VI International Congress on Earth Sciences, 2000 Santiago, Chile

Application of Remote Sensing to Environmental Monitoring and Assessment

Yoshifumi Yasuoka
Professor, University of Tokyo

Abstract

Monitoring of environmental variables and parameters is the first step to tackle with all kinds of environmental issues from local, regional to global scale. However, since environmental monitoring requires the measurements of wide variety of parameters covering physical, chemical, biological, or geographical areas, and furthermore since it needs to cover the areas from local to global, operational and practical environmental monitoring system is not established yet. Conventional ground observation method may not cover extensive areas such as continental or global scale. Remote sensing from space is expected to provide a new tool for observing wide range of environmental variables from local to global scale regularly. Recent developments in remote sensing technology have been rapid, and spatial resolution or spectral resolution in observation has been drastically improved. These advances have enabled us to measure spatial distribution of environmental parameters in extensive areas in a short time. In this presentation application of remote sensing to environmental monitoring is introduced with emphasis on its new technical trends. Application examples are also demonstrated.

1. Introduction

Deforestation, land degradation, and urbanization have become critical environmental issues during past decades all over the world, and monitoring of environmental parameters in atmosphere, water or land is now essential to the proper management of environment from local to global scale.

Monitoring of environment requires the measurements of wide variety of parameters covering physical, chemical, biological, or geographical areas. Furthermore it needs to cover from local to global scale and from short to long time scale. Only with conventional ground observation method efficient environmental monitoring system can not realized. Remote sensing from space is expected to provide a new tool for observing wide range of environmental variables from local to global scale regularly. In this presentation application of remote sensing to environmental monitoring is introduced with emphasis on new technical trends in remote sensing and on its application to terrestrial ecosystem monitoring.

2. **Principles of Remote Sensing**

(1) Spectral characteristics

Remote sensing is an observation tool to identify, measure or analyze the characteristics of objects without directly contacting the target. Remote sensing utilizes electro-magnetic radiation as a media for the measurement, and it is based on the principle that all matter reflects, absorbs, penetrates and emits electro-magnetic radiation in a unique way. For example, the reason why a leaf looks green is that the chlorophyll in a leaf absorbs blue and red spectra, and as a result reflects the green spectrum. This unique characteristic of matter for electro-magnet radiation is called spectral characteristics (spectral signature). Figure 1 shows the typical spectral reflectance characteristics of vegetation, soil and water.

(2) Remote sensor

In remote sensing the reflected or emitted electro-magnetic radiation from a target is detected with a device, and the characteristics of the object are identified, measured or analyzed based on the difference in the spectral signature of the detected radiation. A device to detect the electro-magnetic radiation reflected or emitted from an object is called a "remote sensor". Cameras or scanners are typical examples of remote sensors. A vehicle to carry the sensor is called a "platform", and usually aircrafts or satellites are used as platforms.

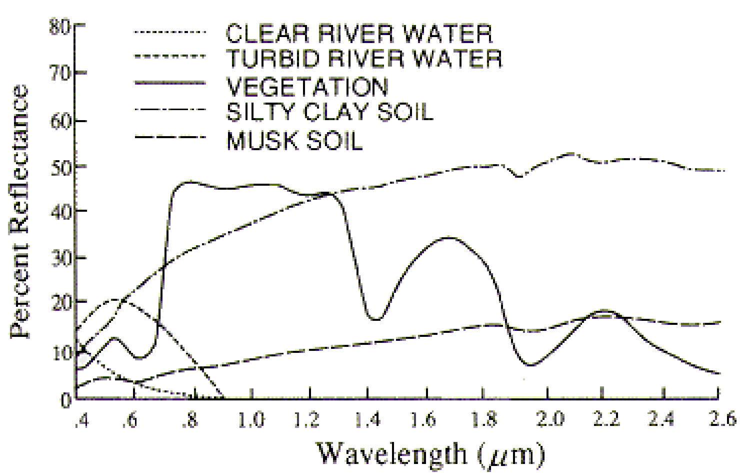

Fig. 1 Typical spectral reflectance characteristics of vegetation, water and soil.

Human eyes can only detect the specific range of electro-magnetic radiation called “visible range”, however, remote sensing can utilize a wide wavelength range covering visible, near-infrared, infrared to microwave range with various types of remote sensors. Utilization of different wavelength range enables to monitor various types of environmental parameters. For example, vegetation condition is characterized primarily in near-infrared range whereas thermal characteristics are characterized in thermal infrared range.

Specifications of remote sensors are characterized by various parameters including spectral range, spectral resolution, spatial resolution, observation width (swath) or observation period. There have been developed different types remote sensors. Table 1 summarizes the specifications of typical remote sensors used for environmental monitoring. High spatial resolution sensor such as LANDSAT TM, SPOT HRV or IKONOS are used for local or regional observation whereas low spatial resolution (but wide coverage and high observation frequency) sensors such as MOAA/AVHRR, ADEOS/OCTS or TERRA/MODIS are used for continental or global observation.

Table 1 Specifications of typical remote sensors

Satellite	Sensor	Wavelength	No. of bands	Spatial Res.	Swath	Observation Freq.
LANDSAT	TM	0.45-12.5μm	7 bands	30m	180km	17 days
SPOT	HRV	0.50-0.89μm	4	10-20	60	26
ERS-1	SAR	5.3GHz	1	20	100	35
JERS-1	OPS	0.52-0.86μm	4	18	75	44
?	SAR	1.275GHz	1	18	?	?
NOAA	AVHRR	0.58-12.5μm	5	1km	2700	0.5day
ADEOS	AVNIR	0.40-0.92μm	4	8?16m	80	41
?	OCTS	0.40-12.5μm	12	700	?	?
EOS	ASTER	0.52-11.3μm	14	15?90	60	16
?	MODIS	0.66-14.2μm	36	250-1000	2330	?
IKONOS	Pan/MSS	Vis./Near-infrared	1/4	1-4	11	11

3. Environmental Parameters Measured by Remote Sensing

Environmental parameters measured by remote sensing are ranging from practical or operational level to research level. Examples of parameters are summarized as follows.

Practical level

Land: vegetation index (NDVI, etc.), vegetation classification, soil index, topography

Water: suspended sediment, chlorophyll, surface wind vector

Atmosphere: clouds, aerosols

Others: temperature,

Research level

Land: detail vegetation species, soil type classification, tree height, LAI, biomass, NPP, soil moisture, human habitats, chlorophyll/lignin/cellulose in tree canopy

Water: chlorophyll(high accuracy)

Atmosphere: NOx, SOx, O3, CO2, clo

Others: precipitation

The NDVI is, for example, an index calculated from visible and near-infrared radiance of remotely sensed data and it indicates how much extent the area is covered by vegetation. It is one of the most popularly used index to evaluate green distribution and, in particular, the NDVI distribution is used to assess deforestation and desertification in continental or global scale. Figure 2 shows an example of NDVI image of East Asian region derived from NOAA/AVHRR data. Here all of the AVHRR data observed in June, 1996 was collected, overlaid and composited to produce cloud-free image.

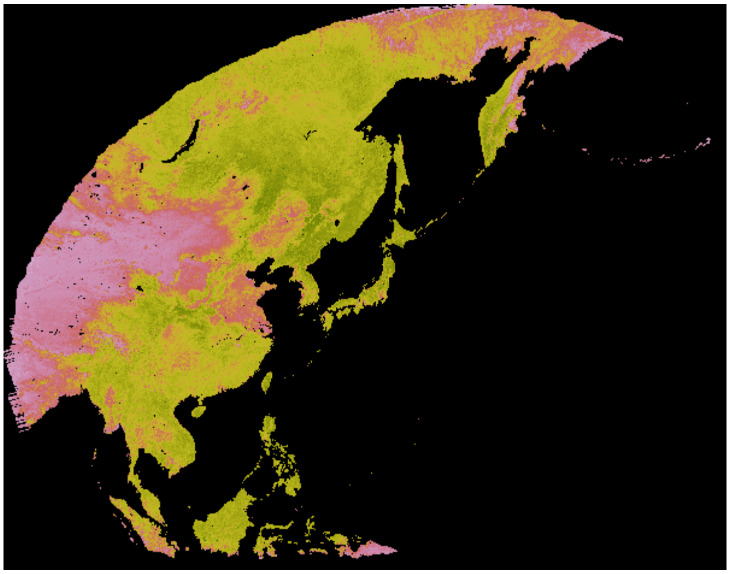

Fig. 2 An example of the NDVI image derived from NOAA/AVHRR image (NIES, Japan).

The NDVI is not a bio-physical parameters but an index, however, it is reported that the NDVI has a correlation with other bio-physical parameters including LAI (leaf area index) or NPP which are very important parameters for carbon cycling and as a result for global warming. There have been several studies to estimate LAI or NPP distribution in global scale based on the NDVI. Figure 3 shows examples of the continental scale distribution of the NPP estimated from the NDVI.

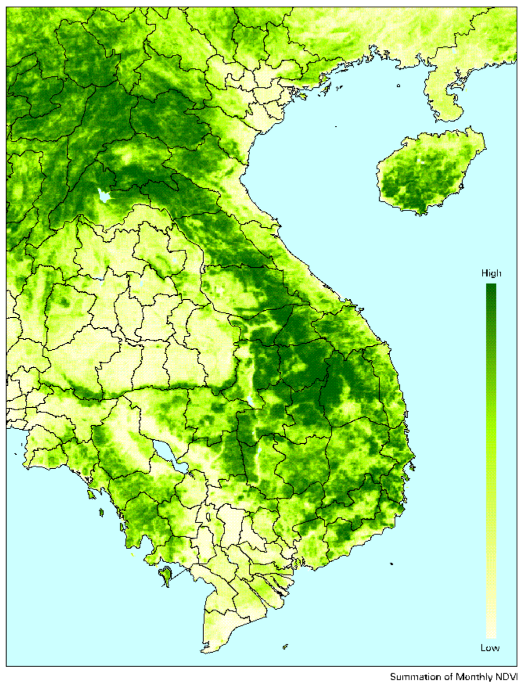

Fig. 3 An example of the NPP distribution estimated from NOAA/AVHRR NDVI (Dr. Tamura, NIES)

4. New Technical Trends in Remote Sensing

(1) Hyper-spatial Observation

Spatial resolution is one of the most important observation performances in remote sensing. It has been drastically improved these twenty years, and today one meter spatial resolution is realized in IKONOS satellite. From these images, for example, individual houses or tree canopies can be identified from space. High spatial resolution observation will enable us to retrieve more detail information on human settlements, land surface characteristics or land topography from remotely sensed data. Figure 3 shows an example of the IKONOS image with one meter spatial resolution over the central area of Tokyo, Japan. In this image very fine spatial structures of the buildings and the roads are identified.


(From IKONOS CD/ROM)

Fig.3 An example of the IKONOS image over Tokyo.

(2) Hyper-spectral Observation

Number of spectral channels in conventional remote sensors has been limited to ten or at most to several tens in satellite and airborne systems. New hyper-spectral sensor systems have the capability of observing land surface in a couple of hundreds channels. For example, the Hyperion on EO-1 which will be launched this year has 256 channels. Airborne sensor systems such as CASI and AVIRIS have also hundreds channels and their spectral wavelength resolution is as narrow as several nanometers. Data from the hyper-spectral sensors has indicated the possibility of observing new ecosystem parameters including water stress condition in vegetation or detail vegetation categories, which could not be observed by the conventional sensors.

(3) Microwave Range Observation

With optical remote sensing we can not observe the ground through cloud or haze. Microwave remote sensing has an advantage of cloud and haze free (all weather) observation due to its longer wavelength. This observation capability enables us to monitor land surface conditions regularly even in heavily clouded regions including tropical regions or high latitude regions. A Synthetic Aperture Radar (SAR) is a typical microwave sensor which enables high spatial observation. Figure 4 shows an example of a SAR composite image over South-American continent from JERS1 SAR. Microwave remote sensing has a possibility of monitoring precipitation and soil moisture conditions which are one of the most important environmental parameters. Microwave range observation may provide us of the information that may not be obtained by optical remote sensing.

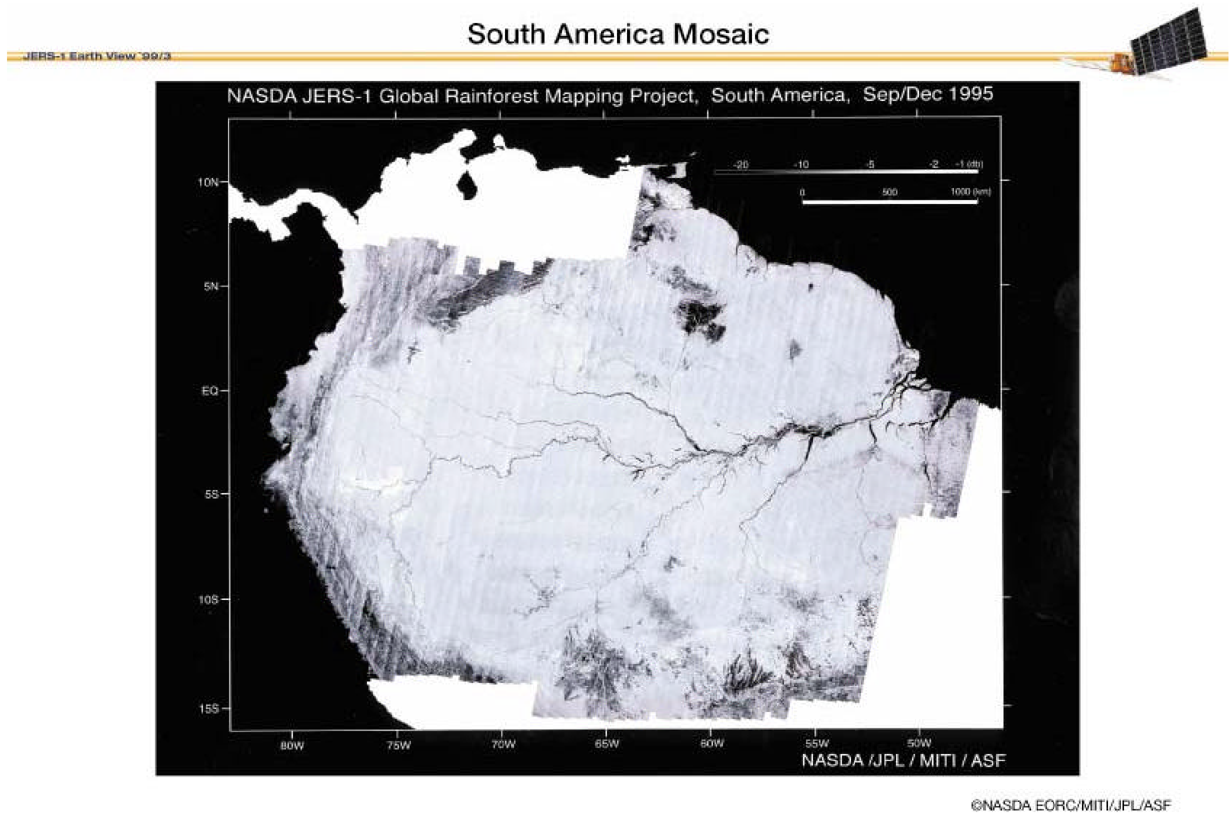

Fig.4 An example of SAR composite image (NASDA, Japan).

(4) Data Fusion and Integration

Today many different types of sensors are available in remote sensing. Integration of data from multiple different sensor systems may provide us with more detail information that may not be retrieved from the data obtained by one single sensor. For example combination between microwave sensor data (SAR) and optical sensor data provides us with new information on land surface characteristics. Also integration of satellite data and the topographic data enables us to produce three dimensional data set (3-D digital world) which is very useful to disaster assessment or environmental assessment. Integration of data from different sources is usually called data fusion, and it is one of the new data analysis methodologies in remote sensing.

(5) Scaling between low resolution and high resolution sensor data

High spatial resolution data (e.g. LANDSAT TM, SPOT HRV or IKONOS data) does not cover a whole continent or globe because of its narrow coverage. Combination between high spatial resolution data with low resolution but wide coverage data (e.g. NOAA AVHRR data) enables to extrapolate local information from high spatial resolution data to global scale by introducing the scaling model between them. Scaling is a way to link local with global, and one of the most important concepts in applying remote sensing to terrestrial ecosystem monitoring.

(6) Coupling remote sensing with modeling

Physical or mathematical models play a vital role in predicting the future environment. Precipitation or soil moisture conditions in the future are, for example, key parameters to manage land surface processes. However it has been difficult to obtain various parameters or boundary condition data for models in two or three dimensional format. Remote sensing is expected to provide boundary conditions or parameters to climate models or environmental models.

4. Conclusions

Environmental monitoring with remote sensing has the potential advantages as follows;

@ it does not disturb the object in measurement

@ it can cover extensive areas in a short time

@ it can measure parameters in the same spatial and temporal scale equally for any area of the world

@ it can cover land, ocean and atmosphere areas where we can not get into and where we can not do direct observation.

Development of remote sensing technology has been very rapid, and today various types of remotely sensed data are available ranging from high spatial resolution sensor data for local monitoring to wide coverage sensor data for global monitoring and covering land, ocean atmosphere. Efficient monitoring of environmental variables is the first step to tackle with these issues, however, operational and practical monitoring is still difficult. It is expected to realize practical and operational environmental monitoring system with remote sensing in combination with traditional ground survey methods.

References

1. American Society of Photogrammetry and Remote Sensing: Manual of Remote Sensing
2. Japan Association on Remote Sensing: Remote Sensing Note (1996)
3. G. Asrar, J. Dozzzier: EOS Science Strategy for Earth Observing System, AIP Press (1983)