

Urban Planning and Development

Viewed from above, most cities appear as a sprawling mass of structures of varying size, shape, and construction, interwoven with particular street patterns. Being particularly a representation of the infrastructural properties of the urban morphology, this view is known to leave out the "life pulse" of the city as well as many peripheral areas. Furthermore, extrapolating from the same aerial or satellite data time and/or information about social demographics is a challenging problem, especially in more diverse multicultural urban areas.

Cities are melting pots of domain-specific knowledge and decision making/problem solving processes [9]. Consequently, research has to address many different aspects before delivering an operative knowledge transfer tool to city administrators: Methodology has naturally to tackle a variety of issues that range from data access and pre-processing to knowledge discovery and mapping of population variables. User needs have to be diversified across users coming from different specializations.

The realm of usage includes planning, zoning, residential distribution studies, local policy assessment, spatial capitalization, environmental analysis, tourism, marketing, and alike. At the same time, the intended solution needs to respect the multidisciplinary aspect of the problem of interest. Hence, the relationships between techniques, data, and results should be clear to experts in the various domains involved. Such a system should allow the user to navigate through space and time, access to historical data and explore data in an efficient way so as to enable the scientific examination of indicatively low socioeconomic status urban areas. In recent years, various efforts have been undertaken in order to develop instruments that could assist in the realization of such a vision.

Land Use Mapping

In 1973, NASA (National Aeronautics and Space Administration) launched the Earth Resources Technology Satellite (ERTS.) Since the inception of the program, NASA, in cooperation with various federal, state, and local agencies and private interest groups, has made a considerable amount of photographic and photographic-type imagery available for analysis. Early investigations have provided evidence that spectral differences, and hence management-related differences, can be identified. Interpretation of the imagery, however, suggests that variations in land use and land cover are not as well defined as predicted. In 1973, the Skylab 1 Laboratory was utilized to obtain one set of color infrared (CIR) photographs of the Wareham, Massachusetts study area. Commercially available color infrared prints were obtained. Photographs from the Massachusetts–D.C. (District of Columbia) study areas have been analyzed for forest/non-forest and water/land proportions. The estimated area was 75% under forest, 15% water and 10% under various non-forest land use categories. This analysis however was subjective and estimates are approximated to the nearest 5%. Commercial CIR photographs were obtained and observed with stereo-microscopes. The price of photographs for a user-specified area precluded analysis over large regions. Changes in color photography from year to year and differences in image tone between the different sources of ERTS-1 imagery make the determination of management-related differences difficult. Using multi spectral-scanning film obtained from the EROS Data Center, film positives of the RB-57 color positive film were made. Time limitations on the availability of the ERTS-1 photographic-type imagery precluded repeat passes analysis. The ERTS-1 LANDSAT 1 spacecraft has passed over the Wareham, Massachusetts study region several times, but Earth imaging was conducted on only three of those passes during the late summer and leaf-off periods. On October 9, 1972, the southern acquired six scenes of the Barnstable, Wareham, and Quabbin Reservoir study areas. Seventy-five percent land/water masks of the 13 scenes were prepared on 1:1,000,000 topo base maps. Since image tone changes with season for the color IRA film, preprint corrections were made with a photo-spectrometer. Using a model of forested and CIR tonal targets developed from prior ERTS-1 and CIR imagery, map comparison techniques quantitatively assessed the relationship of the characteristics [10]. Tidal channels and therefore intermittent streams have reflectance characteristics similar to those of the non-forested wetlands. Nonetheless, drainage patterns sufficiently differentiable on the photographic prints had not yet begun to show man-made development. Four land use maps of the Goose Pond, Massachusetts study region were prepared independently. The first three maps were preformation of the various remotely sensed data sources. outlined standard field practices for the interpretation of single-date color and color-infrared photographic film. The fourth map was prepared over a comparable time frame as the first three, but utilized cluster analysis of multi-date multi-spectral scanner data.

Infrastructure Monitoring

Infrastructure monitoring is fundamental for ensuring daily-life safety and availability of the considered infrastructure. Regular monitoring is traditionally performed by qualified personnel on-site, possibly flanked by periodic instrumental acquisitions to track possible structural variations. As a matter of fact, very often the instrumentation consists of high-resolution geodetic stations or surveying campaigns with traditional GNSS (Global Navigation Satellite System). This acquaintance is, however, sparse and hardly providing an overall health status of the structure. Moreover, these kinds of techniques are labor-intensive, not always safe or possible on large infrastructures, and only allow to monitor point-wise displacements. Satellite-based technologies have been attracting interest within the geomatic field since they come to guarantee a denser spatiotemporal morphological description of the area under scrutiny at affordable costs and without safety concerns. A review of several SAR satellite-based monitoring techniques is provided discussing their main features, issues due to particular morphological or geophysical context, and state-of-the-art monitoring of relevant structures. An integrated use of remote sensing data with other more traditional acquisition strategies is highly encouraged to enhance the effectiveness of the foreseen monitoring campaign.

Aside from selected field observations, calibrated numerical predictions of dam response are irreplaceable for structure management and for the planning of eventual reinforcement interventions. The latter require a detailed characterization of the causative mechanisms and of the involved materials and pre-stressed structures. The long-outlining example of a dam demonstrates the capability of short-term A-DInSAR and GNSS data to detect dam displacement precursors at specific critical locations, condition necessary for their predictive capabilities. Dam triggering is provided by comparison of the geodetic and InSAR monitoring with a 3D thermo-mechanical model of the rock-dam-reservoir system. Observations and simulations of the expected trigger mechanism are in agreement. This enables development of displacement scenarios, which may be the focus of future detailed monitoring and risk mitigation strategies. The different nature of A-DInSAR and GNSS data guarantees the robustness of the proposed methodology, which does not require dam-specific rheological information that is indeed rarely available.

MONITORING AND MANAGEMENT

Healthful places are safeguarded by an assemblage of not only human resources, such as health departments or hospitals, but also policies and regulations based on scientific information. The highest standard of living on Earth is found in Denmark, a small country consisting of over 400 islands situated on the continental land-mass in northeast Europe. The cities are characterized by the humane scale and pedestrian character of the streetscapes, and by the lively street life. Here, apartment buildings provide a pleasant living environment offering good indoor and outdoor space and having an excellent energy performance. Home-based eldercare services are available. Healthful places can enable individuals to live in good health. On the island of Funen, Denmark, the health care system has acquired digital tele-mammography for rapid data exchange and second opinion for routine mammography screenings. As a result, premature deaths from breast cancer have declined. The journey to school is considered the most dangerous of all the everyday journeys undertaken by a child. The Ørestad project is an urban precautionary plan to secure the highest health quality of the urban infrastructure. Here, open space for the opportunities of physical activity has been reserved. In order to offer to the citizens a healthier urban environment, the city of Copenhagen is developing a new traffic policy and implementing actions aimed at regulating traffic volume and speed. A clear definition of the specific scope and aims is important in providing a rationale for the intervention. On the island of Sjaelland, the administration of health in the workplace is decentralized. Local multi-professional health and safety groups have been established for companies with more than 35 employees, advice being provided and preventive strategies developed. Functionally relevant information is a powerful lever to design for a location-based prevention service. Here, decentralized multi-professional health and safety groups can generate benefits in the form of epidemiological patterns. Perceived safety and access of public places in a neighborhood are key to mental health.

Crop Health Assessment

Monitoring crop health in a timely and spatially precise manner can help growers mitigate issues from pests, pathogens, water and nutrient stress, hail damage, lodging, and weeds [11]. Common methods of crop health monitoring involve either in situ measurements or remote sensing. In situ methods, such as visual inspection, chemical analysis, sensor-based technologies, and drones, are important information sources, offering detailed findings to observations. Conversely, the results from in situ analyses often depend on a bounded sample and convey local, nondeterministic information, requiring geo-spatial statistics for trend analysis. Remote sensing information has a wider reach, offering geographically continuous and transversally deterministic results; hence it is popular in landscape analysis. However, the vegetation indices extracted from these remote datasets will not have the same effects as the physiological aspects of interest, differing from on-the-ground observations [12]. There are two modern challenges concerning remote sensing data application: (1) watershed-scale spatiotemporal noise and (2) autonomous and computationally-efficient crop health delineation.

Expert systems are among the methods used to merge databases and information modules to address complex issues. However, the appearance of a local design will increase the requirement for computing power, so the expected results will not always be reproducible. State-of-the-art procedures such as convolutional neural network (CNN) feature extraction using artificially derived training samples are able to map general features at a very high resolution with a short period of time. Nevertheless, the feature is not directly interpretable to the plant level since the spawning storage mimics rather than explicitly representing elements. Furthermore, the level of reliability is not guaranteed since artificial tools extrapolate data patterns but not real-world phenomena. This paper presents a novel GEOBIA pipeline based on custom spectral profiles for crop health indexing. In conclusion, the automatic crop health indices are used as a uniform spatial entity definition. The shareholding operator is designed to precisely delimit the crop boundaries inside the field border, rendering the accurate segmentation of crop regions. This new definition-maximized GEOBIA methodology with a health indexing stands ready to be used for crop health assessments at an autonomous image mathematical level.

Precision Agriculture

Precision agriculture is an intensively "data hungry" agricultural management approach that can immensely benefit from the capabilities of remote sensing. Following the first remotely sensed images acquired by Landsat-5 in 1984, the next two decades saw the flourishing of experimental and pre-operational investigations aimed at studying the potential of satellite systems for monitoring crop properties. Besides the documented capability of translating remotely sensed vegetation indexes into information on crop density and health status, two main branches of research emerged: crop boundary detection and need for mapping and interpretation, focal mechanisms of spectral indexes.

Social requests and commercial efforts aimed at the progressive advent of new satellite missions promoted during the first decade of the twenty-first century an operational use of remote sensing in precision agriculture. Related studies deal generally with the (pixel-wise) calibration of spectral indexes based on the comparison of vegetation indexes with crop/biomass properties, and the use of the Earth Observation data to detect relevant changes in crop properties. A rotation of the most common temporal evolutions of vegetation indexes characterizing the main crops provides a synthetic view of the most recent literature results. These extensive review works helped identify and analyze the key advances that have been made until now in precision agriculture from a remote sensing perspective [13]. On the other hand, this historical perspective helped highlight a number of relevant knowledge gaps that are still open between the remote sensing and the agricultural experts and between industry and academia in this field.

DISASTER MANAGEMENT AND RESPONSE

In the past decades, the increasing availability of Earth Observation (EO) data, together with continuously improving methods and techniques, has fostered the use of satellite-based applications to investigate, assess and monitor the causes, impacts and consequences of natural or manmade disasters and to quantify subsequent adaptations and responses that can lead to the environmental change of affected areas [14]. In the frame of ongoing international cooperation between "Satellite EO" group of CNR-ISSIA and other research institutions, universities, and aid organizations located in different nations, a large panel of such applications has been developed. Four representative research activities are presented: study of the 2011 Arcinazzo landslide in central Italy, investigation of the 2013 Tyndall Glacier lake outburst flood in the sub-Himalayan Sikkim state of India, design of a semi-automatic methodology in QGIS environment for the study of the changing coast of Madagascar, and a post-event study of the 2015 Nepal earthquake which also included an emergency mapping service concerning critical infrastructures under the unlabeled ETRD umbrella.

EO data sources are also classified, and a comprehensive list of main available space and airborne-borne sensors is given. The main objective of final data applications, consisting in making all the original datasets and accomplishments in their use or analysis available to the research community is highlighted. Finally, results that demonstrated the suitability and capabilities of EO for such applications are also provided, and new research frontiers are addressed. A Wikipedia-like format is utilized as the most practical way to provide detailed descriptions about the research activities and results concerning each considered case study.

Flood Monitoring

According to the Global Climate Risk Index of 2017, during the past 20 years, 4373 events left many countries in economic distress and even brought about bankruptcy. Emergency responders often request crisis information derived from satellite sensors to understand the development, outcome, and impact of a disastrous event on resources and population. This allows responders to focus on the distribution of limited resources and to prioritize reaction measures. The proposed methodology of flood monitoring is based on the use of Sentinel-2 data in operational mode, as its two-band synthesis with Sentinel-1, a similar spatial resolution to Landsat, not only characterizes the top-of-atmosphere and surface physics of the water bodies but also allows optimal complementary data in cases with cloud coverage equal to or exceeding 30% on a local and global scale. Images taken every 5 days ensure a higher image collection frequency of compatible imagery than Landsat 8. Processing of the obtained 10 or 20 m resolution data is performed by the means of a modular processing chain specifically developed during a pilot flood monitoring project for rapid flood detection [15].

A defined automated methodology for flood monitoring from multi-spectral-image time-series data, particularly the implementation of this methodology in the form of a generic and modular processing chain, is presented. The methodology consists of five principal processing modules: routine data search and ingestion and preparation, water segmentation, a posteriori water extent processing, regular mapping of the flooded areas, and semi-automated validation and product quality. Water segmentation approaches using the random forest classifier and the modified normalized difference water index are discussed. Similar modules developed for the handling of SAR data will also be shown. The methodology has been designed to ensure the reliability and robustness of the derived flood information. Nevertheless, some requirements should be met. Floods are complex and in most cases, difficult to monitor over large areas as they are determined through the interaction of numerous conditions such as precipitation, hydrology, soil saturation, and terrain, among others. Thus, the water bodies might not always be apparent from the spectral signature or even the texture information of the images. This study is focused on the preparation of tools and methods based on remote sensing using free or low-cost data not provided by commercial services. As disasters are multifaceted, analysis of multi-sensor integrality creates very high standards. Emergency responders must have a detailed understanding of the detrimental effects these events have on the economy but also on the local human populations and infrastructure. Given the associated risks from disasters, the automatic monitoring of possible and actual disasters and their effect on the economy is receiving an enormous amount of attention. For this reason, the value of using the satellite sensor program operated by a national government or an international organization, together with the characteristic land-spill data, is emerging in disaster assessment and grasping the disaster situation. It may help the improvement of sustainable development goals and resiliency by estimating and generating a quantitative economic impact.

Wildfire Detection

Wildland (forest and grassland) fires consume more than 3 million square kilometers of the earth's ecosystem. Global monitoring plays an essential role in detecting and quantifying the number and intensity of wildland fires, especially in less developed countries where large or intense fires may not be observed and reported. Improved global detection has benefits in regional air quality, global climate change and land cover change analysis. Remote sensing through satellites is a versatile method to detect such hazardous events as wildfires. One of the most important goals of Earth observing systems has been and will be land and environment monitoring.

Although land fires are less common than those in agriculture, livestock, and deforestation, this type of fire is of prime importance, since the intended area cannot be extinguished under control. The burned area depends to a great extent on wind and air humidity. It means that the same type of land (forest, peat land, grassland etc.) with almost the same fuel and ignition source can differ in the area burned by a factor of five or more. Up to now, the best-known method of global land fire monitoring through satellites is the nighttime imagery from the Defense Meteorological Satellite Program (DMSP) satellite orbiting at an 800 km polar sun-synchronous orbit. Since 1990, the DMSP satellite has provided data on the temperature of fires on the ground. At the same time, studies were undertaken to search for methods to monitor wildfires using morning and afternoon orbiting satellites, which are much more appropriate for observing the amount of burned areas. At the 20–100 km, 1110–1800 km, 165.350–335 GHz polar synchronous orbit, there is an opportunity to simultaneously observe identical earth's locations twice a day (the geostationary satellite) [16].

There have been some previous related works. At high spatial resolution (1 km), the fire detection system does not issue fire alerts when there is cloud coverage present over the area of the potential fire. A comparison involving other fire products cannot be made [17]. k_{ISC} (ISC = indirect speed control) is typically able to monitor mesoscale meteorological phenomena (fronts, outflow boundaries, lines of convergence) and frequently observe fires, dust storms, and volcanic eruptions. There are few works in the literature that have proposed to analyze such images to detect and track these events over a global scale.

ADVANCEMENTS IN SENSOR TECHNOLOGY

Satellite remote sensing began with the launch of several satellites. Since the launch of the first satellite on July 23, 1972, an unbelievable amount of activity has occurred in all aspects of satellite remote sensing. Nearly 20 Earth Resource Satellites have been launched into polar, near polar, and geostationary orbits. A number of countries have undertaken analogous programs. Platforms have been evaluated and launched with a wide variety of sensor complements. Much more sophisticated resources are currently planned. Associated technologies of computer compatibility, digital image processing, and data transmission have grown in a stair-step fashion to accommodate the burgeoning requirements of the satellite remote sensing industry. Biomass, agricultural land-use, net primary productivity, and weather/ climate prediction studies are focal applications with large area, baseline, multi-temporal, and modeling requirements and are in various stages of satellite data acquisition and evaluation. Forest canopy bio-mass, soil type, and mineral composition represent remote sensing platforms capable of important contributions to these studies. Ultimately, realization of remote sensors, platforms, data systems, and a model may be obtained which synergistically combine the satellite remote sensing industry into a unique and powerful tool for land-related monitoring, management, and prediction. Modes of operation are especially vectored towards the inventory, analysis, and monitoring functions of natural resource managers. The emphasis herein is on proposed applications of data from the vantage point of an earth resource economist evaluating the system with respect to picture frequency, scale, and quantitative analytical requirements typical of this discipline.

Hyperspectral Imaging

Satellite-based hyperspectral sensors are able to increase the dimensionality of spectral information by dividing the optical spectrum into dozens and sometimes hundreds of contiguous relatively narrow wavelength bands. Observations provided by hyperspectral imagery, otherwise known as imaging spectroscopy, enable enhanced discrimination of material properties and identification of fine spectral features compared to broadband multispectral sensors. Visible to near-infrared absorptions of chlorophylls and carotenoids can be indicative of aquatic algal concentration. Dissolved organic matters in the surface water are easily observable as dark features around 715 and 775 nm, which is related to its strong absorption peak at that area. For this reason, the water quality of estuarine and coastal environment can be estimated by using the hyperspectral remote sensing. The visible spectrometer obtained 18 m ground resolution hyperspectral data over. The nonnegative matrix factorization (NMF) method was used to unmix the hyperspectral data and to obtain the endmembers and their abundance fraction maps. It was possible to discriminate water, soil, residential areas and forest areas by using fully constrained minimum/maximum angle convex cone analysis (FCM/MACC) method as an endmember finding method of the hyperspectral data. Ground truth information shared from the Turkish Statistical Institute, also the spectral signature of the materials for the field campaign was given to the the TÜBİTAK Space Technologies Research Institute. The accuracy assessment was done by using the obtained endmember and fraction maps, which had similarities with the shared ground truth material. As a result, the hyperspectral remote sensing can be used with high performance and confirm the potential usages by the satellite-based hyperspectral remote sensing. Now, the European Space Agency will launch a hyperspectral satellite named EnMAP. This satellite will have high spectral resolution, 30 m ground resolution hyperspectral imagery within an area of 30 km swath width. A scientific research project is planned for the operations of EnMAP together with GAU. The results confirmed that monitoring of the dumped mine waste mineralogy in a flexible and efficient way with the current and forthcoming hyperspectral satellite missions in the push-broom concept. In addition to any other electromagnetic technology, the usage of hyperspectral sensors can become more common by the compactness and cost reduction of such instruments. The impact of hyperspectral satellite sensors will carry out and provide a unique approach for operational tasks [18].

Synthetic Aperture Radar

High-Resolution Microwave Imaging from the Data-Focused Approach

Actually, the most common approach consists in computing the raw data of the relevant satellite pass taking into account the position of the targets of interest. A more realistic approach consists in designing a suitable sampling/processing grid on the area, taking into account the nadir position of the platform for the current antenna beam in combination with the relative scan angle specified in the mission plan. High-resolution microwave images of the observed scene can be obtained under various environmental conditions [19]. The approach aims to suggest the easiest possible way to obtain such images by the user side not having access to adequate SAR information. Focusing raw data by considering the targets as a series of point scatterers the most relevant data focusing parameters that depend on the location of the given scene may be explained and computed, obtaining the configurations of the sampling grid and the SAR acquisition, modeling the position of the points from real maps and exploiting a simple but effective data-focused algorithm that takes into account the proposed grid and beam parameters. A resulting high-resolution image is shown, and a satisfying comparison with an image of the scene obtained by the Italian COSMO-SkyMed SAR is provided, to validate the whole proposed approach.

In recent years, unmanned aerial vehicle (UAV)-SAR has attracted a growing interest among the remote sensing community. However, the development of commercial low-cost systems is limited by the intrinsic complication of SAR development, due to the very precise need for mission parameters to obtain good-quality images, the most relevant of which are largely undesired by current standard civilian users. For instance, ultra-stable platforms able to maintain angular stability in the order of few milliradians are required, and very stringent requirements on flight trajectory and velocity must be enforced. Such parameters are unstable for this kind of applications, making it difficult to obtain good images and effectively increasing very much the final cost of the images themselves. Still, the effort is traditionally addressed to improving general system performance and compensating the ill-conditioning of the problem offline, resorting to parametric and model-based focusing of the data. A data-driven data-focused approach for microwave imaging is for the first time introduced, and first computational results coming from the on-purpose implementation of the sampled model are illustrated. To this aim, the most common point scatterers (PSs) driven focusing approach has been extended to the more general case of squint angles. Additional features not treated so deeply in the existing scientific literature, like the influence of the highest order of squint and how the orientated PSs are projected in the 3D scene, are discussed. Finally, with the view of the upcoming Cosmo-Skymed-X and TerraSAR-L launches, the two types of NiSOSAR systems usually considered are characterized in terms of technological readiness degree combinations of LEO satellites, SAR systems, and high-resolution cameras. Three examples of data focusing of the Cosmo-Skymed LEO SAR image are also provided. The raw data of an interferometric pair has been processed, and the interference fringes have been easily extracted. Two further examples of VHR satellite images are provided. Even if the technique cannot be advantageously applied, it is shown how the interference fringes can be easily extracted, also enhancing the good performance and phase stability of the proposed technique.

INTEGRATION WITH GEOGRAPHIC INFORMATION SYSTEMS

Geographic information system (GIS) technology is becoming an essential tool for combining various map and satellite information sources in models that simulate the interactions of complex natural systems. Remote sensing provides the most important informative contribution to GIS which furnishes basic informative layers in optimal time and space resolutions [20]. Among the features produced by GIS are water balance models of lake catchment systems. However, the GIS application on the representation and the flow simulation of the processes among the land and water of the catchments and lakes is never easy. It is great challenge to delineate data sources and modelling efforts applied on growing terrestrial, atmospheric, aquatic and marine natural systems in connection of aquaculture. The Earth is a water planet of ground, surface or its vapor being more than 99%. Precipitation from freshwater evaporated oceans causes agriculture which depends on one hand weather forecast and on the other hand flood control due to surface water runoff, directly by cultivation using rainfall, lakes, dams or by well irrigation and indirect management of drainage system like aqueducts, canals, diversion and flood keeping of rivers.

GIS is an elective tool to process the spatial data produced by the developing remote sensing and computer technologies [21]. Remote sensing has automatic aerial and manual surface technology to get information by different wavelengths and their interactions on the electromagnetic spectrum from the earth or the phenomenon occurred. Earth Observation has closed meaning to review of natural or artificial features by in situ, aerial and satellite imaging for issues related to economic, cultural, political, sociology, defence and the environment. Increasingly information technology has advanced the handling and analysis of spatial data in the geographical and temporal domain.

CHALLENGES IN SATELLITE REMOTE SENSING

Research in satellite remote sensing promises to improve our ability to understand and mitigate a variety of environmental and human health challenges on a global scale. The emerging field of multi-sensor data synergy investigates the additional information that can be derived from the joint interpretation of measurements obtained from different satellites. However, the automatic and harmonized processing of data sets obtained by different imaging sensors still remains a big challenge. Satellite instruments observe the Earth continuously from space, providing essential information on a variety of physical and bio-geochemical parameters at local, regional or global scales. Thereby, remotely sensed data adds valuable information to better understand complex processes on Earth's surface and in the atmosphere [22]. Nonetheless, the scientific challenge is to develop retrieval algorithms that describe the physical measurement process in sufficient detail yet are simple enough to allow a robust inversion of the remotely sensed signals. The future objective should be in automated data processing and the development of robust and transferable algorithms that require little or no human intervention. Such algorithms can result in necessary input for decision-makers to eventually improve actions on environmental pollution, biodiversity and food security. Implementation of remotely sensed data could ideally contribute to a better understanding and monitoring of Earth processes and support decision making. An additional goal is to draw attention to the increasing number of satellite missions in order to inform the relevant scientific communities about upcoming events and new possibilities related to the provision of spaceborne data. This paper is organized according to the nature of the challenges facing the satellite remote sensing community.

Data Quality Issues

The second generation of high-resolution satellites allows acquiring both panchromatic and multispectral imagery for cartographic purposes and the generation of digital surface models (DSMs).

The spatial resolution ranges from 0.6 m in the panchromatic band to 2.4–30 m in the multi-spectral bands. Although high resolution satellite imagery (HRSI) cannot replace aerial photos with resolutions of 0.1–0.2 m, satellite remote sensing offers advantages in monitoring natural or technological phenomena over time and in acquiring images of hard-to-reach areas. An acquisition in stereo mode allows the generation of Digital Elevation Model (DEM) or Digital Surface Model (DSM) that can be used for environmental monitoring. Furthermore, the availability of the appropriate software of GIS for the analysis presents the commodity of working directly on satellite images, reducing the uncertainty in processing data that might affect thematic map accuracy. The quality of the images plays a crucial role in this context. The equivalence of the radiometric properties of the image to those of the object it represents is a known requirement of cartographic images. It is said that the radiometry of an image (both aerial and satellite) is satisfactory when the ground reflectance of the target/brightness and the grey level of the pixel are matched [23]. This requirement is difficult to guarantee in high resolution satellite images where the transfer function between target reflectance and sensor digital number (DN) is much less obvious than for the aerial camera. Ground resolving power, as in the case of photo-interpretation, is the principal characteristic for distinguishing between pixels and relates to the apparent shape, size, and radiometry of objects. The smallest discernible object represents detail. The increasing array flies so high that the size of the ground objects becomes too small compared to the pixel resolution. This means that some objects, especially small or thin ones relax unsubstantial, become unrecognizable or undiscernible according to the DTE (digital terrain elevation) and the shape and the radiometry are becoming the primary differentiator. Moreover, the ability to resolve such radiometrically different objects inside an image depends on the digital processing tools available for image enhancement and modeling. A broad class of HRSI of 0.61 to 4 m resolution includes LANDSAT 5 TM, LANDSAT 7 ETM+, IRS (Indian Remote Sensing – LISS III, PAN), IKONOS, and KOMPSAT. Most of the linear array sensors provide more than 8-bit/pixel digital image as output; this is significant as height bits per pixel allow preserving the radiometric performance of the 8-bit/pixel picture. The most serious radiometric problems are slight variations in the sensor view angle, sun angle and the presence of shadows combined with the image noise of the system and with inherent deficiencies of the lens system such as the absence of coherent lenses or the effect of diffraction. The image quality concept, at the beginning of the digital era and for linear object, meant signal to noise ratio and contrast evaluation. Isolating a target from the background (determining whether a specific pixel belongs to an object) depends on point spread function characterizing the sensor-system figure of merit. This is chain-relationship function whose interconnections create the modulus transfer function and spectrally separability of the system. Hence several parameters could describe the imaging system: radiometric resolution, radiometric accuracy, and geometrical resolution. The Multi-Angle Imaging Spectro Radiometer (MISR) parameters represent the description of how the ground to image process occurs. The fall of light underpins the raster visualization and the nature of the flight-line; the optic, spectral frame of the field and the way of scanning project how an object is seen on the image; the satellites/aircraft orbits establish the time, the space, the direction views; image format and scan strategy along with the sensor amount and window settings affect the pixel number and their distribution across the image and finally the resolution constraints combined with the viewing geometry will provide how much pixels it can be for the single band. In between the term modulating transfer function is a function, which describes how an image is modulated/unmodulated the object and represents the end product of the physical modeling of the overall remote sensing model (CRESP). Given this statement of quality, a procedure for the estimation of the noise level and the MFR of HRSI is presented. It is implemented in a user-friendly software and tested on images acquired by different satellite platforms. Further, parameters characterizing the quality of a remote sensing image fast, retain, and relatively easy to measure are discussed as the implementation of a protocol of quality evaluation and control to define a formal procedure of image acceptance and rejection. It is here and reported, a simple and immediate interpretation of the analysis performed could allow a wider range of the user to verify the results given by the raw image provider both before the correction carried out by the company of after precaution gain the damage visible in the image. Furthermore, the use of the estimate quality parameters could allow benchmark comparisons with the result of different means/separate methods avoiding possible disputes data. A total of 26 papers were submitted in response to the SI (special issue) call. After a peer-review process, 11 papers were recommended for publication and are included in this special issue [24]. The first paper of this SI elaborates on the problem of denoising optical very high-resolution (VHR) images. The next three papers mainly focus on the restoration problem of hyperspectral images (HSI). This SI also includes four papers that illustrate different approaches for improving the quality of SAR data. Finally, the last two papers aim at improving the spatial resolution of remote sensing images by data fusion.

Regulatory and Ethical Considerations

Satellite remote sensing (SRS) combines low-volume operations in spectroscopy and photographing with telecommunication and space technology. Subsequently, it is said to be highly attractive by security and dual-use aims. The essential difference between satellite remote sensing information and other data based on satellite remote sensing is that the last one usually creates standard data and map products suitable for operational using [25]. Such data-based use requires special data license agreements. Afterward, care must be taken in preparation not to endorse the publication of information which cannot be fully verified. Special monitoring is necessary if rapidly changing events call for repeated acquisition and informative reception of satellite remote sensing raw data [26].

Spectroscopy and photographing using low-volume operations are low-volume operations producing a huge amount of data that have to be reduced into composite images for permanent storage and analysis. Telecommunication addresses the broad availability in real or near real time of satellite remote sensing data in areas where there are no fundamental resourcing limitations. This is the case for the spaceborne radar data acquired from the European remote sensing satellites prior to the South Asian tsunami in 2004. It also encompasses remote sensing taken seriously in an influential sense focusing on imaging through active and passive use of electromagnetic radiation in various bandwidths. This is distinguished from, for instance, telecommunication regulation and remote sensing of the human body under magnetic resonance imaging (MRI) equipment.

FUTURE TRENDS IN SATELLITE REMOTE SENSING

Over the past 50 years, an array of sophisticated remote sensing systems has been mounted on board satellites in orbit around the Earth. The data acquired can be used to generate maps of various environmental variables over space and time, from temperature to land-cover type. The MODIS sensor, for example, is able to provide information on global-scale environmental variability, including numerous variables related to vegetation, land-surface temperature, and atmospheric aerosol properties. From a scientific perspective, these remote sensing data provide the opportunity to better understand the Earth's system. To an ever-increasing degree, remote sensing has provided, and will continue to provide, policy-makers with vital information to support decision-making. Governments are becoming more transparent but also ever more accountable for their management of tax-payers' money. This has led to an increased demand for public goods and services to be delivered as cost-effectively as possible. While some have found great use in the provision of remote sensing services over the years, non-governmental organizations (NGOs), private industry and the wider public remain largely untapped [22]. Earth observation is an under-utilized tool for analyzing complex strategies such as the Millennium Development Goals (MDGs). If employed correctly, such tools can be used to monitor progress, forecast future outcomes, and support the development of plans and policies aimed at meeting these goals. With half of the MDG indicators requiring information on changes in the state of the environment, the space-based perspective offered by remote sensing is essential. By investigating the barriers to the use of remote sensing in complex strategy analysis and a wider range of stakeholders in developing states, and by developing guidelines for these stakeholders on how to overcome these barriers, it is proposed that access to such analysis can be considerably widened. For developed society, advances in satellite remote sensing (SRS) traditionally have been driven by space and defence agencies. However, in recognition of the multifaceted potential benefits to society, the commercial sector increasingly is contributing to SRS technology development. Recognizing that natural phenomena can be observed from space, a variety of applications can be facilitated. From the perspectives of disaster recovery, soil management and economic research, the utility of SRS in improving our understanding of Earth's systems is obvious. Applied wisely and consistently, SRS can yield significant benefits in areas as diverse as financial investment, public health regulation, and pest management. With the expected explosion in the number of satellites to be launched over the next decades, the coming era of SRS could see a very significant burden of change management activities, not to mention potential environmental impacts. Another, not inconsiderable hurdle to the effective exploitation of the coming wealth of satellite imagery is finding the right data. Remote sensing technology is advancing rapidly, with new sensors being developed and launched to orbit at an accelerating pace, and existing sensors being re-calibrated and re-engineered. Fixed-wing aircraft provide a stable sensor platform from which to acquire ground imagery, while the high resolution afforded by remote sensing satellites - down to a pixel resolution of 5m - allows mapping at fine scales. In addition, high-quality passive remote sensing can be augmented with data from radar, LiDAR (light detection and ranging), and electro-optic equipment.

Miniaturization of Satellites

In the recent few years, a variety of breakthroughs on space technologies have reduced the cost and enlarged the capability of satellite remote sensing. This new age of earth observations has made the effective, efficient, timely, and sustainable monitoring of terrestrial ecosystems for huge data available. It is estimated that the volume of remotely sensed data from satellites is increasing at an exponential rate at more than 50% per year; it is expected that many Petabytes of satellite image data is collected and distributed every year by 2023. This provides a tremendous opportunity to improve the prediction and understanding on how ecosystems shape and change under the pressures of human and natural forces [27]. One of the important expansions will be in the use of different spatial and temporal resolutions sensors combined with innovative processing algorithms. This necessarily has to consider advances in miniaturization of satellites, internet of things (IoT) sensors, machine/deep learning and big data, integration of different data sources, cloud based/supercomputing platforms, data sharing and open science, access to very-high spatial resolution data, launch opportunities, etc. Sentinel satellites are a family of operational satellites that have been developed by the European Space Agency as part of the Copernicus Programme. They embark a broad range of cutting-edge and innovative technologies. Both the Sentinels instruments and space mission record continuity and consistently high quality, long-term monitoring data of the Earth's atmosphere and climate. Measuring the distribution and the temporal evolution of the Earth's land-membrane temperature from space represents a challenging scope, and dust is a limiting factor. The potential constrains of Sentinel-3 SLSTR LST measurements due to thin cloud presence in all different the mesoscale imaging modes are assessed, and the cloud contamination in LST RDR products is estimated. On the other hand, the integration of multi-source satellite observations in active and passive microwave sensors is promising for water and agriculture applications, offering improved accuracy, higher information content, and complementary sensitivity and potential for improved inversion.

Artificial Intelligence in Data Analysis

Remote sensing is the technology of acquiring information about the Earth's surface without physical contact. To stand out from other geographic data collection technologies, the characteristic of the object being sensed and the sensor used to collect the data are involved. In this sense, satellite remote sensing involves sensors mounted on satellites that collect data of the Earth's surface. This is crucial for monitoring purposes since it can be repeated over time, is widely available, is not affected by international borders, and has a wide range of uses. Many countries launched for research purposes Earth observation satellite projects while larger space agencies provide extended satellite data free of charge. Over the past years, the spatial, spectral, and time resolution of satellite data have increased considerably.

Artificial intelligence has experienced a renaissance over the last few years due to the more powerful hardware and the vast increase in the amount of data available. Data analysis from remote sensing employed artificial intelligence techniques before the term was repeatedly mentioned in mainstream media. These techniques are especially useful in the treatment of big datasets. Nowadays, with more advanced techniques used, they can easily outperform classical approaches and are also used in less developed fields. It makes artificial intelligence and machine learning one of the most popular topics in the remote sensing community. There are various fields where machine learning, including deep learning, can be efficiently used towards enhanced goal achievement. While some of these fields are not new to the audience, it makes sense to summarize them here. Executors at the beginning of their research could follow these guidelines and methodologies until they reach specific performance metrics and figures of merit. Land cover and land use classification are the primary goals for satellites employed in Earth observation. Nonetheless, new frontiers remain to be explored in terms of feature extraction and data analysis. This also is of paramount importance for data fusion techniques, an advantageous step in the chain starting from data acquisition and going down to information extraction [28].

CASE STUDIES OF SUCCESSFUL REMOTE SENSING PROJECTS

Since the first Landsat was launched on June 23, 1972, satellite remote sensing has progressed tremendously. Satellite remote sensing and associated airborne and in situ measurements have provided vital observations for understanding planet Earth through time, while also resulting in improvements to numerical simulation models of the highly coupled atmosphere-land-ocean systems. These observations collectively define the Earth's climate, documenting the changing surface and atmosphere—leading to the emerging consensus that Homo sapiens is currently changing the climate of the planet through emissions of greenhouse gases and other impacts.

Measured parameters vary widely and may include surface temperature, soil moisture, topographic height, albedo, radiometric properties in the reflected and thermal domains, concentration of atmospheric constituents including aerosols, and the chemistry of the atmosphere, including presence of greenhouse gases and pollutants. Since 1988, sea level rise on the U.S. Atlantic coastline has increased between 2 and 5 mm per year at the same time that coastal flood damages have increased by orders of magnitude. It is now thought that in general coastal flood damages increase as the cube of sea level rise and that the recent acceleration of the rate of rise portends a significant increase in the rate of damages. That said, coastal hazards are growing worldwide, with many low-lying coastal communities confronting unmanageable choice between expensive engineering projects and abandonment.

There are many notable examples of the use of remotely sensed satellite data in addressing planet-wide issues through the medium of regional studies. Perhaps one of the most far-reaching early programs was the monitoring of deforestation in Brazilian Amazonia using the wide-field view of the multispectral scanner (MSS) system on Landsat, which was first used in 1978. A less well known but equally far-reaching program, initiated by the USGS (United States Geological Survey) to perform a national inventory of land cover use of the United States, used imagery starting in 1972. Another example of the great need for regional and global studies is the Desertification Workshop, an international workshop supported by the United States, attracting over 150 scientists from around the world [22].

Global Monitoring for Environment and Security

One of the key objectives of the European Commission is to develop and implement the Global Monitoring for Environment and Security (GMES) initiative. This initiative is being prepared by a reasoned proposal based on the feasibility study which quantifies costs and socio-economic benefits. The ultimate aim is to enable the European Union to take a decision on the improvement of operational services by 2008. The concerned sectors include monitoring changes in the Earth occurring locally and/or over large scales; foreseeing global environmental trends including climate change; anticipating changes due to natural hazards and human-made pressures.

Inland water observations are needed for the management of water resources, addresses the need for the protection of water quality. Geodetic observations are needed for monitoring targets prone to large deformations; it deals with the monitoring of areas susceptible to subsidence induced by ground-water extraction or mining activity. The main goal of the project is to establish the unified European capacity to support the European Union and international institutions in an operational reliable and periodic monitoring of the agricultural area and yield over large regions of the world. The specific objectives are the Implementation, validation and exploitation of a suite of derived information layers to support crop monitoring; the development of the information service based on the project products; research and development of the methodologies necessary for implementing the service in an efficient and cost-effective way; the development and validation of a flexible back-end integration system capable of generating the regional crop monitoring products and distributing them to the users; and the development and implementation of a global database on agriculture status and prospects enabling to combine and validate the regional products.

NASA's Earth Observing System

Satellite remote sensing continues its astonishing progress since the launch of the first Landsat on June 23, 1972. In addition, to the digital satellite remote sensing data, airborne and in situ programs have been developed in almost every state. Airborne and ship borne concert with those of Landsat, NOAA, SPOT, or ERS satellites are still required, for: (1) the matching of ground sampling distance, (2) convenient near simultaneous acquisition, (3) additional spectral bands, and/or (4) the retrieval of geophysical parameters such as rainfall rate. All of these requirements have been met for regional research programs by the ER-2 aircraft, the Airborne Self-Calibrating Radiometer (ASCR), and other multispectral scanning instruments [29]. In addition to computer systems for digital image processing, the EPPL information system has developed hardware and software for nearly all phases of the remote sensing cycle. It is intended to promote the broader and more effective use of Landsat data in policy and decision making by federal organizations, the Congress, and others such as the LANDSAT user community.

Satellite remote sensing started with the launch of Landsat 1 and the development of the first digital analysis systems almost three decades ago. In fast succession, the first spaceborne multispectral scanners were followed by the launch of SPOT and the advent of the first high-resolution systems. Polar orbiters for monitoring a number of global parameters have been operating very successfully with the advanced very high-resolution radiometers (AVHRR) since the late seventies and more recently ADEOS with the NSCAT [1]. Land and surface water changes can be observed through the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). The last developments in airborne push-broom sensors have the potential to become the airborne equivalent to Landsat, Spot, and Archiva. These aircraft observations will be used for algorithm development of the future EnMAP mission.

Policy and Regulation in Remote Sensing

Remote sensing technology is constantly changing and manufacturers are making new products readily available to those interested in utilizing it. The Outreach Committee of the Applied Geospatial Sensing educational initiative has started the following national inventory of US states concerning policy and regulatory issues related to remote sensing of the environment. To date this inventory has been done for a number of states as of fall 1991 that information has been published about electronic implementation. This will provide a status report of the policy and regulatory issues regarding the use of remote sensing, aerial and satellite, for environmental monitoring and analysis of natural and managed resources on a state-by-state basis.

New products and sensors that are now on the market or will soon be of interest to the states include the near-back scatter sensors for improved detection of oil on water, the satellites with 5-meter resolution, the increase arc cover of land area at 30 meter resolution for the field and laboratory communities, and the gridding of Digital Terrain Elevation Data (DTED) for improved understanding of slope, contouring, Raster Overlay System (ROS), and ease of overlay of two or more images. Herein the current policy and regulatory structure and future needs under these new tactics will be addressed and there will be a discussion of the potential use of the new technologies as tools for the more effective administration of state resources [30]. Unfortunately, the imagery collected under the oversight and control of the new Department of Defense agency, the National Reconnaissance Office, concerning national security is not archived and available for the religious of natural resource investigations conducted by the scientific agency and university community as it had been in the past. Also, the imagery made available to the research community under the NASA sponsorship of the Landsat program, although free of charge, shall be reviewed monthly by persons outside of government. This is in contrast to the present Landsat policy for the distribution of thematic mapper and related multispectral data.

EDUCATION AND TRAINING IN REMOTE SENSING

The response of UK education establishments to the increasing demands for education and training in remote sensing is surveyed in terms of recent developments in facilities and courses. These include a European-wide initiative of educational image processing packages, suitable for individual user workstations, which are commercially available and in use in a number of British universities and higher education establishments. This equipment, together with other facilities such as access to remote sensing data at an economic price, is helping to increase public access to remote sensing technology. Despite an apparent commitment of resources to remote sensing, there has not been the expected growth of Earth observation in the UK. What is the status of remote sensing education and training now? A summary of experience, particularly within a northern English academic environment since initial involvement with remote sensing has revealed ways in which the specialist techniques of using satellites and many other forms of aerial imagery are becoming much more accessible for analysis by a wider range of scientists. This note will also touch on future directions for remote sensing in terrestrial ecological research, bearing in mind that two of the most significant documentary resources for this kind of landscape may no longer be freely available.

Curriculum Development

For over the past four decades, environmental monitoring by satellite remote sensing has primarily been the observation of land cover change, usually performed by comparing multi-spectral images of a given location that were collected at two different points in time. Rather than directly measuring physical parameters or material properties, satellite observations have been used to estimate these from a comparison with field measurements or using proxies, such as the Normalized Difference Vegetation Index (NDVI) that is indicative of vegetation density and health. A significant feature of such analyses is that decisions concerning appropriate satellite instruments, image processing techniques, and biophysical models are taken beforehand, irrespective of the land cover type, forcing a choice of generic parameters and formulations that are most representative of the various possible conditions that could be encountered. There have been very few attempts to systematically evaluate these preconceptions for model development, and little consideration of how the processing chain itself can introduce errors that may limit the understanding that could be gained from data collected by operational systems [22].

The objective of the work is to develop an empirical method to describe the spatiotemporal change of some observational parameter that is closely related to the physical or biological processes of interest, and in a way that is consistent over different land cover types. As there are many influential factors and potential mechanisms at play, the description of the change is done semi-parametrically, with a number of easily interpretable principal functions describing the overall trend and its modulation by gradually-varying explanatory variables which are themselves interpolated by penalty-splines. The residuals of this regression are then further modelled parametrically to account for other monotonically-increasing covariates and short-range correlation. For the remote sensing of the land surface, the observational parameter of interest is the temporal evolution of spectral indexes, and the framework proposed characterizes this for a given spectroradiometer applied to a specific land cover, so that the approach is entirely generic and it is hoped will find broad applicability. A particular focus is given to the change of vegetation as observed in the NDVI, but the theory is equally applicable to other indexes and parameters representative of the underlying signal that could be measured.

Workshops and Conferences

In 1990 the United Nations initiated annual Workshops on Basic Space Science for developing countries. These Workshops were planned to be held in the following order in five regions: Asia and the Pacific (1991 and 1996), Latin America and the Caribbean (1992 and 1997), Africa (1993), Western Asia (1994), and Europe (1995). To date, six such workshops have been held, respectively in India (1991), Costa Rica (1992), and Colombia (1996), Nigeria (1993), Egypt (1994), and Sri Lanka (1995). The seventh workshop is currently being planned to be held in Tegucigalpa, Honduras. Interest has been expressed for a future workshop in Tunisia. The Seventh United Nations Workshop on Basic Space Science was hosted by the Secretaria de Recursos Naturales y Ambiente (SERNA) in Tegucigalpa, Honduras from 3 to 5 December 1997. This workshop was be organized by the United Nations Office for Outer Space Affairs (OOSA) in Vienna in collaboration with SERNA. The United Nations Workshops on Basic Space Science are organized with the support from the Government of Germany and the Planetary Society. Participation in the Workshop is by invitation only to nominated scientists and Local Organizers. The United Nations Workshops are an inherent follow-up activity to the recommendations made in 1983 by the COSPAR Present Exercise on Space Research Development in Developing Countries. These workshops are in response to needs expressed at the UNISPACE III Conference and to the role of OOSA as the focal point for the UT In the past, studies by various organizations have identified major disparities existing between developed and developing countries in the field of space sciences. Created in 1991, the United Nations Office for Outer Space Affairs (OOSA) in Vienna has as one of its major responsibilities to promote international cooperation in the peaceful uses of outer space and, in particular, to increase the capacities of developing countries in space sciences [31].

COLLABORATION AND PARTNERSHIPS IN REMOTE SENSING

Satellite remote sensing has come a long way since the first Landsat satellite was launched in 1972. Initial systems were limited to either MSS or TM sensors in the visible, NIR, and SWIR portions of the electromagnetic spectrum, offering three to six channels. Now one can choose from among two dozen Earth-observing satellite systems, each offering between three and 36 sensors. Available bands span the electromagnetic spectrum from the visible through the thermal-IR and have varying spatial resolutions. Reflecting changes in technology, modern satellites have a spectral and spatial resolution that far exceeds that of the first Landsat satellites.

Given this tremendous diversity of choice, satellite sensor selection must be made on a case-by-case basis depending on the region to be studied, the time scale required, and the particular land cover change being investigated. Generally, for global mapping, immediate or rapid change may be measured based on just one band. For more detailed investigations, medium-resolution sensors might yield better results due to better spectral fidelity of land cover types. High-resolution satellites may be appropriate in cases of opaqueness with large surrounding clear areas, well-defined large and easily detectable changes. Multi-source data would be most effective, as high-resolution image pairs may guide medium-resolution change detection. Thermal infrared bands may be useful for fire detection and monitoring non-vegetation land covers. Sensors with a skip for each bad line or band, however, are not recommended for land cover studies, as image compositing would be needed. Six months or more may elapse between a change occurred and its coincidental observation. Hence, temporal continuity of Landsat TM observations is integral to evaluate and monitor land cover change [32]. Intercomparing sensors pressed into complementary status in multiple countries could provide more valuable and precise information concerning various land cover changes. For environmental change detection where multi-date decadal spectral information is essential, sensor program should be operated continuously and compatibility of present and up-coming sensors should be ensured [1].

International Cooperation

The challenge before the international community is to effectively apply a multi-sensor, multi-platform approach capable of providing the flood of geo-referenced Earth observations required to confront the scale, diversity and equity of global environmental change. The complementarity of the onboard sensors on each platform must be more fully exploited. The decision to charge full commercial satellite data prices for Landsat 7 data has posed a severe hardship for the largely unplanned and unfunded use of Landsat data by the developing nations of the world. International cooperation for the procurement, long-term archiving and exchange of satellite data is imperative, so that the results of scientific research on the utility of the data can be widely disseminated. Without such cooperation the plight of countless individuals in developing nations will be bleak [32]. Proposed international commercial data centers have raised serious questions about the sustentative effects of this ongoing process. International cooperation is discussed that could provide an equitable economic stimulus for global data exchanges, an overside multilateral marché for satellite data and an incentive for the non-signing of the agreements. While most of the international commercial data centers that had been proposed by 1986 are now in operation, there are many difficulties. The steep, across-the-board price increases introduced by each center have posed a severe hardship for many developing nations that had been drawn to rely on Landsat data for the evaluation of their resources and the management of their environment. In 1980, the price of a standard Landsat 4/5 product in digital form was $170, but the same product purchased through the Earthdata Center (EDC) in 1987 is $3190. This increase has had three direct adverse effects: (1) multi-date analysis has been reduced, limiting the overall utility of the data, (2) only panchromatic data is purchased, while the six other bands go unsold, and (3) fewer training sessions are given and only those who had purchased data in the past were receiving training sessions. All Landsat 7 data have been priced some 50% above the Landsat 4/5 data prices. By promoting the use of off-shore processing facilities the EROS data center will have a great negative economic impact on American industry and the US trade deficit. The charging of 100% full commercial data prices for data purchased for developing nations has violated the spirit of the policy.

Public-Private Partnerships

Growth in commercial earth observation small satellites is requiring government agencies to address their utilization of commercial satellite imagery data. As of March 2018, for the first time, the number of commercially funded earth observation satellites has cumulatively surpassed the number of those government funded. As more small satellite owner/operators enter the commercial geospatial industry, additional geospatial data governance and standards become increasingly important. Changes in geospatial governance, licensing standards, and compliance are occurring at all levels from the United Nations and NATO to individual nation states. Small satellite owner/operators wanting to enter the commercial geospatial industry will face global compliance, standards, licensing, and data access technology challenges along with opportunities. Existing machine learning algorithms continue to advance at high rates, underpinning the importance of business models that accommodate different data access licensing requirements. A business road map checklist will be presented to assist the small satellite owner/operator in leveraging industry partners and leading to use of their data at scale.

The commercial geospatial industry is advancing to allow both commercial and government clients to gather high-resolution imagery data. As the availability of constituent remotely sensed data continues to increase, persistent surveillance capabilities are changing how remotely sensed data is consumed. Hand-held data are being brought to the forefront of national security applications, underscoring the importance of data accessibility. A service allows users to task a government constellation of Earth-observing satellites and receive a collection of overlapping images every day, effectively allowing for persistent monitoring of over 50,000 sq. km. per day. As of the first quarter of 2018, there were 27 commercially funded Earth observation small satellite owner/operators with intentions to launch 898 satellites, 521 of which have already reached orbit, or 9700 kg. These numbers are set to increase. Global Geospatial Standardization can be addressed through publicly available documents including a commercial imaging contract there will be strong interest to fly on orbits/sharing data with friendly nations.

RESULTS AND DISCUSSION

Recent advancements in satellite remote sensing technologies have led to significant improvements in data quality, spatial and temporal resolution, and the breadth of applications across various scientific fields. The results presented here reflect the progress made in key areas such as sensor development, data processing techniques, and the use of advanced analytics for environmental monitoring and disaster management.

1. *Sensor and platform advancements:* New satellite sensors, including SAR, hyperspectral imaging, and LiDAR, have dramatically enhanced the ability to capture detailed information about the Earth's surface. These sensors provide high-resolution images that allow for more accurate mapping of land use, vegetation health, and urban sprawl. Furthermore, improvements in multispectral and hyperspectral sensors enable the detection of subtle changes in the Earth's surface that were previously difficult to identify. For example, hyperspectral imaging has enabled better identification of soil properties, vegetation species, and water quality.
2. *Improved temporal and spatial resolution:* Advances in satellite constellations and miniaturization technologies have allowed for more frequent revisit times and better temporal resolution, improving the monitoring of dynamic processes like deforestation, coastal erosion, and seasonal agricultural changes. The development of small satellite networks, or CubeSats, has particularly enhanced real-time monitoring capabilities, providing a cost-effective alternative to traditional satellite systems. This improvement allows for more detailed and timely decision-making in resource management and emergency response efforts.
3. *Data processing and analytics:* The integration of artificial intelligence (AI) and machine learning (ML) algorithms has revolutionized the interpretation of satellite data. These techniques are increasingly being used to automate the extraction of valuable insights from vast amounts of imagery, enabling more efficient and accurate analyses. For example, AI-powered classification algorithms are now able to detect land cover changes, monitor crop health, and even predict the spread of wildfires with higher accuracy than traditional methods. Furthermore, ML models can now predict environmental events such as floods, droughts, or hurricanes based on satellite data, improving early warning systems and preparedness.
4. *Applications in environmental and climate monitoring:* Satellite remote sensing has become a vital tool in understanding and mitigating the effects of climate change. By providing long-term data on atmospheric conditions, sea level rise, and carbon emissions, satellites are essential for tracking the progress of global environmental initiatives. Recent applications also include monitoring the health of critical ecosystems, such as forests and wetlands, and providing data for climate modeling. The ability to monitor changes in ice caps and glaciers has been instrumental in understanding the impacts of global warming on polar regions and sea-level rise.
5. *Disaster response and management:* Advances in satellite remote sensing have greatly enhanced disaster management capabilities. Real-time data from satellites has proven invaluable in the aftermath of natural disasters such as hurricanes, earthquakes, floods, and wildfires. For instance, high-resolution imagery helps assess damage, plan recovery efforts, and monitor the movement of displaced populations. The rapid availability of such data enables authorities to make more informed decisions regarding resource allocation, evacuation plans, and infrastructure restoration. Furthermore, ongoing monitoring of disaster-prone regions allows for more effective preparedness and mitigation strategies.
6. *Challenges and future directions:* Despite these advances, several challenges remain in satellite remote sensing. Data accessibility and interoperability between different satellite systems continue to be significant issues, particularly for developing countries or organizations with limited resources. Efforts to improve data-sharing frameworks and standardization across platforms are essential for maximizing the potential of satellite remote sensing. Additionally, privacy concerns regarding the use of high-resolution imagery need to be addressed through regulations and ethical guidelines. As satellite technologies continue to evolve, future research should focus on enhancing the sustainability of satellite missions, reducing costs, and improving data accuracy for a wide range of applications.

In conclusion, the ongoing advancements in satellite remote sensing have not only enhanced our understanding of Earth's environment but also provided invaluable tools for addressing some of the most pressing global challenges. With continued innovation and collaboration, satellite remote sensing will play an increasingly crucial role in environmental management, disaster response, and the fight against climate change.

CONCLUSION

Satellite remote sensing has advanced significantly since the 1970s and there is new danger in falling into the trap of seeing this 40-year anniversary in the field as an end in itself. Also, developers like to hear the remote sensing community are looking forward to what we might achieve in the 5, 10, or 20 years ahead. Common use of satellite data in each field, thereby giving a snapshot of the state of the art and forecast of capabilities beyond 2015. The following reviews on satellite remote sensing of urban, cryospheric, and oceanic applications are presented.

With increasing concerns over resource scarcity and climate change, researchers are turning to satellite remote sensing as a needed tool for detailed study and management of the urban-environment system. An accurate characterization at the city level has become crucial as more than half the global population currently resides there. With this in mind, this work presents an overview of the most recent studies based on Earth observation in urban applications, giving an insight into both remote sensing multi-sensor data and the most recent retrieval techniques [1]. It starts by discussing the data sources generally used in urban studies, including both panchromatic and spectral high-resolution optical systems, radar, and thermal data. The subsequent overview then addresses retrieval techniques within urban morphology studies including, but not limited to, urban mapping/modelling, urban growth, risk assessment and urban-rural interaction evaluation.

The cryosphere consists of all Earth’s frozen regions, including snow, ice caps, glaciers, permafrost, and ice sheets. Decreasing snow and ice cover results in a lower albedo and therefore in more solar energy being absorbed by the Earth’s surface and local atmosphere, contributing to atmospheric warming. Furthermore, the reduction of Northern Hemisphere snow cover will trigger a greater release of methane gas to the atmosphere and accelerate global warming due to “Arctic amplification.” The Greenland and Antarctic Ice Sheets contain enough fresh water to raise the global sea levels by 7.1 and 61.1 m, respectively. Between 1992 and 2009 the mass loss of the Greenland Ice Sheet was 248 ± 36 Gt per year and 152 ± 80 Gt per year for the Antarctica Ice Sheet. Before the satellite era continuous ice mass change observations were hard to acquire as in situ observations were scarce due to logistic difficulties and the lack of available remote sensing devices. To observe changes in the cryosphere, polar platforms are needed and the first Landsat satellite was launched on July 23, 1972. However, studies of the extent and characteristics of the cryosphere are much older and date back to the first half of the 20th century. An expansion of application of satellite remote sensing in the cryosphere is foreseen for the next years as it provides unique tools to monitor ice sheets, sea ice, snow, ice caps, pyroclastic deposits and their interaction with lava and water and in-situ data are hard and expensive to acquire.

In 2025, the field of remote sensing will see continued advancements, with conferences like International Conference on Advances in Remote Sensing (ICARS), International Geoscience and Remote Sensing Symposium (IGARSS), and Joint Urban Remote Sensing Event(JURSE) focusing on global challenges, sustainable development, and the integration of AI and geospatial technologies.

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