Satellite imagery

Satellite imagery (or spaceborne photography) are images of Earth or other planets collected by imaging satellites operated by governments and businesses around the world. Satellite imaging companies sell images by licensing them to governments and businesses such as Apple Maps and Google Maps.

The first images from space were taken on sub-orbital flights. The U.S-launched V-2 flight on October 24, 1946 took one image every 1.5 seconds. With an apogee of 65 miles (105 km), these photos were from five times higher than the previous record, the 13.7 miles (22 km) by the Explorer II balloon mission in 1935. The first satellite (orbital) photographs of Earth were made on August 14, 1959 by the U.S. Explorer 6.

The first satellite photographs of the Moon might have been made on October 6, 1959 by the Soviet satellite Luna 3, on a mission to photograph the far side of the Moon. The Blue Marble photograph was taken from space in 1972, and has become very popular in the media and among the public. Also in 1972 the United States started the Landsat program, the largest program for acquisition of imagery of Earth from space. Landsat Data Continuity Mission, the most recent Landsat satellite, was launched on 11 February 2013. In 1977, the first real time satellite imagery was acquired by the United States's KH-11 satellite system.

All satellite images produced by NASA are published by NASA Earth Observatory and are freely available to the public. Several other countries have satellite imaging programs, and a collaborative European effort launched the ERS and Envisat satellites carrying various sensors. There are also private companies that provide commercial satellite imagery. In the early 21st century satellite imagery became widely available when affordable, easy to use software with access to satellite imagery databases was offered by several companies and organizations.

Satellite application

Satellite images have many applications in meteorology, oceanography, fishing, agriculture, biodiversity conservation, forestry, landscape, geology, cartography, regional planning, education, intelligence and warfare. Images can be in visible colors

and in other spectra. There are also elevation maps, usually made by radar images. Interpretation and analysis of satellite imagery is conducted using specialized remote sensing applications. There are probably hundreds of applications - these are typical:

1. Meteorology - Study of atmospheric temperature, pressure, water vapor, and wind velocity.

2. Oceanography: Measuring sea surface temperature, mapping ocean currents, and wave energy spectra and depth sounding of coastal and ocean depths

3. Glaciology- Measuring ice cap volumes, ice stream velocity, and sea ice distribution. (Glacial).

4. Geology- Identification of rock type, mapping faults and structure.

5. Geodesy- Measuring the figure of the Earth and its gravity field.

6. Topography and cartography - Improving digital elevation models.

7. Agriculture monitoring the biomass of land vegetation

8. Forest- monitoring the health of crops, mapping soil moisture.

9. Hydrology- Assessing water resources from snow, rainfall and underground aquifers.

10. Planning applications - Mapping ecological zones, monitoring deforestation, monitoring urban land use.

11. Oil and mineral exploration- Locating natural oil seeps and slicks, mapping geological structures, monitoring oil field subsidence.

12. Military- developing precise maps for planning, monitoring military infrastructure, monitoring ship and troop movements.

Resolution and data

There are four types of resolution when discussing satellite imagery in remote sensing: spatial, spectral, temporal, and radiometric. Campbell (2002) defines these as follows:

1. Spatial resolution: is defined as the pixel size of an image representing the size of the surface area (i.e. m^2) being measured on the ground, determined by the sensors' instantaneous field of view (IFOV);

2. Spectral resolution: is defined by the wavelength interval size (discrete segment of the Electromagnetic Spectrum) and number of intervals that the sensor is measuring;

3. Temporal resolution: is defined by the amount of time (e.g. days) that passes between imagery collection periods for a given surface location;

4. Radiometric resolution: is defined as the ability of an imaging system to record many levels of brightness (contrast for example) and to the effective bit-depth of the sensor (number of grayscale levels) and is typically expressed as 8-bit (0-255), 11-bit (0-2047), 12-bit (0-4095) or 16-bit (0-65,535).

While Geometric resolution refers to the satellite sensor's ability to effectively image a portion of the Earth's surface in a single pixel and is typically expressed in terms of Ground sample distance, or GSD. GSD is a term containing the overall optical and systemic noise sources and is useful for comparing how well one sensor can "see" an object on the ground within a single pixel.

For example, the GSD of Landsat is ~30m, which means the smallest unit that maps to a single pixel within an image is ~30m x 30m. The latest commercial satellite (GeoEye 1) has a GSD of 0.41 m. This compares to a 0.3 m resolution obtained by some early military film based Reconnaissance satellite such as Corona.

The resolution of satellite images varies depending on the instrument used and the altitude of the satellite's orbit. For example, the Landsat archive offers repeated

imagery at 30 meter resolution for the planet, but most of it has not been processed from the raw data. Landsat 7 has an average return period of 16 days. For many smaller areas, images with resolution as high as 41 cm can be available.

Satellite imagery is sometimes supplemented with aerial photography, which has higher resolution, but is more expensive per square meter. Satellite imagery can be combined with vector or raster data in a GIS provided that the imagery has been spatially rectified so that it will properly align with other data sets.

Imaging satellites

1. GeoEye:

GeoEye's GeoEye-1 satellite was launched on September 6, 2008. The GeoEye-1 satellite has the high resolution imaging system and is able to collect images with a ground resolution of 0.41 meters (16 inches) in the panchromatic or black and white mode. It collects multispectral or color imagery at 1.65-meter resolution or about 64 inches.

2. DigitalGlobe

DigitalGlobe's WorldView-2 satellite provides high resolution commercial satellite imagery with 0.46 m spatial resolution (panchromatic only). The 0.46 meters resolution of WorldView-2's panchromatic images allows the satellite to distinguish between objects on the ground that are at least 46 cm apart. Similarly DigitalGlobe's QuickBird satellite provides 0.6 meter resolution (at NADIR) panchromatic images.

DigitalGlobe's WorldView-3 satellite provides high resolution commercial satellite imagery with 0.31 m spatial resolution. WVIII also carries a short wave infrared sensor and an atmospheric sensor.

3. Spot Image

The 3 SPOT satellites in orbit (Spot 2, 4 and 5) provide images with a large choice of resolutions – from 2.5 m to 1 km. Spot Image also distributes multiresolution data from other optical satellites, in particular from Formosat-2 (Taiwan) and Kompsat-

2 (South Korea) and from radar satellites (TerraSar-X, ERS, Envisat, and Radarsat). Spot Image is also the exclusive distributor of data from the high resolution Pleiades satellites with a resolution of 0.50 meter or about 20 inches. The launches occurred in 2011 and 2012, respectively. The company also offers infrastructures for receiving and processing, as well as added value options.

4. ASTER

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is an imaging instrument onboard Terra, the flagship satellite of NASA's Earth Observing System (EOS) launched in December 1999. ASTER is a cooperative effort between NASA, Japan's Ministry of Economy, Trade and Industry (METI), and Japan Space Systems (J-spacesystems).

ASTER data is used to create detailed maps of land surface temperature, reflectance, and elevation. The coordinated system of EOS satellites, including Terra, is a major component of NASA's Science Mission Directorate and the Earth Science Division. The goal of NASA Earth Science is to develop a scientific understanding of the Earth as an integrated system, its response to change, and to better predict variability and trends in climate, weather, and natural hazards.

1. Land surface climatology—investigation of land surface parameters, surface temperature, etc., to understand land-surface interaction and energy and moisture fluxes

2. Vegetation and ecosystem dynamics—investigations of vegetation and soil distribution and their changes to estimate biological productivity, understand land-atmosphere interactions, and detect ecosystem change

3. Volcano monitoring—monitoring of eruptions and precursor events, such as gas emissions, eruption plumes, development of lava lakes, eruptive history and eruptive potential

4. Hazard monitoring—observation of the extent and effects of wildfires, flooding, coastal erosion, earthquake damage, and tsunami damage

5. Hydrology—understanding global energy and hydrologic processes and their relationship to global change; included is evapotranspiration from plants

6. Geology and soils—the detailed composition and geomorphologic mapping of surface soils and bedrocks to study land surface processes and earth's history

7. Land surface and land cover change—monitoring desertification, deforestation, and urbanization; providing data for conservation managers to monitor protected areas, national parks, and wilderness areas

5. BlackBridge

BlackBridge, previously known as RapidEye, operates a constellation of five satellites, launched in August 2008, the RapidEye constellation contains identical multispectral sensors which are equally calibrated. Therefore, an image from one satellite will be equivalent to an image from any of the other four, allowing for a large amount of imagery to be collected (4 million km^2 per day), and daily revisit to an area. Each travel on the same orbital plane at 630 km, and deliver images in 5 meter pixel size. RapidEye satellite imagery is especially suited for agricultural, environmental, cartographic and disaster management applications. The company not only offers their imagery, but consults their customers to create services and solutions based on analysis of this imagery.

6. ImageSat International

Earth Resource Observation Satellites, better known as "EROS" satellites, are lightweight, low earth orbiting, high-resolution satellites designed for fast maneuvering between imaging targets. In the commercial high-resolution satellite market, EROS is the smallest very high resolution satellite; it is very agile and thus enables very high performances. The satellites are deployed in a circular sun-synchronous near polar orbit at an altitude of 510 km (+/- 40 km). EROS satellites imagery applications are

primarily for intelligence, homeland security and national development purposes but also employed in a wide range of civilian applications, including: mapping, border control, infrastructure planning, agricultural monitoring, environmental monitoring, disaster response, training and simulations, etc.

1. EROS A – a high resolution satellite with 1.9-1.2m resolution panchromatic was launched on December 5, 2000.

2. EROS B - the second generation of Very High Resolution satellites with 70 cm resolution panchromatic, was launched on April 25, 2006.

7. Meteosat

The Meteosat-2 geostationary weather satellite began operationally to supply imagery data on 16 August 1981. Eumetsat has operated the Meteosats since 1987.

1. The Meteosat visible and infrared imager (MVIRI), three-channel imager: visible, infrared and water vapor; It operates on the first generation Meteosat, Meteosat-7 being still active.

2. The 12-channel Spinning Enhanced Visible and Infrared Imager (SEVIRI) includes similar channels to those used by MVIRI, providing continuity in climate data over three decades; Meteosat Second Generation (MSG).

3. The Flexible Combined Imager (FCI) on Meteosat Third Generation (MTG) will also include similar channels, meaning that all three generations will have provided over 60 years of climate data.

Model of a first generation Meteosat geostationary satellite.