MACHAKOS UNIVERSITY

CENTRE FOR OPEN, DISTANCE AND e-LEARNING

IN COLLABORATION WITH

SCHOOL OF AGRICULTURE, ENVIRONMENT AND HEALTH SCIENCES
DEPARTMENT OF ENVIRONMENTAL SCIENCES

MODULE

ENS 331: REMOTE SENSING FOR ENVIRONMENTAL SCIENCES

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ENS 331: Remote Sensing for Environmental Sciences

The purpose of this course is to is to equip the learners with knowledge, skills and information regarding fundamental principles of remote sensing and its application in environmental sciences. By the end of this course, you should be able to;

i. Demonstrate understanding of the key concepts and the underlying theory of remote sensing process
ii. Discuss the digital remote sensing image analysis and validation techniques
iii. Interpret remote sensing data for scientific applications in environmental science

Mode of Delivery: Lectures; Tutorials; Assignments; group discussions and presentations

Instructional Materials and Equipment: Lecture Notes; text books; Journal papers; Videos and audio recordings

Course Assessment: Continuous Assessments-30%; Examination - 70%; **Total - 100%**

Course Schedule

Lesson 1	Introduction to remote sensing
Lesson 2	Physical Principles of Remote Sensing
Lesson 3	Interaction of EMR with Earth's Atmosphere and Surfaces
Lesson 4	Interaction of EMR with Earth's Surfaces
Lesson 5	Sensors and remote sensing satellites
Lesson 6	Pre-processing of remote sensing data
Lesson 7	Enhancement of remote sensing data
Lesson 8	Visual Interpretation of remote sensing data
Lesson 9	Classification of remote sensing data

ENS 331: Remote Sensing for Environmental Sciences

Lesson 1

1 INTRODUCTION TO REMOTE SENSING

1.1 Introduction

The desire to study extensive landscapes, mountain ranges, volcanoes, hurricanes, river basins and other natural resources is the key basis for space-based Earth observation (EO). This lesson provides an overview of the concept of remote sensing and different remote sensing systems.

The lecture covers:

1. Lecture objectives
2. The meaning remote sensing
3. Remote sensing systems
4. Summary
5. Further activity
6. Suggestions for further reading

1.2 Lecture Objectives

By the end of this lesson, you should be able to:

1. Explain the maninf of remote sensing.
2. Describe different remote sensing systems.

1.3 Remote sensing

Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information. It involves the detection, recognition, or evaluation of objects by means of distant sensing or recording devices.

Remote sensing of earth's environment comprises measuring and recording of electromagnetic energy reflected from or emitted by the planet's surface and atmosphere from a· vantage point above the surface, and relating of such measurements to the nature and distribution of surface materials and atmospheric conditions.

E-tivity 1

Numbering, pacing and sequencing	**1.1**
Title	Remote Sensing Basics
Purpose	The purpose of this e-tivity is to enable you to explain the concept of remote sensing
Summary of overall task	i. Watch video 1 ii. Access and read this reading material
Spark	
Individual task	Explain the concept of remote sensing and different types of remote sensing systems as provided in this reading material
Interaction begins	a) Post three unique characteristics of remote sensing as a data collection technique. Do this in the discussion forum 1.1 b) Comment on the posts of your colleagues.
E-moderator interventions	1. Ensure that learners are focused on the contents and context of discussion. 2. Stimulate further learning and generation of new ideas. 3. Provide feedback on the learning progress. 4. Close the e-tivity
Schedule and time	This task should take one hour
Next	Physical basis of the remote sensing process

1.4 Remote sensing systems

From the video you have watched, the following are the types of remote sensing systems.

i. ***Active sensing system***: they generate and uses its own energy to illuminate the target and records the reflected energy which carries the information content or entropy.

ii. ***Passive sensing systems:*** they mainly depending on the solar radiation operates in visible and infrared region of electromagnetic spectrum. The nature and properties of the target materials can be inferred from incident electromagnetic energy that is reflected, scattered or emitted by these materials on the earth's surface and recorded by the passive sensor (for example, a camera without flash). The remote sensing system that uses electromagnetic energy can be termed as electromagnetic remote sensing.

1.5 Summary

In this lesson we have defined the concept of remote sensing and different remote sensing systems. Remote sensing means that something is sensed remotely, that is, from a certain distance. This implies that there is a certain interaction between the object and the sensor that captures the former. For example, our eyes are sensors that can see a tree by deciphering the visible radiant energy that is reflected by the tree, by reflecting either sunlight or another illumination source. In the next lesson you will learn about the components of the remote sensing process.

1.6 Further activity

With examples describe the remote sensing process.

1.7 Suggestions for further reading

1. Joseph, George. (2005). *Fundamentals of Remote Sensing*, (2^{nd} Ed.), Universities Press Limited.

2. Jensen, John R. (2009). *Remote Sensing of the Environment: An Earth Resource Perspective*, (2^{nd} Ed.), Dorling Kindersley Private Limited

Lesson 2

2 PHYSICAL BASIS OF THE REMOTE SENSING PROCESS

Remote sensing has a strong physical basis, as it implies collecting electromagnetic (EM) signals coming from objects with different physical and chemical properties. This lesson explores the physical processes that make this interaction possible.

The lecture covers:

1. Lecture objectives
2. The electromagnetic spectrum
3. Summary
4. Further activity
5. Suggestions for further reading

2.1 Lecture Objectives

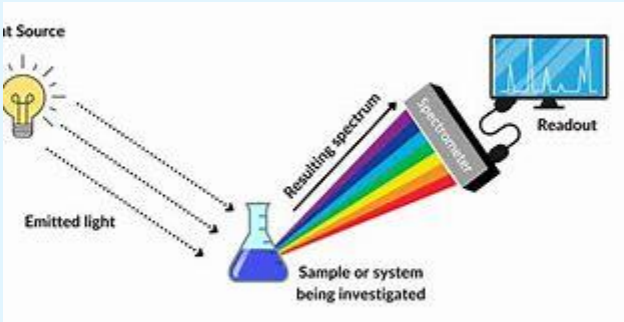
By the end of this lesson, you should be able to:

1. Explain the physical basis of remote sensing.
2. Describe different regions of the electromagnetic spectrum

2.2 Electromagnetic radiation (EMR)

As was noted in the previous lesson, the first requirement for remote sensing is to have an energy source (A) to illuminate the target (unless the sensed energy is being emitted by the target). This energy is in the form of ***electromagnetic radiation (EMR)***. EMR is the term used to describe all of the different types of energies released by electromagnetic processes. Visible light is just one of many forms of electromagnetic energy. Radio waves, infrared light and X rays are all forms of electromagnetic radiation. The electromagnetic spectrum is the term used to describe to entire range of all possible frequencies of electromagnetic radiation.

E-tivity 2

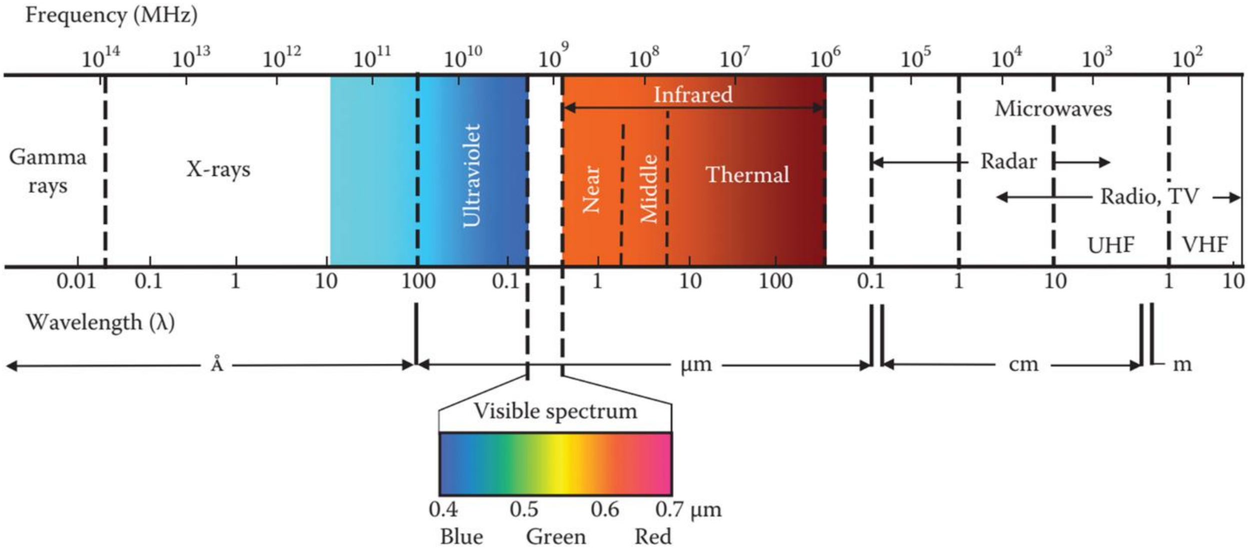
Numbering, pacing and sequencing	**2.1**
Title	Physical basis of remote sensing process
Purpose	The purpose of this e-tivity is to enable you to explain the physical basis of remote sensing process
Summary of overall task	Watch a video on physical basis of remote sensing process provided here
Spark	
Individual task	**(a)** Explain the concept of electromagnetic spectrum **(b)** Which form of electromagnetic radiation has the highest frequency? **(c)** Which form of electromagnetic radiation has the longest wavelength?
Interaction begins	a) In discussion forum 2.1, discuss the main regions of the electromagnetic spectrum b) Read and respond to the posts of your colleagues on the electromagnetic spectrum.
E-moderator interventions	1. Ensure that learners are focused on the contents and context of discussion. 2. Stimulate further learning and generation of new ideas. 3. Provide feedback on the learning progress. 4. Close the e-tivity
Schedule and time	This task should take one hour

Next	Main regions of the electromagnetic spectrum

1.1 Electromagnetic spectrum

Since radiation sources are very diverse and therefore EM radiations vary from very small to very long wavelengths, most textbooks tend to classify them in certain groups of wavelengths of frequencies that are finally organized in the so-called EM spectrum. It includes a continuous range of wavelengths or frequencies, but commonly several spectral regions or bands are identified, with particular radiation properties. Although most spectral bands are referred to in length units, MWs are commonly expressed in frequency units (gigahertz, GHz=10^9 Hz).

The shortest wavelengths, with the highest radiation energy, are gamma rays and x-rays, whose wavelengths range from 10^{-9} to 10^{-3} µm (or 10^{-15} to 10^{-9} m) and which are commonly used in astronomical observation and medical applications, respectively. The longest wavelengths are used for telecommunications, radio, and television, with wavelengths in the range of 10^8–10^{10} µm (or 100–10,000 m). The spectral regions most commonly used in remote sensing observation are the following:



1. The VIS region (0.4–0.7 µm). It covers the spectral wavelengths that our eyes are capable of sensing and at which the Sun's energy is the highest. The VIS region can be further divided into the three primary colors: blue (0.4–0.5 µm), green (0.5–0.6 µm), and red (0.6–0.7 µm).

2. The NIR region (0.7–1.2 µm). This portion of the spectrum lies just beyond the human eye's perception capability and is sometimes known as the reflective infrared or photographic infrared because part of this spectral region (0.7–0.9 µm) can be detected with special films. The NIR is of special interest because of its sensitivity to determine plant health status.

3. The mid-infrared region (MIR, 1.2–8 µm). This spectral region lies between the NIR and TIR regions. From 1.2 to 2.5 µm, the influence of the Sun's energy is still very relevant, and this band is commonly referred to as the SWIR region. This region provides the best estimations of the moisture content of soil and vegetation. From 3 to 8 µm, the signal becomes a continuous mixture of solar-reflected and a surface-emitted energy, becoming the more relevant emitted component as the wavelengths become longer. The 3–5 µm interval is particularly useful for detecting high-temperature sources, such as volcanoes or forest fires.

4. The thermal infrared region (TIR from 8 to 14 µm). This is the emitted energy from the Earth's surface that is commonly used to map surface temperatures. The thermal region has been widely used in detecting vegetation evapotranspiration (ET), ice and cloud properties, urban heat effects, and rock discrimination.

5. The microwave (MW) region, for radiations larger than 1 cm. This spectral region is where the imaging radar systems work. Its main advantage is the very low atmospheric absorption, which enables us to "see" through clouds. MW radiation can also penetrate forest canopies to various depths and are very useful in soil moisture and surface roughness analyses.

2.3 Summary

In this lesson we have covered the physical basis of the remote sensing process. The energy that is measured by a remote sensing instrument and that is used to produce an image, is called electromagnetic radiation. This energy is composed of several regions categorized in terms of their wavelengths and frequencies.

2.4 Further activity

Discuss the physical basis of the remote sensing process.

2.5 Suggestions for further reading

1. Joseph, George. (2005). *Fundamentals of Remote Sensing*, (2nd Ed.), Universities Press Limited.

2. Jensen, John R. (2009). *Remote Sensing of the Environment: An Earth Resource Perspective*, (2nd Ed.), Dorling Kindersley Private Limited

Lesson 3

3 INTERACTION OF EMR WITH EARTH'S ATMOSPHERE

The Sun is the primary source of electromagnetic radiation (EMR) measured in remote sensing techniques. In the previous lesson, we learned that the Sun radiates electromagnetic energy over a wide range of wavelengths and emits the most radiation in the visible portion of the spectrum. Before the electromagnetic energy from the Sun reaches the Earth's surface, it must pass through the atmosphere. As the energy passes through the atmosphere, it interacts with the molecules and particles present in the atmosphere. In this section we will learn about how the atmosphere and the surfaces on the Earth interact with EMR and how this is fundamental to remote sensing.

The lecture covers:

1. Lecture objectives
2. The electromagnetic spectrum
3. Summary
4. Further activity
5. Suggestions for further reading

3.1 Lecture Objectives

By the end of this lesson, you should be able to:

1. Explain the influence of the atmosphere on electromagnetic energy.
2. Describe the concept of atmospheric windows and the importance of these regions to remote sensing.

E-tivity 3

Numbering, pacing and sequencing	**3.1**
Title	Interaction of electromagnetic radiation and earth's atmosphere

Purpose	The purpose of this e-tivity is to enable you to explain the main interaction between electromagnetic radiation and earth's atmosphere
Summary of overall task	Watch the following videos on interaction between electromagnetic radiation and earth's atmosphere a) Video 1 b) Video 2
Spark	
Individual task	(a) Explain the key atmospheric conditions that influence EMR (b) Explain the main types of interactions between EMR and earth's atmosphere (c) What are atmospheric windows?
Interaction begins	a) In discussion forum 3.1, discuss the main types of interactions between EMR and earth's atmosphere b) Read and respond to the posts of your colleagues on the electromagnetic spectrum.
E-moderator interventions	1. Ensure that learners are focused on the contents and context of discussion. 2. Stimulate further learning and generation of new ideas. 3. Provide feedback on the learning progress. 4. Close the e-tivity
Schedule and time	This task should take one hour
Next	Main types of interactions between EMR and earth's atmosphere

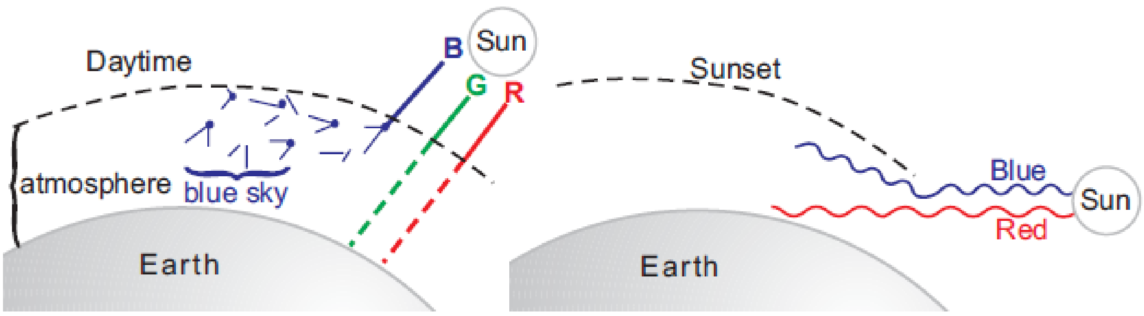
3.2 Mechanism in the interaction between EMR and the atmosphere

Before radiation used for remote sensing reaches the Earth's surface it has to travel through some distance of the Earth's atmosphere. Particles and gases in the atmosphere can affect the incoming light and radiation. The interactions between EMR and earth's atmosphere can be categorized into three mechanisms: **scattering**, **absorption** and **transmission**.

3.2.1 Scattering

Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path. How much scattering takes place depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere. There are three (3) types of scattering which take place: Rayleigh scattering, Mie scattering, and non-selective scattering.

Rayleigh scattering occurs when particles are very small compared to the wavelength of the radiation. These could be particles such as small specks of dust or nitrogen and oxygen molecules. Rayleigh scattering causes shorter wavelengths of energy to be scattered much more than longer wavelengths. Rayleigh scattering is the dominant scattering mechanism in the upper atmosphere. The fact that the sky appears "blue" during the day is because of this phenomenon. As sunlight passes through the atmosphere, the shorter wavelengths (i.e. blue) of the visible spectrum are scattered more than the other (longer) visible wavelengths. At sunrise and sunset the light has to travel farther through the atmosphere than at midday and the scattering of the shorter wavelengths is more complete; this leaves a greater proportion of the longer wavelengths to penetrate the atmosphere.



Rayleigh scattering causes us to perceive a blue sky during daytime and a red sky at sunset. (Image source: Tempfli et al. 2009)

Mie scattering occurs when the particles are just about the same size as the wavelength of the radiation. Dust, pollen, smoke and water vapour are common causes of Mie scattering which tends to affect longer wavelengths than those affected by Rayleigh scattering. Mie scattering occurs mostly in the lower portions of the atmosphere where larger particles are more abundant and dominates when cloud conditions are overcast.

The final scattering mechanism of importance is called ***non-selective scattering***. This occurs when the particles are much larger than the wavelength of the radiation. Water droplets and large dust particles can cause this type of scattering. Nonselective scattering gets its name from the fact that all wavelengths are scattered about equally. This type of scattering causes fog and clouds to appear white to our eyes because blue, green, and red light are all scattered in approximately equal quantities (blue+green+red light = white light).

Nonselective Scattering

3.2.2 Absorption

Absorption is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere. In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths. The primary gases that are responsible for the majority of the atmospheric absorption of energy are water vapor, carbon dioxide, and ozone.

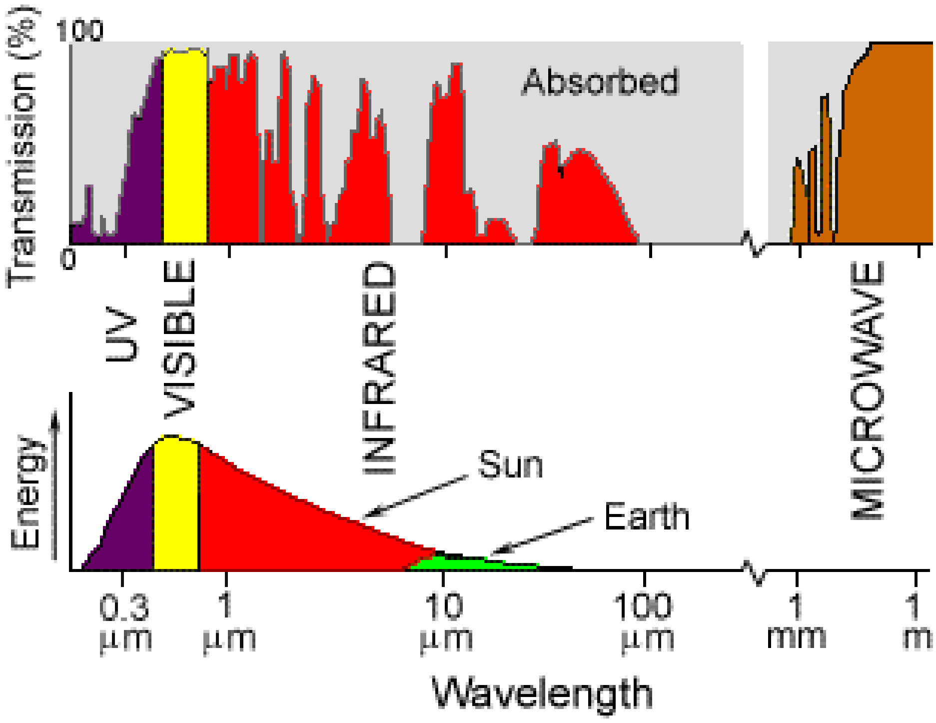
i. ***Water Vapor (H_2O):*** Very strong absorber in 5.5-7.0 µm range and > 27 µm. Note that water vapor in the atmosphere is also variable in time and space. This means absorption rates may vary depending on the location and the time of day and year. For example, the air mass above a desert would have very little water vapour to absorb energy, while the tropics would have high concentrations of water vapour (i.e. high humidity).

ii. ***Carbon Dioxide (CO_2)*** : Primarily absorbs radiation in the mid and far (thermal infrared) infrared portions of the spectrum. You may have heard **carbon dioxide** referred to as a greenhouse gas. This is because it tends to absorb radiation strongly in the far infrared portion of the spectrum - that area associated with thermal heating - which serves to trap this heat inside the atmosphere.

iii. ***Ozone (O_3)*** : Absorbs strongly in the UV portion of the spectrum (very short wavelengths) and is responsible for protecting us from damaging radiation that causes skin cancer.

3.2.3 Transmission

In contrast to the absorption, transmission is when electromagnetic energy is able to pass through the atmosphere and reach the Earth's surface. Visible light, largely passes (or is transmitted) through the atmosphere. The ability of the atmosphere to allow radiation to pass through it is referred to as its transmissivity, and varies with the wavelength of the radiation. The gases that comprise our atmosphere absorb radiation in certain wavelengths while allowing radiation with differing wavelengths to pass through. Because these gases absorb electromagnetic energy in very specific regions of the spectrum, they influence where (in the spectrum) we can "look" for remote sensing purposes. Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called **atmospheric windows**. By comparing the characteristics of the two most common energy/radiation sources (the sun and the earth) with the atmospheric windows available to us, we can define those wavelengths that we can use most effectively for remote sensing. The visible portion of the spectrum, to which our eyes are most sensitive, corresponds to both an atmospheric window and the peak energy level of the sun. Note also that heat energy emitted by the Earth corresponds to a window around 10 µm in the thermal IR portion of the spectrum, while the large window at wavelengths beyond 1 mm is associated with the microwave region.



Atmospheric transmission percentages throughout the electromagnetic spectrum. 100% transmittance indicates that all radiation is able to pass through the atmosphere at the given wavelength. Conversely, values close to 0 indicate that all radiation is blocked and no radiation is able to pass through the atmosphere at the given wavelength.

3.3 Summary

In this lesson we have learnt about the interactions between EMR and the earth's atmosphere. These interactions influence the EMR that reaches different target objects on the earth's surface and therefore affects the remote sensing process.

3.4 Further activity

Discuss the concept of atmospheric windows.

3.5 Suggestions for further reading

1. Joseph, George. (2005). *Fundamentals of Remote Sensing*, (2nd Ed.), Universities Press Limited.

2. Jensen, John R. (2009). *Remote Sensing of the Environment: An Earth Resource Perspective*, (2nd Ed.), Dorling Kindersley Private Limited

Lesson 4

4 INTERACTION OF EMR WITH EARTH'S SURFACE

Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface. A basic assumption made in remote sensing is that a specific target has an individual and characteristic manner of interacting with incident radiation. The manner of interaction is described by the spectral response of the target.

The lecture covers:

1. Lecture objectives
2. Types of interaction between EMR and earth’s surface
3. Spectral reflectance of different objects
4. Summary
5. Further activity
6. Suggestions for further reading

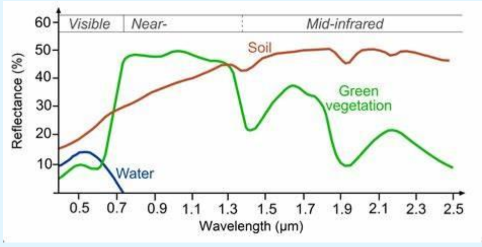
4.1 Lecture Objectives

By the end of this lesson, you should be able to:

1. Demonstrate understanding of the types of interaction between EMR nad earth’s surface.
2. Explain spectral reflectance curves and describe what they look like for common materials.

E-tivity 4

Numbering, pacing and sequencing	**4.1**
Title	Interaction of electromagnetic radiation and earth’s surface
Purpose	The purpose of this e-tivity is to enable you to explain the main interaction between electromagnetic radiation and earth’s surface

Summary of overall task	Watch the following videos on interaction between electromagnetic radiation and earth's surface a) Video 1 b) Video 2
Spark	
Individual task	Describe the interactions between EMR and different objects on the earth's surface
Interaction begins	c) In discussion forum 4.1, discuss the concept of spectral reflectance d) Read and respond to the posts of your colleagues on the electromagnetic spectrum.
E-moderator interventions	1. Ensure that learners are focused on the contents and context of discussion. 2. Stimulate further learning and generation of new ideas. 3. Provide feedback on the learning progress. 4. Close the e-tivity
Schedule and time	This task should take one hour
Next	Main types of interactions between EMR and earth's surface

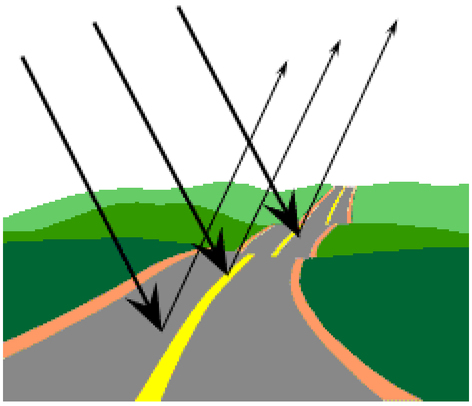
4.2 Types of interaction between EMR and earth's surface

There are three (3) forms of interaction that can take place when energy strikes, or is **incident (I)** upon the surface. These are: **absorption (A)**; **transmission (T)**; and **reflection (R)**. The total incident energy will interact with the surface in one or more of these three ways. The proportions of each will depend on the wavelength of the energy and the material and condition of the feature.

Forms of interaction between EM radiation and target object

Absorption (A) occurs when radiation (energy) is absorbed into the target while transmission (T) occurs when radiation passes through a target. Reflection (R) occurs when radiation "bounces" off the target and is redirected. In remote sensing, we are most interested in measuring the radiation reflected from targets. We refer to two types of reflection, which represent the two extreme ends of the way in which energy is reflected from a target: **specular reflection** and **diffuse reflection**.

When a surface is smooth we get <u>specular</u> or mirror-like reflection where all (or almost all) of the energy is directed away from the surface in a single direction. <u>Diffuse</u> reflection occurs when the surface is rough and the energy is reflected almost uniformly in all directions. Most earth surface features lie somewhere between perfectly specular or perfectly diffuse reflectors. Whether a particular target reflects specularly or diffusely, or somewhere in between, depends on the surface roughness of the feature *in comparison to the wavelength of the incoming radiation*. If the wavelengths are much smaller than the surface variations or the particle sizes that make up the surface, diffuse reflection will dominate. For example, fine-grained sand would appear fairly smooth to long wavelength microwaves but would appear quite rough to the visible wavelengths.



Specular Reflection

Figure 1: Diffuse Reflection

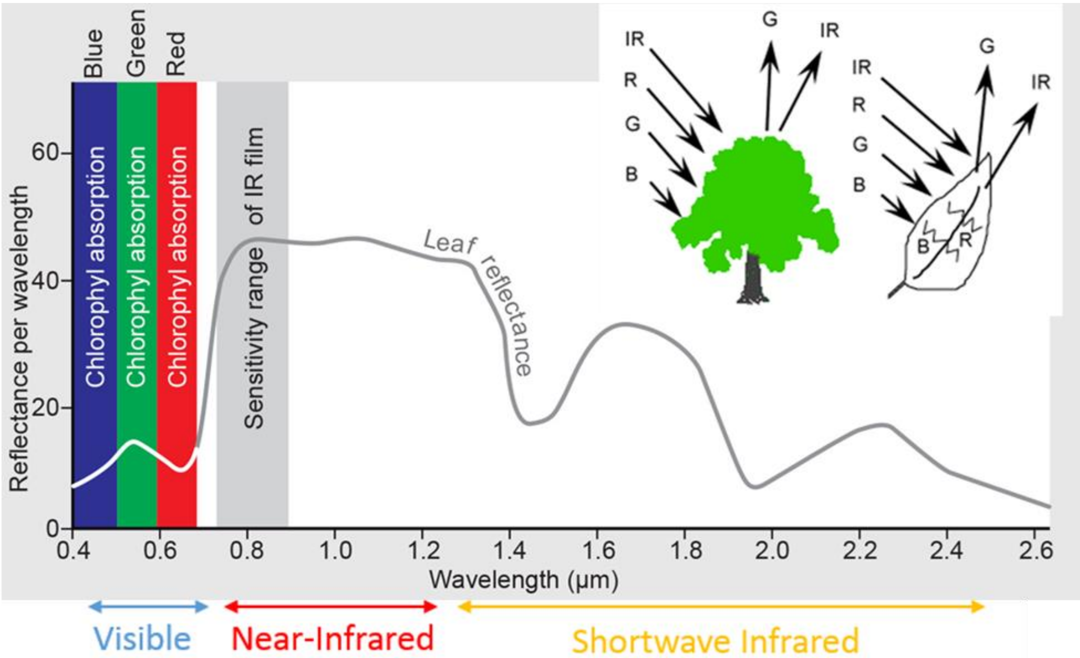
4.3 Spectral reflectance of different objects

The total quantity of incoming energy (light) from the sun is known as irradiance. Satellites measure radiance (brightness), or the amount of light. Objects on the ground are often characterized by their reflectance, or the percentage of the total energy that is reflected. The atmosphere affects the radiance received by the sensor in two ways: It can reduce (or attenuates) the energy, or Atmosphere itself is a reflector, adding energy or "path radiance" to the signal detected by the sensor. In remote sensing we are generally interested in the reflectance characteristics of surface features. Reflectance ***is the percent of incoming incident energy that is reflected***. This is always measured as a function of wavelength and is given as a percent.

Different surface features reflect and absorb the sun's electromagnetic radiation in different ways. The reflectance properties of an object depend on the material and its physical and chemical state, the surface roughness as well as the angle of the sunlight. The reflectance of a material also varies with the wavelength of the electromagnetic energy. The amount of reflectance from a surface can be measured as a function of wavelength, this is referred to as Spectral Reflectance. ***Spectral Reflectance*** is a measure of how much energy (as a percent) a surface reflects at a specific wavelength. Many surfaces reflect different amount of energy in different portions of the spectrum. These differences in reflectance make it possible to identify different earth surface features or materials by analyzing their spectral reflectance signatures. Spectral reflectance curves graph the reflectance (in percent) of objects as a function of wavelengths. Let's take a look at a couple of examples of targets at the Earth's surface and how energy at the visible and infrared wavelengths interacts with them.

4.3.1 Vegetation

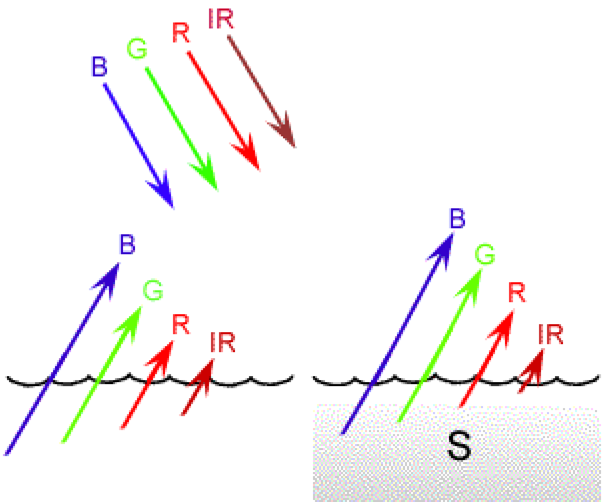
A chemical compound in leaves called chlorophyll strongly absorbs radiation in the red and blue wavelengths but reflects green wavelengths. In the visible bands the reflectance is relatively low as the majority of light is absorbed by the leaf pigments. Chlorophyll strongly absorbs energy in the blue and red wavelengths and reflects more green wavelengths. This is why healthy vegetation appears green. When there is less chlorophyll in the leaves, there is less absorption and proportionately more reflection of the red wavelengths, making the leaves appear red or yellow (yellow is a combination of red and green wavelengths). The reflectance is much higher in the near infrared (NIR) region than in the visible region due to the cellular structure of the leaves, specifically the spongy mesophyll. In fact, measuring and monitoring the near-IR reflectance is one way that scientists can determine how healthy (or unhealthy) vegetation may be. If our eyes were sensitive to near-infrared, trees would appear extremely bright to us at these wavelengths. The reflectance in the shortwave infrared wavelengths is related to the water content of the vegetation and its structure. Water has strong absorption bands around 1.45, 1.95 and 2.50 µm . Outside these absorption bands in the SWIR region, reflectance of leaves generally increases when water content in the leaf decreases.



An idealized spectral reflectance curve of a healthy vegetation. (Image source: Tempfli et al. 2009)

4.3.2 <u>Water</u>

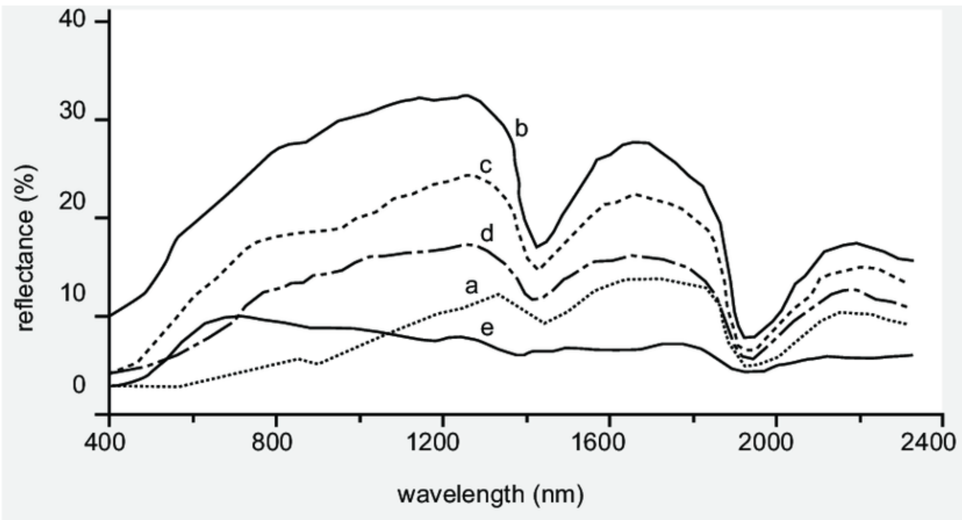
Longer wavelength visible and near infrared radiation is absorbed more by water than shorter visible wavelengths. Thus water typically looks blue or blue-green due to stronger reflectance at these shorter wavelengths, and darker if viewed at red or near infrared wavelengths. If there is suspended sediment present in the upper layers of the water body, then this will allow better reflectivity and a brighter appearance of the water. The apparent colour of the water will show a slight shift to longer wavelengths. Suspended sediment (S) can be easily confused with shallow (but clear) water, since these two phenomena appear very similar. Chlorophyll in algae absorbs more of the blue wavelengths and reflects the green, making the water appear greener in color when algae is present. The topography of the water surface (rough, smooth, floating materials, etc.) can also lead to complications for water-related interpretation due to potential problems of specular reflection and other influences on color and brightness.



Idealized spectral reflectance of a water body

4.3.3 Bare soil

Reflection from bare soil depends on so many factors that it is difficult to give one typical soil reflectance curve. The main factors influencing the reflectance are soil color, moisture content, the presence of carbonates, and iron oxide content. The Figure below gives the reflectance curves for the five types of soil. Note the typical shapes of most of the curves, which show a convex shape in the range 0.5 to 1.3µm and dips at 1.45µm and 1.95µm. At these dips we have again water absorption bands; they are caused by the presence of soil moisture. The iron-dominated soil (e) has quite a different reflectance curve, which can be explained by the iron absorption dominating at longer wavelengths.



Spectral reflectance of five mineral soils, (a) organic dominated, (b) minimally altered, (c) iron altered, (d) organic affected and (e) iron dominated

4.4 Summary

In summary, the relationship between the incident solar energy at the surface and the spectral composition of the remotely sensed reflected energy provides a wealth of information about the biogeochemical nature of the surface (leaf chemistry, soil mineralogy, water content) and the physical and structural characteristics of the surface (e.g., canopy height, leaf area, and soil roughness). The area observed by a sensor will most likely contain a variety of the surface materials (soil, vegetation, water, litter) in varying proportions and arrangements, and thus, remote sensing measurements often consist of mixed signals comprising multiple reflectance signatures.

Vegetation has unique spectral reflectance signatures with low reflectance in the VIS, high reflectance in the NIR, and low reflectance in the SWIR portion of the spectrum. The spectral signatures of vegetation are modified by leaf type and morphology, leaf physiology, chlorophyll content, plant stress, and senescence. Soils, on the other hand, have spectral reflectance signatures that gradually increase with increasing wavelengths in a manner dependent on their iron, organic matter, water, mineral, and salt content. The spectral signature of a soil will also be modified by its structural and morphologic properties at the surface (e.g., roughness), as well as by the presence of plant litter and its stage of decomposition.

4.5 Further activity

With examples discuss the fundamentals of remote sensing signals.

4.6 Suggestions for further reading

1. Joseph, George. (2005). *Fundamentals of Remote Sensing*, (2nd Ed.), Universities Press Limited.
2. Jensen, John R. (2009). *Remote Sensing of the Environment: An Earth Resource Perspective*, (2nd Ed.), Dorling Kindersley Private Limited

Lesson 5

5 SENSORS AND REMOTE SENSING SATELLITES

Earth observation satellites are designed for environmental monitoring, meteorology and mapping. The ability to observe and record data from space has dramatically improved our understanding of the Earth and its environment. Earth observing satellites have been in place since the 1970s and serve to highlight environmental changes. Satellite based sensors also allow scientists to gather data globally in regions that would otherwise be too remote or inaccessible to gather data.

The lecture covers:

1. Lecture objectives
2. Concept of image bands
3. Spaceborne sensors
4. Resolution of sensor systems
5. Summary
6. Further activity
7. Suggestions for further reading

5.1 Lecture Objectives

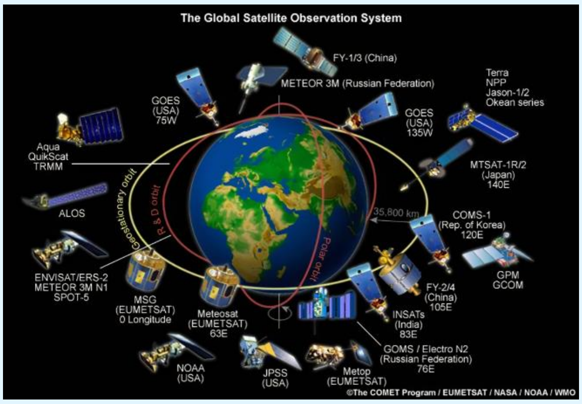
By the end of this lesson, you should be able to:

1. Demonstrate understanding concept of image bands
2. Explain concept of resolution and how it applies in Earth observation
3. Describe a variety of Earth observing satellites

1.1 Image bands

Many remote sensing data, including color digital photos, are made up of multiple bands or layers. You can think of image bands (also called channels or layers) as a collection of images taken simultaneously of the same place. Many sensors on earth observing satellites measure the amount of electromagnetic radiation (EMR) that is reflected or emitted from the Earth's surface. These sensors, known as multispectral sensors, simultaneously measure data in multiple regions of the electromagnetic spectrum. The range of wavelengths measured by a sensor is known as a band and are commonly described by the name (Red or Near-IR for example) and the wavelength of the energy being recorded.

E-tivity 5

Numbering, pacing and sequencing	**5.1**
Title	Sensors and remote sensing satellites
Purpose	The purpose of this e-tivity is to enable you to explain the main features of different sensors and remote sensing satellites
Summary of overall task	Watch the following videos on sensors and remote sensing satellites a) Video 1 b) Video 2 c) Video 3
Spark	
Individual task	Explain the main types of remote sensing systems
Interaction begins	a) In discussion forum 5.1, discuss the concept of resolution in remote sensing b) Read and respond to the posts of your colleagues on the electromagnetic spectrum.
E-moderator interventions	1. Ensure that learners are focused on the contents and context of discussion. 2. Stimulate further learning and generation of new ideas. 3. Provide feedback on the learning progress. 4. Close the e-tivity

Schedule and time	This task should take one hour
Next	Main types of remote sensing systems

5.2 Spaceborne sensors

One of the most common ways to classify sensor systems is on the basis of the main mechanism they use to detect electromagnetic energy. In this regard, we could establish two broad groups of sensors: (1) ***passive sensors***, which collect radiations derived from external sources; and (2) ***active sensors***, in which the sensor system emits its own energy to the target and collects later the reflection of that flux to characterize the observed areas. Alternatively, remote sensing sensors can be classified into imaging sensors and non-imaging sensors. In terms of their spectral characteristics, the imaging sensors include optical imaging sensors, thermal imaging sensors, and radar imaging sensors.

5.3 Resolution of a sensor system

In general terms, we can define the resolution of a sensor system as its ability to discriminate between information. Resolution of a sensor system can be described in terms of its spatial, spectral and radiometric resolutions.

Spatial resolution is the size of the smallest object that can be discriminated by the sensor. The greater the sensor's resolution, the greater the data volume and smaller the area covered. In fact, area coverage and resolution are interdependent and these two factors determine the scale of an imagery. Alternatively, spatial resolution can be said to be the length of the size of the area on the ground represented by a pixel on an image.

Spectral resolution the width of the spectral band and the number of spectral bands in which the image is taken. Narrow band widths in certain regions of the electromagnetic spectrum allow us to discriminate between the various features more easily. Consequently, we need to have a greater number of spectra! bands, each having a narrow bandwidth, and these bands should together cover the entire spectral range of interest

Radiometric resolution is the capability to differentiate the spectral reflectance I emittance between various targets. This depends on the number of quantization levels within the spectral band. In other words, the number of bits of digital data in the spectral band or the number of gray level values, will decide the sensitivity of the sensor. It is the smallest difference in exposure that can be detected in a given film analysis. It is also the ability of a given sensing system to discriminate between density levels.

5.4 Summary

Sensors are devices that detect and quantify physical characteristics or environmental situations. Sensors are employed aboard remote sensing satellites to collect data about the Earth's surface and atmosphere from space. These satellites orbit Earth and use a variety of sensors to collect information.

5.5 Further activity

With examples discuss the LANDSAT program.

5.6 Suggestions for further reading

1. Joseph, George. (2005). *Fundamentals of Remote Sensing*, (2nd Ed.), Universities Press Limited.
2. Jensen, John R. (2009). *Remote Sensing of the Environment: An Earth Resource Perspective*, (2nd Ed.), Dorling Kindersley Private Limited

Lesson 6

6 PRE-PROCESSING OF SATELLITE IMAGES

Before interpretation or analysis of satellite images, raw data usually needs to be corrected and adjusted for errors and inconsistencies. In this topic, we will learn about image pre-processing techniques. This can include a variety of processes and is an important step in producing the highest quality data. The lecture covers:

1. Lecture objectives
2. Image preprocessing
3. Summary
4. Further activity
5. Suggestions for further reading

6.1 Lecture Objectives

By the end of this lesson, you should be able to:

1.Explain concept of pre-processing and its importance

2.Explain image pre-processing approaches

3. Explain causes of radiometric errors and the importance of correcting for these errors.

6.2 Pre-Processing

Before interpretation or analysis of satellite images, raw data often need to be corrected and adjusted for errors. ***Pre-Processing*** is the general term used to describe all techniques that are employed to correct for radiometric and geometric errors that can occur in remote sensed data. When imagery is acquired, various types of errors can be introduced into the data. These errors can be caused by the sensor movement, orbital characteristics and atmospheric and environmental conditions. These errors can be categorized as *radiometric* and *geometric errors*.

Radiometric errors produce inconsistencies in the pixel values of an image. These can be caused by issues with the sensors and by environmental factors. For example, sometimes a sensor fails to properly collect data in part of the image or in a particular wavelength or band. This can lead to gaps in the data or what is known as “striping”. Environmental factors including the atmosphere, topography and time of day and year can also cause errors or inconsistencies in the values. Images taken from different angles and during different times of the year can also impact radiometric accuracy. Radiometric calibration and correction aim to minimize errors and normalize datasets.

Geometric errors produce spatial distortion in images and image pixels not being aligned to their proper geographic location. These distortions are due to variations in sensor position, satellite orbits and terrain effects. Some distortions are predictable and can easily be fixed, while others are more complicated and can be difficult to correct for. These distortions can be categorized as either systematic or random.

i. ***Systematic Distortions:*** This refers to distortions which are predictable, such as the effects of the Earth’s rotation and camera angles. Since they are predictable, correction values can be applied systematically. For example, data collected from satellites have distortion due to the eastward rotation of the earth beneath the satellite’s scanner. This leads to each sweep of the scanner to cover an area that is slightly west of the previous sweep, producing skew distortion.

ii. ***Random Distortions:*** these are non-systematic distortions which can occur due to changing terrain (relief displacement) and variations in the sensor altitude.

E-tivity 6

Numbering, pacing and sequencing	**6.1**
Title	Pre-processing of satellite images
Purpose	The purpose of this e-tivity is to enable you to explain different re-processing techniques used to correct error in satellite images
Summary of overall task	Watch the following videos on sensors and remote sensing satellites a) Video 1 b) Video 2 c) Video 3
Spark	

Individual task	Explain the main pre-processing approaches used to correct errors in remote sensing data
Interaction begins	a) In discussion forum 6.1, discuss the differences between geometric and radiometric errors in remote sensing data b) Read and respond to the posts of your colleagues on the electromagnetic spectrum.
E-moderator interventions	1. Ensure that learners are focused on the contents and context of discussion. 2. Stimulate further learning and generation of new ideas. 3. Provide feedback on the learning progress. 4. Close the e-tivity
Schedule and time	This task should take two hours
Next	Pre-processing approaches used to correct errors in remote sensing data

6.2.1 Geometric correction

The purpose of the geometric correction processes is to compensate for the distortions and to ultimately produce a corrected image with a high level of geometric integrity. If images are not corrected for geometric distortions, the x, y location of a given pixel will not be in the correct geographic location. Geometric correction techniques include:

i. *Georeferencing*: this is the process of aligning geographic data to a known coordinate system so it can be viewed, and analyzed with other geographic data. Georeferencing may involve shifting, rotating/skewing, scaling, skewing, and in some cases warping, or orthorectifying the data. Many remote sensing datasets need to be georeferenced before they can be viewed or analyzed with other geographic data.

ii. *Orthorectification*: this corrects for distortions from sensor tilt and the Earth's terrain (relief displacement). This process requires more information than georeferencing. Generally, to orthorectify a raster dataset you will need the rational polynomial coefficients (RPCs) and an accurate digital elevation model (DEM).

6.2.2 Radiometric correction

Radiometric correction is done to calibrate the pixel values and correct for errors in the values. The process improves the interpretability and quality of remote sensed data. Radiometric calibration and corrections are particularly important when comparing multiple data sets over a period of time.

i. *Restoration of Missing Lines and Pixels*: Random problems in sensor performance, communications, or reception systems may cause missing lines or pixels, resulting in images with anomalous lines or pixels highly contrasting with their surroundings. In both cases, the missing information was never acquired and thus is permanently lost, so the correction process is aimed at just enhancing the visual appearance of the image, but they do not provide a biophysical measurement for those missed pixels. A simple way to estimate the values of missing or corrupt pixels is to rely on neighboring pixels.

ii. *Correction of Striping Effects*: Another common problem of sensor performance is calibration deterioration. In a cross-track scanning sensors, each scan collects several lines simultaneously to cope with the along-track speed of the satellite. Each line is detected by a different sensor, which should be well calibrated with the others to ensure uniform response along the image. The radiometric performance of the detectors may deteriorate, producing a striping effect in the image, especially in areas of low radiance (shadows, marine surface). This effect is caused by intercalibration discrepancies in the sensor detectors, which provide a systematically lower or higher signal than the others.

6.3 Summary

Preprocessing satellite images entails a number of procedures to improve their quality and prepare them for further analysis. These preprocessing procedures are essential for ensuring accurate characterization of radiation reflected or emitted from Earth's surface. In this process, distortions brought about by movements of satellites and sensors, Earth's curvature, and terrain variations, are corrected to ensure accurate spatial alignment of pixels. In addition, the process reduces or eliminates the effects of atmospheric interference, such as scattering and absorption, and thus improves the accuracy of quantitative analysis.

6.4 Further activity

With examples discuss the main causes of error in remote sensing data.

6.5 Suggestions for further reading

1. Joseph, George. (2005). *Fundamentals of Remote Sensing*, (2^{nd} Ed.), Universities Press Limited.
2. Lillisand, Thomas, Ralph W. Kiefer, and Jonathan Chipman. (2007). *Remote Sensing and Image Interpretation*. Wiley India
3. Jensen, John R. (2004*). Introductory Digital Image Processing: A Remote Sensing Perspective*. Prentice Hall.

Lesson 7

7 ENHANCEMENT OF SATELLITE IMAGES

While pre-processing is done to correct for errors and distortions in data, enhancements are performed to improve the visual quality of images. The techniques covered in this section are designed to improve the visual interpretation & analysis of remote sensed data. In this section we will cover common radiometric and spatial enhancement techniques.

The lecture covers:

1. Lecture objectives
2. Radiometric enhancement methods
3. Spatial enhancement methods
4. PanSharpening
5. Summary
6. Further activity
7. Suggestions for further reading

7.1 Lecture Objectives

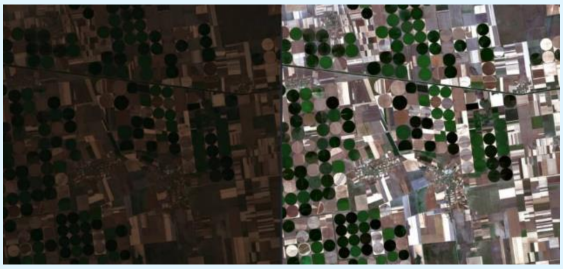
By the end of this lesson, you should be able to:

1.Explain radiometric image enhancement techniques

2.Explain spatial image enhancement techniques

E-tivity 7

Numbering, pacing and sequencing	**7.1**
Title	Enhancement of satellite images

Purpose	The purpose of this e-tivity is to enable you to explain different image enhancement techniques used to improve the quality of remote sensing data
Summary of overall task	Watch the following videos on remote sensing image enhancement a) Video 1 b) Video 2 c) Video 3
Spark	
Individual task	Explain the main image enhancement techniques used to improve the quality of remote sensing data
Interaction begins	a) In discussion forum 7.1, discuss the differences between geometric and radiometric errors in remote sensing data b) Read and respond to the posts of your colleagues on the electromagnetic spectrum.
E-moderator interventions	1. Ensure that learners are focused on the contents and context of discussion. 2. Stimulate further learning and generation of new ideas. 3. Provide feedback on the learning progress. 4. Close the e-tivity
Schedule and time	This task should take two hours
Next	Enhancement techniques used to improve in remote sensing data

7.2 Radiometric Enhancements

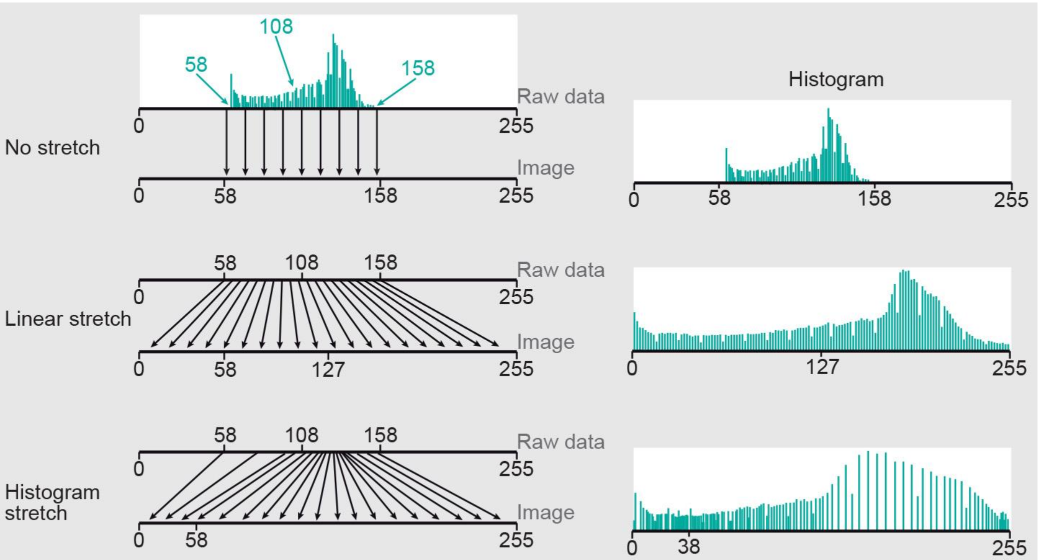
In the previous section we covered radiometric errors and atmospheric correction techniques. Radiometric enhancements differ from the pre-processing techniques in the fact that they are primarily designed to improve or alter the appearance of the image. These methods can enhance subtle radiometric differences so that the eye can easily perceive them. Radiometric enhancements manipulate the digital numbers in the images and change how the image or data is displayed on the computer screen. Many of these techniques use the image statistics and histograms to produce the intended results.

7.2.1 Contrast Stretching

As we learned earlier, computer monitors have a range of brightness from to 0 to 255 (8-bit) and often pixel values in raw images don't fill the full range or may have a range greater than 256. Contrast stretching improves the contrast of the image by "stretching" the pixel values (or DNs) to take advantage of the full range. Most image processing software automatically apply a contrast stretch when displaying images. It is important to note that most contrast stretching does not change the actual pixel values of an image, it simply changes how it is displayed.there two main types of contrast stretching: linear contrast stretch and histogram contrast stretch.

i. *Linear contrast stretch* linearly expand the original pixel values of data into a new distribution. There are several methods of linear contrast enhancement, the most common are Minimum-Maximum and Percent Linear contrast stretch. In the minimum-maximum linear contrast stretch, the original minimum and maximum values of the data are assigned to 0 and 255 respectively and all other values are stretched evenly between. The percentage linear contrast stretch is similar to the minimum-maximum linear contrast stretch except this method uses a specified minimum and maximum values that lie in a certain percentage of pixels from the mean of the histogram.

ii. *Histogram Equalized contrast stretch* assign more display values depending on the frequently of these values. This way there is more detail in areas with the greatest frequency of pixel values. These areas will be better enhanced relative to those areas of the original histogram where values occur less frequently.



Linear contrast stretch versus histogram equalization.

7.2.2 Level/Density Slicing

Density or Level Slicing divides up raster pixel values into a series of intervals or "slices", with different colors applied to each slice. This technique is often performed on single band images to highlight differences in values. The process essentially takes continuous data values and divides them into discrete classes or slices based on histograms or user specified values. Most density or level slicing operations use histograms and image statistics to create the levels or slices.

7.2.3 Image Thresholding & Masking

Image thresholding is a simple form of image segmentation. It is a way to create a binary image from a single band or multi-band image. The process is typically done in order to separate "object" or foreground pixels from background pixels to aid in image processing. In this process, a threshold level is selected where all pixel values below the threshold are mapped to zero and an upper threshold value is chosen so that all pixel values above this threshold are mapped to 255. The thresholding process can be used to create binary masks for an image.

7.3 Spatial enhancement

Spatial enhancement techniques use the concept of spatial frequency within an image. Spatial frequency is the manner in which gray-scale values change relative to their neighbors within an image. If there is a slow, gradual change in gray scale in an image from one side of the image to the other, the image is said to have a low spatial frequency. If pixel values vary radically for adjacent pixels in an image, the image is said to have a high spatial frequency. Spatial Filtering is done to emphasize or de-emphasize certain features depending on the spatial frequency. Spatial filters can be used to sharpen or emphasize the edges in an image or to smooth an image. Spatial filtering is a "local" operation, the pixel values in an original image are modified based on the values of the neighboring pixels.

i. *Low Pass Filters*: In effect the high and low values within each "neighborhood" will be averaged out, reducing extreme value in the data. Low pass filters are used for noise reduction and to reduce local variation.

ii. *High Pass Filters*: High-pass filters are designed to emphasize high frequency changes and de-emphasize more general, low frequency change. High pass filters are also known as sharpening filters and can bring out the boundaries between features (for example, where a water body meets the forest), thus sharpening edges between objects.

7.4 PanSharpening

Pansharpening is a process of merging high-resolution panchromatic and lower resolution multispectral imagery to create a single high-resolution color image. As we learned in previous sections, multispectral images have multiple bands and a higher degree of spectral resolution but often lack high spatial resolution. Panchromatic images on the other hand only one wide band of reflectance data but tend to have higher spatial resolution. The pansharpening process merges the multispectral and panchromatic images, which gives the best of both image types, high spectral resolution and high spatial resolution. Most high-resolution imagery used in Google Maps and other mapping software is produced by pansharpening.

7.5 Summary

Satellite image enhancement entails a set of techniques aimed at improving the visual quality and interpretability of satellite imagery for better analysis and decision-making. These techniques increase the visual separation between different features and enhance their visibility, changes the brightness of an image to improve its overall appearance, as well as improving spatial resolution and fine details in satellite imagery to improve the clarity of features.

7.6 Further activity

With examples discuss the relevance of image enhancement in the application of remote sensing data.

7.7 Suggestions for further reading

1. Lillisand, Thomas, Ralph W. Kiefer, and Jonathan Chipman. (2007). *Remote Sensing and Image Interpretation*. Wiley India
2. Jensen, John R. (2004*). Introductory Digital Image Processing: A Remote Sensing Perspective*. Prentice Hall.

Lesson 8

8 VISUAL INTERPRETATION OF REMOTE SENSING DATA

In order to take advantage of and make good use of remote sensing data, we must be able to extract meaningful information from the imagery. This brings us to the topic of image interpretation and analysis. The lecture covers:

1. Lecture objectives
2. Process of image interpretation
3. Basic elements of image interpretation
4. Summary
5. Further activity
6. Suggestions for further reading

8.1 Lecture Objectives

By the end of this lesson, you should be able to:

1. Explain the key elements of visual image interpretation
2. Carry out visual interpretation of remote sensing data.

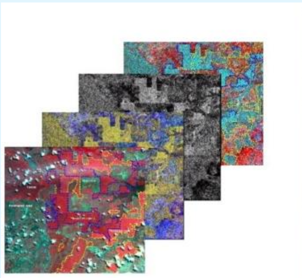
8.2 Process of Image Interpretation

Interpretation and analysis of remote sensing imagery involves the identification and/or measurement of various targets in an image in order to extract useful information about them. Interpreters study remotely sensed data and attempt through logical process to detect, identify, classify, measure, and evaluate the significances of physical and cultural objects, their patterns and spatial relationship. Targets in remote sensing images may be any feature or object which can be observed in an image, and have the following characteristics:

i. Targets may be a point, line, or area feature. This means that they can have any form, from a bus in a parking lot or plane on a runway, to a bridge or roadway, to a large expanse of water or a field.

ii. The target must be distinguishable; it must contrast with other features around it in the image.

E-tivity 8

Numbering, pacing and sequencing	**8.1**
Title	Visual interpretation of remote sensing data
Purpose	The purpose of this e-tivity is to enable you to explain key elements considered in visual interpretation of remote sensing data
Summary of overall task	Watch the following videos on visual interpretation of remote sensing data a) Video 1 b) Video 2 c) Video 3
Spark	 
Individual task	Explain the key elements used in visual interpretation of remote sensing data
Interaction begins	a) In discussion forum 8.1, discuss the importance of visual interpretation prior to analysis of remote sensing data b) Read and respond to the posts of your colleagues on the electromagnetic spectrum.
E-moderator interventions	1. Ensure that learners are focused on the contents and context of discussion. 2. Stimulate further learning and generation of new ideas. 3. Provide feedback on the learning progress. 4. Close the e-tivity
Schedule and time	This task should take two hours
Next	Basic elements of image interpretation

8.3 Basic elements of image interpretation

Recognizing targets is the key to interpretation and information extraction. Observing the differences between targets and their backgrounds involves comparing different targets based on any, or all, of the visual elements of tone, shape, size, pattern, texture, shadow, and association.

i. ***Tone*** refers to the relative brightness or colour of objects in an image. Generally, tone is the fundamental element for distinguishing between different targets or features. Variations in tone also allows the elements of shape, texture, and pattern of objects to be distinguished.

ii. ***Shape*** refers to the general form, structure, or outline of individual objects. Shape can be a very distinctive clue for interpretation. Straight edge shapes typically represent urban or agricultural (field) targets, while natural features, such as forest edges, are generally more irregular in shape, except where man has created a road or clear cuts. Farm or crop land irrigated by rotating sprinkler systems would appear as circular shapes.

iii. ***Size*** of objects in an image is a function of scale. It is important to assess the size of a target relative to other objects in a scene, as well as the absolute size, to aid in the interpretation of that target. A quick approximation of target size can direct interpretation to an appropriate result more quickly. For example, if an interpreter had to distinguish zones of land use, and had identified an area with a number of buildings in it, large buildings such as factories or warehouses would suggest commercial property, whereas small buildings would indicate residential use.

iv. ***Pattern*** refers to the spatial arrangement of visibly discernible objects. Typically, an orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern. Orchards with evenly spaced trees, and urban streets with regularly spaced houses are good examples of pattern.

v. ***Texture*** refers to the arrangement and frequency of tonal variation in particular areas of an image. Rough textures would consist of a mottled tone where the grey levels change abruptly in a small area, whereas smooth textures would have very little tonal variation. Smooth textures are most often the result of uniform, even surfaces, such as fields, asphalt, or grasslands. A target with a rough surface and irregular structure, such as a forest canopy, results in a rough textured appearance. Texture is one of the most important elements for distinguishing features in radar imagery.

vi. ***Shadow*** is also helpful in interpretation as it may provide an idea of the profile and relative height of a target or targets which may make identification easier. However, shadows can also reduce or eliminate interpretation in their area of influence, since targets within shadows are much less (or not at all) discernible from their surroundings. Shadow is also useful for enhancing or identifying topography and landforms, particularly in radar imagery.

vii. ***Association*** takes into account the relationship between other recognizable objects or features in proximity to the target of interest. The identification of features that one would expect to associate with other features may provide information to facilitate identification. In the example given above, commercial properties may be associated with proximity to major transportation routes, whereas residential areas would be associated with schools, playgrounds, and sports fields. In our example, a lake is associated with boats, a marina, and adjacent recreational land.

8.4 Summary

Visual interpretation of Satellite involves visually analyzing satellite imagery to extract information about Earth's surface and features. Before carrying-out visual interpretation, it is important to ensure that the imagery is accurate, calibrated, and suitable for interpretation. Visual interpretation elements include tone, shape, size, pattern, texture, and shadow.

8.5 Further activity

Describe how you would carry out visual interpretation of high-resolution satellite image to assess green spaces in an urban area.

8.6 Suggestions for further reading

1. Lillisand, Thomas, Ralph W. Kiefer, and Jonathan Chipman. (2007). *Remote Sensing and Image Interpretation*. Wiley India
2. Sabins, Floyd F. (2007). *Remote Sensing: Principles and Interpretation*. Waveland Press
3. Jensen, John R. (2004*). Introductory Digital Image Processing: A Remote Sensing Perspective*. Prentice Hall.

Lesson 9

9 CLASSIFICATION OF REMOTE SENSING IMAGES

Image Classification is the process of grouping areas of an image into a number of classes or categories that represent similar features. The process produces "thematic maps" based on the original image or data. Unlike image interpretation, which is carried out by a human, the majority of these classification techniques are carried out by a computer. Image classification is used in many regional-scale projects and is often done to generate land cover data sets. Computer aided classification can help provide data for landscape-level planning and assessment. Image classification can also help with tracking and modeling changes in the environment over time. This lesson covers several approaches to image classification.

This lecture covers:

1. Lecture objectives
2. Image classification approaches
3.Summary
4. Further activity
5. Suggestions for further reading

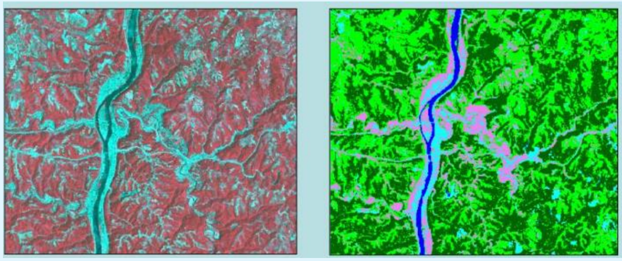
9.1 Lecture Objectives

By the end of this lesson, you should be able to:

1. Explain different image classification approaches
2. Evaluate image classification accuracy.

E-tivity 9

Numbering, pacing and sequencing	**9.1**
Title	Classification of remote sensing data

Purpose	The purpose of this e-tivity is to enable you to explain classification approaches that can be applied on remote sensing data
Summary of overall task	Watch the following videos on classification of remote sensing data a) Video 1 b) Video 2 c) Video 3
Spark	
Individual task	Explain the key approaches used in classification of remote sensing data
Interaction begins	a) In discussion forum 9.1, discuss how you would carry-out classification of remote sensing data b) Read and respond to the posts of your colleagues on the electromagnetic spectrum.
E-moderator interventions	1. Ensure that learners are focused on the contents and context of discussion. 2. Stimulate further learning and generation of new ideas. 3. Provide feedback on the learning progress. 4. Close the e-tivity
Schedule and time	This task should take two hours
Next	Image classification approaches

9.2 Image classification approaches

When talking about classes, we need to distinguish between ***information classes*** and ***spectral classes***. Information classes are those categories of interest that the analyst is actually trying to identify in the imagery, such as different kinds of crops, different forest types or tree species, different geologic units or rock types, etc. Spectral classes are groups of pixels that are uniform (or near-similar) with respect to their brightness values in the different spectral channels of the data. The objective is to match the spectral classes in the data to the information classes of interest.

There are several approaches to image classification and this module will focus on computer-based classification techniques. The main types of image classification are: *Manual Classification*, *Pixel Based Classification and Object or Feature Based Classification.*

i. *Manual or visual classification* refers to the interpretation and classification of imagery by the human eye. Before computers, this was the only way classification could be done. In modern geospatial analysis, this is now achieved through "heads-up" digitizing. Manual digitizing can be useful and appropriate in many scenarios. It tends to work well for small contiguous areas but it may not be ideal for large, non-contiguous areas of study. Digitizing can also be time consuming and repetitive, but when done well can produce reliable and consistent results.

ii. *Pixel Based classification methods* use the pixel values in an image to assign every image pixel to a class. Each pixel is assigned to a class based on its spectral characteristic; this is known as *Spectral Pattern Recognition*. The objective of pixel-based classification is to assign all pixels in the image to particular classes or themes (e.g. water, coniferous forest, deciduous forest, agriculture).

iii. *Object-based* or *object-oriented classification* uses both spectral and spatial information for classification. The process involves categorization of pixels based on their spectral characteristics, shape, texture and spatial relationship with the surrounding pixels. Object-based classification methods were developed relatively recently compared to traditional pixel-based classification techniques. While pixel-based classification is based solely on the spectral information in each pixel, object-based classification is based on information from a set of similar pixels called objects or image objects.

9.3 Summary

Satellite image classification involves categorizing pixels or regions within satellite imagery into asset of predefined classes or categories based on either spectral properties, spatial patterns or both. Before image classification, satellite imagery should be prepared by applying preprocessing techniques including radiometric calibration, geometric correction, atmospheric correction, and image enhancement. In this process, the pixel values in different bands of the imagery define spectral features while spatial and textural features capture the spatial arrangement and texture patterns within the image.

9.4 Further activity

With examples compare and contrast the supervised and unsupervised image classification approaches.

9.5 Suggestions for further reading

1. Lillisand, Thomas, Ralph W. Kiefer, and Jonathan Chipman. (2007). *Remote Sensing and Image Interpretation*. Wiley India
2. Sabins, Floyd F. (2007). *Remote Sensing: Principles and Interpretation*. Waveland Press
3. Jensen, John R. (2004*). Introductory Digital Image Processing: A Remote Sensing Perspective*. Prentice Hall.