Earth Observation via Satellites

Satellite circling Earth

Source: istock/aapsky

Relevance of this Tool Type within the Project Cycle

Definition

Earth Observation (EO) is a discipline that allows us to gather information about our planet. It often involves remote sensing sensors (usually onboard satellites). The data collected using satellites is designated as satellite or geospatial data. Optical (visible, near- and mid-infrared, and thermal infrared) ultraviolet and radar images (microwave) cover the full radiation spectrum beyond the optical domain.

Step 1: Which EO Applications Should I Consider?

- Land (all surface features, such as landscape topography, build-up, soil moisture, vegetation, inland waters, forestry, and agriculture)
- Ocean (e.g., topography and currents, salinity, and surface temperature)
- Atmosphere (e.g., aerosols, humidity, cloud particles, ozone, and trace gases)
- Snow and ice (e.g., sea ice cover and glaciers)

Step 2: What Information Do I Need?

Satellites provide an excellent means for tracking changes, that is, comparing baseline data with the actual status and drawing conclusions on the impact data for many sectors and types of projects. Depending on project type, they can also be used for progress monitoring. Since they do not require intermediaries, they are often used for remote verification, but they can be used by all stakeholders for decision making along the project cycle and during every step in the project cycle (e.g., planning and appraisal, implementation, progress monitoring and verification, impact monitoring, and evaluation). Some examples:

- **Feature mapping** (e.g., buildings, roads, landcover, and water extent)
- **Change Detection** (e.g., urban growth, deforestation, agricultural expansion, bio-diversity monitoring, climate vulnerability, and glacier melting)
- **Elevation or Digital Elevation Models** (DEM) (e.g., 3D terrain models for flood risk and 3D urban models)
- **Monitoring in fragile or disaster contexts** (refugee routes, drought and floods, locusts, etc.)

How Can I Get Access to Satellite Imagery? Is Open Data Available?

Step 3: What Should I Consider When Acquiring Satellite Imagery?

First, define and formulate your information need. Your need (e.g., detecting deforestation in the Amazon) will direct you to choose the type of satellite image suitable for your case and analysis. Your options:

- **Open and free-access satellite data:** this includes most of optical and radar satellites from public-funded satellite missions from the EU and the US (such as, Landsat, Sentinel or

ASTER). These data are available with high and low resolutions under free and open data policies and are accessible through several platforms (e.g., through the USGS, the Landsat mission, and Copernicus Access Hubs) > Links below

The Fact Sheets Geospatial Tools and Data Sources provide further information regarding free and open access to satellite imagery. KfW's evaluation department has initiated a **search engine for open geodata sets:** https://mapme.shinyapps.io/geodata

- **Commercial satellite data** (privately funded or sometimes publicly funded missions accessible for free under restricted terms (proposals, project context, research) or against a commercial fee): If the imagery requirements are much higher (e.g., very high resolution, near-real time, tight observation windows), the image data products will need to be purchased under commercial licenses from EO industry platforms directly (> Links to Further Sources below) or using image broker services.
- **Satellite Image data** from public or commercial sources **can be procured at various processing levels**, also saving several preprocessing steps and thus time and cost (the pre-pro-cessing levels include radiometric, atmospheric, geometric corrections and orthorectification using DEM). This will ensure the correct geolocalization of the images and the correct atmospheric effects.
- **Specialized image processing and GIS experts** might have to be recruited to process and interpret the data.

Types of Resolution to Consider:

The higher the resolution, the higher the probability that costs occur. A satellite image is geospatial raster data. This raster is formed from structured adjacent pixels. The arrangement of pixels describes the spatial structure of a satellite image. Every pixel contains a coded number that refers to the intensity of the reflected electromagnetic signal coming from the earth targets and recorded in the satellite sensor. Satellites are often characterized by several types of resolutions:

a) Spatial resolution

is equivalent to the level of detail the satellite sensor can distinguish on the ground. This spatial resolution is often similar to the pixel size (that only applies to optical data, for SAR-RADAR data due to the geometry of acquisition, the pixel size and the image spatial resolution are different). It specifies how detailed images need to be: Very high resolution (0.3 m – 5 m), high resolution (6 m – 30 m), or low-coarse resolution (>30 m).

See the link below to view imagery samples to help select the required resolution. For example, large roads can already be hardly distinguished at a 5-meter resolution https://landscape.satsummit.io/capture/resolution-considerations.html

b) Temporal resolution

is the time period a satellite requires to revisit the same area (revisit time); for example, hours, days, months, or years.

Most satellites have a standard temporal resolution of about 1–14 days. But there are also satellites with very high temporal resolution, capable of acquiring images of the same area every few hours.

c) Spectral resolution

is the number of spectral bands (number of electromagnetic wavelength intervals) the sensor can record in. It results in a satellite image that contains several spectral bands –for example, multi-spectral (3 – 10 bands) or hyperspectral (hundreds of bands). Spectral bands contain information about the sensed objects on earth (for instance, leafy forest and healthy vegetation will reflect back to the sensor highly in the red edge band or near the infrared band, while sick vegetation will also reflect in other bands).

Sensors like the ones onboard the Landsat or ASTER public domain satellites have a spectral resolution of 7 bands (visible light [3], infrared light [3], and thermal radiation of the surface).

d) Radiometric resolution

is the ability of the sensor to distinguish different radiometric values. The finer the radiometric resolution of a sensor, the more sensitive it is to distinguish the emitted or reflected signal from Earth targets. Sensors feature 6 – 16 bit corresponding to approximately 64.000 gray-scale values and meaning there are 64.000 coded numeric values to represent/code the radiometric values of the satellite image (e.g., to better distinguish between different vegetation types).

Step 4: Which Types of Satellite Sensors Are Required (Remote Sensing)?

- **Optical imagery (passive remote sensing technique):** Uses the sunlight reflected by the Earth's surface and records the visible and near infra-red spectral range of the light spectrum. This requires further processing to derive *maps for vegetation types, crop vitality, or water quality, for example.*
- **Radar** (Radio Detection and Ranging, **active remote sensing technique):** This involves sending in the microwaves part of the light spectrum and recording independently from sunlight. The returned echos from the Earth targets to the satellite sensor are called backscatter. Besides the intensity of the backscatter (reflected microwave signals), the phase and polarization of the returned signal are stored as well in the image pixels. Microwaves are very sensitive to metal structures and soil moisture and can penetrate the Earth's surface to different depths according to their wavelength under certain conditions. RADAR images contain complementary information to optical imagery especially in atmospheric conditions of quasi-permanent cloud cover in some regions of the world. This type of imagery can be highly substituting or complementary. *Examples: detection of power poles, deforestation, geological structures, and buried wadi (river) courses.*
- **LiDAR** (Light Detection and Ranging, **active remote sensing technique**): also known as laser detection and ranging (LaDAR) or optical radar which uses electromagnetic radiation in the optical range (laser) to determine the distance between the object and the instrument. It can be onboard a plane, drone, or satellite. This technique primarily allows the estimation of the elevation of the Earth's surface and Earth targets

(e.g., the heights of buildings or trees and thus, indirectly, the trees' biomass). *Example: highly precise DEM Digital Elevation Model.*

Image Data Processing

Image processing is a set of mathematical methods and algorithms that allow the extraction of useful, so-called thematic information from images (e.g., processing of a satellite image to map land use and land cover, to identify built-up areas, to extract water bodies, or to estimate the crops yields or vegetation health, etc.). Usually, the image processing towards the derivation of the thematic product will follow steps. *Examples of a few processing steps are: geometric-correction, selection of optimal band combinations, contrast and spatial enhancement, and feature extraction and classifications (using machine learning algorithms) and visualization true and false color enhancement.*

Image processing tools are software applications (ESA SNAP, GRASS-GIS, ERDAS, or coding language libraries available for customized processing flows) that aid in the visual, semi-automatic interpretation or fully automated analysis of remote sensing data using complex algorithms. The goal is to produce additional derived information that is not necessarily visible or is badly visible to human eyes but is contained in the image radiometric information > Fact Sheet Geospatial tools/GIS.

Standards and Interoperability Requirements

- At KfW, a geo data project template is being developed that uses the International Aid Transparency Initiative location attributes, and the Open Geospatial Consortium (OGC) for feature classes > RMMV Guidebook Annex 3;
- Additional standards/definitions/requirements from established international initiatives should be considered depending on the sector, for example: the Multinational Geospatial Co-production Program (MGCP); for vegetation mapping: the Land Cover Classification System (LCCS) from the Food and Agriculture Organization (FAO); for land cover in a non-arid environment: Copernicus EAGLE; for forests: Reducing Emissions from Deforestation and Forest Degradation (REDD+, MRV following IPCC guidelines).
- File-formats for handling image (raster) and (vector) data are manifold. It is recommended in both cases to use industry standards for data exchange, such as GEOTIFF and SHP. Important is the preservation of any coordinate information, the meta-data, and keeping track of the pre-processing that the image has undergone to warrant full GIS operability.

Legal Aspects

National legislation is generally not applicable to imagery from space.

Human rights risks: In countries with human rights issues or in conflict settings, satellite images could be used against the population or vulnerable parts thereof, such as minorities, if they are used to identify individual households when combined with survey data or other sources of information. This information could be used for discriminatory policies, (state) terror attacks, and so on. Careful attention to data protection and data security (below) is required in order not to risk harming individuals or groups. > RMMV Guidebook Section 2.3.3.

Data protection: Very high-resolution images (finer than 0.31 m) or combined with other identifiers, such as address information, tracking of individuals, and groups and their movements ("patterns of life"), for example, through data mining can cause an invasion of personal privacy. Avoid this by choosing lower resolution images, blurring individuals visible in the images, and by avoiding triangulating the images with personal data. Only strictly relevant personal data should be collected and processed by the data controller. If initial data minimization is impossible, data must be anonymized (e.g., by blurring or pixilation) > RMMV Guidebook Section 2.3.1.

If KfW (or persons acting on its behalf) is (also) processing personal data, the privacy check in > RMMV Guidebook Section 2.3.1 must be followed.

Data security requirements can also arise from data protection regulations (local and/or GDPR), which stipulate basic security requirements for storing and processing satellite images. Entities may be required under those rules to ensure the ongoing confidentiality, integrity, availability, and resilience of storing and processing systems and services (technical and organizational measures) > RMMV Guidebook Section 2.3.2.

Project Examples / Use Cases

- In the Improving Energy Efficiency in Rural Areas in Vietnam Project (BMZ: 2009 66 663), impact was evaluated by measuring changes in nightlight on the satellite.
- In the city development project, Innercity Bypass in Lomé/Togo (BMZ: 2009 67 182), satellite images were used to evaluate increases in the numbers of trucks and upgraded buildings.
- In an irrigation project in Mali (PN: 39309), publicly available satellite data was used to supervise construction, verify and estimate crop yield, and maintain an alarm system of cultivated (rice) areas.

Links to Further Sources

- The KfW evaluation department's geodata locator list https://mapme.shinyapps.io/geodata/
- Earth Observation Handbook http://eohandbook.com/sdg/
- Remote Sensing Guide https://fis.uni-bonn.de/en/recherchetools/infobox/professionals
- Basics (guide) on resolution types https://landscape.satsummit.io/capture/resolution-considerations.html
- Database of agencies and missions http://database.eohandbook.com/measurements/overview.aspx
- Copernicus Open Access Hub https://scihub.copernicus.eu/
- In the satellite imagery platform UP42, credits are purchased to acquire VHR satellite imagery mainly from Airbus image provider (SPOT and Pléiades with Spatial resolution up to 0.3 m): https://up42.com/
- MAXAR platform: https://www.maxar.com
- Planet explorer platform: https://www.planet.com/explorer, access granted by the Norwegian government through the NICFI initiative to preserve tropical forests and support the climate agenda on the AFOLU sector, offering imagery with spatial resolution up to 4 m.

Linkages to other tool types

Geospatial Tools

(Remote) Management Information Systems

Crowdsourcing Tools

Drones / UAV

Cameras

Data Sources

Further information on how to use this tool type in an RMMV context can be found here: