ENVIRONMENTAL GEOSCIENCES

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Lecture-60

Remote Sensing

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We will discuss today the module twelve that is Remote Sensing and GIS Applications, Impact of Climate Change in Water Resources. Today I will discuss the lecture one that is Remote Sensing. In this lecture, the important concepts will be covered like concept of remote sensing, definition of remote sensing, remote sensing processes, source of energy, energy interaction, remote sensing sensors, remote sensing platforms, classification of remote sensing, resolution and its types, advantages of remote sensing and limitations of remote sensing. First of all we will understand the concept of remote sensing.

Normally in remote sensing the term remote means far away and sensing means believing or observing or acquiring some information. Remote sensing means acquiring information of things from a distance. Out of our five senses, we use first three, that is a, b and c as remote sensors. When we first a, watch a cricket match from the stadium, that is sense of sight. b, smell freshly cooked curry in the oven, sense of smell.

And hear a telephone ring, that is sense of hearing. d and e, that is try to feel the smoothness of a desktop, which is sense of touch, and eat a mango to check the sweetness, that is sense of taste. In the case of d and e, we are actually touching the object by our organs to collect the information about the object. In the world of geospatial science, remote sensing, also known as the earth observation, means observing the earth with sensors from high above its surface. Sensors are like simple cameras except that they not only use visible light but also other bands of the electromagnetic spectrum such as infrared, microwaves and ultraviolet regions.

They are positioned so high that they can capture images of a very large area. Nowadays, remote sensing is mainly done from space using satellites. Now, the definition of remote sensing. A formal and comprehensive definition of applied remote sensing as given by the National Aeronautics and Space Administration, that is NASA, is Remote sensing is the science and art of acquiring information that is in spectral, spatial and temporal ways about the material objects, area or phenomenon without coming into physical contact with the objects or phenomenon under investigation.

Remote sensing means sensing of the Earth's surface from space by making use of the properties of electromagnetic wave emitted, reflected or diffracted by the sensed objects for the purpose of detecting natural resource and the protection of the environment. Without direct context, some means of transferring information through space must be utilized. In remote sensing, information transfer is accomplished by use of electromagnetic radiations. Remote sensing in the broad sense, the measurement or acquisition of information of some property of an object or phenomenon by a recording device that is not in physical or intimate contact with the object or phenomenon under study. The technique implies such devices as the camera, lasers, radio frequency receivers, radar systems, sonar, etc.

Now we will see the remote sensing process. The figure explains the different elements that is A to G that comprise the most common remote sensing processes from beginning to end. Here A is the radiation by energy source. It is required. Then B interaction with the earth's atmosphere. B, interaction with the Earth's atmosphere.

C, the interaction with the target. D is the recording of energy by the sensor. E is the transmission, reception and processing. F is the interpretation and analysis. And lastly, the G is the application of remote sensing process.

Now let us discuss A, radiation by energy source. The first requirement for remote sensing is to have an energy source that illuminates or radiates electromagnetic energy to the target of interest. B is the interaction of energy with the atmosphere. As the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. When the energy source is Sun then first of all the energy passes through vacuum where no interaction happens before interacting with the Earth's atmosphere.

C is the interaction of energy with target that is once the energy makes its way to the target that is near to the Earth's surface through the atmosphere, it interacts with the target depending on the properties of both the target and the incident that is incoming energy. Some amount of incident energy is then reflected from the target. D is the interaction of energy with atmosphere again. As the reflected energy travels from the target to the sensing or imaging device, it interacts with the atmosphere once again. E is the recording of energy by the sensor after the energy has been reflected by the target, a sensor that is remotely placed not in contact with the target is used to collect and record the electromagnetic radiation. F the transmission reception and processing. The energy recorded by the sensor is transmitted, often in electronic form, to a receiving and processing station on the ground where the data is processed into an image.

G is the interpretation analysis. The processed image is interpreted visually and or digitally or electronically to extract information about the target of interest. H is the application. Finally, we apply the information we have been able to extract from the imagery about the target to better understand it, reveal some new information or assist in solving a particular problem. So the whole process described in this section is for satellite remote sensing. Though aerial remote sensing is similar, transmission and receptions are not required because the aircraft comes back to the ground. However, processing is required to generate interpretable imagery.

Now source of energy. As it was noted earlier that the first requirement for remote sensing is to have an energy source to illuminate the target unless the remotely sensed energy is being emitted by the target itself. Just as our eyes need objects to be illuminated by light so that we can see them, sensors also need a source of energy to illuminate the earth's surface. The sun is the natural source of energy. Artificial energy sources are also used in remote sensing. Whether the energy is radiated from an external source or emitted from the object itself, it is in the form of electromagnetic radiation.

Now we will see the electromagnetic radiation. In the definition of remote sensing, we described a remote sensing system as having several components including an energy source, transmission path, target and sensor. These components work together to measure and record information about a target without actually coming into physical contact with it. In order for this to happen, something must act as a medium for transmitting information from the target to the sensor. In most instances of environmental remote sensing, that something is nothing. It is the electromagnetic energy.

The electromagnetic radiation is normally used as an information carrier in remote sensing. Electromagnetic radiation is energy that travels in waves, is described as a self-propagating wave in space with electric and magnetic components. These components oscillate at right angles to each other and to the direction of propagation. Electromagnetic radiation carries energy and momentum unlike heat transfer by convection or conduction, heat transfer by electromagnetic radiation can travel through empty spaces requiring no intervening medium to transmit it. Waves have measurable properties that help us in describing radiations including wavelength, frequency, amplitude and velocity.

The point of maximum upward displacement of a wave is called its crest and the area of maximum downward displacement is called a trough. A wave's amplitude is defined as the magnitude or distance of the vertical displacement caused by the wave. In more general terms, amplitude can be thought of as the height of the waves. The wavelength of a wave is defined as the distance between two successive crests or between two successive troughs. Frequency is a measure of how many waves pass a fixed point in a given unit of time and is therefore dependent on the speed or velocity at which the wave is traveling.

All electromagnetic energy travels at a constant speed that is just the speed of a light. A standard measure of all electromagnetic radiation is the magnitude of the wavelength which is usually stated in units of nanometers. Now emission of electromagnetic radiation. All matter at temperatures greater than absolute zero that is zero degree Kelvin or minus two seventy three degree celsius, continuously emits electromagnetic radiation. Generally, the hotter an object, the higher its energy level and the more it radiates.

The reverse is also true, the colder a material, the lower its energy level. All materials in the universe emit energy of some form. In terrestrial remote sensing, the temperature of the sun and the Earth's surface play an important role in determining what types of energy will be collected. The Sun with a surface temperature of approximately six thousand Kelvin emits radiation that peaks in the visual portion of the spectrum and the Earth with a temperature of approximately three hundred Kelvin emits radiation that peaks in the infrared portion of the spectrum. Since these two forms of energy are the most readily available, the energy detected during terrestrial remote sensing is either reflected visible energy from the sun or thermal infrared energy emitted from the Earth.

Electromagnetic radiation is classified into types accordingly to the frequency of the wave: these types include, in order of increasing frequency, radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation-rays and gamma rays. In some technical context the entire range is referred to as just light. You can see in the diagram also the different types of electromagnetic radiations with having different wavelengths and frequency. Now we will understand the energy interaction. Electromagnetic waves that originate from the sun are radiated through space and eventually enter the Earth's atmosphere.

In the atmosphere, the radiation interacts with atmospheric particles which can absorb, scatter or reflect it back into the space. Much of the sun's high-energy radiation is absorbed by the atmosphere, preventing it from reaching the Earth's surface. This absorption of energy in the upper atmosphere is an important factor in allowing life to flourish on the earth. Atmospheric particles such as dust, sea salt, ash and water droplets will reflect energy back into the space. Visible light can be scattered by particles in the atmosphere allowing only selected wavelengths to penetrate to the surface.

A portion of the energy is able to penetrate the atmosphere, allowing it to reach the earth's surface. Radiation that is able to penetrate the material and pass through it is said to be transmitted. Most wavelengths of visual light energy from the sun are transmitted to the atmosphere, allowing it to come into contact with the Earth's surface. Once this radiation reaches the surface, it interacts with the surface materials where it can be reflected back into space or absorbed and re-emitted as thermal infrared energy. Here in the diagram you can see the characteristics of atmospheric spectral reflectance.

Interaction with 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. These effects are caused by the mechanism of scattering and absorption. Scattering occurs when particles or large gas molecules presents 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 types of scattering which takes place. The first is the Rayleigh scattering. Rayleigh scattering occurs when particles are very small compared to the wavelength of the radiation. Rayleigh scattering occurs when particles of the atmosphere 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. Second is the Mie scattering.

Mie scattering occurs when the particles are just about the same size. Mie scattering occurs when the particles are just about the same sizes as the wavelength of the radiation.

Dust, pollen, aerosols, smoke, and water vapour are common causes of Mie scattering, which tends to affect longer wavelengths than those affected by the Rayleigh scattering. Mie scattering occurs mostly in the lower portion of the atmosphere, where larger particles are more abundant and dominates when cloud conditions are overcast. And third is the non-selective scattering.

It 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. Non-selective 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 selected in approximately equal quantities. That is blue plus green plus red is equal to white light.

Effects of scattering. It causes haze in remotely sensed images. It decreases the spatial details on the images and it also decreases the contrast of the images. Second phenomenon is the absorption. Absorption is the other mechanism when electromagnetic radiation interacts with the atmosphere.

In contrast to scattering, this phenomena causes molecules in the atmosphere to absorb energy at various wavelengths. Ozone, carbon dioxide, water vapor are the three main atmospheric constituents which absorb the radiation. There is a little absorption of the electromagnetic radiation in the visible part of the spectrum also. The main atmospheric constituents responsible for infrared absorption are water vapor and carbon dioxide molecules. The atmosphere is practically transparent to the microwave radiation.

Ozone serves to absorb the harmful ultraviolet radiations from the sun. Ozone in the stratosphere absorbs about ninety nine of the harmful solar UV radiation, shorter than three twenty nanometer. Without this protective layer in the atmosphere, our skin would burn when exposed to sunlight. Second is the carbon dioxide. It is referred to as a greenhouse gas.

This is because carbon dioxide absorbs radiations strongly in the mid and far infrared portion of the spectrum-that area associated with thermal heating which serves to trap this heat inside the atmosphere. And then the water vapor in the atmosphere absorbs much of the incoming long wave infrared and short wave microwave radiations. The presence of water vapor in the lower atmosphere varies greatly from location to location and at different times of the year. Now remote sensing sensors. A sensor is a device that receives a stimulus and responds with an electrical signal.

Factors influencing the quality of remote sensing, remote sensed images, factors influencing the quality of remote sensed images, geometric precision, spatial resolution, spectral information, spectral resolution, temporal resolution, and radiometric resolution. Sensors can be classified as passive or active. Passive sensors, these sensors detect reflected electromagnetic radiations from natural source. For example, camera without flashlight and all remote sensing sensors. Passive sensors measure light reflected or emitted naturally from surfaces and objects.

Such instruments merely observe and depend primarily on solar energy as the ultimate radiation source illuminating surfaces and objects. A major limitation of passive systems is that in most cases they require sunlight in order for valid and useful data to be acquired. Photographic Camera, the most common sensor system is the photographic camera, a simple passive sensor designed to detect energy in the visible and near-infrared portions of the electromagnetic spectrum. Second is the active sensor. These sensors detect reflected responses from objects which are irradiated from artificially generated energy source. For example, radar, camera with flashlight are the active sensors. Some advantages of active sensors have over passive sensors are that they do not require solar illumination of surfaces or perfect weather conditions to collect data.

Consequently, they can be deployed at night or in conditions of haze, clouds, or light rain, depending on the wavelength of the system. Now remote sensing platforms. Remote sensing platforms can be defined as the structures or vehicles on which remote sensing instruments, that is sensors, are mounted. For remote sensing applications, sensors should be mounted on suitable, stable platforms. These platforms can be ground-based, airborne, and space-bound based.

As the platform height increases, the spatial resolution and observational area increases. Thus, higher the sensor is mounted, larger the spatial resolution and synoptic view is obtained. The types or characteristics of platform depend on the type of sensor to be attached and its application. Platforms for remote sensors may be situated on the ground, on an aircraft or balloon, or on a spacecraft or satellite outside of the Earth's atmosphere. Typical platforms are satellites and aircraft, but they can also include radio-controlled aeroplanes, balloon kits for low-altitude remote sensing, as well as ladder trucks or cherry pickers for ground investigations.

There are three important types of platforms, i.e. ground-borne platforms, air-borne platforms, and space-borne platforms. Ground borne platforms. The ground borne platforms are used to record detailed information about the surface, which is compared with information collected from aircraft or satellite sensors, that is for ground observation. Ground observation includes both the laboratory and field study used for both in designing sensors and identification and characterization of land features. Ground observation platforms include handheld platforms, cherry picker towers, portable masts and vehicles, etc.

Portable handheld photographic cameras and spectroradiometers are largely used in laboratory and field experiments as a reference data and ground truth verification. Second is the airborne platforms. Airborne platforms are used to collect very detailed images and facilitate the collection of data over virtually any portion of Earth's surface at any time. Airborne platforms were the sole non-ground-based platforms for early remote sensing work. Examples of airborne platforms are balloon, drone, aircraft.

Space-borne platforms. In space-borne remote sensing, sensors are mounted on board, that is, a spacecraft orbiting the Earth. Space-borne or satellite platforms are one-time cost-effective, but relatively lower cost per unit area of coverage can acquire imagery of entire Earth without taking permission. Spaceborne imaging ranges from altitude two fifty kilometers to thirty six thousands kilometers. Now we will discuss the classification of remote sensing.

Remote sensing is a complex technique and may vary based on the application and technological development. Considering technological advancement, for example, in the earlier days, remote sensing was performed from balloons, but nowadays satellites are being used. Earlier photographic cameras remained the only option, but nowadays digital camera sensors are dominating. Considering applications, for example, mapping purposes can be fulfilled by optical images, but information about temperature needs thermal image. Remote sensing may be classified from many perspectives, for example, based on platform, based on source of energy, based on number of bands, and so on.

Classification based on energy source, first is the passive remote sensing. Passive remote sensing depends on a natural source to provide energy. The sun is the most commonly used source of energy for passive remote sensing. In this case, the satellite sensor records primarily the radiation that is reflected from the target. A portion of the sun's radiation that is not reflected back to the sensor is absorbed by the target, raising the temperature of target material.

The absorbed radiation is later emitted by the material at a different wavelength. Passive remote sensing can also be carried out in the absence of sun. In this latter case, the source of energy is the target material itself and the sensor records primarily emitted radiation. Remote sensing in the thermal infrared portion of the electromagnetic spectrum is an example of passive remote sensing. Second is the active remote sensing.

Active remote sensing uses an artificial source of energy. For example, the satellite itself can send a pulse of energy which can interact with the target. In active remote sensing, humans can control the nature that is wavelength power duration of the source energy. Remote sensing in the microwave region of the electromagnetic spectrum is an example of active remote sensing. Active remote sensing can be carried out during day and night and in all weather conditions.

Now, classification based on the platform. Airborne, that is in the air, these platforms are within Earth's atmosphere like aircraft, drones, or even older platforms like balloons and kites. Aircraft are the main platforms used today. Spaceborne, these platforms are outside Earth's atmosphere, typically satellites that orbit the Earth. Remote sensing from space is known as satellite remote sensing.

Now classification based on number of bands a sensor can detect, that is panchromatic remote sensing. This involves capturing images in a single band of the electromagnetic spectrum, usually within the visual light range, that is zero pot four to zero point seven micrometers. If the sensor captures images in a wider range, including the visual region, it can still be considered panchromatic. Multispectral remote sensing, this involves capturing images in multiple bands across the electromagnetic spectrum. Multispectral sensors usually detect energy in a few broad bands which could include visible light, infrared and even microwave regions.

And next is the hyperspectral remote sensing. This is a more advanced technique where sensors collect image data in many narrow bands, sometimes as small as zero point zero one micrometers wide. Hyperspectral sensors can capture detailed spectral information and are mainly used in the optical region of the spectrum. Now classification based on wavelength regions. Visible and reflective infrared remote sensing.

The energy source used in the visible and reflective infrared remote sensing is the sun. The sun radiates EM energy with a peak wavelength of about zero point five micrometer. Remote sensing data obtained in the visible and reflective infrared regions mainly depends on the reflectance of objects on the ground surface. Thermal infrared or emitted remote sensing. The source of the radiant energy in the thermal infrared remote sensing is the object itself, because any object with a normal temperature of about twenty seven degrees Celsius will emit EM radiation with a peak at about nine point seven micrometres.

Microwave remote sensing. There are two types of microwave remote sensing, passive microwave remote sensing and active microwave remote sensing. In passive microwave remote sensing, the microwave radiations emitted from an object is detected while the back scattering coefficient is detected in active microwave remote sensing. Resolution and its types. In remote sensing, the term resolution is used to represent the resolving power which includes not only the capability to identify the presence of two objects but also their properties.

The resolution is the minimum distance between two objects that can be distinguished in the image. In qualitative terms, resolution is the amount of details that can be observed in an image. Thus, an image that shows finer detail is said to be of finer resolution compared to the image that shows coarser details. Spatial resolution is a measure of the area or size of the smallest dimension on the Earth's surface over which an independent measurement can be made by the sensor. Four major types of resolution in remote sensing.

First is the spatial resolution. Spatial resolution is dependent on the field of view, altitude, and viewing angle of a sensor. Spectral resolution refers to the number of wavelength regions or bands in the electromagnetic spectrum to which the sensor is sensitive. Temporal resolution is a measure of how often data are obtained for the same area. And radiometric resolution is a measure of the sensitivity of a sensor to differences in the intensity of the radiations measured.

Based on the spatial resolution, satellite systems can be classified as follows. Low resolution systems, medium resolution systems, high resolution systems, very high resolution systems. A high resolution image refers to one with a small resolution size. Fine details can be seen in a high resolution image. On the other hand, a low resolution image is one with a large resolution size. Only coarse features can be observed in the image. Advantages of Remote Sensing. Remote sensing has several unique advantages as well as some limitations of remote sensing to use it more effectively.

Remote sensing is unobtrusive if the sensor is passively recording the EM energy reflected from or emitted by the phenomenon of interest. This is very important consideration as passive remote sensing does not disturb the object or area of interest.

Under carefully controlled condition, remote sensing can provide fundamental biophysical data including X, Y location, Z elevation or depth, biomass, temperature, moisture content, etc. In this sense, it is much like surveying, providing fundamental data that other sciences can use when conducting scientific investigations. However, unlike much of surveying, the remotely sensed data may be obtained systematically over very large geographic areas rather than just single point observation.

The major advantages are stated below. The major advantages are synoptic view coverage, that is remote sensing process facilitates the study of various earth surface features in their spatial relation to each other and helps to delineate the required features and phenomena. Data about the entire earth is obtained in a short period of time and it can be used for different purposes without taking permission. Second advantage is repeativity. The remote sensing satellite provides repetitive coverage of the earth and this temporal information is very useful for studying landscape dynamics, phenological variations of the vegetation and other land features and change detection analysis.

Accessibility, next advantage, remote sensing process made it possible to gather information about the area when it is not possible to do ground survey like in mountainous areas and foreign areas. Passive remote sensing can be used in all weather and all time of a day. Then time-saving, since information about a large area can be gathered quickly, the technique save the time and efforts of humans. It also saves the time of field work. Cost-effective, remote sensing, especially when conducted from space, is an intrinsically expensive activity. Nevertheless, cost-benefit analysis demonstrates its financial effectiveness and much speculation or developmental remote sensing activity can be justified in this way.

It is a cost effective technique as again and again field work is not required and also a large number of users of different disciplines can share and use the same data. Now the limitations of remote sensing. Remote sensing science has various limitations. Perhaps the greatest limitation is that its utility is often oversold. It is not providing all the information needed for conducting physical, biological, or social science. It simply provides some spatial, spectral, and temporal information of value.

Human beings select the most appropriate sensors to collect the data, specify the resolution of the data, calibrate the sensor, select the platform that carries the sensor, determine when the data will be collected, and specify how the data are processed. Powerful active remote sensor systems such as lasers or radars that emit their own electromagnetic radiations can be intrusive and affect that phenomenon being investigated. Remote sensing instruments like in situ instruments often become uncalibrated, resulting in uncalibrated remote sensing data. Finally, remote sensors data may be expensive to collect, interpret or analyze. The limitations of satellite remote sensing also include the inability of many sensors to obtain data and information through cloud cover and relatively low spatial resolutions achievable with many satellite-borne Earth remote sensing instruments.

In addition, the need to correct for atmospheric absorption and scattering and for the absorption of radiation through water on the ground can make it difficult to obtain desired data and information on particular variables. Now let us summarize the lecture. Firstly, I have discussed about the definition of remote sensing. We have discussed that remote sensing is the science and art of acquiring information that is spectral, spatial and temporal about material objects, area or phenomenon, without coming into physical contact with the objects or phenomenon under investigation. Then we have discussed about the remote sensing process.

We have seen the elements A to G totally comprise the most common remote sensing processes from beginning to end. Then we have discussed the source of energy, whether the energy is radiated from an external source or emitted from the object itself, it is in the form of electromagnetic radiation. Electromagnetic radiation is energy that travels in waves is generally described as a self-propagating wave in space with electric and magnetic components. Then we have discussed about the remote sensing sensors. We have seen that there are two types of sensors, passive and active.

And thereafter we have discussed the remote sensing platform. We have seen the three types of platforms that is ground-bound, air-bound and space-bound. Then we have discussed the classification of remote sensing. We have seen the classification based on energy source, classification based on platform, classification based on number of bands of a sensor, and classification based on wavelength regions. And lastly, we have discussed about the resolution and types, where we have discussed the four major types of resolution, that is spatial, spectral, temporal, and radiometric.

Thank you very much to all.