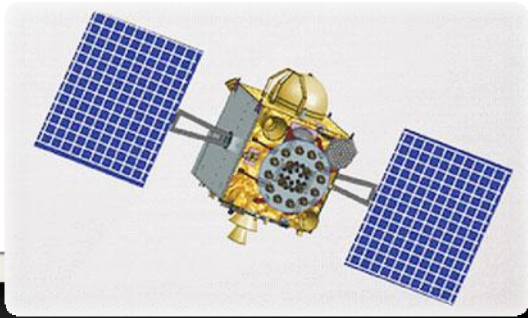
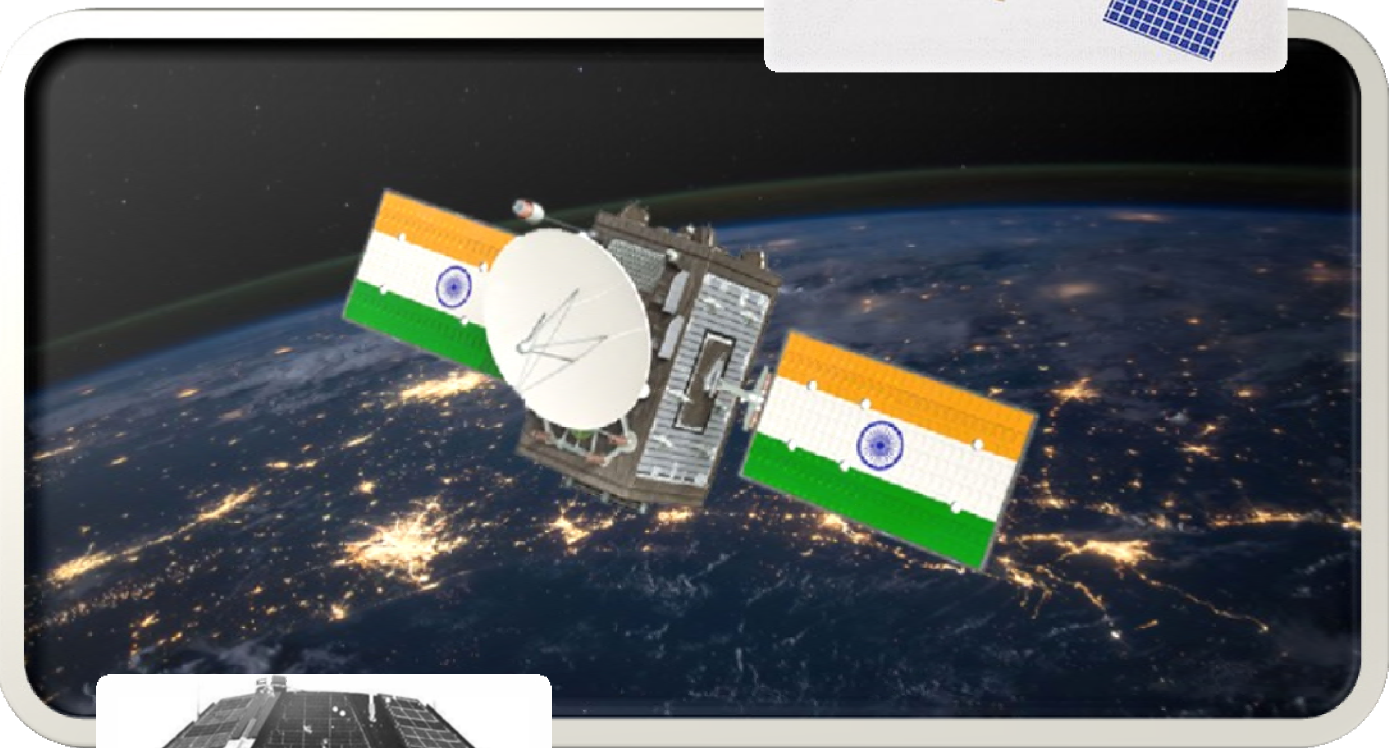
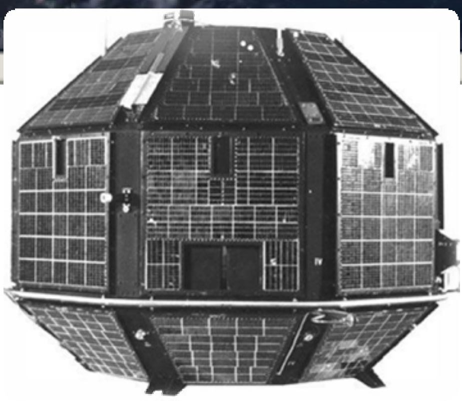
विश्व अंतरिक्ष सप्ताह
World Space Week 2020

Satellites Improve Life







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RESOURCE MATERIAL

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WSW Resource Material 2020

"Satellites Improve Life"

Satellites are part of our every day life. Since the launch of the first satellite 'Sputnik 1' in 1957, space technology has evolved rapidly. Today a large number of satellites orbit around the earth; for observing Earth, to support communications and navigational purposes. While we may not always realize or acknowledge their existence, the important roles these systems play in our daily lives are unsurpassed. They contribute considerably to our well-being and enable us to achieve our objectives in new and innovative ways.

Sizes and Orbits of satellites

Satellites vary in size from 10 cm (Cube Satellites) to about 7 m long (many communication satellites). The largest artificial satellite is the International Space Station (ISS). The main part of this is as big as a large five-bedroom house. Altitudes of satellites above the Earth's surface also vary depending upon their application they are planned for. There are three common orbits for the satellites to orbit around the earth.

- *Low Earth orbit (LEO) – from 200 to 2,000 km, many remote sensing and experimental satellites. For example, the ISS orbits at 400 km with a speed of 28,000 km/hour, and time for one orbit is about 90 minutes.*
- *Medium Earth orbit (MEO) – most MEO satellites are at an altitude of 20,000 km, and time for one orbit is 12 hours. Many navigational satellite constellations (for example GPS) orbit around this altitude.*
- *Geostationary orbit (GEO) – 36,000 km above the Earth. Time for one orbit is 24 hours. This is to match the rotation of the Earth so that the satellite appears to stay above the same point above the Earth's surface. This is used for many communications and weather satellites.*

The altitude chosen for a satellite depends on the job it is designed for.

Types of satellites

Satellites can be classified based on their functions. Thus, there are three broad categories of satellites based on their service for our day to day life. They are,

1. *Remote Sensing satellites*
2. *Communication satellites*
3. *Navigation Satellites*

Remote sensing satellites

The remote sensing satellites are "the eyes in the sky" and constantly observe the earth as they go round in orbits. In satellite remote sensing of the earth, the sensors are looking at the surface through a layer of atmosphere. So, they can be used for various applications like the study of oceans, clouds, land surface, deserts, forests etc. Similarly, the effects of atmosphere on the electromagnetic radiation travelling from the earth to the sensor through the atmosphere provide vital inputs on the atmospheric constituents. India has an array of Earth Observation (EO) Satellites with imaging capabilities in visible, infrared, thermal and microwave regions of the electromagnetic spectrum, including hyper-spectral sensors under the IRS (Indian Remote Sensing) satellite Programme.

Communication satellites

Communication satellites relay and amplify radio telecommunication signal through the use of a transponder between a source and a receiver. These are primarily used for television, phone or internet transmissions. The Indian National Satellite (INSAT) system by ISRO is one of the largest communication satellite systems in the Asia-Pacific region, with nine operational communication satellites placed in Geo-stationary orbit. INSAT provides services for telecommunications, television broadcasting, satellite newsgathering, societal applications, weather forecasting, disaster warning and search and rescue operations.

Navigation satellites

Navigational satellites provide all-weather, long-term navigation support to determine accurate geodetic position, speed, and direction of a surface vehicle or aircraft. All space faring countries are having their own navigational satellite constellation. For example, The GPS (global positioning system) of USA is made up of 24 satellites that orbit at an altitude of 20,000 km above the surface of the Earth. For Indian region, ISRO has established a regional satellite navigation system called Indian Regional Navigation Satellite System

(IRNSS) to facilitate accurate positioning, navigation and timing services to the common man.

Satellite Remote Sensing for better societal life

Natural resources can be scarce, unpredictable, difficult to locate and difficult to manage. Significant economic, social and environmental benefits can be realized by using satellite systems to manage available natural resources and also to locate new sources thus guiding the way to better societal life.

India has its own “Indian Remote Sensing Satellite (IRS)” series which generate resources of data for carrying out various important projects like Groundwater Prospects Mapping under Drinking Water Mission, Forecasting Agricultural output using Space, Agro meteorology and Land based observations (FASAL), Forest Cover/Type Mapping, Grassland Mapping, Biodiversity Characterization, Snow & Glacier Studies, Land Use/Cover mapping, Coastal Studies etc. The information generated by large number of projects have been used by various departments, industries and others for different purposes like development planning, monitoring, conservation etc. With the availability of very high spatial resolution satellites in the recent years, the applications have multiplied. Few of the applications are given below.

Resource Management, which includes water resource information system, assessment of irrigation potential, characterization of biodiversity, forecasting of agricultural output, potential fishery zone forecasting etc.

Water resource information system, which provides a comprehensive, credible, and contextual view of India’s water resources data along with allied natural resources data and information using multiple satellite images

Assessment of Irrigation Potential under Accelerated Irrigation Benefit Program, in which High resolution satellite data is used for assessing the irrigation potential created, through mapping of irrigation infrastructure consisting of canal network, cross drainage and other related irrigation structures.

Biodiversity Characterization, a program using satellite remote sensing to develop baseline database for important landscapes in India, which have representative characteristics of biodiversity.

Disaster Management and Natural Hazards mapping

Apart from locating and accessing energy and resources, satellites help in saving precious human lives in the event of natural disasters. For example, meteorological satellites help us to forecast natural disasters in advance and communications satellite transfer the information to the whole world. Disaster Management can be very efficiently and cost effectively handled by satellite remote sensing. The remotely sensed data can be used very effectively for quickly assessing severity and impact of damage due to flooding, earthquakes, oil spills and other disasters. It also helps in planning efficient escape routes from coastal areas during cyclone season, charting quickest routes for ambulances to reach victims and locating places for shelter for victims or refugees.

Natural hazards are intense *events* occurring naturally causing harm to humans, animals and other natural as well as manmade things. Natural hazards are classified into several categories like geological hazards, hydrological hazards, meteorological hazards as well as biological hazards.

Geological hazards are related to earth'splate tectonics and include earthquakes and volcanic eruptions.

Meteorological hazards are hazards caused by weather processes. These include cyclones, hurricanes, rain, forest fires etc.

Hydrological hazards are driven by water related processes. Floods, droughts, landslides, and tsunamis are a few examples.

Biological hazards include various types of diseases, affecting large number of people. COVID19 is one such hazard which has engulfed the entire planet currently.

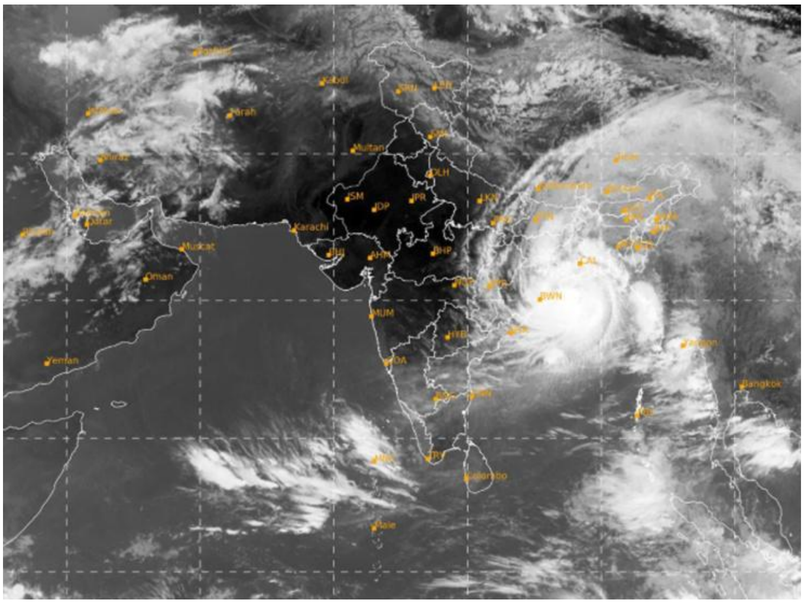
The impacts of these natural hazards are so large that they can affect the life and economy of the people in detrimental ways. Though their occurrence cannot be prevented, advance planning can be done to reduce the severity of these events. In the current scenario, satellites from their vantage point acting as an eye in space play an important role in detecting many of the natural hazards in their early stage of development providing early warning thereby enabling the officials to take sufficient measures to save lives. These aspects are discussed in the following paragraphs.

Cyclone tracking

Cyclone is an intense storm originating over warm tropical oceans. It is characterized by a region of low atmospheric pressure, high winds, and heavy rain. Once the cyclone moves over land, it causes severe damage to human lives, agriculture livestock and settlements, due to the associated strong winds and heavy rainfall. Hence the best way to avoid damage to life is evacuating the predicted region of landfall of the cyclone prior to the event.

Satellite information is very important for tracking and determining the cyclone strength and its path so that the region of maximum devastation can be identified early enough. Weather forecasters use satellite imagery (both visible and infrared) to continuously track the cyclone path and its development. Further, the magnitude and direction of the wind system at the ocean surface is a key parameter for tracking cyclones. This will help meteorologists to accurately predict the cyclone formation, its movement and estimated landfall. Such crucial global wind data is provided by ocean monitoring satellites launched by different countries.

By the proper utilization of satellite data in conjunction with weather prediction models, the early prediction system has been successful in tracking cyclones recently. As a result, the loss of lives in recent cyclones is very minimal owing to the timely evacuation measures taken by different government agencies.



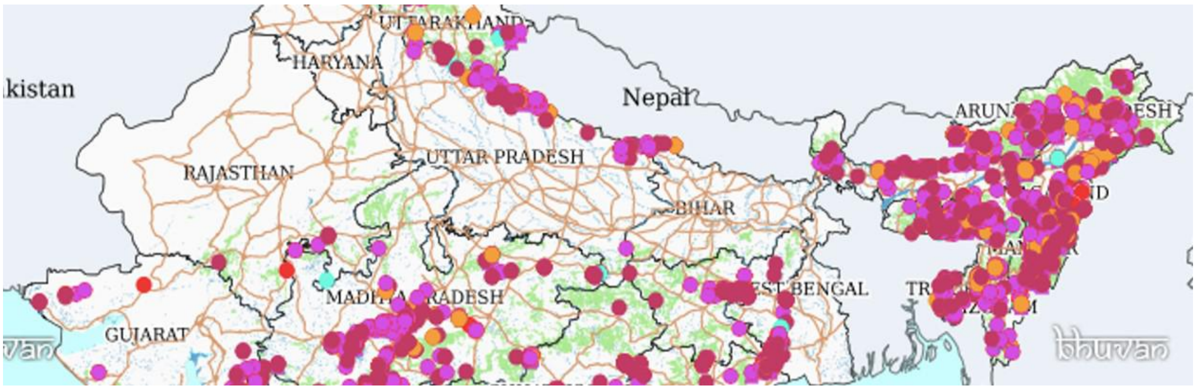
Satellite image of super-cyclone Amphan moving towards head Bay of Bengal.
Courtesy: https://www.timesnownews.com/india/article/super-cyclone-amphan-barrels-down towards-indian-coast-some-satellite-images-of-the-massive-storm/594471Courtesy:trackinghttps://www.eumetsat.int/website/home/Images/ImageLibrary/DAT_4880081.html

Forest fire

Forest fires are uncontrolled fires occurring in regions having vegetation with more than 1.8 m height. A big forest fire spreads rapidly through the topmost tree branches before burning the undergrowth or the forest floor. Forest fire can be a real ecological disaster as seen in the recent Australian, Amazon and California fires leading to smoke and pollution. It can be caused naturally or triggered by human activity. Forest fire risk zones are locations where a fire is likely to begin and from where it can easily spread to other areas (dry vegetation, grass land etc.). Understanding the factors controlling the occurrence of fire and the dynamics leading to its spread are critical aspects of fire management. Hence, forest fire risk zones have to be mapped and suitable preventive measures need to be taken to minimize the frequency of fire occurrences.

Satellites play a vital role in observing and identifying forest fires using visible and infrared channels of observation. Spectral signatures of vegetation have unique characteristics. Healthy living vegetation reflects radiation in near infrared (NIR). However, dry or burnt areas reflect more radiation in the visible and short-wave infra-red (SWIR) region. This helps in demarcating the healthy forest from the dry area vulnerable to forest fires. Later a geographic information system (GIS) can be used effectively to combine different forest-fire-causing factors for demarcating the forest fire risk zone. Using satellite data, it was reported that in last decade nearly 350 million hectares of land was affected by fires worldwide.

From space, the Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) sensors have been extensively used for mapping forest fires. ISRO also regularly prepares forest fire alert maps using satellite data and provides it to forest departments. This near real time data dissemination has helped the forest department to take quick action to curb the forest fires.

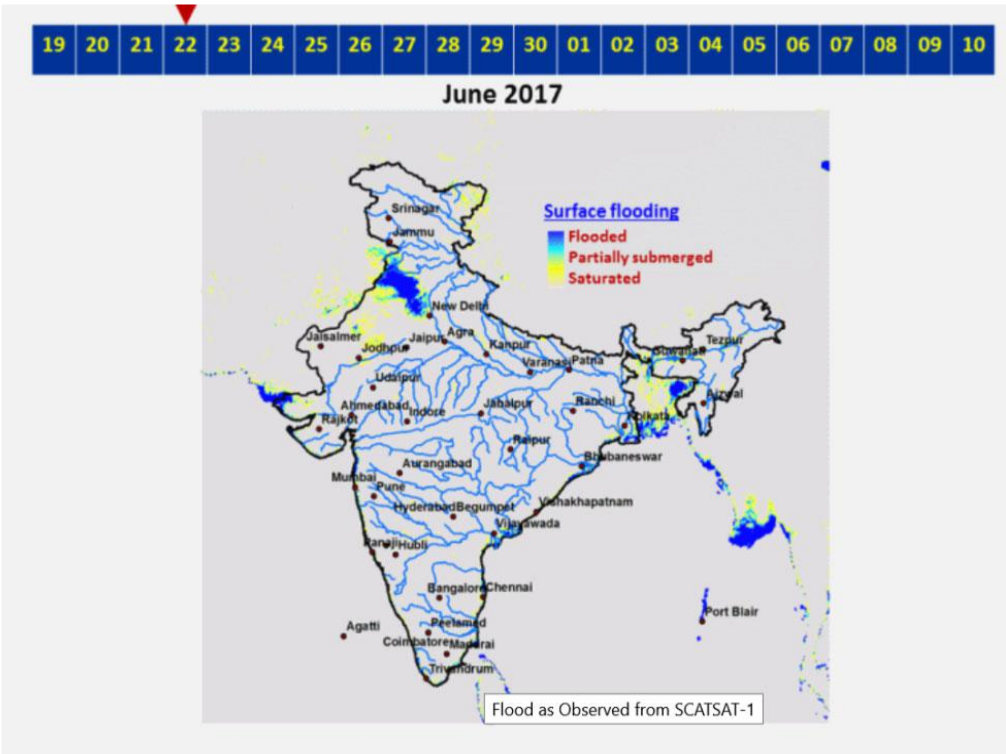


Occurrence of forest fires in HimalayanForests Dots indicate fires
Figure courtesy : https://www.isro.gov.in/forest-fires

Flood mapping

When heavy rains occur, water begins to overflow from rivers and lakes leading to floods in the banks. Satellite data is a powerful tool to map flooded areas and can be very helpful for quick assessment of flood extent. In a predictive mode, satellite-based data on rainfall can provide information on how an excess rainfall event will impact river flow, and also whether there is a potential for flooding downstream away from the heavy rain event. Satellite remote sensing is also used to assess a variety of physical and biological parameters in aquatic ecosystems post floods, like change in salinity, thereby providing inputs to fishing and agricultural community. This has been put to use widely in the recent floods in Kerala also. A particularly dangerous scenario is the occurrence of flash flood. It is a sudden, unexpected torrent of muddy and turbulent water rushing down a canyon. Using satellite data on rainfall as well as on ground moisture conditions, forecasters can predict before few hours, the possibility of flash floods. This assessment is very much required in vulnerable zones like hilly areas where such a deluge can cause huge devastations as in the case of Kedarnath in 2013. As no safety measures were taken, the massive flash floods and landslides lead to loss of human lives in thousands. This reiterates the need for the thorough mapping of the terrains and identifying the areas prone to flash floods, so that ample precautionary measures can be taken to avoid mass destruction.

SCATSAT-1 is ISRO's continuity mission for Oceansat-2 Scatterometer for Ocean weather forecasting. SCATSAT-1 observations have been analyzed for flood detection and monitoring over India.



Flood as Observed from SCATSAT-1

Flood as observed on 22 July 2017 using SCATTSAT-1 data.

Figure courtesy: https://www.isro.gov.in/flood-monitoring-using-scatsat-1-satellite

Land slide

Radar and multispectral optical remote sensing data are increasingly used to understand terrain properties based on their texture and mineral properties. Information on important terrain parameters such as lithology, structure, drainage, slope, land-use, geomorphology etc. can be extracted from the satellite data. Then this satellite data is used to prepare detailed landslide prone area mapping. Object-Based Image Analysis (OBIA) of optical satellite images can also support the landslide detection and mapping of past and present mass movements. During an emergency event phase, the focus is on the rapid assessment of the extent and damages caused by the event as well as on the current ground motion situation and its evolution. Synthetic Aperture Radar (SAR) Interferometry can provide ground displacement estimates with millimetre precision obtained from processing of large stacks of radar satellite images. Using high resolution optical imagery, big boulders and alluvial soil in the river channel can be identified, which will indicate the occurrence of huge landslides in the uphill side.

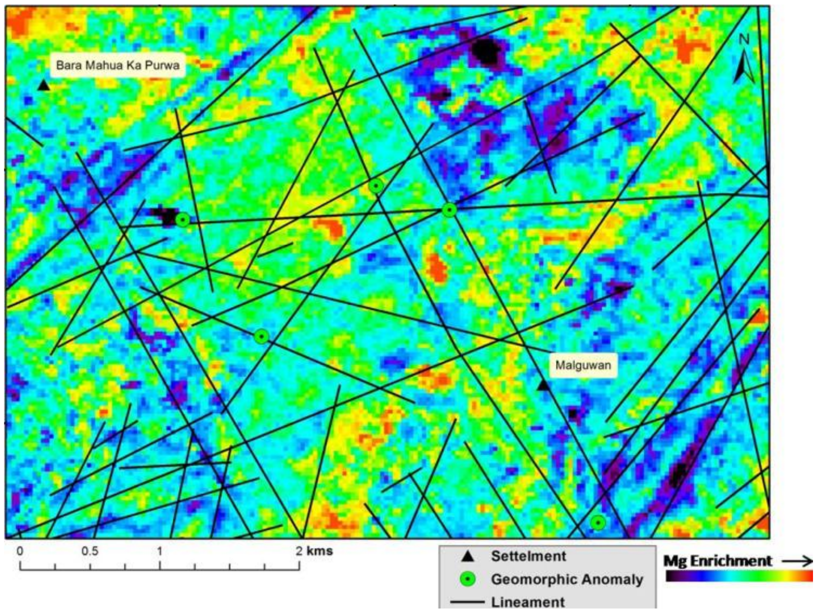
Image showing high accumulation of slided alluvial soil in Alakananda river bed near Lambagar Bairaj.
Figure Courtesy: Landslide Monitoring in Space and Time using Optical Satellite Imagery and DEM derived Parameters: Case Study from Garhwal Himalaya, Uttarakhand, India by Dipender Singh Chand.

Identifying natural resources

Natural resources are materials produced in nature that are used and usable by humans. They include natural substances like soil, water and energy supplies like coal, gas etc. that serve to satisfy human needs and wants. Naturally occurring minerals like iron, copper, Nickel, gold, diamond etc. are mined from their sources. Identifying their sources/mines is of great importance to sustain the world economy as such. Remote sensing as a tool is being used for major exploration programmes in the country by several agencies. Satellites based remote sensing plays a major role in natural resources mapping, which is discussed below.

Mineral Mapping

As is known each mineral has a characteristic property by which it reflects a particular band of radiation. This property is made use of in identifying different minerals present in soil. Multispectral imaging and thematic mapping help to collect reflection data, which in turn are utilized to identify clays, oxides, and soil types from satellite imagery. IRS data has contributed immensely to this aspect. Remote sensing data helps in lithological and structural mapping, while the spectral characteristics are used for mineralogical identification. Satellite data is widely used in geological exploration of Diamond and Iron deposits by National Mineral Development Corporation (NMDC), India. Spectral anomaly maps are derived using specific spectral channels of space data thereby giving the density of various minerals. Magnesium enrichment zones are taken as surface indicators for Kimberlite (indicator of diamond) in Diamond exploration.



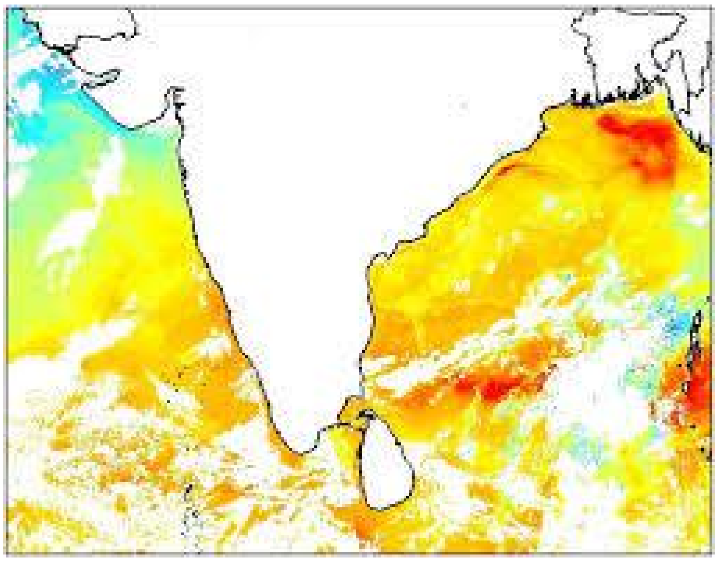
Magnesium enrichment, lineaments and geomorphic anomalies, as surface indicators for Kimberlite in Diamond exploration over Malguwan region
Figure courtesy: https://www.isro.gov.in/Mineral_Exploration

Potential fishing zone (PFZ) identification

More than 7 billion people in India live near the seashore and fishing is their major source of income. Satellite remote-sensing provides large scale views of the ocean and is capable of locating *potential fishing zones (PFZs)* by detecting features through thermal infrared and visible sensors. This can significantly reduce the time and effort made in searching the shoals of fish, thus improving the profitability and hence, the socio-economic status. The PFZ is identified by integrating the information about the Chlorophyll concentration and sea surface temperatures (SST).

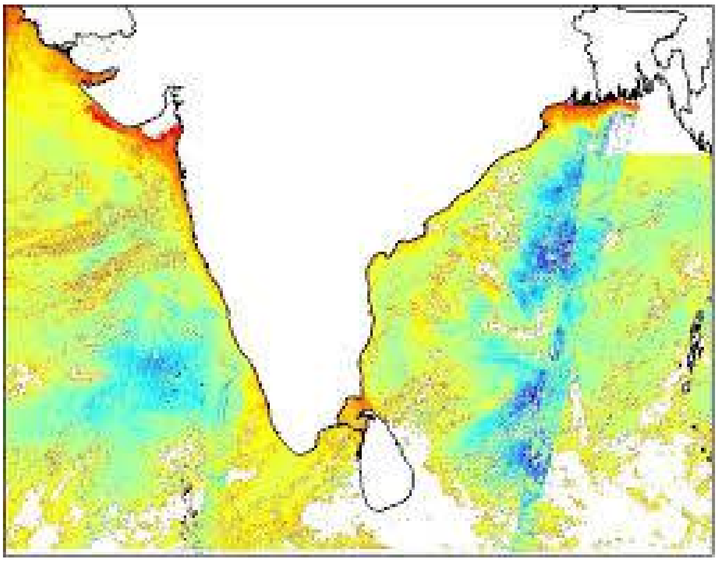
Satellite-derived Chlorophyll concentration provides a measure of enhanced biological production area, while SST provides information to explain oceanic environment suitable for enhanced production. The use of both parameters would improve our understanding about the physical and biological processes of the oceans, periods of high productivity and food resource availability in an ecosystem for exploring fishery resources.

Fishes are known to respond well with changes in temperature i.e., they are known to congregate in the temperature boundaries. Surface circulation features like location and evolution of frontal boundaries, upwelling zones, currents, eddies etc., are important in defining marine fish habitats. SST is the most easily observed environmental parameter and it has been frequently used in correlation with fish availability. The sea surface is considered as black body and emits the radiation based on its temperature and it's in the infrared regime. The satellite sensors measure the radiance and from this the SST can be retrieved. It serves as a useful indicator of prevailing and changing conditions and variations in temperature indirectly account for distribution of fishery resources.



SST image retrieved from AVHRR (advanced very high-resolution radiometer) satellite (https://incois.gov.in/MarineFisheries/PfzAdvisory)

Another parameter which helps in identifying the fishing zone is chlorophyll content. The monitoring of Ocean color provides the information on the Chlorophyll content in the ocean. The Chlorophyll absorbs and emits the solar visible radiation in a particular wavelength and reflects the radiation. The reflectance from the ocean is measured to get the Chlorophyll content in the water.



Chlorophyll Image retrieved from Oceansat-2 Satellite Data (https://incois.gov.in/MarineFisheries/PfzAdvisory).

Urban planning: Satellites are the future of urban planning

As population continues to grow across the globe, more citizens in the rural areas will move towards cities. In India, it is envisaged that about 25-30 persons will migrate to cities at every one minute, in search of a better livelihood and lifestyle. It is also estimated that by 2050, the number of people living in Indian cities will touch 843 million. Smarter ways to manage complexities, reduce expenses, increase efficiency and improve the quality of life are required to accommodate this rapid urbanization, and make cities smart.

Urban planning covers both the development of open land sites and the renovation of developed parts of the city. In several countries the lack of reliable mapping is a serious constraint to development in many sectors, particularly within the fields of rural and urban development. Analysis of the aerial data has been a method of monitoring land use and tracking urban growth for many years. But the use of Earth Observation satellites (EOS) and remote sensing for urban planning is now in the front line as it provides a very high-resolution imagery allows the information to be gathered more systematically, more cost effectively and in greater quantities.

https://earthi.space/blog/future-urban-planning/

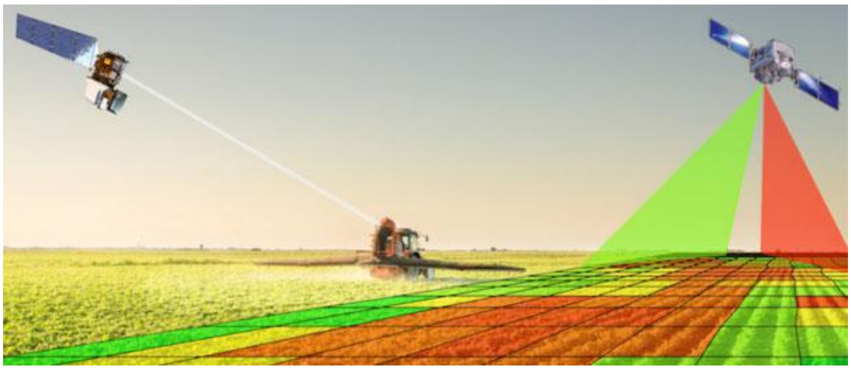
Until recently, maps and land survey records from the 1960's and 70's were used for urban studies, but now the trend has shifted to using digital, multispectral images acquired by EOS and other sensors. The trend towards using remotely sensed data in urban studies began with first-generation satellite sensors such as the Landsat and advanced now to third generation very high spatial resolution satellite sensors.

Advancement in the technology of remote sensing has brought miracle in the availability of the higher and higher resolution satellite imageries. For example, IRS-P6 Resourcesat imagery with 5.8-

meter resolution in multispectral mode, IRS -1D Pan image with 5.8-meter resolution, Cartosat-I imagery of 2.5-meter resolution with stereo capabilities, Cartosat-II with 1 m, IKONOS imageries of Space Imaging with 4 meter in multispectral mode and 1 meter in panchromatic mode, Quick bird imagery of Digital Globe with 61 cm resolution in panchromatic mode. These high resolution sensors provide a new dimension to the methodology used for.

Satellites provide unique views of Earth: Agriculture

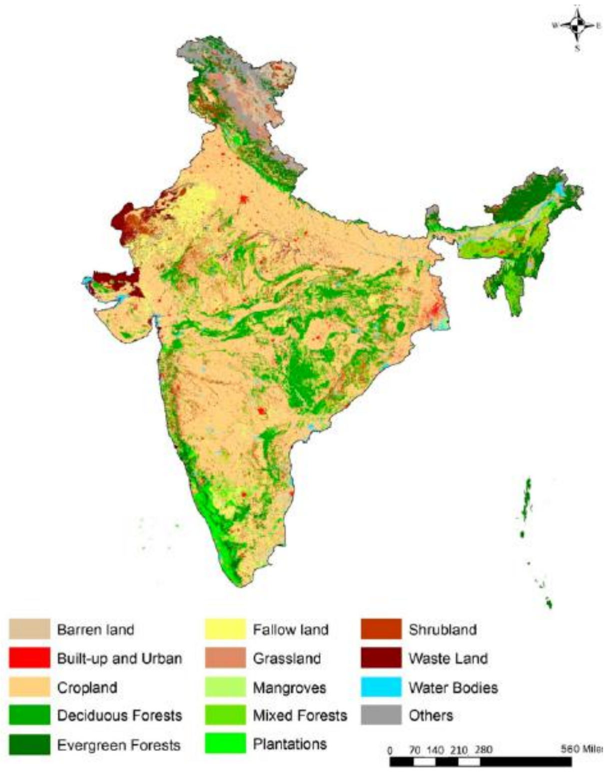
Satellite applications along with ground-based observations revolutionized large-scale agriculture practices. Satellites are widely used for crop identification, yield modelling, stress detection, identification of pest and diseases, soil mapping and soil moisture detection. Satellites provide end-to-end support for the agriculture sector. It helps to identify the suitable crop for a particular region by assessing the soil type and availability of water and also provide prior information on the crop yield so that the farmers and Government agencies could plan in advance. More than 51% of country's net sown area depends on monsoonal rainfall, hence the weather forecasting, which predominantly use satellite data, is very crucial for the rain-fed agriculture. Crop production forecasts using satellite remote sensing data has been conceptualized by ISRO in early eighties. The national level pre-harvest crop production forecasts are issued for wheat, rice, jute, mustard, cotton, sugarcane, rabi etc. Since 37% of the land on Earth is already used for agriculture, with an ever-growing population, precision farming using satellite technologies has to be adopted to make the farm field more and more productive.



Artistic representation of the satellite based crop identification.
Source: Vultus- https://www.cleantechconcepts.com/

Land cover and Land-use change

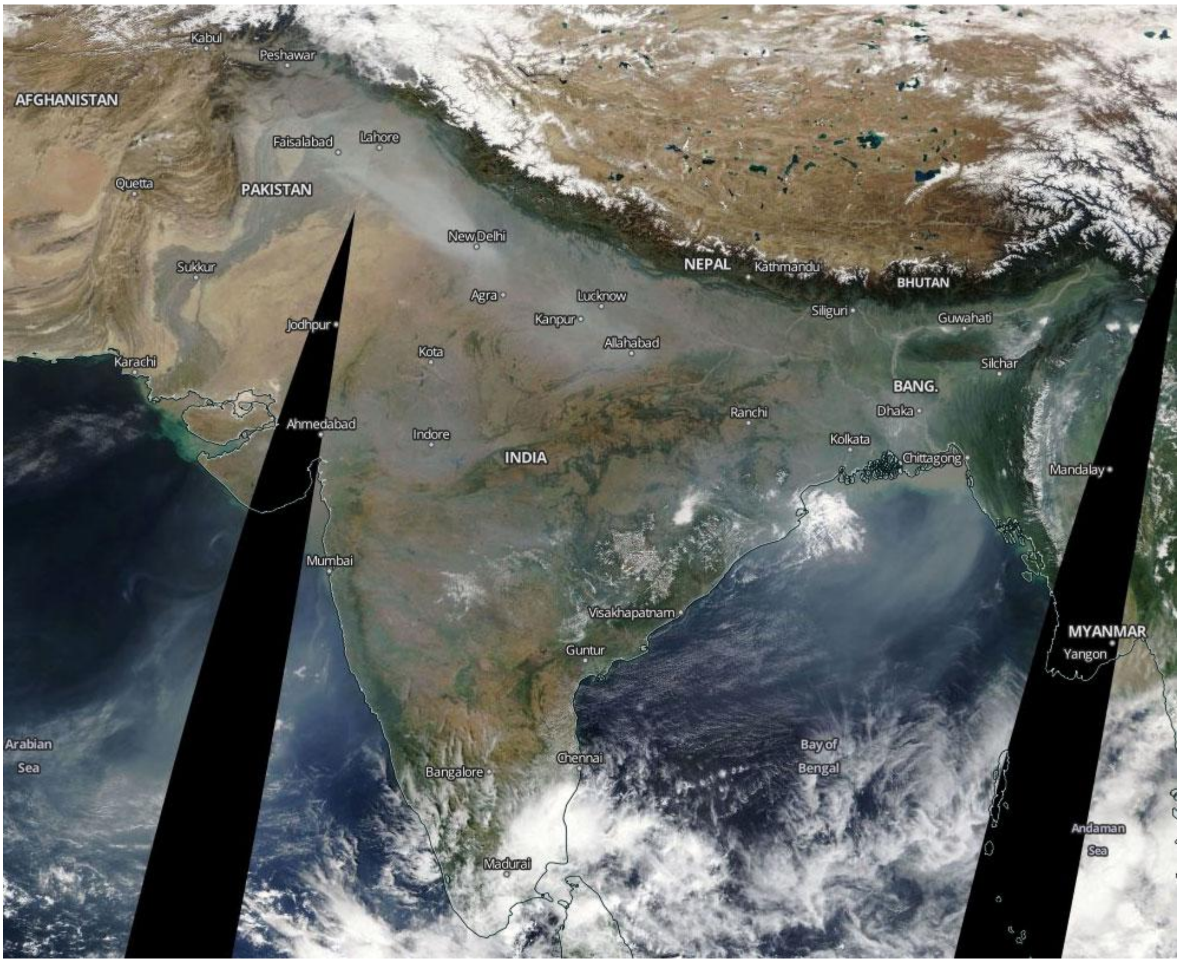
Land cover includes physical land features such as snow, water, grassland, forest and soil. Land use is the term used to describe the human use of the land, e.g. grazing and agriculture. Human activities continuously transform the natural land cover for agricultural, commercial and residential purposes. This large-scale change in land surface features has significant implications on regional as well as global climate. Satellites provide excellent information on the land use and land cover change at high spatial and temporal resolution. This information is considered as a backbone for sustainable development and urban planning. Using satellite radar data, scientists have created a global map that quantifies the amount of wood in our forests - a key to understanding Earth's carbon cycle and, ultimately, climate change. Forests are 'carbon sinks' as they absorb and store carbon dioxide from the atmosphere. Forests that are logged or burnt down, however, release parts of the stored carbon into the atmosphere.



Different land terrains across india.

Pollution Detection

In recent decades, satellite remote sensing is considered as the basic tool to monitor the environmental changes, especially air pollution, visibility, dust storm, water pollution and oil spill. To identify the trace gases and submicron particles in the atmosphere, satellites make use of the intrinsic signature of each atmospheric constituent while interacting with electromagnetic radiation. The five pollutants used to estimate air quality are O_3, SO_2, NO_2, CO, and PM2.5 (called “criteria pollutants”). All these can be measured by remote sensing instruments operating from satellites. Small-size particulates can enter the lung causing breathing problems; they can also deposit cancerous materials, often found on the surface of these aerosols, into the lung. Mortalities associated with the poor air quality over South Asia are close to 1 million as suggested by several recent studies. Other than health issues, low air quality over North India has significant implication on our economy due to the cancellation of public transport (train, flight and buses), shut down of offices and shops.



Widespread dense smog over South Asia from space. (Image courtesy: AGU).

The clean water for drinking and the environment is one of the 21^{st} century's most pressing issues, where satellite remote sensing provides easy and cost-effective information. For many decades, scientists have known that water's colour tells us something about what is in it. Bright tan water likely indicates a river full of sediment. Green swirls over Lake Erie show algae growing and producing chlorophyll. Dark brown waters draining tannin-rich forests and swamps turn blue water into a tea-coloured brown because of how light interacts with certain dissolved organic carbon compounds. The detection of oil spill on the ocean surface is the utmost threat to the marine ecosystem. Satellites are also used to monitor the discharge of plastic in the ocean. It is estimated that around eight million tons of plastic is dumped into the sea every year.

Satellite imagery showing the havoc unleashed by plastic dumping.
https://rus-training.eu/

Oil pollution monitoring

Oil spills that can happen in rivers, bays and the ocean most often are caused by accidents involving tankers, barges, pipelines, refineries, drilling rigs and storage facilities, but also occur from recreational boats and in marinas.

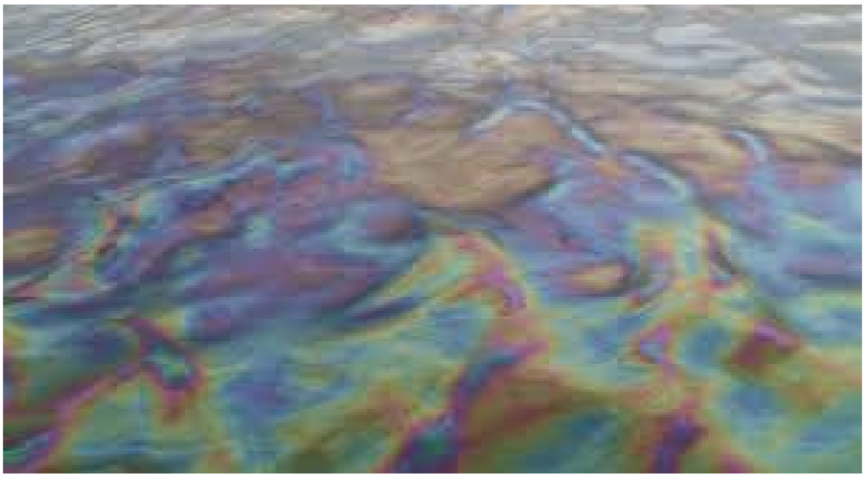
Spills can be caused by:

- *people making mistakes or being careless*
- *equipment breaking down*
- *natural disasters such as hurricanes, storm surge or high winds*
- *deliberate acts by terrorists, acts of war, vandals or illegal dumping.*

Most oils float on the oceans' saltwater or freshwater from rivers and lakes. Oil usually spreads out rapidly across the water's surface to form a thin oil slick. After the spill, oil undergoes several processes such as spreading, evaporation, dissolution, drifting, photolysis, biodegradation, and the formation of oil-in-water and water-in-oil emulsions. The largest accidental oil spill in history began in the Gulf of Mexico on April 20, 2010, after a surge of natural gas blasted through a cement well cap that had recently been installed to seal a well drilled by the Deepwater Horizon oil platform.

Harmful impact of oil spill on marine life.

Oil spills is very harmful to marine birds, sea turtles and mammals, and also impact fishes and shellfishes negatively. Oil destroys the insulating ability of fur-bearing mammals, such as sea otters, and the water-repelling abilities of a bird's feathers, exposing them to the harsh elements. Because most kinds of oil are less dense than water, most spilled oil floats on the water surface. It spreads out and is pushed across the water by wind and currents. Since birds preen themselves to clean their feathers, they can also ingest oil, causing illness or death. The marine habitat has been under pollution threat, which impacts many human activities as well as human life.



Oil spread over water surface..

Remote sensing using satellite imagery is a potential tool to study the environmental impacts of these types of disasters. The satellite sensors can help us to define the extent of oil spread over water bodies and oceanic surfaces. Satellite-based oil pollution monitoring systems are being used to take precautions and even to determine the possible polluter.

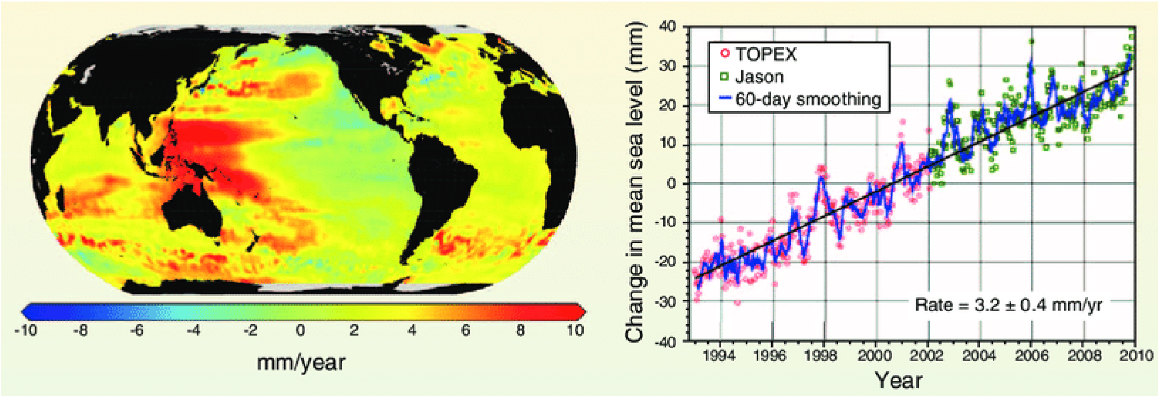
The detection and mapping of oil on a water surface is the most common uses of oil spill remote sensing. Oil spreads are visible in satellite images, it is because they have changed how the water reflects light, either by making the sun's reflection brighter or by dampening the scattering of sunlight. The most common method for oil spill remote sensing is to use passive observation of the sea surface to detect and map oil spills. These include the techniques of using cameras in the visible and infrared spectra. Other wavelengths such as ultraviolet and near infrared are less frequently used. Depending up on the thickness of the oil layer, different portions of electromagnetic spectrum is used.

A view of the Deepwater Horizon oil spill from NASA's Terra Satellites on May 24, 2010. (https://en.wikipedia.org/wiki/File:Deepwater_Horizon_oil_spill).

Satellites for Climate and weather studies

Climate change is one of the major challenges facing humanity today. The satellite technology has completely changed our perception about the weather and climate. It is hard to elucidate where satellite observations did not contribute significantly to improve the basic understanding of our environment to ease life. Currently, various satellite constellations provide invaluable and voluminous information on the various parameters such as sea-level rise, land/sea surface temperature, cloud properties, lightning detection and ocean colour. Real-time observations of extreme weather events and floods save millions of lives every year.

Thermal expansion of the oceans as well as increased meltwater and discharged ice from terrestrial glaciers and ice sheets have increased ocean volume and hence sea level. Sea level rise is not uniform across the global oceans, where some locations experience greater rise than others because of local terrain, local hydrological factors, and oceanic currents, among other regional factors. Unfortunately, many large cities are located on coastlines that are particularly vulnerable to sea level rises. More than five decades of satellite observations (Landsat) clearly showed the accelerated retreat of glaciers and these glaciers are calving more ice into the ocean than they were in the past.



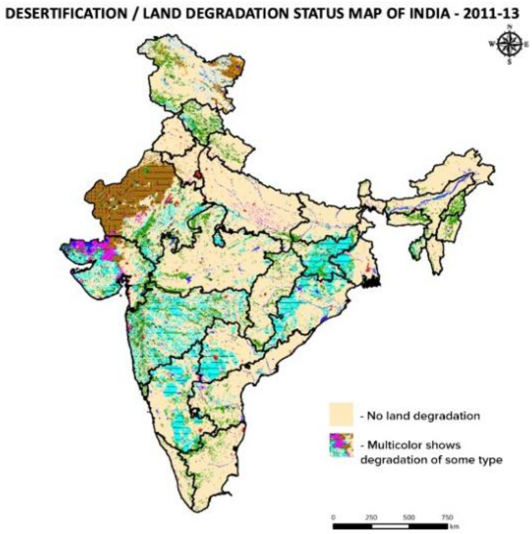
Sea level rise across the globe.
Source: Hoegh-Guldberg and Bruno, Science 2010

It is easy to measure the temperature of a person or object using a thermometer, but it is challenging to measure the temperature of the Earth's surface due to the large spatial-temporal variabilities. Though satellite measurements are less accurate than the in-situ measurements due to the inherent uncertainties and complexities involved in the retrieval techniques, satellite measurement are highly preferred because of its large spatial coverage and repeativity of measurements. Satellites measure the Earth's temperature from the electromagnetic radiation emitted from the surface and the atmosphere. These space-borne temperature sensors (like a thermometer) show an increasing trend (so-called fever) during the last several decades.

Desertification

The term desertification refers to the formation of new deserts through land degradation in arid, semi-arid and dry-sub humid areas, which is attributed to the deforestation, over-cultivation, and lack of irrigation. These dry lands cover 40% of the Earth's land surface and roughly 20% of this dry land is degrading. This desertification will potentially threaten the livelihood of millions of people living over there. Global warming is increasingly leading to desertification. Each year around 12 million hectares of productive land become barren every year due to desertification and drought. Satellite images can highlight relevant land use change along with increased surface reflectivity, temperature, dryness and dustiness. Infrared sensors can detect vegetation stress due to environmental shifts. Inventory and monitoring of the desertification using high-resolution satellite observations are the primary requirement in preparation of mitigation plans to combat desertification. ISRO has developed state-wise desertification and land degradation status maps depicting land use, process of degradation and severity level.

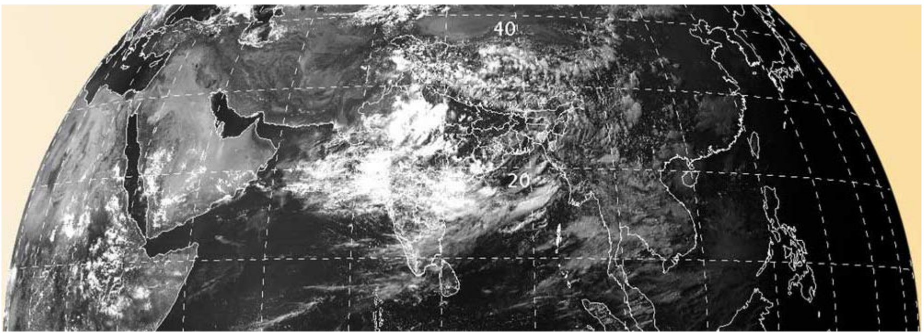
(https://vedas.sac.gov.in/vedas/downloads/atlas/DSM/Desertification_Atlas _2016_SAC_ISRO.pdf).



Land degradation status map of India (Source: SAC, Ahmadabad).

Weather forecasting

Satellite data is used to forecast the weather in two ways: (i) the use of global data in numerical weather prediction models and (ii) the use of satellite imagery for weather warning. The images from the geostationary satellites are mainly used to interpret and analyze the evolution of weather events over a region. Weather forecasters routinely analyze current satellite observations and today's weather-forecast models rely on satellite data more than any other weather observation. Three areas wherein satellite data have significantly contributed to numerical weather prediction are: defining the initial conditions of the model, setting of the boundary conditions, and defining the forcing functions. The key advantages of satellite observations are the synoptic view of large areas especially over remote/inaccessible locations with harsh weather conditions where direct observations are challenging, simultaneous observation of various parameters, uniformity and temporal repetition. The imagers (visible, infrared, microwave), sounders (infrared, microwave), scatterometers and radar altimeters are used to derive various parameters of Earth Atmosphere system. These data include the vertical distribution of temperature and humidity; extend of sea ice and snow, land cover and land use, cloud and water vapour distributions, land and sea surface temperatures, soil moisture, location of volcanic ash, and wind speeds and directions. The impact of these data was phenomenal in weather forecasting and cyclone monitoring. The improved weather forecasting supports various sectors of day to day life of billions of people especially related to the food security and the socio-economic growth of the country.

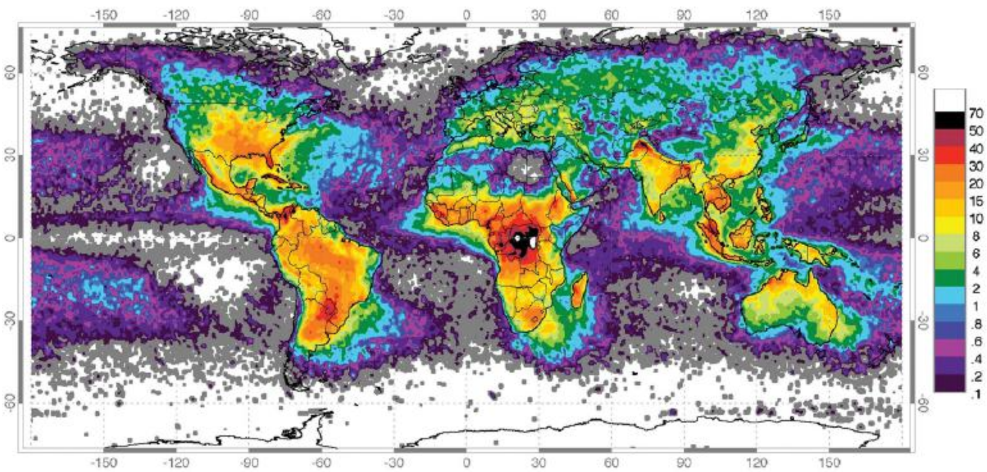


Satellite based cloud image (Source: ISRO INSAT 3D).

Weather experts used cloud images for qualitative weather forecast. With the launch of TIROS-1 in 1960, we gained our first total views of the cloud patterns that accompany low pressure systems and fronts.

Lightning detection and prediction

Space-borne lightning detection sensors are capable of detecting total lightning activity during both day and night, over land and sea, potentially filling in data gaps in areas of poor or no radar coverage or where ground-based lightning detection networks offer low detection resolution. Lightning can be detected via electro- and magnetostatic field charges, atmospheric pressure variations (i.e. thunder), radio frequency (RF) emissions and optical signals. Detection of optical signals emitted from lightning is the most practical method as it does not suffer from ionospheric absorption, although there are problems with cloud attenuation. DEMETER (Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions) and FORTE (Fast On-orbit Recording of Transient Events) satellites uses VHF frequency emissions from lightning for lightening detection. OTD (Optical Transient Detector onboard MicroLab-1 satellite) and LIS (Lightning Imaging Sensor onboard Tropical Rainfall Measuring Mission) were the first instruments specifically designed, built and flown to detect, locate and gather data on global lightning activity.



Annualised distribution of total lightning activity, in units of flashes km^{-2} year^{-1} (Weather, DOI: 10.1002/wea.2903))

Atmospheric Composition

Though the major components of the atmosphere (nitrogen and oxygen) do not vary significantly during the last several decades, the concentration of trace gases (CO_2, O_3 etc.) changed notably associated with manmade (anthropogenic) activities. Atmospheric compositions, including greenhouse gases (CO_2, CH_4, O_3, N_2O), polluted trace gases (CO, NO_2, and SO_2), and particles (aerosol), have played important roles in impacting air quality, public health, and climate. Recent advances in remote sensing technology, especially the development of hyperspectral space-borne satellite sensors, enable us to make more accurate measurements of these species over the globe with high spatial and temporal coverage.

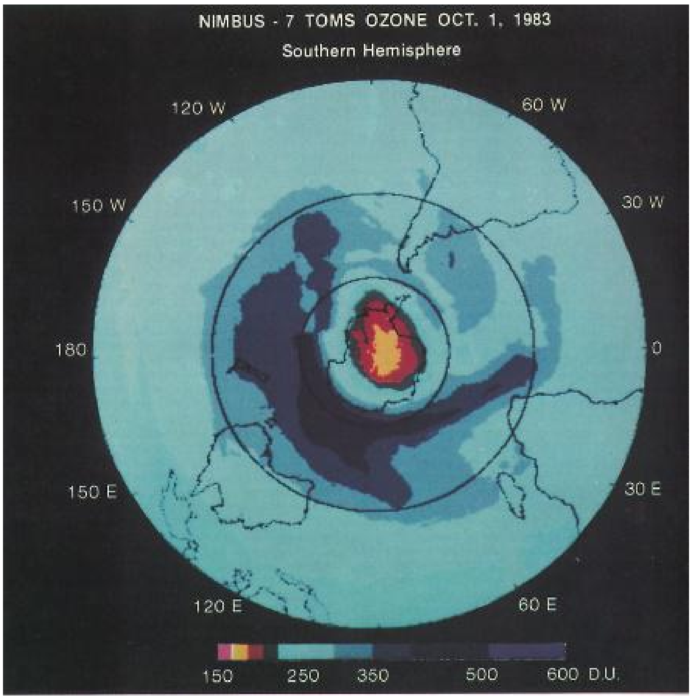
Satellites use the absorption of solar UV radiation by the atmosphere or the absorption of sunlight scattered from the surface of Earth to measure ozone over nearly the entire globe on a daily basis. Reflected radiation from the atmosphere and earth surface in the visible spectrum of the solar radiation is used to retrieve the particle loading in the atmosphere. Hyper spectral data is used to retrieve the concentration of trace gases like CO_2 and methane.

Ozone Monitoring from Space

Ozone forms layer in the stratosphere and it protects life on earth by filtering solar light for UV radiation to prevent it from reaching the surface of earth. Satellites have been monitoring ozone from space since 1960S. The first active ozone sensor was a single channel UV radiometer based on solar occultation limb technique launched in 1962 onboard USAF satellite SAMOS -9. At present several satellite payloads are in orbit (OMI, OMPS. etc).

Ozone hole: Why satellite didn't get that correctly

In May 1985, using ground-based spectrophotometer scientists have reported a large secular decrease in the total ozone column over the Halley Bay station in Antarctica. Unfortunately, Spring 1983 satellite data were not processed at NASA until June 1984. Initially, the low ozone values retrieved by the satellite observations were quickly flagged out as invalid considering the degradation or satellite malfunction (as the satellite was well past its one-year design lifetime). In addition, satellite retrievals couldn't be correctly retrieve the low ozone values using the standard profiles. Further, October 1983 total ozone values initially reported by the S. Pole station showed normal ozone, which was found erroneous and retracted later. The problem was identified and re-analyzed the data, which showed the large extent of ozone depletion over Antarctica. This analysis catalyzed the international deliberations to decrease the substances reducing the ozone. Montreal Protocol entered into force on 1 January 1989 and as a result the ozone hole in Antarctica is slowly recovering.



Ozone hole over Antarctica.

Satellites for archaeological & Historical studies

As our population grows, our society often encroaches on archaeological sites of interest both knowingly and unknowingly, putting them at risk of destruction as we urbanize the landscape. Throughout history, and even today, archaeological sites have also been plundered and looted by humans, often for profit as items are sold via black market trade. This has occurred in sites already known to archaeologists as well as in those yet to be identified by researchers. If these previously unmapped areas are destroyed or looted, irreplaceable information about history is lost before it can even be recorded. Reliable identification and protection of archaeological sites is vital for effective heritage and cultural management, which helps to enable sound archaeological research and protection of sites of interest for future generations.These methods of archaeological prospection must be non-destructive and capable of studying large areas of ground in order to identify the location of relics or structures that remain buried.

Satellite sensor information creates massive, complex data sets that are constantly being updated, known as big earth data. Archaeologists have already been using satellites that can optically image the Earth to detect buried remains, as well as study changes over time (temporal changes) in the landscape and predict new potential locations of archaeological sites using statistics and spatial analysis.

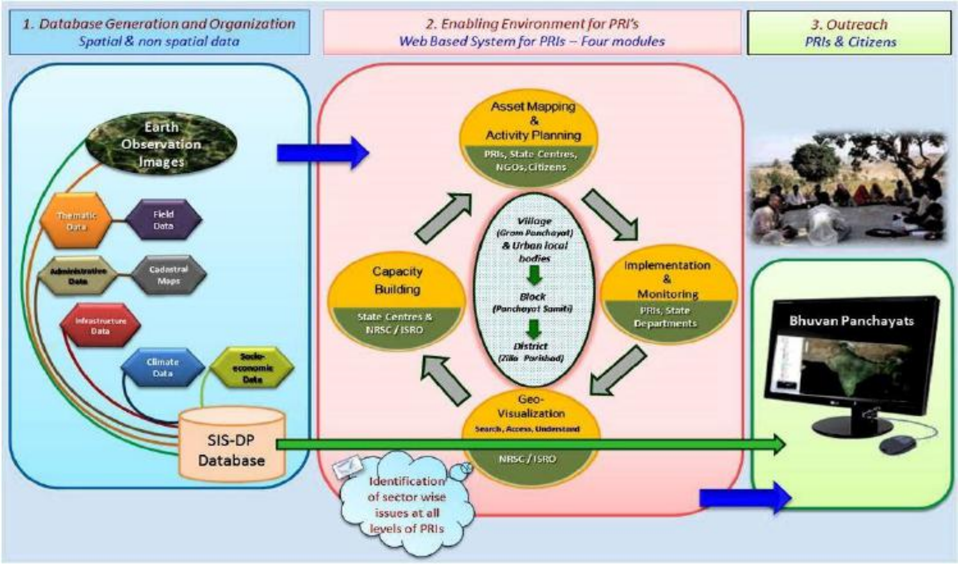
Satellites to monitor night lights

Night time light observations from satellite sensors provide spatially explicit measure of human activities. This information can be used for tracking urbanization and socioeconomic dynamics, evaluating armed conflicts and disasters, investigating fisheries, assessing greenhouse gas emissions and energy use, and analysing light pollution and health effects. Night time light data have been extensively used in urban mapping. The decrease in night-time lights can be caused by armed conflicts and natural disasters such as tsunamis, hurricanes, and earthquakes providing an opportunity to evaluate the damage of these disasters. More light is clustered along coastlines, near rivers, or near major over-land transportation hubs (e.g., highways, railroads) where the climate is moderate, terrain is flat, resources are plentiful, and soil is fertile.

Global map of earth at night (Source: NASA)

Acquisition, processing and dissemination of Satellite data in India

National Remote Sensing Centre (NRSC) of ISRO is responsible for remote sensing satellite data acquisition and processing, data dissemination, aerial remote sensing and decision support for disaster management. NRSC has archived a wealth of satellite images from Indian and foreign satellites since 1983. NRSC/ISRO is extending satellite data support under the International Disaster programmes also. The Decision Support Centre (DSC) is a single window information provider on major natural disasters like Floods, Cyclones, Earthquakes and Landslides. It provides near real time information to State and Central government for relief, rehabilitation and planning.



The sketch of the data flow starting from acquisition to reaching out to the public.

Bhuvan-Geoportal of ISRO, allows host of services including free data download, thematic map display and analysis, timely information on disaster, since August 2009 and available in English, Hindi, Tamil and Telugu languages. The 2D /3D images showcased on Bhuvan are from Multi-sensor, Multi-platform. (http://bhuvan.nrsc.gov.in). Bhuvan provide Land services, Weather services, Disaster services and Ocean services to cater the scientific community and administrator for their needs towards societal-good.

Satellite for Telecommunication

Communication that takes place between any two earth stations through a satellite is called as Satellite Telecommunication. In this communication, electromagnetic waves are used as carrier signals. These signals carry information such as voice, audio, video, or any other data between ground and space and vice-versa. Since the satellites are located at a certain height above the earth, the communication takes place between any two earth stations easily via satellite. So, it overcomes the limitation of communication between two earth stations due to the earth's curvature.

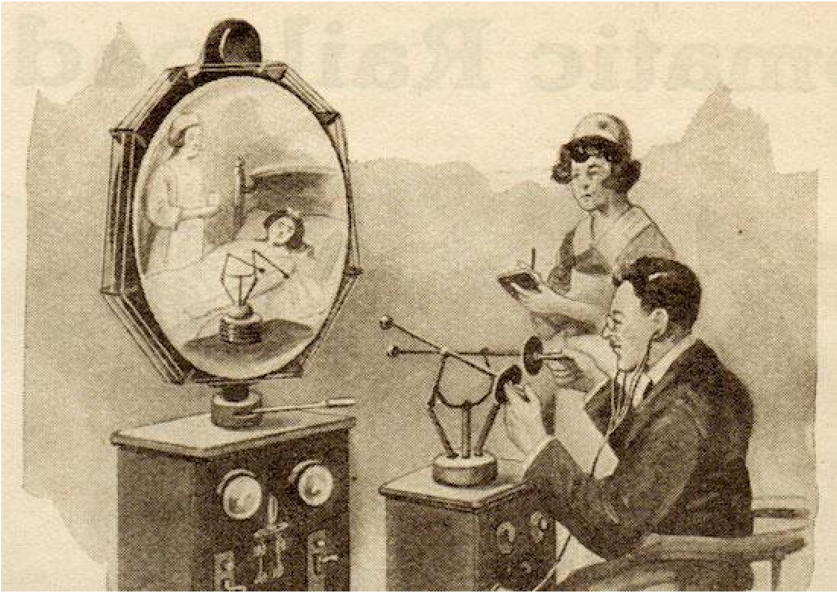
The transmission of a signal from the first earth station to satellite through a channel is uplink. Similarly, the transmission of a signal from the satellite to second earth station through a channel is called downlink. Satellite communications plays a vital role in our daily life.

The applications of satellite communications include, radio broadcasting and voice communications, TV broadcasting such as Direct to Home (DTH), internet applications such as providing Internet connection for data transfer, GPS applications, Internet surfing, etc., Military applications and navigations etc.

India has a series of geo-stationary satellites known as Indian National Satellite System (INSAT) which are used for telecommunications, broadcasting, meteorology and search and rescue operations. The INSAT commissioned with the launch of INSAT-1B in August 1983 brought a major revolution in the communication sector over the sub-continent. The societal services offered by INSAT series in the area of tele-education and telemedicine are remarkable. Tele-education network has more than 50,000 class rooms connected to the various academic institutes. ISRO's telemedicine network facilities cover hundreds of rural hospitals, super speciality hospitals providing health care to citizens, especially in rural areas

Satellite help us to stay healthy - Telemedicine

It wasn't until the beginning of the 20th century that the innovations in communication technologies were thought to be useful in the field of medicine. In 1925, the cover illustration of the Science and Technology Magazine featured a curious technology by Dr. Hugo Gernsback, named "teledactyl." There, it was imagined that using radio technology, the doctor could inspect a patient who is in a far-away place and the patient's video feed could be available to the doctor.



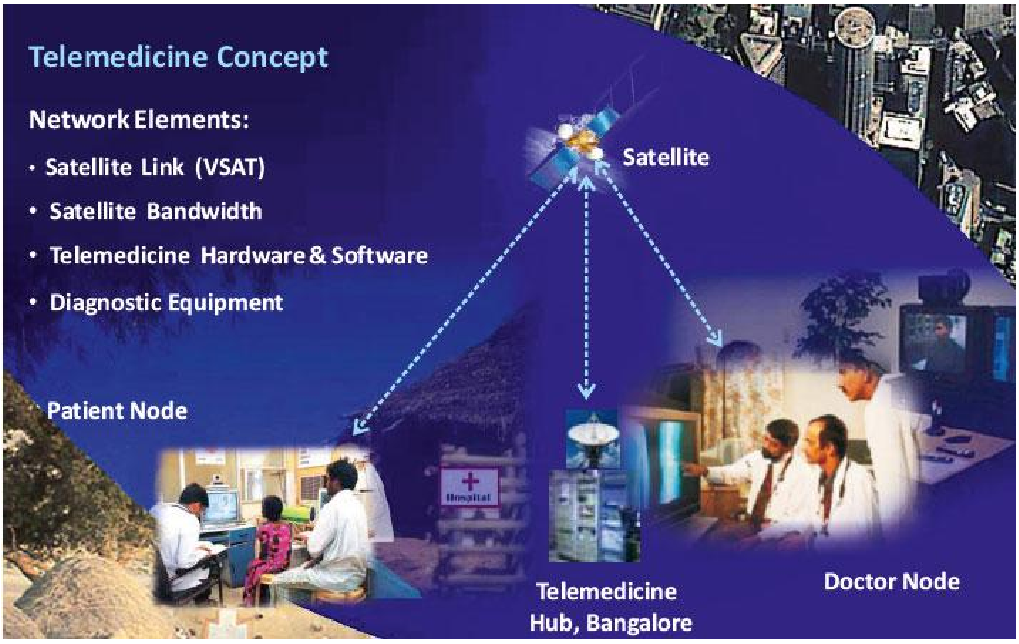
The concept of telemedicine in 1920s. The doctor feels the movement of the hand of the patient, who is in a remote location, using radio signals (reproduced from the website, https://www.smithsonianmag.com/history/telemedicine-predicted-in-1925-124140942/.)

Decades later, in the 1950s, several hospital systems and medical centres with the help of universities experimented with telemedicine. By 1964 they developed a telemedicine program at Norfolk State Hospital 112 miles from campus to provide them with health services. Telemedicine was initially intended to treat patients situated in remote locations, far from local health facilities or in places where there was a shortage of medical professionals. Although this purpose is still served with wider reach, telemedicine is also used more and more as a method for functional medical care, where patients, who don't want to spend much time in hospitals, use this facility for addressing urgent medical problems or a quick care they wish to have. This convenience led to the rise of many telemedicine companies and more job opportunities as well. Many of these companies offer 24 x 7 services and doctors-on-call services. Virtual visits of patients by doctors and specialists, access to extra clinical staff and specialists etc. are some of the successful telemedicine models now. This method is not only a time-saver, but also a way of getting medical attention whenever needed, and is beneficial for patients in rural areas Telemedicine need not always be real time. Store-and-forward methods in telemedicine enable healthcare providers to forward and share patient medical data (lab results, images, videos, records) with a provider at a different location so that specialists can examine those results and suggest treatment procedures. In the remote patient monitoring (RPM) category of telemedicine, healthcare providers track a patient's vital signs and other health data from a distance. This makes it easy to watch for warning signs and quickly intervene in patients who are at health-risk or are recovering from a recent surgery. This type of telemedicine is sometimes also called tele monitoring or home telehealth. In real-time telemedicine, live interaction between either a health professional or patient or between health professionals, using audio and video communication, is arranged. While most real-time telemedicine software is much more sophisticated than a simple video chat platform, the primary goal is to both see and talk to the patient from afar. This type of telemedicine is meant to offer a virtual alternative to the in-person doctor's visit. Top telemedicine specialties include, Tele-radiology, Tele-psychiatry, Tele-dermatology, Tele-ophthalmology, Tele-nephrology, Tele-obstetrics, Tele- oncology, Tele-pathology, Tele-rehabilitation etc.

Telemedicine is also used for astronaut health monitoring. In one of the real-time examples, an ISS crew member with a history of knee injury (who was symptom-free before the mission) developed knee pain. NASA ultrasound specialists guided the crew step-by-step through a comprehensive imaging procedure. After reviewing the full set of imagery (downloaded from the ISS within the hour), the radiologist confirmed the problem. The astronaut was then prescribed a temporary reduction of exercise loads and some medications. He was soon able to return to the regular exercise routine, and he completed the mission without difficulty.

Telemedicine and ISRO

Telemedicine is one of the unique applications of Space Technology for societal benefit implemented by ISRO. The telemedicine program of ISRO started in 2001. It connects remote/rural/medical college hospitals and Mobile Units through the Indian satellites to major specialty hospitals in cities and towns. ISRO Telemedicine network covers various states/regions, including Jammu & Kashmir, Ladakh, Andaman & Nicobar Islands, Lakshadweep Islands, North Eastern States, and other mainland states. Many tribal districts of Kerala, Karnataka, Chhattisgarh, Punjab, West Bengal, Orissa, Andhra Pradesh, Maharashtra, Jharkhand, and Rajasthan are covered under Telemedicine Programme.



Telemedicine concept in India.

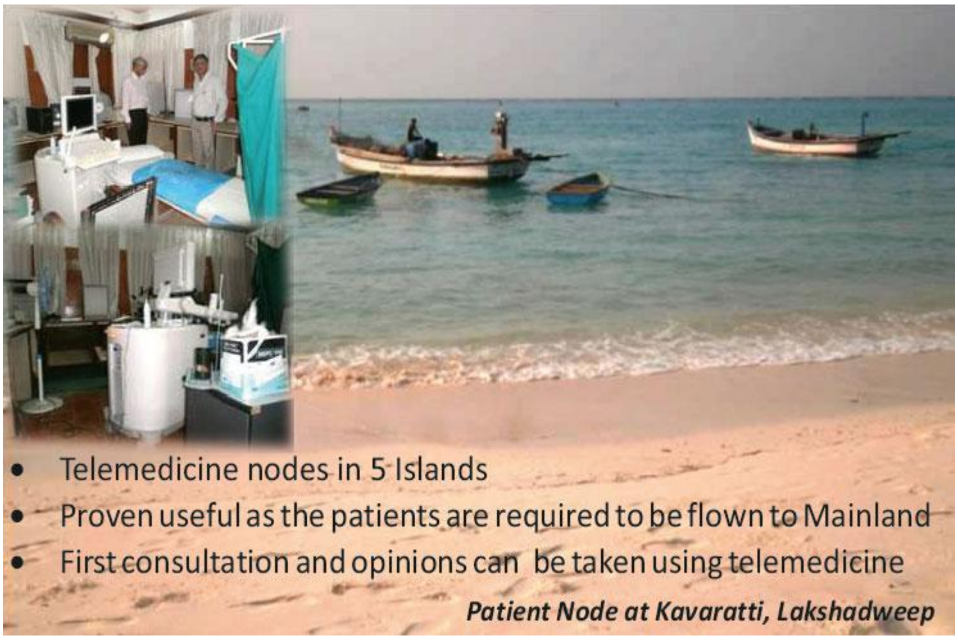
Presently, the Telemedicine network of ISRO covers about 384 hospitals with 60 specialty hospitals connected to 306 remote/rural/district/medical college hospitals and 18 Mobile Telemedicine units. The Mobile Telemedicine units cover diverse areas of Ophthalmology, Cardiology, Radiology, Diabetology, Mammography, General medicine, Women, and Child healthcare.

While DOS/ISRO provides Telemedicine systems software, hardware, and communication equipment as well as satellite bandwidth, state governments and the specialty hospitals have to allocate funds for their part of the infrastructure, workforce, and facility support. In this regard, technology development, standards, and cost-effective systems have been evolved in association with various state governments, specialty hospitals, and industry.

The recent activities under Telemedicine Programme involved migration and operationalization of the nodes which were affected due to non-availability of EDUSAT (GSAT-3). Most of 190 nodes operating on EDUSAT were migrated to operational GSAT-12 satellite. Around 139 nodes are now operational on INSAT-3A and the remaining nodes on INSAT-3C and INSAT-4A satellites. ISRO is in the process of bringing in annual maintenance support for the Telemedicine systems to ensure continuity of service.

A Telemedicine monitoring node is established in DECU, Ahmedabad, which is used for testing and supporting users for minor troubleshooting, etc. A Telemedicine Users' Meet was held at Ahmedabad to assess the utilization and the future plans of the states/hospitals/institutions regarding the telemedicine nodes.

In the present scenario of COVID 19 spread, telemedicine has gained unprecedented importance. In order to limit visits to hospitals and to reduce the spread of infections, several hospitals are now providing online consultations in most of the branches of medicine across the country.



Telemedicine nodes in Lakshadweep.

Satellites for Education: Tele-education

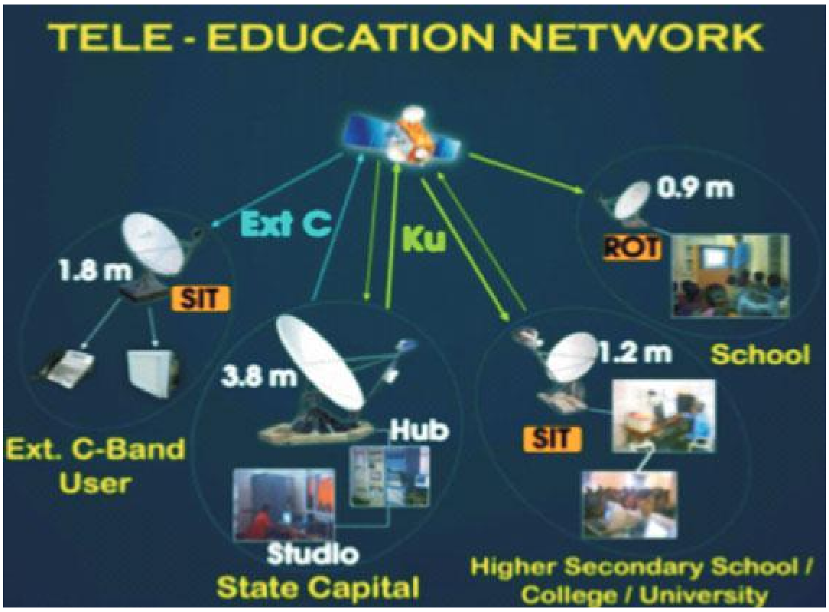
Tele-education can be defined as "education in which students receive instruction over the Internet, from a video, etc., instead of going to school". Also known as E-learning, it "comprises all forms of electronically supported learning and teaching." Tele-education has become all the more popular in this pandemic era due to Covid-19, where schools and academic institutions are closed and Government is encouraging on-line classes. Several on-line class platforms have been emerged during this time to meet the ever-increased demand. Like telemedicine, tele-education also became popular with the emergence of the latest technologies in satellite-based telecommunication.

Importance of education in developing countries is well recognised. But the extension of quality education to remote and rural regions becomes a Herculean task for large countries like India with multi-lingual and multi-cultural populations separated by vast geographical distances and, in many instances, inaccessible terrain. Though there is a substantial increase in the educational institutions, lack of adequate rural educational infrastructure and non-availability of good teachers in sufficient numbers adversely affect the efforts made in education. Tele-education plays an important role here.

Tele-education and ISRO

'EDUSAT', India's first thematic satellite dedicated exclusively for educational services, was used extensively to cater to a wide range of interactive educational delivery modes like a one-way TV broadcast, video conferencing, computer conferencing, web-based instructions, etc. EDUSAT had manifold objectives - to supplement the curriculum-based teaching, imparting effective teacher training, providing access to quality resource persons and new technologies, thus finally resulting in taking education to every nook and corner of India. EDUSAT provided connectivity to schools, colleges, and higher levels of education and also supported non-formal education, including development communication.

EDUSAT Programme was implemented in three phases: pilot, semi-operational and operational phases. Pilot projects were conducted during 2004 in Karnataka, Maharashtra, and Madhya Pradesh with 300 terminals. The experiences of pilot projects were adopted in semi-operational and operational phases. During semi-operational phase, almost all the states and major national agencies were covered under EDUSAT programme. The networks were expanded under operational phase with funding by respective state governments/user agencies.



Elements of Tele-education.

Tele-education using Edusat.

The EDUSAT (GSAT-3) satellite provided its services till September-2010, supporting Tele-education, Telemedicine and Village Resource Centres (VRC) projects of ISRO. After its decommissioning, the traffic of Tele-education networks was migrated to other ISRO satellites. Most of the tele-education networks were migrated from GSAT-3 to INSAT-4CR and further to INSAT-3A, INSAT-3C and GSAT-12.

A Technical Support and Training Centre (TSTC) is established at Guwahati, Assam to provide technical support on a continuous basis to all the remote sites, Hubs, and Teaching-Ends of various state networks in the North East Region. The efforts are being initiated to setup similar TSTCs for Northern parts of the country, namely, Uttarakhand and Jammu & Kashmir. The tele-education programmes India is now catered by satellites like INSAT-3C, INSAT-4CR and GSAT-12. It benefits around 1.5 crore students per year.

Satellite & Advanced Multimedia Interactive Education (SAMIE) launched by *IIM Bangalore's Centre for Public Policy*, has been able to address the problem of poor-quality education in rural Government and aided schools. The technology and delivery mechanism provide live and multi-way interactive education enriched with multimedia content delivered in real-time through a studio by well experienced and subject matter experts.

The South Asia Satellite (designated GSAT-9), is a geostationary communications and meteorology satellite operated by ISRO for the South Asian Association for Regional Cooperation (SAARC) region. The satellite was launched on 5 May 2017. The South Asia Satellite provides crucial information on telemedicine, tele-education, banking and television broadcasting opportunities. It is also equipped with remote sensing state of the art technology which enables collection of real-time weather data and helps in observations of the geology of the South Asian nations.

The major benefits of Tele-education program are as follows:

- *It effectively supplements curriculum-based teaching.*
- *Teachers' training is facilitated.*
- *It improves access to quality resources.*
- *The rural-urban gap in the area of education is filled by taking education to every nook and corner of the country.*
- *Users with special requirements such as visually challenged or mentally challenged benefit by accessing networks specially designed for their needs.*

Satellites for banking

In July 2016, an Indonesian bank BRI (Bank Riakyat Indonesia) became the first bank in the world to own its dedicated satellite. The satellite, named BRIsat, was launched to provide communications for BRI's banking services and business operations. BRIsat was launched to allow for the bank to reach additional customers, support existing clients and transmit information in real-time as they need to update their internal accounts instantly. The latter need is currently a priority; as more significant numbers of financial transactions are completed at a higher frequency per customer.

In India, ICICI bank started using satellite data—imagery from Earth observation satellites—to assess the credit worthiness of its customers belonging to the farm sector. This bank is the first in India and among a few globally to use satellite data to measure an array of parameters related to the land, irrigation, and crop patterns and use it in combination with demographic and financial parameters to make expeditious lending decisions for farmers. The use of innovative technology helps farmers with existing credit to enhance their eligibility, while new-to-credit farmers can now get better access to credit. Additionally, since the land verification is done in a contactless manner with satellite data, credit assessments are being done within a few days as against the industry practice of upto 15 days.

High reliability and universal coverage of satellite communication have prompted in the banking sector to use satellite communication networks to ensure that ATM service points and Point of Sale (PoS) devices are always connected.

ATMs and PoS devices require reliable connectivity to transmit data from their location to a server and from the server back to their location. The aforementioned reasons prompt banks to employ satellite connectivity as very high availability back-up, for trusted ATM and point-of-sale or as a failsafe for disaster recovery connectivity. Communications need to be assured not just for ATMs and PoS transactions, but also between the institution's headquarters, data centers, and branches. The constant demand for more sites and more bandwidth to support the operational data and financial transactions make satellite communication the ideal choice for banks.

Innovations such as mobile payments and mobile banking are shifting the focus from traditional networks towards connectivity-based applications, especially in emerging markets. Primary or back-up satellite connectivity easily blends into existing IT networks. Integrated with terrestrial networks, satellite access services can enable very high levels of availability. Along with fixed location requirements, a satellite solution is easily adaptable to a transportable configuration, where it can serve the connectivity needs for transactions during events

Satellite services can be made extremely cost-effective through proper planning for communication architecture. Current and future trends in banking sector heavily rely on satellite networks which can complement and expand its existing terrestrial communication networks.

Satellite based rescue operations

Satellites play a vital role in search and rescue, especially in view of disaster management. Search and rescue satellites are designed to provide a way for vessels at sea and in the air to communicate from remote areas. These satellites can detect and locate emergency beacons carried by ships, aircrafts, or individuals in remote or dangerous places. The International Cospas-Sarsat Programme is a satellite-aided search and rescue initiative. It is organized as a treaty-based, non-profit, intergovernmental, humanitarian cooperative of 45 nations and agencies. It is dedicated to detecting and locating radio beacons activated by persons, aircraft or vessels in distress, and forwarding this alert information to authorities that can take action for rescue. The system utilizes a network of satellites that provide coverage everywhere on Earth. Distress alerts are detected, located and forwarded to over 200 countries and territories at no cost to beacon owners or the receiving government agencies. A Cospas-Sarsat beacon is a powerful means of signalling to search and rescue forces that someone is in distress and is in need of immediate assistance. These emergency beacons are considered as the last resort for people in distress for saving their lives, when all other modes of emergency communications prove futile. The ground system, tracks, receives and processes distress signals from the Cospas-Sarsat beacons.

Overall system configuration of COSPAS-SARSAT (from https://earth.esa.int/web/eoportal/satellite-missions/c-missions/cospas)

India is a member of the international COSPAS-SARSAT programme for providing distress alert and position location service through LEOSAR (Low Earth Orbit Search And Rescue) satellite system

INSAT-3A and INSAT-3D are equipped with Search and Rescue payloads that pick up and relay alert signals originating from the distress beacons of maritime, aviation and land users. It provides coverage to a large part of the Indian Ocean region rendering distress alert services to Bangladesh, Bhutan, Maldives, Nepal, Seychelles, Sri Lanka and Tanzania.

Development of indigenous search and rescue beacons has been completed, and is now under qualification phase through international agencies. INSAT-3DR similar to INSAT-3D, is an advanced meteorological satellite of India configured with an imaging System and an Atmospheric Sounder. And, like its predecessor INSAT-3D, INSAT-3DR carries a Data Relay Transponder as well as a Search and Rescue Transponder. Thus, INSAT-3DR will provide service continuity to earlier meteorological missions of ISRO and further augment the capability to provide various meteorological as well as search and rescue services.

Satellites for Navigation

Navigation refers to any method of determining the position and direction. The field of navigation includes four general categories: land navigation, marine navigation, aeronautic navigation, and space navigation.

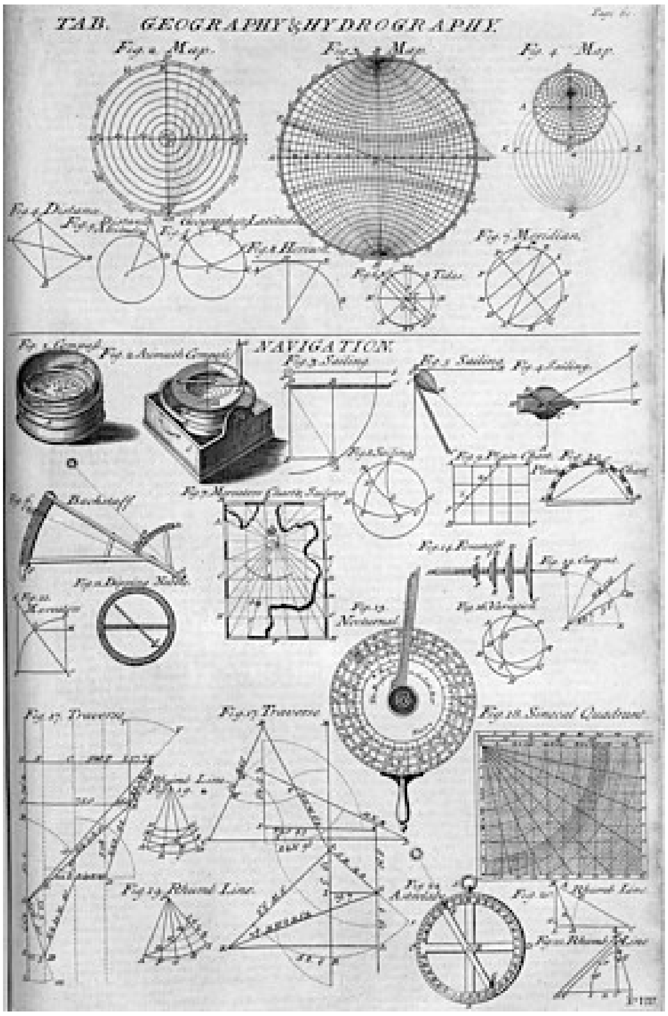


Table of geography, hydrography, and navigation, from the 1728 *Cyclopaedia.*

Methods of navigation have changed a lot over the time. One of the most important judgments the navigator must make involves choosing the most suitable method to use. Commonly recognized types of navigation are listed below.

Dead reckoning (DR)

This traditional method of navigation is used in marine navigation. It involves determining the position by advancing a known position for courses and distances. A position so determined is called a dead reckoning (DR) position.

Piloting

This method involves navigating in restricted waters with frequent determination of position relative to geographic and hydrographic features.

Celestial navigation

In this method the celestial measurements are reduced to lines of position using tables, spherical trigonometry, and almanacs. It is used primarily as a backup to satellite and other electronic systems in the open ocean.

Radio navigation

This type of navigation uses radio waves to determine the position by either radio direction finding systems or hyperbolic systems (Decca, Omega etc.).

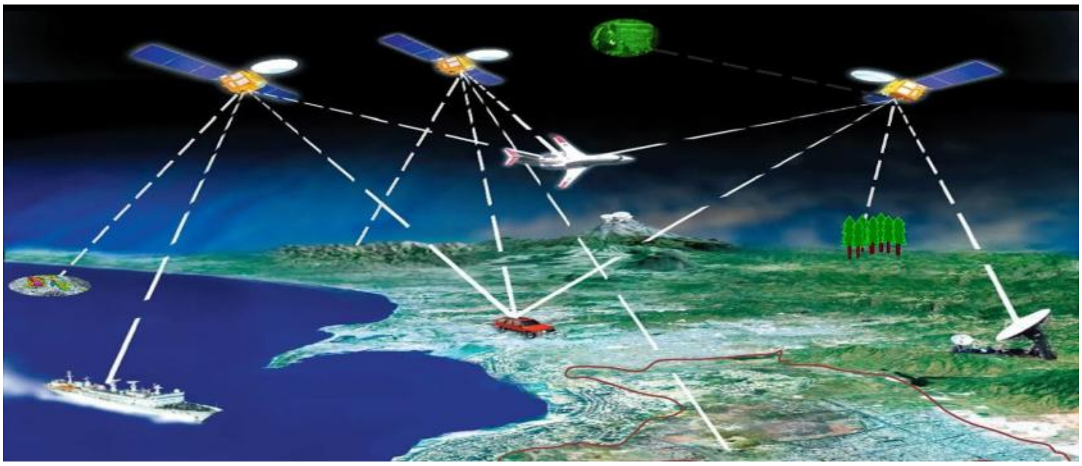
Radar navigation

The Radar navigation uses radar to determine the distance from or bearing of objects whose position is known.

Satellite navigation

In the present era we have more accurate and precise navigation data using the satellite navigation techniques. This method uses artificial earth satellites for determination of position.

The GPS (global positioning system) is made up of 24 satellites that orbit at an altitude of 20,000 km above the surface of the Earth. The difference in time for signals received from four satellites is used to calculate the exact location of a GPS receiver on Earth.



(Courtesy: https://techcrunch.com/)

Auto pilot

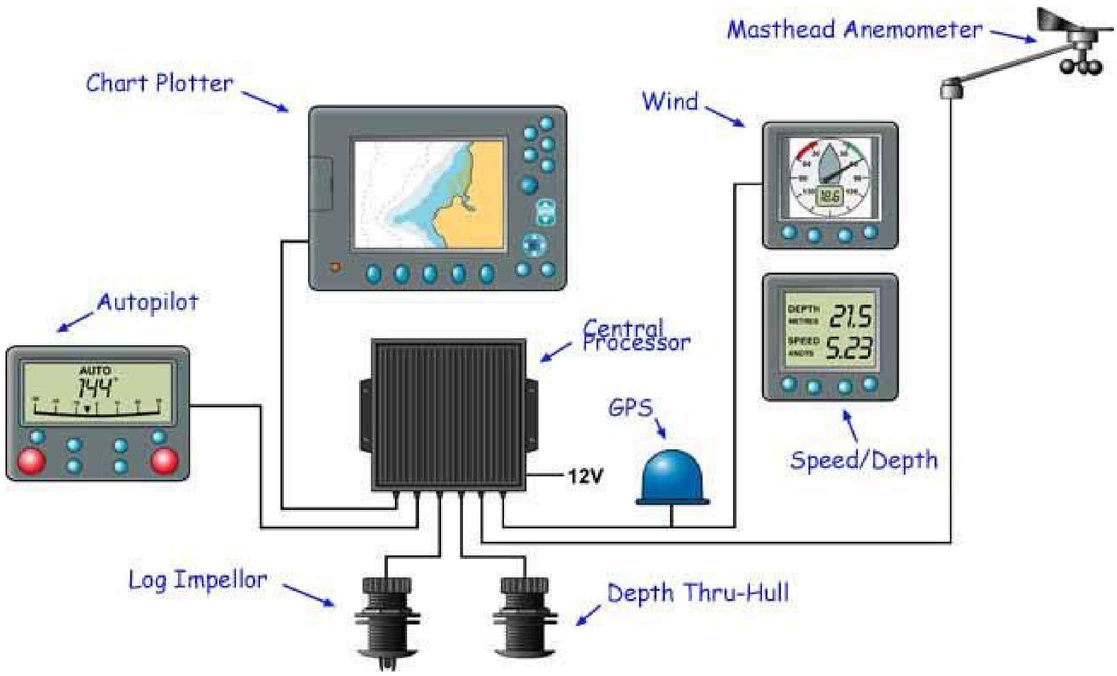
Auto pilot is a system used to control the trajectory of an aircraft, marine craft or spacecraft, where constant manual control by a human operator is not required. Autopilot assists the operator in controlling the vehicle thereby allowing the operator to focus on broader aspects of operations (for example, monitoring the trajectory, weather and on-board systems). The first aircraft autopilot was developed by Sperry Corporation in 1912. The lunar module digital autopilot of the Apollo program was an early example of a fully digital autopilot system in spacecraft. Autopilot in automobiles utilizes numerous sensors located around the vehicle to navigate the environment. These systems rely on radar/sonar, cameras, and digital monitors to sense the environment and keep the vehicle traveling within the appropriate lane. Modern autopilots can receive data from a Global Positioning System (GPS) receiver installed on the vehicle.

Aircraft navigation using satellites: In case of an aeroplane a GPS receiver can determine a plane's position in space by calculating its distance from three or more satellites in the GPS network. With such positioning information, an autopilot can control the flight as well as execute a flight plan.

On land (Car) navigation using satellites: The auto drive cars proposed by Tesla uses satellite imagery as one of the modules of autopilot. Road monitoring using satellite system consists of three parts: an in-car unit, a central computer server and a mobile satellite communication system. The in-car system reads the vehicle's position every second using the GPS. An algorithm called the ‘map matcher’ uses that position and tachometer data, which has vehicle’s speed, to identify the road on which it is being driven. Any traffic congestion is automatically detected for each road segment, based on a prior knowledge of that road, such as the expected speed of traffic under non-congested conditions.

Tesla autopilot navigation

Marine navigation using satellites: The GPS has changed the way the world operates. This is especially true for marine operations, including search and rescue. GPS provides the fastest and most accurate method for mariners to navigate, measure speed, and determine location. An enhancement to the basic GPS signal known as Differential GPS (DGPS) provides much higher precision and increased safety in its coverage areas for maritime operations. This enables increased levels of safety and efficiency for mariners worldwide.

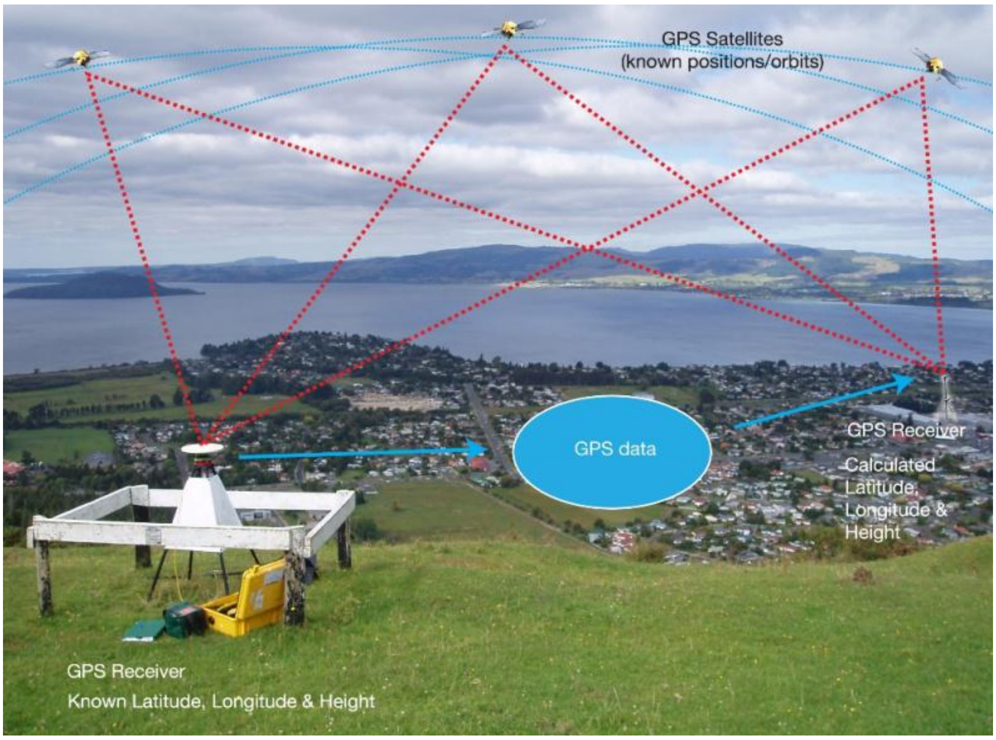


A sailboat navigation using GPS (Courtesy: https://www.sailboat-cruising.com/)

Land survey

Land surveying is the technique of determining the three-dimensional positions of points and the distances and angles between them. These points are usually on the surface of the Earth, and often used to establish maps and boundaries for ownership, locations, such as building corners or the surface location of subsurface features, or other purposes required by government or civil law, such as property sales. Surveying has been an element in the development of the human environment since the beginning of recorded history. The planning and execution of most forms of construction require it. It is also used in transport, communications, mapping, and the definition of legal boundaries for land ownership. It is an important tool for research in many other scientific disciplines. The two types of surveying are geodetic surveying and plane surveying.

Modern top-of-the-line total stations are fully robotic, and can even email point data to a remote computer and connect to GPS. Real Time Kinematic GPS systems have increased the speed of surveying with horizontally accuracy of ~20 mm and vertically ~30–40 mm. GPS surveying differs from other GPS uses in the equipment and methods used. Static GPS uses two receivers placed in position for a considerable length of time. The long span of time lets the receiver compare measurements as the satellites orbit. The changes as the satellites orbit also provide the measurement network with well-conditioned geometry. This produces an accurate baseline that can be over 20 km long.

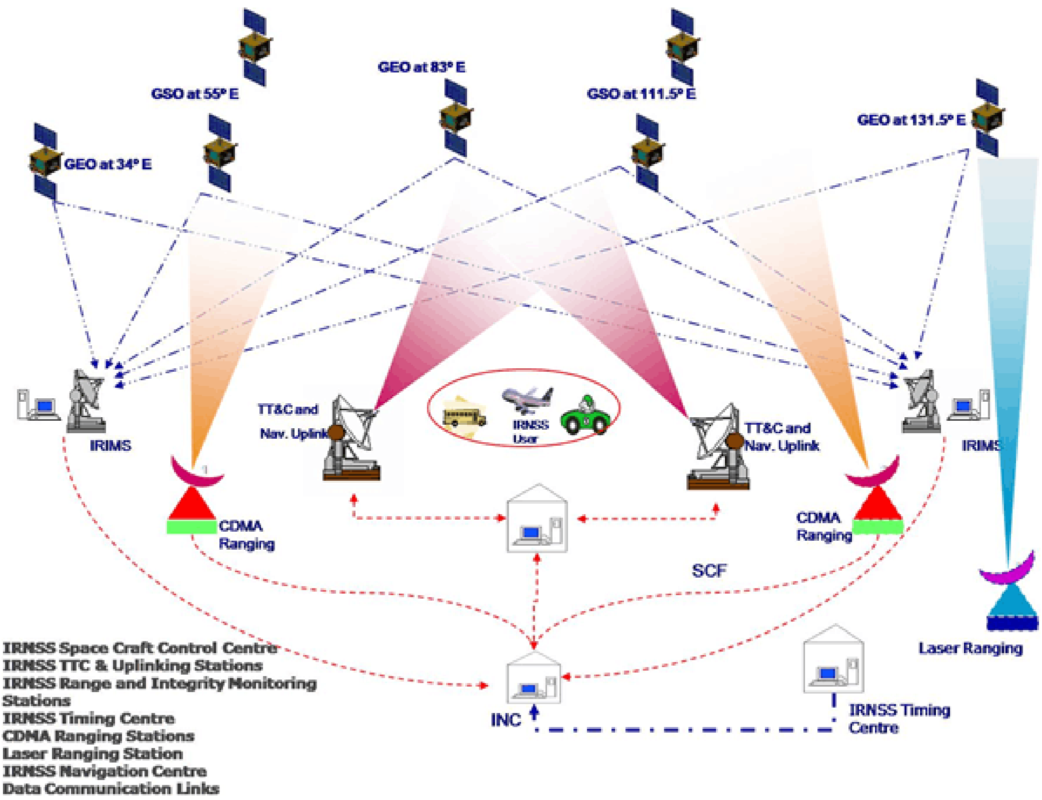


GPS based surveying (Courtesy: https://www.icsm.gov.au/)

Global positioning

Global positioning involves use of satellites to provide autonomous geo-spatial location and navigations. Electronic receivers are used to determine the location (longitude, latitude, and altitude/elevation) to high precision (within a few centimeters to metres) using time signals transmitted along a line of sight by radio from satellites. The system can be used for providing position, navigation or for tracking the position of something fitted with a receiver (satellite tracking). The signals also allow the electronic receiver to calculate the current local time to high precision, which allows time synchronization. The systems operate independently of any telephonic or internet reception, though these technologies can enhance the usefulness of the positioning information generated. Global coverage is generally achieved by a satellite constellation of 18–30 medium Earth orbit (MEO) satellites spread between several orbital planes. The actual systems vary, but use orbital inclinations of >50° and orbital periods of roughly twelve hours (at an altitude of about 20,000 kilometers).

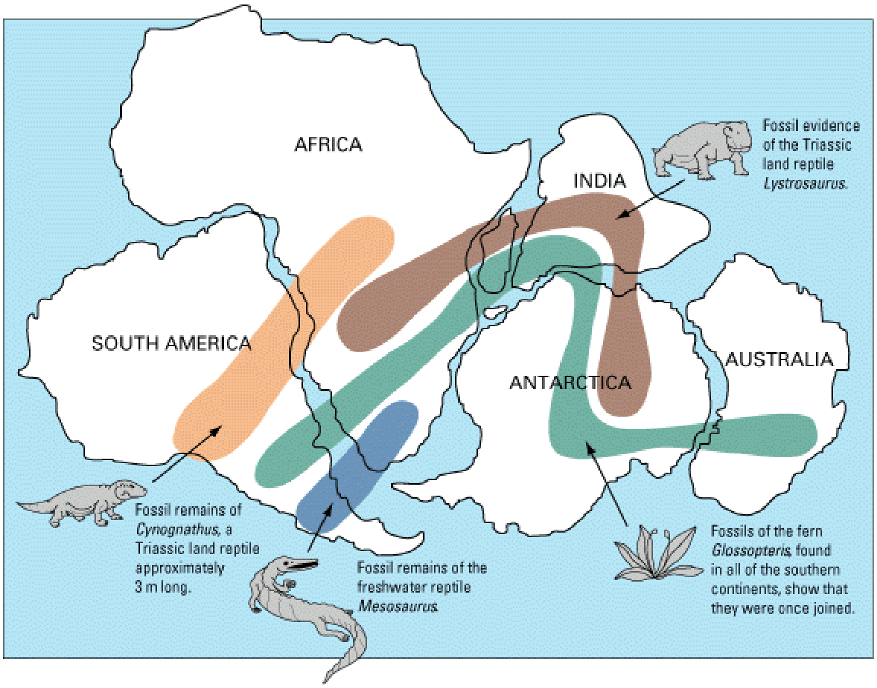
A satellite navigation system with global coverage may be termed a global navigation satellite system (GNSS). United States 'Global Positioning System (GPS), Russia's Global Navigation Satellite System (GLONASS) and China's BeiDou Navigation Satellite System (BDS) are fully operational GNSSs, European Union's Galileo scheduled to be fully operational by the end of 2020. Japan's Quasi-Zenith Satellite System (QZSS) is a GPS satellite-based augmentation system to enhance GPS's accuracy, with satellite navigation independent of GPS scheduled for 2023. The Indian Regional Navigation Satellite System (IRNSS), with an operational name of NavIC (acronym for Navigation with Indian Constellation), with the constellation in orbit in 2018, plans to expand to a global version in the long term.



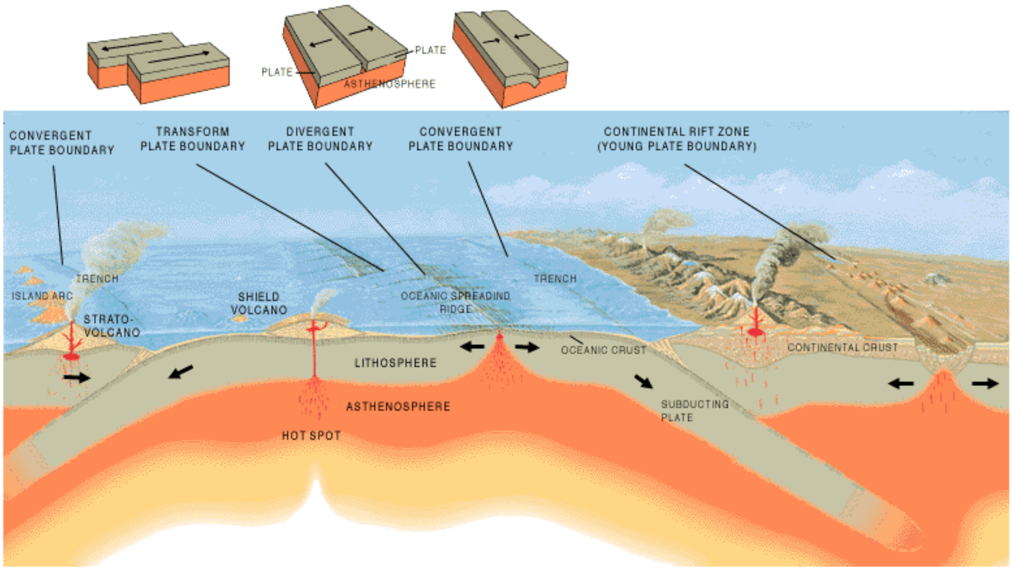
IRNSS Architecture.

Monitoring the Tectonic plate movement

Tectonic plate (lithospheric plates) is the cold, brittle upper layer of the Earth. Plate Tectonics is based on the theory of continental drift proposed by Alfred Wegener in the early 1900's, where it has been proposed that the continents move freely over Earth's surface changing their position relative to one another, eventually drifting into the positions we see today. A plate is a rigid slab of the lithosphere moving as a unit and may be composed of ocean floor, be entirely continental, or it may contain both oceanic and continental crust. Plate boundaries are defined and identified by mapping narrow belts of earthquakes, volcanoes, and young mountain. The rigid lithospheric plates on earth's surface are constantly in motion relative to each other.



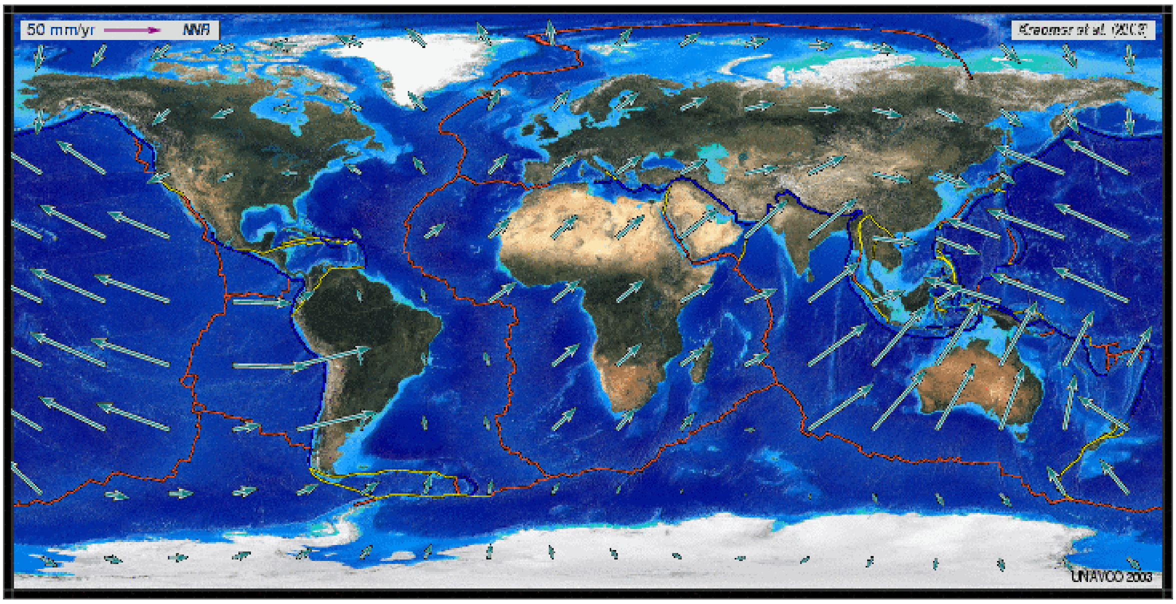
Cross section of a tectonic plate, *featuring subduction zones, oceanic and continental crust, the lithosphere and the asthenosphere (from https://www.britannica.com/science/asthenosphere).*



Types of plate boundaries include divergent, convergent, transform fault boundaries. New ocean crust is constantly being formed at divergent plate boundaries while older ocean crust is being destroyed and recycled at convergent boundaries (Courtesy https://cimss.ssec.wisc.edu/)

With the advent of technology, these movements can be tracked to know the current direction and speed of plate motion with ground surveying techniques using laser-electronic instruments as well as by space-based methods such as with satellite networks. Since plate motions are at a global scale, they are best measured by satellite-based methods. The three most commonly used space-based techniques are: very long baseline interferometry (VLBI), satellite laser ranging (SLR), and the Global

Positioning System (GPS). Among these three techniques, GPS has been the most useful for studying plate motions. From any one position on earth one must simultaneously receive signals from at least four satellites, recording the exact time and location of each satellite when its signal was received. By repeatedly measuring distances between specific points, geologists can determine the active movement between plates. Plate motion can be measured as relative movement or absolute movement. Absolute plate movement is the motion of a plate with respect to the Earth's deep interior. Relative movement refers to the movement between two plates at a given point on the plate boundary. This determines the amount and type of earthquake and volcanic activity present along a plate boundary.



Global map of current absolute plate motion as calculated using GPS technology.. The direction of arrows indicates the direction of plate movement. The length of the arrow indicates the speed of movement (courtesyhttps://cimss.ssec.wisc.edu/).

Endangered species tracking

Threatened by habitat loss, poaching, pollution and other factors, wildlife species across the globe are declining in number at an alarming rate. Therefore, protecting the endangered species is an important responsibility. GPS monitoring offers a way to effectively track and study endangered animals while letting them remain in their natural habitats whenever possible, with minimum or no human intervention.

Data collected through satellite tracking helps us understand and protect the endangered and threatened species of the world. An automated system is desired, equipping natural spaces with numerous networked sensor nodes to enable long-term data collection at times (even at night), scales and resolution which are very difficult if not impossible, to achieve by manual monitoring. It also allows collecting data without disturbing the ecology and yet represents a substantially more economical method for conducting long-term studies than traditional one.

Migrating animals have for a long time been tracked by recapturing tagged individuals. Radio-telemetry, which requires an observer to physically follow the tagged animal, has also been used. If an individual long-distance migrant needs to be tracked, another technique, which is the satellite telemetry, is the best one. Satellite telemetry has been used extensively in the tracking of animals since the 1980s. After an animal has been captured and a tracking device has been attached, its movements can be monitored for extended periods of time without having to recapture it. Satellite telemetry uses Platform Transmitter Terminals (PTTs) that are either attached externally or surgically implanted. The PTTs then communicate via radio-signals to orbiting satellites, which localize the signal and give positional fixes (latitude and longitude) on the PTT.

Grey seal on Helgoland, Germany, with a satellite telemetry sender attached (from https://www.nature.com).

Railway signalling and traffic signal

Railway Signalling: The advances in the satellite technology will bring several new concepts to railways as well, which increase railway safety standards, operational efficiency and quality of passenger services. These concepts are mainly based on the dissemination of the Information and Telecommunication Technology (ITT) into the railway environment. One of these concepts is to build signaling and train control systems if possible free of track-side equipment.

A key element of the concept is a satellite navigation-based train-born position locator system, which is able to determine position of the train anytime and anywhere on the track with required accuracy, availability, integrity risk, time-to-alarm, and other important parameters regarding safety applications.

Current standalone GPS and GLONASS satellite navigation systems don't meet these strong safety-related parameters. Not even integration GPS/GLONASS with inertial navigation systems (INS) satisfies these strong parameters.

Concept of satellite navigation-based train-born position locator system.

Traffic signal:

Human life is a valuable asset for any country. Accidents and medical emergencies such as fire, road accidents etc. occur every day and needs to be addressed immediately. It is critical for emergency teams to reach the accident spot so as to save human lives. However rapid population growth in cities has resulted in high traffic densities on city roads. An innovative and economic traffic signal pre-emption system which uses the accuracy of GPS and the advantages of a server-centric networked system could prove to be a lifesaving solution.

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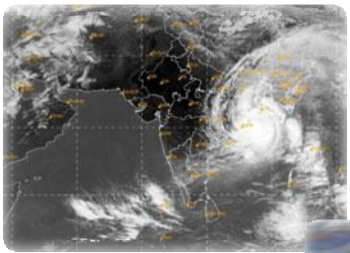

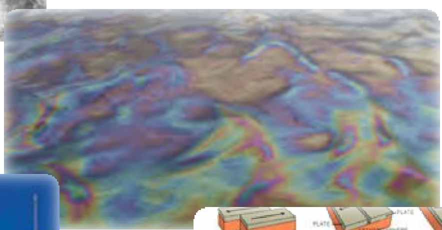

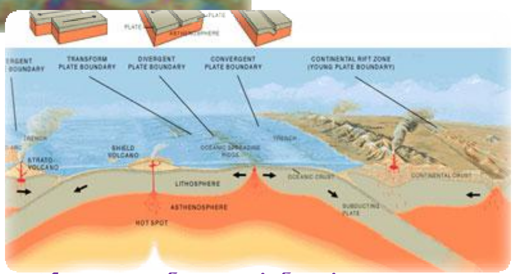

You were born with wings,
Don't crawl
Learn to use them to
Fly and fly

- Dr. APJ Abdul Kalam

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