Overview of Basic Remote Sensing (focus: ALOS Satellite)

THE USE OF SATELLITE REMOTE SENSING (ALOS SATELLITE DATA)

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I. Introduction

In a general understanding, remote sensing is a technology of acquiring and analyzing information about objects or phenomena from a space. We are intimately familiar fact that the remote sensing can provide us much information surroundings our lives. As sensors, however, our eye is greatly limited by 1) sensitivity from the visible range of electromagnetic energy; 2) viewing capability detected by the location of our bodies; and 3) the inability to form a lasting record of what we view. Due to these limitations, humans have continuously makes efforts to develop the technology to increase ability to seeing and recording the physical properties of our environment.

In terms of the early use of aerial photography, remote sensing was recognized as a valuable tool for viewing, analyzing, characterizing, and making understanding about our environment. In the past few decades, remote sensing technology has advanced on three items: 1) Through predominant military uses, a variety of environmental analysis was applied to land, ocean, and atmosphere issues; 2) photographic system to sensors that converts energy from electromagnetic spectrum to electronic signals; and 3) change of flatform from aircraft to satellite. Today, we define satellite remote sensing as usage of satellite-borne sensors to observe, measure, and record the electromagnetic radiation, reflected or emitted from the Earth.

II. Electromagnetic Spectrum

The fundamental unit of electromagnetic field is the photon, the smallest possible energy of electromagnetic element of a particular wavelength. Photon, which is without mass, and moves at the speed of light 300,000 km/sec (186,000 miles/sec) in the form of waves. The energy of a photon determines the frequency (and wavelength) of light. The greater energy of a photon, is greater frequency of light and vice versa.

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to easily pass through the atmosphere to Earth's surface.

Most visible remote sensing instruments on aircraft or space-based platforms applies in windows using detectors tuned to specific frequencies (wavelengths) that can pass through the atmosphere. When a remote sensing instrument has a line-of-sight with an object which is reflecting sunlight or emitting heat, the instrument collects and records the radiant energy.While most remote sensing systems are designed to collect reflected radiation, some sensors, especially meteorological satellites, directly measure absorption phenomena, such as those associated with carbon dioxide (CO2) and other gases. The atmosphere is nearly opaque to EM radiation in part of the mid-IR and all of the far-IR regions. In the microwave region, by contraries, most of this radiation move through unimpeded, so radar waves reach the surface (although weather radars are able to detect clouds and precipitation because they are tuned to observe backscattered radiation from liquid and ice particles).

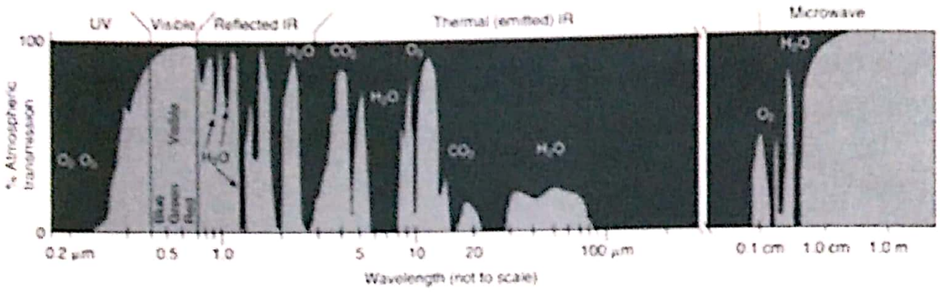


Fig. 2. Diagram of atmospheric windows—wavelengths at which electromagnetic radiation will penetrate the Earth's atmosphere. Chemical notation (CO2, O3) indicates the gas responsible for blocking sunlight at a particular wavelength.

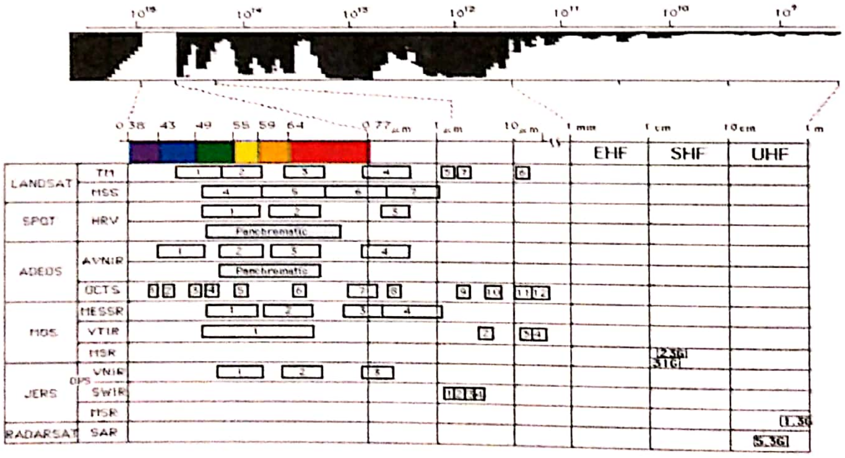


Fig. 3. Sensors and bands onboard the satellites

IV. Remote Sensing Methods

There are two types of remote sensing instruments—passive and active. Passive instruments detect natural energy that is reflected or emitted from the observed scene. Passive instruments sense only radiation emitted by the object being viewed or reflected by the object. Reflected sunlight is the most common external source of radiation for passive instruments as shown in Figure 4. Scientists use a variety of passive remote sensors such as:

1). *Radiometer*

An instrument which can quantitatively measure the intensity of electromagnetic radiation in some band of wavelengths in the spectrum. Usually a radiometer is further identified by the portion of the spectrum it covers; for example, visible, infrared, or microwave. A radiometer that includes a scanning capability to provide a two-dimensional array of pixels being produce image is called an imaging radiometer. Scanning can be performed mechanically or electronically by using an array of detectors.

2). *Spectrometer*

A device designed to detect, measure, and analyze the spectral content of the incident electromagnetic radiation is called a spectrometer. Conventional, imaging spectrometers use gratings or prisms to disperse the radiation to spectral discrimination.

3). *Spectroradiometer*

A radiometer that can measure the intensity of radiation in multiple wavelength bands (i.e., multispectral). Oftentimes the bands are of a high spectral resolution—designed for the remote sensing of specific parameters such as sea surface temperature, cloud characteristics, ocean color, vegetation, trace chemical species in the atmosphere, etc.

Active instruments provide their own energy (electromagnetic radiation) to illuminate the object or scene they observe. They send a pulse of energy from the sensor to the object and then receive the radiation that is reflected or backscattered from those object. Scientists use many different types of active remote sensors such as:

1). *Radar (Radio Detection and Ranging)*

A radar uses a transmitter operating at either radio or microwave frequencies to emit electromagnetic radiation and a directional antenna or receiver to measure the time of arrival of reflected or backscattred pulses of radiation from distant objects. Distance to the object can be determined since electromagnetic radiation propagates at the speed of light.

2). *Scatterometer*

A scatterometer is a high frequency microwave radar designed specifically to measure backscattered radiation. Over ocean surfaces, measurements of backscattered radiation in the microwave spectral region can be used to derive maps of surface wind speed and direction.

3). *Lidar (Light Detection and Ranging)*

A lidar uses a laser (light amplification by stimulated emission of radiation) to transmit a light pulse and a receiver with sensitive detectors to measure the backscattered or reflected light. Distance to the object is determined by recording the time between the transmitted and backscattered pulses and using the speed of light to calculate the distance traveled. Lidars can determine atmospheric profiles of aerosols, clouds, and other constituents of the atmosphere.

4). *Laser Altimeter*

A laser altimeter uses a lidar (see above) to measure the height of the instrument platform above the surface. By independently knowing the height of the platform with respect to the mean Earth's surface, the topography of the underlying surface can be determined.

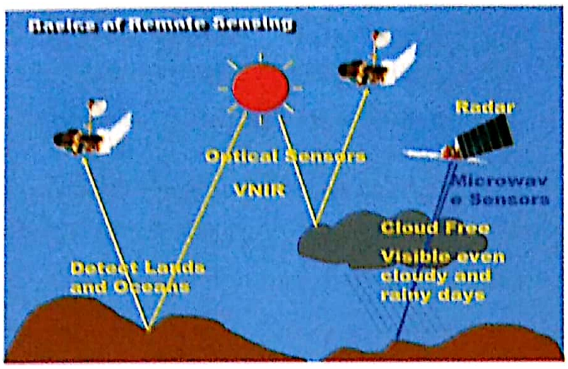


Fig. 4. Basic of remote sensing with passive and active sensor

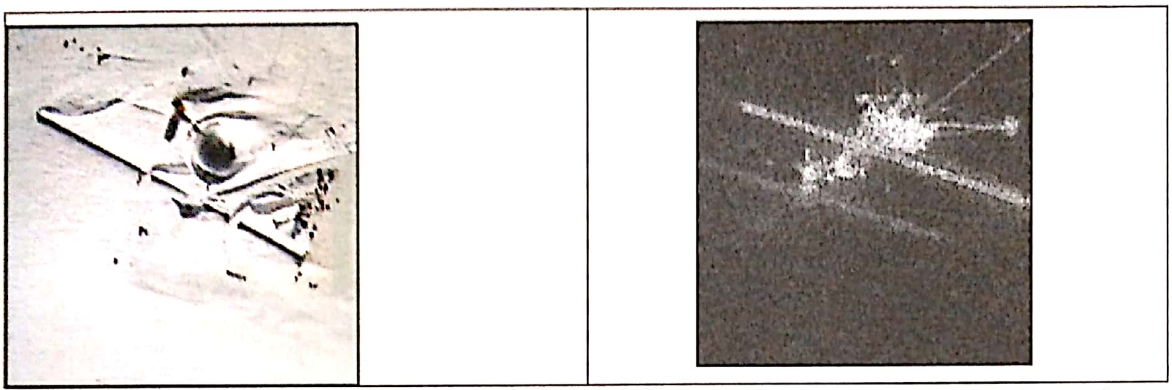


Fig. 5. This pair of images demonstrates some of the differences between passive and active sensors. The left image is an aerial photograph (which records reflected light) of Amundsen-Scott Station, a research facility built on the South Pole. The right image is the same area, at approximately the same scale and orientation, from RADARSAT

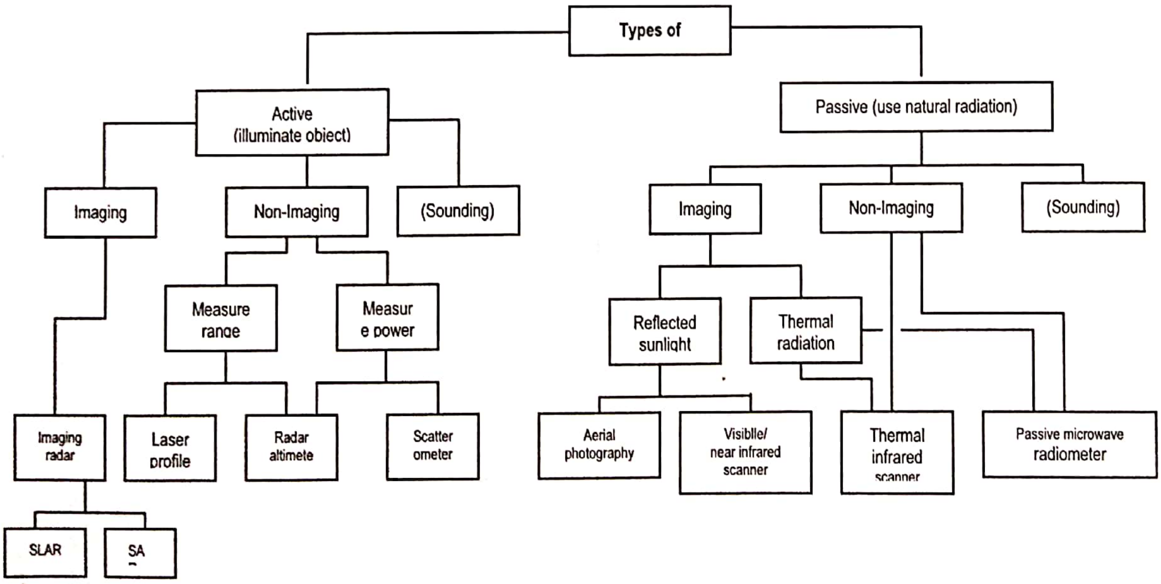


Fig. 6. A schematic of the types of remote sensing system

V. Classification of Remote Sensing System

Remote sensing system may be classified in a number of ways, but the most useful distinctions we can draw are between active and passive systems, and between imaging and non-imaging systems. We may also distinguish sensors by the wavelength of the radiation to which they respond.

Active systems is the object of study with their own supplied radiation, whereas passive systems sense naturally occurring (emitted thermal or reflected solar) radiation. The choice between active and passive systems is influenced by number of factors. A passive system will be inappropriate at certain wavelengths at which insignificant amounts of radiation occur naturally. An active system may be technically infeasible if the amount of power which has to be radiated in order to obtain a measurable reflected signal is too great. It may be desirable to have exact knowledge of the nature of the illuminating radiation, which can be tailored to some particular aspect which is to be studied.

An imaging system is slightly harder to define. We shall take the term to mean a system, either active or passive, which measures the intensity of the radiation reaching it and which does so a function of position on the earth's surface so that a two-dimensional pictorial representation of the intensity can be constructed. A non-imaging system is thus one which either does not measure radiation intensity, or does not do so as a function of position on the earth's surface. We are thus employing a rather restricted definition of the word 'image'. Note that the spatial condition on an imaging system can be reduce to a statement that, for a single location of the system can be reduced to statement that, for a single location of the system, it should measure the radiation intensity from a number of discrete regions distributed in one or two dimensions. One dimension is adequate for the production of an image, since motion of the platform (on which the system is supported) in the perpendicular direction achives the necessary two-dimensional scanning. Figure 6 iilustrates the division of remote sensing systems according to whether they are active or passive, imaging or non-imaging.

VI. The Need for Remote Sensing

The principal advantages of remote sensing is the speed at which data can be acquired from large areas of the earth's surface, and the related fact that comparatively inaccessible areas may be investigated in this way. The uses, both existing and potensial, of such data within the various environmental disciplines are religion. A good summary of the applications of remote sensing to environmental problems is given by Barrett and Curtis (1982). It is impossible to list all the applications, but is perhaps revealing to mention a few (in no particular order) as shown at Figure 7 and Table 1.

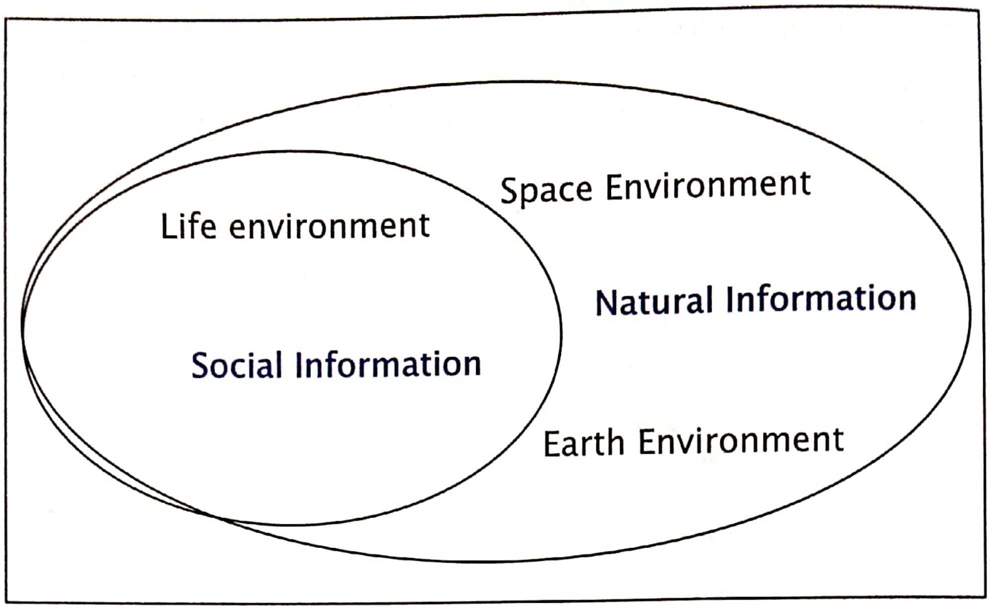


Fig. 7. Scheme of information can derived from earth

Table 1. Satellite applications to environments problem

APPLICATIONS	USE FOR
Meteorology	Profiling of atmospheric temperature, pressure and water vapour content, measurement of wind velocity.
Oceanography	Measurement of the sea's surface temperature, mapping ocean currents and wave energy spectra.
Glaciology	Mapping the distribution and motion of ice sheets and sea ice, determining the navigability of sea ice.
Geology, geomorphology and geodesy	Identification of rock type, location of geological faults and anomalies, measuring the figure of the earth and observing tectonic motion.
Topography and cartography	Obtaining accurate elevation data and referring them to a given coordinate system, production and revision of maps
Agriculture, forestry and botany	Monitoring the extent and type of vegetation cover and its state of health, identifying the host plants of pests, mapping soil type and determining its water content, forecasting crop yields
Hydrology	Assessing water resources, forecasting meltwater run-off from snow
Disaster control	Warning od sand dust storms, avalanches, landslides, flooding etc., monitoring the extent of floodwater, monitoring of pollution (the use of satellite remote sensing data, particularly from meteorological satellites, for disaster warning has already saved thousands of human lives).
Planning applications	Generation of inventories of land use and monitoring changes, assessing resources, performing traffic surveys
Military applications	Monitoring the movement of vehicles and military formations, assessing terrain

VII. ALOS Satellite Data

The Advance Land Oserving Sattelite (ALOS) is a Japanese satellite lounched on 24 January 2006. For most of 2006, the satellite underwent extensive calibration validation before the products were release. The satellite provides high quality, low cost Earth observation data for topographical mapping, disaster and environmental monitoring and climate change studies. ALOS also provides an alternative source of data and a level of back-up to the Landsat series of satellites.

ALOS is one of the largest Earth observing satellites in the world. Its objectives are to:

- provide maps for Japan and other countries including those in Asia-Pacific region;
- perform regional observation for sustainable development (harmonisation between Earth environment and development);
- conduct disaster monitoring around the world;
- survey natural resources; and develop technology necessary for future Earth observing satellites.

Table 2. Major Characteristic of ALOS

Launch date	:	24 January 2006
Expected life	:	3-5 years
Altitude	:	Approx. 692 kilometres
Orbit	:	Sun-Synchronous Sub-recurrent
Inclination	:	98.16°
Period	:	98.7 minutes
Recurrent period	:	46 days
Local time at descending node	:	10:30 AM ±15 minutes
Weight	:	3850 kilograms

The ALOS satellite carries three main sensors:

1). **PRISM:** Panchromatic Remote-sensing Instrument for Stereo Mapping

The PRISM sensor is mainly designed for mapping. It consists of three sets of telescopes for forward, nadir and backward viewing with each telescope providing 2.5 metre spatial resolution. These specifications facilitate generation of precise Digital Elevation Models (DEM), and achieve the accuracy for 1:25,000 scale maps. The PRISM also has a capability to acquire in wide swath mode (70 kilometre) although it is expected most acquisitions will be in triplet mode (35 kilometre swath).

Table 3. Characteristic of PRISM sensor

Swath width – triplet mode (forward, nadir and backwards) (most commonly used mode)	:	35 kilometres (at nadir)
Swath width – wide swath mode (mainly for disaster response)	:	70 kilometres (at nadir)
Spatial resolution	:	2.5 metres (at nadir)
Wavelength	:	0.52 - 0.77 µm (visible green)
Scanning method	:	Push broom with 6 CCDs for Nadir telescope and 8 CCDs for each Forward and Backward telescopes.
Stereo imaging base-height ratio	:	1.0
Pointing angle	:	±1.5° capability +1.2° for odd numbered cycles -1.2° for even numbered cycles
Quantisation	:	8 bits

2). **AVNIR-2:** Advanced Visible and Near Infrared Radiometer type 2

The AVNIR-2 sensor is useful for observing land and coastal zones and provides better spatial land coverage maps and land-use classification maps for monitoring regional environments. The instrument has a cross track pointing function for disaster monitoring. This may also allow simultaneous observation with PALSAR.

Table 4. Characteristic of AVNIR-2 sensor

Spatial resolution	:	10 metres (at nadir)
Wavelength	:	band 1: 0.42 - 0.50 µm (visible blue)
	:	band 2: 0.52 - 0.60 µm (visible green)
	:	band 3: 0.61 - 0.69 µm (visible red)
	:	band 4: 0.76 - 0.89 µm (near infrared)
Scanning method	:	Push broom with 1 CCD for each band.
Pointing angle	:	±44 degrees
Quantisation	:	8 bits

Table 5. Characteristic of PALSAR sensor

Observation mode		***Fine beam single* (High resolution)**	***Fine beam dual* (High resolution)**	**Direct downlink**	**ScanSAR**	**Polarimetric**
Frequency		L band (1.27GHz)				
Polarisation		HH or VV	HH+HV or VV+VH	HH or VV	HH or VV	HH+HV + VV+VH
Direct downlink		No	No	Yes	Yes	No
Incidence angle		9.9 - 50.8°	9.9 - 50.8°	9.9 - 50.8°	24.6 - 27.1°	9.7 - 50.8°
Spatial resolution	Range	10 metres	20 metres	20 metres	100 metres	30 metres
	Azimuth	6.25 metres (2 looks) 12.5 metres (4 looks)	6.25 metres (2 looks) 12.5 metres (4 looks)	12.5 metres (4 looks)	100 metres	12.5 metres (4 looks)
Swath width		70 kilometres	70 kilometres	70 kilometres	250 kilometres (3 scans) 300 kilometres (4 scans) 350 kilometres (5 scans)	30 kilometres

3). PALSAR: Phased Array type L-band Synthetic Aperture Radar

The PALSAR is an active microwave sensor for cloud-free and day-and-night land observation. It has a number of modes:

Fine beam or high resolution mode is the main mode and chiefly used for detailed regional observations and repeat-pass interferometry. Data in this mode can be acquired as single polarisation (FBS) or as dual polarisation (FBD).

Direct downlink mode is suited for direct downlink by international ground stations such as ACRES.

ScanSAR mode will allow acquisitions of about 250-350km width by sacrificing spatial resolution. This is considered to be useful for sea ice extent and rain forest monitoring. This mode is suited for direct downlink by international ground stations such as ACRES.

Polarimetric mode will operate on an experimental basis. Polarization is changed in every pulse of the transmission signal and dual polarization signals are simultaneously received.

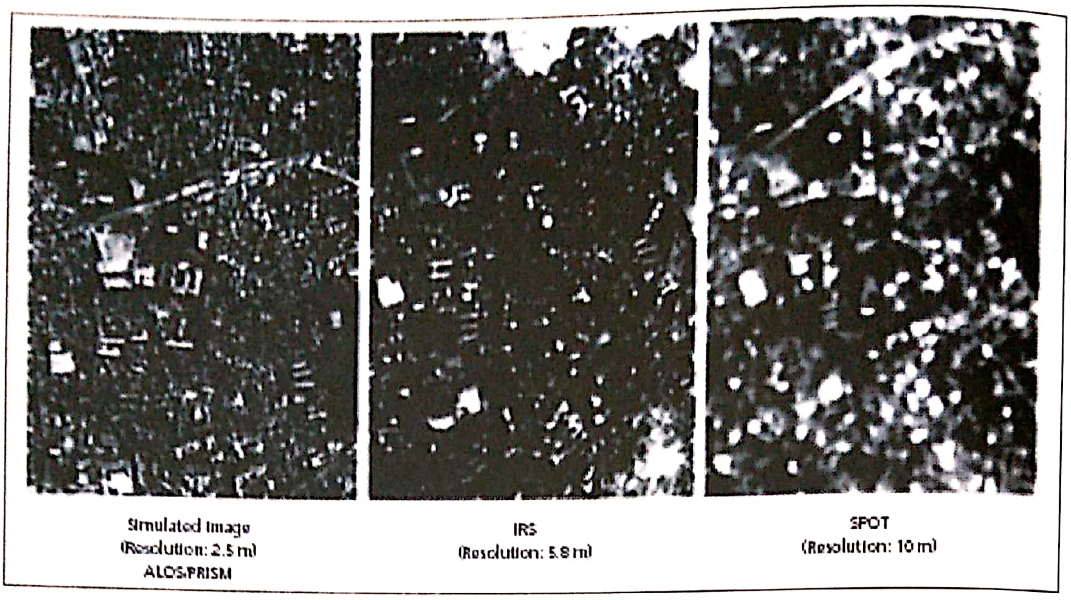
Expected Use of ALOS Data

1). Cartography

PRISM images are useful for large scale mapping because even roads and rivers that are shown in a 1/25,000 map are visible in its image data. They are also very helpful for efficiently updating maps due to their immediate transmission and vast area coverage.

2). Regional Observation

One of the conditions to produce “tasty rice” is said to be less protein in a grain of rice. By using the satellite to cover the vast observation area, we can find out the content rate of the protein in rice for efficient quality control.



Simulated image
(Resolution: 2.5 m)
ALOS/PRISM

IRS
(Resolution: 5.8 m)

SPOT
(Resolution: 10 m)

Fig. 7. Detailed map with immediate data transmission

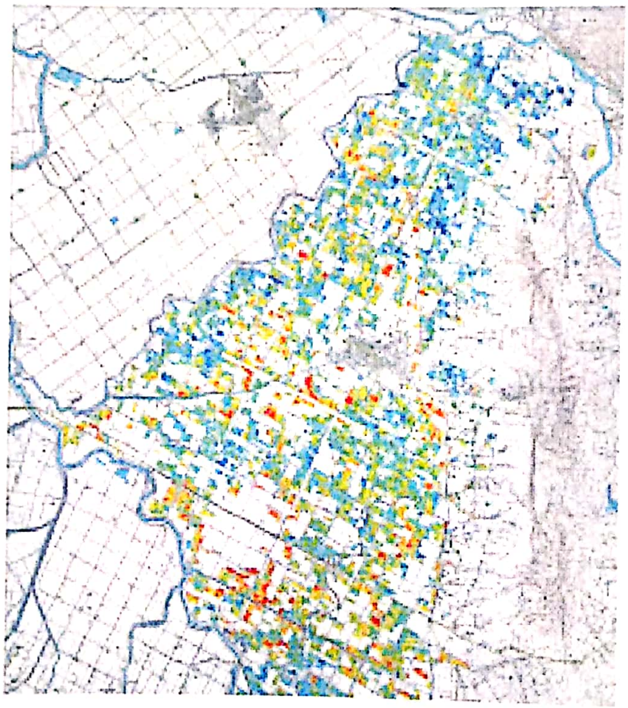


Fig. 8. Rice protein content map (SPOT/HRV Data, Sep. 5, 1999). Red and yellow areas indicate more protein in rice.

3). Monitoring a disaster

As to minimize the damage of a natural disaster. When we consider measures to deal with a disaster, it is important to understand the exact range and status of a disaster-stricken area by comparing its images taken before and after the disaster.

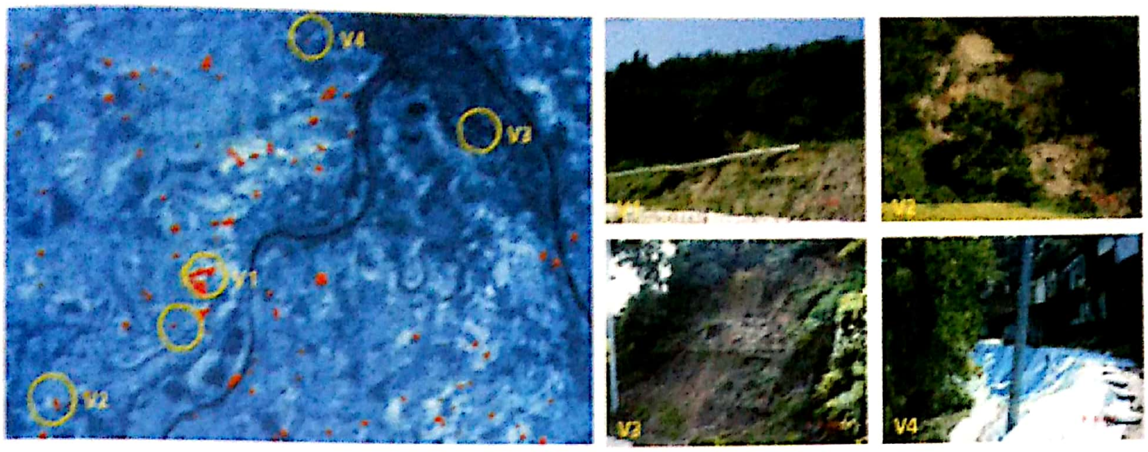


Fig. 9. A map of destroyed areas by landslide and photos of those areas (A map was made by combining the SPOT-5 images taken on August 15, 2001 and July 24, 2004)

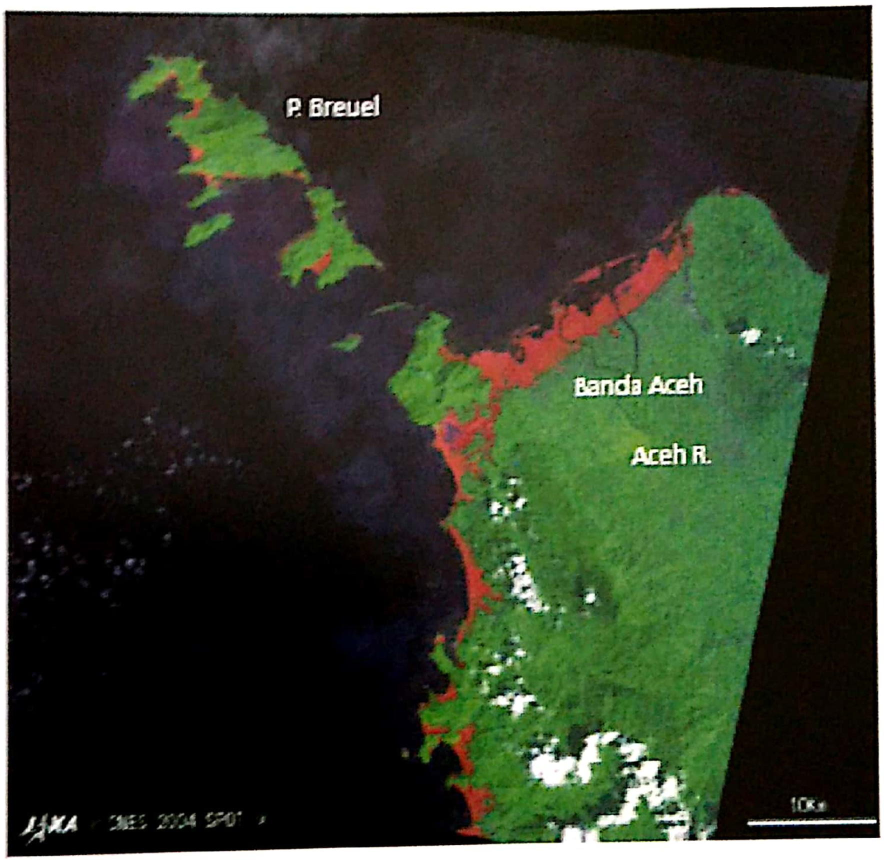
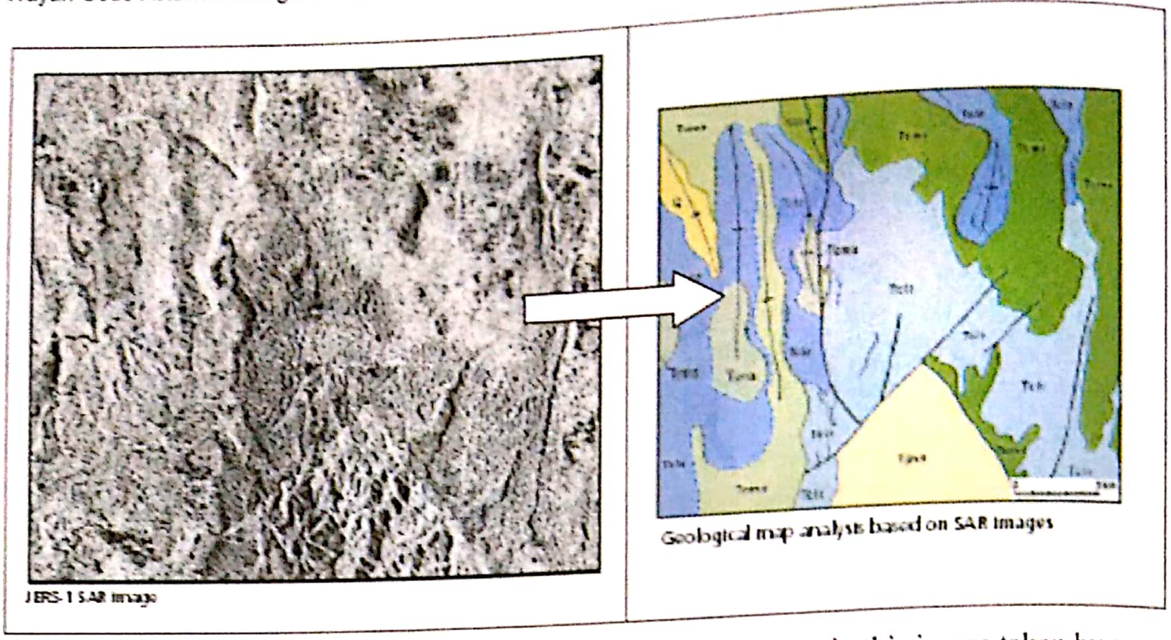


Fig. 10. Tsunami damage following earthquake off Sumatra (combination of images taken by SPOT and JeRS-1)

The photo shows damage in Banda Aceh, Indonesia, by the tsunami tidal wave caused by a huge earthquake off Sumatra on December 26, 2004. Flooded areas are in vermilion.

4). Resource Surveying

To find natural resources such as oil and minerals. Analysis of image data can be helpful for surveying resources such as extracting rocks and geological features which are indexes of resource distribution.



JERS-1 SAR image

Geological map analysis based on SAR images

Fig. 11. Karst, which is unique in limestone areas, can be seen in this image taken by a microwave sensor (Synthetic Aperture Rader, SAR.) Although this area is vastly covered by a tropical rain forest and unevenness of the land surface can be observed (Sulawesi Island, Indonesia)

VIII. Discussion and Conclusion

Satellite remote sensing as the use of satellite-borne sensors to observe, measure, and record the electromagnetic radiation reflected or emitted by the Earth and its environment for subsequent analysis and extraction of information. Each of these sensors enables direct observation of the global land surface in a consistent fashion, with data having unique characteristics of spectral, spatial, and temporal resolution. To varying degrees, the data gathered by each sensor are suited for the variety of specific interests associated with monitoring the effects of natural events and human actions on land cover. Such interests may alternatively require high frequency of coverage, specific combinations of spectral information, or high spatial resolution. In many cases, the data of two or more sensors offer complementary characteristics, making joint use of data advantageous. (Joint use refers to the computerized merging or fusion of different data types into a single product, as well as to the synergistic use and analysis of different data types in the course of research.)

The Advanced Land Observing Satellite (ALOS) aims at collecting global topographic data with a high resolution by upgrading the land observation technology of the Japan Earth Resources Satellite-1 (JERS-1,or Fuyo) and the Advanced Earth Observing Satellite (ADEOS or Midori). The ALOS is equipped with three earth observation sensors, namely the Panchromatic Remote-sensing Instrument of Stereo Mapping (PRISM) for obtaining terrain data including elevations; the Advanced Visible and Near Infrared Radiometer type-2 (AVNIR-2) for providing land coverage maps and land-use classification maps; and the Phased Array type L-band Synthetic Aperture Radar (PALSAR) for day-and-night observations of land and ice sheets regardless of the weather. With these three sensors, the ALOS has detailed land observation functions.

References

Australiant Government, Geoscience Australia. 2007. ALOS satellite data. amht.htm. avalaible at http://www.ga.gov.au/acres/prod_ser/alosdata.jsp (verified 22/08/2007)

CIESIN Thematic Guides. 2007. Satellite Remote Sensing and its Role in Global Change Research. Available at http://www.ciesin.columbia.edu/TG/RS/satremot.html. (verified 25/08/2007)

Cracknell, A and L. Hayes. 1991. Introduction to Remote Sensing. University of Dundee.

Earth Observatory. 2007. Avalaible at http://earthobservatory.nasa.gov/Library/ RemoteSensing/remote_04.html (verified 15/08/2007)

Earth Observation Satellite. 2006. ALOS\JAXA Advanced Land Observing Satellite Daichi (ALOS). amht.htm. Available at http://www.eorc.jaxa.jp/hatoyama/satellite/sendata/prism_e.html (verified 25/082007)

Rees, W.G. 1990. Physical Principles of Remote Sensing. Cambridge University.