Study on Remote Sensing Applications and Role of Geoportals

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Project Report
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DECLARATION

I hereby declare that the project report on 'Study on Remote Sensing Applications and Role of Geoportals' being submitted by me is an original and bonafide work carried out under the guidance of Shri Rajeev Jyoti, Distinguished Scientist, Indian Research Space Organisation, Ahmedabad.

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Summary

India has made great strides in Earth Observation (EO) by combining three key technologies: Remote sensing, Geographic Information Systems (GIS), and Geoportals. These tools work together to monitor, study, and manage India's vast and varied natural resources. EO through satellite technology has become an indispensable tool for understanding and managing the Earth's resources and environments. By providing comprehensive, real-time data on climate, land use, biodiversity, and more, EO enables better decision-making and supports efforts towards sustainable development. Geographic Information Systems (GIS) serve as the analytical engine of India's EO capabilities. These systems offer powerful tools for storing, processing, and visualizing spatial data, enabling complex geographical analyses that inform policy decisions and resource allocation. The integration of GIS with remote sensing data has created a synergy that enhances our understanding of geographical patterns and relationships, crucial for sustainable development practices. India's geoportals, including Bhuvan, Bhoonidhi, VEDAS, and MOSDAC, represent the interface between complex EO data and end-users. These platforms democratize access to geospatial information, offering a range of functionalities from 2D and 3D mapping to specialized mobile applications. They cater to diverse user needs, from academic researchers to government officials and citizen scientists. The geoportals play a pivotal role in fostering data-driven decision-making across various sectors of the Indian economy.

The importance of EO extends beyond resource management. EO enhances crop management practices and yield predictions, contributing to food security and economic growth. It improves transport efficiency, boosts agricultural productivity, optimizes energy and mining operations, aids disaster management, and supports infrastructure development. EO also supports the development of applications to monitor environmental health and inform risk assessment in the insurance and finance sector. Several trends have been identified that significantly impact the field of EO. Technological advancements have led to more sophisticated and cost-effective satellites, enabling higher resolution and more frequent data collection. To effectively manage the vast amounts of data generated by EO, geoportals are necessary elements for faster data visualisation and decision making. These geoportals facilitate the collection, limited processing, visualisation and analysis of satellite data, ensuring its timely usage by various stakeholders. By integrating advanced data analytics – artificial intelligence (AI) and machine learning (ML), some of these platforms enhance the ability to derive actionable insights from EO data, supporting informed decision-making across sectors. This centralized approach also promote collaboration and data sharing, driving innovation and maximizing the impact of EO on sustainable development and economic growth of the country. In conclusion, by leveraging the latest technological advancements and addressing key challenges, EO can add significant economic value by improving agricultural efficiency, optimizing urban planning, enhancing disaster response, and conserving natural resources, thereby fostering a more resilient and prosperous economy.

Keywords: Earth Observation, Remote Sensing, Geographic Information Systems (GIS), Geoportals, Mobile Applications, Geospatial Technology

1. Introduction

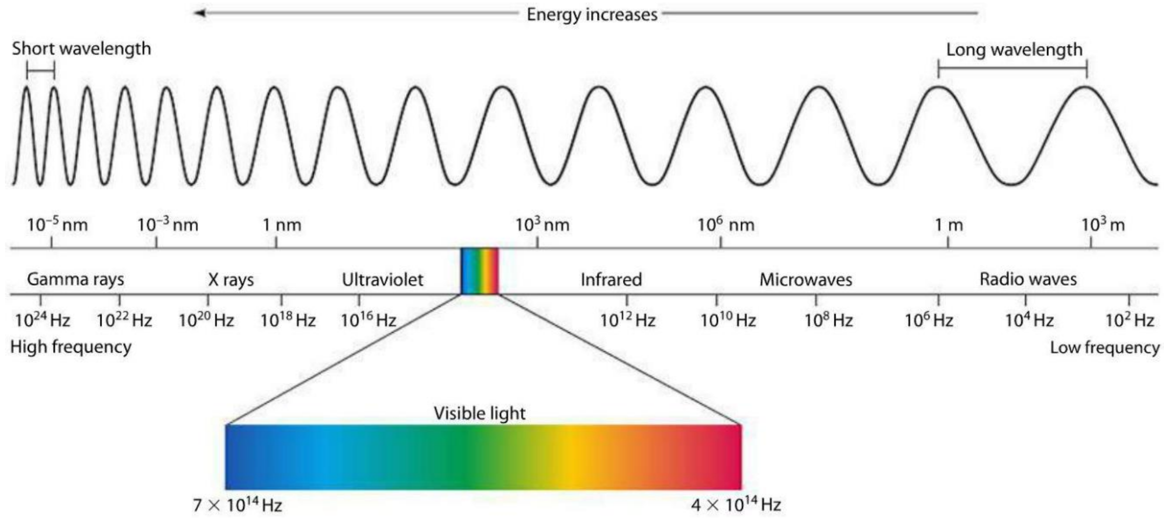
Rapid development and growing demand owing to increase in human population has made significant impact on environment and are altering the earth surface processes and creating ecological challenges. This is further compounded by the ever-increasing occurrences of natural hazards. Therefore, there is a greater demand for most authentic timely information on a suit of geophysical parameters and environmental indicators. Towards this earth observation from space provides a vantage point where a large number of sensors have been deployed onboard satellites providing geospatial information needed to understand the earth system as a whole.

Remote sensing is instrumental in providing vital geo-information for monitoring the Earth's surface, oceans, and atmosphere across various spatial and temporal scales. Its significance extends to protecting the global environment and fostering sustainable development. Space-based observations, particularly during natural and human-induced hazards, are crucial for mitigating disaster losses. The integration of remote sensing, Geographic Information Systems (GIS), Geoportals, and mobile applications has transformed the way we observe, analyze, and engage with our planet, revolutionizing our understanding of the world around us.

1.1. Remote Sensing

Remote sensing also called as Earth Observation (EO) is defined as "*the science of acquiring information about the Earth's surface without actually being in contact with it*." This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information.

It involves detecting and measuring the radiation of different wavelengths from the electromagnetic spectrum (fig.1) which is reflected or emitted by Earth's surface or atmosphere. The atmosphere attenuates some of the energy in certain wavelengths while allowing other wavelengths to pass through. The places where energy passes through are called "atmospheric windows". We use these "windows" in remote sensing to do earth observation.



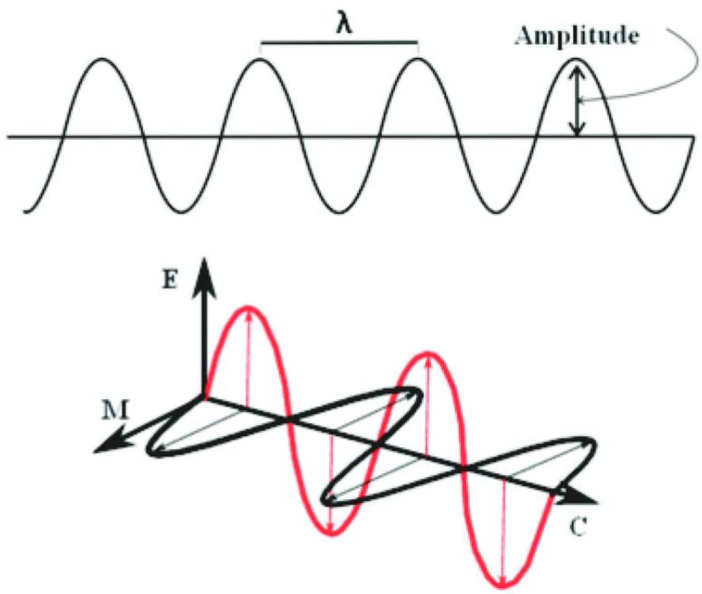


Figure 1: The Electromagnetic Radiation (EMR) Spectrum and its properties

Remote sensing systems have five basic components to measure and record data about an area from a distance (fig. 2). These components include:

- Interaction of EMR with the earth's surface: reflection and emission
- Transmission of energy from the surface to the remote sensor
- Sensor data acquisition (Multispectral, Hyperspectral and Microwave Radar imaging)
- Data transmission, processing, interpretation and analysis
- Applications in various fields such as agriculture, forestry, urban planning, and disaster management

Special cameras and sensors collect remotely sensed images, which help researchers "sense" things about the Earth that would be difficult or impossible to observe from the ground.

With respect to the type of energy resources, the RS technology is defined as passive or active.

- Passive Remote Sensing makes use of sensors that detect the reflected or emitted electro-magnetic radiation from natural sources.
- Active remote Sensing makes use of sensors that detect reflected responses from objects that are irradiated by artificially generated energy sources, such as radar.

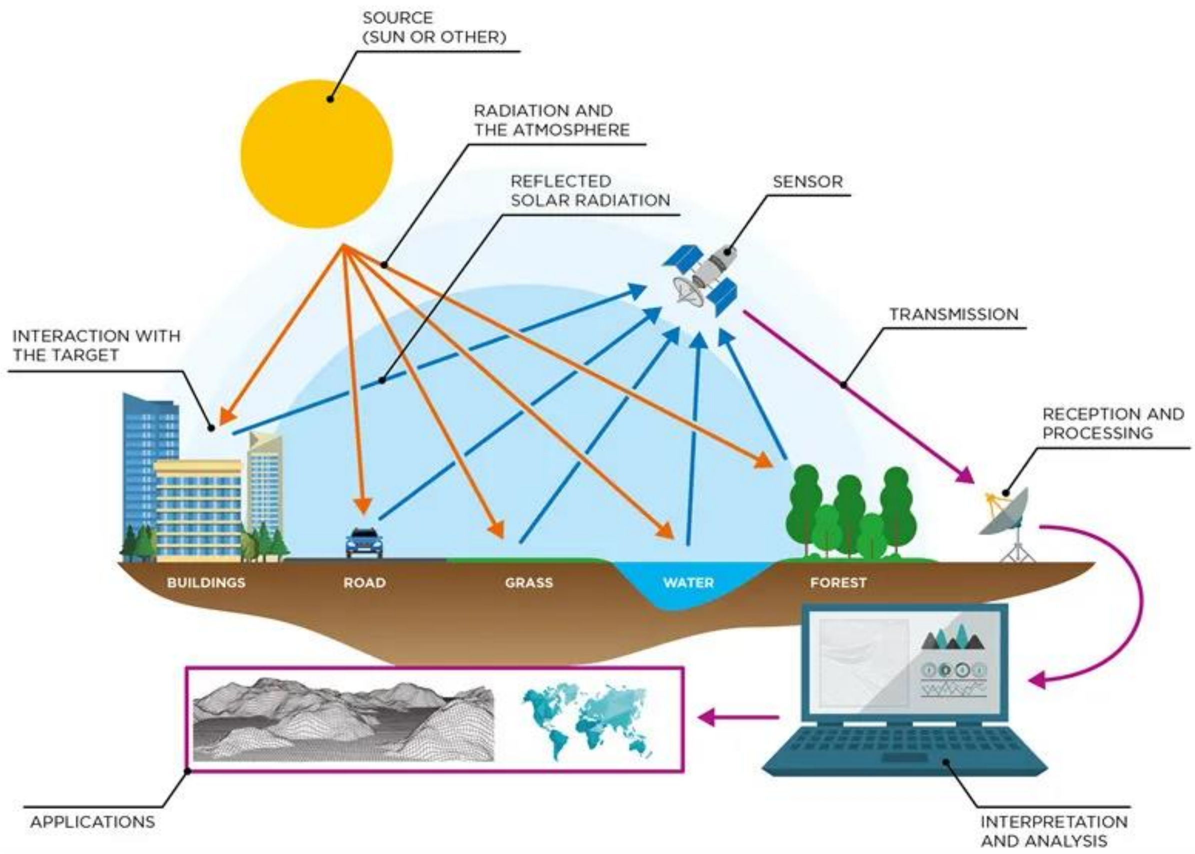


Figure 2: The Remote Sensing Process: Data Acquisition to Application

Electromagnetic Radiation (EMR):

As electromagnetic energy forms the basic source for Earth observation cameras, its pertinent to understand some of the basic properties of EMR, which help us to understand image formation.

To explain the nature of EMR and its propagation through space and its interaction with matter two different models, i.e. Wave model and Particle model have been given.

a) Particle Model of Electromagnetic Energy

The particle model of electromagnetic energy was given by Sir Isaac Newton in 1704. According to this theory, light behaves as a stream of particles or corpuscles and travels in straight line. He also knew that light had wave like characteristics based on his experiments. Following are the properties of the particle model of electromagnetic energy:

- light travels in straight lines
- light can be reflected
- light can travel through a vacuum

b) Wave Model of Electromagnetic Energy

The wave model was formulated by Maxwell in 1862. According to this theory, light travels like a wave which has electric and magnetic fields. This model is able to explain phenomenon such as propagation, dispersion, reflection, refraction and interference of electromagnetic waves. Eventually, work of some scientists seemed to point out that there were aspects of light that could be explained more clearly using a wave model.

c) Wave Particle Duality

Scientists like Huygens (1690) and Young (1804) had given definite proof that light behaves like a wave. Planck and Einstein showed that light must be a particle. Both aspects (wave and particle) make up light at the same time. This leads us to the current way of describing light, the model known as *Wave Particle Duality*. Wave particle duality postulates that all matter exhibits both wave and particle properties. Albert Einstein was able to come up with a solution as long as he assumed that energy came in little pieces, called *Quanta*. This led Einstein to come up with a theory that joined the idea of Quanta to an explanation of light. This meant the light came in little pieces that were named *photons*. This also helped to explain the phenomenon called *Blackbody Radiation*.

Electromagnetic fields have many interesting properties. These properties make them very unique and enrich the science of remote sensing. Three characteristics of EMR, which are particularly important for understanding the concept of the remote sensing, are wavelength, amplitude and frequency.

- ***wavelength*** is the distance over which the wave's shape repeats. It is usually determined by considering the distance between consecutive corresponding points of the same phase, such as crests or troughs. It is denoted as λ.
- ***frequency*** is the number of occurrences of a repeating event per unit time. It is denoted as ν.
- ***amplitude*** is the maximum extent of a vibration or oscillation.

The wavelength 'λ', frequency 'ν', and the velocity of the EM wave 'c' are related as:

$c = \nu \lambda$

Some of the other properties of EMR are:

• the electric (E) and magnetic (F) fields are always perpendicular to the direction of travel of the wave. Thus, the wave is a transverse wave

• the electric field is always perpendicular to the magnetic field.

• the cross product of electric and magnetic fields always gives the direction of travel of the wave

• the variations of fields are sinusoidal, so also are the transverse waves. Moreover, the fields vary with the same frequency and in phase with each other

• the speed (c) at which electromagnetic waves move in vacuum is ~ 3×10^8 m/s.

As it can be seen in fig.1 EMR ranges from very high energy radiation such as gamma rays and X rays through ultraviolet light, visible light, infrared radiation and microwaves to radio waves. The range of frequencies of EMR is known as electromagnetic spectrum. All the types of EMR are wave forms which travel at the speed of light. The radiation can be defined in terms of either their wavelength or frequency. Shorter wavelength radiations (infrared or shorter) are generally described in terms of its wavelength, whereas longer wavelength radiations (microwave, etc.) are generally described in terms of its frequency. In remote sensing, mostly visible, infrared and microwave bands are used and remote sensing is based on properties of electromagnetic energy. The properties of EMR interacting with matter are systematised in a simple set of rules called ***radiation laws***, which define quantitative aspects of the properties of electromagnetic energy. These laws apply when the radiating body is a *blackbody radiator* which emits the maximum amount of radiation at each wavelength. All materials above absolute zero (-273.14°) temperature emit radiation but no real materials are a perfect blackbody.

The radiation being emitted by a blackbody is given by *Planck's Radiation Law*, which governs the intensity of radiation emitted by unit surface area into a fixed direction (i.e. solid angle) from the blackbody as a function of wavelength for a fixed temperature. The Planck's Law can be expressed through the following equation:

$$B_\nu(\nu, T) = \frac{2h\nu^3}{c^2} \frac{1}{\exp\left(\frac{h\nu}{k_B T}\right) - 1}$$

where

B_ν is the spectral radiance ($Wm^{-2}\mu m^{-1}$) of a body for a given frequency (ν) and temperature (T in Kelvin),

k_B is the Boltzmann constant, (1.3805×10^{-23} JK^{-1})

h is the Planck constant, (6.6256×10^{-34} Ws^2)

c is the speed of light (2.9979×10^8 ms^{-1})

The relationship given by Planck's radiation law, given below, shows that with increasing temperature, the total radiated energy of a body increases and the peak of the emitted spectrum shifts to shorter wavelengths.

From the Planck's law, one can derive two other radiation laws i.e. the *Stefan-Boltzmann law* and the *Wien's displacement law*. These two laws are very important in remote sensing to understand characteristics of EMR:

Stefan-Boltzmann law defines relationship between total emitted radiation (E) and temperature and is expressed as:

$E = \sigma T^4$

where,

E = radiant energy per surface unit measured in Watts m^{-2} leaving a blackbody

$\sigma = 5.6697 \times 10^{-5}$ (Watts m^{-2} k^{-4} is the Stefan-Boltzmann constant, and

T = absolute temperature of the blackbody in Kelvin (K).

The *Wien's displacement law* defines the relationship between the wavelength of the radiation emitted and the temperature of the object and is expressed as:

$\lambda_{peak} = b/T$

λ_{peak} is the wavelength at which radiance is maximum,

T is the absolute temperature in Kelvin (K),

b is a constant of proportionality called *Wien's displacement constant*, $b \approx 2898$ μm·K.

The Wien's Displacement law gives the wavelength of the peak of the radiation distribution, while the Stefan-Boltzmann law gives the total energy being emitted at all wavelengths by the blackbody (which is the area under the Planck's law curve). Thus, the Wien's law explains the shift of the peak to shorter wavelengths as the temperature increases, while the Stefan-Boltzmann law explains the growth in the height of the curve as the temperature increases.

We know from the principle of conservation of energy that when a surface intercepts incident (incoming) radiation it interacts with it and some amount of radiation is reflected, absorbed and transmitted. This can be expressed as

$E\text{i} = E\text{r} + E\text{a} + E\text{t}$

where,

Ei is incident radiation

Er is reflected radiation

Ea is absorbed radiation, and

Et is transmitted radiation

These are essential fundamentals to understand the way remote sensing imaging is carried out using satellites.

Orbits:

For earth observation from space, sensors and camera systems must reside on a vantage point in space and there are two prominent orbits generally used: the geo-stationary orbit and the polar orbit (fig.3).

The geo-stationary orbit is such a position that it keeps pace with the rotation of the Earth. These platforms are covering the same place and give continuous near hemispheric coverage over the same area day and night. These are mainly used for communication and meteorological applications. This geo-stationary orbit is located at an altitude of 36,000 km above the equator. Satellites in a polar orbit cycle the earth from North Pole to South Pole, inclined in such a way that at the equator it maintains a sun synchronous overpass i.e. the satellite passes over all places on earth having the same latitude at the same local time. This ensures similar illumination conditions when acquiring images over a particular area over a series of days. The altitude of the polar orbits varies generally from 600 to 900 km.

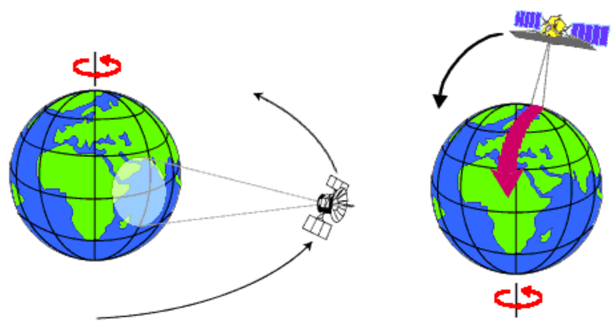


Figure 3: Geostationary and polar orbits

Resolution:

There are four types of resolution in remote sensing observations:

<u>(i) Spectral Resolution:</u> The number of spectral band in which the data is collected.

<u>(ii) Radiometric Resolution:</u> The capability of the sensor to differentiate two objects based on the reflectance / emittance differences.

<u>(iii) Spatial Resolution:</u> It is the capability of the sensor to discriminate the smallest object on the ground. Higher the spatial resolution smaller the object that can be identified. Spatial resolutions vary from few Kms to half a meter.

<u>(iv) Temporal Resolution:</u> It is the capability to view the same target, under similar conditions at regular intervals.

Remote sensing technologies continue to evolve, providing increasingly detailed and accurate data about our planet. This information is crucial for understanding Earth's systems, managing resources, and addressing global challenges such as climate change and environmental degradation.

1.2. Geographic Information Systems (GIS)

GIS stands for Geographic Information Systems. It is a powerful computer-based tool that stores, analyzes, and visualizes data for geographic positions on Earth's surface. GIS examines spatial relationships, patterns, and trends in geography, allowing us to understand complex spatial data in a more intuitive way. The core design of GIS itself is based on modelling of real-world phenomenon to assist in better decision making. Analysis of the data in GIS domain is carried out through two types of data models viz. raster model and vector model (fig.4). The vector model is the discrete model of the real-world phenomena where the entities are represented using point, line and polygon features along with associated attributes whereas the raster data model represents the real-world entities as continuous grid i.e. pixel. Accordingly, the methods of spatial analysis vary for both the data models.

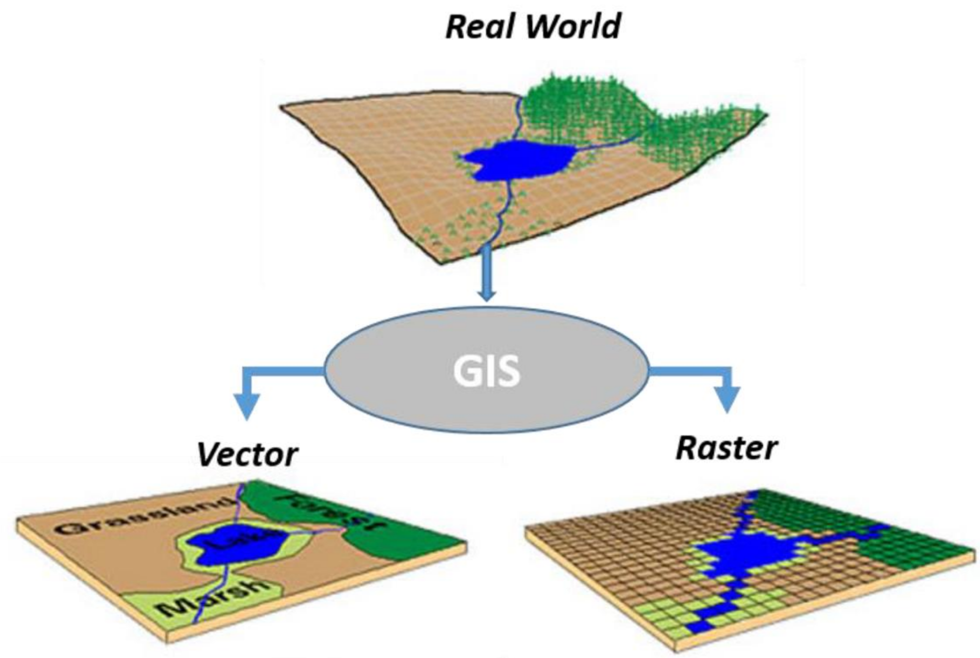


Figure 4: Basic concept of GIS data model

GIS can combine and allow to overlay analysis using various thematic layers (point, line, polygons and raster grids) on top of each other once they are properly projected on a geographic coordinate system (fig.5). The four main components of Geographic Information Systems (GIS) are:

1. Creation of geographic data: Collecting and inputting spatial information from various sources such as Geographic Positioning System (GPS) devices, satellite imagery, and field surveys.
2. Managing the database: Organizing and storing geographic data in a structured format that allows for efficient retrieval and analysis.
3. Analysing and finding patterns: Applying various spatial analysis techniques to uncover relationships, trends, and patterns within the data.
4. Displaying it on a map: Presenting the results of analysis through maps, charts, and other visual representations.

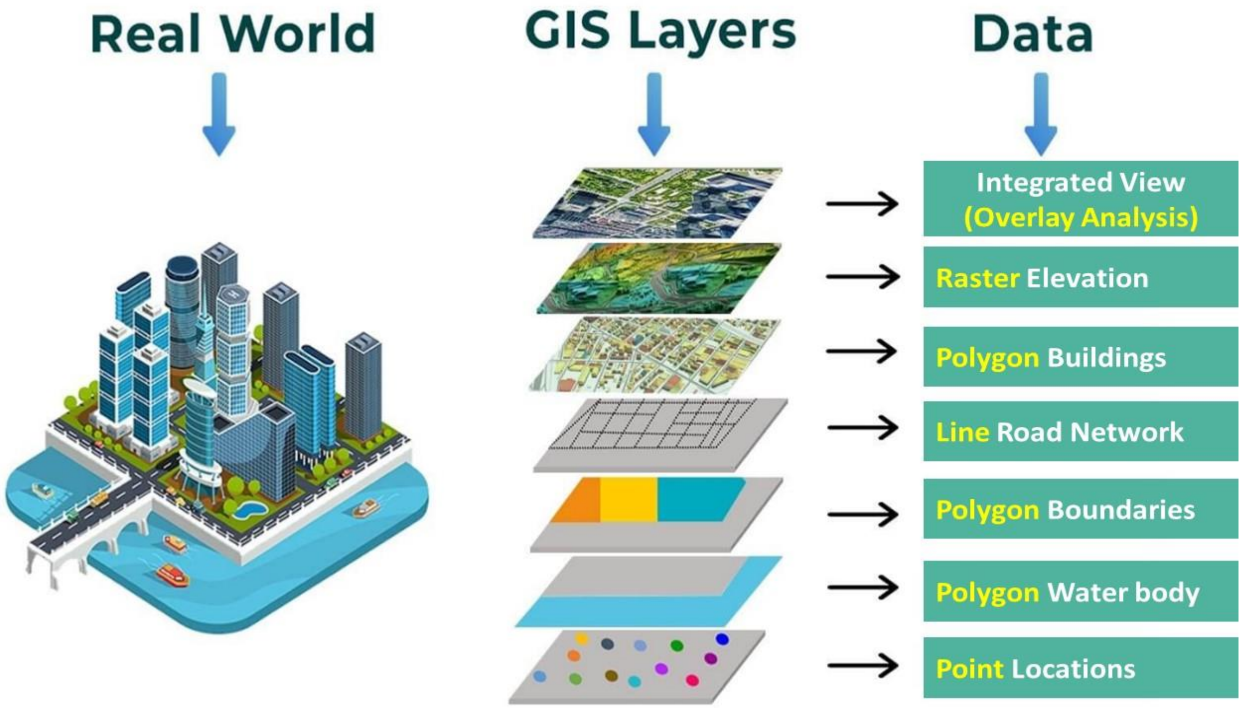


Figure 5: Layers in Geographic Information System (GIS)

Key features of GIS are:

- Spatial data management
- Data analysis and modelling
- Cartography and visualization
- Integration with other technologies (e.g., GPS, remote sensing)
- Decision support for various applications

GIS mapping produces visualizations of geospatial information, which significantly impacts our understanding of data. By seeing how different factors relate to each other in a geographic context, we can make better-informed decisions. GIS helps us understand "what" is "where," simplifying complex analyses and making answers clearer.

The power of GIS lies in its ability to reveal hidden patterns and relationships that are not easily visible when looking at data in traditional formats like spreadsheets or charts. By visualizing geographic features as a function of points, lines and polygons on a map, GIS provides a geographic context that enhances our comprehension and enables more effective problem-solving across various fields.

1.3. Earth Observation Applications

Earth observations (EO), obtained mainly through satellites, play a vital role in understanding our planet and addressing various challenges. EO satellite data have emerged as a vital and indispensable tool, offering crucial measurements and support for a wide range of environmental, social, political, and economic studies. As demand in these fields continues to grow, innovative applications of EO satellite data are being developed to meet the increasing need for accurate and timely information. For instance, the evolving requirements of land use policies have driven the development of high-resolution land cover mapping products with enhanced real-time capabilities. Consequently, high-resolution EO satellite missions are gaining popularity for their ability to closely monitor natural phenomena, environmental changes, and disasters, providing valuable insights for informed decision-making. The applications of earth observations are diverse and widespread, transforming the way we live, work, and interact with our environment and earth systems. Here are some of the significant applications:

i. **Natural Resource Management:** Earth observations help monitor deforestation, land degradation, water resources and water quality, supporting sustainable resource management and conservation.
ii. **Agriculture and Food Security:** Earth observations enable crop monitoring, yield prediction, and soil moisture assessment, supporting precision agriculture and food security.
iii. **Urban Planning and Development:** Earth observations provide insights into urbanization patterns, city growth, special economic zone development, digital twin applications, informing urban planning and policy decisions.
iv. **Infrastructure Development and Maintenance:** Satellite imagery supports infrastructure planning, monitoring, and maintenance, reducing costs and enhancing efficiency.
v. **Disaster, Response and Recovery:** Satellite imagery facilitates rapid damage assessment, response planning, and recovery efforts after natural geohazards or mand-made disasters.
vi. **Environmental Monitoring:** Satellite data tracks air and water pollution, enabling effective environmental monitoring and policy enforcement.
vii. **Climate Change Monitoring:** Earth observations help track climate patterns, sea-level rise, and glacier melting, enabling scientists to predict future changes and develop strategies for mitigation, adaptation, awareness and assessment of sustainable assessment goals (SDGs).
viii. **Weather Forecasting:** Satellite data provides critical inputs for accurate weather forecasting, enabling timely warnings for natural disasters like cyclones, floods, forest fire and droughts.
ix. **Ocean and Coastal Management:** Satellite data helps monitor ocean currents, sea surface temperature, and coastal erosion, supporting marine conservation and sustainable fishing practices.
x. **Human Health and Epidemiology:** Earth observations help monitor disease outbreaks, track vector-borne diseases, and understand the impact of environmental factors on human health.

Figure 6: Major Domains of Earth Observation (EO) Applications - *(Source: https://link.springer.com/article/10.1007/s12145-023-01032-5)*

In nut-shell, earth observations have revolutionized our understanding of the planet and transformed various aspects of our lives. Continued advancements in earth observation technologies will further enhance our ability to address global challenges and create a sustainable future.

1.2.1 Examples of Geospatial Application

(a) Geospatial Applications for Agriculture

The need for addressing World's food security is critical and urgent and geospatial information system comes handy in decision making to solve some of the problems. Geospatial technologies (EO, GIS, GPS, IoT etc) can gather critical information such as: (a) crop types, (b) precise location of crops, (c) cropping intensities (e.g., single crop, double crop), (d) cropping calendar, (e) crop health\vigor, (f) watering methods (e.g., irrigated, supplemental irrigated, rainfed), (g) flood and drought information, (h) water use assessments, and (g) yield or productivity. Possibility of such system can be set-up at global level through geo-spatial integration of information from various earth observation platforms in combination with national statistics, meteorology & ancillary data (e.g., elevation, precipitation, temperature), and field level ground observations data. A comprehensive remote sensing based global agricultural monitoring system has been realized by Group on Earth Observation Global Agriculture Monitoring Project (GEOGLAM)—a joint effort of NASA, USDA, UMD and SDSU. This system presents remote sensing data, derived products, and analysis tools of GLAM for agricultural crop-condition monitoring and production assessment at global level. GEOGLAM aims to provide timely forecasts of crop production and early warnings of potentially significant harvest shortfalls on a national, regional, and international basis.

With these backdrops in India, some of the key remote sensing applications in agriculture demonstrate how if it is used strategically in well-knit institutional framework could help in crucial policy decisions especially in food security context. India exemplifies a variety of remote sensing enabled products and services, which have formed the basis to enhance the information base in agriculture and to facilitate well-informed decision making processes with regards to food security issues.

Present day satellite systems can support food security issue for supplying information and services through village resource centres, distance education, communications on crop mapping, crop monitoring, production forecasting, early warning & crop insurance (pests/disease, drought and extreme events) and weather and climate observation etc.

Advantages of remote sensing based agricultural resource survey over traditional survey are as below:

- The potential for accelerated survey;
- Capability to achieve synoptic view under relatively uniform illumination conditions;
- Availability of multi-spectral data providing increased information;
- Capability of repetitive coverage to depict seasonal and long-term changes;
- Permitting direct measurement of several important agro-physical parameters which are used in crop growth assessment and yield prediction;
- Relatively inexpensive (monitoring from space);
- Remotely sensed data provide a permanent record.

(b) Geospatial Applications for Forestry

The forestry sector in India plays a key role in maintaining the ecological balance along with meeting the direct needs of a large rural human and livestock population in the country. Forest degradation and encroachment monitoring and to control on the use of forestland for non-forestry purposes we need constant monitoring of our forests. The conventional methods of forest resources assessment and monitoring are time consuming and full of various issues and inadequacies. The remote sensing and GIS technologies have positively impacted the process of forest resource assessment, monitoring and management.

Forest management is a multi-faceted activity involving forest change monitoring, forest fire prevention and monitoring, biodiversity assessment, protected area management, terrestrial biomass/carbon assessment, ecodevelopment planning, forest damage detection and forest development planning.

In view of the immense possibilities of geospatial technologies in forest management, its extensive use has been emphasized in the current forest management plans (e.g. Forest Working Plans). India's national forest monitoring system executed by Forest Survey of India (FSI) is expanding through advanced and innovative forest applications of remote sensing and geoinformatics techniques. The Indian space program has been the backbone in providing a continuous supply of remote sensing data to the National Forest Monitoring System, demonstration of technical methods and sharing of expertise. India's future satellite projects include missions like NISAR, TRISHNA, High Resolution Sampler, Advanced LISS etc. to address the challenges of better monitoring of forests.

1.4. Geoportals

Geoportals are web-based GIS interfaces designed to provide access to geospatial information, services, and applications. It acts as a gateway to a vast collection of information about the Earth's surface and its features whether collected through remote sensing or field survey.

Key functions of geoportals are:

- Data discovery and access
- Data visualization and analysis
- Sharing and collaboration
- Integration of multiple data sources
- User-friendly interfaces for users

1.3.1 Examples of Geoportals in India

The Indian Space Research Organisation (ISRO) has developed several user-friendly geoportals, including:

- **Bhuvan:** Offers a 3D visualization of India with thematic data layers and historical maps.
- **Bhoonidhi & Bhoonidhi Vista:** Provide access to Earth observation satellite data from Indian satellites.
- **VEDAS:** Enables visualization and analytics on various Earth observation and GIS datasets.
- **MOSDAC:** A comprehensive archival and near real time data of weather and oceanographic data.

Geoportals are powerful tools that democratize access to geospatial information. They empower individuals and organizations to understand and analyze our planet in new and innovative ways, making a significant contribution to sustainable development and informed decision-making.

1.5. Mobile Applications (GeoApps)

Mobile applications, or geoapps, bring the power of geospatial data and analysis to smartphones and tablets. They allow users to access and interact with geographic information on-the-go.

Key Features of Geo-Information Mobile Apps are:

1. **Real-Time Data Access**
   - Many apps provide up-to-date satellite imagery and geographic data, allowing users to monitor changes and events as they happen.
2. **User-Friendly Interfaces**
   - Mobile apps are designed with intuitive interfaces that make it easy for users to navigate maps, layers, and data sets without needing specialized training.
3. **GPS Integration**
   - Integration with GPS allows users to track their location, collect geotagged data, and navigate using maps.
4. **Offline Functionality**
   - Some apps offer offline access to maps and data, which is crucial for fieldwork in remote areas without internet connectivity.
5. **Interactive Tools**
   - Tools for measuring distances, drawing areas of interest, and annotating maps enhance the functionality of mobile geo-apps.

Advantages of GeoApps:

- Portability and accessibility
- Real-time data collection and updates
- Location-based services
- Integration with device sensors (GPS, camera, etc.)
- Offline functionality for field use

1.5.1. Examples of Mobile Apps for Earth Observation

1. **Google Earth**
   - Provides satellite imagery, maps, and 3D terrain data. Users can explore virtually any location on Earth, view historical imagery, and create custom maps.
2. **ArcGIS Mobile**
   - Developed by Esri, this app allows users to view and analyze GIS data, collect field data, and collaborate with others.
3. **Bhuvan Mobile App**
   - An Indian app developed by ISRO, providing satellite imagery and thematic maps for various applications such as agriculture, forestry, and urban planning.
4. **NASA's Earth Now**
   - Offers visualizations of near-real-time global climate data, including surface air temperature, carbon dioxide levels, and ozone concentrations.

Applications in Various Fields

1. **Disaster Management**
   - Apps like GDACS (Global Disaster Alert and Coordination System) provide real-time alerts and maps for natural disasters, helping in efficient disaster response and resource allocation.
2. **Agriculture**
   - Apps such as Plantix and FarmLogs assist farmers by providing crop health data, weather forecasts, and pest identification through remote sensing and field data.
3. **Environmental Monitoring**
   - Apps like EarthObserver and EcoTrack allow users to monitor environmental parameters such as air quality, water quality, and deforestation.
4. **Urban Planning**
   - Apps like CityMapper and UrbanFootprint help urban planners and citizens navigate cities, analyze urban growth, and plan sustainable infrastructure.

GeoApps have significantly democratized access to geospatial technology, allowing a wide range of users to benefit from location-based information and analysis. From professional applications in fields like urban planning and environmental management to everyday use in navigation and social networking, GeoApps have become an integral part of how we interact with and understand our spatial environment.

As mobile technology continues to advance, we can expect GeoApps to become even more powerful and integrated into our daily lives, further bridging the gap between digital geographic information and the physical world around us.

The integration of these technologies has led to the development of comprehensive Earth Observation Portals, which provide valuable tools for monitoring, analyzing, and managing our planet's resources and environments. In the following sections, we will explore the global landscape of these portals and focus on their applications in India.

2. State-of-the-art: Global scenario of geoportals and GeoApps including India

The global landscape of geoportals and GeoApps has evolved significantly over the past few decades, driven by technological advancements and changing user needs. Globally, several countries have developed advanced Earth observation portals. The European Space Agency's Copernicus Open Access Hub and NASA's Earth Observatory are prominent examples. India has emerged as a leader in the field of Earth observation. The Indian Space Research Organisation (ISRO) plays a vital role by operating a fleet of Earth observation satellites and disseminating data through user-friendly portals. These portals offer a vast collection of satellite data along with tools for analysis and visualization. This section explores the key trends, major players, and notable examples that characterize the current state of geospatial web services worldwide and in India.

2.1. Evolution and Trends:

1. Generational Development:
    - First-generation (late 1990s - early 2000s): Focused on metadata catalogues, limited interactivity.
    - Second-generation (mid-2000s - early 2010s): Introduced interactive map viewers, improved search functionalities.
    - Current-generation (2010s - present): Emphasis on user-friendly interfaces, diverse data integration, advanced visualization and analysis tools.
2. Technological Advancements:
    - Cloud computing: Enabling scalable storage and processing.
    - Big Data technologies: Handling large geospatial datasets and diverse data sources.
    - Artificial Intelligence and Machine Learning: Automated feature extraction and predictive modelling.
    - Web technologies: Improved browser-based visualization and API integration.
    - Mobile optimization: Responsive design and integration with mobile sensors.
    - Virtual and Augmented Reality: Immersive 3D visualization and on-site data overlay.
    - Blockchain: Ensuring data integrity and facilitating secure data sharing.

2.2. Key Players and Initiatives

1. Government Agencies:
    - National mapping agencies (e.g., USGS, Ordnance Survey)
    - Space agencies (NASA, ESA, ISRO)
    - Environmental protection agencies
2. International Organizations:
    - United Nations (UN-GGIM)
    - World Bank (ENERGYDATA.INFO)
    - Group on Earth Observations (GEOSS Portal)
3. Private Sector:
    - ESRI (ArcGIS Online)
    - Google (Google Earth Engine)
    - Maxar Technologies (formerly DigitalGlobe)

4. Open-source Communities:
    - OpenStreetMap
    - GeoNode
    - CKAN

2.3. Notable International Geoportal Examples

1. GEOSS Portal (Global Earth Observation System of Systems):
    - Integrates multiple Earth observation networks and satellite systems.
    - Covers nine societal benefit areas including agriculture, climate, and disasters.
    - Facilitates global cooperation in Earth observation.
2. INSPIRE Geoportal (European Union):
    - Harmonizes spatial data across 34 themes and 27 EU member states.
    - Supports cross-border and cross-sector interoperability of geospatial data in Europe.
    - Serves as a model for regional spatial data infrastructures.
3. USGS Earth Explorer (United States):
    - Provides access to satellite imagery, aerial photography, and other earth science data.
    - Supports scientific research, environmental monitoring, and land management applications.
    - Demonstrates the power of open data policies in promoting innovation.

2.4. Overview of Leading Global Geoportals

1. **Google Earth Engine**
    - A cloud-based platform for planetary-scale environmental data analysis. It combines a multi-petabyte catalog of satellite imagery and geospatial datasets with powerful analysis capabilities.
2. **NASA Worldview**
    - Part of NASA's Earth Observing System Data and Information System (EOSDIS), it provides interactive browsing of global satellite imagery, including real-time data.
3. **USGS Earth Explorer**
    - A portal for accessing remote sensing data, aerial photography, and geospatial data from the United States Geological Survey.
4. **Copernicus Open Access Hub**
    - Provides access to Sentinel satellite data, part of the European Space Agency's Copernicus program. It offers free and open data for environmental monitoring and management.

2.5. Indian Scenario:

India boasts a rich tradition in spatial data collection, with the more than 250 years old organisation named as “Survey of India”. India has developed a comprehensive geospatial organizational infrastructure covering the entire value chain, involving both government and private sector entities.

1. Government Initiatives:
   - Indian Space Research Organisation (ISRO) has developed various geoportals and decision support systems.
   - Bhuvan Panchayat (Version 4.0) for decentralized planning.
   - National Database for Emergency Management (NDEM Version 5.0) for disaster management support.
2. Geospatial Cloud-based Data Centre: A state-of-the-art facility is being established to manage high-resolution datasets from NSDI and State SDIs efficiently.
3. Major Geoportals:
   - E-Nakshe (Survey of India): Free access to authenticated Open Series Maps
   - BHARATH Maps: Multi-layer GIS platform integrating national datasets
   - India Geo Portal (NSDI): Offers interoperable geographic information services
   - BHUVAN (ISRO): Showcases Indian Earth Observation capabilities
   - KRISHI Geo Portal: Centralizes agricultural knowledge resources
   - IBIN - Indian Bioresource Information Network (IBIN)
   - SACHET – National Disaster Alert Portal of India
   - VEDAS (ISRO): Online geoprocessing platform for Earth observation data

2.6. Common Trends Across Geoportals

1. Integration of diverse data sources and promotion of open data policies
2. Advanced search and visualization capabilities
3. Emphasis on interoperability and data standards
4. Support for decision-making across various sectors

As geoportal and GeoApp technologies continue to advance, we can expect:

- Further integration of real-time data streams
- More sophisticated analysis tools and increased use of AI-driven techniques
- Enhanced mobile and cloud-based solutions
- Greater emphasis on user-friendly interfaces for non-expert users

The state-of-the-art in geoportals and GeoApp demonstrates a robust and growing field, with significant contributions from both global and Indian initiatives. The global scenario of geoportals and GeoApp is characterized by rapid technological evolution, increasing integration of diverse data sources, and a growing emphasis on accessibility and usability. These trends are reshaping how geospatial information is shared, analyzed, and applied across various sectors worldwide, including in India. These platforms play a critical role in advancing our understanding of the Earth, supporting various applications from disaster management to sustainable development.

3. Bhuvan: Gateway to Indian Earth Observation

Bhuvan, a versatile web-based Earth Observation platform, developed by ISRO, is a captivating geoportal offering a 3D visualization of India. It was launched in 2009 as a platform for accessing, visualizing, and analyzing geospatial data. Bhuvan, meaning 'Earth' in Sanskrit, is a key component of India's National Geospatial Information System (NGIS). It serves as a one-stop solution for various data products and services, showcasing the distinctiveness of Indian Earth Observation capabilities. Users can explore a wide range of thematic data layers, including land use, water resources, and infrastructure. Bhuvan also integrates historical maps and features like 3D flythroughs, making it an engaging tool for education and public awareness.

Vision: To demonstrate Indian Earth Observation (EO) capabilities through online rendering of multi-resolution, multi-temporal, and multi-sensor IRS imagery. Bhuvan overlays value-added thematic information on a 2D/3D virtual globe, provides satellite data and products for download, and offers thematic datasets as OGC web services for online geoprocessing, all while serving societal needs.

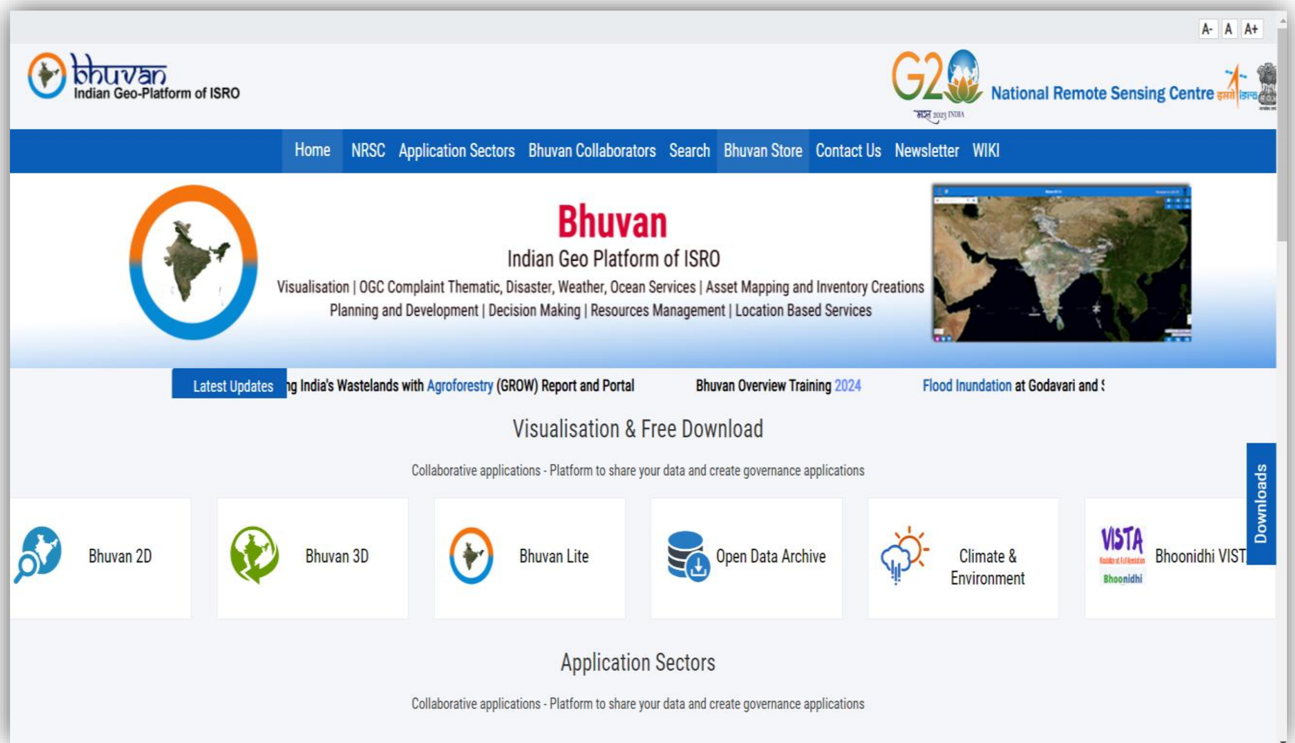


Figure 7: Bhuvan: ISRO's Comprehensive Geoportal for Earth Observation

Facts about Bhuvan:

- Bhuvan is a free online tool created by ISRO (Indian Space Research Organisation) that lets you explore and study the Earth using satellite images of India. It's like a special version of Google Earth focused on India.

- Bhuvan can:
    - Show you detailed satellite images of different parts of India
    - Display information about weather, fishing zones, and natural disasters
    - Let you download satellite data for research or projects
    - Allow you to mark important locations and share them with others
    - Help you measure distances and areas on the map
    - Connect with GPS devices to track locations in real-time

- On Bhuvan, you can see:
    - High-quality satellite images of India
    - 2D and 3D views of the Earth's surface
    - Detailed views of cities and important places
    - Information about natural resources

- The detail (or resolution) of images on Bhuvan varies:
    - Most of India is shown with at least 6-meter spatial resolution
    - Some areas have less detail (55-meter spatial resolution)
    - Many cities have very high detail (2.5-meter or even 1-meter spatial resolution data)

- Students can use Bhuvan to:
    - Explore places they're studying in subjects like science, geography, or history
    - See the landscape and surroundings of different areas in India
    - Create maps and mark interesting locations for projects
    - Learn about how satellite images are used in real-world applications

- Bhuvan is free to use. You don't need to register for basic features, but some advanced features require registration. Creating an account lets you share data, collaborate with others, and join discussions.
- Bhuvan has several main parts:
    - Bhuvan 2D: For viewing flat maps
    - Bhuvan 3D: For viewing 3D landscapes (requires a plugin download)
    - Open EO data archive: For downloading satellite data
    - Thematic data: For accessing specific types of information layers

- Bhuvan is special because it:
  - Focuses specifically on India with high-resolution images
  - Uses images from Indian satellites
  - Provides information about India's natural resources
  - Allows users to download free satellite data and products
  - Offers tools for analyzing geographic information
  - Offers information in multiple Indian languages
  - Combines map data with other useful information like weather and disaster alerts
  - Allows users to contribute and share their own data and observations
- With Bhuvan, you can:
  - Download satellite data for research or projects
  - Use mapping tools to organize and analyze geographic information
  - Access special map services (called OGC web services)
  - View how areas have changed over time
  - Learn about India's natural resources
- Bhuvan can be useful for:
  - Scientists studying the environment or geography of India
  - Government officials monitoring development projects
  - Educators teaching about India's landscape and resources
  - Students working on geography or environmental projects
  - Anyone interested in exploring detailed maps of India
- Bhuvan helps by:
  - Showing changes in natural resources over time
  - Raising awareness about how our environment is changing
  - Providing tools for researchers and the public to study these changes
  - Encouraging public participation in preserving natural resources
- Bhuvan is continuously developing. ISRO plans to add more features and services to make it even more useful for understanding and protecting India's natural resources.

3.1. Bhuvan Wiki

Bhuvan Wiki is a web application designed to publish information and engage Bhuvan users in sharing and contributing their knowledge. It serves as a collaborative platform where users can find and explore topics of interest. By providing a space for users to share their insights and experiences, Bhuvan Wiki helps to better connect the Bhuvan community and enhance the overall user experience.

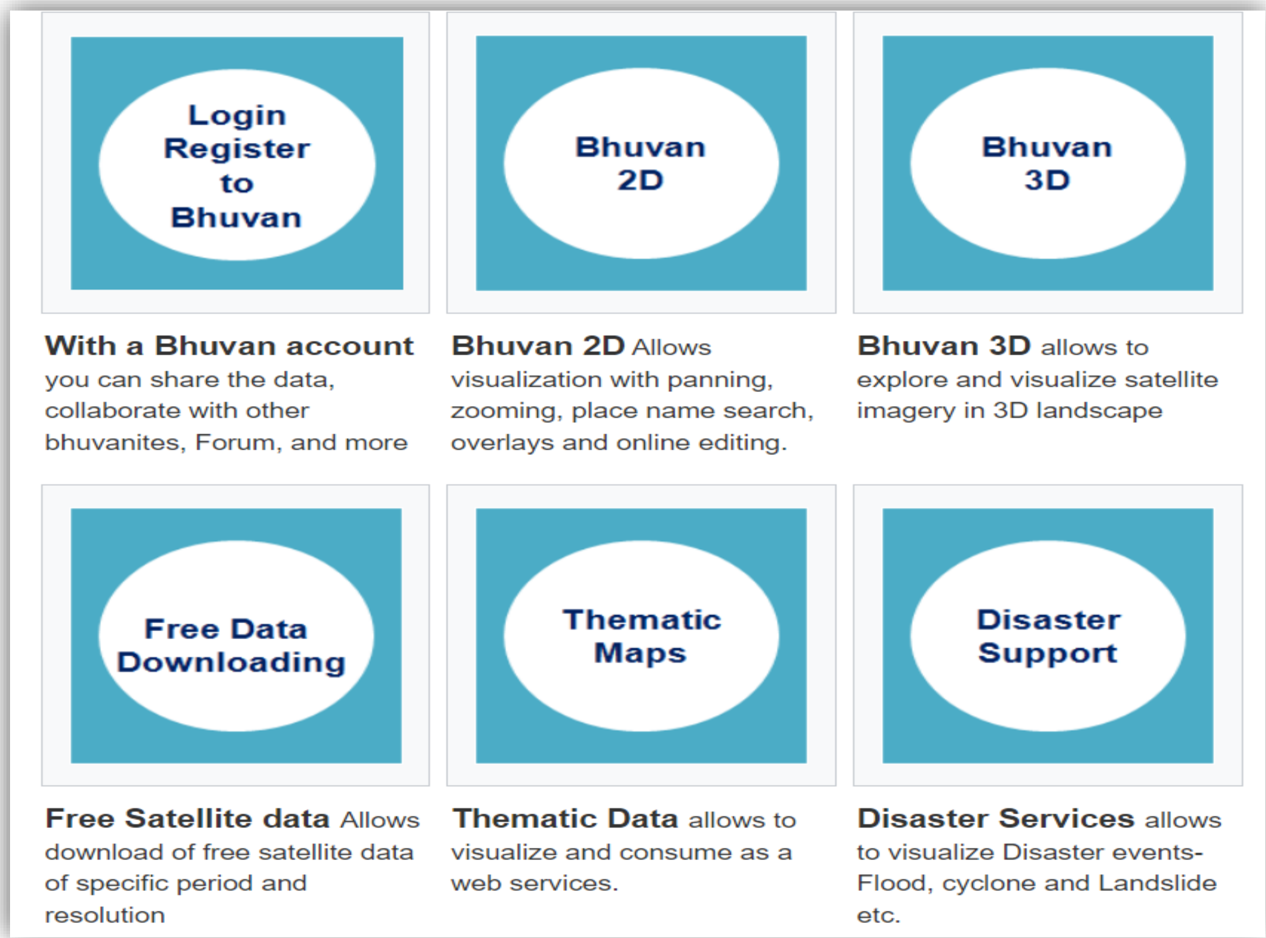


Figure 8: Bhuvan Wiki: Collaborative Knowledge Sharing Platform

3.2. Bhuvan 2D

The two-dimensional (2D) Bhuvan is a web mapping service application created using the OpenLayers open-source project. It provides easy-to-use mapping technology to organize satellite data and maps with lots of geographical information. What's great is that it doesn't need any special server setup, making it easy for anyone to use. Bhuvan 2D is an exciting and slick online mapping tool. It has a very responsive and user-friendly interface with detailed images and map data. Here are certain things you can do with Bhuvan 2D:

- **Map Navigation**: Move around and zoom in/out on maps easily.
- **Drawing Tools**: Draw points, lines, and shapes (polygons) on the map.
- **Shapefile Creation**: Create and upload your own map files directly online.
- **Geoprocessing**: Perform various map analysis tasks.
- **Overview Map**: See a smaller map to get a big-picture view while you work on details.
- **Measurement Tools**: Measure distances and areas on the map.

These features make Bhuvan 2D a really useful and fun tool for anyone interested in maps and geography.

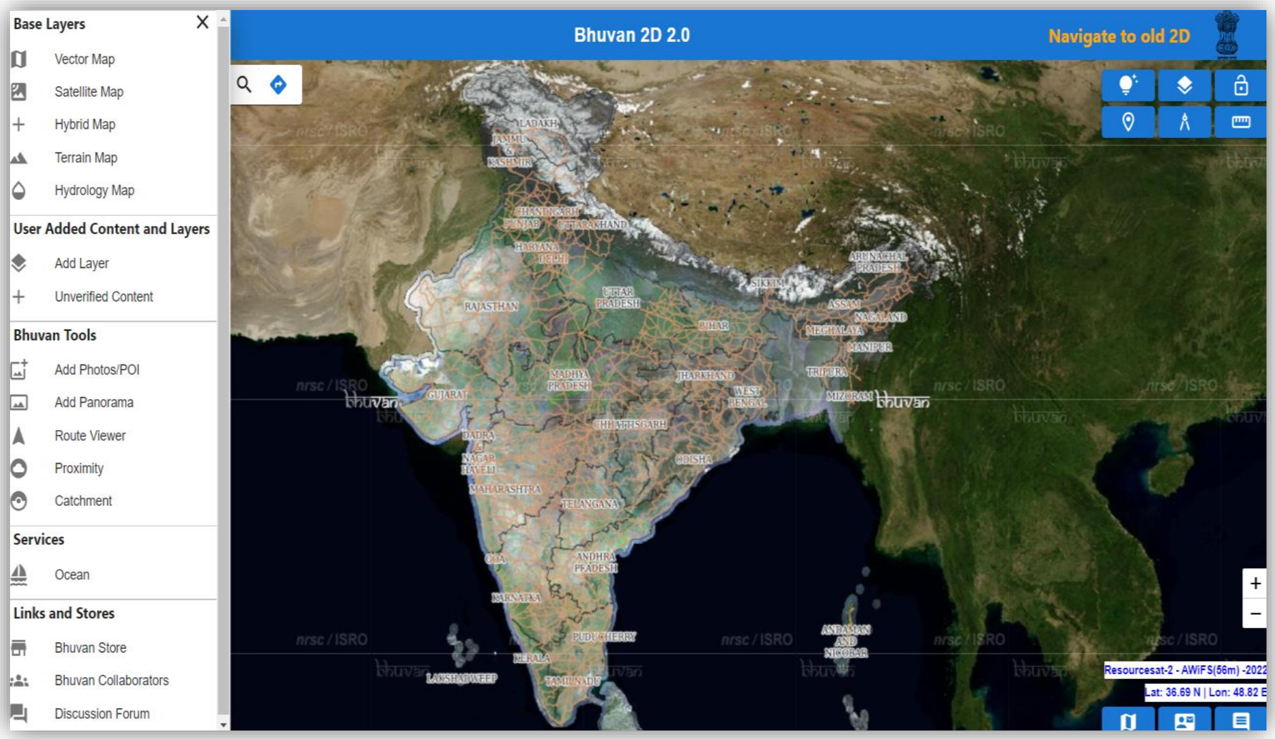


Figure 9: Bhuvan 2D Interface: User-Friendly Mapping and Analysis Tools

3.3. Bhuvan 3D

Bhuvan 3D is a geoportal that shows images in a 3D view using different sensors, platforms, and times. It lets you access, explore, and visualize images from the Indian Remote Sensing (IRS) satellites and lots of detailed information in a 3D landscape.

On Bhuvan 3D, you can:

- **Fly to Different Locations**: Move around and explore different places in 3D.
- **3D Navigation**: Experience amazing 3D navigation like flying over terrain.

Bhuvan 3D has many unique features and an easy-to-use interface. Here, you can:

- **See Physical Characteristics**: Virtually explore the physical features of the Indian landscape.
- **Urban Design Tools**: Design and build virtual roads, junctions, and traffic lights in a city setting.

Figure 10: Bhuvan 3D: Exploring India's Landscape in Three Dimensions

3.4. Pocket Bhuvan

Pocket Bhuvan is a mobile app that brings the features of the Bhuvan geoportal to your handheld devices.

Key Features:

- **Directions and Proximity:** Get directions and find nearby places easily.
- **Voice-Guided Navigation:** Get turn-by-turn driving instructions with voice guidance and live traffic information.
- **Downloadable:** You can download the app from the MSeva Application Store. The link for the same is copied here: https://apps.mgov.gov.in/
- **Earth Browser:** Access Earth Browser on your smartphone.

Pocket Bhuvan supports devices running on Android, Windows, Symbian, iOS, and BlackBerry OS.

With Pocket Bhuvan, you can explore and navigate using geospatial data right from your smartphone.

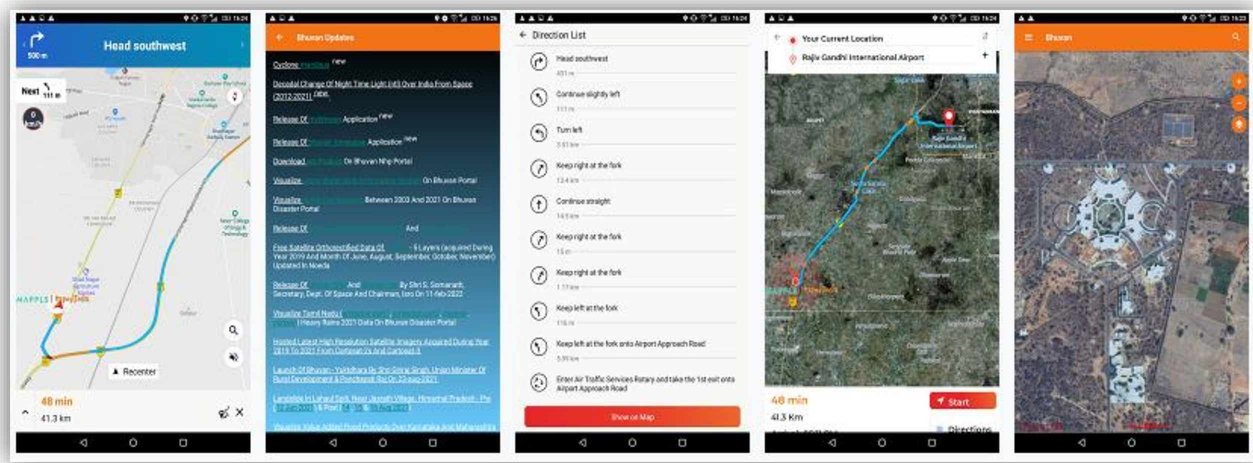


Figure 11: Pocket Bhuvan: Mobile Access to Geospatial Data

3.5. Bhuvan Lite

BhuvanLite is an easy-to-use and fast mobile app designed to work on both Android and iOS devices. It's built with the idea of "Utility with Simplicity," making it a lighter version of Bhuvan for the public. Here's what BhuvanLite offers:

- **Improved Search**: Find places and information quickly and easily.
- **Satellite Images and Base Map**: View high-quality satellite images and maps.
- **Distance and Directions**: Measure distances and get directions.
- **Sharing**: Easily share maps and locations with others.

Special Features:

- **Progressive Web Application (PWA)**: Works like an app but can be used from your web browser.
- **Device Level Caching**: Stores data on your device for faster access.
- **Push Notifications**: Receive updates and notifications directly on your device.
- **Tracking Mode**: With location permission, use GPS-enabled tracking for navigation.

BhuvanLite is designed to be simple yet powerful, making it easy for anyone to use on their mobile devices,

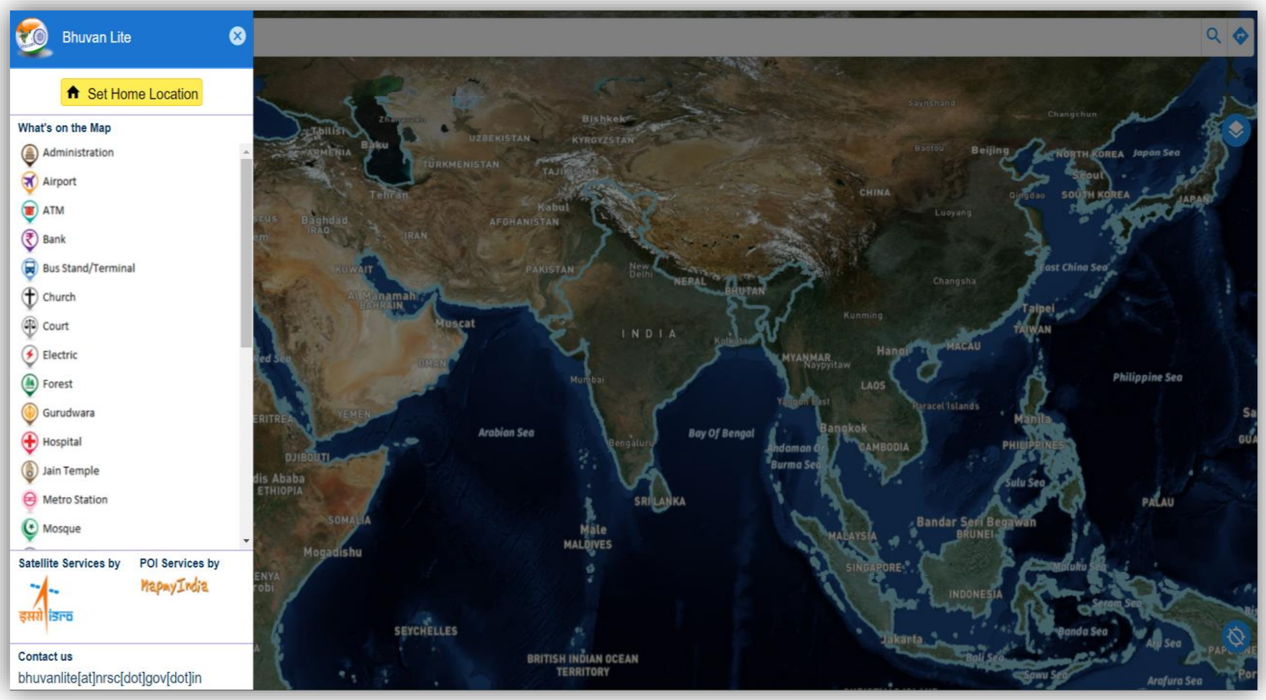


Figure 12: BhuvanLite: Simplified Geospatial Tools for Mobile Devices

Technological Advancements

The technological advancements in Bhuvan offers specialised data for India with unmatched details. This detailed information helps users at all levels make informed decisions using satellite imagery and other spatial data. Tools like Bhuvan-Panchayat enhance local governance, while Government improves disaster management. Bhuvan represents a significant leap in India's geospatial capabilities, providing robust solutions that meet diverse needs across the nation.

Key Features:

1. Interactive Earth-Browser: Showcases multi-sensor, multi-platform, and multi-temporal images
2. Thematic Overlays: Capability to overlay interpreted thematic information as vector layers
3. Real-time Information: Integrates data from Automatic Weather Stations (AWS), Potential Fishing Zone (PFZ) information, and disaster support related information
4. High-Resolution Data: Offers detailed mapping down to village level, covering over 7.5 lakh villages and 7,500 cities
5. Privacy-Focused: Ensures user data is not monetized or used for advertising
6. Indigenous Solution: Part of the Aatmanirbhar Bharat initiative
7. Specialized Services: Includes disaster management support, urban planning, and agricultural monitoring

Applications and Impact:

- Agriculture: Crop monitoring, soil health analysis, resource management
- Urban Planning: Infrastructure project design, land use optimization
- Disaster Management: Enhanced response time

3.6. Hands on Activity: Exploring Local Environment with Bhuvan

This exercise can be done to demonstrate how satellite data can be used to study our local environment.

Steps involved are:

1. Open your web browser and go to https://bhuvan.nrsc.gov.in/

2. In the search bar, type the name of your city or nearest large town.

3. Once you've found your area, try these tasks:

   a) Identify familiar landmarks: Spot your school, a nearby park, or a famous monument.
   b) Explore different layers: On the left side, you'll see options for various "layers". Try turning on and off layers like "roads", "railways", or "water bodies". Its interesting to see how does this change your view of the area.
   c) Measure distances: Find the measurement tools and try measuring the distance between two points you know. Try to understand how accurate it is compared to what you know in real life.
   d) Analyze land use: Look at the different colors and patterns in the satellite image. Can you identify areas of vegetation, urban development, or water bodies?
   e) Time travel: If available for your area, use the historical imagery feature to see how your locality has changed over time.

4. Prepare a report on findings around following key points:

   - What surprised you about how your area looks from above?

   - Did you notice any environmental changes or urban development patterns?

   - How could this tool be useful for urban planners or environmental scientists in your area?

This will give you real hands-on experience with geospatial technology and help you see your familiar surroundings in a new light.

4. Bhoonidhi & Bhoonidhi Vista: Treasure Trove of Satellite Data

Bhoonidhi is an online portal established by ISRO for accessing and purchasing Earth observation satellite data from various Indian satellites. It offers a wide range of data products with varying resolutions and coverage areas. Students, researchers, and industry professionals are empowered with valuable data categorized as Open Data, Open On-Order Data, and Priced Data as per the Indian Space Policy 2023. Bhoonidhi offers easy browsing and ordering with new filter-based search options, a new CART interface, and color-coded map displays. Users can search for data using filters like Open/Priced, Resolution, Imaging Spectrum, Satellite, Sensor Type, Products, and Themes. Bhoonidhi Vista is a user-friendly interface within Bhoonidhi, specifically designed for visualizing and analyzing data before purchase.

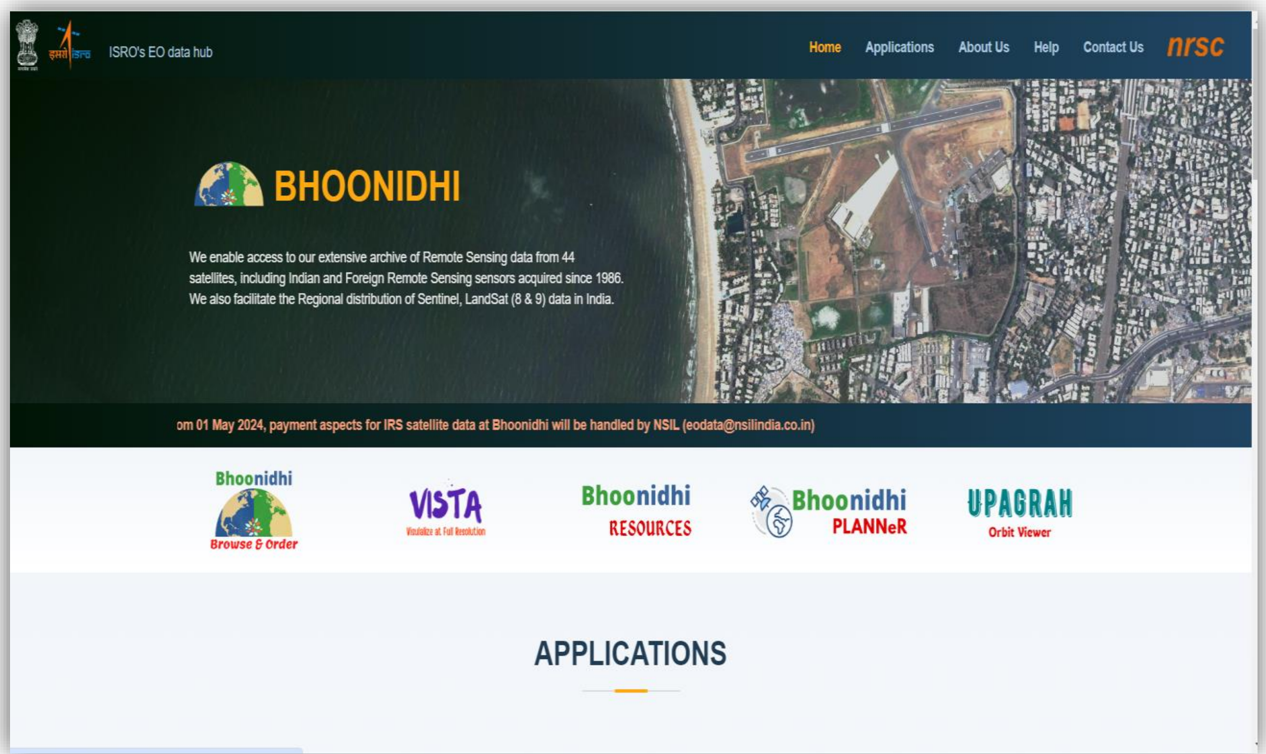


Figure 13: BHOONIDHI - ISRO's Earth Observation Data Hub Interface, showing available applications and remote sensing capabilities

- Bhoonidhi was created to make it easier for people to access and use India's satellite data and geospatial information. It aims to support various fields like research, education, and planning by providing valuable earth observation data.
- While basic access to Bhoonidhi is free, some advanced features or specific datasets might require registration or have usage restrictions. It's best to check the website for the most up-to-date information on access and use.

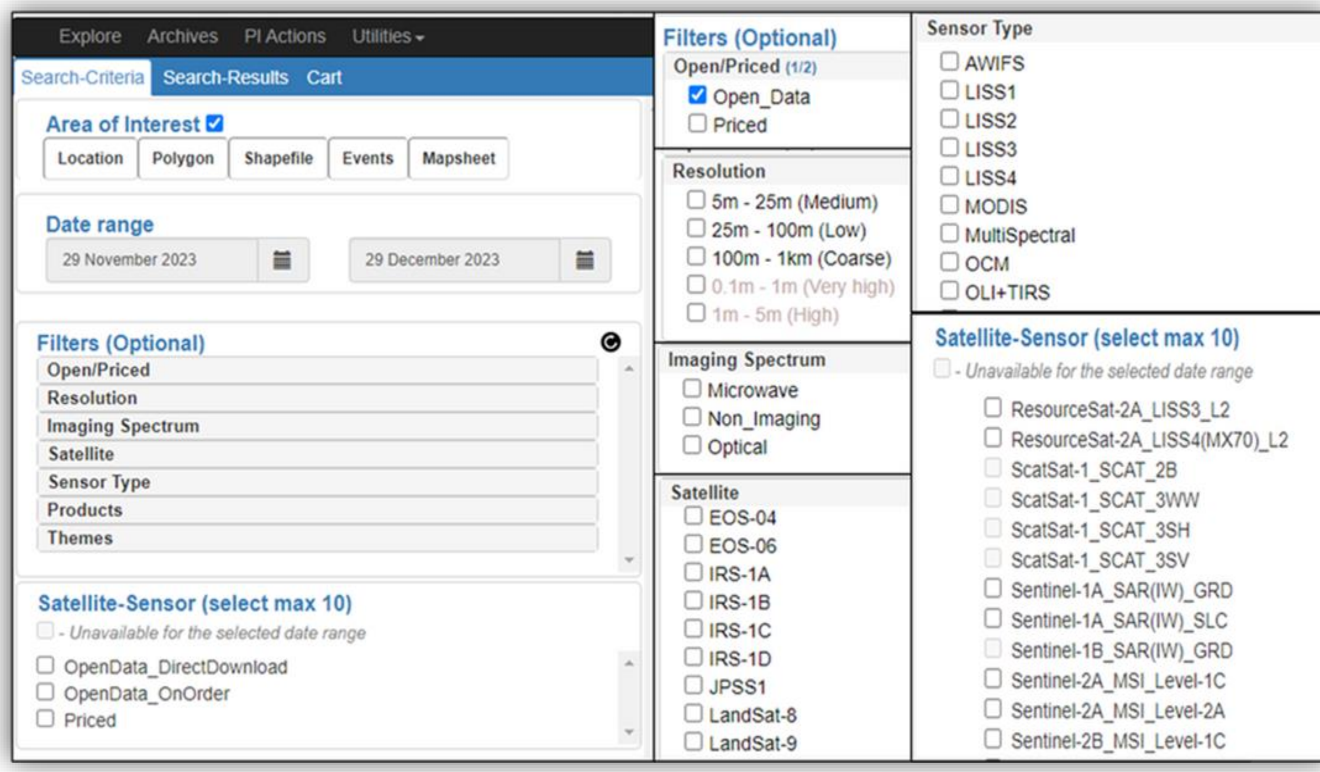


Figure 14: Data Selection Filters from Multiple Satellite Sensors in Bhoonidhi

Bhoonidhi is designed for a wide range of users, including:

- Students and researchers
- Government agencies
- Urban planners and developers
- Environmental scientists
- Anyone interested in exploring India's geography and resources

Bhoonidhi offers various types of data, including:

- Satellite images of India
- Topographic maps
- Land use and land cover information
- Vegetation data
- Urban area maps
- Disaster management information

Bhoonidhi is different because:

- It focuses specifically on India
- It provides access to official Indian satellite data

- It offers specialized geospatial information that might not be available on general map services
- It's designed to support scientific research and planning activities
- For basic use, you only need a web browser to access Bhoonidhi. However, to work with some of the data you download, you might need specialized GIS software.

Understanding and using Bhoonidhi can be valuable for:

- Pursuing studies in geography, environmental science, or urban planning
- Developing skills in data analysis and interpretation
- Understanding how satellite technology is used in real-world applications
- Preparing for careers that involve working with geospatial data

4.1. Bhoonidhi Planner

Bhoonidhi PLANNeR is an online tool provided by ISRO that allows users to plan and request new satellite data acquisitions.

Planning future acquisitions: This feature lets users request that satellites capture new images of specific areas in the future. It's useful when you need very recent data or if existing images don't meet your requirements.

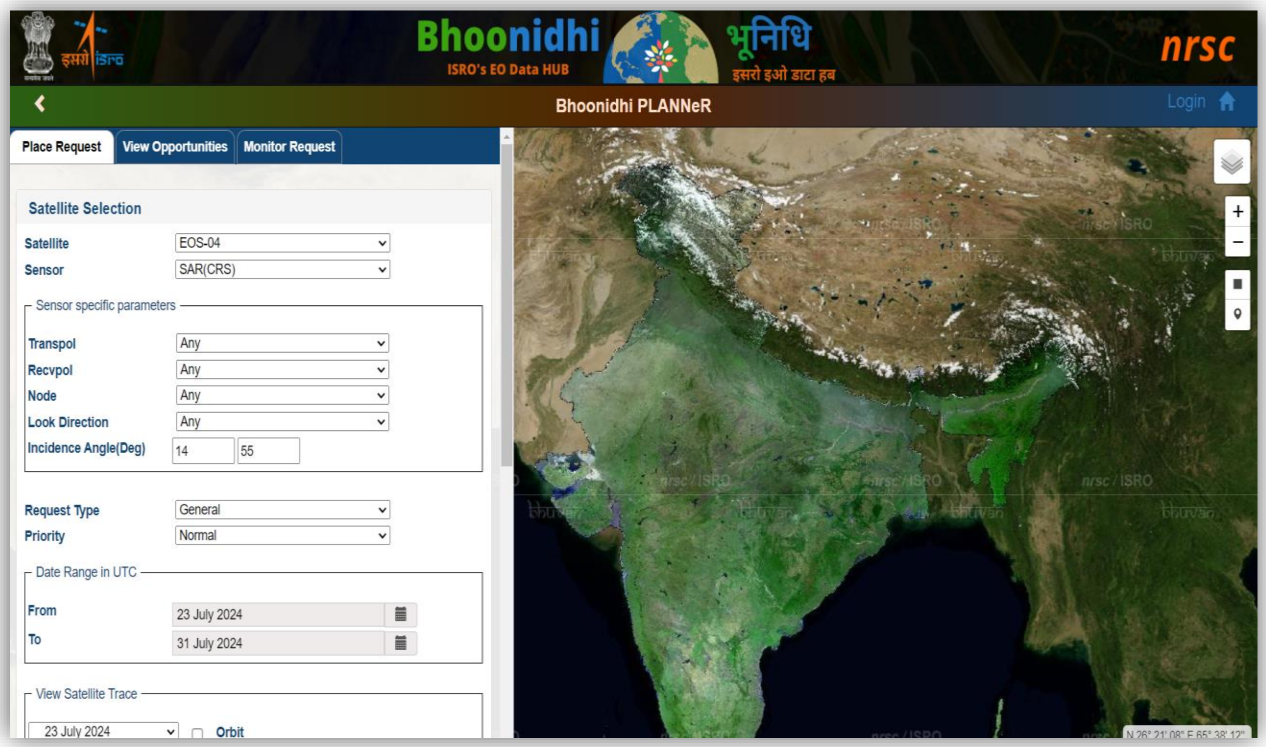


Figure 15: Bhoonidhi PLANNeR: Future Satellite Data Acquisition Planning Tool

Here's how it works:

- **Check Possibilities and Dates**: Users can look up when and where new satellite data can be collected.
- **Submit Requests**: If users need new data, they can submit requests for future acquisitions. To do this, users must be registered with Bhoonidhi and authorized by the NRSC (National Remote Sensing Centre).
- **Authorization**: User authorization is required to place a request. This ensures that only approved users can make new data requests.
- **Post-Acquisition**: Once the data is acquired, users can view the coverage area and order the data products from Bhoonidhi.
- **Availability for EOS-04**: Currently, PLANNeR is enabled for the EOS-04 satellite.
- **Request Process**: Users can use the online application to place requests for future dates, ensuring they get the data they need at the right time.

To access this service and place future acquisition requests for EOS-04, users can visit the https://bhoonidhi-planner.nrsc.gov.in/

4.2. Bhoonidhi VISTA – Multi Layer Visualization

Bhoonidhi VISTA - Visualization of Terrestrial Acquisitions is a portal that offers full-resolution multi-mission data visualization capabilities. It supports multiple missions and sensors, publishing visualization layers incrementally with each acquisition. Users can access various visualization and analysis modes, including day-wise layer visualization, latest cycle visualization, date-range visualization, change visualization through time-lapse animation, and change analysis using a comparison slider. Bhoonidhi VISTA provides essential insights for decision-making in diverse application domains and eliminates the need for users to search, download, or purchase satellite data and process it for visualization. Administrative and infrastructure overlays are also available for users to overlay on visualization layers. Bhoonidhi Vista is a feature within the Bhoonidhi geoportal that allows users to visualize and analyze multiple layers of satellite data at the same time. Multi-layer visualization means you can look at different types of map information stacked on top of each other, like putting transparent sheets with different information on top of a base map.

You can see two main types of layers:

1. Standard satellite layers (showing satellite images of the Earth)
2. Thematic layers (showing specific information like forest cover, water bodies, or urban areas)

Bhoonidhi Vista lets you choose which layers you want to see. You can:

- Add or remove the standard satellite layer
- Select which thematic layers you want to display
- Hide or show any layer you've added

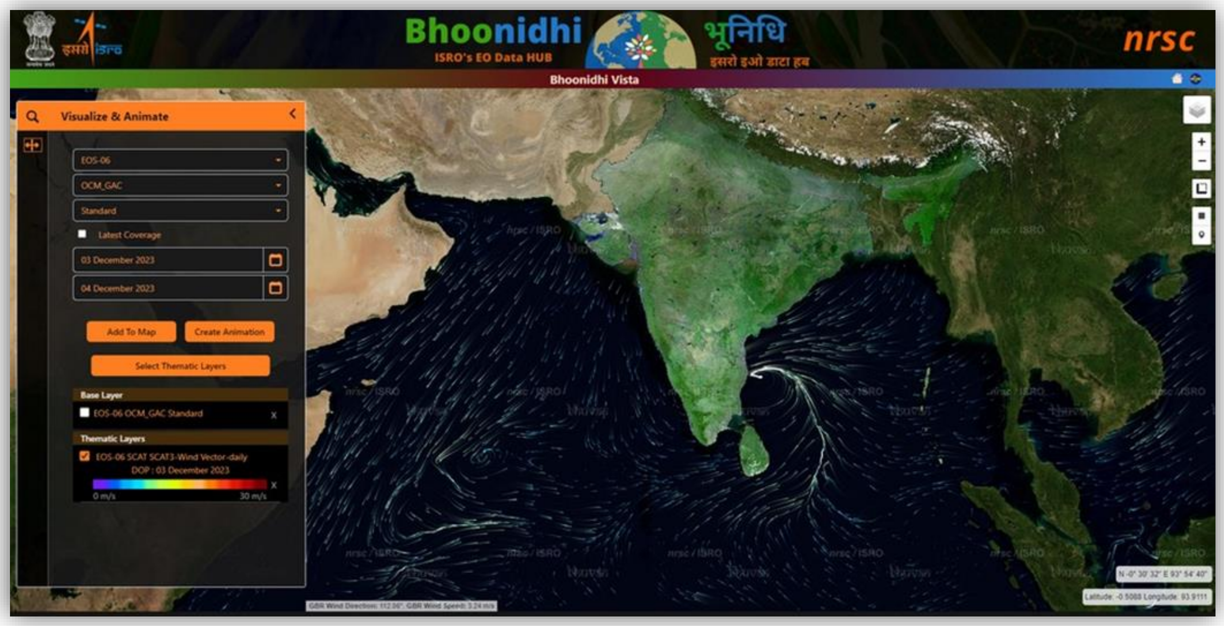


Figure 16: Bhoonidhi VISTA: Multi-Layer Visualization Interface

Seeing multiple layers allows you to:

- Compare different types of information about the same area
- Understand relationships between different geographic features
- Get a more complete picture of an area's geography

To "toggle" a layer means to switch it on or off. This allows you to quickly hide or show a layer without removing it completely from your view.

Bhoonidhi Vista is valuable because it:

- Gives users flexibility in how they view data
- Allows for easy comparison of different types of geographic information
- Helps users make connections between different aspects of geography
- Can aid in decision-making by providing a comprehensive view of an area

Unlike regular maps or simple satellite images, Bhoonidhi Vista allows you to:

- Combine different types of geographic data
- Customize your view based on what you're studying or interested in
- Interact with the data by turning layers on and off

Figure 17: Multi-Layer Visualization of Michaung Cyclone in Bhoonidhi VISTA

4.3. Hands-on-Activity: Exploring Your Local Environment with Bhoonidhi

This exercise will help us understand how geospatial data can be used to study your local environment.

Steps Involved Are:

1. Open your web browser and go to https://bhoonidhi.nrsc.gov.in/bhoonidhi/
2. In the search bar at the top, type the name of your city or nearest large town.
3. Once you've found your area, try these tasks:
4. a) Identify familiar landmarks: your school, a nearby park, or a famous monument

   b) Explore different layers: On the left side panel, you'll see various "layers" under different categories like "Base Layers", "Administrative Boundaries", "Infrastructure", etc. Try turning on and off layers like "Roads", "Railways", or "Water Bodies". How does this change your view of the area?

   c) Use drawing tools: Find the drawing tools in the toolbar and try measuring distances or areas. How does the size of familiar places compare to what you expected?

   d) Analyze thematic maps: Explore thematic maps under categories like "Land Use Land Cover" or "Soil". What can you learn about the natural resources in your area?

e) Explore disaster management data: If applicable to your region, look at layers related to floods, cyclones, or other natural disasters. What insights can you gain about vulnerability and preparedness in your area?

5. Write a short report on your observations. Consider these questions:
   - What new information did you discover about your area using Bhoonidhi?
   - How does the land use pattern in your area relate to its natural resources?
   - How could this tool be useful for disaster management or resource planning in your region?
   - What surprised you most about the data available for your area?
6. Bonus task: If you're familiar with GIS software, try downloading some layers and importing them into a GIS program (Q-GIS is a free software which can be used) for further analysis.

This activity will give you hands-on experience with a professional geospatial tool and help you understand the wealth of geographic information available about your area. It will also introduce you to how such tools can be used for resource management and disaster preparedness.

Bhoonidhi VISTA provides essential insights for decision-making in diverse application domains and eliminates the need for users to search, download, or purchase satellite data and process it for visualization. Administrative and infrastructure overlays are also available for users to overlay on visualization layers.

5. VEDAS: A Platform for Speedy Data Analysis

VEDAS (Visualization of Earth Observation Data and Archival System) is an ISRO project that provides a web-based platform for viewing and analyzing Earth observation data. It allows users to work with different types of satellite data, such as optical images, radar data, thermal imagery, and hyperspectral images, without having to download large files.

VEDAS makes it easy for users to perform quick analysis tasks using a user-friendly web and mobile interface. This platform is useful for a variety of fields, including research, urban planning, agriculture, and renewable energy. It helps users access and use geospatial data effectively, making it a valuable tool for understanding and managing our environment.

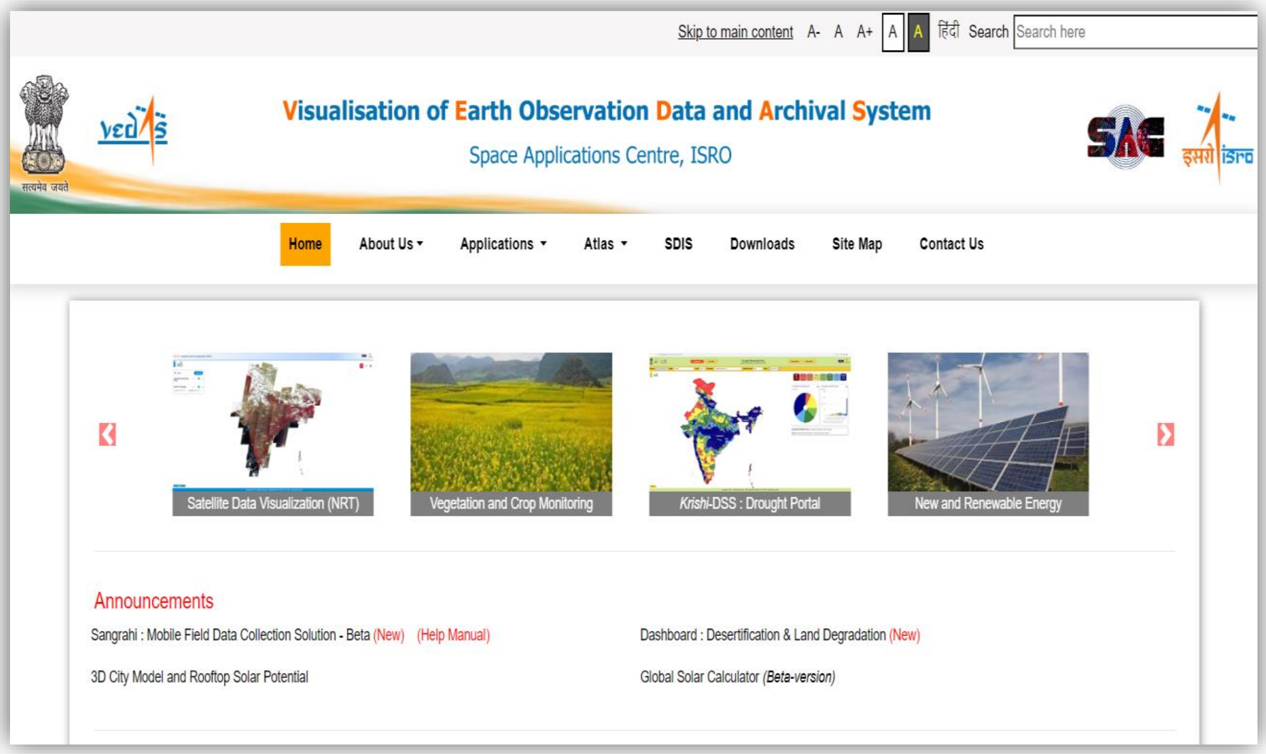


Figure 18: VEDAS Platform: Integrating Various Earth Observation Data Sources

VEDAS uses various types of satellite data, including:

- Optical (regular camera-like images)
- Microwave (radar-type images)
- Thermal (heat-detecting images)
- Hyperspectral (images that capture many different light wavelengths)

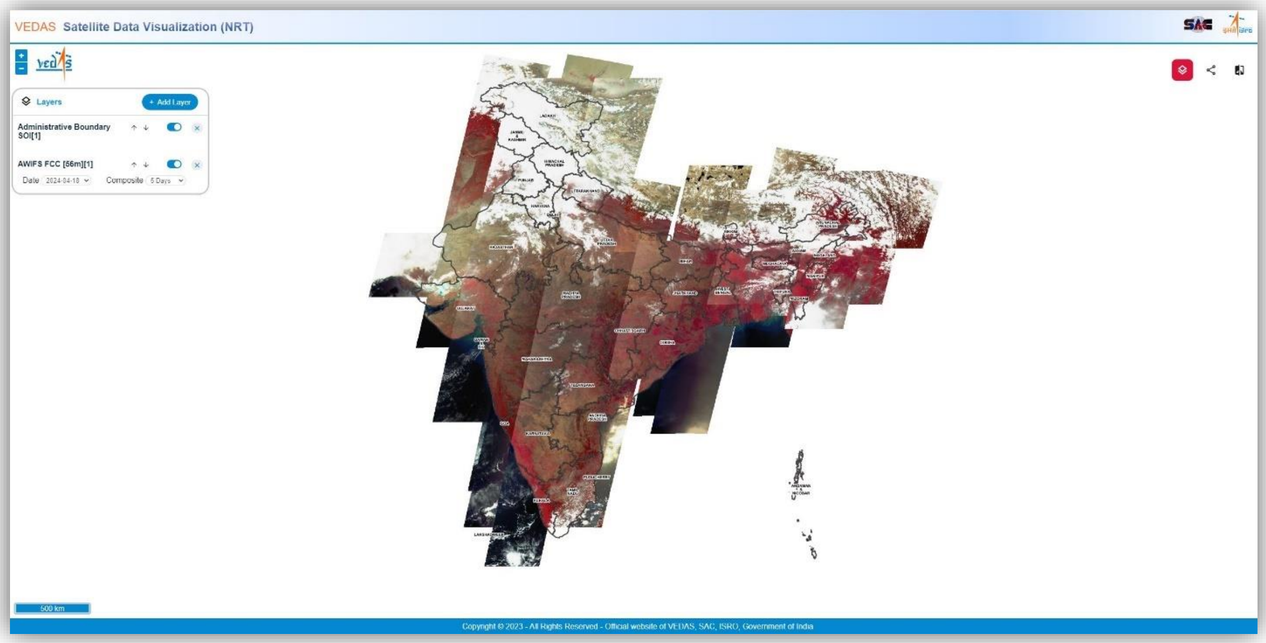


Figure 19: Unified Visualization and Analysis Tools in VEDAS

The key features of VEDAS include:

1. A platform for research and training
2. Tools to visualize data and create graphs on the web
3. Online tools for geographic data analysis
4. The ability to combine map data from various sources

VEDAS helps by:

- Providing data and tools to create custom geographic applications
- Allowing users to analyze patterns in data over time and space
- Offering "what-if" scenario tools for decision-makers

VEDAS covers many themes, including:

- Agriculture
- Forestry
- Desertification (land turning into desert)
- Wetlands
- Snow and glaciers
- Coastal zones
- Marine ecosystems
- Polar science
- Hydrology (study of water)

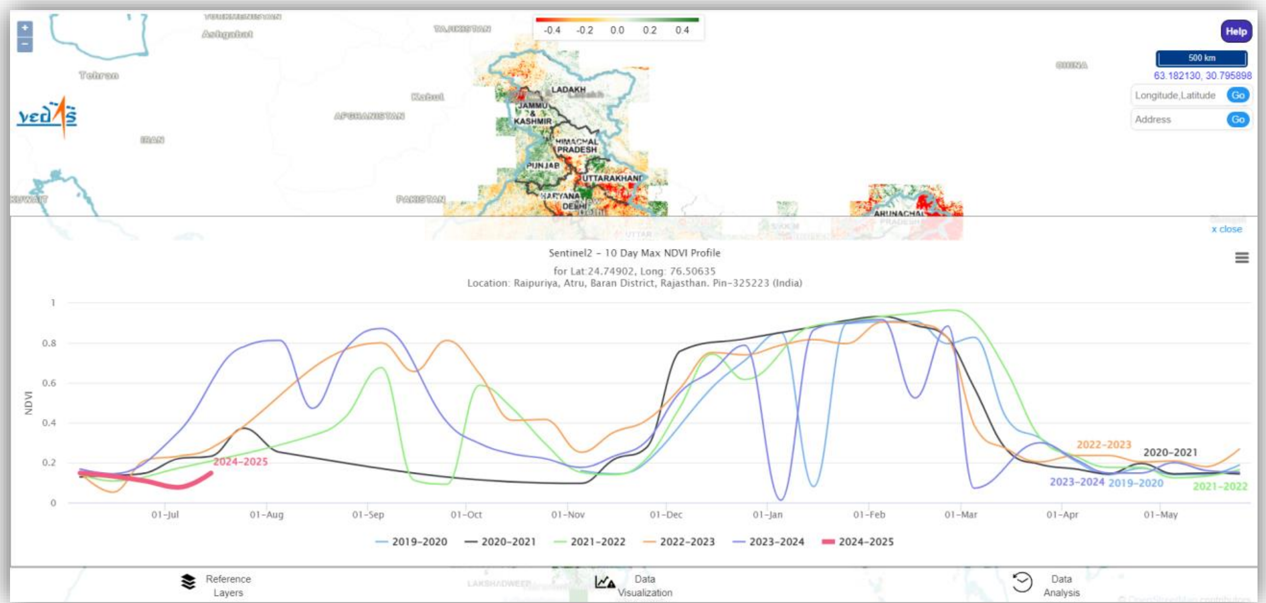


Figure 20: VEDAS Thematic Applications and Analysis Tools (Vegetation Analysis using Normalised Difference Vegetation Index - NDVI patterns)

NDVI (Normalized Difference Vegetation Index) is a way to measure plant health using satellite data. Forecasts of NDVI can help farmers make better decisions about crop management.

The above kind of analysis help by:

- Allowing farmers and managers to assess crop health
- Monitoring crop growing conditions
- Providing forecasts of vegetation health (NDVI) to help in crop management

Some important applications on VEDAS include:

1. Vegetation monitoring
2. New and renewable energy analysis
3. Urban sprawl information system
4. Hydrological (water-related) applications
5. Cryosphere (ice and snow) applications
6. Air quality monitoring

VEDAS offers several Android GeoApps, including:

1. Solar Calculator (for India and Africa)
2. Wind Calculator
3. National Wetland Inventory Assessment (NWIA)
4. Track Record (for collecting geo-tagged video data)

These GeoApps help users:

- Calculate solar and wind energy potential in different areas
- Access information about wetlands
- Collect location-based data and videos
- Gather various types of field data on mobile devices

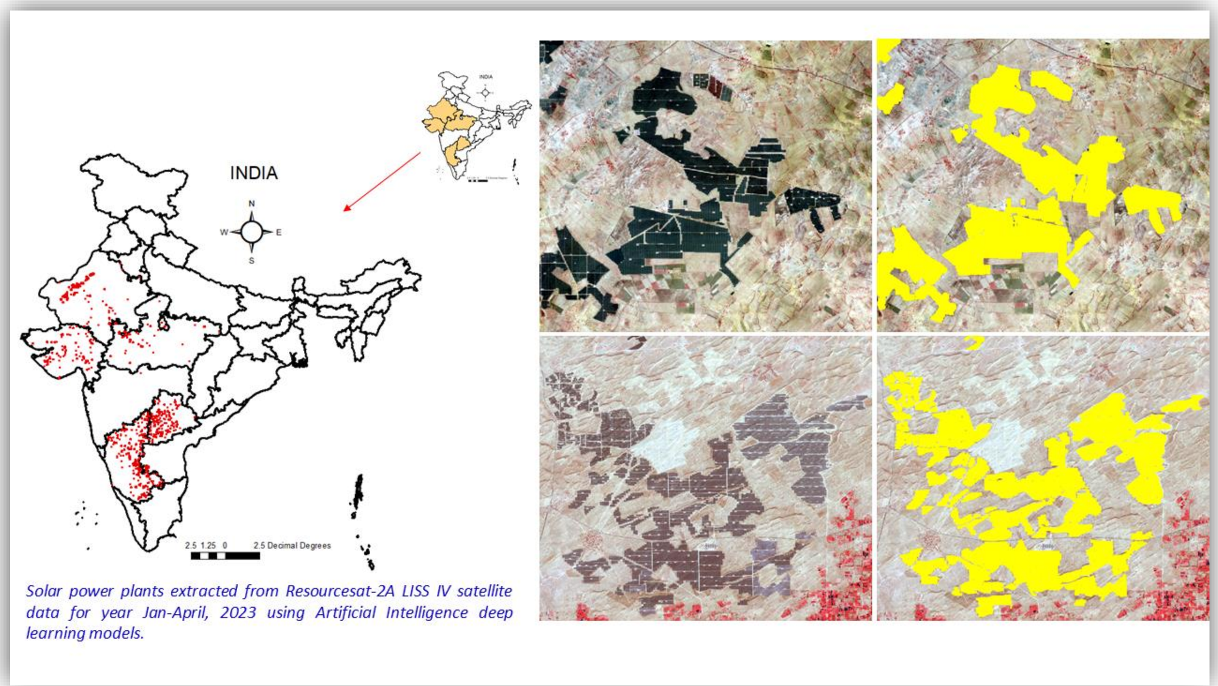


Figure 21: AI-based Solar Power Plant Extraction in Rajasthan using Resourcesat LISS IV Data

VEDAS helps with renewable energy by:

- Identifying potential areas for solar, wind, and wave energy
- Providing 72-hour forecasts of sunlight intensity for solar energy planning
- Offering mobile apps that give location-based information on renewable energy potential

Urban planners can use VEDAS to:

- Make informed decisions about city development
- Understand and predict urban sprawl (how cities grow outwards)
- Study how urban growth affects the environment

VEDAS offers data on hydrology (water) and the cryosphere (ice) to help:

- Plan for water security

- Monitor and manage water-related disasters
- Understand changes in glaciers and snow cover

The mobile apps are important because they:

- Allow researchers to collect and store field data easily
- Provide a systematic way to archive valuable data collected at great cost and effort
- Make it easier to gather location-specific information

VEDAS is important because:

- It makes complex scientific data accessible to more people
- It helps in making informed decisions about resource management and development
- It encourages the use of satellite data for solving real-world problems
- It provides valuable tools for research and education
- It expands the societal benefits of India's investments in Earth science research
- It encourages innovative use of data from Indian satellites
- It supports decision-making for various environmental and developmental issues
- It helps in identifying "hot-spots" and discovering hidden patterns in geographic data

In essence, VEDAS acts as a bridge between raw Earth observation data and meaningful insights. It empowers researchers to unlock the secrets hidden within these vast datasets, contributing to advancements in various fields such as environmental monitoring, resource management, and disaster preparedness.

5.1. Hands-on Activity: Exploring Your Local Environment with VEDAS

Following are the steps for practical activity using VEDAS:

1. Open your web browser and go to https://vedas.sac.gov.in/
2. On the homepage, click on "Geoportal" under the "Tools" section.
3. In the search bar at the top, type the name of your city or nearest large town.
4. Once you've found your area, try these tasks:

   a) Identify familiar landmarks: spot your school, a nearby park, or a famous monument.

   b) Explore different layers: On the left side panel, you'll see various data layers categorized under different themes like "Atmosphere", "Land", "Ocean", etc. Try turning on and off layers such as "Land Use Land Cover", "Forest Cover", or "Surface Water".

   c) Use analysis tools: Find the toolbox icon and explore options like "Area Calculator" or "Distance Calculator". Try measuring the area of a nearby park or the distance between two landmarks you know.

   d) Analyze environmental data: Explore thematic layers like "Aerosol Optical Depth" or "Land Surface Temperature" to learn about the environmental conditions in your area.

e) Time series analysis: For certain layers, you can view data over time. Try this with layers like "Normalized Difference Vegetation Index (NDVI)" to see how vegetation has changed in your area over different seasons or years.

5. Write a report on your observations by consider some of the questions like:
   - What are the prevailing values of local environmental parameters in your area?
   - Did you notice any patterns in environmental parameters like air quality, vegetation health, or urban heat islands?
   - How could this tool be useful for environmental scientists or policy makers in your area?
   - What surprised you most about the satellite-derived data available for your region?

This activity will give you hands-on experience with a sophisticated Earth observation data portal and help you understand how satellite technology is used to monitor and study our environment. It will also introduce you to the types of data used by scientists to study climate change, urban development, and other environmental phenomena.

6. MOSDAC: Monitoring Our Weather

The Meteorological & Oceanographic Services Data Archive System (MOSDAC) is a comprehensive archive of weather and oceanographic data maintained by ISRO. This portal provides access to historical and real-time data on various weather parameters, including rainfall, temperature, and wind speed.

Purpose and Functionality:

- **Data Archival**: MOSDAC serves as a central repository for meteorological and oceanographic satellite data. It stores large volumes of satellite data collected over time.
- **Data Processing and Distribution**: The centre processes raw satellite data and makes it available for users, providing a range of products and services related to weather and ocean observations.

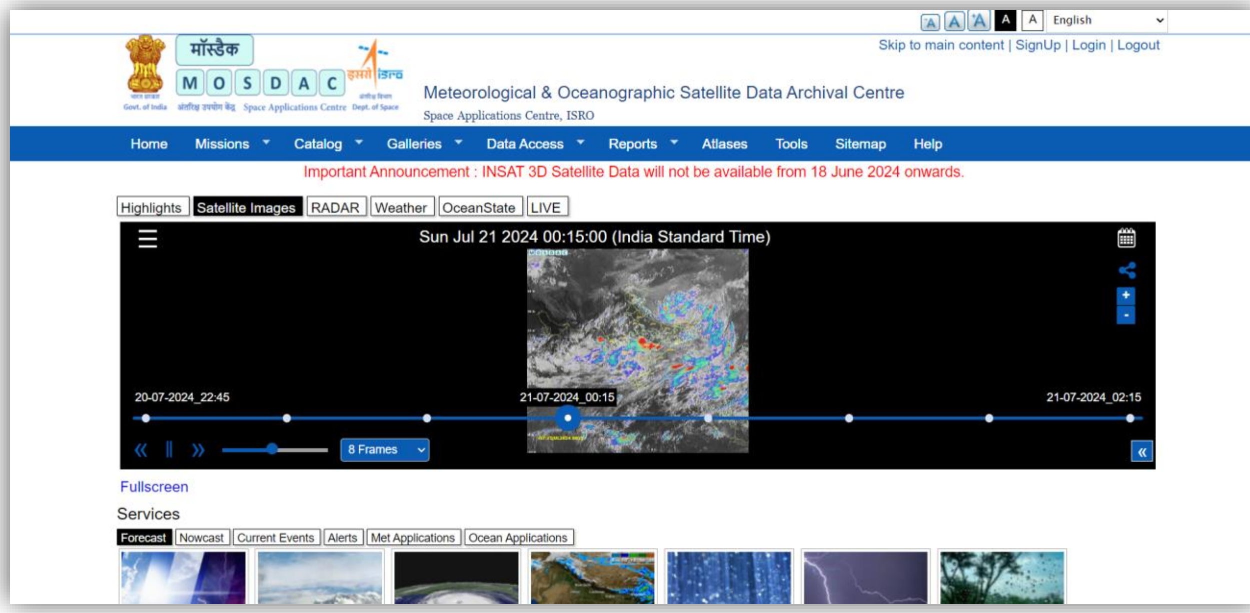


Figure 22: MOSDAC: Meteorological and Oceanographic Satellite Data Archival Centre

MOSDAC is a data repository (a place where data is stored and managed) for Indian Space Research Organisation (ISRO) missions related to weather, oceans, and the water cycle in tropical regions.

MOSDAC provides data on:

- Meteorology (weather)
- Oceanography (study of oceans)
- Tropical water cycles

- Satellite Based Cyclone Observation and Real-time Prediction over Indian Ocean (SCORPIO) as a WebGIS based Cyclone Information System service.

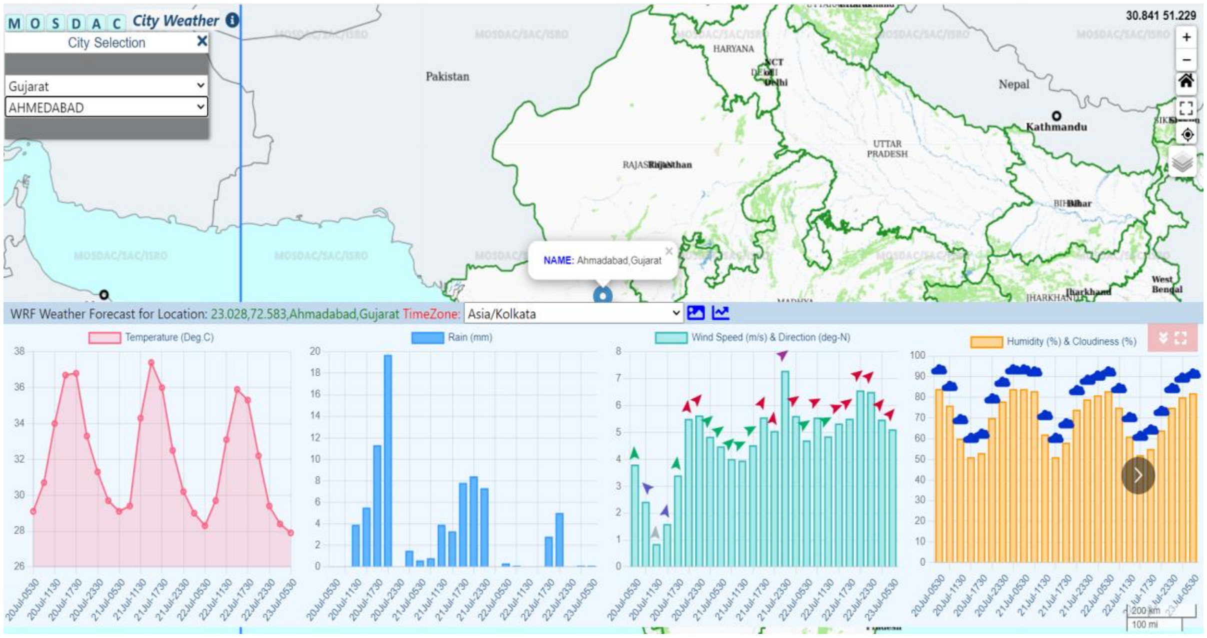


Figure 23: MOSDAC Real-Time Weather Forecast Display

The data is disseminated (shared) in near real-time, which means very quickly after it's collected by satellites. There's a free Android app also that provides access to forecasts and weather alerts.

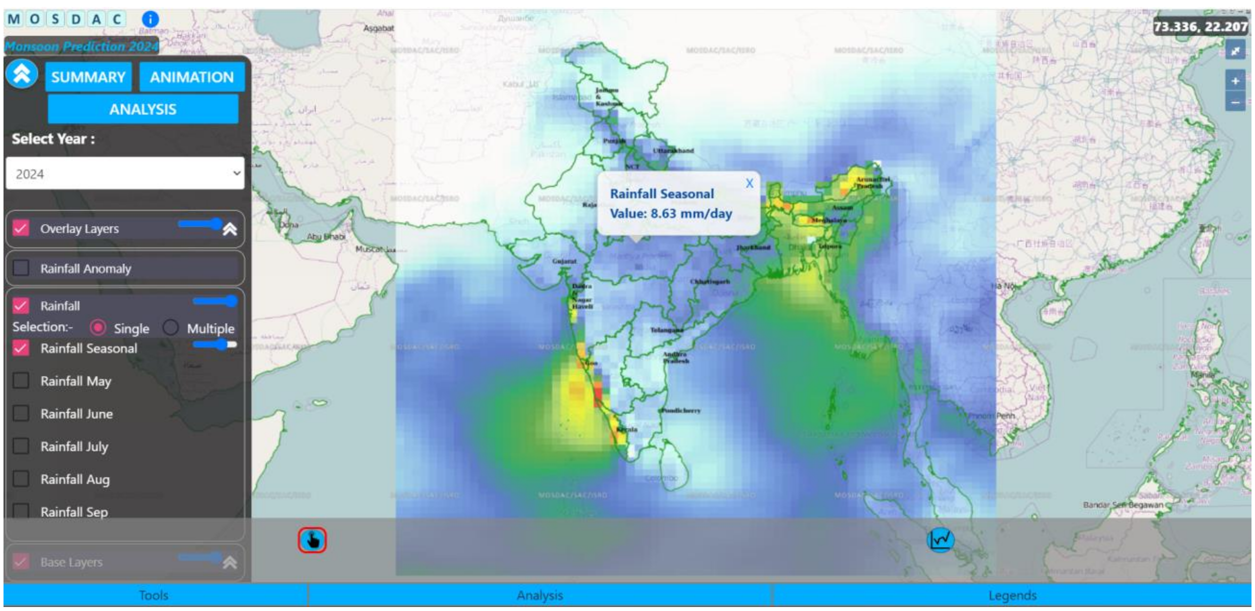


Figure 24: MOSDAC Real-Time Monsoon Prediction Forecast Display

MOSDAC offers several weather services, including:

1. Cloud burst and heavy rain alerts
2. Information on tropical cyclones in the Indian Ocean, including their paths and intensity predictions
3. Weather forecasts every three hours for the next 72 hours

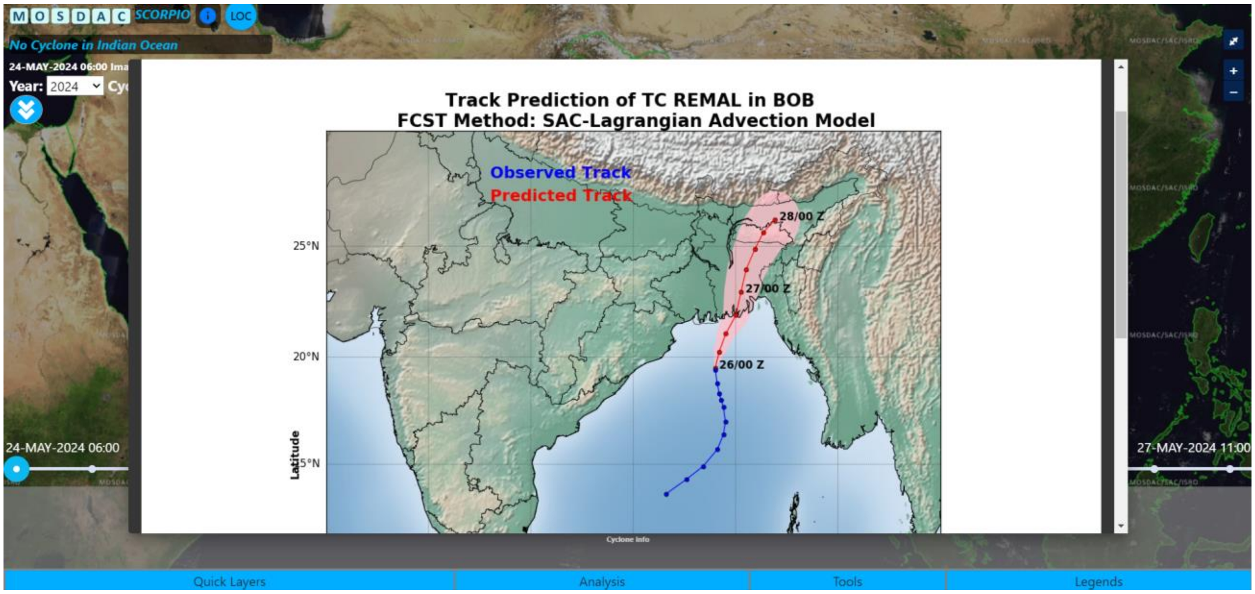


Figure 25: MOSDAC Cyclone Tracking and Intensity Prediction Interface

MOSDAC plays a role in global weather monitoring by:

- Providing data to the Committee on Earth Observation Satellites
- Ensuring quick availability of data from the Meghatropiques mission for the Global Precipitation Measurement (GPM) project

MOSDAC is important because it:

- Provides crucial data for understanding and predicting weather patterns
- Supports research in meteorology and oceanography
- Contributes to global weather monitoring efforts
- Offers practical weather services that can help in disaster preparedness

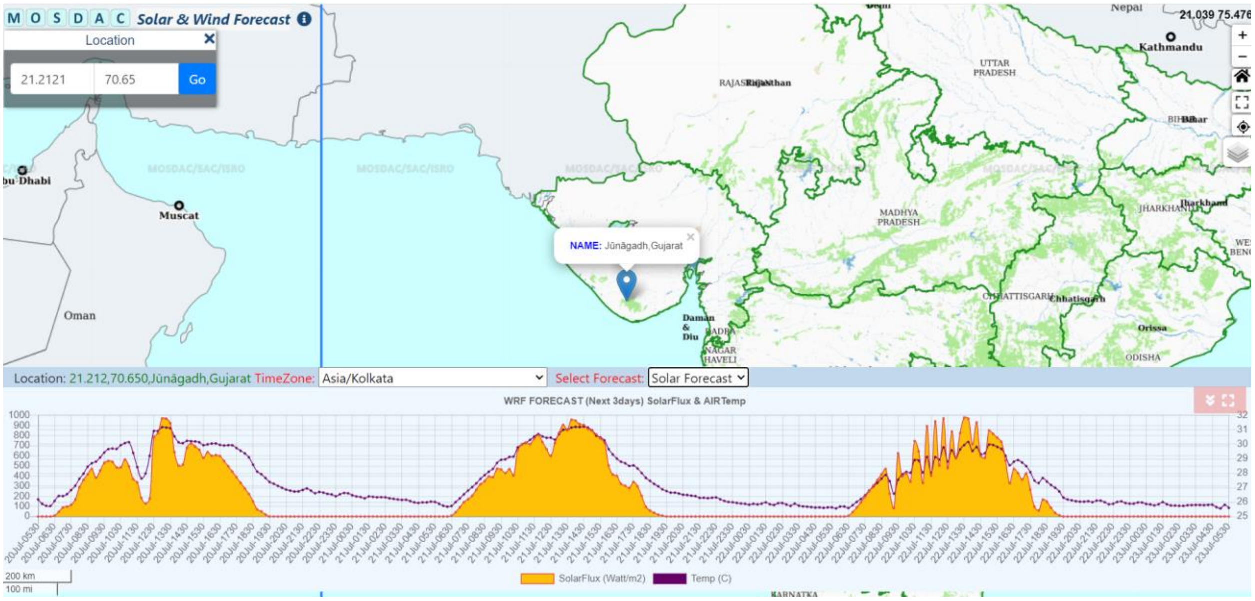


Figure 26: MOSDAC Mobile App Interface for Weather Services

<u>Access and Usage:</u>

- **Data Access**: Users can access a wide range of data products through MOSDAC's online portal. The portal offers tools for searching, downloading, and analyzing satellite data.
- **Products and Services**: MOSDAC provides various products, including satellite images, data sets, and analytical tools. These products are often available in different formats to suit various needs.
- **User Support**: It offers support and guidance for users to help them effectively use and interpret the data.

Key Satellite Missions Supported:

- **METSAT (Meteorological Satellite)**: Provides data on weather patterns and atmospheric conditions.
- **INSAT/IRS Satellites**: Collect data on meteorology and oceanography, including sea surface temperatures and weather forecasting.
- **OCEANSAT Satellites**: Specialize in oceanographic observations, including sea surface temperature and ocean color.

MOSDAC plays a crucial role in providing high-quality meteorological and oceanographic data, supporting various applications from weather forecasting to climate research and disaster management.

6.1. Hands-on Activity: Exploring Weather and Ocean Data with MOSDAC

Let's embark on an exciting practical activity using MOSDAC, India's portal for meteorological and oceanographic satellite data. Following are the steps:

1. Open your web browser and go to https://www.mosdac.gov.in/
2. On the homepage, click on "Visualization" under the "Services" menu.
3. In the map viewer, navigate to your local area or a coastal region you're interested in studying.
4. Once you've found your area of interest, try these tasks:

   a) Explore weather data: In the left panel, under "Layers", expand the "Weather" category. Try turning on layers like "Cloud Top Temperature" or "Rainfall". What can you learn about current weather conditions?

   b) Analyze ocean data: If you're looking at a coastal area, explore layers under the "Ocean" category. Try options like "Sea Surface Temperature" or "Chlorophyll". What do these tell you about ocean conditions?

   c) Use different satellites: MOSDAC offers data from various satellites. Try switching between different satellite products (e.g., INSAT-3D, SCATSAT-1) and see how the available data changes.

   d) Time series analysis: For many layers, you can view data over time. Use the time slider at the bottom of the screen to see how weather patterns or ocean conditions have changed over recent days or weeks.

   e) Compare with forecasts: If available, compare current satellite observations with forecast layers. How accurate are the predictions compared to actual observations?

5. Write a short report on your observations. Consider these questions:
   - What new insights did you gain about weather patterns or ocean conditions in your chosen area?
   - Did you notice any interesting meteorological phenomena or oceanic features?
   - How could this tool be useful for meteorologists, oceanographers, or disaster management officials in your region?
   - What surprised you most about the satellite-derived data available through MOSDAC?
6. Bonus task: If your school has access to weather instruments, compare the satellite data with your local ground-based observations. How do they differ and why might that be?

This activity will give you hands-on experience with a sophisticated meteorological and oceanographic data portal. It will help you understand how satellite technology is used to monitor and predict weather and ocean conditions. This knowledge is crucial for various applications, from daily weather forecasting to long-term climate studies and disaster preparedness.

7. Comparison between Indian and International Geoportals

Now, let's take a global perspective on Earth observation portals. While India has made impressive strides with platforms like Bhuvan, VEDAS and MOSDAC, it's interesting to see how these compare with international counterparts.

A. <u>Bhuvan vs. Google Earth:</u>

- Bhuvan focuses specifically on India, offering more detailed and frequently updated data for our country.
- Google Earth provides global coverage but may have less detailed information for some parts of India.
- Bhuvan offers many India-specific applications, like watershed management tools, which aren't available on Google Earth.

B. <u>VEDAS vs. NASA Worldview:</u>

- VEDAS focuses specifically on Indian satellite data visualization, offering more detailed analysis for our country.
- NASA Worldview provides global coverage but may have less detailed information for some parts of India.
- VEDAS offers many India-specific applications, like monsoon monitoring tools, which aren't available on NASA Worldview.

C. <u>MOSDAC vs. EUMETSAT Data Store:</u>

- MOSDAC specializes in meteorological and oceanographic data for the Indian region, providing more accurate local forecasts.
- EUMETSAT Data Store offers broader European and global weather data but may be less precise for Indian conditions.
- MOSDAC provides India-specific products, like cyclone tracking in the Bay of Bengal, not found in EUMETSAT.

D. <u>Bhoonidhi vs. USGS Earth Explorer:</u>

- Bhoonidhi focuses on natural resource management data for India, offering more detailed local information.
- USGS Earth Explorer provides global satellite imagery but may lack specific data layers relevant to Indian ecosystems.
- Bhoonidhi offers India-specific tools, like detailed soil mapping at district levels, not available in USGS Earth Explorer.

E. <u>NRSC Geoportal vs. ESA's SNAP:</u>

- NRSC Geoportal specializes in Indian remote sensing data, providing more tailored products for our country.

- ESA's SNAP offers global satellite data processing tools but may not have India-specific algorithms.
- NRSC Geoportal provides India-centric applications, like crop yield estimation models, which aren't available in SNAP.

The key advantage of India's portals is their focus on our specific geographic and environmental contexts. They're designed to address India's unique challenges in areas like monsoon prediction, agricultural planning, and disaster management. By using and understanding these Indian portals, you're not just learning about global technology – you're engaging with tools specifically designed to help our nation grow and develop sustainably.

8. Case Study: Cyclone Preparedness – The Role of EO Portals in Mitigating Cyclone Impact

Cyclone formation:

The word Cyclone is derived from the Greek word Cyclos meaning the coils of a snake. It was coined by Henry Peddington because the tropical storms in the Bay of Bengal and the Arabian Sea appear like coiled serpents of the sea.

A cyclone is a low-pressure system that forms over warm ocean waters in the tropics. The formation process involves a combination of atmospheric and oceanic conditions.

1. Warm Ocean Waters: Warm ocean waters (at least 26.5°C) heat the air above them, causing it to rise and create a low-pressure area.

2. Moisture and Instability: The warm air rises, creating convection currents that drive the air upward. This process releases heat, which in turn fuels further rising motion.

3. Low Pressure and Rotation: As the air rises, a low-pressure system forms at the surface. The Coriolis force, a result of the Earth's rotation, causes the winds to rotate around the low-pressure centre.

4. Thunderstorms and Strengthening: Thunderstorms develop and release latent heat, strengthening the system. The rotation increases, and the system becomes a tropical depression.

5. Cyclone Intensification: If the conditions persist, the tropical depression strengthens into a tropical storm and eventually a cyclone, with sustained winds of 119 km/h or higher.

This process can take several days to develop, and the cyclone can bring strong winds, heavy rainfall, and storm surges that can cause significant damage and loss of life.

The centre of a cyclone is very calm and clear with very low air pressure. A cyclone will eventually weaken and dissipate when it moves over cooler waters, encounters dry air, or interacts with land, which disrupts the system's supply of warm, moist air.

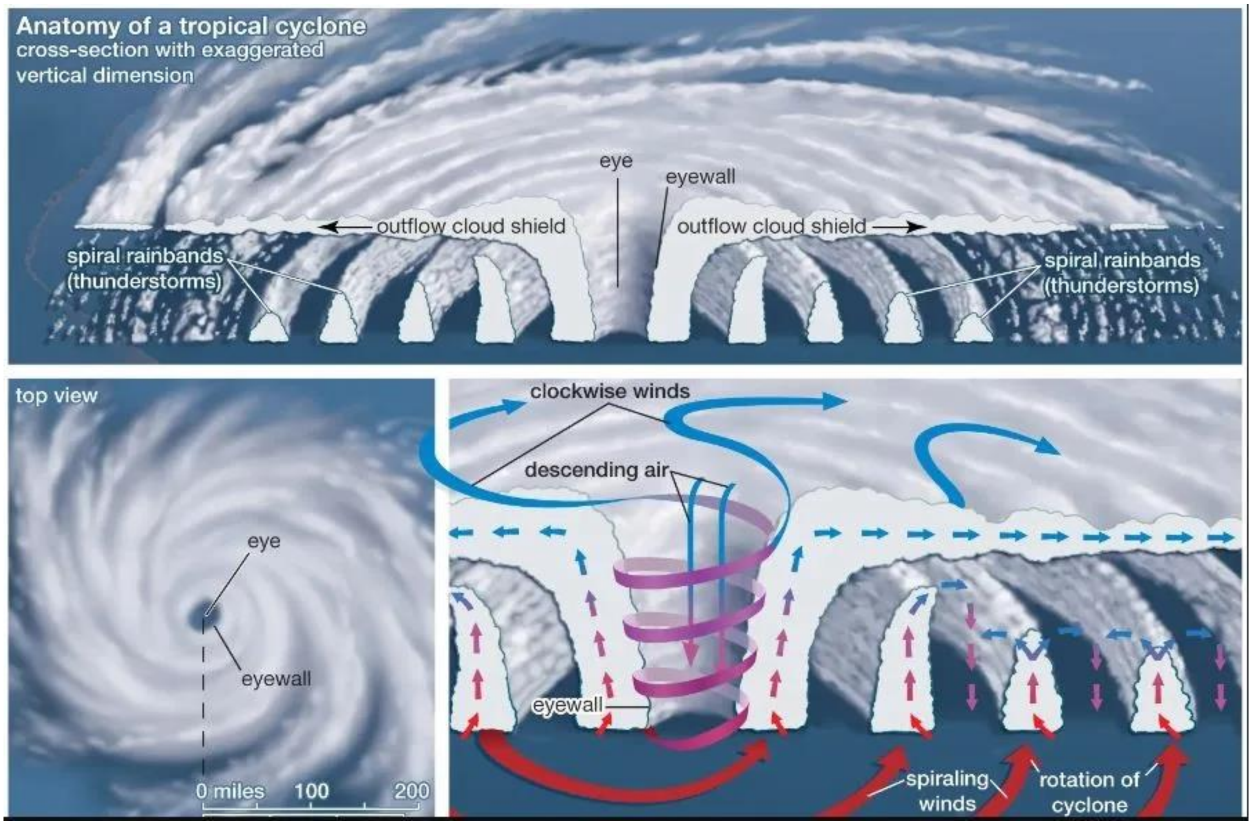


Figure 27: Anatomy of a tropical Cyclone

Case Study:

(a) Cyclone Amphan:

In May 2020, the eastern coast of India faced one of its most severe cyclonic storms known as Amphan. This case study examines how Earth Observation (EO) portals, particularly MOSDAC (Meteorological and Oceanographic Satellite Data Archival Centre) and Bhuvan, played a pivotal role in disaster preparedness, management, and post-cyclone rehabilitation efforts.

Pre-Cyclone Phase: As Cyclone Amphan intensified over the Bay of Bengal, MOSDAC's real-time satellite imagery and data became crucial for tracking and predicting its path. For instance:

- On May 16, 2020, MOSDAC's INSAT-3D satellite images showed the cyclone's eye forming, indicating rapid intensification.
- By May 18, the portal provided hourly updates on wind speeds, which had reached up to 240 km/h, classifying Amphan as a super cyclonic storm.

Simultaneously, Bhuvan, ISRO's geoportal, offered high-resolution maps of coastal areas in West Bengal and Odisha. These maps included:

- Detailed topography of low-lying areas prone to flooding
- Population density data of coastal districts
- Locations of critical infrastructure such as hospitals and emergency shelters

This information enabled authorities to:

1. Identify high-risk zones: For example, the Sundarbans delta region was flagged as extremely vulnerable due to its low elevation and dense population.
2. Plan targeted evacuations: Over 4.2 million people were evacuated from coastal areas, with a focus on the most vulnerable regions identified through Bhuvan's maps.
3. Allocate resources efficiently: Emergency supplies and personnel were strategically positioned based on the projected path and intensity data from MOSDAC.

During the Cyclone: As Amphan made landfall on May 20, 2020:

- MOSDAC provided real-time updates on the cyclone's position and intensity, allowing authorities to adjust their response dynamically.
- Bhuvan's mobile app was used by field teams to navigate through affected areas and report on immediate impacts.

Post-Cyclone Assessment and Rehabilitation: In the aftermath of Cyclone Amphan, these EO portals proved invaluable for damage assessment and rehabilitation planning:

1. Rapid Damage Assessment:
    - Bhuvan quickly provided post-cyclone satellite imagery, allowing for a preliminary assessment of affected areas.
    - For instance, images revealed that about 1,600 km² of the Sundarbans mangrove forest was damaged.
2. Detailed Impact Analysis:
    - MOSDAC's historical data was compared with post-cyclone imagery to quantify changes in vegetation cover and identify areas of severe flooding.
    - Bhuvan's analysis showed that over 28% of Kolkata's tree cover was lost due to the cyclone.
3. Rehabilitation Planning:
    - Bhuvan's maps were used to identify safe locations for reconstructing damaged infrastructure.
    - The portal also helped in planning the restoration of power lines by providing detailed imagery of affected transmission towers and lines.

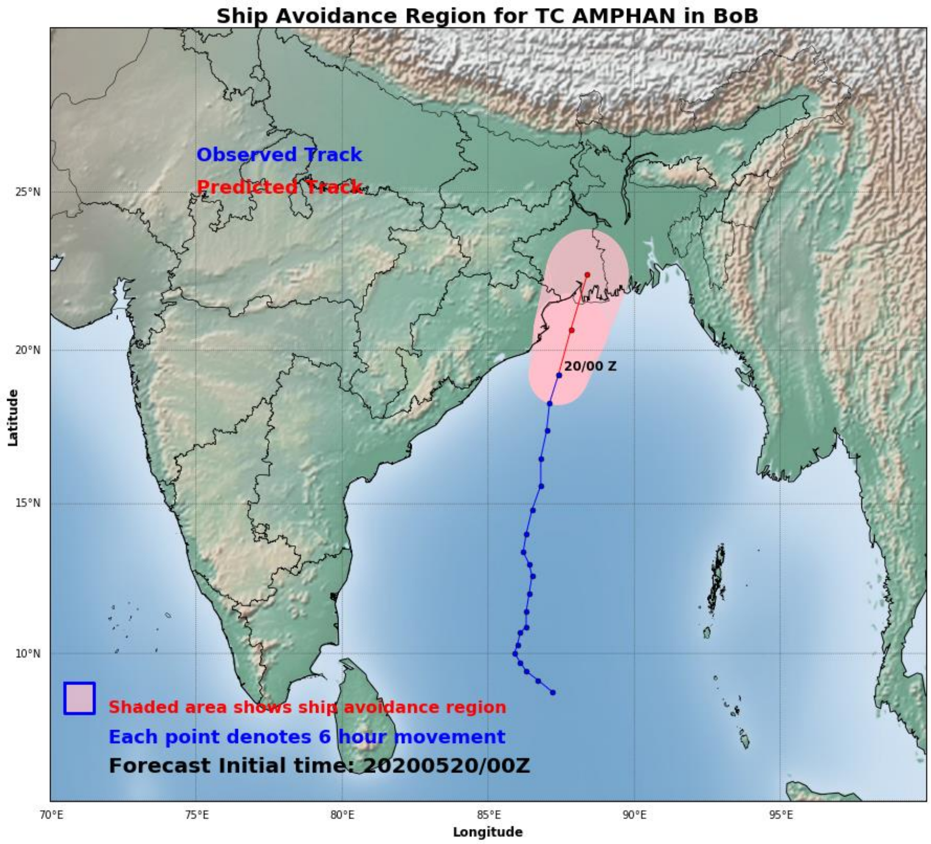


Figure 2828: Cyclone Amphan landfall and track prediction by MOSDAC

Inference: The case of Cyclone Amphan demonstrates the critical role of Earth Observation portals in disaster management. By providing timely, accurate, and detailed information, MOSDAC and Bhuvan significantly contributed to:

- Minimizing loss of life through early warning and efficient evacuation
- Optimizing resource allocation during the crisis
- Facilitating rapid and effective post-disaster assessment and rehabilitation efforts

This case underscores the importance of continued investment in and development of Earth Observation technologies and data sharing platforms for enhancing disaster resilience.

(b) Cyclone Biparjoy:

Cyclone Biparjoy, track prediction and landfall forecasting using satellite information helped save thousands of lives. The Indian Meteorological Department (IMD) and the National Disaster Management Authority (NDMA) utilized satellite data from the MOSDAC portal to predict the cyclone's track and landfall with high accuracy. As a result of timely warnings and evacuations, the reported death toll was only 2-3 people, despite the cyclone affecting over 1 million people in the coastal districts of Gujarat and Maharashtra. The successful prediction and evacuation efforts were credited with saving few tens of thousands lives, making it one of the most successful disaster management operations in India's history.

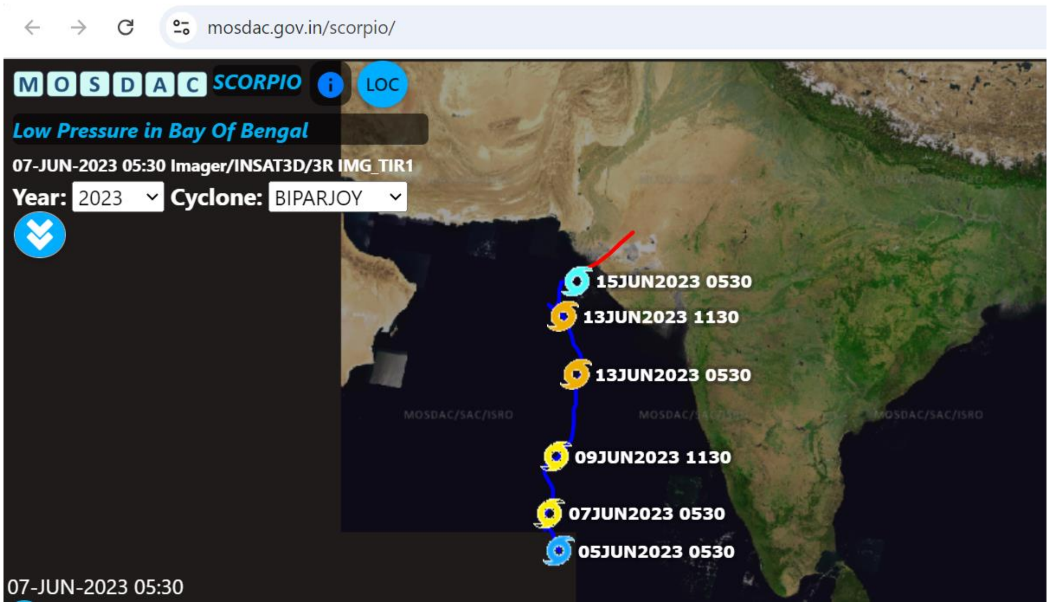


Figure 29: Cyclone Biparjoy landfall and track prediction by MOSDAC

(b) Cyclone Asna:

Cyclone Asna on 30 September 2024 moved past Gujarat, which formed over the coast of Kutch, moved into the Arabian Sea and is predicted to head towards Oman. Cyclone alert was issued by weather agencies and authorities evacuated over 3,500 from danger prone areas and moved them into a safer location.

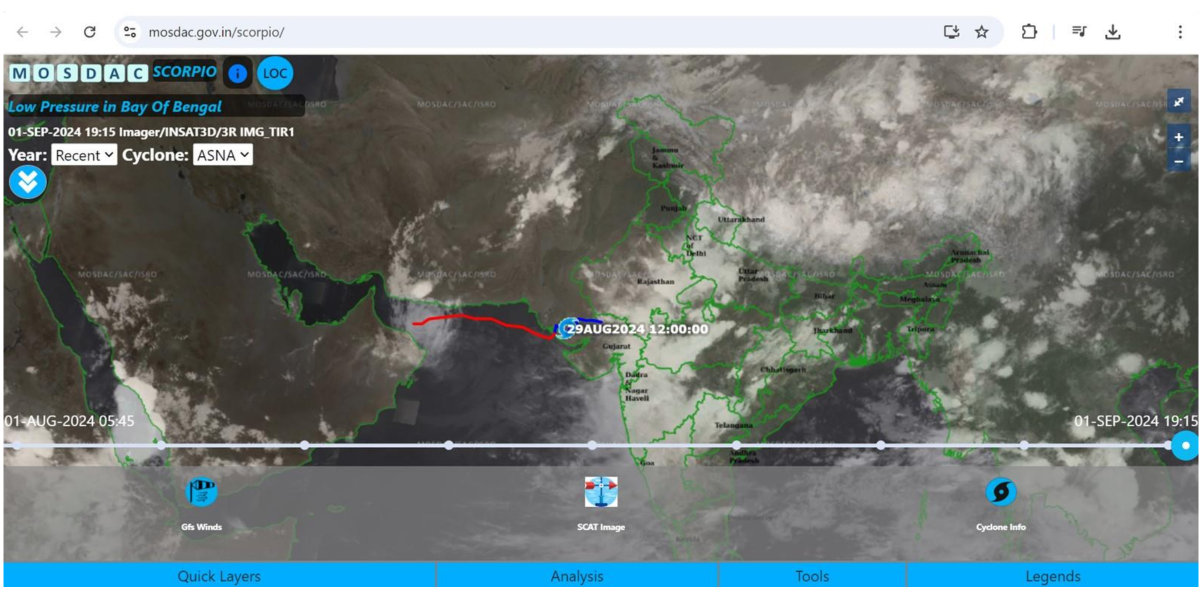


Figure 3030: MOSDAC SCORPIO Geoportal Interface for cyclone

9. Conclusion

Earth observation portals have revolutionized the way we access and utilize geospatial information. These portals empower various stakeholders in India to manage resources effectively, mitigate disasters, and plan for a sustainable future.

The evolution and integration of Earth observation technologies, particularly remote sensing, Geographic Information Systems (GIS), geoportals, and mobile applications, have significantly transformed India's approach to managing its vast and diverse landscape. These advancements have ushered in a new era of data-driven decision-making across various sectors, from agriculture and urban planning to disaster management and environmental conservation.

India's progress in this field, spearheaded by the Indian Space Research Organisation (ISRO), has been remarkable. The development of comprehensive platforms like Bhuvan, Bhoonidhi, VEDAS, and MOSDAC demonstrates India's commitment to harnessing the power of geospatial technology for national development. These platforms not only provide access to high-quality satellite data but also offer user-friendly tools for analysis and visualization, democratizing access to critical geospatial information.

The impact of these Earth observation portals extends beyond mere technological advancement. They play a crucial role in:

1. **Enhancing Resource Management**: By providing detailed, up-to-date information on land use, water resources, and vegetation cover, these platforms enable more efficient and sustainable management of natural resources.
2. **Improving Disaster Preparedness and Response**: Real-time monitoring and early warning systems facilitated by these portals significantly enhance India's capacity to predict, prepare for, and respond to natural disasters.
3. **Supporting Urban Planning**: Detailed geospatial data helps urban planners make informed decisions about infrastructure development and city expansion, promoting sustainable urbanization.
4. **Advancing Agricultural Practices**: Farmers and agricultural experts can leverage these tools for crop monitoring, yield prediction, and optimizing resource use in agriculture.
5. **Facilitating Environmental Conservation**: By providing comprehensive data on forest cover, biodiversity, and climate patterns, these portals support conservation efforts and environmental policy-making.
6. **Empowering Research and Education**: The availability of rich geospatial data and analysis tools fosters innovation and research across various scientific disciplines.

As India continues to refine and expand its Earth observation capabilities, the potential for more accurate, timely, and actionable geospatial information grows exponentially. The integration of emerging technologies like artificial intelligence and machine learning with these geoportals promises to unlock even more powerful insights and applications.

However, challenges remain, particularly in terms of data integration, user training, and ensuring these technologies benefit all sections of society. Addressing these challenges will be crucial for maximizing the impact of Earth observation portals in India.

In conclusion, India's Earth observation portals represent a significant leap forward in the country's geospatial capabilities. They exemplify how technological innovation can be harnessed to address real-world challenges and support sustainable development. As these platforms continue to evolve, they will undoubtedly play an increasingly vital role in shaping India's future, contributing to informed decision-making, efficient resource management, saving lives from potential disasters and overall national progress.

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