An Introduction to Remote Sensing & GIS

Introduction

Remote sensing is the measurement of object properties on Earth's surface using data acquired from aircraft and satellites. It attempts to measure something at a distance, rather than *in situ*, and, for this research's purposes, displays those measurements over a two-dimensional spatial grid, i.e. images. Remote-sensing systems, particularly those deployed on satellites, provide a repetitive and consistent view of Earth facilitating the ability to monitor the earth system and the effects of human activities on Earth. There are many *electromagnetic* (EM) band-length ranges Earth's atmosphere absorbs. The EM band ranges transmittable through Earth's atmosphere are sometimes referred to as atmospheric windows.

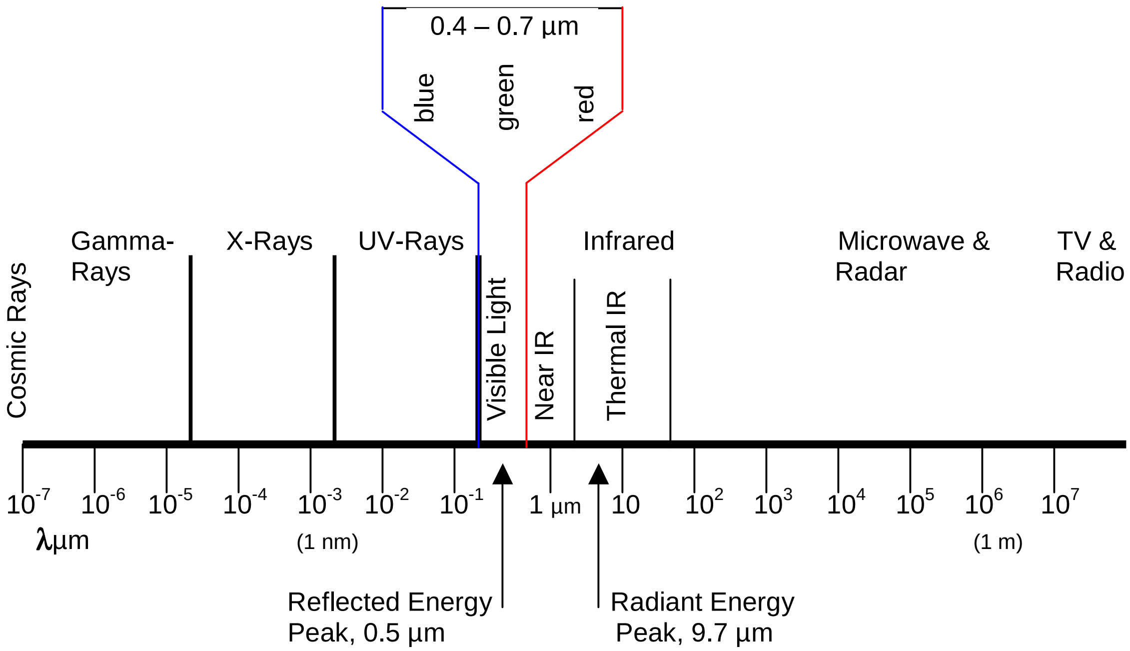
The human eye only detects, viz. the reflective solar radiance humans actually see, that part of the EM scale in the band length range 0.4 – 0.7 µm. But remote sensing technology allows for the detection of other reflective and radiant (e.g. thermal) energy band-length ranges that reach or are emitted by Earth's surface, and even some Earth's atmosphere reflects, e.g. the EM reflective qualities of clouds. Hence, for viewing purposes red, green, and blue (RGB) false color assignments are used to express the reflective qualities of objects in these EM band-length groups, and the combination and mixing of these false color assignments express the true physical reflective qualities of all objects present in an image.

The primary benefit of *Geographic Information Systems* (GIS) is the ability to interrelate spatially multiple types of information assembled from a range of sources. These data do not necessarily have to be visual. Shape files are helpful for interpolating and visualizing many other types of data, e.g. demographic data. Many study and research models rely on the ability to analyze and extract information from images by using a variety of computer available research tools and then express these findings as part of a project with images in a variety of layers and scenes.

When utilizing satellite images to assess most types of land cover change, primarily those involving change in vegetation coverage, variations in climate must be considered. For better control and accuracy in these analyses, comparing images acquired during the same month or season is advisable. But due to the limited availability of satellite images, obtaining materials corresponding both spatially and temporally to the location and period under research are not always possible. Furthermore, annual and seasonal climate data are not always available for the region or temporal period being researched. Sometimes, changes in average rainfall, temperature, etc. must be inferred using more macro regional or global data.

One standard remote sensing application for detecting temporal change in land cover, especially vegetation, is the *Normalized Difference Vegetation Index* (NDVI). The NDVI application involves a ratio formula between the visual red and NIR EM bands. This ratio application helps to distinguish healthy and stronger vegetation reflection from other materials with similar reflective qualities in those EM band wavelength groups. NDVI applications are useful because two images can be processed into a false color composite, which allows for visual temporal change detection in vegetation coverage. Moreover, by applying standardized thresholds to multiple NDVI manipulated images, one can create classification training regions and execute supervised computer-generated classifications of multiple images. From these resulting images, area summary reports are calculated. These empirical data enable a more accurate assessment of change in area of the corresponding land-cover classes. Information pertaining to some of the above topics, as well as a more comprehensive description on some remote sensing technologies including a glossary of terms, is given in the sections below.

The Electromagnetic Spectrum



The Electromagnetic Spectrum

Gamma rays	**<0.30 nm**	This range is completely absorbed by the upper atmosphere and not available for remote sensing.
X-rays	**0.03—30.0 nm**	This range is completely absorbed by the atmosphere and not employed in remote sensing.
UV-rays	**0.03—0.40 µm**	This range is completely absorbed by the atmosphere and not employed in remote sensing.
Photographic UV	**0.30—0.40 µm**	This range is not absorbed by the atmosphere and detectable with film and photo detectors but with severe atmospheric scattering.
Visual Blue	**0.45—0.52 µm**	Because water increasingly absorbs electromagnetic (EM) radiation at longer wavelengths, band 1 provides the best data for mapping depth-detail of water-covered areas. It is also used for soil-vegetation discrimination, forest mapping, and distinguishing cultural features.
Visual Green	**0.50—0.60 µm**	The blue-green region of the spectrum corresponds to the chlorophyll absorption of healthy vegetation and is useful for mapping detail such as depth or sediment in water bodies. Cultural features such as roads and buildings also show up well in this band.
Visual Red	**0.60—0.70 µm**	Chlorophyll absorbs these wavelengths in healthy vegetation. Hence, this band is useful for distinguishing plant species, as well as soil and geologic boundaries.
Near IR	**0.70—0.80 µm**	The near IR corresponds to the region of the EM spectrum, which is especially sensitive to varying vegetation biomass. It also emphasizes soil-crop and land-water boundaries.
Near IR	**0.80—1.10 µm**	The second near IR band is used for vegetation discrimination, penetrating haze, and water-land boundaries.
Mid-IR	**1.55—1.74 µm**	This region is sensitive to plant water content, which is a useful measure in studies of vegetation health. This band is also used for distinguishing clouds, snow, and ice.
Mid IR	**2.08—2.35 µm**	This region is used for mapping geologic formations and soil boundaries. It is also responsive to plant and soil moisture content.
Mid-IR	**3.55—3.93 µm**	A thermal band which detects both reflected sunlight and earth--emitted radiation and is useful for snow-ice discrimination and forest fire detection.
Thermal IR	**10.40—12.50 µm**	This region of the spectrum is dominated completely by radiation emitted by the earth and helps to account for the effects of atmospheric absorption, scattering, and emission. It is useful for crop stress detection, heat intensity, insecticide applications, thermal pollution, and geothermal mapping. This channel is commonly used for water surface temperature measurements.
Microwave-Radar	**0.10—100 cm**	Microwaves can penetrate clouds, fog, and rain. Images can be acquired in the active or passive mode. Radar is the active form of microwave remote sensing. Radar images are acquired at various wavelength bands.
TV & Radio	**>10 m**	The longest-wavelength portion of the electromagnetic spectrum.

Satellite Sensors

AVHRR

The Advanced Very High Resolution Radiometer (AVHRR) produces 1 km multispectral data from the NOAA satellite series (1979 to present). The AVHRR's four or five spectral bands are used primarily for mapping large areas, especially when good temporal resolution is required. Applications include snow cover and vegetation mapping; flood, wild fire, dust and sandstorm monitoring; regional soil moisture analysis; and various large-scale geologic applications.

Spatial Resolution:	1 km
Spectral Bands:	**Band 1:** (visible red, 0.58-0.68µm)
	Band 2: (near IR, 0.725-1.10µm)
	Band 3: (IR, 3.55-3.93µm)
	Band 4: (thermal IR, 10.30-11.30µm)
	Band 5: (thermal IR, 11.50-12.50µm)

Landsat MSS

The Landsat Multi-Spectral Scanner flew on the first five Landsat missions, providing continuous, comparable data over a period of about 20 years, from 1972 to 1993.

Spatial Resolution:	57 m
Spectral Bands:	**Band 1**: (visual green, 0.50-0.60µm)
	Band 2: (visual red, 0.60-0.70µm)
	Band 3: (near IR, 0.70-0.80µm)
	Band 4: (near IR, 0.80-1.10µm)

Landsat TM

The Landsat TM missions began in 1982 with Landsat-4 and have continued to the present with the Landsat-7 mission.

Spatial Resolution:	30 m
Spectral Bands:	**Band 1**: (visual blue, 0.45-0.52µm)
	Band 2: (green, 0.52-0.60µm)
	Band 3: (red, 0.63-0.69µm)
	Band 4: (near IR, 0.76-0.90µm)
	Band 5: (mid IR, 1.55-1.74µm)
	Band 6: (thermal IR 10.40-12.50µm)
	Band 7: (mid IR, 2.08-2.35µm)

Landsat ETM+

The Enhanced Thematic Mapper Plus (ETM+) sensors record data using the same seven bands as the TM sensors. One advanced feature of this enhanced sensor is the addition of a panchromatic band with 15 m spatial resolutions and a bandwidth from 0.52 to 0.90 µm. The second major enhancement is the increase in spatial resolution of the thermal band (6) from 100 to 60 m. It was launched in 1999 on the Landsat-7 mission.

Glossary

Albedo	Ratio of the amount of electromagnetic energy (solar radiation) reflected by a surface to the amount of energy incident upon the surface.
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer.
AVHRR	Advanced very high-resolution radiometer.
AVIRIS	Airborne visible-infrared imaging spectrometer.
Band	Broadcasting frequency within given limits. A subdivision within an electromagnetic region.
Bandwidth (*spectral resolution*)	The total range of frequency required to pass a specific modulated signal without distortion or loss of data. The wavelength interval recorded by a detector.
CEO	Center for Observing the Earth from Space at Yale University
ETM+	Enhanced Thematic Mapper Plus
EM	Electromagnetic
GPS	Global Positioning System
GIS	Geographic Information System
IFOV	Instantaneous field of view: the solid angle through which a detector is sensitive to radiation. In a scanning system, the solid angle subtended by the detector when the scanning motion is stopped.
IKONOS	A high-resolution earth observation satellite launched in 1999, which occupies a 682-km sun synchronous orbit and employs linear array technology collecting data in four multispectral bands at a nominal resolution of 4 m, as well as a 1-m-resolution panchromatic band.
Landsat	A series of unmanned NASA earth resource satellites that acquire multispectral images in the visible and IR bands.
NAD	North Atlantic Datum
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
Radiation	Act of giving off electromagnetic energy.
RGB	Red, Green, and Blue—the colors used in constructing visible and false color image representations.
MIR	Mid Infrared
Spatial Resolution	The ability to distinguish between closely spaced objects on an image. Commonly expressed as the most closely spaced line-pairs per unit distance distinguishable.
Spectral Reflectance	Reflectance of electromagnetic energy at specified wavelength intervals.
Spectral Resolution *(bandwidth)*	Range of wavelengths recorded by a detector.
SWIR	Short Wave Infrared
TM	Thematic Mapper
UTM	Universal Transverse Mercator
VI	Vegetation Index
VNIR	Visible and Near Infrared
WGS	Worldwide Geographic System
WRS	Worldwide Reference System

References

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http://landsat.usgs.gov/